Initial Graphics Exchange Specifications

Drawings created with Computer-Aided Design (CAD) tools, which were introduced in the 1960s, represented tremendous productivity gains over paper drawings, such as ease to revise and archive. CAD tools also opened new opportunities, such as enabling manufacturing instructions to be derived automatically and executed directly from the drawing. Nevertheless, as computer design and manufacturing tools proliferated to meet increasingly complex and diverse engineering needs, so did the formats that each tool used to capture and store product data. While paper drawings can be marked up by anyone with a pencil, a product model that cannot be interpreted by the necessary CAD tool is useless. For organizations to share designs across various CAD and Computer-Aided Manufacturing (CAM) tools, their data files must be formatted in a manner that the tool can recognize. This requirement has become increasingly important in an age where large manufacturers often form joint ventures to address a business opportunity, and where partners in a supply chain are being called upon to deliver an increasingly complex array of services.

Most companies find it difficult to enforce the use of a common set of CAD/CAM tools within their organization, much less across (multiple) supply chains and among joint venture partners. Because of the lack of any common set of tools, a common format for neutral file exchange is needed. Using a neutral standard for transferring information across systems drastically reduces the requirements for translators. The cost benefits are suggested by the reduction in necessary translators shown in Fig. 1. It illustrates that by using a neutral file exchange, the number of translators (for N systems) can be reduced from scaling as $n(n-1)$ to $2n$.

In 1979, a series of events catalyzed the CAD vendor and user community to create the first national standard for CAD data exchange, which is documented in the report *Initial Graphics Exchange Specification, Version 1.0* [1]. CAD systems were less than ten years old, and only a handful of products had any significant market penetration. Even at this early stage, users were overwhelmed by the inability to share data among these tools and with their own internally developed databases.

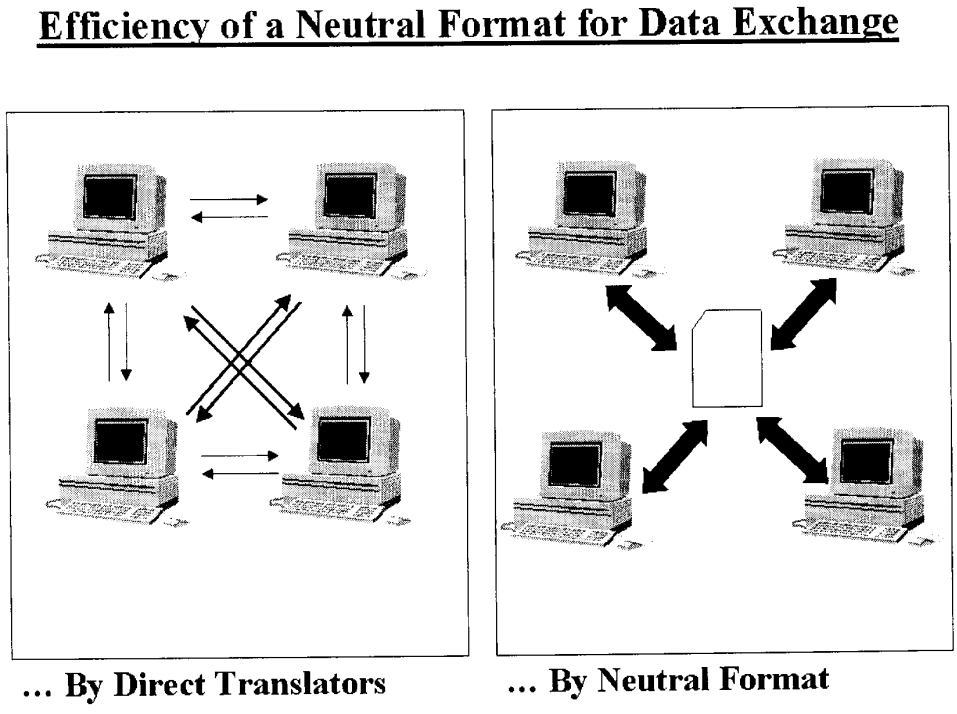

Fig. 1. Illustration of the benefits of using a neutral file exchange.

