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Harmonizing CALS Product Data Description Standards		

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February 1989

Harmonizing CALS Product Data Description Standards

An
Evaluation Report
by
The EIA Ad Hoc CALS Study Group

Electronic Industries Association
Engineering Department
2001 Eye Street, N.W.
Washington, D. C. 20006



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FORWARD

In December 1987 EIA established an Ad Hoc CALS Study Group for the purpose of evaluating the applicability of existing electronic industry standards for use in the CALS Program.

The Study Group met six times, three days each meeting during 1988. As a result of its deliberations, the report contain herein has been produced.

Members of the Study Group were:

John M. Kinn	EIA, Chairman
Nelson Samhammer	General Electric
Robert Ventimiglia	General Electric
R.L. Bourn	IBM Corporation
Nancy L. Klimavicz	IBM Corporation
Joe Montgomery	Intel Corporation
R. Lydick	GE/RCA
R. Edsen	GE Aircraft Engine
Dieter Bergman	IPC
Richard Smith	National Semiconductor/Fairchild
Don Hall	OASD (P&L) WSIG
Marvin Greenberg	IBM
Al Lowenstein	PCA Electronics, Inc.
Dr. Paul H Stanford	Texas Instruments, Inc.
William Guzek	GE Electronic Laboratory
J. Rudolph	IBM
Richard Newton	University of California, Berkley
Kevyn Salsberg	IBM

The EIA thanks the CALS Industry Steering Group, the CALS Office and the member companies of the Study Group participants for their support of this effort.

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REPORT OF THE
EIA AD HOC CALS STUDY GROUP

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REPORT OF THE
EIA AD HOC CALS STUDY GROUP

1.0 INTRODUCTION

This report documents the findings of an industry study panel convened by the Electronic Industries Association (EIA) under the auspices of the Computer-aided Acquisition and Logistics Support (CALS) Industry Steering Committee to determine the best utilization of product data description standards for electronic configuration items in the near term. Appendix A contains a brief outline of the CALS Program. The study group's objective was to determine the most advantageous mix of existing standards for application in specifying digital delivery of product data items in support of weapon system development and support contracts. The evaluation was accomplished by means of a product data requirements matrix in which types of data required by the government throughout the development process were mapped against the applicability of the various standards. A delphi approach, in which users of all of the standards participated, was used to determine applicability. It is anticipated that the results of this study will be used to guide the generation of application requirements specifications, similar in intent to MIL-D-28000, as well as influence the direction of further development of the standards. In addition, this committee was also charged with recommending: implementing language for MIL-STD-1840A; a strategy for resolving overlaps in standards developing organizations; and suggestions for future work.

The study group membership consisted of representatives from electrical and electronic manufacturing companies. These representatives were conversant with each of the standards under review, thereby providing an experienced input into the evaluation. The study group met every other month for three days each meeting to arrive at the conclusions and recommendations contained herein.

The purpose of this study was to establish a strategy and detailed implementation of industry specifications that would enable generation of automated descriptions of the electrical/electronic product at all levels of abstraction and design hierarchy. The term "automated descriptions" is meant to imply: formulation of the descriptions of the product solely from computer-aided design/engineering data bases at the source, electronic transmission; and the potential for fully automated processing (analysis or development synthesis) based on the description at the destination without manual intervention, i.e., "machine processable". Since CALS goals and policy call for digital data exchange in the near term, specifications used for

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implementation must be based on existing data exchange standards. However, no existing standard is suitable for application on a blanket basis. As a result, numerous application groups have been meeting to guide the use of these standards in specific areas of interest.

2.0 STUDY GROUP ACTIVITY

The electronics industry has been aware of the need for electronic delivery of technical information prior to articulation of the CALS initiative by the DOD. Several substantial standards efforts, by an ad hoc industry group, an industry trade association, and the DOD, have made major progress in particular niches. The visibility, afforded by CALS, of the broad spectrum of information that could be or should be delivered digitally introduced new opportunities for expansion by ongoing standards activities, but also raised questions as to the areas of applicability of each as well as their interfaces.

