IGES: An Exchange Standard for Computer-Aided Design Data

Jon H. Pittman
HOK Computer Service Corporation
St. Louis, Missouri

Fred I. Stahl
IBM Corporation
Poughkeepsie, New York

Co-Chairmen, IGES/AEC Subcommittee

INTRODUCTION

In recent years, the building process has grown increasingly complex. One result is that architects spend a significant proportion of their time evaluating, modifying, and using drawings and other information prepared by various project participants, few of whom are located within the architect's own organization. As drawings, schedules, and other "paper" representations of a building change hands with greater frequency, the liklihood of error mounts; project efficiency declines; and overall design quality may suffer.

Enter computer-aided design and drafting (CADD). CADD technology provides the design team with powerful facilities for creating, changing, and storing project data, and for producing contract documents. It stands to reason that this technology also should enable the virtually trouble-free exchange of design data among project participants. All things being equal, the architect developing a design concept using a CADD system, the structural engineer performing analysis using a finite element modeling (FEM) system, and the construction manager scheduling work at the job site using a critical path method (CPM) system should be able to exchange data freely. But as architects and engineers embrace CADD technology in ever increasing numbers, the communication of project information among design professionals and clients grows more -- not less -- complex.

The problem of data exchange is not unique to the building industry. During the 1970's the U.S. Air Force considered the solution of this problem so crucial to the efficient production of aircraft and parts that it initiated the *Integrated Computer-Aided Manufacturing* (ICAM) Project. A significant product of the ICAM activity is the *Initial Graphics Exchange Specification* (IGES).

In principal, the IGES standard specifies a "neutral" file format for transferring geometric and other data between any two CADD systems. When exchanging data between CADD system A and CADD system B, for example, data in the native format of the sending system first are translated (or "pre-processed") into the neutral file format. Data in the neutral file are then translated (or "post-processed") into the native format of the receiving system for input to the system. The basic concept is illustrated in figure 2. IGES has been a national standard (ANSI Y14.26) since 1981. The standard is continually reviewed and refined. To date, some 18 leading CADD system vendors offer translators implementing the IGES standard.

The actual task of exchanging CADD data is accomplished by the pre- and post-processors. These

are computer programs which read data in one format and translate them into another format (i.e. CADD system to IGES, and IGES to CADD system). Whenever reference is made to any particular IGES "translator" or "processor" product, it is these pre- and post-processor products that are being discussed. If a CADD system vendor supplies an IGES product compatible with their equipment, that product likely contains within a single software package the pre- and post-processors needed for two-way communications between their system and the IGES file format. Once your data have been moved into an IGES file, they can be shared with anyone possessing IGES data handling capability.

In this article we consider these concepts in some detail and in relation to the unique requirements of CADD users in the architecture-engineering-construction (AEC) industry. More specifically, we will try to answer the following questions:

What is the data exchange problem as it relates to AEC work?

How does IGES facilitate data exchange, and why is the IGES standard important to the AEC community?

What should the user look for when evaluating IGES products?

What differences exist between the "principles" of data exchange using IGES, and the realities of data exchange using IGES translator software available today?

THE DATA EXCHANGE PROBLEM: an illustration

To illustrate the problem of data exchange between two computers, imagine a situation in which two architects need to communicate information about a project but the only means of communication available to them is a letter. [figure 1] The project information is contained on a drawing which the architect has created. In creating this drawing, the lines on the paper have much more meaning than is apparent to the casual observer. The lines reflect standards, office and professional conventions, data from handbooks, product specifications, reproduction techniques, rules of thumb, and engineering data. This information is expressed implicitly on the drawing. In other words, a trained architect looking at the drawing would understand the configuration of lines on paper and be able to ascribe meanings to them which are not immediately obvious to the casual observer. In addition, each architect looking at a given drawing would impart slightly different meanings to the drawing based on his or her own experiences and expectations.

In our illustration, the architect's secretary looks at the drawing and types a letter describing the drawing. This letter can be as detailed as necessary to describe the lines and text on the drawing, but cannot have any drawings or figures describing the drawing. This letter is analagous to an IGES file.

At the receiving end, a draftsperson working for the receiving architect reads the letter and, following the instructions in the letter, recreates the drawing for interpretation by the architect. This new drawing is analagous to data that has been transferred between computers.

