

Building Information Modeling for the e-Lab at LBNL

The Building Information Model (BIM) for e-Lab represents that status of the building during and at the end of schematic design for a proposed new laboratory building on a steep site at the Lawrence Berkeley National Laboratory (LBNL) in Berkeley, CA (Fig. 1). The design includes unique facilities for buildings related research, such as two physically rotating laboratories, ten areas of “replaceable” façade systems, wet labs, completely naturally lit and ventilated offices, public display areas, and more. The building itself is designed to be a “living laboratory” for study of energy efficiency and sustainability by providing measured data during its operation and use.



Figure 1 – e-Lab at LBNL (image generated with Art-lantis)

While the project achieved its primary objectives, it was shelved after schematic design for lack of further project development and construction funding. The BIM is available as a downloadable IFC 2.0 file at http://iaiweb.lbl.gov/vlado/e-Lab_BIM.ifc.

Project challenge that led to the adoption of BIM technology

Environmental Energy Technologies Division (EETD) management decided to apply for a new division laboratory building that would consolidate division laboratories scattered all over the LBNL campus and would also provide new and unique facilities for research in the division. These included laboratories for research on windows, daylighting, high-tech façades, lighting, electricity reliability visualization, OLED/thermal and optical materials, electrochemistry, HVAC and advanced controls, and a computer laboratory. The original project was named Energy Efficiency and Electricity Reliability Laboratory (EEERL); it was later renamed e-Lab.

By the time the decision was made (summer 2001), the new building request process had already started for the year. The U.S. Department of Energy (DOE) typically treated applications on “first come first serve” basis and the e-Lab request was going to be placed at the end of the queue. The typical application consisted of a large number of prescribed forms, very preliminary building floor plans and elevations, and a long narrative describing how the facility would function in the future. To attract the attention of DOE selectors (and move the request upward in the queue), it was decided to submit a different type of application: Besides the regularly required forms and documents, the application would feature results of *simulation of actual performance* of each key feature of the building, rather than a narrative offering promises. Since LBNL is a DOE laboratory, the critical building performance to demonstrate was energy.

The time remaining for the schematic design of the building was short, and the number of different simulation sets needed to be performed was substantial. Each simulation set required the use of different simulation software that shared one common characteristic: input of building geometry. The process of entry of building geometry could be dramatically shortened with the development of a Building Information Model (BIM) and the subsequent use of interoperable software.

An IFC 2.0 based BIM was developed in parallel to the schematic design. It served as depository of building geometry data that were then imported into interoperable cost estimating and building energy performance simulation software.

Interoperability between software applications

The project started in a conventional manner. Internal discussions about perceived and real space needs, energy efficiency, air quality and sustainability resulted in charrettes, presentations and small group workshops (Fig. 2). The results were incorporated in schematic design.

