AN APPLICATION PROTOCOL FOR CAD TO CAD TRANSFER OF ELECTRONIC INFORMATION

N93-22154

Charles C. Azu Jr.
Engineer
Naval Command Control, and Ocean Surveillance Center
Research, Development, Test, and Evaluation Division
San Diego, CA 92152

ABSTRACT

The exchange of Computer Aided Design (CAD) information between dissimilar CAD systems is a problem. This is especially true for transferring electronics CAD information such as multi-chip module (MCM), hybrid microcircuit assembly (HMA), and printed circuit board (PCB) designs. Currently, there exists several neutral data formats for transferring electronics CAD information. These include IGES, EDIF, and DXF formats. All these formats have limitations for use in exchanging electronic data. In an attempt to overcome these limitations, the Navy's MicroCIM program implemented a project to transfer hybrid microcircuit design information between dissimilar CAD systems. The IGES (Initial Graphics Exchange Specification) format is used since it is well established within the CAD industry. The goal of the project is to have a complete transfer of microelectronic CAD information, using IGES, without any data loss. An Application Protocol (AP) is being developed to specify how hybrid microcircuit CAD information will be represented by IGES entity constructs. The AP defines which IGES data items are appropriate for describing HMA geometry, connectivity, and processing as well as HMA material characteristics.

INTRODUCTION

There exists today within the Microelectronics industry a variety of established ECAD (Electronic Computer Aided Design) systems. These systems all have their own proprietary formats for representing ECAD information. To communicate with another ECAD system, design information must be converted to a neutral format. The data is then transferred to the other system which in turn translates the information from the neutral format to its own proprietary format, figure 1. This process is executed everyday within an engineering company, a company's engineering department, between a design organization and a manufacturing organization, and between a customer and a fabricator. Unfortunately, this process is not robust, numerous errors occur during the translation portion of the processes. Errors are often in the category of missing, incomplete, or extraneous information, see Table 1. As a result, the design file received into the receiving CAD system must often be edited or updated. The update process consist of returning the file into a robust state. The goal is to have the transferred file be equal (functionally and informationally) to the original file. This can often be a very tedious, expensive and time consuming process for larger CAD files depending upon the extent of repair to be done.

Table 1
Typical Transfer Problems Using IGES

1. Loss of information on different layers.
2. Loss of dimensional intelligence.
3. Alteration of text and line fonts.
4. Loss of non-geographical information.
5. Loss of connectivity information
6. Loss of components configuration info.
7. Loss of routing information.

The U.S. Navy must often bear the final cost of the problems its manufacturers/suppliers have in transferring CAD information. For this reason, the U.S. Navy, through its MicroCIM project office at NCCOSC RDT & E Division, decided to investigate this problem. The MicroCIM program was charged with working with the military hybrid microcircuit assembly (HMA) industry to implement/develop new technology. One such technology is the errorless transfer of hybrid microcircuit ECAD information between dissimilar CAD systems. A method for achieving this exchange using an established neutral format has been developed. The neutral format chosen is IGES (Initial Graphic Exchange Specification) for reasons which will be discussed later. The method was put in the form of an Application Protocol (AP), so called because the method is a protocol for applying IGES in the successful transfer of CAD information. The AP is intended to be used by manufacturers of ECAD systems and software when building their next generation systems[1]. The AP details to the manufacturer how to represent hybrid design constructs in the IGES format. It standardizes the IGES representation of a hybrid microcircuit assembly CAD file. This standardized method of representing HMA design file entities will allow the errorless transfer of HMA ECAD files. Referring to Table 1 it is seen that the majority of errors are rooted in the lack of standardization in the representation of HMA ECAD file constructs when using neutral formats.

The remainder of this paper will present some background information and then explain the AP, how it was developed, and how it can be used.

BACKGROUND

HMAs

The focus of the AP is on the electronic information necessary to fully represent hybrid microcircuit assemblies. Generally, HMAs are non-monolithic integrated circuits, made up of two or more different technologies, and may consist of semiconductor chips and capacitors attached to a ceramic substrate with printed resistors and interconnections[1]. This is the basic definition which is used in the AP. This definition is meant to be inclusive of Multi-chip Modules, thick film HMAs, thin film HMAs, and low temperature co-fired ceramic (LTCC) HMAs.

IGES

As stated earlier, IGES is a neutral format specification for describing electronic information such as CAD files. IGES is an acronym for Initial Graphics Exchange Specification. It is a specification which had it first release in the early 80s. The purpose of the standard is to provide a means by which to represent and communicate product definition data in a digital format. IGES has grown to be inclusive of almost all types of production definition data, especially CAD/CAM information. This data can be in the form of engineering drawings, documentation, 2D & 3D designs, and solid models.

