# DEVICES OF DESIGN

Colloquium & Roundtable Discussion
18 November to 19 November 2004

presented by the Canadian Centre for Architecture
and the Fondation Daniel Langlois

TRANSCRIPTS

## Colloquium



## Roundtable Discussion

## Colloquium, 18 November 2004

[Welcome by Jean Gagnon, Fondation Daniel Langlois, and Mirko Zardini, CCA]

## Derrick De Kerckhove
## Introduction

I really want to thank you, Benjamin [Prosky], and the Canadian Centre for Architecture for the opportunity of talking with you this morning. But I have to say right away that I am neither an expert in architecture nor in bibliographical and library practices, in spite of the fact that I am holding this chair at the Library of Congress. What I am going to try to do is to sort of situate the whole issue of architecture and time and space in the context of what I could say are the three great eras of the manipulation of language by man.

The oral era has its own dimensions, its own proportions, rather restricted to the immediate contact between people. The literate era is the one that creates technology after technology and arrives at a concept, a conception of space, which is very peculiar and continues to dominate our perceptions, but is threatened today by different types of experiences of space. These are in the third era, that is, the era of the electronic – the electronic man, you could say. So, here are, rapidly – it's very pedagogical, but it's interesting to know the basic relationship between space and person in various contexts so that the dominant medium can be speech, writing, or electricity. That means the dominant medium is ... language. Obviously, the dominant role will be oral and speech, literate and writing, but it is digital in electricity. And that's very interesting because the digital era of electricity is only its second one – it's an extension, it's a transformation, in fact, of electricity into cognition. We'll get back to that.

Social structure, collective and tribal, individual person – this may not be as pertinent to the architectural dimension here, but it is interesting. Collective and interest groups are the correspondence to this. In my opinion, the most important element of this tableau is here. The meaning is found and created in context in a culture that doesn't have support for languages other than the human body. And that means that language is always shared, and always, in the interval, between people. In a society of text, the text is removed from the context and becomes the blueprint for fiction or for technology, or for architecture. It is the possibility of removing the text from the context that creates this extraordinary freedom from the past from the springs of the culture, from the fundamentals, in some ways, and creating the future of projection of a world that is obviously forever better.

The world of hypertext, which is the one we are in now, combines the values and, I would say, the properties of both context and text, combines the archiving possibilities of text and this continuous exchange of the world of context. At the same time, it changes completely the relationship between elements of language. So here are spatial modalities, which are very interesting – in a tribal culture, in a dance group, in a school of, let's say, Arabic school, or tribal school, the space is filled with the interaction. I don't know if some of you have read "proxemics," a work with the proxemics of Edward Hall, but Hall talks about the culture of interval and space between people, and how it is managed by different kinds of cultures. For example, a great example, he says that if Arabic people can't smell each other they won't be able to communicate, so they have to talk very, very close. The space is absolutely filled – it's a filled space. We have, in the West, created the illusion of empty space – the central margin space – whereas the oral is immersive with developed perspective. You will see how interesting it is to relate perspective to the writing system that we have adopted, which is the text.

And now we are into a very fluid kind of dimension: moving from the immersive, back to the immersive. The immersive is the natural condition of a tribal situation, but the fluidity is also immersive. We are also immersive in the electronic environment … we are now in what I call the post-Galilean moment, at the time when the world moves from solid to liquid again. Galileo – the moment was a time when the world was moving from liquid – mystical, religious, theocratic – to the solid – scientific, natural, phusis. That's what Galileo was doing, and the pope, by the way, agreed with him, but he had officially to condemn him. Anyway, we are in the post-Galilean moment now, and we're moving from solid to fluid. "TransArchitecture" by Marcos Novak … there's work here by Greg Lynn that has that kind of fluidity, all of Gehry's work – there's no question that it is today expressed right now. The dominant shape is circular in the oral … because it is the surround of the voice. It is fixed and planned in the text world, and it is not *decorum* in the electrical environment. And we have today added a very strong ludic element in this management of space and of architecture.

Let me just say that how I look at this is the relation between the alphabet and the brain. I'll spare you the details of that research only to say that literacy: (a) allows people to appropriate language and to retire in a point of view against the world – the invention of perspective, which begins with the Greeks and the alphabet – is an invention ... is a way to expel the spectator from the spectacle, and has created a healthy distance, a neutral space. Not intervals anymore that we pick up by music, but a space of theory, a space of theatre, a space of looking from some point to something else, which is a condition from the split from subjectivity and objectivity, and also rationality…. Here is one aspect of it – internalization of space: when suddenly you position yourself, not anymore as a body feeling the interval of space around you or as a body invaded by the space around you as is the case of the … First Nations of this country, a very interesting way of dealing with space. No, you internalize a vision of the spatial area in yourself at the centre and you create mental mappings, you project the world. We actually have now a satellite-based geography in our sensibility. That's what happens there.

This is a terrible digression, but I want to make it because it has to do with why I am saying that all of this has happened to the Western mind. The Western mind has actually developed a writing system that imposed horizontality, and that imposed lateralization – the left to the right. If we read and write from the left to the right, we think from the left to the right. I can prove it very easily by drawing a diagonal; you will decide where it rises from the start. A culture reading from the left would say, the one you think is rising, actually it's going down. Here is a case of an obsessive observation of Chinese architecture, and this goes to the primitive, I would say, as probably we will hear from Greg Lynn. But Chinese architecture is always very surprising, and it's based on something – can you see what is absolutely unique about these two modern buildings of Beijing? The primitive there is a square, and I have discovered this for a long time. I thought, our primitive is the TV screen or the Renaissance horizontal, the roller sector – our primitive spatial structuring is this way, but the primitive there is a square. Ours corresponds to the book and the lateralization of reading and writing. The Chinese correspond to that plate, the invisible plate of the baseball – it's the space for the ideogram. So they are obsessed with ideogrammatic structure and their primitive is ideogrammatic.

This is only to say that literacy, in my opinion – and to me it's still a hypothesis that cannot be really proved – but that literacy will throw its shapes in a specific contested environment. You will find this in Korea, you will also find it in Japan, although with much more moderation because the Japanese don't only write in a graphic manner. Here is an example of a media boulevard that is planned for – I forgot the name of the area, about four miles away from the Forbidden City. It's Megalo; it's amazing. I'll give you a few images. Look at how the role of the square continues to be prevalent in the planning of all these buildings and so forth. And then here's an amazing Beijing architecture story. I was walking with a guide, who was telling me how all these read. And this is a media boulevard, by the way – all the media are going to be there, whether it's the press, TV, filmmaking, basically all of it, and housing for everybody, that's their big plan. I say, "Oh, how wonderful, you are keeping these little houses that were there before, the Beijing houses." And the man said, "Oh no, no, replica, replica."(laughter) I didn't think I understood. I mean, at first, it's not that easy to get understood or understand the Chinese context, but the fact of the matter is, I just didn't think I understood. Then that evening I went to a zone that had been done that way, and I understood that it came because of this, largely. It's also a very Chinese thing to do, but they pick everything up. You know that the Forbidden City has burned seven times, and they redid it every time, exactly the same, so they know how to do "exactly the same." The reason they do this is sanitary planning and putting the electricity in.

So I just wanted to show that we have, always, when an amazing medium takes over, a whole social scene, it actually transforms it from the East. So electricity and the alphabet, that's the biggest technological, mythical marriage, maximum speed, by maximum complexity – that was language, the speed of light by language. The babies are still being born.  Telegraph language accelerates and amplifies and redistributed by electricity, maximum speed, relentless refinement of the code from the twenty-six letters of the alphabet to 01. We are going to go beyond 01 with the quantum, but right now that's the refinement of the code. Twenty-six letters to the 01 via Morse long, short, and not – 01 becomes the smallest common denominator of all experiences – physical, mental, actual, and virtual. That was phase one. Heat, light amplification, and transportation of signals – that's the muscular phase of electricity, that's when we start using electricity, but right away the telegraph promises what is going to follow.

But what gives us heat and light and energy is the analogue phase, and opposing it to the digital so that we can see how cognitive electricity will be going. Information, knowledge, and instant reconstruction of signals – computers work building signals in the display as our mind works – it doesn't simply drag it or repeat it. That's a very important difference. Computer network simulation. And right now it's the take-off point with the wireless revolution, which is happening right now. There is a third phase ... my feeling is that it's the quantum phase – very, very useful to think about it now because we are almost in a quantum computing stage. We're almost at the same stage as Von Neumann between 1946 and '55, so it might just go the same way. Key biases of phase two: I chose only those which I felt to be related to architecture because you can add biases forever. There are so many things, so many trends that are very specific to electricity – globalization is a natural consequence of electricity – convergence is integrated within the 01 smallest common denominator and electronic principle. Integration is the motor functioning of electricity. Real time, the same connection we have, which is cognitive with our own mind, evoking our own ideas and images, is the one we need with our machines. So the tendency of real time, maximum language, and maximum interconnected speed is actually the tendency of both research and technology. Ubiquity is obvious. Immersion – total immersion, permanent immersion in the light of bulbs, obviously, but immersed in data … we put our hands into the screen following our cursor. Total surround is again watch your back – we have now not just frontal but total surround … this is a frontal world. Virtual, banal. Liquidity, we talked about. Connectivity, natural. Interactivity, we all do it. Transparency, that's one which is less frequently thought about, but the tendency of electricity, which is both inside the body and outside, to actually eviscerate us and translate us into numbers, and numbers that can be stored and that can be retrieved, makes the world transparent, ourselves transparent, our companies transparent. And we have Parmalat, and Enron, and all kinds of nasty business coming through – it will get worse before it gets better. And we have Homeland Security. Homeland Security is a typical effect of electricity – Bush is a victim of electricity. (laughter) Random access is clearly what we need from our machines the way we have it again in our own mind.

Hypertextuality, I mentioned it before, but I would like to say one more thing about it: we as people, with or without technology, practise hypertextuality naturally. But now we have to recognize how it works, so I usually ask my … audience to say whether they read their horoscope or not. And I find that there are never more than two or three really honest people in the room. But how does one read one's horoscope practically? You actually put together things that this horoscope has written for 350,000 people – or for nobody, and certainly not for you. In any case, you make it yours by picking this, that, and that, and putting it together, and … you make sense, hypertextually of this thing that had nothing to do with you in the beginning. The Chinese have been doing this for four thousand years, using the *I Ching*, which is a method of thinking where you throw the dice and what you are looking at is not your future at all. The Chinese don't have a future – it's that enormous presence of theirs, which enclosed the future and the past. When you live in total presence permanently, you are in a deep situation where everything is interrelated to everything else. Hypertextuality is picking whatever it is that is related to everything else that actually makes sense and connects at the moment of your thought….

So now we're dealing with three spaces: we're dealing with the organic one, which is the mental one, which has its own disciplines; we're dealing with the physical, which is the city space, which is where we are now; and we're dealing with cyberspace, which appears on our screen. And since we spend now more than half our waking time in front of a screen, whether it's that of your *telefonino*, your television, or your computer, I think … chronology should be invented. The screen is where the physical, mental, and virtual space coincide. Isn't it interesting that there is a place where the three of them are together, in a kind of constant interchange? We also see that mind, that appropriation of language that had put so much under our personal and silent, and internalized control, which made ourselves in the Western alphabetic structure, had also endowed us with a quantity of skills including design and architecture. But the quantity of skills that we have had more or less integrated – every now and then we use paper and put it out writing it or designing it.

All of that now is emigrating to the screen, including strategies of design and including the strategies of the actual, physical movement of the design. The hand somehow is changing; the ratio is completely changed. So is any relation of the mind from the hand to the screen, where it's going to meet other minds. It could very well be that the invention of the screen's purpose, the "teleo" of the psychotechnological, or the technobiological integration between people and screen actually is the way by which people can interconnect mentally on the same space. So, reasons are [sharing] communication, sharing the responsibility of making sense with the screen.... It is important to realize that the alphabet made our lives abstract, and now all of that is coming into a secondary sense of reality, as Walter Ong said. Tactile, visual, auditory, olfactory to a certain extent, and I am not entirely sure people worked on taste, but sharing the responsibility of making sense of the screen – we are basically not any more autonomous in the way we were when we were just silent readers. Penetrating the screen, literally. My machine direct connect is the tendency of technology today, where you will look at the screen and get and think about what you are looking for on the Web and you will be getting it, of course – the search engine will be highly pertinent at that time.

The body electric, as I mentioned; we are constantly exchanging between the body and the world in this whole electronic environment. And I just wanted to show it, again, in a Chinese context. The interesting thing is that this is a fourteenth-century description of the acupuncture point, where the Chinese would have known very well about the currents in the body and the relationship of everything within the body to everything else. So now we are pushing a world from the world of vision, the visual dominance, to the world of touch – that is what is now occurring with electricity. And so the way we go from visual to tactile is that we are moving away from the point of view of the Renaissance to the point of being of the cybernaut: he is somewhere, his body is somewhere, and that's where he is, but the point of view was that separation. Here's a case of a *trompe l'oeil* – the fantastic story of the *trompe l'oeil* was invented to give the power of the hand, the power of touch to the eye alone. It is like the eyes saying to the hand, "I don't need you anymore." The dominance of the visual over the other senses in our culture is going to be characteristic. So coming to this, which is entirely the reverse of it – in 3-D you penetrate the screen, you're not anymore expulsed from the space, you're invited to actually play the intervals between the various objects within the space. So there's a complete reversal of sensorial reality that is happening – a reversal of perspective with the end of theory, as well (here I am theorizing like mad), but we do a lot. But it's the end of theory as the dominant mode of learning, or the dominant mode of practising, multimedia, the recovery of the senses. Vuillard is wearing the image as an extension of the skin....

