



Levels of Information Systems Interoperability (LISI)



C4ISR
AWG
Architectures
Working Group

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Executive Summary

“Information Superiority is the capability to collect, process, and disseminate an uninterrupted flow of information while exploiting or denying an adversary’s ability to do the same... The unqualified importance of information will not change in 2010. What will differ is the increased access to information and improvements in the speed and accuracy of prioritizing and transferring data brought about by advances in technology. While the friction and the fog of war can never be eliminated, new technology promises to mitigate their impact.”

- Joint Vision 2010
Chairman of the Joint Chiefs of Staff

Assuring Interoperability in an Uncertain Environment is the Challenge

DoD and its component organizations are placing an increasing premium on the ability to access, manipulate, and exchange information adaptively and flexibly among themselves, with multinational partners, with other Federal Government organizations, and with commercial information enterprises. National strategy, priorities, and missions continue to shift and respond to changing world situations, where the unpredictable nature of an impending crisis often precludes an *a priori* understanding of information-exchange requirements and preferences. Similarly, the need for quick response obviates the ability to pre-posture our C4ISR capabilities and systems to ensure that they can operate and interface with each other prior to deployment.

Ironically, the same advances that are dramatically enhancing the inherent capabilities of information systems to access and exchange information are also compounding the challenge to field information systems that can interoperate with each other at comparable levels of sophistication. The rapid evolution of information technology is providing the system developer with many product choices that offer similar functional capabilities, yet few of these choices are compatible or interoperable with each other. In many cases, commercial industry is moving faster than the policy bodies can prescribe standards. Many vendors are vying to establish the “de facto standard” for selected functional capabilities such as browsing, collaboration technology, and electronic publishing. Often, products are provided “free” to the marketplace as a strategy to achieve this objective. In other cases, subsequent releases of a given vendor’s product may not be compatible with versions currently in widespread use.

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And, though the availability and accessibility of information itself is exploding worldwide, the tendency to structure, regulate, and facilitate access *within* each information domain runs the risk of inhibiting our agility to access and integrate critical information *across* the global information enterprise.

Current Interoperability Initiatives Provide Only Parts of the Solution

The Department's Commands, Services, and Agencies are making progress within their organizations to more efficiently manage their information technology investments and to improve system capabilities and interoperability. In addition, many DoD enterprise-wide efforts are underway to improve information systems interoperability.

Some enterprise initiatives involve the promulgation of DoD policy and strategic direction. The *Joint Technical Architecture (JTA)* defines standards governing the implementation of system capabilities and interfaces. The goal of the *Defense Information Infrastructure (DII) Common Operating Environment (COE)* is to establish a commonly defined executable environment for systems. This environment is intended to drive developers toward a common set of solutions that work together and that compliment each other. The *DII Master Plan* is meant to ensure that an infrastructure is in place to allow for the establishment of a common link between systems as they develop. The *Shared Data Environment (SHADE)* is intended to reach agreement on common data models for systems, a critical step toward standard data definitions and relationships.

Other enterprise initiatives focus on pre-planned and crisis-triggered systems testing and experimentation. The *Joint Interoperability Test Command (JITC)* tests and certifies systems based on standards conformance and demonstrated application-to-application interoperability. The *Joint Battle Center* is a forum for conducting experiments regarding information systems interoperability, integration, technology insertion, and system performance in a Joint environment.

Still other initiatives are being undertaken in communities outside of DoD. Federal Government consortiums are dealing with ways to improve cross-domain interoperability with respect to system-to-system interactions. NATO has adopted a construct that addresses incremental levels of system interconnectivity, ranging from manual "man-in-the-loop" capabilities to fully automated, system-to-system connections.

These initiatives are all-important elements of the interoperability assurance equation. However, whether taken individually or collectively, these initiatives are not sufficient. Additional thrusts are needed to leverage current initiatives and to institute a process to help guide DoD's numerous information systems along a common path toward achieving higher and higher states of assured information-exchange capability and interoperability.

So What's Missing and How Does LISI Complete the Interoperability Assurance Equation?

We lack a discipline that recognizes that there are different levels of sophistication that logically apply in conducting various system-to-system information exchanges



The *LISI Interoperability Maturity Model* fills this void

Operational information-exchange requirements vary dramatically with respect to the degree of IT sophistication and interoperability needed to respond appropriately. In some cases, the need to exchange information between one node and another may simply involve transmitting an informal voice or text message. In other cases, more elaborate exchanges of information may be required that involve the need to disseminate multi-media information, or the need for mission participants to collaborate simultaneously over a shared picture of the battlespace, or the desire for distributed organizations to author a decision brief jointly. *DoD lacks a formal construct that addresses different levels of information-exchange sophistication.* Such a construct, or maturity model, would provide the basis for DoD architects to reflect operational differences appropriately, and for *Mission Needs Statements* and *Operational Requirements Documents* to be much more specific than they are today.

Another important value of a maturity model is driven by fiscal and technological realities. A new acquisition or a migration system might desire to attain a high state of interoperability, but it may not be affordable to get there all at once. A maturity model would provide the basis for a system investment strategy and transition plan. The maturity model would target well-defined, incremental levels of improved interoperability as the system progresses toward the desired capability. In cases where the desired state of interoperability is not yet supported by industry, the maturity model would provide a basis for “develop versus wait” decisions, and for prompting industry to accelerate progress.

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Information Exchange

Distributed global info. and apps.
Simultaneous interactions w/ complex data
Advanced collaboration
e.g., Interactive COP update
Event-triggered global database update

Shared databases
Sophisticated collaboration
e.g., Common Operational Picture

Heterogeneous product exchange
Basic collaboration
Group Collaboration
e.g., Exchange of annotated imagery, maps w/ overlays

Homogeneous product exchange
e.g., FM voice, tactical data links, text files, transfers, messages, e-mail

Manual Gateway
e.g., diskette, tape, hard copy exchange

Level

4 -- Enterprise

Interactive manipulation
Shared data and applications

3 -- Domain

Shared data
"Separate" applications

2 -- Functional

Minimal common functions
Separate data and applications

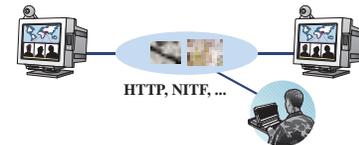
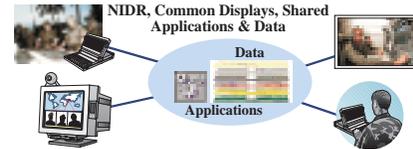
1 -- Connected

Electronic connection
Separate data & applications

0 -- Isolated

Non-connected

Computing Environment



The *LISI Interoperability Maturity Model* Provides a Common DoD Basis for Requirements Definition and for Incremental System Improvements

The *LISI Interoperability Maturity Model* provides DoD with a common basis for requirements definition and for incremental system improvements. The *LISI Interoperability Maturity Model* identifies the stages through which systems should logically progress, or “mature,” in order to improve their capabilities to interoperate. LISI considers five increasing levels of sophistication regarding system interaction and the ability of the system to exchange and share information and services. Each higher level represents a demonstrable increase in capabilities over the previous level of system-to-system interaction.

We lack a common understanding of what full suite of capabilities our systems need in order to interoperate at various levels of sophistication, what options are available to implement those capabilities, and which of those options conform with current DoD technical criteria



The *LISI Capabilities Model and Implementation Options Tables* satisfy this need

Typically, organizations and system developers know what overall target capability they want their system to attain with respect to accessing and exchanging information. “*How to*” guidance, contained in prevailing DoD policy and guidance documents and reference models, certainly assists the developer by providing common criteria or standards governing the implementations of most of the capabilities that the developer has chosen to implement. However, at least three realities continue to inhibit the achievement of assured, Joint interoperability across system or program boundaries, *even when system developers agree on the overall information access and exchange capability they want to attain.*

First, developers do not share a common, comprehensive view of all of the system enablers or attributes that need to be addressed in order to achieve a particular maturity level. Almost all developers focus on enabling functional applications and services, and most developers address associated data considerations. Few developers adequately address the requisite infrastructure dimensions of an information system nor enabling policies and procedures.

Second, even when two system developers focus on the same enabling attribute, e.g., functional applications, each developer may well have a different view of what specific capabilities are needed to achieve the same maturity level of interoperability. For example, one developer may choose a file-transfer capability for exchanging information products, and another developer may be satisfied with an e-mail attachment capability. Either capability will accomplish the same job, but neither capability will interact in a Joint environment.

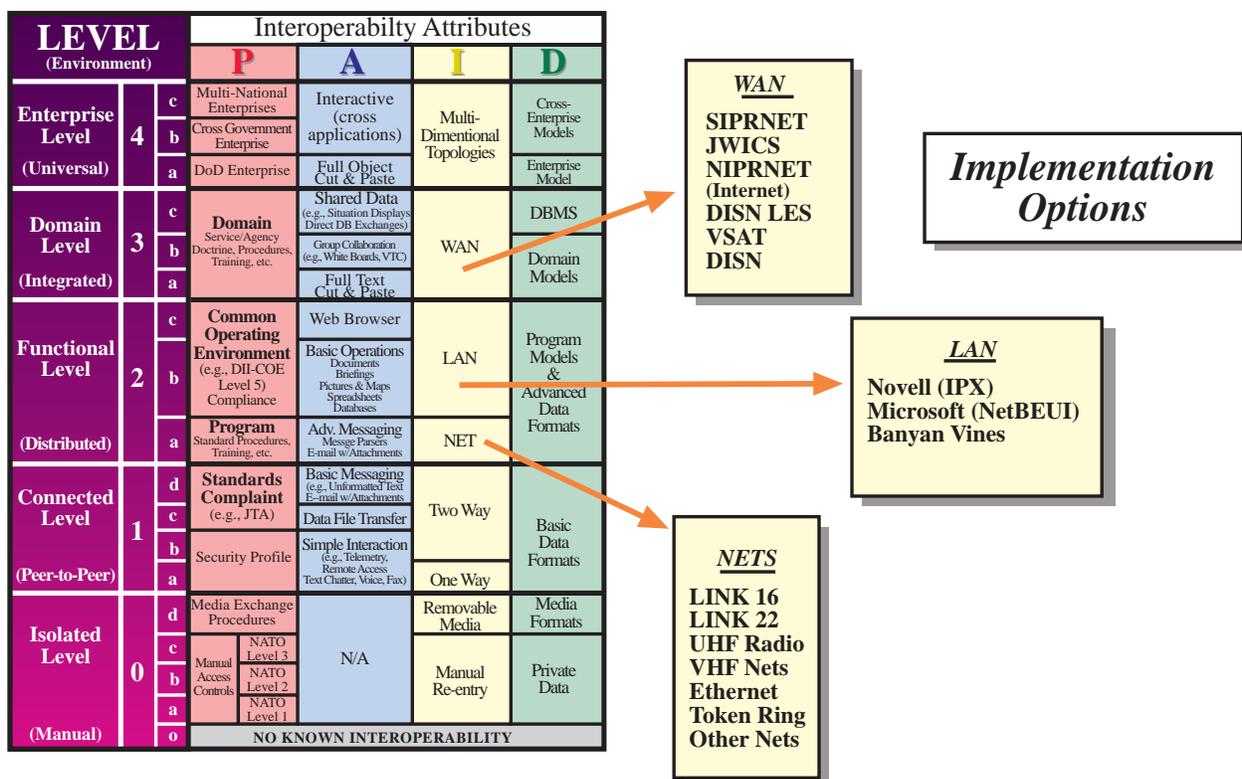
Third, even when two system developers have focused on all of the enabling attributes and have agreed on the same set of capabilities within each attribute, there is still a tremendous margin for error simply because of the multitude of choices generally available for implementing each specific capability. For many system capabilities, there are no standards yet defined or matured. Commercial, government, and “freeware” products that are “standards-compliant” still might not be able to interoperate with each other, often due to the latitude in the standard itself. This latitude provides vendors with freedom in interpretation and the incorporation of permissible options and capabilities.

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Thus, a critical element of interoperability assurance is a clear prescription of the common suite of requisite capabilities that must be inherent in *all* information systems that desire to interoperate at a selected level of sophistication. Each level's prescription of capabilities must cover all four enabling attributes of interoperability, namely:

- **Procedures**
- **Applications**
- **Infrastructure (hardware, communications, security, and system services)**
- **Data**

In addition, for each prescribed capability, system developers need to know what implementation options are available, and which options conform with prevailing DoD criteria.



The *LISI Capabilities Model* and its Associated *Implementation Options Tables* Identify the Full Suite of Capabilities and Available Technical Implementations, Respectively, for Attaining Each Level of Interoperability, Thus Providing a Common-Ground Basis for Cross-Community Coordination, Assessment, and Decisions

The *LISI Capabilities Model* extends the maturity model by identifying, for each level of interoperability, a common suite of capabilities across procedures, applications, infrastructure, and data that must be incorporated by system developers in order to have a “common-ground” basis for Joint interoperability assurance. In addition, for each capability identified in the capabilities model, LISI provides *Implementation Options Tables* that identify specific Government, commercial, and any other technical implementations or products that are currently available to the system developer. LISI further identifies those implementation options that conform to DoD policies and criteria.

Thus, LISI eliminates the guesswork associated with identifying the full suite of capabilities needed to attain a given level of information system interoperability, and identifies the options available for implementing each capability. *Note that LISI does not prescribe nor mandate specific options, but rather provides system developers with the basis needed for coordination, assessment, and interoperable implementation decisions.*

We lack a practical assessment process for determining the interoperability maturity level or “metric” of a given system or system pair, and we lack a means for the community to work collaboratively toward achieving higher states of assured Joint interoperability

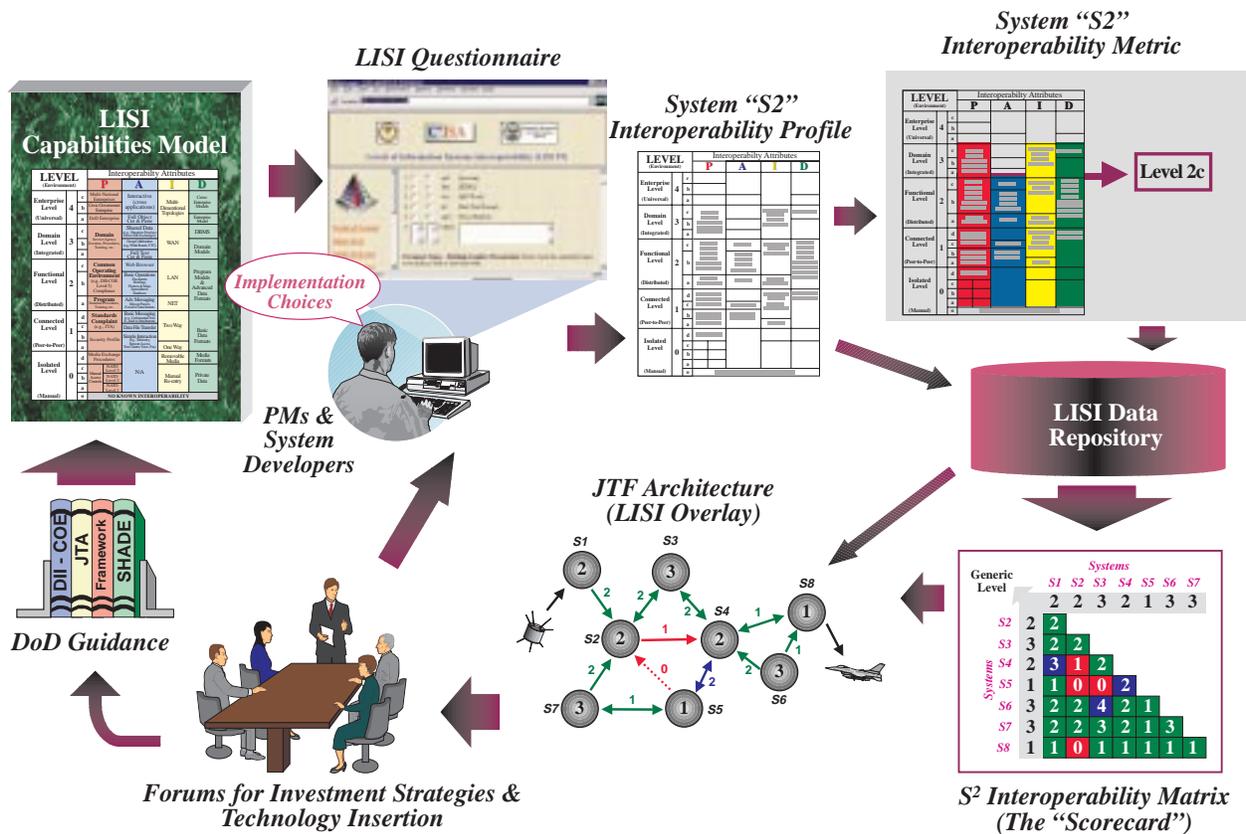


The *LISI Assessment Process*, with its associated tool, system profiles, and data repository, fills these needs

As revealed above, LISI provides the *basis* for assessing and improving information systems interoperability across DoD in a uniform and incremental manner. This basis is instantiated in the maturity model, the capabilities model, and the associated implementation options.

What is needed is a pragmatic *process* that exploits the LISI assessment and improvement basis. The process should provide expedient and collaborative mechanisms to engage the various DoD interest groups who are involved in the planning, development, deployment, and improvement of Joint information systems. Interest groups include, but are not limited to, system planners, system developers and maintainers, DoD and command architects, and “on-the-fly” operations planners. Furthermore, the process must provide the means to periodically assess standardized IT performance measures, i.e., system interoperability metrics, to satisfy recent Government legislation requirements such as those articulated in the Clinger-Cohen Act and the Government Performance and Reporting Act.

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The LISI Interoperability Assessment Process Provides Expedient and Collaborative Mechanisms and Common Metrics for DoD to Assess Current Interoperability Postures, to Identify Quick-Fix Options, to Develop Strategies for Achieving Higher States of Interoperability Maturity, and for Providing Timely Feedback to DoD Standards Bodies

The LISI assessment process provides the methodology and the means for synthesizing and bringing to bear the various LISI models, formal DoD technical guidance, and implementation options to evaluate the current and postulated interoperability status of DoD systems.

The LISI process includes the application of an automated tool, currently a MITRE prototype in the form of an easy-to-execute Web-based questionnaire, that efficiently generates the interoperability metrics of an existing or proposed system based on the capabilities and implementations that the system possesses. The LISI process includes the determination of cost-effective strategies and cross-community agreements for improving interoperability and for achieving incrementally higher states of information-exchange capabilities over time. The LISI process includes the ability to access the interoperability profiles of other systems and to coordinate with other system developers to reach agreement on specific capability implemen-

tations that are compatible with each other. The *LISI process* includes a partnership with, and continuous feedback to, the various DoD standards bodies with respect to systems conformance issues and opportunities for revisions based on the emergence of new technology and the choices being exercised by system developers.

Thus, LISI provides the DoD community with the interoperability maturity model and its associated capabilities and options constructs. It also includes a pragmatic process for conducting system assessments, coordinating interoperability improvements and transition strategies, and maintaining a close partnership with DoD standards bodies.

How Can the DoD Enterprise Benefit from Applying LISI?

Many users across the DoD enterprise can receive direct benefits from applying LISI. *Joint mission planners* can use LISI in context with mission area assessments to facilitate the development and dissemination of interoperability requirements for new systems. *Program managers* can use LISI to identify potential interoperability problems early in the analysis phase of system development (the period during which implementation choices are made) rather than discovering issues after system fielding. *Command architects* can use LISI to assess the interoperability of systems in an existing or planned architecture and evaluate alternative strategies to improve interoperability to meet the mission and operational requirements. *JTF planners* can use LISI to assess the interoperability of existing systems prior to deployment, including the rapid identification and resolution of interoperability shortfalls. *System evaluators* can use LISI during laboratory or field experimentation to determine the impact of various interoperability levels on mission effectiveness.

Some major benefits that all users can receive through LISI application include:

- ***Increased mission effectiveness*** — reduced JTF set-up time due to “up-front” identification of the interoperability gaps and shortfalls
- ***Appreciable return on investment*** — early detection and resolution of interoperability gaps or shortfalls
- ***Reduction in system development costs*** — knowledge of other systems implementations as a basis for making informed implementation decisions

Current considerations include continuing the evolution, refinement, application, and institutionalization of LISI to a point where its process and methodology are adopted across the DoD enterprise. LISI implementation in organizations outside DoD presents a challenge whose answer may best reside with the Federal CIO Council and their strategy for implementing initiatives such as LISI that have cross-government applicability.

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Prologue

Levels of Information Systems Interoperability (LISI) is a process that has evolved since its inception in 1993. Specifically, LISI has progressed through three major stages. The first effort resulted in the concept and initial process, and was conducted under the auspices of the Intelligence Systems Council (ISC). Subsequently, the LISI concept and scope was significantly expanded and detailed during 1996, by the C4ISR Integration Task Force (ITF). The third effort, which has led to LISI's current instantiation, as documented in this report, was conducted during 1997 under the tasking and auspices of the C4ISR Architectures Working Group.

The following paragraphs present a brief re-cap of these efforts in order to give the reader some historical perspective. Readers who are familiar with LISI's inception and growth can skip to section 1.

Initial Efforts at Defining and Assessing Levels of Interoperability

In 1993, the ISC was at an impasse. U.S. military force deployments continued to indicate that the automated information systems used by the military departments did not interoperate well, if at all. Individual organizations and program managers had their own interpretations of "interoperability." When consensus could not be reached, the member organizations turned to the formal definition.

According to Joint Publication 1-02, *DoD Dictionary of Military and Related Terms*, interoperability is defined in two contexts as follows:

- (1) DoD, NATO: "The ability of systems, units, or forces to provide services to and accept services from other systems, units, or forces, and to use the services so exchanged to enable them to operate effectively together."
- (2) DoD: "The condition achieved among communications-electronic systems or items of communications-electronic equipment when information and services can be exchanged directly and satisfactorily between them and/or their users. ***The degree of interoperability should be defined when referring to specific cases.***"

The ISC participants focused heavily on the last sentence in the DoD definition, and recognized the need to define "degrees" or "levels" of interoperability that could:

- Serve to discriminate major variances in required Joint information transactions and sophistication from one system to another
- Provide for a simple construct to facilitate cross-organizational coordination

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- Enable interoperability assessments of intelligence and C2 systems that need to interact
- Serve to guide or discipline interoperability improvement actions

In support of the ISC, MITRE developed the initial “Levels of Interoperability” model under the joint sponsorship of the ISC and INCA (subsequently renamed the C4I Integration Support Activity [CISA] under ASD[C3I]). Though the model and its use were not institutionalized in formal policy, the ISC, the Services, and DISA adopted the model as a useful means to analyze cross-systems interoperability issues.

The following “lessons learned” capture the utility and acceptance of the “levels” model that was used during the relatively short tenure of the ISC (less than 1 year):

- The levels construct was highly successful in quickly bringing Command, Control, and Communications (C3) and Intelligence organizations together with a common understanding of AIS interoperability.
- The resulting systems assessment matrix gained the enthusiastic participation of the member organizations. The cross-systems “green/yellow/red” assessment view led to friendly competition, voluntary actions, and pronounced improvements at the lower levels in less than six months.
- Selective system-to-system laboratory demonstrations proved the necessity of testing system transactions beyond “paper compliance.” (Some interoperability problems were discovered between system applications that had been certified as standards-compliant.)

The C4ISR Integration Task Force

In October 1995, the Deputy Secretary of Defense tasked the ASD(C3I) “...to define and develop better means and processes to ensure C4I capabilities most effectively meet the needs of our warfighters...” In response to this tasking, the C4ISR ITF was established. and an Integrated Architectures Panel was created “to engineer a C4ISR architecture process,” including identifying ways to improve systems interoperability. As one of its six major findings, the Integrated Architectures Panel endorsed the “levels of interoperability” concept. The panel advocated “...the concept of ‘levels of interoperability’ as a mechanism for C4ISR practitioners to negotiate an affordable and technically appropriate capability mix among C4ISR systems intended to interoperate, and to ensure Joint interoperability...”

The Panel’s found that LISI provided a viable approach for:

- Identifying an appropriate degree of interoperability
- Assessing system capabilities and implementations
- Managing incremental system improvements
- Testing systems for interoperability

The final report of the C4ISR ITF, under the purview of the Under Secretary of Defense for Acquisition and Technology (USD (A&T)), the ASD(C3I), and Vice Chairman of the Joint Chiefs of Staff (VCJCS), endorsed the levels of interoperability concept and tasked the ASD(C3I) to lead a follow-on effort to “Define and Use Levels of Interoperability.”

The C4ISR AWG Interoperability Panel—Continuing the Development of the LISI Process

Building upon the recommendations of the C4ISR ITF and the LISI report published in June 1996, CISA tasked MITRE to continue to work with the C4ISR community to further evolve LISI. In an effort to engage DoD community participation, an Interoperability Panel was formed in January 1997 as part of the C4ISR AWG sponsored jointly by the ASD(C3I) and the Joint Staff (JS) J-6.

This document describes the current state of the LISI process, and reflects the progress made in coordination with the C4ISR AWG Interoperability Panel.

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Section 1

Introduction and Overview

1.1 The Need

The primary challenge of conducting Joint operations can be increasingly summed up in one word: interoperability. The Joint Task Force (JTF) that fights the next conflict, small or large, will not exist until the need arises. Its approach to information management, and the set of information systems it uses, will be based in large part on which Service is in charge of the operation. Though all Services provide and use an essential set of automated tools, the particulars of which ones, how many, where they are located, et cetera, are all dependent on the situation and the decisions of the assigned Service commander.

Determining how these systems are, or can be, pulled together to accomplish a Joint mission is one of the major challenges facing DoD information system architecture developers. Information systems built to meet specific Service-unique requirements must still meet Joint requirements to provide the appropriate level of interoperability. Understanding the specific nature and degree of interoperability required, therefore, becomes a key consideration in the design, construction, and deployment of any information technology system or architecture. Unfortunately, there is currently no clear and universally accepted way to assess the nature and degree of interoperability among systems.

The challenges associated with developing and fielding interoperable systems are not limited to DoD. Every organization must deal with an increasingly chaotic environment forced upon it by evolving technology and the increasing demands of its customers. For the U.S. Government, interoperability is essential for many critical activities. Some of those activities include life-saving with the Red Cross, and humanitarian relief with the Federal Emergency Management Agency (FEMA). Likewise, the ability of multinational forces to coordinate and perform effectively in varying situations such as Desert Storm or Bosnia points vividly again to the critical need for interoperability in order to save lives. Interoperability was critical to these operations, and it will continue to be a driver for mission success in future endeavors.

1.2 Legislative Context

The Information Technology Management Reform Act (ITMRA) of 1996 (Public Law 104-106), also known as the Clinger-Cohen Act, requires the Federal government to develop *“a process and procedure for establishing goals for improving the efficiency and effectiveness of government agencies operations and the ability to deliver goods and services to the public using Information Technology. The goals must be measurable.”* Within DoD, “efficiency and effectiveness” in the

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application of information technology translate to mission accomplishment, i.e., achieving information superiority on the battlefield of the future. The critical factor in achieving information superiority is the improvement of interoperability between and among all DoD information systems. DoD has also acknowledged interoperability as a critical success factor for reducing costly infrastructures and making the Department more efficient. The DoD Chief Information Officer is responsible to manage and acquire information technology for the department. Thus, the DoD CIO must ensure that all DoD information systems will be “born joint,” managed from a joint perspective, developed for joint use, and fielded to ensure they can interoperate at the levels of sophistication required to achieve joint mission requirements. In order to achieve this goal, the DoD CIO must implement a process to define, evaluate, measure, and certify information systems interoperability.

1.3 Purpose

The purpose of LISI is to provide DoD with a maturity model and a process for determining joint interoperability needs, assessing the ability of our information systems to meet those needs, and selecting pragmatic solutions and a transition path for achieving higher states of capability and interoperability. The purpose of this document is to describe the LISI process.

1.4 Scope

LISI is a process for defining, evaluating, measuring, and assessing information systems interoperability. LISI uses a common frame of reference and measure of performance.

LISI applies throughout the information system life cycle, i.e., from requirements analysis through systems development, acquisition, fielding, and subsequent improvement and modification. In this context, LISI:

- Facilitates a common understanding of interoperability and the suite of capabilities that enable each logical level of system-to-system interaction
- Provides an interoperability maturity model and associated requisite capabilities as the basis for making comparisons between heterogeneous systems and maturing individual systems
- Provides a methodology for assessing and improving interoperability by guiding requirements and architecture analysis, systems development, acquisition, fielding, and technology insertion.

LISI strengthens the ability to effectively manage information systems. It complements other activities that support the improved use of information technology in the DoD mission, such as the Defense Information Infrastructure (DII) Master Plan, the DII Common Operating Environment (COE), the DoD Technical Reference Model (TRM), and the Joint Technical Architecture (JTA).

1.5 Approach

LISI provides:

- An *interoperability maturity model* that describes increasing levels of sophistication regarding the ability of systems to exchange information with each other
- The ability to identify *operational and system requirements* in terms of specific levels of interoperability by examining the nature of required mission-related information transactions in context with the levels defined in the *interoperability maturity model*
- The *suite of capabilities* associated with procedures, applications, infrastructure, and data that must be inherent in an information system to achieve each level of interoperability
- The *implementation options* that are available for each prescribed capability, including clear distinctions between those options that conform with current DoD technical criteria (e.g., JTA, DII COE, SHADE, ...) and those that do not
- A practical *assessment process* for determining the interoperability maturity level of a given system or system pair, capabilities that may be lacking, implementations that are not compatible, and options available for resolving deficiencies and for achieving progressively higher levels of maturity
- A *collaborative means* for the community to work together to resolve system-to-system disconnects and evolutionary strategies, and to engage with formal standards bodies to provide constructive feedback regarding the currency and feasibility of existing implementation guidance

The fundamental information set that drives the LISI assessment process is the source of all information systems interoperability issues — the specific implementation choices made by system developers for each capability and service contained within their information systems.

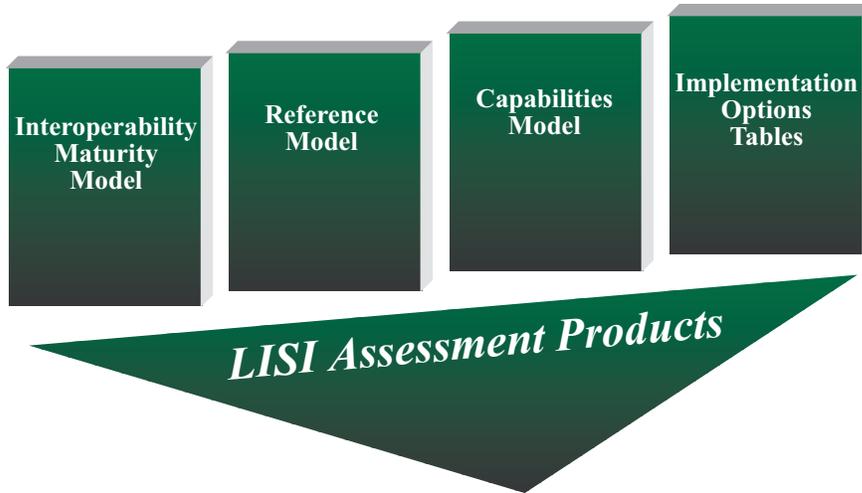
The LISI assessment process begins with an *Interoperability Questionnaire* designed to obtain this “fundamental information set.” The LISI questionnaire presents structured questions that list the available implementation choices for each capability and service that can be implemented in an information system. The system developer answers each question by placing an “x” next to the implementation choice(s) or answer for each applicable capability/service. The data generated from the questionnaire is then used, in context with the LISI elements highlighted below, to build system interoperability profiles and assess interoperability from both a systems maturity perspective and a pair-wise comparison perspective. The LISI web-based prototype tool is designed to generate many of the interoperability assessment products directly from the questionnaire.

Figure 1-1 presents a general overview of the major elements that comprise LISI. Each of the LISI elements highlighted here is explained in detail in the remainder of this document.

Introduction and Overview

- (a) The **LISI Interoperability Maturity Model** defines the five levels of interoperability expressed within LISI. The LISI Interoperability Maturity Model describes the increasing sophistication of system-to-system interactions as one progresses from one level to the next.
- (b) The **LISI Reference Model** characterizes the five levels of interoperability in terms of four comprehensive, integrated attributes: procedures, applications, infrastructure, and data (*PAID*). At any particular level of interoperability, a set of specific capabilities must be present for each attribute in order to achieve the degree of interoperability maturity defined by that level.

LISI Assessment Basis



LISI Assessment Products

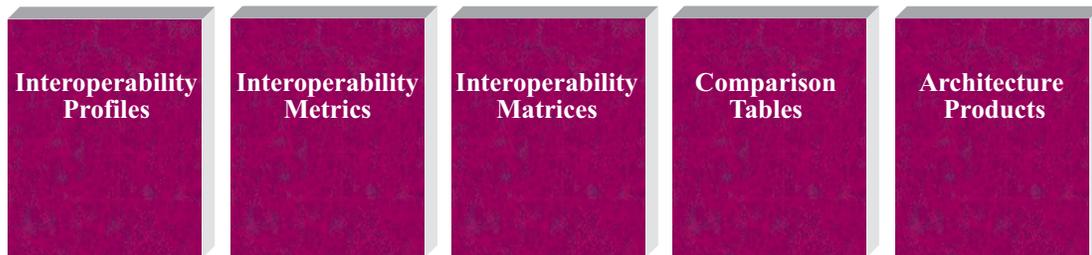


Figure 1-1. Overview of the LISI Elements

- (c) The **LISI Capabilities Model** defines the specific capability thresholds, i.e., capability suites across *PAID*, required for attaining each level of interoperability. This model provides the level of detail needed to determine systems interoperability profiles and metrics, and provides the basis for conducting LISI assessments.

- (d) The **LISI Implementation Options Tables** capture the full range of possible implementation choices that are available to developers for implementing each of the capabilities identified in the Capabilities Model.
- (e) The **Interoperability Profile** for a particular system is produced as a result of completing the LISI questionnaire. This profile contains the specific implementation choices made by a particular developer regarding a specific system or application.
- (f) The **LISI Metric** is calculated by applying the Capabilities Model to the data collected from the questionnaire. Through this mapping, a profile emerges which depicts the organized set of capabilities exhibited by a system in terms of the LISI levels. The result is a “metric” which captures the level of interoperability that a system possesses.
- (g) The **LISI Products** are developed via comparison and assessment of the interoperability profiles and metrics for a given suite of systems.

1.6 Document Organization

Section 2 of this report presents the “levels” concept and discusses LISI as an interoperability maturity model. Section 2 also discusses the interoperability attributes, namely procedures, applications, infrastructure, and data (*PAID*), that combine to define the information systems capabilities that must be present to attain each interoperability level.

Section 3 is a detailed description of the basis for LISI assessments — the *LISI Reference Model* and the *LISI Capabilities Model*.

