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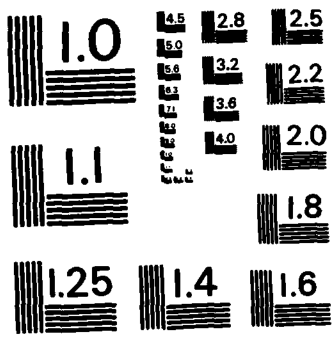

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Intelligent Gateway Processors as Integrators of CAD/CAM Networks

Viktor E. Hampel
Bruce L. Garner
Jack R. Matthews

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Intelligent Gateway Processors as Integrators of CAD/CAM Networks*

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ABSTRACT

They

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The integration of dissimilar CAD/CAM hardware and software on local and geographically distributed networks is the major problem faced by large organizations today. We begin by examining the existing system for storage, retrieval, control, and distribution of design information at Lawrence Livermore National Laboratory (LLNL) and describe a new prototype Engineering Information System (EIS). We then discuss the Department of Energy neutral Data Exchange Format (DOE/DEF) for the sharing of mechanical drawings among DOE installations. Finally, we describe the potential role of the Intelligent Gateway Processor (IGP) as a transaction controller for engineering resources among contractors of the Air Force Logistics Command (AFLC). IGP capabilities include a unique interpreter-driven user interface which permits the installation and modification of resources and the translation of dissimilar data formats, commands, and protocols, in a unified manner while running non-stop.

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TABLE of CONTENTS

INTRODUCTION

Two major problems faced by CAD/CAM planners today are the lack of authenticated databases of material properties (1), and the difficulty of integrating the rapidly expanding number of advanced - and possibly incompatible - CAD/CAM systems (2). Authenticated databases of material properties for CAD/CAM production do not exist. Manufacturers adjust the bits and pieces of relevant data and prepare their own proprietary datafiles which are then normalized to their in-house equipment, machines, and know-how. These data are not being shared, as a rule, and will be discussed in a future report.

In this paper, we focus on the second problem, the integration of local CAD/CAM systems into nationwide networks. Present-day CAD/CAM systems involve sophisticated hardware and software and a diversity of protocols and file management systems. Yet, they are expected to perform in an efficient, controlled, and practical manner. One solution is the adaptation of Intelligent Gateway Processors (IGPs) to translate incompatible formats, to whatever extent possible, and to control the flow of information among CAD/CAM users and their differing systems in a unifying manner.

The TIS/IGP has been under development at Lawrence Livermore National Laboratory (LLNL) since 1975, independent of the local and DOE CAD/CAM programs. It has been used to prepare the technology for future, nationwide information networks which would link the immense federal information centers of the DOE, the DOD, and NASA with commercial information centers. Lessons learned are potentially applicable to the integration of CAD/CAM systems.

The IGP is also under evaluation for use in the integration of resources and equipment in a future Automated Technical Information (ATI) prototype network of the Air Force Logistics Command (AFLC). This poses a considerable challenge and requires collaboration among experts in the field. To examine what role IGPs might have in this network, we begin by surveying the present state of CAD/CAM operations at LLNL.

1. THE LLNL CAD/CAM PROGRAM, A MIX OF TECHNOLOGIES

Historically, engineering design information has been manually produced. Today, computer assisted design (CAD) tools provide the ability to generate and visualize geometric information without pencil and paper. This information has been used to control computer aided manufacturing (CAM) without recourse to hard-copy engineering drawings. But because CAD design information is expressed in digital form, a new set of problems must be addressed: The generation, storage, retrieval, distribution, and control of the digital design information when combined with the larger volume of conventional, hard-copy engineering drawings. The following is a short summary of methods currently used at LLNL, together with some notes on the advantages and problems of each.

The procedures for generating and controlling engineering design information at LLNL have evolved over a long period of time (3). A manually maintained system of forms, files, cards, punched cards, aperture cards, punched paper tapes, batch programs and digital data files works well, though not efficiently. The control of this volume of diversified engineering information is now gradually being replaced by some degree of automation on a VAX-11/750, which necessarily preserves many of the features of the older system, including batch updates of master retrieval files on a CDC-7600 computer. The system controls drawings only; it does not permit control and effective use of CAD-generated files, unless they are converted to hard-copy drawings. Ideally, it should be the other way around.

1.1 <u>Storage and Archiving</u>

The current method of data storage is still based largely on hard copy. Drawings are required for the generation of high-resolution images on 105mm film used for archiving. Film images can also be created directly by an Electron Beam Recorder (EBR) from a CAD plot file. This method is useful but has several drawbacks. Since drawings represent only a partial view of the complete design, information is lost in converting a CAD design file to a drawing. Furthermore, all processing is mechanical and the film must be printed on paper if it is to be distributed for use by others.

To be of value, CAD-generated information must be archived in digital form. Magnetic tapes and disks provide effective storage for design data, but the files must be copied and recopied over the lifetime of the data. Moreover, magnetic media are volatile and vulnerable to accidental erasure by magnetic fields, hardware failures, or human error. It also is expensive to maintain an ever-growing magnetic disk or tape library. Finally, information maintained as images, either on film, on paper, or digitized, cannot be reconverted to an accurate CAD database without human intervention at considerable cost.

1.2 <u>Retrieval and Distribution</u>

Retrieval of drawings archived on film in the present system usually requires copying the image from film onto paper for distribution (4). If changes are to be made to the drawing, a new tracing must be generated from the original tracing or from the film copy. Original tracings are usually only kept for two years.

Retrieval and distribution of CAD-generated digital information presents a different set of problems. Each vendor's CAD system uses a different internal storage format for the design information, and a different protocol for retrieval and printing of designs. Even though IGES, the Initial Graphics Exchange Specification (5), provides a neutral representation of CAD data, information often is lost in the conversion to the IGES format, or in the transformation from IGES into a second CAD representation of the data. Significantly, there is no provision for a central directory to storage locations of CAD/CAM files among several dissimilar CAD systems.

The primary medium for sharing design information in the LLNL engineering community continues, therefore, to be the distribution of drawings. Of course, drawings created by CAD systems can be distributed in the same manner as manually-produced drawings. But, distribution of information in non-digital form precludes the use of most electronic communications media, such as direct data lines or satellite links among the National Laboratories and contractors' plants. Any desired changes to design information must be laboriously re-entered and re-converted to digital form and then processed and reduced to hard copy drawings. The secure and controlled distribution of hard-copy drawings, and of their digitized counterparts, is an ongoing concern.