I just want to say that we are immersed in a sea of data, so we're moving into an extremely thick era of referencing and connecting with the RFID. The RFID is a "radio frequency identifying device," and it costs no more than your label in your shirt…. It is individualized, and the energy comes from light, so it's easy to send messages in a radio emission form. Now it's possible to know not only where you are, but what you're wearing. And that kind of situation creates an incredibly new architecture, an architecture of connectivity... This is a case of design of architectural networks in a community … this is the [Single] Hub-and-Spoke Network where you have the Hub responsible for the distribution of various things within the network. Here's the Multi-Hub Small-World Network, which is yet another configuration that developed on the Internet today.…

What I find very interesting about the connectivity, for example, of blogs, is that blogs create a new kind of technological image of a psychological development that's happening right now. A blog is a projection, not anymore the closing-in on yourself with your diary, but projecting and posting your ideas, your diary, whatever, online, you do so as a mode of interesting people in exchanging with you. You then have more than just a posting. You have the list of things that interest the blogger, and then you have the network of the blogger, which is in constant change. That's an image of an architecture of consciousness that is new, even though it's practised in various formats. In the particular focus sense that the blogger allows you to do, we are dealing with a new kind of sensibility.

I'm just going to finish on this, the new perspective for Internet architecture. The Internet itself is a self-organizing architecture, but it has reached a certain point of maturity, and it needs to go to the next state. "Internet Two" is the new architecture that is planned for the existing Internet, which will now be called "Internet One." That architecture contains provisions for increasing the speed, increasing the number of access URLs, facilitating the actual interchange between them. "Internet Zero" is an invention of the director of the center at MIT, the Center for Bits and Atoms, Neil Gershenfeld, an invention that actually would not harm the existing situation of the Internet. It would remove code instead of adding code, the practice of Microsoft, usually, and they would actually allow to connect – and this is where it gets hot – every bulb, everywhere in the world, every electrical device, anywhere in the world, every URL, every address, everything. And the RFID I told you about, all of it interconnected. All of it accessible without intermediate servers, that's another thing, without handshake problems. Like a universal genie.… "Internet Zero" is really, really an interesting architecture for the future of art consciousness.

"Creative Commons" is another brilliant one – it's the idea of Lawrence Lessig that instead of having copyrights everywhere, which stops you from borrowing, taking, re-using, you have "copy given," "creative commons." That's what it means: you click on that button and you open up a page that tells you, here are the conditions by which you can take and use this piece. Now that's in architecture. Just like Linkous was an architecture of intelligence because it allowed all open sources, [this] allows people to actually go and remodel whatever there is in their own terms. Creative commons is this content, which is an extraordinary, brilliant architecture, if you want, of intelligence.

But you see that's why I was saying at the beginning architecture is single – is it single anymore? It isn't. It's impossible anymore to talk about networks without talking about architecture. I've tried to search the common ground between architecture and networks, and I feel I have only half accomplished the matter.... But what can we do with the accumulated data is exactly what we are about to discuss today and tomorrow with various experts. I will be introducing those experts, and I would like to very much emphasize that everybody in their questions is also invited to propose suggestions of what to do with the accumulated data.

But I can tell you one thing: we're inviting from the Library of Congress Brewster Kahle, who was "Mr. Archive," and he is going to come and tell us, if you archive the Web, how many times do you do it? What do you do with it? What within it do you keep? What are the conditions? Archiving the Web is a process that's going on constantly. There's an enormous quantity of data that's going [on], and it's not going to stop. As I said before, the multiplication is going to be such that storing all of that will require, I suppose, holographic techniques. I don't know what it is. What do we keep of going digital? One of the biggest issues at the Library of Congress is that we don't want to spend money buying the paper [copy] if another library has already bought it. So somebody should be taking care of *The American Journal of History*, for example. What do we keep of paper? What do we keep of going digital?

My experience, thanks to Ford Peatross, who is among us right here – I was allowed to go and see the place in the Library of Congress where the architectural designs are laid. And what I found – I was sorry I didn't have my photograph machine – was very nicely, beautifully done. What I found was the amazing quantity of paper documents that one is both tempted to keep and tempted to throw away. There's an anxiety constantly. What can you keep of all that? Anything before a certain period, of course, once it's there, it's there – it's to be kept. But of the things that are coming up right now, there are tremendous problems and *crises de conscience* that are happening all the time. It is that kind of *crise de conscience* that today we are going to be examining together – an interesting one, of course. I would like to remind people that the questions will be all at the end of the first of the four speakers, of whom I am the first. Thank you.

Now I have the pleasure of introducing Marco Frascari.... His professional experience began in the early sixties under the tutelage of Carlo Scarpa, and he has maintained an architectural practice since 1970. He studied at the Istituto Universitario di Architettura di Venezia, where he received a doctorate in architecture in 1969. He has published in many journals including *Casabella*, *AA Files*, *Terrazzo*, and the *Nordic Journal of Architectural Research*. He has an important essay called "The Tell-the Tale Detail," which was published in *Theorizing a New Agenda for Architecture*. Marco Frascari is going to talk about … what I was just talking about, paper. Put it on paper! Marco Frascari. (applause)

# Marco Frascari
# Architectural Ideas … Put Them on Paper!

Thank you. I really like to be here and to talk about paper, of course, and now I have to start with a personal story. I was eleven years old, I went to watch a movie, and in the movie there was a butler who pulled out his cuff and wrote down notes – I loved it! I went home and ruined two shirts, and my grandmother caught me. And she said, you know, come to my chest of drawers. She pulled out a box. Inside of the box there was a bunch of cuffs and collars of my grandfather, and she showed me one where there was "Ti amo Rosina" (I love you Rosina). That was probably when they were engaged. And she showed me that the cuff was in paper, and I was completely surprised, because I didn't realize how really paper is all around us. We are talking about all this paper as a support where you write, but paper is really a dominant part, to the point, for instance, that in 1870, one Boston manufacturer was producing 75 million cuffs, so it was really an amazing story. There was a song in London in the 1860s, where the refrain was "For paper now is all the rage, and nothing else will suit the age," and it was sung by this man Howard Paul, and he was all dressed in paper! It doesn't look like it from the drawing, but I guess he was.

Now, a little picture in answering a request made by an English newspaper to a staff member of the IBM J.T. Watson Research Center: he was asked what was the most famous invention. He said it was the Chinese invention of paper, and he compared the paper to the Internet because in reality, paper and the Internet break the barriers of time and distance. And really, architecture came in the age of paper in the fourteenth century. Basically, paper was invented by the Chinese, and moved along the Silk Route down to the Arabs. There is an eleventh-century treatise in Arabic on "The Writing Base of Scribes and the Instruments of Their Intelligence," and it was about how to make paper. So paper came, of course, from the Arabs, came to Europe. In the beginning paper was really considered bad in the sense that the church was forbidding [scribes] to write the word of God on paper because paper was "pagan art," it couldn't be used for the Sacred Word. But slowly, paper landed on the table of the architect, and I think paper played a major role in the transformation of architecture. You can see, for instance, in this painting of Lotto, there is an architect, and of course, he's holding up a compass, and with the index he is really touching the top of the paper. Unfortunately, this is a slow misunderstanding of the nature of paper in relationship to architecture, and that has been caused by two lines: on one side the profession, on the other side Cartesian thinking, and the profession is very easy.

I was quite surprised when I came to the States and I learned that the light yellow tracing paper … is called "trash." Then I learned another word – and of course, I didn't know what it meant –"bum wad." Then I was told, don't use that in front of clients! But if you go on the Internet and punch in "bum wad," you get that picture, and they sell it, with the name. And basically, what happened here is, paper became something that doesn't have value. Of course there are exceptions. People can use tracing paper properly, like Venturi in the States. But paper, because of the way the profession billed the client, and because of the card saying that an image is like a little bit of ink that was through here and there on paper, basically, he invented the inkjet. Paper doesn't have an interaction with what you are designing, so the work of paper had become completely settled. And in 1994, when there was the invention of the so-called paperless studio, there was this pushing out of paper, the negative factor of the profession, and moving from the analogue to the digital mode was this way of breaking the condition and pushing for the environment.

But in reality, to understand what's going on with paper, we have to go a little bit back in time and use this distich, which was [used] for analyzing the text in medieval times: *Littera gesta docet, quid credas allegoria – Moralis quid agas quo tendas anagogia*. Basically, it is the four senses of writing: the literal, the allegorical, the moral, and the anagogical. Now a drawing really has these four conditions: it is literal because it is telling you the envelope of the building; allegorical because you have to rely on this kind of modification of representation; moral because it has to respect the very simple way, the building code; and what is pointing is the anagogical. Now when we transfer the idea from analogical to digital, we lose an *anogogia*, and that, I think, is the key issue: that we should really be able to understand how analogy is in the drawing or on the paper.

Now to try to understand a bit better what anagogy means, I have to do a little bit of etymology. Anagogy comes from the Greek, and it is the combination of two words, *ana* ("above, high"), and *agein* ("to lead"). The proper Latin translation, which was done immediately, was *sursumductio*, and can be found in writings of Isidore of Seville, Venerable Bede, or Rabanus Maurus. But slowly, the word *anagogia* came out, and really, in architectural drawings, the literal, the allegorical sense refers strictly to analogical constructs that speak to the tectonic and formal imagination. And of course they are didascalic in that sense, the tropological sense, which is, the moral sense speaks to the intellect free from the imagination. But what is the most important is *anagogia*, which really speaks to the tailors of that drawing, demonstrating that basically the future is in front of the past. And it is very important to understand, especially in the distich, that *anagogia* is the last one. There were many ways that it has been memorized for teaching, but there is always this condition – anagogy is the last one.

So it is in this formal equalitive condition that architecture is drawn to analogy. Of course, as we know, architecture started paperless … a paperless studio was nothing new. This, for instance, is the story that I copied from a book about how people went to build a paperless building. One went to the site marked with pegs and then looked where the woods were, where the city was, where the river was. He made all the connections necessary to build a building, and that was the first step. Then the second step was the use of the tracing floor. There was drawing, but this drawing took place on site, and they were in large dimensions. They belonged to the building and the operation was there. Now, of course, the next step is the analogical step, and it is beautifully described by Cesare Cesariano. The test is … when he shows the *iconographia* that is the plan of the cathedral, Milan cathedral, and he says that *iconographia* is an impression made over the ground or on dust (he is referring to the traditional abacus, which was a tray full of sand) – (this one is my favourite) – or on pasta. I could imagine the guy running with the pasta and a large sheet, and working this step on that or on snow ... and that is done with steps and leaving prints.

And then, of course, the game becomes that this operation on paper is done with two things: the compass (and that is clearly analogical ), the leg of the compass becomes the leg of the architect on the site, and with the litmus, which is the device that the Roman augur used to figure out the temple. And the litmus is this device – you know, the temple is something that was in the sky, not on the ground, so you had to draw with this stick of wood (which was supposed to not burn) the four divisions, waiting for the flight of birds. Then it was the projection down on the ground, done by crossing two lines, and that is basically what is called the sketch. Of course, I had to jump a little bit in history … because otherwise I would go on for hours and hours.

So I have to move from Cesariano … to Vincenzo Scamozzi, who has a very long chapter where he says, "I have been asked too many times how you prepare paper." So he [gives] this very complicated description of how he prepares his paper, how he makes it very nice with using sheets, one on top of the other, pushing, pulling, making the surface completely in support of the paper…. He talks about tracing the cross on the paper, but at this stage, paper becomes another tool, it's not only the support. He takes a piece of paper, folds it in four and it becomes a square. He is using these two lines and the paper itself on top of paper; he is performing this transformation of the design. So there is this change of the material; it's not the support anymore, but it becomes an active part of the game.

Now I have to talk about ink, because through ink we understand something peculiar. All of Scamozzi's descriptions about how you draw on paper, he says, you smooth it, you run ink on top of that – [this] is the normal understanding about how we think about the use of paper. But then he has a completely different understanding of it, and it comes through when he talks about how you make ink. He says, you get your gall, you put the [gall in wine] – of course it has to be Romanian wine because it is very dry and the gall is from Istria. Then you put it in a big jar and you put it in the sun for thirty days (which, by the way, is the same technique to prepare noccino: you take a big jar, you fill it up with nuts, you put it thirty days in the sun and you get your noccino!). He says that this is a very good ink because it works beautifully on the surface. Now toward the end he says that the ink has to be prepared, modified, and adjusted. It is the colour that is coming up, and he says from the purple hue, he washes, which gives elegance to the drawing, and from the fact that these light markings appearing in the back of the paper are the same colour. So what he's thinking about is the percolating of the ink through the paper.

There is this drawing, of course, what it does – there is the percolating and when the ink goes through you can draw on the other side. So paper takes a completely different nature because of these percolating qualities. (By the way, the drawing is here in the archives, if you want to see it.)  It is really the power of the paper that allows another understanding of the surface. Now let's move to *carta da luccita*, which is tracing paper – heavy tracing paper. *Carta da luccita* was there from the beginning. Cennino Cennini described how to make *carta da luccita*. He says, you take the paper, you take linseed oil, you run it on top of that, it becomes transparent, and you can work. Now the problem with that was it was very greasy, and it doesn't work. Sure, you could do a few things, but you couldn't use it in the architectural field. You had to wait until basically 1850, 1860 that finally someone comes up with a patent that is able to make good tracing paper. And, of course, there are the great inventions of drawing on tracing paper and the possibility of reproducing the image. . . . in Italian we call it *ideograffica*. They don't exist anymore, they are gone, and this obsolete machine made a different relationship between the papers.