Section 4 describes the current suite of LISI products and discusses the LISI process.

Section 5 presents a variety of scenarios for applying LISI within the DoD environment. These scenarios encompass all stages of the information systems life cycle, from requirements analysis through operational engineering in the field.

Section 6 discusses the relationships between LISI and the architecture views currently defined by the Office of the Secretary of Defense (OSD) — Operational, System, and Technical.

Section 7 examines the relationship between LISI and other DoD interoperability efforts, including the DII COE, the JTA, and the DII Master Plan. This section also discusses other non-DoD initiatives.

Section 8 concludes with a brief discussion of the next steps in LISI evolution.

Appendix A is a detailed description of the characteristics thresholds delineated with the current *LISI Capabilities Model*.

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Section 2

The LISI Interoperability Maturity Model

The LISI process focuses on defining and assessing systems against increasing levels of sophistication for system-to-system interaction. The process defines thresholds of capabilities that a system exhibits as it improves and matures in its ability to interact with other systems. These thresholds become levels of interoperability that can be measured consistently throughout the system's life cycle. Thus, LISI provides a frame of reference for discussing system-to-system interoperability issues and establishes interoperability measures of performance in the form of an *Interoperability Maturity Model*.

This section discusses LISI as an *Interoperability Maturity Model*. It begins with a generic discussion of “maturity models” for context. The remainder of the section:

- Defines a “level of interoperability”
- Describes, in generic terms, the five LISI levels
- Introduces a set of four highly integrated “attributes” (procedures, applications, infrastructure, and data – *PAID*) that provide the categorical construct for defining the capabilities needed to achieve each “level.”

2.1 Maturity Models

A maturity model describes the stages through which processes progress as they are defined, implemented, and improved. The model provides a guide for selecting improvement strategies by determining the current capabilities of specific processes and identifying the issues most critical to quality and process improvement within a particular domain, such as software engineering. For example, the Capability Maturity Model (CMM) defined by the Software Engineering Institute (SEI) may take the form of a reference model to be used as a guide for developing and improving a mature, defined process. It may also be used to appraise the existence and institutionalization of a defined process that implements the referenced practices. A CMM can cover the processes used to perform the tasks of the specified domain (e.g., software engineering). In addition, a CMM can cover the processes used to ensure effective development and use of human resources, and the insertion of appropriate technology into the products and into the tools used to produce the products.

LISI provides the reference implementation for an *Interoperability Maturity Model*. As a maturity model, LISI identifies and assesses the stages through which systems progress in order to improve their capabilities to interoperate. As a reference model for interoperability maturity, LISI can be used as a guide to develop and improve a system's general capability to interoperate with other systems without predefined or formal sets of requirements necessarily established between them.

Interoperability Maturity Model

DoD's increasing need for "interoperability on the fly" to support rapid JTF implementation and deployment creates conditions wherein many independent systems and applications are tossed into the joint cauldron to brew with the hopes of fermenting into an operational capability. This process cannot continue to be left to chance. LISI provides the basis for removing these chance implementations by providing a measurable way of assessing the interoperability achieved by any system or application (and, to a certain degree, hardware) procured or developed within or outside of DoD.

2.2 The "Levels" Concept

The concept of levels is intrinsic to LISI and to maturity models in general. In order to achieve the goal of assessing interoperability, a means must be devised to characterize multiple systems and/or applications and signify where they fall within the broadest definition of interoperability. Further, in order to compare and contrast multiple, heterogeneous systems from an interoperability perspective, a consistent description of interoperability, regardless of specific implementation, must be developed. To accomplish this, LISI defines a set of increasingly sophisticated or mature "levels" of interoperability. Each level represents a specific characterization of various elements and the associated set of capabilities present to foster interoperability. A level of interoperability is defined as a composite of the three different aspects described below:

- **Statement of Need** (*operational aspect*): This statement summarizes the most demanding *operational* aspects of the information sharing required. The group or set of Information Exchange Requirements (IER) between any two organizations commonly defines the statement of need. For example, one type of required interaction could be characterized as simply having the need to exchange homogeneous information such as a text message or an image. A more sophisticated interaction might involve the ability to exchange a product composed of multimedia components. Each of these requirements can be directly mapped to a stated level of interoperability as defined within LISI. Thus, a *non-technical* statement that Joint mission users can derive based on their information needs can be used, via "table lookup," to identify the level of interoperability required between systems. Thus, LISI provides the construct for bridging the mission operations and systems acquisition communities.
- **Set of Enabling Capabilities** (*system aspect*): The suite of capabilities that enable a level of interoperability to be achieved. These capabilities are described in terms of procedures, applications, infrastructure, and data. Examples include multimedia applications, supporting graphical user interface (GUI) capabilities, and common data models.
- **Governing Implementation Criteria** (*technical aspect*): The rules and criteria that govern the implementation of the suite of enabling capabilities comprise the technical aspect of a LISI level. These criteria include standards and conventions, specific product-based solutions, and gateways that technically describe a specific capability. Examples include JTA standards, specific office automation products, and operating systems.

By design, the three components of a LISI level are closely related to DoD’s *Architecture Framework*. The *Framework* provides guidance for architecture development and design in context with three interrelated architecture views, namely, *operational*, *system*, and *technical*. These architecture views correspond to the three aspects of an interoperability level described above. If an information technology implementation is to be successful within DoD, it must include and clearly reference the requirements and current conditions of interoperability that are present within all three architecture views. In order to improve interoperability, there must be a known basis for making changes. The use of LISI in support of architecture development and in response to implementing the resulting architecture is a key to developing this basis. The specific relationships of LISI to the DoD *Architecture Framework* will be discussed in Section 6.

Figure 2-1 presents an example that illustrates the three components of a LISI level. An Air Operations Center (AOC) and Commander, Joint Task Force (CJTF) need to exchange information in a target folder. There are numerous ways to perform this activity, such as passing hard-copy information via courier, using simple “text” file exchanges via dial-up, or having direct exchange of information between databases over a WAN. Each of these methods represents a different level of interoperability that can be characterized by a statement of need, a list of enabling capabilities, and a set of governing criteria.

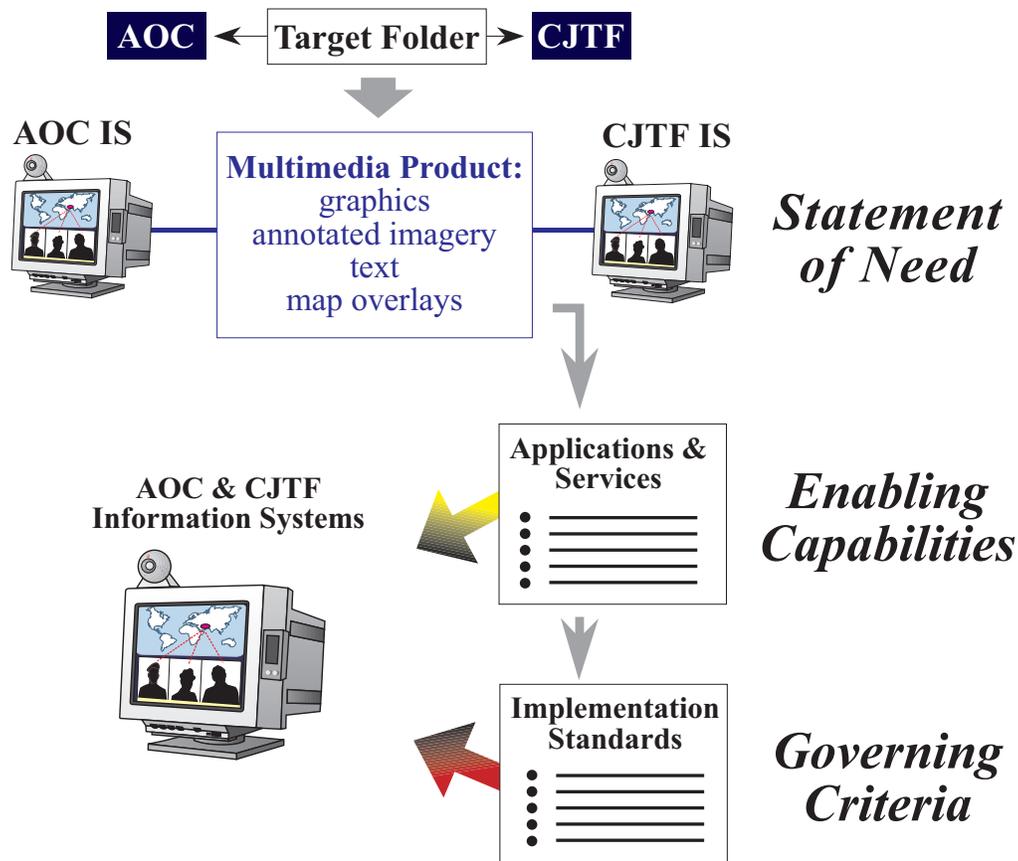


Figure 2-1. Example Decomposition of a LISI Level

Interoperability Maturity Model

To develop the statement of need, it is necessary to break down the target folder. As shown, the nominal target folder contains graphics, annotated imagery, text, and map overlays. These components differ in many ways, including format, structure, and organization. Together, they define the target folder; separately, they must be individually understood and processed to retain the proper overall context of the target folder. All are necessary to prepare an effective operations order. Thus, the target folder is a multimedia product. The operational statement of need that can serve to characterize the relevant level of interoperability is, therefore, “the ability to exchange multimedia products.”

Determining the capabilities required to provide this exchange is more complicated. Each information system involved in the exchange must have the capability to pass files and to display and manipulate the data contained in those files. These system capabilities include, for example, a data transfer protocol, a GUI, a mapping application, a word processing application, a graphics application, and an imagery viewer. Other applications and services may also be required.

Each capability or application has an associated set of technical governing criteria. These criteria describe the implementation and operational environment. For example, the TCP/IP data transfer protocol may be dictated by the governing criteria at a given level (as is the case with DoD systems that intend to be DII COE compliant). If that is the case, then any capability at that level must include TCP/IP. Alternatively, “sneaker-net,” i.e., a person manually transferring files on a floppy disk, may be the designated transfer protocol. In this case, the standards governing the format of the disk would be the important technical criteria that characterize the level.

Taken together, the statement of need, the set of requisite capabilities, and the set of technical implementation criteria describe a level of interoperability. In the above example, if TCP/IP is designated as the technical criteria, the system-to-system interaction is obviously at a higher level of sophistication than if a sneaker-net were used.

It is important to remember that from a LISI perspective, one level is not necessarily “better” than another, even though each higher level does imply added capabilities and flexibility (beyond known or projected requirements) for interaction between systems. The term “better” must be taken in the overall context of a specific mission requirement. For example, a LISI level does not directly reflect the performance aspects of a mission requirement. From a “levels” perspective, the nature of systems interoperability is a wholly dynamic factor. That is to say, the judgment of success is highly subjective and changes with each situation and the corresponding, supporting system. For LISI, a system’s level of interoperability is a direct reflection of the degree of sophistication (i.e., level of interoperability maturity) that is inherent. Using the earlier example, TCP/IP versus “sneaker-net,” if the information exchanged is to be used for long-term target analyses or trends development, the slower, less sophisticated disk transfer may fully meet the performance requirement. If so, costly improvements to existing systems may be unwarranted. However, if the transfer is designated to support near-real-time targeting, the use of manual disk transfer is unlikely to be an acceptable implementation. In fact, some third option may be “better” suited to meet the performance conditions.

2.3 The LISI Interoperability Maturity Model

The interoperability maturity levels defined by LISI are illustrated in Figure 2-2. Each level is identified by a number (0, 1, 2, 3, or 4). The level is further identified, as shown in the center of the figure, by the general nature of the interoperability (*Isolated, Connected, Functional, Domain, and Enterprise*). The left column provides a brief description of the nature of information exchange that occurs at each level (the blue text expresses this nature in DoD operational terms). The right of the figure provides a high-level graphical illustration of the computing environment at each level.

LISI considers five increasing levels of sophistication with respect to exchanging and sharing information and services. Each higher level represents a demonstrable increase in capabilities over the previous level of system-to-system interaction. This increase is expressed in terms of **PAID** — the *procedures* (i.e., policies and processes) imposed by information management, the capabilities of *applications* that act on that data, the type of *infrastructure* required, and the nature of *data* transferred. A general description of the nature of each level follows.

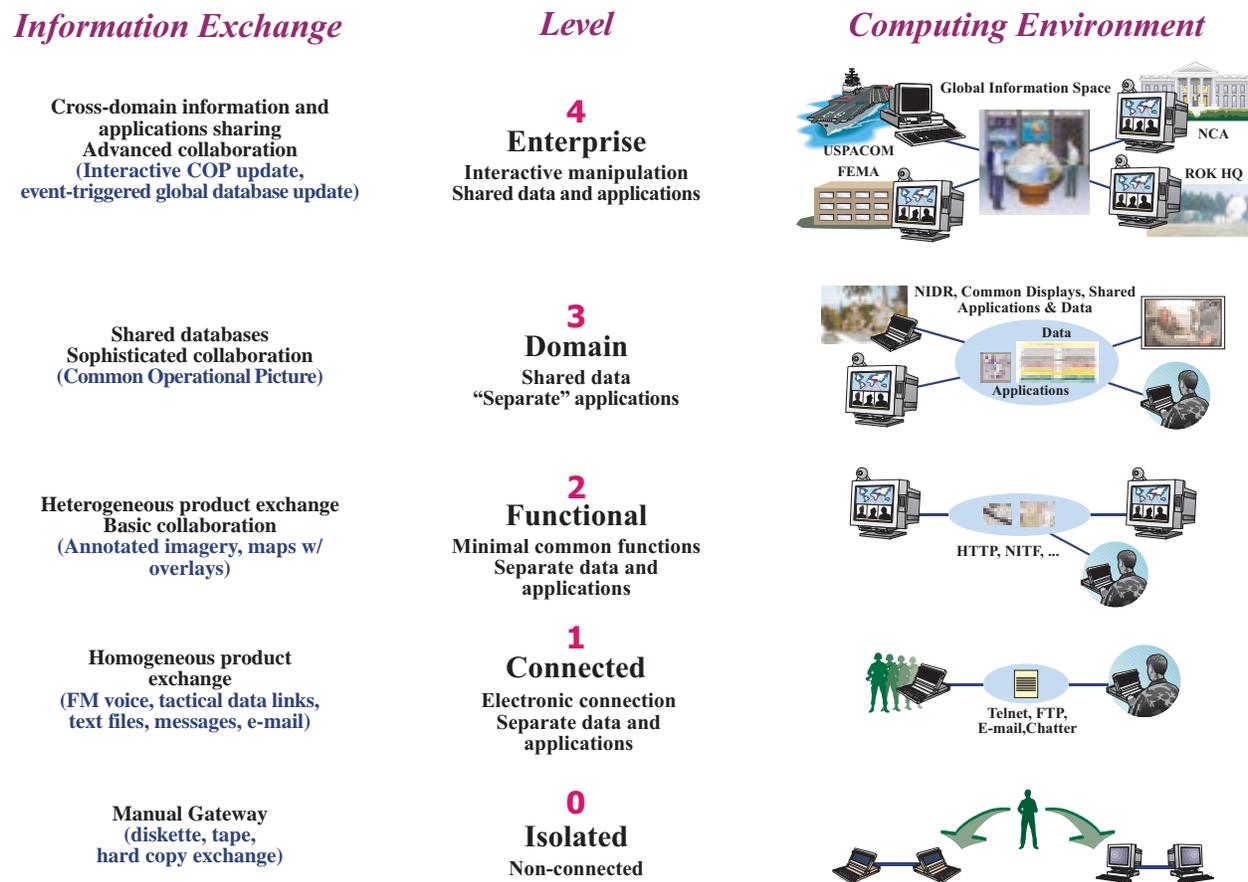


Figure 2-2. LISI Interoperability Maturity Model

Interoperability Maturity Model

Level 0 *Isolated Interoperability in a Manual Environment*

Level 0 encompasses the wide range of isolated, or stand-alone, systems. No direct electronic connection is allowed or is available, so the only interface between these systems is by manual re-keying or via extractable, common media. Fusion of information, if any, is done off-line by the individual decision-maker by other automated means.

Level 1 *Connected Interoperability in a Peer-to-Peer Environment*

Level 1 systems are capable of being linked electronically and providing some form of simple electronic exchanges. These systems have a limited capacity, generally passing homogeneous data types, such as voice, simple “text” e-mail, or fixed graphic files such as GIF or TIFF images between workstations. They allow decision-makers to exchange one-dimensional information but have little capability to fuse information together to support decision-making.

Level 2 *Functional Interoperability in a Distributed Environment*

Level 2 systems reside on local networks that allow data sets to be passed from system to system. They provide for increasingly complex media exchanges. Formal data models (logical and physical) are present. Generally, however, only the logical data model is accepted across programs and each program defines its own physical data model. Data is generally heterogeneous and may contain information from many simple formats fused together, such as an image with an annotated overlay. Decision-makers are able to share fused information between systems or functions.

Level 3 *Domain-Based Interoperability in an Integrated Environment*

Level 3 systems are capable of being connected via wide area networks (WANs) that allow multiple users to access data. Information at this level is shared between independent applications. A domain-based data model is present (logical and physical) that is understood, accepted, and implemented across a functional area or group of organizations that comprises a domain. Using agreed-upon domain data models, systems must now be capable of implementing business rules and processes to facilitate direct database-to-database interactions, such as those required to support database replication servers. Individual applications at this level may share central or distributed data repositories. Systems at this level support group collaboration on fused information products. Decision-making is supported by fused information from a localized domain.

Level 4 Enterprise-Based Interoperability in a Universal Environment

Level 4 systems are capable of operating using a distributed global information space across multiple domains. Multiple users can access and interact with complex data simultaneously. Data and applications are fully shared and can be distributed throughout this space to support information fusion. Advanced forms of collaboration (the virtual office concept) are possible. Data has a common interpretation regardless of form, and applies across the entire enterprise. The need for redundant, functionally equivalent applications is diminished since applications can be shared as readily as data at this level. Decision-making takes place in the context of, and is facilitated by, enterprise-wide information found in this global information space.

In summary, LISI is organized into maturity levels that represent increasingly sophisticated user capabilities and the associated computing environments that support them. Within each of these maturity levels, however, many additional factors influence the ability of information systems to interoperate. LISI categorizes these factors into four key attributes, *Procedures*, *Applications*, *Infrastructure*, and *Data*. These attributes, collectively referred to as **PAID**, are broad enough by definition to encompass the full range of interoperability considerations.

PAID provides a methodology for defining and identifying the set of characteristics required for exchanging information and services at each increasing level of sophistication within LISI. A detailed discussion of the attributes and the roles they play as “enablers” for achieving higher degrees of interoperability are defined in the following paragraphs.

2.4 The LISI Interoperability “Attributes” — PAID

LISI categorizes the various aspects of information systems interoperability in terms of four comprehensive, closely interrelated attributes: *Procedures*, *Applications*, *Infrastructure*, and *Data*. Individually, these attributes are like pieces of a puzzle — each possessing its own identity (shape) and purpose (content).

When joined together (pictured in Figure 2-3), these attributes can be represented as a complete circle whose “circumference” encompasses the entire realm of interoperability issues and considerations and whose “area” defines the full set of conditions, characteristics, and criteria necessary for achieving interoperable environments.

Consideration and understanding of the interrelationships between all the **PAID** attributes is critical for moving interoperability beyond the simple connection between systems. In order to assess interoperability completely, it is necessary to apply **PAID** throughout each of the levels described in section 2-3.

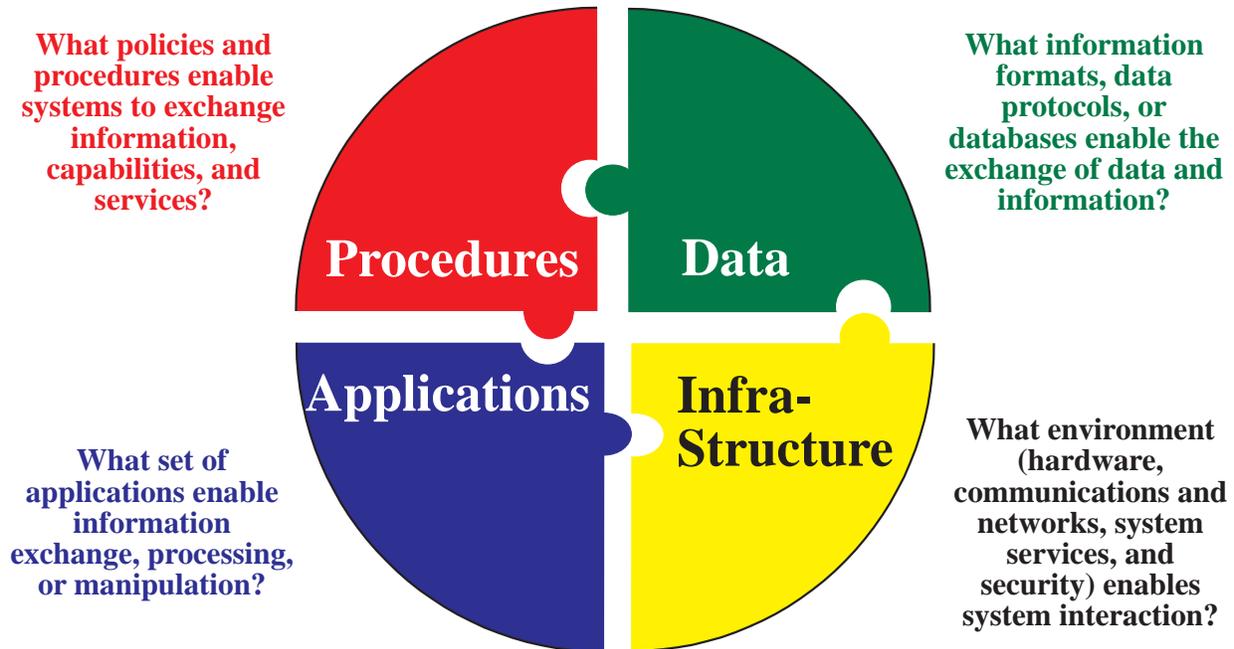


Figure 2-3. The *PAID* Attributes

Figure 2-4 demonstrates the concept of the *PAID* attributes as they are used to describe and assess levels of interoperability. The circle as shown previously in Figure 2-3 is extended to form a column across the levels. Thus, this figure shows that there are selective considerations of each attribute of *PAID* that cut across Levels 0 through 4. These considerations are discussed in detail with respect to the LISI Reference Model and the LISI Capabilities Model in section 3.

Individual considerations within each attribute are shown within the boxes surrounding the circle. For instance, key considerations with the *procedures* portion of *PAID* include doctrine, architectures, and adherence to standards. Each of these considerations will be discussed in greater detail later in this section.

None of the *PAID* attributes is sufficient on a stand-alone basis to provide enough detail to complete a meaningful definition of interoperability. Each, however, does represent a critical, interdependent, and interlocking piece of the overall interoperability puzzle.

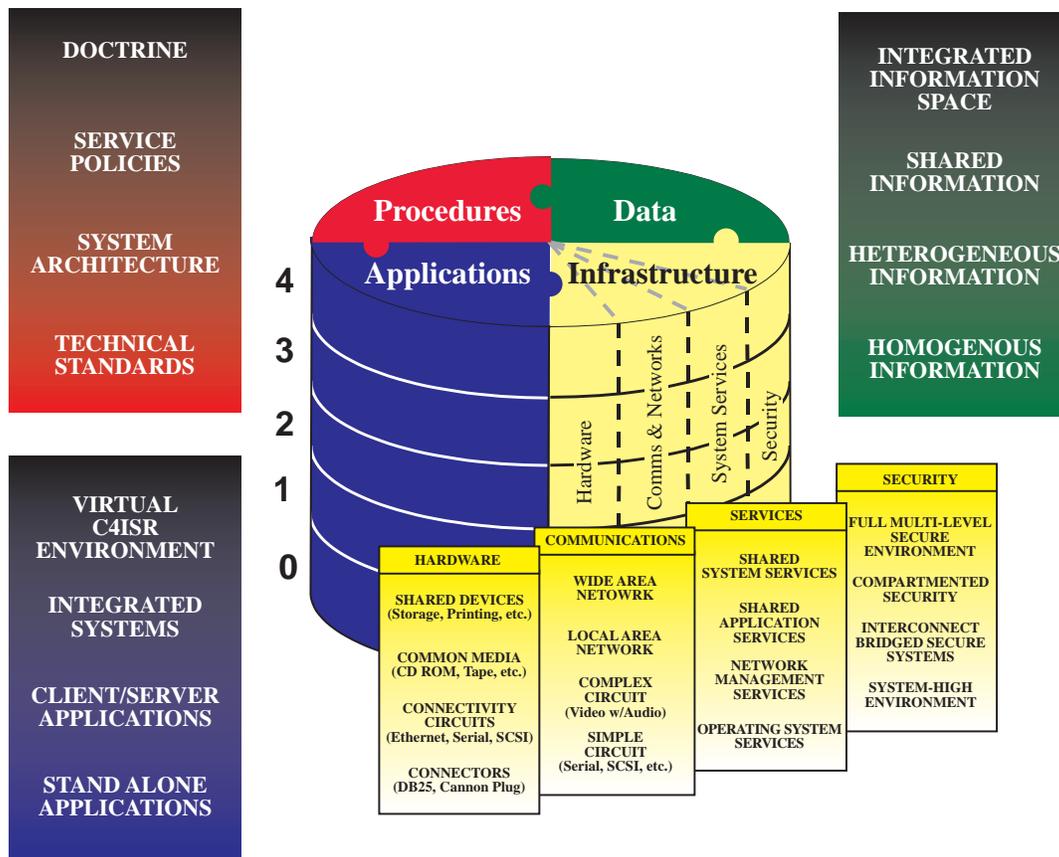


Figure 2-4. The *PAID* Attributes and Levels of Interoperability

The remainder of this section provides a brief description of each attribute as it applies to LISI .

2.4.1 The *Procedures* Attribute of Interoperability

The *procedures* (*P*) attribute of *PAID* encompasses the many forms of documented guidance and operational controls that affect all aspects of system development, integration, and operational functionality. This attribute addresses specific implementation options selected for a system or systems as well as overarching standards and architecture guidance for the given enterprise. It encompasses operational and functional program development guidance as well as technical and system architecture standards (hardware, system software, communications, data, applications, et cetera). Items that make up the *procedures* attribute are organized into four major categories that span the levels of interoperability. The categories are as follows:

- Standards
- Management
- Security Policy
- Operations

A discussion of each of these categories follows.

Interoperability Maturity Model

2.4.1.1 Standards

Standards compliance is a major part of interoperability. Standards include a variety of aspects such as individual technical standards, architectures, and common operating environments. Many sets of standards exist, including DoD, national, and international technical standards. Examples of these include Federal Information Processing Standards (FIPS), Institute for Electrical and Electronics Engineers (IEEE), and International Standards Organization (ISO). There are also de facto standards that have not been formally approved but are accepted as common practice within communities.

Technical Standards: Standards apply across all parts of a system, from the packaging and footprint to the software and interfaces. Unfortunately, compliance to standards alone does not ensure interoperability. There are choices in design and implementation that vary between systems, or even within the same system, yet these differences may still be compliant with the standards. For example, there are many ways to connect two computers. They can be directly connected with a wire, they can reside on the same local area network (LAN), or they can be connected via Radio Frequency (RF) link. These options for connection all have standards associated with them (e.g., protocols such as Point to Point Protocol (PPP) and Serial Line Internet Protocol (SLIP)). However, even though two systems completely comply with standards, if they are not compatible standards, interoperability cannot be achieved. Two radios that provide an RF link may both comply completely with ISO standards, but if they operate in different frequency bands they will not be able to exchange information with each other without an intermediary. LISI examines both compliance with, and the compatibility of, standards when determining interoperability levels between systems within the *procedures* attribute of interoperability.

Compliance with standards begins to facilitate general interoperability by ensuring that a common set of rules is used in design and implementation of diverse systems. For interoperability considerations, some standards are more important than others, namely those related to interfaces and to common applications and data implementations. Within LISI, standards are found throughout **PAID**. Data standards such as the National Imagery Transmission Format (NITF) apply to the *data* attribute and its associated capabilities; hardware standards that set interfaces (e.g., RS 232, TCP/IP) apply to the *infrastructure* attribute and its associated capabilities; and standards that apply to application development (e.g., HTML, CORBA) apply to the *applications* attribute and its associated capabilities.

Within the *procedures* section, standards compliance is examined for those standards that do not directly impact the other areas or for those standards that are in themselves procedures. For example, WGS-84 is a standard frame of reference for map coordinates. This could be viewed as only a data standard. In the Joint environment, however, current guidance dictates that systems should use WGS-84 exclusively when passing map coordinates externally to other systems. Each individual system may be able to read coordinates based on other datum. However, when transmitting coordinates, interoperability is attained via compliance to procedures whereby systems must internally convert and use other formats in the WGS-84 standard. In principle, this is a *procedure* for ensuring interoperability between mapping programs.

“Technical Architectures:” Collections of standards can provide even more structure than individual standards. A “technical architecture” is a collection of standards and recommended or required implementation options that structure a system, organization, or enterprise. Technical architectures abound in the DoD and elsewhere. For most enterprises, there is a set of applicable architectures. For example, in the DoD enterprise, the JTA is the governing body of standards and implementation options for systems.

Common Operating Environments: In addition to “technical architectures,” common operating environments are emerging as a way to facilitate interoperability within a domain or enterprise. The prevailing common operating environment within the Joint world is the DII COE. Compliance with the DII COE is essential within DISA-approved systems for DOD. The DII COE has four sets of metrics for determining compliance. Of these four, probably the most familiar metric is the “level of runtime compliance” which is based on a scale ranging from one to eight. Currently, in order to be considered for fielding in a Joint environment, systems must demonstrate compliance at DII COE level five or better. A system may be considered a prototype at a DII COE level of four. The DII COE is discussed further in section 7.

2.4.1.2 Management

The area of management within the *procedures* attribute encompasses many aspects of program management, from systems requirement definitions to installation and training. This area is where mission and doctrine are examined to ensure that systems are part of an established mission area and follow accepted doctrine. Procedures governing interfaces to domain- and enterprise-wide resources are essential to have a chance of achieving interoperability between disparate information systems. Plans for installation, training, staffing, testing, and evolution are part of this area.

2.4.1.3 Security Policy

Systems and networks operate at specific security levels, but the level may vary from one operation to another. Therefore, *procedures* must be in place to ensure that proper security precautions are maintained for each implementation. A system that operates on an unclassified network for one operation may be technically capable of operating and providing identical interfaces on a classified network.

Within LISI, security appears in both the *infrastructure* and *procedures* parts of **PAID**. The *infrastructure* describes security in a technical way to ensure that secure pieces of systems follow accepted practices and standards. Security within *procedures* examines whether security aspects of systems are compatible. For example, two systems, or even the same system on two machines, may operate at different levels of security. If one is unclassified and the other is secret, then, without additional considerations, they may not pass data. If guards are in place, or some other means of one-way security filter, then the unclassified system may pass data to the secret system, but not vice versa. However, if Multi-Level Secure (MLS) applications are operational and accredited, then the systems may pass information seamlessly.

Interoperability Maturity Model

2.4.1.4 Operations

Operational considerations are important to interoperability, but they are exceedingly difficult to measure. These considerations are most applicable to large systems or organizations when they are used in specific operations or exercises. Data for these considerations will change for a given system depending on the exercise or operation. Examples of these considerations include network, e-mail servicing, and bandwidth considerations as described below:

Network: A system may be fully capable of interfacing with a network, but if a network server is required and not present, the network will not function and data transfer will not occur. Likewise, if no naming plan or system Internet Protocol (IP) identification convention has been determined, the IP network will not function properly and interoperability will not be possible.

Mail: A system may be fully capable of utilizing a mail server to send and receive e-mail messages with attachments, but if the mail server is not present or is not compatible with the available mail client, e-mail transactions will fail.

Bandwidth: In an environment that depends on connections and bandwidth capability to provide interoperability between systems, the proper size bandwidth and agreed upon frequency allocation plans must be in place.

The operational considerations do not consider whether these plans have been implemented properly. LISI cannot measure user errors. However, if no plans are in place to handle such operational aspects, then there is little chance of interoperability occurring consistently.

2.4.2 The Applications Attribute of Interoperability

The *applications (A)* attribute of **PAID** encompasses the fundamental purpose and function for which any system is built — its mission. The functional requirements specified by users to perform an operational activity are the very essence of the software application. Whether it is the need to do simple word processing or perform advanced nuclear targeting, the functions being accomplished and the applications that support them represent the system's capabilities to the user. For interoperability to occur effectively, similar capabilities or a common understanding of the shared information must exist between systems; otherwise, users have no common frame of reference.

As with the other attributes of interoperability, software applications demonstrate increasing levels of sophistication as they progress upward with the interoperability maturity levels. At the low-end, stand-alone applications such as word processors provide a type of discrete functionality. At the mid-range, client-server based applications provide a means for data separation — that is, information is not formatted for use by only a single function; it is accessible in a common format from a commercial database environment. At the higher end, applications are designed for cross-discipline or cross-organizational boundaries where common data definitions are required to provide the semantic understanding of the information being shared. Finally, at the highest maturity level of interoperability, the need for duplicate functions and applications is reduced or

eliminated through common understanding, a “system of systems” may now emerge, and the ability to function using a global, integrated, information space becomes readily viable.

2.4.3 The *Infrastructure* Attribute of Interoperability

Infrastructure (I) is the attribute that supports the establishment and use of a “connection” between systems or applications. This connection may be a simple, extremely low-level exchange (e.g., transfer of removable media between systems where no electronic connection actually exists), or it could consist of wireless IP networks, operating at multiple security levels. These two examples point out the breadth of the communications and hardware aspects. *Infrastructure* also includes “system services” that facilitate systems operations and interactions. These are items such as communication protocol stacks and object request brokers that are used by functions to establish and affect interactions between systems. The security devices and technical capabilities that are used to implement security procedures also make up a part of infrastructure.

2.4.3.1 Communications and Networks

There are numerous ways to establish an actual electronic connection between systems. One way is to utilize a simple point-to-point connection at the lowest levels. A cable or other trivial connection between systems may form it. Sometimes, a more complex communication network is used to establish what is still a simple connection. Such is the case when two systems use a modem to connect over a telephone network in a peer-to-peer manner. Here, a simple connection exists at another level of abstraction (i.e., within a complex switched network that involves a many-to-many relationship), even though for the two systems it appears as if a simple cable connects them. At higher levels, systems can conduct communications with many other systems on a local connection. A LAN is a familiar example. Systems may also participate directly in complex communications networks. A computer connected to the Internet can establish connections with a great variety of systems across a multi-dimensional network.