In the ECAD world there are several existing neutral file specifications for various areas of electronic information[1]. Two such specifications used in the analysis and hardware areas respectively are EDIF (Electronic Design Interchange Format) and VHDL (VHSIC Hardware Design Language). IGES was chosen over EDIF and VHDL for implementation in the AP for several reasons; 1)It is a standard format available in the majority of CAD systems, ECAD, drafting, or other, 2)It is widely used in industries for transferring design file between machines, 3)IGES is a very flexible language with multiple ways to define entities, and 4)It can readily represent information within the scope of the AP.

To put ECAD information into an IGES format a translator is required. The translator operates by mapping information contained in a proprietary ECAD database into the IGES format[2]. The mapping can be in either binary or ASCII where the ASCII generates a readable IGES file. The IGES file structure contains five distinct sections. The Start Section contains 72 columns of human readable comments which are not processed by the program. The second section is the Global Section which is a free format area specifying the information needed by the pre-processor and information needed by post processor to manage a file. The Directory Entry (DE) section and Parameter Data (PD) sections are usually the largest sections in the IGES file. The DE section contains the descriptive attribute data for each entity used in the original file. The Parameter Data (PD) section follows, and it contains entity definition and actual parameters for each of the entities in the DE section. The last section in an IGES file is the terminate section which contains a single record that has the count of the records in each previous section. The IGES version 5.0 manual has more detailed information about this as well as detailed information on current entities supported by IGES.

APPLICATION PROTOCOL (AP)

An AP, in its most generic form, is a protocol for applying some type of information or technology[1]. In our case, we describe how to apply the IGES neutral data format for representing HMA ECAD information. This AP develops a standard representation for HMAs so as to minimize cost, maximize efficiency in the design process, and provide a means for handling the increasing complexity of HMAs[2]. The procedure used in this AP (and similar APs) involves identifying the information required to fully describe an application area (HMAs) and representing that information in the form of a conceptual model. This model is then used to select the appropriate IGES constructs for representing the information.

Our AP is centered around three models: AAM, AIM, ARM. The AAM, Application Activity Model, presents the generic activities needed to design and fabricate HMAs. The ARM, Application Reference Model, represents the information needed to support the AAM activities or the information generated from those activities. The physical location of the information contained in the ARM can be found in the AAM. The AIM, Application Interpreted Model, specifies the constructs of a standard, such as IGES, for use in transferring some to all the information described in the ARM. Together, these models define the appropriateness of IGES constructs for describing the geometry of the various parts of a hybrid microcircuit, its inner connectivity, and processing and material characteristics.

The scope of the AP is to support design, fabrication, and final assembly information for an HMA[1]. The AP does not support all information required for electrical testing of HMAs. The information contained in the ARM limits the AP scope to layered electrical products information which is currently contained in ECAD systems. Other sections of the AP describe a) definition of the terms used in the AAM, ARM, and AIM, b) implementation and conformance test guide lines, and c) AP relationship to Units of Functionality.

Modeling Methodology

The AAM and ARM were developed using IDEF methodology in order to represent the information being conveyed to the reader. IDEF was developed through the Air Force's Integrated Computer Aided Manufacturing Definition Program. The AAM is built using IDEF0 which is an activity modeling method. The ARM is built using IDEF1X modeling method which is an information modeling method. The AIM modeling method was created specifically for this AP and is based upon various modeling techniques. The component parts of IDEF0 and IDEF1X models are shown in figures 2a and 2b respectively. IDEF0 models are composed of ICOMs, arrows, and boxes. Each activity or function is represented by a box which takes in any combination of Inputs, Controls, Mechanisms, and Outputs through arrows. Each activity can be decomposed into further activities. An entire IDEF0 model is a hierarchal representation of a process composed of activities and functions. In each sub-level are the activities making up an upper level function. Arrows pass information, data, and product between levels as necessary.

In the IDEF1X method a piece of information is represented as an entity, a relationship, an attribute to an entity, or some type of assertion[3]. The IDEF1X structure is top-down where top entities (objects) are composed of bottom entities. Entities are represented by rectangles as shown in figure 2b. The syntax for describing relationships between entities is also shown. Entities which are beyond the scope of the model have a dashed rectangular outline. These entities are in the model to complete an open relationship or clarify a relationship.

