Photogrammetrische Woche 1985
Institut für Photogrammetrie
Schriftenreihe, Heft 11, 1986

REVIEW OF STANDARDS FOR CARTOGRAPHIC DATA EXCHANGE

K. Menke, Oberkochen

1. Introduction

Systems for computer-aided graphic data processing (GDP) are being used in many applications, in particular in CAD/CAM and surveying. GDP systems generally offer tools and methods for several combined applications, e. g. photogrammetry and cartography, but are no allrounders and are generally optimized for only certain tasks. This is one of the reasons why data exchange between different GDP systems is so relevant.

Data exchange between different GDP systems is not easy. There are standard data media, of course, e. g. magnetic tape, but the data produced by different GDP systems differs in syntax (coding) and semantics (significance of the codes). This necessitates format conversions.

This paper reviews GDP system interfaces and some common data exchange formats.

2. Terminology

A difference should be made between
standards = definite specifications established and published by standardizing organizations
and
products = commodities available from a manufacturer that satisfy specific requirements.
Refer also to /5/.

In the following the term "format" is used as a broader term for standards and products defining data interchange formats.

3. Standardizing Organizations

A multitude of national and international organizations is working on standards for graphic data processing. Table 1 only shows some.

Country	Code	Name/Organization
USA	ANSI	American National Standards Institute; Coordination agency for voluntary standardization; X3H3 Technical Committee "Computer Graphics Programming Languages"
USA	NBS	National Bureau of Standards; Standards for Government Agencies, prepared IGES for ANSI, for example
GB	BSI	British Standards Institute; IOS/5/WG5 "Computer Graphics"
F	AFNOR	Association Française de Normalisation
D	DIN	Deutsches Institut für Normung; NI-UA 5.9 Technical Committee "Information Processing", Subcommittee "Graphic Data Processing"; NAM-AA 96.4 Technical Committee "Mechanical Engineering", Working Group "CAD Interfaces"
EC	CEC	Commission of the European Communities
International	ISO	International Standards Organization; Represents national standardization organizations (ANSI, BSI, DIN, etc.) TC97/SC5/WG2 Technical Committee "Information Processing", Subcommittee "Programming Languages", Working Group "Graphics" TC184/SC4 Technical Committee "Industrial Automated Systems", Subcommittee "Internal Representation of Product Definition Data"

Table 1: Standardization Organizations of Graphic Data Processing

4. Standards and Products for GDP Systems

To illustrate the importance of data exchange, the typical components of a GDP system and the associated standards and products are described first.

4.1 GDP System Components

Fig. 1 shows a simplified block diagram of GDP system components. User access to the application programs forms the top level. Efforts are currently being made to standardize this interface, e. g. the icons used for graphic display of command menus /7/, /11/.

Programs for graphic applications are based on a graphics package that performs complex tasks such as the creation of map frames or complex symbols. This package contains a subroutine library for elementary functions such as plotting a vector sequence or deleting image elements. The next lower level comprises device drivers which convert the general graphics commands to the codes (protocols) required by the device for performing the task.

Devices are display terminals, plotters, digitizers etc. which are generically referred to as "graphics workstations". Vector or raster data for a graphic output device can be stored in a file for later reading or output on a plotter, for example. These files are called plot files or metafiles.

The path from the application program to the device drivers comprises device-independent interfaces. Device-dependent data protocols are only generated and interpreted at the interface between the drivers and the devices. A further requirement is the computer operating system which, for simplicity is not shown in Fig. 1.