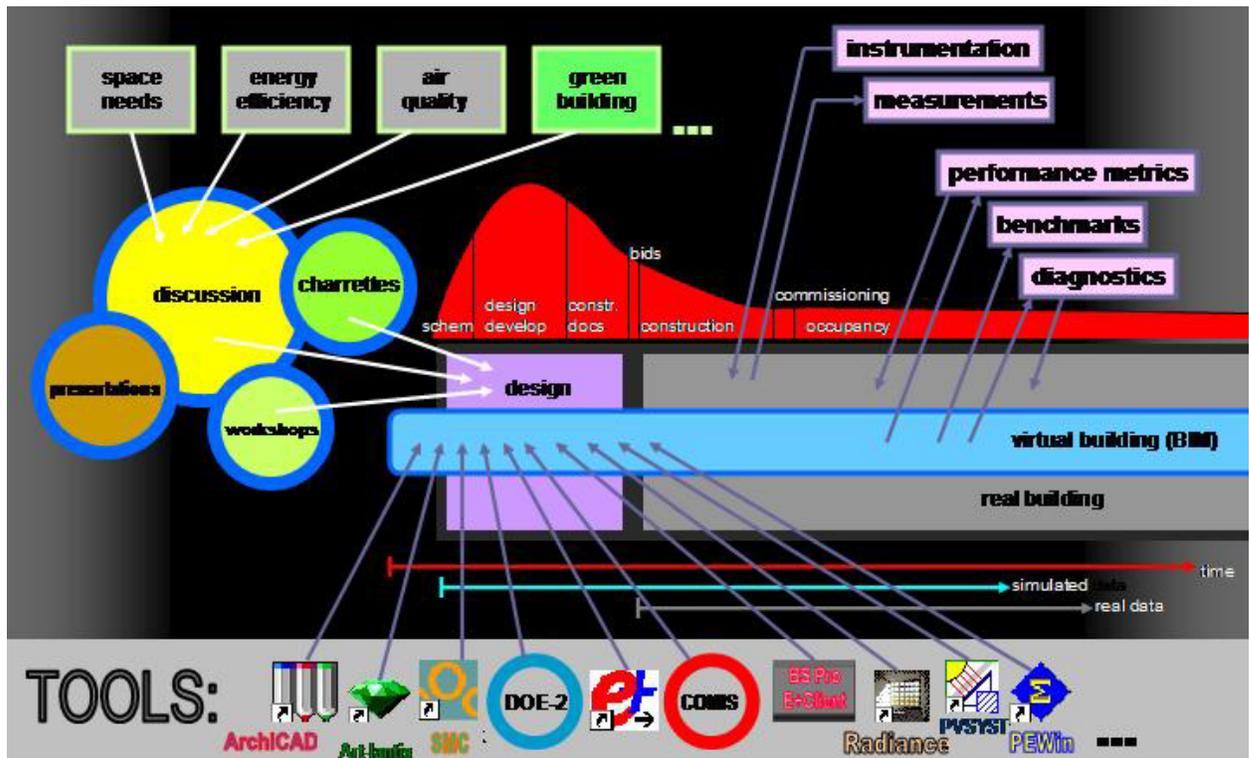


Figure 2 – e-Lab design process and use of interoperable tools

The architect used two dimensional tools in the design process – they “drew” the building in AutoCAD. As the design progressed, an object oriented definition of the building was developed with

ArchiCAD using information from AutoCAD files, and was saved as a BIM in IFC 2.0 format. Building geometry definitions were imported directly from the BIM into interoperable tools.

The suite of directly and indirectly interoperable software tools used in the project included nine applications. Directly interoperable tools included ArchiCAD, Solibri Model Checker (SMC), EnergyPlus (E+), COMIS, BS Pro Server and PrecisionEstimating (PEWin). Indirectly interoperable tools (i.e. tools that can exchange data with an interoperable tool and thus import geometry data from a BIM via that interoperable tool) included Art-lantis, DOE-2 and Radiance. ArchiCAD was used for the development of the BIM. SMC was used extensively to test the accuracy of the BIM (Fig. 3). EnergyPlus served as the main tool for energy performance analysis and natural ventilation. Air flows were checked with COMIS. BS Pro served as middleware to reduce “rich” geometry to that required by energy simulation. PEWin generated cost estimates. Visualization was generated with Art-lantis, running on top of ArchiCAD. Radiance was used for photometrically accurate lighting simulation of offices.

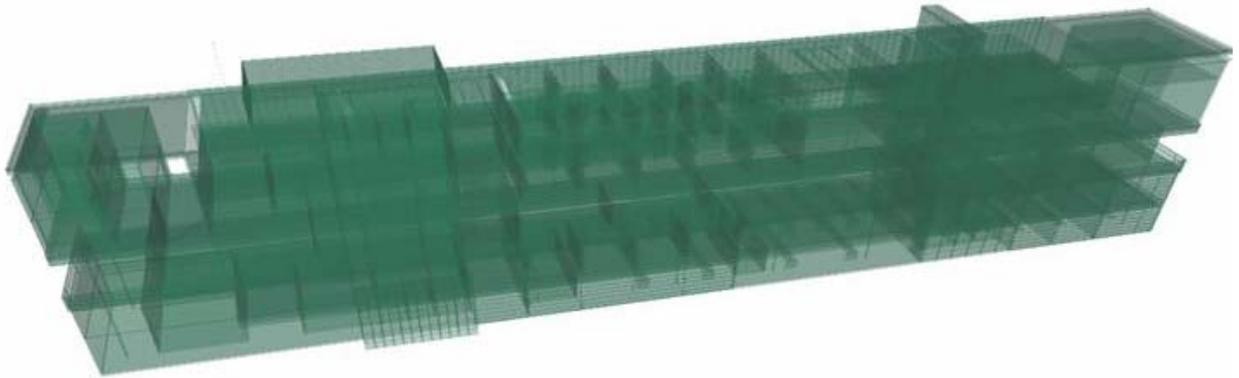


Figure 3 – e-Lab BIM viewed in Solibri Model Checker

A tenth application, PVSYST (a simple stand-alone tool that calculates capacity of photovoltaic systems) was not interoperable; it does not require any building geometry for its calculations. 4-D software would have been used for construction planning and management, but the project did not reach that stage of development. In addition, plans included the development of performance metrics and benchmarking based on the BIM later in the project, and instrumentation and real time measurements with diagnostics once the building was to be in operation. The comparison between simulated and measured data would have yielded a lot of information very useful to calibration of simulation tools.

