NBSIR 81-2297

A Technical Briefing on the Initial Graphics Exchange Specification (IGES)

Automated Product Technology Division
Center for Manufacturing Engineering
National Engineering Laboratory
U.S. Department of Commerce
National Bureau of Standards
Washington, DC 20234

July 1981

U.S. DEPARTMENT OF COMMERCE

NATIONAL BUREAU OF STANDARDS

INITIAL GRAPHICS EXCHANGE SPECIFICATION

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A TECHNICAL BRIEFING ON THE INITIAL GRAPHICS EXCHANGE SPECIFICATION (IGES)

J. C. Kelly, Ph.D., Sandia Labs, Co-Chairman
Robert Wolf, Xerox Corp., Co-Chairman
Philip Kennicott, Ph.d., General Electric
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U.S. DEPARTMENT OF COMMERCE, Malcolm Baldrige, *Secretary*
NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Director*

A

TECHNICAL BRIEFING

on

THE INITIAL GRAPHICS EXCHANGE SPECIFICATION (IGES)

Introduction

This technical briefing is composed of two parts. Part 1 consists of a set of slides, and some associated text. The slides and the text are organized in tandem. The intent of the text is to furnish associated information (for each slide) as opposed to furnishing specific text that is to be read verbatim. The information in this section is "soft", that is, not overly technnical. In this Part the suggested slides for each section follow the first page of the text of the section.

Part 2 consists of the more technical material. Here the intent is to furnish text that can be read verbatim for each slide. In this Part the suggested text follows each slide.

There is minimal overlap between the two sections.

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Part 1

I. Introduction To IGES

1.1 Overview

The Initial Graphics Exchange Specification (IGES) is a communication file structure for data produced on and used by Computer-aided Design and Computer-aided Manufacturing (CAD/CAM) systems in widespread use today. It has been designed to serve as a receptacle for the data generated by today's commercially available interactive graphics design-drafting systems. It is intended that this structure provide a common basis for the automatic interchange of data between these systems, for the transfer of data to and from external application programs, and for the archiving of the data.

IGES represents an initial, organized attempt to address and resolve the interface problems that arise as a result of the introduction of the computer into the design and manufacturing environment. The interface problems may have their origins in either hardware or software, and, roughly speaking, can be characterized by the fact that the data as produced by one system (or subsystem) is not able to be used by another system (or subsystem). It is the common experience of many users that the resolution of the interface problems associated with the creating, transmitting, storing, and retrieving of computer-generated data is necessary in order that the full potential of the computer for increased productivity be realized.

Several large companies have expended significant resources in individual attempts to resolve their own internal interface problems. Thus, translators have been written so that data can be communicated from system to system. Subsequently, some companies felt the need to devise standard data structures and formats in order to curtail the resulting proliferation of translators. It is also the common experience of these companies that the translators were expensive to develop, expensive to maintain, and achieved only limited efficiency.

These individual attempts at resolving interface problems have emphasized the lack of any appropriate standardized specification for a communication format for data exchange, and they have also emphasized the need for some such specification. Furthermore, with the increasing variety of vendors, and the present acquisition rate of CAD/CAM systems by both government and private organizations, the need will continue to exist. IGES is an attempt to address this need. Thus IGES represents an organized effort on a national level to introduce a set of specifications where none presently exists.

Initial
Graphics
Exchange
Specification
— IGES —

IGES
A Project
of the
Air Force
ICAM Program

Funding Provided By Air Force, Army, Navy, and NASA. Coordinated Through ICAM Office

Contract To National Bureau of Standards For Direction and Coordination

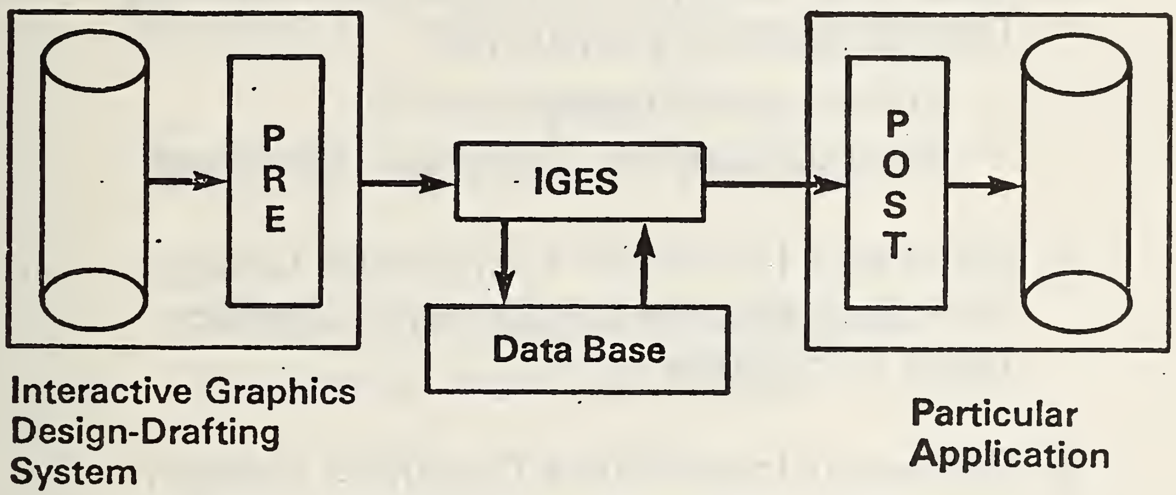
IGES Chairman

Bradford Smith
of
National Bureau of Standards

Introduction
to
IGES

IGES
Is A
Communication
File
Structure

Functional Implementation of IGES



The Interface Problem:

Data as produced by one system is not able to be used by another

Interface Areas:

1. Between Different Interactive Graphics Design-Drafting Systems
   - Different Suppliers
   - Same Supplier, Different Versions
2. Between Interactive Graphics Design-Drafting Systems + External Applications Programs
3. Between Interactive Graphics Design-Drafting Systems and Archival Storage

The IGES Goal:

Resolve The Interface Problems To Provide

1. Increased Productivity
2. Increased Flexibility

Heretofore —
Isolated, Individual Company Attempts To Resolve Interface Problems

1. Write processors (translators)
2. Develop local standards

Shortfalls Of Isolated Attempts — Company Viewpoint

1. Expensive to Develop
2. Expensive to Maintain
3. Limited Efficiency

Shortfalls Of Isolated Attempts

1. Duplication Of Effort
2. Isolation Still Exists — Now On Company Level
3. Lack Of Forum For Convergence Of Ideas

IGES Provides

1. An Initial Framework Where None Presently Exists
2. An Organized Attempt On A National Level
3. A Forum For Convergence Of Ideas

IGES Accomplishments

1. Produced A Set of Specifications
2. Embarked On A Schedule For Testing, Benchmarking, Implementation
3. Initiated Efforts Toward Becoming An American National Standard
4. Filled Over 1000 Requests For The Set Of Specifications

IGES

Is Rapidly Becoming
Accepted As A
DeFacto Standard

Basis Of User Interest In IGES

1. Resolve interface problems associated with creating, transmitting, using, and storing of computer-generated product definition data
2. Provide insulation from supplier revisions

Indications Of User Commitment To IGES

1. Number and variety of organizations on IGES committees
2. Many written declarations of support for development and success of IGES
3. Users are beginning to specify IGES compliance in procurement specifications

Companies Having a Representative
on
At Least One IGES Committee

Advanced Technology, Inc.	IBM
Applicon	International Harvester
Auto-trol	John Deere
Aydin Controls	Manufacturing Data Systems, Inc.
Bechtel	Martin Marietta
Bendix	McDonnell Douglas Automation Co.
Boeing	NASA
CALMA	National Bureau of Standards
CAM-I	National Computer Systems
Combustion Engineering, Inc.	Ocean Data Systems
Computervision	Racal Redac
Control Data	Rockwell International
DMT Corporation	Sandia Labs
DuPont	Society of Manufacturing Engineers
Evans and Sutherland	Structural Dynamics Research Corp.
Ford	Time Engineering
General Dynamics	Union Carbide
General Electric	U.S. Air Force
General Motors	U.S. Army
Gerber	U.S. Navy
Harry Diamond Labs	Vought
Holquin and Assoc.	Westinghouse
Hughes	Xerox

Basis of Supplier Interest In IGES

1. IGES provides a recognized, common receptacle for getting data out of their own system
2. It is good business—customers want the IGES type capability

Indications Of Supplier Commitment To IGES

1. Written and oral declarations of commitment at the managerial level from several suppliers
2. Detailed technical design meetings scheduled between IGES and participating suppliers

An IGES Self-Assessment

"... IGES is not perfect, it will not solve all the information needs of CAD/CAM systems, and it will need further extension beyond its current definition. However, IGES goes a long way toward alleviating the current data exchange problems, and is a significant response to today's needs."

The IGES effort has thus far produced a published set of specifications within the time frame which was originally laid down, and it has embarked on an implementation, testing, and benchmarking schedule. [See Reference 8] It has attracted national attention. [See Reference 10] The IGES mailing list now contains over one thousand names. There is currently underway an effort having to do with IGES becoming an American National Standard. In actual fact, it is rapidly becoming a de facto national standard!

It is important that both users and suppliers of CAD/CAM systems have a legitimate basis of interest in the development and ultimate success of IGES. It is also important that both users and suppliers make commitments to the development of IGES. At the present time, there is evidence that such commitments have been made.

It is also important to note that IGES is not being billed by itself or by anyone else as the answer to all database exchange problems that currently exist. Hopefully, IGES will succeed on the basis of its demonstrated merits, or fail for lack of same. The following self-assessment statement concludes the Introduction of the IGES report: "In summary, IGES is not perfect, it will not solve all the information needs of CAD/CAM systems, and it will need further extension beyond its current definition. However, IGES goes a long way toward alleviating the current data exchange problems, and is a significant response to today's needs."

1.2 A typical scenario of development of user need for IGES

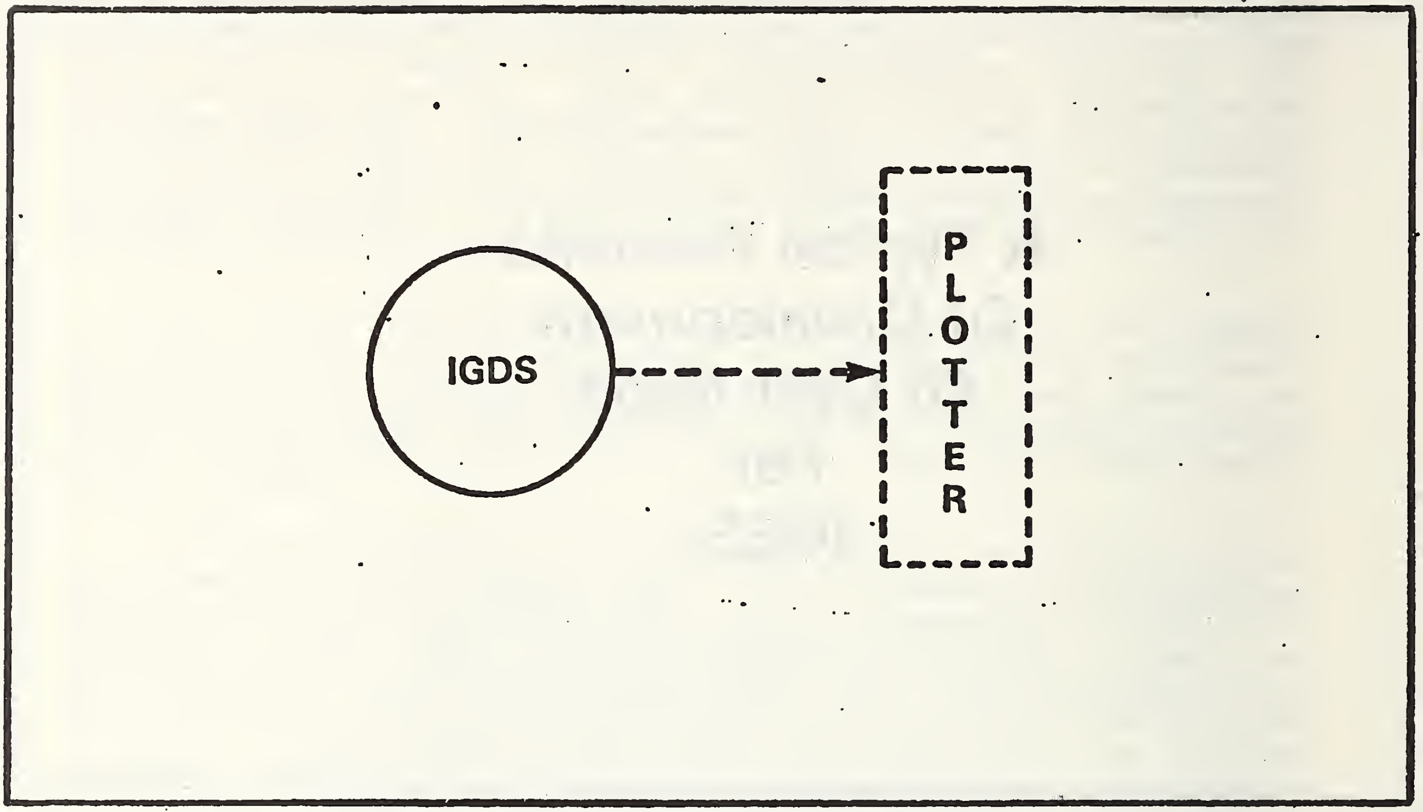
Historically, the interface problems have become apparent - and acute - in parallel with the introduction of commercially available interactive graphics design-drafting systems. Interface problems associated with these systems have continued unabated to the present day, and these systems constitute the focal point of the IGES effort.

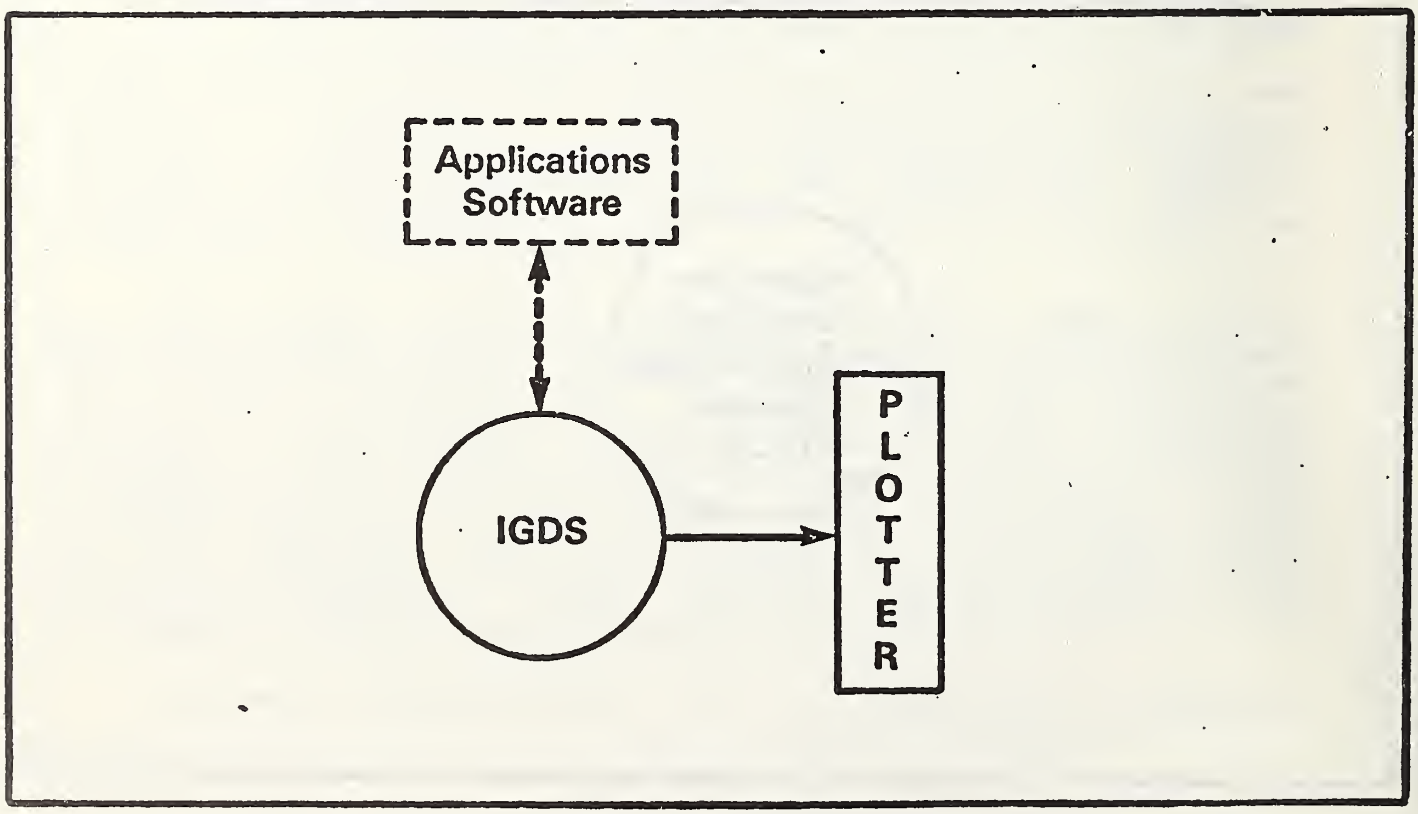
For example, the first acquisition for many companies was the procurement of an interactive graphics drafting system. This self-contained system brought about significant improvement over manual drafting. The next acquisition was usually the addition of a high speed plotter, possibly from a different supplier. This acquisition brought about further improvements in productivity, but it also brought about a new concern - the interface compatibility of the two systems. Further procurement of new generation drafting systems, again possibly from different suppliers, gave extended capability but also additional compatibility problems.