I want to use these two cases: what happened is when there was the invention of the tracing paper, the architect prepared – and I am going to use Italian terminology because I like it better – *sotto lucido*, and then someone was going to draw on top, which was the *lucido*. In drawing in the *lucido*, you lost the analogical dimension of the drawing. That one on top by Carlo Scarpo, which is a *sotto lucido*, has been conceived as a *sotto lucido*, by which a second person will set on top, understanding all the notations that are around. He will prepare the piece of *lucido* to be printed and then sent for production. Now in this sense, the four senses are in the drawing, but the anagogic is lost when it is transferred. The one on the bottom is by Louis Kahn, and this is exactly the opposite mode. The draftsman prepares the drawing and he puts a piece of yellow tracing paper on top and he pulls it out, the anagogic sense. So the three senses, the literal, the moral, and the allegorical, are left in the *sotto lucido*. And the anagogic comes only in the *lucido* performed in charcoal and drawing. So basically, paper is this amazing device, that if we are going to transfer our understanding to the digital world, means not only that we have to understand how the phenomenon of paper was related to the analogical realm, but how the anagogical condition is there. It [then] becomes very difficult to know if the architecture is in the stone, in the paper, or in the Internet. But the key question is, what is that meaning that we can use behind the line? Thank you. (applause)

BENJAMIN PROSKY: Thank you very much, Marco. We will take a short, twenty-minute break for coffee....

# Peter Galison
# Epistemic Machines: Image and Logic

Ce qui m'intéresse dans l'histoire de la physique et l'histoire des sciences en général, c'est de suivre l'histoire, non à travers la théorie et les théoriciens, mais à travers les instruments, les techniques – et les techniques divise l'histoire de la physique et des sciences en général en trois tranches, si vous voulez. Une tranche qui représente le point de vue des expérimentateurs, une tranche qui représente le point de vue des gens qui font des instruments, des instrumentateurs, et puis des théoriciens, et ça divisent les périodes, en fin, les continuités, les non-continuités dans l'histoire de la physique différents. Alors, par exemple, pour les théoriciens il y a une différence énorme, coupure, dans l'histoire de la physique en 1926 avec l'introduction de la mécanique quantique, mais par contre pour les gens qui font des instruments, les gens qui font des expériences, il n'y a pas de non-continuité en ce moment là. Par contre, où il y a des non-continuités pour ce qui font des instruments, là il y a très souvent des continuités théoriques. Donc, ce que je veux vous proposer aujourd'hui, c'est comment on peut voir l'histoire de la physique moderne et surtout la physique abstraite […] si vous voulez, de la physique des particules en suivant cette histoire à travers les instruments, à travers la culture matériel. En particulier je suivrais comment il y a deux traditions qui ce sont developé dans le 20$^{e}$ siècle, une tradition qui représente la logique, si vous voulez, de statistique non-visuels et une autre tradition qui est plutôt visuel et que j'appelle la tradition image. Donc, Image et logique – Image and Logic : c'est le sujet que j'adresse aujourd'hui et puis on peut en discuter après comment ça peut faire des analogues avec l'histoire d'autres domaines en suivant aussi à travers la culture matériel. Donc, je m'excuse que je n'est pas peut venir à cette conférence très passionnant et vous êtes très tolérant de me recevoir en télévision. Je montre maintenant le "Power Point"; je continue comme ça.

I am going to be speaking about two traditions that organize the material history of modern physics: an image tradition and a logic tradition. These divide up the history of physics very differently from the way you would understand the history of physics if you only followed it from a theoretical perspective. From the point of view of theory, which is how we usually organize the history of science, you would see the great breaks as occurring at the introduction of special relativity in 1905, general relativity in 1915, quantum mechanics in 1926, quantum field theory in the 1940s, quark theory in the 1970s, and so on.

But we can look at this very differently. And if we look at it through the material culture of the discipline, then I think one sees a very different perspective on how history might be thought of. In particular, there's a traditional way that goes back to the time of the logical positivists in philosophy of thinking about science as being grounded by observation. And observations were cumulative, continuous; they mounted one after the other into a great aggregation of observations, and theories came and went.  You had a theory, and then a break, and then another theory. But theory was there only to organize the observations, which were the true strength of what science was about. I'll call this for short "the positivist periodization."

Then in the 1960s and afterwards, there was a new way of looking at the development of science that was made very popular by Thomas Kuhn and Mary Hesse, Gerald Holton Hanson, and many others, who said that essentially that's not right – there is no thread of observation that carries through all of science, and that, in fact, science is divided into blocks that are discontinuously related one to the other. Theory and observation went together in the old account, for instance, of Newton and classical physics, and that was replaced by a new way of looking at theory and observation under Einstein. Between them was a revolutionary paradigmatic break, a change in program, a radical disjuncture so enormously deep-going that it really became impossible to speak about science as being a unitary phenomenon that carried on over time, instead only in discontinuous blocks.

What I want to propose today in this discussion, and what I have been pursuing in my work for quite some time now, is to think of this in a rather different way. To say that the anti-positivists like Kuhn, for instance, were onto something very important when they said that observation was not continuous, that certain things came into view as possible observations and other things became impossible as theory changed – that's true. But that, in fact, from the point of view of the different subcultures of physics, from the subculture of the experimentalists, the theorists, and the instrument makers, there are different periodizations – they don't march in lockstep. That the instrument makers may find a break with the invention of the cloud chamber, for example – that's not a break for the theorists. The theorists may see a break in the development of general relativity – that's not a break for the experimentalists, and so on. In fact, the intercalated nature of this periodization, the way that they fit together like a brick wall or an old stone fence, gives it the strength that we recognize in science. What's interesting to scientists is, in fact, that they are able to move across different theories. But partly, I want to suggest, not because theory is continuous or indeed any part of science by itself is continuous. Rather, because the breaks occur differently since they are intercalated rather than lined up.

But that raises another question. If there are really three subcultures of physics or more, how do they talk to one another? How is it possible for the experimentalists, who find different ways of proving things or demonstrating things than the theorists do, if they have different epistemic approaches to the discipline, then how do they have contact? And what's been very useful to me in thinking about this is to think about the different cultures of physics, or of science, more generally, as being rather strongly analogous to the languages that we know in everyday life.

When anthropological linguists address the way languages relate, they don't, in fact, look only at radical disjunctions of language, which is the model, for say, the Kuhnian picture of great epistemic revolutionary breaks. Rather, the anthropological linguists have increasingly been interested in the way partial exchange languages or inter-languages function. They distinguish between jargons, very limited terms that are shared by different languages, and pidgins, which are more developed sets of ways of speaking that allow, for instance, a wheat-growing culture to exchange goods with a fish-based culture. But these are now more developed in order to allow them to make these very important exchanges: to negotiate agreements, to form cultural commonalities between them. And then there are Creoles, which are full-fledged inter-languages that are developed to the point where you can grow up in them, and in a certain sense, all of our modern languages are themselves Creoles of earlier combinations. There's no reason to think that there is, from everything we know about the history of language, to think that English, or French, or German are primordial languages – they are themselves compositions of earlier languages. And in fact, that's the rule, not the exception.

So what I want to do is to look at this. Take, for example, chemistry and biology, and to see the formation of an inter-language that eventually becomes biochemistry, but begins with very limited terms, develops into a more elaborate form of exchange, and eventually blossoms into a discipline, biochemistry, that one can indeed grow up in. That happens too, in ways that I'll point to, between the instrument makers, the experimentalists, and the theorists. What do I mean by a tradition of material culture? I have in mind three layers of handing-down, the literal meaning of tradition in this sense.

First, there is a tradition of technology. So, for example, one goes from the cloud chamber, which is a device that precipitated little droplets of water around the track of a charged particle as it went through the chamber (you may have seen these very beautiful devices that leave these wispy tracks in them, in demonstration); to bubble chambers, which are devices that make tiny little bubbles boiling as if a charged particle goes through them; to film, which can be used to allow a particle to skim along the surface of the film and then develop it and look at the tiny depositions of silver composites that allow one to follow the tracks under a microscope. And so at one level, I'm talking about a technological tradition, a handing-down on the one side on the image tradition of optics, photography, of the measurement of the path of particles, and on the other side the more electronic, logical, statistical tradition. I have in mind the use of high-voltage machines, electronics, scalers, which are devices that count, and so on.

Then there's the tradition of pedagogy. And when one looks at the history of experimental science, one sees that there are certain forms of devices that are handed down, just as the cloud chamber and the bubble chamber, and the film share certain techniques. Also the actual handing-down from physicists like [Robert] Millikan, who won the Nobel Prize for showing that you can make little droplets form around individual electrons and determine their charge, his student Anderson, who built cloud chambers, his student Glaser, who built the first bubble chamber, and so on. People tend to remain, generation after generation, scientific generation after generation, within these pedagogical traditions that carry on, for instance, from the cloud chamber to the bubble chamber, or from the emulsion to the bubble chamber, or from the cloud chamber to emulsion, rather than crossing from one to the other.

And finally, there's a tradition of demonstration, an epistemic tradition. There are certain ways of arguing that are characteristic, that go with each of these traditions. So, for example, within the image tradition, physicists from many scientific generations and over all of these different instruments – bubble chambers, cloud chambers, nuclear emulsions, that is to say, films – there are golden events, individual images that are so clear, so compelling to the physics community that that forms a kind of demonstration. Whereas on the other side, is the side combining clicks and counts of objects from a device like a Geiger counter, where any one click means nothing and only the statistical aggregation of clicks amounts to something. I have in mind these three meanings of a tradition or a culture of physics at the instrumental level: technology, pedagogy, and the epistemic forms of demonstration....

Looking back at the history of physics over the course of the twentieth century of particle physics, instead of saying, let's break this up into the great discoveries or even the great objects of physics from atoms to quarks, for instance, as a standard way of understanding the development of modern physical science, instead you could say, let's look at these two traditions. On the one side, a tradition of image, in which the cloud chamber hands down its techniques, pedagogy, and forms of argumentation to the nuclear emulsion to the bubble chamber and the logic tradition begins with the ordinary Geiger counter that you've probably seen many times, which clicks when it gets near a radioactive source, but then can be combined in much more sophisticated ways. So, for example, will only click if three Geiger counters in a row are all struck by a charged particle, and these then could be expanded to form not just the tubular Geiger counters but flat sheets of conductors that can be used to make sparks and wire chambers, thousands and thousands of wires that are then used to measure the passage of a charged particle – all of these share their own pedagogical, technological, and epistemic forms of argumentation.

Then in the 1970s these begin to join, and you have on the one side the ability to produce images and even to argue from individual images in the way the image tradition had for many, many decades. And on the other side to control the situation, to have a kind of statistical approach and an ability to manipulate the device and the phenomena the way one had in the logic tradition. I think this is a much more general pattern if you look at astronomy – optical astronomy and radio astronomy and how they've joined in image-making electronics, or in medicine, between a non-visual and a visual tradition joining in nuclear magnetic resonance and other devices that actually produce pictures based on the combination of thousands of channels of electronic data, you see a similar development.

Just to elaborate on this a bit, to show you the idea of the logic, a logic ... the way physicists mean, for instance, that counter "A" gives off a signal and counter "B" gives off a signal, but not counter "C." So it's this combination of either/or and *and* that composes the way these electronic devices function. And that's true for the counters that I illustrate on top here, for spark chambers, which are an extension of those ideas. These are unrolled Geiger counters, if you will, or wire chambers, which in a certain sense are thousands and thousands of the inner wires of these chambers spread out in such a way that you can make extremely precise determinations of where the particle went and reconstruct its path.

The cloud chamber sits at the beginning of the development of the image tradition and the cloud chamber leads to, on the one side, to looking at tracks on film, the nuclear emulsion, and on the bottom of the screen, the bubble chamber where the tracks leave not a wispy line of droplets as they do in the cloud chamber, but a wispy line of bubbles boiling along a highly compressed and superheated liquid. That image tradition begins in a certain sense, out of natural history, not out of anything to do with atomic physics or chemistry.

C.T.R. Wilson, who invented the cloud chamber, began by being interested in clouds. These are pictures that he took as a young man up by Ben Nevis, where he grew up. He was fascinated with beetles, and natural history, and all of its aspects in the Scottish Highlands, but especially with clouds and weather formations. He spent time, for instance, as an apprentice to the meteorologist on top of Ben Nevis, where this drawing is from, and there he saw devices like what is called a dust chamber. A dust chamber was used – it's been a standard way used by meteorologists – to take samples of the air and then to change the pressure around it and allow water droplets to condense around the dust particles, which then fell on a glass slide, so you could count them. Victorian Britain was obsessed with dust – they thought it was the source of disease but also the mark of progress – and these devices became very popular and part of the standard account of what launched rain, how rain worked. It was, they thought, the condensation of water around dust particles.

Well, Wilson saw this and began to wonder whether it might be possible to change the device – this is one of his first sketches of what he wanted to do from 1895 – but he changed something very interesting. Aitken, who invented the dust chamber, would take a sample, which you see on the left, from the reservoir from the local atmosphere, pump it into the reservoir, and then it would go into the chamber where the pump would change the pressure and cause the droplets to go around the dust particles, which would fall on a glass slide. Wilson took essentially the same device, but he filtered the air before it went to the reservoir. Now on the face of things, that should have made this device completely useless: it was designed to measure dust. But Wilson had the hope that he might be able to show that water droplets could condense around ions, atoms that were somehow more or less charged than their normal neutral state would indicate. So he changed this, and he changed it because he had been exposed to the new physical theories and new physical approaches of the Cavendish Laboratory of Cambridge. What Wilson did was essentially to say, how could we use this device that's used to measure dust – just ordinary dust that you can sometimes even see with the naked eye, or certainly with a microscope – and instead use it to explore a possible source for rain on the one side or a way of tracking these ions, on the other, by looking at water droplets condensing now around purified air, around air that has no dust in it.

