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Virtual Reality and Ancient Rome:

The UCLA Cultural VR Lab's

Santa Maria Maggiore Project

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(1) Introduction

Since the fall of 1995, professors of Classics, Architecture, Education, and Information Science at UCLA, in conjunction with colleagues in the United States, Britain, and Italy, have been developing virtual reality (VR) models of buildings and monuments in ancient Rome (cf. fig. 1). This collaborative research effort is called the Rome Reborn Project in honor of the first systematic study of Roman topography, Flavio Biondo's mid-fifteenth century *Roma Instaurata* (de Grummond 1996: 160-61). Since January, 1998 the project has been housed in the UCLA Cultural VR Lab, which was created with support from Intel, the Creative Kids Education Foundation, Mr. Kirk Mathews, the UCLA Division of Humanities, the UCLA Humanities Computing Facility, the UCLA Center for Digital Innovation, the UCLA Graduate Division, the UCLA Office of the Vice Chancellor for Research, and the UCLA College of Letters and Science.

The Lab's mission is to provide technology support for projects like Rome Reborn that strive to recreate authenticated three-dimensional computer models of sites of great historic and cultural interest around the world. The Lab was founded on the assumption that in the next few years it will be as usual for archaeologists to commission highly accurate 3D computer models of their sites as it is for them to order radiocarbon dating of their organic finds or other tests. Just as there are several laboratories commonly used for radiocarbon dating, it is logical to expect that there will be a handful of 3D modeling facilities known for providing this new kind of archaeological service. The UCLA Cultural VR Lab hopes to be one such service provider.

Fig. 1. A view of the interior of the model of the Roman Senate House in the Roman Forum produced by
the UCLA Cultural VR Lab for the Rome Reborn Project

Research and planning to date strongly suggest that the vision of Rome Reborn which a few short years ago would have been a utopian dream is practicable today. The 1990s have seen a fortuitous convergence of scholarly and technical advances that make a high-fidelity VR model of Rome feasible and affordable. For example, several comprehensive reference works on the building and topography of ancient Rome have been recently published (see

Richardson 1992; Steinby 1993--99). Those responsible have become collaborators on the project, and their success in synthesizing previously published material has greatly simplified for us the task of data collection. New technologies available today are especially well-suited for a study and recreation of lost worlds like ancient Rome. For example, realtime VR--which even three years ago was possible only on a supercomputer costing hundreds of thousands of dollars--is now available on a personal computer. Thus, today the challenge is not so much to gather the data needed for a virtual reality model or to create exotic new technology to run the model, as to integrate the information and computer resources already available in a scientifically accurate and coherent way.

Rome Reborn is producing its model of the ancient city in reverse chronological order, starting with Late Antiquity; and in concentric circles starting from two centers: the old civic center in the Roman Forum, and the new Christian quarter of the city in the southeast sector of the city, between S. Giovanni in Laterano and Santa Maria Maggiore (see Krautheimer 1980: 54-58). The project's short-term goal is to connect the individual sites modeled and to recreate an itinerary from the pagan civic center to the Christian religious center. In 1998-2000, the Basilica of Santa Maria Maggiore and buildings in the Roman Forum are being modeled. As with all models produced by the Cultural VR Lab, the basilica has been created in MultiGen a software package that supports highly detailed 3D modeling run in realtime.

In the long-term, the Lab's goal is to work with other interested parties in developing open standards for cultural VR so that a chronologically and geographically full model of ancient Rome (or, indeed, of any other archaeological site) can be created by hundreds of individual scholars or scholarly teams publishing their work in a compatible digital, scientific, and aesthetic format through dozens of electronic publishers. That is to say, UCLA researchers are acutely aware of the fact that a single team or laboratory is unlikely to have the manpower and resources to complete the entire model of ancient Rome from its beginnings in the Iron Age until Late Antiquity. Moreover, in a certain sense the task of modeling the ancient city will never be complete. As long as the field of Roman Topography is kept alive by new discoveries and new scholarly interpretations and controversies, it will be necessary and indeed desirable to update old models and to create new ones. Furthermore, it is important for scholars and modelers to maximize the value of their efforts by utilizing compatible technologies to allow for the exchange of building models.

In this article, the project to model the Early Christian Basilica of Santa Maria Maggiore is discussed. This model has been chosen because it exemplifies the values and methodologies of the entire Rome Reborn project. These include close cooperation with cultural authorities responsible for management of the site; collaboration between the 3D modelers, on one hand, and the archaeologists and architectural historians, on the other; the use of VR to help illustrate, detect, and resolve archaeological controversies; and the use of VR to facilitate visualization of the past by students and the public.

