# 4D: Science Fiction or Virtually Reality?

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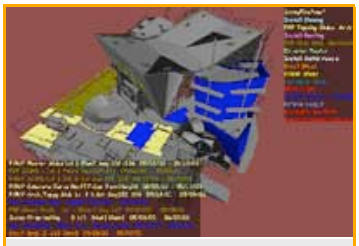
## By Harry Goldstein

Your hands are sweaty, your is breath short, and your stomach has lurched into your throat. Then the plunge, steep and unrelenting, up and down and around. You scream, but nobody hears you. You're riding a roller coaster that doesn't exist.

That's the promise of realistic computer simulations of the sort virtual reality enthusiasts clad in VR goggles, control gloves and electrode-encrusted lycra body suits have been talking about for years. As computer-processing power increases and prices drop, this version of virtual reality is coming ever closer. So is the version of virtual reality that is being touted for use in the AEC sector. 4D-3D plus time-links 3D models to schedules. 4D isn't as sexy as the kind of virtual reality popularized by movies like Brainstorm and The Matrix, but it could be far more useful. Even now, the people who build real rollercoasters inside entire recreational worlds-the Walt Disney Co.-are investing a lot of time, effort and money into making 4D simulations relevant, even vital, to the construction of theme parks and other large projects.

Disney's Imagineers-the people responsible for the design and construction of Mickey's theme parks the worldover-see tremendous value in 4D, especially in terms of increased productivity and decreased waste on job sites. Ben Schwegler, executive director of Walt Disney Imagineering Research and Development Inc., says that he was motivated to investigate 4D by witnessing the staggering amount of waste produced by construction in comparison to other industries, such as manufacturing. "Any operation that produces this much waste has to have room for productivity improvements," he says. He believes that 4D could do for construction what lean manufacturing techniques did for that sector.

The main value from 4D is derived from using it proactively to visualize the construction sequence. "Conflict resolution is the first place everyone can see it-what goes first, where can you store materials on site, will the crane fit there," Schwegler says. Another benefit is the ability to run what-if scenarios to determine optimum scheduling and resource management. Also, by linking 3D drawings to a project schedule, all project stakeholders, from the owner to the tiling subcontractor, can see how the project is supposed to progress.



**This image shows a "logic bust" that the 4D models helped discover. The metal skin activity requires a 'lay down' area, which was negotiated between the metal skin subcontractor and Mortenson. This laydown area subsequently interfered with an architectural concrete pour (shown in yellow). Photo courtesy of Walt Disney Imagineering/Stanford University.**

Despite these advantages and the growing list of large companies that are using it on pilot projects, skeptics believe that 4D is too labor intensive and too complicated to be widely adopted by an industry that is slow to cotton to new technologies. And while it's clear that increased understanding among stakeholders results in better communication across the board, how this effects the bottom line is a question advocates of the technology will have to answer. To people who have seen what 4D can do, however, the eventual adoption of 4D visualization and project management technologies is a foregone conclusion. The price of admission to what has been, until now, an exclusive club, is coming down, while the computer-savviness of construction professionals is on the upswing.

"This industry is driven by risk avoidance, but we see that situation changing," Schwegler contends. "Add in the dimension of productivity to that--and the construction industry has been enormously resistant to the productivity gains realized in the discreet manufacturing business--when they [AEC companies] learn to capture some of those benefits, that will put a huge pressure on their peers."

If construction professionals waste less time rigging work-arounds and fixing mistakes that could have been foreseen using a 4D model, the firms that realize the cost savings will push adoption of the technology as other firms find it increasingly difficult to compete without it, Schwegler reasons. And with 8-15% of labor costs on an average project going down the drain thanks to mistakes that cause change orders, delays and rework, the notoriously slim margins of the construction industry could increase.

Since June 1998, Imagineering has been working with Martin Fischer, Stanford University associate professor and Director of Stanford's Center of Integrated Facility Engineering (CIFE), and a group of Fischer's graduate students to develop a 4D tool. Imagineering used the tool to model the Paradise Pier at Disney's new California Adventure theme park adjacent to Disneyland in Anaheim, Calif. Disney plans to use the 4D tool on future projects, including on at least part of the new theme park it has planned for Hong Kong, which is slated for completion in 2005. Imagineering is currently in the process of determining whether or not it

wants to commercialize the 4D tool and if so, how.

