**GEHRY TECHNOLOGIES……..……A CASE STUDY**


ARCH 497……DIGITAL DESIGN AND FABRICATION
DEEPA NARAYANAN……..…..SPRING 2006

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## INTRODUCTION…….

Building projects are increasingly complex undertakings. Tougher building codes and performance requirements, tighter schedules, distributed teams, and the possibility of new architectural forms, all add up to a building design and construction process whose demands exceed the capabilities of 2D CAD and paper based delivery processes. Additional complexity in the design phase has created downstream problems in construction where poor data coordination translates directly into an average of 20% costs overruns during construction. The result of this trend is that, while over the last 20 years technology applications have resulted in productivity gains in virtually every industry, AEC has actually experienced productivity losses over the same period.

As building projects have become more complicated in their technology, regulation, concerns for safety, energy and the environment, as buildings have changed from field crafted custom constructions to an assembly of standard products, custom fabrications, and increasingly complex environmental, energy and communications systems, the risks have increased and the project delivery process has become more complex. The design, engineering and building of 'one of a kind' buildings is unlike the manufacturing of mass produced products. At the start of a building project one usually does not know what it will be, how it will be made, or who will build it. Building requirements, codes, and practices vary from project to project and from region to region. Few universal standards of practice exist. Outside of the environment of integrated design build companies, teams of architects, engineers, and consultants are brought together to start a project. They must either integrate their ways of working virtually overnight, or perpetuate a fragmented process. Later in the design process they may know who will manage the construction, and even later, often after the design is complete and bid, they will know who will fabricate its components and provide the products that are to be assembled or crafted in the field as coordinated building elements. As a result each player in the process has developed its own ways of working and come to rely on itself. This has resulted in a system where each player can only develop processes and solutions in its own limited field of influence.

Through the life of a project, information is often regenerated; technology, knowledge and expertise is carefully guarded; and the risks associated with the development of a project are isolated or transferred to others. The software industry has responded by developing niche solutions for each industry segment that are usually incompatible, and often redundant. This redundancy of information has lead to more conflict, more risk, and more inefficiency. Management too often focuses on accountability, rather than coordination, in an effort to isolate the source of the problem and assign blame. A whole legal industry has grown up around this problem only adding to project costs and inefficiencies. Most AEC software solutions have been developed through the lenses of this fragmentation and most are rooted in a 20th century paper process (or a paper like digital version of this process).

The management of a paper bureaucracy has itself grown around this process and adds more cost in the effort to manage confusion. Most of the management time on a project is spent dealing with this fragmented, redundant paper process and conflicts rooted in the process itself. This is why, in spite of over 30 years of evolution of software applications for the AEC industry, productivity has dropped, errors and claims have increased, and clients, architects, engineers and contractors are as insecure as they have ever been. The buildings usually take far longer to complete than expected and cost much more than calculated.

There is growing interest, within the architectural design, engineering, fabrication and construction communities, in the potential for digital technologies to change the nature of professional practice and to address the underlying inefficiencies and conflicts resulting from an outdated process.

**Gehry Technologies** was formed in 2002 to provide these technologies and methodologies to the building industries. Gehry Technologies ("GT") is a building industry technology company providing integrated, digitally driven construction tools and methodologies to companies and their projects. GT brings fifteen years' experience applying advanced digital technologies to complex building projects undertaken by Gehry Partners and other leading architecture and engineering companies. Its clients are firms and building teams interested in moving beyond the limits of drafting and paper driven project management and into 21st century, digitally enabled design and construction practices. Gehry Technologies promotes this transformation of building design and delivery practices through three inter-related centers of effort: Software Products, Consulting and Services and Research and Education.

Vision

"Communicating project data to the building team in a digitally integrated form, and rethinking the collaborative processes of project teams in light of new design, management and communication technologies."

Project teams working with GT's technologies and services can anticipate many benefits relating to improved quality and reduced costs, including:

- Improved visibility by project leadership into information developed by the extended building team,
- Integration of financial and other non-geometric data with project geometry,
- Improved coordination of building systems to identify and address potential conflicts before construction,
- Management of project data through version and revision tracking,
- Integration between AE documentation and fabrication or construction activities,
- Reduced project transaction costs (paper printing, rework, etc.)

Gehry Technologies promotes design & construction methodologies that views three dimensional models of construction information as components of the project contract documentation. These methodologies - referred to collectively as digital practice - include not simply the technical aspects of tracking data, but also the contractual and procedural advances that need to take place. Digital practice enhances - and is compatible with – traditional construction and contracting methods.

# Digital Practice

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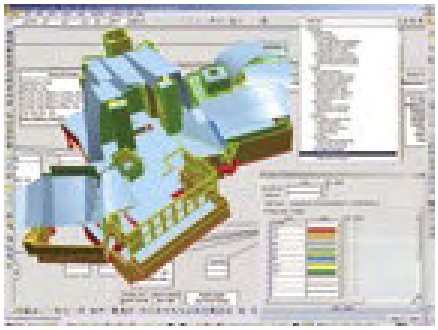
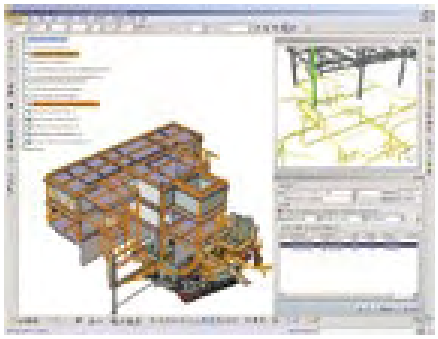
Digital practice is realized on building projects through several inter-related project activities including:

**Digital Contracting**



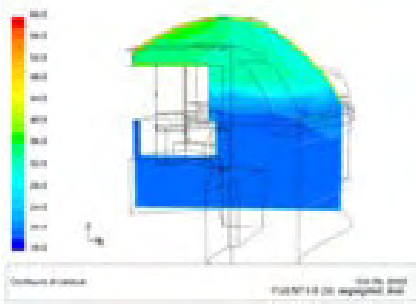
Contracting based on 3-dimensional project data is a key enabler for re-engineering the building value chain. Three-dimensional project descriptions, when properly built and managed, provide highly accurate information on which construction contracts can be based with confidence. Digital Project allows robust access to project data for viewing and verification, and supports the integration of geometric and non-geometric project information.

**Project Coordination and Control**



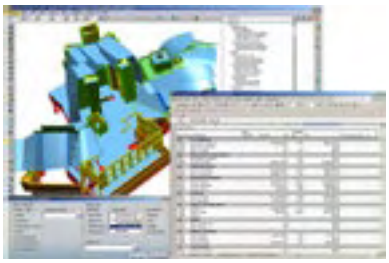
Project geometry is developed and used by team members across the building project. This information needs to be coordinated and quality controlled to ensure error free construction. The comprehensive 3D model at the core of the GT's process provides an enormous aid for coordination. Engineering and fabrication documentation may be developed directly in the Digital Project environment, or imported from 3rd party applications in 2D or 3D format. System interferences may be detected, either via visual inspection or through tools that automate checking for spatial clashes or violations of required offsets between systems.

**Building Performance**



Powerful computational engineering analysis techniques are now available to perform many difficult engineering tasks, including structural analysis, energy simulation and computational air flow studies, equipment performance simulation, and lighting and acoustic simulation. With the availability of a comprehensive, three dimensional project description, the level of effort required to generate specific analytical models becomes greatly reduced, since some representation of the system under inquiry is often available in the master model by the time that the analysis is required.

**Cost Estimating**

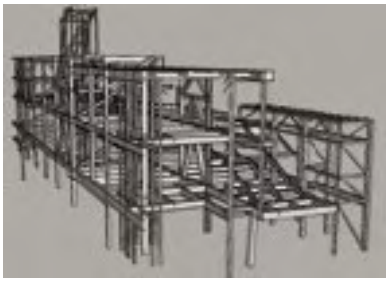


Control of estimating is a critical aspect of project success. Conventional estimating techniques – where quantity takeoffs are produced by measuring off of paper drawings – have substantial potential for error. An accurate digital project model removes the ambiguity and potential disagreements about project quantities. Digital Project includes tools for rapidly and accurately producing quantity takeoffs and piece counts, and for automatically extracting quantities to spreadsheets and 3rd party estimating software.

**3D > 2D Integration**

The generation of accurate, 2-dimensional project documentation remains a requirement for construction and needs to be supported while the industry moves to fully 3D processes. The Digital Project modeling platform streamlines the process of producing dimensionally accurate and coordinated 2-dimensional drawings, by extracting this documentation from the integrated 3D model. The software allows parametric definitions of drawing extractions to be defined in the 3D environment in a persistent manner. When project geometry is modified, drawing extraction is achieved through a simple update request.

**Digital Fabrication**



Emerging practices support the direct integration of design and engineering data with fabrication activities. Digital design information is provided directly to fabrication shops to provide the dimensional specification and component placement information. Increasingly, project information is being repurposed directly to drive digital fabrication equipment. Shop drawings may be submitted in 3D form back to the master project database, allowing tight quality control of the construction process from design through fabrication.

**On Site Integration**

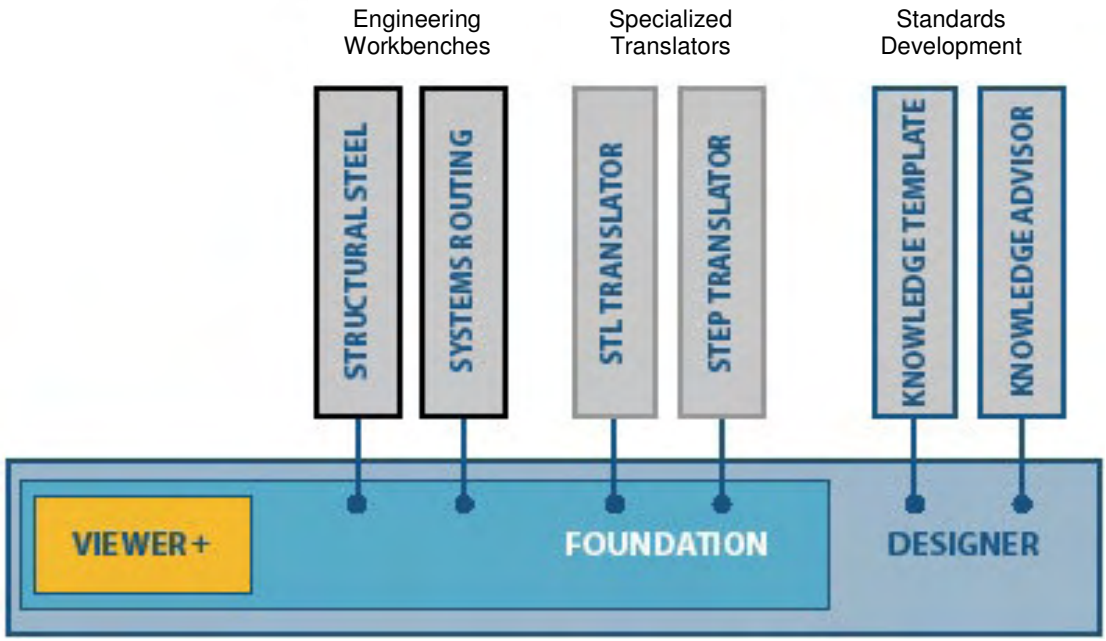
Digital Project viewing stations are often provided to the job site trailer, allowing direct access by construction personnel to the project data. Digital Project offers integration with digital surveying technologies to allow points from the 3D master model to be downloaded to digital surveying equipment. Rapid advances in consumer technology products, including wireless networking, cloud of points scanning, digital photography, tablet computers and PDAs offer the possibility of the potential for placing project information directly in the hands of construction personnel as they perform work in the field.