(2) Introduction to the Site and Early History of Santa Maria Maggiore

Among the Early Christian basilicas of Rome, S. Maria Maggiore is the one which best preserves its structure and an essential part of its original decoration. As a manifesto of the rebirth of Classicism expressed in a new Christian idiom, the building looks backwards toward the monumental civic architecture of the high Roman empire and forwards toward the religious architecture of the Christian Middle Ages (cf. Krautheimer 1980: 49). Despite its historical importance and good state of preservation, many points remain to be clarified about the oldest phases of the church.

Several recent publications on Santa Maria Maggiore have explored the building's history, early use, and decorative program. Nevertheless, a three-dimensional understanding of its original architectural form has remained somewhat illusive. A reconstruction drawing of Santa Maria Maggiore's early Christian form by Spencer Corbett was published in the third volume of Richard Krautheimer's corpus of Christian basilicas in Rome and again, somewhat revised, in Krautheimer 1980 (p. 48, fig. 41). Updated reconstructions appeared in later publications, yet these tended to be small in scale, and to focus on specific aspects of the building (De Blaauw 1994). Since no comprehensive 3D reconstruction of the basilica has incorporated all the new findings and interpretations postdating the efforts of Corbett and De Blaauw, the Basilica of S. Maria Maggiore is an ideal subject for VR modeling. In particular, the model created by the Cultural VR Lab is heavily dependent on the concepts of De Blaauw, who, as a member of the Scientific Committee, has further developed the ideas he published several years ago.

The main problem of the reconstruction of the fifth century basilica by Krautheimer and Corbett was that it contradicted a ninth century text in the Liber Pontificalis. This description of the liturgy in Santa Maria Maggiore under Pope Paschal I (817¬824) suggests strongly that the apse had openings to a space lying behind it, where women were standing during the mass. According to the text, the women annoyed the pope, who was sitting on the cathedra in the apex of the apse. Krautheimer could not accept an open apse with a deambulatory because it did not correspond to the conventional typology of urban basilicas. Nevertheless, Geertman had already established in 1976 that the layout of the thirteenth century apse and transept was fully coherent with the modular system of the original design of the church. At the same time, liturgical sources did not allow the presumption of the papal cathedra of Santa Maria Maggiore standing in any position other than the traditional one: in the apex of the apsidal hemicycle. These considerations, taken together, already tended toward a correction of the reconstruction by Krautheimer and Corbett. But the suspicion of a deambulatory behind the original apse was entirely confirmed by the discovery of a fifth-century foundation wall by De Blaauw in 1986. It exhibits the same building technique as the other foundation walls of the basilica; is concentric with the original apse and an integral part of the original modular system; and it was partially reused as a foundation of the thirteenth-century rebuilding of the apse.

New important pieces of evidence also emerged from the excavation conducted at the beginning of the 1970s. These excavations under the side aisles of the basilica were undertaken in order to eliminate the source of humidity that was damaging the fabric of the building. On that occasion there came to light remains of an impressive Roman house which occupied the northwest half of the area on which the church stands (Magi 1972; Liverani 1988), as well as ample stretches of the foundations of the fifth-century basilica (fig. 2). The house was built around the middle of the first century A.D. and was transformed and redecorated many times in the four centuries of its existence. Its richness and its position in one of the best quarters of the ancient city indicate that its owners were part of the Roman elite who occupied this high point of the city. Part of the house's large peristyle was excavated, as were several rooms on the northwest (the side of the basilica's apse); but the principal part of the house still remains buried to the northeast of the basilica where there are also traces of a small bath complex. In the last quarter of the second century A.D., the peristyle of the house was painted with the fresco of a calendar illustrating country scenes. Each month had a painting showing the work appropriate to the season of the year. It is probable that this decoration alluded to the rural properties of the owner. According to a recent hypothesis (De Spirito 1995) the last occupant of the house may have been Flavius Anicius Auchenius Bassus, the consul of 431, whose family was known to have owned property in this part of Rome. New observations made during research which is still in progress make this hypothesis appear less likely; instead it seems that there was a period in which the house was abandoned between the end of the fourth century A.D. and the time when the new basilica was built. A conflicting theory, however, associates the initiation of the project with Pope Celestine (422-432). Other remains found during the excavations include the foundations of the nave and side aisles and of the original apse. In the 1290s, under Pope Nicolaus IV, the fifth-century apse was demolished and rebuilt in a new position behind the old one.