2.4.3.2 System Services

System services are usually provided by software, though they are generally not considered part of the *applications* attribute. An operating system is one example of an *infrastructure* item that provides system services. One easily understood example is print services as they are provided in many of today’s commercial operating systems. The applications that support a particular function usually do not provide their own print capabilities directly to the printer. They instead rely on common services provided to the system that allow them to print in a generic way. Currently, LISI does not directly consider the area of common print services, but it does take into account similar concepts that contribute to interoperability between systems. Object request brokers used to conduct transactions between systems using the Common Object Request Broker Architecture (CORBA) are one example of a system service that LISI is currently designed to consider.

Interoperability Maturity Model

2.4.3.3 Hardware

There is a wide variety of hardware an information system requires to perform its intended function. Some is important to the system itself and required for its very existence (such as a Central Processing Unit [CPU]). Much of this hardware facilitates interactions between and among systems. The network interface card allows a system to connect to a local network that may be part of a larger Wide Area Network (WAN). The removable media disk drive and the disk itself support transfer of information between systems in the simplest way. Hardware items are considered by LISI to the extent that they directly contribute to interoperability between systems.

2.4.3.4 Security Equipment

Encryption devices are probably the most familiar examples of security equipment that make up this part of the *infrastructure*. These play an important role in the DoD to help implement security policies that are put in place for information exchange. Other equipment also is used to establish and enforce security policies. Firewalls are critical to enforcing security policies on a communications infrastructure. There is also equipment that supports much more advanced security policies. One- or two-way guards between different classification levels are examples.

2.4.4 The *Data* Attribute of Interoperability

The *data* (**D**) attribute of interoperability focuses on the information processed by the system. This attribute deals with both the data format (syntax) and its content or meaning (semantics). It includes all the forms of data that support every level of a system's operations — from its operating system and communications infrastructure to the full set of end-user applications. The *data* attribute embodies the entire range of information styles and formats: free text, formatted text, databases (formal and informal), video, sound, imagery, graphical (map) information, et cetera. As such, the *data* attribute is understandably the most critical aspect of attaining systems interoperability. It is within this attribute where much of today's focus and work towards building interoperable systems is taking place (e.g., defining standard file formats, standards of databases, data definitions).

The following provides example forms of the *data* attribute that directly influence system interoperability:

Homogeneous Information: The simplest form of information is a file composed of one content type (e.g., text, image, sound, maps without overlays). These files are commonly entirely single-application dependent (e.g., word processor, spreadsheet, image viewer).

Heterogeneous Information: This form of information represents data repositories that contain more than one data format. This includes files that contain multiple forms of information in a single file or in a collection of homogenous files that have been organized or interrelated to present a single, consolidated object. Examples of these types of files include multimedia documents, annotated imagery, overlaid maps, target folders.

Shared Information: Data of this type represent the broad group of information typically associated with large databases that can be shared between independent, but common, discipline-based applications. Unlike the homogeneous or heterogeneous file formats which are basically defined by a formal syntax, shared forms of information also add some level of semantic meaning based on common data definitions, common data models, or a common rule base for knowledge representation.

Information Space: The integration of data into an information space that supports all forms of data representation, presentation, and exploitation represents the C4I goal architecture. Today, these form of information are beginning to be expressed as “objects” that combine the traditional data “value” with a set of valid “operations” that can be performed and are a part of the data’s definition. This type of information space provides a high level of system interoperability through common informational/object definitions and their use across all functional domains and organizational boundaries.

The **PAID** attributes represent the four key building blocks upon which each level is constructed. The next section will expand upon the relationship of the LISI levels and **PAID** in the form of the LISI Reference Model and the LISI Capabilities Model.

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Section 3

LISI Assessment Basis

A reference model, such as that defined within LISI, is commonly described as a set of concepts, entities, interfaces, and diagrams that provides common ground for understanding and comparisons. The use of a reference model provides a valuable means for evaluating and comparing information systems. In the case of LISI, this involves collecting, analyzing, measuring, and comparing systems against a common basis of assessment to determine the level of interoperability inherent in a system or that is present between any pair of systems. Generally, a reference model does not provide a specific system design or prescription for implementation, but it does define a common set of services and interfaces for building specific designs.

For example, the DoD Technical Reference Model (TRM) was developed as a framework for evaluating technical implementations and for specifying overall system characteristics. The JTA was developed to specify technical implementations used in building a system. Jointly, the TRM and JTA provide implementation guidance for systems so they exhibit the technical characteristics deemed important to DoD. In a similar manner, the *LISI Reference Model* does not prescribe specific implementation choices necessary to attain a level of interoperability. Instead, LISI draws heavily from commonly existing organizational directives and mandates. In the case of DoD, these implementation choices are derived from related sources such as the JTA, DII COE, and SHADE.

3.1 The LISI Reference Model

The *LISI Reference Model* is the foundation for the LISI process. The rows of the *LISI Reference Model* are the five LISI interoperability levels, and the columns are the four **PAID** attributes. The level/attribute intersections provide the broad classifications for addressing what specific capabilities are needed. At a particular level, the referenced capabilities (discussed in section 3.2) must be present for each attribute in order to achieve the degree of interoperability maturity defined by that level.

The *LISI Reference Model* is shown in Figure 3-1. The first three columns supply the identification of the interoperability level being defined, and the next four columns provide a broad representation of the contribution provided by each attribute of **PAID** (i.e., what general types of *Procedures, Applications, Infrastructure*, and *Data* capabilities need to be present to acquire this level of interaction).

LISI Assessment Basis

<i>Description</i>	<i>Computing Environment</i>	<i>Level</i>	P	A	I	D
Enterprise	Universal	4	Enterprise Level	Interactive	Multi-Dimensional Topologies	Enterprise Model
Domain	Integrated	3	Domain Level	Groupware	World-wide Network	Domain Model
Functional	Distributed	2	Program Level	Desktop Automation	Local Networks	Program Model
Connected	Peer-to-Peer	1	Local/Site Level	Standard System Drivers	Simple Connection	Local
Isolated	Manual	0	Access Control	N/A	Independant	Private

Figure 3-1. LISI Reference Model

The complete *LISI Reference Model* provides a baseline for the major capability thresholds across **PAID**. The *LISI Reference Model* also provides the common vocabulary and structure needed to discuss interoperability between systems. At each level, a word or phrase highlights the most important aspect of **PAID** needed to achieve that level. For example, a system targeting interactions with other systems working at Level 3 (*Domain Level* in an *Integrated Environment*) must build toward the specific set of capabilities that underlie the **PAID** thresholds of the *LISI Reference Model* at Level 3 (domain level procedures, groupware applications, access to world wide networks, and domain data models).

Although each attribute (**PAID**) is significant and must be considered in defining a level of interoperability, the significance and relative impact of the contributions from each attribute varies by level. Though attainment of all of a specific level's capabilities prescribed across **PAID** is critical, one attribute emerges as a primary enabler for achieving each level of interoperability while the other three attributes tend to provide "supporting" contributions.

The following paragraphs describe each level of interoperability with respect to the influence provided by the four key **PAID** attributes. Understanding the influence and relationships of these attributes is critical. These relationships help to show the increasing complexities of the computing environments. This understanding assists in determining where and how critical resources can be applied to improve future systems interoperability.

3.1.1 LISI Level 0 — Isolated Interoperability in a Manual Environment

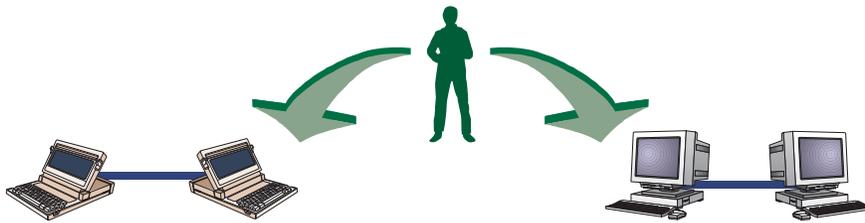


Figure 3-2. Level 0 — Isolated Interoperability in a Manual Environment

Figure 3-2 represents Level-0 interoperability. Level 0 is described as isolated interoperability in a manual environment. The key feature of Level 0 is human intervention to provide interoperability where systems are isolated from each other. Level-0 systems need to exchange data or services, but cannot directly interoperate. The lack of direct, electronic connectivity may exist solely due to differing security or access-control policies, or it may be a lack of physical connection between two systems.

*The primary enabler of Level-0 interoperability is **procedures**.* Procedures must exist to permit interaction between disparate systems via a human interface.

Procedures: The important procedural items at Level 0 are access controls. Procedures must exist to enable a human to interact with the systems so that information can be passed from a system to a human and on to another system. These procedures include physical security, login procedures, and other such security issues. One major contributor to Level 0 is the inclusion of the first three *NATO Levels of System Interconnection*. These levels apply in the form of access controls for personnel between information systems. At the top end of this level, media exchange procedures become the important aspect in interaction.

Applications: The *application* attribute does not come into play at this level. While there may be some software applications that must interact with data transferred by removable media, these items are not considered here. The actual transfer of information at Level 0 is independent of any applications used.

Infrastructure: The *infrastructure* capabilities that Level-0 systems exhibit are largely independent. Since two systems are unable to connect physically, only the infrastructure items that allow information sharing by other means are important. This primarily involves hardware-based interactions, usually by removable media. The important characteristics of media devices are the types of media they support and the low-level form that information is placed on the media. There are many types of removable media in the information systems arena. The more common items, such as floppy disks or CD-ROMs, have standards associated with them that facilitate compatibility between systems. Beyond the physical structure of the media, the file system placed on the media is also important.

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Another way for isolated systems to interact is by manual intervention of operators. This “swivel-chair” or “sneaker-net” approach is facilitated in a basic way by the hardware. Monitors on systems facilitate the readout of information from one system and entry into another. Printers can support a very low level of interoperability by allowing output from one system to be moved to another system and potentially re-input. These interactions are of a trivial nature from the infrastructure perspective. LISI does not attempt to capture the ability of printers or monitors to support this type of interoperability beyond that already covered as *procedures*.

Data: Private data models characterize the *data* attribute at Level 0. Information exchange is limited to magnetic media exchange. Data are organized independently with unknown commonalities. Interaction or pseudo interoperability, if possible, is accomplished through disk, tape, or similar media that can be used to transfer data manually between systems. File formats differ greatly and compatibility is possible only if the same type systems are used by both. Isolated systems use only homogeneous data or files composed of one data type (e.g., text, image, sound, maps without overlays).

3.1.2 LISI Level 1 - Connected Interoperability in a Peer-to-Peer Environment

Figure 3-3 represents LISI Level-1 interoperability. Level 1 is described as connected interoperability in a peer-to-peer environment. The key feature of Level 1 is physical connectivity providing direct interaction between systems. Level-1 systems have an established electronic link characterized by separate peer-to-peer connections. At this level of interoperability, the interactions are between discrete systems. Links can locally support simple file exchanges between systems. The type of files exchanged is typically homogeneous in context (e.g., text-only file, a bitmap file).

*The primary enabler of Level-1 interoperability is the **infrastructure**.* Infrastructure provides the physical link between the systems that allows data to flow from one system to another.

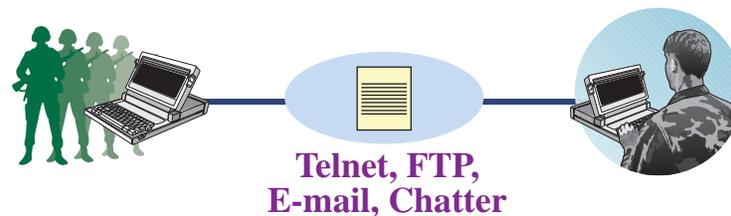


Figure 3-3. Level 1 — Connected Interoperability in a Peer-to-Peer Environment

Procedures: The *procedures* attribute of Level-1 interoperability is characterized by local and site-level procedures. These include conformance and compliance to standards and the existence of a security profile. For a given implementation, there may be additional procedures at the local or site level, such as ensuring that system names and addresses are not duplicated on a LAN and that appropriate servers are present at the site.

Applications: Level 1 of the *applications* attribute commonly relates to the simple exchange of homogeneous information electronically. Examples include file transfer software and simple interaction software such as e-mail without attachments and text chatter. Other functionality characterized here includes applications that process voice (transmit/receive), process telemetry, and provide remote-access capability. Simple text editing and graphics programs as well as basic functional-specific applications also appear at Level 1.

Infrastructure: The *infrastructure* supporting a Level-1 interoperability is concerned with establishing an electronic connection between systems. This connection could be a one-way broadcast at the lowest level. This gives only limited interoperability due to the inability to respond back. There are interoperability-related issues that must be considered for a one-way connection, but they do not facilitate a higher level of sophistication in system-to-system interaction. The two-way connection is important to conduct the type of interactions that are embodied in improving the level of interoperability.

Beyond simply sending a spark across a wire, there is a need for common protocols and understanding at both ends of the link before valid information exchanges can occur. The myriad of technical details required to guarantee a connection can quickly become overwhelming. LISI does not attempt to track every one of these details. Instead, it focuses on those choices made by a system developer that are the primary contributors to the potential for an interpretable connection. Regardless of the technical details of bits and timing, it is clear that if one system chooses to use LINK-16 and another LINK-22, they will not be able to connect. The two systems are not compatible in their basic forms. Simply knowing this information and having it available for comparison between systems can be more than enough to show that, in the absence of other connections, Level-1 interoperability cannot be achieved between these systems.

The types of infrastructures that support a Level-1 interoperability are those that establish simple peer-to-peer connections. Cables used to plug two systems together are important at this level, as well as the low-level protocols used to move data across the wire. Radio links are also considered at Level 1. These links allow a system to set up a two-way connection and support transfer of voice or data. A simple voice radio is an example of the type of infrastructure that is found at Level 1.

Data: Local data models characterize the *data* attribute at Level 1. Information exchange is generally restricted to simple homogeneous data product formats. Level 1 includes individual, independent databases with some data dictionaries and models, standard data elements, and data architectures; but Level 1 can only handle simple forms and styles of homogeneous data.

3.1.3 LISI Level 2 — Functional Interoperability in a Distributed Environment

Figure 3-4 represents Level-2 interoperability. Level 2 is described as functional interoperability in a distributed environment. The key feature of Level 2 is the ability of independent applications to exchange and use independent data components in a direct or distributed manner among systems. Level-2 systems must be able to exchange and process complex (i.e., heterogeneous) files. These files consist of items such as annotated images, maps with overlays, and multi-media

LISI Assessment Basis

or hyper-linked documents. The systems are generally connected to multiple systems on local networks. A key capability provided by systems or applications, at the top end of this level, is the ability to enable and provide web-based access to data.

*The primary enabler of Level-2 interoperability is **applications**.* The applications must be able to read, write, and process the information that is exchanged.



Figure 3-4. Level 2 — Functional Interoperability in a Distributed Environment

Procedures: Level 2 of the *procedures* attribute is characterized by program types of procedures. These procedures include such things as training, staffing, and planning in a program environment so that other systems within the same program environment will have similar procedures in place. In addition, other procedures are based on adherence to a common operating environment. In the DoD enterprise, the common operating environment is the DII COE.

The data segments used at Level 2 either implement DoD 8320 data standards or have an approved plan for doing so. They do not use machine-dependent data types. Data objects and elements follow DoD naming conventions based on definitions for schema components provided in the DBMS data dictionary.

Applications: Level-2 systems are identified by their increasing level of sophistication and complexity and by their ability to provide a heterogeneous understanding of the data being exchanged. E-mail at this level includes the successful exchange of attachments. Software necessary to parse formatted messages such as U.S. Message Transfer Format (USMTF), Variable Message Format (VMF), Over-the-Horizon – Gold (OTH-G), and AUTODIN is present. Office automation is associated with this level, and is characterized by software products such as word processing applications, spreadsheet applications, desktop data base applications, presentation graphics applications, and image and map viewers. Web browsers and their associated “helper” applications complete Level 2.

Infrastructure: The primary change in *infrastructure* capabilities from Level 1 to Level 2 is the transition from a peer-to-peer connection to a many-to-many connection, as represented by LANs. This need to work with multiple systems is driven by application functions such as e-mail. This form of collaboration requires connections to more than one system before it is truly effective. The ability to establish connections to multiple systems without reconfiguring hardware or the infrastructure is a major characteristic of this level. Support for protocols that can be used to establish even larger networks also comes into play. The TCP/IP protocol is used to

exchange information on a LAN through such functions as a web browser. The TCP/IP protocol also has the capability to support more complex infrastructures that are seen at Level 3.

Level-2 infrastructures support moving information locally between multiple systems. The differentiation between the particular systems is supported by the infrastructure with minimal need for user involvement. Hardware and communications protocols are designed to move information between multiple systems. Some examples are Network Interface Cards (NICs), and LAN protocols such as Ethernet or Token Ring.

Data: Level 2 of the *data* attribute is characterized by a program data model and consists of sub-domain or program-wide, generally independent, duplicate databases that:

- Contain heterogeneous information,
- Use conversion protocols as required, and
- Are based on the following program-wide tools: data dictionary, encyclopedia, logical and physical data models, existing data architecture, and data servers.

The program databases are not generally cleanly separated from applications.

Systems use heterogeneous data to represent data repositories that contain more than one data format. These repositories include files that contain multiple forms of information in a common operational file or as a collection of homogenous files that have been organized or interrelated to present a single, consolidated information object. Examples of these types of files include multimedia documents, annotated imagery, maps with overlays, and target folders.

3.1.4 LISI Level 3 — Domain Interoperability in an Integrated Environment

Figure 3-5 represents Level-3 interoperability. Level 3 is described as domain interoperability in an integrated environment. The key feature of Level 3 is a domain perspective that includes domain data models and procedures where data is shared among the independent applications which may begin to work together in an integrated fashion. Level 3 is characterized by multiple application-to-application interactions. Systems and applications are interconnected, but generally operate on a single functional set of data (e.g., intelligence, C2, logistics). Implementations at this level usually have only a localized view of the distributed information space and cross only one operational or functional domain.

The primary enabler of Level-3 interoperability is data. The direct use of shared databases without data translation, re-mapping, or duplication within a function characterizes this level. To achieve Level 3, common data definitions and functional/physical data models play the critical role. Additionally, the design of object-oriented databases should increase information and process reusability. As object technology is implemented and the systems mature, the distinctions between data and applications become increasingly blurred.

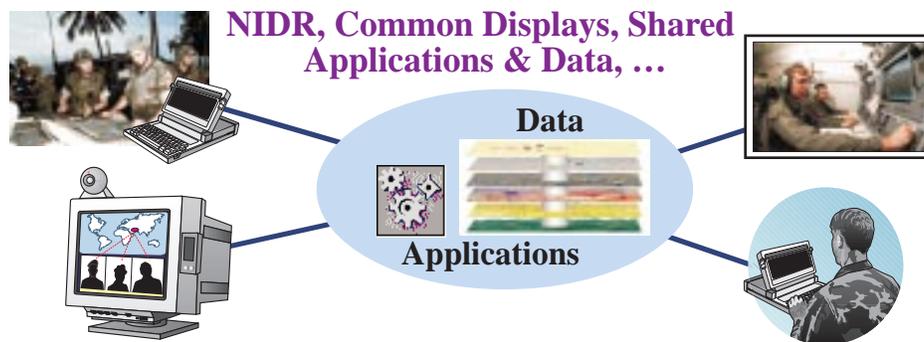


Figure 3-5. Level 3 — Domain Interoperability in an Integrated Environment

Procedures: Level 3 of the *procedures* attribute is characterized by how well a system conforms to domain doctrine and missions. Doctrine represents the broadest form of system guidance by a Service or Agency. By definition, it should provide the greatest influence on overall system development for successfully conducting Joint operations. Unfortunately, it is also the most difficult arena for gaining common agreement. Each Service and Agency operates in a different culture, and even the most basic vocabulary can take on multiple meanings. For example, the word “tank” is both a weapon system (Army) and a fuel storage device (Air Force). The broader the doctrine that is followed in any given system, the better chance that system has of interoperating with other Joint systems. *Joint Chiefs of Staff Publications* are the primary vehicles for providing current, common doctrine for Joint operations. However, other publications, provided by the Services, provide guidance for Service doctrine that may limit Joint interoperability opportunities.

One way to assess how well a system complies with domain doctrine is to examine the documentation associated with the system and its requirements. A domain type of system should fulfill domain types of requirements and missions. User requirements for a system are most commonly reflected in its Required Operational Concept (ROC), Mission Need Statement (MNS), and Operational Requirements Document (ORD). Other types of guidance that may directly influence interoperability considerations include Joint Mission Areas (JMA) and the Universal Joint Task List (UJTL).

Applications: Level 3 of the *applications* attribute is focused on integration either across organizational boundaries or across discipline-based applications. Transition toward object-oriented programming languages increases software reusability and supports increasing levels of interoperability. Applications that support full-text cut and paste, group collaboration (e.g., White Boards, Video Teleconferencing [VTC]), and shared data (e.g., Situational Displays, direct data base exchanges) are present at Level 3.

Infrastructure: A Level-3 *infrastructure* represents the transition from a local network to a wider area network. This is broadly referred to in the *infrastructure* area as WAN. The distinction at Level 3 is an ability to connect to other users that are not connected to the same shared local media. This gives a Level-3 infrastructure the ability to work between LANs to make up a broader domain. The need to cross between different media of multiple LANs dictates the need

for switching or routing at Level 3. This is the case with the Ethernet's Address Resolution Protocol (ARP). One result of this consideration is the need for protocols that support this form of networking. These protocols often assign a particular address to each system on the WAN. This address is globally known and used to address the system at Level 3.

An evolution from Level-2 to Level-3 systems is that information packets are not globally broadcast at Level 3. This was the case with LANs or a Net, where any information sent to other systems on a Level-2 infrastructure could potentially be picked up by all systems on that infrastructure. A Level-3 infrastructure is more selective regarding how information packets are exchanged. The combination of unique global identifiers for each entity and the routing and switching functions of Level 3 allow support for more robust security models. The infrastructure can be configured to allow or deny access to particular areas. Simple firewalls are the most prevalent example today of this feature.

Data: Level 3 of the *data* attribute is characterized by a domain model that allows direct database exchanges. This level is comprised of domain data models, dictionaries, and standard data elements.

Domain-wide shared databases contain heterogeneous information and are based on the following domain-wide tools: data dictionary, encyclopedia, logical and physical data models, data architecture, shared data, and shared data servers. The domain organizations' requirements (normally from Services in a Joint environment) are based on standard and shared domain-wide data element definitions. Level-3 data is consolidated into manageable, shared assets that are correlated and loosely fused, or integrated, by using middle-ware.

Level-3 information represents the broad group of information typically associated with large databases that can be shared between independent, but common domain-based applications. Unlike the homogeneous or heterogeneous file formats which are basically defined by a formal syntax, shared forms of information also add some level of semantic meaning based on common data definitions, common data models, or a common rule base for knowledge representation. The database is relational (e.g., ANSI Standard Query Language (SQL)).

3.1.5 LISI Level 4 — Enterprise Interoperability in a Universal Environment

Figure 3-6 represents Level-4 interoperability. Level-4 is described as enterprise interoperability in a universal environment. The key feature of Level 4 is a top-level perspective that includes enterprise data models and procedures, where data is seamlessly shared among the applications that work together across domains in a universal access environment. Level 4 is the ultimate goal of information systems seeking interoperability across functional activities and informational domains (e.g., Intelligence, C2, and Logistics). At this enterprise level, information is shared globally through a distributed information architecture. Applications and systems operate as necessary across all the functional data domains. The "virtual" workspace uses shared applications operating against an integrated information space. Level 4 represents the capabilities necessary to achieve concepts proposed in DoD's *Joint Vision 2010* documents.

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The primary enabler of Level-4 interoperability is **procedures**. Agreement must be reached on enterprise-wide functions, activities, and operational procedures that cross domain-level doctrine and definitions to ultimately allow universal interoperability.



Figure 3-6. Level 4 — Enterprise Interoperability in a Universal Environment

Procedures: Level 4 of the *procedures* attribute is characterized by how well a system conforms to enterprise doctrine and missions. Where domain systems meet domain requirements for Level 3, enterprise systems fulfill enterprise requirements for Level 4. The systems that are considered Level-4 are not designed or limited to providing Service- or Agency-unique functions. Rather, they provide cross-domain functions that contribute to the entire enterprise. One way to assess how well a system complies with enterprise doctrine is to examine the documentation associated with the system and its requirements. For DoD, documents such as a MNS and ORD will reveal the degree of “Jointness” intended. Other types of guidance that may directly influence interoperability considerations include JMAs and the UJTL.

Plans are also examined at this level to ensure that, where applicable, an evolutionary approach has been taken to support changes in technology and implementation across the enterprise. Additionally, plans must be in place to comply with evolving architectures and standards that govern Joint operations. Plans for training, staffing, and other operational needs at this level must comply with enterprise requirements.

Applications: Level 4 of the *application* attribute focuses on elimination of duplicative functions and redundant applications. Systems serve the primary functions across Service and Agency boundaries using component-based architectures such as CORBA, Java, and Distributed Component Object Model (DCOM) on a multi-platform infrastructure. Full “object level” cut and paste between systems is a component of this level.

Infrastructure: The *infrastructure* required to support a Level-4 interaction is more advanced than the standard WAN structure of today’s IP networks. “Multi-dimensional” is the key descriptor of a Level-4 infrastructure. This multi-dimensionality can exist in geography, security, virtual configuration, or numerous other forms. One characteristic is that it allows the user to set up the infrastructure to duplicate features of lower levels within the WAN context. For example, a Level-4 infrastructure may be used to establish a secure peer-to-peer connection using Point-to-Point Tunneling Protocol (PPTP) within the broader global network. It could be used to set up a

virtual LAN between users on four different continents to collaborate on a mission. It supports features such as protocol wrapping and has mechanisms to control quality of service.

Another feature of a multi-dimensional topology is the ability to support multiple security levels and access controls on the WAN. This could include portions at different classification levels with appropriately configured guards or gateways controlling information exchange. There are some basic examples of this in use today. This aspect of a multi-dimensional topology has been one of the most difficult to reach, especially when different classification levels are considered.

Data: Level 4 of the *data* attribute is characterized by an enterprise-wide model that is comprised of universally accepted data models, dictionaries, and standard data elements. The fully integrated enterprise information space is based on shared data servers and shared database; adheres to a common enterprise data model, standard data elements, shared data server, and data architecture; and supports full data conversion capability when required outside of the defined enterprise.

An integrated, distributed information space supports all application domains and leads to a virtual, shared database that includes a full data conversion capability. Level-4 data is integrated into an information space that supports all forms of data representation, presentation, and exploitation; and represents the C4I goal architecture. Today, information of this form is beginning to be expressed as an object, which combines the traditional data value with a set of valid operations which can be performed and are a part of the data's definition. This type of information space provides a high level of system interoperability through common informational/object definitions and their use across all functional domains and organizational boundaries.

The Joint community is the primary user of the single logical C4ISR database that reflects a cost-benefit analysis of integration techniques. To meet the Joint requirements, DoD has reengineered and migrated databases into shared data servers. As a result, the DoD information is being logically unified into a single, fully integrated, and shared database that is transparently distributed throughout the enterprise. It adheres to the Shared Data Environment (SHADE) architecture, which has been established by a SHADE management process and supported by an integrated repository of SHADE products.

In summary, The *LISI Reference Model* describes, in broad terms, the intersections of the "levels" defined in the interoperability maturity model and the *PAID* attributes that define the composition and makeup of each level. Although the discussion of each level presented herein provides additional details beyond those presented in the maturity model (section 2), more refinement is necessary in order to bring a more definitive, "quantitative" factor to LISI. This quantitative factor is required in order for the LISI process to provide a formal measurement in the form of an "interoperability metric." The quantitative aspects of LISI are captured in the *LISI Capabilities Model*.

3.2 The LISI 97 Capabilities Model

As discussed in section 3.1, a reference model is a set of concepts, entities, interfaces, and diagrams that provides common ground for comparisons. It is a valuable tool for evaluating and comparing information systems. A reference model, however, does not provide the amount of detail required regarding a level and nature of interoperability to establish a formal metric for interoperability. Therefore, a further extension or “decomposition” of the reference model is necessary to capture the detailed characteristics exhibited by each level in terms of *PAID*. This extension is called the *LISI Capabilities Model*.

A capabilities model provides a means to identify the distinctions among systems. It is defined in terms of the discriminators that characterize the specific capabilities within a system. These discriminators determine the specific nature and level of interoperability of a system. Using a capabilities model, developers can also identify what characteristics their emerging systems must possess to attain a specific level relative to other systems.

A capabilities model also provides a consistent way to describe new capabilities to facilitate technology insertion. New technologies can be evaluated based on the types of interactions they support (*reference model*) and the characteristics they possess (*capabilities model*). The results of these evaluations lead to modifications and additions to the model that represent emerging technologies.

The process of adding new technologies requires input from many sources. The views of the acquisition community, users of emerging systems, industry representatives, and experimentation test beds are valuable for technology insertions. Conversely, LISI can be an important resource for these groups to guide them towards developing interoperable products that possess greater flexibility.

The *LISI Capabilities Model* will continue to evolve as technology advances and new paradigms are achieved. The *LISI 97 Capabilities Model* is based on the state of technology and conservative projections as of the end of calendar year 1997, and defines the specific thresholds required for attaining each level of interoperability. In addition to “decomposing” each broad level/attribute characterization of the *LISI Reference Model* into specific capabilities needed, the *LISI 97 Capabilities Model* also extends the *LISI Reference Model* by further subdividing each level where additional granularity is meaningful.

The *LISI 97 Capabilities Model* provides the essential evaluation detail needed to determine an interoperability profile and metric. It does not *prescribe* the particular technical implementations for attaining a level or sub-level; instead, the model highlights capabilities that are acceptable to the using enterprise as reflected in documents such as technical architectures and common operating environment specifications, and in de facto operational environments. Figure 3-7 shows the *LISI 97 Capabilities Model*.

LEVEL (Environment)			Interoperability Attributes					
			P	A	I	D		
Enterprise Level (Universal)	4	c	Multi-National Enterprises	Interactive (cross applications)	Multi-Dimensional Topologies	Cross-Enterprise Models		
		b	Cross Government Enterprise					
		a	DoD Enterprise	Full Object Cut & Paste		Enterprise Model		
Domain Level (Integrated)	3	c	Domain Service/Agency Doctrine, Procedures, Training, etc.	Shared Data (e.g., Situation Displays Direct DB Exchanges)	WAN	DBMS		
		b		Group Collaboration (e.g., White Boards, VTC)		Domain Models		
		a		Full Text Cut & Paste				
Functional Level (Distributed)	2	c	Common Operating Environment (e.g., DII-COE Level 5) Compliance	Web Browser	LAN	Program Models & Advanced Data Formats		
		b		Basic Operations Documents Briefings Pictures & Maps Spreadsheets Databases				
		a	Program Standard Procedures, Training, etc.	Adv. Messaging Message Parsers E-mail w/Attachments	NET			
Connected Level (Peer-to-Peer)	1	d	Standards Complaint (e.g., JTA)	Basic Messaging (e.g., Unformatted Text E-mail w/o Attachments)	Two Way	Basic Data Formats		
		c		Data File Transfer				
		b	Security Profile	Simple Interaction (e.g., Telemetry, Remote Access Text Chatter, Voice, Fax)	One Way			
		a						
Isolated Level (Manual)	0	d	Media Exchange Procedures	N/A	Removable Media	Media Formats		
		c	Manual Access Controls		NATO Level 3	Manual Re-entry	Private Data	
		b						NATO Level 2
		a						NATO Level 1
		o						NO KNOWN INTEROPERABILITY

Figure 3-7. LISI 97 Capabilities Model

LISI Assessment Basis

Like the LISI Reference Model, the first three columns of the LISI 97 Capabilities Model provide identification information for the interoperability level and sub-levels, and the next four columns associate the specific contributions of the **PAID** attributes to each level. Major thresholds are crossed in order to transition from one broad maturity level to the next; whereas, minor interoperability thresholds exist between the sub-levels of a given level. For example, to move from the Isolated Level (Level 0) to the Connected Level (Level 1), a major event/set of capabilities (direct electronic connectivity) is required. Comparatively, the threshold crossed moving from Level 1 to Level 0d requires the additional availability of removable media; however, the systems are still interacting in an Isolated (Level 0) fashion

3.2.1 The LISI Sub-Levels

As illustrated in Figure 3-7, implementations of the various **PAID** characteristics do not fall exactly in line with the major thresholds established in the reference model. The *LISI 97 Capabilities Model* introduces and defines the sub-levels necessary to provide this essential, additional granularity. The use of sub-levels allows distinctions between systems that exhibit an operational portion of the capabilities suite attributed to a major level. Sub-levels represent small improvements in the ability to exchange information within an interoperability level, and also represent incremental or transitional steps towards reaching a higher degree of overall interoperability.

The sub-levels within LISI correspond to increments within a level for at least one of the **PAID** attributes. For example, the Connected Level of Interoperability (Level 1) is characterized by a distributed computing environment wherein there are four defined sub-levels: Level 1a, Level 1b, Level 1c, and Level 1d. Within this level, the *applications* attribute displays three specific sub-level thresholds: systems at Level 1a and Level 1b provide simple access or limited-exchange interactions; systems at Level 1c support limited data transfers; and systems at Level 1d provide basic messaging. All of these capabilities represent basic, connected Level-1 interoperability. They do not yet exhibit the set of capabilities present within Level 2, Functional Interoperability. They do, however, show a distinct progression in sophistication and capabilities present within the Connected Level for *applications*.

3.2.2 Threshold Rules and LISI Levels

The idea of thresholds is vital to how a LISI level is stated. *In order to be assessed at a certain level, systems must fulfill all of the requirements identified within the PAID attributes up to the level attained.* In effect, the LISI level attained by a system is the “highest line” across **PAID** up to which all of the requisite **PAID** capabilities have been implemented *and* whose implementations have been assessed as interoperable. Furthermore, for each **PAID** attribute (i.e., the columns shown in Figure 3-7), the level attained within the individual attribute is attained only when all capabilities of the lower thresholds are represented within that attribute.

The term “represented” is used in a very broad sense for this purpose—it often implies “grandfathering” of lower level capabilities. In practice, the presence of a higher-level capability, intrinsically or by definition, frequently provides the representation (i.e., “credit”) for all or some portion of the lower-level thresholds. The decision of which *LISI Capability Model* thresholds are

essential vice grandfathered comes from careful analysis of the capabilities being performed at the higher level. Considerations include: what does it intrinsically foster, and what functionality is lost without the forced presence of the lower-level threshold(s) in terms of “backward interoperability” with lower-level systems. This “inheritance” effect is not restricted to sub-levels alone. For example, a system assessed with WAN (Level-3) capability, by definition, already possesses the capabilities exhibited by a LAN (Level-2). In layman’s terms, a WAN is simply a higher level version of a LAN with a broader set of capabilities.

Decisions about which thresholds within each attribute are essential or can be treated as inherited are embodied within a rules table. This table is applied during the LISI assessment process described later. The conditions captured within this table are the reflection of asserting two basic rules:

Threshold Rule 1: Within the capabilities model, there are explicit, essential capabilities that every system must possess. These capabilities act as barriers to being rated at a higher level until they are accomplished.

