Beyond Illustration:
New Dimensions of 3D Modeling
of Cultural Heritage Sites
and Monuments

Keynote Address to CNI Plenary, Dec. 15, 2009

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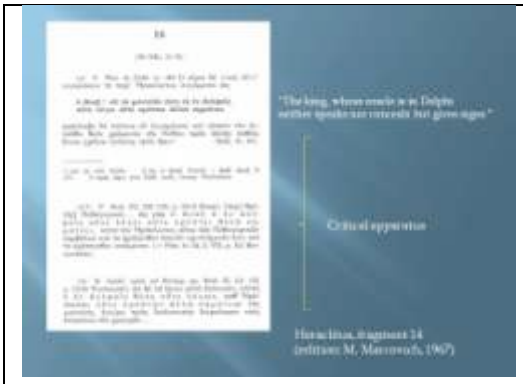
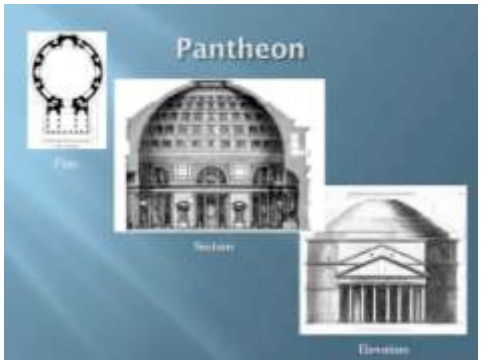
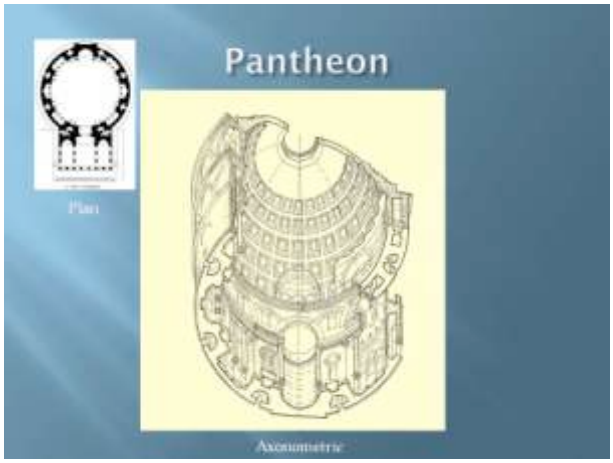
PPT Slide	Text
	Edward Gibbon explained the inspiration for his masterpiece, *The Decline and Fall of the Roman Empire,* in the following famous words: "It was at Rome, on the fifteenth of October, 1764, as I sat musing amidst the ruins of the Capitol, while the bare-footed friars were singing Vespers in the temple of Jupiter, that the idea of writing the decline and fall of the City first started to my mind." In the slide, you are seeing Giambattista Piranesi's view of what Gibbon will have seen looking down from the Capitoline in the direction of the Roman Forum below.

	I begin with Gibbon not only because I will be talking quite a bit about "Rome Reborn," our digital 3D model recreating ancient Rome, but also because his words are a typical (if an unusually eloquent) expression of what initiates so much research in the humanities: a fascination with human creations in relation to time. And so with due apologies to any string theorists in the room, I begin with the observation that we live in a four-dimensional world, and this fact has not escaped humanists. For us, the goal of humanistic research is and--long before Gibbon--had already been the documentation, interpretation, preservation, and transmission of the human record. This is true whether we are concerned with texts, two-dimensional images, or three-dimensional artifacts, monuments, or even entire settlements and cities. Today I would like to talk to you about the subset of humanists who deal with four-dimensional objects: they are mainly art historians, archaeologists, and architectural historians. My thesis is that the humanists who deal with 4D have benefited from the digital revolution in a special way: for us digital technologies have blurred the fine line separating the act of documentation from that of interpretation. I do not think that this blurring has occurred in quite the same way or to quite the same extent in the other branches of the humanities. All branches of the humanities have developed their craft rules about how the objects of study







entrusted to them should be documented—here I may remind you of the complexities involved in editing a text whose transmission is as long and tortuous as that of the works of Homer, Virgil, or Heraclitus. But those of us documenting three-dimensional objects have a special problem: the philologist can document a text with text; an art historian can document a painting with a photograph. But, apart from physical models (of which we have never had enough, doubtless because of their expense), 4D structures such as a building have not usually been documented with 4D representations; rather, they are, as a rule, denoted by drawings that are abstractions which, as Sir Ernst Gombrich reminded us, "[are] not a faithful record of a visual experience but the faithful construction of a relational model." To the extent that they are "objective," they have traditionally been orthographic projections, that is 2-dimensional reductions to a plan, section, and elevation. The one concession made to non-reduction was the axonometric view, an intentional skewing of perspective to allow a simultaneous impression of the section and elevation.

But all such projections are only possible in the case of a structure such as the Pantheon that still survives more or less intact. For monuments and buildings that have been damaged or destroyed, something else was needed—what might be called a *reconstructive* vision. This is a characteristic that we especially associate with the Ecole des Beaux-Arts in Paris, which since

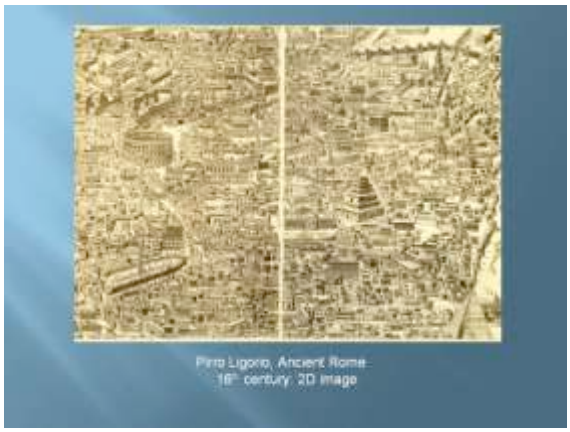
Envois: Charles Louis Boussois (1884-1918), *Hadrian's Villa, Tivoli* (1912)

the 17th century has sent its best students to Rome to complete their education by studying and reconstructing on paper an ancient monument. The results were the "envois," dispatches sent back to Paris where the younger students—few of whom would ever be able to travel to Italy—could study the Classical monuments. As the distinguished contemporary archaeologist Paul Zanker noted, as we study these envois, we admire their boldness but also recoil from it.

