4D Modeling on the Walt Disney Concert Hall

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Objekttyp: **Article**

Zeitschrift: **Tec21**

Band (Jahr): **127 (2001)**

Heft 38: **Interkontinental Lernen**

PDF erstellt am: **05.08.2024**

Persistenter Link: https://doi.org/10.5169/seals-80209

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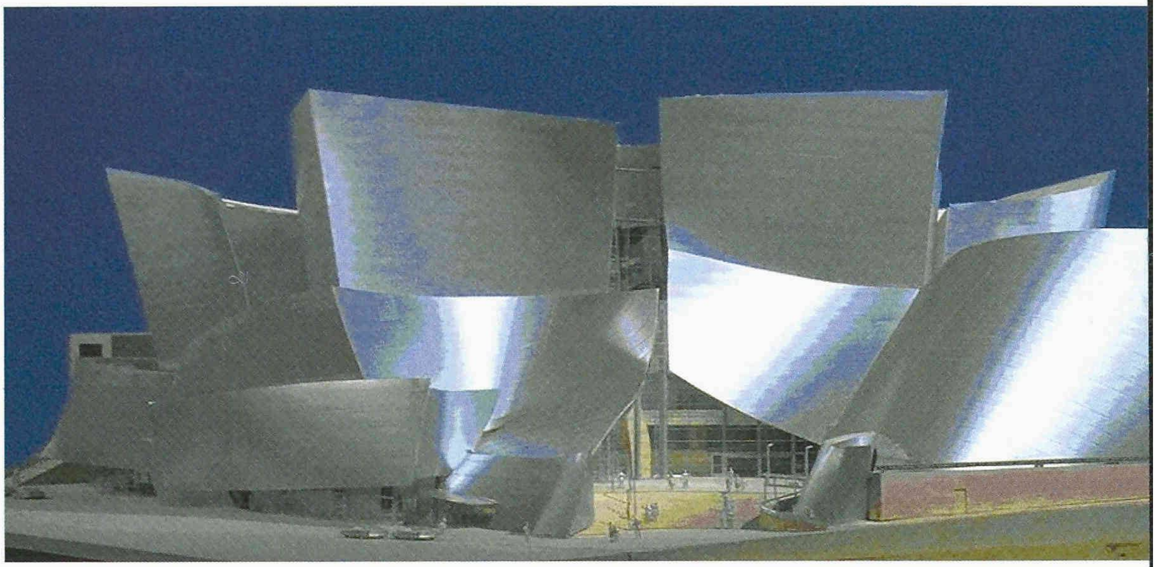

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Photo of the physical model of the Disney Concert Hall

4D Modeling on the Walt Disney Concert Hall

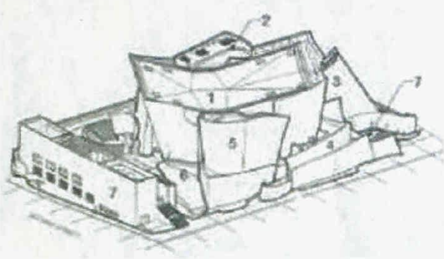
4D models (3D plus time) combine a project's spatial representation with the project's schedule to display graphically on a computer screen how a project will be built. In the last twelve months, such models are being used increasingly on projects across the United States.

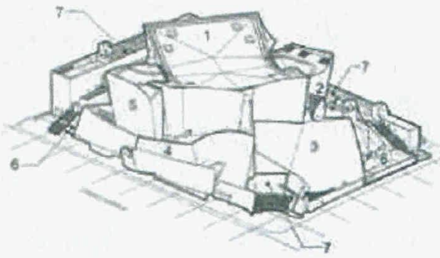
3D modeling has become more cost-effective with the latest software releases from CAD vendors, and time pressures on projects have increased, making it possible and necessary to improve project schedules by building a project first virtually in the computer. This article describes the application of 4D models for construction scheduling and constructibility analysis on the Walt Disney Concert Hall project in Los Angeles, California.

