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Computer-aided Acquisition and Logistic Support (CALS) Testing: Programs, Status, and Strategy

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Executive Summary

This report is written from the perspective of the National Institute of Standards and Technology (NIST). It is a deliverable against the 1992 Computer-aided Acquisition and Logistic Support (CALS) Statement of Work NIST has with the CALS Evaluation and Integration Office (CEIO).[1] It contains both tutorial information and issues associated with the various types of testing activities under the purview of the CALS initiative. Others may benefit from this report since it additionally provides general tutorial information about the various types of testing activities and associated terminology, and summarizes conformance testing activities for several national and international standards.

The four primary testing activities discussed in this report are: standards testing, component testing, conformance testing, and acceptance testing.

Standards testing determines whether the national, international, or military standards (and specifications) are viable and implementable.

Component testing is conducted to verify the implementation of the design for one software element (e.g., unit, module) or a collection of software elements.

Conformance testing tests the extent to which an implementation under test is a conforming implementation.

Acceptance testing determines whether a software system satisfies its acceptance criteria and enables the user to determine whether to accept the system. This includes the planning and execution of several kinds of tests (e.g., functional, interoperability, performance tests) to demonstrate the implemented software satisfies the user requirements.

Where two or more people are gathered to discuss the topic of "testing," there are usually as many definitions of testing as there are people in the

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[1] The opinions and recommendations of this report are not necessarily those of the CALS Executive or the CALS Evaluation and Integration Office Management.

room. To emphasize this bedlam, a few key testing terms and their many definitions are highlighted: certification, validation, verification. Because terminology is important for communicating in the testing community, an extensive glossary of terms has been added as an appendix.

Key to this report for CALS is a section devoted to several of the testing issues facing the CALS initiative:

- Whether the CEIO should recognize any acceptance testing performed by the systems integrator prior to government procurement.

- Whether it is cost-effective for the CEIO to fund a validation testing system for the Standard for the Exchange of Product model data (STEP), and if so, where should such a system be hosted.

- Although NIST develops conformance testing services for some standards which are Federal Information Processing Standards Publications (FIPS PUBS), no means exist to perform conformance testing on the additional requirements imposed on the supplier through military specifications. Should NIST be responsible for CALS military specification conformance testing?

- Accreditation of testing laboratories is often viewed as an expensive overhead, both in actual dollars required to initiate, and time required to establish such a program. Should the CEIO invest in accreditation?

- The CALS Test Network (CTN) affirms CALS compliance only for DoD-owned systems. Is this appropriate?

- The CTN performs standards testing and interoperability testing without routinely performing conformance testing. This CTN practice is not the same sequence that occurs in general practice.

- Should the CEIO try to leverage industry's test suite and tool development resources to benefit conformance testing and reduce industries' investment costs?

- Should the CEIO fund the development of a conformance testing service for the FIPS and associated military specification?

- Even if conformance testing services existed for all the CALS military specifications, how does the CEIO guarantee enterprise users will take advantage of such services?

For each issue, alternatives are provided, pros and cons considered, and recommendations drawn.

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I. INTRODUCTION.

A. Content of this Report.

If the CALS initiative is to be successful, government and industry have to attain a high level of confidence that the CALS specifications and standards are adequate to satisfy the requirements for digital delivery of technical data supporting user applications. Equally as important, both government and industry must be satisfied industry implementations can deliver this technical data according to a set of specifications and standards. For this to happen, CALS has to influence testing in three areas: standards, conformance, and acceptance testing [JCMO91].

The content of this report covers those testing activities which have been or are funded by CALS, by DoD services, or by industry to support CALS. Although specific activity descriptions may be limited to the CALS community, the types of testing activities generically described in the following pages, the author believes, satisfy most enterprise users' application requirements.

B. Scope of this Report.

The audience of this report includes: the CALS Executive and supporting CALS Evaluation and Integration Office (CEIO) managers; CALS/CE Industry Steering Group (ISG) participants, particularly those who have invested in testing activities relative to CALS; suppliers of CALS implementations; and enterprise users responsible for implementing CALS solutions into their logistic support life cycle processes.

C. Structure of this Report.

The body of the document is divided into nine sections with additional supportive appendices. The following is a brief description of each section:

I Introduction. This section introduces the need for testing realized by the CALS Evaluation and Integration Office.

II Terminology. This section attempts to raise the reader's consciousness on how nebulous testing terminology really is.

III Background. Background is divided into two primary parts: an introduction to the standards-making activities, then the types of testing as they relate to the standards. A listing of publications relative to the types of testing is also presented.

IV Testing Activities. There is a general introduction of the primary testing participants as they relate to those testing activities associated with CALS. This is followed by brief descriptions of participants' activities relative to each type of testing.

V Issues. Through the course of discussion under section III and IV, several issues are highlighted in bold. Under the Issues section, these issues are examined in more detail, some alternatives proposed, and the pros and cons associated with each alternative listed. Additional issues not found elsewhere in the text are also included here for discussion.

VI Conformance Testing Status of CALS Standards. Although this section is a snapshot in time, it gives a status update of various conformance testing activities for current CALS standards, as well as those potentially on the horizon. For some standards, additional system, process, or programmatic detail is provided.

VII Conclusion. This section is a recapitulation of the report as a whole.

VIII Bibliography. These works are used throughout the document and have provided the author of this report with a source of expertise relative to particular standards, programs, or testing activities.

IX Acknowledgements. Beyond the many references reflected in Section VIII, there were also several individuals who helped compose graphical representation and technical interpretation of their particular conformance testing service. These individuals and others who have provided additional assistance are acknowledged in this section.

II. TERMINOLOGY.

Where two or more people are gathered to discuss the topic of "testing," there are usually as many definitions of testing as there are people in the room. Add personal expectation to the formula, and one is left with a nebulous understanding of what "testing" provides. To emphasize this bedlam, a few key testing terms are highlighted below.

Certification.

There is a discrepancy in the use of the word "certification" between DOD-STD-2168:

> "a process, which may be incremental, by which a contractor provides objective evidence to the contracting agency that an item satisfies its specified requirements" [2168]

and ISO/IEC (International Organization for Standardization / International Electrotechnical Commission) Guide 2:

> "procedure by which a third party gives written assurance that a product, process or service conforms to specified requirements" [2-91].

DoD's definition primarily applies to the quality of software to be purchased and meeting the enterprise user's specific requirements, i.e., acceptance testing. The ISO/IEC Guide relates to the formal process for judging conformity of a product, process, or service, primarily used in reference to conformance testing. The ISO/IEC definition is reinforced by a similar conformance testing application in American National Standards Institute (ANSI) Z34.1-1987's definition:

> "the procedure by which written assurance is given that a product or service conforms to a standard or specification" [Z34.1].

Validation.

There are several uses of the term "validation" both within the CALS community and outside. The type of validation testing the National PDES[2] Testbed (NPT) and the CALS Test Network (CTN) performs during standards testing is closely aligned with Webster's definition:

> "an act, process, or instance of making valid. (Valid - having legal efficacy or force)" [WEB79].

DoD-STD-2167A and FIPS PUB 132 use the term as it applies to software development, the component testing phase:

DOD-STD-2167A -

> "the process of evaluating software to determine compliance with specified requirements" [2167A]

and FIPS PUB 132, which adopts ANSI/IEEE Std 1012 -

> "the process of evaluating software at the end of the software development process to ensure compliance with software requirements" [FIPS132].

In conformance testing, validation is performed by a third-party testing laboratory, described at length in the American National Standard (ANS) Z34.2-1987 [Z34.2]. This ANS definition does not include issuing a certificate at the end of the process. The NIST draft proposed FIPS for Conformance Testing Policy and Procedures does include issuing a certificate:

> "the process of checking the conformity of an implementation of a standard to its standard specification through conformance testing, and when compliance is demonstrated, issuing a validation certificate" [FIPS88].

---

[2] Product Data Exchange using STEP (Standard for the Exchange of Product model data).

A last definition on the word validation also supports a conformance testing type of activity and comes from FIPS 11-3, Guideline: American National Dictionary for Information Systems [FIPS11-3]:

> "(1) tests to determine whether an implemented system fulfills its requirements. (2) see data validation [(1) a process used to determine if data are inaccurate, incomplete, or unreasonable; the process may include format checks, completeness checks, check key tests, reasonableness checks and limit checks. (2) the checking of data for correctness or compliance with applicable standards, rules, and conventions.]"

Since there is so much double entendre in using the word "validation," one must define the use applicable to the document. This report is primarily addressing the validation activities associated with standards and conformance testing; therefore, the two relevant definitions, which apply to these testing phases, have been defined in the glossary.

Verification.

DOD-STD-2167A:

> "the process of evaluating the products of a given software development activity to determine correctness and consistency with respect to the products and standards provided as input to that activity" [2167A],

and FIPS PUB 132:

> "the process of determining whether or not the products of a given phase of the software development cycle fulfill the requirements established during the previous phase" [FIPS132]

are consistent in referring to an evaluation process applied to software during its development cycle---component testing.

The only solution to resolve misunderstanding is to define the terms in the context of a document or conversation, using one of the several references available for doing so. Appendix A defines terminology as it relates to testing and this report. Acronyms used in this report are also enumerated.

Individual information technology standards often have their own established testing terminology beyond those terms universally accepted. An example of some of this unique terminology is the "PICS" (protocol implementation conformance statement) used in GOSIP (Government Open Systems Interconnection Profile) and STEP (Standard for the Exchange of Product Model Data) conformance testing. The reader will be introduced to some of this unique terminology when reading about the status of several conformance testing services described near the end of this report. Supportive definitions for such terms are also provided in Appendix A.

III. BACKGROUND.

A. Standardization and Implementation Process Flow.

> The explosion of technology standards in the last decade has brought the issue of conformance testing to the fore. Through standards, we have arrived at the dawn of the age of Open Systems, where one can employ configuration components from disparate vendors to achieve cost and operating efficiencies.
>
> Multi-vendor systems without conformance testing, however, are a scourge upon the landscape, as they almost certainly will fail to operate in a heterogeneous product environment. Although standards have unlocked the door to openness, they can be ambiguous, occasionally irrational and imprecise; standards are almost always implemented in a manner somewhat unique from someone else's implementation. This often leads to operational failure unless testing is performed beforehand [JC90].

Figure 1 is a modification of a diagram developed by the CALS/CE Industry Steering Group Ad Hoc Testing Committee. This interpretation of their figure presents an example of the overall structure within which standards are developed (step 1), tested (step 2), implementations built (step 3), conformance testing performed (step 4), high level acceptance testing done (step 5), and finally, at a more detailed level, the output data sets of the implementations verified (step 6).

There are specific expected outputs from this diagram in order to meet the enterprise user's requirements. At the culmination of step 2, an international, national, federal, or military standard or specification is created. Step 3 culminates in an implementation of that standard in off-the-shelf supplier offerings, and step 4 qualifies the supplier's implementation against the standard. Step 5 is the integration of the supplier's implementation into the enterprise user's installed base. Step 6 checks data integrity, and concludes with acceptable data sets.

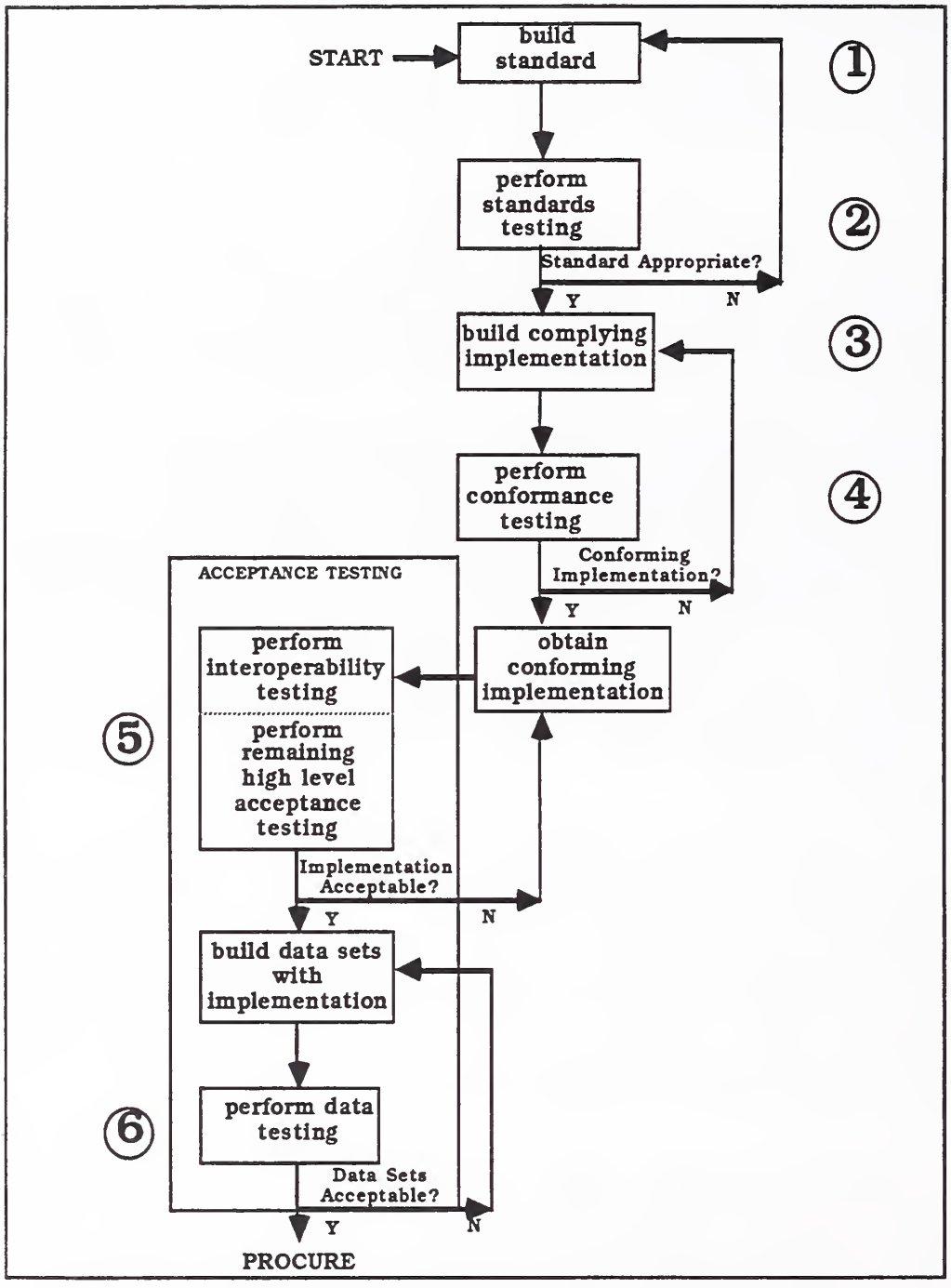

Figure 1: Meeting Enterprise User Requirements
[TEST2 modified]

Step 1 is typically performed by standards bodies (e.g., international, national, governmental). Step 2, for the purposes of this report, is the shared province of the CALS Test Network (for CALS standards and specifications) and the National PDES Testbed (for STEP). Step 3 is

accomplished by the supplier. Oversight of step 4 is the responsibility of NIST; however, actual conformance testing processes may be delegated to other agents acting on behalf of NIST, or performed as a suppler's declaration. In step 5, an enterprise user may optionally choose to perform interoperability testing prior to the remaining high-level acceptance testing activities, e.g., performance testing, robustness testing. Interoperability as a first step of acceptance testing is particularly important if the enterprise user has a high investment in legacy systems. Steps 5 and 6 are typically performed by the enterprise users of the standard implementations [TEST2]. Although interoperability is ultimately the responsibility of the enterprise user, suppliers may optionally perform interoperability assessment among themselves. An example of such a practice occurs for GOSIP implementations, where an on-line system is available for access by suppliers.

In general, an enterprise user is an organization or person who builds, uses, maintains, or disposes of information generated from an implementation. It is important to recognize two different enterprise users benefitting from the output of steps 5 and 6: the systems integrator or a government agent. If the buying government agent recognizes and approves the requirements which a systems integrator must meet when performing system and data acceptance, then, although the agent's acceptance testing task may not be complete, the workload for evaluation is minimized. **The CALS Evaluation and Integration Office (CEIO) could propose a consistent method for defining the requirements which the systems integrator must meet when assessing the supplier's implementation for a potential government acquisition.**

An introduction to the various levels of standards, which play a role in CALS, seems necessary in order to understand the implication on testing activity.

International Organization for Standardization (ISO).
In 1946, national standards organizations from 25 countries formed the International Organization for Standardization (ISO). The U.S. representative, American National Standards Institute (ANSI), is the sole U.S. representative to ISO. ISO develops, coordinates, and promulgates

international standards that facilitate world trade, contribute to the safety and health of the public, and protect the environment. The standards cover all fields except the electrotechnical, which is the responsibility of the International Electrotechnical Commission (IEC) [NCGA].

International Electrotechnical Commission (IEC).
"In 1906, the IEC was formed by national committees from what is now a total of 44 countries. The IEC develops and promulgates electrotechnical standards" [NCGA].

Many of those international standards, which CALS has adopted or is considering (e.g., Standard Generalized Markup Language {SGML}, Computer Graphics Metafile {CGM}, GOSIP, Database Language SQL), are developed under joint ISO/IEC sponsorship. (In some cases, the standards' initial development began in ISO before the creation of a joint ISO/IEC technical committee.) Although STEP is being developed in an ISO Subcommittee, one of its working groups which will address electrotechnical aspects of STEP was formed as a joint ISO/IEC activity in 1991.

