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An Overview of
Computer Graphics Industry Standards

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ABSTRACT

This paper presents the status of the family of computer graphics standards that have been under development in recent years. In order to take advantage of the graphics standards, the industrial communities should be aware of what standards exist, and the relationship of the standards to each other. Since it is also beneficial to understand the process for the development of standards, the role of organizations in the standards-making field and the standardization process is presented.

This discussion will provide an introduction and reference source for the computer graphics standards for those who have a need to understand the emerging standards, but have no technical involvement in their development. A level of understanding is provided which will assist in determining whether or not a particular standard would be appropriate for an intended application, and if further research into the standard might be required.

INTRODUCTION

The commitment of industry to standards is a result of the benefits that standards offer. Standards exist throughout industry at both a national and international level. In the realm of computer and information technology these standards include definitions for programming and languages, and address rules for exchanging information. It has taken many years for the communications and the graphics standards established for the computer industry to be developed. Now, however, these standards have emerged, and individuals who will use computer graphics have a responsibility to themselves to understand this family of standards and their relationship to existing communications standards. This paper is primarily directed to the family of computer graphics standards that are evolving. These include: Graphical Kernel System (GKS), GKS-3D, Programmer's Hierarchical Interactive Graphics System (PHIGS), Computer Graphics Interface (CGI), and the Computer Graphics Metafile (CGM).

These standards have been developed under the auspices of the American National Standard Institute (ANSI), and the International Organization for Standardization (ISO). ANSI, headquartered in New York city, was founded in 1918. It is the coordinating organization for America's voluntary standards activities, and also the coordinator for U.S. participation in the ISO arena. There are 900 companies with membership in ANSI, and 200 trade, technical, professional and consumer organizations participate in ANSI activities.

ISO develops standards at the international level; these standards cover all fields except for electrotechnical standards which are covered by the International Electrotechnical Commission (IEC). ISO has standards organizations from over 75 different countries, with 160 technical committees and 2100 subcommittees participating as working groups.

STANDARDIZATION PROCESS

American National Standard Institute

ANSI is a non-profit, privately funded organization. ANSI itself does not develop the standards, but rather coordinates the efforts of qualified organizations to develop the standards. The organizations participating in the standards making process are technical experts from technical, trade, professional, labor and consumer organizations, government agencies and industry. ANSI identifies the need for a standard, provides the guidelines and procedures to be followed by the standards-making organizations, and serves as the distribution point for the purchase of standards.

Committees, which are recognized by ANSI, define a scope of work for the project area-of-interest. These committees are staffed by individuals who have the credentials, expertise, and interest to work on the standard. These individuals can be from industry, government, business, or academia. The standards are developed under the procedures specified by ANSI, and then submitted for public review. After the public review period, and provided that all comments received during the public review are satisfied, the work is submitted to the ANSI Board of Standards Review (BSR). The BSR reviews the proposed standard to assure that it was developed under an open process with all interested parties having opportunity to participate or express their views, and that all comments were carefully considered. After all conditions are met, BSR will take action to approve the standard. For the information processing field, X3 is the standards development committee accredited by ANSI. The X3 committee is administered by the Computer Business Equipment Manufacturer's Association (CBEMA), located in Washington D.C. There are approximately 30 technical committees within X3.

Standards can also be developed by an independent group or organization which has been accredited by ANSI (such as the IEEE). Such a group can take a standard which they have developed, and use the "canvass method" for review. To accomplish this, a list of knowledgeable persons or experts in the area of interest for the standard is submitted to ANSI. The proposed standard is then distributed by ANSI to those included in the list. The results of the canvass are submitted to the BSR, and again, when the proper conditions are met, the BSR will take action to approve the standard.

ANSI is also the manager and coordinator of U.S. participation in ISO. ANSI is influential in governing ISO through its membership on the ISO council, and participates in the Executive, Finance, and Planning Committees. This provides industry in the U.S. an avenue by which they can influence the contents of international standards.