Clearly, this ia an ineffective way to transfer information between architects. It is, however, similar to the way computers exchange data. When two computers store information in a different way, the information communicated by the two must be placed in some intermediate form that is understood by both. This intermediate form, in most cases, does not carry as much information as exists in

either computer system. There is potential to lose information in the translation from the original system to the intermediate form (just as the secratary typing the letter may misinterpret the drawing) and in the translation from the intermediate form to the receiving system (just as the draftsperson may misinterpret the letter). In addition, the intermediate form may not accomodate all of the information in the original system (this is analagous to the letter not being capable of expressing exactly the same information as a drawing). [figure 2, figure 3]

The problem of losing information in data transfer gets even worse when one wishes to produce information on one system, transfer it to another system, modify it, and send it back to the original system. Instead of two transfers in which information may be lost, this case has four. [figure 4].

This example illustrates some of the problems involved in transferring information between computers. We will now look at the IGES means of transferring information between computers.

THE IGES CONCEPT

The IGES format is a neutral mechanism for exchanging project data among CADD systems of different manufacture. Data contained within the sending CADD system are pre-processed to create an IGES file. This file may be transported easily on magnetic tape to the receiving installation, where it is post-processed to recreate the project description within the receiving CADD system.

Within CADD systems at each end of an exchange, geometric and other data are stored as entities which are linked logically to define an individual building plan, assembly, piece of equipment, or other component. Geometric entities define points, lines, circular arcs, and other geometric elements. Annotation entities define dimensions, text notes, and other annotation elements. Structure entities specify logical connections between geometric, annotation, and other entities.

Data exchange between two CADD systems via the IGES concept requires that data in the sending system be mapped into IGES entities, and that IGES entities in turn be mapped into the receiving system. The success of any exchange, which can be directly measured in terms of the "match" between sent and received CADD data, depends on the quality of this mapping process.

Thus, if the database sent contains entities that cannot be mapped directly into the IGES file, certain data will never reach the receiving CADD system. Similarly, if all sent data map into the IGES file, but the receiving system is not capable of processing all incoming entities, data again will be lost. In some instances, IGES translator developers anticipate entity mismatches and provide mechanisms (some automatic, others optional at the user's discretion) for approximating intended data. For example, a user might approximate splines and other complex curves. Incomplete exchange of CADD data is a serious and complex problem. It may result from dissimilar implememtations of the IGES standard at both the sending and receiving ends, from the inability of the standard to accomodate all CADD entities and data forms, and from basic differences between communicating CADD systems. Often, however, problems can be avoided if *humans* at each end of the exchange verbally communicate their intentions and system capabilities.

FREQUENTLY ASKED QUESTIONS

In working with IGES, we have frequently been asked the following questions.

> *How does IGES relate to other standards (such as SIGGRAPH CORE and GKS)?* IGES is a data exchange standard. It describes the way in which two computers can exchange information stored in their

databases. Although GKS and Siggraph CORE both have some limited mechanisms to transfer data, their primary goal is to standardize means of graphics programming and communication with graphics devices. Thus, GKS and Siggraph CORE describe how a computer program communicates with graphics devices such as color displays and plotters while IGES describes how a computer can communicate with other computers. Currently, in the U.S., the only other standard used extensively for data exchange in the fields of architecture, engineering, and construction is SIF, the Standard Interchange Format. The French are developing a standard called SET and the German DIN group is working with IGES to attempt to form a standard for data transfer that is acceptable on an international basis.

Can "attribute" data be transferred? Although the title "Initial Graphics Exchange Specification" might imply that IGES is meant to transfer only graphic data, it is the intention of the group defining IGES that it be used to transfer "product definition data." That is, all of the information necessary to describe the design and fabrication of a product. To do this, of course, it is necessary to transfer non-graphic data such as part numbers, written specifications, notes, etc. IGES currently has mechanisms for passing "associativities" and "properties" (i.e. relationships between things, and non-geometric attributes). In addition, a fairly extensive set of capabilities for transferring annotation (such as dimensions, notes, and other textual entities) is included in IGES. Some of these mechanisms are difficult to use and not yet complete, but as the initial problems with exchanging graphic data are solved, these areas will get more attention.

What happens to levels, colors, pen weights, text fonts, etc? IGES provides mechanisms to transfer colors, pen weights, text fonts, and levels. However, the receiving system might not have the same capabilites as the sending system. The approach usually taken by vendors in such cases, is to try to find the closest fit possible between the attribute specified in the IGES file and the system's capabilities. For example, if a line in the IGES file is specified as magenta and the receiving system only supports white, red, green, and blue, the line would probably be defined as red or blue in the receiving system. Another problem with such descriptive data is that some minimal implementations of IGES may not take advantage of such capabilities that are built into the standard.

How many translators do I need? IGES is a neutral file format. To transfer data between two computers using IGES, one needs one translator that is capable of creating an IGES file from the database on the originating system and one translator capable of translating an IGES file into the database on the receiving system. Of course, if two-way transfer is desired, one needs translators capable of translating both to and from the native database on both systems.