Wilson soon began to see something quite astonishing. People had begun to predict that atoms, actually when they collided with one another, were like little BB's hitting one another. Not that matter was more like a pudding, but rather it was divided as Rutherford argued into very hard nuclei surrounded after a big distance by electrons. So people began to speculate, as in this picture here, about how those collisions would look. When Wilson actually could show photographs of charged particles moving through his cloud chamber – it's called a cloud chamber because it really issued from his interest in clouds, but suddenly was able to see the paths of individual particles – they looked so much like what the physicists had expected that it caused a true sensation, and almost immediately physicists around the world – this is starting in about 1913 – began to say this would be a way of actually seeing atoms, of making the invisible world of physics, visible.

On the other side, that is to say, on the logic side, people were beginning to combine Geiger counters using complicated – what for the time was complicated – electronics, and even began exploring ways to use Geiger counters, under certain circumstances, to launch a cloud chamber. [They were] trying to combine the enormously helpful ability of the counters to pick out a certain kind of event and to count only those events that are interesting, and to combine that ability to be selective with the beautiful visualization capabilities of the cloud chamber – and this was a device like that. Some physicists in the early 1930s were trying to use counters to launch the cloud chamber only when something interesting happened – only when, say, counters "A," "B," and "C" fired, but not "D," "E," and "F." By using counters in this selective or logic way, they could get more control over the cloud chamber.

And the cloud chamber, meanwhile, blossomed into one of the most influential instruments ... in some ways, the first half of the twentieth century had the cloud chamber the way earlier centuries had the microscope or the telescope. The cloud chamber, in this picture, showing an electron spiralling around in a magnetic field as it loses energy and winds in a helix more and more tightly, was so fascinating that [they] even began to make atlases, scientific atlases, of cloud chamber pictures, which is where this picture is from. And the young physicists would study these atlases the way young doctors would study atlases of physiology, abnormal physiology, or pathological physiology, in order to recognize things that were new. In this case, the physicists, rather than finding departures from the norm to be pathological as the doctors did, they would say, once you learned what the standard pictures were, the hope was that then if you saw something different it would be a discovery.

So this new form of device became the basis for a new kind of epistemology, a new way of looking at the world, and new kinds of arguments began to develop out of it. In a sense, you could see the history of the cloud chamber this way. You could think of, in 1895, Wilson joining two completely disparate fields, on the one side, Cambridge-style matter theory – what is matter made of, are they little ions, how big are these ions, how do they compose the ordinary objects that we know – and then this other tradition, practised, for instance, high up on Ben Nevis, trying to understand what made thunder storms, how do they work, how did lightening happen, how did large-scale meteorology function. What Wilson did was to do something that was a contribution to both, and indeed was inseparable from both. He was looking at how water condensed on ions that showed the ion physicists where the ions were, because you could see these droplets, and watch the paths that they made or even move the droplets around as Millikan did to determine how much charge there was on an electron. On the other side, it was a way of showing how rain formed, and Wilson believed very strongly, against what we later came to think about rain, Wilson believed strongly that this was the true source of the rain that made up thunderstorms.

So for some years between 1895 and 1911, roughly speaking, there was one subject, a new subject composed as a hybrid of matter theory and thunderstorm theory, if you will, or thunderstorm observations, and that you might call condensation physics – it was the condensation of vapour around a charged particle that was at one and the same time part of understanding matter and part of understanding drops. In about 1911 that begins to splinter into all these other areas, but for this period of sixteen years there’s a joint feel. They form what you could call a trading zone, an inter-language that’s materialized in these new devices, a form of acting in the laboratory that is both connected to morphological meteorology and Cambridge- style analytic matter theory.

And that’s the phenomenon that interests me, where you see the different scientific cultures or even scientific and non-scientific cultures joining together, sometimes for long periods, sometimes for short periods, borrowing pieces of each and combining them into a conjoined effort. Wilson’s students go on. They become the leading cloud chamber physicists. They are also the people who begin to develop nuclear emulsions. One of his students, [C.F.] Powell, is interested in steam, and steam in the way turbines work.... Powell actually did detailed studies of how something as practical as steam functioned in these massive turbines. He also became interested in how steam worked in explosive volcanic eruptions like this one on Montserrat, which was a tremendous fear.  In fact, Powell was there to study these very dangerous explosions in which superheated steam goes down under the lava and makes it possible for the lava to travel, not at a stately pace, but actually to race down the slopes too fast for anyone to get out of the way. These are extremely dangerous forms of volcanic eruptions, and Powell was sent to the island to understand the way this condensation physics worked.

One of the interesting things he does is get to Montserrat to set up observers, what he calls "untrained observers," who are going to make seismographic and other forms of observation all over the island. That becomes extremely important for him when he hears about the new discoveries that are being made in physics, and, in particular, hears about the discovery in the 1930s of nuclear fission. So he comes back and begins to try to use the cloud chamber to study this new phenomenon. He soon discovers that it's not really a very good instrument for that, but takes this visual orientation and starts to think, "How else could I make these charged particles visible?" And he says, "Maybe I could do it with film."  Interestingly enough, he takes a piece of film – this is probably no bigger than a couple of postage stamps – and divides it into little sectors and sends them out to what he calls "untrained observers." Again, modelling what he's doing in the laboratory now on the way these observations of volcanic activity had been organized back on the island of Montserrat. And he sends them out to group "A," group "B," group "C." Each one of them receives a tiny slice of the film and then has to study it under enormously delicate measurements through the microscope. That instrument then gets adapted using film in this way to study how nuclear fission works in bomb physics.

In fact, for a long time it was a great mystery to me why in the middle and just after World War II this study of these nuclear emulsions, just ordinary film, to try to see how and where particles go, was so lavishly funded when, in fact, in Britain in '46, '47, '48, everyone, in sciences, in particular, was desperate for money; there was no money for any of this. It turns out from these declassified documents, one I show you here, that the emulsion had actually been very useful in understanding how neutrons move around in atomic bombs, and this was work that was conducted in part in Canada in Chalk River and part in England, and then in part in the United States. And so little by little they needed to get better and better film. One of their problems was they had film – like that shown on the left, here – that was very difficult to actually see the track and measure it against the background of random other silver particles. So the physicists struck what I think of as a Cassandra deal with Ilford and Kodak, and they said to Kodak and Ilford, "Will you make us an emulsion that will show the tracks of all particles very beautifully?" and the company said, "Sure, we'll make you a film like that, but we'll have to do it in such a way that we will never tell you, ever, how this film works. We will design this in such a way that you will never really have the confidence that you understand your own instrument, but we will make you a film where you can see everything, but you may not be able to believe it."

In any case, the physicists accepted the deal. They had little choice; it was such complicated chemistry. There was only one physicist in the world who was actually able to make these emulsions – and I'll come to him in a moment – but the picture on the right is what was given by these new emulsions. The one physicist who was able to do this on his own, actually a Canadian physicist named Demers, showed how he thought of the field in this very interesting picture. It may be hard to read, so let me just give you broad outline. He says that there are two aspects: the *aspect processus* and the *aspect detection*, and he essentially divides the world into physicists who are looking at the way cosmic rays work, the way the basic elements of matter function – they're on the top and all the applications that they're going use these films for are up there. And then there are the people, in some parts like him, who are interested in the way film works and what this tells us, much the way Wilson was interested in the way the droplets condensed over the ions, and you could either think of that as telling you about droplets or telling you about ions.

So Demers said you could either look at this from the detection aspect or from the process aspect, and he formed a kind of trading zone between the two with his allies and co-workers. And they began to form a way of thinking where the physicists could talk to the film people in a way that they could communicate with one another, but which required a lot of adjusting because people that made film knew nothing about nuclear fission or other processes of physics, and the physicists knew nothing about how emulsions worked or how suspended colloidal particles worked; this was really a mystery. In fact, when you wanted to make these films, you had to use the hooves of pigs that had grazed in a certain form of clover, the kind of things that physicists never wanted to know. But again, one could form a trading zone where they could learn enough of each other's language to communicate, and these pictures then became crucial, again providing golden events that were able to show individual phenomena well enough to persuade people on the basis of a single picture.

Now after the war, the Americans took a path into physics that was predicated largely on these very large-scale approaches to the discipline, but which they, in fact, had developed during the war, either with the radar project, which was a two-billion-dollar project or through the development of the atomic bomb, which was another two-billion- dollar project. The Europeans obviously had nothing like the resources that were available in the postwar scene. Many of their laboratories had been destroyed, many of their students had been killed or murdered, or emigrated – it was a completely different scene. So the Europeans turned hopefully to the idea that you could make small-scale physics work by taking your cloud chamber or some other instrument, or nuclear emulsions, up to the top of a mountain, like this one – that's a laboratory that you see there, wedged into the side of the mountain. But these were tiny experiments that cost nothing, whereas the Americans had predicated, had drawn up plans for their laboratories during the war, based on the large military and industrial-scale efforts. In fact, this chart, which was drawn the day after Pearl Harbour, December 7, 1941, was a model for the laboratory that was going to build radar based on the techniques of organization that had been used in military and industrial situations.

So you can begin by looking at the material culture of science, the physics, you can begin to see these much broader features about what scientists want from their discipline, what kind of culture do they want to live in, and what counts as being a physicist. It wasn't all Europeans versus Americans in this sense. Here's a very important example of dissent from the large-scale physics inside the American tradition. As I mentioned before, Millikan was used to working by himself or with one collaborator. He won the Nobel Prize for work that was done essentially by himself. His student Anderson won the Nobel Prize for work that he did with the cloud chamber, too. Also just a two-person collaboration, and his student Glaser grew up – he was too young to participate in the World War II projects – and he began to wonder, "Could I make a device – like this cloud chamber that you see here – that would be able to show a much more accurate development of an image, say, in a liquid, causing bubbles to form in a liquid rather than droplets in a vapour?" And so – this is from his notebook in the early 1950s, and you can see there are conclusions – tracks can be photographed. What he did was a tiny little experiment – this is the first bubble chamber – it's about as big as your thumb, and you see the track forming, no track on the upper left, the track forms on the upper right, and then the bubbles begin to grow bigger and bigger into a useless mess, on the bottom of those pictures. And these are pictures taken with a Polaroid camera taped into his notebook, using his parents' old movie camera, 16 mm movie camera, and the speaker magnet from his stereo. This is very small-scale physics built deliberately, so he wouldn't have to work in laboratories of a scale and scope that had come out of the war where the big accelerators that followed were.

But as soon as this device was shown to people, the big physics types, like Luis Alvarez at Berkeley, said, "I want one of those, only I don't want it as big as my thumb, I want it as big as a factory," and within a few weeks he was working with the people who came off the atomic bomb tests in the Pacific atoll building versions of this behind a blast wall – this is a heat exchanger that's used. The scale of these things is immense. But even then as physics was growing in size, there were others who wanted to keep it small.  In fact, at my university joined with MIT, there was a bubble chamber laboratory just down the street from where I am now, where they insisted on not following Atomic Energy Commission rules, not having safety officers, and not having the military-style discipline, and security system, and code words, and so on. Instead, they allowed people to build these bigger and bigger chambers on their own. Unfortunately, they were working with liquid hydrogen, and one day the much-feared event happened, and one of these chambers blew up. This is from that explosion in the early 1960s, and it was a catastrophe. It not only killed one technician, wounded several other people, young physicists, but it also put an end, definitively, to big physics conducted in the style and manner of an earlier age of physics. After this event, and even some of the physicists admitted that it could have happened in one of the more militarized laboratories, after this, nowhere in the world were people allowed to work with bubble chambers outside of this much more industrial scale and form of work. This is what the large-scale bubble chamber looked like out at Berkeley, or a piece of it. It's actually much bigger than this, and it represented, in some sense the pinnacle of the pure visual tradition.

But by the early 1970s, the more and more sophisticated electronic tradition and the more and more sophisticated image tradition began to realize that in some way they needed one another. Instead of trying to do experiments in which particles came in and went through a series of detectors, as you see on the bottom here, they wanted to make experiments in which, say, a proton and an anti-proton or an electron and an anti-electron would collide head on and annihilate each other, producing much more energy than would be possible than from these so-called fixed targets. And now the target is another particle heading in the opposite direction, and the amount of energy released was enormous. These sorts of experiments created devices that looked like this, and now at a scale that was going to produce, in some ways, electronic images, and these devices were built out of teams that were composed half from the image tradition, and half from the logic tradition. So they began to produce images like this from an oscilloscope, and the logic tradition people took this and counted them and did statistics, and the image people tried to treat them like old- fashioned bubble chamber pictures. It shows you how powerful the epistemic aspect was – the way of thinking that went with each of these traditions. And then, other devices: here's a model of one – this is a much bigger version of it beginning to be formed, where each laboratory is responsible for one of these different colour-coded parts.

So you have a collaboration that instead of being two or ten or fifty or one hundred in the current epic is beginning to have thousands of people, and certain experiments that are running now have between two and three thousand physicists and an equal number of engineers. These are gigantic episodes that create a new sociology of work where people argue about whether a cable will go through one part of the machine or another as if they were defending their turf from the invasion of a high-power line running through their community. We're looking at this device, which shows you what happens when the mechanical engineers and the electrical engineers won’t talk – the electrical engineers wouldn’t talk to the mechanical engineers until the mechanical engineers had to wire these ... tubes of copper around the edges to cool the machines that the electrical engineers had built. And the machine, in fact, was so badly designed that it blew up....

Even in the software you can see an architecture of separation where different groups … you could look at this picture and look at the right- hand side there and see that there’s a line that doesn’t connect to any other lines. And, in fact, that corresponded to a group within this larger meta-group that wasn’t talking to the others. Its software wasn’t communicating between raw data and the final conclusions of the experiment. There was a flow that did not connect. So in the architecture of hardware and the architecture of software and the architecture of the machine, in all of these aspects, one begins to see the sociology of the material culture itself that affects the kinds of arguments that are made. But eventually by the 1980s you begin to see images like this one that are actually electronically composed. So this is the first image of a particle whose existence was argued for on the basis of a single picture produced as a hybrid between image and logic.