ANSI Process for Developing Standards

The process is started by submission of Standing Document 3 (SD-3) which is a project proposal stating the goals and scope of the standard. The SD-3 is submitted by the Technical Committee which will be responsible for the standard. The project must be approved by the X3 Standards Planning and Requirements Committee (SPARC).

The Technical Committee then prepares working drafts (WD) which are circulated for comments within the Technical Committee.

When a Technical Committee feels the proposed standard has been developed into a stable state, the document is sent out for public review as a draft-proposed American National Standard (dpANS). SPARC will review the document to assure it meets the goals established in the SD3, and falls within the scope of the project defined.

The initial public review period is four months, subsequent public review is two months. If a standard is complex, it may well go out for more than one public review. If any comments are received as a result of the public review, they must be addressed by the Technical Committee and responses generated for each comment.

When the Technical Committee has approved a document after the public review period that results in no technical changes, it is forwarded to the Board of Standard Review (BSR) for acceptance as a standard. If the BSR approves the dpANS, ANSI is then authorized to publish it as a standard.

The International Organization for Standardization

The International Electrotechnical Commission (IEC) was formed in 1906 by national committees from 44 different countries. ANSI represented the US National Committee. The International Standards Organization was formed in 1946, and develops, and monitors international standards that facilitate world trade, protect the environment, and benefit the safety and health of the public (the exception is electrotechnical standards).

As a member of ISO, ANSI has participants in technical committees, and/or subcommittees which take an active part in the development of international standards. This includes sending delegates to the various meetings, technical contributions to a draft standard, review of the proposed standards, and initiating, resolving, and voting on the issues relating to a draft proposed standard. These activities are accomplished through Technical Advisory Groups (TAG's). The TAG is frequently the committee or organization developing the parallel American standard. A Secretariat is appointed as the TAG administrator. It is the duty of the Secretariat to arrange and conduct the international meetings, and to develop and advance the proposed standards.

Technical Committee 97 is the international equivalent of X3. The TC97 Open Systems Interconnection (OSI) subcommittee (called SC21) has computer graphics assigned as Working Group 2 (WG2) Other subcommittees within SC21 include:

- Working Group 1 (WG1) - OSI Architecture and Reference Models
- Working Group 3 (WG3) - Data Bases
- Working Group 4 (WG4) - OSI Management
- Working Group 5 (WG5)-Operating Systems Virtual Terminal, and File Transfer
- Working Group 6 (WG6)-Common Upper Layer Services and Protocols.

The ISO nomenclature for computer graphics standardization is TC97/SC21/WG2.

ISO Process for Standardization

At the ISO level, the standardization process is started when a Subcommittee or member body submits a proposal for a New Work Item (NWI) to TC97. The NWI is sent out for a three month letter ballot. Each country has one vote on whether or not to accept the NWI. The NWI is often forwarded with a base document.

If the NWI is approved, the proper Subcommittee Working Group prepares Working Drafts (WD). Projects are managed through the creation of a Rapporteur Group (a subgroup within the Working Group). The Rapporteur Group holds meetings as necessary to prepare the WD.

When the Rapporteur Group feels that major issues concerning the WD have been resolved, and the WD is in proper condition, the Working Group submits the document to the Subcommittee to be sent out as a letter ballot to register it as a Draft Proposal (DP). (There can also be a resolution by the Subcommittee at one of their regularly scheduled meetings to accept the WD for DP). An ISO number is then assigned to the proposed standard and it is sent out for a three month DP ballot among member bodies. An editing committee responds to comments. If appropriate, changes are made to the document. Additional DP cycles may be necessary.

If consensus is reached that the DP is acceptable, it is promoted to Draft International Standard status. This document is then distributed by the ISO Central Secretariat for a six month ballot by TC97 and all ISO member bodies.

Comments to the DIS must be responded to by an editing committee and the document editor. If any substantial technical changes are made to a DIS, it will again be sent out for DIS; if the document is accepted, the final International Standard text is submitted to the ISO Secretariat for approval by the ISO Council. It can then be published as a standard.