## Digital Project

Digital Project is a revolutionary new software platform for building teams to realize ambitious building projects working through digital technologies. Digital Project products support the lifecycle of construction projects in a common digital environment, from design and engineering to fabrication, construction project management and on site construction activities. It is designed by people from the industry for the industry. It brings together the concepts of PLM emerging in the aerospace, automotive, ship building, and product design industries with real world practical experience from the building industry gained over 15 years of innovation by Gehry Partners and the architects, engineers, and contractors who have collaborated on their projects.

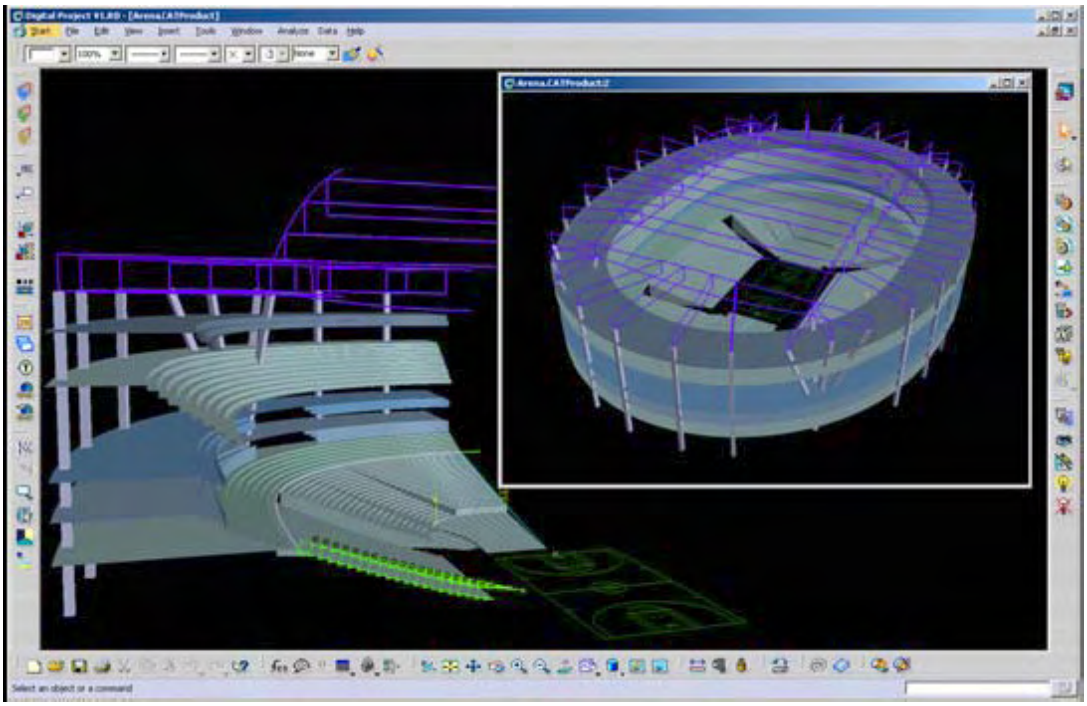
GT is trying to move away from the need to produce copious numbers of drawings by using the digital model as the sole reference. It has been pragmatically designed to allow for the evolution from a paper based process to the new world of digital design and contracting. It is an open architecture that allows it to integrate AEC industry niche market solutions that exist today into a single collaborative master model for architects, engineers, contractors and project managers that can be directly linked to the advanced applications emerging in the fabrication industry. Digital Project supports the development of a comprehensive project database in a contractually controlled fashion, allows teams to realize the full benefits of building information modeling including:

- Greatly facilitated visibility by project leadership into the project status, information developed by the extended building team,
- Cost estimating with accuracy and confidence,
- Integration of financial and other project management data with project geometry,
- Dramatic reduction of errors, omissions, and rework in the field,
- Up to date coordination and delivery of project data team-wide,
- Integration between AE documentation and fabrication or construction activities,



## DESIGNER……...

**Designer** is the premier configuration of Gehry Technologies' Digital Project product line. *DESIGNER* provides full functionality geometry and knowledge modeling capabilities for advanced architects and engineers, who want to conduct their work using the industry's 3D highest performance modeling tools. *DESIGNER* provides an extensive set of tools for creating and managing knowledge enabled building information, from schematic design through construction documentation.



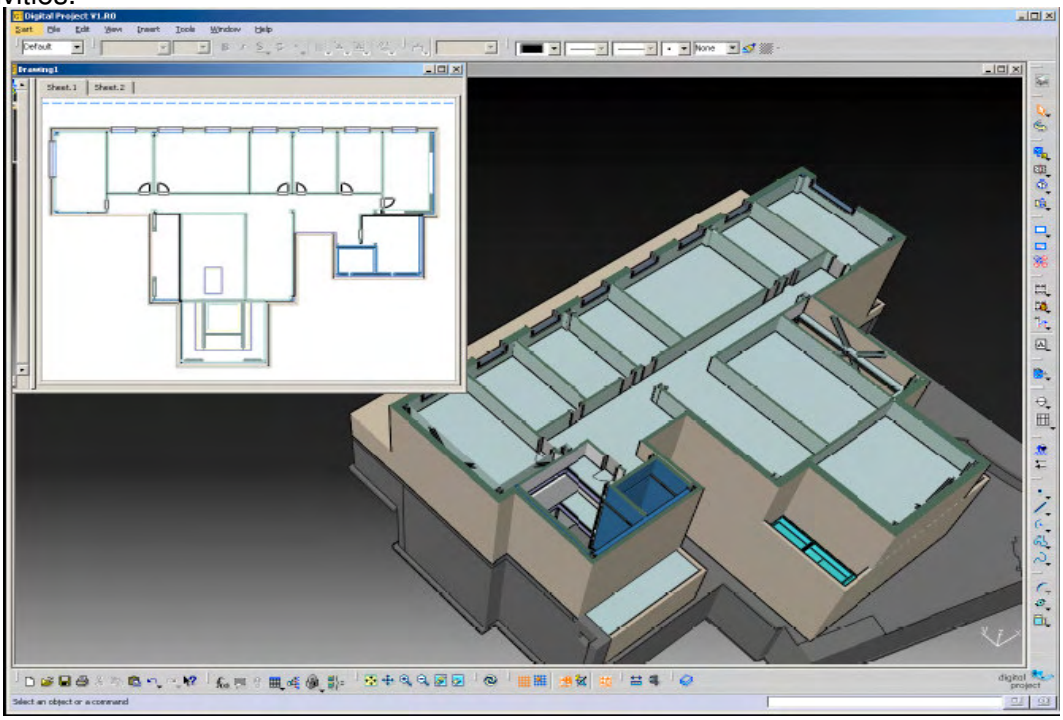
*DESIGNER* includes Digital Project's attribute modeling capabilities, allowing building professionals to overlay project geometry with a rich set of construction information. Project data can be integrated with construction scheduling information through a direct interface with Microsoft Project. *DESIGNER* comes with Uniformat and CSI attribute schema for to support cost estimating and specification referencing, as well as attributes for quality control, and utilities for user extensions of attribute schema.
The product includes libraries of architectural components and utilities for extracting information to architectural schedules.

**Product Highlights**

- Supports user development of intelligent building components.
- High performance, immersive 3D environment for all design operations.
- Best in class solid, surface and wireframe geometry tools.
- Parametric, specification driven geometric modeling.
- Knowledge copy and re-use through power copy technology.
- Libraries of parametrically-driven architectural components.
- Attribute overlaying, viewing and extraction.
- New grouping infrastructure facilitates bi-directional integration with Excel, and functionality for construction coordination processes, and issue management.
- 2D drawing extraction from 3D.
- Quantity takeoffs and schedules.

## FOUNDATION……

**Foundation** is the production and coordination configuration of Gehry Technologies' Digital Project product line. *FOUNDATION* provides basic geometry and knowledge modeling capabilities for architects and engineers. The product also includes full access to Digital Project's attribute modeling and review infrastructure.
Digital Project *FOUNDATION* is an appropriate entry level product for project team members who require core geometric modeling capabilities, combined with powerful data extraction, processing, and quality control capabilities. In an architectural setting, *FOUNDATION* provides functionality appropriate for supporting architects who perform basic modeling, as well as drawing production, quality control and data coordination activities.



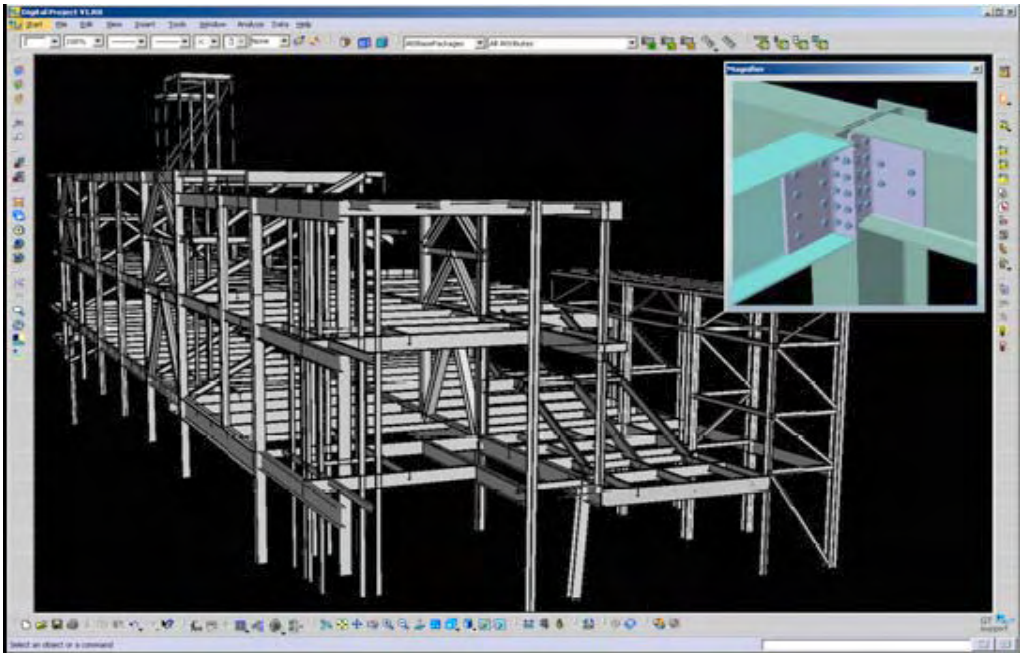
*FOUNDATION* is a base product that includes over 200 commands and functions. The package supports high quality geometric modeling from wire frame and surface modeling through feature based solid geometry. KnowledgeWare parametric modeling capabilities are integral to all Digital Project technologies. Geometric modeling operations can be defined schematically by specifying parametric relationships. Geometry dimensions can be refined without redrawing.