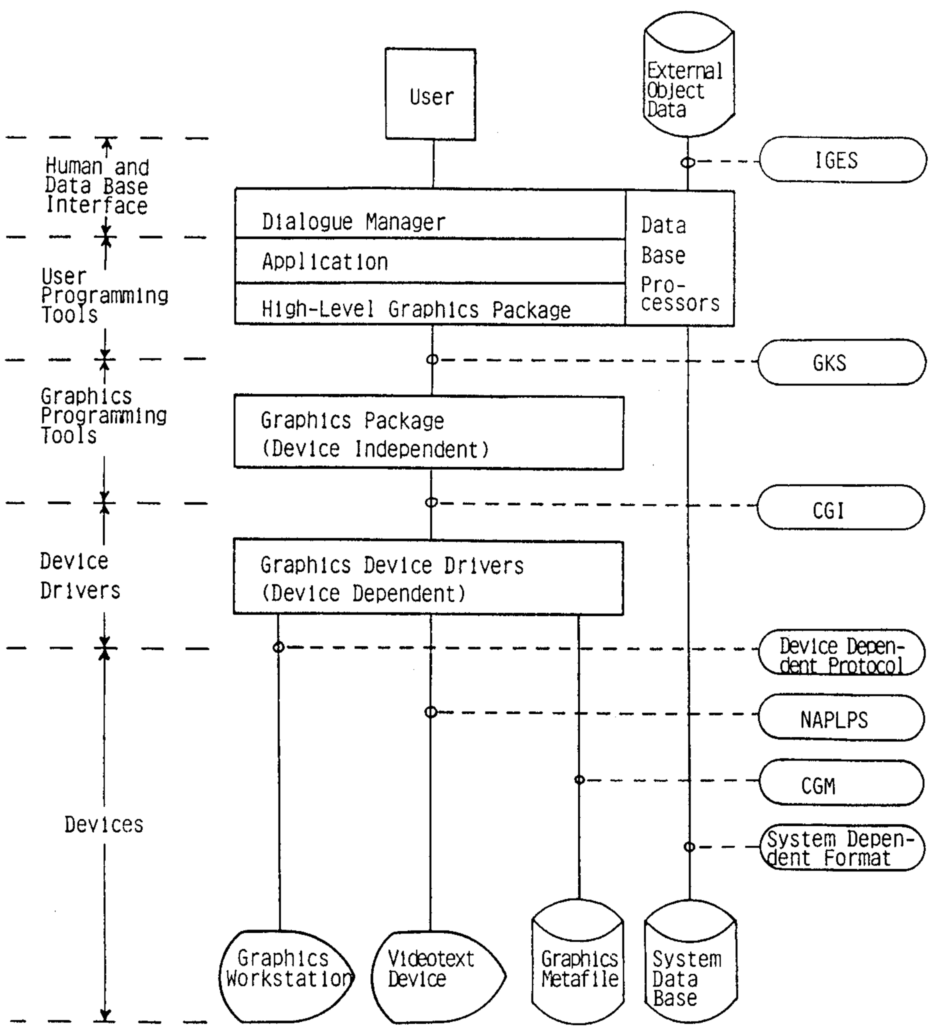


Fig. 1: GDP System Components

The interface for object data exchange among different systems is located on the same level as the user interface. Appropriate processors convert the remote format to the local data base format (postprocessor) and viceversa (preprocessor). Unlike the image data, the data base content is generally graphics-independent. Hatching lines for houses, for example, do not exist, only outlines with the meaning "house". This ensures that the data can be used in many ways, for example also for maps with differing symbolization.

Transferring image data is possible, but this paper concentrates on object data exchange.

4.2 Selected Standards and Products

A variety of standards and products already exists for the interfaces between the components described above. Tables 2 and 3 list the names of the most important standards and of some arbitrarily selected products, and correlates them to these components (see also Fig. 1).

Code	Designation, Remarks	Standardization Institute	Status
	-- Data Base Interface --		
IGES	Initial Graphics Exchange Specifications	ANSI BSI	S DP
STEP	Standard for Exchange of Product Model Data	ISO	WI
SET	Systeme d'Echange et de Transfer	AFNOR	S
CAD*I	CAD Interfaces	CEC	WI
TAP	Transfer und Archivierung produktdefinierender Daten	DIN	WI
VDAFS	Verband der Automobilindustrie-Flächenschnittstelle	DIN	S
	-- Graphics Programming Tools --		
PHIGS	Programmer's Hierarchical Interface to Graphics	ANSI ISO	DP WI
GKS	Graphic Kernel System (DIN also contains a metafile definition)	ANSI DIN	S S
PMIGS	Programmer's Minimal Interface to Graphics	ANSI	WI
	-- Device Drivers --		
CGI	Computer Graphics Interface (initially VDI - Virtual Device Interface)	ANSI ISO	DP WI
CGM	Computer Graphics Metafile (initially VDM - Virtual Device Metafile)	ANSI ISO	DP DP
	-- Device Interfaces --		
NAPLPS	North American Presentation Level Protocol Syntax	ANSI	S
	-- Devices --		
	CRT workstations	DIN	S

Table 2: Selected Graphic Data Processing Standards
(S= Standard, DP=Draft Proposal; WI=Work Item)