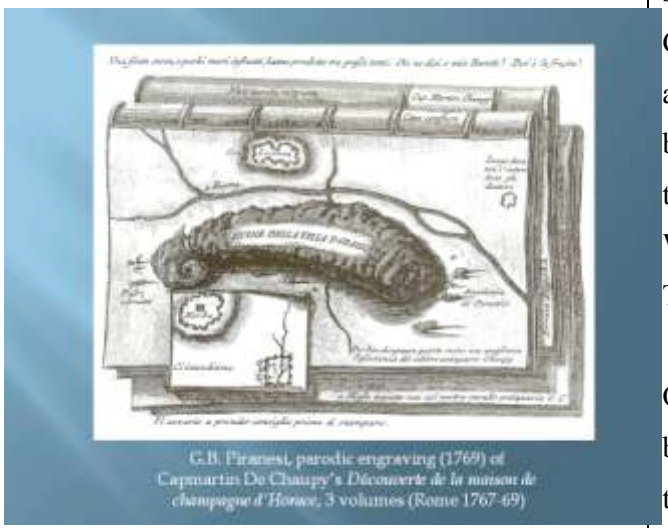
This duality runs through the history of documenting 4D monuments and arises from a mediatic feature of that history which only a Marshall McLuhan could have done justice to: the almost complete separation between, on the one hand, the philological approach through ancient texts and inscriptions written up in modern texts; and, on the other hand, the graphic approach drawn up in modern projections and reconstructed in architectural exercises like the envois.

Thus, the founding work of European archaeology—papal secretary Flavio Biondo's *De Roma Instaurata* ("On Rome Restored"), written in the 1440s—was a systematic account of the ruins of ancient Rome without a single map or image. In the next century, papal architect Pirro Ligorio composed his "Image of Ancient Rome" as an elaborate 2D bird's eye view, but none of the features of the city is identified with an inscription, and no written explanation for the thinking behind the reconstruction is provided.

Flavio Biondo, *Rome Restored*, 15th century: text



Pirro Ligorio, Ancient Rome 16th century: 2D image



G.B. Piranesi, parodic engraving (1769) of Capmartin De Chaupy's *Découverte de la maison de champagne d'Horace*, 3 volumes (Rome 1767-69)

Indeed, by the time of Piranesi in the late 18th century, there was even an explicit battle between the textual and graphical approaches. Piranesi, the great architect and engraver, was of course on the side of the graphicists. His enemies were scholars such as Mariette and De Chaupy whose works on the monuments were all text and no images. The most amusing expression of this quarrel is perhaps the work of Piranesi which you see illustrated on the screen. In it, Piranesi sends up the three-volume publication on the archaeological site of Horace's Villa near Tivoli published in the late 1750s by the French Abbe' Bertrand Capmartin de Chaupy. Chaupy's 3-volume work obviously has many words, but not one illustration. And as far as those words are concerned, by my estimate, no more than 5% have anything to do with its ostensible subject of study, Horace's famous Sabine Villa! On the spine of the books you can see that Piranesi calls Capmartin "Capo Confuso," or Muddlehead. He also gives the site plan missing from Capmartin's book. The scatological shape of the structure on the plan explains why Piranesi scholar John Wilton-Ely gave it its technical name of "The Turd Engraving"!

Of course, since the nineteenth century, which brought us the idea of *Altertumswissenschaft*, or the interdisciplinary study of antiquity, the textual and graphical traditions of archaeological documentation have been successfully merged, at least in the Gutenbergian medium of the printed


Holyland Hotel physical model of Jerusalem prior to the Roman destruction in 70 C.E. Scale: 1:50 (Israel Museum, Jerusalem)

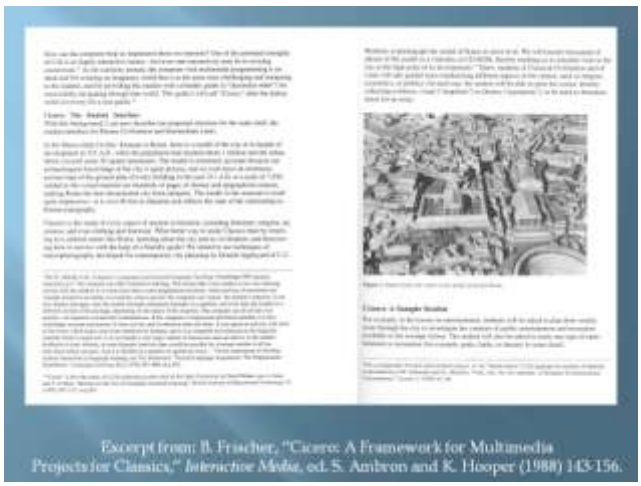
report. But given the 2D nature of the printed page, the graphical expression was always the reductive solution of the plan, section, and elevation with an occasional axonometric drawing thrown in for good measure.

Unfortunately, the odd and indefensible separation of text from image survived in the best, if rarest, form of 3D illustration: the 3D physical reconstruction model. Here I am thinking of such great twentieth-century examples such as the Holy Land Hotel model of Jerusalem just prior to the Roman destruction; or the great "Plastico di Roma Antica" in the Museum of Roman Civilization in Rome. The latter was made over a forty year period under the direction of archaeologist Italo Gismondi at the enormous scale of 1:250, so it fills a room that is 20 meters square. It has the reputation for being very accurate, but it is difficult to check the validity of this claim since Gismondi published nothing at all about his sources and methods. So when we look at Gismondi' model—especially the thousands of structures that are not obvious landmarks such as the Colosseum—we simply do not know what we are looking at and why Gismondi's team reconstructed it as they did.

So, to sum up my main point thus far: humanists who work with 4D objects have not had an easy time of fulfilling the first of their four charges to document, interpret, preserve and transmit the human record. Has the introduction of digital technology changed anything? Yes, but it took us

Italo Gismondi's physical model of Rome in 320 C.E. Scale 1:250. (Museum of Roman Civilization, Rome)

Publication of the presentations given at the Apple CD-ROM conference held June 19-20, 1986.



Excerpt from: B. Frischer, "Cicero: A Framework for Multimedia Projects for Classics," *Interactive Media*, ed. S. Ambron and K. Hooper (1988) 143-156.