The last thing I wanted to mention was that these trading zones, these zones of exchange between these different cultures, can sometimes be seen in the physical architecture of the laboratory itself. This is the first nucleus of the radar laboratory at MIT, where each of the components of the radar had a different room, and yet, if you look at the people – I found this wonderful picture that showed who was sitting at which desk, and you can actually see within the components, say, within the antenna group, or within the transmitter group, you would find engineers, experimentalists, and theorists, all talking to one another, all desperate to figure out how to understand devices like this that required some theoretical work as well as more of engineering work. In fact, you can see that structure for creation of these exchange zones. Here is a picture which was drawn because the engineers and the physicists at Chicago were at such loggerheads that the physicists told the president of the United States they would fail in the war effort against the Germans if the physicists were not allowed to dominate the project. And the engineers wrote back and said, “It’ll fail if you trust the physicists.” Finally, one of the heads of the atomic bomb project wrote down this chart and specified exactly how the lines of communication were going to work. I know this blueprint is a little hard to read, but there’s engineering, and experiment, and theory, all brought together and put into, in a sense, the forced contact it gave rise to [as] a new way of understanding physics.  So I leave you then with this thought, that if you look at the development of physics or of science, or of science and technology by focusing on practices and techniques, we find ourselves very quickly raising questions that are on the one side as grubby as machines, as sociological as who talks to whom, and as linguistic as the kinds of terms that are used, and as abstract as the forms in which scientific knowledge is composed. Thank you.

DERRICK DE KERCKHOVE: What a sensational lecture!  Peter, thank you very much for this. This lecture actually taught me a new way of interpreting the medium as the message –what you call the epistemic affect. I thought that was totally fascinating. We are now going to listen to Mario Carpo, who is the Consulting Head at the Study Centre, Canadian Centre for Architecture, and Associate Professor in Architectural History, École d’architecture de Paris, La Villette, and he’s going to talk about building with geometry and drawing with numbers. After his talk we will have a chance to ask questions and talk to everybody. And, grazie, Peter, you are staying with us, so thank you very much. Mario Carpo ...

# Mario Carpo
# Building with Geometry, Drawing with Numbers

According to a commonplace of recent historiography, the Renaissance might have been the only period in architectural history when the rise of a new style was not related to technology change. The Gothic forms of the Middle Ages were abandoned and the old forms of classical antiquity were brought back to life, and reinterpreted, but no new machinery, no new material, nor building technique accompanied this revolutionary change in architectural forms. True as this may be, one might argue that some technological change did nonetheless accompany the rise of Renaissance classicism. These technological changes may have gone unnoticed because they did not pertain directly to building technologies. In the Renaissance, like now, new information technologies, instead of building technologies, were the agent of change. New information technologies brought about some new devices of design that in their turn revolutionized the process of building and changed architectural forms.

The Renaissance design process disrupted the traditional medieval way of getting things built, but the early modern way to manufacture or to reproduce the architectural forms of classical antiquity was also completely different from the way the ancients had followed, to create both forms in the first place. The same forms were obtained using two very different technologies of design. The modern way, invented in the Renaissance, remained a staple of Western architecture for the five centuries that followed; it is only now being phased out and replaced by a new one. This is, perhaps, one reason why we are more likely to be aware of this all-important historical watershed that took place in the sixteenth century. We tend to recognize the beginning of a historical age only when we have a perception that the same age may be coming to an end.

To better [illustrate] my point, let me compare a very simple component of the system of the architectural orders that was a bestseller, so to speak, in classical antiquity, as it was for generations of modern classicists from the fifteenth century to the twentieth century. And now we can see the picture.

The Attic or Doric base, which means a base, you must imagine, at the bottom of the column (which is not drawn here) as described by Vitruvius, here illustrated by a drawing – which I have to confess is not by Vitruvius – I made the drawing, as Vitruvius apparently forgot to provide drawings – is composed of six superimposed parts. As you see, each part has a name, but for brevity, let’s just call them from top to bottom: part 1, 2, 3, 4 (which is identical to 2), 5 (which is identical to 1, but it is proportionally bigger), and 6 (which is the plinth).

The rules for establishing the proportions of the path of each part, as explained by Vitruvius and marginally edited for clarity by Leon Battista Alberti fifteen centuries later, read as follows (we can have the next picture):

First, you take the diameter of the column and you divide it into two equal parts.
You divide that segment into three equal parts. Take away the lower third (that is, the plinth). Next step, take what remains, make a new unit of it, divide it into four equal parts. Take away the upper fourth: that gives the upper torus. Take what is left, make of it a new unit, divide it into two equal parts. Take the lower half, that is, the lower torus. You take what is left, divide it into seven identical parts, take away the upper seventh and the lower seventh: that gives the two fillets. Take what is left, and, fortunately, it is over because

there is nothing else to be proportioned. And that's the end of the process.

I have rendered Alberti's instructions in this diagram to determine the size of each part of the base. Alberti (here acting as an editor of Vitruvius) guides the reader through a five-step sequence of successive divisions – letters A to F, at the bottom. Each step, however, is formally identical to any other step in the sequence, and each reads as follows, as I just emphasized:

Take a segment, divide it into a given number of equal parts, take away one of these parts, take what is left, assume it as a new unit, then go back to step one and rerun the program, as we would say today, this time five times.

This way of determining the proportions, and then the dimensions of an architectural part, has its charms, but it is not the way we would do it. Our way, which is the modern way, came into being by steps in the course of the sixteenth century. First images of the Attic base were printed thanks to the then new technology of printing, something which neither Vitruvius nor Alberti could have done (picture 3). And of course the then new technology of printing was depending on the newly found availability of paper, as was said earlier today. Serio printed the proportional (newly arrived in the West, I mean) drawings of the base, proportionally drawn to scale, and he added the name of the parts, which of course can always help. Then a bit later in the sixteenth century, both Vignola and Palladio printed the same scaled drawing, but they added the proportional or modular measurements of all the parts (picture 4). This is Vignola – and we actually should see the numbers, so shift it either to the right or to the left, or alternatively to the right and to the left because there are numbers on each side – and the next is Palladio, a few years later. And actually, Palladio himself put the numbers twice – on the left and on the right. You can see the very small numbers, which indicate the modular proportion of each three parts of the base. Don't try to add them up because the addition on the left and the addition on the right do not correspond; I never could ascertain if that is by chance or by design. The difference is between Vignola and Palladio. Vignola used a module divided into eighteen parts. Palladio used a sexagesimal partition, as we still do with minutes and seconds. Vignola and Palladio could not use the decimal point for the simple but determinant reason that the decimal point – in Europe the decimal comma – had not yet been invented. However, these differences apart, this is a language both visual and numerical that twentieth-century engineers would still understand and would still be fully conversant with. Even more so, engineers trained in the foot and inch or Imperial system, as many tend to be on this side of the Atlantic, a system which is much closer to Vignola's and Palladio's fractional universe than to the Napoleonic empire of decimals.

In short, what we have seen here are two ways to produce the same object. The first way, the Vitruvius/Alberti way, which is classical but also medieval, is based on text and geometry. The second way, which is the Palladio/Vignola [way], which is modern and basically still the one we use, is based on drawings and measurements. The result may be the same, but the two processes are not. In the first case, each operation in the sequence is an elementary geometrical partition, which can be performed mechanically, perhaps, manually, I should say, with a straightedge and a pair of compasses, and without any need to perform any number-based operations. A pair of compasses can divide a given segment into a given number of equal parts, without any need to measure the segment or to use numbers to calculate the result. It is perhaps not by chance that compasses are also known in English as, I was told, "dividers" – I hope this is still the case. Does it make sense? Good. Because compasses – this is what they do best, they divide, but [they are] not good for multiplying. On the contrary, the second way, which is still on the screen, obliges the user to read the measurements with proportions in the drawing, in this case, sexagesimal degrees; multiply these numbers by one or more other numbers in order to determine the final dimensions of the real size of the object. This second method, which presupposes, requires, numeracy, and the use of Hindu-Arabic numerals to perform the basic four operations of arithmetic was a relatively new discipline in Europe in the fifteenth and sixteenth centuries, when it was know as "algorism," from the Latinized name of its inventor, Al-Khwarizmi, a ninth-century scientist from Baghdad, a city which still exists (or still existed two hours ago).

The old geometrical method had some advantages. It did not require the use of numbers – a decisive advantage at a time when most people did not know how to use numbers, and modern, Hindu-Arabic numbers did not exist. (next picture) [Roman] numbers are not good for calculating. We can do that on the left, but try and do that with the numbers on the right, and we would still be here very late in the day. We could use an abacus or finger reckoning, but then you would need 136 fingers! So additionally, a sequence of geometrical instructions, as the ones we have seen, is a narration, a recital of sorts. It can be recited aloud, unfolding in real time – more or less, as I did – the time that is necessary to perform the operations that are described. And then as now, one remembers a story more easily than a list of telephone numbers: geometry is the doctor of orality, and a good friend of memory. On the contrary, the new number-based instructions of Vignola and Palladio are difficult to memorize, and they are better recorded and transmitted in writing. (next picture) They are even better recorded and transmitted in print. This is Vignola's rules of the orders, translated into numbers by a nineteenth-century manual for the École des Beaux-Arts. Difficult to learn by heart, but also, it is better if it can be printed rather than hand-copied, because mechanical reproduction reduces the risk of mistakes that would inevitably occur when copyists could transcribe pages and pages of apparently meaningless numbers. Now print made this transmission reliable.

The geometrical way, however, featured another even more crucial advantage. A geometrical construction, such as the division of a segment into two equal parts, is an entirely mechanical and analog operation that can be performed regardless of scale or size. With a small pair of compasses, it can be carried out at the small scale of a drawing on paper, provided that you do have paper …we know when that happened. With a bigger pair of compasses, you can perform the very same operation, but at the real size of the building – or at any other scale, for that matter. (next picture) This is Serlio's title page, 1540, and the lady in the middle, Mrs. Architecture, as it happens, doesn't have many accoutrements on her, but she does have a big pair of compasses – you can see that – fairly big. I try to carry a small pair of compasses because I wanted to make an on- site demonstration, but that was foolish of me. I could not bring them on the plane; they were detected by a metal detector. I had to explain to the customs security officer what that thing is. I said, "Well, I need them to argue, as I am trying to argue, but for centuries this was a weapon of mass construction." (laughter) Which in retrospect was not a wise thing to say – security officers are not keen on learning the history of architecture, so don't do that! But anyway, we agree that geometrical constructions are a tool for building if you use them with a big pair of compasses, as well as ... a tool for drawing, if I had had here the small pair of compasses, which I had to leave at the security control. So much so that in a geometrical environment the making of scaled project drawings may sometimes be unnecessary. Let's think of it – geometry can generate the real thing at real size on the real site without the need to go through the laborious mediation of a preliminary small-scale drawing on paper. We have seen some tracing on stone just one hour ago, made presumably with a pair of big compasses.

On the contrary, small-scale proportional project drawings, with or without the addition of number-based, or digital, measurements, are separated, both physically and ideologically, from the materiality of building – again, thanks to paper. You could not do that on parchment or papyrus because it would be eaten by rats. Design and computation, so long as they can be put on paper, do not belong to the building site. Project drawings exist and reside on paper. Such paper prefigurations of future buildings must at some later point be translated into real-size, full-scale, three-dimensional objects. These translations of drawings into buildings is an operation of proportional enlargement, also known in French as *homothétie* –I don't know what it is in English, homothety, perhaps – Scaled project drawings must be enlarged by 10, 50, or 100 times or in the foot and inch system, 96 times, which many Europeans still find peculiar, in order to be converted into stone. Only – this is the snag – this translation or proportional enlargement is not always an easy matter. In some cases, a three-dimensional model might help, but in most cases, the iron law of transference from two-dimensional drawings to three-dimensional objects applies – we can only measure what we can draw, and we can only build what we can measure in a drawing. In short, if you cannot draw it, you cannot measure it, and if you cannot measure it, you cannot build it.

It follows that within this logic, the forms that we can build are determined by the power or the potency of the mathematical language at our disposal. If this language is basic algorism, or the arithmetic of the four operations, as it was for centuries, we can better measure, hence build, segments of straight lines that are all parallel or perpendicular to one another or that intersect at fixed angles on the same plane or on parallel planes. Such limits lead to objects that are grid-like, repetitive, and discrete, as numbers are. On the contrary, geometry can construct lines and surfaces that are continuous and bending, and curves that might be difficult, or even impossible, to measure. This is because geometry does not need to measure lines – lines are simply laid out mechanically, they are made on site, full-size, using compasses, and ropes, and nails, and chalk, and chisels, and all kinds of mechanical tricks.

Builders in classical antiquity constructed sophisticated curved surfaces and continuous lines that a twentieth-century engineer would have struggled to describe these numbers, such as the barely perceptible rise towards the centre of the platform or stylobates of Greek temples – so barely perceptible that I do not have an image of it – or the spirals of the Ionic volute (next picture), geometrical construction, or the entasis of the shaft of the column (next), another mechanical operation. So this is how to build the entasis – two ways: a geometrical construction on the right, but even better, a machine with two sliders – if you can operate it, you create the line for cutting the stone with the curved continuous line of the entasis of the column on site, full-size, without any need to measure it – which is just as good, because if you needed to measure it, you could not do it. Using a similar but more advanced geometrical construction, medieval stereotomy built complex curving surfaces that up to twenty or thirty years ago would have been almost impossible or sometimes simply impossible to draw and measure with numbers. (picture 11) And this is Philibert de l'Orme, of course, and (picture 12), this is still Philibert de l'Orme referring to the same object, but mind you, this is not the plan of the orthogonal projection ... which we have just seen, because that would still be an exceedingly difficult thing to do with descriptive geometry today – it would have been absolutely impossible in 1567. This is the diagram of a geometrical construction that you should follow in order to cut the stones that you will then use to build that thing that you have just seen.