Code	Designition	Company/Institute
	-- Human Interfaces --	
UIMS	User Interface Management System (Association for Computing Machinery, Special Interest Group on Human Interaction)	ACM/SIGCHI (USA)
	-- Data Base Interfaces --	
ISIF	Intergraph Standard Interchange Format	Intergraph (USA)
DLG	Digital Line Graphs	US Geolog. Survey
DEM	Digital Elevation Model	US Geolog. Survey
EDIF	Electronic Design Interchange Format	about 60 companies in USA, Europe, Japan
	-- Graphics Programming Tools --	
CORE	ACM Standard, Special Interest Group on Computer Graphics (not yet a standardization institute)	ACM/SIGGRAPH (USA)
EZS	Einheitliche Zeichenschnittstelle	Bundesanst.f.Straßenwesen (D)
AZP	Allgemeines Zeichenprogramm	Contraves (CH) ISSCO (USA)
DISSPLA		ISSCO (USA)
PLOT 10 TCS	Plot 10 Terminal Control System	Tektronix (USA)
CalComp		CalComp (SA)

Table 3: Selected GDP Products

5. Benefits and Drawbacks of Standards

Standards for computer-aided cartography offer the user the following benefits:

- Portability of
  * users (human interface)
  * object data (data base interface)
  * image data (metafile interface)
  * programs (graphics programming tools)
  * programmers (graphics programming tools)
- Independence of
  * computers and operating systems
  * peripheral equipment (display terminals, plotters etc.)

But standards also have drawbacks. They generally offer much but not all the user might wish on the relevant level.

One of the reasons is that user demands grow continuously as equipment performance increases. Missing elements can sometimes be assembled from other elements, e. g. arcs replaces by vector sequences, but the resulting interface is not very efficient (the arc generator of a unit is not used, for example).

The efficiency can also be reduced if the standard offers more than the user requires for a particular application, i. e. uses only a limited part of the performance range (overlength programs or large data volumes).

Thus the drawbacks are:
- Reduced efficiency due to
  * insufficient performance
  * excessive performance.

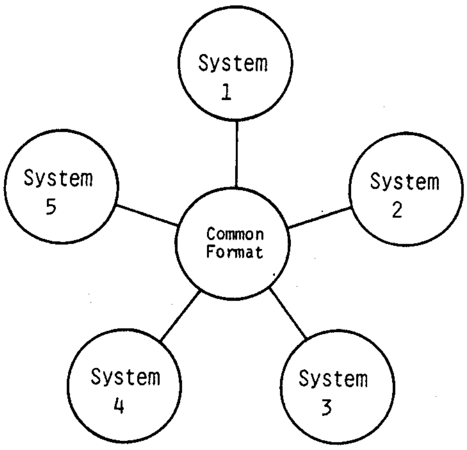
Therefore the benefits of a standard (portability, independence) must be weighed against its drawbacks (reduced efficiency) in every single case.

6. Interchange Format Requirements

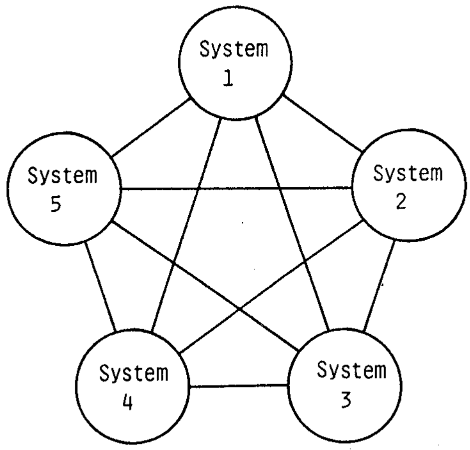
There is a series of criteria for assessing individual data exchange standards and products. The following list presents a selection of general requirements.

- Provisions for all possible element classes
- Clear separation of element classes (in particular of geometry and representation)
- Hierarchical element structure in element classes
- Unique description of syntax and semantics
- Simple and compact format
- Defined levels (e. g. 2D, 3D)
- Expandability
- Compatability with standards of other levels
- Implementation specifications (error lists, range of values, options)
- Test procedures.

The effort involved in developing the required conversion routines (processors) has not been included in this list. Standards offer advantages in this field, for when a network of GDP systems features a common standard interface, only one additional postprocessor and preprocessor each are required to add another system (Fig. 2a). If no identical format is used, a processor pair is required for each connection (Fig. 2b).