To realize the full power of CAD/CAM tools, a transaction-driven procedure for distribution of the design information in digital form is being implemented at LLNL. Several issues have to be resolved before this can become a reality:

- Definition of a practical standard format for the exchange of technical design information. Without a common format, information cannot easily be passed between different vendors' CAD systems. In fact, different versions of the same vendor's equipment may be incompatible.

- Integration of hard-copy drawings and CAD-files in a unifying and cost-effective manner.

- Implementation of engineering control, transaction history, and record-keeping procedures.

- Installation of data links among the various CAD systems, and between the systems and potential users of the design information in a local and geographically distributed network.

At present, none of these problems has been satisfactorily resolved. At LLNL, we continue to expand the role of CAD in the design process. Thus, these problems and those caused by the differences between CAD-generated and manually-generated engineering design information are becoming progressively more serious.

1.3 A New Approach

To deal with the problems of integrating CAD/CAM design information into existing engineering systems at LLNL, a prototype Engineering Information System (EIS) is being developed (6). The EIS will serve two primary functions:

First, it will provide information services to the Engineering records center and the CAD systems in use in several Engineering divisions. Second, it will serve as a test bed for development of a future, more comprehensive system encompassing much of LLNL's engineering community and its programmatic requirement to communicate with other DOE facilities. The prototype EIS is based on the following design criteria:

- A central data pool and file archive,
- Control of engineering transactions,
- A menu-driven user environment, and
- Intra-system transfer of digitized plot-files and IGES files.

Digital design information will be stored directly in the EIS data pool; drawings will be stored in the Engineering Records Center as images on film and as tracings. Information about both digital and hard copy designs will be maintained in the EIS data pool as a global directory.

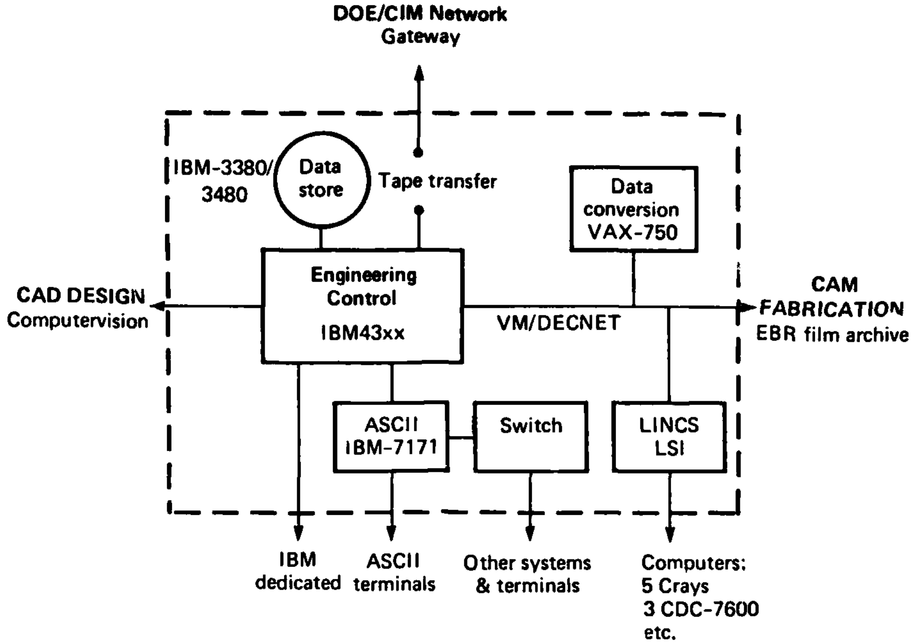
The prototype will be used to develop practical solutions to the immediate problems of control, storage, retrieval, and distribution in consideration of all required security provisions.

Administrative and procedural functions also will be handled by the prototype. Administrative tasks such as the execution of technical engineering orders, and control functions such as sign-off procedures, access control, and transaction logging, are all being built into the system. We expect the EIS prototype to demonstrate the following improvements over the existing system:

- Immediate, on-line access to information about each design file and drawing, such as the names of engineers and draftsmen, design numbers, material lists, etc.
- An integrated source of information about digital designs and hard-copy drawings.
- Viewing (but not modification) of designs at EIS terminals. This will free the relatively smaller number of CAD workstations for design work rather than for data entry or viewing. The prototype will not initially provide the capability to view digitized images produced by video scanning.
- Efficient archival storage of all digital design information. This goal will depend on the availability of optical disk systems which are expected to provide reliable, high-capacity on-line storage. Optical disk systems will also be used for backup of mirror images of the files and to enhance data integrity and security by cross-correlation.

The EIS initial system is envisioned as a distributed local network under control of a central computer with connections to four CAD systems, to the Electron Beam Recorder (EBR), and to the mechanical shops. The connection between the information system's IBM computer and four existing Computervision CAD systems will use Computervision's proprietary implementation on Ethernet. The connection to the EBR and to the shops are planned initially via an Interlink DEC/VM interface and DECNET.

Communications will be done by hard-wire connections wherever possible. Dial-up lines will not be used until secure dedicated lines and facilities of the secure DOE satellite network become available. Information transfer to and from non-secure CAD systems, when required, will be by physical transport of magnetic or optical media.



LLNL Engineering Information System (EIS)

Archival storage will ultimately be provided by an optical disk storage system of the type under development by several manufacturers including Philips, FileNet, and Integrated Automation. The optical disk system will connect directly to the EIS computer and will thus minimize protocol and interfacing problems. When it becomes available, the Computations Department's massive digital archive at LLNL will be used to supplement storage on the EIS. While fault tolerance is not a major concern today in view of the other dominant problems yet to be solved, recovery features have to be implemented, such as mirrored backup disk storage files, journaling, and error correction.

Software for the prototype has been purchased, leased or, where necessary, developed at LLNL. It provides file handling capability, system support, and software tools for the control and recording of engineering transactions. The EIS prototype software is being developed in multiple layers to provide a modular, expandable, and easily modifiable system.