Fig. 2. Cutaway view of the Basilica of Santa Maria Maggiore showing Roman domus at lower level

Construction of the Early Christian basilica required the partial destruction of the earlier Roman house. The southwest wall of the house was pushed into service as both a retaining wall and the foundation for the church. The remainder of the house was buried under six meters of earth to create a level platform atop which the new church could be built. The new ground level conformed to the high point of the hill, where the facade of the basilica was built. Extending 86 meters in length and 35 meters in width, the new basilica subsumed several properties atop the Cispian Hill. New information that came to light in the excavations have solved an old problem. According to the biography of Sixtus III, this Pope supposedly built the Basilica of S. Maria Maggiore "which the ancients called the Basilica of Liberius" (Lib. Pont., I, 46 c.3). If correct, Sixtus' basilica will have been the rebuilding of a basilica originally constructed a century earlier by Pope Liberius (352-356). This notice in the biography has caused numerous difficulties, and it has been suggested that it grew out of an erroneous identification made by the redactor of the sixth-century biography (Krautheimer, Corbett, Frankl 1967: 56-57). Recently, an attempt has been made to defend the notice in the Liber Pontificalis by proposing to limit the building of Liberius to the area of the nave of the Basilica of Sixtus III (Cecchelli 1988). Such a solution is, however, not convincing. The excavations have shown that there is no evidence of a basilica older than the fifth century; furthermore, the foundations brought to light by the excavations are all part of a single project which is coherent both with regard to its building technique and its architectonic modules (Geertman 1986-87: 286-287; De Blaauw 1994: 346). We must therefore search for the Basilica of Pope Liberius in another area nearby.

(3) The Santa Maria Maggiore Scientific Committee: Procedures and Issues

The Scientific Committee for the Basilica of Santa Maria Maggiore Project was composed of distinguished international scholars in the area of ancient and early Christian art, architectural history, and archaeology. Prof. Diane Favro of the UCLA Department of Architecture and Urban Design served as chair. Other Committee members were: Dr. Paolo Liverani, Curator of Classical Antiquities of the Vatican Museums; Prof. Sible de Blaauw, Art

Historian, Istituto Olandese; and Prof. Arnold Nesselrath, Curator of Byzantine, Medieval and Modern Art of the Vatican Museums. The Principal Investigator of the project, Prof. Bernard Frischer of the UCLA Department of Classics, charged the Scientific Committee with ensuring the highest possible scientific and historic accuracy for the reconstructed VR model by carefully evaluating the data used, identifying specific issues for examination, and periodically reviewing the model during construction. The complex technical, architectural, and historical issues involved in researching, modeling, and archiving require modelers with special expertise. The Scientific Committee worked closely with the modeling team headed by Dean Abernathy, a registered architect with a great deal of archaeological experience as well as a professional 3D computer modeler. Helping Mr. Abernathy were advanced graduate students at UCLA with training in architecture, architectural history, and archaeology. Altogether the model went through three major revisions before being given final approval by the Scientific Committee in December, 1999 after twenty months of work.

Identification and evaluation of sources

At the initial meeting of the Scientific Committee, the members first discussed and agreed upon a date for the building reconstruction of approximately A.D. 440, just after the full mosaic program was installed in the basilica. The creation of 3D computer models requires almost the same range and type of information needed to actually build a structure, including accurate topographical plans, and complete "working drawings" (reconstruction elevations; floor, ceiling, and roof plans; sections; details; structural analyses; and identification of materials). To start, the Committee used the modeling subject questionnaire developed for the Rome Reborn project. This questionnaire asks for both information sources, including scholarly publications, archaeological archives, photographic resources, secondary representations (e.g. paintings showing the early basilica), and for the names of individuals with specific expertise relating to the building (e.g. archaeologists, archivists, historians, photographers). The Committee discussed the merits of each source and debated various reconstructions and interpretations, selecting those to be used for the VR model. Since no one reconstruction satisfied the Committee, the group analyzed various components and compiled a variety of sources to create the model. For building parts lacking documentation, the Scientific Committee identified extant buildings of approximately the same date to provide analogues. For example, reconstructions of the fifth-century atrium at the nearby church of S. Prassede were used to create a hypothetical plan for an atrium at S. Maria Maggiore (fig. 3); the pavement inside the basilica was derived from the contemporary floor of S. Giovanni in Laterano. As a further aid for the model-makers, the Scientific Committee also identified general information on the architecture of the era, such as surface treatment of materials, favored proportional systems, and construction techniques. In addition to an initial meeting regarding research sources, the Scientific Committee along with the primary modeler, Dean Abernathy, made several site visits to examine the extant building and the preserved archaeological remains. Such hands-on examination was vital for a comprehensive understanding of the building's form, materials, and construction.