So geometry is about continuous lines and surfaces. Numbers are discrete entities, and classical geometry neither needed, nor used them. Indeed, some classical thinkers and scientists had little affection for numbers, and in the classical age, many practical issues that we now solve with numbers were solved with geometry.

But as it happens, in the seventeenth century numbers took over. Differential calculus empowered numbers to describe continuity, and through analytic geometry, curves could be written down as algebraic equations. This is in fact what we mostly still do, as for most of us an ellipse is an X, Y function, not a concoction to be obtained mechanically with a rope, a stencil, and two nails, which is what Serlio could have done. And it is also well known, as Greg Lynn has been reiterating for years, that architects did not start to use calculus as a tool to create forms – as a device of design – until some ten or perhaps fifteen years ago. This was when computers first made differential calculus available to the masses, so to speak – not so much calculus, as the possibility of visualizing continuous functions generated by algebraic equations. And as we all know, this brought formal continuity prominently back to the architectural centre stage after an exile of almost five centuries.

I must abridge the story and simplify here a little bit because it is evident, but continuity of form did not completely disappear during the five centuries of the dominion of the number. Let us just think of the survival of traditional stereotomy well into the seventeenth century, and occasionally beyond. Or let us think of Antoni Gaudí, or Erich Mendelsohn, or even the later work of Le Corbusier. But in each of these cases there is some explanation. During the age of architectural numeracy, non-measurable forms could still be built following the traditional geometrical approach, or by using the modern number-based method in disguise and, in fact, somehow, cheating. We must keep these exceptions in mind. Yet what follows from all the above is a challenging, and at times, exciting historical paradox.

If all, or if even only some of the above is true, we must come to the conclusion that one of the main consequences of the digital revolution in architecture is the revival of geometry as a tool for design. As most revivals, this is not exactly the revival of the same: some more recent developments in geometry are now also involved, and what is being brought back to life is geometry translated, first, into a new, number-based format by seventeenth-century calculus; second, translated into a new machine-readable format by twentieth-century electronic computing. This new geometrical tool for design is managed by machines, and the objects that we can produce using, let me say, computer-based geometry, are machine-made not handmade. We can now mass produce what used to be artisanal *pièces uniques* – a marginal point in the economy of this paper, but a major point in the global economy of the present, as this is one reason why we must use the new technologies and make the most of them.

But geometry is still geometry, regardless of the machines that process it – compasses or computers. Not only is geometry about continuity of form, it is also – as it always was – a process that is mostly indifferent to scale. The separation between design and building site, an estrangement that started with the rise of architectural numeracy and the availability of paper in the Renaissance, is now being epistemically challenged by file-to-factory technologies, whereby the same software manages computer-generated images as well as the three-dimensional manufacturing of the same object. In time, the gap between design and production, which started in the sixteenth century, will most likely be reduced by the logic of the new digital tools. These tools are new, but their logic is not – it was in force and it worked well for many centuries before the mechanical age of printed drawings and numbers. In fact, fully digital projects are acts of design, but in spite of occasionally misleading appearances, such designs are not based on drawings. Each digital design is ideally a three-dimensional ersatz or replacement of an object for which all measurements are known and automatically calculated in a three-dimensional space of x, y, z coordinates. Although endless two-dimensional images of this object can be printed out at will, the source and matrix of all of these variable manifestations is a virtual substitute for the object itself. All parts and each point of this digital archetype can be automatically drawn, measured, and built. The iron law of transference from drawing to building – if you cannot measure it, you cannot build it – has ceased to be. In a digital environment, if you have a drawing you already have all of its measurements, or to be precise – you don't have them – your computer has them.

It is a commonplace of the digital revolution that the new digital environment is in many ways the print environment in reverse. As many have pointed out, the new digital environment is closer to the age of the manuscript as it existed before the age of print, than it is to the age of print that is now coming to an end. An assessment of the first ten years of the digital revolution in architecture would appear to reinforce and to corroborate this assumption. As I could just briefly hint at here, numeracy could exert its influence over architectural design only when numbers and drawings could be printed together. It is the alliance of Arabic numerals and printed images that brought about the rise of architectural numeracy and changed the course of architectural history in the sixteenth century. Now, as it seems, the new digital tools are bringing architectural design back to an Edenic state of pure geometry, which is where architecture lived and thrived for centuries before that paradise was lost, as it fell under the dominion of numeracy and of print.

But if this is so, and this is my conclusion, Thomas Aquinas, a very unlikely name in this environment, and right on the eve of a revolution of print and numeracy, Leon Battista Alberti – they could probably understand the present digital environment and the principles of contemporary digital design much better than Walter Benjamin or Mies van der Rohe could or would – to mention only two of the most eminent advocates of art and design in the age of identical mechanical reproduction. For Aquinas and Alberti lived, as we do, in a universe of variable media. For them, the fixity of print and measured drawings had yet to come. For us, the fixity of print and measured drawings has already gone. And it is certainly one of the most significant paradoxes that mark the latest stage in the evolution of number-based computing that thanks to computers, we can now mostly forget about numbers, and when necessary, manipulate intersecting curves and bending surfaces regardless of scale and measurability just as our ancestors did at the time of compasses. Computers are just as good, and to be honest, in many ways, I think they can even be better. Thank you.

DERRICK DE KERCKHOVE: Thank you very much, Mario Carpo. It's fascinating how your very detailed research dovetails with the previous talk by Peter Galison. It's been quite a stimulating presence.

**Discussion**

DDK: We are now going to put chairs on the stage and invite … you, Mario, to come back here, and also Marco Frascari…. And of course, Peter Galison will be among us, virtually, so we will be able to ask questions. And while this is set up, maybe I could say a few words about what impression this has made on me. It is a very detailed analysis of a transfer of media that brings out some of the fundamental characteristics of our epistemology, in fact. One thing that I find interesting is to remember that the Greeks developed geometry from the same process, that geometry has the same type of transition from the geometry of cadastre of the Nile. The Egyptians had practised the art of cadastre because they were supposed to give back the property of people after the Nile had overflowed its banks; it would wipe out all the areas, which were owned by people who cultivated these banks. And when the Nile retired they'd have to … use a cadastre – they got the idea of geometry from that and they transferred and they'd start measuring.

And this is what I find so interesting: not a single moment was the word "rationality" pronounced during this morning, when rationality, the principle of rationality, is the introduction of measurement in time and space. And so we will find it expressed, obviously, in geometry as a rationalized measured rapport between surfaces and lines. Harmony will be the same. This dividing principle, which I associate with the alphabet, comes from – indeed, this kind of measuring that one has to do of the reading line in order to create the meaning that comes out of it – it's a sort of analysis. Analysis of space in terms of time, that's what perspective is – analysis of space in terms of time....

There are questions for everybody. I am sure that's the idea, but just to start the ball rolling, I would have one for Marco Frascari, and of course, Peter, also be free to jump in with questions. But my question to Marco Frascari would be – it's fascinating how he secularized the biblical exigencies – principles of the four levels of literal to anagogical, and by secularizing them actually pointed out something, which is a very serious business in the whole question of architecture. Is the building ever to be built? But what did you think about the original – how do you relate that non-building of the building to the original meaning of anagogical ends?

MARCO FRASCARI: The question there is … because being that the process of interpretation of senses … (fiddling with microphone). When it gets to the interpretation of the three senses and the final course, basically, is what the analogical sense is revealing. But the problem is, if we take the classical [viewpoint], there is always confusion about what is the final course. And the final course tends to be captured in architecture in a different sense of what really is the final course of architecture. Because the traditional interpretation of Aristotle is – we have the material course, so a building is made in brick, and that is the material course of it. There is a form, and the formal course is a simple building. There is the efficient course, done by Italian bricklayers, and then we have the final course, and in general, the answer is, oh, it's going to be a church. But that is not the correct answer to the final course. It's a misleading understanding of the final course where the analogical sense will allow us to understand better what is the architectural sense that is given to the building. And the rediscovery of it in a technological age, as we do it now with digital, is an essential of a discovery, because practically it has disappeared from the profession. And the fact that we can go back to this almost tactile interpretation of it … because when you talk about geometry and the practising of geometry in the Renaissance, the essential elements were the tools. You say, you know, the compass is a small thing, but in reality when I manoeuvre the compass, and there are many compasses, you do learn what is the [use] of the compass by a tactile relationship, not by a verbal expression of it, and you can develop a better understanding…. So the question is: sure, we can go from the number, and I agree with you, the number lost the dimension and the computer is going to bring that back, but, you know, we move from [numerical] to typographic, and the question is: how do you get to read the typographic?

MARIO CARPO: Well, when I was talking about the age of drawings and numbers, it was about painted drawings and numbers, which have this almost uncanny vocation to be always the same. Printed colour exactly repeatable, meant to be exactly repeatable – exactly repeatable visual statements, so to speak, always the same, the same for all. This was the age of printed drawings, printed numbers, and it is also the age of the paper-based separation between building and conception design. All this, as it turns out, is a segment of a few centuries, which was preceded by many centuries during which this did not happen. And it appears that with the end of the mechanical paradigm, we are in fact re-integrating or going back to where we always were – exception made for this, in historical terms, short interlude of exactly repeatable visual stuff. Alberti and Aquinas didn't deal with exactly repeatable visual stuff – they transmitted formulas, paradigms, algorithms – exactly transmissible invisible algorithms, whereas we are now moving out of five centuries where the dominion was part of the exactly repeatable visual statement. Well, all you said about the age of paper overlays with chronology, but I have been describing without paper. There is no separation between design and building. You need paper to print and put numbers on them. It is the same story and the same chronology.

DDK: I would certainly like the public to ask questions….

SPEAKER: Please raise your hand and speak into the microphone so that the translator can hear. Questions can be asked en français, si vous voulez ou en anglais également. Questions.…

DDK: I'll send one to Peter Galison. I would like to know his opinion about how he situates simulation between the image and the logic. The whole world of simulation today – it seems apparent immediately that it would be related to image more than to logic, but there are some … maybe you have another idea about this, Peter.

PETER GALISON: I think it is, that is to say, the simulation has occupied a very hybrid role here, because on the one side it borrows from both the numeric and the visual, and on the other side it actually borrows from the experimental and the theoretical. So that in a simulation in physics – there was a lot of debate when they first were used in the 1950s and '60s about what the status of these things were. The theorists said, "Look, they're like theory, they don't involve apparatus, they are weak," and set arbitrarily the conditions under which they are run. And the experimentalists said, "But they're not like theory, they're more like experiment." Because every time you run a simulation of an experiment you get a somewhat different result. You have to check for the kinds of errors that you have; accuracy becomes an issue. Even saying that you get a result with a simulation, say, the ratio of one kind of interaction to another, if you give it with an error bar, that's something that the experimentalists were very familiar with and theorists not. So there was a great deal of debate – each side, in some ways, both wanting to assimilate this new technique to their own way of reasoning and at the same time, uncomfortable with it. I think over the long term, simulation has actually become a third thing, a kind of *tertium quid* that is neither experiment nor theory and occupies its own station, it seems to me, in the epistemic field.

DDK: That's actually quite a good observation – to think that it belongs to both and is something else. That's exactly what is happening with the digital transformation as it stands – where we have paradoxical senses, a secondary sense of reality, which combines the world of simulation and numeracy along with the world of imagery.

Well, I guess, my question right now is to what extent in the architectural design world, to what extent all these processes are – to talk to the project and to the issue of the time – to what extent are all these processes worthy of storage? In your wonderful defensive paper there is clearly a desire and a necessity neither to keep all the aspects of paper drawings … that we have developed because they are the evidence and the witnesses to the process. When the process is constantly capable of changing, what do we keep, in your opinion?

MF: The question, really, to pose, is to understand how this information and the understanding of the process can be transformed into digital means, and what are the tactile input and the tactile output, of digitalization – which is, I think, the major problem that we have to face because the senses are all these combinations of elements. Almost to think about synesthesia, which will address the perception that is taking place, of course, on paper, or any other tool that we are using. Now the conservation of that is – for instance, it's fantastic to take in your hand a drawing of a tracing done … in ink, with an old pen, by which the ink has this very light reveal on it, and when you read it, you don't read it only with the eye, but you read it also with the finger. If that is put in a digital format, the output right now is an image, which doesn't have this third dimension of the ink – it disappears completely. Now the question is, when we are working in the digital format, how we can introduce these other senses in the perception of the drawing?

PHYLLIS LAMBERT: Is that not a false analysis? You're trying to translate one medium into another. You can't. I don't see how you can say – you do these little fine lines, you do something else with the computer, if you don't try and do these little fine lines. So I think it's a completely false analysis.

MF: I agree. I don't want to transfer a medium to another because that is like, you know, one of the big problems: how you translate poetry.

PL: Pardon?

MF: How do you translate poetry? It never works very well. Always the act of translation can generate a lot of confusion.

PL: But that's translation of words. You're doing two different systems – they're both called drawing.

MF: Yes.

PL: So, they are two different systems, completely, and so I think that is not correct. Translation of poetry is another form of translation where words replace words.

MF: Yes, but let’s say in different media, what I want to keep is – architecture is related to all senses, and what are the senses used in one medium and what is the balance between the senses.

PL: But they are just very different in each case. They’re just very different – the whole mechanism of the drawing and computers is completely different, and so you can’t compare what you’re keeping. I am sure that Greg can talk about that much more than I can, but it’s just logical, my dear, logical.