GRAPHICS STANDARDS /RELATIONSHIPS

ANSI X3H3 is the Technical Committee appointed to address graphics standards. This committee is currently working on five standard activities.

- Graphical Kernel System (GKS)
- Graphical Kernel System-3D (GKS-3D)
- Programmer's Hierarchical Interactive Graphics System (PHIGS)
- Computer Graphics Virtual Device Interface (CGI)
- Computer Graphics Metafile (CGM)

GKS, GKS-3D, and PHIGS each represent a different level of functionality, and therefore are available to a different user constituency. All of these standards are developed to allow both application-program portability, and programmer portability. Figure 1 shows a reference model for this family of graphics standards, and also the relationship between these standards and standards for communication protocols and the representation and transmission of graphical data.

GKS - GKS provides a basic set of computer graphics functions for applications to produce two-dimensional computer generated pictures. It supports graphics output primitives (polylines, polymarkers, text, etc.), and supports logical input device classes that are readily mapped into a variety of physical input devices: joysticks, trackball, mouse, lightpen, etc.. It provides device independence -- i.e., the ability to create graphics on a wide range of output devices: vector-refresh CRT's, direct-view-storage tubes, color CRT's, X-Y plotters, etc. GKS also serves manufacturers of graphics equipment as a guideline in producing useful combinations of graphics capabilities in a device. GKS does not support image processing applications or window management facilities.

The GKS workstation is the central concept for realizing device independence. GKS has the functionality to manage multiple workstations which allows simultaneous output to and input from a variety of graphics equipment. GKS also supports the concept of grouping logical output primitives and primitive attributes together into a segment to facilitate the manipulation and change for a group of objects. Such changes include: transformations of a segment, making a segment visible or invisible, or highlighting a segment.

GKS provides a set of inquiry functions which allow read-only access to the GKS state list and workstation description tables. This allows GKS to supply information about primitive attributes, the state of the system, the capabilities provided by the system, etc. This information is very useful for processing errors.

GKS distinguishes between user and device coordinates and supports three coordinate systems. The World Coordinate (WC) System is a device independent system specified in user coordinate space by the application programmer. The Normalized Device Coordinate System (NDC) is an intermediate system used by GKS that maps the WC into a virtual space on x and y axes from 0 to 1. The Device Coordinate System (DC) is device dependent, and coordinates are expressed in terms of the device being used.

GKS provides an interface into a system for storing graphical information for the purpose of long term storage and exchange. It provides functions to read and write metafiles, and suggest a method for metafile formats for the storage of an"audit-trail" work session. GKS supports both an output metafile workstation, and an input metafile workstation.

GKS is the first official standard for graphics applications. It is both an American National Standard (ANSI/X3.124-1985) and an International Standard (ISO 7942-1985). GKS provides the first step in allowing applications programs to be developed on one system and ported to another with little or no changes. Figure 2 shows the architecture for a GKS implementation that was realized using the Ada® programming language. The CGI interface for this implementation is a "data stream" binding which facilitates distributed networking.

GKS-3D There will be applications for which the GKS-2D standard will be suitable, but it is also possible that an additional requirement for the production of 3D objects might exist. GKS-3D specifies the extensions necessary to GKS for defining and viewing 3-dimensional objects. A major design goal was that GKS-3D must be fully upwardly compatible with GKS.

GKS-3D has been extended to include:

- 3-dimensional output primitives
- An additional primitive, Fill Area Set which has one or more planar polygonal regions.
- A viewing transformation to incorporate a 3D view reference model.
- A new workstation setting, Hidden Line/ Hidden Surface Removal (HLHSR)
- Input model extended to provide 3-D locator and stroke input.

GKS-3D does not provide specific functions such as light source shading, texturing, and shadowing computations.

GKS-3D will incur additional computational ability (approximately 50% more) and data capacity (approximately 30% more) from the host computer than a GKS system. GKS-3D is known as ISO DP 8806, and is still under development. It is projected for ANSI public review sometime in late 1987.

