

# Comprehensive BIM Collaboration

Integrating A/E/C implementation for building information modeling

by Alberto Cavallero, AIA

**B**etween 2002 and 2004, this author's design team—the Philadelphia, Pennsylvania-based offices of KlingStubbins—teamed with millwork subcontractor Rick Herskovitz of Architectural Woodwork Industries (AWI), and construction manager Bovis Lend Lease to create a geometrically complex and systems-intensive auditorium for Merck Research Labs (MRL) in Boston, Massachusetts.

Part of a 55,742-m<sup>2</sup> (600,000-sf) basic research facility, this 300-seat auditorium was unique with regard to its

use of building information modeling (BIM). Devoid of parallel surfaces or horizontal lines, the room's challenging form meant it was unlikely to have been constructed on time, on budget, and to the highest levels of craftsmanship without the use of BIM processes through both design and construction.

This article's case study highlights the benefits provided by the BIM process when taken through the construction phase. To that end, this author proposes a fundamental



distinction between ‘design-focused’ and ‘comprehensive’ BIM. In the first, traditional category, building information modeling yields benefits for the design team regarding the coordination and quantification of building elements, but the process essentially ends with the creation of conventional construction documentation (*i.e.* plans and specifications).

In comprehensive BIM, techniques are distinguished by expanding the use of the building information model to the entire architectural/engineering/construction (A/E/C) team. The MRL project provides a useful case study for this comparison. While the entire building was developed using BIM to create conventional documentation, the auditorium’s model was further developed by the subcontractor throughout the pre-construction process, shared with the architect for review and approval, and finally used to drive and manage the manufacturing and coordination of building elements.

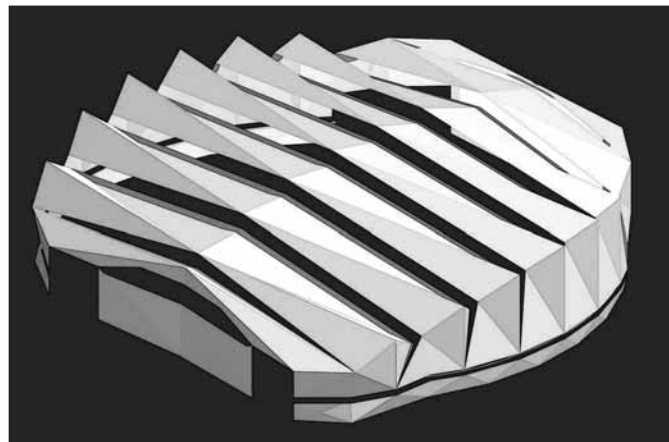
#### Calibrating the model

The simplest way to define building information modeling is to consider a digital simulation of a building.<sup>1</sup> The various software platforms (Autodesk’s Revit, Bentley’s Triforma, and ArchiCAD comprise the ‘big three’) offer different levels of data and interoperability, but there is a common goal in providing a precise simulacrum of the building within the computer. As with all simulation techniques, calibration to real-world conditions is important.

The best simulation software is developed through a comparison of physical models with their simulated counterparts, and then using the data to refine the digital simulation techniques. For example, Radiance, a light-analysis software platform developed under the auspices of the U.S. Department of Energy (DoE), has been periodically validated against physical models, with subsequent adjustments made in the software to more closely emulate reality.<sup>2</sup>

To use BIM effectively during construction, a similar calibration approach is required to account for material and construction tolerances, as well as unexpected site conditions that may affect the site dimensions. In the auditorium project, this calibration was critical from the start.

The slab opening within which the isolated enclosure was to be located was measured by a Bovis surveyor and shown to be approximately 98 percent of the design dimension along the short axis, and 100 percent of the design dimension on the long axis. This small discrepancy was arguably within tolerances, but was nevertheless significant—the type of issue leading to complexities on the construction site.<sup>2</sup> However, the survey was accomplished in a timely manner (*i.e.* before the physical manufacture of the interior segments). As such, the digital model of the auditorium interior millwork was simply scaled



*The preliminary building information model (BIM) of the Merck Research Labs (MRL) auditorium in Boston, Massachusetts.*

by the millwork contractor to fit the physical space, with care taken by the architect to ensure the resulting space would meet all design and code criteria.