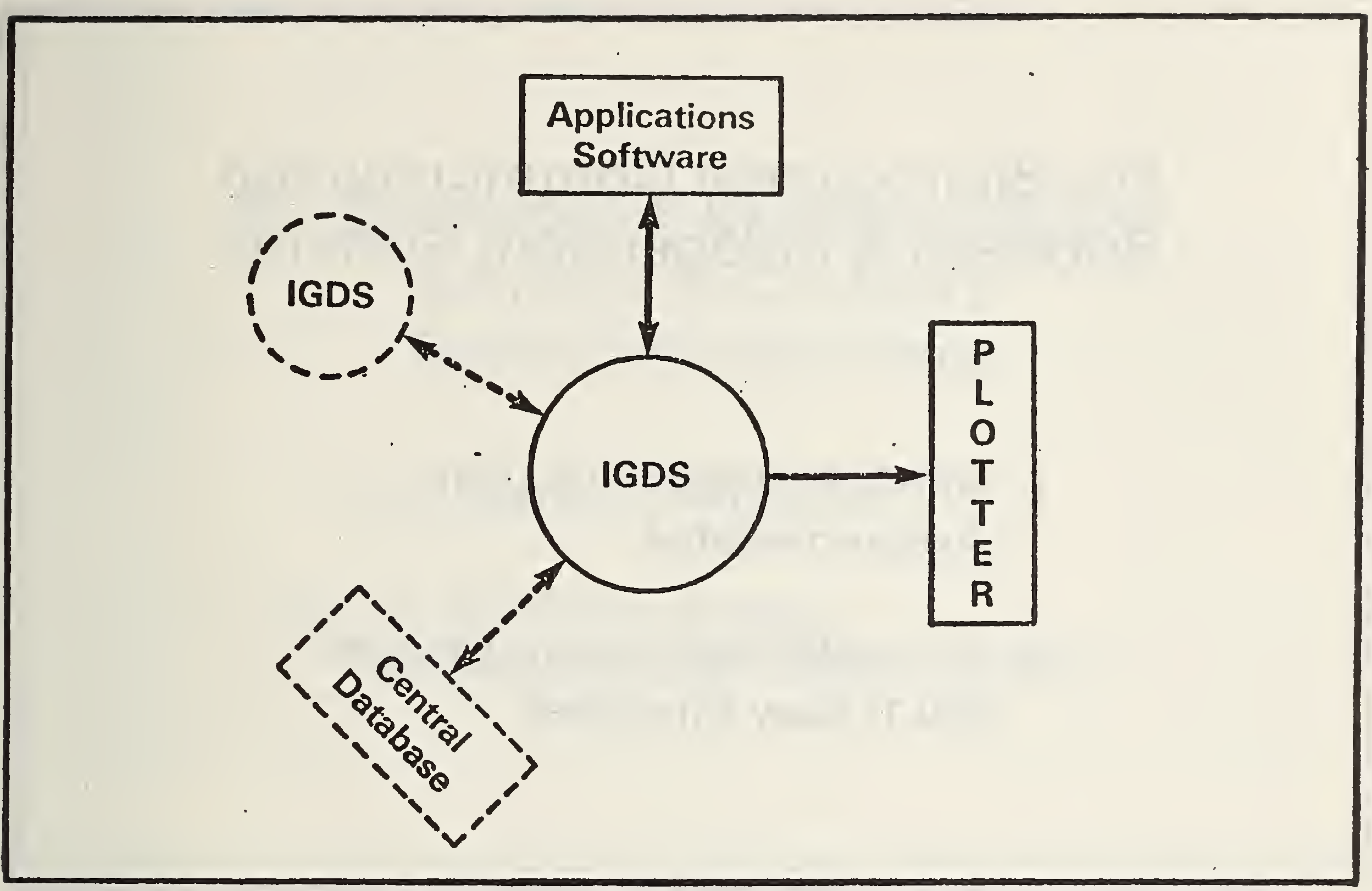
Increased sophistication of the commercially available

A Typical Scenario
Of Development
Of User Need
For
IGES

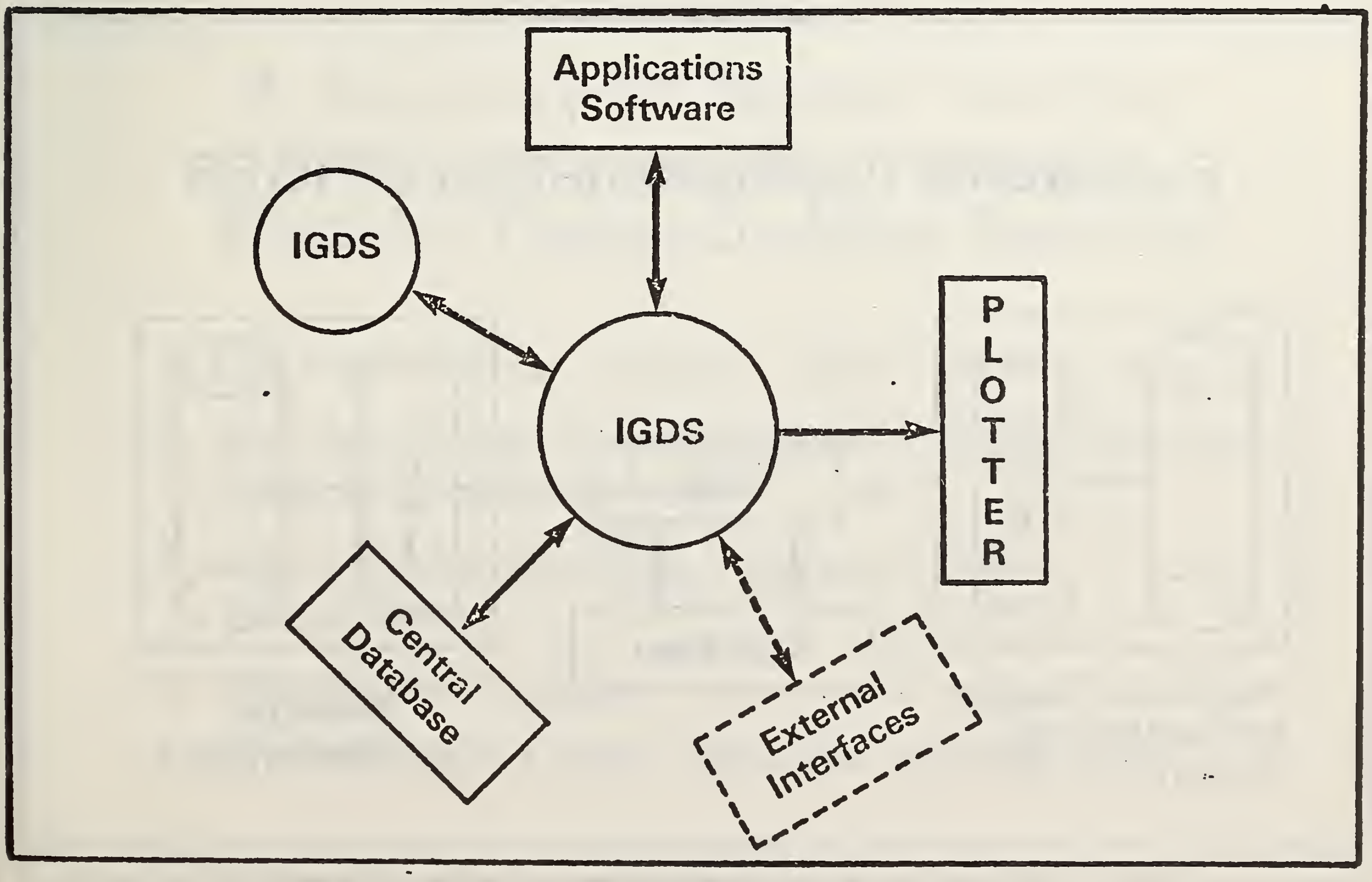
Interactive
Graphics
Design-Drafting
System
(IGDS)


IGDS
PLOTTER


Applications Software
IGDS
PLOTTER



Applications Software
IGDS
IGDS
PLOTTER
Central Database



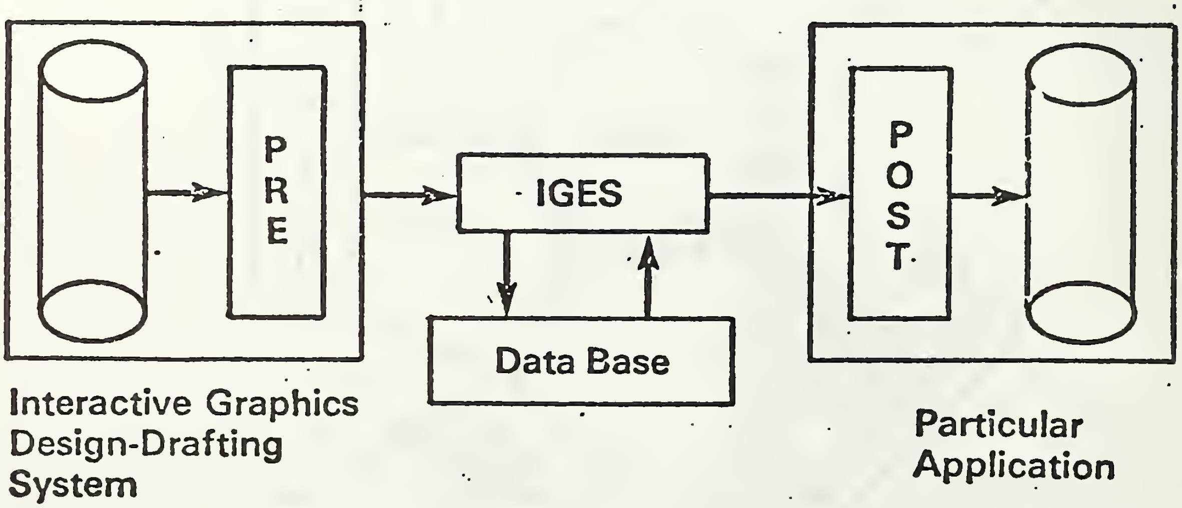
Applications Software
IGDS
IGDS
PLOTTER
Central Database
External Interfaces

For Bidirectional Communication Between N Independent Systems

1. N(N-1) Interfaces Must Be Accommodated

2. An Additional System Creates 2(N-1) New Interfaces

Functional Implementation of IGES



For Bidirectional Communication Between N Centrally Connected Systems

1. 2N Interfaces Will Suffice
2. An Additional System Necessitates Only 2 New Interfaces

A Summary Of Typical Interface Problems Involving Interactive Graphics Design-Drafting Systems

1. Hardcopy-postprocessing—COM, plotters, etc.
2. Mainframe-based applications—Mass Properties, other Involved Analyses
3. Other Design-Drafting Systems—Cross-Translation
4. Mainframe Storage
5. Manufacturing data—NC data, routing data

systems brought about an evolution of their role in the design process, and with that came more interface problems: interfacing internal applications-specific software to these systems, now aptly described as general purpose design-drafting systems.

Growth in the size of the company user base for these systems resulted in further interface problems, as other divisions made their procurements. Increased user sophistication resulted in the formation of large central databases, and this led to still another interface area - the interface between a commercial system and the database. Reflected here was a basic change in the user view of these systems. Instead of being viewed strictly as a self-contained unit, they could be given the added role of an interactive communication tool between a user and a database.

Progressions of events such as these led to the local development of system-to-system translators and standard data formats for internal communication. However, while these efforts might possibly have been locally beneficial, they provided no help in dealing with either actual or potential external interfaces. What was needed, and is needed, is a single, recognized structure for communication of data between CAD/CAM systems.

1.3 Cross-translation, the focal point of IGES

The competitiveness and the diversity that exist in the world in which we live accounts for the focal point of the IGES effort. This is cross-translation, or, database exchange between interactive graphics design-drafting systems of different brand name. From the competitive point of view of the user, progress in this interface area would allow the best buy to be made. From the competitive point of view of the supplier, progress in this area would open potential new markets.

This interface area is the most demanding one. Almost certainly, this is the one which will serve as the primary barometer for the success of IGES. The need - and the expectation - is that IGES be able to accommodate the exchange of the structure of the databases in question, as opposed to being able to accommodate only the exchange of the equivalent of pen position information. In fact, the exchange of this latter type of information was declared at the very outset of IGES to be inadequate because it did not constitute database exchange. The motivation behind striving for the exchange of as much structure as possible is that, following an exchange, the data should be usable on a par with what it was when it was created.

IGES pre- and post-processors comprise the ingredients for

The Focal Point Of IGES:

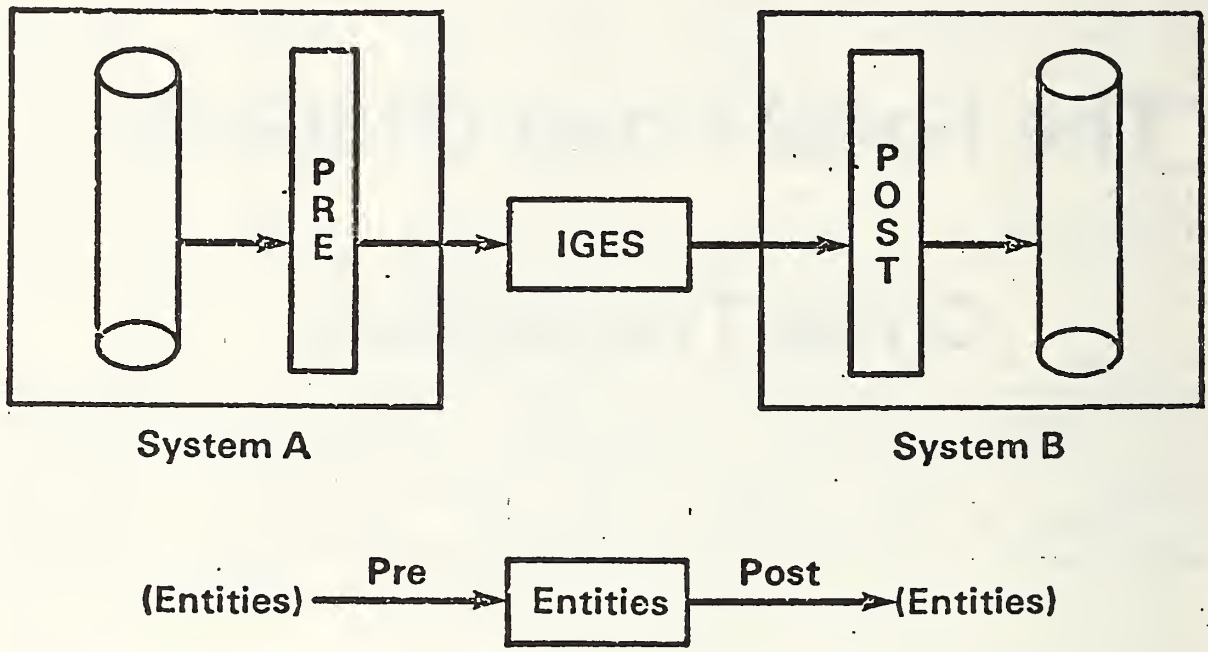
Cross-Translation

IGES Contents

Entities — The Basic IGES Units of Information

1. Geometry Entities
2. Annotation Entities
3. Structure Entities

Cross-Translation
Between Interactive Graphics Design-Drafting Systems



IGES Design Goals for the Cross-Translation Application

1. Basic database information, including complex structures and relationships, be exchanged.
2. Following exchange, the data should be usable on a par with what it was when it was created

Basis of User Interest In Cross-Translation

1. User presently owns more than one type of system
2. User wishes more supplier independence in the future
3. User wishes to accommodate his customers by providing data in the form they wish to see it.