American National Standards Institute (ANSI).
The American National Standards Institute (ANSI) coordinates voluntary standards activities in the United States and is the agency that approves standards as American National Standards. It coordinates and manages U.S. participation in the work of several nongovernmental international standards organizations, including ISO and IEC [NCGA].

Federal Information Processing Standards (FIPS).
The National Institute of Standards and Technology (NIST) works through voluntary industry standards organizations, such as ISO and ANSI, to develop standards that will meet the needs of Government users and be implemented in commercial off-the-shelf products. Standards that promise sizable benefits to the Government are issued as Federal Information Processing Standards (FIPS) [SJK88]. FIPS are developed by NIST and issued by the Secretary of Commerce to serve as legislative and executive mandates for improving the use and management of computers and ADP systems in the federal government. The goals of the FIPS program are to:

- "Improve the life-cycle efficiency and effectiveness of federal information technology resources;
- facilitate the competitive and economic procurement of systems, components, and services;
- improve the portability of data, software, and technical skills across systems;
- protect systems and networks against unauthorized access, manipulation, abuse, and protect information from unauthorized modification or disclosure;
- reduce waste, errors, and unnecessary duplication in the application and use of systems; and
- increase the productivity of the federal work force" [FIPS91].

Military Standards and Specifications.
Military standards (MILSTDs) establish engineering and technical requirements for processes, procedures, practices, and methods that have been adopted as a standard. Military specifications (MILSPECs) are prepared specifically to support defense acquisition. They are intended to clearly and accurately define essential technical requirements as well as define that those procedures necessary to determine requirements have been met [DOD 4120.3M]. Specific to CALS, the purpose of MILSTD-1840 is to standardize the format and information structures of digital data files used for the transfer and archival storage of digital technical information [1840]. The MILSPECs 28000, 28001, 28002, and 28003 identify requirements for specific applications using the Initial Graphics Exchange Specification (IGES), Standard Generalized Markup Language (SGML), Raster, and the Computer Graphics Metafile (CGM), respectively.
"Tailoring" standards for unique requirements, while still maintaining technical attributes from the standard, is a potential occurrence, given the generation of standards at the international, national, federal, and defense levels. For example, given the existence of an ISO standard, ANSI can:

- Accept it in total.

- Delete portions unnecessary to achieve United States objectives.

- Add additional functionality not included in the original standard.

- Make the standard more restrictive for the United States than what was approved internationally by limiting options specified in the standard.

Any action other than option 1) would be carried out only to tailor the standard more closely to United States needs. These same options would also be considered when developing a FIPS in order to best accommodate the requirements specific to the federal government. Then, in turn, the CEIO may apply further tailoring when issuing military specifications to address specific needs of the Department of Defense (DoD).

B. Types of Testing.

Figure 2 selects testing activities of Figure 1 which are general to all CALS enterprise user environments, emphasizing that testing activities occur as a continuum. Standards testing (which includes military specification testing) determines whether the national, international, or military standards (and specifications) are viable and implementable.

Component testing is the routine checking performed during the development cycle of an implementation. Conformance testing and acceptance testing ensure the implementation meets the standard and also meets the enterprise user's requirements respectively. At all levels of testing, there is preparatory work that occurs prior to the actual testing activities. With the exception of acceptance testing, the degree of testing activity diminishes and levels off as the standards, military specifications, and products become more stable. Since acceptance testing is tailored to meet each enterprise user's requirements, the level of activity remains somewhat constant.

Standards testing has not traditionally occurred during the standard's development process. The decision to conduct such testing is based on the level of available technology to support the standard during its development. Historically, standards have been produced after the

technology is established and implementations are developed. For the development of STEP, a different approach was chosen. Building on research and development (R&D), but not on vast implementation experience, STEP is being designed through the visions of many individuals. Without reference implementations developed during standards testing, which may be used to pass quality judgement on the concepts, the result may be a product data exchange standard that is (1) not implementable or, if implementable, (2) does not solve the functional requirements the enterprise user community initially expressed. Hence, "validating" the standard is necessary prior to its adoption.

The CALS military specification testing was founded on a similar need. These specifications were written to minimize the flexibility usually found in consensus-built national or international standards, and add any additional requirements specific to the CALS initiative. No implementations of these military specifications existed prior to their adoption, and the concept of requiring computer standards for the exchange of weapon system data was relatively new. Given this

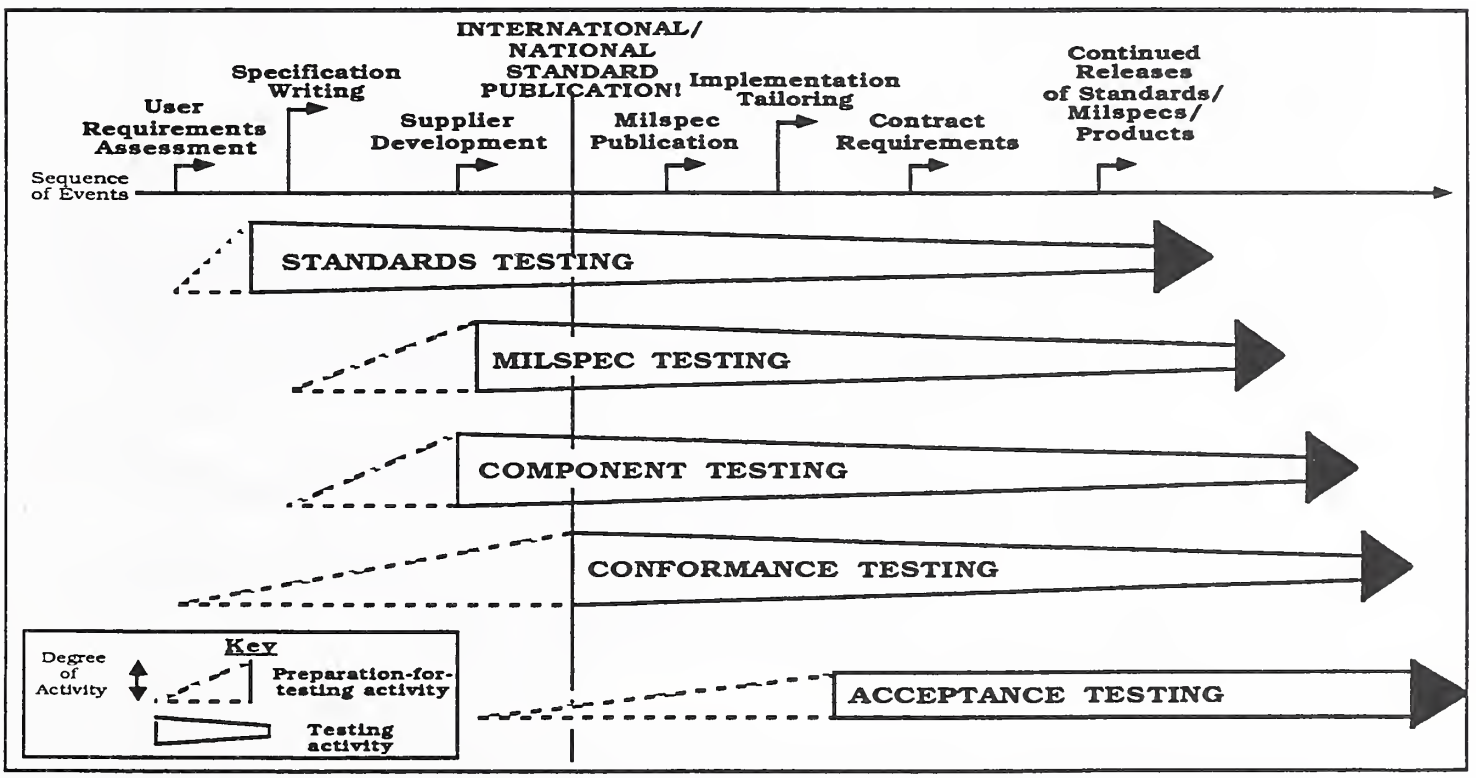

Figure 2: TESTING ACTIVITY CONTINUUM

environment, it was necessary to establish a CALS testing program to assess the viability of the military specifications themselves. Although the mission of standards testing and military specification testing is similar, the distinction in Figure 2 is due to timing of each testing activity relative to the adoption of a national or international standard.

Component testing is conducted internally by a supplier against his implementation of a standard during the product development cycle. It is testing that has occurred since software development began and is not

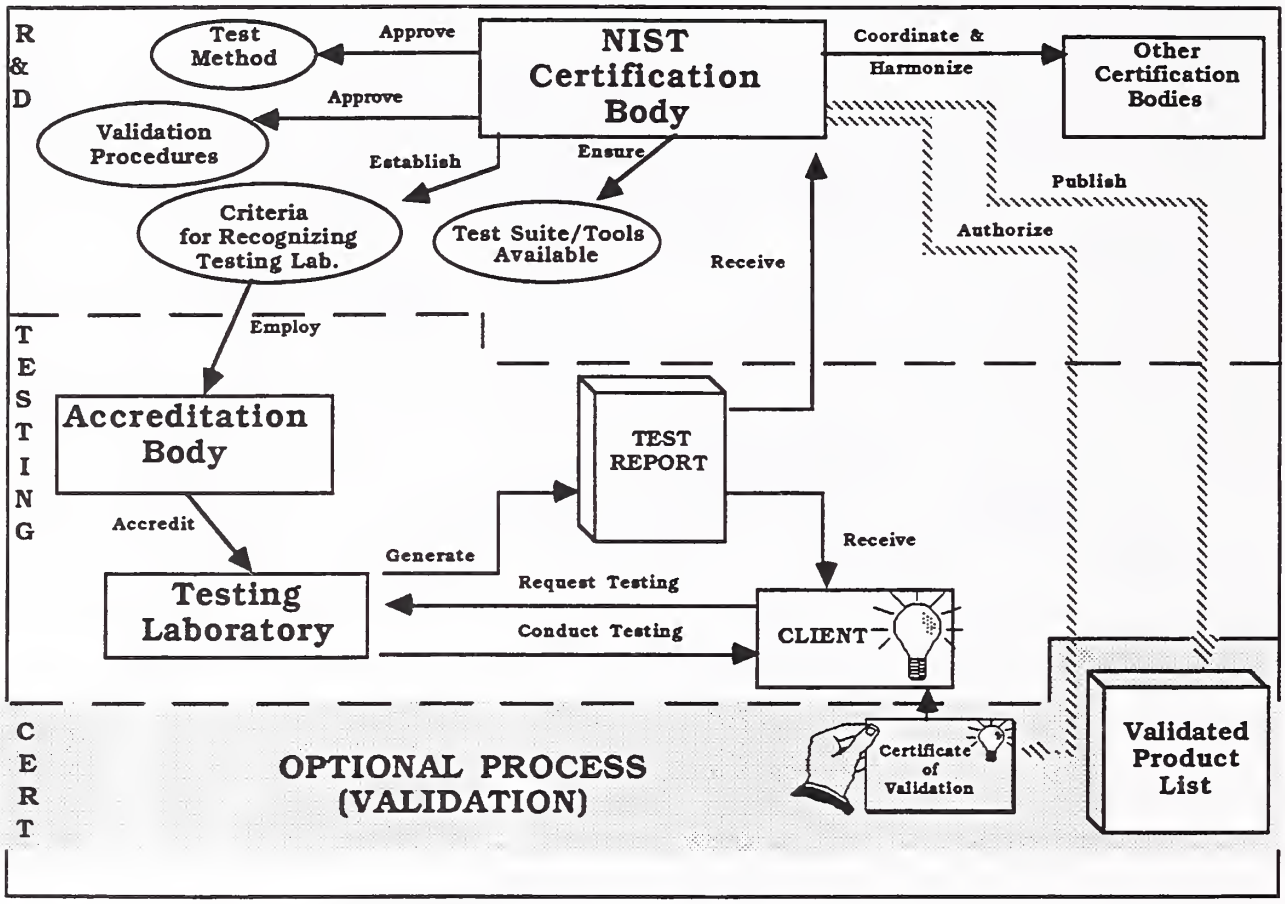

Figure 3: CONFORMANCE TESTING PROGRAM MODEL

directly influenced by the CALS initiative. It is mentioned here only to acknowledge the continued importance of such testing.

Conformance testing is the testing of a candidate product for the existence of characteristics required by a standard. Its primary activity is to ensure specified behavior of implementations. Additional benefits include: clarifying the standard for guiding future implementation, producing a feedback loop to the standards-making bodies for improvements to the standard, encouraging commercial development by supporting a baseline for commonality in all products, and providing greater confidence on the part of the potential enterprise user. Conformance-tested implementations increase the probability these same implementations will be able to interoperate, but provides no guarantee. Figure 3 portrays the activities of conformance testing.

In the formal conformance testing process, the client is the organization or individual seeking recognition that a product complies with the standard. Upon completing conformance testing, the client obtains a conformance test report. This test report may enhance a commercial client's selling power to bid on a government contract or show a potential system's integrator or commercial user the product has been tested under a controlled environment by an unbiased testing laboratory using approved test methods. This formal process improves the competitive edge for the client against those suppliers who have not undergone the same process. It is also important for a government developer to undergo conformance testing of its implementations to ensure conformity prior to use.

An alternative to this formal process is the supplier's declaration. This is where the supplier performs its own testing, generates a test report, and makes a "declaration" of conformance for a given implementation against a given standard.

Although conformance testing provides a means to evaluate syntactic and semantic alignment of an implementation to a given standard, it does not measure fitness for use in a particular environment. The enterprise user is interested in a systems approach. Enterprise users must provide their own way to measure robustness, performance, interoperability, or data integrity of an implementation and the system under which it operates. These activities are known as acceptance testing. Basically, the burden falls to the enterprise user to perform acceptance testing, since it is defined for a particular functional requirement in the context of a

particular operation. Acceptance testing might be applied to applications used to capture, manipulate, and manage data which is to be delivered or made available to customers for their use.

"Acceptance" is defined in the Federal Acquisition Regulation paragraph 46.101 as: "the act of an authorized representative of the government by which the government, for itself or as agent of another, assumes ownership of existing identified supplies tendered or approves specific services rendered as partial or complete performance of the contract." Modified to apply to this report, acceptance testing is the act of an authorized agent of the government, whereby the agent assumes ownership of data products or approves specified data services rendered for the contract.

Two major factors influence the type and degree of acceptance testing appropriate in a CALS environment: (1) the volume of information and frequency of interchange and (2) the inherent quality improvements using computers, computer networks, and software-controlled quality. When data products, data interchange, and on-line access services have undergone conformance testing to CALS military specifications, acceptance testing is greatly simplified [ISG90].

When one discusses the current CALS military standards, **interoperability testing should be part of acceptance testing since the enterprise user has the ultimate responsibility for interoperability.** This will ensure that any introduction of new hardware and software can communicate with current legacy systems. Interoperability testing is used to evaluate the effectiveness and usability of data exchange mechanisms with respect to an enterprise user's environment and requirements. The effectiveness of the data transfer may be influenced by combined interactions of the legacy system and enterprise user's practices [ITM91].

C. Existing Directives and Guidelines.

The continuum of testing activities is not new to the government or the commercial sector. Many policies have been generated, standards written, and guidelines prepared to better facilitate smooth testing operations.

Appendix B is a list of directives and guidelines of general value to the testing continuum, as well as those of specific value to the CALS initiative. Although the list is not exhaustive, it should impress upon the reader the many interested domains that have given thought to testing activities.

IV. TESTING ACTIVITIES.

A. General Description of Primary Participants.

Before describing a particular testing activity performed by a specific organization, it seems appropriate to introduce the three primary participants within the CALS community: the CALS Test Network (CTN), the National Institute of Standards and Technology (NIST), and the CALS/CE Industry Steering Group (ISG). All have some level of activity across the breadth of testing under the CALS initiative.

1. CALS Test Network

The CALS Test Network (CTN) is a confederation of over 300 industry and 30 government organizations that have agreed to evaluate and demonstrate the interchange and functional use of digital technical information using CALS standards. This is accomplished through a collaborative multi-service effort. Test beds in support of the CALS Test Network Office have been established by each of the DoD Services, Defense

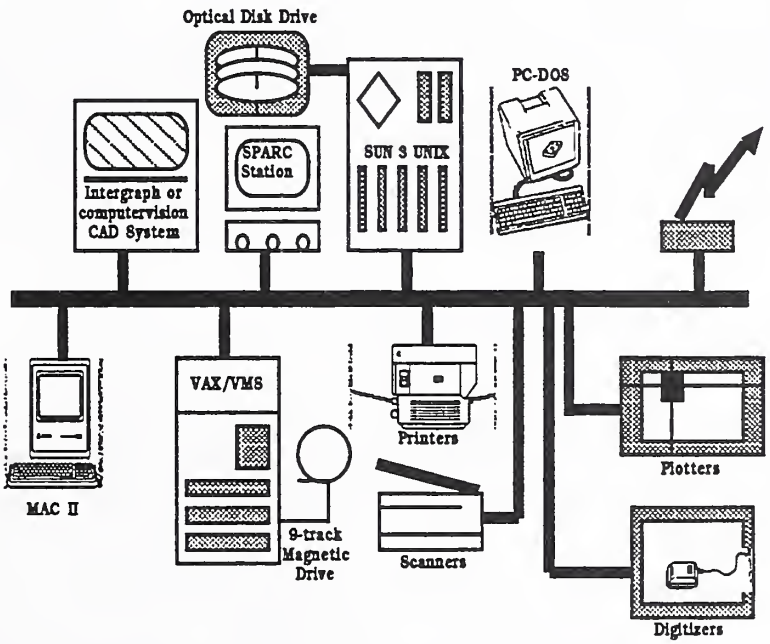

Figure 4: Representative CTN Test Bed Hardware Configuration[MTR91]

Logistics Agency (DLA), and Lawrence Livermore National Laboratory. Figure 4 is a representative configuration of a typical test bed used to support CTN activities [CTN91].