Based on present experience, the prototype is expected to handle data storage requirements for approximately 60,000 design drawings per year. Each conventional design, if stored digitally, consists of about 2 megabits of data. This translates to a total storage requirement of 120 gigabits per year. If solid modeling techniques are employed which are under intensive development at LLNL (7,8), the data volume will increase by about a factor of ten. Currently, the LLNL/EIS prototype is being designed with a capacity of managing an estimated 156,000 transactions each year.

2. THE DOE COMPUTER INTEGRATED MANUFACTURING (CIM) PROGRAM, A DISTRIBUTED NETWORK

To benefit from available expertise and know-how, the major CAD/CAM systems in the United States have been carefully studied by DOE and by the engineering staff at the DOE national laboratories and their CAD/CAM design teams. Much has been learned from interactions with other experts in the field. However, a transfer and direct adaptation of existing major CAD/CAM systems is difficult because of the very different mix of computer and CAD design hardware used.

Problems of CAD/CAM integration have traditionally been tackled with site-dependent solutions: Boeing developed their successful airplane design system with IBM computers (9); Chrysler builds their cars with powerful CDC computers (10). In each case, we note an intimate dependence on local computer mainframes, their innate database management systems, and preferences toward particular CAD/CAM equipment.

At LLNL, the goal is applied research and development, rather than the efficient design and fabrication of commercial products required in industry. Each addition of advanced, high-technology CAD equipment is made in light of the needs of the individual project or organization. Some additional components integrate well into our existing CAD system, but others represent new approaches to CAD and require special attention. Any integrated CAD/CAM system at LLNL must necessarily accommodate a variety of design tools from a variety of vendors.

On a larger scale, to unify independent efforts at the national laboratories, the Department of Energy (DOE) asked the Sandia National Laboratories at Albuquerque, NM, in 1982 to be the lead agency for the *DOE Computer Integrated Manufacturing (CIM)* program (11). A major goal was the definition of a practical Data Exchange Format (DOE/DEF) (12). This project was to develop software to automate the manipulation of IGES files to permit useful transfer of mechanical product definitions among CAD/CAM systems at and among DOE laboratories. The IGES manipulations to be performed were expected to change over time as the IGES specifications and vendor implementations of IGES processors matured. Flexible provisions capable of accepting these evolutionary changes, when a better understanding of what "useful" transfer may mean, were also to be incorporated.

2.1 The DOE Data Exchange Format (DOE/DEF)

The DOE Data Exchange Format (DEF) is planned as a neutral format for the DOE Mechanical CAD/CAM. It is a restriction of IGES in that those IGES entities not currently used in DOE mechanical design files, e.g., ruled surfaces, are not included in DEF. DEF is also an extension of IGES since it defines new entities within the rules of IGES extensibility for DOE specific uses. The need for a neutral form of IGES is twofold:

First, data exchange among commercial IGES processors does not provide sufficient visual equivalency or functionality of files, due to the unique "flavors" of IGES output produced by different CAD systems. A re-flavoring of files is needed. Re-flavoring, carried out in two steps, is expected to minimize the number of separate translators required and should localize the code changes needed if a system's flavoring changes. This includes de-flavoring to the neutral DEF and then re-flavoring for the receiving system. Second, a neutral format is required as a uniform interface for application programs.

Phase-I of the DEF project addresses currently available IGES processors and current DOE usage of CAD systems. Phase-I of the DEF is being implemented without syntactic ambiguities and with minimum semantic ambiguity, where it is understood that a semantic ambiguity may permit more than one syntax for a given functionality of the data. Later phases of DEF may reduce semantic ambiguity and provide new application-oriented entities. The DOE/DEF specification uses the IGES 2.0 manual as its base, although conformity with IGES 3.0 and subsequent derivative standards is planned. Current specifications for Phase-1 are summarized in a recent DOE/DEF report which is based only on a portion of the IGES manual (12).

Ultimately, the DOE Data Exchange Format Specifications will encompass the broad spectrum of IGES, inclusive of electronic, electric, hydraulic, and pneumatic designs. Here, we are only concerned with the neutral format for the exchange of mechanical drawings. A DOE/DEF Subgroup has been made responsible for this task. It is to define and implement a software environment for the effective translation of CAD-based product definition data between various CAD systems within the DOE family of laboratories.

An initial task is the transfer of visually accurate mechanical drawings. Additionally, transfer of 2D and 3D geometries for manufacturing and engineering applications is desired. A long-term goal is the full transfer of all CAD-based product definition data without loss of information and functionality.

Mechanisms are being developed for verification of translated CAD data files. Responsibilities between sending and receiving agencies have been defined. A neutral format for CAD-based data will be the medium for exchange between systems, and may become an official format for storage of released CAD-based product definitions within the DOE.

As much as possible, the environment to be developed conforms to existing applicable standards. The IGES data format standards, and IGES translator software supplied by CAD vendors, is utilized as a basis for the neutral format. ANSI drawing standards are adhered to in the neutral format. Standard programming languages are used in software development. Standard DOE software quality assurance procedures are adhered to for the DEF software development.

Growth and support of the Neutral Database Standards are essential to the success of the DEF work. The DEF Subgroup provides CAD vendors and the IGES standards community at large with information concerning the nature and extent of the DEF effort and participates whenever possible in the development and evolution of IGES standards.

The DOE/DEF Subgroup also participates in the development of DOE-wide procedural standards governing generation, transfer, and receipt of CAD data files. These standards, plus individual agency conventions and DEF-developed translator software, must combine to make data transfer successful.