Basis of Supplier Attitudes Toward Cross-Translation

1. Pro—Opens Up Potential New Markets
2. Con—Tends to Decrease Individuality

The IGES Role in Cross-Translation

1. Consider, react, advise, concerning entity associations specified by suppliers

2. Provide forum between users and suppliers

3. Facilitate future demonstration of capability in this area

the cross-translation application. In the IGES scheme, each participating supplier of an interactive graphics design-drafting system will implement processors between his own system and the communication file. Thus supplier commitment and involvement are crucial to the IGES effort.

A pre-processor is a software module designed to accept information structured according to a specific format, and translate it into the communication file format. A post-processor accepts information structured according to the communication file format, and translates it into a specific system format. For example, in transferring information from system A to system B, the pre-processor lies between system A and the communication file, and the post-processor lies between the communication file and system B.

The first generation of IGES processors will rely on fixed, predetermined entity associations in both the pre- and the post-processors.

The general role that IGES will play in this area will be that of coordinator between users and suppliers. IGES will seek to involve itself in discussions in an effort to consider, react, and advise concerning the entity associations specified by suppliers. IGES will try to promote understanding, and will seek to develop concensus, but will not become involved in legalisms, or in certification situations such as deciding whether or not a given supplier "meets" IGES.

1.4 Preset goals for the IGES Specifications*

Work toward producing the present set of IGES specifications began on October 11, 1979. On that day, the IGES Technical Committee was formed, and commissioned to produce a set of specifications. This Committee was chaired by Dr. Roger Nagel of the National Bureau of Standards, and contained as members Walt Braithwaite of Boeing, and Dr. Phillip Kennicott of General Electric. Because of the immediacy of the need, the driving force of this Committee was to publish a set of specifications by early 1980. Three months of intensive effort resulted in the presently available set of specifications being put in the mail in late January.

Other goals influenced the IGES development. These were

1. Completeness - The format had to allow communication of

* As evidence of the fact that acronyms do indeed assume a life of their own after a while, the phrase "IGES Specifications" will continue to be used in spite of the redundancy involved.

Preset Goals for the IGES Specifications

The Overriding goal — Published Early 1980

Others

1. Completeness
2. Extensibility
3. Processor Compatability
4. Responsive to Community Input

IGES Technical Committee

1. Roger Nagel, Ph.D., National Bureau of Standards
2. Walt Braithwaite, M.S., Boeing Commercial Airplane Co.
3. Philip Kennicott, Ph.D., General Electric Co.

basic geometrical, annotation, and structural entities (an entity is the basic unit of information in IGES.)

2. Extensibility - The format had to allow the communication of material defined after IGES was published.

3. Processor compatibility - The format was not to demand a quantum jump in the state of the pre- and post-processor art.

4. The format was to be based on as much input as possible from the interested community.

1.5 Brief history, present committee structure of IGES

The idea to create a graphics exchange specification as an immediate step in the solution of the data exchange problem first surfaced at the DOD/MTAG* meeting in Detroit in September, 1979. The CAD/CAM workshop at that meeting recommended that a meeting be held within thirty days to formulate a set of exchange specifications for publication early in 1980. As a result of that recommendation, a meeting was convened by the Air Force, Army, Navy, NASA, and NBS at the National Academy of Sciences on October 11, 1979.

The October 11 meeting was used as a forum for a discussion of the IGES concept. Presentations were made by suppliers, corporate system designers, and standards groups concerning their respective efforts to address data exchange problems. Various offers were advanced as to which existing specifications could be made available in order to assist in the development of the IGES set of exchange specifications.

It was decided to use the Boeing CAD/CAM Integrated Information Network (CIIN) standard format as the basis on which to define the exchange specifications. This was done because that system had been in use for several years and was known to work. (As a result, the IGES structure is similar to that of CIIN. However, IGES is not purely a CIIN derivative. Many of the features presently in IGES were not in CIIN.) Information stemming from General Electric's work on a Neutral Data Base was used as a source of advanced concepts, as were numerous other formats provided to the Technical Committee. [References 3 and 4 pertain to CIIN, Reference 7 pertains to the General Electric Neutral Data Base.]

The upcoming effort was officially dubbed as IGES, and the

* Department of Defense Manufacturing Technology Advisory Group

Brief History, Present Committee Structure of IGES

IGES Milestones

September, 1979	— DOD/MTAG Workshop Session On CAD/CAM Interaction
October	— Boeing CIIN System Offered As Basis for IGES
	— Technical Committee Established
	— Work Began for Jan. 1, 1980 Publication of Specifications

November — First Input Meeting;
Suppliers, Corporate
Systems Personnel

December — Second Input Meeting;
Interested Public

January, 1980 — Publication of
Specifications

February — IGES Committee Structure
Set Up

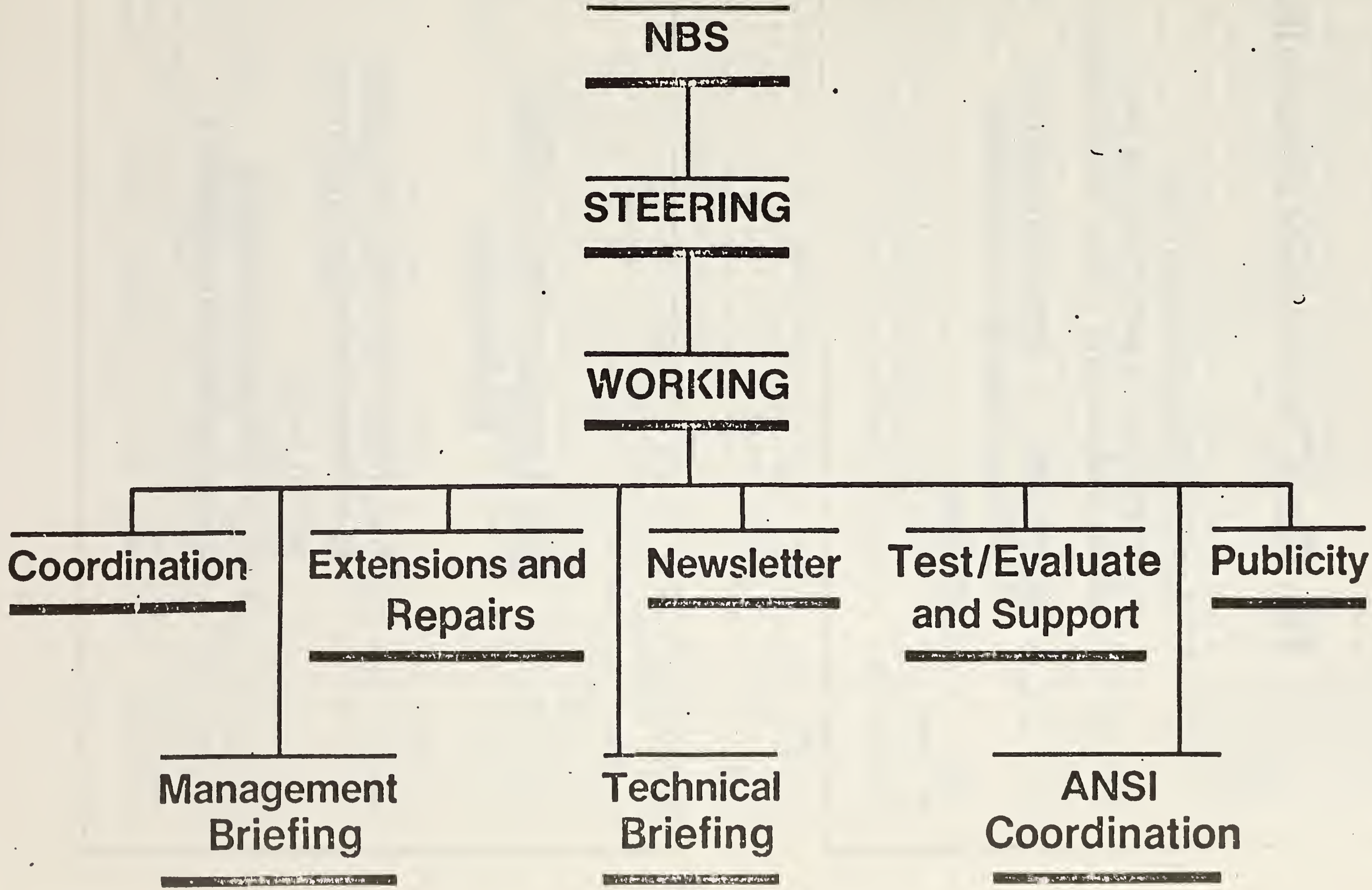
March — Early Thoughts on Testing,
Benchmarking, Demonstration

May — IGES Adopted by ANSI Subcommittee Y14.26 to be Part of Proposed
American National Standard

June — Detailed Technical Design
Meetings Between IGES and Participating Suppliers

IGES Committee Structure
Bradford Smith
National Bureau of Standards
IGES Chairman

IGES
Committee Structure



The Near-Term IGES Schedule

1. June — Detailed technical meetings with participating suppliers concerning entity mappings.
2. September — Tapes containing IGES descriptions of individual entities

The Longer-Term IGES Schedule

1. Summer, Fall, 1980—Suppliers continue processor implementation work
2. Public demonstration of cross-translation capability

Technical Committee was formed to produce the specifications. IGES is officially a project of the Air Force Integrated Computer-Aided Manufacturing (ICAM) Program. It is supported by funds from the Air Force, Army, Navy, and NASA, which are coordinated through the Air Force ICAM office. (It should be emphasized that this funding has gone only to the National Bureau of Standards for directing and coordinating the IGES work. The considerable participation by Boeing and by General Electric, by means of the Technical Committee, was voluntary, and the cost was borne by these two organizations.)

Two public meetings were held while the specifications were being drawn up. The first, on November 20 in Schenectady, NY, was for suppliers and corporate systems personnel. The second, on December 14 in Washington, was for the interested public. In each case, opportunity was provided for reaction to what existed at that time, and for suggestion and criticism.

The IGES specifications were published in January, 1980. In May, these specifications were recommended by American National Standards Institute (ANSI) Subcommittee Y14.26 to be part of a proposed American National Standard. (See Section 2.4)

Publication of the IGES Specifications marked the end of one period in the IGES effort, and the beginning of another. With publication, the Technical Committee ceased to exist. New committees were then formed whose concerns reflect the fact that IGES is moving toward being used.

The two standing IGES committees are the Steering Committee and the Working Committee. The Steering Committee is a management advisory group. Its function is to see that IGES is promoted, accepted, and used. The Working Committee is the umbrella technical committee, and serves as the focal point for technical information exchange. It has several subcommittees, each of which performs a specific technical task. It will also be concerned with carrying out the directives of the Steering Committee.

At its first meeting, in January, 1980, the Steering Committee requested that other committees be formed. One is the Management Briefing Committee. This Committee will prepare material for a scripted slide presentation on IGES, tailored to be of interest to management.

The Steering Committee also requested the formation of a Test, Evaluate, and Support Committee. The function of this committee is to provide cohesion to IGES activities by determining and supplying what is needed in the IGES community by way of technical support. One present concern is with the formulation of test, benchmark, and implementation procedures. For example, in initial meetings of this committee, discussion involved the idea of a phased implementation for IGES. This led to a grouping of the IGES entities into two exhaustive subsets. One subset is intended to form a useful set of entities for mechanical applications, the other for electrical applications. (There are no present plans for identifying rigid, well-defined subsets of IGES, with the thought in mind that a supplier would implement all of a certain portion, and would then be justified in proclaiming that he "meets" that portion. There is instead the attitude that the marketplace will dictate what phased implementation will take place. Thus the two subsets mentioned above are offered more in the spirit of attempting to establish concensus than to establish any type of official designation.)

There has been discussion in the Test, Evaluate, and Support Committee to the effect that the role of IGES in the benchmarking procedure will be to make various "standard" IGES tapes available. These could be applications oriented, and possibly graded in sophistication in some manner. Users could then make use of these tapes as they chose, to assist them in their decision making in their dealings with suppliers. Several companies have volunteered to make sample parts available for use in these tapes. Also, definitive current plans call for the production of tapes containing IGES descriptions of individual instances of some of the basic geometry and annotation entities.

The Test, Evaluate, and Support Committee has a direct role in IGES providing a forum for coordination between users and suppliers, and between suppliers themselves. In particular, this committee will meet individually with participating suppliers in order to discuss entity mapping schemes to and from IGES. The Committee will then consider pairs of schemes, to try and anticipate potential cross-translation problems based on the schemes put forth, and will provide feedback to the suppliers.

For an initial public demonstration of the IGES concept and capabilities, a sample mechanical part has been agreed upon in order that suppliers may work toward being able to accept and produce an IGES description of it. (See Appendix B) No date has been fixed for a demonstration.

An Extensions and Repairs Committee has been set up within the Working Committee. This committee is concerned with finding and repairing errors and ambiguities in the specifications document, and with clarifying parts of the manual that prove difficult to understand. For extensions, the concern is not with the addition of new entities of IGES. Rather, the concern is with such things as the definition of new standard properties and associativities, and with possible macros. In fact, concern thus far has been with these things for the area of electrical design. (The idea of standard associativities is further explained in the material for the associativity instance entity.)

An ANSI Coordination Committee has been formed. Future concerns of this committee are: getting the IGES specification into the required ANSI format, and coordinating comments received during the ANSI review processes.

A Newsletter Committee and a Coordination Committee have also been established. Vol. 1, No. 1, of the IGES Newsletter was dated May, 1980. It will be published on an as-needed basis. The Coordination Committee is a liason committee to other interested groups and to professional societies.

A Software Library will be established for coordinating the sharing of public domain software generated in the area surrounding IGES.

II. IGES Related To The Technology Of Product Definition

Fundamental changes in the technology of product definition have brought about the need for IGES. These changes may be put in perspective by concentrating on the nature of the models used to define the product and to communicate design intent.

2.1 The technology of product definition

Present product definition methods reflect the fact that this technology is in a transition period. The influence of both the conventional human-oriented technology and of the newer computer-oriented technology can currently be found.

The traditional model for product definition consists of human-oriented engineering drawings and associated documents. Over the years, the art of creating this model has received much attention. The discipline of drafting methodology has evolved to insure that design intent can be communicated in an orderly manner according to established standards.

At the opposite extreme lies a currently intensive research area concerned with automated production via "integrated systems". In particular, much attention is being focused on the modeling of the geometry of individual components. Here the intention is that the solid shape of a part be completely described, by means of a software system called a geometric modeler, in a manner capable of supporting later (automated) processing. It is envisioned that, eventually, larger software systems containing geometric modelers within them will have the capability to give precise, complete representations of complicated assemblies, including all information relevant to the design and manufacture of the product, and also all

IGES
Related To
The Technology Of
Product Definition

The Present Technology
Of
Product Definition

Product Definition — Involves Creation Of A Model To

1. Define the Product Itself (Geometry)
2. Communicate Design Intent

Traditional Product Definition

1. Human Oriented
2. Engineering Drawings and Associated Documents
   — Configuration Data
   — Mathematical Tables
   — Fabrication Information

Future Product Definition Technology

1. Complete Computer Description Of
   - Product Geometry Sufficiently Sophisticated to Support Automated Processing
   - Information Necessary to Manufacture, Inspect, Modify, etc. Product
   - Information Necessary to Manage These Processes
2. Computer Description Will Accumulate From Design Onward

Present Product Definition Technology

1. Transition State Between
   - Human Oriented Traditional Model
   - Computer Oriented Future Model
2. Today's Design-Drafting Systems Reflect Both Models
   - Computer Generation of Human Oriented Traditional Model
   - Rudimentary Geometry Capability for Computer Oriented Future Model

3d Wire Frame
Limited Planar, Curved Surface Capability

information necessary to effectively manage these processes. Thus for a given product, a description will accumulate from initial design onward, and will provide a consistent source of information for everyone working on the product.