Application Activity Model

An organization intending to implement this AP would look at the AAM to see if their information is within scope and within the context needed for planning the necessary automation changes[1]. The viewpoint of the model is from that of designers and manufacturers of hybrid microcircuit assemblies. The model is meant to be generic, i.e. it is not specific to a particular manufacturers operations. Unfortunately, the generality of the model leaves many open issues. For example, the model as it stands, applies to MCMs, thick film hybrids, thin film hybrids, etc. The fundamental differences between these technologies is not represented in the AAM. The other AP models, especially the ARM has facilities for differentiating between various hybrid technology types. The AAM shows where the information in the ARM is used.

Figure 3a and 3b show model diagrams page A-0 and A0. These are the first and second level diagrams which present the major activities necessary to produce an HMA. The A-0 shows the basic inputs, controls, and mechanisms required to produce the various outputs from a manufacture hybrid devices activity. The inputs are physical things such as Supplies & Materials and Industry Technology as well as information from Customer Requirements. Controls on the activities are documentation like military, industry, and company standards. Controls are usually those things which are not changed in any form by the activity they enter into. The outputs are not only Shipped Hybrids but also Scrap generated in production process, Prototypes built before production and required to be delivered to the customer, and response to the customers request for price quotes.

The A-0 activity is decomposed into four activities which are the core of an HMA manufacturer's operations. The first activity is the Management Of Customer Orders which uses the Customer Requirements from diagram A-0 to generate a Quote Response. The second activity is Performs Engineering which uses Industry Technology and Supplies & Materials to produce Prototypes in accordance with Standards and Customer Requirements. Data generated from prototype fabrication as well as Scrap Information is used to produce various engineering documents. This activity also produces drawings, schematics, layouts, released design, etc. The third activity Assure Product Quality, takes in drawings and other documents from Perform Engineering and Customer Requirements information to produce a quality plan. Production data from Produce Hybrids is analyzed using statistical methods and results are fed into Produce Hybrids and Perform Engineering. The final activity is the actual production of hybrids. Supplies and Materials are taken in and the hybrids along with documentation are produced according to the released design drawings and in keeping with standards. Scrap and Production data are also generated. The remainder of the AAM in the AP is composed of decompositions of A0 activities to various levels.

The AAM was arrived at by consulting previous AAM models built under Navy contract by various HMA manufacturers. Active participants in the building of the AAM were the Navy and two major military HMA manufacturers. Agreement of the AAM was received from the US Navy's MicroCIM program Ad-Hoc Advisory Panel, a group composed of government, industry, and academia interested in HMAs.

Application Reference Model

The ARM describes the hybrid product information. The model presents an enterprise-view of information of the hybrid as a product[1]. The ARM is a reference point for implementation of the AIM. It shows how various types of product information relate to one another and how a particular piece of information fits into the concept of an HMA. The documented information as presented in the ARM supports the activities of the AAM. It also provides the baseline for the development of the AIM.

Figure 4 presents the top most diagram of the ARM for HMAs. This page in the model can be read as follows (refer to figure 2b):

The highest level entity in the model is the Hybrid CAD Presentation. This entity has one key attribute. The key attribute uniquely identifies every instance of the entity. The other attributes are characteristics of a Hybrid CAD Presentation such as; layers of an HMA are built on separate CAD Layers. The connection between the entities Hybrid CAD Presentation and Hybrid Version can be read: Hybrid CAD Presentation is a CAD design of zero, one, or more Hybrid Versions. A Hybrid Version is uniquely identified by an attribute called Hybrid ID. The Hybrid Version was designed using zero, one, or many Design Rules and a Design Rule is involved during the design of zero, one, or many Hybrid Versions. The dotted line between these two entities indicates that they are not dependant upon one another. A Hybrid Version is zero or one Assembly Occurrence and contains zero, one, or many Assembly Occurrences. An Assembly Occurrence is uniquely identified by an Assembly Occurrence ID, it also has an attribute representing various types. An Assemble Occurrence is dependant upon its relationship with Hybrid Version. An Assembly Occurrence involves zero, one, or more Process Steps. A Process Step instance is uniquely identified by a Process Step No. and has Station, Process Description, and Log Requirements as attributes. The Process Step is dependant upon the relationship it has with Assembly Occurrence. The remaining entity to entity relationships for Process Step can be read as follows. A Process Step is produced using zero, one, or many Tools. A Process Step is used in one or more Assembly Consumables. A Process Step utilizes zero, one, or more Patterns. A Process Step is followed by zero, one, or many Process Steps. A Process Step has attached zero, one, or many Hybrid Assembly Components. A Process Step achieves an assembly using zero, one, or more Process Operations. The entities Hybrid Assembly Component, Pattern, and Process Step are dependant upon their relationship with Process Step.