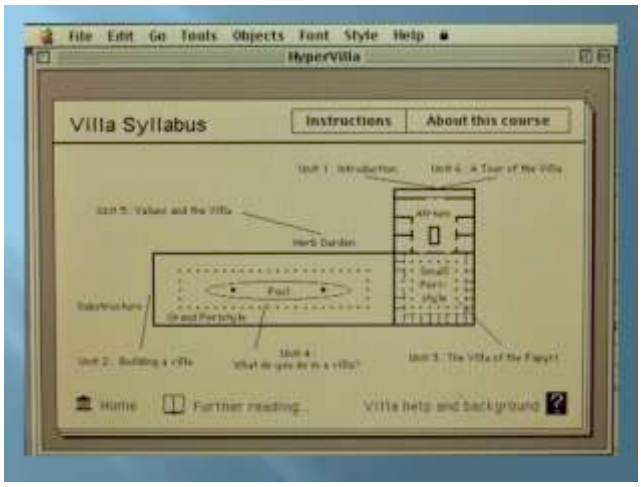
twenty years to reach the point where we could begin to make that claim. Until then, digital tools in the humanities were used more to improve our efficiency in doing the same old things in a different way, not to transform our methods and our disciplines. I can cite myself as a case in point.

I first publicly proposed making a 4D digital model of ancient Rome at a small conference held at Apple Computer in 1986. The idea went back to discussions I had had with UC Berkeley Urban Planner Donald Appleyard in Rome in 1974. The theme of the Apple conference was the CD-ROM, a new storage medium that could hold 750 megabytes of data. Leading lights including Doug Englebart were invited to discuss what one could possibly do with all that storage capacity. It may seem odd that back then this was an issue, but I recall buying my first PC just five years earlier in 1981. It was a Kaypro and cost $2,000. For storage, it had two 128kilobyte floppy disk drives. I asked the salesman if there was a Winchester—which is what we called hard drives back then—available for sale. He said, "yes. The bad news is that it costs $10,000. The good news is that it holds 10 megabytes, so it will last the rest of your life!" So you can see why in 1986, 750 megabytes seemed like a lot of storage.

At Apple, I proposed to use the CD to hold the data needed for a digital representation of Gismondi's model. My motivation was to promote interest in my field of Classics by

Gismondi's physical model of ancient Rome.
(Museum of Roman Civilization, Rome)

Villa' Multimedia courseware, 1987



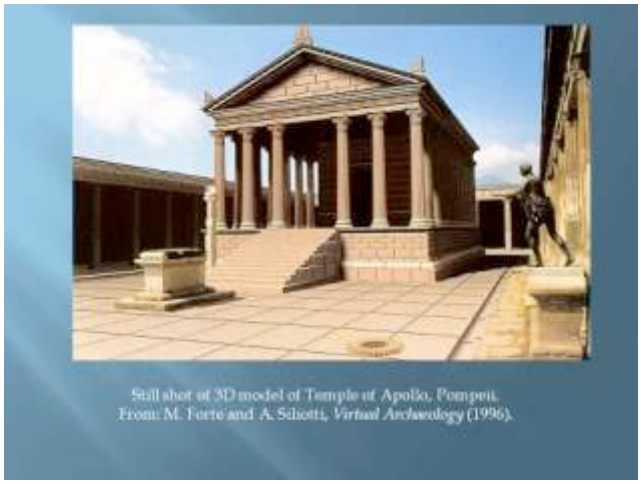
making it possible for students to do virtual time travel to ancient Rome, where they would be met by a guide and taken on tours of the city. I was inspired by the Aspen Project which, as Nick Negroponte stated, "used videodiscs to allow the user to drive down corridors or streets, as if the vehicle were located in those corridors or on those streets…Every street [of Aspen, Colorado] was filmed, in each direction, by taking a frame every three feet. Similarly, every turn was filmed in both directions." (Negroponte, Being Digital).

I thought we could run a miniature robotic camera down the streets of the Gismondi model and do the same thing for ancient Rome that the MIT group had done for Aspen. However, when we studied the Gismondi model, we discovered that this was not in fact a good idea: only about 15% of the surfaces of the buildings are detailed with doors, windows, balconies, etc. The rest—those that cannot be seen by the museum visitor—were left as blank, white plaster. So a videodisk of ancient Rome made in this way would have been quite uninformative, not to say boring. Instead of working on a 3D simulation of Rome, I made a hypermedia interactive tour of the Villa of the Papyri in Herculaneum, using the J. Paul Getty Museum in Malibu—a physical reconstruction of the villa—as my source of data. I tied shots of the Getty Museum to a corresponding plan showing the rooms of the villa, and I provided a library of Roman texts in which the ancient authors addressed topics somehow relevant to a particular space. It is

Still shots of 3D models exhibited in Pompeii show organized by IBM in London, 1990. Stabian Baths (from exhibition catalogue).

strange to see these screen shots today and to recall how cool these black-and-white scanned images seemed in the late 1980s. But visual quality aside, the idea of tying texts to spaces in order to create places invested with meaning was to have a bright future. Today it has led to the famous "spatial turn" in the humanities. This is a widespread movement across our disciplines show how humans project meaning onto their physical environment.

My interest in 4D digital reconstruction proper revived when I saw an IBM-sponsored show about Pompeii in London in 1990. In the slide on the screen you see one of the 3D models shown at the exhibition—a model reconstructing the Stabian Baths. In retrospect, the Pompeii exhibition was less important for its inspirational displays of such reconstructions than for the essays in the catalogue presenting the research results of IBM's SEMEA lab on the potential of IT for cultural heritage. In one of these, entitled "Von Neumann Meets Pliny," Stefano Bruschini explained how digital technology could help represent the complex knowledge that archaeologists assemble about the archaeological artifact and site. He described a digital implementation of Vannevar Bush's Memex in which the "the computer screen becomes a window open onto texts, codes, archaeological and technical maps, images of documents, frescoes and iconographic sources" (p. 113). He recognized that creation of this digital memex could greatly improve the efficiency with which



archaeologists, conservators and cultural resource managers could do their jobs. But he also threw out the tantalizing idea that the memex could also be a "knowledge multiplier" when the computer is "no longer a mere organizer of knowledge but a methodological operator that provides not only information but proposes precise actions and research…" (p. 113).

But it has to be said that, for understandable reasons, knowledge multiplication had to wait a long time to emerge. First, those graphics I just showed you had to be improved. By the mid 1990s this had clearly happened as research advances in the then-hot field of Computer Graphics were applied in new software packages such as Maya and 3D Studio Max. A compendium of work from this period was published in 1996 by Maurizio Forte and Alberto Siliotti. As you can see from this shot of another reconstructed building in Pompeii—the Temple of Apollo—photorealism had by now reared its beautiful head.