DDK: Do you want to go back to the question?

MF: Yes. Really, what I want to raise as a question is not that I have anything against the use of the computer or that the computer is different … what I am trying to look is toward us. And since as an architect I am designing a building that is going to touch the five senses or the multiple senses of it, that is, how do you understand and how do we move what has been done for centuries of these multiple understandings of senses in the new media?

DDK: Two questions there – one for Greg, and one in the back.

GREG LYNN: I just wondered that this morning there’s been – it just hasn’t been discussed, I don’t think it’s a subtext – but there’s a kind of anthropomorphism and a logic of – I mean, with Mario’s talk, not anthropomorphism so much, but a logic of proportionality and wholism that comes from the whole fractional system. And I just wondered, you know, to kind of extend this a little bit … a museum typically wouldn’t collect working drawings; they would collect a kind of generative sketch, let’s say. Or the … you know, what’s the status of the original, or the status of the proportional, or the whole of how you see all these questions relating, all three of you, to a kind of classical focus on the person, the proportional system: just what you guys haven’t really spoken about so much, like kind of the individual whole model that seems to run through all of the talks.

DDK: Yeah, except that as we are going to do a digital kind of rendition of thought, we are moving from a world dominated by memory and the replay of evidence, the replay – paper is a permanent replay of itself. All these documents stay in time and space and they are precisely located. I try to make the point that with digital form you remake the thing. You move from a memory-dominated mix to an intelligence- or a creation-dominated mix. And this is a big difference, I think – moving from media that supports replays and media that supports remakes. So that every time, what you just said about what we keep, you’d keep the algorithm, you’d keep the generating principle behind that particular drawing, yours, for example, as opposed to keeping the evidence and the printout of all the drawings. I would say that that would be one of first kinds of relationship. I see that Mario might be interested in that question, as well.

MC: Well, the main watershed, which comes out from most of what was said this morning between a paradigm where a drawing is the bearer of information and the paradigm where the drawing is only the occasional and ephemeral epiphany of a generating algorithm, which may generate an infinitive number of other epiphanies, all irrelevant, or all equally minimally relevant. This is not a new problem. [Vitruvius?]
had the same problem when he had to disseminate the maps which he had drawn. Alberti had the same problem for the replication of his map of Rome, or three-dimensional objects. They lived in a time of variable, unreliable transmission

of images. Each image was a one-off, which would stand alone – it would not be, and it was not meant to be, transmissible. The only thing that could be recorded and transmitted was the data, which would be embedded in many epiphanies, which would be by definition, ephemeral. But this is the frame of mind, which the transmission of images meant to carry quantitative information. They lived in this environment up to the revolution of print and paper. And now, in a sense, we are rediscovering this variability. It's new for the media, what we use, but it is not new for the paradigm, which is underpinning it. It is the paradigm of the variability of the epiphany and the transmissibility of the matrix. We have been familiar with that for many centuries.

DDK: Thanks for that, Mario. Question in the back?

SPEAKER: Well, I don't know that it's a question but an observation, and I am wondering if it would stimulate some conversation. I was taken by trying to imagine, briefly, while Mario, while you were describing the process of making buildings before the onset of the measured drawing as being, literally, in the field with the compass. And that that represents an entirely different model of working and of generating ideas, a different kind of knowledge organization that many of us who work in digital media have had this feeling that we are actually working in a pre-modern scenario again, where that distance between the planning and the creation has been collapsing.

One of the difficulties, I think, of working in the current moment is, especially if you were trained in numeracy, even if you weren't necessarily a scientist, but you would still accept the notions of measuring and drawing as a prelude to creating a design, that it is so different now. I was thinking in the course of Peter Galison's talk – he's talking literally about essentially an anthropology or a sociology of work – the way that people speak to each other, and the way, again, that ideas actually are a result of working relationships. We are in the middle, or we certainly are, I guess, not in the middle, but the onset of this fast, fast change in the way that the ideas are generated. And I wondered if we could talk about both the working methods and the … you know, to me it's not just the issue of the paper that's generated, and what do we save, but literally turning our minds around how we even define what the design process is.

DDK: Peter, would you like to pick that one up?

PG: I think that's a very good observation, and I think it's something that characterized the way we study work in a lot of different fields now. That is to say, using the objects, not just as traces of results, but as indicators of process. And I think that it's tremendously exciting on the one side and quite worrying on the other that we are in the midst of the digital archive that is so, in some ways, eternal because it's a set of numbers. But in some ways it's the most fragile medium imaginable – I know. I was on a commission some years ago where the big particle physics laboratories were worried about what they should save in terms of the data from their experiments, and the instabilities were many. The programs evolved over time and soon became unreadable as a pure question of software. The media were unstable, whether they were tapes or drums, or diskettes – all of them turned out to be much more fragile than anyone expected.

And then there's the viewing mechanisms, the hardware of being able to read these things. The chances in five hundred years that we're going to have somebody being able to read anything that we write on digitally now is zero, without an enormous, complicated process of relays along the way. There is something strange about entering this very open-ended form of being able to think about the world that we're in now and the history of the present, as Foucault liked to say, that depends on this extremely fragile and ephemeral form that has the possibility of opening up an examination of process at a microscopic as well as macroscopic level that could be tremendously interesting to understand how designs of buildings or experiments or whatever you're interested in, evolves key stroke by key stroke or move by move. So I think that there is the possibility of a kind of sophisticated or philosophically propelled study of work process that is closely tied to digitization at the same time. How this is going to actually function, how a modern archive will look, seems to me completely problematic on all of these levels.

DDK: I have a question for the three of you that follows up on this, which is, does anyone of you interpret or see a connection between the actual fluidity of the architectural forms being developed right now, whether it's Gehry or Libeskind or Novak or so many people, and that in prominence of the unstable media – what you describe, the general, the collective Alzheimer's that we are about to suffer when we get into changes of programming and various things with the digital … is this moment of impermanence, this moment of passage from the hardware to the software, from the hard to solid base to the liquid – I mean, the next thing we know we're going to quantum and quantum change because of the way you observe them and then we get into plasma. God knows where we're going to go! Certainly, we are not coming back to something nice and solid like we used to think it was. [Does] the architecture, in your opinion, the actual forms of present architecture from the Netherlands or from other parts of the world except in Shanghai, have this bizarre kind of fluidity?

MC: I was not talking about fluidity. I was just talking about new technologies, which enabled us to measure and to manufacture forms, which could not have been measured, that could only have been manufactured manually up to a short time ago. It's just a matter of forms that were unmeasurable, now are measurable and they are mass-producible. This is the non-standard environment. There is nothing fluid about that, not necessarily. It is just that some forms now can be made and can be mass-produced, and variability within a line of production can be added at no extra cost. This has nothing to do with the fact that we need this variability, we want it, or there is a market for it. It is just a technical fact. It is feasible, it wasn't. Then a second chapter begins: who needs it, for whom, to do what?

BERNARD CACHE: I want to comment on your question, which is that if you look at what is architecturally produced in the world, 99.99 percent of the buildings remain square.

DDK: Yeah, sure.

BC: So I think this is really the important point, because what we have to know now is what we can do with these new technologies in regard to this 99 percent of the architectural production.

DDK: Phyllis is disagreeing….

PL: I take it, you know, most people bandage themselves.… It's the people who are leading on the edge – it takes so long to have that go down to … making a cottage for somebody. I think that's false again, another false way of looking at it. You can't say, just because most people are doing these square boxes they haven't caught up to what they could do and they're not using that sophisticated equipment that they could do. It gets to … the question of what is architecture and what it's not. I don't even want to get into that. But I think that … people can do this. If other people don't want to do it, they don't do it. But that doesn't mean that this validates the kind of forms that you can create with the computer that you could not ever create before. Mario, you had this 100 percent right.

BC: I am ready to bet that within a hundred years we will still be in a situation where we have the octagonal box as a high majority.

PL: So what?

BC: So, what is the important point, is that I think that the new technologies today do not necessarily induce a certain type of form, but that the revolution in the process of design is much more profound. That means that there can be, for instance, variable cubes, variable octagonal boxes. I think what is occurring has a potential to be a revolution, which is not just a revolution of style, but a revolution of methods and way of thinking.

DDK: Mario, do you want to respond to that?

GL: Bernard, I think you're doing a very odd thing, though, which is – you know, 99.9 percent of all the steel that's manufactured today is manufactured in a CNC digital environment, so we already have variable cubes. I think the reason that you're saying the future is what's already here, but we don't even notice, is because it's a false statement to say that the technology comes first and the concepts come second. I mean, I think Peter's talk was very nuanced in the way that he showed that there were certain diagrams or certain concepts, which migrated from the massive scale to the cottage scale, from a field of one type of morphology, which was looking at natural phenomena to theoretical physics and back and forth, and it was making all these mergers.

So I think it's actually the concepts and the diagrams that are usually coming first and the technology, whether it's a compass or whatever, is usually following some diagram. The big issue, I think, is that those diagrams are not always socially and culturally explicit – they are implicit between a small community of people that they move around through. So I do think that it's a task to articulate what are the new diagrams, what are the new – you know, is it as dumb as just saying that there are clouds? That you know particle clouds constitute a new kind of model of space that everybody is working with. That doesn't mean you have to make a building like a particle cloud. I mean, I wouldn't jump to that literal an assumption, but I do think these diagrams are in the air.

MC: Just one minor point. Let's calculate not the amount of cubic feet which are being built. Let's calculate the amount of time that we spend in cars, trains, and planes, all mass-produced and they are not square. So I think that 60 or 70 percent of the time of our own physical life, we already spend in industrially manufactured serial, reproduced, curved spaces.

BC: Yes, and I would like to add that the fact that a building be manufactured with the CNC machine doesn't mean at all that you really have a digital process of thinking behind it, which is a valuable process. I am, myself, very sceptical to which extent a non-standard architecture can find a market within the general architecture field.

MF: One thing that was fascinating with Peter was the presentation at the beginning. He showed a brick wall – three brick walls. One was funny, one couldn't stand up, and the third was a classical English [wall]. (laughter) Now, how you can argue, basically, that is a concept, and what is the problem of architecture that you were raising, is where is architecture? In a sense, it is in the building, is in the drawing, is in the computer, and the power of architecture has allowed us to do conceptualization. Otherwise, his argument for the change in the history and reading this epistemological framework, it started just by a simple consideration on a tectonic event and we buy it, we live it, we say, "Oh, it was very good!" We got the change in paradigm … I think that is really the important thing, more than anything else, is to understand how the power of architecture, which is behind the power of thinking, can be carried on in this new condition.

DDK: There's time for two more questions and then we'll have to wrap up because we are passed the *quarto d'ora accademico*. Peter, do you have something to say?

PG: I just wanted to add something about a shift that happens in the scientific technological sphere … about simulations again and the function of the digital: the scientists or physicists and philosophers often worry about what's real and what's not real. Engineers worry about what's going to hold up or work, or function, and what won't, but they are less worried about whether a bridge is real or not than a physicist or a philosopher might be about whether a quark has the same reality status as a table. But in the course of what's happened with simulations, something very dramatic has happened. You had a moment when there were doubts about the validity, the epistemic solidity of the use of simulations to understand nature. And there was a longstanding debate that was in part generational – on the one side there were people who said if you could simulate a phenomenon and show that some new thing existed, that was a good starting point, but then it had to be demonstrated either through experiment or theory.

What's happened that seems to me so interesting in science over the last few years is that that's begun to shift. First of all, engineers now build with simulations routinely, so all the new large-scale airplanes are not ever tested in wind tunnels; they go directly from a simulation to a manufacturing plant. There's a sort of bypassing of the older "show me how it will work in miniature in the physical world" attitude. That's then fed back into the sciences in a way that people now will say, "I believe that such and such in astrophysical phenomena takes place because when I simulated it, it is so." And the older claim – well, that was only a starting point to an eventual demonstration that the classic means of experimental theory has begun to shift. So I think that in the combination of the technological and the scientific philosophical, something rather dramatic has happened, and that the simulation is occupying a place that is no longer a preliminary. It would be interesting to me to hear from some of you about whether there's something analogous that functions in architectural thought.

DDK: We unfortunately have to wrap up, but this question is a very, very exciting one. Perhaps what we could do is to pick it up in the next discussion session. I certainly would like to get back to it.

I would like to thank the three speakers. Thank you very much, Peter. (applause) It was fantastic. Marco and Mario.... I'm looking forward to this afternoon. Thank you…. I would also like to thank the technical staff that worked so hard to bring Peter here, from the CCA, and from Harvard. It's fantastic! (applause)

## Mark Wigley
## Black Screens: The Architect's Vision in a Digital Age

Thank you very much. I am very happy to be here, always happy to be in the CCA because it is one of those not-so-common places in which actually people are thinking. And one of the reasons for that is that they are collecting, and you cannot collect without thinking. And the reverse is also true – you can't think without collecting. So there are a lot of places that think that they are thinking, but they're not. And this is one of the places that does. And of course when you speak in a conference you, in a way, have been collected yourself ... so you end up sort of positioned on the stage like an object more or less in a vitrine exposed to the audience. So I just speak, let's say, for the entertainment of the CCA, and you make up your minds about what it means. Some questions …What does it mean to collect visionary architecture in a digital age? … That is to say, what kind of vision does the architect have today? In other words, you can't collect visionary architecture if you don't have a theory of what kind of vision an architect could have. That is to say, how is architecture being visualized if collecting architecture began with preserving, reframing, classifying, and interpreting drawings? And I could certainly spend an hour defending this position. What has happened to drawing today, and therefore what would happen, and which way would we collect it, and therefore in which way would we visualize, and in that sense, which way would we think?