The remainder of the diagram can be read as above. As stated previously, the ARM is the baseline from which the AIM is developed. The AIM shows how the information contained in the ARM is to be expressed by subsets of IGES entities.

Application Interpreted Model

The scope of the AIM is limited to LEP (layered electrical products) information which most ECAD systems contain. HMAs are a subset of the wide range of LEP types (ie. MCMs, Printed Circuit Boards, etc.). The IGES entities selected for implementation in the AIM were selected so as to minimize the total file size. The selected IGES entities have restrictions placed upon their use either through the Global, Direct Entry, or Parameter Data sections. This is done so as to restrict the number of different ways a particular entity is used within an HMA CAD file. Other IGES entities can be used within a file but they should not be used for purposes stated in the AIM[1]. Table 2 is a subset of the selected IGES entities. The Type and Form headings are IGES numbers set by the standard itself. They are listed so that an implementer of the AIM can refer to the standard for specific information on the entity. The Status field describes the entities current status. Standard means that the entity exists and does not need to be modified to be used in the AIM. Gray means that the entity is located in the Gray pages of the current IGES version document. RFC (Request For Change) means that the entity is either new or needs to be modified and an RFC exists and is in the ballot process. New means that the entity does not exist and an RFC needs to submitted. Modified means that an existing entity needs to modified to be used in the AIM. The AIM individual object definition entity models contain usage restrictions appropriate to the application. These restrictions are described in detail in the AP with the object models. Figures 5a and 5b are two sample object models from the AP.

Table 2
A Sampling of IGES Entities used in AIM

Status	Type	Form	Description
Standard	100	0	Circular Arc
Standard	102	0	Composite Curve
Standard	106	63	Copious Data
Standard	124	0-1	Transformation Matrix
Modified	125	All	Predefined Planar Shape
Standard	312	1	Text Display Template
Modified	402	18	Flow Associativity
New	402	5xxx	Net Connectivity Assoc.
Grey	406	27	Property- Generic Data
New	406	5xxx	Property- Region Fill
RFC	406	5xxx	Property- Definition Extent

The graphic notation developed for the AIM object models is meant to ease the development of unambiguous translators conforming to the AIM. The notation is composed of several principle elements; Object Definition Block, Object Instance Block, Object Value Block, and Cardinality code. The latter three elements are related and derived from the Object Definition Block which designates an IGES entity type, form, directory entry value, parameter data values, and relationships to other IGES entities. Definitions for the other graphic notations in the AIM can be found in the AP.

For readability, the diagrams in the AIM are divided into six subsections. Section one contains the AIM interface object models. These represent a perspective of an LEP in which one can exchange data. The interface object models describe the set of independent entities in a IGES file which are part of an LEP. Currently, there exist three interface objects in the AIM; Part Library, Physical Layout, and Technical Illustration.

Section 2 defines objects specific to LEPs. Display Geometry is section 3 and defines objects that are common to CAD/CAM systems that use 2D geometry. A miscellaneous section contains subordinate objects which are used in combination to form an LEP specific object. There is also a section that defines objects referenced from the Direct Entry sections of other objects. In the final section are objects that represent pre-defined Direct Entry values. Figure 5a is an example of a model from the Interface Section, figure 5b comes form the Display Geometry section.

INDUSTRY IMPLEMENTATION

As stated in the introduction it will be up to private industry to implement the AP. Specifically it is expected that ECAD system manufacturers such as Mentor Graphics, Intergraph, Cadence, Harris, and Computer Vision will implement the AIM in their next generation of translators for ECAD systems. To successfully conform to the AP, these vendors must design their ECAD system translators to be capable of reading and writing CAD/CAM files that conform to the AIM. The designers and manufacturers of HMAs can then use these systems without having to worry about the cost and loss in efficiency currently inherent when transferring CAD files between dissimilar ECAD systems and sometimes between the same type of system. The U.S. Navy ,by building this AP, has served as a catalyst for a solution to the file transfer problem. It is now up to the HMA industry to demand the implementation of this solution from ECAD system manufacturers.