At this point, three things started to happen. First of all, scholars started to review the work done by the very companies, and the result was a grade of C-. In a thoughtful review of the Pompeii model, archaeologist Daniel Brigman wrote:

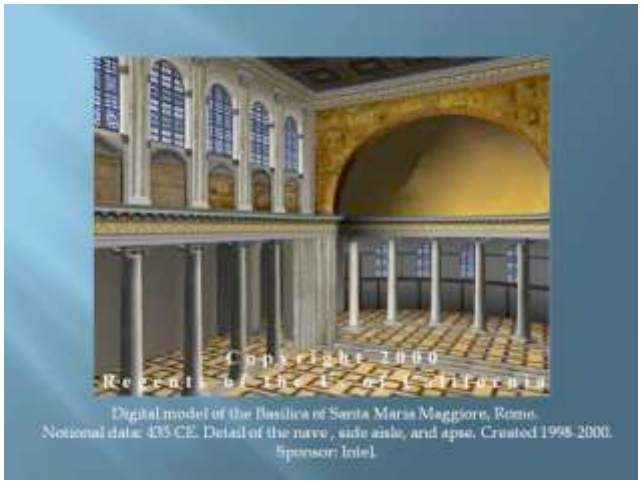
"… the design team had fashioned their temple complex out of mural vignettes excised from several different archaeological sites and contexts. Painted panels along the periphery of

the reconstructed sanctuary were unsettling to many precisely because they had been filched from other Roman cities. Thus, the reconstruction took form as a pastiche…. Not the kind of thing scholars of Antiquity are bound to love."

On the bright side, at least we scholars had started to sit up and take notice. The Temple of Apollo model, like almost all the models illustrated in this book were made by commercial companies—typically the companies that made the hardware and software needed to produce digital creations like this. By the second half of the decade, some humanists started to produce models themselves. A milestone event was the meeting of the leading professional organization for digital archaeology—Computer Applications to Archaeology (CAA for short)—in Barcelona in 1998. The title of the meeting that year was "Virtual Reality in Archaeology." In the introduction to the conference proceedings, CAA President Nick Ryan expressed the view that digital modeling was useful because it was a better form of illustration:

"The advantage of virtual computer models in comparison to traditional analysis is evident. …models permit spatial queries such as 'what is next to what, what surrounds what, what is above, below, to the side of what," Another advantage is the ability to generate sections, views and elevations, and to visualize physical properties."

I n other words, according to Ryan, with digital



Digital model of the Basilica of Santa Maria Maggiore, Rome. Notional date: 435 CE. Detail of the nave, side aisle, and apse. Created 1998-2000. Sponsor: Intel.


Santa Maria Maggiore Scientific Advisory Committee. L-r: Paolo Liverani (Curator of Antiquities, Vatican Museums), Sible De Blaauw (Professor of Art History, Nijmegen), Arnold Nesselrath (Superintendent of the Basilica), Bernard Frischer. 1999.


Digital model of Santa Maria Maggiore (435 CE): alternative reconstructions of the nave (1998-2000).

modeling, we can have our plan, section and elevation without resorting to the trick of the axonometric view.

My group from UCLA presented our first model of Rome at CAA in Barcelona—a reconstruction of how the pilgrimage church of Santa Maria Maggiore in Rome looked when it was new, in the year 435 A.D. In the related publication, we stressed that the model had been made as a collaboration of modelmakers working with subject experts. In fact, the members of our scientific advisory committee were quite distinguished and qualified (with the exception of the chap on the right): the curator of antiquities of the Vatican Museums, the superintendent of the church itself, and the Dutch scholar who had written the most recent monograph on how the building looked when it was new 1500 years ago. We also pioneered the idea of having a software switch that could visualize alternative reconstructions. In this slide, you see our two versions of the nave. So we were not only making our models look photorealistic, we were also learning how to go about the task in a scholarly way.

The next big problems were how to publish online models like our reconstruction of the

Roman Forum; and how provide a built-in digital link between features in the models and the underlying archaeological documentation. In 2002 we received a grant from the National Science Foundation to experiment with how those things might be done in the days when good bandwidth was not something we could assume most of our end-users around the world would have. We took our model of the Roman Forum and converted it to QuickTime VR format. We tied panoramic views of the digital reconstruction to a time-sensitive map of the Forum; and we synchronized the views found at the various spots with views of how the Forum looks today from the same vantage point. Finally, we provided documentation from the foundations to the roof tiles explaining what our evidence—or, in the absence of physical evidence, our reasoning—was behind each major element of a monument.

Others elsewhere were working along similar lines, and the climax of our independent efforts to tame the new technology and make it a legitimate medium of scholarly expression came in the early years of this decade with an important initiative: the London Charter for the Computer-Based Visualization of Cultural Heritage. The Preamble says it all: "a set of principles is needed that will ensure that digital heritage visualisation is, and is seen to be, at least as intellectually and technically rigorous as longer established cultural heritage research and communication methods." One almost wants to

add: "harrumph!"

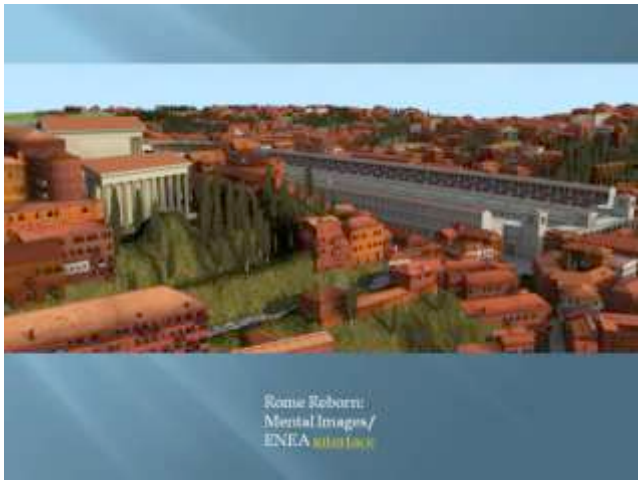
Now, in the second half of this decade, things are shifting again. The community of 4D humanists has come around to the view that we understand fairly well how to use this technology as a form of scholarly expression and communication. Thus, at the annual meeting of CAA held in March 2009 in Williamsburg, it was no longer possible to have a paper accepted that merely presented the results of creating a 3D reconstruction model of a cultural heritage site. That was considered old-hat in the absence of some additional innovative feature. What are the challenges that require innovation today? I want to talk to you in some detail about the three most important because I am sure that there are many present in today's audience who can help us over hurdles that seem so daunting. In brief, they are:

- providing real-time use of the models on the Internet with secure remote rendering
- collecting, preserving, and disseminating the models on the Internet
- figuring out how to use a model not simply as illustrations of what we knew before we made it but as an instrument of new discoveries like a telescope or microscope.