The Project, Participants and Motivation for 4D Modeling

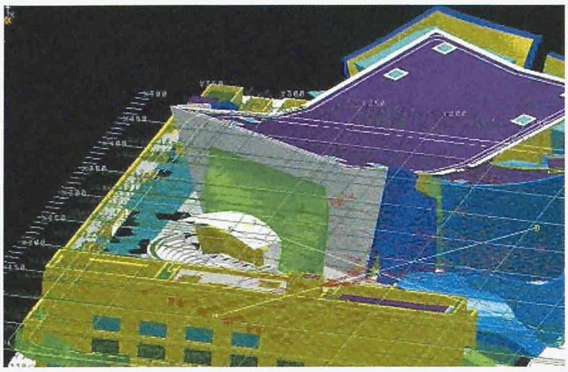
The Walt Disney Concert Hall (DCH), designed by Frank O. Gehry and Associates (FOGA), is the new 2,400 seat home of the Los Angeles Philharmonic Orchestra. Located in downtown Los Angeles, the US$ 200,000,000 project incorporates complex architectural, structural, and acoustical requirements in a tight one-city-block site. The project is scheduled for completion in early 2003. Figure 1 shows a photo of the front entrance to the Walt Disney Concert Hall.

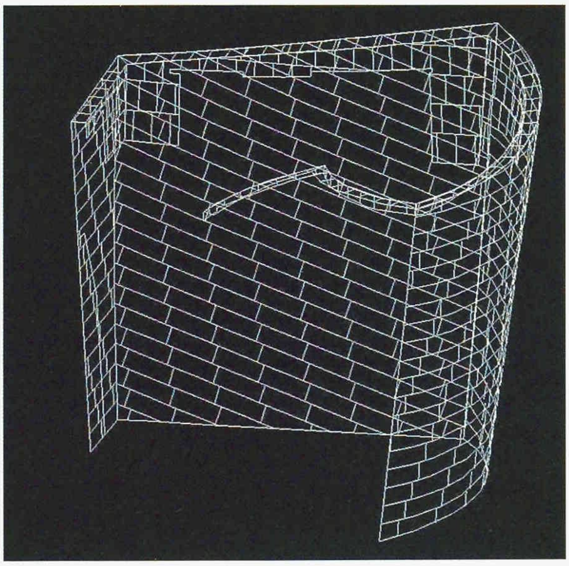
FOGA's design process yields a highly developed 3-dimensional CAD product model, which is used extensively for dimensional control and fabrication in the construction process. This 3D model and the construction schedule prepared by M. A. Mortenson Company, the general contractor (GC), with input from the many subcontractors, provide the information necessary for 4D models. John Haymaker from the 4D research team at Stanford University worked on site to help build the 4D models and to introduce the GC and key subcontractors to the 4D modeling process. He used the 4D modeling software developed in collaboration by Walt Disney Imagineering (WDI) Research and Development and Martin Fischer's 4D CAD research group at the Center for Integrated Facility Engineering (CIFE) at Stanford University.





2 a und b
Walt Disney Concert Hall broken down by building element
3
Surface models for all building elements
4
Element 2 surface model
5
Element 2 pattern model





The complex project and a tight site make precise coordination of construction activities a very high priority. M. A. Mortenson uses the 3D and 4D models as communication tools to share project information with all project participants including architects, engineers, the general contractor, subcontractors, and the owner to accomplish four objectives:

1. Schedule creation: 4D models help visualize schedule constraints and opportunities for schedule improvements through resequencing of activities or reallocation of workspace.

2. Schedule analysis: 4D models help analyze the schedule and visualize conflicts that are not apparent in the Gantt charts and CPM diagrams.

3. Communication: Many participants join the project in midstream, and it is critical to bring new participants up to speed quickly.

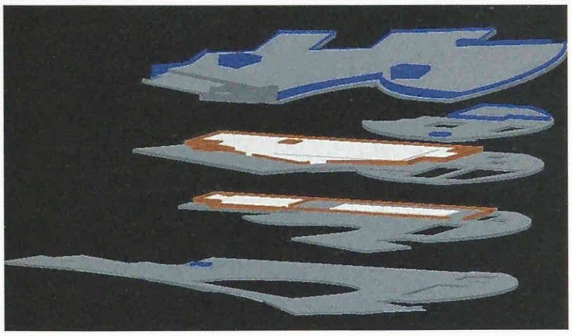
4. Team building: The GC's project superintendant, Greg Knutson, feels strongly that it is very important to construct a team atmosphere, where people solve problems together. A shared, visual model to externalize and share project issues was a valuable team building tool.