FUTURE DEVELOPMENT

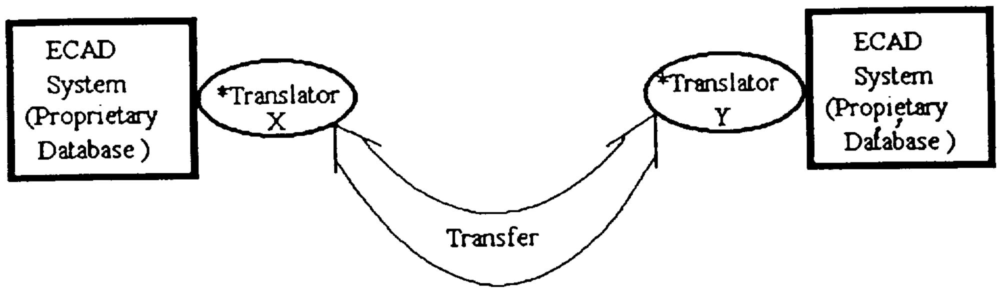
Conformance requirements and testing applications have not yet been fully developed for the AP. It is hoped that industry will take on these tasks as part of a continuing effort to improve this Application Protocol for hybrid microcircuit assemblies.

REFERENCES

1. Parks, C., McCollough R., et al., "IGES Hybrid Microcircuit Application Protocol (AP) version 1.0", NIST TN 1295 Draft, July 1, 1992

2. Parks, C., McCollough R., et al., "IGES Hybrid Microcircuit Application Protocol (AP) version 0.1", NIST TN 1295 Draft, April 1, 1991, NOT AVAILABLE