(a) Data exchange using a common format



(b) Data exchange using system formats

Fig. 2: Data Interchange between Different GDP Systems
(each tie line represents a processor pair)

7. Formats for Cartographic Data Interchange

There is a virtually unlimited number of products but only two standards (CGM, IGES) for cartographic data exchange.

CGM serves to transfer images, e. g. from an editing unit to an output unit in a decentralized GDP system. The purely geometrical description of objects is lost in part. It is therefore not particularly well suited for data exchange between data bases.

IGES has been developed for exchanging geometric and alphanumeric data but also graphic data. Many manufacturers of interactive graphic systems, the largest sellers included, already support it albeit in most cases the standard is implemented only in part.
IGES and some products are described in the following with IGES being emphasized.

7.1 IGES

IGES = Initial Graphics Exchange Specification
Origin: US Standard
Purpose: Interchange of product definition data between CAD/CAM systems, e. g. in mechanical engineering.

File structure:
- Start Section (general text)
- Global Section (word lengths,..)
- Directory Entry Section (element-independent data of fixed length)
- Parameter Data Section (element-dependent data of variable length)
- Terminate Section (check information, end of file).

Element classes:
- Geometry (point, line, area, node, transformation matrix, ...)
- Representation (general text, dimensions, hatching, ..)
- Structure and definition (associativity, fonts, views, perspecitve, etc).

Features:
- Many elements
- Much Directory Entry Section data per element, e. g. visibility, classification, line width, color, name, etc. for each element
- Hierarchical structures can be used
- ASCII and binary formats (version 2.0)
- Structured files
- 3-dimensional (surfaces).

Shortcomings:
- No clear separation between geometry and representation
- No clear hierarchical element classification
- No assignment of free labels to geometry elements
- No specification of surface definition algorithms
- Ambiguous semantics description (one of the reasons why all IGES processors are very error-prone!)
- Complex and intensive format (many unused characters, 80-character card format with ASCII)
- No defined levels
- No discernible expansion potential
- No implementation specifications
- No test procedures.

Presumably there will be an international standard (STEP) in a few years which will differ markedly from today's IGES.

For further information refer to /3/, /4/, /10/, /12/ and /13/.

7.3 DLG

DLG= Digital Line Graphs
Origin: National Cartographic Information Center (NCIC), USA
Purpose: Interchange of digitized topographic maps

File Structure:
- Header
  * Description of coordinate system, coordinates resolution, coordinates area, transformation parameters file to map, number of stored data
- Type data sets
  * Nodes or areas
  * Line segments with pointers to nodes and areas left/right
  * Coordinates
  * Classification
  * Text
- Ende of file
  * Precision information.

Element classes:
- Geometry (point, line, area)
- Structure (pointers within geometrical elements).

Features:
- Compact ASCII format
- Defined object classification
- No pure representation elements
- Texts without location specifications
- Structured files
- 2-dimensional
- Alphanumeric data within texts (user-defined).

Shortcomings:
- Tailored to specific maps (7.5 and 15 minutes quadrangle series, 1 : 2 000 000)
- Low coordinates resolution (2 bytes, resolution about 0.006 mm in the map = 0.15 m at scale 1 : 24 000)
- Only one line interpolation method (linear), i. e. no curves and arcs
- No representation of hierarchical object structures.

The NCIC offers digital map data in DLG for sale. For further information refer to /8/.

7.3 Standarddatenformat

Complete name: Das Standarddatenformat zum Austausch kartographischer Daten (Standard Data Format for Cartographic Data Exchange)
Origin: Surveying Agencies of the Federal Republic of Germany
Purpose: Exchange of digitized topographic maps

File Structure
- 2 header records
  * Description of map type, map sheet, year, digitizing scale, coordinate system, transformation parameters
- Type data sets
  * Object codes (additional information such as axis/left/right line, elevation optional)
  * Geometry (planimetric) (interpolation type - linear(curves/arcs -, 4 planimetric coordinates XY)
  * Geometry (planimetric and elevation) (interpolation type, 2 coordinates XYZ)
  * Geometry (planimetric and elevation) with point number
  * Text layout (name type as additional representation information;location and direction of text described by geometry record)
  * Names
- End of file
  * Version of used Standarddatenformat

Features:
- Compact ASCII format, 48 characters per record
- Defined object classification
- No pure representation elements
- Simple editing instructions (deletion)
- Sequential file structure
- 3-dimensional (point by point)
- Alphanumeric data (user-defined)

Shortcomings:
- Low coordinates resolution (5 unsigned digits)
- No representation of hierarchical object structures

The Standarddatenformat is currently not being used in the Federal Republic of Germany, but a somewhat modified version is being used in the Netherlands.