Threshold Rule 2: Within the capabilities model, thresholds are considered as being “credited” to the next higher level if they have not been designated as an essential, required capability as defined in Rule 1.

The following example illustrates both rules:

By LISI definition, a system is rated Level 2b only when all the **PAID** attributes are assessed (i.e., “measured”) as being fully represented up to and across that level. Again the term “represented” is being used broadly. Consider the following two cases:

Case 1: Missing Essential Capability

IF: Standards compliance is defined by the enterprise to be an essential characteristic of the *procedures* attribute for Level 1c/d

THEN: A system that is not standards compliant cannot be rated higher than Level 1b. This condition applies, regardless of whether all the other characteristics of the **PAID** attributes are otherwise fully Level-2b compliant, including those capabilities higher up within the *procedures* attribute.

For example, within the DoD, the JTA is a required architecture that represents the set of standards with which systems must comply. A system can be DII COE Level 5 compliant (captured at LISI Level 2b in *procedures*) and may not meet all JTA requirements (captured at LISI Level 1c/d). In this case, JTA compliance is a missing essential capability and the system cannot be higher than Level 1a/b.

REASONING: Without the presence of the essential or required characteristic defined by the *procedures* attribute (standards compliance), the system cannot be rated higher than Level 1a/b.

ULTIMATE VALUE: Through this form of attribute definition, enterprise standards, procedures, et cetera are forced upon systems by intentionally limiting the level attained

Case 2: “Grandfathered” Capabilities

IF: A system possesses the LAN characteristic for the *infrastructure* attribute (Level 2b) and the other three **PAID** attributes also assess at this level

THEN: The system does not specifically require the existence or implementation of each lower-level threshold (e.g., removable media) within the *infrastructure* capability to be assessed as Level 2b.

REASONING: All of the infrastructure sub-level capabilities described by the *infrastructure* attribute are considered as “inherited” (i.e., Level 2a—Net; Level 1b/c/d—Two-way; Level 1a—One-way; and Level 0d—Removable Media). In this situation, the absence of removable media (Level 0d) in an electronically connected environment does not impair the quality or functionality exhibited by interoperable systems across a LAN. However, knowledge that these systems may possess this capability can still be registered using the LISI process in case connectivity is lost.

ULTIMATE VALUE: This form of attribute definition removes the requirement for systems to unnecessarily implement lower-level functions and capabilities simply for the purpose of being compliant to the model (i.e., fully backward-level compatible). Since “cost” is a significant aspect of any system, careful judgment is required to determine the proper subset of lower-level capabilities a system should include in order to facilitate legacy or low-level interoperability.

3.2.3 Transitions between Sub-Levels within LISI

Sub-level transitions are not necessarily consistent across all of the **PAID** attributes. The impact of an attribute varies at each level, with particular attributes being the primary enablers for achieving a certain threshold. Because each attribute has its own characteristics at a particular level, some have more refined sub-levels than others. For the example given above at Level 2, the *data* attribute has no further refining thresholds, meaning that the existence of basic program models and advanced data formats is the primary criterion for attaining Level 2 for *data*. The *infrastructure* attribute, however, has two divisions: one-way and two-way connectivity. One-way connectivity occupies Sub-level 1a. Once two-way connectivity is accomplished, the *infrastructure* assessment moves to Sub-level 1b/c/d. (This notation implies that two-way connectivity is the highest form of threshold for a Level-1 assessment. This notation corresponds to a refining threshold that occurs between Sub-level 1a and Sub-level 1b. There are no other refining thresholds until a major threshold is encountered between Level 1 and Level 2. The next highest *infrastructure* capability is *Net* which occurs at Level 2.) Appendix A provides a detailed definition of each of the capabilities present at each threshold delineated in the current *LISI Capabilities Model*.

Implementation *Options Tables* provide further detail about the choices developers can make for attaining a specific capability within the capabilities model. These tables contain all known choices available for implementation. For those capabilities where there are established enterprise procedures for development or procurement (i.e., acquisition guidance), the standards and associated technical criteria are highlighted as are the available implementation choices (GOTS or COTS products or services) that are in compliance with the prevailing policies. Information gathered about systems is compared with the *LISI Options Tables* to create a “characterization” or profile of a system.

In summary, the *LISI Capabilities Model* and its supporting *LISI Options Tables* together constitute the “engine” that drives the LISI process and provide the basis for developing the LISI products described in section 4. The following paragraphs present a generic discussion of how to apply the *LISI Capabilities Model* as the basis for systems evaluation.

3.2.4 Applying the LISI 97 Capabilities Model

The *LISI Capabilities Model* provides the basis for assessing and comparing systems. Using the model described above as a reference, the individual attributes and capabilities of a system can be captured. Recording these attributes generates *Interoperability Profiles* for each assessed system or application. In effect, this creates a system-unique profile that only shows those capabilities that a particular system possesses. The profile of the system is across all **PAID** components.

There are three metrics that are used to express the interoperability level of information systems: generic, expected, and specific. The *generic* level of interoperability is the highest level at which the full suite of capabilities is implemented in a given system across **PAID**. The *expected* level of interoperability is determined by comparing the generic levels of any two systems. The *specific* level of interoperability is determined by comparing each systems’ specific implementation choices. The *specific* level may be lower, equal to, or higher than the *expected* level, and this will be explained in Section 4.1.2. The *LISI Implementation Options Tables* are necessary to determine the *specific* level of interoperability. In summary, generic and expected levels are obtained by comparing capabilities, while specific levels are determined by comparing implementation choices.

3.2.4.1 Generating an Interoperability Profile

The first step in generating a system’s *Interoperability Profile* is to gather information about the system. Questions must be answered about the *procedures, applications, infrastructure, and data* attributes of the system. The information gathered must contain enough detail to allow selection of options that characterize the system, based on the implementation choices available in the *LISI Options Tables*. The details are then overlaid on the *LISI Capabilities Model* to form the system’s *Interoperability Profile*. For each entry identified in the *LISI 97 Capabilities Model*, there is typically a variety of means and implementations possible. The LISI process does not dictate which implementation must be used; it captures what has been selected or what is being considered.

LISI Assessment Basis

Figure 3-8 illustrates the process of generating a system's *Interoperability Profile*. The *LISI 97 Capabilities Model* is shown on the left. Samples of the associated *LISI Options Tables* for *infrastructure* implementations are shown in the center of the figure. As implied in the figure, for any capability described in the *LISI 97 Capabilities Model* and associated *LISI Options Tables* (e.g., WAN), multiple implementations are possible (e.g., SIPRNET, NIPRNET, JWICS). Based on the answers to the LISI questions for the system under analysis, the system's characteristics are captured and mapped against the options tables. In this example, the system represented by S1 has SIPRNET and DISN-LES *infrastructure* capabilities. These characteristics are captured in the system's interoperability profile. Figure 3-8 shows the *infrastructure* portion of the system's interoperability profile.

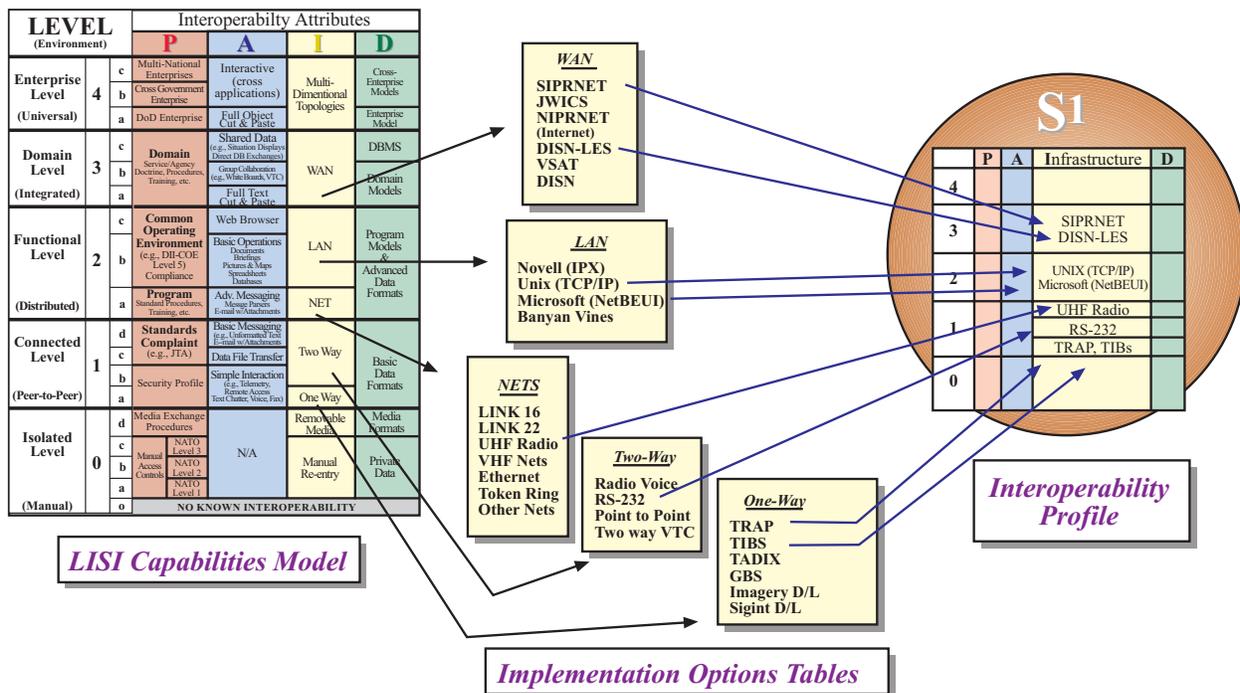


Figure 3-8. Generating an Interoperability Profile

Figure 3-9 contains an example of a complete *Interoperability Profile* for a notional battlefield command information system. The notional system allows the geographical location of soldiers, weapons, platforms, command posts, and other operational facilities to be presented collectively on a display. Figure 3-9 captures the essential technical characteristics of the notional system, mapped to the *LISI 97 Capabilities Model* template. The level of interoperability attained for each *PAID* attribute (the highest threshold at which the requisite capabilities are represented by a system implementation) is: *P* = 1d, *A* = 2b, *I* = 2c, and *D* = 1d. These attribute levels are highlighted in red. The overall *generic* level of the notional system is Level 1d, based on the highest threshold achieved across all four components. This level and profile can then be used in a number of analyses to generate several products. These products are discussed in detail in the next section.

Level			P	A	I	D
Enterprise	4	c				
		b				
		a				
Domain	3	c				
		b				
		a				
Functional	2	c			•UDP/IP	
		b		<ul style="list-style-type: none"> •GUI •Text docs •Applique Map Display •Applique Software 		
		a		•Army VMF Messaging	•Ethernet	
Connected	1	d	•Standards Compliant		•PPP	•Army VMF Messages
		c			<ul style="list-style-type: none"> •PLGR Int •PCMCIA Slot •SCSI 2 Int. •RS 232 •RS 422A 	•PLGR Data
		b	<ul style="list-style-type: none"> •Security Profile •U, S operations allowed 			•Map Data
		a				
Isolated	0	d			<ul style="list-style-type: none"> •Floppy Drive •Removable Disk 	•Disk formats
		c				
		b				
		a				
		0				

Figure 3-9. Interoperability Profile for Notional Battlefield Command Information System

3.2.4.2 Automating Information Collection

The process of collecting information about systems can be automated to facilitate consistent data automated mapping using the *LISI Capabilities Model* to generate an *Interoperability Profile*. This ensures that the mapping shown in Figure 3-9 is done consistently across all systems. The prototype currently contains a questionnaire that can be completed through a web interface to capture relevant data about a system. The tool then performs the mapping of the capabilities against the model, and calculates the resulting profile and level. The prototype tool can also be used to generate a number of other products, discussed in section 4.

Section 4

LISI Assessment Process and Products

This section describes the LISI assessment process, the current suite of LISI assessment products, and several representative scenarios for using LISI within the DoD. These scenarios encompass all stages of the information systems life cycle, from requirements analysis through operational engineering and upgrades in the field.

4.1 The LISI Assessment Process

The LISI process involves the methodology and the means for bringing to bear the LISI Interoperability Maturity Model and its associated assessment basis to evaluate the current and postulated interoperability of DoD systems. The LISI process includes the determination of cost-effective strategies and cross-community agreements for improving interoperability and for achieving incrementally higher states of information-exchange capabilities over time.

Figure 4-1 presents a summary of the LISI process. As program managers (PMs) and system developers register their system's questionnaire, existing and postulated systems can then be assessed to identify what level of interoperability a particular system provides (shown on right).

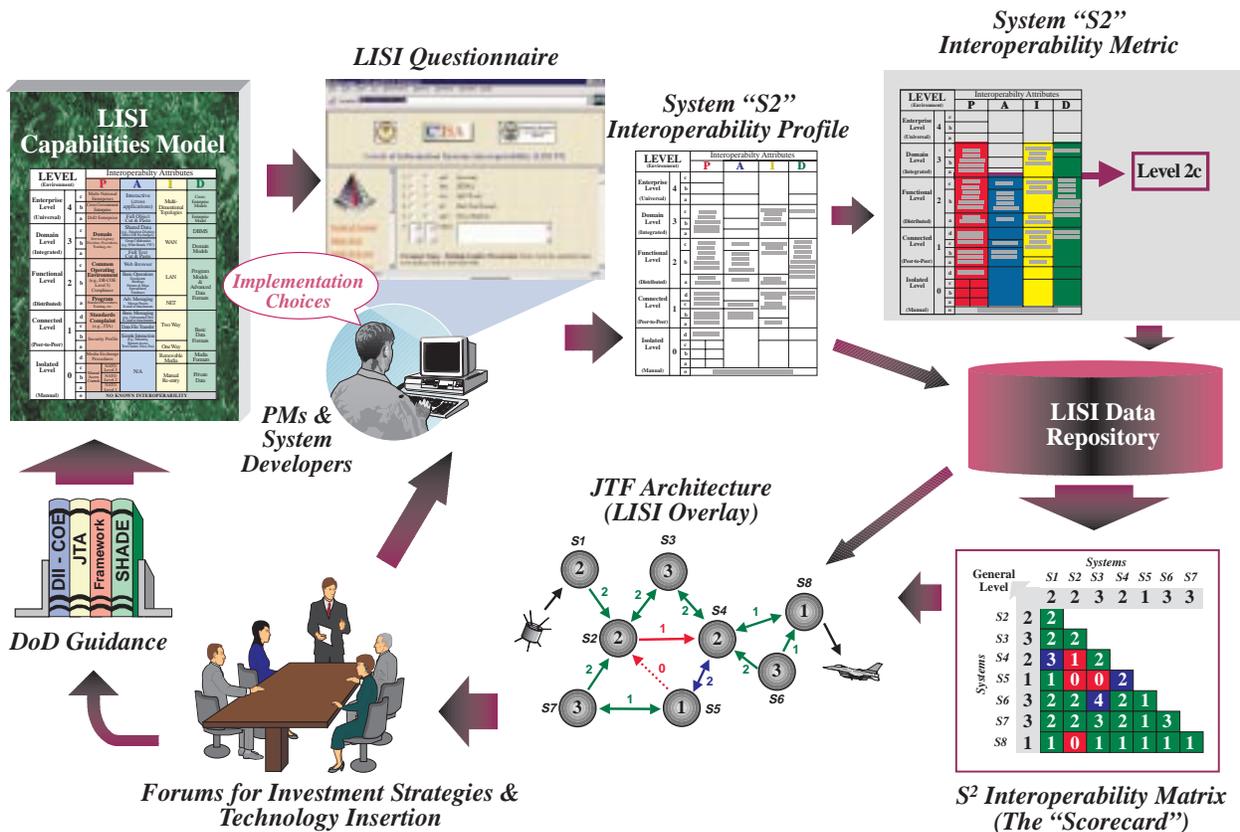


Figure 4-1. A Capsule View of the LISI Assessment Process

LISI Assessment Process and Products

The collection of these registered profiles provides the basis for conducting system comparisons.

The results of these comparisons can be displayed in a number of products. Two of the key types of LISI products are shown in the lower right and lower center of the figure — the interoperability assessment matrix and JTF architecture (LISI Overlay). Each product type plays a critical role for improving enterprise interoperability.

Shown in the lower left corner of Figure 4-1 is the critical role that management plays with the use of the LISI products to identify gaps, shortfalls, and improvement strategies and agreements. Products such as an architecture interoperability overlay serve to relate systems interoperability shortfalls or proposed improvements to measured impacts on the ability to support specific mission operations. In other words, LISI provides the interoperability metric for a given system (level of interoperability), and the operational architecture overlay answers the “so what?” question in context with mission effectiveness. This “audit trail,” from systems to operational needlines, provides a critical input in the form of “measures of performance” that DoD CIOs must now report in accordance with recent legislation governing IT management and oversight.

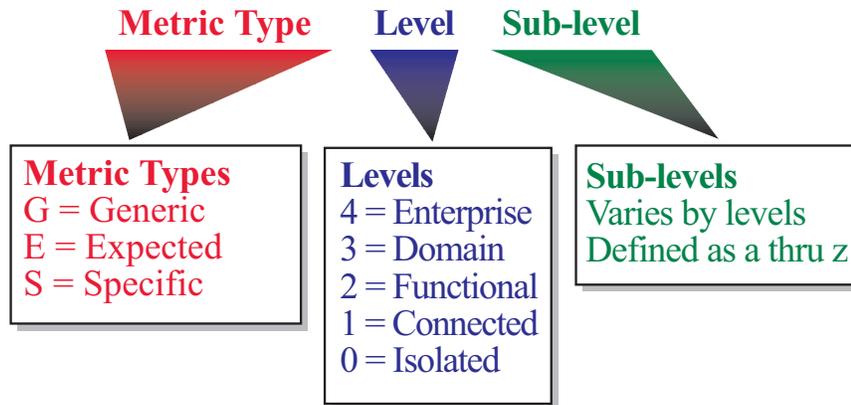
The systems assessment matrices help to identify disconnects brought about by the implementation choices being made by developers. Many times these choices are based on new technology that is not yet a part of the enterprise standards but is already being adopted by industry. Through analysis and discussions regarding the impacts these choices make on enterprise interoperability, decisions will often lead to modifications of existing guidance in order to keep it current, useful, and affordable for developers.

4.2 LISI Metrics

The value of conducting an interoperability assessment using LISI is fully realized in the expression of its results in the form of an interoperability metric. The LISI metric is a quantitative portrayal of the “degree of interoperability” attained between systems. It is derived using the *Interoperability Questionnaire* as the data source and the *LISI Capabilities Model* as the measurement template.

The purpose of the LISI metric is to capture the essence of potential interactions available between systems, as registered through the implementation choices made by developers. The metric is therefore a direct reflection of the comparison of interoperability profiles between systems.

The LISI interoperability metric comes in various flavors based on the nature, purpose, and approach to performing and displaying the results of the comparisons. An example of the various options for describing LISI metrics is shown in Figure 4-2.



LSI Level (Short Form) G2
LSI Level (with Sub-level) G2b

Figure 4-2. The LSI Interoperability Metrics

The LSI metric provides a shorthand definition of the particular form of interoperability as expressed in the LSI maturity model. The LSI metric provides the maturity-level entrée to the LSI Capabilities Model for rapid identification of the system’s inherent characteristics. For example, Figure 4-3 describes the inherent characteristics of a system rated as “G2b.”

“G2b” means the system or application has a Generic Level of “2b,” therefore:

- It complies with JTA and DII-COE
- It can operate on a LAN
- Its environment is built within a GUI
- It supports common office functions
- Its database information is compliant with a particular functional program

Figure 4-3. Interpreting the LSI Interoperability Metric

As described earlier in Figure 4-2, there are three types of LSI metrics based on three kinds of relationships being measured. The main distinction between these three types is the comparison of a single system against the capabilities model (*generic*) and the two different cases where two or more systems are compared to each other (*expected* and *specific*). These are defined more formally in the following paragraphs.

4.2.1 Generic Level of Interoperability

The *generic* level of interoperability is derived for a single system and is the value calculated by comparing a single system against the *LISI Capabilities Model*. The *generic* level is determined by the collective set of capabilities across *PAID* that a system exhibits in practice. For a given system, the *generic* level of interoperability is the highest level within the *LISI 97 Capabilities Model* at which *all* of the *PAID* capabilities for that level have been implemented (independent of specific implementation choices). This requires that a system must have implementations for each capability within the *PAID* attributes, and that all sub-levels have been represented as discussed in section 3.



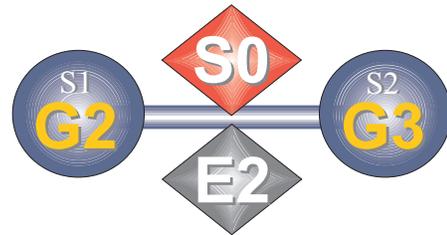
4.2.2 Expected Level of Interoperability

The *expected* level of interoperability is assessed for a pair of systems and is the level that is anticipated using the *LISI Capabilities Model* as a reference, but without performing an implementation-by-implementation comparison between the two systems. The *expected* level of interoperability between two systems is simply the lesser of the two systems' generic levels, i.e., the level at which one would *expect* the two systems to interoperate. The *expected* level is based on the principle that two systems should be able to interoperate at a given level if each system has the suite of generic capabilities required to achieve that level's types of information exchanges. For example, if a system (generic Level 2d) is being assessed for interoperability with another system (generic Level 1d), then it is expected that the two systems will be able to perform interactions characterized by Level 1d. This principle reflects the cumulative nature of the interoperability levels; however, variations in implementation choices made between the two systems may not make this assumption accurate.



4.2.3 Specific Level of Interoperability

The *specific* level of interoperability is the calculated metric between two systems as a result of comparing the specific implementation choices that each system has made regarding the registered *PAID* capabilities. The *specific* level represents the highest level at which the two systems have documented common or interoperable implementations across all aspects of *PAID*. The *specific* level may be different than the *expected* level based on the added use of the *LISI Options Tables* and the consideration of the technical implementation criteria.



Example Case One: The specific level may be lower than the expected level if the implementation choices made to facilitate a particular capability are not compatible (e.g., the two systems have different data security constraints and therefore cannot be directly connected).

Example Case Two: The specific level may be higher than the expected level if there is an extended interface between these two systems which allows them to interoperate at a higher level than otherwise expected. This interface may be unique to the two systems being assessed (e.g., a special ICD) allowing a degree of interaction to be attained that is not supported in general by other systems. For this reason, their expected levels are not as high as the specific level.

The LISI metric obtained from these comparisons can be represented in several formats, including those described below:

Summary LISI Metric: Only the major level and/or sub-level is shown
Examples: G2, E3, G2b, S3c

Detailed LISI Metric: Individual values of **PAID** are each portrayed as separate components within the metric
Examples: G2(P3A2I3D2), S1b(P3a,A2c,I2b,D1b)

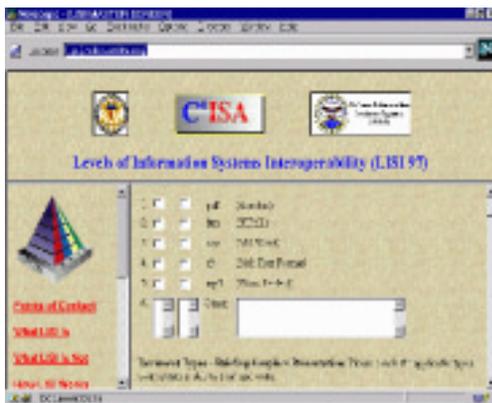
4.3 LISI Assessment Products

This section presents detailed descriptions of each of the key LISI products. The LISI products are the products that are directly used, built, or analyzed in assessing systems interoperability.

LISI employs a structured method of collecting information concerning system capabilities. The data gathered via this structured method is directly related to the interoperability maturity level of the system. The information collected represents the choices in implementation that a Program Manager (PM) or other developers made when building their system. The composite of these implementation choices forms an interoperability profile of the system. Using these profiles, all levels of management can compare different systems using a common basis of assessment from an interoperability perspective. Different views of the LISI data can be constructed to facilitate decision making on a number of topics (i.e., how to build it, who to connect to, what information to share in what format, what resources to employ, et cetera). These views are defined in a set of products that can be used in various combinations when evaluating LISI data. The use of these products allows different types of systems to be represented in a standard way. This standardized set of products can also be used to support interoperability discussions between different users of LISI (senior management, PMs, developers, end-users, et al.).

The LISI Interoperability Questionnaire forms the bridge between the LISI assessment basis (Maturity Model, Reference Model, Capabilities Model, and Options Tables) and the LISI assessment process and products. LISI leverages the data captured in the questionnaire to generate four primary sets of assessment products. Each set differs in its presentation, the intended use, and the interoperability aspects it considers. The remainder of this section describes the LISI Interoperability Questionnaire and the four types of assessment products.

4.3.1 The LISI Interoperability Questionnaire



LISI uses the Interoperability Questionnaire to collect the pertinent information required to assess information systems interoperability. Because the questionnaire is linked to the LISI models and tables that comprise the assessment basis, the questionnaire covers all of the different implementation choices and characteristics currently defined in the *Options Tables* for the capabilities described within the *LISI Capabilities Model*.

The system information collected is then consolidated and presented by subject area (e.g., all characteristics related to document types are together — ASCII, .doc, wp5, ...) and is also mapped to the LISI levels. This information is then kept as the basis for constructing Interoperability Profiles and performing LISI assessments.

4.3.2 Interoperability Profiles

The Interoperability Profiles map LISI Questionnaire data (answers) to the LISI Capabilities Model template. Thus, the profiles capture the implementation choices for each **PAID** capability present in the system(s) being assessed in a format that facilitates system-to-levels and system-to-system comparisons. Individual system metrics can be generated from profiles.

The Interoperability Profile is the basis for other LISI assessment products and analyses. It is the structured form in which collected information on systems is fully represented. As such, profiles provide the essential framework needed to evaluate a system's interoperability level and compare it to other systems.

Figure 4-4 shows a notional example of a system's Interoperability Profile. As mentioned above, the profile is formatted in accordance with the LISI Capabilities Model. Only the characteristics of the specific system appear in the columns for the **PAID** attributes. In this example, the system's generic interoperability level is 2c, the highest level at which a capability is implemented for each of the **PAID** attributes.

There are four different types of Interoperability Profiles. The most common type of profile describes the capabilities of a single system. Information about more than one system can also be put into an interoperability profile. These multiple system profiles have many uses, and help to determine where there are commonalties or differences. The four types are described below.

LEVEL (Environment)		Interoperability Attributes				
		P	A	I	D	
Enterprise Level (Universal)	4	c				
		b				
		a				
Domain Level (Integrated)	3	c	Service-Approved MNS & ORD, WAN addressing scheme	TCP/IP WAN, NFS, SNMP, ISDN card	MIDB, SQL	
		b				
		a				
Functional Level (Distributed)	2	c	DII COE Complaint, Windows-std file name extensions	IE 4.0 MS Office, Access, CMTK, SD, MPEG Viewer	IP LAN NES, NTP, X.500	
		b				
		a	On-line Documentation	Eudora	TIBS, LINK 16 & 22	NIFT, 2 USMTF, x.400, wks, xls, DTED, DBDB, .ppt, .doc, RPF, CGM, JBIG, JPEG, HTML, VPF
Connected Level (Peer-to-Peer)	1	d	Windows Interface Design Guide (JTA)	FTP	HF Data Modem, Kermit, STU III, GSM Cellular	
		c				
		b	ITU-T Rec X.509, Mil Std 2045-28500 Security Labels	Chat 2.0, Win32 API, PPS	GBS	MPEG1.2, GKS, .wmf
		a				
Isolated Level (Manual)	0	d	Login Procedures			
		c				
		b				
		a				
		o	NO KNOWN INTEROPERABILITY			

Figure 4-4. Sample Populated Interoperability Profile for a System

4.3.2.1 Generic Interoperability Profile — Single System

The *Generic Interoperability Profile* maps a single system’s responses to the questionnaire directly to the LSI Capabilities Model template. Refer to section 4.2.1 for a description of a system’s generic level of interoperability.

4.3.2.2 Specific Interoperability Profile — Two Systems

Two individual systems’ Generic Interoperability Profiles can be overlaid to derive a *Specific Interoperability Profile*. This profile shows only the common or compatible implementations between the two systems – the basis for determining the highest level of sophistication that the two systems can support in their interactions with each other. Refer to section 4.2.2 for a description of a system’s specific level of interoperability.

4.3.2.3 Composite Interoperability Profile — Three or More Systems

Information on more than two systems can be combined to form a *Composite Interoperability Profile*. This profile shows the commonalities between a group of systems.

4.3.2.4 Target Interoperability Profile

A *Target Interoperability Profile* represents a notional set of system characteristics for use by developers when designing new systems or updating existing systems. This profile is different than the other three interoperability profiles in that it represents a goal or direction for types or classes of systems. It may initially be constructed from the results obtained using a Composite Interoperability Profile for a set of systems from a particular domain. In effect, it provides a reference and migration target that other systems must consider to ensure routine interoperability with this class of systems. For example, a Target Interoperability Profile for “Fire Support” systems registers the anticipated level of interoperability for this class of systems and defines the specific set of implementation choices that should be included.

The desired or consensus implementations of systems that support a particular domain can be captured in a Target Interoperability Profile although it may not necessarily be based on any existing system implementations. As systems within a given class are developed or improved, they can be compared against the Target Interoperability Profile to determine their interoperability maturity with respect to the target. Target Interoperability Profiles can be used as management tools to guide the developer community and to coordinate with procedures and standards bodies. Target profiles can be generated for particular domains or functional areas, e.g., finance systems, personnel systems, and mission planning systems.

4.3.2.5 Variations of Interoperability Profiles

The profiles described above can be varied in different ways to change the conditions under which the information about a system or group of systems is presented. Variations can be applied to any of the above profiles. The following paragraphs describe some potential variations.

Projected Interoperability Profiles

A *Projected Interoperability Profile* adds a “time” dimension to any selected interoperability profile(s) to facilitate the planning process. In other words, an interoperability profile can be presented in time phases where the phases portray current and planned or postulated suites of implementation choices. This can be extremely useful for determining the interoperability characteristics of future systems or even the interoperability between different version releases. This type of interoperability information is also useful in determining the funding trade-offs involved in various investment strategies.

Inverse Interoperability Profiles

Up to now, the focus has been on the implementation commonalities between systems. This variant examines the differences between systems. This *Inverse Interoperability Profile* shows what implementations systems do not have in common by level and *PAID* attribute. This profile is useful in highlighting the disconnects between systems that require reconciliation. Users or program managers can readily see where gaps exist and work together to resolve the issues.

Implementation Conformance Profiles

A profile that highlights what implementations conform to particular sets of guidance is also instructive. A system’s Generic Interoperability Profile could be annotated to highlight what implementations comply with prevailing enterprise guidance. Similarly, two systems’ Specific Interoperability Profile can be annotated to reflect which common implementations are also in conformance with prevailing standards. An example for the DoD would be a profile in which all implementations that comply with the JTA are highlighted. Any set(s) of guidance can be chosen to show conformance.

4.3.3 Interoperability Assessment Matrices

These products interrelate groups of systems based on their generic, expected, and specific interoperability metrics, i.e., levels. The results are presented in a “system²” format that enables each system pair to be compared in depth. The “scorecard” nature of this product makes it highly useful to all players involved in systems development, acquisition, testing, and oversight, as well as to those responsible for mission and crisis planning and execution. Three types of Interoperability Assessment Matrices are described in the following paragraphs.

4.3.3.1 Potential Interoperability Matrix

A *Potential Interoperability Matrix* (see Figure 4-5) can be generated for a group of systems based on the generic interoperability level of each system and the specific interoperability level for each system pair within the group.

In this example, systems are represented as S1, S2, S3, et cetera. The first (gray) shaded row and column next to the system name contains the Generic Interoperability Level for each system. In Figure 4-4, S1 (System 1) has a Generic Interoperability Level of “2” while S3 (System 3) has a Generic Interoperability Level of “3.” The intersections throughout the matrix contain the Specific Interoperability Level between each pair of systems identified on the two axes. For example, the Specific Interoperability Level between systems S1 and S2 is shown as “2” and the Specific Interoperability Level between systems S2 and S4 is “1”.

Color is used to highlight whether the Specific Interoperability Level is less than, equal to, or greater than, the Expected Interoperability Level. See section 4.2.2 for a definition of the Expected Interoperability Level.

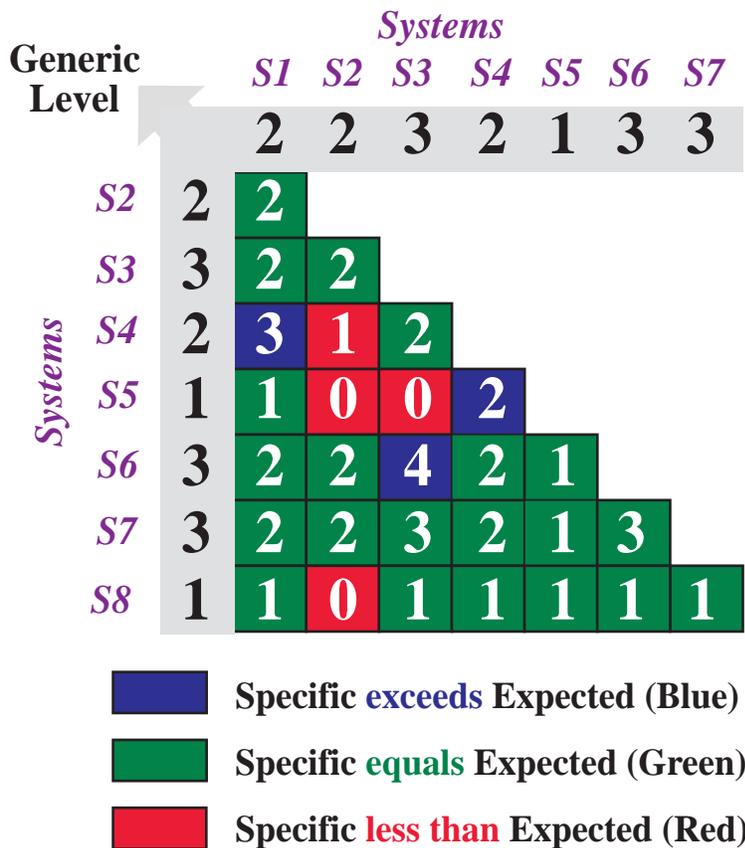


Figure 4-5. Potential Interoperability Matrix

- *Green* indicates that the Expected and Specific levels are equivalent. The two systems have compatible implementation choices for the set of capabilities that defines the level of interoperability they attained.
- *Red* indicates that the Specific level is less than the Expected level. This indicates that the two systems have selected at least one different implementation of some key capability that will not allow them to interoperate at the Expected level.
- *Blue* indicates that the Specific level is greater than the Expected level. This means that the two systems may have dedicated interfaces or other common implementations that allow them to interact at a level higher than Expected.