Let's start with the first problem. So far in this talk, I've shown you static screen shots of the digital models I have been discussing like this shot of Rome Reborn in the slide. [start video]

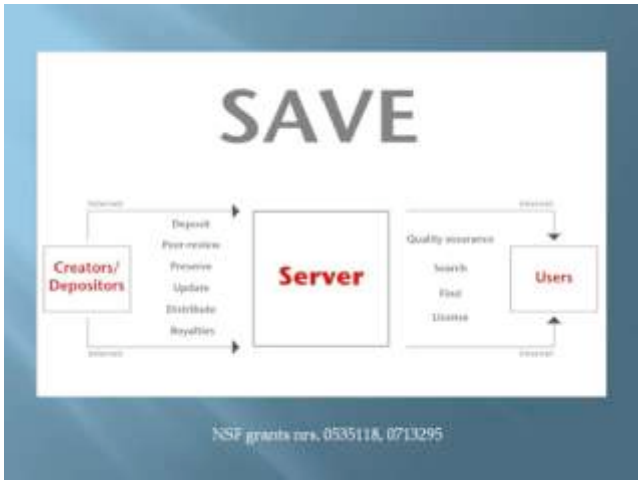
	But, of course, the models were not primarily created to be used that way but as virtual spaces that can be explored interactively, which means that we see them at a frame rate of 20 or more fps and have complete freedom to move up, down, sideways and to change our pitch, yaw, and orientation as we do so. Achieving this frame rate can require great computational power if the geometry being manipulated is complex; and transmitting the frames over the Internet requires good bandwidth. You have been watching a screen capture of a real-time fly-through of Rome Reborn, our digital model of the entire city of Rome in the year 320 A.D. The model represents over 7,000 buildings covering 25 square kilometers of space. It consists of over 400 million polygons, which makes it a very complex piece of geometry indeed to try to run in real time. The video was made for us by IBM on one of their BladeCenter QS21 servers, which costs well over $100,000. At the moment, we cannot get this kind of performance on standard PCs, nor can we pipe it over the Internet to the screen of an end-user. Even when the average PC can run a model like this, it is unlikely that the creators of cultural heritage models will in general permit their products to be downloaded for local use. I say this because of an experience I have repeatedly encountered when obtaining permission to scan an important monument: the authorities in charge are happy to grant the permission, but only if we guarantee that their intellectual property rights

are protected. So we have had to develop a system that simultaneously offers the end user a high-resolution photorealistic view of the digital replica, while not letting him simply download it to his local machine, something that could facilitate cybertheft. The solution was ScanView. It was developed by Dr. David Koller, a member of Professor Marc Levoy's graphics group at Stanford in the late 1990s when they were getting permission to scan Michelangelo's David and other works in Florence. In the slide, you are seeing the Stanford model of David. ScanView implements the idea of "secure remote rendering." Using this approach, the end-user download a very simplified (and commercially worthless) digital model of the monument onto which is draped a high-resolution view from the full model, which is securely stored on a remote server. With decent bandwidth, the whole process seems to be happening in real-time, as you can see in the screen capture I have been showing you of a typical session viewing the digital David.



What about a much bigger digital model such as Rome Reborn? We are working with Mental Images, a subsidiary of Nvidia, and the Italian company ENEA to find an analogous solution which will take advantage of ENEA's 2800 core IBM server cluster to do the remote rendering. You are watching the screen capture of a recent real-time session. We started south of the Arch of Constantine and then proceeded north toward the colossal bronze statue of the Sun God next to the

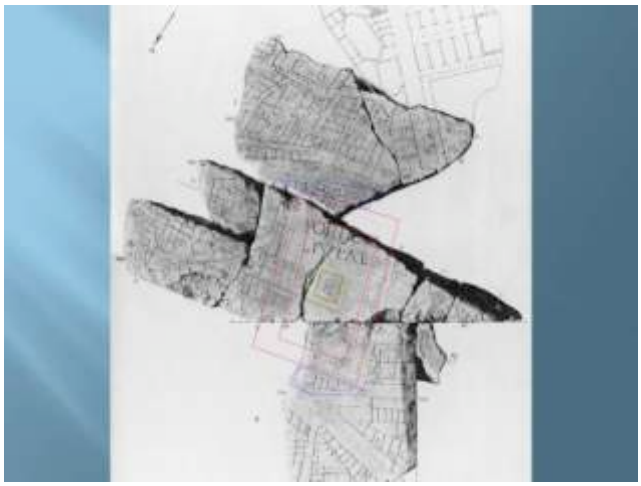
	Flavian Amphitheater, home of the gladiators. By the way, we call this facility the “Colosseum” because it was next to the now-vanished statue. You can see how we can move quickly through the model, despite its 400 million polygons. This is because Mental’s software progressively renders each frame: the longer we tarry, the more pixels comes in. Ultimately, when we find a location of special interest, as you can see in the video, we can stop and set up a high resolution rendering. The Mental/ENEA system will be implemented in the first six months of 2010. It should allow us to greatly improve the frame rate and also to support the simultaneous log-in of dozens of users. Stay tuned to this channel next year to see the first results. Once we have figured out how to securely serve even very complex models, we can confront the second challenge: collecting, preserving, and disseminating the models on the Internet. Ironically, 4D humanists who devote their careers to preserving the world’s cultural heritage have not spent much time thinking about how their own contribution to that heritage can be saved for future generations. Remarkable as it may seem, to date there is no online scholarly repository in which 4D humanists can deposit their digital models and in which students, scholars and the general public can find a scientifically produced and vetted model. The only thing we have along these lines is Google’s 3D Warehouse, which, of course, only collects the very simple kind of models you can make in



Google's KML format; and which offers no guarantee of quality control by cultural heritage experts. Thanks to two generous grants from the National Science Foundation, our research group has been working on a better solution. We call it SAVE, which stands for "serving and archiving virtual environments." Our vision is a peer-reviewed online journal in which scholars can publish their 4D models with links to the documentation along with related monographs. Through a needs assessment survey, which over 300 scholars took, we found that over 90% consider creation of something like SAVE to be a top priority for the field. We have also had a strong expression of interest from one major European publisher to support the journal, and we would be happy to talk to others, especially in this country.