Whether or not Imagineering's 4D tool becomes commercially available any time soon, the Imagineering/Stanford team is having no problem finding people willing to try the software. Currently, Fischer's team, led by graduate student John Haymaker, is working on the Walt Disney Concert Hall project in Los Angeles in conjunction with M.A. Mortenson Co., Minneapolis, Minn. and Frank O. Gehry & Associates, Santa Monica, Calif. Greg Knutson, general superintendent on the concert hall project, says that the Imagineering tool "has definitely helped, " especially in terms of getting subcontractors to understand their roles on this extremely complex project as well as aiding Knutson in identifying coordination conflicts.

Knutson believes that the 4D tool has helped subcontractors and others on the project, including schedulers, get their heads around the project. "It is really a challenge trying to figure out how to put the project together," says Knutson. "Once we figure it out, it's even a bigger challenge to communicate it to the subcontractors." The 4D model is used at the monthly meeting Knutson has with subcontractors as well as for ninety-day look-ahead meetings. "Just by looking at it, it gets people to understand how [the structure] goes together," he says.

On a structure as complex as a Frank Gehry concert hall or a Disney theme park, it's virtually impossible for anyone, even an experienced superintendent or scheduler, to visualize an entire project, much less anticipate potential conflicts before they arise. In fact, it's the seasoned professional who stands to gain the most from 4D tools, says Fischer. He likens 4D for construction to a telestrator in football, where a color man like John Madden takes a slow motion replay and annotates it with slashes, circles and arrows. "I think John Madden gets a lot out of those replays and annotations. Because he sees so much more, he knows what the opportunities are. I have seen same thing on 4D--if an experienced person digs into the model they see so much more than any lay person could see, the value they get out of it is that much greater."

**A group of subcontractors and contractors view 4D models of the Disney Concert Hall in the Walt Disney Imagineering CAVE. Photo courtesy of Walt Disney Imagineering/Stanford University.**

4D proponents believe that firms could save a lot of time-a lot of money-by fixing schedule conflicts in virtual space before they materialize in the real world. That's the promise of 4D for construction. And with start-up software companies looking to dig a niche, 4D's virtually a reality today.

**COMPETITION SPURS INNOVATION**

While Fischer and colleagues were busy plugging away at 4D in the mid-to-late 1990s, Moore's Law clicked into high gear. Supercomputers that used to cost $500,000 or more shrunk in size, increased in speed and decreased drastically in price. Powerful software that had at one time been accessible only in defense and automobile laboratories and a few major research universities is now available to anyone with a decent PC.

"The sense is that the tools are becoming more economical," says Dennis Shelden, director of computing for Gehry. "Clearly the industry is in a position where it needs help on a number of levels and improved tools can do that. It takes a commitment from everybody to understand the benefit that comes out of that [in terms of] reduced risk, fewer errors in the field, better coordination. To us it's obvious that's the way that should be done."

It's also obvious to established AEC software vendors who sense that the time is ripe to push their 4D add-ons out to a wider user base. Intergraph Corp., Huntsville, Ala., has recently released a souped-up SmartPlant Review 4.2. Bentley Systems Inc., Exton, Pa., is supercharging its Schedule Simulator by merging it with its Dynamic Animator program. Large AEC firms like Parsons Brinckerhoff, New York, NY, have been using in-house resources to plan and manage mega-projects in real-time using custom-built, time-dependent solutions. Company 39, a subsidiary of Parsons Brinkerhoff, has done extensive work with visualization using 2D drawings for a major telecommunications project that entailed building a $3-billion, nationwide fiber optic network. Company 39 linked a Primavera P3 schedule to 2D models, a geographical information system (GIS) database and a procurement database. The digitized project was accessible to 320 users across the country via the Web. Users can see the fiber network being built in real time. "You can do gap analysis and ad hoc queries that are visually tied to the database," explains Doug Eberhard, chief technology officer of Company 39. "It allows the construction managers and the whole team to identify where to put resources when based on real time local conditions."

Eberhard also admits that Company 39 has been losing some work to the "guys in basements," as he calls them. Those "guys" are start-ups such as VirtualSTEP Inc., Hayward, Calif., and Balfour Technologies LLC, Bethpage, NY, which have appeared on the market with commercial solutions over the last year. Other companies such as Construction Systems Associates Inc., Marietta, Ga., and Visual Engineering, New York, NY, are also developing 4D tools and looking for a niche.