Benefits achieved

The effort to deploy a BIM and interoperable software achieved its primary goal: The application for e-Lab caused a lot of discussion and visibility at DOE and was at the time apparently moved to the top of the queue. The eventual lack of funding to proceed with the project resulted from forces that had little to do with the application evaluation itself.

The main quantifiable benefit was a reliable cost estimate. First cost estimates generated with PEWin were very low, as they were based on a not yet fully developed BIM and generic unit cost data (Fig. 4). The Division Director decided to fund an external cost estimate (by Davis Langdon Adamson from San Francisco, CA) derived at by conventional cost estimating methodology. The first conventional external cost estimate was deemed too high; it was based on gross area calculations. Using precise quantity take-off (from the BIM), that estimate was reduced from \$20M to \$14.5M; subsequently, using firm manufacturers’ bids for unusual equipment it was further reduced to \$13.2M. In the meantime, localizing cost data to account for construction costs on a steep hill and the proximity of an earthquake fault increased the cost estimate obtained from PEWin to \$7.9M; adding additional design data to the BIM increased that figure to \$9.8M. At that point the Laboratory Director provided an experienced negotiator who “negotiated” an estimate of \$11.9M that was deemed reliable and acceptable to everyone involved.

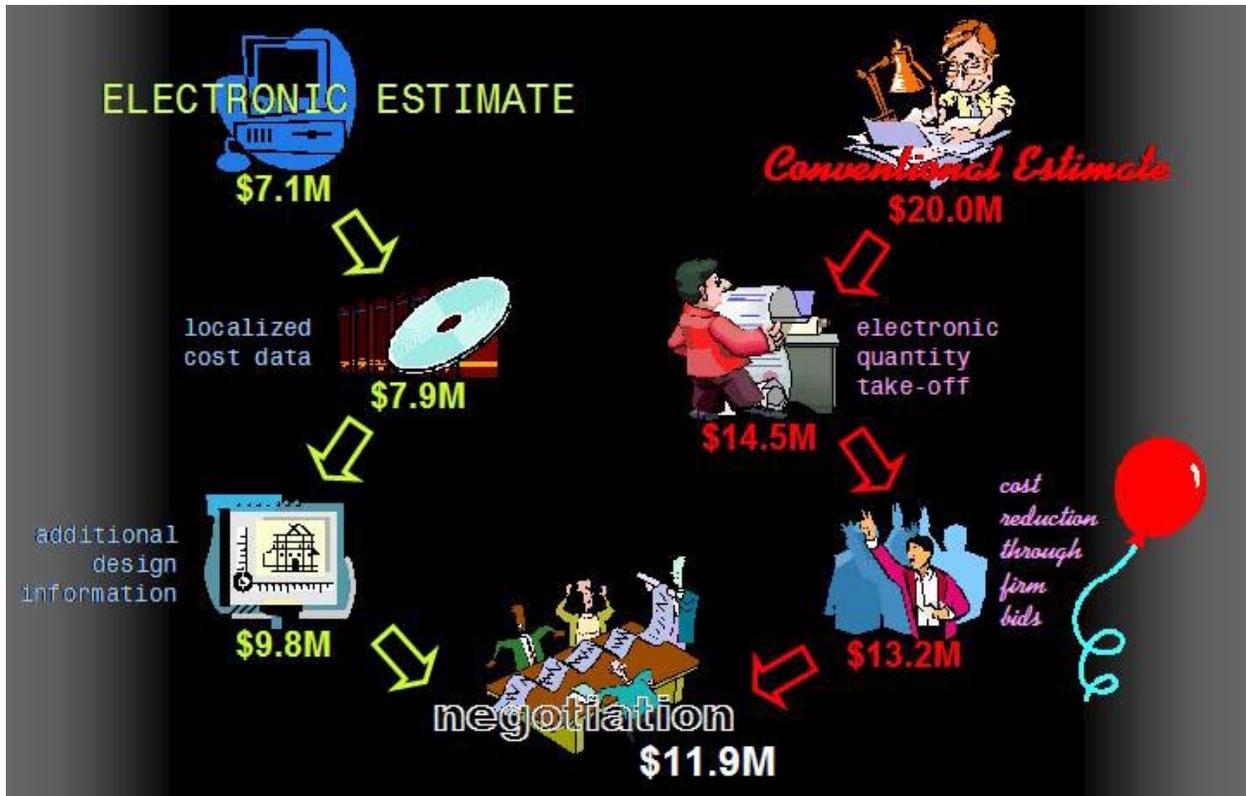


Figure 4 – Process of arriving at a reliable early cost estimate for e-Lab

The *total* budget predetermined by DOE for this building category was \$20M. The original conventional cost estimate of \$20M would have rendered the design scheme too expensive – the design would have had to be abandoned. The process of fine tuning both cost estimates on the basis of data contained in the BIM and the subsequent negotiation made the critical element in arriving at an estimate in which LBNL management had confidence. That confidence was one of the key factors in the decision to proceed and submit the application to DOE for a building as designed.

Other benefits are impossible to quantify. Using BIM and software interoperability it was possible to create and run all the simulations that required building geometry definition as part of the input – without that ability it would have taken much more than the three available months to do it. Inter-relating results from the different types of simulation brought a much better understanding of the design problem than it would have been possible otherwise, which resulted in the design of a better quality building.

Defining a BIM forced changes to the conventional design process. Many design decisions, normally done in design development or even later, had to be made in schematic design to provide meaningful information for inclusion in the BIM. Preliminary foundation and structural design, and exterior shading were designed in much more detail than they usually are in schematic design.