These test beds and the activities they perform are funded and managed by the CEIO. The Air Force serves as the Operations Manager of the CTN for the CEIO, and oversees the day-to-day technical and administrative operations of the various test beds.

2. National Institute of Standards and Technology.

Created in 1901 as the National Bureau of Standards and renamed in 1988, the National Institute of Standards and Technology (NIST) works to strengthen U.S. industry's international competitiveness, advance science, and improve public health, safety, and the environment. NIST conducts science and engineering research in commercially important fields such as advanced materials, information systems, biotechnology, optoelectronics, computer-integrated manufacturing, and sensor technology.

NIST's laboratory research is designed to support development of critical emerging technologies and the new measurement methods and standards necessary to make them commercially viable [NIST91]. There are several functional operations within NIST which contribute to some aspect of testing activity relevant to the CALS initiative. The CEIO has sponsored standards testing and conformance testing activities within several NIST laboratories.

3. CALS/CE Industry Steering Group.

The Industry Steering Group (ISG) provides the National Security Industrial Association (NSIA) thrust in CALS and concurrent engineering. The CALS/CE ISG acts as the formal industry interface with the Department of Defense CEIO. Several hundred volunteers participate in the more than 30 committees. The ISG also coordinates the efforts of 20 industry associations to respond to DoD direction for the CALS effort. The CALS/CE Industry Steering Group (ISG) has recognized the necessity of testing for some time. Two committees have been created to assess requirements and make recommendations.

B. Standards Testing Activities.

1. National PDES Testbed (NPT).

The goal of the National PDES Testbed (NPT), located at the National Institute of Standards and Technology (NIST), is to provide technical leadership and a testing-based foundation for the complete development of STEP. Meeting the objectives associated with several processes is necessary to validate the viability and implementability of the International Organization for Standardization (ISO) Committee Draft (CD) for STEP:

Model Scoping and Construction. Identify and model an application use of the draft STEP specifications.

Test Definition Tool. Define test scenarios for evaluating STEP models.

Test Case Generation Tool. Convert real world product data into STEP structures.

Test Execution and Evaluation Tool. Run test, analyze results, and produce final reports [4417-90].

Of the many technical threads pursued within the NPT, those related specifically to CALS standards testing include:

- Testbed Initiation Activities. Establishing the operational testbed facility, coordinating efforts with outside organizations, performing initial technical studies, developing prototype systems, and performing preliminary testing of the draft STEP. (These initiation activities were completed in fiscal year 1990.)

- Validation Test System. Developing a system for testing and evaluating the application protocols which are defined as standardized parts of STEP. (NIST released a version at the end of

March 1992 which conformed to the April 1991 release of Express.[3] A tool, which allows population of an application test model written in Express, is currently under alpha test mode.

- Application Protocol (AP) Specification and Validation. Specifying and validating at least one application protocol defined in STEP [4438-90]. (The NPT is refining the process used previously, and recognized the need for more stable resource models. The process is being aligned with the current AP Development Guidelines. An AP validation workshop was held at the April 1992 joint IGES/PDES Organization (IPO) and ISO TC184/SC4 Working Groups' meeting which brought consensus on several issues concerning this process of validation and the AP development process.)

2. CALS Test Network (CTN).

The standards testing operation of the CTN covers: testing and demonstrating access and exchange of digital technical data in actual use conditions; developing reference test data and criteria for test planning; and developing procedures to be followed by government and industry test facilities [CTN90]. Some of the initial target testing areas include: technical publications (text and graphics), engineering data (engineering drawings and computer-aided design (CAD) files), support data (on-line access to logistic support analysis (LSA) data), digital data protection and security, digital data configuration management, digital data acceptance procedures, and CALS for small business [CTN91].

C. Conformance Testing Activities.

1. CALS Test Network.

The perception of the CTN by many is that any one of the identified CTN test beds performs conformance testing for the participating suppliers. In fact, the CTN is chartered **to affirm CALS-compliance only for**

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[3] Express is a specification language for capturing structural and semantic aspects of the STEP information model. It will become a standardized part (ISO 10303-11) of the STEP suite.

DoD-owned systems [JUN91]. The CALS Test Network has been requested, on occasion, to evaluate implementations of CALS specifications which are already procured under contract by one of the services or DLA. Their first activity of this nature was to ascertain CALS-compliance for the raster compression software (Type I) on the DSREDS, EDCARS, and EDMICS systems.

2. FIPS and Military Specification Conformance Testing.

Computer users and the computer equipment, software, and services industries receive support from NIST in the form of standards and technical methods. These standards and technical methods are applied to advance the effective use of computers and related telecommunications equipment. One aspect of this support is the issuing of Federal Information Processing Standards Publications (FIPS PUBS). NIST has responsibility for providing conformance testing programs for FIPS PUBS where a need has been identified and resources are available. **Under the CALS initiative, the conformance testing responsibilities of NIST have been expanded to include conformance testing against the CALS military specifications.**

NIST's approach to CALS conformance testing has been: (1) establish a conformance testing service for the FIPS if warranted and (2) adapt the FIPS conformance testing service to meet CALS requirements as specified in the military specification 28000 series. The formal policies and procedures to define a conformance testing service for either a FIPS or a military specification are similar.

With the exception of Mil-D-28000, based on the Initial Graphics Exchange Specification (IGES), the CALS military specifications require FIPS compliance. A proposed FIPS for IGES is now under consideration. The FIPS for CGM (FIPS PUB 128) is being modified to include the full functionality of MIL-D-28003. Once this process is complete, FIPS CGM conformance testing and MIL-D-28003 conformance testing will be synonymous.

3. National Voluntary Laboratory Accreditation Program (NVLAP).

Independent of other NIST activities, NVLAP is a formal accreditation program which qualifies first, second, and third party testing laboratories for performing specific tests or types of conformance tests. Specifically, it:

- Provides national recognition for competent testing laboratories.
- Provides testing laboratory management with a quality assurance check of the performance of their laboratories.
- Identifies competent testing laboratories for use by regulatory agencies, purchasing authorities, and product certification systems.
- Provides testing laboratories with guidance from technical experts to aid in reaching a higher level of performance resulting in generating improved engineering and product information.

NVLAP is comprised of a series of laboratory accreditation programs which are established on the basis of requests and demonstrated need. The specific test methods, types of test methods, products, services, or standards to be included in an accreditation program must be requested. The Director of NIST does not unilaterally propose or decide the scope of a laboratory accreditation program. Communication with other laboratory accreditation systems is promoted to encourage development of common criteria and approaches, and promote acceptance of test data produced by the accredited laboratories. NVLAP is intended to be compatible with and recognized by domestic, foreign, and international laboratory accreditation systems which enhances the universal acceptance of test data produced by NVLAP-accredited laboratories [4493-90].

There is a cost to the testing laboratory desiring accreditation. Table I shows some examples of accreditation costs associated with other computer standards, as well as an example for a military standard accreditation program.

Criteria for judging a testing laboratory's competence include: evaluating the laboratory's quality system, staff, facilities, equipment, test methods and procedures, records, and test reports. The actual accreditation of the

testing laboratory includes an on-site assessment by a team technically competent in the standard and testing tools for which the laboratory is being accredited. The testing laboratory's accreditation is based on the on-site assessment reports, actions taken by the testing laboratory to correct deficiencies, results of proficiency testing, and information from any monitoring visits which may have been performed.

Fee Schedule (effective 10/1/91)

PROGRAM	ANNUAL AD/TECH SUPP. FEE(1)	INITIAL APPLIC. FEE(2)	ON-SITE ASSESS. FEE(3)	PROFICIENCY TESTING FEE	TEST METHOD FEE (each)
Computer/GOSIP	$5,600	$500	$2,100	$0	$300
Computer/High Level Protocols	3,500	500	1,300	100	150
Computer/POSIX	3,600	500	3,000	0	150
Computer/X.25-Blacker	3,500	500	1,300	100	150
ECT/MILSTD-462	3,550	500	3,000	200	30

(1) The Administrative/Technical Support Fee is assessed annually, regardless of a laboratory's accreditation status.
(2) One time per program only. This fee not paid if a renewal application.
(3) The On-Site Assessment Fee is due every other year. This fee paid only in the year in which notification is received that an on-site assessment will be performed.

Table I: NVLAP Fee Structure [1144K]

4. National PDES Testbed (NPT).

Besides the standards testing activities mentioned above, the National PDES Testbed has also been funded by the CEIO in the past, to actively participate in the development of the STEP conformance testing standards

within the ISO community.[4] Some of the services provided in this area included: representing U.S. and CEIO interests in the international STEP development process, coordinating the U.S. position on the STEP conformance testing part ballot, providing a development plan for building and institutionalizing a conformance testing system and framework for validating implementations of STEP application protocols [4641-91], and assessing the general requirements of STEP conformance testing [4743-92].

5. CALS/CE Industry Steering Group Committee.

An Ad Hoc Testing Committee was formed to assess the status of testing activity and identify the voids. Ultimately, the Committee was concerned with ensuring whether the facilities existed to guarantee commercial availability of CALS-conforming products. Representatives from industry, NIST, CTN, and Sandia Laboratories participated in evaluating the level of testing coverage. The ad hoc committee culminated its initial activity by delivering two reports to the CALS Office[5] in the fall of 1990, and spring of 1991. In the spring of 1992, the Committee reconvened to assess where it left off and draft the final report of recommendations to the CEIO. These recommendations include:

- Create FIPS for all CALS standards and military specifications.

- Require NIST to develop third-party certification procedures.

- Apply certification procedures to NIST and third party product validation laboratories.

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[4] The Class 30 series on conformance testing methodology and framework will eventually be part of the STEP suite: 10303-31: general concepts; 10303-32: the requirements on testing laboratories and clients; 10303-33: structure and use of abstract test suites; and 10303-34: abstract test methods.

[5] During the calendar year 1991, the "CALS Office" was changed to the "CALS Evaluation and Integration Office" (CEIO).

- Place all software vendor offerings that have completed the certification process on the Validated Products List (VPL)[6] [ISG92].

D. Acceptance Testing Activities.

1. CALS Test Network.

As an overall tasking, the CTN Office is responsible for government user application, interoperability, and other related testing. All of the test beds perform interoperability testing to the level of the test bed capability, i.e., test bed system hardware and software available. The Army test bed has been designated the lead service specific to data acceptance testing. Particularly, CTN Test Report 91-028 presents models that define the entities and attributes related to the acceptance of CALS-conforming digital data for technical manuals. These models are expandable as the CALS specifications mature.

2. CALS/CE Industry Steering Group Committee.

The CALS/CE ISG Acceptance Testing Committee developed a report for industry and the CALS Office to:

- Recommend approaches which may be applied to assure successful data exchange for near term CALS deliverables.

- Recommend approaches which may be applied to ensure successful access to and use of information which resides within the Contractor's Integrated Technical Information Service (CITIS) for its intended purposes.

- Provide, for any given type of CALS deliverable, a framework for determining: what the evaluation method options are, what the acceptance criteria should be, what constitutes contractual

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[6] The Validated Products List is an internationally-recognized document which publishes results for several conformance testing services. It is available through the National Technical Information Service: subscriptions, phone: 703/487-4630; individual copies, phone: 703/487-4650; ordering number PB91-937300.

delivery, and when and how formal acceptance should be accomplished [ISG90].

The Acceptance Testing Committee submitted this report to the CALS Office in July 1990. Generally speaking, this report tells how an enterprise user knows when data has been received, not whether or not the data received is good.

V. TESTING ISSUES ASSOCIATED WITH CALS INITIATIVE.

The following issues have been raised and were highlighted in the previous text (sections I through IV), and are gathered here for further elaboration. After each issue is raised, alternatives are offered, the pros and cons for each alternative listed, and a recommendation made. The author is providing only recommendations; The CEIO has to consider DoD flagship program priorities, adaptation with other defense initiatives such as CIM (Corporate Information Management), and budgetary constraints when determining the most appropriate alternative. In some cases more than one alternative may be selected since the alternatives are not always mutually exclusive. The order of presentation is not meant to reflect a priority.

A. Should the CEIO Allow the Systems Integrator to Perform Acceptance Testing?

The CEIO could propose a consistent method for defining the requirements which the systems integrator must meet when assessing the supplier's implementation for a potential government acquisition. Since acceptance testing is a responsibility associated with each procurement, it can often be very expensive.

Issue. Whether the CEIO should recognize any acceptance testing performed by the systems integrator prior to government procurement.

Alternative 1. Prior to obtaining a system, the government user performs full acceptance testing.

Pros.

- Ensures the highest level of confidence for the government user that the system meets the requirements.

Cons.

- Expensive and repetitive for each and every government user, especially when buying systems which meet similar requirements of other earlier procurements.

- Most likely duplicating the expense and effort previously performed (at least in part) by the systems integrator.
- Government staff and equipment must be brought up-to-speed to perform the acceptance testing tasks.
- Adds overhead cost to overall procurement.
- May not be legal prior to contract award under the procurement process.

Alternative 2. The government user provides for some level of acceptance testing being performed by the systems integrator without consideration of due process.

Pros.
- Diminishes workload and cost requirement on government user to perform acceptance testing.
- Requires less in-house expertise and equipment for performing the remainder of the acceptance testing activities.

Cons.
- Provides no consistent means of measurement from systems integrator to systems integrator.
- Requires level of trust that systems integrator performed the required steps to meet the procurement criteria.
- Each government user must determine what can be performed by the systems integrator and what must be left for the government user to do.

Alternative 3. The government user applies predefined requirements which the systems integrator applies in-house, and the government user accepts the results.

Pros.
- Diminishes workload and cost requirement on government user to perform acceptance testing.
- Requires less in-house expertise and equipment for performing the remainder of the acceptance testing activities.
- Provides a consistent means of measurement across systems integrators.

- Provides a consistent means of measurement across procurements.
- Diminishes workload of government user to establish means of measurement for each procurement.
- Leverages what is usually performed by the systems integrator anyway.

Cons.
- Government user still left with some acceptance testing.
- A predefined measurement of the systems integrator process may have to be tailored for each systems integrator or each standard.
- The systems integrator may believe the government has no business assessing the way it conducts business in-house.

Recommendation. Alternative 3: The government user applies predefined requirements which the systems integrator applies in-house, and the government user accepts the results.

Support of such a recommendation would require the development of the requirements for this level of acceptance testing. Time and cost could be reduced if some of the acceptance tasks were performed by the systems integrator prior to the government user's assessment. There are too many unique requirements associated with any given procurement to develop one grand scheme for acceptance testing. Developing a definition of the requirements would create a controlled yet flexible environment. The CTN staff would be appropriate resources to assist the CEIO to develop such requirements since they have a combination of technical expertise in the testing arena, as well as an understanding of DoD requirements.

B. How Should CEIO STEP Validation[7] Funds be Apportioned?

Develop a system for testing and evaluating the application protocols which are being defined as parts of STEP. Should the CEIO invest in a system for testing and evaluating the STEP application protocols as they are being drafted? Is such a testing system necessary?

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[7] Within the STEP community, standards testing, as defined in this report, is commonly referred to as STEP validation.

Why evaluate the application protocols prior to standardization? Why should NIST be the host site of the testing system and the resources?

Issue. Is it cost-effective for the CEIO to fund a validation testing system, and if so, where should such a system be hosted?

Alternative 1. Develop a Validation Testing System to test the viability of the STEP draft specifications (e.g., application protocols).

Pros.

- Since a reference implementation is built as part of validation, it ensures the standard is implementable.
- Early testing builds enterprise user and supplier confidence in the standard.
- Proactive U.S. participation in testing the standard strongly influences the content of the standard; therefore, the alternative helps to meet CALS requirements.
- Provides tools for potential use in component testing, conformance testing, and acceptance testing of STEP AP implementations.
- Validation testing system hardware, software, and environment have long-term use even after the initial release of STEP is published (uses include: AP development and testing, conformance testing, and acceptance testing).

Cons.

- Such a system is potentially an expensive CEIO investment, since current investment levels are based on the projected utility of the standard to meet DoD requirements.

Alternative 2. If a Validation Testing System to test the viability of the STEP draft specifications is developed, NIST should be the host site.

Pros.

- NIST has no vested interest in the requirements STEP supports; therefore, NIST can offer technical guidance to help STEP meet CALS requirements.

- Early participation in the standardization process increases NIST understanding of the technologies for global federal agency application.
- NIST can better harmonize DoD's requirements and priorities with other federal agencies and the international community.
- NIST has strongly established relationships with other STEP-supporting organizations, e.g., PDES, Inc.
- The physical location of the National PDES Testbed is centrally located along with the office of the National Product Data Exchange Initiative.

Cons.
- STEP expertise is not being developed within DoD.
- Hardware and software investment is not at a DoD site.
- NIST may not understand DoD requirements as well as DoD.

Alternative 3. Instead of the CEIO investing in hardware, software, and test bed environmental support resources for the development of STEP, it should invest in additional technical human resources.

Pros.
- Funding levels can more easily fluctuate because not impacted by hardware, software, site maintenance costs.
- Provides more participation at technical working group level when developing the standard.
- Human resources could be split between DoD and sponsored agency participation to balance objectivity with understanding the requirements.

Cons.
- CALS less in control of influencing implementable content of STEP, since other test beds (e.g., European and Asian activities) would drive the standard's content.
- Potentially less implementable APs as output, since specification text would be written on assumption that it was implementable.
- When human resources move on, no retention/record of corporate knowledge occurs.

- Less credibility when introducing specification content because test data does not exist; therefore, politics rather than technical efficacy may win out.