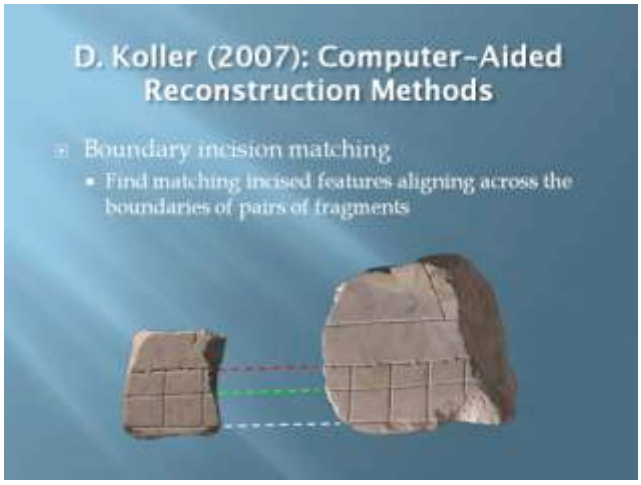
Finally, let me talk about the new, hot thing in the 4D world: how to use a model to make new discoveries: in other words, for what Stefano Bruschini called "knowledge multiplication" way back in 1990. A year ago, we published a book with a dozen examples of pioneering work along these lines. Let me just cite one example—the research of David Koller on the Severan Marble Plan.

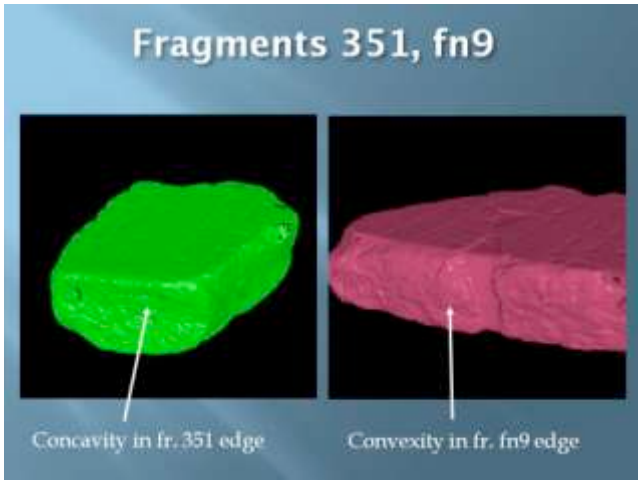
First, a word about the remarkable monument itself. The Marble Plan is a highly detailed map of Rome in the early third century A.D. It was made at a scale of 1:240 and was exhibited on the wall of a room in the Temple of Peace in the city



center. The map was incised on 150 blocks of marble and measured 17 meters x 20 meters. It showed not only all the streets of the city—as you would expect in a map—but also the ground plans of all the buildings. In this slide, you see a close up of the map showing the ground plan of the Porticus of the Empress Livia, a site that offered a place for relaxation in the heart of the city and which has never been excavated. On the basis of the map, we can see all the columns (which I've highlighted in red) and we can observe that the structure was surrounded by shops (highlighted in blue) opening onto the neighboring streets. We can see a stepped square structure (highlighted in yellow) in the middle of the courtyard, which we know was a garden so the square structure was probably a fountain. We can see something else: the fact that the map comes down to us in fragments. In fact, we have over 1900 fragments constituting about 10% of the original map. This slide shows what remains, highlighted in orange. The other 90% was melted down for lime in the Middle Ages. The name of the game for scholars since the Marble Plan was discovered in the 16th century has been to find joins between the fragments so that the map—or what is left of it—can be reconstructed. By 1995, about half of the fragments had been joined, but that still left hundreds in cartographic limbo.

In the late 1990s,Stanford Computer Scientist Marc Levoy had the idea of doing 3D data capture and modeling of all the fragments in Rome while he was in Italy scanning the

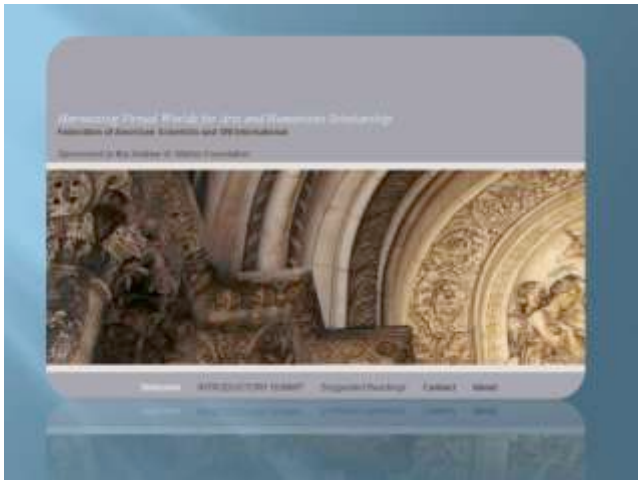




sculpture of Michelangelo in Florence. His doctoral student, David Koller, eventually took over the task of making the models and making sense of the data. He developed algorithms for solving the puzzle automatically, and in his dissertation he presented these and his application of his work to the insanely difficult case of the Marble Plan—a jigsaw puzzle which comes with no picture on the box!

In this series of slides, I'll show you how Koller matched up two fragments. First, the computer noted a similarity in the lines incised on two pieces catalogued as 351 and fn9. This made it likely that the two fragments belonged to the same part of the map, but it didn't tell us how far apart they were. Then in manipulating the 3D models on his computer screen in Stanford Koller noticed that there was a convexity on a side of fn9 that seemed to fit nicely with a concavity on a side of fragment 351. Of course, to be sure that the two fragments actually fit together, there was no substitute for going to Rome and opening the cases where all 1900 remaining pieces of the map are stored. So Koller went, the cases with the fragments were opened, and –lo and behold—the fit was as snug as the computer models had suggested it would be. Koller demonstrated over twenty such new joins, and this was an amazing achievement coming after 400 years of archaeologists working with traditional methods.

Koller's software works offline. What we need to do next is to make it possible for end-users to



make such discoveries online. A new group of 4D humanists was formed this year to do just that. It is called the Humanities Working Group of the Virtual World Alliance. We were brought together by SRI International and the Federation of American Scientists through a Mellon-funded project called "Harnessing Virtual Worlds for Arts and Humanities Scholarship."

So what is this all about? Potentially, it is a way to convert our 3D worlds from being places that the end-user can only passively view to places she can explore like a scholarly time traveler in search of new insights and discoveries. Another way to think about the Alliance is that our goal is to tame Second Life.

Don't get me wrong: Second Life is wonderful and I use it all the time. As the Linden Lab website claims, it's a place where we can unlease our imagination, socialize with people from all over the planet, buys things, visit museums, have serious meetings, and get educated. But can you do Humanities scholarship in a Virtual World? I mean, of course, can you do anything besides use the virtual world as a place to meet and discuss scholarly matters?