While the issue of electronic data transfer standardization has been a subject of discussion at many conferences, it was brought to a head in December, 1987, when the CALS Office released the Phase 1.0 series of specifications, MIL-D-28000 and MIL-STD-1840A. Included in MIL-D-28000 is the optional application to electronic product items of standards originally developed for description of aircraft structures. However, MIL-STD-1840A permits the use of any of the established standards for product description at the discretion of the government program manager. The Electronics Industry raised concerns with respect to the suitability of the structures standard to the electronic computer-aided engineering environment and the impact of arbitrarily making one standard mandatory to the exclusion of all others on the substantial industry investments already made. Furthermore, it is apparent that industry is not likely to invest further until the issue of applicability is resolved. This situation is a major factor inhibiting the progress of CALS. In response to the electronic industry concerns, the CALS Policy Office requested that the CALS Industry Steering Committee assemble a study group to be chaired by the Electronic Industries Association.

During its initial meeting, the study group agreed that, given the minimal amount of hard user data in existence owing to the relative newness of most of the standards being evaluated, the most effective approach to any evaluation would be to use a Delphi Technique. To this end, a representative list of product description data elements was created that represented all stages of the design process, commencing with a product behavioral description and ending with a shipping container drawing. This list, supplied by the CALS Steering Committee, was then used to compare each

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standard using an agreed upon (but subjective) set of criteria for evaluation. A comprehensive matrix was created that would enable evaluators to assign a numerical value representing relative applicability for each design element for Systems, Boxes, Boards and Components. A detailed description of the Study Panel's methodology, including the matrix, along with the evaluation criteria is given in Appendix B. A brief description of the standards evaluated by the study group is given in Appendix C.

3.0 CONCLUSIONS

Based on the process described above, the committee concluded that:

- 3.1 Harmonization of these standards was effectively accomplished. This process permitted the development of guidance material for use in revising MIL-STD-1840. All sections of MIL-STD-1840 need to be modified in accordance with the proposed changes given in Appendix D.
- 3.2 For a given application, each standard provides an optimum mechanism for handling requirements of specific elements in the design process. Overlap exists, but is beneficial and manageable.
- 3.3 Multiple standards reflect the realities of the current Design Automation environment. The matrix method provides a viable tool to monitor and determine harmonization needs and communicate them to industry.
- 3.4 Areas in the design process needing additional standards development include: experimental test products, timing description, qualitative performance, fault simulations, detailed thermal analysis, R & M analysis, reference designations, assembly socket test and burn-in requirements for systems and boxes. The appropriate standards bodies responsible for these standards should be asked to look at possible techniques for the expansion of standards to include electronic product data description for these requirements.

4.0 RECOMMENDATIONS

4.1 MIL-STD-1840A

This Standard should be updated in accordance with Appendix D, and reissued as MIL-STD-1840B. The Study Group would be pleased to provide a pre-circulation review of the document prior to Industry coordination.

4.2 RESOLUTION OF OVERLAPS

In analyzing the Delphi Matrix there are areas of inherent overlap which prove useful as crossover points to bridge between the standards. Thus, it is recommended delivery of data in multiple formats is acceptable because this provides a mechanism for optimizing the design and manufacturing process that should not be constrained by a single format. Furthermore it is also recommended that consistent with the use of a functional design profile, this problem should prove to be minimal.

4.3 DESIGN PROFILES

Based on the study conclusions, the concept of a matrix showing a functional design profile defining specific standards for use in specific applications should be considered. The use of these standards in each design element will be based on actual practice current in that application area by a given company. A sample profile is given in Appendix E.