**Product Highlights**

- High performance, immersive 3D environment for all design operations.
- Supports user development of intelligent building components.
- Parametric, specification driven geometric modeling.
- Core solid, surface and wireframe geometry tools.
- Knowledge copy and re-use through power copy technology.
- Attribute overlaying, viewing and extraction.
- New grouping infrastructure facilitates bi-directional integration with Excel, and functionality for construction coordination processes, and issue management.
- 2D drawing extraction from 3D.
- Quantity takeoffs and schedules.

## STRUCTURAL STEEL……...

**Structural Steel** provides a comprehensive suite of tools and component catalogs for the design of steel structures. Users can draw on a complete set of international industry standard steel member types to create virtually any kind of structural framework which is rich in data and fully integrated into Digital Project's parametric-associative data model. The *STRUCTURAL STEEL* workbench builds on the same V5 core engine used by the entire Digital Project family. This gives GT's structures solutions an unprecedented level of flexibility, data richness and interoperability in structural steel modeling, ensuring that geometric models are maintained up-to-date through associativity, and attribute information can be leveraged throughout the span of a project model.

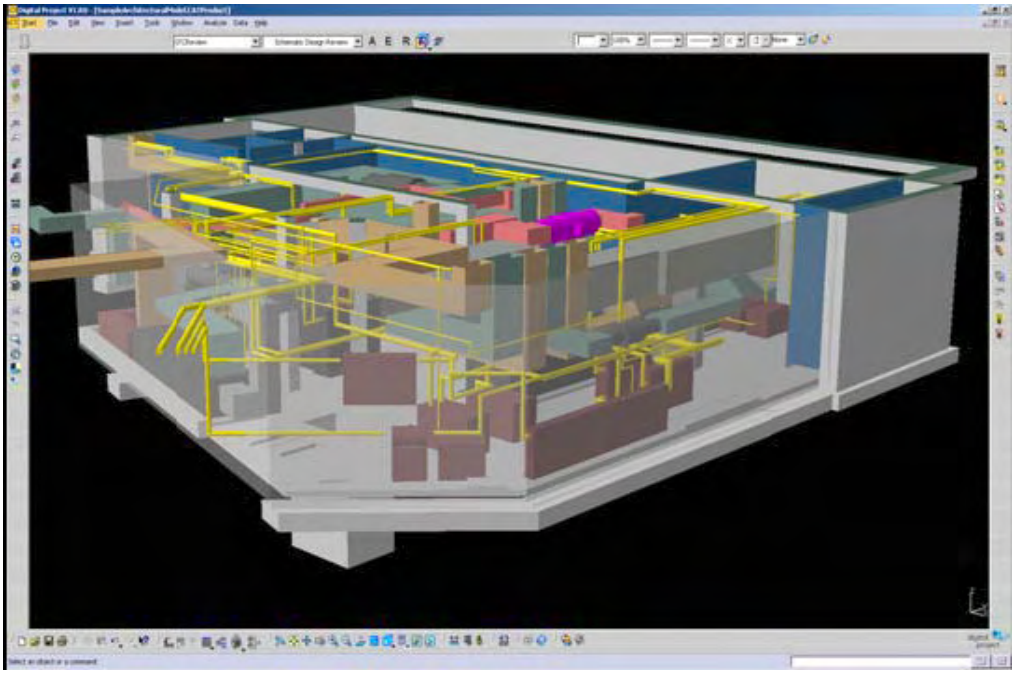


**Product Highlights**

- **Plate and Extrusion modeling**: Provides powerful tools for directly modeling structural steel frames in an immersive 3D context.
- **Industry Standard Catalogs**: Comprehensive sets of industry standard steel members are available out of the box, allowing the users to build steel industry-compliant structural assemblies without the need for further modeling.
- **Custom Component Definition**: Beyond the available industry-standard catalogs of steel members, users can easily create catalogs of proprietary section used on a project or across an office.
- **Functional Wireframe-driven Design**: Members are intuitively placed on a 3D structural wireframe model which is built in Digital Project, or can be imported from other 3D software. V5's associative technology ensures that subsequent modifications to the underlying wireframe are reflected in the members' updating sequence dynamically.
- **Drawing extraction**: produce accurate 2D plans and sections from 3D structures models, either independently or in the context of additional building systems.
- **Industry Standard Data Translation**: CIS/2 and SDNF translators maintain geometric data as well as semantic information such as member section type, cardinal point, steel grade and such.

## MEP……..

**Systems Routing** is the Mechanical, Electrical and Plumbing dedicated application of Gehry Technologies' Digital Project™ product line. As such it is a conceptual design application that provides system planners with the ability to reserve the space needed for eventual functional and detail layouts of HVAC, raceways, piping and tubing. By designing within context of the project, integrity of the systems with surrounding environment are analyzed, interferences are avoided and different disciplines can be free to optimize their designs knowing that their spatial needs and installation sequences are taken into account. The parts come already parameterized and are linked with design tables in Microsoft Excel enabling the parts to be easily sized at the time of the placement. Using Digital Project™ *SYSTEMS ROUTING*, users can model the initial space claim by simply defining the geometry and size of the runs that are used to define the desired route. This allows spatial considerations to be analyzed early in the preliminary design process and to uncover potential problems early in the design cycle when they're easier, faster and less costly to correct.



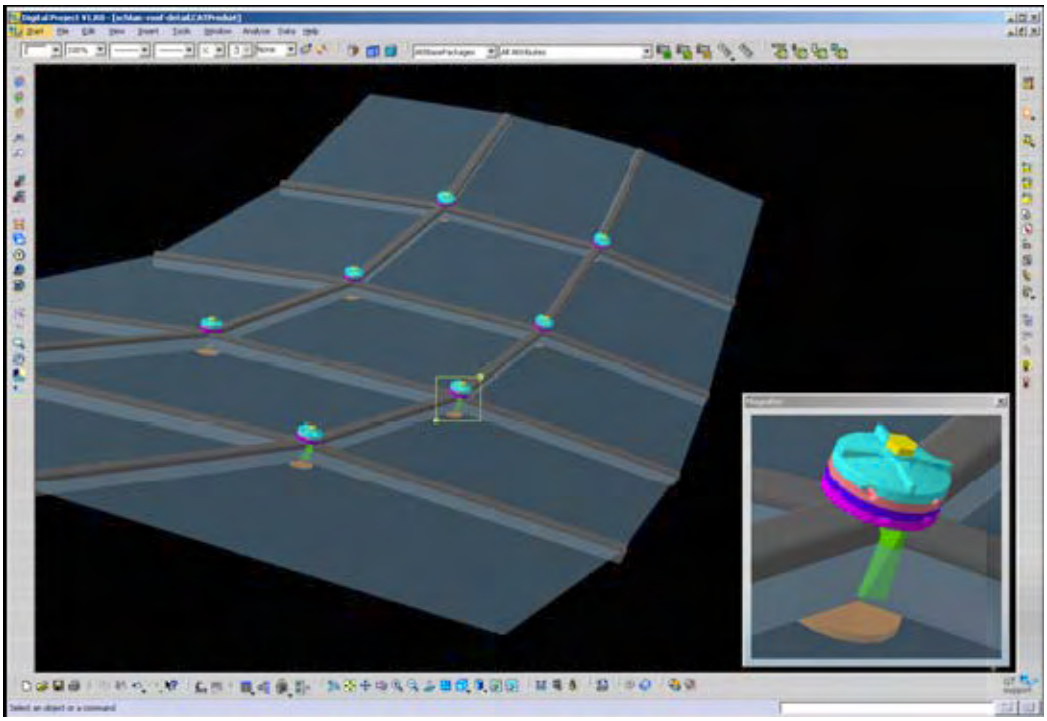
**Product Highlights**

- A fully detailed, integrated solution providing an advanced design in context environment for equipment and systems.
- Intuitive 3D layout and sizing of duct, wire, and plumbing pipe via advanced parametric and standard catalog based features.
- Production of synchronized 2D drawings via automatic extraction from the 3D master model, reducing time and errors.
- Advanced collaboration analysis tools allowing interference detection within systems design and between systems, layout and structures to detect and eliminate all design and construction conflicts within the 3D virtual model.
- Advanced analysis tools for code requirement verification such as for example ensuring minimal clearances.
- Support of industry standard translation formats, including 3D and 2D DWG / DXF, IGES.

## KNOWLEDGE TEMPLATE……...

**Knowledge Template** provides utilities to develop 'intelligent design templates' for re-use across multiple projects. Knowledge Templates adds onto Digital Project's Designer product, capturing design operations into libraries of reusable, re-configurable, intelligent design components. When instantiated in project models, Knowledge Templates will self configure to address the unique geometric context into which they are applied. They can be stored and organized into catalog sets that can be shared team and organization wide. The functionality allows specific designs to be captured as operation sets, complete with parametric dimensional variables, geometric and functional constraints and feedback information.

Knowledge Templates capture the design intent behind operations that generate geometry. Knowledge templates are parametrically enabled, and can automatically update their geometry if the design context or external parametric values are changed. Knowledge Templates can capture almost any kind of component or knowledge that is developed in the Digital Project environment, including geometric features such as solid, surface and wireframe geometric operations, as well as KnowledgeWare elements including parameters, formulas, rules, checks and embedded VBScript features.



**Product Highlights**

- Supports user development of intelligent building components.
- Provides encapsulation of component objects' internal and operator exposed behaviors.
- Allows repurposing of developed geometry across users and projects.
- Supports incorporation of Digital Project attribute schemas.
- Provides utilities for developing project accessible object libraries.
- Allows the definition of consistent object behaviors across similar components.

## KNOWLEDGE ADVISOR……..

**Knowledgeware** (KWA) is one of the main core V5 technologies used by Digital Project, controlling all aspects of parametric functionality including the creation of parameters, formulas and measurements. Knowledge Advisor builds on this functional core to allow the advanced control and manipulation of parametric components and features.

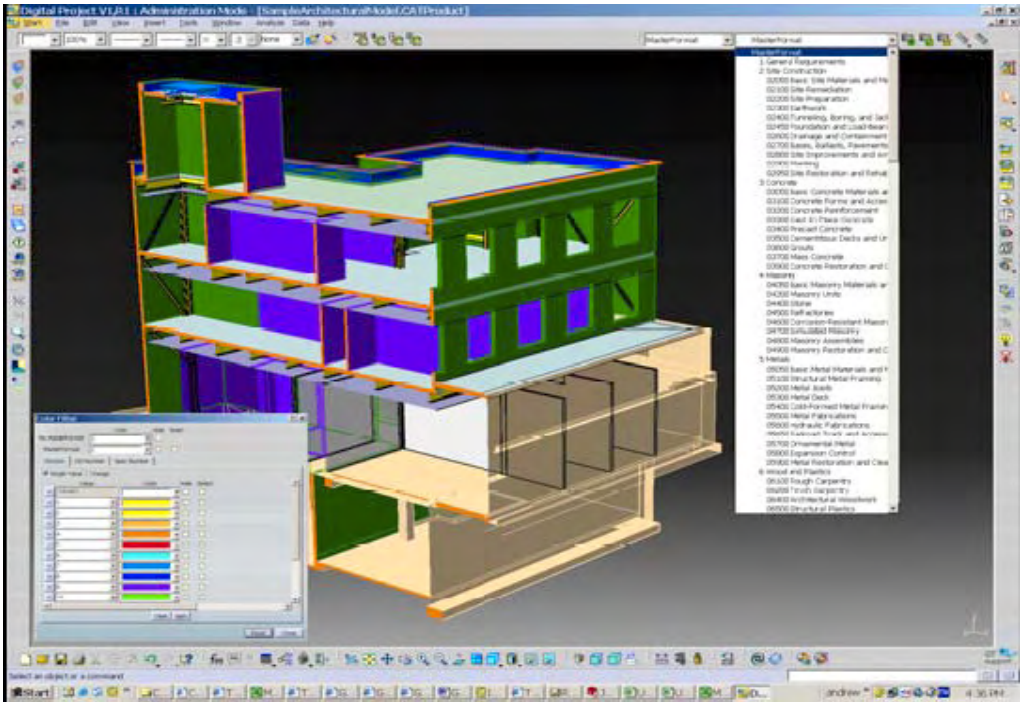
Knowledge Advisor functionality gives access to the Knowledgeware engine beyond the basics, including the ability for a parametric-associative design to check the for the validity of a geometric configuration or parametric value against a user-defined set of rules and even the ability to make decisions depending on certain design-dependent conditions. The ability to control designs as rule-based systems allows users to define their designs as self-controlling schemas that are able to adapt and validate themselves against existing or varying geometric or parametric conditions.