No such "integrated" system is in production use today. However, integrated systems designed to address various portions of the entire production process are being vigorously pursued in both the United States and abroad.*

The present technology for product definition lies between the two extremes of the established human-oriented drafting methodology and the research in automated production. On the one hand, the capabilities of the interactive graphics design-drafting systems being marketed today reflect the fact that these systems have been based on the drafting application. This is appropriate, since drawings are still used as the primary means of data definition, data communication, and data storage. Thus the predominant current effect of the computer having been introduced into the process of product definition is that conventional human-oriented methods have been automated to some degree.

On the other hand, with the systems being marketed today, three dimensional "wire frame" models can be constructed, and both planar and curved bounding surfaces are available to be used in the product definition. (In fact, the systems being marketed today are characterized by some as "edge-surface" systems.) It is true that at present the emphasis is still on the preparation of an engineering drawing from the three dimensional model. But the stage is now set for the shift in attitudes - and practices - that will result from the computer-oriented model eventually being considered as the

* For example, the "I" in both the IPAD and ICAM acronyms represents "Integrated". (IPAD is Integrated Programs for Aerospace Vehicle Design, and ICAM is Integrated Computer Aided Manufacturing.) CAM-I is the acronym for Computer Aided Manufacturing-International, Inc. Within CAM-I, standing "projects" exist, each having specific concerns within the production process. There is, among others, the Geometric Modeling Project, and the Advanced Numerical Control Project. A new project, the CAM-I Framework Project, has recently been formed, and will act as "Integrator" for the various projects. Reference 1 provides information relative to the structure and concerns of CAM-I. References 5 and 6 give overviews of ICAM and IPAD.

primary definition of a part, and the production of human-oriented drawings as an application feeding off the model definition.

2.2 IGES related to the present technology of product definition

IGES has been tailored to accommodate the technology of product definition as it exists in today's interactive graphics design-drafting systems.

First, this technology is accommodated in the type of entities provided in IGES. IGES entities allow support of the traditional drafting application - the production of two dimensional drawing models. In addition to this, IGES is equipped to accommodate the eventual shift which will have the computer-oriented model definition as primary and the human-oriented drawing as a derivative of it. Thus, there are IGES geometry entities which support the definition of three dimensional wire frame models, and the use of planar and curved bounding surfaces. IGES can further support the distinction between three dimensional computer models and conventional two dimensional drawing models by means of the view entity and the drawing entity. The view entity allows communication of a particular "picture" of a given three dimensional geometry configuration. For example, parameters pertaining to the view point and to clipping may be communicated. The drawing entity allows communication of a two dimensional surface onto which views have been projected and arranged in a selected manner. Drafting annotation entities may also be included.

IGES also contains entities to allow communication of data base structure. The property entity enables integer, real, or textual data to be related to a specific entity. Any entity in IGES may point to one or more property entities.

The associativity definition entity allows for the definition of a logical relationship which is to exist between entities, without the specification of which entities are to be used in any given "instance" of this relationship. The associativity instance entity specifies this information.

The IGES macro definition capability provides for the definition of "new" IGES entities in terms of other IGES entities and supplied parameters. For example, a variable sized rectangle could be defined in terms of the variable parameters of length and width.

The associativity definition and the macro definition entities allow extension of IGES as necessary in order to meet short term needs.

IGES
Related To The Present
Product Definition
Technology

IGES
Accommodates The Technology
Of
Product Definition
As It Exists In Today's
Interactive Graphics
Design-Drafting Systems

IGES Does This Through:

1. The types of entities it has
2. The particular application—independent format it uses

The IGES Entities

1. Can Accommodate Computer-Aided Generation of Traditional Engineering Drawings
2. Can Accommodate Current Capabilities for Geometry of Computer-Oriented Model
   - 3D Wireframe
   - Planar, Curved Surfaces
3. Allow Maintenance of Distinction Between Human Oriented Model and Computer Oriented Model
   - View Entity
   - Annotation Entity

The IGES Entities, cont'd.

4. Allow Maintenance of Database Structure
   - Property Entity
   - Associativity Entity
5. Allow Extension as Necessary to Meet Short-Term Needs
   - Macro Definition
   - Associativity Definition
   - Text Font Definition
   - Line Font Definition

The IGES Entity Format Has Been Designed To Resemble Those Found In Today's Commercially Available Interactive Graphics Design-Drafting Systems

Entity Format

1. In Today's Systems
   - Attribute parameters which are same for every entity
   - Definition parameters varying from entity to entity
2. In IGES
   - A fixed length directory entry which is same for all ehtities
   - A variable length parameter data entry varying from entity to entity

A second way in which IGES accommodates the technology of product definition in today's systems is by means of the application-independent format used to define each entity in a product definition file. Entities in today's systems are determined by definition parameters varying from entity to entity, and by attribute parameters which are the same for every entity. Typical examples, respectively, are geometry related parameters, and the construction layer on which a given entity is defined.

IGES supports this format in a one-for-one manner in that each IGES entity has two parts: a directory entry format which is the same for all entities, and a parameter data entry which can vary between entities.

2.3 IGES related to the hierarchy of the geometry of product definition

It has been observed already that present day design-drafting systems, and IGES too, are at the level of "wire frame" geometry in their three dimensional description of solid objects. In this section, various kinds of computer representations for solid objects are touched upon, and some perspective is sought regarding their relationship one to another.

At the present time there are three types of computer models commonly used to represent solid objects. These types may be arranged hierarchically.

The first type is the edge representation model. Here, the model consists of stored computer definitions of the edges of the object. Depending on the sophistication of a particular implementation, such information as which edges bound a given face, or which edges meet at a given vertex may or may not be contained within the data structure of the model.

The advantages of this type of model are that it is basically a simple model, and, provided the object is not too complicated, it can be used profitably in generating usable views of the object. The fatal disadvantage of this type of model is that it is "informationally incomplete" in the sense that more than one solid object can correspond to the same edge model. (This remains true even when only polyhedral objects are being considered!)

The second type of solid representation is the boundary representation model. Here, the intention is to be able to specify precise mathematical definitions for the various bounding surfaces - the faces - of the object, in such a way that the totality of these surfaces comprises a complete

IGES

Related to the Hierarchy
Of the Geometry
Of
Product Definition

Three Current Types Of Computer Representations For Solid Objects

1. Edge Representation Model
2. Boundary Representation Model
3. Volume Representation Model

Edge Representation Model

1. Conceptually Simple
2. Natural Extension of Drafting Technology
3. Does Not Necessarily Delineate a Single, Unique Object

Boundary Representation Model

1. Involves mathematically specifying all exterior "faces" of the object
2. The totality of faces defines a unique physical object
3. Implicitly contains the Edge Representation Model
4. Difficult to verify integrity of model

Volume Representation Model

1. Involves specifying all points in 3D space occupied by the object
2. Defines a Unique Physical Object
3. Implicitly contains the Boundary Representation Model

1. IGES is oriented to the edge representation model, but also accommodates limited surface capability.
2. IGES in its present form does not accommodate either boundary representations or volume representations of solid objects.

Various Geometric
Modeling Systems For
Solid Objects
Are In Development

bounding envelope for the object. With this type of representation, there is no possibility of associating more than one object with any given boundary model. Thus the uniqueness problem that was mentioned above as being the primary disadvantage of the edge model has been overcome.

It is easy to see that there is inherently more information in this type of representation than there is in the edge representation. In fact, for a given object, the required geometrical information needed to construct an edge representation is implicit in the boundary representation. However, it is not a trivial task to verify that the totality of the faces does indeed form exactly a complete bounding envelope — that is, with no part of the object left unenclosed, and with no superfluous "dangling" faces.

The third type of computer model is the volume representation model. Here the intention is to specify all points in three dimensional space that are occupied by the object. There is sufficient information in the volume representation model to be able to derive a boundary representation model from it. However, while this is very easy to accept on an intuitive basis, neither is this trivial to actually carry out in an automated manner.

Current design-drafting systems deal predominantly with edge representations, although as mentioned earlier, certain bounding surfaces are available to be used to augment the edge representation. Geometric modelers are presently under development at various places around the world, based on both the boundary representation technique and the volume representation technique. [Reference 2 describes a recent CAM-I sponsored seminar on geometric modeling. In addition to general discussion on geometric modeling, this seminar featured reports on the status and capabilities of several existing geometric modelers.] The prototype modeler PADL-1 out of the Production Automation Project at the University of Rochester, and its successor PADL-2, now under development there, both use the volume representation to automatically generate the boundary representation and the edge representation. [See References 11 and 12] Reference 9 provides a technical comparison between edge representation models and volume representation models of a certain type.

IGES in its present form does not accommodate either boundary representations or volume representations of solid objects. This is considered appropriate, in view of the fact that these representations are not in common use today, and in view of the fact that the underlying motivation for IGES was to address immediate needs. It remains to be seen how extensible IGES proves to be relative to this current research area — or, even if it is desired for it to be extensible in this manner. However, it is certainly reasonable to expect that CAD/CAM systems offered by suppliers will eventually utilize these types of representations of solid objects.

As explained below, there is a current standards effort concerned with devising a system capable of accommodating both boundary and volume representations of solid objects.

2.4 IGES related to the standards technology for product definition

Various standards currently exist which pertain to the communication of product definition data by means of conventional engineering drawings. However, in spite of the fact that IGES is rapidly becoming a de facto national standard, there are no existing national standards pertaining exclusively to the communication of a complete computer-oriented product definition.

The ANSI Subcommittee Y14.26 has as its title "Computer aided preparation of product definition data". This Subcommittee has been in existence since 1970. Task Group 1 of this Subcommittee (Y14.26.1) has been concerned with computer representation of physical object shape - that is, with the geometry portion of product definition data. A system for describing geometry has been devised by Y14.26.1. The intended use of this system is to facilitate communication of object shape descriptions between CAD/CAM programs, and between data bases of intercommunicating companies - for example, between contractors and subcontractors. The system has been designed to accommodate edge, boundary, and volume representations of solid objects. The feasibility of the writing of pre- and post-processors for the system proposed by Y14.26.1 has yet to be pursued by Subcommittee Y14.26.

Task Group 11 (Y14.26.11) was formed in 1978, and is concerned with all product definition data other than geometry - what is termed "non-geometry" data.

A brief history of the recent work of Subcommittee Y14.26 is appropriate. At the August, 1978 meeting of this Subcommittee, it was decided to begin the work of public coordination, and thus to issue the work of Y14.26.1 as a Proposed American National Standard, entitled "Digital Representation of Physical Object Shapes". The subsequent voting at the Y14 level produced comments on the Proposed Standard, as did the six week public review period which ended in June, 1979.

The main order of business at the August, 1979 meeting of Y14.26 was the resolution of these comments (or, at least to resolve how to resolve the comments). Resolution of all

IGES

Related To The Standards Technology For Product Definition

1. There are no existing national standards pertaining expressly to a complete computer-oriented product definition.
2. IGES does pertain expressly to computer-oriented product definition data. It deals with both CAD and CAM. It is rapidly becoming a de facto standard.

American National Standards Institute (ANSI)

Y14 Committee—Engineering Drawings
And Related Documentation

Y14, Subcommittee 26 (Y14.26)—Computer aided
Preparation of Product Definition

Task Group Y14.26.1—Digital Representation of
Physical Object Shape

Task Group Y14.26.11—Non-Geometry Data

May, 1980 Meeting of Y14.26

Voted to Issue IGES
As the First Three Parts
Of a Five Part
Proposed American
National Standard

comments is dictated by ANSI procedure. The plan adopted was that Y14.26 would work during the months following the August meeting, and that the revised Proposed Standard would be reissued during the summer of 1980, this time as a Draft American National Standard, for a period of one year - the intention being additional, and wider, exposure.

A meeting was convened for Subcommittee Y14.26 on May 1,2, 1980. The main order of business was consideration by the Subcommittee regarding IGES being adopted as an American National Standard. A motion was approved concerning a Proposed Standard Y14.26.X, entitled Digital Representation for Communication of Product Definition Data. (A motion was also approved to the effect that X not be equal to 1. The exact number of this Proposed Standard will be coordinated with ASME, the Y14 Secretariat.)

Y14.26.X is to be composed as follows:

Foreword

Part 1 Data Form (as presented in IGES)

Part 2 Geometry (as presented in IGES)

Part 3 Non-Geometry (as presented in IGES)

Part 4 Geometry (as presented in Y14.26.1)

Part 5 Non-Geometry (as presented in y14.26.1)

Further points expressed in the motion were:

1. IGES (Version 1) be forwarded by Y14 Subcommittee 26 as Parts 1, 2, and 3 of the proposed standard to the Y14 Standards Committee to begin the review and approval process as an American National Standard.

2. IGES group as the proponent be responsible for considering comments arising from submittal of the Foreward, Parts 1, 2, and 3 of the proposal for approval as an American National Standard.

3. IGES and Y14.26.1 Task cooperate in formulating the Y14.26.X Part 4 geometry format.

4. Y14.26.1 and Y14.26.11 Tasks be responsible for considering comments arising from submittal of Parts 4 and 5, respectively, of the supplementary proposals for approval as an American National Standard.

Item 3 refers to the fact that the IGES associativity entity is to be used to express, in the IGES format, the geometry as presented by Y14.26.1. It was recommended at the meeting, and agreed to by the participants, that, in the interest of achieving a single American National Standard format for communication of geometry data, the Y14.26.1 geometry could and should use the IGES format structure.

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Appendix A

IGES STEERING COMMITTEE

Chairman: Bradford Smith, National Bureau of Standards, Washington, DC

Vice Chairman: Roger N. Nagel, International Harvester, Hinsdale, Illinois

Secretary: Joan Wellington, National Bureau of Standards Washington, DC

Committee Members:

John E. Anderson, Naval Weapons Center, China Lake, CA

T.N. Bernstein, USAF/AFML/LTC, WPAFB, Ohio

Robert Blauth, Computervision Corp., Bedford, MA

Gino Carli, Sandia Labs, Albuquerque, NM

Richard Costabile, Xerox Corp., Webster, NY

Olan Bray, Control Data Corp., Arden Hills, MN

Richard Jennings, DMT, Nashua, NH

James Jones, The Boeing Company, Seattle, WA

Glen Petersen, CALMA, San Diego, CA

C. R. Lewis, General Motors, Warren, MI

Fred Michel, DARCOM, Alexandria, VA

Stuart Miller, General Electric Company, Schenectady, NY

Raye J. Montague, Naval SEA Systems Command, Washington, DC

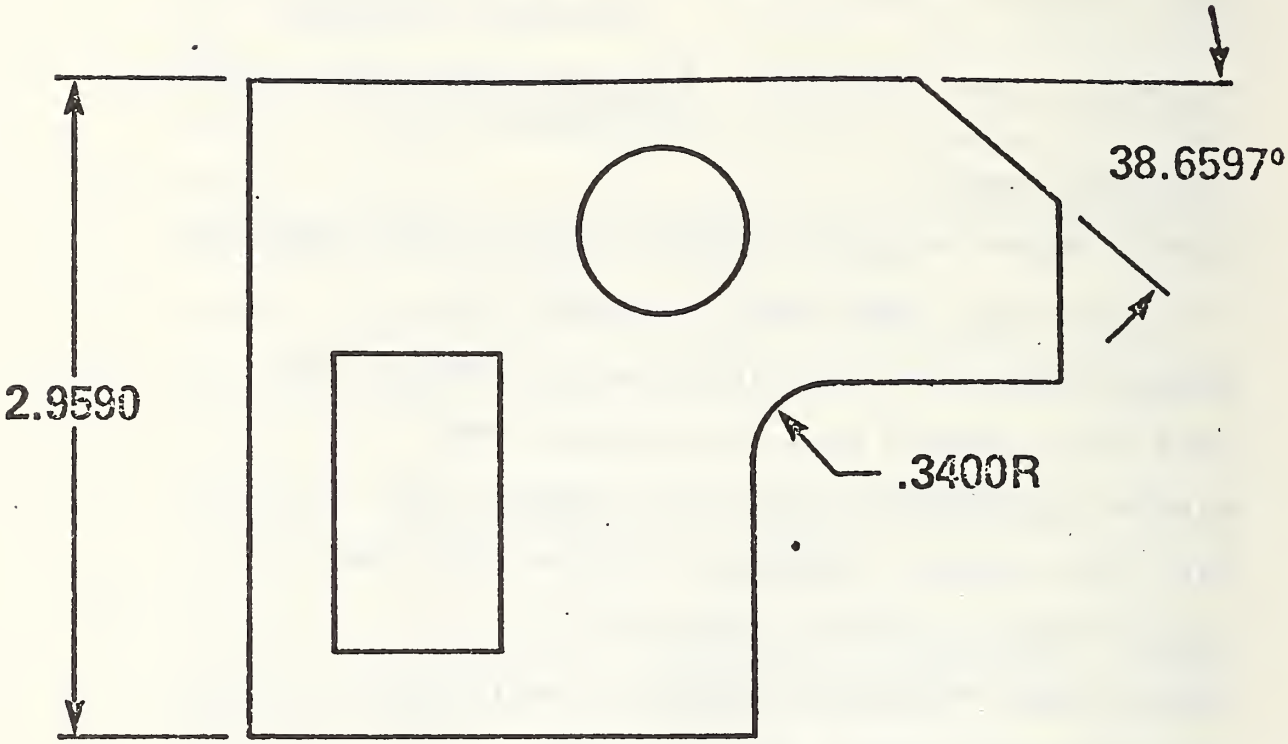
Jack Horgan, Applicon Inc., Burlington, MA

George Salley, NASA, Hampton, VA

B. Neil Snodgrass, CAM-I, Arlington, Texas

Harry M. Taxin, Gerber Systems Technology, Inc., South Windsor, CT

Donald A. Vincent, SME, Dearborn, MI



SAMPLE 2½ D PART

Part 2

IGES

A Specification
For The
Exchange
Of
Product Definition
Data

The Initial Graphics Exchange Specification (IGES) has been designed to accommodate the exchange of product definition information between Computer-aided Design and Computer-aided Manufacturing (CAD/CAM) systems.