3. Yuhwei, Yang "IDEF1X Style Guide For PDES Users", Draft, August 31, 1989



* Process where majority of data loss occurs

Figure 1: Electronic CAD file transfer process

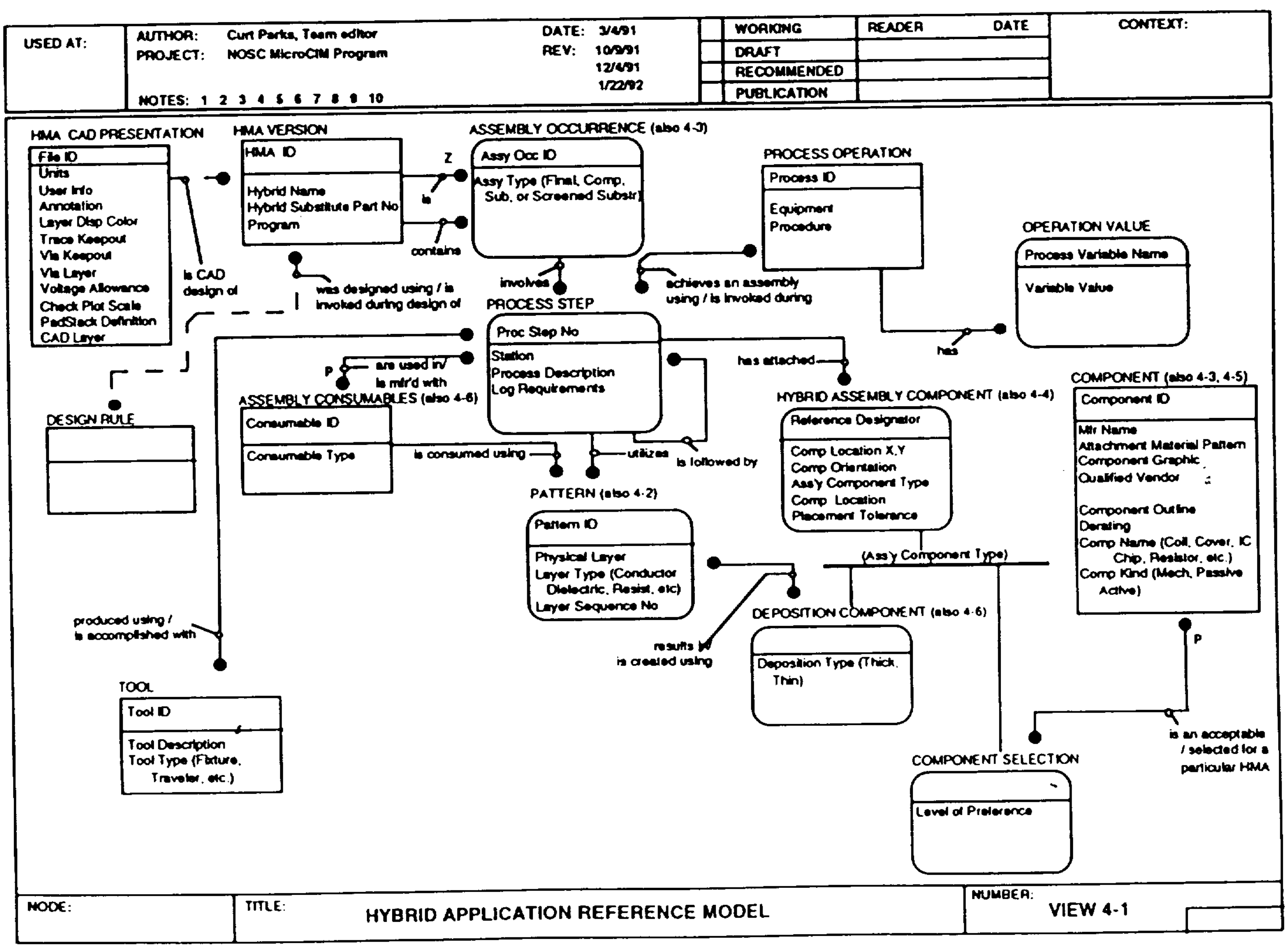


Figure 4: ARM diagram, top of model

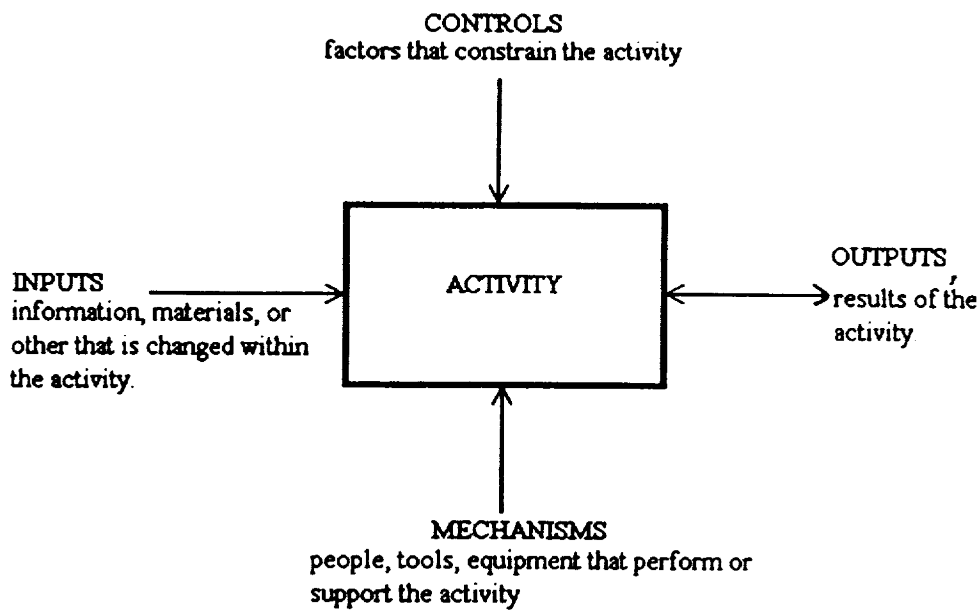


Figure 2a: IDEF0 Methodology Diagram

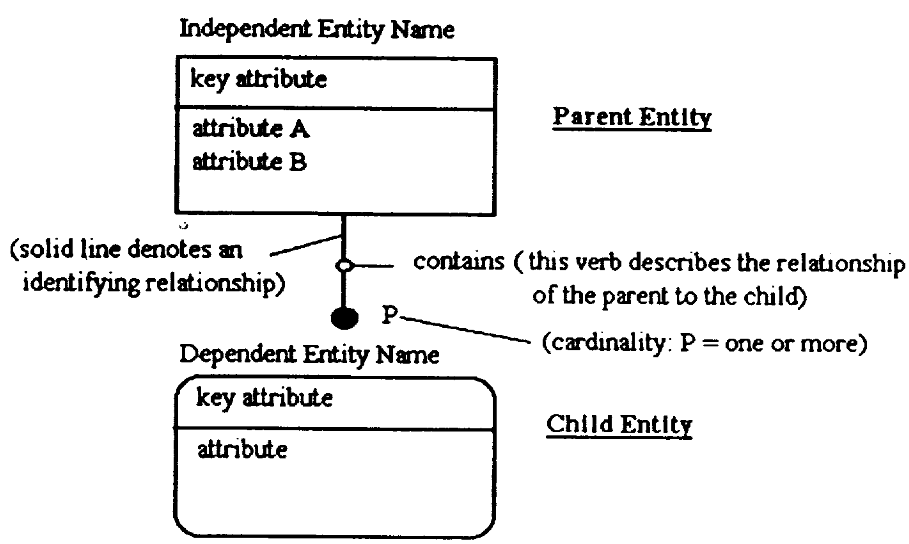


Figure 2b: IDEF1X Methodology Diagram

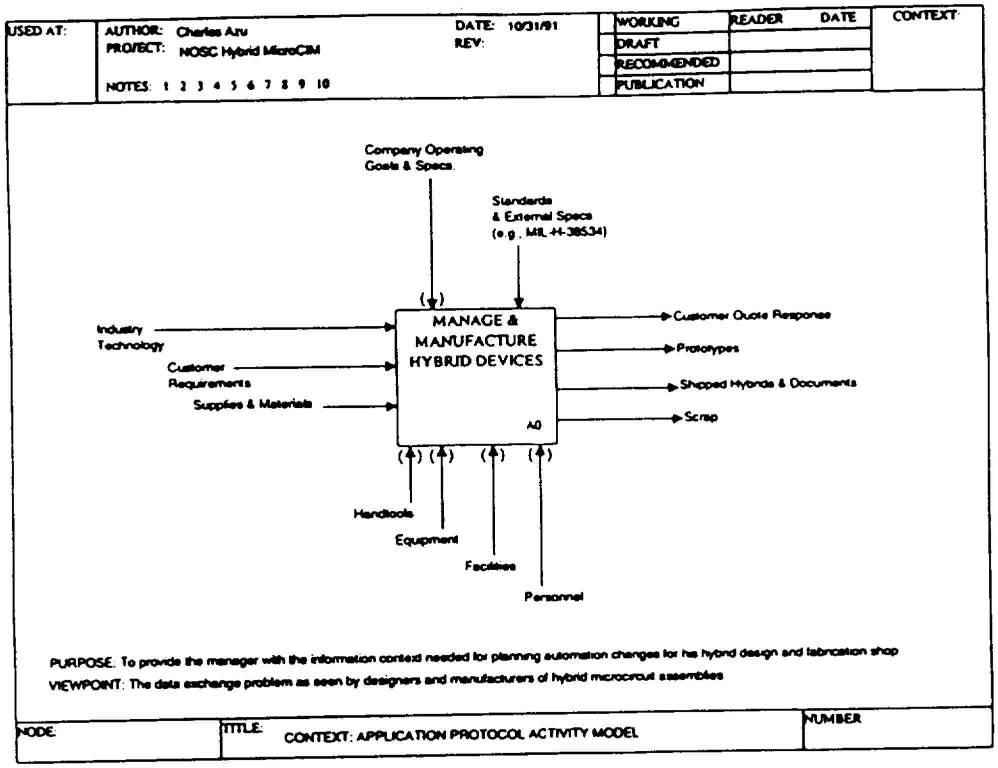


Figure 3a: AAM diagram A-0, top of model

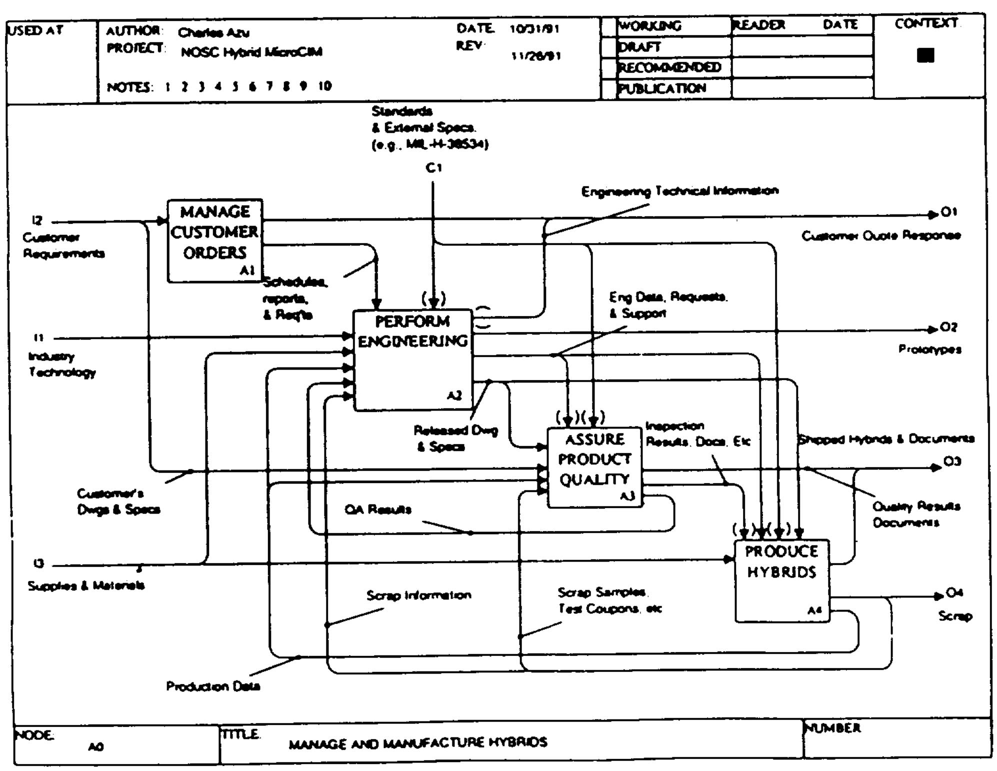


Figure 3b: AAM diagram A0

NIST TN 1295 DRAFT

LEP-Specific Object Models

5.3.2.2 Component Placement Associativity

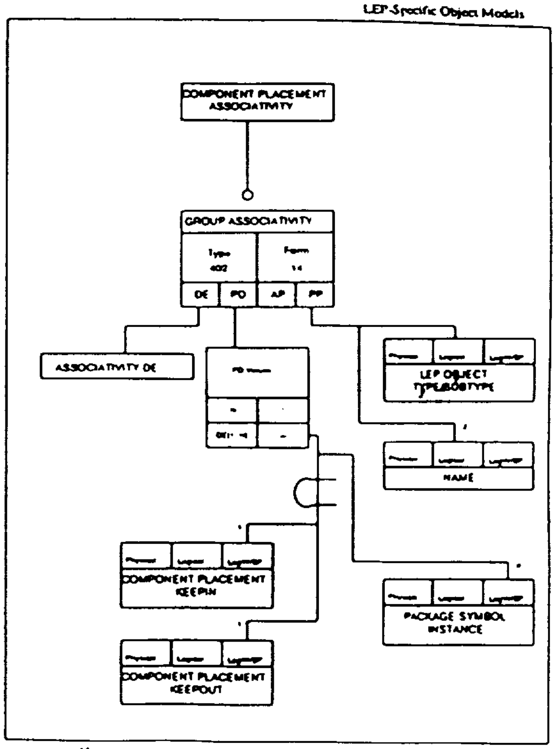
Description:

The Component Placement Associativity object associates a group of Package Symbol Instances for the explicit purpose of being treated as a group with related placement restrictions. The Region Restriction property works in conjunction with the Component Placement Associativity.

Requirements/Restrictions:

4. The LEP Object Type/Sub-Type property, which is referenced from the Group Associativity object, must specify (*otype*=Component_Placement_Associativity, *stype*=*).
5. The first object referenced by the Component Placement Associativity must be either a Component Placement Keepin or a Component Placement Keepout, followed by the Package Symbol Instances which are affected by the Component Placement Associativity.
6. All objects that are subordinate to the Group Associativity, are physically dependent on the same parent as the Group Associativity.

Translation Usage Notes:
General:
Output:
Input:



5 Application Interpreted Model page 45 July 1, 1992

Figure 5a: Example object model specific to Layered Electrical Products (LEP)

NIST TN 1295 DRAFT

Display Geometry Object Models

5.3.3.12 Line

Description:

The Line object represents a line segment.

Requirements/Restrictions:

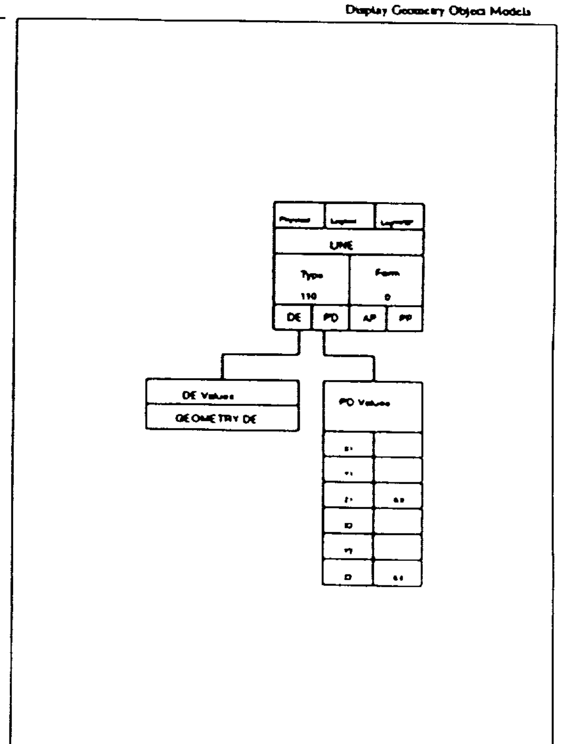
1. The start and end point of the IGES Line entity must not be coincident (with respect to the Global Section Minimum User-Intended Resolution).

Translation Usage Notes:

General:

Output:

Input:



5 Application Interpreted Model page 115 July 1, 1992

Figure 5b: Example object model for Display Geometry