In using the digital model to directly drive the layout of the building, the same logic also applies in reverse. In the auditorium, the millwork contractor provided and installed a laser-cut template for the outer shell of the auditorium enclosure, ensuring to the greatest extent possible the physical context for his millwork panels would be in line with his digital model.

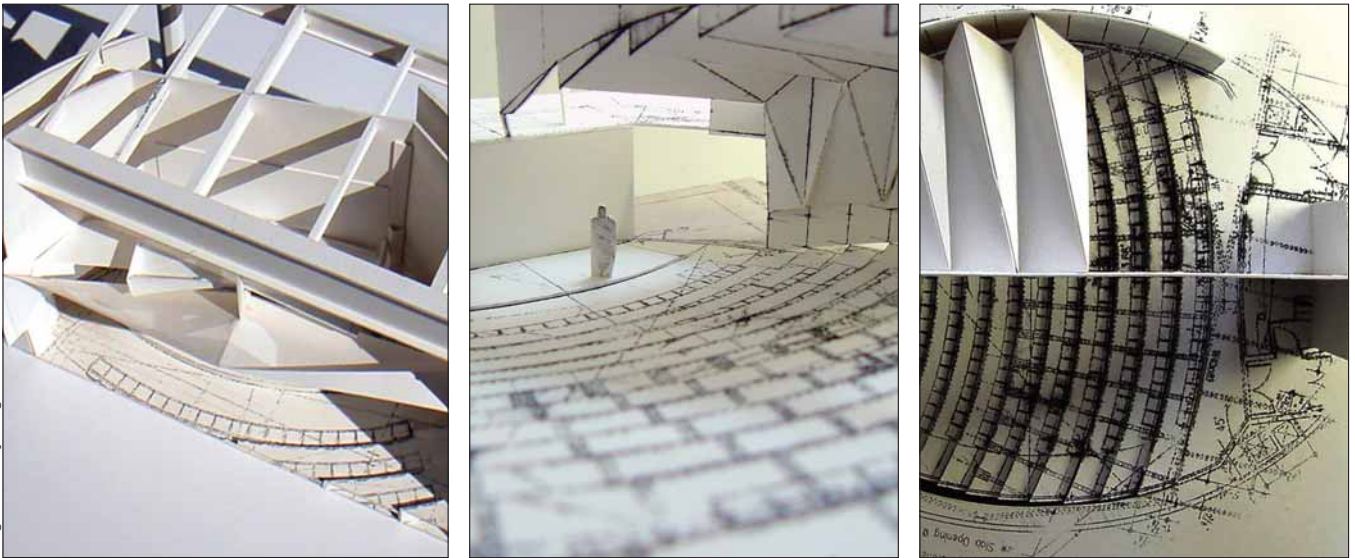
#### The value of openness

As much as the BIM process is about the possibilities provided by software, it is perhaps more importantly about the ways in which the software tools facilitate communication. To put it simply, BIM is about people working together to achieve a common goal.

Within the realms of the architects and engineers, there have been significant improvements in the way a team is able to develop a design. The traditional architectural studio from the era of hand-drafting is still the one many envision as a romantic ideal—a large and open room, with a group of people at drawing boards. The drawing board was an important communications tool because it allowed the most experienced architects to clearly see the development of a drawing by someone with less experience. Throughout the workday, or perhaps after-hours, the senior architect was able to keep control of documentation in this process.

One can compare this to the typical, contemporary architecture studio with architects at computers. In this scenario, the senior architect is often unable to provide real-time critique of documentation, simply because the graphic interface of the digital drawing is frequently out of his or her control. (This author refers to this opacity of knowledge transfer as the ‘generation gap.’) As a result, many modern A/

Images courtesy KlingStubbins



The above images depict scale working models assembled from the BIM by the architectural team for the MRL auditorium project.