PHIGS - PHIGS is a functional specification of the interface between an application program and

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the capability to control the definition, modification, and display of hierarchical graphical data structures. It addresses the needs of dynamic, highly interactive graphics applications. Primary constituents of the PHIGS system includes Computer-Aided-Design, Computer Integrated Manufacturing, Process Control and Monitoring, and scientific modeling and simulation.

A PHIGS model is constructed from geometric models of data elements called structures. The power of PHIGS lies in the way these structures are organized and manipulated. It provides the functionality to interactively edit these data structures which are defined as a hierarchical data organization. Picture construction and user interaction are supported, and the structured data definition allows pictures to share component objects.

PHIGS will take good advantage of the advanced capabilities of the new generation of "intelligent" scientific/graphics workstations. However, many existing graphics devices do not have the capability to handle the storage capacity or complexity demanded by PHIGS. PHIGS will place an increased demand on the host processor, and the graphics device used, at a comparable increase in the cost of the hardware and the software necessary to support it.

PHIGS is known as dpANSI X3.144; the first public review closed March 22, 1986. The second public review will be in early 1987. At the ISO level (document SC21/N819) it has been submitted for the first DP.

CGI - The CGI specifies the set of functions for basic control and data exchange between the device independent and device dependent levels of the graphics system. CGI defines the syntax and semantics of the set of elements which can be exchanged across the virtual device interface. It will primarily operate at the device driver level.

The device driver is that portion of the graphics system that translates commands and data from the device independent structures in the form required by the physical output and input devices. The CGI can be implemented as a software to software interface (known as a procedural interface with a binding to one or more programming languages). It can alternatively be implemented as a software to hardware interface, which would consist of a "data stream" binding to one or more graphical device using a standardized encoding of the CGI as the device protocol.

Since the CGI interface is very complex, the final ANSI and ISO CGI standard are not expected until 1988 or 1989. It is at the draft proposal stage in ISO, and is being readied for the first public review in ANSI. Current implementations of GKS and/or PHIGS are using proprietary CGI schemes. At the time CGI becomes a standard, vendors can consider reimplementing their CGI interfaces to conform to the new standard.

CORE - The Core System was the first proposed graphics standard here in the United States. It was developed by the Graphics Standard Planning Committee (GSPC), Special Interest Group - Graphics (SIGGRAPH), Association for Computing Machinery (ACM). Development was started in 1975, and the work was terminated in 1979 with a special report on CORE issued by SIGGRAPH. The X3H3 committee for computer graphics was appointed by ANSI in 1979, and this committee adopted the CORE report as the starting point for the US national standard. In the ISO arena, the Graphical Kernel System, a software package developed in Germany was adopted as the basis of their standard work. After a great deal of evaluation, ANSI adopted GKS as the basis for the standard in 1982.

Much of the CORE system functionality is contained in the GKS standard, and it has served as a model for both the input functions of GKS, and the definition of interactive operator inputs. A major failing of the CORE was the lack of language bindings which resulted in each implementor defining their own set of subroutine calls with different subroutine names and different parameters. This prevented application programs from being portable. The CORE system is considered a "defacto" standard, and there are many commercial implementations available in the United States. The CORE System is not under consideration as a formal standard by ISO or ANSI because many of its features are already incorporated into GKS.

Language Bindings for Computer Graphics

The graphics standards define the functionality needed by a particular constituency for their particular graphics applications. An important issue considered by the standards committees was how to access these functions from the different programming languages, and maintain program portability across different implementations of the standards. The solution was to define a language binding, which specifies the interface to each function in the syntax of the language being bound.

Language bindings have been developed for GKS in FORTRAN, Ada, Pascal, and C. Each of these language bindings will also become a standard. The FORTRAN binding is already a standard in the U.S., ANSI X3.124.1-1985. The Ada binding has been through the public review period, and is being submitted to the BSR for final review. Pascal is being readied for public review. The C binding is ready but cannot be submitted for public review until the C language itself has become a standard.