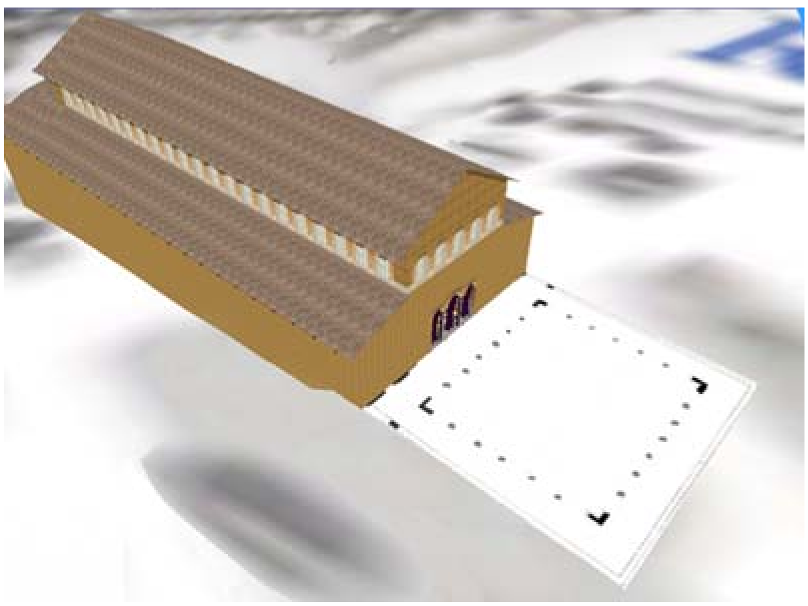

Fig. 3. Bird's-eye view of the Basilica of Santa Maria Maggiore with hypothetical plan of atrium.

Data Collection

Thanks to the cooperation of the cultural authorities responsible for the Basilica, the Committee was able to provide the modeling team with highly accurate data. These included the latest state plan, elevation, and section of the building as well as a selection of color transparencies showing the recently restored nave mosaics. For the final version of the model, the modeling team was able to include digital versions of even more detailed large-format transparencies of the mosaics (18 x 24 cm.), which were licensed for the project. On his several visits to the Basilica, Dean Abernathy was able to take high-resolution digital photographs of such surface materials and architectonic elements as columns, brickwork, trusswork, and marbles. Thus, the model achieves a high degree of photorealism as well as architectural accuracy.

Identification of historical and archaeological research issues

VR models have many uses from educational applications, to didactic aids for heritage diffusion. Equally important, they help scholars to address research issues. The experts on the Scientific Committee carefully discussed various ways in which the VR model of the Basilica of S. Maria Maggiore in the early fifth century could be used to further research agendas. They identified several specific topics of scholarly concern, including the interrelationship between the pre-existing Roman building on the site and the new Christian basilica, the existence of an atrium, the topographical impact of the fifth-century structure, the interior lighting, the ceiling configuration, and the treatment of the original apse, especially as it related to early Christian ritual. By specifically highlighting these topics at the beginning of the modeling process, all concerned (from the data-gatherer to the modeler) were able to give them special attention. The Scientific Committee also discussed various ways to maximize the model's usefulness, evaluating the scholarly value of creating alternative reconstructions and of conducting various analyses using diverse computer programs, e.g. a lighting study using Form Z.

As the modeling progressed, the data-gatherers, primary modeler, and head of the Scientific Committee conferred on a regular basis, with periodic consultation with the rest of the Committee members and the Principal Investigator in person, and via e-mail. Ways were explored to allow the Committee to view the models interactively on a video and on a website. At periodic milestones during the development, the experts on the Committee were all shown the same version of the model in the UCLA Cultural VR Lab, or as a fly-through on video or as printed images. In addition to the Scientific Committee, outside consultants were asked to give advice regarding specific questions. For example, Professor Philip Jacks of George Washington University reviewed the open truss system of the ceiling used in an early version of the model and evaluated the proposed scheme for coffering, which was used in the final version. Professor Fikret Yegül of UC Santa Barbara assessed the construction techniques. Notably, the type of media presentation had a significant impact on the issues addressed by the experts. When the interactive, kinetic model was viewed, they focused on broad questions of form, structure, and experiential impact; with 2D prints they gave greater emphasis to materials, textures, colors, and individual details. The ideal interaction was between the modeler, scientific expert, and head of the Scientific Committee examining the model on the computer together.

