Automation and Robotics in Construction X
G.H. Watson, R.L. Tucker and J.K. Walters (Editors)

INTEGRATION IN DESIGN AND SIMULATION

by

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ABSTRACT

Today, three dimensional (3-D) solids modeling design technology and the deployment of integrated relational databases on projects in the construction industry have provided the opportunity for advancing the level of achievable integration and automation in the design, construction, and operation of major industrial facilities. The key development has been the linking together of these technologies into one system to allow for the exchange of information between the model and the database (geometric versus nongraphic data), while providing an advanced medium for the accessing, retrieval, and presentation of a project's data. This graphically linked database technique allows the design model to be utilized as a simulation tool to display construction sequences, material availability, installation progress, and other functions, in addition to its primary function of drawing production.

INTRODUCTION

Since 1987, Stone & Webster Engineering Corporation (Stone & Webster) has been utilizing 3-D graphically linked database systems to integrate the design process, and to provide graphical simulation capabilities to a number of projects. Integration is brought about through programs developed by Stone & Webster that link IBM's DB2 relational database with the CATIA 3-D solids modeling application.

Three-deminsional solids modeling, by itself, is a powerful design tool that integrates the various design disciplines to detect interferences before the production of drawings. However, its linkage to a relational database expands the capabilities of the process by providing a repository for geometric data associated with the solid elements of a model. These data can then be imported into application programs for processing. Likewise, data contained in the database can be related to the components in the model to allow the user to obtain information about a facility by prompting the model or to use these data to construct simulations that are displayed using the model. Stone & Webster uses a number of these applications, applying these techniques in the areas of project controls, facility engineering, construction sequence modeling, and material management.

APPLICATIONS

Stone & Webster has recently deployed its 3-D modeling system for facility design, and its graphically linked **CO**nstruction **MAN**agement **D**isplay **S**ystem (COMANDS) for planning, estimating, scheduling, and material management on a 550 MW pulverized coal fossil retrofit project. The scope of the project consisted of replacing the existing scrubber and precipitator units, and replacing more than 800 tons of exhaust duct during a 12-week outage.

The facility was one of two attached units on a congested site. Due to the congestion restraints, tight schedule, and penalties for delays associated with the project, it was decided that the 3-D modeling system would be used during the proposal stage as a planning tool to help determine whether the work scope could be achieved in the allotted time. The existing configuration and the owner's conceptual duct design were modeled by two individuals over a 3-week period based on existing drawings and data gathered during site walkdowns.

The purpose of this approach was to create a model that could be used as a communication tool in the planning process which would allow construction specialists to visualize various construction strategies. The geometric data in the model also provided estimated quantities used in the bid preparation and for determining durations of construction activities. Use of the model allowed construction specialists to position construction equipment, to verify access, and to develop sequences of construction that maximized the content of preoutage work. The result of this planning process was a pictorial display of the optimum construction sequence simulating progress over time. This product was then used during internal management reviews and in presentations to the client to convey the scope and execution plan of the project.

After the contract was awarded, detailed design of the facility was conducted using 3-D for all new structural and mechanical items, starting with the model developed during the proposal. This was inclusive of foundations, structural steel, ductwork, mechanical equipment, and piping. The project's design drawings were then produced from the model by employing the 2-D capabilities of the system.

During this process, construction specialists and project control engineers were able to utilize copies of the model for constructibility reviews, planning, and procurement. As the various engineering disciplines completed design, personnel used the design model to customize products for their specific needs.

The construction specialists first used the proposal model to refine the demolition sequence of the existing precipitators and ductwork. Crane studies were performed to analyze crane reach, capacity, and equipment access. The 3-D system allowed for weight densities and center of gravity to be applied to the solids representing the existing ductwork so that the sections to be removed could be sized and rigging pick points determined in accordance with the position, lift capacity, and reach of the crane. Using the geometric data and the graphic images of the model, a demolition sequence was developed using Primavera's Finest Hour scheduling package.

As design approached completion, the construction group used copies of the model to produce sequence models of the installation process. Construction also sized the ductwork sections to be fabricated using the geometric data features of

3-D model to calculate weight and rigging pick points. When these tasks were completed, isometric piece mark sketches were produced detailing the weight of each duct section, piece number, and priority for fabrication (Figure 1). These data were then forwarded to the duct fabricator to coordinate the manufacturing and delivery schedule.