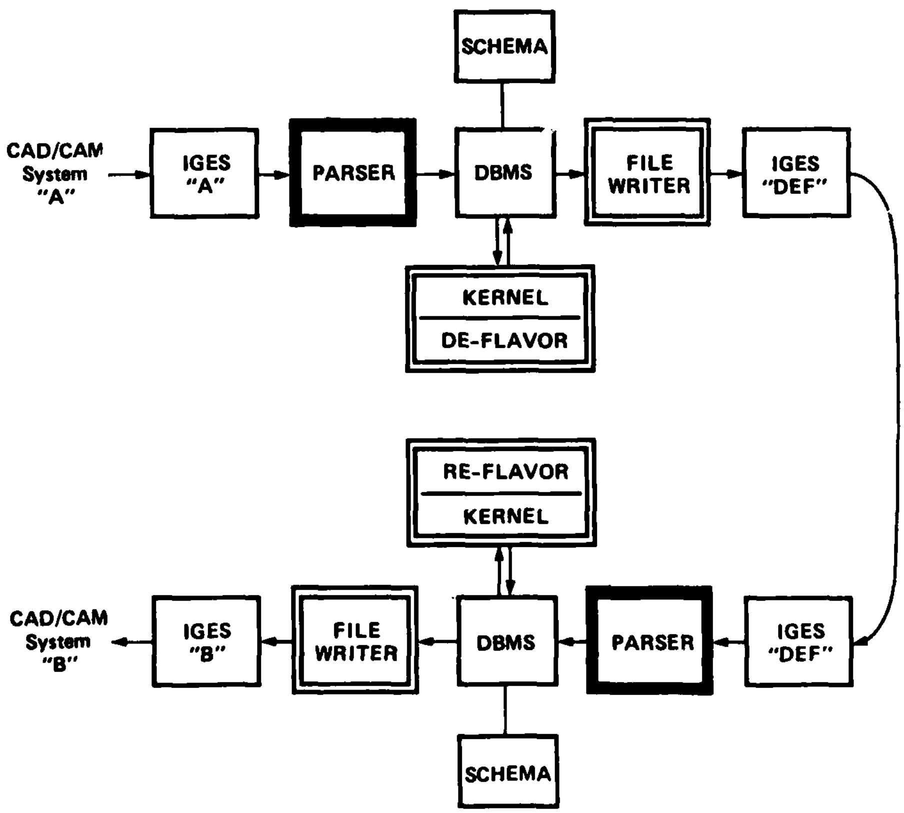
2.2 Translation of CAD/CAM Formats and Protocols

As a result of the DOE program to establish a neutral Data Exchange Format, the translation of incompatible information formats and communication protocols could be solved as an evolutionary ad hoc process at each of the DOE sites. This has given each DOE laboratory a certain degree of freedom and flexibility to make good use of existing facilities and local requirements. However, it has also contributed to the development of site-specific CAD systems so that the transfer of integrated and complex CAD/CAM system software as a whole has only been attempted to date between installations equipped with similar hardware.

To accommodate these changing needs, the DOE/DEF software was designed in a modular way with static modules which support the writing of adaptive and dynamic modules. The static modules, for example, take the form of library procedures for file access. A dynamic module might call a static procedure to retrieve an entity, change values of fields within the entity, and then call another static procedure to store the changed entity.

The programmatic constraints for the DOE/DEF system specified its software to run on DEC/VAX, CDC/Cyber, and IBM/43xx computers. This implies that the software under development could not depend on features of any one of these computers, or their operating systems, which cannot be simulated or converted for use on the other machines. No constraints were imposed upon the operating systems of these computers. However, the format translators and file writers were to be written in standard Fortran-IV.

A database approach had been recommended in the literature for the storage of engineering entitites (13). The initial database software at LLNL was obtained from Boeing Corporation and is known as the Relational Information Management (RIM) system. RIM was originally in the public domain. An improved version has since been developed by Boeing and is being acquired as proprietary software.



The above block diagram describes the basic DOE/DEF concept of moving files between different CAD/CAM systems located at different sites. The basic procedure consists of a parser (14) to facilitate traversal of the IGES file into the RIM Database

Management System (DBMS). The file writer software then produces the inverse of the parser software and creates the IGES Data Exchange Format (DEF). During this process, it is essential to retain, to whatever extent possible, the preferred symbolics and nomenclature of individual IGES representations, also referred to earlier as "flavors". This is being carried out in the static "kernel" modules for database access, and their corresponding dynamic converter modules which restructure the specific flavor of an IGES file to the Data Exchange Format, and vice versa.

2.3 Secure Communications and Information Exchange

An additional major consideration is system integrity and security. CAD/CAM installations at the industrial installations studied by DOE and LLNL are traditionally installed as hard-wired networks inside an office complex. This affords them physical plant security and nominal computer security.

At LLNL, hard-wired connections also predominate. However, the advent of cost-effective broad-band communications, at LLNL and among DOE facilities, should make it possible to consider geographically distributed, yet functionally integrated, CAD/CAM or CAE systems. The DOE secure OPMODEL satellite network is expected to be operational in 1986. It combines voice and data in a T1 communications network (15). This calls for security measures not now available with any of the industrial CAD/CAM systems.

In the meantime, to facilitate the transfer of engineering drawings among the DOE national laboratories in a secure environment, a dedicated secure network has been established. Recently, it was used successfully to move CAD/CAM information from the engineering design stations at one location as direct input to the computer-driven manufacturing of parts, without recourse to hard-copy drawings.

3. THE INTELLIGENT GATEWAY PROCESSOR (IGP) and CAD/CAM OPERATIONS

The concept and software of the **Intelligent Gateway Processor (IGP)** continue to receive requests from federal agencies for test and evaluation. Unlike any other technical approach, the IGP controls automated access to changing heterogeneous computer resources at geographically distributed locations, in a unified and controlled manner, while running non-stop. The IGP capabilities were cited in the recent literature (16,17). The Scientific Advisory Board of the Air Staff reviewed the TIS/IGP software and endorsed its exploratory use for the AFLC modernization program.

The IGP software was conceived in 1975 as a table-driven interpreter for the creation of integrated information systems (18). Instructions to the user and execution strings to the underlying operating system or application programs are deposited in a database or structured file. This makes it possible to use the IGP as a translator of dissimilar commands, formats, and protocols. Unlike the dedicated Data Base Management Systems (DBMS) of the 1960s, or the Information Management Systems (IMS) of the 1970s, the IGP software permits the integration of all resources required by scientists or engineers as an ongoing process:

- Datafiles (text, data, graphs, and images)
- Application Programs and Models
- Local and Distributed Communications

Programmatic resources can be installed on the local gateway or accessed in a controlled manner at distant locations. Each user community can assemble its own directory and controls and revokes access rights through their System Administrator. In addition to the shared resources, users are given the opportunity to establish in their personal workspace an information system of their own by means of self-guided commands, without programmer intervention. Several different user communities may share the same gateway with selective control over common and program-specific resources, in their preferred terminology. The use of the table-driven interpreter permits the sharing of resources with the following controls:

See & Use	See w/o Use	Alter	Grant	SU-1	SU-2
x					
x	x				
x	x	x			
x	x	x	x		
x	x	x	x	x	
x	x	x	x	x	x

In the first class, users of the TIS/IGP see only resources they are entitled to use. In the second class, they are in addition shown resources which they can not use. In the third class users have the right to alter resources in the shared domain. Those who own the resources can grant them for use by others. Finally, we distinguish two levels of Super User (SU) authorization, governing the access to system files. In their personal accounts, users have all rights other than those of SU. These characteristics are essential for the controlled sharing of resources in information and modeling networks (19,20).