The "Katalog zur Verschlüsselung der Information von Grundrißobjekten (OSKA-Objektschlüsselkatalog)" /2/ is intended for object classification. This catalog has gained some significance in Germany, in particular through the ALK (Automatisierte Liegenschaftskarte) project.
For further information refer to /1/.

7.4 ISIF

ISIF = Intergraph Standard Interchange Format (initially SIF)
Origin: Intergraph Co.
Purpose: Interchange of geometric, graphic and alphanumeric data between different systems and fields of application (also cartography).

Intergraph system files:

- Environment File	Description of the formats, names of other files, options
- Cell File	Point symbols file
- Pattern Definition File	Hatching library
- DMRS Data Base File	Alphanumeric data (attributes)
- IGDS Design File	Geometric and graphic elements
- Others	

Element classes:
- "Graphics Characteristics Commands"
  Overlay, classification, association (group formation), identifier, (object code and number), font
  Line/area/text/paragraph characteristics
- "Graphic Element Generation Commands"
  Generate line string, circle, arc, symbol,curve, include symbol text
- "Graphic Text Generation Commands"
  Generate text line, paragraph, ...
- "Miscellaneous Commands"
  Associate values (alphanumeric data and assignment to graphical data using identifiers),..

Features:
- Large number of elements
- Many classification options
- Hierarchical structures can be represented
- Defined free alphanumeric data formatting method
- Compact ASCII and binary formats
- Structured files
- 2 and 3-dimensional
- Intergraph implementation with detailed error descriptions, listings etc.

Shortcomings:
- No clear separation between geometry and representation
- No hierarchical element classification
- No defined levels

ISIF is not only used by Intergraph but also by a large number of other companies. Like IGES, it is one of the major interchange formats for interactive graphic systems.
For further information refer to /6/, for example.

8. Final Assessment and Outlook

None of the described and omitted formats can be recommended unconditionally for the interchange of cartographic data.

The available formats should be assessed individually for meeting the requirements of a particular task. If topological information, for example, has to be transferred together with the geometric data (e. g. nodes and edges), the Standarddatenformat cannot be used. ISIF can be recommended only conditionally because the topological information would have to be stored in user-definable data elements. IGES and DLG offer a limited topological data handling capability.

The coordinates dimension and resolution are another important criterion. Considering the purpose for which it has been developed, DLG can handle 2-dimensional planimetric data only and, just as the Standarddatenformat, only as many significant digits as are required for digitizing a conventional map with sufficient precision.

Particularly relevant is the number of different GDP systems data is to be interchanged with, and which interchange formats are supported by these systems. If only 2 systems will be involved also in the future, converting the format of the one into the format of the other will most likely be the easiest and most efficient solution. If data is to be interchanged between many systems, however, the interchange format supported by most should be used as the common interchange format. This could currently be the IGES standard or the ISIF product. Unfortunately the latest IGES version (2.0) still comprises a series of shortcomings (see above). Version 3.0 which is currently being prepared by ANSI, and the furture ISO STEP standard will offer considerable improvements which the user should wait for.

Using a product instead of the IGES or STEP standard may be necessary also in the future in all cases where the standards do not provide for required data elements. This may be in the organizing section, where the requirements are particularly complex. If the standard allows for freely definable data elements, some freedom is provided which can be used individually, but such parts will not be portable, i. e. this is a limited advantage of standards. Also, defining these elements can be very time-consuming.

Neither IGES nor any of the other described formats comprises data elements for coding various editing jobs. (Example of such a job: "Delete point P in line L!"). Such elements are required for communications between independent remote editing terminals and a central data base if parallel access of several such terminals to the data base is required. This concept is being developed in Germany with the EDBS (Einheitliche Datenbankschnittstelle) of the ALK (Automatisierte Liegenschaftskarte) project.