Recommendation. A combination of alternative 1: Develop a Validation Testing System to test the viability of the STEP draft specifications (e.g., application protocols); and alternative 2: If a Validation Testing System to test the viability of the STEP draft specifications is developed, NIST should be the host site. Identifying DoD requirements for the use and functionality of STEP is necessary early in the process, so the technical specifications can be drafted and introduced into the international arena. DoD benefits by supporting a standards testing program so the concepts and ideas are evaluated for implementability and for meeting DoD requirements. Installing such a program of standards testing within NIST allows leverage of the technical expertise and understanding of the international standards-making process.

C. Should NIST be Responsible for Military Specification Conformance Testing?

Under the CALS initiative, the conformance testing responsibilities of NIST have been expanded to include conformance testing against the CALS military specifications. Prior to CALS sponsorship at NIST, conformance testing programs were primarily focussed only on those implementations claiming conformance to the FIPS PUBS. This focus was based on two reasons: (1) NIST is responsible for the development of FIPS PUBS and (2) FIPS PUBS are written to meet the requirements of all federal agencies. With the advent of CALS military specifications, NIST and its CEIO sponsor saw a need for finer qualification of an implementations's claims. These specifications were written specifically for the employ of one federal agency--the Department of Defense.

Issue. Although NIST develops conformance testing services for those standards which are FIPS PUBS, no means exist to perform conformance testing on the additional requirements imposed on the supplier through military specifications.

Alternative 1. Under the sponsorship of the CEIO, NIST should provide conformance testing services for the CALS military specifications.

Pros.

- NIST has conformance testing service experience.
- Military specification-level conformance testing services could be harmonized with FIPS conformance testing services.
- NIST participates in the international efforts; therefore, can best maintain international harmonization.
- NIST is an objective agent; no vested interest in outcomes.
- Service could be used by other DoD programs with similar needs, e.g., CIM; therefore, cost sharing could occur.

Cons.

- Military specifications are application-specific, and tend to support only one federal agency--DoD.
- DoD expertise would not be built if NIST provided the full services.
- NIST may prefer providing conformance testing services at the FIPS level only, since FIPS benefit multiple government agencies.

Alternative 2. Under the CEIO authority, a DoD site, e.g, the Joint Interoperability Test Center (JITC), could be designated to provide conformance testing services for the CALS military specifications.

Pros.

- More easily controlled by CALS.
- Facility could be used by other DoD programs with similar needs, e.g., CIM; therefore, cost sharing could occur.
- Potentially one-stop-shopping site for all the testing needs: standards testing, conformance testing, acceptance testing.
- Builds DoD expertise in-house.

Cons.

- May not be attractive to other federal agencies who have adopted the CALS military specifications.
- Depending on commercial testing laboratory interest, could potentially place the government in competition with the

commercial sector (other testing laboratories performing the same testing).

- Most likely would not be an internationally-recognized testing laboratory; therefore, requiring suppliers to be tested multiple times for the same product. Such costs would ultimately be reflected in DoD procurements.
- All costs to maintain a DoD testing laboratory are DoD responsibility.
- Potentially a conflict of interest, e.g., testing results driven by the chain-of-command desires.
- Since CALS military specifications are the application level of FIPS implementations, supporting conformance testing programs should not be developed in isolation.

Recommendation. Alternative 1: Under the sponsorship of the CEIO, NIST should provide conformance testing services for the CALS military specifications. If the CEIO desires COTS implementations, a coordinated federal and international approach needs to be regarded. Given NIST's current mission, standards involvement with all federal agencies, and role in the international conformance testing alliances, the CEIO can best leverage this activity by sponsoring NIST for the military specifications conformance testing services.

D. Should NVLAP be Used for Testing Laboratory Accreditation?

NVLAP is comprised of a series of laboratory accreditation programs which are established on the basis of requests and demonstrated need. The use of formal accreditation raises a lot of issues for a sponsor such as Department of Defense. As a big buyer of digital data, the CEIO wants to ensure to the best of its ability that software generating the digital data is conforming. This allows a better chance for successful interoperability testing, less cost when conducting acceptance testing, and supports industry for economic competitiveness with other national bodies. All of these issues have to be balanced against the price of initiating and maintaining an accreditation program.

Issue. Accreditation of testing laboratories is often viewed as an expensive overhead both in actual dollars required to initiate and time required to establish such a program. Should the CEIO invest?

Alternative 1. Provide testing laboratory accreditation for first, second, and third party testing laboratories through NVLAP. The upper part of Figure 5 shows the general process for accreditation.

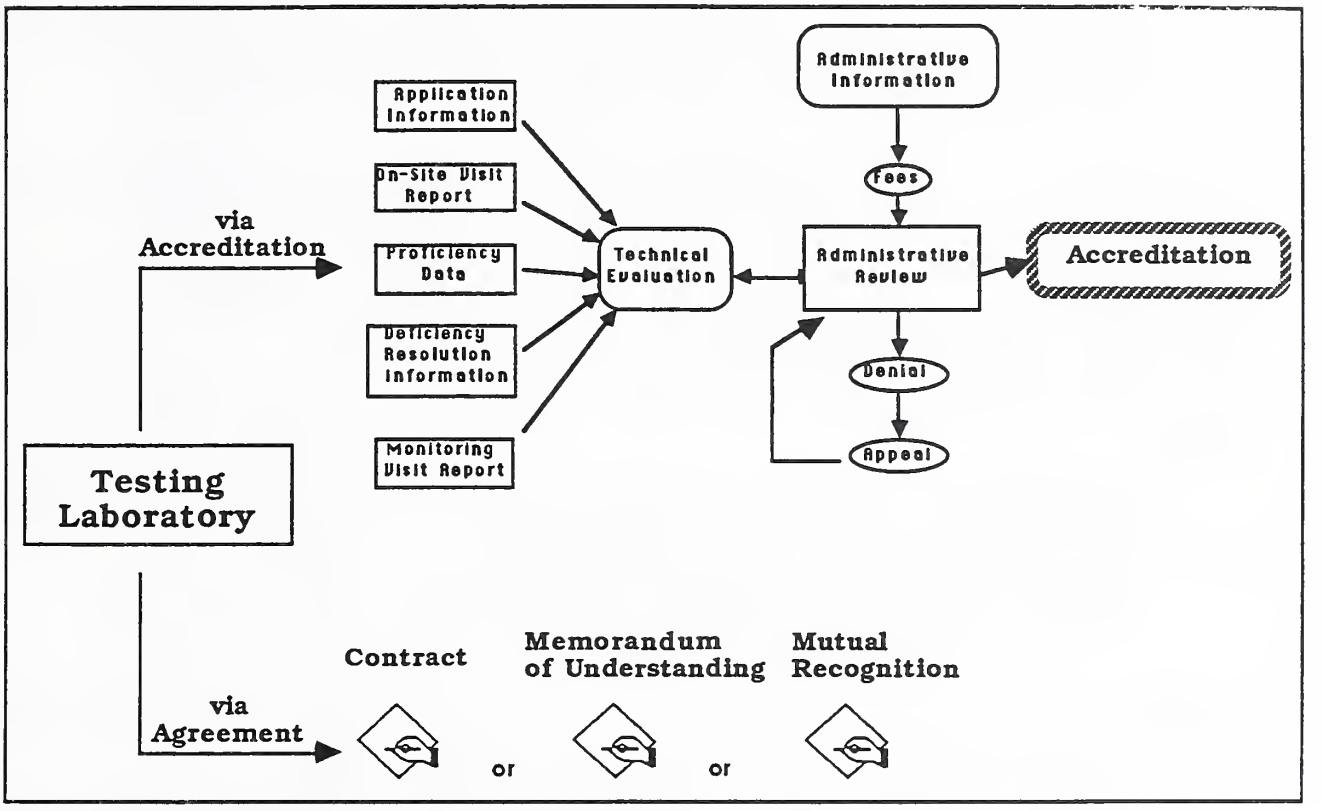

Figure 5: Testing Laboratory Acceptance

Pros.

- Better ensures the quality and accuracy of test data.
- Provides some assurance of the technical proficiency and competence of a laboratory to assess an implementation's conformance to a set of prescribed standards [4576-91].
- Better opportunity for international harmonization.
- Ensures consistent test methods and test tools are being employed during the evaluation process.

- balanced, objective evaluation thus contributing toward market confidence.

Cons.
- More labor-intensive to implement than the alternatives in the lower part of Figure 5.
- More cost-intensive to implement than the alternatives in the lower part of Figure 5.
- Depending on supply and demand, CALS may have to forever subsidize those conformance testing services which are not self-sustaining.
- May require more time to establish accreditation program.

Alternative 2. Allow the alternatives for laboratory recognition that are shown in the lower part of Figure 5. Current examples of such arrangements are the conformance testing services for language compilers, database language SQL, and the graphics standards (CGM and Graphical Kernel System {GKS}).

Pros.
- Establishes mutually recognized testing laboratories among those interested in providing some level of a consistent conformance testing program for a specific standard.
- Usually quicker to establish arrangements.

Cons.
- Requires a Memorandum of Understanding (MOU) to globally ensure mutual reciprocity at the testing laboratory level.
- Since testing laboratory acceptance is via agreement only, cannot ensure consistent testing procedures across testing laboratories.
- Testing laboratory agreements often built on established reputations, not necessarily on supply and demand; therefore, difficult to create new testing laboratories if demand warrants.
- May be suspect to supplier or enterprise user.

Alternative 3. CEIO could permit a supplier's declaration (supplier's declaration replaces use of "self-certification").

Pros.

- No up-front cost to CALS.
- Marketing claims are robust, painting successful progress of CALS initiative.

Cons.

- No consistent set of test suite/tools or procedures for comparison.
- Not performed by objective, unbiased party.
- Assurance for conformance only as good as trust in supplier.
- Often quality assurance or acceptance testing (e.g., performance, robustness, data set testing) versus conformance testing practices performed, forcing conformance testing analysis on each buying enterprise user as part of acceptance testing.
- Practice not commonly recognized internationally for information technology standards' implementations.

Alternative 4. CEIO could recognize specific testing tools or test suite only, making them commercially available through National Technical Information Service (NTIS).

Pros.

- CEIO, suppliers, and enterprise users would not be faced with additional costs associated with accreditation.
- Allows cheaper testing for repeated in-house use.
- Provides something for use to the supplier quicker than waiting for an accreditation program.
- Assists supplier during implementation development and component testing.

Cons.

- Does not ensure the application of such tools would be consistent between enterprise users; therefore, could not ensure consistency of results.
- Results would not be recognized internationally.
- Depending on selection of CEIO testing tools or test suite, results may not be recognized by other federal agencies using the military specifications.

- Testing tools, test suite, and test methods may not be consistent with FIPS conformance testing programs.

Recommendation. Alternative 1: Provide testing laboratory accreditation for first, second, and third party testing laboratories through NVLAP. The upper part of Figure 5 shows the general process for accreditation. When suppliers are driven either by policy or the acquisition process, a market is created for a conformance testing service. Accreditation should be implemented to keep the process objective, maximize international consensus, and minimize the CEIO investment by creating a self-sustaining vehicle to perform conformance testing.

E. Should the CTN Perform Interoperability Testing?

As an overall tasking, the CTN Office is responsible for government user application, interoperability, and other related testing. Interoperability testing should be part of acceptance testing since the enterprise user has the ultimate responsibility for interoperability. When a client sends in data files or an implementation to undergo testing via the CTN, the receiving test bed performs both standards and interoperability testing at the same time. The extent of interoperability testing is only limited by the hardware and software configuration options available at that test bed.

Issue. The CTN performs standards testing and interoperability testing without routinely performing conformance testing. This CTN practice is not the same sequence as occurs in general practice.

Alternative 1. Offer CTN services on two separate levels: first standards testing against one system. Then, after client can offer proof of conforming implementation (e.g., via Validated Products List), allow client's return to the CTN for interoperability testing.

Pros.
- Flows with the serial process of testing that normally occurs (as defined in Figures 1 and 2).
- Reinforces to industry and enterprise users that conformance is necessary prior to interoperability testing.

- Better prediction of time required to test each implementation in the standards testing environment against the CTN test suite.
- Reduces time required to process a given implementation.
- Allows more time for more volunteer supplier participants.

Cons.
- More administrative costs since a new test report would be generated each time an implementation was tested in a different environment.
- Preparatory time and cost would have to be repeated each time the same implementation returned for more testing.

Alternative 2. Offer CTN services for both standards testing and interoperability testing at once (status quo).

Pros.
- Program manager gets his bottom line: interoperability.
- Reinforces that CALS specifications work in multiple environments.

Cons.
- Interoperability performed on two, not necessarily conforming, implementations requires more time since no common ground is established.
- Much redundancy in testing occurs from implementation to implementation; therefore, more expensive.
- CEIO paying for what the individual program manager should pay for.
- Interoperability testing subtracts manpower from standards testing.
- Sends a message to program manager that interoperability is not a program manager's issue; the CEIO will always concern itself with the government user's interoperability requirements.
- Enterprise user may not bother with conformance testing since interoperability is often the greatest concern.

Alternative 3. Offer CTN services for only standards testing.

Pros.
- More cost effective for CEIO.
- Less system maintenance and manpower required.

- More time to test draft specifications prior to publication.
- More time to assist in conformance testing tool and test suite development and assessment.
- Focusses funding and resources on assessment of the standard.

Cons.
- Less testing of implementations in multiple environments.

Alternative 4. Offer interoperability testing only as part of acceptance testing for a given procurement.

Pros.
- Would be funded by the individual DoD program, not the CEIO.
- Would flow with the serial process of testing that normally occurs (as defined in Figure 2).

Cons.
- Need for such a service would not be consistent; therefore, someone must fund the equipment maintenance and staff overhead.

Recommendation. A combination of both alternative 3: Offer CTN services for only standards testing; and alternative 4: Offer interoperability testing only as part of acceptance testing for a given procurement, is appropriate. To better control the funding and associated activities, the CEIO should support the CTN for standards testing only. This would more easily allow identifiable milestones to achieve closure for any given standards testing program.

As the need arises, the CTN test beds should also be able to support their individual agency to perform various aspects of acceptance testing, including interoperability. This takes advantage of the technical expertise already established at the test bed, allows particular agency procurement needs to be met, and requires the individual program managers to fund the effort. Direct CTN involvement with their agencies also surfaces real-world issues, often necessitating improvement to the military specifications themselves.

F. Should the CTN Acclaim CALS Compliance?

To affirm CALS compliance only for DoD-owned systems. In addition to its scope for standards and interoperability testing, the CTN was given authority to affirm CALS compliance for those implementations already on a DoD system. This has created a perception in the CALS community that any client participating in the voluntary CTN program is, in effect, undergoing conformance testing and can make such claims.

Issue. Whether the CTN should affirm CALS compliance only for DoD-owned systems.

Alternative 1. Allow CTN test beds to claim CALS compliance for those implementations already on DoD systems.

Pros.

- Provides complete continuum of standards testing, conformance testing, and acceptance testing (interoperability testing aspects) for the DoD user.
- Provides in-house DoD user service.

Cons.

- Presents an "uneven playing field." Only those suppliers who are already on DoD systems have an opportunity for such evaluation.
- Such an evaluation is occurring AFTER the product is purchased and DoD is already financially committed.
- Creates public image of confusion as to who is responsible for conformance testing of products.
- Negatively impacts competitive procurement for those requests for proposals which specify "must be CTN-approved."
- CEIO continues to fund (forever?) service requirements for testing.
- Measurement of conformance by CTN may not be consistent with other conformance testing programs established by NIST.
- Does not allow same service for other federal agencies using the military specifications.
- Such complete coverage of all testing activities by one organization does not allow for a checks-and-balances system.

Alternative 2. Allow CTN to offer conformance testing service for CALS initiative to any client.

Pros.

- Provides complete continuum of standards testing, conformance testing, and acceptance testing (interoperability testing aspects) for the DoD user.
- Provides in-house DoD user service.
- Alleviates public confusion of who is responsible for conformance testing.

Cons.

- CEIO continues to fund (forever?) service requirements for testing.
- Measurement of conformance by CTN may not be consistent with other conformance testing programs established by NIST.
- Does not allow same service for other federal agencies using the military specifications.
- Such complete coverage of all testing activities by one organization does not allow for a checks-and-balances system.
- Could not predict workload, therefore may adversely impact standards testing.
- Does not lend itself to supporting international harmonization of conformance testing programs for standards.
- Could pose a conflict of interest if performing a conformance testing assessment on a candidate supplier under a Request for Proposal.

Alternative 3. Focus CTN activities on acceptance testing.

Pros.

- CEIO would not have to fund acceptance testing service; individual program managers would.
- CTN technical expertise already established.
- Test beds have readily available "on demand" resources.
- Could delineate end of CTN standards testing from special service acceptance testing requests.

Cons.

- Could not predict workload, therefore may adversely impact standards testing.

Recommendation. Alternative 3: Focus CTN activities on acceptance testing, complements the previous recommendation for separation of standards testing from interoperability testing.

The following issues were not raised in the previous text, but are also some questions facing the CALS community.

G. Could the CEIO Use Supplier-Developed Testing Suites/Tools?

Software and testing tools developed to accomplish component testing by the supplier may be an asset to the CALS initiative if they were made available to accomplish specific testing to CALS requirements. Tools for a commercial conformance testing service are very expensive to develop. Industry also faces a corporate overhead cost.

Corporate development of proprietary testing tools to evaluate the "goodness" and "conformity" of their implementations is usually done in-house. It is costly for the corporation to invest in such testing, but it is deemed worthwhile for such testing to take place. Since this testing is most always done in isolation of other corporations, the cost to develop and implement such testing in tool development and test bed maintenance is high. Such costs are ultimately passed onto DoD through procurements of the implementation itself.