Where do I get translators? Translators are usually available from the vendor of your CADD system. In some cases, it is possible to obtain translator software from third-party sources who work closely with a given vendor. Some large organizations that have developed in-house CADD systems, applications, or design databases, write their own translators.

Are the drawings transferred from one system to another going to look identical? It is certainly the intent of IGES to be able to transfer drawings that look identical. However, due to a mismatch of capabilites in the sending and receiving systems and information lost in the translation process, the attributes of some elements might be changed. This is particularly true of such characteristics as line fonts and text fonts. In general, position information, such as endpoints of lines and location of text, should be consistent across systems.

What do I do if my vendor doesn't have the translator for the system I need? IGES is intended to be a neutral data transfer format. With an IGES translator, one should be able to write a file that can be read on any other system with an IGES translator and to read an IGES file written by any other system. In practice, however, vendors often "tune" their translator to a particular system. If you cannot transfer data from one system to another, then it is fair to say that your vendor's translator (or the other vendor's translator) does not conform to IGES standards. Your only recourse is to complain to your vendor. If you discover this problem after purchase of a system, this may or may not be effective. For this reason, it is important to evaluate IGES capabilites *before* acquiring a system (see below).

Once I get the drawings, can I work with them the way I work with drawings created on my own system? Again, that depends on the capabilies of the original system, the capabilies of your system, and information lost in the translation process. If the original drawing contained say, a door, that gets translated into a collection of lines and comes into your system as such, you will have to treat it as a collection of lines rather than a door. You will not be able to transfer more capability using IGES than your system has.

Can I use standard component databases? IGES provides a mechanism to use standard components. This is a relatively new addition to the IGES specification, however, and it has not yet been extensively implemented. In addition, a standard IGES component database for architecture, engineering, and construction applications has not yet been produced. The use of such databases is clearly important to the AEC community and we expect to see development of such capabilities in the near future.

Can I use standard product libraries? No product manufacuturer has yet produced a standard product library for some of the same reasons discussed above. It is clearly in their best interests to do so when translators capable of interpreting standard component

databases become available. We expect to see standard product libraries for AEC applications in the near future.

Can I use application programs with data transferred through IGES? Since the intent of IGES is to transfer all of the data necessary to define a product (or in the case of an AEC application, a project) it is certainly within the scope of IGES to handle data necessary for an application program. This has happened in other fields, but is not yet common in AEC. Related fields such as finite element analysis, plant design, and piping have begun to make use of IGES and have developed mechanisms to transfer data to application programs. As IGES gains acceptance in the AEC community transfer of project data to and from application programs using IGES will become commonplace.

Can I transfer programs using IGES? IGES is a mechanism to transfer project data. It does not transfer programs between one computer and another.

Can I use IGES with my TRS-80, McIntosh, IBM PC, etc.? An IGES translator is a fairly sophisticated piece of software that usually requires more memory and secondary storage capabilities than are typically provided on a PC. In addition, to produce data of sufficient quality, a CADD system must usually run on a computer larger than a PC. Although some vendors claim to be able to translate IGES files on PCs, it is not likely that one would be able to do much useful work with the data from such a translation.

If I have a problem with my translation, who do I talk to? What can I do? Your vendor is the first party to talk to. The problem may be with your vendor's software or with the translation software on the other system. In this case, the two vendors will have to come to an agreement as to the nature of the problem and the correct way to fix it. It is also possible that the problem lies in the IGES specification itself. If this is the case, you or your vendor may participate in the IGES committee to change the specification to meet your needs.

EVALUATING VENDOR-SUPPLIED IGES TRANSLATOR CAPABILITY

When looking at IGES translator capablities, it is important to understand your own needs. To do this you must analyze what your system can do and what your needs really are. It is important to ask yourself the following questions:

What kind of data do you wish to transfer? Before trying to evaluate how well data is transferred between computers, it is important to know what you are trying to achieve.

Between which systems do you wish to transfer data? Although IGES, in theory, works equally well between any two systems, it is not always fully implemented. If you know which systems you wish to exchange data between, you will be able to make a more complete

evaluation.

Do you need to transfer data back to the original system? Typically, much less information is lost in a one-way transfer than a two-way transfer. If you do only need to perform one-way transfers of data, the IGES capability that you need will be much less than that necessary for two-way transfer.

Do you need to transfer a drawing or "intelligent" data? If you are only interested in transferring drawings, much less IGES capability will be necessary than transferring the information behind the drawing.

Must non-graphic data be transferred? What attribute data, if any must be transferred. Where does that data come from in the sending system and what will be done with it in the receiving system?

What data may be lost in the transfer and what data must be preserved? Inevitably, some information will be lost in the data transfer process. It is important to know what information is critical in the transfer and what information may be lost without defeating the purpose of the transfer.