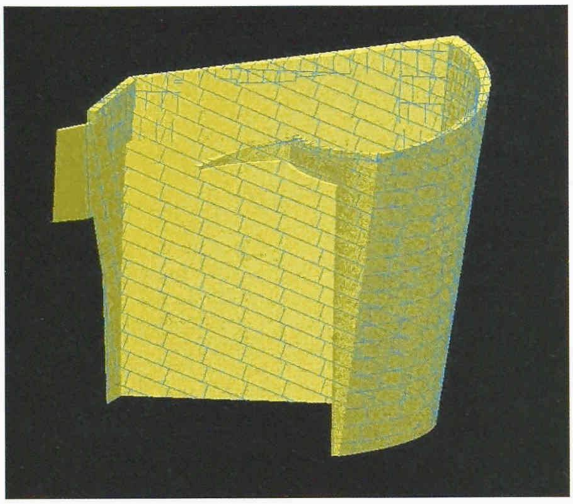
Available Electronic Information

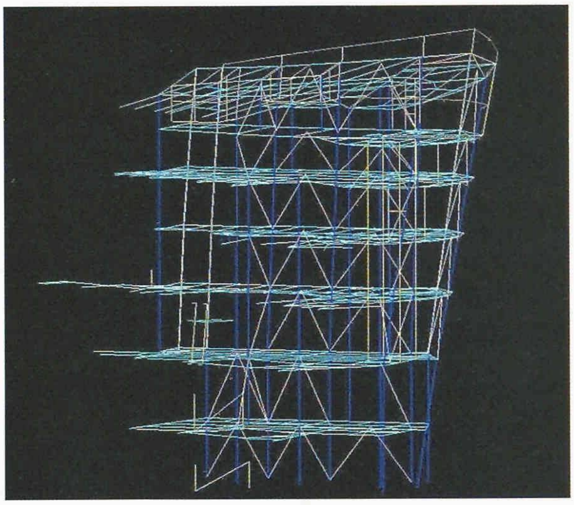
This section describes the format and level of detail of the project information at the beginning of 4D modeling process.

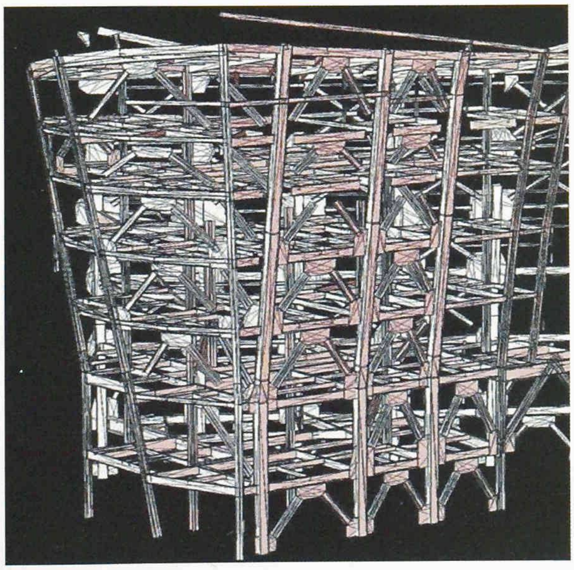
Available 3D Geometry

The architect constructed the 3D models with CATIA. To reduce complexity, FOGA divides the 3D model into sub-models. First, FOGA divides the project geographically into «building elements», as shown in figure 2. Figure 3 shows all of the building elements' surface models incorporated into one view. Each building element is then further divided into models for the various building systems. Figures 4 to 9 show different 3D models available for building element 2. Figure 4 shows the surface model for element 2. The surface model contains everything that can be seen, from plaster, to glazing, to carpet, to wood panneling, etc. Figure 5 shows a pattern model. A pattern model describes any pattern in an element that is relevant for architecture or construction. Figure 5 shows the pattern of the stainless steel panels for the exterior of element 2. Figure 6 shows the concrete model, which models the structural and architectural concrete surfaces. Figure 7 shows an example of an air and water barrier model. The air and water barrier model defines the surface in space where the waterproofing systems should be placed. Figure 8 shows the structural wireframe model. This model defines a wire for each piece of steel