As an example, consider two systems, each rated at a Generic Level 2b, that support word processing. Because they are both rated at level 2b, their Expected Level of interoperability is Level 2b. However, if one system only reads and writes Lotus Wordpro documents, while the other can only read and write Microsoft Word documents, they will not actually interoperate at Level 2b. *This gap can only be identified by examining and comparing the implementation options each system has selected to support word processing. Examination at this level of detail is required to derive the Specific Level of interoperability.* In Figure 4-4, this condition is shown at the intersection between System 2 (S2) and System 4 (S4) by the use of the color “red.”

A variant of the *Potential Interoperability Matrix* may also be useful. Using the information from time-phased interoperability profiles, a matrix could be generated that would compare the projected interoperability characteristics of a group of systems, thus providing a basis for uniform systems transition.

4.3.3.2 Evaluated Interoperability Matrix

This product is a form of the *Potential Interoperability Matrix* that has been validated via testing and experimentation. Thus, this product reflects *demonstrated* levels of interoperability attained between systems. It is derived via editing the *Potential Interoperability Matrix* to reflect actual field posture.

4.3.3.3 Projected Interoperability Matrix

The *Projected Interoperability Matrix* is developed in the same manner as the *Potential Interoperability Matrix*, except that matrices are provided for phases in time, each phase corresponding to a planned or postulated suite of capabilities/implementations. The color-coding scheme is the same as that used in the *Potential Interoperability Matrix*. Over time, a collected history file of systems characteristics could be used to show transitions for various systems as they mature using a series of past, present, and future timeframes to create this type of matrix.

4.3.4 Interoperability Comparison Tables

These products present the results of a system-to-system **PAID** implementation assessment. These products provide a comparison of interoperability implementation information between systems in terms of **PAID**.

4.3.4.1 PAID Implementation Comparison Tables

The LSI Interoperability Assessment Matrices just described are products that present system pairwise analysis using the LSI “metric.” Frequently, in order to pinpoint an interoperability shortfall, the specific set of implementation options corresponding to the **PAID** attributes needs to be examined.

LISI Assessment Process and Products

The set of LISI products known as *PAID Implementation Comparison Tables* facilitate attribute-by-attribute examination of the specific *PAID* implementation choices between system pairs, and provides linkages to solution alternatives. Note that these tables would be used to determine the Specific Interoperability Level between systems as well as to examine the nature of the gaps and solution options available. Each table focuses on one of the *PAID* attributes. The four comparison tables are now described.

Procedures Comparison Table

This table displays the conditions and state of conformance between any two systems regarding the policy and procedures identified for the *procedures* attribute of *PAID*. This table could be used to assess where and why systems are limited in attaining interoperability based on guidance and policy conformance to enterprise standards. Its *inverse* would present the set of conditions that one system or the other has *not* attained in order to achieve conformance to the enterprise standard.

Applications Comparison Table

This table displays the set of implementation options that correspond to the functions and capabilities that comprise the *applications* attribute of *PAID*. This table could be used to assess how many systems are using particular products or common implementations of e-mail, word-processing, web-interfaces, et cetera. Its *inverse* would present the set of conditions that one system or another possess but are not in common with others. This table and its inverse serve to identify popular implementation choices and anomalies, and facilitate decisions and agreements regarding common, interoperable improvement strategies for *applications* attribute implementations.

Infrastructure Comparison Table

This table displays the set of systems implementation choices that characterize the communications and services that comprise the infrastructure component of interoperability. This table could be used to assess how many systems are using particular forms of connectivity. Its *inverse* would present the set of conditions that one system or few systems possess, but which do not represent popular choice. This table and its inverse serve to identify popular implementation choices and anomalies, and facilitate decisions and agreements regarding common, interoperable improvement strategies for *infrastructure* attribute implementations.

Data Comparison Table

Information about data exchanges that is collected by LISI can be used to directly generate a *Data Comparison Table*. When systems or applications complete the *LISI Interoperability Questionnaire*, the full set of data formats and protocols supported are a part of this registration process. For each system, the questionnaire records the

ability of that system to both input and output each type of data. With this recorded information, pair-wise matching can easily be done which shows what formats two systems have in common for information exchange. The table shown in Figure 4-6 is an example of a *Data Comparison Table*.

OUTPUT →

		Demo 2	Demo 3	Demo 4	Demo 5	Demo 6
INPUT	Demo 2		JBIG	VPR JBIG		NITF1
	Demo 3	VPR JBIG		JBIG	VPR	
	Demo 4	JBIG	JBIG			HTML
	Demo 5	VPR JBIG	JBIG	JBIG		
	Demo 6	NITF1		HTML		

Figure 4-6. Data Comparison Table (System Inputs/Outputs)

The table is formatted as a system-by-system matrix. The cells correspond to the system-to-system intersections. The entry in each cell represents the capabilities of the system on the vertical axis to provide readable output to the system on the horizontal row. For example, the Demo 2 system can provide (output) data in JBIG format to the Demo 3 system (input).

If the two systems both have input and output capabilities for a common data format, the cell is highlighted in green. For example Demo 2 and Demo 6 both can input and output data in the NITF1 format. This shows that the systems can support a two-way data transfer using the highlighted data format. Where there is only the capability for a one-way transfer, the data format is listed, but not highlighted. This is the case if one system can input a data format from another system, but cannot return (send data back) the same format to the other system. Note that this table is not symmetric about the diagonal. Only items that are highlighted (in bold) are symmetric.

LISI Assessment Process and Products

Inverse of this table: The *Data Comparison Table* is clearly useful when describing numerous systems that must exchange information. An inverse of this product is also very useful. Such a product is in a similar format, but instead shows what data formats each system has that “cannot” currently be exchanged. This information can help a system developer identify potential data formats to add to one of the systems to enable them to work together.

4.3.4.2 Interconnection Requirements Table

As part of the LISI process, a major factor that drives interoperability relationships and requirements is agreement among organizations and program managers on the need of particular systems to share inputs and outputs with one another. These relationships are captured as part of the *LISI Interoperability Questionnaire*. This information should be captured “top-down” in Joint operational architecture views. It should describe the information needlines and transactions required between operational nodes. The *Interconnection Requirements Table* is derived from these evolving top-down joint architecture views. In fact, the *C4ISR Architecture Framework, Version 2.0* requires architecture developers to define node-to-node information exchanges in a product called the *Operational Information Exchange Matrix*. But until the *Framework* is widely used and an adequate joint architecture basis is available to draw upon, the LISI process serves to fill this need.

	Demo 2	Demo 3	Demo 4	Demo 5	Demo 6
Demo 2		Non-Agreement About Flow Requirements (Red)	No Requirements Expressed by Either “Demo” (White)	Input (Red)	Output (Grey)
Demo 3	Input Output (Red)		Input (Grey)	No Requirements Expressed by Either “Demo” (White)	Input (Grey)
Demo 4	No Requirements Expressed by Either “Demo” (White)	Input Output (Grey)		Output (Red)	No Requirements Expressed by Either “Demo” (White)
Demo 5	Non-Agreement About Flow Requirements (Red)	No Requirements Expressed by Either “Demo” (White)	Output (Red)		Input Output (Grey)
Demo 6	Input (Grey)	Output (Grey)	No Requirements Expressed by Either “Demo” (White)	Input Output (Grey)	

	Full Agreement About Data Flow Requirements (Green)
	Partial Agreement About Flow Requirements (Yellow)
	Non-Agreement About Flow Requirements (Red)
	No Requirements Expressed by Either “Demo”

Figure 4-7. Interconnection Requirement Table

In the simplest of terms, the Interconnection Requirements Table represents “data flow” direction between systems. When a PM registers a system using LISI, there is a portion of the questionnaire that calls for the identification of all other systems involved in the system’s one-way or two-way information exchanges. The value of information entered goes much beyond the viewpoint of each PM. When these identified requirements are compared across systems, unknown or unexpected relationships often are exposed. Frequently, PMs are unaware that other systems rely on their system for an input. The LISI process uses this type of data to determine if there exists a common understanding between programs of the need to exchange services. This information is used primarily to highlight areas where there is disagreement between programs. Thus, the table serves to identify conflicts that would require PM-to-PM coordination to resolve – i.e., to coordinate on a desired “level” of interoperability between the systems involved. An example of an *Interconnection Requirements Table* is shown in Figure 4-7.

The axes of the matrix represent systems whose registered requirement to input or output data to another system have been captured. Each intersection contains the identified requirements for input and/or output from the system displayed on the vertical column to the system shown on the horizontal row. For example, in the figure above (reading across the Demo 2 row), Demo 2 registered a requirement to provide “Input” to and receive “Output” from Demo 5. Demo 2 also stated a requirement only to send “Output” to Demo 6. However, in the first case (reading across the Demo 5 row), Demo 5 does not recognize the requirement to provide input to or receive output from any of the other systems under analysis. Therefore, since Demo 2 states a requirement to interface with Demo 5, but Demo 5 states no input/output requirements, there is a disconnect between the two program offices. The table shows red wherever there is a contradictory response between programs. This disconnect can be highlighted so that informed decisions can be made to better coordinate between the two PMs. In the second case, (reading across the Demo 6 row this time), Demo 6 agrees with the requirement to receive “input” from Demo 2. Therefore this agreement on requirements is colored green.

4.3.5 Interoperability System Interface Description

The *C4ISR Architecture Framework, Version 2.0* defines standard products to describe the operational, systems, and technical views and relationships of an architecture. Information from LISI can be incorporated into many of these products to reflect the interoperability aspects of information technology architectures. In addition, the mission impact of systems interoperability shortfalls can be easily ascertained through the operations-to-systems audit trail established by the *Framework*. A more detailed discussion of the relationship between LISI and architectures is presented later in this document. The following paragraph describes LISI’s current direct relationship and contribution to the system architecture view.

Basic information from system interoperability profiles can be directly applied to architecture products. For example, LISI currently supports a system interface diagram that depicts the interoperability level of individual systems and the interfaces between systems that are involved in a particular mission operation or that are under scrutiny. Figure 4-8 shows an example LISI assessment overlay on a system architecture product (system interface description).

LISI Assessment Process and Products

The nodes in the figure represent systems and their Generic Interoperability Levels. The arrows between them reflect the information needlines and direction required by the architecture. The lines are color-coded to show pair-wise Specific Interoperability Levels.

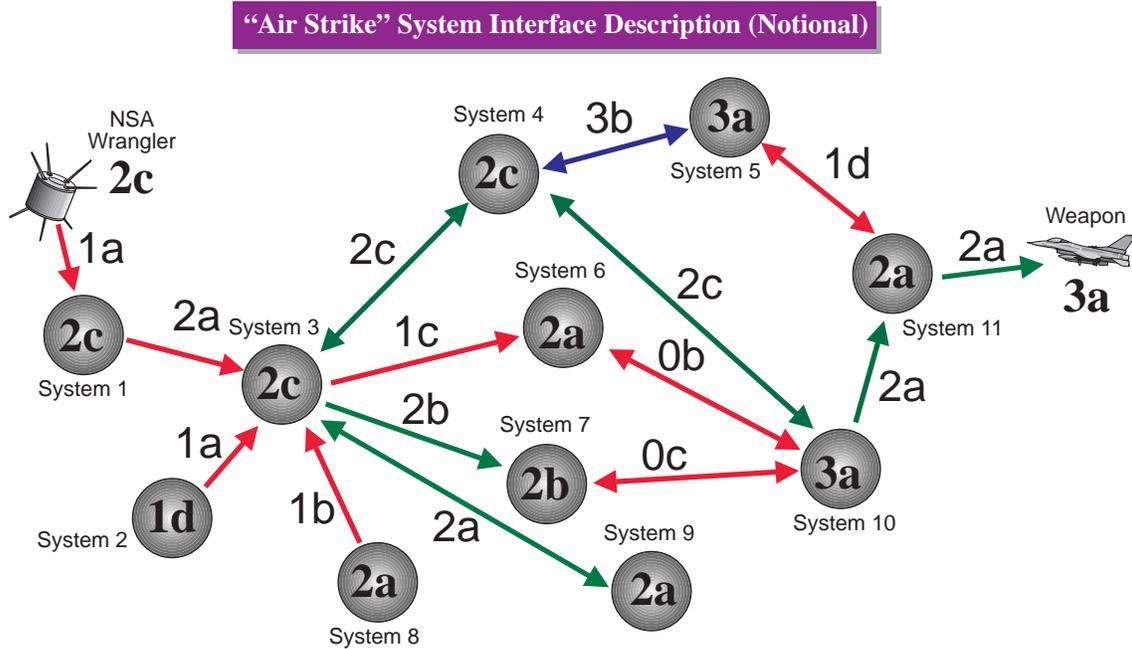


Figure 4-8. Example System Interface Description (LISI Overlay)

An overlay of this type can easily be constructed using commercial network visualization software (e.g., netViz®). This form of presentation is especially useful to system architects for rapidly determining to what degree interoperability requirements are supported by a given architecture.

Section 5

Applying LISI – Representative Scenarios

This section presents various representative scenarios demonstrating the application and use of the LISI process. The scenarios covered in this section focus primarily on the development and employment of information systems. They begin with the assumption that data about existing and developing systems has been registered using the *LISI Interoperability Questionnaire* and is stored in a repository or database for easy access. Though certainly not “complete” with respect to coverage of all potential LISI applications, the scenarios discussed herein serve to illustrate how LISI helps different enterprise users move toward improving interoperability between systems. The collective work performed across all of these efforts can significantly enhance the interoperability maturity of an entire enterprise.

The examples in this section highlight key LISI applications throughout the information system life cycle. Scenario 1 shows how LISI, in context with mission-area assessments, facilitates development and dissemination of interoperability requirements for new systems. Scenario 2 shows how a PM can use LISI to refine and improve the interoperability of an existing system based on the implementations chosen by other systems. Scenario 3 shows how system architects can use LISI to evaluate and assess the interoperability aspects of architectures, including “what if” analysis of various options. Scenario 4 shows how field personnel can use LISI to measure and improve the interoperability of disparate systems that are brought together in a common operational setting. Finally, Scenario 5 shows how the test and evaluation community can use LISI to tightly integrate interoperability into the assessment process.

5.1 Scenario 1 — Use of LISI in Developing Interoperability Requirements

LISI can support “requirements” development and analysis for a new program through the development of a *Target Interoperability Profile*. Current interoperability profiles of existing systems that support a particular function can be evaluated using the composite *Potential Interoperability Matrix*. This product shows the interoperability levels between systems already supporting that function. Using this matrix, a *Target Interoperability Profile* for a given system can then be created that will leverage the implementation choices made by other systems that have the same functional needs and relationships.

Figure 5-1 illustrates the process of generating a *Target Interoperability Profile* for a new system.

Step 1 is to retrieve profile information for existing systems that perform a particular function.

Step 2 is to build the *Potential Interoperability Matrix* for the systems that have been retrieved. This matrix represents the potential for each system to interoperate with the others, and displays the level at which the interactions will potentially take place. This matrix shows the interoperability maturity of the systems supporting the selected function. Gaps are shown and can be targeted for improvement.

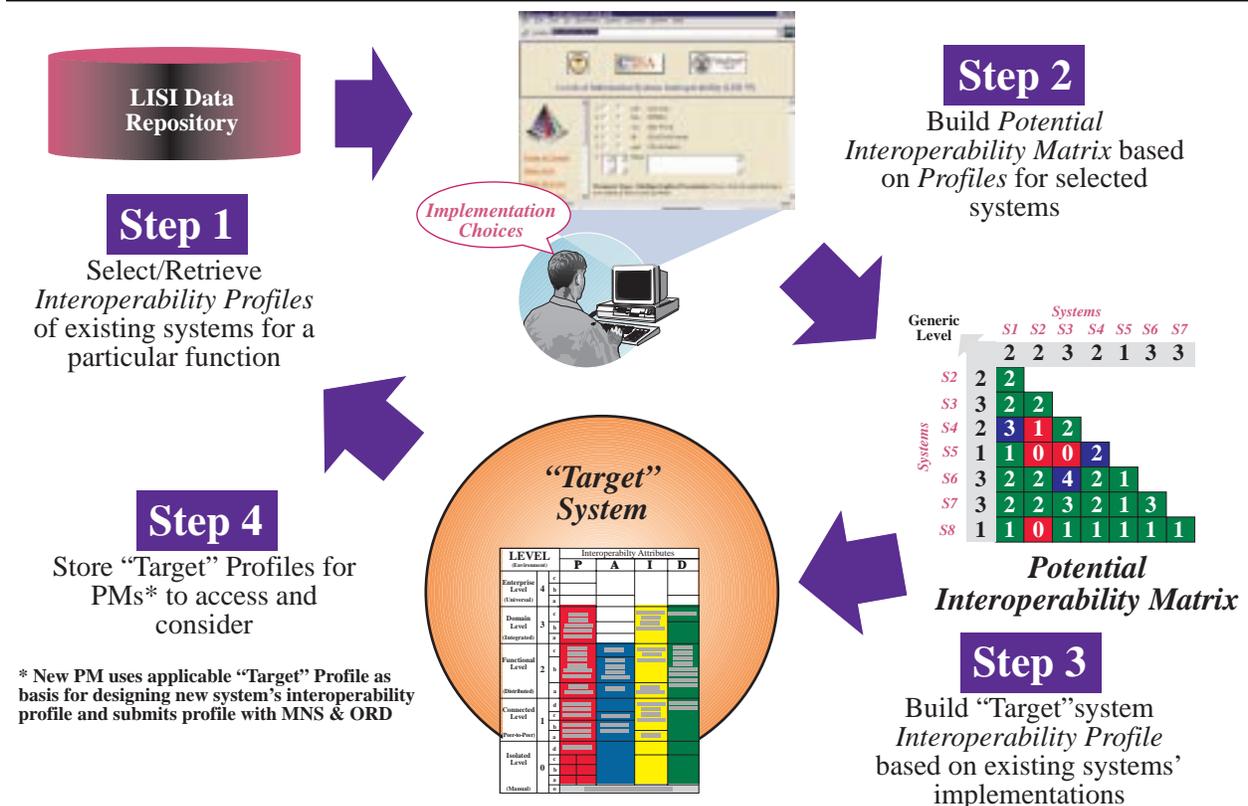


Figure 5-1. Establishing Target Interoperability Profiles

Step 3 is to combine the profile information for all the systems retrieved into a *Composite Interoperability Profile*. This product will show what all the systems supporting this function have in common. This profile can also be added to the previously generated *Potential Interoperability Matrix* to show how such a "composite" system relates to the existing systems. Additions and changes can be made to this profile based on improving interoperability with existing systems and incorporating future technology directions. Risk analysis and cost/benefit tradeoffs can be performed by varying the capabilities represented in the *Composite Interoperability Profile*. The impact of these changes can be viewed in the *Potential Interoperability Matrix* and an iterative process used to arrive at the desired "composite" result.

Step 4 is to publish the results of the analysis as a *Target Interoperability Profile*. This product provides guidance to PMs and system developers and serves as a benchmark for systems that will support this particular function. Thus, as the capabilities of new systems are developed to support the function, they are built toward a target that already includes interoperability and interfaces to existing systems. On the other hand, where the *Potential Interoperability Matrix* shows gaps or system-to-system interoperability issues that preclude the clear derivation of "consensus-based" choices, the PMs of the systems in question would be engaged collaboratively to reach an agreed-upon strategy for resolving the implementation differences. Thus, a two-way benefit is realizable. This set of capabilities in the *Target Interoperability Profile* can be included in requirements documents and specifications for the new system. In the DoD, these documents include a MNS and an ORD.

Using LISI in this manner helps to ensure that interoperability requirements for a given system are not developed in a vacuum. A major benefit of using LISI in this manner is that interoperability requirements and specifications for the given system would be based heavily on the popular or common implementations of the *PAID* capabilities that are inherent in other systems involved in similar Joint information exchanges. This accessible “view” into the profiles and implementations of other systems, all cast in the common discipline and structure of the maturity-based *LISI Capabilities Model*, underlies a fundamental value of LISI in achieving interoperability “convergence” across DoD over time.

Representative types of questions that LISI helps to answer for this scenario include the following:

- What other systems may need to interoperate with System X?
- What are the specific interoperability characteristics of these systems?
- Projecting a System-X profile, what does the *Potential Interoperability Matrix* reveal (any gaps or shortfalls)?
- What strategy will the systems agree to for eliminating interoperability gaps?

One purpose of the program management process is to remedy shortfalls in existing systems and to transition to more mature states or levels of interoperability over time. LISI can identify interoperability shortfalls of an existing system as well as show how changes to that system will improve its interoperability. After entering the information about a system into LISI, a PM can then select and retrieve data about other existing and planned systems for comparison. As in scenario 1, this cross-systems examination allows PMs to find potential gaps and shortfalls in their own programs as well as in other programs.

As an example, a PM of one system may have made a particular *PAID* implementation choice that impaired the interoperability of that system with two other systems. By using LISI, the PM can identify the potential problem in the analysis phase of development rather than discovering the issue after fielding. He can then initiate a dialogue with the other PM early enough to rectify the condition, if necessary.

Such a scenario is illustrated in Figure 5-2. The PM uses a questionnaire to enter data about the system, shown as Step 1. This data goes into a central LISI repository where other system PMs will have access to it for doing comparisons.

Step 2 is to retrieve LISI data about other relevant systems. The PM performs this task by selecting the appropriate systems from the database. The PM can then construct a *Potential Interoperability Matrix*, as shown in Step 3, to compare the systems. This matrix displays where potential interoperability gaps appear between the systems.

5.2 Scenario 2 – Improving Interoperability of a System/Application

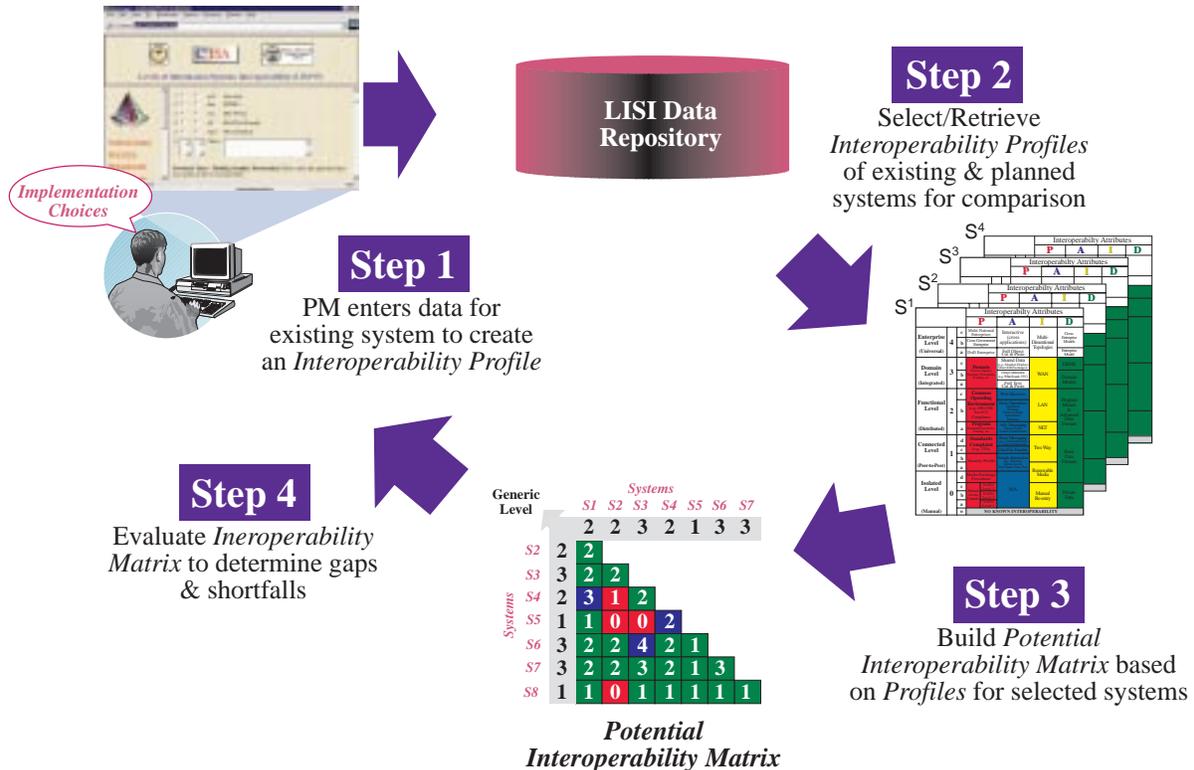


Figure 5-2. LISI use by PM of an Existing System

For each potential problem between two systems, the PM can examine the implementations to determine if the problem can be remedied by changing an implementation selection. The PM can then change LISI data to perform a what-if analysis. The PM can examine the risk and cost-effectiveness of making the changes required.

In this scenario, some answers LISI can provide include:

- What is the specific LISI level of interoperability of System X?
- What specific interoperability issues exist between System X and other systems already in place or planned?
- What is required to raise System X to a higher level of interoperability?

5.3 Scenario 3 — Use of LISI as an Interoperability Tool for Command Architects

Command architects can use LISI to assess architectures. The command architect can retrieve LISI data for systems that comprise an existing or planned architecture. After using LISI to perform an assessment of those systems, the architect can build LISI overlays to architecture products, e.g., the *Systems Interface Description (LISI Overlay)*. The architect can then evaluate alternative strategies to improve interoperability to meet the mission and operational requirements of concern.

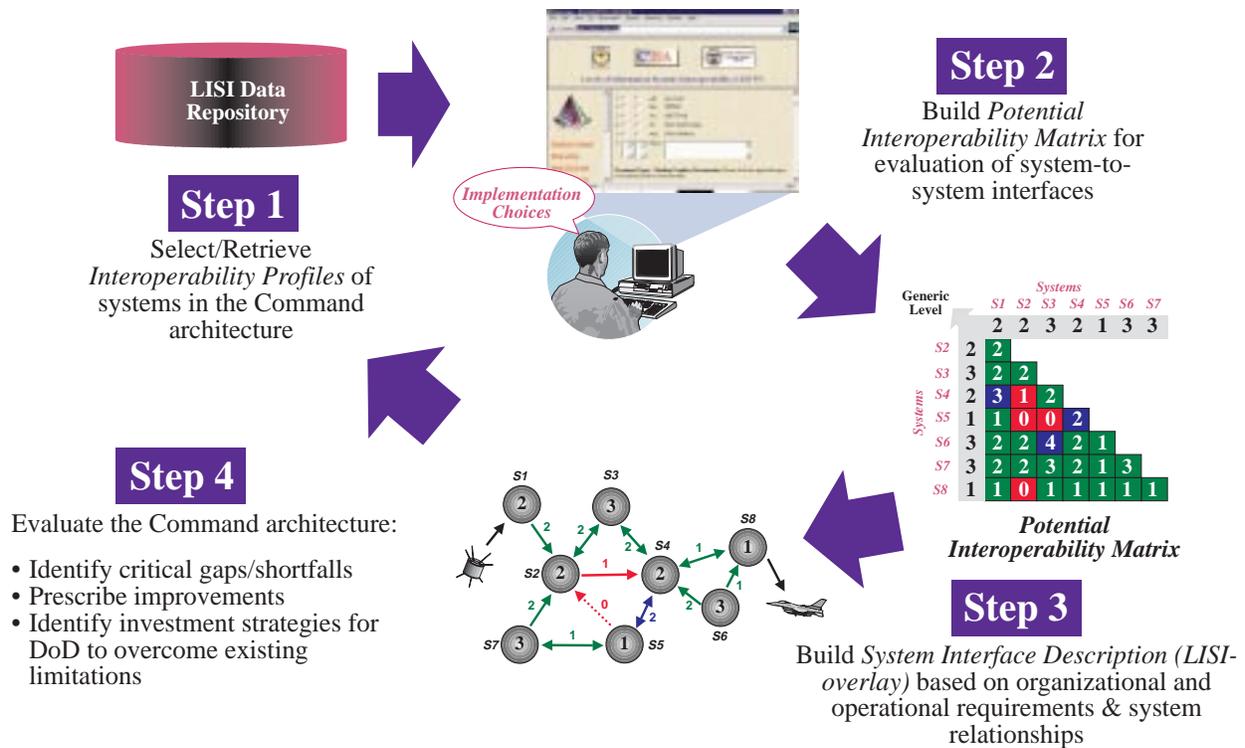


Figure 5-3. LISI Use by a Command Architect

Figure 5-3 illustrates this process. In step 1, the command architect determines which systems are used in the architecture under analysis. In step 2, the architect retrieves LISI information for those systems from the LISI database. Next, the architect builds a *Potential Interoperability Matrix* to evaluate the systems.

In step 3, the command architect builds a *System Interface Description (LISI Overlay)* corresponding to the operational architecture view under evaluation. The diagram clearly depicts the interoperability levels of each relevant system and the connecting interfaces in context with the operational requirements, if known. Using notations and colors, this diagram highlights shortfalls where the achievable interoperability is not sufficient to support the mission needs. Where mission needs are not clearly defined, the diagram depicts discrepancies between the systems’ assessed generic, expected, and specific levels of interoperability.

In step 4, the command architect can use LISI to identify interoperability shortfalls graphically. The command architect can evaluate alternatives by modifying the information on the systems involved and re-running the analysis. Given a new system to integrate into an existing architecture, LISI can help the command architect answer the following types of questions:

- What is the assessed LISI level for the new system?
- Which systems (within the existing architecture) is this system potentially capable of interoperating immediately?
- If known, with which system(s) does this system need to interoperate?

Applying LISI - Representative Scenarios

- What interoperability gaps or shortfalls will exist when adding the new system?
- What are the implementation options available to eliminate the shortfalls?

If the command architect has to develop a new architecture (e.g., for a new JTF), LISI can help the command architect determine the following:

- How well will the systems interoperate?
- Where are specific gaps and shortfalls?
- What is required to improve interoperability between planned or existing operational nodes and their supporting systems?

5.4 Scenario 4 —Use of LISI for Interoperability “On the Fly”

LISI can be used to assess interoperability of existing systems as they are being planned and combined for operational use. As an example, in the DoD most JTFs do not exist until the need arises. When a crisis appears imminent, a variety of systems are brought together by the Services and Agencies who will be participating in the mission. These systems may or may not interoperate, and if recent trends continue, the new crisis could dictate system-to-system relationships that have not been conceived of before. When the JTF has a short lead time, the problems associated with getting disparate systems to interoperate may force the Commander of the JTF (and/or the forces involved) to get by without critical information — information that otherwise would be accessible and transferable if the supporting systems interoperate at the requisite levels. LISI can be used at any point in the JTF crisis “life cycle” to help identify and mitigate interoperability problems.

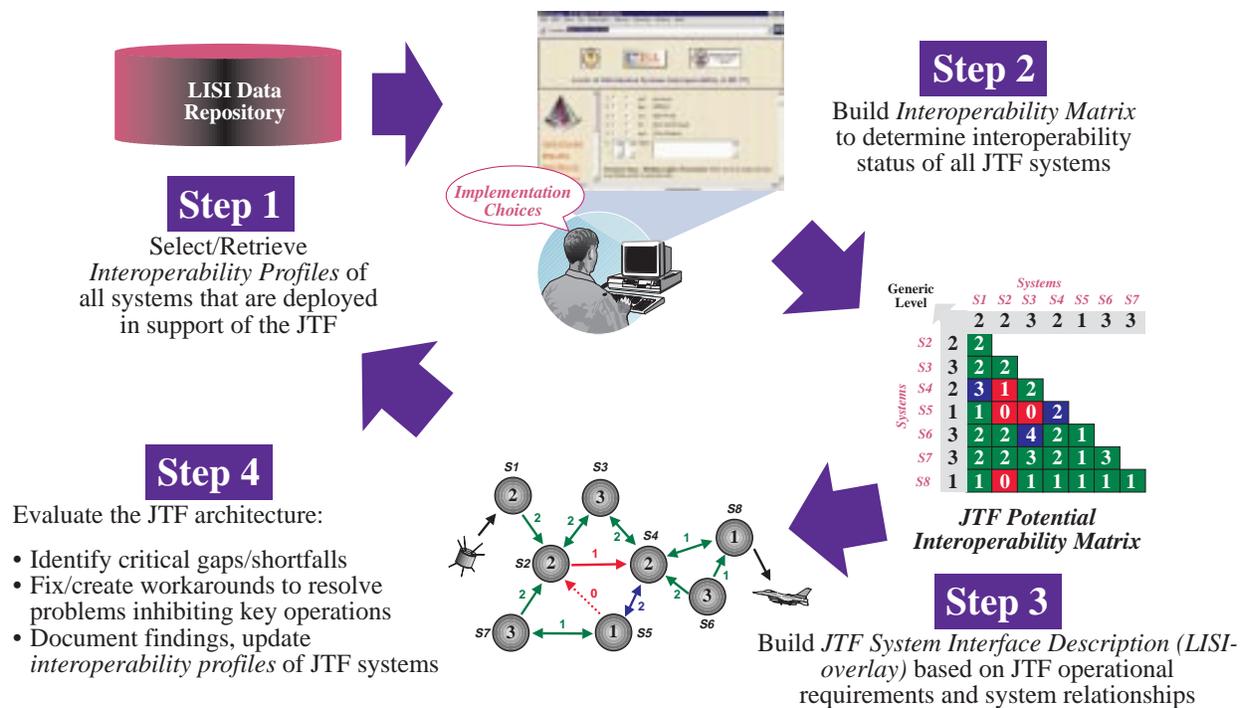


Figure 5-4. LISI to Assess Interoperability “On the Fly”

Figure 5-4 illustrates this scenario. In step 1, the JTF planner determines which systems will support the JTF. Then, the JTF planner retrieves LISI data for those systems from the LISI data repository. In step 2, the planner builds the *Potential Interoperability Matrix* for all of the systems to evaluate the potential of each of the systems to interoperate.

In step 3, the JTF planner builds a *JTF System Interface Description (LISI Overlay)* based on JTF operational requirements and system relationships. The foundation of the diagram shows the mission's node-to-node information needlines and required interoperability levels. The diagram then "overlays" the supporting systems and assesses where the LISI level of interoperability is not sufficient to satisfy the needline requirements.

In step 4, the JTF planner can evaluate alternatives by modifying the interoperability profiles of the systems involved and re-running the analysis. When an acceptable alternative is reached, the systems can be modified, if practical, to change their interface characteristics as required (e.g., adding an Ethernet card to a machine to allow it access to an Ethernet LAN). Rapid analysis and improvements can be facilitated by LISI's process and augmented by an appropriate test environment (e.g., Joint Battle Center and federated laboratories).

The LISI application for this scenario may be repeated throughout the life cycle of the JTF many times as systems and nodes come and go within the architecture.

Given the need to make disparate systems interoperate in a short time, LISI can help a JTF planner determine the following:

- Does the right kind of interconnection exist between systems?
- What are the "critical" pathways?
- What capabilities need to be deployed to augment the infrastructure that is in place?
- Can the necessary data get to the right person in the time required?
- What vulnerabilities exist with respect to interoperability?
- What additional applications are needed to support the required collaborative exchanges?