Successful deployment of interoperable software in the e-Lab project resulted in the beginning of a significant cultural change in procurement of new buildings at LBNL. The Facilities Department has begun to trust the use of electronic cost estimating and other interoperable software applications on other projects.

The calculation of “return on value” (value achieved for the project divided by value expended in the effort) is impossible for this project. Overall “cost savings” cannot be determined for a *design* project for which the objective is to build the building within a predetermined fixed budget. The “value” of such a project is established by meeting the target budget, and doing so convincingly. The real “value” of the e-Lab BIM and use of interoperable software was in making this possible in a short period of time while also demonstrating the performance of the designed building.

Non-technology factors contributing success of e-Lab project

Two factors were instrumental to the success of this project: management that understood and at least partially trusted the technology and the process, and the composition of the team and effective team collaboration.

LBNL management understood the goals of the project, understood the technology that needed to reach these goals, and provided ample and participating support. This resulted in challenges and discussion at a level much higher and better informed than currently encountered on typical industry projects; it saved time and resulted in decisions made with confidence.

The design team formed effectively a Virtual Building Environment (VBE) team. The exchange of information was constant and effective, and all members were involved in each facet of decision making. The work was performed at distributed and partially remote locations without any difficulty; it was coordinated by the Virtual Building Design Coordinator at LBNL.

Design team members and define their roles

- Stanley Saitowitz, principal designer responsible for architectural design
- Neil Kaye (Stanley Saitowitz office), responsible for documentation of building design in CAD
- Tom Simmonds, responsible for BIM development in ArchiCAD and visualization images generated with Art-lantis
- Richard Creveling, responsible for electronic cost estimating
- Eric Elsesser, provided preliminary design of key structural components
- Vladimir Bazjanac, served as Virtual Building Design Coordinator and managed the project

Project summary information

- Project name: e-Lab
- Project/facility type: New laboratory building for the Environmental Energy Technologies Division
- Location: Lawrence Berkeley National Laboratory (LBNL), Berkeley, CA
- Client: Lawrence Berkeley National Laboratory and U.S. Department of Energy
- Date completed/occupied: Schematic design competed in January 2002
- Size: 32,938 sq.ft. (gross)
- Lead design office: Stanley Saitowitz, San Francisco, CA
- Lead construction firm, office: NA
- Design phase collaborators: LBNL, ArchVista (San Francisco, CA), Richard Creveling Consultants (Fort Collins, CO), Forell/Elsesser Engineers (San Francisco, CA)
- Construction phase collaborators: NA
- Submitter's contact information: Dr. Vladimir Bazjanac

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(Vladimir Bazjanac, LBNL)