In September 1979, frustration came to a head at the two-day Air Force Integrated Computer-Aided Manufacturing (ICAM) Industry Days meeting [2]. On the first day, a representative from General Electric (GE) challenged a panel of CAD vendors, which included ComputerVision, Applicon, and Gerber, to work together to enable an exchange mechanism. While this need was intuitive from a user's perspective, this was a very threatening proposition to the CAD vendors—who feared that sharing the structure of their databases publicly would be tantamount to giving away their competitive advantage. It would have been easy to gloss over the challenge; after all, the major vendors all had at least token representation on the ANSI (American National Standards Institute) committee responsible for CAD standards. Instead, the ComputerVision representative responded with a challenge of his own: if Boeing and General Electric (and perhaps others) would contribute the CAD translators they had already developed, the vendors would share their database structures.

What led to this offer was just the right mix of business motivation and intrigue. Large Navy contracts were looming on the horizon, and no vendor wanted to look unresponsive to customer requirements.

In the evening after the panel, several interested parties gathered and asked themselves if a common translator was really possible. The room had the right mix of people and ideas at the right time. This included an Air Force, Navy, and NASA representative, each willing to fund $25,000 for such an effort. A National Bureau of Standards representative, after a call to his boss at home for approval, was willing to champion it as chair and coordinator. The IGES Organization was formed by NBS in the spring of 1980. With the fundamentals to a common translator decided, conversation turned to a name for this new translation project. A minimalist approach was suggested:

I – Interim, to suggest that it would not replace ANSI's work

G – Graphics, not geometry, to acknowledge that academics may come up with superior mathematical descriptions

E – Exchange, to suggest that it would not dictate how vendors must implement their internal databases

S – Specification, not to be as imposing as a standard.

The panel reported on the second day, and the wheels were set in motion to create an "IGES." Once the panel admitted that a common translation mechanism was possible, it was impossible to stop the momentum of the customers' enthusiasm and expectations. Applicon and ComputerVision agreed to open up their internal databases, GE offered its internal database structure, and Boeing supplied the structure of its Computer Integrated Information Network (CIIN) database. Both GE and Boeing contributed their existing translators. A core team formed, including representatives from NBS (Roger Nagel), Boeing (Walt Braithwaite), and GE (Phil Kennicott). Team members had worked closely with each of the vendors on internal integration projects. This prior experience built the expertise and trust needed to craft a solution in a very short time, and neither vendor felt it gave an unfair advantage to the other.

Soon after the ICAM Industry Days, NBS called an open meeting at the National Academy of Sciences (October 10, 1979). Around 200 people attended to herald the birth of IGES. There was an atmosphere of extraordinary excitement, although not everyone was readily supportive. In addition, although it was hotly debated, the name was accepted eventually with the minor change from "Interim" to "Initial."

After two critical reviews, the IGES team released its first draft in 1980, containing geometry, graphical data, and annotations. The IGES specification was brought to the ANSI Y14.26 committee for standardization. The first version of IGES was adopted as an ANSI standard, Y14.26M-1981 [3].

IGES successfully met a critical need. The IGES publication [1] establishes information structures to be used for the digital representation and communication of product definition data. The specification is concerned with the data required to describe and communicate the essential engineering characteristics of physical objects such as manufactured products. Such products are described in terms of their physical shape, dimensions, and information that further describe or explain the product. The processes that generate or utilize the product definition data typically include design, engineering analysis, production planning, fabrication, material handling, assembly, inspection, marketing, and field service. [4]

The Initial Graphics Exchange Specification is the U.S. national standard for the exchange of data between dissimilar CAD systems. The IGES standard, now in its sixth revision, has been expanded to include most concepts used in major CAD systems. All major and most minor non-PC-based CAD systems support some version of the IGES standard. Some of the over 1000 PC-based CAD systems (including all of the major ones) include some IGES support.