5.5 Scenario 5 – Use of LISI to Support Assessment and Certification

LISI can be used to support the assessment and certification of systems and applications. One way this can be accomplished is by using LISI data submitted with requirements documents (e.g., MNS, ORD) for a new program in the preparation of the Test and Evaluation Master Plan (TEMP). The approved TEMP would include LISI assessment criteria that evaluate a system's interoperability level. The results of these interoperability evaluations can be documented in the test reports.

For example, the test report could show that System X is certified at an overall interoperability level of 2a and could also report the individual *P*, *A*, *I*, and *D* levels (i.e., *Procedures* = 2a, *Applications* = 2b, *Infrastructure* = 2c, and *Data* = 2c).

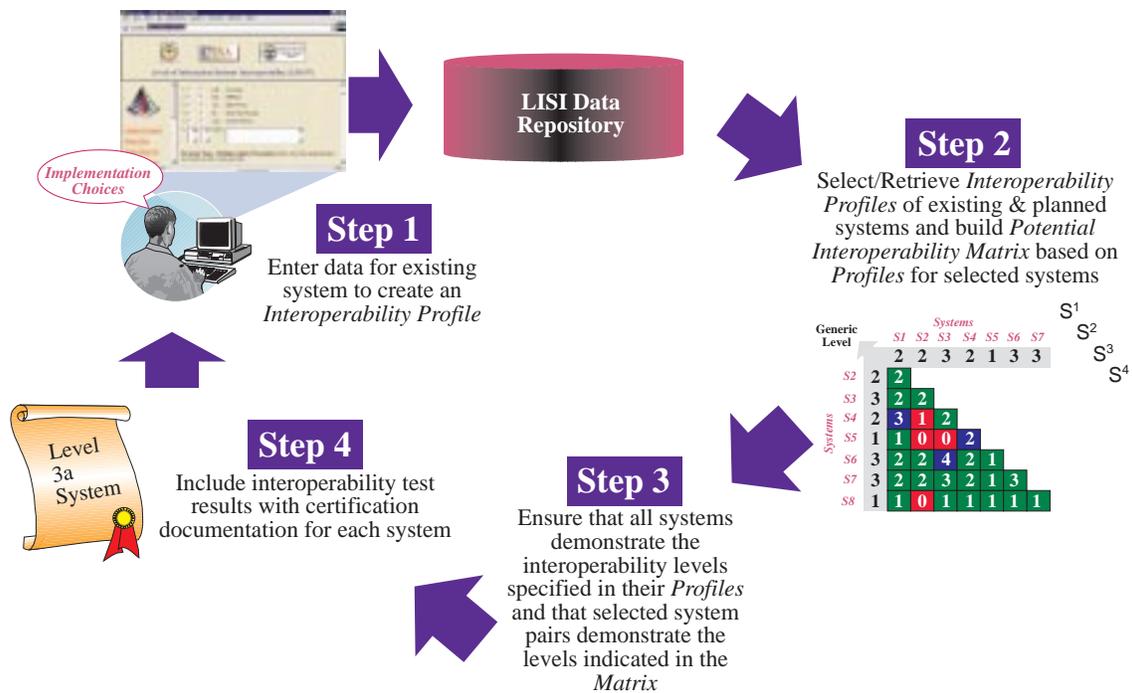


Figure 5-5. LISI Use to Support Systems/Application Assessment and Certification

Figure 5-5 illustrates this process. In step 1, LISI data for the system to be certified is retrieved from the LISI database. In step 2, a *Potential Interoperability Matrix* is built based on the interoperability profiles of the existing and planned systems. In Step 3, testing is conducted to ensure that all systems demonstrate the interoperability levels specified in their profiles. The results are then included with the systems’ certification documentation as shown in step 4.

5.6 Other Potential Uses of LISI

The scenarios described in this section highlight some of LISI’s primary uses within an enterprise. As more organizations become aware of LISI’s value and provide information about their systems, additional opportunities for LISI’s use will continue to arise. For example, an organization recently pointed out that a completed LISI database would assist their efforts to solve their “Year 2000” problem. This organization was unsure whether they had identified all systems that interfaced with systems they knew to have a “Year 2000” problem. A complete set of interoperability profiles for their systems would significantly assist in identifying system interaction and serve as a starting point for initiating the required dialogue between PMs.

Section 6

LISI and DoD Architectures

DoD has been steadily enhancing its information technology architecture guidelines and tools over recent years. LISI's role in providing a common frame of reference and process for analyzing interoperability requires it be an integral part of this governing set of architecture-related guidelines. To this end, the Office of Management and Budget (OMB) included the initial June 1996 description of LISI as one of its referenced documents when it published the *Information Technology (IT) Architecture White Paper*. Efforts are underway to formally extend LISI's relationships to architecture development and analysis so a common methodology exists for assessing and achieving interoperability throughout the government.

On 23 February 1998, a DoD Policy Memorandum established the *C4ISR Architecture Framework, Version 2.0* as the strategic direction for architecture development throughout DoD. The *Framework* is intended to ensure that the architecture descriptions developed by the Commands, Services, and Agencies are interrelatable between and among each organization's operational, systems, and technical architecture views, and are comparable and integratable across Joint and combined organizational boundaries. Together, LISI and the *Framework* provide DoD with a solid basis for managing the improvement of information technology interoperability.

The remainder of this section discusses LISI's applicability to DoD architectures and the specific relationships between LISI and the operational, systems, and technical architecture views defined in the *Framework*. This section concludes with a brief overview of the method for using LISI to conduct an interoperability assessment of an information technology architecture built in accordance with the *Framework*.

6.1 LISI Applicability to DoD Architectures

The use of LISI applies to all dimensions of information management. This is particularly true in the case of architecture development and analysis. The foundation for most architectures is the operational view of the architecture. The operational view describes the mission, function, and/or business processes that need to be accomplished; the mission's participants and their roles, activities, and interrelationships; the nature of the information exchanges (*needlines*) that must take place between the participants; and specific mission performance and protection requirements that must be satisfied for successful execution of the mission. In other words, the operational view of an architecture provides the *business case* for justifying the roles, capabilities, and costs of C4ISR systems and proposed technology. In a broad sense, any needline in the operational architecture view represents an interconnection that can be expressed in terms of the degree of interoperability required to perform the function or mission. This is particularly useful in the case where automated information systems are involved.

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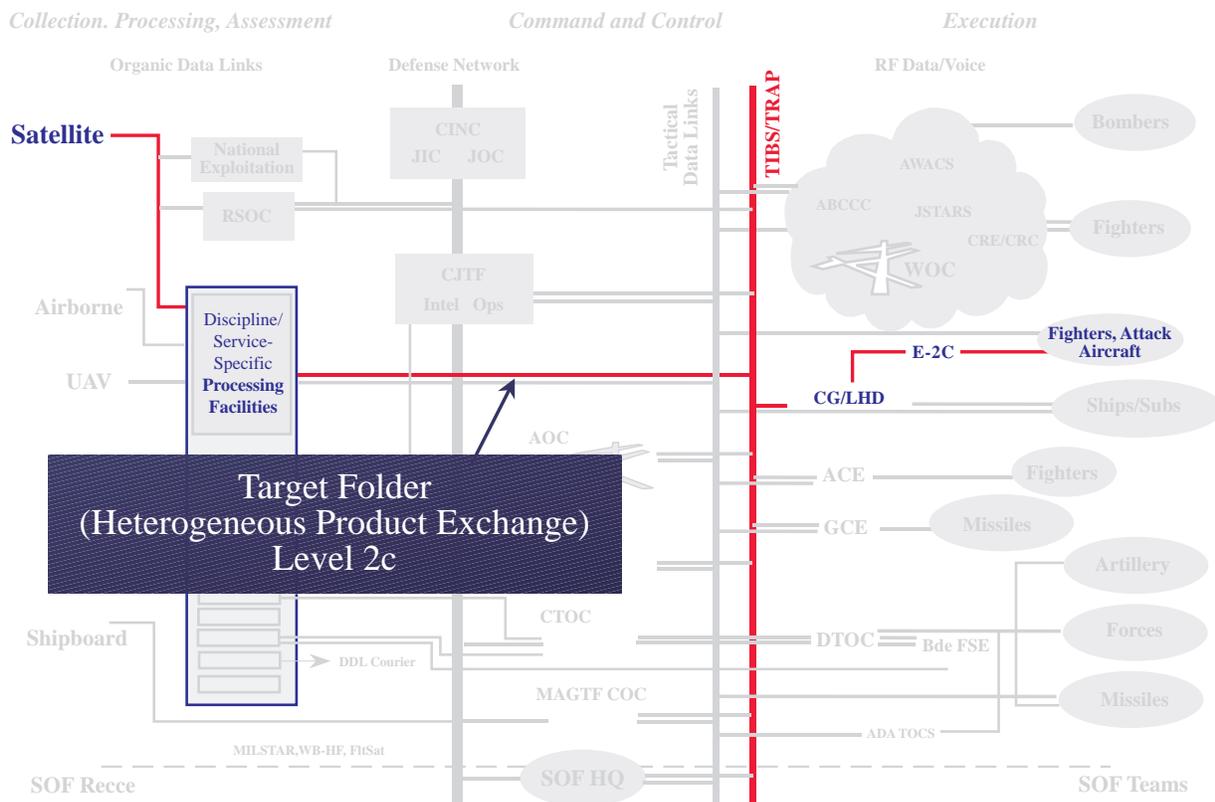


Figure 6-1. LISI Applicability to Operational Architecture Views

Figure 6-1 shows a backdrop that represents a segment of an architecture’s operational view. If the information needlines between the mission participants are described in detail sufficient to determine what LISI level of interoperability applies to each (via table look-up that engages the *LISI Maturity Model* and the *LISI Capabilities Model*), then the interoperability requirements are thereby established for the architecture under consideration. Note that no knowledge of systems or technical expertise is needed to establish requirements for specific needline interoperability levels. All that is needed is a good understanding of the mission to be performed, the operational demands and constraints imposed by the activities and the environment, and the specific nature of the information exchanges that must be conducted. In this light, the *LISI Maturity Model* and *Capabilities Model* provide the bridge from those who understand Joint warfighting needs to those responsible for engineering or acquiring supporting information technology.

For every relationship within an architecture, the following representative questions based on LISI’s *PAID* paradigm serve as a point of departure for penetrating interoperability requirements, systems capabilities, and system implementation criteria:

- *Procedures:* What function or mission is being performed? What set of policies, doctrine, processes, training, et cetera apply for the requisite information exchanges to be conducted properly?
- *Applications:* What aspects of information and its exchange are required or desired? What media? Simple or multi-media products? Any forms of collaboration, or one-way dissemination? Application sharing? Common picture?

- *Infrastructure:* What supporting environmental drivers must be accommodated? What is the typical size of the information product to be exchanged? How fast does it need to get from player A to player B? What are the anticipated threats (adversary-induced, Mother Nature-induced, ...)? What geographic anomalies?
- *Data:* What forms of information are required to be exchanged between mission participants to successfully complete the interaction?

Together, the answers to these questions define the nature of the interoperability that must be attained. Using LISI, the combined answers to these questions serve to identify each specific needline’s required level of interoperability.

6.2 Relationship to Operational, Systems, and Technical Architecture Views

Figure 6-2 illustrates how the LISI process is applicable in the development and evaluation of each of the three DoD architecture views (operational, system, and technical), and is also extremely instrumental in linking the three views together.

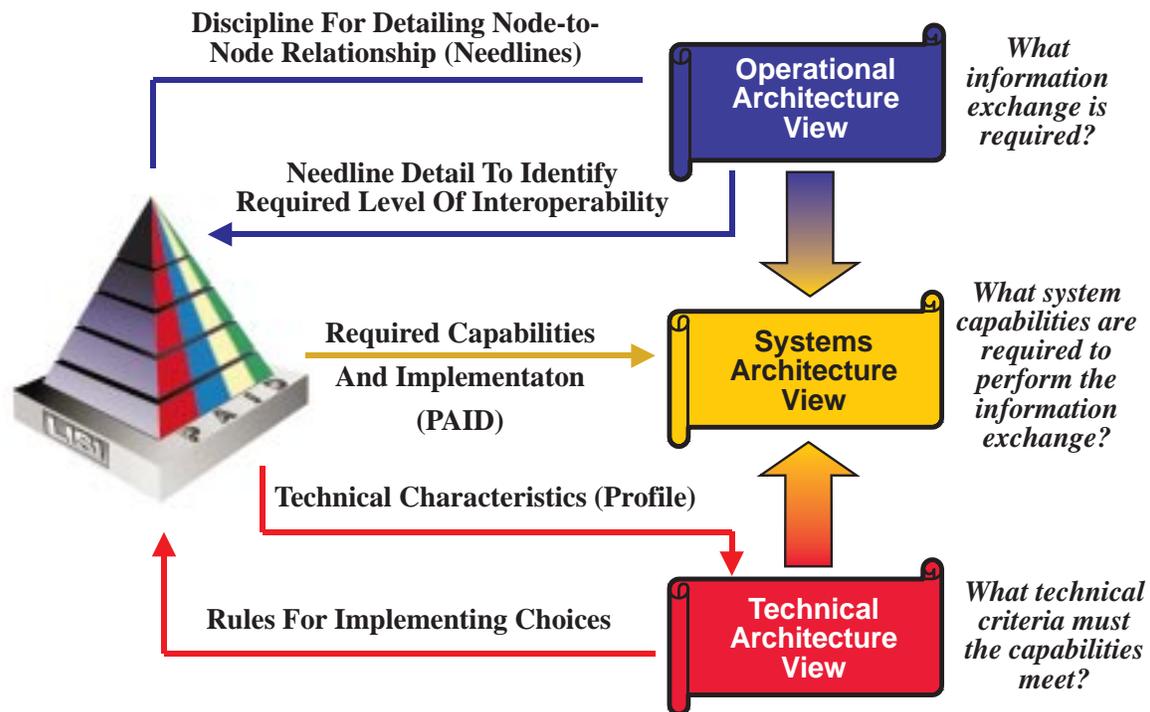


Figure 6-2. The LISI Relationship to DoD Architecture Views

From a broad perspective, an operational architecture captures the nature and purpose of required information exchanges between organizations; a system architecture captures the essential system capabilities needed to perform each information exchange; and a technical architecture captures the profile of technical criteria that govern the implementation of the system capabilities.

6.2.1 Operational Architecture View

As described earlier, the operational view of an architecture describes the tasks, operational elements, and information flows required for accomplishing or supporting a specific mission, function, or business process.

For the operational architecture view, LISI provides (using the *PAID* attributes in context with the maturity and capabilities models) a discipline and methodology for discussing and documenting the information-exchange relationships between organizations. LISI also provides a *metric* to characterize these relationships with respect to *required levels of interoperability*.

6.2.2 System Architecture View

The systems view of an architecture describes the existing or postulated systems and interconnections that provide for the requisite information exchanges identified in the operational architecture view, including the system's capabilities earmarked to support the exchanges.

For the system architecture view, LISI provides a methodology for capturing interoperability profiles for individual applications and systems. As such, LISI provides information (expressed in terms of the *PAID* attributes) about the set of capabilities required to achieve the required operational level of interoperability.

Through an analysis of the systems and specific implementations selected for incorporation, LISI can identify the projected interoperability characteristics between and among each system or application pair. LISI *establishes system interoperability metrics* in the form of *generic, expected, and specific levels of interoperability*. Further, LISI helps to pinpoint interoperability problems and helps the decision maker determine and coordinate improvement strategies.

6.2.3 Technical Architecture View

The technical view of an architecture provides a profile of criteria governing the implementation of the system capabilities under consideration. This profile contains the rules governing the arrangements, interaction, and interdependence of the system elements. The purpose of this profile is to ensure that the resulting system conforms with prevailing implementation criteria.

For technical architecture views, LISI provides an important construct and a bridge to the prevailing formal technical guidance (e.g., for DoD: JTA, SHADE, DII COE, and TRM). To accomplish this, LISI differentiates between those implementation options in the *LISI Options Tables* that conform with prevailing standards and those that do not. LISI can also assist the decision maker by constructing the target technical architecture profile for the system undergoing acquisition or improvement. LISI can accomplish this by relating the appropriate prevailing standards to the specific *PAID* capabilities that the *LISI Capabilities Model* prescribes for the interoperability maturity level to be achieved.

6.2.4 LISI Contributions to *C4ISR Architecture Framework* Products

The *C4ISR Architecture Framework, Version 2.0* provides guidance on the development of a broad set of products used to document the three views of an architecture. Some of these products are designated as *essential* (i.e., to be completed for all architectures) and others are *supporting* (i.e., to be completed as the situation requires). Most of these products are used to document the various interface requirements between organizations, systems, or elements.

Although “interoperability” is a fundamental consideration of every architecture product developed, there are certain products where this factor is more prominently emphasized. Table 6-1 provides a short description of how LISI contributes to the development and analysis of selected *C4ISR Architecture Framework, Version 2.0* products. Some LISI products described in section 4 may constitute *Framework* products. Other *Framework* products incorporate critical LISI assessment contributions. In Table 6-1 (shown on the next page), the essential *Framework* products are highlighted in Italics.

6.3 Interoperability Assessments of Information Technology Architectures

Section 5.3 discussed LISI’s application as a tool for Command architects. This section builds upon that discussion, and describes the use of LISI in assessing the interoperability aspects of architectures in more depth.

6.3.1 Portraying LISI Metrics as Architecture Overlays

The set of nodes or entities involved (organizations and systems) in a mission operation or business process are defined and described with respect to their valid information exchange requirements. These entities and their relationships are then captured in some form of architecture product, e.g., the *Operational Node Connectivity Description* discussed above. The architecture’s *System Interface Description*, in accordance with the *LISI Capabilities Model* and **PAID** attributes, then identifies the existing or postulated information systems and their capabilities and implementations earmarked for supporting the requirements. LISI is then employed to derive each system’s *generic* level of interoperability and to commence the architecture assessment process.

After assigning *generic* levels, the *expected* levels of interoperability are determined for each system pair at both ends of each architecture needline. The *expected* level represents the generic level of both systems if they are equal or the lower generic level of the two systems if they are not equal. The implementation options of both systems are then examined and compared to determine the *specific* level of interoperability between each system pair.

Table 6-1. Contributions of LISI to Selected C4ISR Architecture Framework Products

Applicable View	Product Reference	Framework Product	LISI Contributions
Operational	OV-2	Operational Node Connectivity Description	LISI provides the interoperability maturity model and definitions in accordance with the fundamental nature of information exchanges, including the levels metric, for identifying level required for each information needline.
Operational	OV-3	Operational Information Exchange Matrix	The information used by LISI to determine the “data” attribute of PAID provides for the creation of the “Potential Input/Output Matrix” for registered systems. This LISI product, initially derived in system-to-system format easily rolls up t the operational node-to-node representation for this view.
System	SV-1	System Interface Description	LISI defines the prescribed PAID capabilities that must be accommodated by systems on both ends of each needline identified in OV-2. Establishes the basis for individual and pair-wise systems interoperability assessments.
System	SV-2	Systems Communications Description	The PAID Infrastructure attribute of LISI captures key capabilities and implementation choices of the registered systems to include the form and type of communication exchange needed to satisfy each needline. Mapping the “level” of interoperability to each system-to-system link can assist in early identification of needs and gaps during the architecture analysis process.
System	SV-3	Systems ² Matrix	When this matrix is used to focus on system to system interoperability relationships -- current and postulated -- all aspects of LISI can be used to construct and assess this architecture product, to any degree of depth (level required, capabilities needed, implementations and improvement strategies)
System	SV-6	System Information Exchange Matrix	All four attributes of PAID are integral to the preparation of this product. LISI’s “Potential Input/Output Matrix”, “Interconnection Requirements Matrix”, et al., all contribute to the development of this product. This product also maps into OV-3 as a result of summing the matrix information across systems at each node.
System	SV-8	System Evolution Description	The <i>LISI Maturity Model</i> and realted capabilities and options vehicles combine to facilitate the development of an evolutionary path for achieving higher states of interoperability over time (for a system or suite of systems).
System	SV-9	System Technology Forecast	LISI contributes to this product by providing information about what choices developers are making and what options are emerging from industry. As more and more developers include what was “leading-edge” technology from prior forecasts, LISI provides insight into how these technologies translate into viable implementation choices. LISI also captures the implementation choices that have been selected or programmed which may not have been listed previously—this aids in updating forecasts by drawing attentionto these activities.
Technical	TV-1	Technical Architectures Profile	LISI relates the appropriate prevailing standards to the specific PAID capabilities that the <i>LISI Capabilities Model</i> prescribes for the interoperability maturity level to be achieved, thereby creating the interoperability technical architecture profule for any system and/or enterprise.

Figure 6-3 shows an example of how an interoperability overlay might graphically represent the systems involved in an architecture. In the figure, S1, S2, S3, and S4 represent systems that are part of an architecture. Their *generic* levels are shown as part of the nodes in the node-edge diagram (e.g., S2 has a generic level of 1). The *specific* and *expected* interoperability levels for each system pair are shown on the needles connecting the nodes.

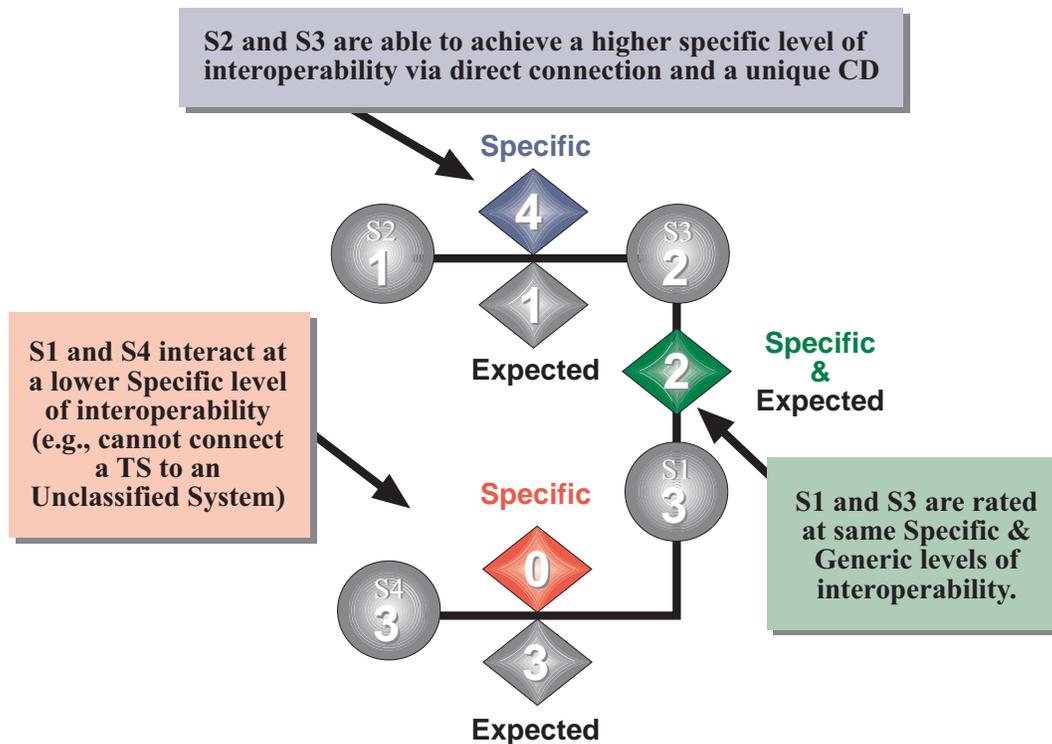


Figure 6-3. Overlaying LISI onto an IT Architecture

An examination of Figure 6-3 reveals that there are three possible outcomes between any pair of systems when assessing interoperability using LISI. The first outcome, illustrated by the connection between systems S1 and S3, represents that condition where the *specific* level achieved is equal to the *expected* level. This level of interaction is color-coded green since the paired systems possess a documented set of common implementations for the requisite *PAID* capabilities.

The second outcome is depicted by the relationship shown between systems S1 and S4. Here the *specific* level is shown to be substantially lower than the *expected* level projected between these two systems. This situation might occur because system S4 (*generic* level 3) uses classified or restricted data while system S1 (also *generic* level 3) uses unclassified data. In compliance with current security policies, these two systems cannot be directly interconnected. Thus, a security *Procedure* precludes any type of information exchange above Level 0 – *Isolated Systems*. A color code of red is used to highlight relationships where the *specific* level of interoperability is less than the *expected* level.

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The third outcome is illustrated by the relationship between S2 (*generic* level 1) and S3 (*generic* level 2), which should have an *expected* ability to interact at LISI Level 1 (the lower *generic* level for that pair). In this case, however, these systems actually interoperate at a higher level than expected by mutually employing compatible technology implementations. Therefore, the *specific* level for this particular interconnection is higher than the *expected* level, and is color-coded blue.

6.3.2 Using LISI to Identify Architectural Gaps, Shortfalls, and Solution Options

The LISI architecture overlay described above, combined with the full complement of LISI products, are used to identify, locate, and resolve gaps or shortfalls in planned or existing architectures. In general, performing an architecture analysis for interoperability involves the following:

- **Identify where the gaps and shortfalls exist** using the *Potential Interoperability Matrix* and other LISI products in conjunction with a LISI architecture overlay.
- **Determine the potential cause of each interoperability deficiency.** This analysis is best performed by evaluating the interoperability conditions present within of the individual attributes of PAID. Figure 6-4 depicts four example views of interoperability, expressed in terms of PAID, which can be used to assist in determining what condition is precluding the level of interoperability from being attained.
- **Identify ways to resolve the deficiency.** Many of the LISI products can be used to examine what options are available for improving or maturing systems interoperability. For example, the *Inverse Input/Output Matrix*, presents information about the existing capabilities for information exchange within registered systems. This provides a complete cross-referenced listing of the existing data formats and protocols available. By adding a data format or protocol from one system into the other, the deficiency may quickly be resolved to provide interaction at a level of interoperability adequate to perform the mission requirement.

As discussed above and illustrated in Figure 6-4, the *Interoperability Assessment Matrix* that examines system-pair interoperability relationships can be “decomposed” and examined with respect to each *PAID* attribute in context with an architecture’s operational, systems, and technical views. This type of graphical view could be an immediate aid towards identifying “why” interoperability is lacking, and the specific factors that are influencing the deficiency. Analyzing an architecture view in terms of LISI makes it possible to quickly recognize interoperability issues that require further analysis and study. These issues may not be as apparent without the aid of LISI’s contribution to the architectural products.

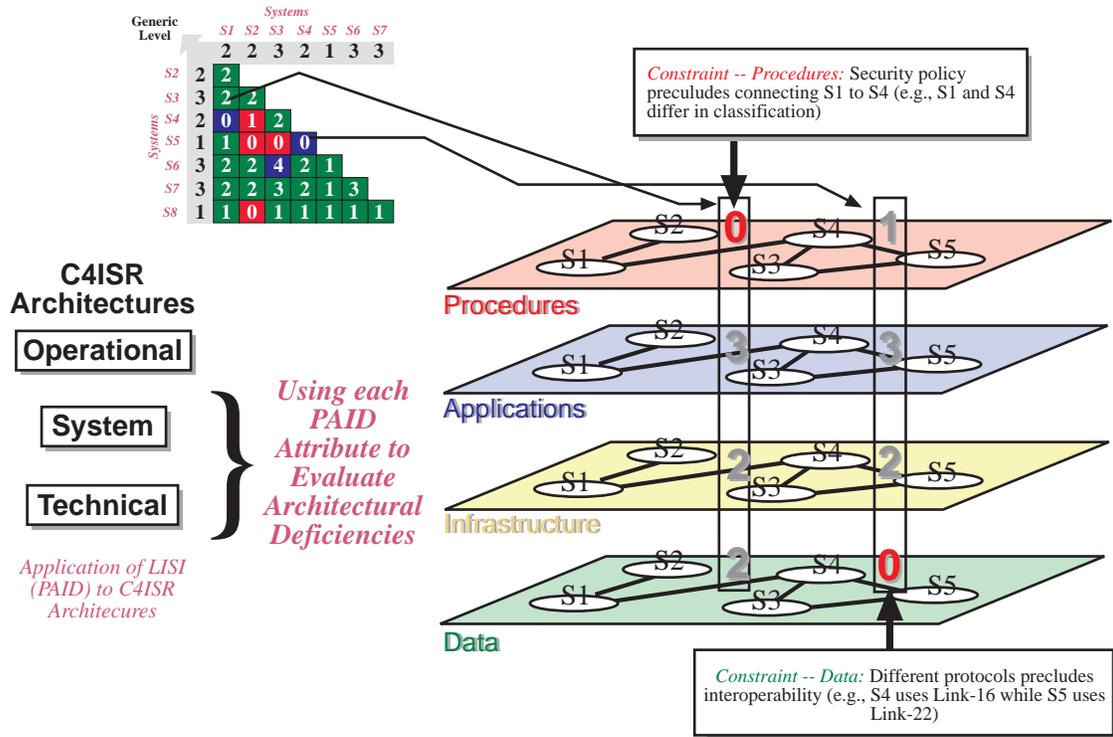


Figure 6-4. Using LISI to Assess Architectures

In summary, the use of LISI is critical for identifying problems, gaps, and shortfalls that may be present within any information technology architecture in time to improve the interoperability posture before the next crisis occurs. In addition, LISI provides the “audit trail” for linking systems interoperability metrics to the ability to conduct specific mission operations through the association of the *specific* levels attainable between systems and the *required* levels of interoperability dictated by the nature of the operational needlines. This audit trail is invaluable as a basis for evolutionary planning and for justifying the need for funds.

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Section 7

LISI Relationships to Other IT Initiatives

LISI contributes significantly to understanding the complex and evolving information systems world, and is designed to bound and manage the emergent property of interoperability. The DoD has acknowledged the complex nature of the information system acquisition process by moving toward evolutionary acquisition processes and away from traditional linear program management.

Several different, but related initiatives are underway within DoD, the federal government, international forums, and commercial industry, each focused on some aspect of information systems interoperability. LISI works to track these initiatives and their associated constructs, interrelate them using the family of LISI models, leverage their findings and positions into the LISI assessment process, and provide the integrated basis for coordinating these initiatives to maintain consistency and currency. The DoD must establish consistent and pragmatic policies that promote interoperability, implement those policies, relate effectively to organizations outside the DoD enterprise, and provide guidance and oversight of distributed systems across DoD as they evolve to higher states of capability and interoperability. The use of LISI as an integration mechanism as well as an interoperability improvement process provides appreciable assurance that individual DoD systems and applications will consistently be achieving higher and higher states of Joint systems interoperability.

7.1 LISI and Current DoD IT Initiatives

LISI serves as the catalyst for integrating and interrelating prevailing DoD IT guidance in context with the *LISI Interoperability Maturity Model* and its family of related models and tables. This integration mechanism is something that has not existed up to now. The DII Master Plan, for example, focuses on establishing an information infrastructure required for the DoD. The interoperability aspects of the Master Plan are captured in LISI under the *Infrastructure* attribute of **PAID**. DISA's JTA and DII COE are incorporated explicitly in the current *LISI Capabilities Model* and its associated *Options Tables*, as will the criteria developed under the SHADE initiative as it evolves.

As stated above, there are numerous DoD initiatives that are focused on one or more aspects of interoperability. What is lacking is a way to pull all of these together to give meaning to statements about interoperability. Dealing with only one of the many variables is not an effective means of achieving interoperability. A PM must consider *all* aspects of interoperability when making implementation choices. Each initiative mentioned above lends an important contribution to the process of improving interoperability. LISI is the key to tying it all together, using a uniform maturity-model structure and discipline, and a comprehensive coverage of all key aspects of the **PAID** attributes, i.e., the enablers of interoperability and its various maturity levels.

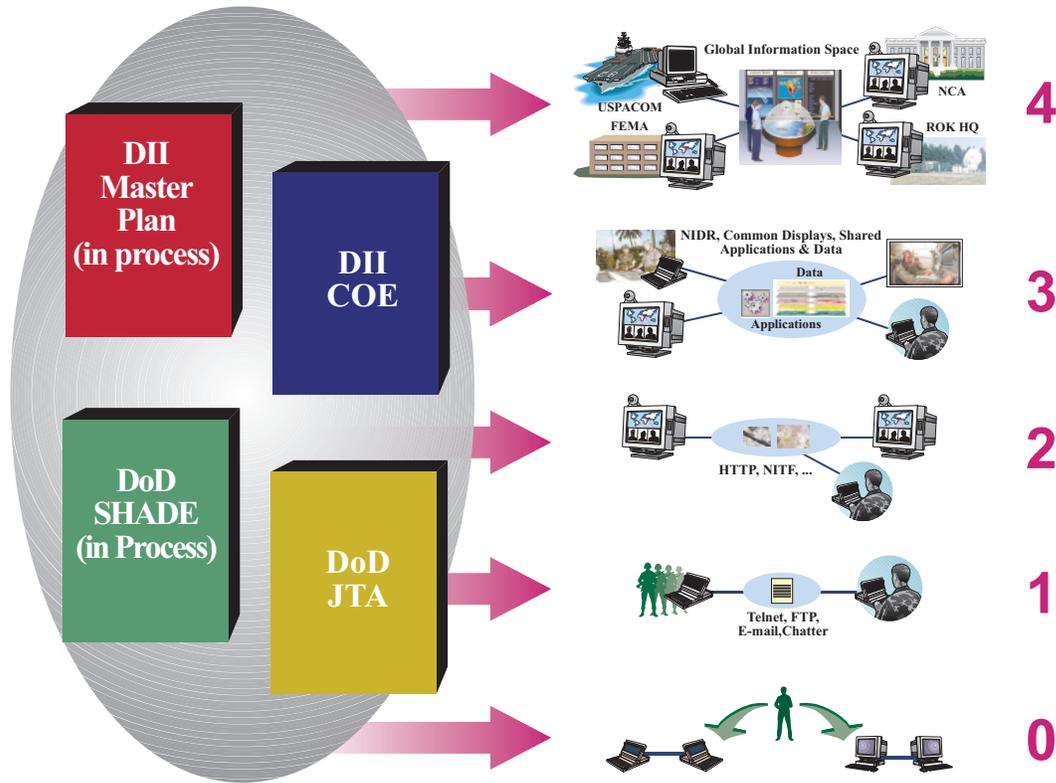


Figure 7-1. Guidance Documents Incorporated into LISI

As Figure 7-1 shows, LISI takes the current implementation criteria of technical DoD guidance initiatives such as the JTA, DII COE, SHADE, and others, and maps them into the family of LISI interoperability models and tables. Thus, the numerous prevailing criteria from multiple documents are categorized and mapped to the specific LISI levels of interoperability, *PAID* capabilities, and implementation options against which they apply. This information helps PMs and others determine what parts of formal guidance apply to a given system, based on the level of interoperability desired.

The LISI process gives insight into the extent to which organizations are adopting DoD acquisition guidelines such as the DII COE and JTA. The LISI process also shows how the prevailing guidance is, or is not, contributing successfully to the improvement of systems interoperability. Thus, LISI provides an important basis for dynamically coordinating with the various DoD technical guidance bodies. The following paragraphs highlight relationships between LISI and some of the current guidance concerning DoD information technology development, fielding, and improvement.