E firms are in some ways less functional thanks to their use of computers.

When correctly used, the BIM process conversely has the potential to close this generation gap. For example, a small team of architects and engineers may work together on a model—sharing knowledge at a fundamentally more sophisticated level—by referencing each other’s work in real-time and in three dimensions. In many ways, the plummeting prices of large, flat-screen monitors to facilitate viewing the model has provided as much of an advantage as the software itself.

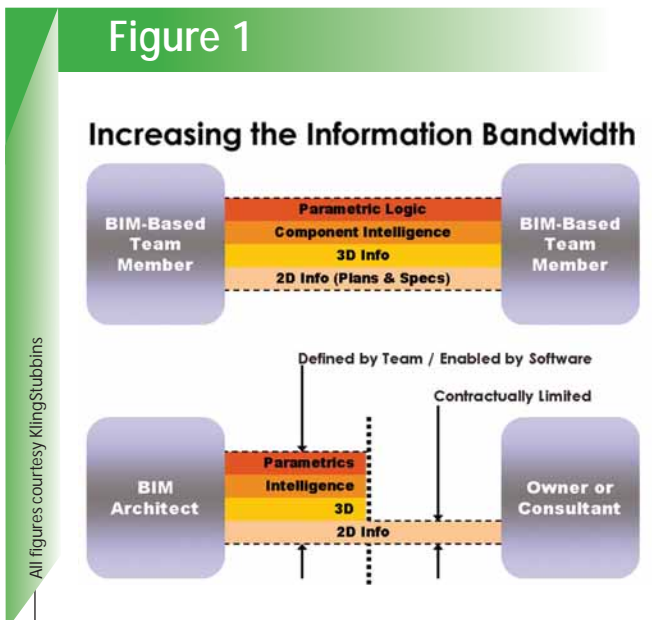
The benefit of this open workflow continues with the use of BIM through the phases of construction. This is not just

about sharing more sophisticated types of drawings; it is also about collaboratively working on a single solution to a set of problems. The medium for information-sharing in this case might not be a big screen—Web-meeting technology or even e-mail attachments can also fulfill this function. Regardless of the vehicle for information, there is an important phenomenon when the A/E and builders are working together on a BIM project—there is less of a tendency to blame, and more to come up with solutions to problems. With the auditorium project, there were essentially no Requests for Information (RFIs).

Expand the information bandwidth

A BIM is capable of providing a wealth of information, far exceeding what design professionals can traditionally provide as a contract deliverable. Well-constructed BIMs can output material take-offs and clash detection in addition to schedules and reports in a variety of formats. This depth and breadth of detail (*i.e.* the information bandwidth) can certainly be useful within the design team to differing degrees, but it is inevitably compressed when it leaves the team’s internal network (Figure 1).

This compression of information is neither new nor always undesirable. Architects and engineers are in the practice of consolidating a building’s complexity into an elegant set of documents that make the design intelligible to those responsible for its construction. The constraint of traditional contract deliverables is that since the medium is paper, the information is always in two dimensions. Naturally, BIM is capable of carrying 2D and 3D information, as well as the ‘intelligent’ componentry of its elements, and often the fourth dimension of time, as well. Without putting too fine a point on it, the essential element of BIM for the construction process is the 3D information, since it





Images courtesy Rick Herskovitz (AWI)



Construction photos showing installation of wood panels. BIM helped avoid duct/steel/millwork conflicts.

allows for the identification and elimination of conflicts in the built environment.