Standards for Graphical Data Storage and Transmission

The previous section discussed the standards developed or under development which specify the semantic functionality that should be supported by graphics software package. It is equally important to consider the storage and transmission of graphical data structures. The standards or proposed standards which address this are given below.

CGM - The CGM is one of the standards developed under the auspices of the ANSI X3H3 and ISO/TC97/SC21/WG2 Technical Committees. It is the standard definition of a file for the capture, storage and retrieval of pictorial information. There are three formats that have been defined for the CGM:

- A binary encoding: minimizes the effort for generating and interpreting the metafile, but not efficient for transmissions across networks.
- A character encoding: requires minimal metafile size, suitable for transmission across networks.
- A clear text encoding: easy to type, read, and edit.

One or more pictures can be stored in a metafile. Access to these pictures can be either sequential, or random.

The Graphical Kernel System Metafile (GKSM) is a metafile system internal to GKS that is suitable for audit trail generation (session capture). A suggested format for this type of metafile is contained in Annex E of GKS. (This annex is not an integral part of the GKS standard.)

The method of creation of a metafile is through a metafile generator, and the method for reading a metafile is through a metafile interpreter. These specific mechanisms are not part of the CGM standard, but an Extended Metafile working document is being proposed which will address the functionality required for the metafile generator and interpreter.

The CGM is an ANSI standard: ANSI X3.122-1986.

Initial Graphics Exchange Specification (IGES)

IGES was designed for the exchange of database information between computer-aided systems. It establishes information structures to be used for the digital representation and communication of product definition data. The primary constituency for IGES is the CAD/CAM industry. It provides a data format for describing manufacturing and product information (in a device-independent manner) which is created and stored in a computer-readable format. The mechanisms for generating and interpreting the data are called pre- and post-processors (translators) which are generally available from the equipment vendors.

IGES was published as ANSI Standard (Y14.26M) in September 1981. In April 1986, the IGES Organization published Version 3.0 of the specification, which is available from the US Department of Commerce, National Bureau of Standards, Document NBSIR 86-3359.

Product Data exchange Specification (PDES)

The goal of PDES is the exchange of product models with sufficient information content that will allow interpretation directly by advanced CAD/CAM application programs. The draft version of PDES will be functionally the same as the current version of IGES with a data migration path defined for conversion from IGES to PDES. PDES will include a geometry model that will include solid model representations. This will be coupled with non-geometric data, and the relationship information from the original data base will be preserved. Version 1.0 of PDES will address mechanical product definition, electronic, architectural and drafting applications.

North American Presentation-Level Protocol

NAPLPS was developed to define a text-and-graphics interface for transmission of data to a display or recording device. These devices would have sufficient local intelligence to process the NAPLPS data stream. It was originally intended to service the VIEWDATA,-VIDEOTEX industries, but some graphics vendors have adapted it for use with their equipment.

NAPLPS uses a code extension technique that allows encoded overlays to be used in conjunction with the ASCII code set. The code generated is very compact and can be efficiently transmitted over narrow band transmission lines. It is similar to the functionality of the CGM, but does not possess as many basic primitives as the CGM.

NAPLPS was originally developed by the Canadian Standards Association. A modified version published by the American Telephone and Telegraph Co. was published in May 1981. This version, with minor changes became ANSI Standard X3.110-1983.

RELATIONSHIP TO NETWORK STANDARDS

Open Systems Interconnection (OSI) Reference Model

The proliferation of computer usage in the office environment has resulted in an increased dependence on computer networks for distributed processing. This situation brought about the need to replace proprietary network communications that were so prevalent. This has been accomplished through the "open architecture" defined by ISO in the OSI Reference Model.This architecture uses universally accepted standard protocols to provide communications between computers, and has been accepted world-wide.

The OSI modularizes network support by providing a layered functionality. This allows networks to be tailored to meet specific needs by using common components. There are seven layers in the model.

- Layer 7 is the Application Layer which provides the network functions for reliable data transfer.

- Layer 6 is the Presentation Layer which provides a common language or data representation.