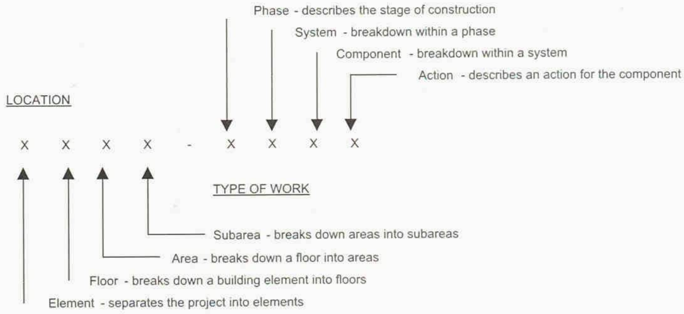


6
Surface model for element 2
7
Air and water barrier model for element 2
8
Element 2 steel wire frame model
9
Detailed steel model

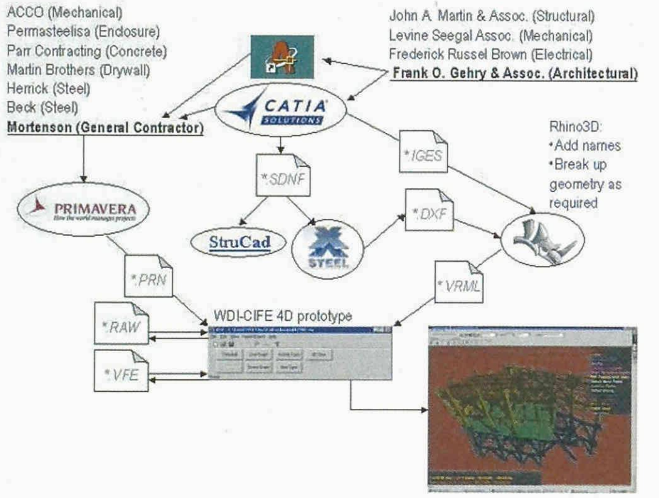
in the building. The steel detailer and the steel fabricator use this wire model as input and place the proper size member with each wire. The detailers detail all the connections in X-Steel or other detailing packages in 3D. The resulting detailed steel model, shown in figure 9, is then reimported into the CATIA model.
Each 3D model consists of layers reflecting different sub-systems. These layers are helpful for 4D modeling because they isolate certain scope information in the 3D model, which facilitates the identification of the appropriate geometric elements for a particular activity. However, frequently the layering organization is different from the organization of the schedule, and the 4D modeler needs to reorganize the geometric information for the 4D model to fit the schedule organization.

Available Schedule Information

The GC created the construction schedule with Primavera's P3 software. At the start of the 4D modeling process in March 2000, the schedule contained about 4,000 activities. By late summer 2001, the schedule consisted of about 8,400 activities with over 20,000 sequence relationships between the activities. The schedule divides the 3D project geometry into chunks that are relevant to an activity. Figure 10 shows the breakdown key for the activity ID in the schedule. Activities are identified by building element, floor, area, and subarea, then by phase, system, component, and action. However, some activities do not fit easily into this break-down. Even though it was useful to have one main way to organize the schedule (as shown in figure 10), many methods for decomposing the geometry and linking a scope of work to an activity are required to suit different types of work.



10
Activity code key for defining activities and relating them to the 3D model



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Process for constructing 4D models from 3D models and CPM schedules

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Steel, concrete, and exterior enclosure model. This 4D model examines the overall sequencing for the major structural and enclosure activities. It shows the sequencing of steel and of structural and architectural concrete. It includes metal decking, roofing, glazing, and enclosure systems, such as metal cladding assemblies including secondary steel supports (number of 3D components: 340; number of polygons: 515,000; number of activities: 512)

4D Modeling Process

Figure 11 maps the process for constructing the 4D models from the project geometry and schedule and shows the file formats used to translate between computer programs. Rhino3D proved to be very useful to import the NURBS-based geometry from CATIA, add names to the geometry, break up the geometry into relevant configurations for the respective activities, and convert the geometries to VRML. Named geometrical elements allow a 4D modeler to match geometry names to activity names quickly.