Issue. Should the CEIO try to leverage industry's test suite and tool development resources to benefit conformance testing and reduce industries' investment costs?

Alternative 1. Such proprietary testing tools could be made available to a CALS conformance testing program for: (1) use if complete or (2) adaptation if incomplete.

Pros.

- May diminish the cost of conformance testing software development.
- May reduce the individual corporate requirements for in-house testing, thus reducing the overhead costs.
- The corporation(s) providing such software may recoup a portion of their investment, thus providing some incentive for sharing.
- Potentially quicker response to provide conformance testing service than waiting for the test suite/test tools to be coded from scratch.

Cons.

- Such testing tools may be viewed as a marketing advantage for commercial sale of the implementation.
- Often the testing tools are developed on a system configuration not easily portable for other system use.
- It may not be possible to separate the conformance tests from those used to meet other requirements such as robustness, performance, interoperability.

Alternative 2. An industrial consortium could be established to fund tool development, motivating corporations to "buy-in" by providing reduced costs for access to a test bed.

Pros.

- Corporate cost to participate should be less than cost to internally develop test tools and test bed.
- CALS EIO investments can be combined with other funds for developing a test bed to perform conformance or acceptance testing.
- Such a consortia could also serve as a supplier's forum to identify deficiencies in the national/international standards and military specifications.

Cons.

- Industry participation may not be substantial enough to establish a test bed in a timely fashion convenient to the consortium members.
- Some corporations may view "sharing" as cutting into their competitive edge.
- Test bed may already be established in a corporation and therefore not worth the participation.

- Industry-driven/developed test suite/test tools may be biased toward consortium participants' implementations.

Recommendation. Alternative 1: Such proprietary testing tools could be made available to a CALS conformance testing program for: (1) use if complete or (2) adaptation if incomplete. Past experience has shown little cooperation by industry to provide testing tools the supplier has already developed to perform its internal component testing. Such development work is expensive, and most suppliers see little benefit in sharing their internal testing tools. There have been a few exceptions to this, however, where test cases or tools have been provided. Although work is usually required to modify or complete such donations of software for conformance testing, they have served as a foundation.

H. Should the CEIO Invest in the Development of Conformance Testing Services?

In order to establish commercial off-the-shelf (COTS) implementations of CALS military specifications and standards, conformance testing services have to be available. ("Conformance testing services" in this context include everything necessary to establish such a service for a given standard: the development or assessment of a test suite/test tool, establishing the accreditation criteria, and writing the policies and procedures for the conformance testing service.) The CEIO faces continuing budgetary restrictions which affects the priorities. NIST may or may not establish conformance testing services for those FIPS on which the military specifications are based. Even if a FIPS conformance testing service was being established, it may not meet the requirements for CALS specifications. Often there are preliminary syntactic and semantic requirements in the FIPS which the military specification assumes; however, the military specifications impose additional constraints on the application of the FIPS in a DoD environment.

Issue. Should the CEIO fund the development of a conformance testing service at either the FIPS or associated military specification level?

Alternative 1. CEIO should fund conformance testing service development at both the FIPS and associated military specification.

Pros.

- Provides consistency across FIPS and military specification conformance testing programs.
- Keeps DoD in sync with the practices that other government agencies may be employing for conformance testing since FIPS apply to all federal agencies.
- Ensures CEIO will get conformance testing services to meet CALS requirements.
- Establishes CALS standards into commercial off-the-shelf implementations.
- Would help advance CALS standards into other federal agencies, at least at the FIPS level; easier for communicating across agencies.
- May be most cost-efficient to support a FIPS conformance testing service only, due to the tailored application disposition of the military specification; something is better than nothing.

Cons.

- Most expensive.
- Given the combination of other priorities, timeliness is sometimes impacted because of multi-year effort.
- Makes CEIO responsible for FIPS conformance testing costs when other government agencies should be contributing.

Alternative 2. CEIO should fund only the conformance testing service requirements associated with the military specification.

Pros.

- Cheaper than funding FIPS conformance testing service also.
- Better CEIO control over testing tools/service since only applicable to military specification.

Cons.

- Since most of the military specifications subsume any syntactic and semantic FIPS requirements, CEIO would be reinventing the wheel for a lot of the work.

- If a conformance testing service were established independently of CALS, coordination with a FIPS conformance testing service or other international activity may be lacking.
- May not be recognized by other government agencies, therefore forcing suppliers to undergo multiple assessments.

Recommendation. Alternative 1: CEIO should fund conformance testing service development at both the FIPS and associated military specification. Unless some other federal agency has identified a strong enough interest in the FIPS to support the development of a FIPS conformance testing service, such a service may not be established. By supporting first the development of a conformance testing service which covers the FIPS, then the military specification, the CEIO can:

- Assess whether further investment in the military specification level is appropriate and efficient.
- Stay harmonized with industry and other government agencies for those FIPS which are based on national and international standards.
- Ensure a conformance testing service will be established which will meet their requirements.

I. How Should the CEIO Ensure Conformance Testing Becomes Part of the Way of Doing Business?

Even if the CEIO establishes conformance testing services, the requirement has to be instilled into both the Defense community and the supporting industry. There are a lot of misunderstandings with terminology, what a specific testing activity provides, and the advent of receiving digital versus hard copy data. Both the enterprise user and the supplier may not appreciate the full value-added in requiring and participating in conformance testing activities.

Even though CALS is funding various conformance testing activities and services, the ultimate measure of success is: whether the procuring enterprise user requires conformance-tested implementations in contracts and whether the supplier is motivated to apply for conformance testing without a request for proposal requirement. The CEIO needs to

consider solutions which educate and support both the enterprise user and the supplier.

Issue. Even if conformance testing services existed for all the CALS military specifications, there is no guarantee enterprise users will take advantage of such services.

Alternative 1. The CEIO should request changes to the Federal and Defense Acquisition Regulations (FAR/DAR) so only those implementations which have undergone successful conformance testing are eligible for defense purchase.

Pros.

- Raises the conformance testing requirement above the CEIO initiative, thus incorporating CEIO requirements into the defense and federal infrastructure.
- Suppliers are more apt to be motivated to undergo conformance testing prior to request for proposal inducement.
- Fosters commercial off-the-shelf availability of conforming implementations.
- Provides universal common ground of implementation evaluation, thus reducing the guesswork of "buyer beware."
- Provides the clout of "law" for government users to mandate such practices.

Cons.

- The process for change is tedious and slow, due to impact on more than just DoD and CEIO.
- Inappropriately scoped, timed, or supported regulations can have a tarnishing impact on conformance testing (and the standard of interest).

Alternative 2. Develop policy (e.g., only those implementations published in the Validated Products List will be considered) and guidelines (e.g., MIL-HDBK-59) which implement conformance testing into the purchasing infrastructure.

Pros.

- Provides primary source of reference for enterprise users.
- The Validated Products List has international recognition as a source document on implementations which have undergone conformance testing.
- Government user's job is made easier when writing requests for proposals (RFPs).
- Creates a more consistent way of doing business.
- Relatively easy to develop policy and guidelines.

Cons.

- Ineffective unless conformance testing readily available.
- May be difficult to enforce policy and guidelines.
- Since the Validated Products List is only published quarterly, it still requires the prompt issuing of a hard copy certificate for a conforming implementation which has successfully undergone conformance testing.
- Adoption of Validated Products List requires CEIO comply with NIST acceptance of test suite/tools, testing laboratory accreditation procedures, and means of reporting test results.

Alternative 3. CEIO provide funding to establish and ensure conformance testing services exist for each of the CALS specifications.

Pros.

- Ensures policies and guidelines are meaningful.
- Ensures the CEIO that testing laboratories will always exist for conformance testing of their military specifications.
- "Tailors" conformance testing services to meet CEIO requirements. (In the case of SGML, other industries [i.e., Aerospace Industry Association] have their own requirements for ensuring conformance testing tools exist specific to their industrial application.
- CEIO can control their budgetary priorities and focus on some standards over others to meet flagship program requirements.

Cons.

- More expensive.
- Face timing constraints given a limited budget.

- The CEIO carries the burden by itself.

Alternative 4: Leverage existing commercial efforts and any commercial demands for conformance testing.

Pros.
- Takes advantage of what is already a resource.
- Keeps DoD aligned with industry thinking.
- Supports COTS implementations along with industry.
- Less expensive.

Cons.
- Focus often too specialized for particular industry.
- Often industry demand for conformance testing based on government demands; therefore, government usually in the lead.

Recommendation. All four alternatives should be employed:

- Alternative 1: The CEIO should request changes to the Federal and Defense Acquisition Regulations (FAR/DAR) so only those implementations which have undergone conformance testing are eligible for Defense purchase. If this alternative is successfully accomplished, it would force the hand for alternative 2; however, it is very difficult to affect such regulations. Therefore, the CEIO will want to employ other means to ensure conformance testing becomes a way of doing business.

- Alternative 2: Develop policy (e.g., only those implementations published in the Validated Products List will be considered) and guidelines (e.g., MIL-HDBK-59) which implement conformance testing into the purchasing infrastructure.

- Alternative 3: CEIO provide funding to establish and ensure conformance testing services exist for each of the CALS specifications. If the CEIO wants to ensure DoD can buy conforming COTS CALS implementations, conformance testing needs to be built into the CEIO budget. Historically, conformance testing activity has been driven randomly by the priorities of the moment.

- Alternative 4: Leverage existing commercial efforts and any commercial demands for conformance testing. The automobile industry both here in the United States and abroad, has recognized the benefits in using standards. As an example, IGES, a U.S. national standard, already has supporting conformance testing services offered in the United Kingdom for any application, as well as in Germany for the automotive industry. Electronic publishing and the use of SGML have also brought conformance testing requirements to the forefront in Europe.

In order to "ensure" conformance testing becomes part of the CALS infrastructure, the CEIO should invest time and resources into all of the alternatives; any one alternative will not give the CALS initiative full benefit.

VI. CONFORMANCE TESTING STATUS OF CALS STANDARDS.

The following provides a status of conformance testing programs of standards already adopted under the CALS initiative, as well as those which are related and may be necessary to support CALS applications. Where appropriate, a distinction is made on the status of conformance testing programs at the military specification, federal, national, or international levels. For selected standards, a detailed description of the supporting test suite, test tools, or conformance testing process is provided.

A. CALS Military Standards and Specifications.

1. Automated Interchange of Technical Information (MILSTD-1840).

The CALS Evaluation and Integration Office (CEIO) is examining the requirements for a conformance testing service for MILSTD-1840.

2. Initial Graphics Exchange Specification (IGES).

The only commercial conformance testing service offered for IGES is located at the CAD-CAM Data Exchange Technical Centre (CADDETC) in the United Kingdom. CADDETC has been formally accredited by their national accreditation body to perform conformance testing for IGES. In addition, there are several U.S. and international suppliers that offer proprietary software tools to test IGES data files of implementations. There is also a public domain library of executable test suites developed by the IGES/PDES Organization Test Case Design Committee. None of these tools has been independently assessed for its capabilities and completeness.

For the proposed IGES FIPS (expected publication by end of 1992), there is no commercially available service available. NIST hopes to evaluate those executable software tools and test suites available as a preliminary step to establish a conformance testing service for IGES FIPS.

There is no commercial conformance testing service available for the Digital Representation for Communication of Product Data (Mil-D-28000).

There are several suppliers in the United States and abroad that claim to have proprietary testing tools to evaluate Mil-D-28000 data files; however, no formal assessment of the quality of these tools has been performed.

3. Standard Generalized Markup Language (SGML).

There is no commercial conformance testing service to test the SGML International Standard 8879-1986. However, some executable test suites exist, but none of these test suites/test tools has been independently assessed for quality and completeness. A collaborative effort is underway to merge a North American proprietary executable test suite candidate with a proprietary European Community (EC) executable test suite candidate. Both developers have turned over their copyright to the EC Consortium created to harmonize the international testing activities. This would enhance the probability that one internationally-accepted executable test suite could be used for conformance testing of an SGML implementation. The Graphic Communications Association (GCA) is assisting in the harmonization of the test suites.

In 1987, under the sponsorship of the CALS Office, NIST developed a publicly available validation parser.[8] This tool was built to support conformance testing of both IS 8879-1986 and FIPS PUB 152, which adopts the ISO standard. Although it is the eventual goal of the international effort to harmonize an executable test suite for Manuals, Technical: Markup Requirements and Generic Style Specification for Electronic Printed Output and Exchange (MIL-M-28001), no such development is underway. Under CALS sponsorship, NIST is conducting an independent assessment of all test tools available for conformance testing FIPS PUB 152, as well as MIL-M-28001.

4. Raster Graphics.

There is no conformance testing service available for Raster Graphics Representation in Binary Format, Requirements for (MIL-R-28002) or

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[8]"The SGML Parser," NTIS publication #PB87-235115/WCC. Available through the National Technical Information Service, Springfield, VA 22161.

FIPS150; however, there are a few proprietary and public domain executable test suites which have undergone a technical assessment for quality and completeness. Initial focus of this assessment has been Raster Type I. Procedures for running a conformance testing service have been beta-tested under the sponsorship of the CEIO and are published as NISTIR 4848, Raster Graphics Validation. Upon completing enhancements to the selected conformance testing suite, a conformance testing service for Type I is expected to be ready at NIST by the end of 1992. Results will be published in the Validated Products List. An accreditation program is currently under consideration to transfer testing laboratory responsibilities from NIST to accredited first, second, and third party testing laboratories. NIST is also in the process of evaluating Type II conformance testing tools.

Figure 6 shows the raster conformance testing process steps of a client's Implementation Under Test (IUT) as follows:

- Client submits the Raster Graphics Request for Validation form to CSL. The client shall specify the testing environment and the type of encoding (Type I or II) to be tested.

- NIST instructs the testing laboratory to assemble and send to the client a conformance test package consisting of instructions, forms, and two sets of test cases formatted in accordance with MILSTD-1840 and MIL-R-28002. The first set (or document) will consist of uncompressed, binary bitmap images of various sizes and contents. The second set will consist of images of various sizes and similar (though not identical) contents to the first set but will be encoded following FIPS PUB 150 (Type I and II) and FIPS "Raster DAP" (Type II only).

- Using the instructions and forms received from the testing laboratory, the client processes the test suite through the IUT. The set of bitmap images (set 1) is processed creating the client's version of the encoded files, and the set of laboratory encoded files (set 2) is decoded/decompressed creating the client's version of the bitmap files. Both sets of these client processed images will then be formatted by following MILSTD-1840 and MIL-R-28002. At the

option of NIST, an observer may be assigned to watch the client's processing of the test suite.

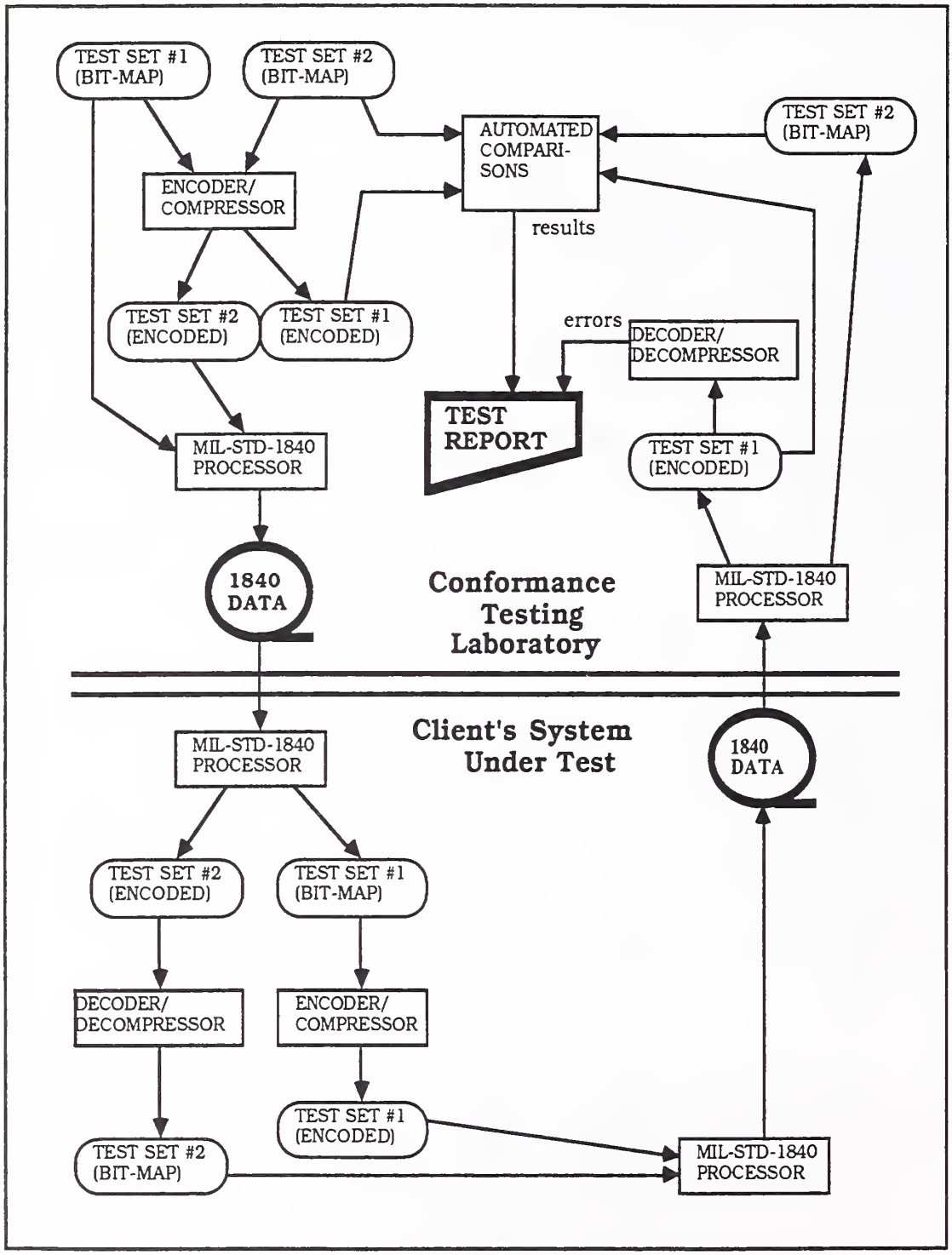

Figure 6: Raster Graphics Conformance Testing Procedure [FS92]

- The client sends the processed files to the testing laboratory for evaluation.