**Product Highlights**

- **Feature-Level Parameters and Parameter Sets:** KWA gives a user the ability to add individual parameter values directly onto an individual design feature (geometric object or operations) using the Parameter Explorer tool. These feature-level values can be fully integrated in all formula, check and rules mechanisms, allowing detailed fine-tuning of parametric designs at the individual component level, as well as the recording of feature-specific information.
- **Artificial Intelligence:** Classic AI is defined as the ability for a system to make autonomous decisions based on a predefined set of rules. KWA provides a family of increasingly powerful AI features that can detect and react to geometric and parametric conditions within an parametric design depending on user-specified conditions.
    - **Checks:** This feature gives the basic capability to notify the user if a preset condition or parametric value is or is not met. A condition is given as a scripted logic expression within the Check.
    - **Rules:** Building on the scriptable logic of the Check, the Rule adds the functionality to make a decision and take action in response to a condition change. Triggering a Rule will result in an action being taken as specified in the Rule's script, which can include changing a parameter value, turning features on and off, or applying different subsequent features to the overall design.
    - **Reactions:** Similar to rules, these 'react' to specific user events in the model rather than changes in parametric conditions. Reactions can help monitor model changes and keep designs consistent.
- **Scripting Features:** KWA provides a special kind of feature, the Script Feature, which is basically the encapsulation of specific macro code snippets that are called during the update sequence in a parametric design. This can help in the updating of certain parts of the design, or the calculation of specific data sets.
    - **KnowledgeWare Language®:** This uses the object-oriented logic-type expressions used in Formulas, Checks and Rules.
    - **Visual Basic (Embedded)®:** This uses syntax similar to the well-known VBA, to provide small pieces of procedural script within a design.

## PROJECT MANAGER……...

**Project Manager** enables the creation and extraction of architectural, engineering and construction modeling and coordination information in the Master Model. It enables generation of customizable reports, and modifications to the model from these reports.
Digital Project's attribute infrastructure provides the technologies for creating and managing non-geometric information associated with project geometry. Attributes are organized in schemas, hierarchical class based sets of typed attributes, with capabilities for defining value types, selectable sets of values, or user defined attribute values. Attributes may be further organized into attribute packages (pre-defined sets of attributes) and Dictionaries of attribute packages for easy sorting in the user interface.
These definition and editing capabilities are enhanced with robust viewing, filtering, importing and exporting capabilities. The attribute technology automatically generates user interfaces to manage defined attribute schemas, including dialog boxes for setting attribute values as well as viewing and filtering capabilities. A powerful set of project management capabilities, built on top of GT's attribute technology, are included in the product.

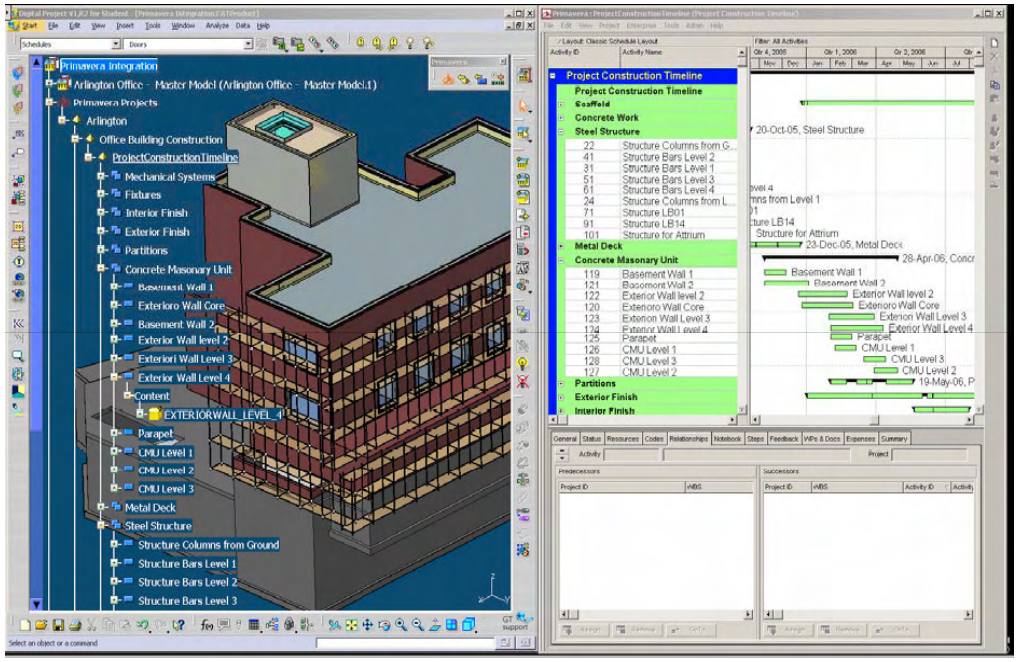


**Product Highlights**

- Select and place pre-defined attribute schemas, on project geometry. Examples of schemas include estimating, quality control review, and scheduling.
- Develop filtered views to quality control and review attribute data.
- Integrate attribute filtering with 2D drawing production capabilities to define custom geometry dress up on the basis of attribute queries.
- Extend and customize attribute schemas to reflect customers' industry practices.
- Interactive datasheets: Bi-directional integration of Digital Project and Excel to easily manage object names, attributes, parameters.
- New grouping infrastructure facilitates datasheets, construction coordination processes and issue management.

## PRIMAVERA INTEGRATION.....

**Primavera Integration** allows Digital Project users to link 3D components to Primavera™ activities and to simulate these activities in 3D (4D Navigation). Integrating Primavera construction scheduling information to a project's construction geometry helps to ensure a smooth and timely construction process. With a project's geometry in Digital Project and Primavera integration, different phasing scenarios can be played out and visualized to understand any critical issues which may arise.

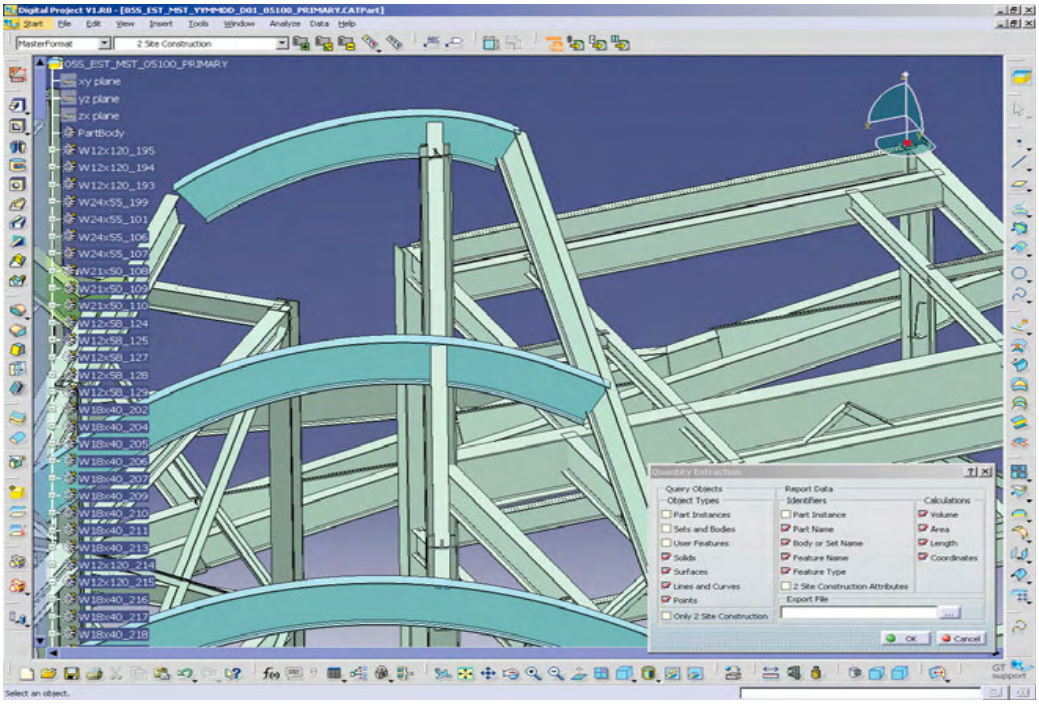



### Product Highlights

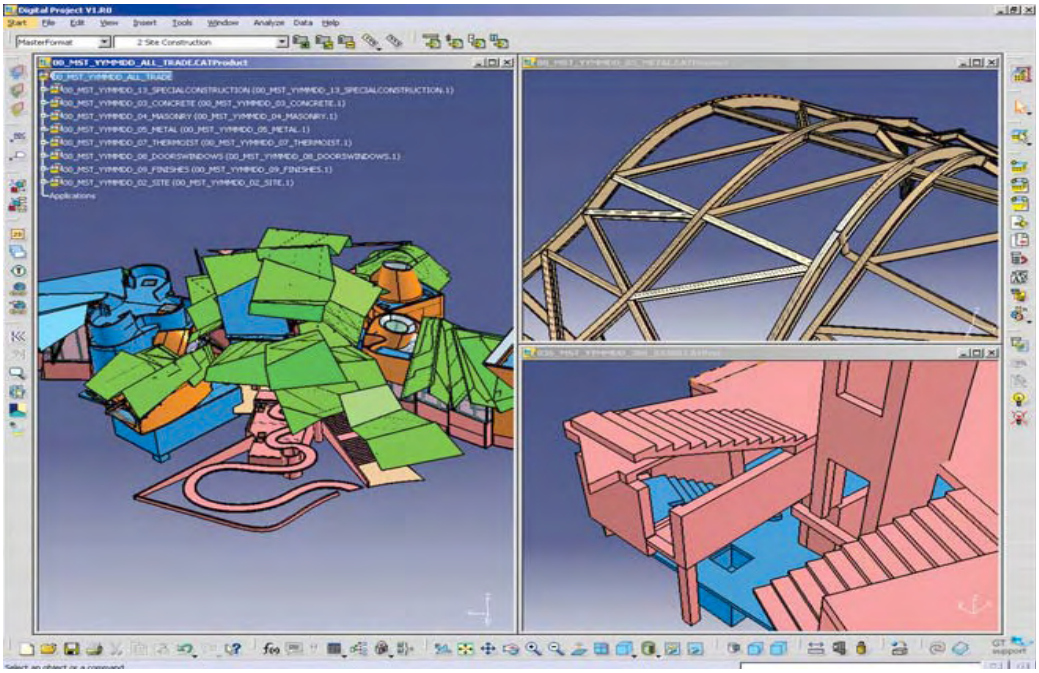
The *Primavera™* product enables:

- Import Projects, Work Breakdown Structures, and Activities from Primavera™ into Digital Project.
- Link imported activities to master model geometry.
- Visualize in 4D: Play a construction schedule over time.
- Propagate any changes made in Primavera™ to the Digital Project environment.