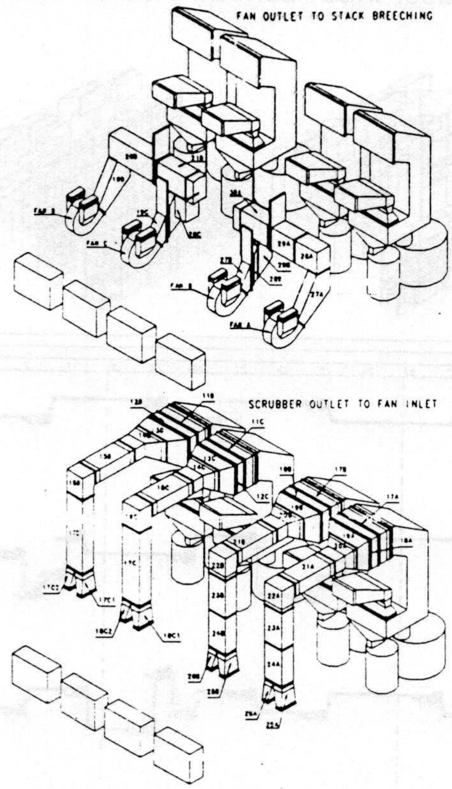

Figure 1. Duct Work Piece Mark Sketch

Isometric sketches were also produced for piping drawings which detailed the location of field welds, spool numbers, hanger locations, and bills of material. These data were incorporated into the prospective pipe fabricator's bid package.

After the Finest Hour construction schedule was completed, the output was electronically passed to the modeling system for integration with the construction sequence model. The resulting document (Figure 2) displayed a construction sequence model linked to a schedule where each week's activity had a corresponding view of the model representing progress arrayed above the scheduled activities.

UTILIZATION OF COMANDS

The material management module of the COMANDS system merges piping specification data contained in the relational database with data extracted from CATIA piping models to produce bills of material that are used to define piping material requirements. What makes COMANDS unique is the graphic data interface that allows the model to be used as a medium for displaying information. In this case, the user is supplied with two graphic data interface functions. The first permits the user to place the curser on any piping component to view an on-screen display of the component's description or a bill of material of all the components on the selected component's piping line number. The second function displays material shortages on the model, and lets the user prompt the model to obtain a component's material status (Figure 3). The material shortages are calculated by identifying all material that will not be on site to meet a user input schedule date; these are displayed in red on the model.

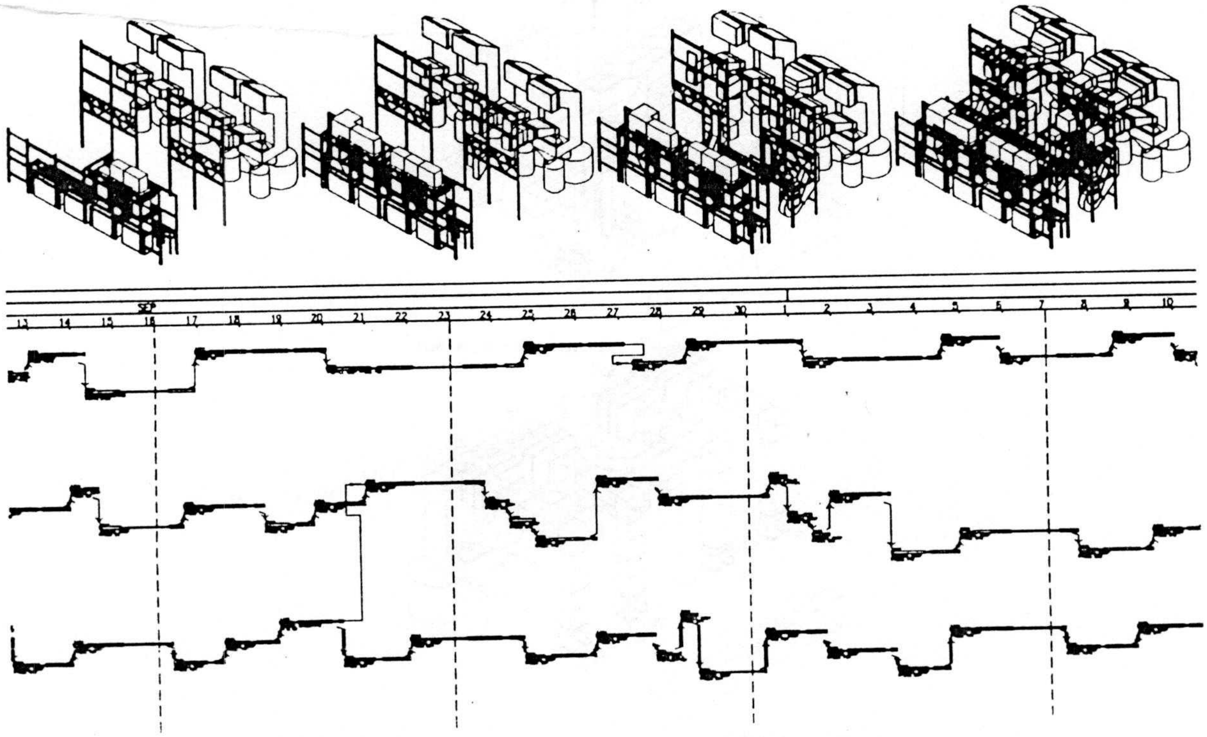

Figure 2. Construction Sequence Model Linked to Schedule

The COMANDS material management module summarizes the material requirements into material summary reports that cross-reference a project's material requirements to their source line numbers and models. These material requirements can be allocated to requisitions within the system by comparing the totals on a commodity basis to materials already on requisition. The requisitions are then processed into purchase orders and an inventory system established to track material delivery, receiving, storage, on-hand availability, and issuance status.