- The testing laboratory will evaluate each of the returned set of files comparing them with the expected results to determine if the client's IUT produced the expected results. The client's encoded images from set 1 will be compared to the laboratory's encoded versions of the original binary bitmap images. The client's bitmap images from set 2 will be compared to the laboratory's bitmap images. This procedure verifies the correctness of the encoding and compression/decompression algorithm, as well as the information contained in the raster data file header records regarding the image orientation, dimension, and pel density. The results of this comparison will be evaluated and documented for inclusion in the Validated Summary Report. The evaluation is based upon only the stated system configuration and does not indicate what the system would produce under a different configuration.

- The testing laboratory prepares a Validated Summary Report containing the results of the conformance testing [FS92].

5. Computer Graphics Metafile (CGM).

A full conformance testing service is available at NIST to test an implementation's data files for conformance to the ISO CGM standard (which is adopted through FIPS 128), as well as the Digital Representation for Communication of Illustration Data: CGM Application Profile (MIL-D-28003). The results of such testing are published in the Validated Products List. To date (August 24, 1992), one conformance assessment has been completed, and two have applied for the service.

NIST anticipates offering a conformance testing program for CGM generators by the end of 1992. Generator testing will be comprised of the metafile conformance testing already offered plus additional steps.

Figure 7 shows the CGM conformance testing process for both a client's metafile and generator.

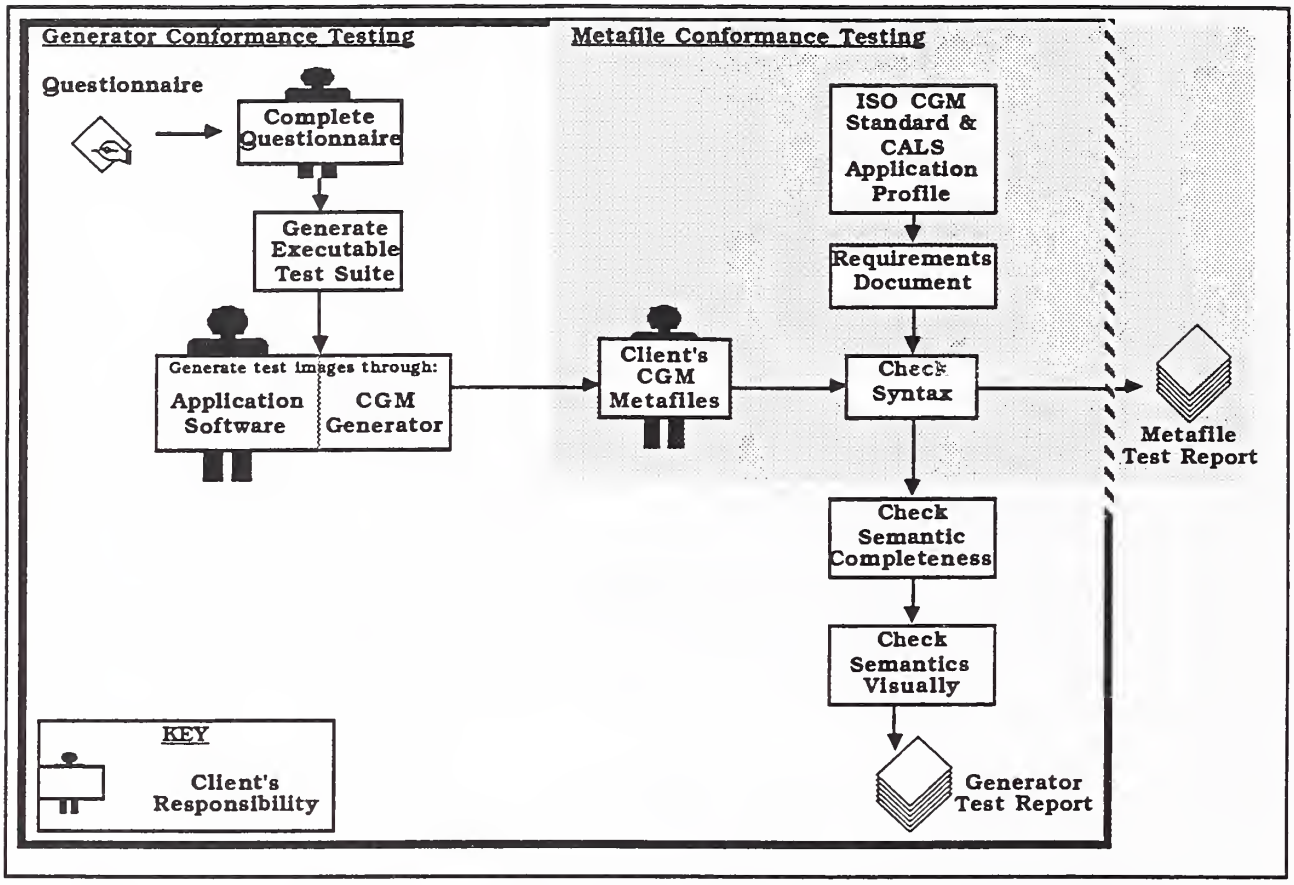

Figure 7: CGM CONFORMANCE TESTING PROCESS

Beginning at the metafile conformance testing level, how the client generates the metafiles for conformance assessment is invisible to the testing laboratory; the conformance testing process begins with the receipt of the metafiles. These metafiles are syntactically checked against the documented requirements of the international CGM standard and the CALS application profile. The results are published in a test report and published (with the client's consent) in the Validated Products List.

Since evaluation of a CGM generator is passing judgement, not just on the metafiles able to be output but on the CGM implementation itself, it is necessary for the client to complete a questionnaire. This questionnaire allows the client to identify functional capabilities of the implementation. A test suite is tailored to meet the specific capabilities of the client's implementation. The client's CGM generator (which sometimes includes the application software, other times calls upon it)

generates CGMs from the test script and test images. These CGMs are analyzed syntactically and semantically for completeness. The client is responsible to provide not only the metafiles, but a hard copy graphical representation of the metafile (if appropriate), and the client's internal format used to generate the metafile.

The same automated syntactical check occurs against the metafiles, as well as automated semantical visual and completeness checks. At the culmination of generator conformance assessment, a test report is prepared, and again, with the client's permission, the results are published in the Validated Products List.

6. Contractor Integrated Technical Information Service (MILSTD-CITIS).

Since CITIS is not yet an accepted military standard, no conformance testing service has been implemented.

7. Government Open Systems Interconnection Profile (GOSIP).

NIST, in conjunction with the Joint Interoperability Test Center (JITC) at Fort Huachuca, Arizona, offers a U.S. GOSIP Register Database (GRD). This GRD provides the following up-to-date reference information relative to FIPS 146 conformance testing: U.S. GOSIP abstract test suites; assessed means of testing; NVLAP-accredited first, second, and third party testing laboratories; and conformance tested GOSIP products. Information about access to this GRD is published in the Validated Products List.

Figure 8 is the conformance assessment process overview for GOSIP IUTs. The conformance assessment process involves three phases: preparation for testing; test operations; and test report production.

The preparation for testing includes producing the system conformance statement, Protocol Implementation Conformance Statement (PICS), and Protocol Implementation Extra Information for Testing (PIXIT); choosing the appropriate abstract test method and abstract test suite based on the PICS and PIXIT; and preparing the SUT and means of testing.

The test operations phase involves a static conformance review, conducted by analyzing the PICS with respect to the relevant static

conformance requirements; test selection and parameterization based on the PICS and PIXIT; and one or more test campaigns. A test campaign is the process of executing the parameterized executable test suite which as been produced as a result of the test selection and parameterization steps. A test campaign consists of the use of a configuration of equipment which allows protocol exchanges to take place between the SUT and the test system.

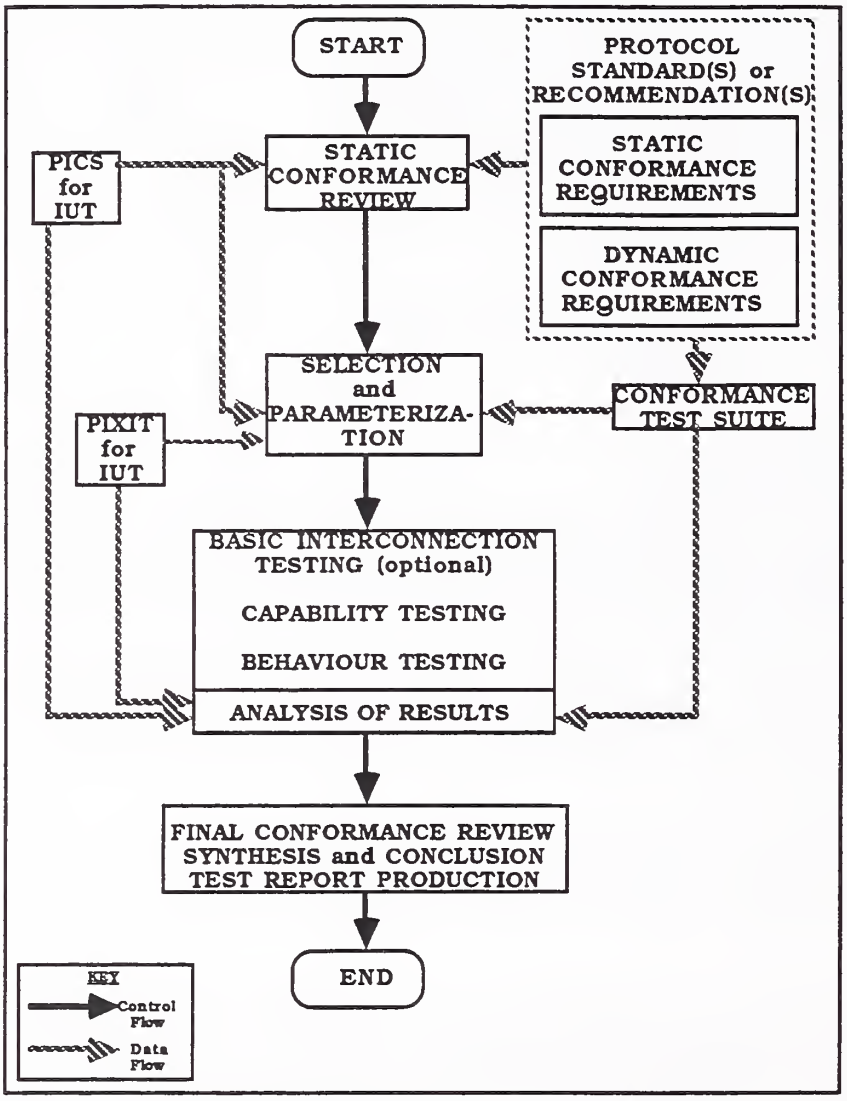

Figure 8: GOSIP Conformance Assessment Overview [9648-1]

The test operations phase culminates in analyzing the results and producing a test report.

8. Very High Speed Integrated Circuit (VHSIC) Hardware Definition Language (VHDL).

There is no conformance testing service available. Virginia Polytechnic Institute (VPI) and State University, Blacksburg, Virginia, has a proprietary executable test suite developed. Seven VHDL CAD suppliers provided funding for the initiative. Vantage, one of the participating CAD suppliers, also provided an initial test suite that was jointly developed by Vantage and Intermetrics under contract to the Air Force (AF Wright Laboratory, Solid State Electronics Directorate). The Vantage/Intermetrics test suite had high granularity tests. VPI designated test points at the paragraph level, then associated the test cases from the Air Force initiative, affecting the initial structure of the Vantage/Intermetrics test suite.

VPI's test suite software is free to universities and $2000 for non-universities. The VPI test suite tests primarily (85%) static semantics, and the remainder dynamic semantics.

The Air Force has assessed the VPI test suite and finds it the most complete in existence to date. The Air Force would like to find funding to build upon this test suite to make it more complete. There has also been preliminary discussion with the CEIO about taking over the VHDL standard and associated conformance testing service requirements [JA92], [JH92].

9. Electronic Design Interchange Format (EDIF).

There is currently no formal activity in conformance testing of EDIF. The University of Manchester, United Kingdom, does have a reference implementation which has not undergone an independent assessment; however, if a supplier so chooses, the supplier may send EDIF files to the University of Manchester to be run against this reference implementation [RP92].

10. Institute for Packaging of Electronic Components (IPC) Standards.

There are several standards by the IPC 350 series. These include:

- Printed Board Description in Digital Form (IPC-D-350).

- Printed Board Drawings in Digital Form (ANSI/IPC-D-351).
- Electronic Design Data Description for Printed Boards in Digital Form (ANSI/IPC-D-352).
- Automatic Test Information Description in Digital Form (IPC-D-353).
- Library Format Description for Printed Boards in Digital Form (IPC-D-354).
- Printed Board Automated Assembly Description in Digital Form (IPC-D-355).
- Printed Board Electrical Test Description in Digital Form (IPC-D-356).
- Guide for Digital Descriptions of Printed Board and Phototool Usage per IPC-D-350 (IPC-D-358).

IPC has a commercially available certification program for the IPC-D-350, revision C. The testing tools were developed under a collaborative arrangement between U.S. IPC and Comargus Data Systems in Berlin, Germany. The software is written to cover both syntax and a graphical view check. Although there is currently no formal international recognition of IPC's certification program, D-350, revision D is about ready to be adopted as an international IEC standard (IEC 1182-1). The Japanese have shown a strong interest in D-350 and have driven the enhancements gained by IEC 1182-1. The international adoption of D-350 through IEC may provide a positive incentive for Euro-Asian adoption of an upgraded version (capturing the changes imposed by revision D) of the U.S. IPC/German test tools. The tools are commercially available through IPC and Comargus Data Systems; IPC offers a discount to IPC members.

The IPC conformance testing process is a collaborative effort among the supplier, an offsite testing laboratory, and IPC. Upon request, a supplier receives and reads in a test vehicle of D-350 (revision C). Also sent are changes the supplier is responsible to make to his file. (These changes are tailored to each conformance assessment.) The supplier makes the designated changes to his file, and provides a new data file (an unbundled D-350 set) which reflects those changes. This data file is sent to the IPC off-site laboratory where the file is run through a syntax checker that evaluates files for correct syntax; "D-350 View" software which verifies that all features of the test vehicle, including any required edits, are

present and correctly defined in the output files; and a Manual view which verifies presence and accuracy of features in photoplots and paper check plots [IPC91]. Assessment of the required changes is made, and the results reported to IPC. IPC issues a certificate of conformity for those implementations meeting the requirements.

Although no work is underway to provide conformance testing services for the remainder of the D-350 series, IEC is expected to embrace the other D-350 standards as part of the IEC 1182 series. This adoption is expected to promote further requests and incentive to develop conformance testing services for the remainder of the D-350 standards [BD92].

11. Electronic Data Interchange (EDI) Transaction Set 841.

The EDI Transaction Set 841 is called out as an alternative transmission in MILSTD-1840B. As mentioned previously, the overall conformance testing requirements for MILSTD-1840 are currently being assessed. However, since the national EDI standard is still under the status of "draft standard for trial use," no known conformance testing activity or test suite development is occurring.

B. Future Candidate CALS Standards.

1. Standard for the Exchange of Product Model Data (STEP).

STEP has not been adopted as an international standard to date; therefore, no conformance testing service is available. Development of abstract test suites to support STEP application protocols is underway, and initial work on a conformance testing system is being funded by the Navy Manufacturing Technology (MANTECH) Program. NIST is providing technical and managerial oversight; the Industrial Technical Institute (ITI) of Michigan is doing the major portion of the technical development. A memorandum of understanding has been established between the National PDES Testbed, ITI, and PDES, Inc., to collaborate on the development of an ATS. Current activities in support of STEP include proposing the abstract test notation for ATSs and performing a requirements and capabilities survey. A survey of existing STEP tools, which may contribute toward a conformance testing system, has been completed. An additional

memorandum of understanding has been drafted between the National PDES Testbed and the European Community's (EC) Conformance Testing Service (CTS) initiative through a representative of the CAD/CAM EC CTS (Deputy Director of CADDETC) to harmonize international efforts on STEP conformance testing.