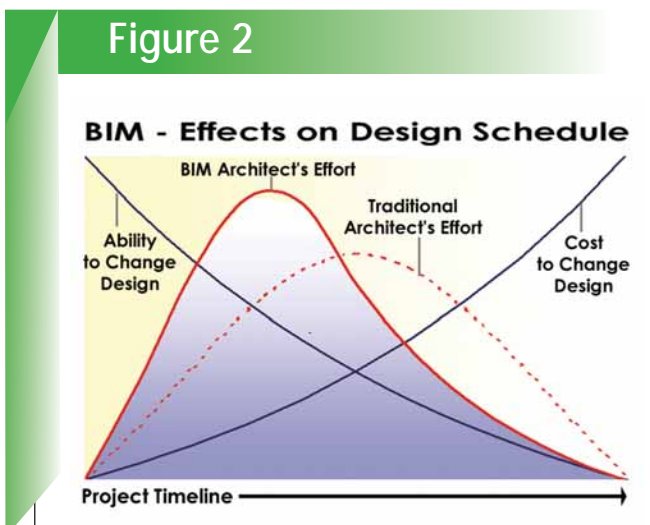
While many of the advanced aspects of BIM output (e.g. material take-offs) present contractual challenges and new opportunities for design professionals, the lesson for the A/E/C effort is the more we can share and collaborate with 3D information, the better. Steel manufacturers, piping contractors, and sheet metal contractors often produce their own 3D models to facilitate manufacturing, but since there is no traditional contractual vehicle or incentive to share this information, these models are rarely coordinated, leaving on-site staff to deal with the problem. This was exactly the case in the MRL auditorium project where, after some effort, the digital models created by the different subcontractors could be used to analyze the tight and highly complex space above the auditorium millwork. The

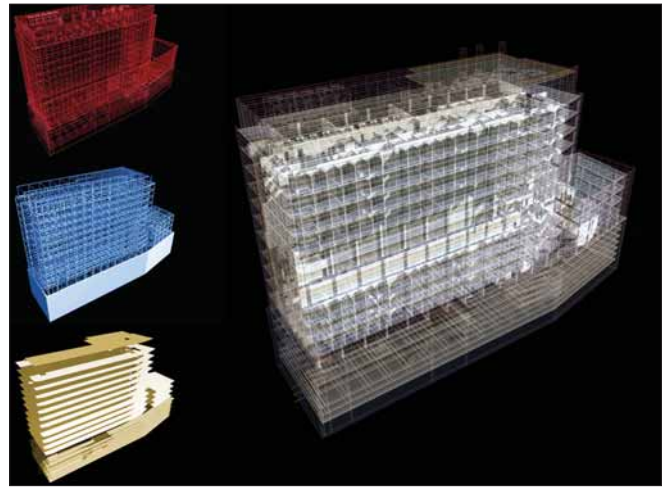
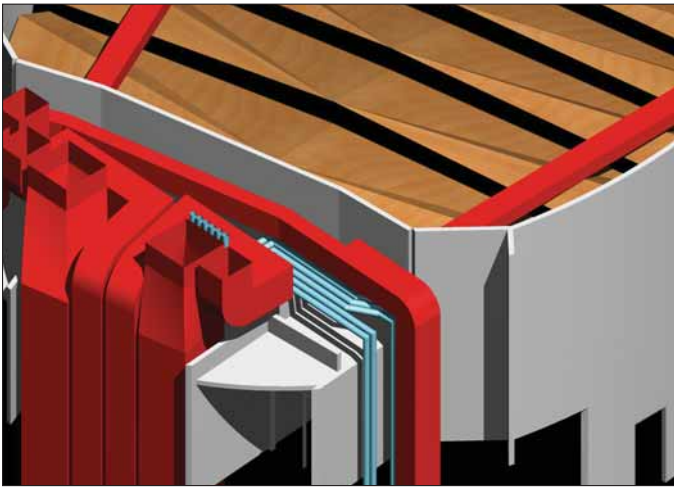
payoff was significant, with a series of major conflicts between duct, steel, and millwork averted before they cost time and money on-site.

BIM's effects on scheduling, cost, waste, and quality  
 There are several beneficial consequences for scheduling (and hence, cost) from the BIM process. From the owner's point of view, there are significant advantages stemming from the A/E's ability to arrive more quickly at design solutions. The front-loading of the A/E's effort allows the owner to review and approve designs earlier in the process. Additionally, the timing of the most critical aspects of design occurs earlier in the construction phases, where changes can be quickly made and the cost of change is relatively low (Figure 2). However, along with this newfound ability to make changes easily, the entire team must be conscious of controlling change and churn.