Traditionally, reconstructions of historic buildings have been executed as 2D drawings of selected views or as simplified three-dimensional models. Both are static forms which can be altered only with great difficulty. With VR technology, the recreated building is constructed in 3D but is also 4-dimensional, since it can be experienced temporally. Viewers can move through the structure in real time, or see a modeled building evolve over time. A VR model is not static, allowing for several simultaneous versions and repeated updates. This flexibility allowed the Rome Reborn team to model new or conflicting interpretations, layer different building phases and test various hypotheses. For example, since scholars do not agree about the treatment of the entry into the nave, the team modeled the building entry with both a trabeated door and an arcuated, curtained opening (fig. 4).

Fig. 4. Alternative reconstructions of the front entrance of the Basilica of Santa Maria Maggiore
(left: curtained openings of final version. Right: doors in an earlier version).

To demonstrate the close connection between the earlier Roman house and the Early Christian building, the team modeled the Roman archaeological layer beneath the basilica (fig. 2). VR models also allow the restoration process to be more transparent. In traditional models, the evolutionary phases passed through during construction of the physical model or of the drawn reconstruction are generally lost, along with an understanding of how and why reconstruction decisions were made. With VR models, various iterations can be preserved through archiving, thereby documenting the creation process and simultaneously preserving progressive versions for reuse. In addition to documenting phases of the model, the Rome Reborn team also archived modeled and scanned data on individual building components and materials. These digital libraries are supported by written files recording the research sources, analogues, and experts consulted for each modeling decision, and for each visual and material source. Since the VR reconstruction model can be continuously updated in response to new discoveries and interpretations, it is never "completed." However, once a version satisfies the criteria of the Scientific Committee it is described as "certified." future updates are possible, though always in consultation with the Committee.

Technical Aspects of Modeling

The goal of the modeling process is to create a high-fidelity, multiple dimension database integrating the research and expertise of the Scientific Committee. Initial modeling efforts focus on the physical data and descriptions of the early basilica. Scaled plans and sections were drawn prior to modeling to assist in making the 3D reconstruction. The sources for the model varied in quality and quantity, requiring a synthesis of information vetted by the Scientific Committee. The reconstruction then progressed from the general building form, commonly known as a massing model, to the specific details. This transition required an initial survey of all the building components. The component types were built, then customized and inserted into the model. The reconstruction thus tends to proceed in an uneven manner, with large improvements during the development of the massing model and almost imperceptible changes after the model components have been customized since the early changes are executed globally through undifferentiated building components, while later changes must be repeated on each custom component. The modeling process lingers in the undifferentiated stage as long as possible, so that changes and improvements can be enacted over all the components of the same type before they are differentiated. As the model matures all components are refined, updated and archived, resulting in the "certified" database in the final version of the model.

The VR database is created by combining two types of information. First is the geometric model created using 3D modeling software like Form Z, Autocad, 3D Studio Max and MultiGen, the primary choice of the UCLA Cultural VR Lab because of its support of many realtime applications. The graphics, or surface textures form the second component. These are manipulated in software like Photoshop, or any other similarly suited software package. The integration and management of the geometry and the textures is a difficult task. More sophisticated modeling softwares like MultiGen or 3D Studio Max facilitate the process with specific tools. MultiGen, because of its development as a virtual reality world-building software, also provides a scene graph view of the data. This allows the simulation designer to program interactivity into the model and to optimize the data for real time simulations like virtual set technology. The MultiGen flight file format can also be translated into other formats allowing the database to be used with other to test lighting, structures, or materials.