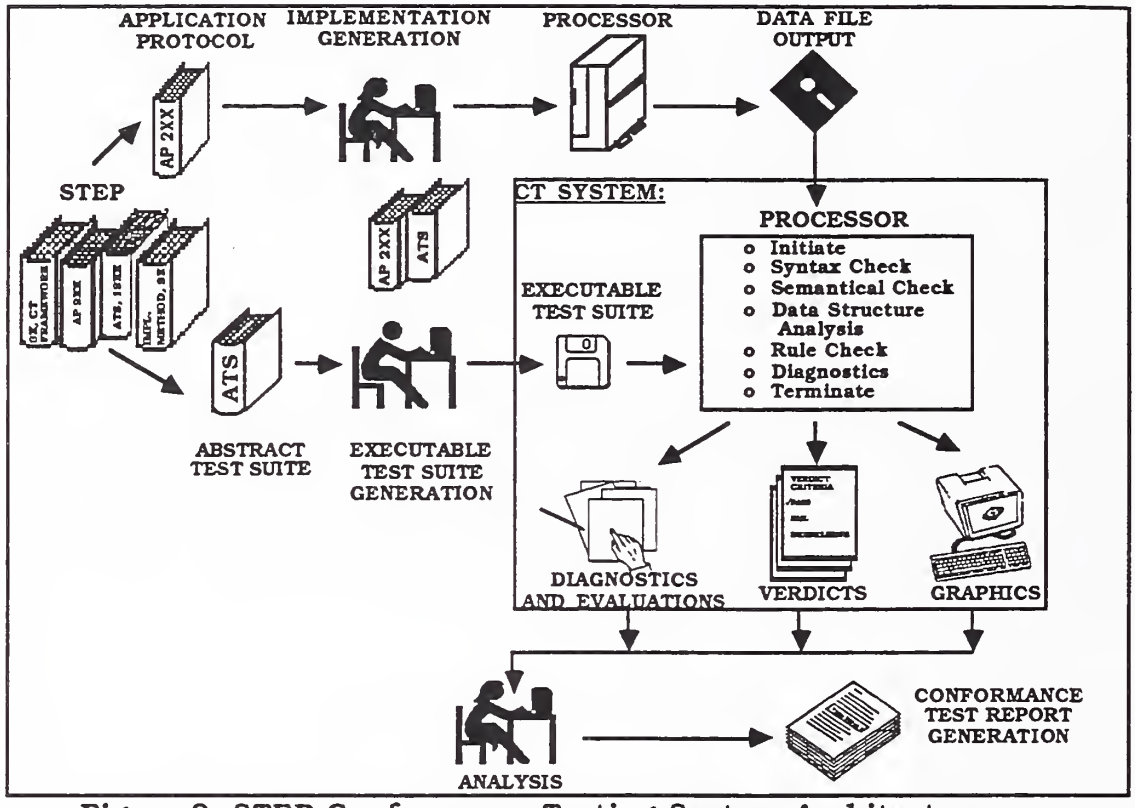

Figure 9: STEP Conformance Testing System Architecture [4641-91]

An issue already identified within the STEP community when one discusses conformance testing is the various implementation forms (and associated test methods) anticipated. Initially, STEP technology will be based on file exchange. Figure 9 is an example of a conformance testing system architecture for the file exchange implementation form using a client's preprocessor. Eventually the goal of the STEP community is product data sharing through shared databases. How one tests the conformance at the database level has yet to be determined.

2. Database Language SQL.

NIST offers a conformance testing service for implementations which claim conformance to Database Language SQL FIPS 127-1 Level II (including the integrity enhancement feature). The results are published in the Validated Products List.

Figure 10 shows a system flow diagram for basic SQL testing. The system flow for testing the integrity enhancement is identical in structure. Running an SQL test suite consists of five steps.

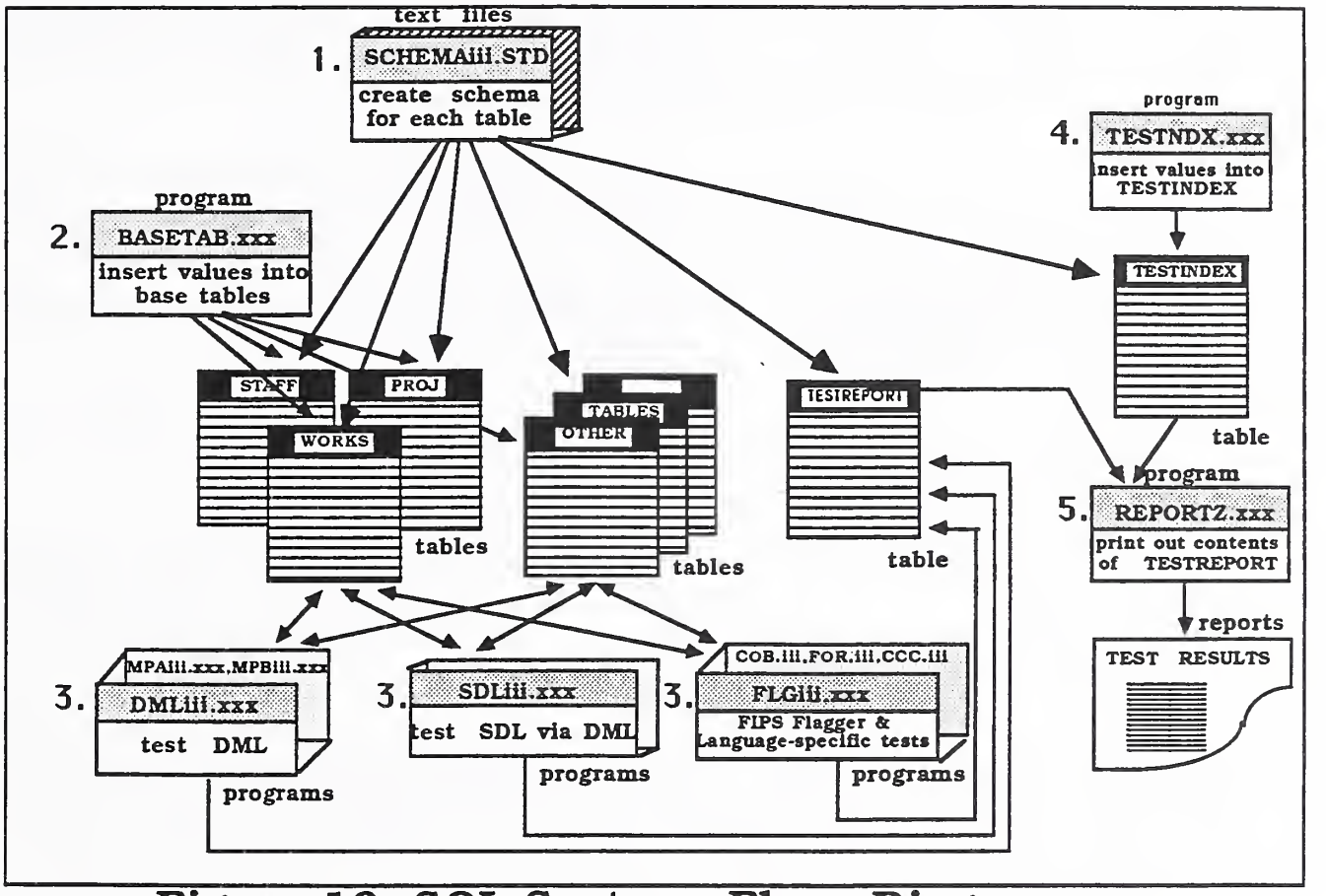

Figure 10: SQL System Flow Diagram [SQL92]

In step 1, the schema files are processed in some implementor-defined manner, perhaps interactively.

In step 2, a program is run to insert values into six of the base tables. The contents of these six tables will remain unchanged throughout

testing; i.e., these values will be restored by each program which changes them.

In step 3, the test programs are run to interact with the database tables. Each program contains logic to evaluate the database responses and determine whether a test passes or fails. This pass/fail decision is recorded by inserting a row into the table TESTREPORT. In general, programs may be run and rerun in any order.

In step 4, values are inserted into the reference table TESTINDEX. This table is required to produce the automated summary report. TESTINDEX is also a valuable resource to testers, since it can be queried interactively to create a variety of useful cross-references.

In step 5, the report programs are run to produce various listings. These listings include: required tests which failed (incorrect performance); required tests which failed (missing); tests requiring printouts to demonstrate FIPS flagging; optional FIPS sizing tests; and a one-page summary of pass/fail counts by category.

To test another programming language or to test Interactive SQL, the tester repeats steps 3 and 5 with another test suite type.

To test for conformance to the integrity enhancement, the tester repeats steps 1 through 5 with additional schema files and another set of programs [SQL92].

Total NIST SQL Test Suite licensing fee for: 1 CPU - $4,995, multiple CPUs (site-wide license) - $7,995; 1 CPU (if already have an existing NIST SQL license) - $3,995, multiple CPUs (site-wide license) (if already have an existing NIST SQL license - $6,495 [TS3.0].

3. Information Resource Dictionary System (IRDS).

NIST has developed a draft executable test suite for conformance testing implementations against the IRDS FIPS 156 Command Language, and is in the process of developing supportive test tools. Upon completion, NIST expects to offer a conformance testing service by the end of calendar year 1992.

A high-level view of the IRDS conformance testing system architecture is provided in Figure 11. The following are the components of the architecture:

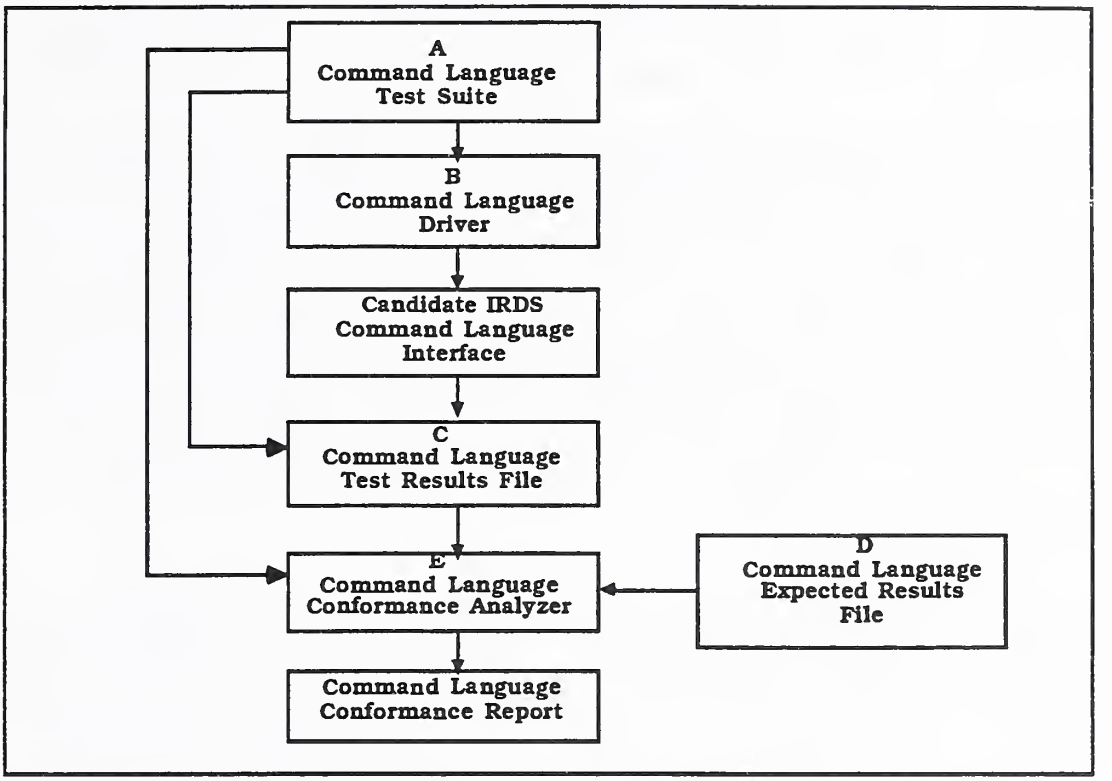

Figure 11: IRDS System Architecture [AL91]

Command Language Test Suite. This is implemented as a set of text files corresponding to the test sets in the suite and is supplied by NIST. The format of each file is precisely that of a batch file of commands.

Command Language Interface Driver. This software component processes the Command Language Test Suite using the candidate IRDS. The organization of the test suite assumes that, as a practical matter, this processing is done on a test set by test set basis. For each command in the test set, the Driver echoes and executes that command; formats all direct output, including error and success messages and Output IRD and Output IRD Schema displays; and writes the results, in the required canonical format, to the Command Language Test Results File.

Command Language Test Results File (TRF). Produced by the Command Language Interface Driver, there is one file for each test set. This file contains a record of the commands that were run, recording for each command a copy of the command string and the output results of that command. These results, written in the NIST specified canonical format, include IRD or IRD Schema data, success messages, and return codes.

Command Language Expected Results File (ERF). This file, produced by NIST, contains the expected results of the processing of the Command Language Test Suite. The expected results are stored in the same format as in the TRF to allow for automated comparison of the test results with the expected results. With one exception, this file is precisely what the TRF would look like if the candidate IRDS were perfectly conformant. The exception is, for Export IRD command, the ERF contains success messages that reference pre-defined, "expected" export/import files, in place of TRF's success messages that contain analogous references to generated export/import files.

Command Language Conformance Analyzer. This software component, developed by NIST, compares the test results in the TRF (including the contents of any pointed-to export/import files) with the expected results in the ERF (including the contents of any pointed-to export/import files). The Command Language Conformance Analyzer produces a report detailing all tests that executed successfully and all tests that executed unsuccessfully, along with any discrepancies or errors found [AG91].

4. Remote Database Access (RDA).

RDA has recently become an international standard. No decision for a conformance testing service has been made; however, RDA conformance testing may either become part of GOSIP or Database Language SQL's conformance testing service.

C. Candidate CALS Standards Contained in CIM Technical Reference Model.

1. Portable Operating System Interface for Computer Environments (POSIX).

As of mid September, 1992, over 70 implementations have been validated for conformance to FIPS 151-1. On a quarterly basis, validated POSIX implementations are listed in the Validated Products List. POSIX conformance testing is operated through accredited testing laboratories, of which there are currently eight. A NIST POSIX Electronic Mail File Service is available for on-line access to the most recent information associated with the POSIX conformance testing service. Via Internet, a system's user only needs to type "posix@nist.gov" at the mail level to access the POSIX Electronic Mail File Service. Current cost for the test suite (through NTIS) is $2,500.

The European Community under the Conformance Testing Services II (CTS2) initiative also has a POSIX conformance testing service. They chose the X/Open test suite VSX for the EC POSIX conformance testing services. Activity has been ongoing to harmonize the U.S. NIST and EC conformance testing services.

X-Open also offers their conformance testing stuie and certification mark program to those suppliers desiring to perform their own conformance testing.

2. Programmer's Hierarchical Interactive Graphics System (PHIGS).

A conformance testing service was started at NIST October 1, 1992. This conformance testing service uses version 2 of the PHIGS Validation Tests (PVT). Both version 2 and its predecessor, version 1, were developed by NIST. Version 1 was made available in July 1990, but was used only for component testing by implementors. The NIST conformance testing service measures conformance of PHIGS implementations to PHIGS FIPS 153.

Figure 12 depicts the processes associated with the PHIGS conformance testing process. Semantic requirements are identified in the PHIGS

international standard and formally restated. They describe the correct behavior expected of PHIGS functions and data. These semantic

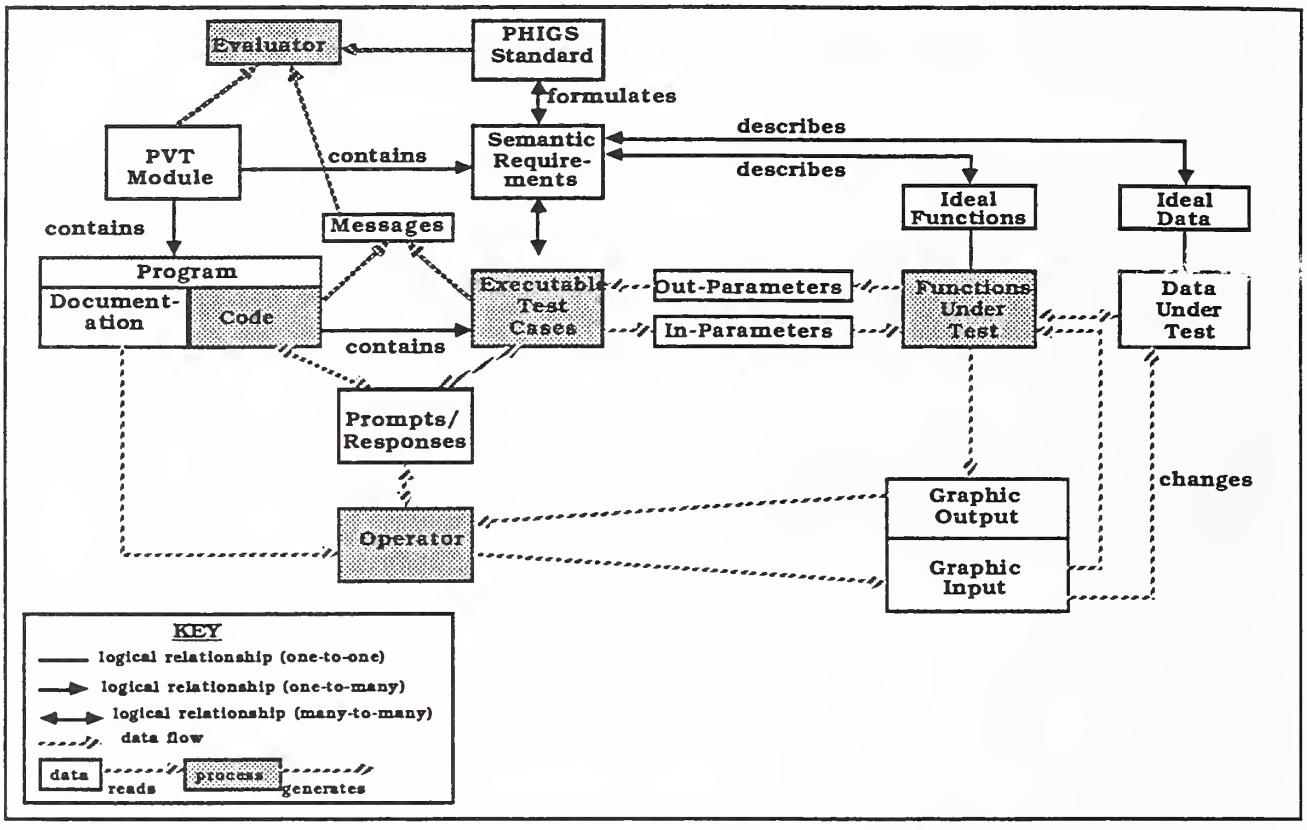

Figure 12: PHIGS CONFORMANCE TESTING PROCESS

requirements logically support test cases. The PVT module contains the semantic requirements and program documentation (including the operator script) and code. The program code includes the test cases and may generate pass/fail messages; generate messages (other than pass/fail); prompt the operator and process responses; and pass input parameters to and receive output parameters from PHIGS functions.