For the above reason, many products for data interchange between GDP systems will remain on the market for quite some time and further products will be introduced even though standards will become more significant in this field. It is hoped that IGES version 3.0 and STEP will satisfy cartographic requirements. A separate standard for the interchange of cartographic data is not desirable because of the wide range of applications of graphic data processing systems.

Literature

/1/ ADV (Arbeitsgemeinschaft der Vermessungsverwaltungen der Länder der Bundesrepublik Deutschland): Das Standarddatenformat zum Austausch kartographischer Daten. 1977

/2/ ADV (Arbeitsgemeinschaft der Vermessungsverwaltungen der Länder der Bundesrepublik Deutschland): Katalog zur Verschlüsselung der Grundrißobjekte (Objektschlüsselkatalog). 1980

/3/ Anderl, R./Glatz, R./ Nowacki, H./ Schuster, R./Trippner, D./ Trödner, K: IGES Review and Proposed Extensions DIN NAM AA 96.4/3-84, 1984

/4/ ANSI (American Standards Institute): Digital Representation of Product Definition Data, (Y14.26M). September 1981

/5/ Blohmeyer-Bartenstein, H. P./ Both, R.: Datenkommunikation und lokale Computer-Netzwerke, München, 1983

/6/ Intergraph: Intergraph Standard Interchange Format (ISIF). 1982

/7/ Marcus, A: Corporate Identity for Iconic Interface Design: The Graphic Design Perspective. IEEE Computer Graphics and Applications Vol. 4, No. 12, 1984

/8/ NCIC (National Cartographic Information Center): Computer Files and Attibute Codes for Digital Line Graphs, 1980

/9/ NCIC (National Cartographic Information Center):
User Guide to Digital Elevation Models. 1981

/10/ NBS (US Department of Commerce. National Bureau of Standards):
Initial Graphics Exchange Specification (IGES), Version 2.0; February 1983

/11/ Olsen, D. R./Buxton, W./Ehrich, R./Kasik, D. J./Rhyne, J. R./Sibert, J.:
A Context for User Interface Management; IEEE Computer Graphics and Applications, Vol. 4, NO. 12, 1984

/12/ Schuster, R./Trippner, D./Glatz, R.:
Was geschieht bei der CAD/CAM Schnittstellennormung.
CAD/CAM 1985, No. 1

/13/ Schuster. R./Trippner, D.:
Anforderungen an eine Schnittstelle zur Übertragung produktdefinierter Daten zwischen verschiedenen CAD/CAM-Systemen. 14. GI-Jahrestagung 1984

Abstract

Review of Standards for Exchange of Cartographic Data

The data exchange between different systems of computer aided graphic data processing is of increasing importance.

For coding these data there are a number of formats in use, partly developed by national institutions partly by companies, but which are no standard, however. Only in the USA there is a standard which is of international acceptance: Initial Graphics Exchange Format (IGES). Because of some shortcomings IGES did not succeed in pushing back the other formats.

STEP is the title of an international standard still on work, which bases on the experience gathered by IGES. Probably STEP as well as the shortly expected IGES version 3.0 will obtain greater importance in CAM/CAM. It remains to be seen, whether these two standards will be suitable for the exchange of cartographic data.

Zusammmenfassung

Standards zum Austausch kartographischer Daten - eine Übersicht

Der Austausch von Objektdaten zwischen verschiedenen Systemen zur rechnergestützten graphischen Datenverarbeitung gewinnt zunehmend an Bedeutung.

Für die Codierung dieser Daten sind eine Vielzahl von Formaten im Gebrauch, die teils von staatlichen Stellen, teils von Firmen entwickelt wurden, aber keine Normen sind. Allein in den USA gibt es eine Norm, die auch international Bedeutung erlangt hat: Initial Graphics Exchange Format (IGES). Wegen einiger Mängel ist es IGES aber noch nicht gelungen, die anderen Formate entscheiden zurückzudrängen.

Unter dem Titel STEP ist eine internationale Norm in Arbeit, die sich auch auf die mit IGES gesammelten Erfahrungen stützt. Es ist damit zu rechnen, daß STEP wie auch die in Kürze erwartete IGES-Version 3.0 im CAD/CAM-Bereich größere Bedeutung gewinnen wird. Ihre Eignung für den Austausch kartographischer Daten bleibt abzuwarten.

Dr.-Ing. Kurt Menke
Firma Carl Zeiss
Geschäftsbereich Vermessung
Postfach 1369/1380
7082 Oberkochen