Model creation

The four-dimensional form of VR models compels a holistic approach to historic architectural reconstruction which, in turn, shaped the ideas of the Scientific Committee. First and most obvious was the visual impact of decisions regarding materials, architectural decoration, and art. Reconstructions of components which seemed logical when seen in isolation or in black and white frequently had a decidedly different visual impact when viewed in the full context of the entire building. For example, the original brickwork of the basilica was photographed and digitized for the reconstruction of the structure's entire exterior surface. When faced with the huge scale of the reconstructed brick walls the Scientific Committee immediately requested this rough surface be plastered. Similarly, the uniform interior columns in an initial phase seemed too regular when seen within the great expanse of the basilica's interior; they were subsequently made more irregular in form and alignment following the example of other Early Christian buildings with *spolia.* Building elements which seemed minor or inconsequential during abstract discussions took on greater importance when seen in the 3D context of the model. Thus, at first the Scientific Committee was not overly concerned with the interior pavement, yet the powerful visual impact of the floor on the perception of the entire basilica soon demonstrated the significance of this feature (fig. 5). Several different pavements were tested and the impact of the colors, textures, and pattern size on the overall visual experience carefully evaluated. The final choice was based on a roughly contemporary floor pattern from the Basilica of San Giovanni in Laterano (see fig. 6). In a few instances, visual intensity became an issue.

Fig. 5. View of the interior of the Basilica, with the first version of floor and the extant thirteenth century mosaic in the semidome

Viewing the interior of the model the Scientific Committee felt the aediculae surrounding the mosaics above the side aisles lacked sufficient visual impact and asked the modelers to enhance their form and shadows. Similarly, the initial color scheme for the interior plaster walls appeared too dominant when seen in context and was subsequently muted. The appearance of the model also called to question some aspects of the building structure. In particular, the visual weight of the apse semidome compelled consultants to question whether there was adequate structural support.

Viewers can examine the VR model from any angle. Such multiple viewpoints immediately compelled an interest in the building's overall urban setting and topography. The Scientific Committee believed the form of the building could not be understood without recreating the surroundings. Unfortunately, information about the topography of Rome in the fifth century is limited. Drawing upon nineteenth-century excavation data, the team located spot points and analyzed the current state of the hill to recreate a topographic map of the area in late antiquity (see fig. 7). The model of the Cispian Hill's northwest slope, along with the appearance of the basilica model, compelled the Scientific Committee members to rethink the reconstruction of the apse end of the building; in response, they recommended removing the buttresses originally modeled around the exterior of the deambulatory of the apse in emulation of the church of S. Agnese in Rome.

Fig. 6. View of the final version of the semidome of the apse and of the floor.

Especially troublesome were building components for which documentation was limited. While most scholars agree the Basilica of S. Maria Maggiore would have had an atrium court in front, no archaeological, pictorial, or written evidence exists. The team experimented with various versions of an atrium based on contemporary analogues. When seen in the context of the entire model, however, these speculative reconstructions garnered too much attention. As a result, the team decided to show the atrium in plan, in contrast to the three-dimensional representation of the basilica itself (fig. 3). This representational convention is an effective compromise, allowing viewers to understand the placement and form of the atrium, without being distracted by a hypothetical structure. Another convention was developed for the apse decoration on the interior. Scholars believe decorations embellished the original semidome of the apse, though no specifics have been preserved regarding their appearance. Rather than show the eye-catching mosaic currently in place which dates to a later period (cf. fig. 5), the modelers decided to mute the shapes and colors to evoke the existence of a decorative program without emphasizing the specifics (fig. 6).