Categories of Product Definition

1. Geometry
2. Annotation
3. Structure

Product definition, as it is generated in today's commercially available interactive graphics design-drafting systems, can be subdivided into three categories: geometry, annotation, and structure.

The category of geometry consists of that part of the product definition which describes the product itself, such as points, lines, arcs, ruled or parametric surfaces, etc.

The category of annotation consists of that part of the definition used to clarify and enhance the geometry and topology of the product. For example, when product information is communicated in the form of an engineering drawing, annotation includes dimensioning and tolerancing information such as dimension lines, text, true positioning symbols, etc.

The structure category consists of the various logical relationships that exist within the product definition file. Logical relationships may exist between the elements of the product definition itself, as when specific manufacturing instructions are associated with a specific element of the geometry. Or, logical relationships may pertain to the system involved in the generation of the product definition, as when several elements in the definition are grouped together to form an entity that can be evaluated and/or manipulated as a single item.

IGES Files

Basic Idea

Product Definition Information
Is Communicated As
A File Of Entities

An entity is the information unit in an IGES file.

The basic idea in an IGES file is that product definition information is communicated by means of a list, or file, or IGES entities. The format of the IGES entities is application independent. The essence of the IGES effort, as far as the publishing of the specifications was concerned, consisted of determining what entities were to be included, and the format for each.

IGES Entity Categories

1. Geometry Entities
2. Annotation Entities
3. Structure Entities

There are three broad categories of entities in IGES: geometry entities, annotation entities, and structure entities.

IGES Entity Structure

Each IGES Entity
Has Two Parts

1. A directory entry
2. A parameter data entry

Each entity in IGES has two parts. The first part consists of a directory entry, the second part a parameter data entry.

The form of the directory entry is fixed. It is the same for all entries. The parameter data entry varies from entity to entity.

Within an IGES file, all directory entries are gathered into one section, and all parameter data entries are gathered into one section. Within a section, each entry occupies contiguous records.

IGES File Format

80 Character
Records
Using ASCII Characters

An IGES file is written on 80 column records, using the ASCII character set. The 80 character records were chosen as being as universal medium as possible for transfer of information between different computing systems. Numbers are recorded in character form, to simplify the problems of differences in word length when going from machine to machine.

Each record in the file has a unique letter in column 73, which identifies the section to which it belongs. For example, the directory entry section has a D in this column. A right-justified sequence number is used in columns 74 through 80 to indicate the position of a record within a section.

IGES Data Types

1. Integer (Fixed-Point) Constants
2. Floating-Point Constants
3. String Constants
4. Pointer Constants
5. Language Statement Constants

There are five data types in IGES: integer (fixed point) constants, floating point constants, string, pointer constants and language statement constants.

Integer constants may be positive or negative or zero. The number of bits used by a particular machine for integer representation can be specified within an IGES file.

Floating-point constants are distinguished by the presence of a decimal point. IGES permits both single and double precision floating point constants. A single precision floating point constant may be expressed with or without an exponent. Double precision constants must be in exponential form.

String constants in IGES use the Hollerith form as found in the ANSI specification of FORTRAN. A string constant is preceded by an unsigned integer (the character count of the string) and the letter "H". Any character from the ASCII character set may be used. There is no limit on the size of a string constant. In particular, string constants may cross card boundaries.

A pointer at a particular location in an IGES file is a device used to indicate that additional information exists elsewhere in the file. For example, within the directory entry for each IGES entry, there is a pointer into the parameter data section specifying the location of the parameter data for that entity.

All other uses of pointers deal with the situation in which one IGES entity is referenced by another. In these cases, there is a pointer from the referencing entity to the directory entry of the referenced entity. The pointer may be located in either the directory entry section or the parameter data section of the referencing entity.

For example, suppose that in given product definition information, the four sides of a rectangle have been related, in an unordered manner, and labeled by a name. Then, in the corresponding IGES file, this association - called a group - is recorded by means of an IGES entity called an associativity instance. Within the parameter data for this associativity instance entity, there will be pointers to the directory entries of each of the four straight line entities of the rectangle. In addition, within the parameter data for each of the straight line entities, there will be a back pointer to the associativity instance entity, to indicate that the particular straight line is a member of the group. The name of the group can be accommodated by the associativity instance entity.

Pointers are implemented using the sequence numbers.

A fifth data type, the language statement constant is used for macro definitions. It consists simply of a string of characters and is not preceeded by the "nH" construction of the string constant. Its length must be determined through the parameter data record count in the directory entry for the entity.

IGES

Free Format

The data in several sections of an IGES file may be entered in free format. The free format feature allows the specification of parameters in a prescribed order, but does not specify a location on the record. When free format is permitted the following rules apply:

1. Blanks are ignored.

2. Commas are used to separate parameters.

3. A semicolon is used to terminate the list of parameters.

4. When two commas appear adjacent to each other (or separated only by blanks) the pertinent parameter is not specified in the file and should be given a default value.

5. If a semicolon appears before the list of parameters is complete, all remaining parameters should be given default values.

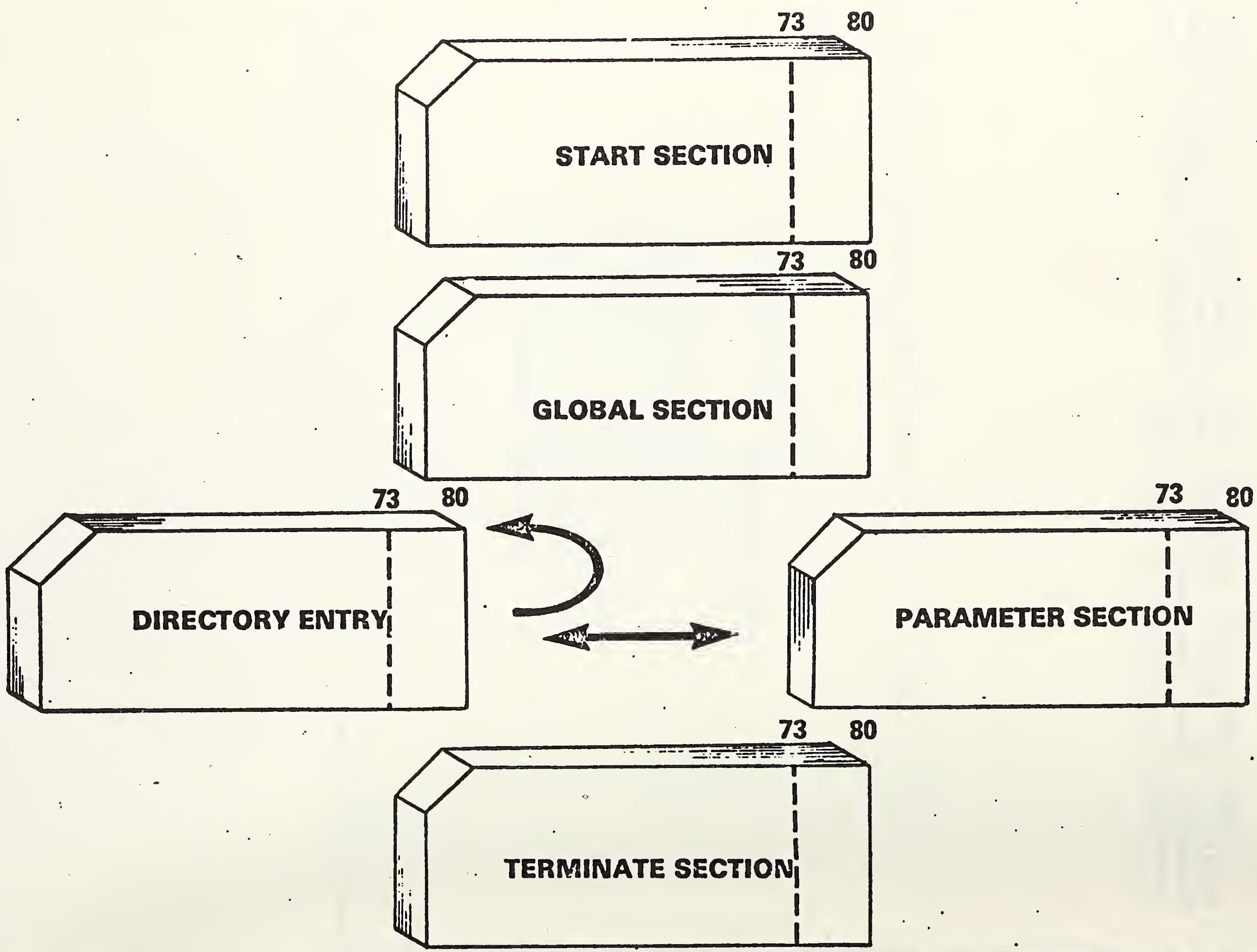
6. Blanks are not ignored in string constants. In addition, the comma and the semicolon are treated as characters in a string constant, and do not have the meaning specified in (2) through (5) above.

IGES File Structure

1. Start Section
2. Global Section
3. Directory Entry Section
4. Parameter Data Section
5. Terminate Section

Each IGES file contains five subsections: the Start Section, the Global Section, the Directory Entry Section, the Parameter Data Section, and the Terminate Section. The subsections must appear in this order.

IGES FILE STRUCTURE



The arrows between the Directory Entry and the Parameter Data Sections illustrate the action of the pointers.

A Closer Look At The IGES File Subsections

START SECTION

THIS SECTION IS A MAN READABLE	S0000001
PROLOG TO AN IGES FILE. IT CAN CONTAIN	S0000002
AN ARBITRARY NUMBER OF RECORDS	S0000003
⋮	⋮
USING ASCII CHARACTERS IN COLUMNS 1-72	S0000020

The Start Section of a IGES file provides a man-readable prologue to the file.

Each Start Section record has an "S" in column 73, and a sequence number in columns 74 through 80. The information in columns 1 through 72 does not have to be formatted in any special way, except that the ASCII character set must be used.

There must be at least one Start record.

GLOBAL SECTION

PARAMETER	FIELD TYPE	DESCRIPTION
1	TEXT	FIELD DELIMITER CHARACTER (DEFAULT=,)
2	TEXT	END OF PARAMETER CHARACTER (DEFAULT=;)
3	TEXT	PRODUCT IDENTIFICATION FROM SENDING SYSTEM
4	TEXT	FILE NAME
5	TEXT	SYSTEM ID • VENDOR • SOFTWARE VERSION
6	TEXT	IGES TRANSLATOR VERSION
7	INTEGER	NUMBER OF BITS FOR INTEGER REPRESENTATION
8	INTEGER	NUMBER OF BITS IN A SINGLE PRECISION FLOATING POINT EXPONENT
9	INTEGER	NUMBER OF BITS IN A SINGLE PRECISION FLOATING POINT MANTISSA
10	INTEGER	NUMBER OF BITS IN A DOUBLE PRECISION EXPONENT
11	INTEGER	NUMBER OF BITS IN A DOUBLE PRECISION MANTISSA

GLOBAL SECTION (Continued)

PARAMETER	FIELD TYPE	DESCRIPTION
(TO SYSTEM)		
12	TEXT	PRODUCT IDENTIFICATION FOR THE RECEIVING SYSTEM
(FILE INFORMATION)		
13	FLOATING POINT	DEFINITION SPACE SCALE
14	INTEGER	UNIT FLAG
15	TEXT	1, INCH
		2, MM
16	INTEGER	MAXIMUM LINE WEIGHT
17	FLOATING POINT	SIZE OF MAXIMUM LINE WIDTH
18	TEXT	DATE & TIME OF FILE GENERATION
19	INTEGER	MINIMUM RESOLUTION
20	INTEGER	SIZE OF DEFINITION SPACE
21	TEXT	NAME OF AUTHOR
22	TEXT	ORGANIZATION

The Global Section contains information describing the pre-processor, and information needed by the post-processor in order to handle an IGES file.

Global Section records have a "G" in column 73. The parameters for the Global Section are input in free format.

DIRECTORY ENTRY (DE) SECTION

RECORD 1	ENTITY TYPE NO.	PARA-METER DATA	VERSION	LINE FONT PATTERN	LEVEL	VIEW	DEFINING MATRIX	LABEL DISPLAY	STATUS	SEQ #
	#	►	#,►	#,►	#,►	►	►	►	#'S	D------
	1	2	3	4	5	6	7	8	9	10
RECORD 2	ENTITY TYPE NO.	LINE WEIGHT	PEN NUMBER	PARA-METER RECORD COUNT	FORM NUMBER	RESERVED	RESERVED	ENTITY LABEL	ENTITY SUB-SCRIPT	SEQ #
	#	#	#	#	#				#	D------
	11	12	13	14	15	16	17	18	19	20

\# – NUMBER
► – POINTER
\#, ► – NUMBER OR POINTER (POINTER HAS NEG SIGN)

The Directory Entry Section of an IGES file has one entry, consisting of two records, for each entity in the IGES file. The two records contain twenty fields of eight columns each. The meaning attached to each field does not vary between entities.

The contents of the directory tend to be that data common to all entities in the file. The first field specifies the IGES entity number. The second field is a pointer to the location within the Parameter Data Section of the parameter data for the entity. Information in the remaining fields is referred to as attribute data. This information may be specified by a number value, or by a pointer to the directory entry of another IGES entity. In some cases, there is a choice.

A typical example of an attribute specified by a value is in field twelve, where the pen number value specifies which pen a plotter would use to draw an image of the entity. A pointer would be used in field five, whenever the entity is to be defined on more than one working level. (Some systems allow entities to be defined on as many levels as is convenient.) In fields involving a choice, a pointer is specified by the presence of a negative sign.