7.1.1 Joint Technical Architecture (JTA)

Implementation standardization is an important first step in the move toward information systems interoperability in the DoD. Once standard interfaces are defined, system developers can provide implementations that are compatible with those standards. The JTA is an overarching DoD

document intended to provide standards guidance to all information systems. It contains the dictionary of accepted standards for use in DoD information systems.

The JTA has been explicitly incorporated into the LISI process. Figure 7-2 presents an extract from the detailed mapping of LISI and the JTA. The *LISI Capabilities Model* includes the relevant standards from the JTA. Those **PAID** capabilities and implementations of each LISI-assessed system or application that comply with JTA standards are identified as such in the system's *Interoperability Profile*. Each entry in the *LISI Options Tables* that is also in the JTA is identified as such. Therefore, LISI can identify which implementations of any system or application conform with JTA standards and which implementations are outside the accepted standards found within the JTA.

7.1.2 Defense Information Infrastructure (DII) Common Operating Environment (COE)

JTA Standards

LISI

JTA Component	Function (JTA Reference)	JTA Paragraph	Description (Capabilities)	Technical Profile	LISI Attribute (PAID)	LISI Level	LISI Question
HCI	User Interface Services	2.2.2.1.2	Window Environment - CDE version 1.0 based on X Window and OSF Motif AND	FIPS 158-1	I	2b	
			Window Environment - CDE version 1.0 based on X Window and OSF Motif AND	OSF Motif AES, Release 1.2	I	2b	
			Window Environment - CDE version 1.0 based on X Window and OSF Motif AND	OSF/Motif ICCCM for GUI clients	I	2b	
			Window Environment - CDE version 1.0 based on X Window and OSF Motif OR	X/Open C323, CDE version 1.0	I	2b	
			Window Environment - Native Win32 for NT 3.5.1	Win32 APIs, Window Mgt and Graphics Device Interface	I	2b	
Data Management Services - 2.2.2.1.3	Data Management Services	2.2.2.1.3	Database Language for Relational DBMS (SQL) AND	FIPS 127-2 (SQL)	D		
Data Interchange Services - 2.2.2.1.4	Document Interchange	2.2.2.1.4.1	Open Database Connectivity Product	ODBC			

Figure 7-2. Cross Mapping of JTA and LISI

Another way to promote interoperability across an enterprise is to establish an executable systems environment that is commonly defined and well understood, i.e., a common operating environment (COE). The Defense Information Infrastructure (DII) Common Operating Environment is intended to establish a common operating environment for the DoD. In essence, the DII COE consists of a strategy, a reference implementation containing a collection of reusable software components, a software infrastructure for supporting mission-area applications, and a set of guidelines, standards, and specifications. It describes how to reuse existing software and how to properly build new software so that integration with the operating environment is seamless and, to a large extent, automated. The basic premise of the DII COE involves adding and removing functionality to or from a system in small manageable units, called *segments*. Structuring the software into segments allows considerable flexibility in configuring the system to meet specific mission needs or to minimize hardware requirements for an operational site. Based on this premise, the DII COE is being applied to resolve Service-unique methods of performing selected

LISI Relationships to Other IT Initiatives

functions by requiring that there be one particular way to perform a function regardless of the system or application performing that function.

The DII COE provides many benefits to the DoD. For example, the DII COE drives the developer community toward a common set of solutions that work together and complement each other rather than overlap or duplicate. The success and acceptance by the commercial market of a consistent executable environment, such as that provided by Microsoft Windows, is a clear example of these benefits.

While the DII COE and LISI are complementary initiatives, they differ significantly in terms of purpose and scope. The DII COE focuses on the portability of software and the configuration management of application-to-operating environment interactions. Considerations of system-to-system interactions are minimal. LISI focuses on the system-to-system interactions that characterize interoperability. LISI puts minimal attention on the operating environment or portability of a system. Thus, the DII COE Levels of Runtime Environment Compliance and the LISI Levels of Interoperability assess very different aspects of system and application interactions.

Because the DII COE and LISI each involve “levels,” the natural inclination is to map levels directly between LISI and DII COE to derive a relationship. However, because of the difference in focus, a mapping of DII COE compliance levels to LISI levels is not appropriately expressed as a “Level X to Level Y” relationship. Rather, the proper comparison and mapping of the DII COE and LISI must be expressed by relating individual DII COE Runtime Compliance Checklist questions to specific LISI implementation options. As shown in the figure below, this mapping results in a “many-to-many” relationship between DII COE and LISI levels. For example, there are specific COE runtime compliance checklist questions pertaining to DII COE level 1 that map to LISI levels 1, 2, 3, and 4, based on the system characteristic that they are addressing (dashed lines). Conversely, there are PAID implementation options within LISI level 1 that are addressed by COE runtime compliance checklist questions at COE levels 1, 2, 3, 4, and 6 (solid lines).

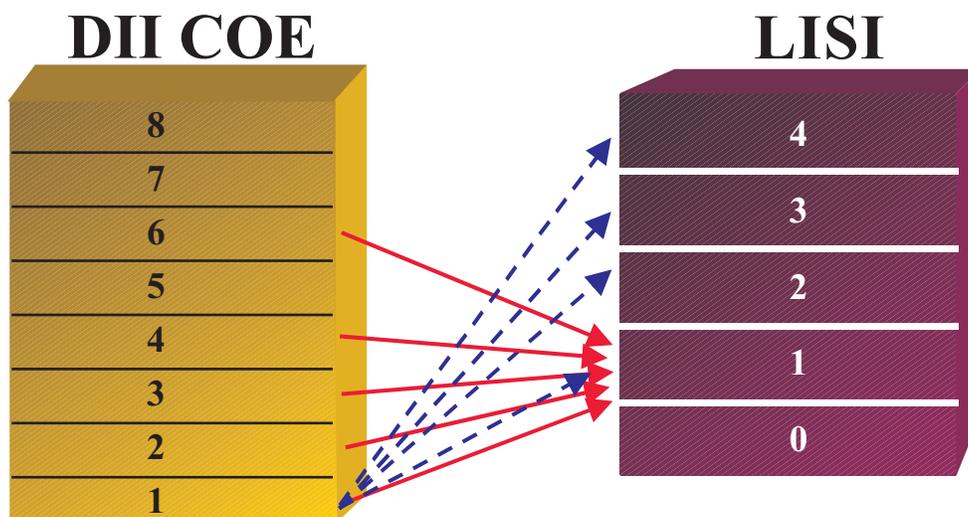


Figure 7-3. Mapping the DII COE and LISI Levels — An Illustration

Even though there is not a direct relationship between the levels in the two processes, there is a direct relationship between DII COE and LISI. Twenty percent of the DII COE Integration and Runtime Standards (I&RTS) Compliance Checklist questions map directly into LISI. These questions relate to topics such as infrastructure implementations (e.g., TCP/IP, DCE SLIP), applications (e.g., FTP), security issues, and naming conventions, among others. The DII COE questions that do not map directly into LISI concern software portability, configuration management, specific documentation requirements, testing in the DII COE, and system recovery issues. These considerations do not directly pertain to system-to-system interoperability but are very important to compliance with the DII COE runtime environment.

In addition, there are many LISI considerations that are not included in the DII COE. These considerations include implementation procedures and criteria (e.g., JTA conformance), mission application capabilities, system-to-system infrastructure relationships, and data interactions between systems that would not be considered when checking for an application’s DII COE runtime environment compliance.

<i>COE Compliance Questions</i>		<i>LISI</i>					
COE Level and Section	Runtime Compliance Assessment Question	LISI Y/N/P	LISI (PAID)	LISI Level	In Matrix	LISI Question	Reason Not in LISI (Other Issue)
COE LEVEL 1 Standards Compliance							
Standards Compliance	1-1 (NT) Hardware components are Windows NT-compliant as defined by the Microsoft document Microsoft Windows NT Hardware Compatibility List #4094.	P					Portability
Operating System	1-2 The operating system and associated software conform to the following standards from the JTA:	P					Portability
	(a) ISO 9445-1:1996, Information Technology - Portable Operating System Interface for Computer Environment (POSIX) - Part 1: System Application Program Interface (API) [C Language], as profiled by FIPS 151-2:1994.	P					Portability
	(b) IEEE 1003.1g:1996 Draft, POSIX - Part 1: System Application Program Interface (API) Amendment 2: Protocol Independent Interfaces (Sockets) [C Language].	P					Portability
	1-3 Unless approved by the DII COE Chief Engineer, the operating system supports the System API for FIPS 119 (Ada95).	N					Portability
	1-4 The operating system is configured to support DCE.	Y	I	4a	N	N	
	1-5 The operating system is configured to support TCP/IP protocols.	Y	I	2c	Y	Y	
	1-6 The operating system is configured to	Y	I	2c	N		

Figure 7-4. Cross-Mapping of DII COE and LISI

The LISI Capabilities Model includes the characteristics drawn from the DII COE I&RTS Compliance Questionnaire that map directly into LISI levels. Figure 7-4 presents a portion of the complete DII COE-to-LISI crosswalk table in order to demonstrate the mapping process. For

LISI Relationships to Other IT Initiatives

each DII COE Level (left column), there is a series of Runtime Compliance Assessment Questions categorized by section (e.g., “Standards Compliance”). Each question is numbered within the level. Each entry in this table represents a single Runtime Compliance Assessment Question. Each of these questions was examined to determine whether and where within the LISI process the technical characteristics represented by that question fit. The result of this examination is in the remaining columns of the table. The “LISI Y/N” column captures relevance to LISI. If the question was relevant to a LISI level, it was examined to determine which PAID attribute was the most applicable, and at what level within that attribute the characteristic was represented. These results are in the “LISI PAID” and “LISI Level” columns. Finally, if the LISI Questionnaire already contained a question relating to this characteristic, that question is captured in the LISI Question column. If the characteristic was not a part of LISI, a reason was given in the last column.

In summary, there is not a one-to-one relationship between LISI Levels of Interoperability and DII COE Runtime Compliance Levels. DII COE compliance measures the ability of a segment to operate within the COE environment of the DoD enterprise. It does not measure the interoperability maturity of a system in terms of capabilities as LISI does.

7.1.3 DII Master Plan

How an enterprise is evolving its information technology architecture plays a critical role in its ability to manage interoperability. Planning must be in line with DoD’s interoperability requirements, and vice versa. Planners need to ensure that as new technologies are developed and inserted, older information systems either keep pace through evolutionary upgrades, or are judiciously replaced.

The DII Master Plan is a broad document meant to ensure that an infrastructure is in place within the DoD to allow for the establishment of a common link between systems as they develop. The ability of systems to work within the Information Infrastructure defined by this plan is critical to ensuring interoperability. The DII Master Plan defines how the DoD’s infrastructure will evolve in the future and must be understood in context with DoD systems interoperability maturation.

Initiatives focused on implementation of the DII Master Plan should be closely coordinated with LISI. In particular, the way that LISI captures the various aspects of the infrastructure that are included within the scope of the DII Master Plan on a “level-by-level” basis should be closely synchronized with Master Plan implementation planning efforts.

7.1.4 Shared Data Environment (SHADE)

There are numerous types of data across an enterprise. It is important that there is a broad and common understanding of data definitions and knowledge of what information needs to be shared and by whom throughout the enterprise. Data definitions must be more rigorous as more sophisticated requirements are developed.

SHADE is representative of the effort within the DoD C4ISR community to reach agreement on common data models for systems. SHADE is a fairly recent initiative, and is not currently as well defined as the DII COE. The SHADE effort is critical to defining those aspects of data needed for interoperability maturity.

A preliminary review of SHADE was performed to determine that the LISI process, especially the *data* attribute of *PAID*, is consistent with SHADE's direction. LISI does not attempt to define data models, but merely records their usage. Deliberate and continuous coordination must be conducted to ensure that LISI and SHADE are tightly integrated as they both evolve.

7.1.5 Joint Battle Center (JBC)

Maintaining the currency of capabilities and implementations captured by LISI is critical as technical standards continue to evolve and as commercial industry continues to release new technologies. The *LISI Options Tables* that identify the numerous alternatives available for implementing the general capabilities profiled in the *LISI Capabilities Model* must be continuously updated. This update process must be performed in close coordination with the operational user community, industry, and the acquisition community. The JBC is an organization where many of these groups come together to examine system performance and interoperability in context with JTF mission operations. The collective insight these groups bring to bear makes the JBC an ideal forum for capturing these integrated views using the LISI construct and process.

Another function of the JBC is to assess systems based on needs determined by the Joint world, specifically the JROC. LISI provides a critical tool to support the interoperability dimensions of this process as discussed earlier with respect to LISI application to architecture development and analysis. LISI allows for systems to be compared on a level playing field and for meaningful comparisons to be made between systems. The metrics and products that LISI provides allow the JBC to consider the interoperability characteristics of systems thoroughly in its recommendations.

7.1.6 Joint Interoperability Test Command (JITC)

The JITC is faced with the daunting task of testing and certifying DoD information systems. The sheer number of systems makes it impractical to test every possible system-to-system combination. By looking at products produced by LISI, particularly the various system interoperability profiles, critical interfaces between systems can be identified. The LISI products, in conjunction with architecture information and JBC experimentation results, serve a "screening" function in pinpointing what specific aspects of system-to-system interoperability are most critical or most at-risk. These are the areas where testing of systems should focus, where compliance and surety are most important, and where testing will yield a high payoff.

The JITC could use the results of LISI assessments to build Test and Evaluation Master Plans (TEMPs). These plans will be able to validate the particular implementations that are most critical to interoperability with other systems.

7.2 LISI and Federal Government IT Initiatives

Once an enterprise is brought under control and interoperability is implemented within that enterprise, there is still significant work to do to achieve interoperability outside of the enterprise. In today's world, cross-domain interoperability is required for most organizations. Governments must work at different levels and across different enterprises. Commercial organizations seek to bring in their suppliers and customers and work to incorporate them into their enterprises in some ways.

Even if an organization does not interface often outside the enterprise, there is still the need to bring new things into the enterprise. Often, the commercial world will develop what appears to be a better solution to a product. The spin-offs from the Internet are prime examples. It is critical to evaluate how commercial solutions will work with other implementations before deciding to acquire or install the product.

The DoD is often required to work together with other agencies of the Federal Government. Examples include FEMA, the FBI, and the non-DoD components of the Intelligence Community. In order to foster interoperability between these disparate agencies, it is necessary to examine interoperability from the perspective of the broad National Information Infrastructure (NII), of which the DII is a part. To this end, LISI representatives have had preliminary discussions with other Federal Government Agency representatives, including DOE, USDA, DOT, and DOL. LISI has the foundation and scope to become a common model and process for assessing and improving interoperability across the NII and the Federal Government.

7.3 LISI and Multinational IT Initiatives

LISI has applications even beyond the Federal Government. NATO, for example, uses a concept of levels in its System Interconnection Levels. Coalition partners have their own information systems, and these systems can vary markedly from crisis to crisis. In addition, host nations must be considered when examining interoperability in order to leverage the existing infrastructure and to exchange information when prudent.

7.3.1 NATO

The NATO System Interconnection Levels define interoperability as the ability of systems, units, or forces to provide services to and accept services from other systems, units, or forces, and to use the services so exchanged to enable them to operate effectively together.

The degree of system interoperability must be justified with respect to a variety of considerations including: personnel involvement required; use access and security aspects; and operational, procedural, technical, and/or other standards/implementation/ development constraints.

The six levels currently defined by NATO are summarized as follows:

- NATO Level 1: Units and/or individuals exchange verbal and/or written information via off-line communications system.
- NATO Level 2: Exchange of verbal or written information through co-located liaison teams where each team has access only to a terminal connected to its own system.
- NATO Level 3: A single operator transfers information from one system to another using a separate terminal for each system.
- NATO Level 4: *System-to-system interconnectivity* with pre-determined constraints and dynamically controlled data access constraints.
- NATO Level 5: *System-to-system interconnectivity* with dynamically controlled data access constraints.
- NATO Level 6: *System-to-system interconnectivity* with full access to all information and programs on each system.

The first three NATO levels involve a person “in the loop” for interoperability to be achieved. These three levels are incorporated explicitly into *LISI Level 0* (Isolated), where the *procedures* attribute of LISI is dominant as shown in the *LISI Capabilities Model*. The complete set of NATO levels relate to LISI as indicated in Figure 7-5.

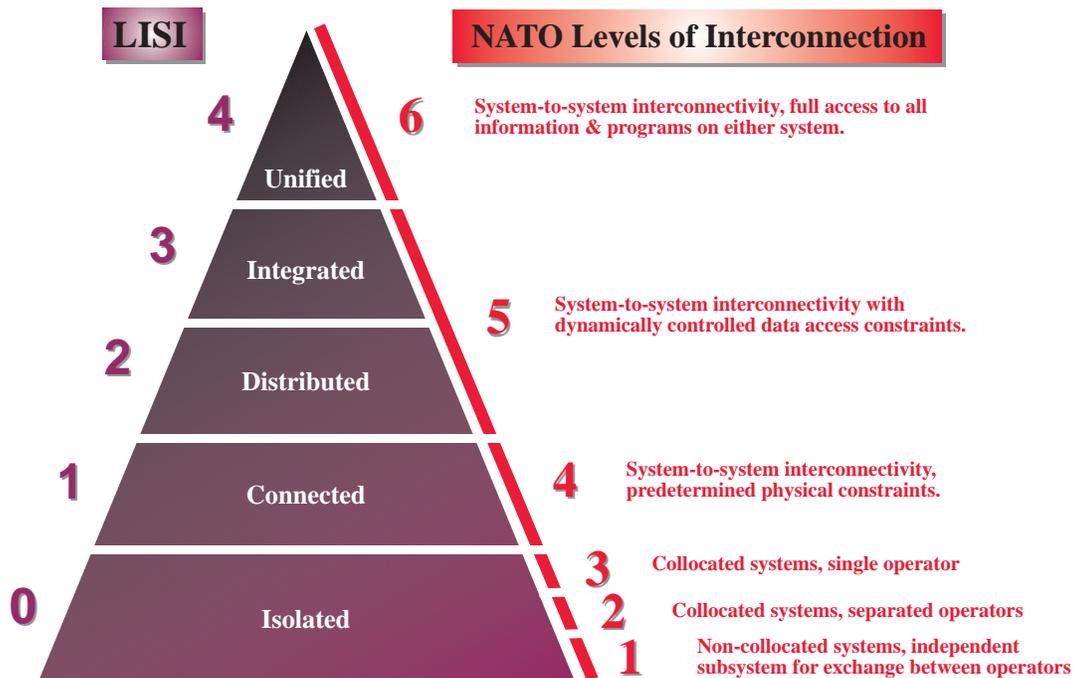


Figure 7-5. Relationship of NATO Levels to LISI Levels

LISI Relationships to Other IT Initiatives

7.3.2 Coalitions

Coalition partners build their own information systems. For many reasons, including security, the option of simply providing coalition partners with U.S. systems is not practical nor advisable. The ability to evaluate how well other systems will work with U.S. systems, and to coordinate measures to achieve limited degrees of interoperability between them, is critical to achieving success in a coalition activity. LISI is an ideal construct for examining strategies, assessing system-to-system postures, and for coordinating agreements with our coalition partners.

7.3.3 Host Nations

Similar to the condition prevailing between U.S. systems and those systems owned and managed by our coalition partners, other nations and foreign organizations pursue their own strategies and approaches to domain-internal interoperability, and some of them have little or no compliance to any form of standards or implementation criteria. At a minimum, U.S. and host-nation system managers need to know the extent to which their systems can and cannot exchange information with each other, so as to make informed decisions on what improvement measures may make sense. LISI is an ideal construct for assessing system-to-system interoperability postures and for coordinating agreements with host nations.

7.4 LISI and Commercial Organizations

There are many organizations in the commercial sector with which the DoD must interact on a regular basis. These organizations are providers of systems, software, or information services. The ability to exchange services with these organizations is paramount as the DoD looks to save money and become more flexible through the adoption of commercial practices and outsourcing. Electronic commerce is one area where the DoD is already automating many of its processes. In an area such as this, it is important for both enterprises to be able to understand and evaluate interoperability in common terms and maturity levels. The use of a commercially provided communications infrastructure is another area where interoperability approaches must be closely coordinated. Ideally the interoperability maturity curve being pursued across DoD should be compatible with the direction that the commercial sector is pursuing.

Government agencies and services are not the only organizations interested in fostering and improving interoperability. There are many parallels to the LISI ideas in the commercial world, especially where common operating environments are concerned. Various commercial organizations have established their own common operating environments. Chevron and General Motors are two examples [ref IW number 04, 1996, Issue 604, section: IT Management]. These organizations have realized reductions in the costs of individual configurations for PCs by forcing a common environment. They have incorporated their own in-house documentation into systems and deployed a standardized set of applications to their personnel. Chevron, in fact, requires vendors to deliver computers with the Chevron COE already installed.

Also, a significant number of the systems fielded today throughout the DoD and other organizations originated in the commercial world. DoD is under increasing pressure to move toward more COTS implementations, a basis for significant cost savings and increases in functionality — *provided that the commercial technology and currently fielded systems can interact.*

The introduction of new technology is a given in the information systems arena. What is important about new technology is that it works with technology that is currently in use. LISI helps to assess the compatibility and the disconnects between the various implementation options—old technology and new—provides a basis for making informed decisions regarding the modification of existing systems, option trade-offs, system replacement, or new technology rejection.

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Section 8

In Conclusion

LISI fills a major need for any enterprise that must bring disparate information systems together and have them interoperate in support of critical operations. LISI provides an enterprise with a common frame of reference and measure of performance for information systems interoperability. LISI's assessment process allows for quick identification and resolution of information systems interoperability issues and problems that inhibit the conduct of any operation. Further, LISI provides the means for transitioning and maturing information systems capabilities consistently across the enterprise.

The LISI assessment basis (i.e., the *Interoperability Maturity Model*, the *LISI Reference Model*, and *LISI Capabilities Model*) is essentially a living entity, constantly evolving in concert with technological advances in information systems and changes in the methods by which enterprises employ information systems technology in support of their operations. Thus, the LISI levels, the capability thresholds within and between levels, and the suite of implementation options for each capability and service at a given level will all change as a function of time and key events.

Therefore, each of the elements that form the basis for LISI's assessment process, including the prototype tool, will continue to evolve over time. This document presents the current versions of the *Interoperability Maturity Model*, the *LISI Reference Model*, and the *LISI Capabilities Model*.

A set of *LISI Implementation Options Tables* exists, but is not published in this report. The tables will be significantly refined as a result of LISI assessments scheduled to be conducted in support of Joint Battle Center (JBC) experiments (e.g., the MIS Experiment in February 1998) and Service exercises (e.g., the Air Force EFX Exercise in September 1998) during the remainder of fiscal year 1998. Thus, a "tried-and-tested" 1998 version of the *LISI Implementation Options Tables* will be released for publication in late 1998.

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Glossary

ADRG	Arc Digitized Raster Group
AIS	Automated Information Systems
API	Application Program Interface
AOC	Air Operations Center
ARP	Address Resolution Protocol
ASD(C3I)	Assistant Secretary of Defense for Command, Control, Communications, and Intelligence
ASRP	Arc Sector Raster Product
ATM	Asynchronous Transfer Mode
AWG	Architectures Working Group
BUFR	Binary Universal Format for Representation
C/S/A	CINC, Service, and Agency
C2	Command and Control (C2)
C3	Command, Control, and Communications
C3I	Command, Control, Communications, and Intelligence
C4I	Command, Control, Communications, Computer and Intelligence
C4ISR	Command, Control, Communications, Computer, Intelligence, Surveillance, and Reconnaissance
CADRG	Compressed Arc Digitized Raster Group
CD-ROM	Compact Disk - Read Only Memory
CIB	Controlled Image Base
CINC	Commander in Chief
CISA	C4ISR Integration Support Activity
CJTF	Commander, Joint Task Force
CMTK	Common Mapping Toolkit
CMM	Capability Maturity Model
CONOPS	Concept of Operations
COP	Common Operational Picture
CORBA	Common Object Request Broker Architecture
COTS	Commercial Off the Shelf
CPU	Central Processing Unit
DCOM	Distributed Component Object Model
DEF	Data Exchange Format
DIA	Defense Intelligence Agency
DIGEST	Digital Geographic Information Exchange Standard
DII COE	DII Common Operating Environment
DII	Defense Information Infrastructure
DISA	Defense Information Systems Agency
DISN	Defense Information System Network

Glossary

DISN-LES	Defense Information System Network - Leading Edge Services
DITDS	Defense Intelligence Threat Data System
DoD	Department of Defense
DoDD	Department of Defense Directive
DoDI	Department of Defense Instruction
DODIIS	DoD Intelligence Information System
DPPDB	Digital Point Positioning Data Base
DTAM	Document Transfer and Manipulation
DTED	Digital Terrain Elevation Data
ELT	Electronic Light Table
FAT	File Allocation Table
FBCB2	Force Battle Command, Brigade and Below
FIPS	Federal Information Processing Standards
GBF	Gridded Binary Form
GBS	Global Broadcast System
GCCS	Global Command and Control System
GCSS	Global Command Support System
GKS	Graphical Kernel System
GRIB	Gridded Binary
GOTS	Government Off the Shelf
GUI	Graphical User Interface
HHS	Health and Human Services
HP	Hewlett Packard
HTML	Hypertext Markup Language
HUD	Housing and Urban Development
IEEE	Institute for Electrical And Electronics Engineers
IER	Information Exchange Requirement
IGES	Initial Graphics Exchange Specification
INCA	Intelligence Communications Architectures Office
IP	Internet Protocol
IPA	Image Product Archive
IPSG	Intelligence Program Support Group
ISC	Intelligence Systems Council
ISDN	Integrated Services Digital Network
ISO	International Standards Organization
ITF	Integration Task Force
JBIG	Joint Bi-level Image Experts Group
JCS	Joint Chiefs of Staff
JCS Pub	Joint Chiefs of Staff Publication
JIER	Joint Information Exchange Requirement

JITC	Joint Interoperability Test Center
JMA	Joint Mission Areas
JPEG	Joint Photographic Experts Group
JROC	Joint Required Operational Capability
JTA	Joint Technical Architecture
JTF	Joint Task Force
JWICS	Joint Warfare Intelligence Center
LAN	Local Area Network
LANE	LAN Emulation (over ATM)
LISI	Levels of Information Systems Interoperability
MBONE	Multicast Backbone
MLS	Multi-Level Secure
MNS	Mission Need Statement
MPEG1	Motion Picture Experts Group 1
MPEG2	Motion Picture Experts Group 2
NCSA	National Center for Statistics and Analysis
NIC	Network Interface Card
NIPRNET	Non-Secure Internet Protocol (IP) Network
NITF	National Imagery Transmission Format
NITF1	National Imagery Transmission Format (version 1)
NITF2	National Imagery Transmission Format (version 2)
NV	Network Video
OA	Office Automation
ODA	Office Document Architecture
ODBC	Open Database Connectivity
ORD	Operational Requirements Document
OSD	Office of the Secretary of Defense
OTH-G	Over the Horizon - Gold
PAID	Procedures, Applications, Infrastructure, and Data
PM	Program Manager
PPP	Point to Point Protocol
PPS	Precise Position Services
PPTP	Point to Point Tunneling Protocol
RAD	Requirements Analysis Database
RF	Radio Frequency
RPC	Remote Procedure Call
SDIF	SGML Document Interchange Format
SDTS	Spatial Data Transfer Standard
SEI	Software Engineering Institute

Glossary

SGML	Standard Generalized Markup Language
SHADE	Shared Data Environment
SIP	System Interoperability Profile
SIPRNET	Secure Internet Protocol (IP) Network
SLIP	Serial Line Internet Protocol
SOP	Standard Operating Procedure
SSL	Secure Sockets Layer
T4	ITUTSB T4:1980
T6	ITUTSB T6:1984
TAFIM	Technical Architecture Framework for Information Management
TEM	Terrain Evaluation and Mapping
TEMP	Test and Evaluation Master Plan
TIBS	Tactical Information Broadcast Services
TIFF	Tagged Image File Format
TRAP	TRE and Related Applications
TRE	Tactical Receive Equipment
TRM	Technical Reference Model
UHF	Ultra-High Frequency
UJTL	Universal Joint Task List
USD A&T	Undersecretary of Defense for Acquisition and Technology
USMTF	U.S. Message Transfer Format
VAT	Video Audio Tool
VCJCS	Vice Chairman of the Joint Chiefs of Staff
VHF	Very High Frequency
VMF	Variable Message Format
VPN	Virtual Private Network
VPR	Vector product format
VTC	Video Teleconference
WAN	Wide Area Network

Appendix A – LISI 97 Capabilities Descriptions

The following sections describe, in detail, the individual capabilities represented by the *LISI 97 Capabilities Model*. The descriptions are organized by *PAID* attribute. Examples are frequently provided of the kinds of information that is captured in the *Implementation Options Tables*.

A.1 PROCEDURES ATTRIBUTE

A.1.1 Isolated Level (Level 0)

LISI Level 0 for *procedures* is generally characterized by manual access controls and the NATO Levels of System Interconnection. There are five sub-levels within this level.

Level 00 **No Known Interoperability:** LISI Level 00 represents systems where there is no known interoperability. This level is illustrated by systems that are completely isolated from each other to the extent that even attempted human intervention cannot provide interoperability. An example of systems that fall into this level is a situation where the humans cannot act as intermediaries because they speak different languages.

Level 0a **Access Control:** LISI Level 0a corresponds to a NATO Level 1 for system interconnection. This level implies that units and/or individuals can exchange verbal and/or written information via off-line communication systems.

Level 0b **Access Control:** LISI Level 0b corresponds to a NATO Level 2 for system interconnection. This level implies that co-located liaison teams can provide an exchange of verbal or written information. Each team, however, has access only to a terminal connected to its own system.

Level 0c **Access Control:** LISI Level 0c corresponds to a NATO Level 3 for system interconnection. This level implies that a single operator can transfer information from one system to another using a separate terminal for each system.

Collectively, these three sub-levels are represented by manual access procedures.

Level 0d **Media Exchange Procedures:** LISI Level 0d corresponds to the introduction of media exchange. Procedures must be in place at this level to govern the “sneaker-net” exchange of information. For example, physical security and login procedures to allow specific authorized personnel access to hardware must be in place so that only approved media exchanges take place.

LISI 97 Capabilities Descriptions

A.1.2 Connected Level (Level 1)

The *Procedures* attribute of LISI Level 1 is characterized by local and site level procedures. These include conformance and compliance to standards and the existence of a security profile. For a given implementation, there may be additional procedures at the local or site level, such as ensuring an e-mail server is present for the site.

Level 1a/b Security Profile: LISI Level 1a/b corresponds to the existence and compliance of a security profile. A security profile contains information that governs at what security level(s) a system may operate. Given that in different circumstances different security levels may be required, the existence of such a profile is a first step towards procedurally allowing direct connectivity between systems. If a system is certified to operate at the unclassified and secret levels, then that system should be able to interoperate directly with either unclassified or secret systems (unclassified-to-unclassified and secret-to-secret). Therefore, without knowledge of the implementation, existence of a security profile provides a potential for direct connection to another system.

The next step, of course, is to examine the particular implementation and determine if both systems are at the same security level. If they are not, some means of interoperability other than direct connectivity (absent the presence of multi-level security capabilities) must be used and LISI Level 1a/b is not achieved. For example, an air gap could be used with media exchange, represented by LISI Level 0d.

In addition to a security profile, other procedural considerations at LISI Level 1a/b include operational characteristics for a given implementation. A frequency management plan must exist to allow one- or two-way connectivity, if connectivity using radio frequency (RF) is required. Also, sufficient bandwidth must be available for transactions to take place, so analysis to determine that adequate bandwidth is available must be performed.

Level 1c/d Standards Compliant: LISI Level 1-c/d corresponds to compliance with enterprise standards. Assessment of standards compliance is a function of the answers to questions regarding all implementation options across *PAID*. Standards compliant implies that selections made when implementing the system followed the appropriate standards, where such standards existed. For example, a system that is intended to work on a LAN must use a standard implementation, such as Ethernet, and not a proprietary method for connection. If all options selected adhere to such standards, the system is assessed as fulfilling the *procedures* requirement for LISI Level 1c/d. However, if selections are made that are not standards-compliant, regardless of the level of the selection, then the system's assessment for *procedures* cannot be higher than LISI Level 1a/b until the selected implementation becomes standard (i.e., the standard changes or the implementation changes). The system could choose to support the standard in addition to the non-compliant implementation. In such a case the system would meet the requirement of LISI Level 1a/b.

A need for further *procedures* assessments may exist based on the presence of an enterprise architecture. An architecture is a collection of standards and recommended or required implementation options that structures a system, organization, or enterprise. In the DoD Joint enterprise, the JTA is the predominant architecture. LISI, therefore, assesses compliance of DoD systems against the JTA. For every implementation option across all of the **PAID** attributes, if there is a JTA option and the system is implemented using that option, credit is given at LISI Level 1 c/d. If, however, an option other than the JTA option is selected, precluding compliance with the JTA option, the system cannot be assessed higher than LISI Level 1 a/b. If the JTA changes, or implementation selections change, the system's assessment would then move up.

As an example, consider a system that is meant to perform video collaboration. The JTA accepted implementation for video collaboration specifies that systems follow the ITU-T H.320 series of standards. These standards are supported by numerous existing commercial conferencing products such as White Pine, Microsoft NetMeeting, and others. Other standards also exist to support video collaboration such as those used by the widely available product Cu SeeMe. A system that uses Cu SeeMe instead of an H.320 compliant product would not be assessed as being compliant with the JTA (as recognized by LISI) and will therefore be assessed as LISI Level 1a/b instead of LISI Level 1c/d. Two obvious solutions to raising the LISI assessment are: 1) the system is modified to include H.320 compliant products or 2) the JTA is modified to include the standard used by Cu SeeMe. In either case, the system's assessment could become LISI Level 1c/d since it now fulfills the requirements for JTA standards compliance.

In addition to the standards compliance considerations discussed above, this level also considers the management and operational aspects of a system. Operational parameters include the existence of a naming plan for systems that are connected so that data file transfers and basic messaging applications can find the correct systems. If an e-mail server is required, then an e-mail server must be present on the network over which e-mail will be sent. The e-mail server must be compatible with the e-mail applications in use on the network and e-mail addressing conventions must be set.

Management parameters include the existence of documentation such as users' manuals and installation guides. At minimum, hard copy documentation must be available for a system to achieve this level for *procedures*. Training and staffing plans must be in place so that trained staff is available on at least an on-call basis.

A.1.3 Functional Level (Level 2)

LISI Level 2 of the *procedures* attribute is characterized by procedures that apply in a program environment so that they are applicable at all sites or locations where the program is implemented. In addition, other *procedures* assessments are based on adherence to a common operating environment.