Gehry Technologies develops, markets, and supports the Digital Project software line as part of its digital practice solutions. Digital Project is a suite of applications designed to support the lifecycle of construction projects in a common digital environment.



Digital Project is differentiated from other emerging technologies supporting building information modeling (BIM), by supporting full lifecycle activities, beyond design and engineering and into fabrication, construction and project management. The product line includes workbenches of functionality for architectural & engineering firms, project owners and estimators, and contractors and fabricators, allowing these organizations to develop and access project wide information in 3D and conventional 2D formats.



## SELECTION OF CATIA SOFTWARE…….

One of the main obstacles between Gehry's design concepts and their construction was the act of documenting three-dimensional shapes with two-dimensional drawings. Gehry's staff would carefully measure his hand-crafted models, perform lengthy calculations, and prepare multiple sections and plan cuts to try to describe the design. Unfortunately, such drawings are time-consuming, costly and tended to make the shape seem more complex than it actually was. Contractors, uncertain about how the unusual forms could actually be built, would err in their cost estimates. That would lead Gehry, concerned about staying within the client's budget, to compromise his design. So in 1990, Gehry's staff began seeking computer software that could handle the complex 3D models yet leave intact Gehry's physical-model-based design process.

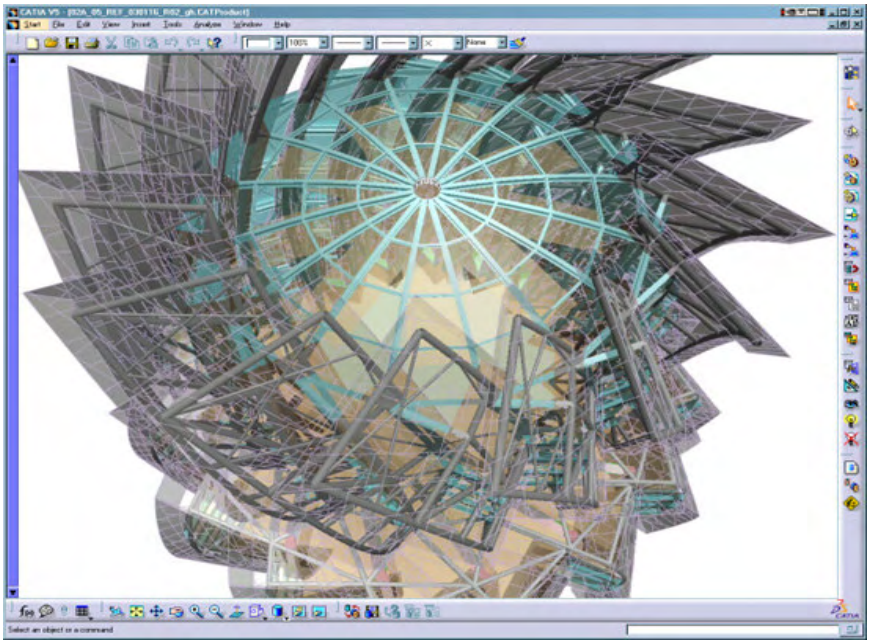
During this search, the firm tested a variety of architectural softwares. The architects' first experiment built with computers was the large fish sculpture for the Barcelona waterfront in the 1992 Olympic Village. The sculpture, about 180 feet long and 115 feet tall, is characterized by complex curves that defy traditional two-dimensional documentation. Initially modeled in wood and metal, its curvilinear surface is clad in flat, woven stainless steel panels that float above an exposed steel structure. Facing severe time constraints, the architects explored computer technology as a medium to communicate their design to the builders. A surface model of the fish was produced using Alias software and although this representation was visually accurate, the software at that time proved limited. Like most architectural and rendering software, Alias defined the fish surface as a grid of polygons.

By contrast, software such as CATIA with complete numerical control could define surfaces utilizing descriptive geometrical mathematical formulas that could be applied by steel fabricators to build the sculpture. Thus, an architect or builder could query a CATIA model for the precise location of any point on any surface. When this process was successfully demonstrated, the builder, Permasteelisa, purchased a CATIA suite. The architects created a CATIA model of the Barcelona fish, then tested the model's accuracy by constructing a paper model with a numerical controlled three-dimensional laser-cutter directly from the computer model. With a few modifications, Gehry verified that this new model matched his original conception.
Construction of the final sculpture followed with astonishing speed and accuracy. From preliminary design to the completion of construction required only about six months. Of the thousands of connections, two were off by 3 millimetres and the rest were perfect. And there were few traditional drafted construction documents or shop drawings. "Flat drawings of curved surfaces can be beautiful," Gehry admits, "but they are deceptive. With this system, you can see how to build it." The fish sculpture convinced Gehry and his associates that CATIA model data could be invaluable in helping to fabricate complex forms quickly and accurately.

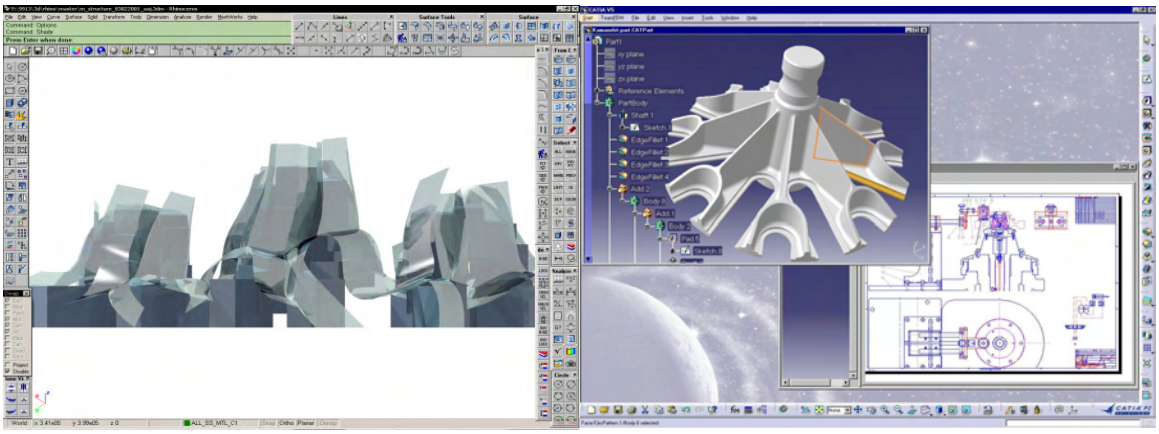
Thanks to CATIA, craftsmen understand architects' elaborate designs precisely. Costs have been reduced by as much as one-third.
"This technology provides a way for me to get closer to the craft. In the past, there were many layers between my rough sketch and the final building, and the feeling of the design could get lost before it reached the craftsman. It feels like I've been speaking a foreign language, and now, all of a sudden, the craftsman understands me. In this case, the computer is not dehumanising; it's an interpreter." Frank Gehry

## CATIA.....

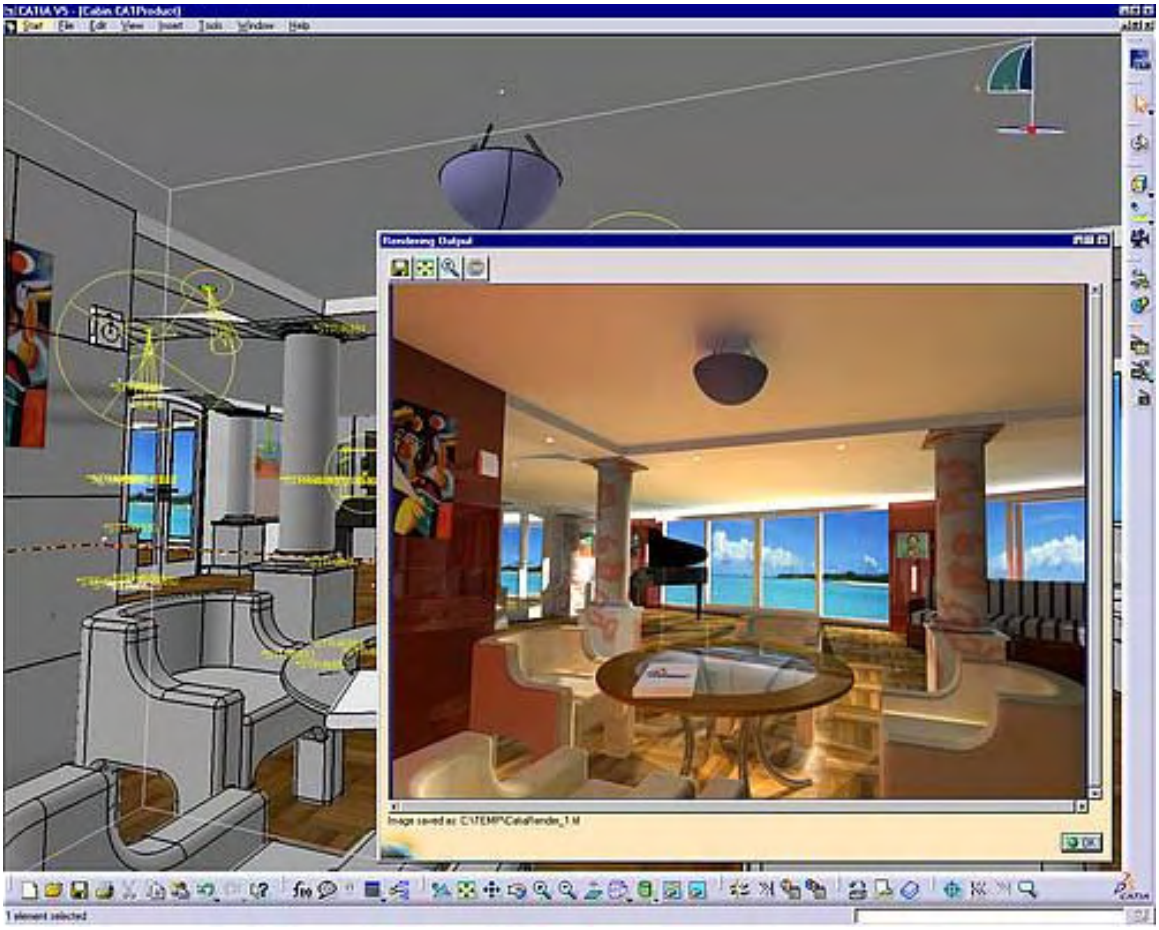
CATIA is an Object-Oriented Graphic program that creates computer graphics out of "**construction elements**". Object-oriented graphics describe an image mathematically as a set of instructions for creating the object in the image. This approach contrasts with bit-mapped graphics, the other widely-used approach to certain images, which represents a graphic as a group of black and white or colored dots arranged in a certain pattern.