Insights

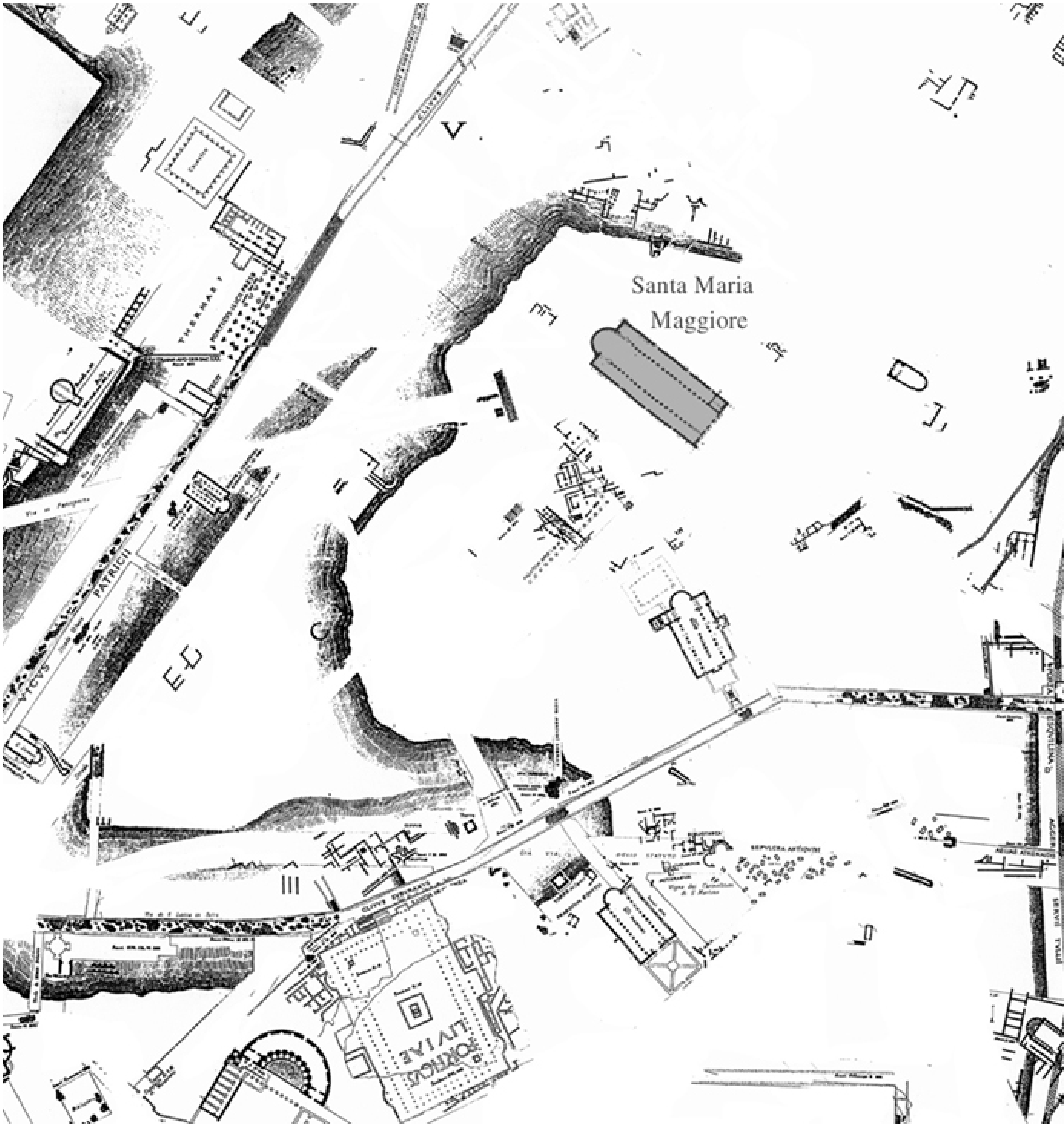

Fig. 7. The topographic context of the Basilica of Santa Maria Maggiore.

Every new tool has an impact on research. In the case of VR modeling, the unique requirements for creating a model compelled the acquisition and integration of complex construction data very different from that required for other types of research or reconstructions. The 4D capabilities of the modeling system also impact our understanding of past buildings. Four significant new insights resulted from the creation of the S. Maria Maggiore model. First, the temporal layering of the basilica over the earlier Roman building underscored the close integration of the two projects and the significant topographic alterations to the site. Second, the reconstructed interior with the original fenestration in place revealed that the upper section of the interior was originally bathed in a golden light which enhanced the impact of the mosaics; conversely, the dark semidome of the apse floated above windows at a lower level. Third, the reconstruction of the apse based on liturgical sources raised significant structural concerns. Fourth, and perhaps most dramatic, were the findings regarding the urban impact of the building. Resituated in the topography of late antique Rome (fig. 7), the basilica was seen to have been oriented for maximum visibility along major thoroughfares and from other hills in the city, following ancient theories of view-planning. The creation of the model also highlighted areas for further research. These include questions about the translucency of the windows, the types and placement of furniture and embellishments; the exterior wall treatments; and the junctions between building parts, especially between the atrium and the facade, and between the apse, the ambulatory, and the side aisles. At the current stage, the model has greatly expanded our understanding of the construction and visual impact of the basilica's form. The next step is to investigate the building's original use through the integration of ritual furniture and live actors or avatars reenacting the ceremonial use of this magnificent structure.

Dissemination and Uses of the Santa Maria Magiore Model

Models can be used for a variety of purposes, including architectural walk-throughs and urban simulations; historical reconstruction; architectural analysis; nondestructive conservation and restoration; recontextualization of works of art that have been moved from their original location; and virtual sets in documentaries or in works of fiction.