In 1976, we selected the UNIX Berkeley System Distribution (BSD) for the operating system of IGP development. Several of our staff have been active participants in the BSD UNIX program. The Uni-Soft Systems company, specializing in M68000-based micro-computers, was founded by a former member of TIS. The February 1985 issue of UNIX Review emphasizes the rapid evolution of a UNIX standard for future computers. For the PDP-11/70 machines, we retrofitted UNIX 4.1/4.2 BSD. For the VAX-11/780 computers, we enhanced the UNIX kernel in six places to provide better control of resources, greater security, and faster asynchronous communications. These changes were submitted to the UNIX BSD developers and are expected to be included in their next release. AT&T is considering them independently for inclusion in their commercial systems. The TIS/IGP concept and software are copyrighted in behalf of the Regents of the University of California.

UNIX has been criticized by casual users as being terse and not user-friendly. To improve this, the IGP software translates English-like commands into the terse UNIX statements where needed. **In the verbose mode,** users can issue commands as imperatives. **In the expert mode,** a one-letter response to judiciously placed prompts speeds up the interaction. Users can specify their own command language by defining of personal dictionaries. Some user communities are placed under full control of the TIS/IGP upon login to their shared resource directory. Others are given the opportunity to select information systems of several user communities when granted a need-to-know and need-to-use.

Quality assurance of the IGP software is an integral part of the DOE/LLNL Technology Transfer program. Three members of our staff, with considerable experience in quality assurance, test each command and option, document deviations, and initiate corrective action.

The documentation of the IGP software covers system administration, installation, acceptance, and users manuals and guides. This work was co-sponsored by the AFLC and the FAA in preparation of our installation of IGP software at the Aviation Center in Oklahoma City.

The TIS/IGP software has been installed on several different-vendor machines with UNIX as the operating system. To utilize all of the IGP capabilities, UNIX 4.2 BSD is preferred. However, we successfully installed the essential components of the IGP software on machines offering only binary versions of UNIX System III, or System V, with or without BSD enhancements. The latter determines the extend to which some or all of the IGP capabilities can be activated. The TIS/IGP software is now operational on the following UNIX-based computers: PDP-11/70, VAX-11/780, PLEXUS P-60, NCR Tower, Parallel 300/40, Pyramid 90X, and soon also on an Elxsi-6400.

We procured an **AISwitch** for the cost-effective sharing of our communication lines from telephone networks, TYMNET, and ARPANET. This machine is now installed and provides a test bed for communication front ends of future IGP installations. To accommodate the diversity of workstations, the current IGP software permits the use of some 260 different ASCII terminals and the major graphics terminals. We received a request to extend this powerful UNIX 4.2 BSD option (**TERMCAP**) to a similar capability for the growing number of graphics terminals (**GRAPHCAP**).

The basic concept of a table-driven interpreter IGP software has served us well. From lessons learned, we initiated conceptual work towards a 3rd-generation gateway with a **Universal User Interface (UUI)** and four types of extensibility:

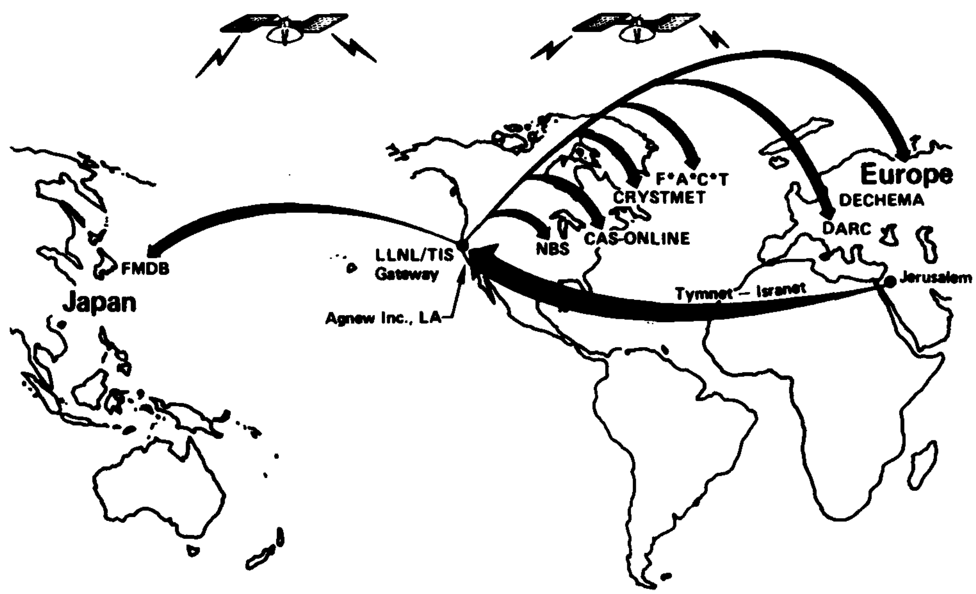
1. Data types (both primitive and compound)
2. Operators
3. Control structures
4. VM primitives (e.g., machine instructions)

This approach will extend the syntax and semantics of compilers and interpreters considerably (21).

The identification of online information systems which offer bibliographic references and numeric data for **measured and evaluated material properties** in the different disciplines has been an ongoing area of interest at LLNL/TIS (22). We are establishing a library, or tool box, of simple commands and procedures by which textual information and numeric data can be transformed and validated as input for use with application programs and models. Information systems, by themselves, are useless unless coupled to data analysis work.