- Layer 5 is the Session Layer which provides the conduct for conversation between two systems.

- Layer 4 is the Transport Layer which provides for reliable end-to-end transfer of data.

- Layer 3 is the the Network Layer which provides for the routing and relaying of messages between systems on the network.

- Layer 2 is the Data Link Layer which provides for error detection and correction.

- Layer 1 is the Physical Layer which arbitrates physical access to the network.

The International Standard Reference Model for OSI allows standards that already exist to be placed into the proper layer in the reference model. It also serves as a coordination point for standards development where systems interconnection is a consideration. Layer 7 of the model provides the user with functions for file transfer, electronic mail, virtual terminals, and user-program callable procedures. All current graphics standards reside at Layer 7.

Manufacturing Automation Protocols (MAP)

MAP is a General Motors specification for Local Area Networks (LAN). The purpose of MAP is to support communications among computers and intelligent control devices that reside in a manufacturing environment. It is meant to support communications structure for multi-vendor factory automation systems, and to aid in the definition of purchase specifications.

It is intended that the MAP specification will reference the appropriate protocol standards for each of the seven layers of the ISO reference model for OSI. A MAP network will be a collection of OSI and non-OSI systems that will be interconnected. It specifies six system architectures, each based on the OSI reference model.

Technical and Office Protocols (TOP)

The rapid growth of the use of computers and word processing equipment in the office environment have prompted the necessity for common communication protocols in business and manufacturing. Boeing Co. addressed this need by producing the original specification for TOP. Although the initial work has been done by Boeing, and is being administered by Boeing, all vendors are welcome to participate in this activity.

The goal of the group is to establish a uniform set of protocols which provide a common communication media for office and technical environments. The first version of TOP (V1.0) is compatible with MAP (V2.1). An objective has been set to be able to move communications (files, messages, etc.) between TOP and MAP networks. TOP is meant to provide data communication in a multi-vendor environment. It intends to provide common communications for:

- electronic mail
- editable text
- file transfer
- videotext
- business analysis
- word processing
- non-text
- graphics exchange
- database management
- product data exchange

A MAP/TOP Users Group has been established with appropriate subcommittees to address technical and administrative goals. They would like to achieve industry-wide endorsement of standards to facilitate hardware-software interoperability. A subcommittee has been established to provide recommendations for GKS and CGM to be included in TOP (V3.0). Other subcommittees exist to evaluate ways existing standards can make use of MAP/TOP facilities.

CONCLUSION

The value and role of standards in our everyday environments, both in the home and in our major industries, is well established. The complexity and technical issues to be addressed and resolved in Space Technology mandate the maximum use of standards to minimize problem areas. There is no doubt that Space Technology will make wide use of graphics systems, office automation, CAD/CAM devices, and communication networks. This paper has defined a set of standards that either already exist or are under development that may be directly applicable to Space Technology. Table I provides the addresses where more information on these various standards can be obtained. The information presented should allow technical leaders and managers to evaluate the applicability of a particular standard for their intended applications, and to further research the standard as necessary.

REFERENCES

1. Bono, Peter, et al, *Graphics Standards:* **IEEE Computer Graphics and Applications,** August 1986

2. Mittelman, Phillip S., et al, *Standards in the Computer Graphics Industry:* **National Computer Graphics Association,** 1986