The Humanities Working Group of the Virtual World Alliance has the goal of answering that question. We are studying how research environments can be created using Virtual World Technologies such as Second Life and especially the Open Source equivalent, which is called

Open Simulator. We like OpenSim not only because it's Open Source but also because it has loaders making it easy to import an existing 3D model into the virtual world—something promised by Second Life for several years but never quite implemented. Since the digital humanities community has by now several thousand scientific models, the ability to port over all this good work to the new technology platform is a major advantage of OpenSim.

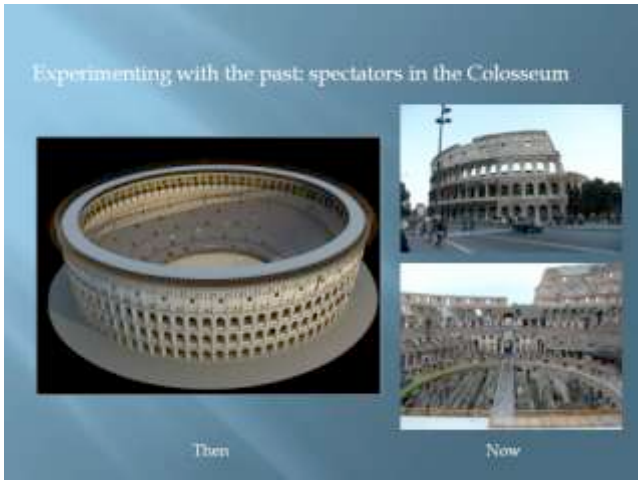
The technology has been defined as follows by SRI and FAS: "a Virtual World is a computer program that generates a dynamic representation of a real or imagined world and embodies the essential qualities required to support higher-order cognitive activities." The key characteristic of this "dynamic representation" is that it takes the form of a simulation of the real world by offering literal replicas of three-dimensional objects, whether animate or inanimate, and the passage of time. The behaviors and interactions of the 3D objects over time can be constrained by their physical properties. Using virtual world technology, we can see a building, the people and furnishings in it. We can listen to what the people are saying and to the music they are hearing. Moreover, we are not limited to passive observation but can actively participate in the scene through a self-representation called an avatar. In short, virtual world technology supports the creations of realistic, literal representations of 4D information.

Once accurately represented, the lost historical world can become the subject of empirical and experiential research in a way unthinkable in the past. We can seemingly turn back the clock and return to the past.

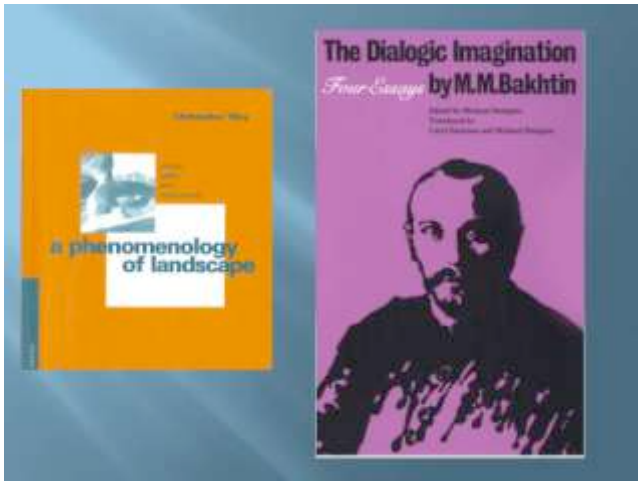
Let me give you a couple of fairly simple examples of what has already been done and then conclude with a project proposal we are developing that would take this kind of research to a new level of sophistication. In the examples, our lab has used Second Life for prototyping encounters between me and Amanda Levin, CEO of Pleiades, our partner for Virtual World development. In Second Life, my name is "Hermarchus Afterthought." Amanda's is a name that can't be pronounced spelled "M3dusa." I'll therefore call her Amanda.

The first encounter I had with Amanda concerned 3D modeling. We met in the Rome Reborn's reconstruction of the Curia Iulia, the Roman Senate House, on the Roman Forum in the heart of ancient Rome. The meeting was staged as a discussion of Pleiades' work in correcting an error I had spotted in reviewing a first draft of their conversion of our model to Second Life format. I think you will quickly appreciate the way in which this technology supports real-time communication between people at a distance who can be in the same place, see the same things, and interact with each other and the space in a way that is otherwise impossible. And best of all, it doesn't cost anything! [play video]

The second video simulates a scholarly encounter. This time, I wear my scholarly hat, and Amanda pretends to be a colleague at another institution. We are discussing the philosophy of restoration: how do you deal with the all-too-common problem in humanistic research of uncertainty owing to the loss of data. To set this up, let me draw your attention to the upper left "now" shot of the interior of the Senate House. You can see that the building is preserved to the ceiling. We have the ancient floor, the three deep steps on either side of the hall where the senators put their chairs, and the speaker's platform at the end of the hall. We have some fragments of the marble wall decoration, but mostly what you see is the unadorned brick since the medieval stripped most of the marble away for reuse elsewhere. Ok, with that background in mind, I'll run the video…



But virtual worlds are not only useful for putting contemporary scholars into past spaces. They also allow us to populate the reconstructed ancient spaces with furnishings, people, and activities to test out hypotheses of how things worked. As an example, I would cite our partnership with the School of Engineering of the University of Zaragoza to study how many spectators could fit into the Colosseum. This is a hoary scholarly problem, and the estimates on record by reputable archaeologists range (almost absurdly) from 35,000 to 78,000. Why is this even a problem? As you can see in the lower-right "now" shot of the Colosseum, none of the



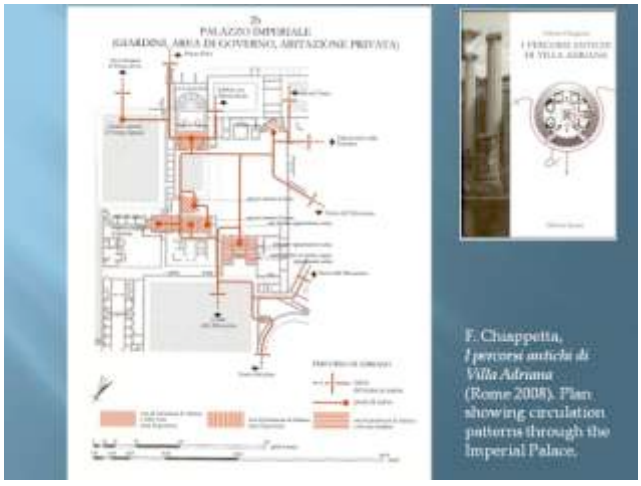
interior seating survives. The engineers at Zaragoza used structural engineering software to populate our Rome Reborn model of the Colosseum with AI figures who may not be handsome but are smart. This video clip shows a screen capture of how the figures entered the seating area and managed to find their seats without falling or bumping into one another. [video clip: click "spectators"]. By the way, the correct answer about the seating capacity is 48,000 to 50,000.