In collaboration with Sandia Laboratories, we are establishing an online directory to material properties data. This work is being carried out in coordination with the Numerical Data Advisory Board of the National Academy of Sciences, the International Committee for Data in Science and Technology (CODATA), and the Office of Standard Reference Data at the National Bureau of Standards. The LLNL Technical Information Department (TID) provides key individuals for the TIS technical and scientific information program.

The reality of an international network for material properties was brought a step closer when scientists and engineers at the Ninth International CODATA Conference in Jerusalem participated in a live demonstration of available S&T resources from three continents via the TIS/IGP Gateway in Livermore, California. By projecting tables and graphs from a CRT computer terminal on a large screen in the main auditorium of the Israel Academy of Sciences and Humanities, attendees of the plenary session viewed interactive retrievals of physical and chemical data derived from seven online information systems and heard corresponding explanations for: CAS ONLINE and NBS/OSRD in the United States, CRYSTMET and F*A*C*T in Canada, DARC in France, DECHEMA in West Germany, and FMDB in Japan.



This audio-visual demonstration was carried out over international packet-switching networks and regular telephone voice communications with the TIS/IGP "link" command (23). In two cases, the information resources were interactively accessed and narrated by experts from their offices in the United States and Canada. The results were simultaneously projected to the 270 attendees of the conference in Jerusalem. A highlight of the demonstration was the searching of a bibliographic database in Paris and the machine-aided translation of a downloaded sample of its French text into English by Agnew, Inc., located in Los Angeles, within the hour (24).

3.1 Overview of TIS/IGP Projects

Since its inception in 1975, the TIS Project at LLNL serves as a testbed for the development of information systems tailored to the needs of several user communities. Some of these are sponsored by DOE. Others, funded by non-DOE federal agencies, are using the TIS facilities for test and evaluation of high-technology hardware and software. Successful combinations of components are then transferred to the sponsors' facilities for extensive test and evaluation under actual operating conditions. The ongoing projects are:

Federal offices responsible for scientific and technical information in the DOE, DOD, and NASA are planning an **Information Center Network (ICN)**. This network is to facilitate interchange and sharing of information in a cost-effective manner (25,26,27).

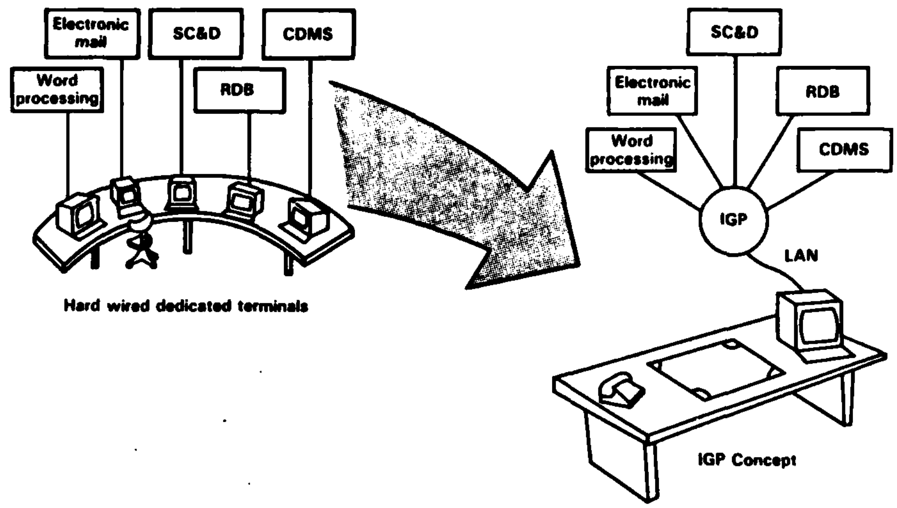
The main emphasis to date has been the development of automated access procedures to bibliographic and numeric information centers and the processing and analysis of downloaded files in a unified manner. Plans for a Common Command Language are in preparation. Mini-gateways, patterned after the TIS/IGP and its software, are envisioned by the DOD Defense Technical Information Center (DTIC) as practical tools for Library Automation, combining a multi-user, multi-tasking book catalog system with controlled access to the large bibliographic and numeric information centers of the world (28). High-density optical disk storage of full-text and video-scanned images are being evaluated for quick delivery of scientific and technical (S&T) information. Subsets of topical information would be distributed on small optical disks, for direct use on personal computers.

The **Nuclear Criticality Information System (NCIS)**, sponsored since 1982 by the DOE Office of Nuclear Safety, received additional emphasis from the aftermath of the Three Mile Island incident. It provides access to accurate data for the safe storage, transport, and manipulation of fissile materials outside nuclear reactors: Annotated topical bibliographies on nuclear safety, reference data to benchmarks for nuclear criticality calculations, different modeling programs on computers at the Oak Ridge National Laboratory, and listings of experts to be called into action in times of emergency (29,30,31). Related to this project is the beginning of a **Human Factors Information System (HFIS)**, intended to integrate the information and data now scattered and inaccessible at different federal and industrial installations. The NCIS is now in its 3rd year of development.

The **Cost Estimating System (CES)** modeling network, sponsored by the DOE Office for Project and Facilities Management, utilizes the TIS Intelligent Gateway since 1983 as a focal point for a number of federal and commercial models to conduct independent cost estimates for construction projects in excess of $1M. By preparing the input to these models from a common database of cost factors, the input files required to run seven of the models can be prepared in a unified and controlled manner via the TIS Gateway. This has made it easier to compare results and to normalize them to a historic DOE/CES database being installed on the TIS/IGP. Access to the national cost-factors database for labor and materiel, as a function of geographic location and inflation, is in preparation. The DOE/CES project has helped to eliminate differences of interpretation and provides a better understanding of costs to be budgeted for large construction projects (32).

The TIS facility and software have been considered as the core technology for a **Material Properties Data Network** by a number of federal agencies and non-profit professional societies. A **Tribology Information System (TRIB)** has been in preparation by the DOE Energy Systems Research office. It is based on the realization that even a small improvement in the reduction of friction and wear through better lubricants and additives can markedly reduce the overall consumption of energy in the country. An integrated information system for tribology is expected to coordinate the available but scattered data and computer programs for optimum design techniques. The TIS Tribology Information System should accelerate ongoing R&D by improved sharing and availability of tribology resources. The project is planned as a joint undertaking with the ASME Tribology Division.