COMANDS was initially deployed to provide piping bill-of-material takeoff data to the pipe fabricator from the engineering models and to provide estimated piping quantities when developing the project's budget and schedule. Later in the project, it was used to take off and requisition field-installed piping systems (fire protection, deluge and small bore piping) and to track piping material availability and status.

The COMANDS Project Controls module uses the design model for quantity development and for reporting and recording of installed quantities. The application employs traditional work breakdown structure and earned value methods for monitoring a project's progress and is integrated with Primavera network planning

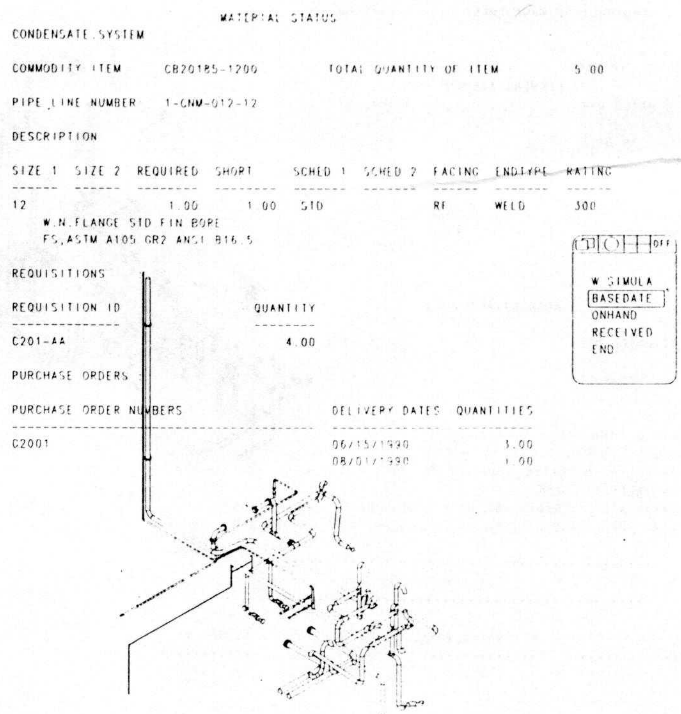

Figure 3. Trial Withdrawal Material Shortage Status

software. The system utilizes a graphic data interface that allows the user to report the installation of a facility's components by positioning the curser on the installed component on the design model. The system then passes the geometric data concerning the item to the database to calculate the design quantity of the installation while highlighting the installed component in the model to provide a visual record of installations on the model. Similarly, the user can also prompt the design model through the graphic data interface to display schedule, budget, and installation status of components in the model (Figure 4).

The Project Controls application of COMANDS is presently being used to monitor steel and duct replacement. The version being deployed was first established on the mainframe where the work breakdown structure was used to cross-reference the solids in the model to the accounting structure and activities in the network. Data extractions were then used to pass the geometric information of the design model to the account structure for establishment of the budget quantities used to track construction progress.

After the database was established, views of the model, along with the database, were accessed, via modem, on a personal computer (PC) located at the site. Stone & Webster's in-house developed software, STONE*view*®, which allows the PC to communicate with the design model and database across regular telephone lines, was utilized. The installed components were then updated on line via the PC and passed by modem back to the mainframe database. The user can also use this method to view the status on line by prompting the model to identify a component's design quantity, installed status, and schedule status. The advantage of this approach is the ability to provide the graphic data interface capability without use of a site-