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Level 2a **Program:** Program-level procedures apply mostly to the management aspects of the *procedures* attribute. These procedures include training, staffing, documentation, and plans. For program-level procedures, training should be embedded in the system, represented by either an embedded training program or, at least, embedded help functions. At the program level, a dedicated, trained, staff should be available 24 hours a day, seven days a week. On-line documentation, including users' manuals and installation guides, should be available. In the plans area, plans should exist for including new technologies as they emerge, for migrating to additional implementations and uses, and for other program milestones. In addition, formal requirements documentation, such as an operational requirements document (ORD), should exist.

Level 2b/c **Common Operating Environment:** Common operating environments exist both within and outside of DoD. These standard environments represent a formalization of requirements for systems to be able to operate in similar (or identical) hardware and software configurations. A common operating environment is generally defined by an enterprise set of standards and installation/fielding procedures that ensures that a system will not cause problems when it is installed on a platform where other systems already operate.

LISI assesses compliance with a common operating environment in a way similar to the assessment of compliance with an architecture. That is, selections that comply with the common operating environment are identified as such in the implementation options tables. Where a system is given a choice of implementations and an identified common operating environment choice is available, at least that choice must be selected. If a different choice is made to the exclusion of the common operating environment choice, the system will not receive credit for common operating environment compliance. The system will be assessed at a LISI Level 2a because it does not meet the criteria for LISI Level 2b/c.

There are some operational parameters to consider at this level, including LAN identifications (e.g., IP addressing scheme in place), and the existence of a web server, if required.

Within the DoD enterprise, LISI assesses these two sub-levels in two different ways for compliance to the DII COE. First, systems must be DII COE compliant at DII COE Level 5 in order to gain a LISI Level 2b assessment. This rating is made by examining the DII COE Compliance Checklist that is defined by DISA.

Second, system developers must make implementation choices that comply with DII COE standards at all levels. This does not mean that a system must implement all aspects of the DII COE to be rated above LISI Level 2c. It does mean that wherever an implementation choice is made, the system must support the DII COE specified choice, if there is one.

The DoD interpretation of the *procedures* attribute for LISI Level 2a and LISI Level 2b are summarized in the following table:

DoD LISI Level 2b	DII-COE, Minimum Levels of Compliance (Level 5): This level is attained for <i>procedures</i> when a system is assessed as being DII COE Level 5 compliant.
DoD LISI Level 2c	DII-COE Overall Compliance: This level is attained for <i>procedures</i> when a system complies with all other applicable implementation choices existent within the system which are defined conditions within DII COE levels 6 through 8.

Exceptions to Policy: Within DoD, exceptions may be granted (according to procedures already outlined in the DII COE) for implementation selections that are not typical to the DII COE. From a procedural aspect, LISI treats those approved exceptions as positive evidence of a system’s compliance with DII COE policy.

Examples of the DoD Interpretation:

Assessed LISI Level	Condition
At most LISI Level 2a	A system uses any implementation choice which fails to comply with any condition of the DII COE Levels 1 through 5 and does not have an approved waiver.
Meets LISI Level 2b	A system meets DII-COE Level 5 (with or without an approved waiver granted by the DII COE Chief Engineer).
Does <i>NOT</i> meet LISI Level 2c	A system implements a function that is not in accordance with (or granted exceptions) DII COE Levels 6 through 8.
Meets LISI Level 2c	A system complies (or has approved exceptions to policy) with all implementation choices within the DII-COE AND the system is DII COE Level 5 compliant.

A.1.4 Domain Level (Level 3)

The *procedures* attribute of LISI Level 3 is characterized by how well a system conforms to a domain’s doctrine and missions. For example within DoD, each Service and Agency operates in a different culture, so this level is attained when a system can operate effectively throughout that particular culture, or domain. Systems at this level meet Service or Agency requirements, as documented in approved requirements documentation. Training is performed across the Service or Agency so that all necessary personnel are exposed to the system. Installation and operations procedures (e.g., Standard Operating Procedures [SOP]) are in place and documented throughout the

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Service or Agency, so that wherever the system is employed, its use and purpose is clear and unambiguous. For example, group collaboration procedures must exist to allow groups across the domain to view, develop, or modify documents using collaborative applications without causing conflicts.

Level 3a/b/c Systems at LISI Level 3a/b/c meet domain requirements and are characterized by management direction from within the domain vice the enterprise level (defined as LISI Level 4). Operational procedures at this level include the existence of an identification plan for nodes and systems that spans the domain. A domain directory is an example, where telephone area codes may establish the first subdivision of the domain into geographic areas.

Where a DBMS requires a server, the server must be operational and compatible with the other applications. WAN requirements must be met so that IP addresses are unique across the WAN and systems can find each other.

In the area of security, systems at LISI Level 3 have procedures in place to handle security (e.g., access controls, firewalls) across parts of the “domain.” Another example is the procedures for implementing one-way guards.

A.1.5 Enterprise Level (Level 4)

The *procedures* attribute for LISI Level 4 is characterized by how well a system conforms to a particular enterprise’s doctrine and missions and its ability to interoperate with other enterprises. Where LISI Level 3 systems meet domain requirements, LISI Level 4 systems fulfill enterprise and beyond requirements. For example, within DoD, the broader the doctrine that is followed across Services and Agencies for any given function, the better chance that their systems will interoperate with other Joint systems.

Level 4a **Enterprise:** In the DoD, JCS Pubs are the primary vehicles for providing current, common doctrine for Joint operations. Systems at this level meet enterprise requirements, as documented in approved Joint requirements documentation such as a Joint Required Operational Capability (JROC), ORD, MNS, and CONOPS.

Level 4b **Cross-Government Enterprises (NII Compliance):** This level represents agreement in the procedures for attaining interoperability across the U.S. Government. For DoD, this level is attained, at a minimum, by fielding systems that are National Information Infrastructure (NII) compliant. Additionally, agreements must be reached on information exchange requirements and supporting implementations before this level is satisfied.

Level 4c **Multinational Enterprises:** This level requires LISI Level 4b satisfaction with the added requirement to reach agreements between nations which require interoperability.

In the area of security, systems at LISI Level 4 have procedures in place to handle multiple levels of security across the enterprise (all domains) at LISI Level 4c.

A.2 APPLICATIONS ATTRIBUTE

A.2.1 Isolated Level (Level 0)

Level 0 The *applications* attribute at LISI Level 0 is not applicable. As mentioned earlier, removable media transfers occur independent of the applications used. Obviously, for data on this removable media to be understood by both ends of the process, common hardware and system software must exist. The ability to read and process the *data* by applications is intentionally not defined.

A.2.2 Connected Level (Level 1)

The *applications* attribute at LISI Level 1 is characterized by applications and functionality associated with the accomplishment of simple connectivity.

Level 1a/b **Simple Interactions:** LISI Level 1a/b applications are characterized by the simplest forms of user interactions. The applications that support this level can usually only interact with one simple data type. An example of such a data type is ASCII text. These interactions also include capabilities such as the ability to process simple telemetry data or interact using text chatter, voice or Fax. Examples of some of the available simple chat programs which represent this level include simple Unix-Chat, DIDTS/MDITS Chat, PARAGON Chat, Simple Unix Chat, and Chat 2.0 (Microsoft). The Precise Position Service (PPS) is an example of an application that provides telemetry services.

Level 1c **Data File Transfers:** LISI Level 1c applications are characterized by the ability to conduct data file transfers. This involves moving an entire data file structure between systems and is more sophisticated than the simple interactions of the previous sub-level. This exchange is performed syntactically without the guarantee of semantic understanding on the other end. Examples of these transfers include software programs that support protocols such as X-Modem, Y-Modem, or Z-Modem. Often the operating system provides intrinsic support for these functions. They are also implemented in commercial software applications such as ProComm, Crosstalk or Kermit.

Level 1d **Basic Messaging:** LISI Level 1d applications are characterized by the ability to provide support for basic messaging capabilities (examples include simple ASCII text messages and the many commercial e-mail programs). At this level, exchange and understanding of attachments is not guaranteed. These messaging functions are distinguished from the earlier, simple interactions in that they are persistent and do not require real-time/simultaneous interaction. “Store and forward” is a phrase that

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often describes this situation. The recipient of a message does not need to be present when the message is sent in order to receive it.

A.2.3 Functional Level (Level 2)

The *applications* attribute at LISI Level 2 is characterized by the ability to provide a heterogeneous understanding of the data being exchanged.

Level 2a **Advanced Messaging:** LISI Level 2a applications are characterized by the ability to process advanced messages through the use of complex messaging applications. These applications make use of parsers to extract understanding from the format of the data. At this level, e-mail with files encoded as attachments can be exchanged. Examples of AUTODIN message formats that require parser software include USMTF, VMF, OTH-Gold, and MIDBTF. Examples of e-mail applications that allow encoded attachments include Eudora, CC:Mail, Teamlinks, Applix Mail, Microsoft Mail, and Netscape Messenger.

Level 2b **Basic Operations:** LISI Level 2b applications are characterized by the ability to perform basic operational functions often associated with common functions known as Office Automation (OA). The basic kinds of operational functions performed here include the ability to create, edit, and view the following key products:

- *Documents (Word Processing):* These are applications that go beyond simple text editing to include formatting and at least rudimentary page layout capability. Example applications used to perform this function include Adobe Acrobat, Microsoft Word, Word Perfect, and Applix Word.
- *Briefings (Presentation Graphics):* These applications provide graphical preparation and editing capabilities. Examples used to perform this function include Freelance Graphics, Harvard Graphics, Corel Draw and Microsoft PowerPoint.
- *Spreadsheets:* These kinds of applications provide a tabular, row and column, capability highly suited to manipulating numbers such as budgetary information. Examples of applications used to perform this function include Lotus 1-2-3, and Microsoft Excel.
- *Pictures & Maps (Graphical & Image Viewers):* Applications used to perform this function include Xview, Sun Viewer, Lview, Adobe PhotoShop, and Applix graphics; and numerous others. This category also includes simple graphical viewers as well as applications with rudimentary manipulation tools. It is not the same as imagery management systems at LISI Level 3. Applications used to accomplish this function include Electronic Light Table (ELT), and 5D client software.
- *Reports (Desktop Data Base):* These applications support simple databases typically designed for use by one user at a time, vice a full-up DBMS, to maintain information in a form that allows report generation. Applications used to perform this function include Dbase, Microsoft Access, and Foxpro.

Level 2c **Web Browsers:** LISI Level 2c applications are characterized by the use of or the ability to facilitate common Internet-like “Web” browsers to deliver information easily, in various formats, to and from a wide range of computing platforms, and from many diverse sources. For DoD and much of the NII, Web browsers provide a strategic direction for providing common display clients for numerous different applications. A browser makes accessing information from disparate platforms easier in the following ways:

- By providing a common graphical interface
- By supporting multimedia (text, sound, video, graphics, et cetera)
- By performing functions through a common interface
- By being based on commercially accepted and understood standards/conventions

These key browser features make it easier to access and provide information. Examples of some Web browsers used to perform this function include Mosaic, Netscape Navigator and Communicator, and Microsoft Internet Explorer.

A.2.4 Domain Level (Level 3)

The *applications* attribute of LISI Level 3 is characterized by multiple application-to-application interactions, focusing on integration either across organizational boundaries or across discipline-based applications. Applications at this level have only a localized view of the distributed information space and cross only one operational or functional domain. Applications can share data and support basic group collaboration on fused information from a localized problem domain.

Level 3a **Full Text Cut and Paste:** LISI Level 3a applications allow the movement of textual data between them through a standard cut and paste (clipboard) interface. This level is reached only when every possible display window created or managed by the application supports local cut and paste of text information.

Although its presence may be viewed as a trivial function, significant difficulties persist in today’s mixed operating system environments. Having this kind of capability is sometimes critical for exchanging information between display windows that a program developer could not envision the need for when the application was created. This capability is based on established conventions and functions similarly for each application. There are numerous examples of applications (e.g., Microsoft Office) that support text cut and paste.

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Level 3b **Group Collaboration:** LISI Level 3b applications are characterized by applications that foster simultaneous group collaboration, such as shared applications, network video and audio conferencing, and shared whiteboards. Some examples of each are shown below:

- Shared applications include Farallon Timbuktu, DataBeam FarSite, Sun ShowMe, Microsoft NetMeeting, HP SharedX, SpectraGraphics Team Conference, and VisualTek X/TeleScreen.
- Network video and audio conferencing capabilities include Connectix VideoPhone, White Pine CU-SeeMe, Sun ShowMe, Paradise Simplicity, Microsoft NetMeeting, Netscape Conference, Speak Freely, MBONE Tools, VIC, VAT, and NV.
- Shared whiteboards include Databeam FarSite, Sun ShowMe Whiteboard, Paradise Simplicity Whiteboard, Microsoft NetMeeting, Netscape Conference, NCSA Col-lage, and MBONE Tool wb.

Level 3c **Shared Data/Direct Database Exchanges:** LISI Level 3c applications are characterized by the ability to share data with other applications through common repositories without the need to maintain duplicate data. Applications that are able to access and share major forms of *data* are characterized by the implementation of common services (such as those provided within the DII COE). Examples of these applications (built using standard software API/RPC libraries) include those with the capability for accessing map and image repositories.

Beyond the basic application, the implementation of database services such as the use of “replication servers” requires the implementation of application-like database procedures and triggers to control data replication. These hybrid application/data-processing packages are the very embodiment of the “domains” business rules for achieving interoperability.

- *Geospatial Services:* These applications either provide or are able to access and manipulate mapping and geospatial services across a network. They may be performed by individual applications, or provided using a common map interface. Examples within DoD include Common Mapping Toolkit (CMTK), Terrain Evaluation & Mapping (TEM), Joint Mapping Toolkit (JMTK) and Oilstock.
- *Imagery Services:* Applications that provide or are able to access and manipulate databases of imagery and the associated searchable meta data fall into this sub-level. Examples include Image Product Archive (IPA) and 5D server software.
- *Situational Awareness Servers:* Applications that support the sharing of information in order to present a “common” picture of ongoing events and conditions represent this level. An example for DoD is the ability to disseminate data about the location of friendly and enemy forces between independent applications sharing a common data server: the Common Operational Picture (COP) of the GCCS.

A.2.5 Enterprise Level (Level 4)

The *applications* attribute of LISI Level 4 is characterized by the consolidation of duplicative or redundant functions and applications within the enterprise. At this level, the strong differences between applications and data becomes blurred. Systems are implemented using technologies such as Object Databases and Object Programming Languages. The ability to access data or services (e.g., applications written in JAVA applets, Beans) equally well within a Web Browser reduces the need and reliance for separately written applications by Services and Agencies for solutions to the same functional requirement. Systems and applications now truly provide for the exchange of “information and services” in a fully interoperable manner.

Level 4a **Full Object Cut and Paste:** LISI Level 4a applications are characterized by products that support an object-based cut and paste function between cooperating systems. This differs from the simple text cut and paste described in LISI Level 3a. Numerous data types and formats, represented as “objects,” can be transferred with full syntactic and semantic understanding between applications. Some evolving examples include software suites, like Microsoft Office or Applixware, which can cut and paste objects (sounds, images, text, multimedia) throughout the suite of products. Similarly, DoD-developed GOTS applications must build towards this interoperable environment by implementing object level exchanges between commercial programs and those developed to provide DoD-unique capabilities.

Level 4b/c **Interactive:** LISI Level 4b/c interoperability is characterized by applications that provide consistent information in a reliable manner, combining information from disparate sources into a single, dynamic presentation at the desktop. Lightweight clients, applets, and Web browsers are some of the technologies that support this sub-level. Applications that use Java, Object Request Brokers (ORB) and other distributed network computing architectures are examples. This allows applications to interact with advanced CORBA services or and Distributed Component object model (DCOM) services, allowing users access to functional area DBMS, mission applications, and map and imagery servers.

A.3 INFRASTRUCTURE ATTRIBUTE

Infrastructure (I) is the **PAID** attribute that supports the establishment of a connection between systems or applications. The security devices and technical capabilities that are used to implement security procedures also make up a part of infrastructure.

A.3.1 Isolated Level (Level 0)

The infrastructure features that LISI Level-0 systems exhibit are largely independent. Since two systems are unable to connect physically, only the infrastructure items that allow information sharing by other means are important.

Level 0a/b/c Manual Re-entry: This sub-level grouping is a place-holder for infrastructures that have nothing else in common. As mentioned earlier, items such as display monitors or printers contribute to manual reentry. These individual items are not specifically assessed. Also at this level are items that use some form of removable media, but not in a readily transferable electronic format. Film from cameras that must be wet-processed is one example. Film needs to be processed and then digitized for transmission by any of the *infrastructures* above this level. For this reason, film and similar products are not treated as removable media (LISI Level 0d) within the LISI assessments. Analog videotape and recordings are also considered examples of the manual re-entry level. While these items have the physical characteristics of removable media, the lack of a digital representation of the information inhibits ready transfer to information systems.

Level 0d Removable Media: For two systems to exchange electronic data by manual procedures, there must be a common removable media format. There are two aspects that must be considered for a piece of removable media. The first is the physical setup of the device. This relates to the particular type of disk, tape, et cetera. It is important to know if a system has the ability to access this type of media. For two systems to share a 3-½ inch floppy disk, they must both have a 3-½ inch floppy drive.

The second aspect that is important is the file systems supported on that removable media. A 3-½ inch disk can be formatted with different types of file systems. If the media is formatted by a computer running Windows, it may have a File Allocation Table (FAT). If the system were running UNIX, it would have a form of UNIX-based file system (often vendor unique). Once it is established that two systems have a compatible hardware device with a file system both can access, an *infrastructure* that allows for removable media transfers is in place.

Illustrated in the table below are some examples of types of removable media and file formats:

Media Format	File System
3 ½ Inch Floppy Disk	File Allocation Table (FAT)
5 ¼ Inch Floppy Disk	NT File System (NTFS)
CD-ROM	Apple File System
Iomega ZIP 100 Disk	DEC File System
Iomega Jaz Cartridge	
4mm DAT Tape	

There are numerous products that support this type of interaction. The important characteristic of the *infrastructure* at this level is that it allows for digital “sneaker-net” transfer of information between systems.

At this level, the “digital” nature of a data transfer is significant because it provides the first big step towards automated manipulation by information systems. Conversely, analog media must first be digitized for meaningful automated manipulation. In either case, the media must also be removable. This extractability allows data to be taken from one system and, at some later time, entered into another system.

A.3.2 Connected Level (Level 1)

The *infrastructure* supporting a LISI Level-1 interoperability is concerned with establishing an electronic connection between systems. The term “electronic connection” is used to represent the broad alternatives for implementing digital communications—direct wire, radios, satellite communications, et cetera.

Level 1a One-way: This sub-level focuses on the infrastructures that support peer-to-peer connections. The most limited style of electronic connection is a one-way communication capability where only one user is able to transfer information to another. The receiver in this situation does not have the capability to send information back to the transmitter. The receiver also is unable to acknowledge receipt of the transmitted information. Transmissions at this sub-level are often broadcast. With any broadcast, there are injection points where information is put into the broadcast.

A one-way connection is distinguished from a Net (detailed later) in that the primary participants of a one-way broadcast do not provide information; they are only receivers. There are numerous examples of one-way infrastructures in existence today. A radio station is the best known, simple example. Basic pagers are another common example. With both a radio broadcast and a pager, the end users operate in a “receive only” mode and cannot use the same infrastructure to send information the other way.

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An example system within DoD that provides this level of information broadcast is the Global Broadcast System (GBS). Although this system has some facilities for two-way connections, by and large, users participate as receive only. TRAP is another common one-way DoD broadcast.

Not all one-way connections are based on wireless transmission. News feeds, which provide information over a modified RS-232 cable using optical isolators to preclude two-way exchange, are an example used in the intelligence community to bring unclassified information into a classified environment. Under this condition, the traditional two-way RS-232 connection is only capable of providing information in a controlled, one-way mode.

Level 1b/c/d Two-way: This sub-level covers a wide variety of simple two-way connections between systems. These connections generally operate in a “peer-to-peer” or point-to-point fashion which characterizes the nature of interaction. This limited form of two-way interaction differentiates this level of the *infrastructure* attribute from higher level two-way communications such as NETs, LANs, and WANs, wherein multiple peers communicate simultaneously.

These connections can be wireless (e.g., the link between two radios) or wire-based (e.g., an RS232 cable connecting two system). Each end of the connection at this level is capable of transmitting and receiving information. This relationship is required to support the type of applications embodied at this level.

Some of these simple, two-way connections are actually established within a context of broader, highly complex, communications infrastructures. An example of this situation is a common telephone call. In reality, a local “call” still goes into a complex, switching network that more closely resembles a LISI Level 4 infrastructure. However, the interoperability represented between telephones is still in a one-to-one mode and therefore categorized as a simple two-way connection. This is distinct from a LAN card that connects to a complex infrastructure and can interact directly with many parts of that infrastructure.

A general rule in differentiating a two-way infrastructure from a networked infrastructure at higher levels is to consider the ease of configuration of a connection to more than one system. A LAN-based system can easily address multiple systems simultaneously. There is no need for the user to rearrange cables or dial a new number. These procedures to establish another peer-to-peer connection are typically required at the LISI Level 1 infrastructure.

Two-way connections are a very common form of interoperability. One example is where two computers are directly connected with an RS-232 cable and the exchange uses a protocol such as PPP. Another LISI Level 1 interaction is the use of local, direct connections between computers and peripheral devices (e.g., the link between a computer and an external disk drive). Wireless links can also be two-way. A microwave link used to pass data between two specific locations is considered an example of this level.

A.3.3 Functional Level (Level 2)

The primary change in the *infrastructure* attribute from LISI Level 1 to LISI Level 2 is the transition from a peer-to-peer connection to a many-to-many connection, represented by LANs. The ability to establish connections to multiple systems without reconfiguring hardware or infrastructure is a characteristic of this level. Support for protocols that can be used to establish even larger networks also comes into play.

Level 2a Net: A Net is the first sub-level of LISI Level-2. It has the primary characteristic of supporting many-to-many interactions. What distinguishes a Net from higher level infrastructures, such as a LAN, is the inability to limit information to certain members of the Net. A network of voice radios clarifies this distinction. A person communicating over this net may only need to pass information to one other member; however, there is no ability to limit the access of others. At this level, the infrastructure does not readily support the ability to discriminate communications between members of the Net.

Another characteristic of a Net is that the participating members both receive broadcast information from the Net and can contribute information back via the same broadcast process. This is a major distinction from the one-way infrastructure described earlier.

The DoD makes extensive use of Net type infrastructures for command and control (C2). An example is a radio Net used to communicate with aircraft in flight. This Net has an assigned frequency and procedures for communicating. During operations, a fighter may exchange transmissions with the Air Operations Center (AOC) regarding its fuel status. These messages may only concern the aircraft and AOC, but every member of the Net hears them.

This property of a Net can be very useful in maintaining situational awareness. If the same fighter were fired on by a surface to air missile, it would transmit a message that indicates this fact and thus warn other aircraft on the Net. A drawback to this infrastructure is the inability to filter out or distinguish between transmissions. If 100 aircraft were on the same Net with multiple aircraft being attacked, the Net could quickly become overloaded with information.

Other examples of Nets used for data exchange are the numerous Link systems and the TIBS broadcasts. In both of these systems, some or all members inject data into the Net which everyone hears.

Level 2b/c Local Area Network (LAN): The next interoperability step up for the *infrastructure* attribute is a LAN, which characterizes LISI Level 2b/c. LANs have the same capability as Nets to allow many-to-many communications. The increase in sophistication present here is in a LAN's ability to control the particular members involved in the interaction. A message on a LAN can be directed to one or multiple members of the LAN.

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Another distinguishing characteristic of a LAN infrastructure is that all participants share the same communications medium. (This was also the case for a Net, though the distinction there was less important.) This characteristic serves to distinguish a LAN from higher LISI Level 3 infrastructures.

In addition to using the same medium, a LAN has procedures that allow for the efficient sharing of the medium between users. These procedures are reflected in the protocols on which a LAN operates. These protocols allow users to interact with players on the LAN selectively and change the selected players without reconfiguring the infrastructure. (This capability is what distinguishes a LAN from the two-way infrastructure discussed earlier.)

There are many LAN implementations in use today both in the DoD and commercial world. LAN standards are widespread and there are many common implementations of LANs. Examples include Ethernet, Token Ring, and Appletalk. In addition there are low-level protocols that allow for communication across a LAN. NetBEUI is in use by most Windows-based architectures while UNIX-based architectures use sockets. The standards for LANs are usually only compatible within themselves. For two systems to interoperate on a LISI Level 2 infrastructure, they must support the same LAN implementations (commercial LANs normally provide add-on packages for operating two or more LAN protocols across a single physical LAN implementation).

A.3.4 Domain Level (Level 3)

A LISI Level-3 *infrastructure* represents the transition from a “local” network to a “wider” area network. There are no significant sub-levels currently identified within this LISI Level.

Level 3a/b/c Wide Area Networks (WAN): This level is broadly referred to in the *infrastructure* area as WAN. Like a LISI Level 2 LAN infrastructure, a LISI Level 3 WAN also allows many-to-many interactions. It is differentiated from LANs and Nets in that WANs bridge together multiple LANs and/or Nets to form a wider communications pathway. Systems that connect over a WAN infrastructure do not all need to be on the same media. To support this level of interaction, there are hardware devices specifically designed to connect LANs. Routers, switches, and associated network management software are typical examples of the firmware required to enable this level of infrastructure.

Users on a WAN can address systems using different shared media. To allow this, systems connected to a WAN usually have a unique address (identification) that is registered and therefore globally known and meaningful throughout the WAN environment.

A LISI Level 3 infrastructure also possesses the ability to support multiple levels of access control or security within the WAN. A router can be used to control access to certain LANs so that users from only certain LANs can access another WAN. Simple firewalls are the first example of such a security device. The ability to segment the network and generically control access is typically the extent of security supported at LISI Level 3. (More advanced security capabilities are represented in the LISI Level 4 *infrastructure* attribute.)

The Internet is the WAN implementation with which most people are familiar. The Internet is a vast connection of numerous networks that connect together millions of LANs. Other examples of infrastructures that connect together multiple LANs are Asynchronous Transfer Mode (ATM)-based switch networks and Integrated Services Digital Network (ISDN) networks. In the DoD, LISI Level 3 WAN infrastructures are used to integrate numerous LANs and provide connectivity worldwide. The Non-Secure IP Network (NIPRNET) and Secure IP Network (SIPRNET) are two prominent examples. The NIPRNET is an unclassified WAN based on IP protocols and the SIPRNET is a classified WAN, also based on IP protocols.

A.3.5 Enterprise Level (Level 4)

A LISI Level 4 infrastructure represents a major increase in sophistication over a general WAN. The distinguishing factor of a LISI Level 4 infrastructure is the fulfillment of a multi-dimensional network topology. There are no significant sub-levels identified within this LISI level.

Level 4a/b/c This level extends beyond the WAN infrastructure by implementing one or more multi-dimensional components. A LISI Level 4 system can be implemented to have multiple geographic topologies, different access controls and security levels, and various options for configuration and flexibility. Another characteristic is the ability to create the characteristics of lower level infrastructures. This ability to modify the dimensionality of the network is something that is controlled by the network itself and requires little user configuration. Support for multiple security models is another example.

There are some examples of multi-dimensional topologies emerging in the DoD and commercial industry today. One of the most well understood examples of a multi-dimensional network topology is an MLS system. Others are PPTP, LANE, there may also be VPN or SSL.

A.4 DATA ATTRIBUTE

The *data* (D) attribute focuses on the information exchanged and processed by the information system. This component deals with both the data format (syntax) and its meaning (semantics). Unlike the other three *PAID* attributes, there are only a few sub-levels presently identified that discriminate particular *data* capabilities. Therefore, the approach chosen to describe this attribute is through the presentation of examples. This approach provides a common reference for comparison when assessing data characteristics not explicitly present within the *LISI Capabilities Model*.

There are two main considerations used to evaluate the *data* attribute and the LISI level to which it is associated.

First is the format and style of the information involved. This aspect of the *data* attribute is identified primarily by the physical structure (syntax) of the information to be exchanged. The term “data protocol” is often used here to describe the format of the information exchange between systems. This terminology describes the transfer of data between systems (e.g., ASCII, GIF, TIFF, VMF, .doc, and .ppt files). Data protocols come in many forms, from the very simplistic to highly complex heterogeneous definitions. LISI Levels 0 and 1, and certain aspects of LISI Level 2, are best described by these interactions (i.e., Private Data, Media formats, Basic Data Formats and Advanced Data Formats).

The second consideration when evaluating the *data* attribute involves the breadth of agreement that has been reached about the meaning and substance of the information it transports between systems. This consideration encompasses the semantic aspects of the data—agreements on meaning, valid values, usage, relationships to other data elements, et cetera. The term used to define this set of conditions of “data model.” Within LISI, the data models (both physical and logical) represent the key words used at LISI Levels 2, 3, and 4 to define the degree of agreement that has been attained to address interoperability (i.e., individual program level models, domain level models used within a particular functional area, and enterprise or cross-enterprise level models which required the broadest level of agreements).

A.4.1 Isolated Level (Level 0)

The *data* attribute at LISI Level 0 includes private data and media format definitions. LISI Level 0 databases rarely, if ever, use data architectures, data dictionaries, or data models. Separate or common organizations use unique, individual, independent data file structures, consisting of homogeneous, system-related, and non-standard data elements.

Types of system file formats include: Digital Information Geographic Exchange Standard (DIGEST); Apple; Personal Computer (FAT); and UNIX (tar).

Level 0a/b/c Private Data: Data structures and formats at this level are treated as private between isolated systems. No common media format exists.

Level 0d **Media Formats:** This level defines formats for removable media which are now available within the infrastructure. Examples formats include the various operating system standards such as PC (FAT), Apple, Unix(tar), et cetera.

A.4.2 Connected Level (Level 1)

The *data* attribute at LISI Level 1 is characterized by basic data formats. Information exchange is restricted to homogeneous data exchange. Data are typically organized within individual, independent data files that can be discretely transferred and are entirely single-application dependent.

Examples of basic data formats include the following:

- *Person-to-Person Voice:* Freeform voice communications.
- *Sound/Video:* Motion Picture Experts Group information types MPEG-1 Audio, video, and systems: CD-ROM; MPEG-2 Audio, video, and systems: HDTV; Video (.mov); QuickTime (.qt); and structured/formatted voice communications.
- *Simple Graphics:* Graphical Kernel System (GKS); Windows Metafile (.wmf); and PCGraphics (.pcx).
- *Simple Text:* Plain ASCII text.
- *Simple Message Format:* Document Transfer and Manipulation (DTAM); Variable Message Format (VMF); E-mail (No attachments); DEF (Data Exchange Format), Gridded Binary (GRIB) Weather and oceanographic data exchange format; Binary Universal Format for Representation (BUFR) Weather exchange/ storage; GZIP (.gz), PKZIP (.zip), and MacCompressed (.hqx).
- *Types of TADIL include:* Digital Geographic Information Exchange Standard (DIGEST) and UNIX(tar)).
- *Simple Graphic/Pictures:* Raster images/pictures (GIF/TIFF)
- *Sound:* Wave (.wav); and Audio (.au).
- *Scanned Technical Drawings:* T4 and T6 interchange of optically scanned engineering drawings and pages of technical publications, and directives to compress raster graphics.

A.4.3 Functional Level (Level 2)

The *data* attribute at LISI Level 2 is characterized by program data models and consists of sub-domain or function-wide shared databases that contain heterogeneous information, use conversion protocols, and are based on function-wide tools. The functional databases are cleanly separated from applications. The term “program” at this level covers any data format or file structure defined for use by an application. These formats are frequently proprietary to the using application. For example, the internal format of a Microsoft Word (.doc) file is entirely different than that of a Microsoft PowerPoint file (.ppt). These two files are considered as “program” level representations within LISI, even though these separate programs do possess advanced means of exchange their individual contents between one another.

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Types of program models and advanced data formats include the following:

- *Markup Language*: Standard Generalized Mark-up Language (SGML) production long-term storage Hypertext Markup Language (HTML) (.htm) and Applix Word (.aw).
- *Maps Vector*: VPF Map vector products: VMAP, UVMAP, DNC, VMAPAD, VITD, DTOPT, LWD, and WVST; and CGM Vector graphics data.
- *Primary Imagery*: Initial Graphics Exchange Specification (IGES); National Imagery Transmission Format, version 1 (NITF1) imagery; NITF2 (Bi-level image compression); and Spatial Data Transfer Standard (SDTS).
- *Secondary Imagery*: CGM (Images), Joint Bi-level Image Experts Group (JBIG), and JFIF/Joint Photographic Experts Group (JPEG) (Image-photographic).
- *Full Documents*: Compound Documents: Acrobat (.pdf), Microsoft Word (.doc), Rich Text Format (.rtf), and WordPerfect (.wp5) Office Document Architecture (ODA); and SGML Document Interchange Format (SDIF).
- *Briefing/graphic*: Freelance Graphics (.pre); Microsoft PowerPoint (.ppt); and Applix Graphics (.ag).
- *Maps-Raster Arc Digitized Raster Group (ADRG)*: Digital Terrain Elevation Data Vector Database (DTED); DBDB geospatial products; and Raster Photographic Format (RPF) raster map images CADRG, CIB, DPPDB, and ADRG.
- *Spreadsheets*: Lotus 1-2-3 (.wk3) and Microsoft Excel (.xls).
- *US Message Text Format (USMTF)*: TACELINT, SENSOREP, ATTACKREP, LOCATOR, GREEN, PURPLE, INDIGO, INDIGO REPORT, INDIGO DEVIATION, TURQUOISE, and JITREP.
- *VMF*: E-mail (X.400).

A.4.4 Domain Level (Level 3)

The *data* attribute at LISI Level 3 is characterized by a domain model that allows direct database exchanges. This level is comprised of domain data models, dictionaries, and standard data elements. Data is shared by all of the domains within each enterprise. The DoD domains include: Acquisition and Technology, Civilian Personnel, Command and Control, Finance, Health, Intelligence, Military Personnel, and Reserve Components.

Examples of document information types handled within Federal Government domains include: Active-X Controls, and JAVA Applets and Beans.

A.4.5 Enterprise Level (Level-4)

The *data* attribute at LISI Level 4 is characterized by the existence and conformance to an enterprise model that is comprised of standard data models, dictionaries, and standard data elements.

Level-4a: The level represents the enterprise model of a fully integrated, information space based on shared data servers; accesses a single, shared database; adheres to a common enterprise data model, standard data elements, shared data server, and data architecture; and requires a full data conversion capability.

Examples of document information and types handled within the Federal Government Enterprises which begin to demonstrate new methods for providing enterprise wide data/application sharing include: Active-X Controls and JAVA Applets and Beans.

Level-4b/c This level represents the extension of individual enterprise models in to a broader global information space. Data models are designed to support syntactic and semantic exchange of information between large enterprise organizations such as between Departments of the U.S. Government and between Multinational Governments and Coalition Forces.

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