The operator reads the program documentation and responds to the prompts, inspects graphic output, and generates graphic input. Actual PHIGS functions generate the graphic output and accept graphic input and inspect or change the PHIGS data. The actual PHIGS data will record some graphical input.

The evaluator examines messages and may inspect module semantic requirements and programs, as well as analyze the standard. Ideal PHIGS

functions and data may or may not correspond to the IUT's actual functions and data.

3. X-Window.

The U.S. Government will provide third-party conformance testing services through NVLAP when test suites and testing policy for FIPS PUB 158 are available. Such availability is expected around 1995.

4. Integrated Services Digital Network (ISDN).

NIST is developing the abstract test suites for ISDN layers one through three, which will be included as part of the conformance testing program for "GOSIP 2" (FIPS 146-1). These ATSs will also cover the conformance requirements associated with the proposed FIPS for ISDN. The conformance testing service for the ISDN applications associated with layers one through three is anticipated by the end of 1992.

The European Community (EC), under the Conformance Testing Service II (CTS2) activities, is also developing a conformance testing service for the ISDN layers. NIST and the ISDN CTS2 EC participants are attempting to harmonize their abstract test suites through the Consultative Committee on International Telegraph and Telephone (CCITT). Currently, there is too much disagreement to harmonize the layer one ATS; therefore, the United States and Europe will each retain their own for ISDN layer one conformance testing activities. Further agreement has been reached for layers two and three: Europe has adopted the U.S. ATS for layer two, and the U.S. has adopted the European ATS for layer three. The CTS2 initiative is working on an ATS for layer four which the United States is considering for adoption [SU92].

VII. CONCLUSION.

Multiple disparate activities have been started and is continuing under the CALS umbrella of "testing." The CEIO continues to assess the overall testing investment and the continued requirements for the various levels of testing within the CALS community. Testing is a recognized and accepted process to be performed at various levels of standard and product development and enterprise user integration:

{standards} test and develop the standard

{component} test and develop the COTS implementation

{conformance} test and deploy the COTS implementation

{acceptance} test and accept the COTS implementation into the user enterprise

These levels of testing activity are dependent on one another. The ultimate goal is to ensure the government user's requirements at the system procurement level have been met. Without the cumulative support from strong standards testing, component testing, and conformance testing programs, the effort and cost associated with CALS acceptance testing would be redundant and inefficient.

Several issues which face the CALS initiative were highlighted in this report. The following are a summary of the issues and their associated recommendations. The CEIO should:

Issue. Whether the CEIO should recognize any acceptance testing performed by the systems integrator prior to government procurement.
Recommendation. The government user applies predefined requirements which the systems integrator applies in-house, and the government user accepts the results.

Issue. Whether it is cost-effective for the CEIO to fund a validation testing system for STEP, and if so, where should such a system be hosted.
Recommendation. Sustain a Validation Testing System for STEP at NIST.

Issue. Although NIST develops conformance testing services for some standards which are Federal Information Processing Standards Publications (FIPS PUBS), no means exists to perform conformance testing on the additional requirements imposed on the supplier through military specifications. Should NIST be responsible for CALS military specification conformance testing?
Recommendation. Sponsor NIST to provide conformance testing services for the CALS military specifications; funding conformance testing service development for both the FIPS and associated military specification if necessary.

Issue. Accreditation of testing laboratories is often viewed as an expensive overhead, both in actual dollars required to initiate, and time required to establish such a program. Should the CEIO invest in accreditation?
Recommendation. Support the use of accreditation for first, second, and third party testing laboratories through NVLAP.

Issue. The CALS Test Network (CTN) affirms CALS compliance only for DoD-owned systems. Is this appropriate?
Recommendation. Remove any conformance testing from the CTN responsibilities, especially if it is limited only to DoD-owned systems.

Issue. The CTN performs standards testing and interoperability testing without routinely performing conformance testing. This CTN practice is not the same sequence that occurs in general practice.
Recommendation. Advocate the CTN for only standards testing; interoperability testing by the CTN should be performed only as part of acceptance testing for a given procurement.

Issue. Should the CEIO try to leverage industry's test suite and tool development resources to benefit conformance testing and reduce industries' investment costs?
Recommendation. Encourage supplier or enterprise user-developed proprietary testing tools to be made available to NIST for CALS conformance testing programs for: (1) use if complete, or (2) adaptation if incomplete.

Issue. Even if conformance testing services existed for all the CALS military specifications, how does the CEIO guarantee enterprise users will take advantage of such services?
Recommendation. Instill conformance testing into the infrastructure through changes to the Federal and Defense Acquisition Regulations; develop policy and guidelines which implement conformance testing into the purchasing infrastructure; provide funding to establish and ensure conformance testing services exist for each of the CALS specifications; and leverage existing commercial efforts and any commercial demands for conformance testing.

The world of information technology standards is not a finite, bounded environment where decisions can be made and proven with mathematical precision. The CEIO must depend on consensus building to acquire standards for the CALS community which reflect the functionality necessary to meet DoD requirements. Testing activities and supportive terminology and policies can also be selected from many correct alternatives. This report has highlighted some of the most commonly recognized terminology and processes, and supports the CEIO in choosing what best meets its environment. The CEIO must assess the technical, political, and economic ramifications of its decisions for any given weapon system acquisition or supporting life cycle program.

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Appendix A: Terminology and Acronyms

A. Terminology.

abstract test method: The description of how an IUT is to be tested, given at an appropriate level of abstraction to make the description independent of any particular realization of the means of testing, but with enough detail to enable tests to be specified for this test method [9646-1].

abstract test suite: A complete set of abstract test cases, possibly combined into nested abstract test groups, that is necessary to perform conformance testing for a standard or group of standards [31-92].

acceptance test: (ISO 2382, Vocabulary - Information Processing) A test of a system or functional unit, usually performed by users on their premises after installation, with the participation of the vendor to ensure that contractual requirements are met [FIPS11-3].

{user} acceptance testing: Determines whether a software system satisfies its acceptance criteria and enables the user to determine whether to accept the system. This includes the planning and execution of several kinds of tests (e.g., functional, volume, performance tests) to demonstrate the implemented software satisfies the user requirements. NOTE - This does not form part of conformance testing [31-92].

(laboratory) accreditation: The formalized initial and continuing process of ensuring a testing laboratory is competent to carry out specific (types of) tests. NOTE - The term "laboratory accreditation" covers the recognition of both the technical competence and the impartiality of a testing laboratory. Accreditation is normally awarded following successful laboratory assessment and is followed by appropriate surveillance [31-92].

accreditation body: A body that conducts and administers a laboratory accreditation scheme and grants accreditation [31-92].

application protocol (AP): A part of STEP that describes the use of integrated resources to satisfy the scope and information requirements for a specific application context [1-92].

application protocol validation: The process of evaluating a candidate application protocol (AP) and its components to determine whether these satisfy specified requirements [AP92].

certificate of conformity, certificate of conformance: A document issued under the rules of a certification system indicating that adequate confidence is provided that an implementation under test is in conformity with a specific standard or technical specification as determined through use of a specified test method [31-92].

certification: Procedure by which a third party gives written assurance that a product, process or service conforms to specified requirements [ISO2].

certification body: An impartial body possessing the necessary competence and reliability to operate a certification system, and in which the interests of all parties concerned with the function of the system are represented [31-92].

client (of a testing laboratory): The organization that submits a system or implementation for conformance testing [9646-1].

compliance: The act or process of complying to a desire, demand, or proposal or to coercion [WEB79].

component testing: Testing conducted to verify the implementation of the design for one software element (for example, unit, module) or a collection of software elements [IEEE-86].

NOTE - This does not form part of conformance testing.

conformance: See conformity.

conformance assessment process: The complete process of accomplishing all conformance testing activities necessary to determine the conformance of an implementation [31-92].

conformance test report: A document written at the end of the conformance assessment process, which provides both summary and detailed information [31-92 generalized[9]].

conformance testing: Testing the extent to which an IUT is a conforming implementation [9646-1].

conformity, conformance: Fulfillment by a product, process, or service of specified requirements [ISO2].

enterprise user. An organization or person who builds, uses, maintains, or disposes of information generated from an implementation.

executable test suite: A complete set of executable test cases (an instantiation of an abstract test case with values) that is necessary to perform conformance testing for a standard or group of standards [31-92].
first party testing laboratory: See third party testing laboratory.

Implementation Under Test: That part of a product which is to be studied under testing, which should be an implementation of one or more characteristics of the standard(s) [31-92 generalized].

implementor: See supplier.

interoperability testing: Related to acceptance testing, but applied to the examination of the information exchange and sharing between two specific implementations under test (IUT) and the ability of each IUT to use such information. NOTE - This does not form part of conformance testing [31-92].

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[9] Those definitions referenced in this manner have been generalized since the definition contained text specific to STEP.

means of testing: The combination of equipment and procedures that can perform the derivation, selection, parameterization, and execution of test cases, in conformance with a reference standardized abstract test suite, and can produce a conformance log [9646-1].

military specification testing: The processes associated with validation (definition relative to standards testing) of the military specifications.

performance testing: Measures the performance characteristics of an IUT, such as its throughput, response time, number of transactions, and responsiveness under various conditions. Note - This does not form part of conformance testing [31-92].

proficiency testing (laboratory): Determination of laboratory testing performance by means of inter-laboratory test comparisons [3768-88].

protocol implementation conformance statement (PICS): A statement made by the supplier of an implementation or system, stating which capabilities have been implemented for a given standard [9646-1].

protocol implementation extra information for testing (PIXIT): A statement made by a supplier or implementor of an IUT which contains or references all of the information (in addition to that given in the PICS) related to the IUT and its testing environment, which will enable the testing laboratory to run an appropriate test suite against the IUT [9646-1].

robustness testing: Determines how well an IUT recovers (for example: from various error conditions) [31-92].

second party testing laboratory: See third-party testing laboratory.

self-certification: term deprecated. See "supplier's declaration" [ISO2].

standards testing: Determines whether the national, international, or military standards (and specifications) are viable and implementable.

static conformance review: A review of the extent to which the static conformance requirements are met by the IUT, accomplished by comparing the PICS with the static conformance requirements expressed in the relevant international standard(s) or CCITT recommendation(s) [9646-1].

supplier, vendor, implementor: An organization or individual who develops commercial off-the-shelf implementations.

supplier's declaration: Procedure by which a supplier gives written assurance that a product, process or service conforms to specified requirements. Note - In order to avoid confusion, the expression "self-certification" should not be used [ISO2].

System Under Test: The computer hardware, software, and communication network required to support the IUT [31-92].

test campaign: The process of running the executable test suite for a particular IUT [9646-1].

test method: Specified technical procedure for performing a test [ISO2]. Specified technical procedure for performing a testing service, including the specification of the individual test cases which comprise a test suite; the test tools (both hardware and software) used to run those executable test cases and the way in which those test tools are used; and the procedures used to select and run the test cases and to analyze the observations and state the test results [EW15].

test tool: Hardware and/or software, excluding the test suite itself, which is run under the control of the testing laboratory, in order to carry out, or assist in carrying out, the testing required [EW15].

testing: Action of carrying out one or more tests (Technical operation that consists of the determination of one or more characteristics of a given product, process or service according to a specified procedure.) [ISO2].

testing laboratory: An organization that carries out the conformance assessment process. This can be a third party, a user organization, or an identifiable part of the supplier organization [31-92].

third party certification program: An organized system (1) under which similar products or services of any number of producers may be certified as conforming to the referenced standards or specifications on a uniform and equitable basis, (2) which uses or is operated by a third-party testing laboratory, and (3) which authorizes the use of controlled certification marks or certificates of conformity as evidence of conformity [Z34.1].

third party testing laboratory: Person or body that is recognized as being independent of the parties involved, as concerns the issue in question. NOTE - Parties involved are usually supplier ("first party") and purchaser ("second party") interests [ISO2].

validation (definition relative to standards testing): An act, process, or instance of making valid. (Valid - having legal efficacy or force.) [WEB79]

NOTE - This does not form part of conformance testing.

validation (definition relative to conformance testing): The process of checking the conformity of an implementation of a standard to its standard specification through conformance testing, and when compliance is demonstrated, issuing a validation certificate [FIPS88].

vendor: See supplier.

B. **Acronyms.**

ANS:	American National Standard
ANSI:	American National Standards Institute
CAD:	Computer-Aided Design
CALS:	Computer-aided Acquisition and Logistic Support

CCITT:	Consultative Committee on International Telegraph and Telephone
CD:	Committee Draft
CE:	Concurrent Engineering
CEC:	Commission for European Community
CEIO:	CALS Evaluation and Integration Office
CITIS:	Contractor's Integrated Technical Information Service
CGM:	Computer Graphics Metafile
CIM:	Corporate Information Management
COTS:	Commercial Off-The-Shelf
CTN:	CALS Test Network
CTS:	Conformance Testing Service
DLA:	Defense Logistics Agency
DSREDS	Digital Storage and Retrieval Engineering Data System
EC:	European Community
EDCARS:	Engineering Data Computer Assisted Retrieval System
EDIF:	Electronic Design Interchange Format
EDMICS:	Engineering Data Management Information and Control System
GCA:	Graphic Communications Association
GKS:	Graphical Kernel System
GOSIP:	Government Open Systems Interconnection Profile
JITC:	Joint Interoperability Test Center
IEC:	International Electrotechnical Commission
IGES:	Initial Graphics Exchange Specification
IPC:	Institute for Packaging of Electronic Components
IPO:	IGES/PDES Organization
IRDS:	Information Resource Dictionary System
ISG:	Industry Steering Group
ISO:	International Organization for Standardization
ITI:	Industrial Technical Institute
IUT:	Implementation Under Test
MOU:	Memorandum of Understanding
NIST:	National Institute of Standards and Technology
NPT:	National PDES Testbed
NSIA:	National Security Industrial Association
PDES:	Product Data Exchange using STEP
PHIGS:	Programmer's Hierarchical Interactive Graphics System
PICS:	Protocol Implementation Conformance Statement

PIXIT:	Protocol Implementation Extra Information for Testing
POSIX:	Portable Operating System Interface for Computer Environments
R&D:	Research and Development
RFP:	Request for Proposal
SGML:	Standard Generalized Markup Language
STEP:	Standard for the Exchange of Product Model Data
SUT:	System Under Test
VHDL:	Very High Speed Integrated Circuit (VHSIC) Hardware Definition Language

Appendix B: Existing Directives and Guidelines

Standards Testing.

- CTN 91-042, CALS Test Network Handbook.

This series of NIST publications are specific to validating various aspects of STEP:

- NISTIR 4417, Development Plan: Validation Testing System.

- NISTIR 4636, Validation Testing System Requirements.

- NISTIR 4684, A Proposed Testing Methodology for STEP Application Protocol Validation.

- NISTIR 4735, Validating STEP Application Models at the National PDES Testbed.

- NISTIR 4742, Architecture for the Validation Testing System Software.

Component Testing.

- ANSI/IEEE Std 1012-1986, IEEE Standard for Software Verification and Validation Plans.

- DOD-STD-2167A, Defense System Software Development.

- MIL-HDBK-287, Tailoring Guide for DOD-STD-2167A, Defense System Software Development.

- DOD-STD-2168, Defense System Software Quality Program.

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- FIPS PUB 101, Guideline for Lifecycle Validation, Verification, and Testing of Computer Software.

- FIPS PUB 132, Guideline for Software Verification and Validation Plans.

- NIST Special Publication 500-165, Software Verification and Validation: Its Role in Computer Assurance and Its Relationship with Software Project Management Standards.

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Conformance Testing.

- ISO/IEC Guide 2, General Terms and Their Definitions Concerning Standardization and Related Activities.

- ISO/IEC Guide 7, Requirements for Standards Suitable for Product Certification.

- ISO/IEC Guide 16, Code of Principles on Third-Party Certification Systems and Related Standards.

- ISO/IEC Guide 23, Methods of Indicating Conformity with Standards for Third-Party Certification Systems.

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If the CALS initiative is to be successful, government and industry have to attain a high level of confidence that the CALS specifications and standards are adequate to satisfy the requirements for digital delivery of technical data supporting user applications. Equally as important, both government and industry must be satisfied industry implementations can deliver this technical data according to a set of specifications and standards. For this to happen, CALS has to influence testing in three areas: standards, conformance, and acceptance testing [JCMO91].

The content of this report covers those testing activities which have been or are funded by CALS, by DoD services, or by industry to support CALS. Although specific activity descriptions may be limited to the CALS community, the types of testing activities generically described in the following pages, the author believes, satisfy most enterprise users' application requirements.

12. KEY WORDS (6 TO 12 ENTRIES; ALPHABETICAL ORDER; CAPITALIZE ONLY PROPER NAMES; AND SEPARATE KEY WORDS BY SEMICOLONS)

acceptance testing; CALS; component testing; conformance; conformance testing; military specifications; standards; standards testing; Validated Products List.

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