On the construction site, BIM's benefits may be even more dramatic. From this author's experience, there is a clear lesson—if you model it, it will fit. This seemingly simple lesson has surprisingly thorough consequences. With a well-modeled building or portion of a building, the pre-manufactured elements brought to the site are all but guaranteed to go exactly where they were intended, without modification. Consequently, the amount of on-site waste is virtually eliminated, and there is minimal work-site adjustment for individual building elements and between trades. This lack of spatial conflicts extends to the ability of on-site staff to understand what is required to complete a task. This can mean a comparatively stress-free construction site with less overtime work.

These significant reductions to waste and on-site churn have yet to be universally quantified, but the empty dumpsters and smooth





Images courtesy KlingStubbins

*The above images depict the final BIM model, which includes the coordinated major mechanical systems. While the technology allows more streamlined projects, determining its scope and authorship can present new challenges to the project team.*

workflow on comprehensive BIM projects have made believers out of many. On a related note, BIM's ability to help a design team side-step many of the waste-intensive processes (often taken for granted) has helped popularize the technique with advocates of sustainability and environmentally responsible design. Further, if builders know they need not account for the traditional amount of waste, there should eventually be a reduction in cost to accompany the more judicious use of materials.

Reaping the benefits of coordination, 3D information, scheduling, and sustainability comes back to the creation of a good digital simulation of the building. For this visualization to have the greatest value during construction means the builders should participate in its construction and analysis.

This process suggests a significant paradigm shift from traditional thinking:

- designers need to open their processes during pre-construction to be inclusive of contractors and subcontractors;
- builders need to provide interoperable 3D information;
- the entire team must devote time and energy to careful scrutiny of the model; and
- a spirit of collegiality and trust must be fostered within the team to ensure collaboration and ingenuity always take precedence over blame. (In this context, finding a digital 'mistake' or conflict is a credit to the team, and has a significant commensurate payoff on the construction site.)

#### Right-sizing the process

There are various potential uses for the BIM process, and it is important to determine the goals and expectations for the model as early as possible in the process. For instance, many architects simply use BIM to create better-

coordinated documentation and visualization of their designs, in which case their use of the models is entirely in-house, and not intended to be shared with the owner or builders.

Going a step further, the designers may use computer-based analytical tools such as daylight analysis or computational fluid dynamics (CFD) analysis for airflow or finite element analysis (FEA) for structural framing. With this approach, the model is constructed with the goal of not only documenting the building in traditional ways, but also of providing an informational feedback loop between the design model and analytical tools.

Another example of BIM use is employing the model itself as a direct source of information during construction and/or as the owner's ongoing building maintenance and operation tool. This type of model will contain a level of detail greater than (and certainly different from) what designers typically include for building documentation.

In all these cases, it is as important to know what not to model, as it is to understand the scope of information to include. For example, the model of the major MRL mechanical rooms was constructed down to the level of 76.2-mm (3-in.) piping; the thought being conflicts with the smaller piping could easily be handled in the field, and the payoff for its modeling did not justify the effort needed to create the BIM. While this proved to be a good decision for a model intended to create drawings expressing the design intent, the builder would certainly benefit from the inclusion of additional detail in the same model.

It is naïve to think everything in a building design should be modeled, if only because of the use of resources. To illustrate the point, one need only look to the automotive industry. The average design/development cost of a new car is approximately \$600 million, roughly 2 million percent the average \$30,000



Image courtesy Rick Herskovitz (AMI)

*Full-scale mockup made from BIM model. The design/construction technique can help minimize tolerance-related problems.*

