8. CONSTRUCTION INTEGRATION AND AUTOMATION

8.1 INFORMATION EXCHANGE STANDARDS FOR CONSTRUCTION

In 1983 Samuel Kramer, Deputy Director of the National Engineering Laboratory (NEL), asked CBT to involve its new Computer Integrated Construction Group in the work to create the Initial Graphics Exchange Standard (IGES) of the American National Standards Institute (ANSI). This request came on the heels of strong building industry expressions of its need for data exchange standards in such forums as the First and Second Congresses on Computers/Graphics in the Building Process cosponsored by the Advisory Board on the Built Environment of the National Research Council and the National Computer Graphics Association.

IGES was intended to provide a neutral (non-proprietary) interchange language for the description of products (initially machine parts) for the automatic exchange of information between dissimilar computer systems used in design and manufacturing. The neutral interchange language was a brilliant and essential concept. Only *n* translators to and from the neutral form are required to interchange information among n dissimilar systems, rather than the *n* times (n-1) translators required for direct interchange between each pair of systems. A new system can be introduced with the development of only one neutral-language translator, rather than *n* direct translators. In addition, the developers of a proprietary system do not need to reveal anything about their data management practices to their competitors or users. Furthermore, the carefully prepared neutral interchange language can serve as an initial or default data structure in the development of proprietary or open system software. Finally, the neutral interchange language provides a natural archiving format for data that may need to be reused long after the originating system is retired.

The IGES effort took off with the stimulation of Air Force, Navy, and NASA management when NBS agreed to champion it as chair and coordinator. The IGES approach was based on technology developed in government and industry projects in the late

1970s, including work in one of Director Ambler's first competence projects in 1978. Bradford Smith of the Center for Manufacturing Engineering headed the IGES Committee that soon became the IGES/PDES Organization.

CBT management was eager to participate in IGES. Automatic exchange of information between dissimilar systems was essential to the effective exploitation of information technology in the construction industry and the whole life cycle of constructed facilities. Many distinct organizations are involved in the life cycle of a constructed facility; owner, designers (architect, structural engineer, mechanical engineer, etc.), contractors (general, site work, concrete, mechanical systems, etc.), regulators, financers (construction loans and long term finance), occupants, maintainers, rehabilitators, etc. Generally, the team of organizations involved in a specific project never has worked together before and never will work together again. It is infeasible for all involved organizations to acquire and use computer hardware and software from the same vendor, or to maintain such hardware and software for the 50 year life typical of a constructed facility. The alternative to automatic exchange of information between dissimilar computer systems is to accept the costs, delays, and mistakes involved in manual transfer of data from one computer's output to another's input.

1983, the beginning of the Administration's efforts to eliminate CBT, was a challenging year to begin a new program thrust. Funds were reprogrammed within CBT and augmented with NEL reserve. Staffing was even more difficult with new skills needed while a CBT cutting staff was unattractive to recruits. Frederick Stahl, who had founded the Computer Integrated Construction Group, departed CBT for work in industry. Kent Reed, a Ph.D. physicist, who joined CBT in 1981 to work in solar energy but had great interest in computer systems, undertook leadership of the group. Reed exemplified the NBS/NIST concept "if you have a challenging new problem, give it to a physicist." Mark Palmer, an architect and engineer experienced in commercial, institutional, and residential building projects, with an advanced degree in Computer Aided Design from the Mechanical Engineering Department of MIT, and infectious enthusiasm for knowledge of and practice in building, joined the Group in 1985. William Danner, a Ph.D. psychophysicist who had retrained himself as an acoustician in response to NBS program changes, joined the group in 1985 to exploit his capabilities in computer simulation and computer aided design. James Barnett, physicist and software engineer, was a founding and continuing member of the group.

The Group promptly organized and led the Architecture, Engineering, and Construction (AEC) effort of IGES and its successor the Product Data Exchange Specification of ANSI. First Stahl and then Reed served as co-chairman, each with a co-chairman elected from industry, of the AEC Committee of IGES/PDES. This committee had a strong influence on the formation of its AEC counterpart in the emerging international standardization effort known familiarly as the Standard for the Exchange of Product Model Data (STEP) and formally as ISO 10303—Product Data Representation and Exchange—that is the international analogue of PDES. Reed took over the editorship of IGES during the balloting of IGES V4.0 [1] and served as IGES Editor for three consecutive versions. During this time numerous capabilities essential for the AEC industry were added as new capabilities or explicated as informative appendices. Reed also served as the NBS/NIST representative to the U.S. Technical Advisory Group to ISO TC184/SC4 (External Representation of Product Definition Data). Palmer chaired the Application Validation Methodology Committee of IGES/PDES and also served on the U.S. Technical Advisory Group.