4.4 RECOMMENDATIONS

The study group recognizes that technology of product data standardizing is rapidly evolving, therefore, in addition to the recommendations in paragraph 4.1, it is recommended that MIL-STD-1840A be modified to specify CALS delivery of information in accordance with the following standards:

1. VHDL: 1 (System, Box), 2 (System, Box), 3, 4, 5, 6, 7 (System, Box), 8, 9, 11, 14, 16, 17, 18, 19, 29, 30, 34, 35
2. EDIF: 1 (Component, Board), 2 (Component, Board), 7 (Component, Board), 9, 12 (Component), 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 33, 34, 35, 36 (Component), 38 (Component), 39 (Component), 41 (Component), 44 (Component), 45 (Component), 47 (Component), 49 (Component), 51 (Component), 53, 54, 55
3. IPC: 1 (Board), 2 (Board), 7 (Board), 12 (Board), 13, 15, 20, 33 (Board), 34, 35, 36 (Board), 38 (Board), 40, 41 (Board), 44 (Board), 45 (Board), 47 (Board), 48 (Board), 49 (Board), 51 (Board), 56, 57, 58

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4. IGES: 9, 10, 12 (System, Box), 31, 32, 36 (System, Box), 37, 38 (System, Box), 39 (System, Box), 41 (System, Box), 44 (System, Box), 45 (System, Box), 46, 47 (System, Box), 48 (System, Box), 50, 51 (System, Box), 52

It is also recommended that the standards bodies be requested to develop a strategy that ensures convergence of representation of information at the cross-over points. It is understood that the VHDL and EDIF people are already accomplishing this in conjunction with the DASS.

4.5 FUTURE REQUIREMENTS

In accordance with the long term goals of CALS, it is recommended that this Ad Hoc Study Group be converted to an Electronic Product Data Exchange Task Group under the CALS Industry Task Force to perform the following functions:

- Assist in implementation of the recommendations outlined herein;
- Provide a smooth transition into PDES for electronic data;
- Be the CALS Industry Steering Group focal point for harmonization of electronic industry standards.

APPENDIX A
BACKGROUND ON CALS



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APPENDIX A

BACKGROUND ON CALS

Computer-aided Acquisition and Logistic Support

The potential exists for substantial quality improvements and reductions in acquisition and support costs by delivery of product description data in digital form. Widespread industry use of computer-aided design and engineering (CAD/CAE) development processes has created the environment in which digital delivery is feasible. Furthermore, digital, rather than "paper", delivery of data items is also highly expedient in order to avoid the wholesale introduction of translation errors from computer-intelligible into human-readable data forms and back again. CALS is a DOD and Industry initiative to enable and accelerate the use and integration of digital technical information for weapon system acquisition, design, manufacture and support. The Deputy Secretary of Defense launched the DOD CALS Program in September, 1985, with the goal that, by 1990, new weapon systems would require delivery of technical data in digital form, or obtain government access to german contractor integrated data bases, in lieu of paper deliveries.

CALS will transition from the current paper-intensive mode to a highly automated and integrated mode of operation, thereby substantially improving productivity and quality. The benefits expected to be achieved by CALS include:

- o Reduced acquisition and support costs for weapon system programs through elimination of duplicative, manual, error-prone processes;
- o Improved quality of delivered technical information;
- o Improved reliability and maintainability of weapon system designs through direct coupling to CAD/CAE design processes and data bases;
- o Improved responsiveness of the industrial base, (i.e. to be able to rapidly increase production rates or sources of hardware based on digital product descriptions). Industry is working closely with DOD to focus and coordinate its efforts to transition to automated modes of operation and digital delivery.

To achieve these benefits, a phased CALS strategy has been planned using a team approach consisting of the Office of the Secretary of Defense, the Military Departments, and Industry. Phase I of CALS will see the replacement of paper document transfers with digital file exchanges and

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initiation of design, manufacturing, and support process integration. It will be implemented between now and the early 1990's. In parallel, technology is being developed for Phase II, which involves substantial integration of current process to take advantage of a shared data base environment in the early 1990's and well beyond. Since Industry will be the principal implementor of CALS capabilities, a major objective of the CALS' strategy has been to involve Industry from the outset in planning the implementation of these technologies. An Industry Steering Group coordinates the efforts of a volunteer 200 member task force that supports standards development, implementation planning and acquisition issues. Many defense contractors, as well as each of the Military Services and the Defense Logistics Agency, have established CALS Offices to coordinate CALS implementation within their organizations. The major activity of the Industry Task Force is the development, adoption, and application of industry standards that would govern the form and content of data delivered digitally to the government.