Models are computer files consisting of 3D geometry and textures applied to the surfaces of the geometry. They may be viewed on the computer either in realtime or in prerendered, pre-encorded video clips. Models may also be used as assets in educational videos for delivery on videocassettes or over broadcast and cable television.

The advantage of realtime is flexibility: the user can explore the model along an infinite number of paths chosen sponstaneously by the user himself. Since persistence of vision in realtime ideally requires the computer to render at least 30 frames per second, the price the user pays for this flexibility is a loss of detail: geometry and textures may have to be simplified to permit the computer to generate frames at a fast enough speed. Effects such as reflections, translucency, shadows, or perspective correction may have to be sacrificed. The advantage of prerendered video is that it supports a high level of visual detail and effects. The disadvantage is that, as the term prerendered implies, the user is limited to precisely those paths through the model that have been selected in advance.

Both realtime and video applications can be enhanced with animations and hot spots linked to other files or World Wide Web sites. Through animations and hot spots models can be linked to information that can help the user to understand the history, cultural significance, and archaeological evidence of a model. Interactivity in varying degrees and through differing tools thus characterizes the use of a model on the computer.
Contrasted to this, a model utilized as an asset on an educational video is linear. Fly-throughs of a model can be outputted to a video recorder. Files of models can be used in a virtual set system to create the illusion that live actors (e.g., an archaeologist or architectural historian) have been transported into the virtual world. When combined in postproduction, fly-throughs and virtual set shots can enable the archaeologist or other expert to give a tour of the site as reconstructed on the computer. Since the medium is video, the same high degree of realism is possible (lighting effects, shadows, translucency, etc.) that characterizes prerendered video delivered on the computer. And since video cassette recorders are commonplace in homes and schools, and since streaming video can now be delivered over the World Wide Web, the educational video offers a combination of low cost and high visual quality that more than compensates for its lack of interactivity.

Each of these delivery modes has its appropriate use. For example, a scholar might use a realtime model during a lecture in order to present his own analysis of a site. It could also be used in a VR theater with a screen wrapping around the audience or in a CAVE environment installed in a museum or on the archaeological site. A CAVE (literally, a "computer-assisted virtual environment") is an immersive virtual environment, typically 3 x 3 meters in size or larger, in which the computer model is projected onto the walls, floor, and ceiling while viewers stand in the middle of the space. CAVEs are thus typically more immersive than are VR theaters (which typically contain projections on just three walls), but VR theaters have the advantage of more readily accommodating a large number of viewers, who, moreover, can be seated during the VR experience. In a CAVE or VR theater, a guide can take visitors on a live, interactive tour of the 3D computer model, answering questions and giving views of the site that even the ancient visitor could not see or see so well. A teacher whose expertise pertains more to the use or history of the site than to its construction might use a videotape with a virtual tour of a site given by an archaeologist or architectural historian. The same videotape can be used in the auditorium of a museum or archaeological site to provide an orientation for visitors.

The UCLA Cultural VR Lab has been actively experimenting with ways of combining the strengths of all the approaches just mentioned into an integrated archaeological information system that is scalable to the needs and interests of users ranging from high school students to advanced scholars. Thus, on the Rome Reborn Web site (www.cvrlab.org) can be found pre-rendered video models, realtime models as well as videoclips of fly-throughs and virtual set shots. Users can simultaneously watch a videoclip while reading the script in a text window. Technical terms in the script are themselves linked to a glossary window. Although the videoclip is linear with respect to the world it depicts, it is presented in a viewing window that permits interactivity in the form of starting, stopping, and reversing the clip itself. Thus the user is empowered to learn at his own pace.

The Office of Academic Computing, the central computing facility on the UCLA campus, is building a virtual theater, which is scheduled to open in January, 2000. The theater, which will be known as the Visualization Portal (www.ats.ucla.edu) is a unique facility at an American university. It will provide seating for over twenty viewers to sit in a space surrounded by an 8 meter x 3 meter highly luminous screen, onto which models and related information can be projected in realtime. The facility will be available to the researchers of the Cultural VR Lab as well as to students in the classes they teach. When it opens, a new era in the Lab's history will begin as it changes its emphasis from model creation to the use of 3D models in teaching and research. It will be a splendid resource to use for immersive viewing of the Basilica.

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For further information about the Rome Reborn Project (www.humnet.ucla.edu/rome-reborn) or about access to the model of the Basilica of Santa Maria Maggiore, please contact Prof. Bernard Frischer (frischer@ucla.edu).

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