The approaches to 4D vary according to the target market, the expertise of the developers and how they envision 4D being used as a collaboration tool. Balfour is run by identical twins Richard and Robert Balfour, who come from the military simulation field. The photo-realistic simulations are as close to the stomach-churning thrill ride of virtual reality as you're likely to find anywhere and make Balfour's solution particularly attractive for public presentations such as for environmental impact statements or airport construction, where community buy-in is necessary for funding.

Balfour debuted its flagship product, fourDviz, at the Transportation Research Board meeting in January. Over the last 18 months, the program has been used by the National Aviation and Transportation Center, Brookhaven, NY, and Frederic R. Harris Inc., Boston, Mass., for several current and proposed projects including the LaGuardia Airport Rail Access project, the Boston Logan Airport Modernization Program as well as on simulations created in conjunction with Auburn University for a project planned for the Huntsville International Airport in Alabama.

"We're replacing spreadsheets with this kind of high fidelity simulation. It's easy to see time-dependent data with things like this," says President and CEO Rich Balfour. As for the emerging competition in the 4D-simulation space, Balfour welcomes it, declaring, "Competition will help grow the market." Growth has been inhibited, by the perception that the

technology is cost-prohibitive, which "isn't the case anymore," he claims.

Like the Balfour brothers, Yee Sue Chiou, co-founder of VirtualSTEP, found the falling price of computer technology to be a prime business opportunity. When he was working at Shimizu Corp., Tokyo, Japan, he decided "that Jacobus [now Bentley's Schedule Simulator] was running only on Silicon Graphics machines too expensive to maintain," and started to develop an open, middleware-type solution that could run on an ordinary PC. Like Imagineering's tool, VirtualSTEP is "agnostic," meaning it can work with data in almost any file format.

While VirtualSTEP isn't looking to go toe-to-toe with the surviving AEC application service providers (ASPs) on the Web, it does provide much of the same functionality that ASPs do, allowing users to not only simulate changes in 4D, but to evaluate cost and schedule impacts, mark up documents, send RFIs and otherwise manage the construction process. The company's Project Studio lets users mix and match several components, including a conflict detection and resolution workflow tool, a project management module and a project analyzer that lets users compare what-if scenarios side-by-side. VirtualSTEP's browser-type interface will be familiar to anyone who has worked with ASPs such as Constructware, e-Builder or Buzzsaw.

Intel and San Francisco-based developer SKS are both beta-testing VirtualSTEP on major projects. Paying customers include T.B. Penick & Sons Inc., San Diego, Calif., Shimizu and Taiwan developer Century Development, which is using VirtualSTEP Project Studio in conjunction with construction of Phase II of the Nankang Software Park in Taipei. Tony Miley, senior marketing director, says that the company is currently in negotiation with a dozen potential customers.

While a number of large companies are investigating the potential of 4D in pilot projects, skeptics believe that 4D is still too labor intensive and too complicated to be widely adopted by the AEC sector. "4D is so on the high end right now, nobody's really doing it," says Tomas Hernandez Jr., associate principal at Kohn Pedersen Fox PC, New York City. He doesn't believe that the 4D tools available today have the horsepower to handle large data sets or that users will be sophisticated enough to take advantage of what 4D has to offer. And he has yet to see a turnkey solution that will provide the functionality he's looking for at a price that makes sense. Despite his skepticism about the commercial viability of 4D, he is still curious enough about the technology's potential that Kohn Pederson Fox has started talking with VirtualSTEP. "It's just not there yet for the projects we do in this office," he says of the shrink-wrapped 4D add-on products offered by traditional AEC software powerhouses. "I hate to be so negative, but there've been promises made about this stuff for years now."

**SHOW ME THE MONEY**

Before future visions of a data-centric, bricks-and-clicks AEC industry come to pass, techno evangelists need to convert today's crop of construction professionals. In the real world, 4D isn't a priority even for customers who have bought a solution. Rick Rowland of Lockwood Greene Engineering & Construction, Spartanburg, SC, an Intergraph SmartPlant Review customer, says, "Because of project schedules being pushed back, we have not had the opportunity to use SmartPlant Review on a project yet. We have a major goal to increase construction utilization of data generated in design, and we see 4D as one potential application. At this time, I do not know when we will try to implement 4D on a project."