Objective

The near term objective of the CALS Program with respect to electronic products is to select a set of standards that provide support for the transfer of technical information of significance to CALS in a manner that minimizes overlaps. In the far term, the CALS Program will try to collapse on a unified product data exchange standardization process of representation (i.e., an electronic PDES). Lessons learned in the near term must feed the PDES development efforts.

APPENDIX B
STUDY GROUP METHODOLOGY

APPENDIX B

STUDY GROUP METHODOLOGY

The Study Group developed its initial set of numerical values for each matrix cell for use as a benchmark using a consensus approach. The matrix and evaluation criteria were then circulated to a broad spectrum of design automation specialists with the request they supply their own evaluation. This first response to the mailing was reviewed by the Study Group, the matrix modified as a result, and a second mailing made. Through an iterative process the Study Group was able to both arrive at a convergence of evaluation and an awareness of areas in the design process that were not being adequately covered; hence requiring further work by standards developers.

As in all evaluations of this nature, both the evaluation and the conclusion tend to be subjective; however, it is the belief of the Study Group that the results achieved using this process are not only representative of the best current thinking and practice within the electronics industry, but also provide a sound basis upon which future planning in CALS may take place. The remaining sections of this Appendix highlight some of the issues addressed by the Study Group that reduced the level of subjectivity.

Information Elements

In selecting its approach, the Study Group wished to avoid the problems that seem to have inhibited past efforts aimed at "harmonization" of the standards. One of the problems has been the difficulty in defining the categories of information that are addressed by each standard. Considerable effort was spent not only in developing a list of information elements, but in their definition in terms that would support a clear cut assignment of scoring criteria. Direct translation of current paper deliverables to digital delivery is misleading. For example, one of the key deliverables now in use is the schematic diagram. However, evaluating standards simply on the basis of their ability to replicate the engineering drawing; called the schematic, by electronic means representation would be counterproductive in that it would ignore a valuable configuration control feature that is embedded within most CAE systems (back annotation).

An initial set of information elements was developed by a separate committee of experts in various engineering specialties (such as, reliability engineering) based on their information needs. This committee went into the level of detail it felt necessary to distinguish between fundamentally different types of information. This list was reviewed by the Study Group that made some changes to reflect a greater completeness and reordered the elements to roughly correspond to the steps of the top-down design process. The Study Group defined each of the elements in

detail with examples, replicating some elements where needed to distinguish between two distinct types of information that might have been grouped under the same heading. For example, "design rules" shows up twice on the list. That was to distinguish between function or electrical design rules and purely physical design rules. The complete set of definitions appears at the end of this Appendix as Chart VI.

Major effort was expended in determining the most probable means of representation of each information element in near term. Where computer interpretable forms of current data items in the matrix are in use or could be anticipated in the near term, the definition of the information element was expressed in those terms. Where current manual methods are expected to continue for some time, those terms were retained. Thus, schematic is not found as a stand-alone information element, although all of the information that would be carried by a schematic is found in various elements. On the other hand, the assembly drawing is found described as a standard drawing (other than a true three-dimensional model) because it was felt that this mechanism will be retained much longer than the schematic, reflecting the greater time required to integrate electronic package design and manufacturing.

The concept has been categorized into four different categories:

T - Textural Data: The semantics carried by the data can be readily converted to text, screen, or hard copy through a printer medium.

P - Pictorial Data: The semantics carried by the data is pictorial material that can be readily converted to graphic screen or a hard copy through laser or plotter printing.

C - Computer: The semantics carried by the data can be readily interpreted by a computer or a computer algorithm without human intervention.

M - Machine Language: The semantics carried by the data, in its lowest form, can be readily interpreted by a computer controlled special purpose machine without human intervention.

Levels of Equipment Integration

Another pitfall of previous harmonization efforts has been extrapolation across levels of equipment indenture. For example, if a standard is found to be particularly good at representing an item of information for integrated circuit components, it is assumed that it would be equally good at representing the same type of information for printed circuit boards or even systems. The working group wished to avoid making this assumption without first testing it. To do so, the exercise of assessing the suitability of each standard to each information item by

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was repeated for different levels of system integration. Although military standards and industry practice recognize nine levels of integration, the study group decided that four would be sufficient to adequately distinguish between different informational requirements.