Description of 4D Models Built

In spring and summer of 2000, we built four 4D models for the project. Figures 12 to 15 show a screen shot from each of these models.

Uses of 4D Models

The 4D models supported M.A. Mortenson's four objectives in the following way:

1. Schedule creation: The GC used the 4D models to assist in planning the laydown areas for the enclosure contractor, to visualize overall project access at critical junctures in the project, to refine the interior and exterior scaffolding strategy, and to plan the installation of the complex ceiling of the main concert hall.

2. Schedule analysis: The GC's project management team used 4D models to discover several conflicts in the schedule which were not discovered in the CPM-based Gantt chart. Figures 16 to 18 show snapshops of the 4D models that show particular problems. Figure 16 shows a situation where a Concrete Masonry Unit (CMU) wall was scheduled too early while steel was being erected directly overhead. Because the wall that is framed by the steel leans outward the steelerection requires shoring (not modelled), which would not only interfere with the construction of the CMU wall but also cause a dangerous situation. Figure 17 shows an Air Handeller Unit (AHU) being installed too late after the steel is completely erected. There would no longer be the access necessary for the large AHU. After consulting with other project team members, the GC decided to leave some of the steel out to make it possible to slide the AHU into the structure at a later date. Figure 18 shows a conflict of scaffolding systems in the same area of the interior hall. The scaffold for the plastering of the walls will need to be removed before the ceiling scaffold can be erected. As a result of the schedule analysis through the 4D model of the interior construction the GC decided to consolidate the scaffolding contracts for the interior hall from three contracts to one contract. The 4D models supported the discovery of these (and many similar issues) during planning, well before construction started and while many different options to address an issue were still open. Because of the physical and temporal interrelationships between many scopes of work an early detection of potential problems is essential to revise the design or schedule economically. For example, even though the AHU was not scheduled to be installed for many months it was critical to iden-

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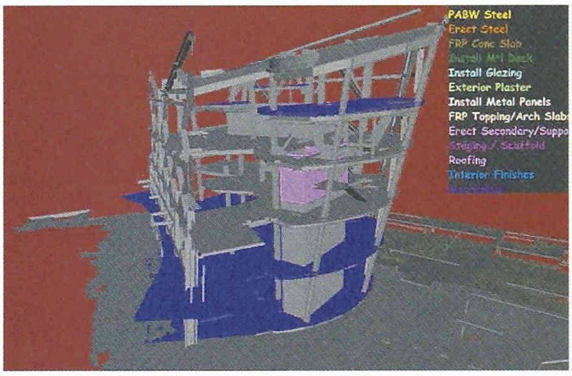
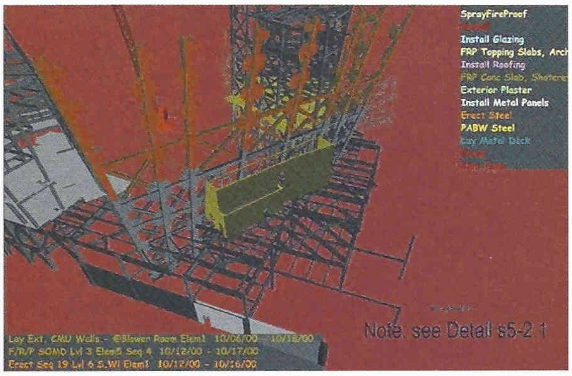
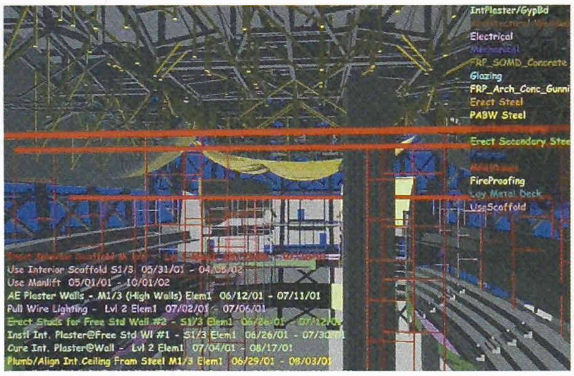
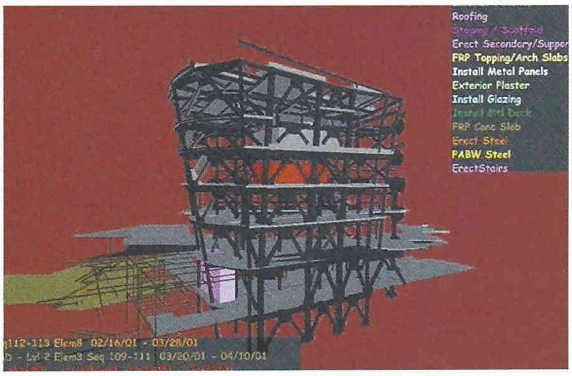
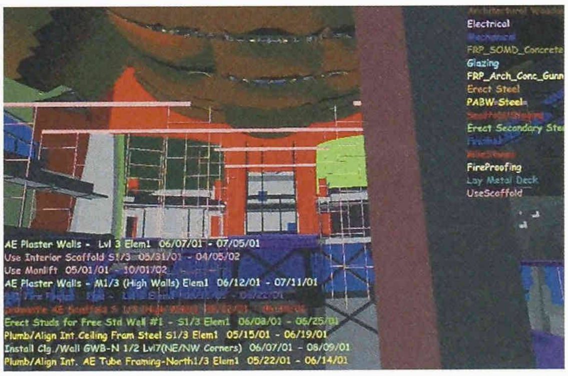
Element 2 model. This 4D model goes into more detail for building element 2. It includes the interior work. The model includes interior stairs, elevators, fire-proofing, and finishing systems. It shows mechanical and electrical activities by highlighting the floor slabs in the area of work (number of 3D components: 105; number of polygons: 85,000; number of activities: 185)
14
Interior hall model. This 4D model developed the interior of the Concert Hall, a highly congested and complex space. All of the interior activities are squarely on the critical path. The model includes all the activities affecting this space: structural steel, concrete, plaster, wood finishes, mechanical, and electrical. The model also includes scaffolding (number of 3D components: 210; number of polygons: 325,000; number of activities: 667)
15
Detailed hall ceiling model. In early 2001, we are constructing a fourth model to help with the detailed planning of the complex concert hall ceiling installation (Number of 3D components: 180; number of polygons: 520,000; number of activities: to be determined)
16
CMU wall scheduled too early
17
Air Handler Unit (shown in red) scheduled too late
18
Scaffolds collide