This first edition of IGES [1] served as a landmark to introduce a change in the way manufacturers thought about capturing and sharing their information about product data. As enhancements to the original version continued and IGES became an American National Standard, the *IGES Specification* was routinely in the top best sellers from the National Technical Information

Service (NTIS). Records show that through 1988 NTIS sold 2055 copies of *IGES 3.0,* and through 1991 sold 1295 copies of *IGES 4.0.* This U.S. national standard was also renowned internationally; it was adopted nationally by Australia, Japan, and the United Kingdom, to name a few. IGES was the precursor and provided the technical groundwork to the international standardization effort known as STEP—Standard for the Exchange of Product model data. The national and international impact on the development and deployment of product data standards in manufacturing has provided economic benefits to many implementing companies using product data standards for exchanging their data.

Examples of improvement brought about by the use of IGES include [5]:

- Electric Boat Corporation, along with the rest of the SEAWOLF (the US Navy's newest attack submarine) Team, pioneered the use of IGES to pass construction data in digital format directly from design to manufacturing.
- Honeywell Commercial Flight Systems (Minneapolis Operations), with its use of IGES, reduced engineering change orders from 40-120 (1989) to 0-3 (1991).
- Piccione Machine Tool & Gear made a significant CAD/CAM investment, using IGES for a neutral exchange format. Consequently, the process of manipulating their data was reduced from a manual operation of 200 hours to a mostly automatic process which was completed in less than two working days.
- Unique Tool & Gauge Inc.'s CAD/CAM department has the responsibility of importing customer CAD files into CAM for manufacturing. Utilizing several software packages, the company found with effective IGES translation they were able to use their IGES prowess as a competitive advantage offering services above and beyond what they were previously able to offer.

Today, IGES is still used as a universal tool, providing a neutral format for many companies to transfer engineering data between CAD/CAM systems. As of late 1999, over 25 vendors offered commercial IGES-supporting tools [6].

In 1987, the three authors of *The Initial Graphics Exchange Specification* were recognized collectively for their contributions to the development of IGES Version 1.0 by receiving the AIMTECH Joseph Marie Jacquard Memorial Award. The first author, Roger Nagel, was a NBS staff member at the time and is now the Harvey Wagner Professor of Manufacturing Systems Engineering in the Electrical Engineering & Computer Science Department at Lehigh University. He created Lehigh's Robotics Research Institute, established and directed the Manufacturing Systems Engineering Program, and served as Executive Director of Lehigh's Iacocca Institute for Competitiveness Research. While an employee of NIST, Nagel was a key member of the scientific team developing the Factory Hierarchical Control System in the Robotics Group. This work on hierarchical control systems, performed with James Albus, Tony Barbera, and Gordon Vanderbrug, has been the basis of hundreds of computer-based control systems for automation over the last 20 years. Nagel continues to serve as a technical advisor and consultant to NIST's Manufacturing Engineering Laboratory.

The other two authors were from industry. Walt Braithwaite is currently Corporate Vice President for Company Offices Administration at the Boeing Company. He has held numerous positions within Boeing, including Director of Program Management for the 737 and 757 airplane programs and Chief of Engineering Operations for the 747 and 767 programs. As the lead engineer responsible for technical direction in developing an information network to integrate computer-aided design and computer-aided manufacturing, he led development of Boeing's common data format and translators, which were used as a basis for developing the IGES protocol.

Philip Kennicott joined the General Electric Research Laboratory in 1961 where he made contributions in the fields of x-ray crystallography and spark-source mass spectrography. As a consultant to General Electric's Computer Aided Design Center, he was instrumental in making General Electric the largest user of CAD/CAM equipment in the world in the 1970s. This work led to the concept of a neutral database, the basis for the General Electric contribution to IGES. Within the IGES community, Kennicott served as a leader of many technical activities, including Editor of the continually evolving IGES standard. He also led a technical team to develop the Department of Energy Data Exchange Format, the first IGES application protocol. He continued this work at Sandia National Laboratories in 1989 and retired from Sandia in 1997.

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Bibliography

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