The four levels and their definitions are:

System: A functionally complete assembly of components, boards, and boxes. Usually implements a complex analog, digital, or mixed task. Examples include general-purpose computer system, including memory disk, and other I/O subsystems, a complete radar system, or the entire electronic and electromechanical system of an aircraft.

Box: An assembly of one or more boards to implement a complex function. Includes back-plane or bus-oriented assemblies, as well as direct-connect assemblies of boards or substrates. Examples are the CPU box of a computer and front-end of a radar system.

Board: An assembly of components on a board or substrate. Examples include single, double, and multilayer board, ceramic, polyamide, silicon and other substrates.

Component: Items that are usually packaged as an indivisible unit, to be assembled on a board or substrate. Examples include IC's, resistors, capacitors, inductors, transformers, discrete transistors, DIP switches, fuses, and encapsulated relays.

Evaluation Criteria

Another topic of concern to the study group was the selection of evaluation criteria. In the past, assertions have been made to the effect that any standard can be made to represent any information element. In fact, some extremists have advocated the use of a general purpose computer programming language such as ADA in this role just to maximize commonality. While these assertions are true in the broad sense, it is also recognized that each standard was developed to address a particular application and thus is more suited to that task. It was clear to the group that there were levels of difficulty in applying different standards based on different goals for representation of the information elements. While two standards might ultimately be equally capable of representing the same information element, one might require much further development than the other to do so or would have much greater risk of ambiguity in a computer interpretable context. The study group found the role of context to be very important.

A good example is the problem of the multi-signal data bus, a very common piece of information that would be found in several information elements. Representing the data bus seems easy, just a line on a drawing with some words associated with it.

However, representing information underlying the line (the fact that the one line translates into N entirely separated wires and connect points or N frequency multiplexed signals on the same wire) is much more difficult. In fact, it was a major issue addressed in transitioning from Version One to Two of EDIF. Since IGES had its roots in the structural world where lines translate into edges on a one-to-one basis, the ability to encode and reliably extract the implied intelligence of a data bus in a variety of environments is lacking in spite of the obvious fact that IGES is fully capable of representing the instance of a line accompanied by words that say it is a data bus.

Thus, a major evaluation criterion is the potential of the standard to unambiguously represent the information element. The study group determined that raw potential should not be the sole criterion directing selection of one standard over others. The level of implementation as measured by number and quality of implementations is also a factor that will dictate how soon the potential is to be realized. Acceptance by the user community is a similar, even more immediate gauge. Finally, the long term survival and potential support and maintenance of the standard in a given area is best measured by the extent the user groups have been formed and the level of user guidance or handbooks developed. The study group settled on the four evaluation criteria as a means of determining and describing the suitability of each standard to each information item. There were:

- o Potential coverage
- o Level of implementation
- o User interest
- o Activity by the standards groups

Scoring Criteria

For each of the four evaluation criteria, a score representing the suitability of each standard was assigned. The scores, which ranged from zero to five, were assigned to reflect the level of potential or attainment. The scoring criteria, as shown in Chart I, were chosen to reflect similar levels of attainment for similar scores. Five represents fully capable or substantially implemented, accepted and supported. Zero means the opposite. A score of three is intended to convey the marginal condition; i.e., could be made to work with significant efforts. Scores in the range of zero to two signify that the standard is so far removed from applicability that it is probably not worth the effort to apply it to the information item in question. A four should be considered closer to a five than a three. The resulting fully populated matrix following four review cycles by Industry is shown in Charts II and III.

Resolving the Matrix

An attempt was made to resolve the four scores assigned to the four evaluation criteria into a single number is shown in Chart II. Note that complex criteria were used to rank standards in each category to avoid loss of some information, the study group felt this was a necessary evaluation step.