The Air Force Logistics Command (AFLC) initiated several projects at LLNL. All make use of the TIS/IGP concept and software for the development of vendor-independent information and communication systems which are basic to the AFLC modernization program. These projects are highly effective technology transfer programs (33). The first utilizes the TIS/IGP software for the development of intelligent gateway processors required for the integration of dissimilar computers and peripherals of the **AFLC Logistics Network (LOGNET).** Here, one of the benefits is the linking of several, separate networks into an integrated system. This permits the replacement of several hard wired dedicated terminals by one terminal and the IGP gateway, and the joint utilization of disparate resources (34).



We are preparing the TIS/IGP software for distribution to several super-micro and super-mini computers and are simplifying its operation for office automation and CAD/CAM. Software quality assurance and documentation are essential aspects of this project. Special applications are the adaptation of the IGP software to the development of the **AFLC InfoCenter Network,** and for the **Computer Security Monitor (CSM)** project to ascertain the integrity of communications over federal and public carriers. The TIS **High-Technology Performance Evaluation Facility (HTPE)** and the **AFLC Automated Technical Information (ATI)** program are recent additions.

The Federal Aviation Administration (FAA) selected the TIS/IGP concept and software in 1983 for the implementation of the FAA Aviation Activity **Information Management System (FAA/IMS),** as documented in Chapter 5 of the FAA Information Resources Management Plan (35). Analysts and administrators of the FAA will thus be able to utilize geographically distributed information resources, derived from national and international aviation statistics, via a one-stop communications control point. This is a four-year program. During FY-84, the FAA studied and tested the TIS/IGP software at the LLNL/TIS facility. During FY-85, the TIS/IGP software was transferred and installed for proof of principle on a PDP-11/70 computer at the Aviation Center in Oklahoma City. Following a year of operation under simulated and realistic operating conditions, the FAA will prepare an RFP with functional specifications for a future major gateway facility with extensive capabilities in information management and communications. An industrial contractor will be selected to implement the FAA/IMS network.

The **High Technology Performance Evaluation (HTPE)** project has been established at LLNL to test and evaluate state-of-the-art hardware and software for their effect on man-machine performance. Unlike ongoing joint projects of the U. S. industry in the field of integrated circuit (IC) research, and computer architecture (MCC), the HTPE project emphasizes the evaluation of increased productivity. We are experiencing an unprecedented creativity among high-technology commercial resources. New super-micro and super-minicomputers, powerful workstations, low-cost mainframes, and integrated voice/data communications demand our attention. Each vendor advertises unique capabilities. This competitive environment makes it difficult to pick winners and to procure hardware and software by traditional procedures. To help our sponsors in the federal government in this dilemma, we distinguish three phases in the HPTE project:

During the First Phase, promising equipment and computer programs are solicited under a 30-90 day borrow letter agreement with the vendor for its installation on the 10 Mbps Ethernet of the Technology Information System (TIS) at LLNL. New, high-technology computers and peripheral processors usually offer the UNIX operating system with UNIX 4.2 Berkeley enhancements. This makes it readily possible to superimpose the UNIX-based TIS/IGP software and to plan integrated systems with a vendor-independent architecture. The preliminary testing takes place on TIS at LLNL as a neutral proving ground. Results of benchmarks are conveyed to the vendors and/or manufacturers for comment and correction where required. During the Second Phase, promising equipment and software are selected for test and evaluation under actual working conditions at representative sites of our sponsors. This equipment is usually bought outright, leased to ownership, or leased with purchase options. Performance evaluations derived with the help of human factors engineering assist our sponsors during the Third Phase with the preparation of improved specifications in their customary Requests for Proposal (RFPs) for the procurement of multiple installations.

3.2 Integration of CAD/CAM Hardware and Components

The development of the Intelligent Gateway Processor (IGP) evolved at LLNL independent of the LLNL and DOE CAD/CAM programs. But the generic objectives to manage information and data in a controlled and secure mannner are similar. The applicability of the IGP technology as an integrator of dissimilar resources for a future geographically distributed CAD/CAM network is being evaluated by the Air Force Logistics Command (AFLC). If successful, the DOE CIM program and the AFLC ATI program are expected to benefit from their independent, yet complementary work and objectives.

In particular, the use of IGP technology looks promising for CAD/CAM operations where the creation and revision of engineering drawings, and their derivative detail drawings, have to be accurately controlled and be traceable in audit files. The IGP software can be set up to monitor and intercept man-machine interaction to the command level and to the data-element level. It thus provides basic capabilities which should satisfy CAD/CAM requirements. This is a challenging task and will require talent from several agencies and industry.

As mentioned, the power of the IGP has been repeatedly demonstrated by linking different computers and peripherals at geographically distributed locations, over redundant communication channels. The translation of dissimilar communication protocols, in addition to the translation of commands and formats, is carried out by the IGPs with an advanced version of the Network Access Machine (NAM) software (36), completely rewritten for TIS/IGP use. The result is a relatively powerful, vendor-independent system architecture for the design of information management and communication systems.

3.3 Automated Technical Information (ATI) Management

The Automated Technical Information (ATI) Program is an integral part of the Air Force Logistics Command's (AFLC) modernization plan. The related demonstration and R&D effort are an extension of the ongoing technology transfer between the Technology Information System (TIS) at Lawrence Livermore National Laboratory (LLNL) and the AFLC. A number of long-term and near-term projects are under development to identify for the Air Force the best hardware and software components. The ATI system requires capabilities to:

1. Receive, from industry or government sources, technical data as engineering drawings, CAD files, and technical orders on different media,

2. Store them in IGES and raw formats, using both magnetic and optical media, and retrieve them with advanced DBMS techniques for revision and controlled dissemination.

3. Modify the text, data graphics, and CAD files, and establish a secure archive of historic images.

4. Transmit them by alternate, redundant, communication channels to remote locations using interactive and batch techniques.

5. Receive the images at multiple depot and wing maintenance levels, and store, retrieve, display, or print the images on demand.

6. Identify portable display and printing devices.

7. Establish fault-tolerant transaction control in a unified and secure manner.

Input formats should be those commonly found with standard DOD aperture cards, E-sized and smaller drawings, typed technical data to accompany images, CAD/CAM files from major vendors in raw or IGES formats, and standard DOD/AFLC technical orders on paper forms, among other media. Processors should be capable of being able to read and digitize aperture cards, optically scan and digitize drawings, and store, retrieve, revise, and transmit images in raster format.