Object-oriented graphics enable the user to manipulate objects as entire units. To change the length of a line, for example, it multiplies the entire unit as a whole in all dimensions in space, whereas bit-mapped graphics require repainting individual dots in the line or circle. Object-oriented graphics also introduce no limits in zoom. Because objects are described mathematically, objects-oriented graphics can also be layered, rotated and magnified relatively easily (Dassault). Views can be easily set and viewed in 3-dimensional space, perspective, **axonometric** and isonometric, allowing designers to view the structure from all possible angles.



While less expensive software is catching up, there is still nothing that can rival CATIA's ability to create, portray, render, and manipulate objects in three dimensions. The program runs on a UNIX operating system and requires the use of a reduced instruction set computer (RISC) rather than a standard personal computer (PC). The required investment in hardware is great, as is the cost of the software itself. While the latest version of CATIA is designed to be run on a typical PC with Windows NT, such systems are considered insufficiently stable for the complexity of such projects.



Foremost on the list of CATIA functions critical for Gehry projects is the "develop surface" feature. This allows the operator to take an irregular surface, such as that which is created when digitizing a three-dimensional physical model, and alter it slightly so that it is "ruled." A ruled surface is one comprising adjacent straight lines. The simplest ruled surfaces are a cylinder, where the ruled lines are all parallel, and a cone, where the lines converge to a single point. By joining parts of these basic forms, one can create more complicated ruled surfaces.

It is necessary for the curving building surfaces to be ruled, as this is the only way to ensure that they can be covered with pieces of flat material (drywall, plywood, sheet metal, waterproofing membrane, et cetera) without kinking.
CATIA allows the user to view the orientation of the ruled lines and establish other lines parallel and perpendicular to them. It was this functionality that allowed the structural steel supports for the surfaces of the building to be placed along straight lines directly offset from the surfaces.

## DIGITAL PROJECT AND CATIA……

**Digital Project** is built on the advanced ***CATIA V5*** geometry and information management engine, provided by Dassault Systèmes, that has revolutionized the automotive, aerospace and product manufacturing industries. The V5 product family includes 300 products developed by Dassault Systèmes and 3rd party partners. Digital Project products are specifically targeted toward building design, engineering and construction professionals. The broader V5 product families extend the capabilities available to project teams working on V5, and include products targeted toward data management, fabrication control, and plant and facilities management.

Gehry Technologies is a PLM business partner of IBM and Dassault, providing CATIA solutions direct to US clients, and working with region business partners around the world to provide these technologies to international clients.

Digital Project is a delivered as a suite of stand alone products with native data compatibility between Digital Project and other V5 products.

**Dassault V5 Products**
Dassault Systèmes offers several software product lines built on the V5 platform, including:

***CATIA V5*** – the flagship product line that has revolutionized the aerospace and automotive industries. CATIA offerings include products addressing manufacturing industry design and fabrication processes, and power plant and equipment & systems solutions.

***ENOVIA*** and ***SMARTEAM*** provide the data infrastructure for distributed teams working together. These products support the management and integration of project team data over the life of the project, including versioning and work flow control. Digital Project models, other V5 data, and 3rd party formats, can be integrated into a common data management environment.

***DELMIA*** is suite of technologies for process planning and simulation that will be used to integrate financial data with project geometry and perform simulations of traffic logistics, life safety, and security.

<table>
<tr><td>GT</td><td colspan="3">Dassault Systems</td></tr>
<tr><td>Architecture<br>Engineering<br>Construction<br>Digital Project</td><td>Manufacturing<br>Fabrication<br>Plant Solutions<br>Catia V5</td><td>Data Management<br>Enovia<br>Smarteam</td><td>Process<br>Simulation<br>Delmia</td></tr>
<tr><td colspan="4">V5 Platform</td></tr>
</table>

## DIGITAL PROJECT FOR CATIA……

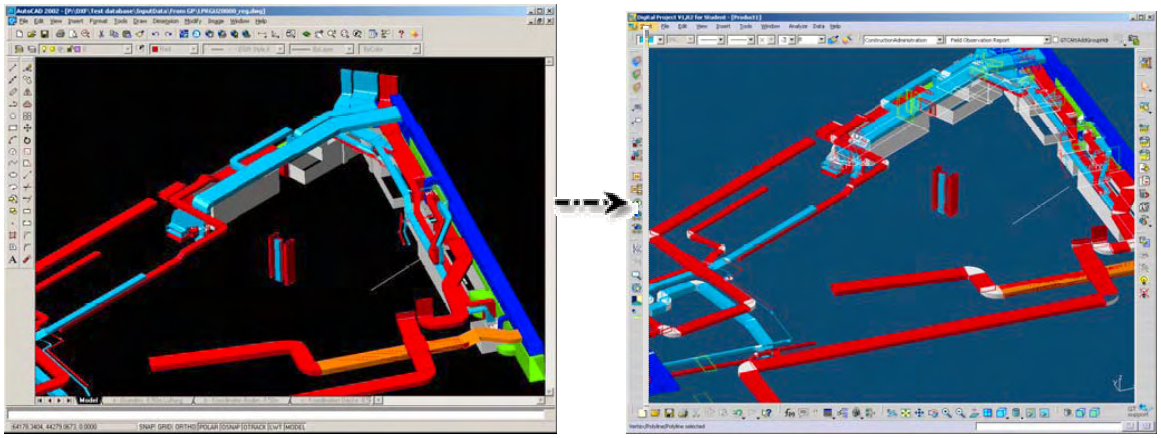
Gehry Technologies also provides Digital Project for CATIA, a packaging of elements of our building industry solutions as add-ons to CATIA V5 solutions. These products may be used by CATIA customers who have occasional requirements for building industry functionality. Digital Project for CATIA products include:

**Attributes & Quantity Management** brings Gehry Technologies' attribute modeling infrastructure to CATIA customers. This technology provides capabilities for defining and managing project standard schemas of attributes in a consistent, centrally defined manner. The workbench includes rich capabilities for defining packages of typed attribute collections, and associating attribute packages to project geometry. These capabilities are enhanced with robust viewing, filtering, importing and exporting capabilities.

**Structures Translators** provide translation capabilities for customers using CATIA Plate & Shape (5691-SR1) and wish to interface with 3rd structural engineering, finite element analysis and steel detailing applications. The product allows export and import of industry standard structural steel neutral files: SNDF and CIS/2. The workbench provides additional functionality to produce customized bill of materials extraction, and utilities for manipulating structures products.

**Primavera Integration** allows CATIA users to link 3D components to Primavera™ activities and to simulate these activities in 3D (4D Navigation). Integrating Primavera construction scheduling information to a project's construction geometry helps to ensure a smooth and timely construction process. With a project's geometry in CATIA and Primavera integration, different phasing scenarios can be played out and visualized to understand any critical issues which may arise.

**3D DWG and DXF Translator** provide translation capabilities for customers using CATIA to import 3D entities contained in a DWG or DXF file format. These widely used, industry standard formats allow for easy integration of 3D models into CATIA. This product provide the ability to convert foreign CAD data from its native format into a format compatible with a digital mock-up development environment and to support collaborative work for implementation of best practices such as review, interference detection by overlaying CATIA and 3rd party geometry



## GT SERVICES……

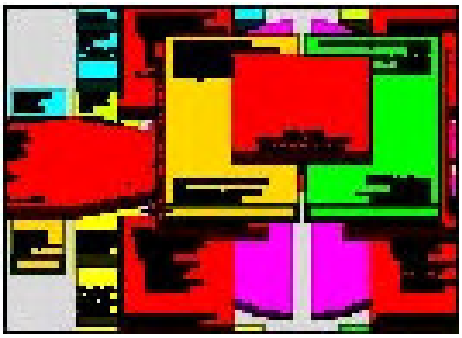
Gehry Technologies (GT) provides a comprehensive range of professional consulting, learning and project integration services, as well as customized tools development and goal-driven research required to solve specific design and/or constructability challenges. Together these make GT a valuable project partner at all stages of design.

### Forms of Consulting

GT can participate across projects in a number of roles, from high-level executive seminars through process and design development, in the form of professional consulting or even technology professionals integrated into client teams:

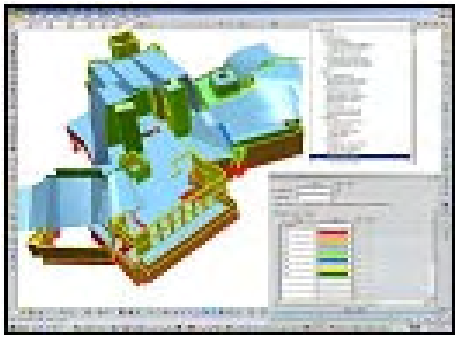
- **Professional Expertise:** GT's team consists of professional architects and technical specialists who can provide a wide range of input on issues of project data structuring, modeling techniques, information interoperability, design problem-solving and general issues of specialist knowledge of the application of 3D integrated process on a project-by-project or firm-wide basis.
- **Executive Seminars:** It is important that the senior decision-makers and stake-holders in a project be fully aware, and supportive, of the implications of an integrated 3D process. Each project and client team differs in scope and structure, and GT can provide either general overview or project-specific knowledge seminars to senior players to explore and identify a specific project's requirements.
- **Embedded Project Resources (EPRs):** GT's team has architectural professionals who can be *incorporated* into client teams, to ensure the smooth deployment, ramp-up and production work services at all stages of project development. EPRs are bona-fide productive team members who function within the auspices of the team, operating to the client project manager's requirements within the scope of a project's overall goals.
- **Production Services:** We recognize that tackling a fully integrated 3D design process can be a daunting task, and is a methodology that some offices would want to develop progressively. GT's experienced team can provide support in building and maintaining 3D integrated project Master Models both in-house and at a client's site, allowing new users to implement project modeling and management skills at their own pace.

**Digital Contracting**



GT leverages fifteen year's experience in issuing and submitting 3D information models as contract documents for geometric control. The use of 3D contract documents as the primary vehicle for the exchange of data between project participants - architect, contractor, consultants and fabricators - is referred to as *Digital Contracting*. Careful planning of a Digital Contract process is critical to its success, and has direct implications for the governance of project data, the structuring of data file hierarchies, and the operating modes of the teams themselves. GT can provide extensive input at both the operations level and the senior/executive management level to fully understand and implement Digital Contracts across the scope of a project.

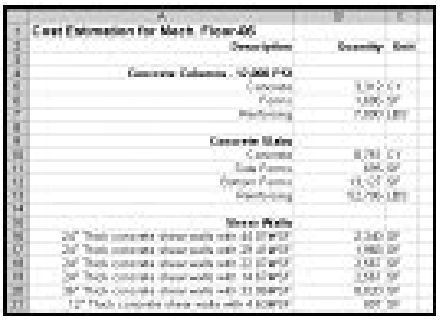
**Project Management & Integration**



Understanding a design and construction project as a comprehensive data *environment* can yield great benefits to all project participants. GT can help highly diversified design and construction project teams integrate heterogeneous project information in a single *Digital Project* model, allowing teams to operate cohesively and effectively. Mapping 3D integrated work methods to the inherent structure and operational organization of a project team further increases productivity.