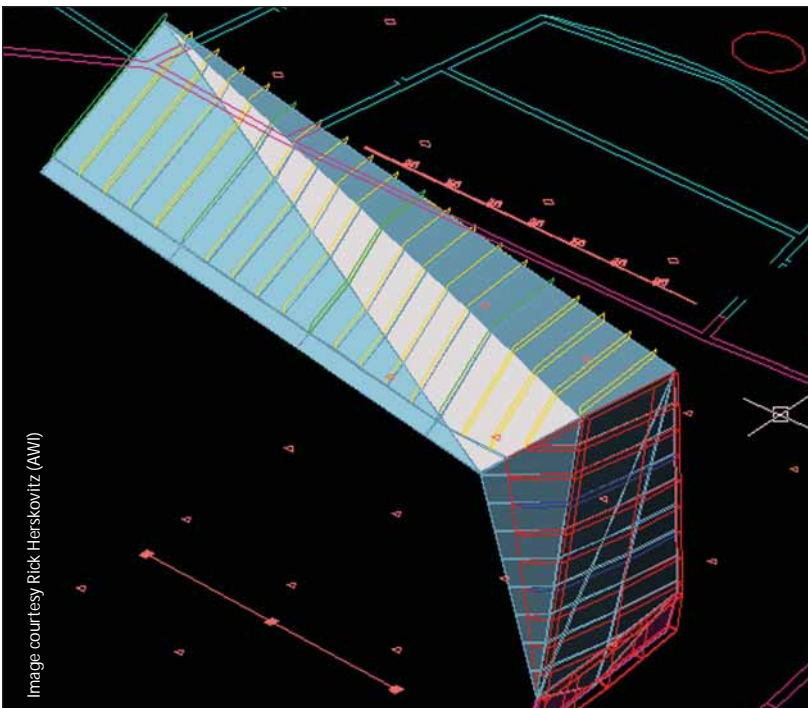


Image courtesy Rick Herskovitz (AMI)

*BIM model used by millwork subcontractor for coordination and fabrication. Not every building component needs to be modeled, but the cost can often be justified.*

price of a new car. Naturally, this scale of resource expenditure is justified for a mass-produced object. All buildings are essentially one-off prototypes where the design team is working within a much tighter margin, and the resources required to simulate, calibrate, and optimize every element of the design are simply not there.

Conversely, we must be mindful of the garbage-in/garbage-out logic of computing, while the simulation process is 'right-sized' for our projects. As an example, one cannot expect to get an accurate quantity take-off of sprinkler piping if the sprinkler system was not included in the model.

Untapped potential and growing demands  
Determining the scope and authorship of BIM in relation to the project's needs and resources is a fundamental challenge, presenting a new hurdle for A/E/C teams. It is also a challenge for which our existing contractual vehicles are not ideally suited. The tendency to fall back on traditional delivery methods is understandable,

given the lack of track record for what this article refers to as the comprehensive BIM process. However, this method's successes—long relegated to the high-dollar, high-complexity world of the most challenging projects designed by Frank Gehry and the like—have successfully trickled down to the point where the software tools are available to the teams responsible for any major project.

At the same time, the growing expectations for building performance and sustainability have joined the continuing pressures for competitive fees and faster delivery times. For an increasing proportion of projects, the reliance on old methods may be a luxury in which our industry can no longer

afford to indulge. A comprehensive BIM approach to design and construction promises to enable a better approach with better results. ♡

#### Notes

<sup>1</sup> For more on BIM, see “Green Building Information Modeling,” by Phillip G. Bernstein, FAIA, LEED AP, in the July 2005 issue of *The Construction Specifier*.

<sup>2</sup> For more information on the delicacies of tolerances, see “Construction Tolerances—Measurement and compliance” by David Ballast, CSI, AIA, in the November 2006 issue of *The Construction Specifier*.

## Additional Information

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#### Key Words

Building information modeling      Design/construction collaboration  
Interoperability      Millwork      Piping      Software      Tolerances

#### Abstract

In traditional building information modeling (BIM), the design team benefits from the coordination and quantification of building elements. However, the process essentially ends with the creation of conventional plans and specifications. In comprehensive BIM, techniques

are distinguished by expanding the use of the building information model to the entire architectural/engineering/construction (A/E/C) team. This article uses a uniquely shaped auditorium project to illustrate the benefits of this software-driven collaboration method.

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