PARAMETER DATA SECTION

		65	73
RECORD 1	ENTITY TYPE NO. (PARAMETERS SEPARATED BY COMMAS)	DE PTR	SEQUENCE NUMBER P #
RECORD 2	(PARAMETERS SEPARATED BY COMMAS)	DE PTR	SEQUENCE NUMBER P #
RECORD 3	• • • •		
RECORD N	(PARAMETERS SEPARATED BY COMMAS) ;	DE PTR	SEQUENCE NUMBER P #

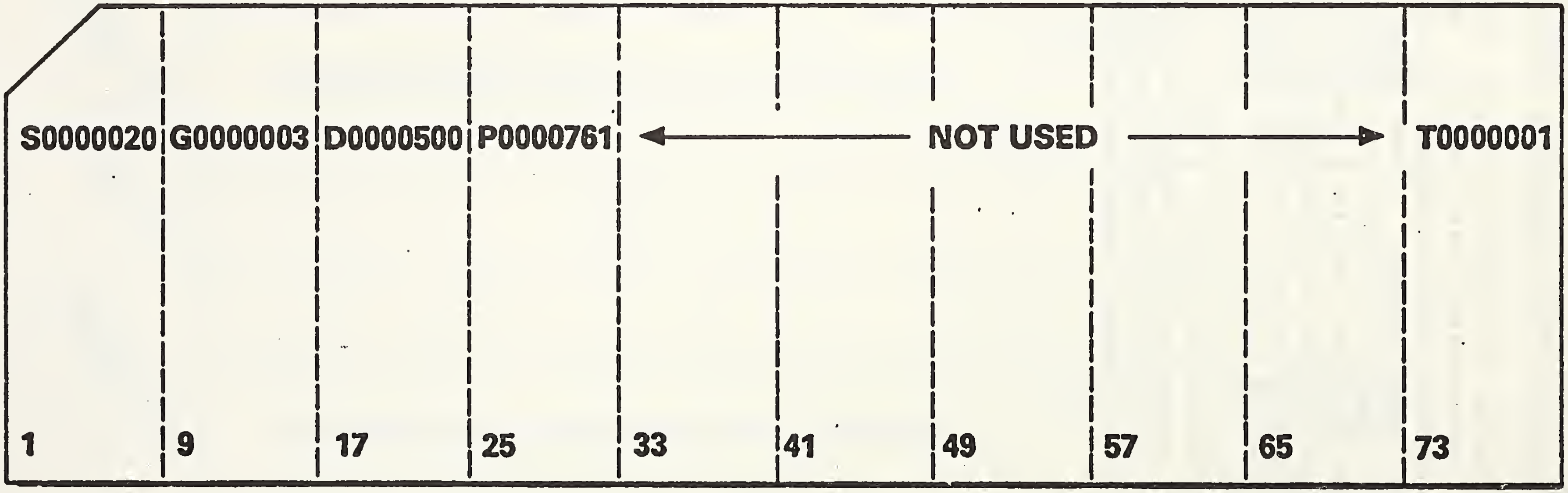
DE PTR POINTS TO THE DIRECTORY ENTRY FOR THIS ENTITY
SEQUENCE NUMBER BEGINS WITH THE LETTER P AND IS SEQUENTIALLY NUMBERED

The Parameter Data Section of an IGES file contains the parameter data entries of the entities in the IGES file. Parameter data varies from entity to entity.

Parameter data is entered in free format, with the first field always containing the entity type number. Thus, the entity type number and a comma always precede the first parameter for each entity. The free field part of each parameter record ends in column 64. Columns 65 through 72 on each parameter record contain pointer to the sequence number of the first record in the directory entry for the entity to which the parameter data belongs. Column 73 contains a "P". As usual, sequence numbers are located in columns 74 through 80.

With the exception of text strings, parameter data values are restricted from crossing record boundaries. For each entry, comments can be added following the parameter data, giving the possibility of furnishing human readable information when necessary.

TERMINATE SECTION



Each IGES file has one record in the Terminate Section, divided into ten fields of eight columns each. This records must be the last record in the file. It has a "T" in column 73, and 0000001 in columns 74 through 80.

The first four fields on the terminate record give the number of records in each of the four previous sections.

A Closer Look

At The

IGES Entity Categories

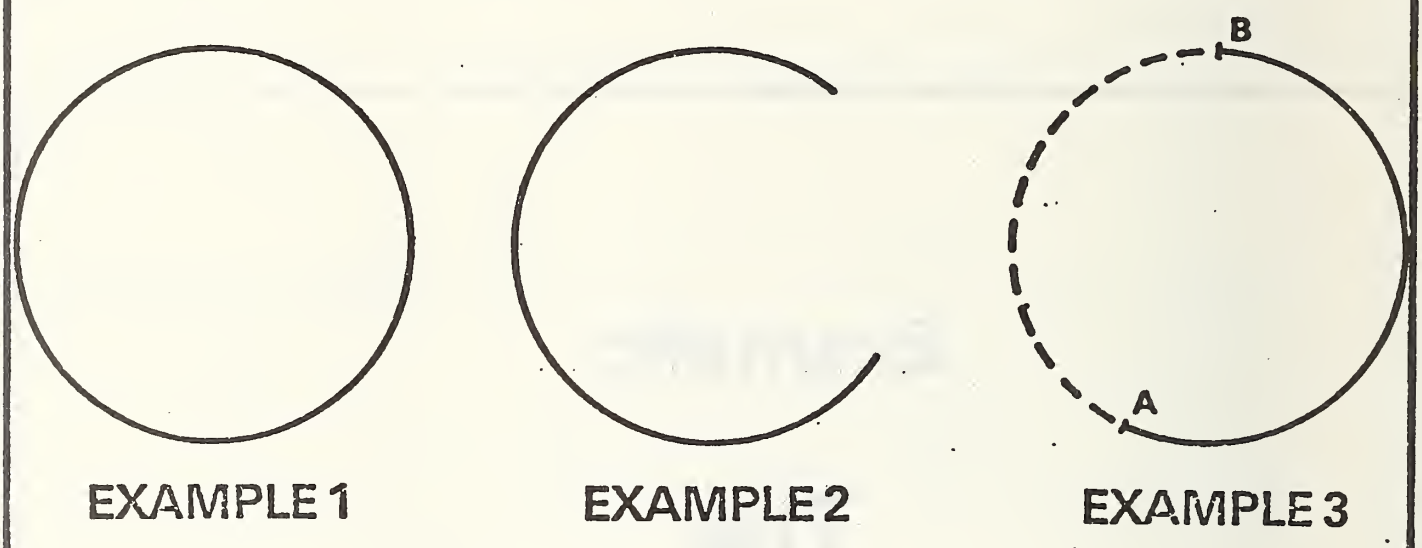
IGES GEOMETRY ENTITIES

ENTITY TYPE	ENTITY TYPE NUMBER
CIRCULAR ARC ENTITY	100
COMPOSITE CURVE ENTITY	102
CONIC ARC ENTITY	104
COPIOUS DATA ENTITY	106
PLANE ENTITY	108
LINE ENTITY	110
PARAMETRIC SPLINE	112
PARAMETRIC SPLINE SURFACE ENTITY	114
POINT ENTITY	116
RULED SURFACE ENTITY	118
SURFACE OF REVOLUTION ENTITY	120
TABULATED CYLINDER ENTITY	122
TRANSFORMATION MATRIX ENTITY	124

The IGES Geometry entities. Most of the geometry entities are defined directly in three dimensional X,Y,Z model space. (That is, the coordinate system in which the model is defined.) The circular arc entity and the conic arc entity are exceptions.

Example:

The Circular Arc



EXAMPLES OF CIRCULAR ARCS

Circular arcs can be defined with the IGES circular arc entity. Coordinate information for arc endpoints A and B is part of the parameter data. By considering an arc to be drawn counterclockwise from the point listed first to the point listed second, a given arc can be distinguished from its complementary arc (which has the same endpoints).

CIRCULAR ARC ENTITY

DIRECTORY ENTRY FIELDS

ENTITY NUMBER	100	STATUS	#
PARAMETER DATA	➤	LINE WEIGHT	#
VERSION	#, ➤	PEN NUMBER	#
LINE FONT	#, ➤	PARAMETER CARD CT.	#
LEVEL	#, ➤	FORM NUMBER	#
VIEW	➤	ENTITY LABEL	
MATRIX	➤	ENTITY LABEL SUB	#
LABEL	➤	SEQUENCE	

PARAMETER DATA

PARAMETER	VALUE	FORMAT	COMMENT
1	Z	FLOATING POINT	CENTER DISPLACEMENT FROM XT-YT PLANE
2	X	FLOATING POINT	CIRCLE CENTER ABSCISSA
3	Y	FLOATING POINT	CIRCLE CENTER ORDINATE
4	X	FLOATING POINT	END POINT ONE ABSCISSA
5	Y	FLOATING POINT	END POINT ONE ORDINATE
6	X	FLOATING POINT	END POINT TWO ABSCISSA
7	Y	FLOATING POINT	END POINT TWO ORDINATE
8	N	INTEGER	NUMBER OF BACK POINTERS (TO ASSOCIATIVITY ENTITIES) /TEXT POINTERS (TO GENERAL NOTE ENTITIES)
9	DE	POINTER	POINTERS TO ASSOCIATIVITIES OR GENERAL NOTES
8+N	DE	POINTER	
9+N	M	INTEGER	NUMBER OF PROPERTIES
10+N	DE	POINTER	POINTERS TO PROPERTIES
•	•	•	
•	•	•	
•	•	•	
9+N+M	DE	POINTER	

In IGES, an arc of a circle is specified by giving planar coordinates for the two endpoints of the arc, and the coordinates of the center of the parent circle for the arc. (See parameters 2 through 7 in the parameter data.)

The definition plane for the arc is termed the XT,YT plane, and is different from model space. The arc can be considered to be rigidly displaced in a direction perpendicular to the XT,YT plane (that is, in the ZT direction), as parameter 1 in the parameter data indicates.

The remaining parameters in this entity have to do with possible related entities. For example, if an arc is one of the entities in a group, then the associativity instance entity specifying the various group elements could be pointed to by the circular arc entity as being an associated entity.

The arc in the XT,YT plane is situated into model space by use of the IGES transformation matrix entity. This entity consists of a rotation matrix and a translation vector. Field 7 in the directory entry for the circle contains a pointer to the matrix entity.

IGES ANNOTATION ENTITIES

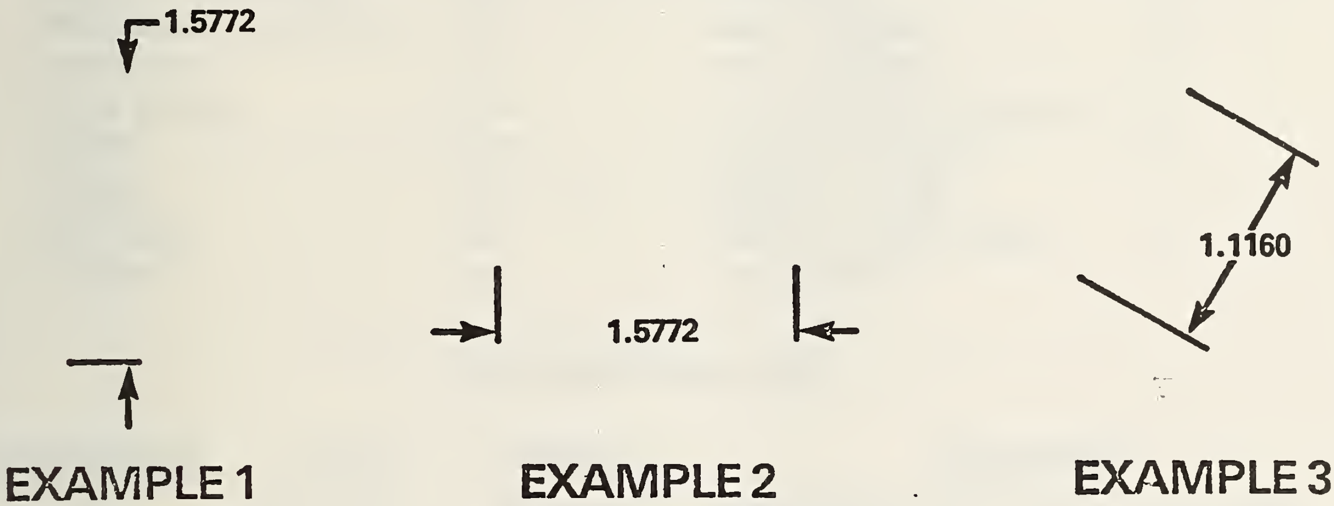
ENTITY TYPE	ENTITY TYPE NUMBER
ANGULAR DIMENSION	202
CENTERLINE	106
DIAMETER DIMENSION	206
FLAG NOTE	208
GENERAL LABEL	210
GENERAL NOTE	212
LEADER (ARROW)	214
LINEAR DIMENSION	216
ORDINATE DIMENSION	218
POINT DIMENSION	220
RADIUS DIMENSION	222
SECTION	106
WITNESS LINE	106

The IGES Annotation entities. Annotation entities are not part of the physical part description itself. Rather, these serve primarily to enhance the physical description of the part, such as in the case of a linear or an angular dimension.

Example:

The Linear

Dimension Entity



EXAMPLES OF LINEAR DIMENSIONS

A linear dimension entity consists of a general note, two leaders, and zero to two witness lines. The IGES general note entity is used for all text in an IGES file. Here, this consists of the numerical values shown. The leaders are the portions of the entity containing the arrowheads. The witness lines are used as needed.

LINEAR DIMENSION

DIRECTORY ENTRY FIELDS

ENTITY NUMBER	216	STATUS	#
PARAMETER DATA	➤	LINE WEIGHT	#
VERSION	#, ➤	PEN NUMBER	#
LINE FONT	#, ➤	PARAMETER CARD CT.	#
LEVEL	#, ➤	FORM NUMBER	#
VIEW	➤	ENTITY LABEL	
MATRIX	➤	ENTITY LABEL SUB	#
LABEL	➤	SEQUENCE	

PARAMETER DATA

PARAMETER	VALUE	FORMAT	COMMENT
1	DENOTE	INTEGER	POINTER TO GENERAL NOTE DE
2	DEARRW1	INTEGER	POINTER TO FIRST LEADER DE
3	DEARRW2	INTEGER	POINTER TO SECOND LEADER DE
4	DEWIT1	POINTER	POINTER TO WITNESS LINE DE,
5	DEWIT2	POINTER	0 IF NOT DEFINED
6	N	INTEGER	NUMBERS OF BACK POINTERS (TO ASSOCIATIVITY ENTITIES)/TEXT POINTERS (TO GENERAL NOTE ENTITIES)
7	DE	POINTER	POINTERS TO ASSOCIATIVITIES OR GENERAL NOTES
.	.	.	
6+N	DE	POINTER	
7+N	M	INTEGER	NUMBER OF PROPERTIES
8+N	DE	POINTER	POINTERS TO PROPERTIES
.	.	.	
7+N+M	DE	POINTER	

A portion of the parameter data for the linear dimension entity indicates that this entity really consists of a set of pointers to other annotation entities. Thus, the witness line in this entity is an example of a subordinate entity. An IGES entity is considered to be a subordinate entity as it was created purely as a subpart of another entity - that is, would not be used independently. A flag in the directory entry is used to indicate if a given entity is a subordinate entity. (Entities formed into a group by means of an associativity instance entity are not subordinate entities.)