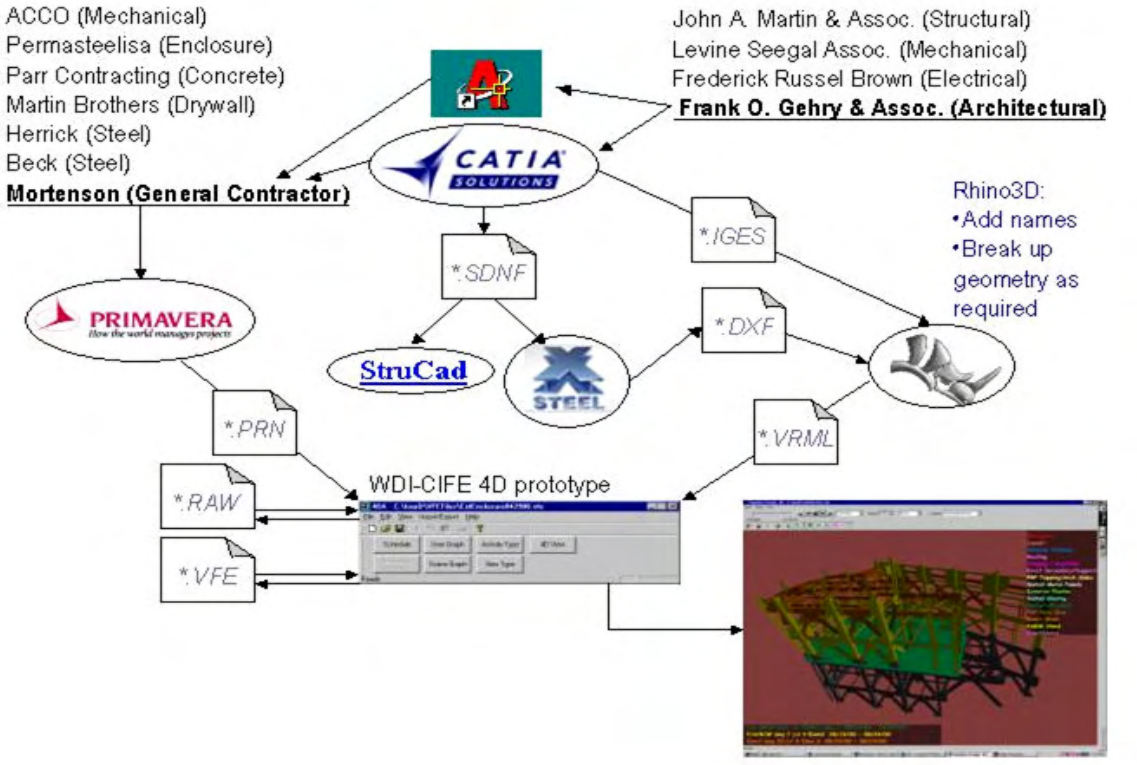
- **Team Integration:** The Human Resources aspect of advanced practice is equally important to the data aspect. GT can provide comprehensive advice on the structuring and operating of 3D-centered project teams, assess individual team members' skills with regards to project requirements, and recommend additional training or reorganization and streamlining of team responsibilities and individual roles in order to maximize productivity.
- **Data Integration**: GT's extensive experience benefits project team in the analysis, implementation and deployment of a common project data platform capable of supporting many different design, modeling and project management tasks.
- **Data Interoperability:** GT can provide expert guidance on *Digital Project's* comprehensive set of data translation tools which allow the bi-directional transposition of information with specialist external modeling and analysis packages. Preserving the *quality of data* beyond simple geometric data interchange is important; each exchange of information maintains its required specification, such as steel profile cross-sections or structural performance attributes.
- **Electronic Data Management:** Orchestrating many different geometric and quantitative data sources in a productive and reliable manner is a mission-critical task for any project. The goal here is to structure the management of data, its document security and backup safety as it relates to the *Digital Project* data models as well as mixed CAD format environments.

**Data Structuring & Cost Information**
The timely delivery of detailed cost estimates based on precise data quantities is a critical step for any project development process. An integrated 3D model is a rich source of comprehensive project data, yielding accurate, real-time cost analysis based on geometric analysis of areas and volumes, as well as itemized bills of quantities of construction components.



- **Modeling for Cost Structuring:** The grouping of geometries in component files which reflect both the project's constructive logic as well as the method by which it will be analyzed financially requires careful planning and evaluation. GT can provide support in understanding how to create models that are organized in order to facilitate the comprehensive reporting of quantity information.
- **Attribute Schema:** A necessary step towards using customized data is the translation of a given cost format (such as Uniformat, CISFB, DIN-276 or a project-specific custom specification) into a viable set of attribute tags. GT supports clients' goals for data identification by implementing custom attribute schemas beyond industry standards supplied with the *Digital Project* platform.
- **Custom Report Creation:** Companion to the attribute schema is the creation of customized reporting functions which format the data output stream from the 3D model into a preset Excel spreadsheet template, ensuring legibility and integrity of reported data. GT can assist in the specification and implantation of such custom reporting tools.

## DIAGRAMMATIC NETWORKING OF DIGITAL PROJECT……..……



## KNOWLEDGE AND LEARNING……

The *Digital Project* product line represents a powerful and complex set of 3D tools. Ensuring its most effective and successful application requires a firm foundation of the fundamental principles of 3D project coordination and parametric design. GT offers a wide range of standardized and tailor-made courses that cover all aspects of the *Digital Project* and *CATIA V5* technologies, as well as project coordination, data management and interoperability with other software platforms.

**Foundation Knowledge**

GT's standard basic training courses provide a strong foundation in *Digital Project* design and data management tools, as well as imparting a comprehensive overview of 3D project process methodologies. BT sessions normally last five days and cover all basic elements of parametric design, 3D modeling, structured design data management, and geometric data interoperability. Foundation knowledge includes:

- **Basic Project Data Concepts:** *Digital Project's* sophisticated data model is directly geared to the logical nested structuring of project data, greatly facilitating the downstream parceling off of data to consultants and fabricators; it is essential to understand the basic concepts of this paradigm before heading into modeling.
- **3D Navigation and Geometric Analysis:** The 3D model is a rich container of geometric and dimensional information; *Digital Project's* navigational and data query tools enable the comprehensive extraction of project data both as individual manual steps or automated operations. Visual analyses operations in turn represent the fundamental operations for ensuring model data correctness and coordination.
- **Data Attributing and Querying:** *Digital Project* enables the assignment, tracking and querying of information attributes to 3D geometry according to international industry-standard schemas such as Uniformat and Masterspec (USA), Uniclass and SMM7 (UK) and others, thus giving true semantic meaning to objects in the model. Attribute organization and usage methodologies are taught, as well as the graphical query and extraction of attributed data. Principles of custom project- or office-specific schemas are also covered.
- **Geometric modeling**: Basic modeling knowledge gives users the fundamental understanding of the parametric design principles used in *Digital Project*, the relationship between associative and fixed geometries, and the interplay between solids, surfaces and wireframe geometric types.
- **Drawing Extraction:** A comprehensive tutorial covering all aspects regarding the creation of 2D drawings from 3D models is provided. Generation of 2D geometric data, its organization to layers according to the 3D attribute schemas, and interoperability with standard drafting packages such as AutoCAD® or Microstation® are fully explored.

**Advanced Learning**

Building on foundation knowledge, advanced learning addresses several topics to include the following areas, but can also be customized for a clients' particular requirements.

- **Knowledgeware:** Understanding the power of *Digital Project's* built-in component re-use and artificial intelligence capabilities can provide a complete new range of design and project control possibilities. Creation, cataloging and usage of custom components is covered, together with the formulation and usage of artificial intelligence features.
- **Advanced Surfacing:** *Digital Project's* advanced geometry capabilities allow the modeling of virtually any surface type with precise control of the underlying geometric specifications. Advanced controls are complemented by a full range of analytical tools including connectivity, continuity and curvature analysis; distance and draft analysis, and many others.
- **Structure Design:** You can model structural steel efficiently with international industry standard libraries, as well as learn to create your own custom extrusion shapes; interoperability with external finite element (FEM) and detailing applications is also examined.
- **Project Data Management:** CAD Data managers responsible for project- or corporate-wide design data management will draw great benefit from an in-depth exploration of different approaches to structuring and governing project data in *Digital Project*, and be able to converge on the most appropriate solution.
- **Visual Basic Programming:** *Digital Project* comes with the full Microsoft Visual Basic (VB) automation tools suite. Virtually any modeling or data control procedure can be replayed through automation, and VB programming gives access to an infinite new range of possibilities.

**Custom Project Workshops**

When 3D integrated methodologies are targeted across the scope of a complete construction project, the team as a whole can greatly benefit from a custom-tailored 'learning-by-doing' workshop. Working directly on project-specific modeling examples, design problems and project data management issues, GT can create custom sessions that leverage the project's own parameters to great effect. In general, initial workshops take about a week as a basic introduction to 3D project process tools and methods, but can also be custom-made as advanced data integration and productivity-enhancement sessions. These can take place at either a GT or a GT Partner location or, by agreement, at the client's own designated site.

## TRAINING COURSES……...

As a Dassault Systemes Education partner, Gehry Technologies (GT) is committed to delivering the highest quality of training and services available.GT promotes the advancement of technology in the building industries through several educational and training programs. These initiatives include software application training, and the development of an educational curriculum through an association with leading universities.

GT offers a full line of Digital Project training. GT training is accelerated and tailored to address activities specific to the building design and construction industries.

| Course | Overview |
|---|---|
| General Contractor Introduction to the Building Information Model | This 3 day training is conducted using the Digital Project suite of products and is geared at providing attendees knowledge in how to use this platform for coordination, information extraction and basic modeling. |
| Introduction to the Building Information Model | This course will take attendees through a 5 day project based introduction to the Building Information Model. |
| Executive Seminar in Building Information Modeling | Taught by senior practitioners, this 2 day management level course provides a forum for formal lectures and informal discussions for senior management from architecture, engineering, construction and client organizations. |
| Advanced Knowledge ware and Parametrics | 3 day expert level class presenting the capabilities for knowledge modeling. |
| Structures Modeling | Learn structural systems design functionality, integration with FEA and detailing applications. |
| Building Systems Modeling | Presents advanced tools and techniques for building MEP systems modeling. |

## ARCHITECTURAL EDUCATION……

One of the other key targets for GT is to build what it describes as a 'digital ecosystem'. The idea being that firms that are willing to work in a different way to the traditional AEC process get to communicate and chose to work with one another. GT has already recruited some of the biggest American Universities to use and train on the project and has added companies like steel fabricators that are happy to quote and cut from within Catia generated 3D models. Once there is critical mass in the ecosystem, then it will be easier for firms to find like-minded project participants.

This year GT has placed Digital Project applications in over 20 academic institutions in North America, Europe, Asia, and Australia. We are consulting with these institutions to develop new teaching programs and promote cross industry collaborations between schools of architecture, engineering, and construction management. GT has also established a research association, “The Digital Project”, with research institutions at MIT, RMIT, Stanford, Georgia Tech, Salford, and Hong Kong Polytechnic to coordinate research efforts and develop industry metrics and attract money for research to the AEC industry. There will soon be a time when the traditional methods of teaching and understanding design might be overruled by the knowledge of systems like Digital Project.