Besides running experiments in the past and making the study of history and archaeology more precise and empirical, we can also use this technology to re-experience the past. The point in doing so is to test out hypotheses of reconstruction of how things happened; and, once we get that right, to create the conditions whereby we can try to interpret the world as someone in the past might have done. In Archaeology, this is actually a hot area called landscape phenomenology pioneered by Christopher Tilly in the book on the screen. In literary and cultural studies, the study of how people make spaces into places by the projection of meaning derives from the notion of the "chronotope" developed by the Russian theorist, Mikhail Bakhtin.

For example, what if we could use Virtual World technology to figure out how the gladiatorial combats actually worked. Up to now, we have been limited in understanding these highly

dynamic and fluid events by the worst possible kind of evidence—static images such as those seen on the screen from reliefs, lamps, and mosaics. The new technology allows us to construct the various kinds of gladiators—the murmillos with oblong shields and high, crested helmets; or the hoplomachi with small, round shields. It allows us to drape motion captured from living people over these virtual figures. Finally, it allows us to give control of the animated figure—or, avatar—to a scholar who can then fight it out with a colleague. Through these tests, the strategies used by the gladiators can be better understood. Once reconstructed, they can then be observed to help us understand things like the audience reaction or the interaction between the crowd and the athletes. Well, in fact all these things are possible, and have been done. I show you now a screen capture of the final result reconstructing the fight of a murmillo and hoplomachus in the Rome Reborn Colosseum. [clip]

The examples I have shown you thus far are fairly simple. But it is easy to predict that Virtual World technology will be used for more complex experiments and experiences. Our lab is developing a Virtual World of the famous Villa of the Emperor Hadrian near Tivoli. This World Heritage site is well documented and studied. It covered almost 300 acres of land filled with enormous pavilions, palaces, porticoed gardens, and so on. It is estimated that it took over 3000 people just to run the place, which was



essentially a retreat of the Roman imperial government where the top 100 or 200 officials could escape from the heat of the city and work in splendid isolation. As that *envoi* I showed you earlier attests, it has even been reconstructed in 2D many times and we have a nice 3D physical model. On the screen you've been seeing a recent artist's rendering of a bird's eye view of the reconstructed villa. So we have chosen to focus on this site because at this point scholarship has progressed from excavation, documentation, and reconstruction to analysis and interpretation. A book published in 2008 by Federica Chiappetta stands out for advancing research in a new direction: the investigation of who used the various rooms and structures in the villa.

Chiappetta's thesis is that Hadrian's Villa was designed to minimize the contact between the service staff and the privileged elite. She furthermore claims that the spaces of the villa were structured to avoid exposing the emperor and empress to environmental irritants such as inclement weather, smoke from everyday activities, noise from the work of the slaves tending the villa and from the animals and vehicles used to transport supplies to the villa. In support of this thesis, Chiappetta develops the first analysis of the functionality of the villa, studying almost every room in each of the building complexes from the point of view of who used it, for what purpose, at what times, and in what way. She divides users into six distinct groups: the emperor, Hadrian; the empress,

	Sabina; high court officials; invited, high-ranking guests; petitioners; and servants and staff. She presents architectural plans that show the typical paths of circulation of each of these groups through the individual building complexes. There are over 130 such plans in the book. The slide you've been looking at shows you one example: the so-called "Imperial Palace." Chiappetta supports her thesis by argumentation that is both logical and cultural. Architectural plans of the individual components of the villa are enhanced with lines showing the itineraries of the groups that used them. But these plans are simply illustrations of the thesis: they do not permit the thesis itself to be tested. Moreover, Chiappetta's form of illustration is 2D, but the problem she addresses is 4D. The users of the villa are 3D, as is the villa itself. The movement of the users through the villa adds the important fourth dimension of time: for example, two groups who ought not to be in the same place at the same time appear to do so in Chiappetta's 2D illustrations because the element of time is ignored. Finally, each of Chiappetta's 2D views is devoted to a single complex in the villa. There is no composite diagram showing all the itineraries. This is not surprising because such an illustration would be extremely large, would require many different colors, and, in the end, would be so complex as to be practically impossible to decipher. By the way, I hasten to add that I don't intend these comments to be

critical of Chiappetta, who is on our team and who would be the first to agree with what I’ve just said.

To test and refine Chiappetta’s thesis, we need to have a Virtual World of Hadrian’s Villa: a 4D architectural reconstruction of the villa with avatars representing the dynamic motions of the people in the six groups and including dynamically spatialized environmental features such as smoke, sound, and light. This resource will allow for experimental history of a kind otherwise impossible short of rebuilding the villa. Having created a highly detailed CAD model of the villa the past two years, we are now seeking funding to convert it to virtual world format so that we can test out Chiappetta’s ideas.

Last summer David Koller (who had in the meantime moved from Stanford to our university) joined with me to start the Virtual World Heritage Lab to support research that takes 3D technology and moves it beyond illustration. The scope of our interests--as implied by the phrase "World Heritage"--includes the entire human record. The focus of our investigations, as is suggested by the phrase "Virtual World"--is this new technology and how it can make possible experiences and experiments that would otherwise not be possible. We are working with scholars such as Federica Chiappetta to use this technology go beyond research undertaken with traditional tools and methods. We are cooperating with our partners in

the Humanities Working Group of the Virtual World Alliance to create the cyberinfrastructure needed to link multiple historic Virtual Worlds so that each fits into the right cell of the time-space matrix. We don't make the wild claim that Virtual World technology is going to transform *all* of scholarship in the humanities, anymore than we would claim that the GUI of today's Internet will be replaced anytime soon with a Virtual World interface. But we do believe that there are some—probably many--concrete problems in traditional humanities research that have had to be graphically reduced from their normal four dimensions to an abnormal and abstract two owing to the limits of Gutenbergian technology. And we think that by using the new technology to restore the two missing dimensions, we can more accurately and interactively test historical hypotheses about how culturally significant spaces functioned and were symbolically invested with meaning. And we think that that is a good thing. If you know of humanists at your institutions who might benefit from a collaboration with our lab, please do not hesitate to put them in touch with us. Thank you very much….