Technology becomes a priority when people understand how it can help them do their jobs faster, cheaper and better. Because 4D technology seems like it could be one of those costly "bells and whistles" that are easily cut from a budget, determining the cost-savings benefit is vital if the technology is ever going to be adopted on a mass basis.

Some 4D users, such as Westinghouse Electric Co., Nuclear Systems, Windsor, Conn., have done their own analysis. Westinghouse used CSA's PM-Vision to model a System 80+ Advanced Nuclear Power Plant as part of a project to investigate the use of 4D on nuclear plant construction sponsored by the Electric Power Research Institute, Palo Alto, Calif., Westinghouse, Duke Engineering & Services, Marlborough, Mass. and Korean Power Engineering Co., Kyunggi-Do, Korea.

"We were trying to improve the construction schedules-that was our basic goal," says Donn Matteson, a senior consulting engineer at Westinghouse. "We attained reduction in the schedule by being able to visualize the sequence of construction activities and identify conflicts. We saved months," he says, "about 15% in terms of time." Westinghouse is currently using PM-Vision on a couple of projects and as the company considers new nuclear power plant construction, Matteson believes that it's highly probable that "we would use some form of 4D visualization down the road."

Determining the bottom-line benefits of 4D visualization poses a difficult challenge, one that CIFE Stanford Ph.D. candidate Kathleen Liston, along with Christopher Holm, senior technical staff, Walt Disney Imagineering Research and Development Inc. are trying to solve. For the last two years, Liston and Holm have been sitting down with teams involved with several 4D projects and talking to them about the benefits of 4D.

"The anecdotal evidence is primarily related to communication and is extraordinarily hard to quantify," says Liston. Knowing that, Liston has been categorizing project documentation in an attempt to glean trends-change orders, RFIs, and other documents. Liston compares projects that have used 4D to those that haven't, as well as to projects where 4D had been used to a certain extent, but its real use not maximized. She then tries to determine what percentage of change orders or mistakes could have been prevented through 4D discovery.

Liston's conclusion? "Our general numbers have fallen into the category of, very conservatively, 20%, but more in the range of 45% of change costs could have been prevented through the 4D model." Imagineering/Stanford's approach to quantifying the 4D benefits on the Disney Concert Hall project has been to attach dollar tags to the problems that were discovered before they took place by estimating what the cost of that problem in the field would have been. The results are not final, but already those cost savings well exceed the investment to date in the 4D model being used on that project, claims Liston. Since the 4D models implemented by the Imagineering/Stanford team have been approximately 0.25% of estimated project dollars, the payoff has been substantial in terms of cost-benefits to the projects Liston has studied. She believes that potential savings could be in the range of 4%-6% of overall project costs. In many cases, Liston says, cost savings have gone well beyond that.

The construction industry needs a good set of baseline tools to measure efficiency and productivity so that the benefits of 4D, or any digital tool for that matter, can be accurately assessed. "Metrics is a big part of driving technology adoption from a value approach," says

Liston, with the ultimate goal being a way to automatically generate cost-benefit analysis data before, after and during a project so that organizations can do these analytics themselves.

Owners are one party to the construction process that many observers believe will have to drive adoption of most new technologies, including 4D, in the AEC sector. Jonathan Cohen, author of Communication and Design with the Internet (W.W. Norton & Company, 2000) and an advisor to VirtualSTEP, says that the industry has been hearing about 4D technology for 25 years. "I believe that the real push has to come from the owners, and I'm looking to them as the ones who will get interested [in 4D] because they will ultimately benefit. I would look to big owners like the University of California or GSA [General Services Administration] or the Navy or big real estate companies to tell their contractors and architects 'that's what I want I do.'"

Like so much in the virtual world of 4D, only time will tell.

**Glossary**

**Moore's Law:** Gordon Moore, co-founder of Intel Corp., famously predicted that the number of transistors on a microchip would double every 18 months, increasing computer processing power while at the same time decreasing the price of computer processors.

**application service provider (ASP):** a third party company or institution that distributes and manages software applications and services via wide area networks, including the Web.