AEC information exchange is technically more challenging than that for most manufacturing [2]. A product, for instance a door, carries much more information that its dimensions, information such as acoustical properties, thermal properties, fire resistance, security capabilities, appearance, etc. Danner, Palmer, and colleagues in the IGES/PDES Organization and ISO TC184/SC4 developed the data modeling concept [3] and the Application Protocol [4] approach for its implementation to meet these AEC needs.

With support from the U.S. Navy (exchange of piping systems information is as important for ships as it is for chemical plants and buildings), BFRL led the development of the first IGES application protocol [5]. BFRL led the development of the STEP AP methodology and the corresponding Guidelines [6] by which ISO applies this methodology in the development of STEP. To sustain this methodology, Palmer served as the first AP Coordinator for ISO TC184/SC4.

The PlantSTEP Consortium was formed in 1995 by leading process plant owners, contractors, software suppliers, and BFRL to advance information exchange standardization. BFRL also worked with pdXi (Process Data Exchange Institute of AIChE), PIEBASE (Process Industry Executive for Achieving Business Advantage Using Standards for Data Exchange), NIDDESC (U.S. Navy-Industry Digital Data Exchange Standards Committee), and the International Alliance for Interoperability, advancing contributions to STEP and other data exchange standards. BFRL contributed to a number of STEP Application Protocol projects relevant to the AEC industry. In particular, BFRL led the development of STEP AP227, Plant Spatial Configuration [7].

BFRL also has been especially involved in developing methods for validating draft specifications and for testing translators for conformance to STEP standards.

William Danner and Mark Palmer received the Bronze Medal Award of the Department of Commerce in 1993 for their contributions to the international standards for automatic exchange of design and construction information. Kent Reed received the Silver Medal Award of the Department of Commerce in 1994 jointly with two colleagues in other NIST laboratories for their contributions to the initial release of ISO 10303, STEP.

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8.2 CONSTRUCTION SITE METROLOGY

In the mid 1980s, CBT and the Robotics Systems Division of the Center for Manufacturing Engineering of NBS, led by James Albus, became aware of large Japanese investments in research for automation in construction and decided to determine what research the U.S. should perform to retain technical leadership for competitiveness in construction. A workshop of fifty technical experts from universities and the industries of automation and construction was convened in February 1985 [1] to determine needs and priorities for research in measurement technologies for automation in construction and large-scale assembly (such as ship building). Top priority research on construction metrology was determined to be justified for productivity in construction even without automated equipment on the construction site and also to be essential for integrated automation of construction site activities:

1. Computerized data bases, particularly an as-built data system including standardized data elements and interfaces.
2. Automated systems for inventory management, particularly on-site part labeling and tracking of materials handling equipment.
3. On-site metrology to measure the characteristics of construction as

actually built to feed an as-built data base with data on position, dimensions and quality control.

CBT's Computer Integrated Construction group led by Kent Reed addressed the standardization of data and interfaces needed for automatic exchange of information between the information systems of construction project participants. William Stone, structural engineer and underwater explorer, built upon both sets of interests and skills to champion CBT/BFRL efforts in construction site metrology. The publications referenced in the following describe the technologies and the software produced to improve real time construction site metrology.

Pulse-synthesized, base-band electro magnetic signals were used to measure distances to targets through solid walls [2]. Accuracy to 10 mm was achieved when obstacles were well characterized (the dual problem solved was non-destructive characterization of the obstacles).

A prototype world model of a construction site was developed to demonstrate the feasibility of real-time remote control of construction operations with a simulation tracking both equipment and resources using real-time data from the site [3]. The National Construction Automation Testbed was established to assist contractors and manufacturers of sensors, controls and equipment in developing and evaluating products for construction site automation.

Auto-registered Lidar range sensing systems integrated with wireless communications, high speed networking, temporal project databases, web-based data analysis and 3D user interfaces have been demonstrated for on-site and remote control of earthworking operations [4,5].

BFRL has worked with the Construction Industry Institute to establish the FIATECH consortium to conduct research and development in partnership with construction equipment suppliers, information technology suppliers, owners of constructed facilities and contractors for fully integrated and automated project processes. BFRL's construction site metrology efforts are a key element of FIATECH. BFRL's prospective assessment of the benefits of its construction metrology research [6] indicates potential cost savings of five times BFRL's investment for applications in industrial construction projects alone.

References

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