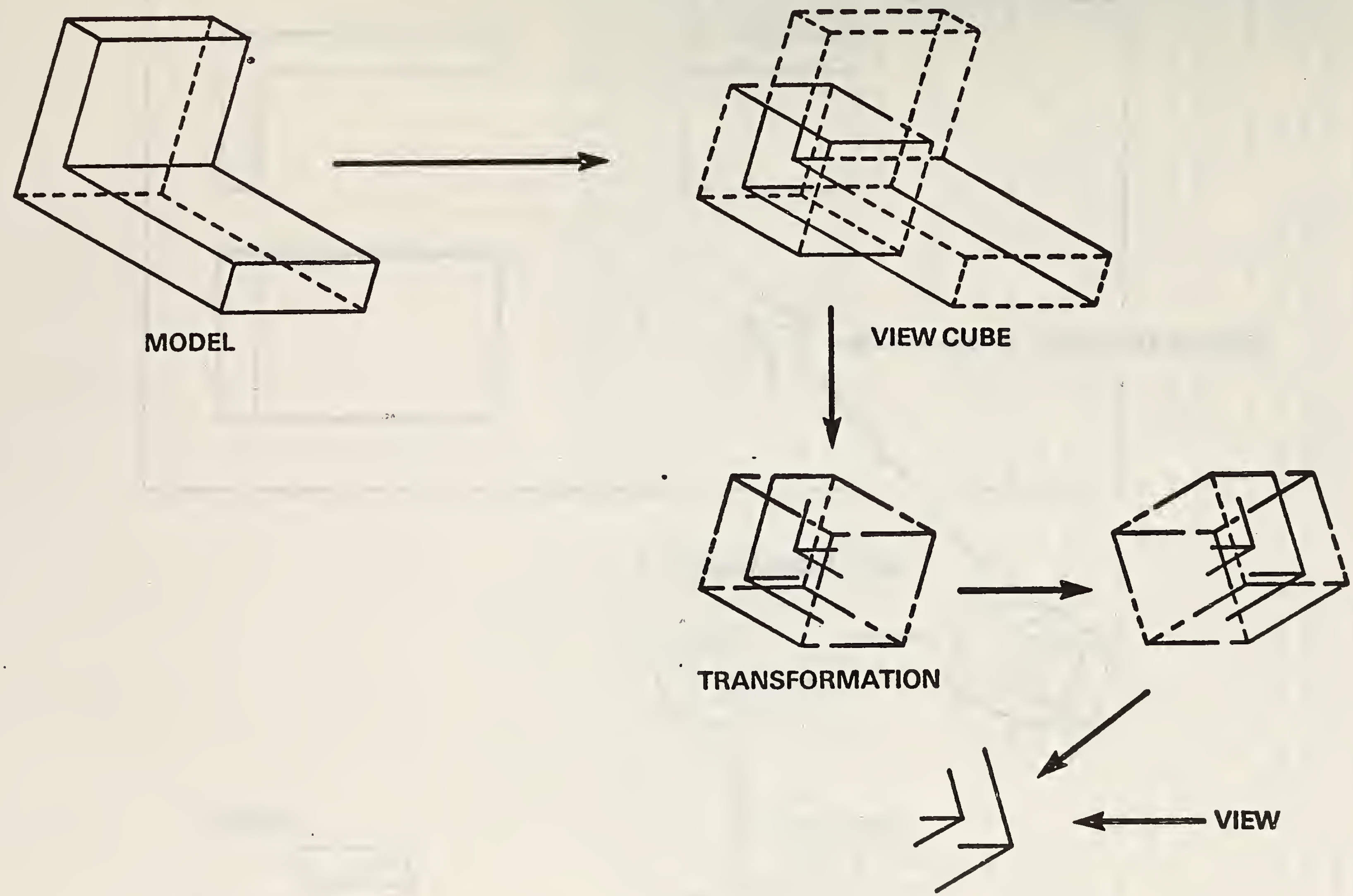
For a linear dimension entity, an associated entity could conceivably be the geometry entity to which the dimension value refers.

The IGES

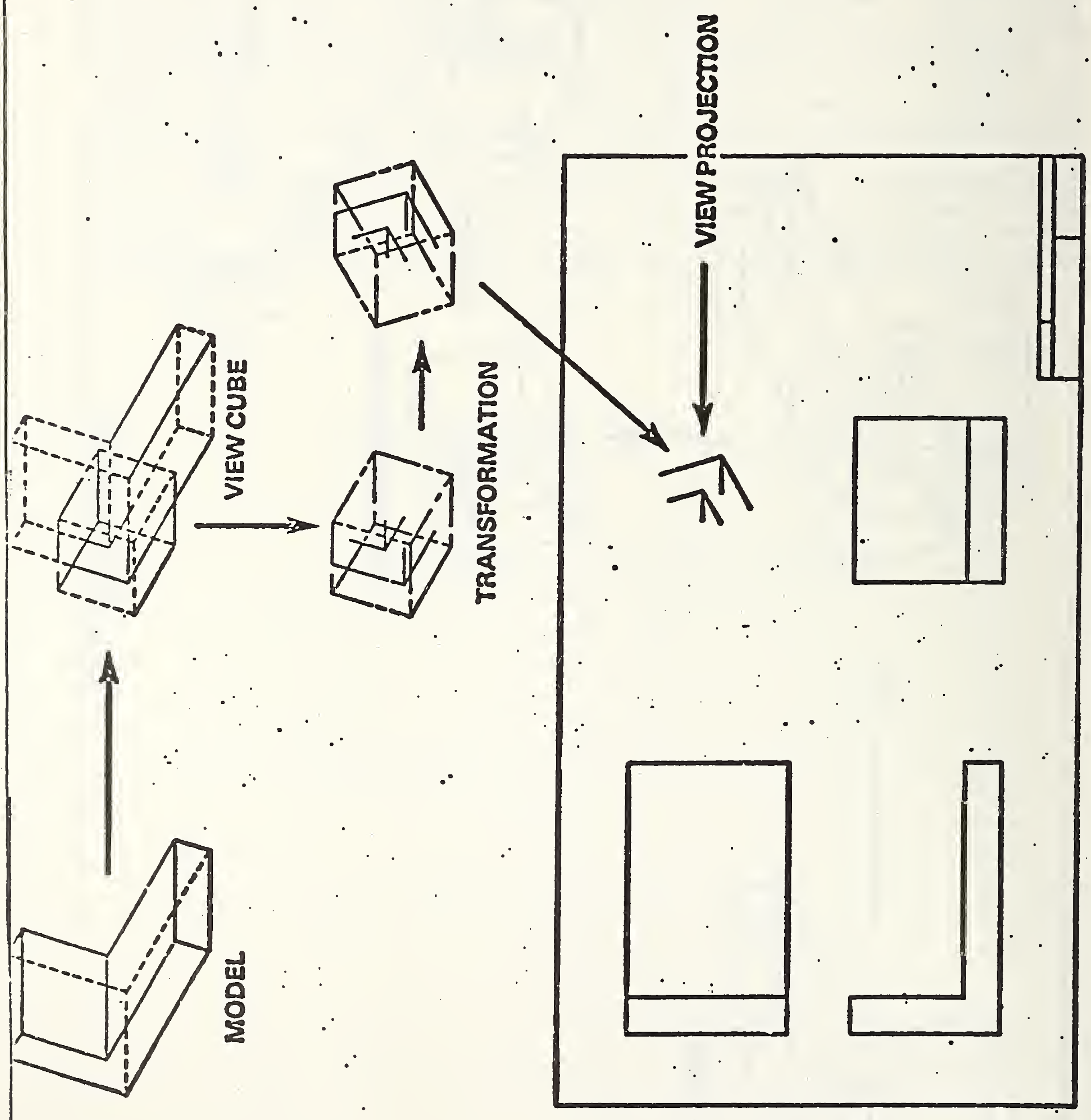
View and Drawing

Structure Entities

Two other IGES structure entities are the view entity and the drawing entity. These two entities reflect an attempt to maintain within IGES the distinction between the three dimensional description of a model, and a two dimensional representation of the model, as, for example, in the form of an engineering drawing. The intent is to allow the two ideas of model and two dimensional representation to be dealt with separately, while maintaining a single model description within the database. This contrasts with the situation where either the model description itself must be changed in order to get a two dimensional representation such as a draftsman would produce, or else a copy of the model description is changed, thus admitting to potential compatibility problems when updates are made.



VIEW MECHANISM



VIEW AND DRAWING

The concept of what type of information the view entity and the drawing entity can accommodate is illustrated in these two pictures. A portion of the model is selected using a view cube. (In two dimensions, the term "view window" might possibly be used instead. View cube is a generalization of this idea to three dimensions.) The view cube is used to identify the portion of the model that is of interest. (For example, a portion might be selected and scaled in order to "blow up" a certain detail.) Portions of the model outside the view cube are "clipped", or removed. Information within the view entity is then used to rotate as necessary the portion of the model within the view cube, in order to present the selected geometry on the two dimensional drawing in the desired orientation. As the projection onto the two-dimensional drawing is made, additional control is allowed over entity attributes within each view. For example, it can be arranged that a line be dashed in one view and be solid in another.

The drawing entity gives the capability of collecting the results of view operations and arranging them in two dimensional space in a manner similar to conventional drafting practices. While it is not essential to do so in the use of IGES, the drawing entity also provides a convenient place to collect the drafting annotation entities which aid in the description of the model. The drafting annotation entities are essentially two dimensional objects. By confining these entities to the two dimensional representation via the drawing entity, rather than attaching them to the model itself, the model is kept in a pure form, while the drawing entity is used to collect this additional descriptive information.

IGES Structure Entities

1. Associativity Definition
2. Associativity Instance
3. Annotation
4. Line Font Definition
5. MACRO Definition
6. MACRO Instance
7. Property
8. Subfigure Definition
9. Subfigure Instance
10. Text Font Definition
11. View

The purpose of the IGES structure entities is to communicate logical relationships between IGES entities. The intent is to be able to faithfully accommodate the structure within an originating product definition file.

The associativity definition and the subfigure definition entities have been mentioned elsewhere.

The macro capability provides for the definition of a "new" entity in terms of other IGES entities. The "new" entity schema is provided for by a macro definition, written using the macro entity. The statements permissable are the assignment statement(LET), the entity definition statement(SET), the REPEAT statement, causing a group of statements to be repeated a specified number of times, the CONTINUE statement, which terminates the REPEAT group, and the MREF statement, used to refer to other macros from inside a macro definition.

The text font definition entity is used to define characters and character fonts not provided in the font definitions of IGES. (In the IGES General Note entity, font characteristics are identified by an integer between 0 and 6. These integers are determined on a system dependent basis.) The text font entity pairs an ASCII value with a subfigure. The subfigure contains the geometric components necessary to draw the character.

The line font definition entity is used to generate line fonts with repeating patterns. Repeating patterns are specified by on or off line segments. Up to 16 segments can be used in the basic repeating pattern. A repeating subfigure pattern can also be accommodated by this entity.

The IGES

Subfigure Definition

And

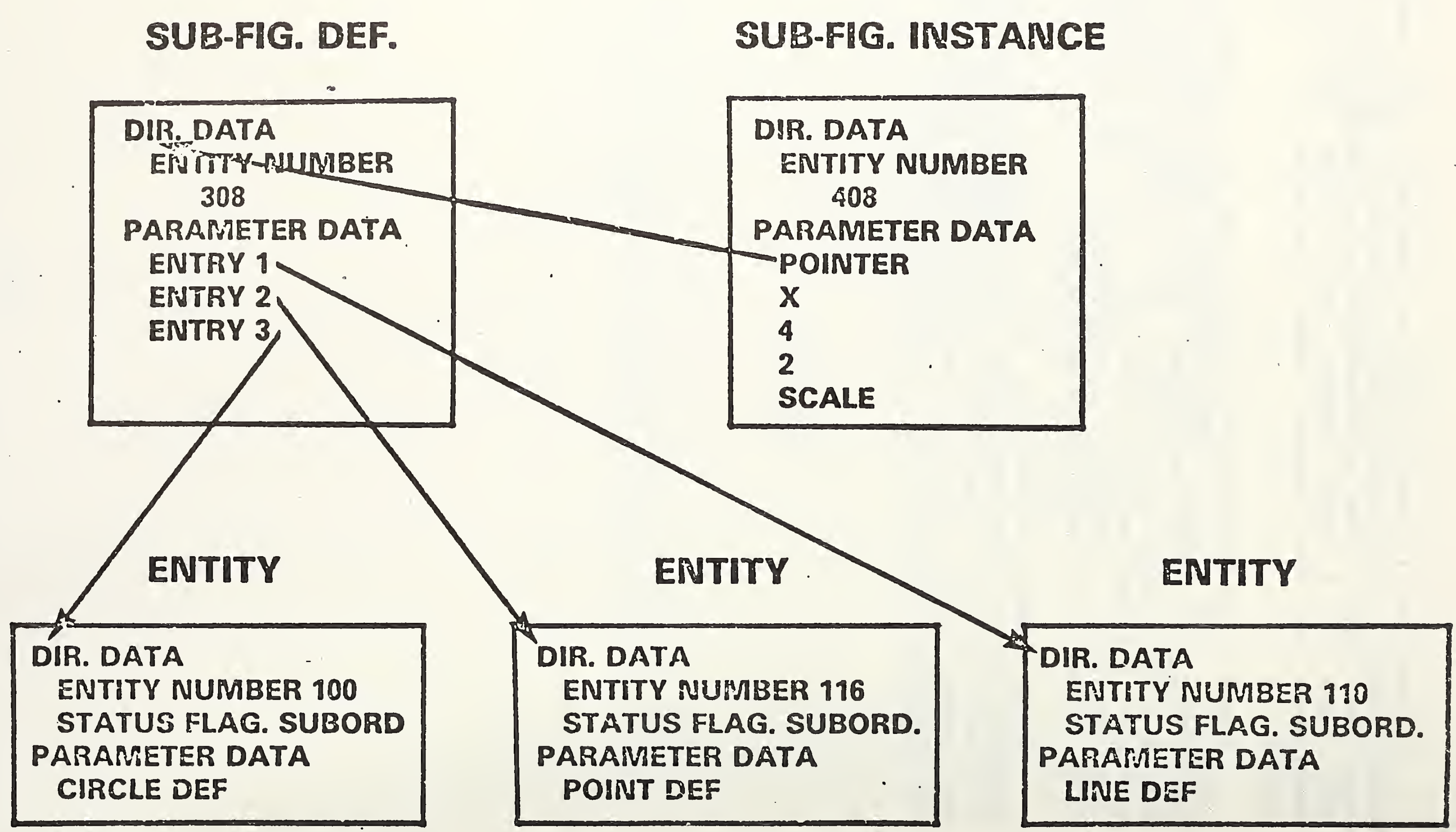
Subfigure Instance Entities

A subfigure is exactly like a complete part description, except that it is intended to be used within the description of some other part. Thus an "instance" of a subfigure may occur only once in a part design, or it may occur many times. Subfigures may be nested, thus providing a hierarchical capability.

There is an IGES entity dealing with the definition of a subfigure, and also an IGES entity used with each occurrence of the subfigure. The subfigure definition entity specifies pointers to specific entities or to other subfigures. The subfigure instance entity refers back to the definition, and also contains information pertinent to the location and the scale factor for a particular occurrence.

As an example of the use of a subfigure, consider the occurrences of a hex-head screw in a number of different places in a part design. A subfigure entity could be used to represent the screw, and a subfigure instance for each occurrence within the design.

SUBFIGURE DEFINITION & INSTANCE



The

IGES

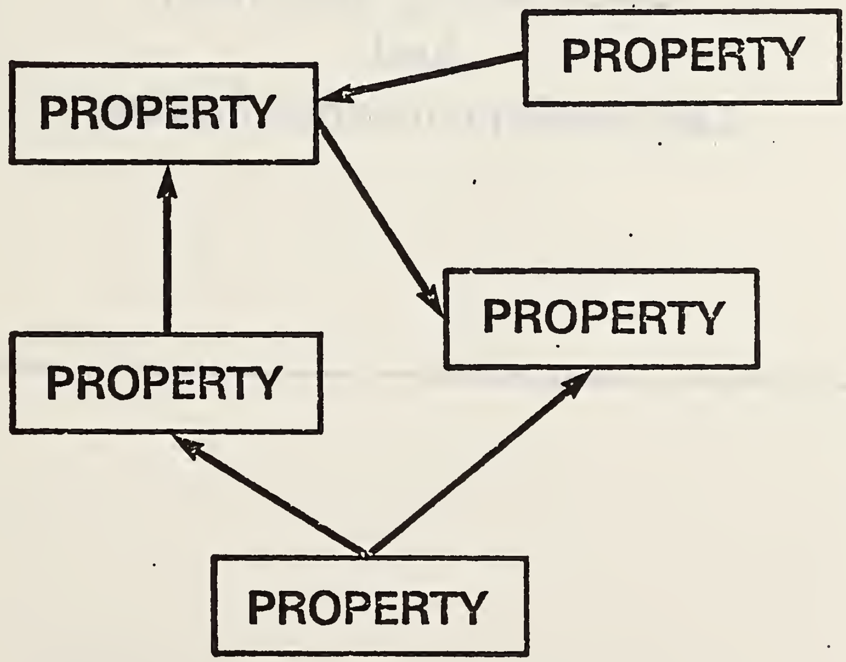
Property Entity

The property entity is meant to contain any type of data (integer, real, or text) which is necessary to enhance the description of a particular entity. For example, on a printed wiring board, the width of a line which is part of a conductive path could be specified as a property value.

Any entity in IGES may point to one or more property entities. Properties are referred to by the "associated properties" pointers in the parameter data of the IGES entities.

In particular, a property entity may point to other property entities, thus allowing the construction of networks. Networks are useful for maintaining information such as signal strings, dimension dependencies, etc.