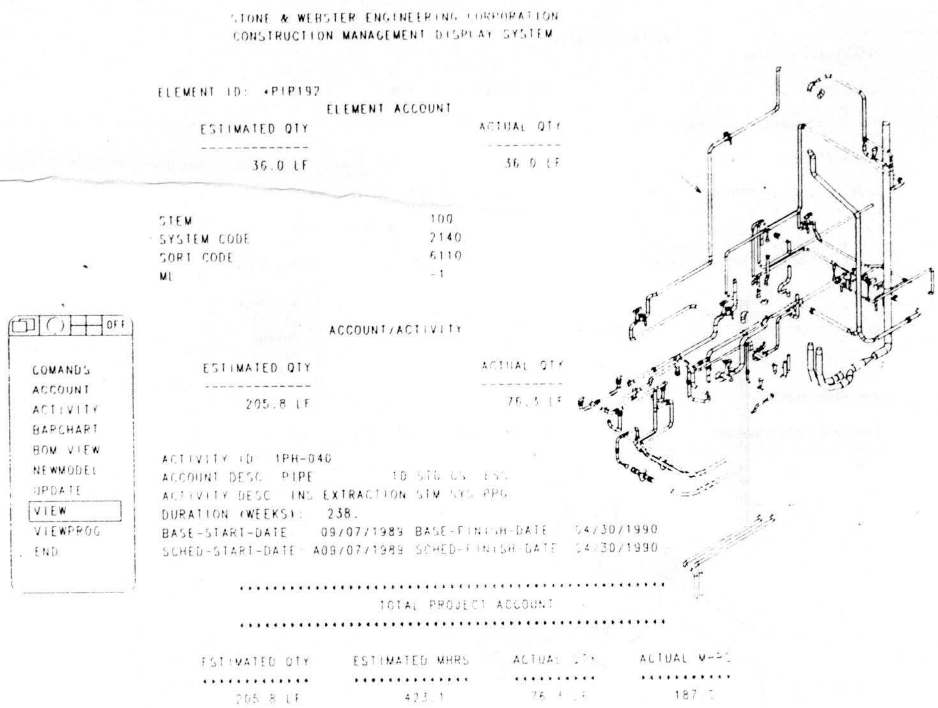

Figure 4. Schedule\Account Status

installed, high-end graphics workstation, which would have necessitated the installation of a dedicated data communication link to the jobsite.

OTHER APPLICATIONS

Recently, Stone & Webster utilized its 3-D solids modeling system, coupled with animation software, to assist the Corporation in obtaining a major contract award. After award, the system was used as an integral part of the process selection work scope. The project award consisted of a $430-million emission control system for a major western coal-fired power plant consisting of three 750 MW units. The work scope includes process selection, engineering for refurbishment of existing stacks, installation of crossover duct work, and installation of a scrubber system for each of the three units.

As part of the proposal effort, the existing site facilities were modeled in CATIA. This modeling effort consisted of envelopes of the main powerhouse structure and yard structures combined with previously modeled generic scrubber configurations. The modeling was performed over a 2-week period, and the resulting product was then animated utilizing Wave Front software to display on video a computer simulation of the construction process. Construction sequence models integrated with Primavera schedules were produced and utilized as part of the proposal presentation to communicate Stone & Webster's project execution plan.

After the award of the engineering contract, the 3-D modeling system was used extensively as a simulation tool to evaluate alternatives during the process selection. As part of this scope, 10 scrubber vendors submitted multiple proposed designs for the project. These configurations were then modeled with the proposal model, resulting in a total of 25 separate model designs. The evaluation process used these models to review the scrubber designs from a constructibility, capital cost, access, schedule, and safety perspective with the client.

The models provided geometric data used to calculate quantities of duct, piping, and steel, as well as a visual display for the various layouts. In turn, these quantities were used to formulate the capital cost estimates. This procedure provided the basis for selection of the process and configuration layout of the project.

In preparation for client review, STONE*view*® was used to transfer isometric views of the various model, configurations to a laptop PC. The presentations were made at the client's offices with the use of overhead projection equipment. STONE*view*® allowed Stone & Webster personnel to visually display the various designs to aid the client in process and layout selection. The model views could be panned, zoomed, and rotated. Comments could be annotated on the views, thus providing a superior medium for communicating the various project configuration options and layouts.

When the final selection was agreed upon and comments had been incorporated, a construction sequence and walk-through animation video were produced. These were incorporated into a informational videotape about the project that was used in presentations to the public.

CONCLUSION

Today's 3-D solids modeling design tools coupled with relational database, network, and animation software products are expanding the integration and portability of the design and construction functions. Computerized design models are replacing the traditional plastic models as a tool for detecting design interferences and for performing constructibility and operability reviews. Examples of this integration are the electronic interface of a models geometric data into engineering structural analysis and stress programs, and the importation of quantity data for procurement and estimate development.

The design model is being incorporated into the construction planning and scheduling process to refine construction sequences through simulation of the construction process. This provides a communication tool for presenting project execution plans to clients, as well as construction forces. Animation software allows the model to be used for the creation of videos that provide a portable, dynamic means for displaying a project's scope for internal reviews and to the general public.

In addition to STONE*view*®, other software products are allowing the importation of model data to PCs for conceptual and detailed design reviews or processing of data locally. The integration of graphics systems to relational databases is providing intelligent design models that can display data in an advanced medium for applications in project controls, material management, and plant operations. These applications can visually simulate material shortages and construction progress on the model. They provide a graphic data interface that acts as a window to a facility's database for obtaining project information.

The results of this technology are automating the engineering/construction process, while improving coordination and communication among engineering, construction, and client organizations. This is increasing the quality and productivity of the construction industry today.