IGES formatted drawings should be managed and controlled in vector format. The processor should be able to originate either vector or raster drawings and ASCII text into standard technical orders, produce output through a phototypesetter, and transmit final documents via digital communications, EDCARS-compatible optical disks, magnetic media, and compatible terminals. These long-term goals are based on the following near-term objectives.

a. **Automated Technical Order System (ATOS).** This system should be capable of receiving technical orders from contractors, digitize and store the technical orders under a Database Management System (DBMS) and provide technical order information to Depot Maintenance users. Later phases of ATOS call for the electronic distribution of technical orders to organizations and intermediate levels of maintenance. Technical orders encompass communications, requests for procurement of parts for tactical aircraft, manuals, and engineering drawings in raster and CAD vector notation.

b. **Engineering Data Computer Assisted Retrieval System (EDCARS).** This system will receive engineering drawings from contractors in different formats, digitize and store the drawings under a DBMS, and provide drawings to AFLC users and management in a controlled manner on demand.

c. **Preparation of interim interface specifications for Technical Orders and Engineering Drawings.** SYSCON Corporation, long involved in the AFLC technical engineering program, has been subcontracted by LLNL/TIS to study this problem and to propose common formats and procedures for the interface specifications to allow contractors to pass technical information to ATOS and EDCARS using electronic digital data transfer in a preferred common format. This information would then be used to assist SYSCON Corp. in their preparation of an AFLC standard for ATI data storage and dissemination.

d. **Enhancements of the Intelligent Gateway Processor (IGP) software.** Basic to the above objectives is the utilization of the IGP software for the storage, retrieval, and dissemination of technical information. Specifically, it is envisioned that translator tables be installed on a prototype gateway at LLNL, and/or at Wright-Patterson AFB, or the translation of dissimilar CAD formats into a common format suitable for storage on optical disks.

The overall project is intended to demonstrate a limited capability of the combined features of EDCARS, ATOS, and LOGNET elements via the core technology of the TIS Intelligent Gateway Processor (IGP) concept and software, in collaboration with the DOE Computer Integrated Manufacturing (CIM) program and other federal agencies and industry.

Recent reports summarize the state-of-the-art in optical device mass storage systems (37,38). The test and evaluation of new hardware and software from competing vendors is planned for installation at Wright Patterson AFB and at LLNL/TIS. This will include high resolution image scanners and optical disk storage devices. The table below, taken from reference (4), gives estimates of unformatted, formatted, and compressed storage capacities now available from vendors like FileNet and Integrated Automation.

Media	Capacity Unformatted	Formatted	Approx. Number of Compressed Drawings at 200 dpi A/A4	E/AO
Tape Cartridge	45MB	varies	1000	60
3200 bip Tape	80MB	varies	1900	120
Fixed Winchester	825MB	620MB	14800	930
Single Sided Optical Disk	1000MB	1000MB	24000	1500
Single Sided Jukebox (64)	64000MB	64000MB	1.5M	96000
Double Sided Optical Disk	2600MB	2600MB	62400	3900
Double Sided Jukebox (64)	166400MB	166400MB	4M	250000
Double Sided Jukebox (200)	520000MB	520000MB	12.5M	780000

To provide guidance for optical disk drives expected from industry, a Consortium was formed a year ago to write a comprehensive specification document for an Automated Cartridge Repository. Members of the Consortium include:

- Lawrence Livermore National Laboratory
- Los Alamos National Laboratory
- National Magnetic Fusion Energy Computer Center
- National Security Agency
- National Center for Atmospheric Research
- Rome Air Development Center
- Shell Development Company

The expectations at large computer facilities are to replace existing magnetic cartridge storage, and automated magnetic tape libraries, by an "automated warehouse" of optical read/write disks. The specifications were reviewed by the Consortium and were released for public comment (39).

Although erasable disk drives are not yet available with the accuracy, precision, and longevity required by the powerful computer networks of the Department of Energy, the write-once, read-only devices available today are exactly what is needed for the retention of archival engineering data.

Furthermore, equipment has come on the market which is capable of converting hard-copy engineering drawings into digitized raster files for computer-based revision. It is under development by Integrated Automation and IMPRES (4), a UNIX-based system, among other vendors. This could greatly simplify the joint utilization of raster and vector engineering data.

3.4 Controlled and Secure Communications

The concentration of large volumes of engineering data, and their utilization over broad-band public transmission carriers, make the integrity and security of the concentrated information highly vulnerable.

The controlled transmission of messages, binary files, graphs, and images has been under development as an integral part of the TIS Intelligent Gateway software. The TIS/IGP electronic parcel delivery system, commonly referred to as electronic mail, is a super-set of commands and options available on the major federal and commercial electronic mail systems to which it interfaces (40). The IGP mail delivery system has also provisions for automated filing and indexing of received transmissions.

In addition to these customary electronic mail options, we provide encryption in several levels of complexity and with different algorithyms and techniques. Users may also establish their own trusted methodologies to the encryption interface. Even though users may elect to change their keys and encryption methods from time to time, the TIS/IGP electronic mail system permits the reconstruction and reading of archival data. Communication channels can in addition be secured by the customary Data Encryption Standard (DES) hardware and software. This makes the IGP electronic mail system a potential vehicle for the safe conveyance, storage, and retrieval of technical engineering orders and CAD/CAM information. In conjunction with a forthcoming version of UNIX from AT&T, a geographically distributed file system for CAD/CAM data appears feasible.

CONCLUSION

In summary, the Technology Information System (TIS) program at Lawrence Livermore National Laboratory (LLNL) is evolving into a center for information research in science and technology. To devise the best tools available, we test and evaluate new high-technology hardware and software in conjunction with the TIS Intelligent Gateway Processor (IGP) software. This leads to the development of advanced capabilities in information management, analysis, graphics, and communications. The unique aspects of the TIS Intelligent Gateway is its capability to integrate heterogeneous resources at geographically distributed locations in a unified manner. The TIS projects contribute to the effective transfer of technology in support of the programmatic objectives of the Department of Energy, and of other federal agencies, by bringing together state-of-the-art expertise available at LLNL, at other national laboratories, universities, and industry.

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