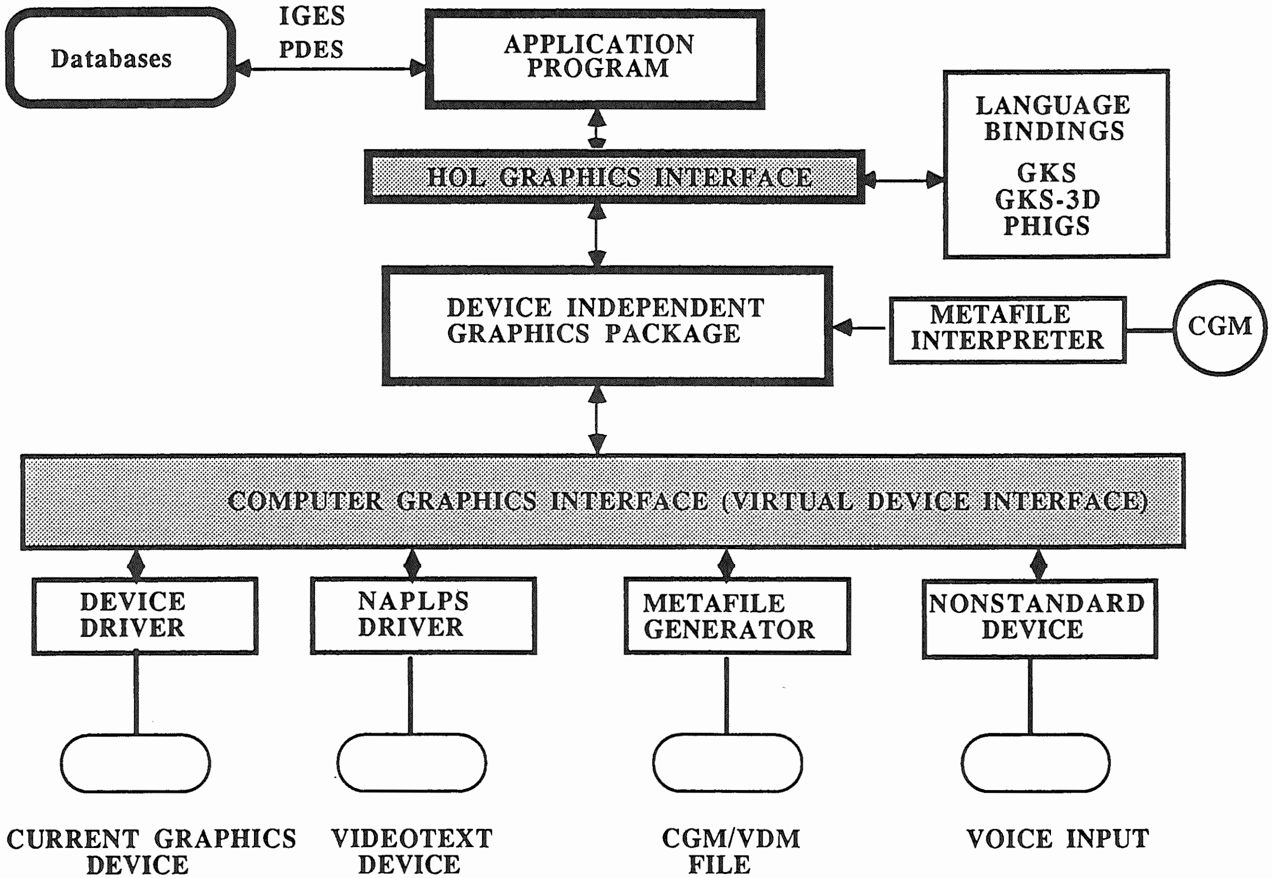

FIGURE 1. REFERENCE MODEL FOR THE FAMILY OF GRAPHICS STANDARDS

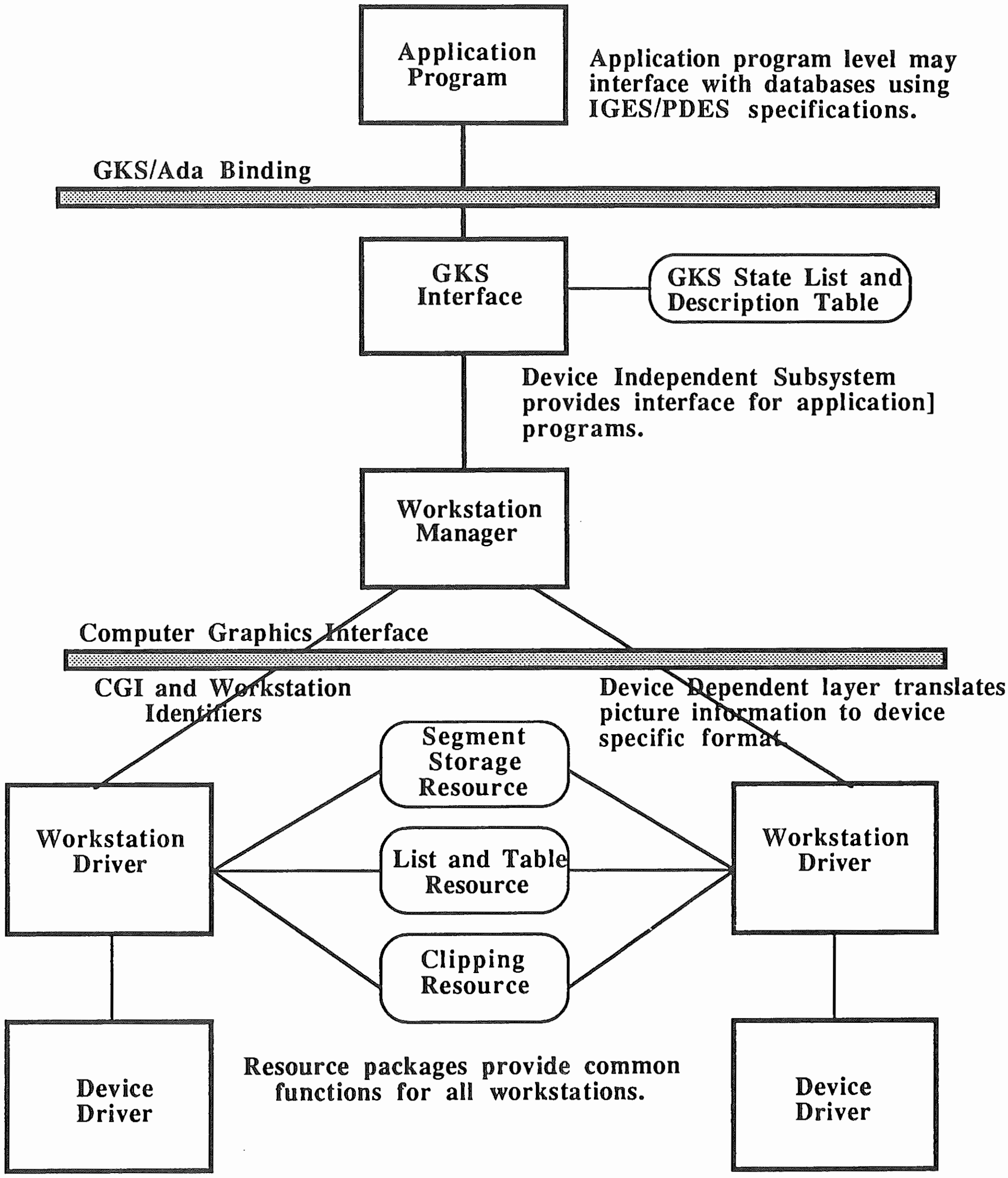

Figure 2 GKS/Ada Architecture

Table I

ADDRESSES FOR THE AVAILABILITY OF STANDARDS DOCUMENTS

Document Name and Number	Information and/or Order From:
Programmer's Hierarchical Interactive Graphics Standard, (dpANS) X3.144 Computer Graphics Interface, ISO DP/9636 Graphical Kernel System for 3-D	CBEMA 311 First St. N.W. Washington D.C. 20001 (202) 737-8888
Initial Graphics Exhange Specification Product Data Exchange Specification	IGES Coordinator National Bureau of Standards Building 220, Room A-353 Gaithersburg, Md. 20899 (301) 921-3691
Graphical Kernel System ANSI X3.124-1985 Computer Graphics Metafile ANSI X3.122-1986 North American Presentation-Level Protocol Syntax (ANS) X3.110-1983	ANSI 1430 Broadway New York, NY 10018 (212) 354-3300