It is important to realize that there will be a mismatch between the capabilities of any two CADD systems. If all of these systems were the same, there would be no need or market for many different systems. Each type of system has a unique way of storing and manipulating information. In evaluating translation capabilities, one must be aware of and anticipate this mismatch.

It is also important to understand that IGES or any other data transfer mechanism cannot transfer more capability than your system has. Because one system can produce, say, a color rendering, another system which receives color data but does not have the capability to produce a color rendering, will still be unable to do so.

After analyzing your needs and understanding exactly what you want to achieve through data transfer, it is time to begin evaluating IGES capability. To do this, you should develop a "benchmark" test and use that to test your vendor's capabilities. The benchmark test should be representative of the kind of information that you wish to transfer and should contain at least one case of all of the areas that you might anticipate problems. In essence, this benchmark is analagous to a study model. It is used to see if translation will work as you need it to in practice. To perform the benchmark test, you will need to take the following steps:

- o Create a database of the test case on your own system
- o Move it to another system using IGES
- o See if you can do what you want to do with the data on the other system.
- o If required, move the data back to the original system and see if you can do what you want to do.

The time to evaluate translation capabilities is *before* purchasing a system. Before acquiring a system you have much more leverage with your vendor than after acquisition. In addition, it is much better to evaluate translation capability before acquisition than to discover that you cannot translate the data you want to translate in the middle of a production deadline. In evaluation a vendor's translation capabilities, you should adopt a "show me" attitude. Seeing is believing, hearing it from

your salesman is not.

RELATING IGES TO BUILDING INDUSTRY NEEDS

The basis for all IGES translators is the IGES standard. To date, development of the standard has largely reflected the demands of mechanical parts manufacture, as in the aerospace and automotive industries. Indeed, many CADD systems now available to building designers are themselves variations of, or enhancements to, systems perfected in the mechanical industries. But as CADD usage by architects became more mature and commonplace, the need for more specialized tools for problem solving, modeling, drafting -- and also for data exchange -- became evident.

Realizing the need for a building industry voice with the IGES development process, some 35 CADD users from the AEC industry, CADD system vendors, and representatives of other interested groups met in the fall of 1983 to share common concerns and plan a strategy for influencing the IGES process. In February, 1984, the group formally reconvened as the IGES/AEC Subcommittee, under the co-chairmanship of Jon H. Pittman of the *HOK Computer Service Corporation* and Fred I. Stahl of *IBM Corporation* (then with the *National Bureau of Standards Center for Building Technology*).

The primary objectives of the AEC subcommittee are to:

> *Represent the building industry in all IGES deliberations, and educate the general IGES community in the specialized requirements of the industry.*
>
> *Propose and implement specific IGES enhancements intended to improve data exchange among CADD system users in the building industry.*
>
> *Provide a forum for evaluating software implementations of the IGES standard, using building industry criteria;*
>
> *Recommend specific practices for developing IGES translator software for use in the building industry.*

In pursuit of these goals, the IGES/AEC Subcommittee maintains, through both voluntary and company-sponsored efforts of its members, an active technical program. Highlights of work in progress include:

> *Development of a building industry application model;*
>
> *Development and refinement of building industry test cases for evaluating available IGES translator software;*
>
> *Proposal of specific enhancements to the IGES standard and recommendations regarding its more effective implementation.*

To carry on its technical work, the Subcommittee meets quarterly in conjunction with the general IGES meetings. THe IGES/AEC Subcommittee works in concert with numerous other IGES groups, among the more relevant being the Testing and Drafting Subcommittees.

There is considerable evidence that the IGES concept is becoming an important industrial force and that individual application groups such as the IGES/AEC subcommittee are exerting their influence on future directions of the standard. The next generation of the IGES standard (the *Product Data Exchange Standard*, or PDES) is on the "drawing board" now.

An entire layer of the PDES concept is devoted to specialized industry data exchange requirements. Although still several years off, the PDES approach already is driving international efforts to achieve effective CADD data exchange.

As the building industry continues to embrace CADD technology at an ever increasing pace, new data exchange capabilities will be required. As IGES itself matures and expands to eventually become PDES, the AEC subcommittee expects to meet its expanded responsibilities as the building industries agent. This, of course, requires industry support.

CONCLUSIONS

It is clear that data transfer is an issue that is just beginning to confront the AEC community. It will become much more important in the future as more participants in the building process begin to use computers. Data transfer is a difficult problem because it can involve very technical issues but has an impact on professional services.

IGES is one solution to the data transfer problem for the AEC community. It is not, however, a cure-all. One must be aware of its capabilities and limitiations.