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Collaboration in the CAVE

tify potential AHU installation problems prior to work being released for steel fabrication to ensure that the right steel was installed (and not more).

3. Communication: The GC used the 4D models in training sessions with as many as 40 people, where subcontractors, owners, designers, and the GC reviewed the models and discussed the strategy and constraints for erecting the project. Figure 19 shows a view of subcontractors in a meeting in a CAVE (Computer-Assisted Virtual Environment).

4. Team building: After a 4D review session ended, it was not unusual to have people from different subcontractors remain in the room for an hour or more beyond the scheduled meeting time to discuss issues and solutions to problems or questions identified during the meeting. The GC's project superintendant mentioned that, in a tight labor market, where everyone is committed to too many projects, it is critical to get the attention and collaboration of the subcontractors focused on his project. Given the complexity of the project he wanted to make sure that the subcontractors put their creative energy into improving the construction of his project.

Acknowledgments
We would like to acknowledge the following people for their help with this 4D modeling effort: Jim Glymph, Kristin Woehl, and Dennis Sheldon from FOGA; Ben Schwegler and Chris Holm from WDI; Greg Knutson, Derek Cunz, Jim Yowan, David Mortenson, Lorri Stapleton, and Lisa Wickwire from M.A. Mortenson; David Aquilera, Martin Brothers; and Joe Patterson, Columbia.