Following this the leading standards for each particular application were selected. The aim was specifically not to try to pick a "winner", but rather the leaders based on the Delphi assessment of potential and utilization experience. Where there was a clear winner, it was selected, but where any reasonable case could be made, both leaders were chosen. In doing so a heavy weighting was placed on standards for which there is an implementation experience. The result is shown in Chart IV which uses the following intuitive coding scheme:

VHDL: V

EDIF: E

IPC: P

IGES: G

An upper case letter was usually used, unless the leader selected was the best of four weak candidates. Lower case was then used. The NA stands for "Not Applicable" as before. The NW stands for "No Winner".

Although the result confirms the general high-level perceptions of applicability of the standards (i.e., VHDL for high level behavior, IGES for low level physical data, IPC and EDIF somewhere in between), some surprises were uncovered.

1. There was far more overlap than originally anticipated. For example, VHDL is a strong winner only 24 times and EDIF 21 times, while VHDL and EDIF overlap (are coleaders) each other (and maybe others) 37 times. Furthermore, EDIF overlaps one or more other standards 78 times. This is surprising because implementation as well as the rather stringent criteria for potential was taken into account in arriving at the matrix in Chart III. Obviously, increasingly tight (and thus, arbitrary) criteria could be levied to arrive at one winner in each case, but that would be artificial. A better view is that there is a fortunate range of flexibility in the standards.

2. Certain categories of information stand out as areas of substantial overlap, because either three standards converge or the overlap extends across the full range of equipment levels. A case in point is information category (9), Functional Partitioning, EDIF, IGES, and VHDL are leaders across all four categories of equipment type. Item 40 is another example of, in this case, strong EDIF and IPC overlap.
3. Other than for item (9) as stated above, there are no overlaps between IGES and VHDL.
4. There are a number of information items for which the leading standard(s) is largely a function of the equipment level in question. They are 1, 2, 7, 12, 36, 38, 39, 41, 44, 45, 47, 48, 49. With the exception of 1, 2, and 7, there is a strong favoring of IGES and the level of the system and box, IPC at the printed circuit board and EDIF at the component. For 1, 2, and 7, VHDL replaces IGES at the system and box level, and EDIF replaces IPC at the board level.
5. Only two categories (42 and 43) of information lack, even a weak, leader of any type at this time.

The items of strong overlap are potentially of greatest use for transitioning from standard to standard. An example is item (9) again. It provides the potential for a common denominator of interface between the three standards since all are more or less equally capable of representing the information expressed by the item. It would be unfortunate to arbitrarily pick a "winner" in these cases. Not only would it suffer from the problems common to arbitrary decisions, it would also deny the advantage of a vehicle for interfacing the standards. Item 9 is also intuitively a good item of information to cross over between EDIF, IGES, and VHDL because it is useful in design functions that would most likely be supported by all three.

Other good candidates for cross over items of strong overlap are: 15 and 20 (Symbol Definition to share libraries) and 40 (Reference Designators to indicate which symbol in the library) between EDIF and IPC; 34 and 35 (Parts and Interconnectivity information from the netlist) between EDIF, IPC, and VHDL (Printed Circuit Board descriptions only); 3 and 4, 16 and 17, (Signals and Ports), 18 and 19 (Timing and Logic simulations, and 30 (Test Vectors) between EDIF and VHDL. These all confirm the intuitive sense of which items of information would be the best to cross over at since shared symbols, interconnections, signals, and port definitions are common design features of many diverse design functions.

As indicated by number 3 above, there is a substantial block of items, (14), for which the applicability of the leader standard is largely a function of equipment indenture level. In most cases, these items deal with detailed physical design and documentation and among IGES (System and Box, IPC (Board) and EDIF (Component). In a few cases, the interaction is between EDIF, IPC and VHDL generally involving textural information types. The differentiation occurs because there is a substantial body of work performed on each standard in a particular niche area but not across the board. It would be a mistake to try to pick one standard across information types for two reasons. Firstly, it would require applying a standard where there was insufficient base of knowledge for application, while discarding a potentially useful standard in the particular area. There is no reason to encourage any further work in the area since PDES should be expected to fill in the detailed design information first.

Finally, once the block of equipment level-specific standards is set aside, the remaining information items are easily dealt with. In each case, there is a strong convergence to one standard across all equipment levels. This and the results of the previous discussion are contained in Chart V.