## DIFFERENCE BETWEEN DIGITAL PRACTISE SOLUTIONS……...

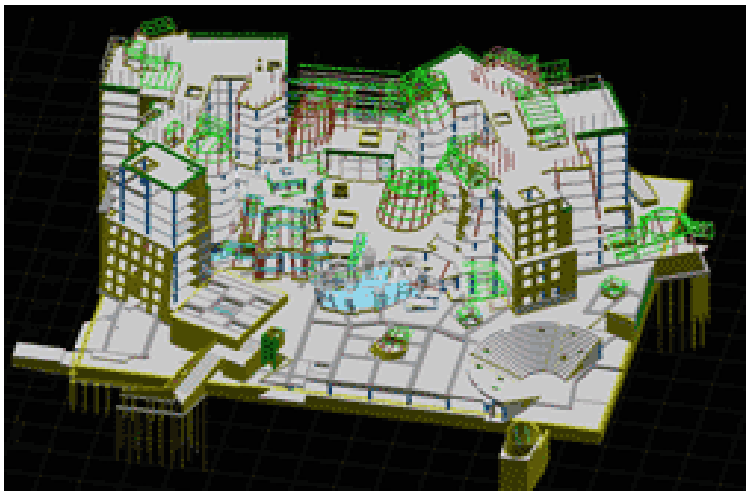
| Revit / ArchiCAD | Digital Project |
|---|---|
| • Distinct set of parts, extensive library | • More of a User Created Library |
| • Easy Interface for the novice user | • Not User friendly for a novice |
| • Mass appeal modeling tools, not used for management | • Used for more complex project design and management. |
| • Targeted towards the traditional architectural practice. | • Targeted towards the larger AEC firms who work on big, complex projects. |
| • Geometric Limitation to Custom Designed Components | • Great Flexibility for Custom Designed Components |
| • 2D drawings generated from 3D Model require ‘touching up’ | • 2D drawings considered obsolete |
| • No links to manufacturers | • Direct Links to manufacturers especially steel fabricators. |

## CASE STUDIES……...

### THE RAY & MARIA STATA CENTER FOR COMPUTER, INFORMATION AND INTELLIGENCE SCIENCES, MASSACHUSETTS INSTITUTE OF TECHNOLOGY

When Massachusetts Institute of Technology launched an ambitious $1 billion campus improvement plan in 1996, it decided to anchor the plan with a building that would make a statement. By choosing Gehry Partners, MIT made a statement not only about the campus plan, but also about the process of design and construction. "Project team members were asked to work in unique ways," notes Jim Glymph, project principal with Gehry Partners, in understatement. "There were slightly different tools and varying regulations about how to work together." At the center of those "unique ways" was the use of 3D modeling to guide the design, engineering, fabrication, and construction of Frank Gehry's avant-garde design.

Once Gehry Partners settled on the initial design, it was committed to a 3D model in CATIA. Skanska USA used the model as part of the subcontractor bid process. The initial design assumed a stick-built approach as the most affordable construction method. But consultations with the 3D model revealed that the use of prefabricated panels in much of the building would be more cost-effective.



As consensus formed around the design intent, the 3D master model in CATIA became the basis for engineering and fabrication. At the same time, 2D and 3D plans extracted from the CATIA model were detailed in AutoCAD to create contract drawings and specifications. As new data was created in the CD/specification process, it was imported back to the CATIA model, where attribute information was added to design elements. "We attributed almost every element in the 3D model," notes Gehry Partners' Salette. The attributes would then be linked to spreadsheets, allowing subcontractors to find systems information quickly.

The final CATIA 3D construction model offered detailed representations of five structural elements: concrete, structural steel, exterior skin, framing, and assembly patterns. While concrete was being poured and placed on site in Cambridge directly from the 3D model, the structural steel was being fabricated, by Capco, Corp. in Rhode Island using a 2D translation from the model. The metal and glass for the skin were also being fabricated off-site directly from the 3D model using CNC technology.

The 700,000 square-foot office and research laboratory opened Spring 2004 to rave reviews from architectural critics and members of the MIT and Cambridge communities.

**BARCELONA 'FISH', GERMANY**

A bus stop in Hanover, Germany, extended the capabilities developed for the Barcelona fish. The bus stop's shallow arching vault of silver and green stainless steel is supported by a dense grouping of vertical steel 'T' shapes. Both the canopy and structure were modelled in CATIA and used to create design documentation. A distinct advantage came about when using CATIA on the bus stop project when it went out for bid. The winner, Permasteelisa's bid, was one-third lower since they knew that they would be receiving CATIA data.

**GUGGENHEIM MUSEUM, BILBAO**

More recently, FRANK GEHRY & ASSOCIATES has used the benefits of CATIA in designing the Guggenheim Museum in Bilbao, Spain. Using CATIA to completely define the complex sculptural surfaces of the 24,000 square meter facility was essential for the firm to meet the aggressive fast-track schedule required by the project. Using lessons learned in the Barcelona fish, Hanover bus stop, Disney Concert Hall and Prague projects, FRANK GEHRY & ASSOCIATES integrated the application of advanced 3D CATIA models to construction and fabrication with the production of more traditional construction documents in AutoCAD.

As in previous projects, the 3D CATIA surface model acted as the master model for dimensional control. The AutoCAD models were derived from CATIA geometry that was translated to AutoCAD using IGES through an in-house derived process. A complex integration of CATIA and AutoCAD had to be implemented in order to facilitate the design process and to satisfy the need for quality construction documents.

Once each of the distinct pieces of the building were completed in CATIA, the CATIA model containing face and surface elements was sent out to a machine shop. A scale model was NC milled directly from the CATIA data using a foam material. Each piece was then positioned to create a complete computer verification model to confirm the design to the project team.

**WALT DISNEY CONCERT HALL, LOS ANGELES**

In further exploring the possibilities of using CATIA, the firm's next test was in the limestone cladding for the 200,000 square foot Disney Concert Hall in Los Angeles. The stone cladding has been developed using CATIA for both design and cost control. Using the thickness of a raw block of stone and cutting time as prime drivers of cost, it is easy to understand that cost increases in direct relation to the geometric progression from flat surfaces through to single, double and complex curvature surfaces. Gehry began design by building a paper model characterised by irregular, flower-like curves. The design model was then digitised using a Firefly optical digitising system and the resulting x, y, z coordinates were fed into an IBM RISC/6000 running CATIA. The surfaces were then rationalised in CATIA to achieve repetition without sacrificing form. Using the CATIA database of the rationalised surface models, a physical model was computer milled, compared to the original cardboard model and adjusted where necessary.

The CATIA database, which has also been used to generate construction documentation, was subsequently passed on to the stone subcontractor. The stone cladding and cladding support package was tendered to 14 firms with three-axis and five-axis milling capability. As part of their submission, four were required to build a 3x8 metre piece of wall using only numerically controlled computer milling. The selected subcontractor, Harmon Contract with Furrer Spa of Carropuo, Italy, was on budget. Both Harmon and Furrer intend to use their own CATIA stations to execute the project when it proceeds.

The advantages of using CATIA have not been unique to the Disney project.

## SUMMARY……..

With the high seat cost, wide-spread resistance to 3D, relative famine of Catia-trained staff and considerable process change required, it's hard to see how GT will succeed to 'wake' the architectural market where all of the 'off-the shelf' established developers have failed miserably. But the target market for GT is not the traditional architectural practice, it will never be a mass-appeal modelling tool like Rhino or Revit, it's the niche architects that want more control in the building process, who want higher predictability in the cost of their projects and industry players that are looking to adopt a different way of working with project participants. And to a larger extent GT has already proved the technologies value in numerous Gehry projects around the world. The company already has 15 companies running Digital Project pilots. As a side note, one architectural practice in the UK that wanted to purchase Catia was quoted a figure somewhere in the region of $140,000 for two seats. By comparison, Gehry Technologies has negotiated a good deal with Dassault Systemes as the same two seats (in terms of modelling capability) would now only cost $29,000. Of course, there's a yearly maintenance to add to each seat, which would equate to a seat of a competitive product per year, but this is Catia, which is one of the most capable modelling tools on the market today.

FRANK GEHRY & ASSOCIATES's use of CATIA has led to closer relationships with contractors and direct relationships with suppliers and subcontractors. By generating the CATIA database to which everyone works, the practice increases its responsibility. The hope is that the accuracy of the information and the elimination of middlemen reduce everyone's cost and risk, and make the schemes more buildable. However, notwithstanding the high degree of accuracy of CATIA models and computer generated construction documentation, the achievable tolerances for both fabrication and erection which are inherent in the materials used remains largely unchanged, and FRANK GEHRY & ASSOCIATES is conscious that this must be kept in mind continuously when working with computer models.

Fortunately, this technology that may bolster architects' position in the industry promises to encourage creativity. By translating complex design through CATIA, Gehry believes that curved forms in building will become more feasible. "I'm excited about them because I like the sense of movement. They feel genuine, accessible, joyful. If I do a lot of buildings with curves, and people enjoy them, then clients will begin demanding them and more architects may follow."

Using the CATIA program allows Gehry to think big. He still starts a project by sketching and manipulating physical models. But when his design is put into the computer using CATIA, with its precise replication of his sculptural and arrhythmic surfaces, means contractors can estimate the cost - and can see how to build his elaborate designs. "I was doing this stuff anyway," says Gehry, "but I feel more confident that we can build it. It demystifies it."

## BIBLIOGRAPHY……

GEHRY LAUNCHES DIGITAL PROJECT
AEC MAGAZINE
DESIGN, MANAGEMENT & COLLABORATION IN THE BULT ENVIRONMENT
OCTOBER 2004, VOL 16

FRANK GEHRYS HIGH TECH SECRET
BUSINESS WEEK
OCTOBER 6, 2003

CHALLENGES AND BENEFITS OF 4D MODELING ON THE WALT DISNEY CONCERT HALL PROJECT
JOHN HAYMAKER, MARTIN FISCHER
CIFE (CENTER FOR INTEGRATED FACILITY ENGINEERING)
WORKING PAPER #64
JANUARY, 2001

STRUCTURE AS ART
VINCENT J. DESIMONE, DERRICK D. ROORDA
CIVIL ENGINEERING MAGAZINE
JUNE 2002

GEHRY, DASSAULT AND IBM TOO
AEC MAGAZINE
MARTYN DAY
SEPTEMBER/OCTOBER 2003

CURVES OF STEEL: CATIA AND THE WALT DISNEY CONCERT HALL
DAVID BALIAN, KRISTINA FERRIS
ILLUMIN MAGAZINE
VOLUME 6, ISSUE II
JANUARY 1, 2004

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ARCHITECTURAL RECORD
JUNE, 2004

CLUES FROM THE PAST
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OCTOBER 22, 2004

WWW.GEHRYTECHNOLOGIES.COM

WWW.CADDIGEST.COM

WWW-03.IBM.COM/SOLUTIONS/PLM/DOC/CONTENT/PARTNER/1152386113.HTML

WWW.ARCHITOSH.COM/NEWS/2003-09/2003C-0909-GEHRYTECH.PHTML