PROPERTY GRAPH



NETWORK

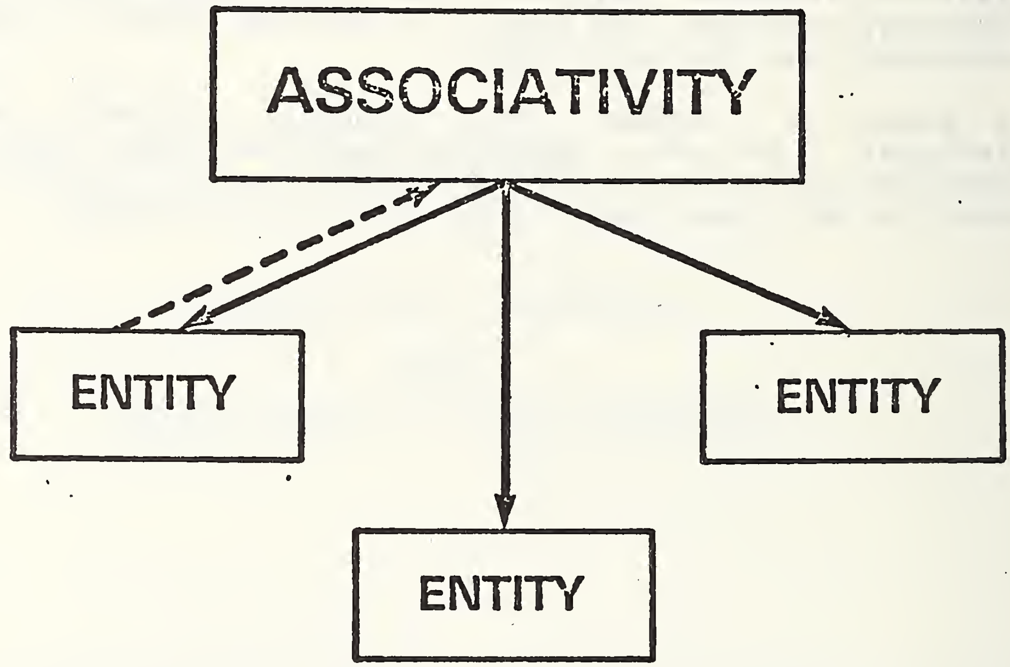
The IGES

Associativity Definition
And
Associativity Instance Entities

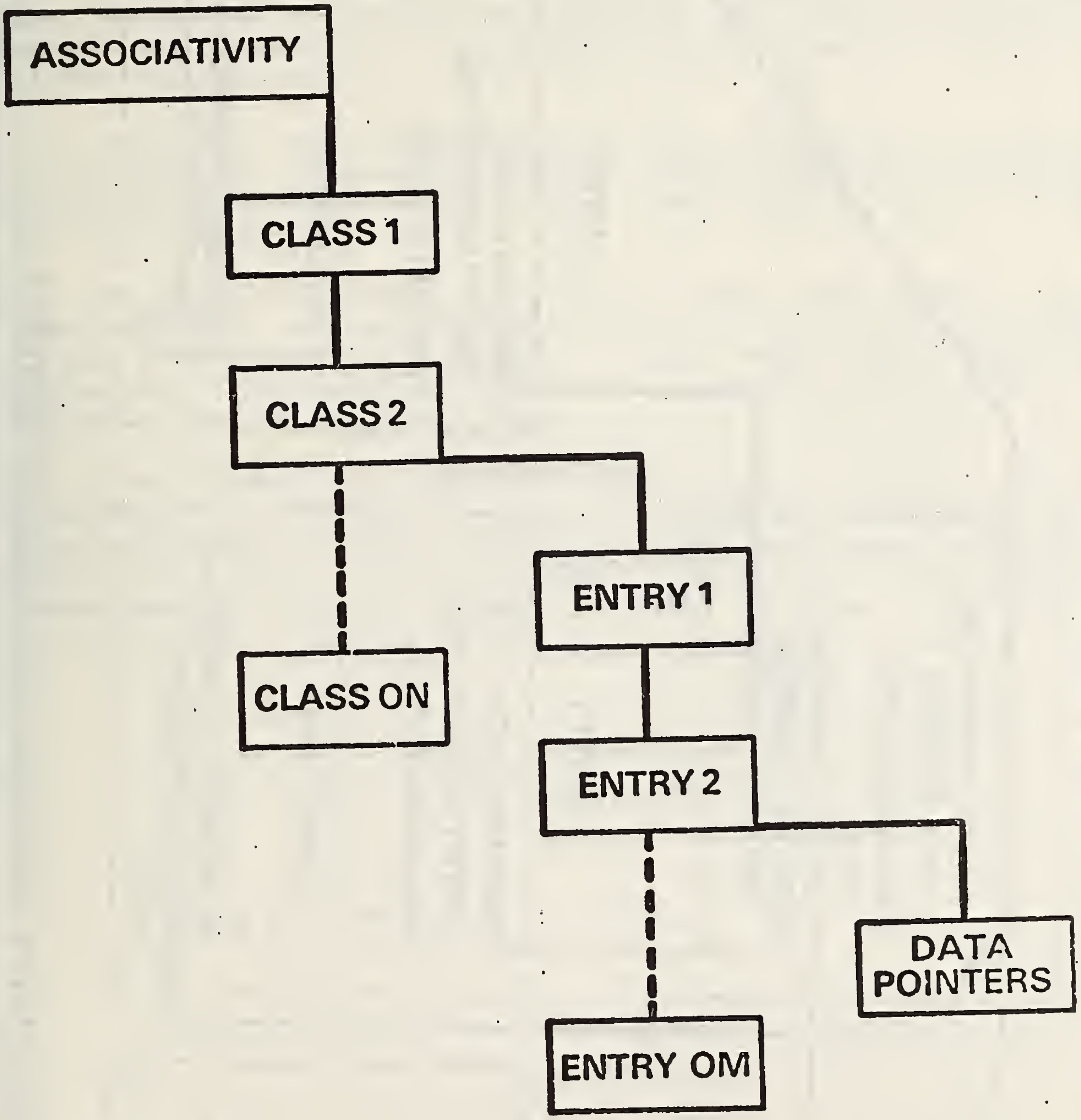
The IGES associativity entity is like the subfigure entity in that there is an associativity definition entity and an associativity instance entity. The associativity instance entity is used each time the defined associativity relation occurs.

However, the associativity definition entity is quite general. It specifies the structure of a logical relationship rather than specific entities which are to take part in the relationship. The logical relationship may entail one or more independently defined "classes", each of which may have one or more entries. A class may be ordered or unordered. The associativity instance defines, for each occurrence of the associativity relation, the number of entries in each class, and the necessary data for each entry.

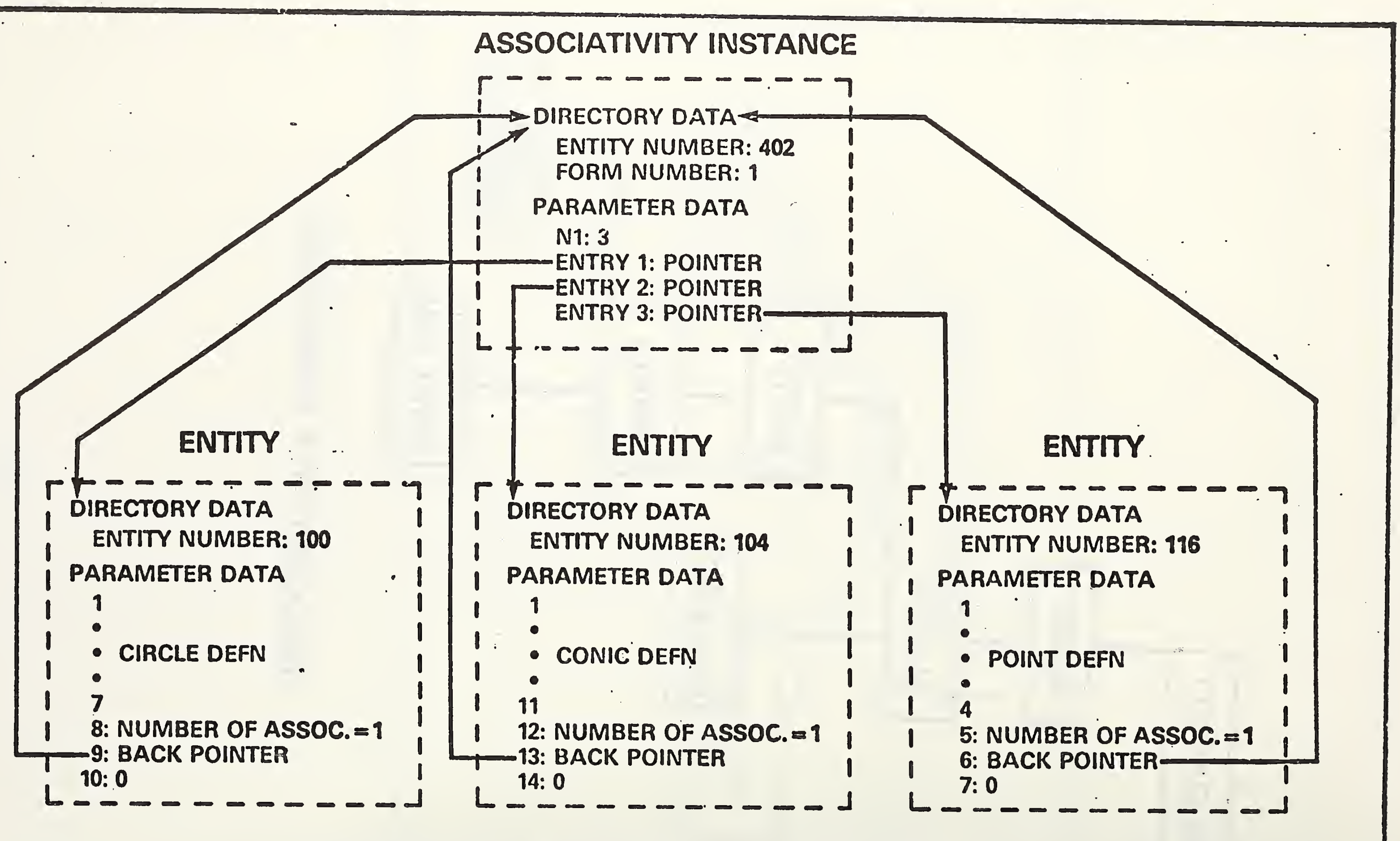
A group is perhaps the simplest example of an associativity. For this, there would be one class, which would be unordered (by definition). In a given instance, each entity to appear in the group could be specified by a pointer.



ASSOCIATIVITY



ASSOCIATIVITY DEFINITION



ASSOCIATIVITY INSTANCE AND RELATED ENTITIES

An example of an associativity instance for a group.

This associativity instance entity specifies, by means of the parameter N1, that three entries are to be involved in this particular instance. The pointer for each entry identifies the participating entity.

The form number parameter is the mechanism by which the associativity instance entity identifies the corresponding associativity definition entity. Form numbers from 1 to 9999 can be accommodated.

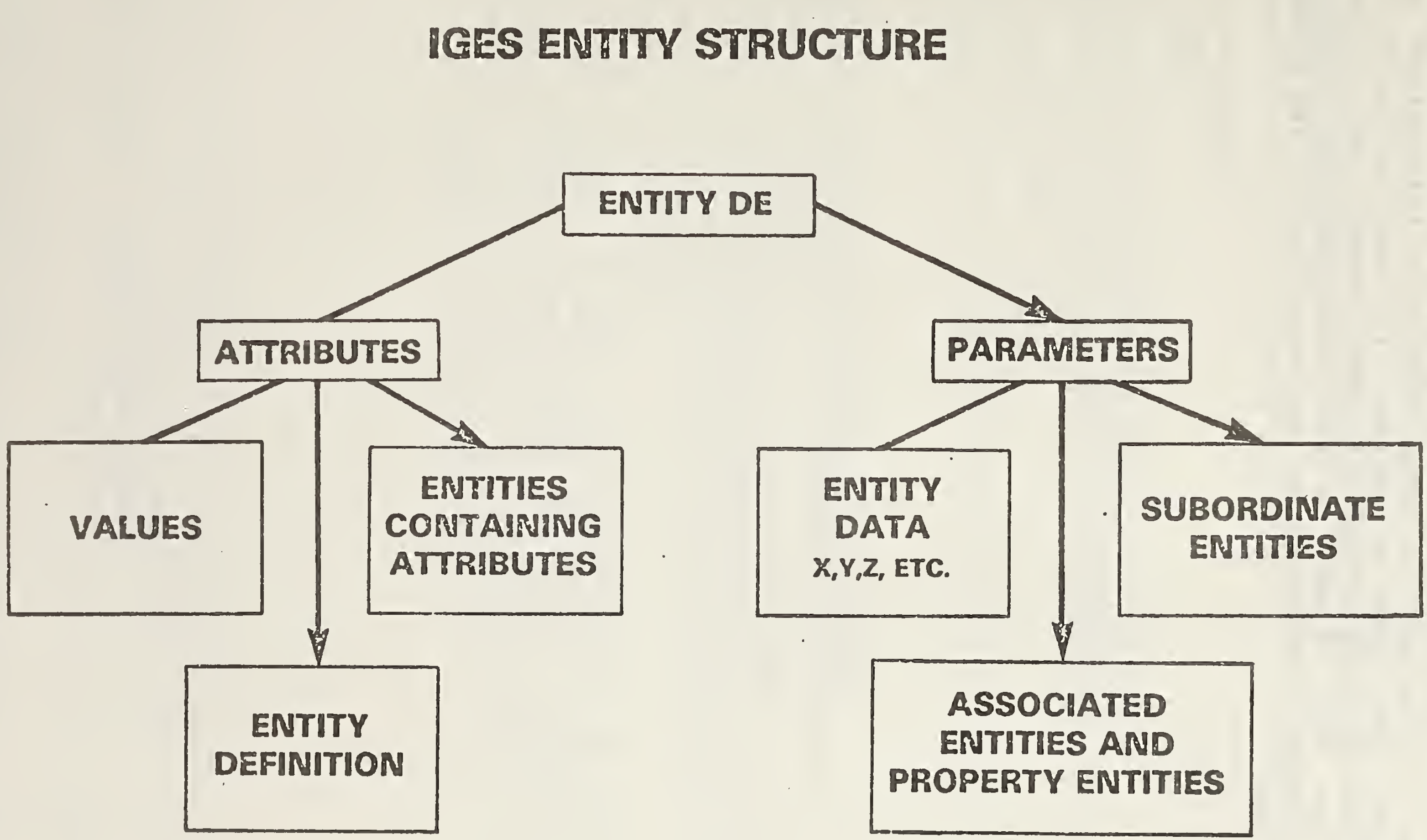
If the form number is between 5001 and 9999, then the associativity definition will be included within the IGES file. If the form number is between 1 and 5000, the associativity definition is considered to be a "standard" one, and need not be included within the IGES file.

Form number 1 is the form number for a group. Thus, the definition is known to specify one class, unordered, one data item for each entry in the class, which will be a pointer. The definition also specifies that each entity participating in a group instance will contain a back pointer to the parent associativity instance entity.

A Closer Look

At The

IGES Entity Structure


IGES ENTITY STRUCTURE
ENTITY DE
ATTRIBUTES
PARAMETERS
VALUES
ENTITIES CONTAINING ATTRIBUTES
ENTITY DEFINITION
ENTITY DATA X,Y,Z, ETC.
SUBORDINATE ENTITIES
ASSOCIATED ENTITIES AND PROPERTY ENTITIES

The IGES entity structure. A line between two boxes means that the information in both boxes is within the same set of records. A line with an arrow means that information is located elsewhere, and that a pointer is used to locate it. Thus, attributes are part of the directory entry (DE). The entity definition box is used in those cases where it is necessary to either change an existing entity definition or add a new entity definition.

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10. SUPPLEMENTARY NOTES

☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

11. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)

This publication is a technical briefing on the Initial Graphics Exchange Specification (IGES) which was published as NBSIR 80-1978 (R). The briefing serves two purposes: (1) to give the reader a broad overview of the Initial Graphics Exchange Specification and (2) to provide material for use in preparing briefings about IGES for presentation to technical groups.

The briefing is divided into two parts. Part 1 consists of a set of slides and associated text. The slides and text are organized in tandem. The intent of the text is to furnish associated information (for each slide) as opposed to furnishing specific text that is to be read verbatim. The information in this section is "soft" (not overly technical). Part 2 consists of more technical material. In this section text that can be read verbatim is provided for each slide.

12. KEY WORDS (Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)

computer aided design (CAD), computer aided manufacturing (CAM), exchange format, geometry, interface, graphics, file, entity

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