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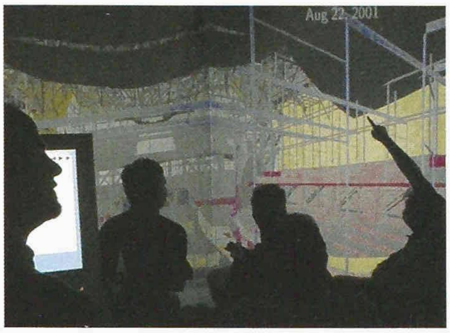
Beda Meyer



Geschäftsbeziehungen über das Internet

Noch vor wenigen Jahren stellte das Internet ein für Wirtschaft und Juristen unbekanntes Gebiet dar. Heute wächst der elektronische Geschäftsverkehr enorm rasch und wird von vielen Unternehmen genutzt. Da dem Austausch von Dienstleistungen und Waren auch im World Wide Web immer Verträge zugrunde liegen, wird das rechtliche Augenmerk auf den Vertragsschluss im Internet gerichtet. Die juristische Diskussion um diesen gilt heute als weitgehend abgeschlossen. Auch im Web kommt ein Vertrag gemäss Obligationenrecht durch «die übereinstimmende gegenseitige Willensäusserung» der Parteien zustande, welche die Einigung über alle wesentlichen Vertragspunkte enthalten muss. Ein Vertragsabschluss über das Internet – etwa per E-Mail, Chat-Raum oder Video-Konferenz – ist grundsätzlich ohne Weiteres möglich. Gesetzlicher Anpassungsbedarf besteht bloss bei Verträgen mit Formvorschriften (z.B. bei der Abtretung von Forderungen oder Teilzahlungsgeschäften), welche in der Schweiz jedoch in der Minderzahl sind. Hier ist die Gleichstellung der elektronischen Signatur mit der handschriftlichen Unterschrift vorgesehen.[1]

Besonderheiten bei einem elektronischen Vertragsschluss: Ein Vertrag kommt durch übereinstimmende Willenserklärungen zustande, also dann, wenn das Angebot, die Willenserklärung der einen Vertragspartei, durch die Annahme der anderen bestätigt wird. Im Internet wird beim Angebot von Waren oder Dienstleistungen davon ausgegangen, dass es sich bloss um eine Aufforderung zur Offertstellung handelt. Derjenige, der zur Offertstellung einlädt, ist nicht bereits durch die Erklärung der andern Seite an einen Vertrag gebunden, sondern muss zuerst seinerseits eine Willenserklärung abgeben. Immerhin liegt dann ein rechtsverbindliches Angebot vor, wenn die Leistung direkt vom Rechner des Anbieters bezogen werden kann, also etwa bei Software oder Online-Börsenkursen.[2]

Eine wesentliche Unterscheidung, die das Obligationenrecht in Bezug auf den Abschluss von Verträgen macht, ist diejenige zwischen dem Vertragsschluss unter Anwesenden und unter Abwesenden. Die Übermittlung eines Antrags mit elektronischen Kommunikationsmedien ist grundsätzlich als Erklärung unter Anwesenden zu verstehen. Somit kann der Adressat des Antrags innert einer den Umständen angemessenen Frist – welche im Internet relativ kurz bemessen sein dürfte – entscheiden, ob er die Willenserklärung annimmt. Während dieser Zeitspanne bleibt der Anbieter an sein Angebot gebunden. Die Möglichkeit des Widerrufs ist beim elektronischen Geschäftsverkehr technisch kaum gegeben, da der Widerruf gleichzeitig oder vor der zu widerrufenden Erklärung eingehen müsste. Liegt ausnahmsweise, wie bei der Internettelephonie, eine Kommunikation unter Anwesenden vor, muss die Annahme unmittelbar erfolgen.[3] – Ausgeklammert blieben in dieser kurzen Betrachtung insbesondere grenzüberschreitende Rechtsfragen und vertragsrechtliche Sonderfragen wie der Einbezug von Allgemeinen Geschäftsbedingungen oder konsumentenschutzspezifische Normen.[4]

Beda Meyer, lic. iur., wiss. Ass. am Lehrstuhl für Technologie- und Informationsrecht der ETH Zürich

1 H. Honsell / Th. Pietruszak: Vernehmlassungsentwurf zu einem Bundesgesetz über den elektronischen Geschäftsverkehr, AJP 2001, S. 772.
2 R.H. Weber: E-Commerce und Recht. Zürich 2001, S. 314 f.
3 Ders., S. 316 f.
4 Vgl. hierzu anstelle vieler: U. Widmer / K. Bähler: Rechtsfragen beim Electronic Commerce. Sichere Geschäftstransaktionen im Internet. Zürich 1997, 135 ff.