Drawing, of course, is classically happening, let's say, on the paper, and the classical understanding of the drawing is that the drawing is the shadow of a shadow. It's not even the shadow of something clear like the ideas in the mind of an artist. It's a shadow of a shadow, where what is in the mind of the artist is also a shadow. And the classical image of drawing is actually that the drawing is coming from behind your head and the drawing is, as it were, passing through your head onto the paper. The introduction of the concept of the artist is the introduction of ideas themselves formulating, let's say, in the mind of an artist, but let's say, no mind to the artist beforehand. So the artist is from the beginning a mind, a thinker. But a special kind of thinking, usually sitting beside the window receiving the glories of the cosmos coming with the light somehow being modulated by the gifts of the artist. And they leave their shadow ... on the page, a dark shadow on a light surface. In fact, shadows can only be seen ... against a light surface. The shadow is then treated as a residue, a trace, a delicate trace, a kind of ghost of a ghost – that ephemeral, unthinkable trace in the mind.

It's as if the white paper is just a delicate screen for catching the trace of an immaterial thought. And the classical understanding of the paper is that it's not material or immaterial, that it's exactly that surface which allows us to think the relationship between the two. So the drawer is [doing] something like [tracing] a shadow. Now that means that the whole point of the paper is to be there, but also to be absent. To be there as the support, but invisible and unseen, so that the marks upon it can be seen. We have literally been trained over the last five hundred years to act as if the paper is not there, in the same way that when we read a book, we tend not to reflect upon the nature of the white surface on which the words appear. We have been trained to see only the words. We have been trained ... to see through paper, noticing only the dark marks made upon it, which no longer seem to be in the room, but to be, as it were, in the cosmos, in the abstract. So the white surface then is acting not just as a way of positioning art – and art must always be positioned. It could be argued that art is in our current understanding that which could move but does not. So strange

– the experience of an object in a gallery is an object that could move, but for whatever reason does not move, and the white surface stage is there for us.

Now this invisible white paper explicitly institutionalized by figures like Vasari is absolutely tied into the definition of art, a word which does not have meaning before this definition: its production, education, criticism, collection, and history. Vasari being, of course, a privileged figure of the innovation of the concept of the education of the artist, of the criticism of art, of the collection of drawings, and of history itself. Now this very, very long history has left us with an understanding of drawing, to quote the definition of the Museum of Modern Art, "an original work on paper." That's how they decide what should be collected within the drawing collection. And most institutions that collect drawings use some variation of the Museum of Modern Art definition, which has itself a history that can be examined.

But it's a bit of a problem for us because drawings today in the hands of architects – and I don't know if we can say in the "hands of architects," but let's say what used to be the hands of the architects – the drawings today are obviously not original works on paper. They are not originals, for a start. They are mainly prints, and even "printouts." So then the question is, "printout of what?" What is the interior out of which a print appears, as it were, space of design, but also they are not on paper. Famously, they are paperless, which doesn't mean that there is no paper, it just means that paper is no longer the sign of the original mark by an artist. In fact, as you know, there are huge sections of the Amazon jungle going down in order that paperless studios can carry out their work, because paperless studios print everything out endlessly. So there are mountains of paper being used, precisely because we are in a paperless mode. The paper, though, is understood to be just a provisional "printout," and in that sense, I suppose, we have a kind of unexamined theory that the drawing is, let's say, in the machine. And I just want to tell you that that's an image. It's not the absence of an image, it's an image…. So I just rehearsed that for you again. (laughter) That's an image. But you have been trained to see this not as an image, but as a space in which an image will appear. I'll just say there's something wrong with the projector at this point. You've been trained to think of this as having an entirely different kind of quasi or pseudo immateriality…. And in this moment then, we print out onto a surface like this, and that printing out is in our own mind somehow related to the shadow of the shadow idea. Somehow the projection out of a print is associated in our mind with the classical understanding of a shadow, and yet we have not really explored either the shadow theory as it applies to architecture, nor the printout theory as it applies to contemporary architects. But to say one thing: the drawing, I suppose, in our minds is in the machine now, the out, the interior from which this comes out is a machine, and even there in the machine it's not an original, a stable figure, but some kind of fluid organization of information.

So in a certain way we are describing the interior of the computer in a similar way to the interior of the mind of the artist, which was described in order to create the idea of an artist, therefore somebody that would have a life, a childhood, and so on. This is the sort of mood that we are operating with. But from a technical point of view, the state of architectural drawing today is that it cannot be exhibited as drawing. So let's say, from an institutional point of view, the Museum of Modern Art actually cannot exhibit architectural drawings as drawings according to its own definitions. And if you watch them, they are trying to negotiate around this little problem.

This is an echo of a very old argument, of course – whether or not photography could be considered an art. And you have to remember it took forever for photography to be accepted as one of the arts, even in a museum like the Museum of Modern Art devoted to that art which is modern. And surely that art which is modern cannot be separated in our mind from the arrival of photography. But even [at] the Museum of Modern Art, so closely identified with photography, and with the great photographers they had collected, and so on, there was not a photography department until 1940 – just to give you a sense that there is a delay even within that institution dedicated to the phenomenon that we're discussing. The question for us – what might happen to digital drawings – we might reasonably expect that it'll take some years for institutions to come up with some kind of answer. And this, I think, this very conference that we're in, is a wonderful kind of symptom of the fact that we're all trying to figure out the answer.

And I only want to concentrate, very quickly, today, on one aspect of digital drawings, which is the default black background of digital drawings. Just to offer you some very quick examples, one example, in fact, well known to architects: Project Paramorph II from a few years ago. It's just typical that the white project floats now against the black background even where, as it were, plans had been registered. The thing floats there like a spaceship, and we are now looking at that white figure in the same way that we have been trained for years to see a dark figure, but now we see it as a light figure against a dark background. And, of course, this kind of presentation of architecture within a black field, a field that's not even visible as a field, is very much associated with the arrival of digital drawings in architecture. Basically, white paper with black marks on it has given way to white lines on a black field. Architectural presentations, lectures, and publications are now entirely filled with glowing forms suspended in black space. People are now drawing with light rather than with shadow, and that's just such a fundamental change that we need to really consider this. It's really a complete reversal, and it's very, very deeply reversed. In other words, black has become the default setting – it's quite a miracle to imagine that white is not a colour, that it doesn't exist, that it's not in front of you. It's really a shocking achievement of our culture to have us believe that white is not there, simply not there. It might be even more miraculous to start a new form of drawing with a black background and have us treating it in exactly the same way.

Black is, of course, technically the actual default of the software that you're using. If you want to define black in the HEX system, it's zero, zero, zero, zero, zero, zero. If you're in the IGB system, it's zero, zero, zero. So those are the two systems, and you see in the middle of the right one, zero, zero, zero is the reference point for IGB, and zero, zero, zero is the beginning point for HEX. And, of course, we live in an age in which … even the most stupid computer you can have has access to something like three hundred, four hundred, five hundred million potential colours depending on how fast your machine is. All of those colours are referenced back to a zero, zero, zero point. So there is this logic within the world of digital drawing that you start with black. And even this image has already started with black because I am showing you this against the black background, the effect of that being you can't even see the point at zero, zero, zero. So the default disappears, let's say, inside the default. The IGB system, of course, having an interesting history and the use of that system to be then applied to computers has a lot to do with … in 1953 the adoption by RCA of the particular colour TV standards and so on. So … you're actually looking at television, basically. Anyway, colour is also the colour of your monitor when the monitor is off. So actually, now what happens is, if you walk towards your computer and it's not on, it's black, so if you turn it on, it's colour-irize and light-irize.

Interestingly, that would be another lecture, blue-irize. So there has been an attempt to institutionalize blue as a default setting both for the death of your computer, when software crashes, and also for its arrival. One of Microsoft's great achievements has been to position a certain tone of blue at the beginning and the end of every program. And there are reasons for that, which are much more interesting than what I'm going to talk to you about today. My purpose today is to identify six or seven really interesting lectures that could have taken place and instead offer you a very dull … anyway, your computer is black before you touch it, as is your cell phone, as is your television. In other words, the entire world around you is bristling with electronics and when they are not doing anything, they are black. And, of course, there's an enormous industry, a global-wide effort to make sure your screen is never black. And we can rehearse all of that logic, and so on. I don't think screensavers were invented to save your screen. They were invented to save you, by keeping you perpetually surrounded by the marketplace of images, and I mean that in a positive sense. So literally ... our entire digital environment, which is to say, our environment, since these days even your toothbrush is electronic – there is an attempt to keep everything alive all the time and by so doing, keeping you alive.

Nevertheless, black remains understood to be the default setting, which is great for those of us who live in New York because it means our normal clothes are defined as the universal starting point for all cultural life. But this is an astonishing shift, I think, and quite remarkable that it's never commented on. There's an enormous amount of talk, particularly, for example, in architecture, about animation, about the life that you see in these drawings, and about the lively drawings. And that would make sense if you're drawing with light and now shadow, you would be drawing with life. But meanwhile, we don't seem to bother speaking about the black background, and I would say that if the blindness to the white background is a remarkable effect of centuries of institutional practice, blindness to a sudden absence – and it's a pretty sudden absence – is even more impressive. So in a little way, what I want to do is run a very, very quick narrative to try to explain how it's possible for the black background to arrive, as it were, as a non-event – how could an entire revolution in the way we construct and conceive drawings not have been perceived at all?

Now how does this shift occur? Computer graphics, of course, begins as a military research program at an MIT laboratory setup by the air force in the mid 1950s. For the first time, information could be entered into the computer with a light pen, an electronic pencil with light at its tip rather than graphite. That simple move from the light that's activating the pen, of course, in reverse, the light coming from the screen versus the dark graphite coming out of the pencil – the pencil being, of course, an instrument that we now have to explain to students.... If you want to begin the question of how to collect digital drawings, you might start by putting a pencil in a vitrine and teaching the young kids exactly what it is and what it could do and how it would connect to the hand, and all of that. This is Ivan Sutherland, who was a young graduate student working at the MIT laboratories. He was very, very low ranking and therefore only allowed to use the machine in the middle of the night. During that time, he developed "sketchpad," which is the first drawing program that allows drawing directly upon the screen. When the military would periodically come to the lab to see whether the guys had cooked up anything interesting – the military, of course, being enormously intelligent in not trying to control the research going on in this lab – just putting brilliant people in there and seeing what happens. The people who were running the lab at that time, Claude Shannon, being a teacher of Sutherland, didn't think that this guy was good enough to show the military. The military insisted on seeing him, saw it, was very excited about it – and Sutherland was not seen again for another four years. Just literally just went off to another wing of architecture exploration.

Now this program "sketchpad"– and I'll show you the kind of drawings I'm talking about. In other words, starting off with a chair being able to be visualized in all dimensions, immediately, I hope you notice, immediately the architectural ... ambition of the project was revealed for the first time to engineers in 1963, and later that same year, the first commercial systems evolved. This is the DAC system – design aided by computer. Again, when we say something like CAD, they were rivals at that time that are very important. This is the CAD, this is the DAC system. We could be talking about a DAC, anyway. Design automated by computer system developed by IBM and General Motors. You see the sort of machinery, and this is the kind of drawing that's being produced. In the same year was developed the first software specifically for architecture – this is Co-Planner, which was produced for hospital design on what was called the electronic drafting machine. And again, these are the really phenomenally fantastic hospital plans produced by that – I can reassure you that this kind of geometry is simply not possible without the help of the computer…(laughter) We could do this with any number of variations – those can be quite large rooms or quite small …(laughter).

Not by chance, this program was assembled by a group of the original air force team. That is to say, of course, there is a kind of trickle-down theory, which, by the way, tends to occur with people who have fallen out of favour with the military – those no longer so efficiently tied in to the generation of new developments. They then start moving out to a more commercial world because the military will let them do it, but it's not a risk. So these guys that were not quite hot enough to be a risk to the military were then, as it were, allowed out on the open market to develop this kind of software. All of these programs were then shown to architects in 1964, a huge year for computer graphics in the architectural community. This is now "Sketchpad III."... When Sutherland had disappeared off into a secret military lab, this is the more commercial version of his software – the latest development of it. You see it's very much hand-based on the left hand. I can show you very quickly – Sutherland is very much working with his left hand and ... his right hand at the same time, like a kind of a concert pianist. Same logic is still working here, and again you're getting very, very sophisticated modelling in perspective of objects. The big challenge at that time being, how to hide the lines that you would not see – in other words, how to make a non-solid behave like a solid – and quite brilliant work was done in order to make that possible. Once they got through that hurdle – but you can see here they haven't got through the hurdle yet – things would move along.

This is the sonic pen. This is a pen that you move in space, in three-dimensional space in order to construct and work with three-dimensional objects, in certain ways more advanced than what we use today. This is, of course, the first "mouse" as introduced to architects – there's a wonderful history of the "mouse," but the "mouse" is shown to architects in 1968 at Yale. There were numerous conferences, school courses, organizations, essays, special issues of magazines, and books, all promoting computer graphics as it was then defined by one of the people working for the IBM General Motors team. Along with this comes an entirely new iconography of the architect, so this is now the figure of the architect. No longer leaning over a horizontal table, but working not only looking down at the drawing and letting the shadow, as it were, fall on the drawing, but lined up with the screen. And this simple shift of drawing from the horizontal to the vertical would be a three-hour lecture, much more interesting again, very, very important, fundamental. But again, you can see the nature of it. The drawing is being constructed in front of the person rather than behind the person. Not even in the head but in front, and therefore it's something more like a dialogue. The architect starts to wear a different kind of clothing – there is of course, of necessity, this sort of nerdish look (laughter) that develops. But you see again, the position, the ability even to be sitting in that chair with a hand on one knee, to be drawing while looking forward, that is to say, the drawing being constructed in front of you – this is a really big shift, and there's an architecture to these images.

This was the great screen they were using in those days – fantastic screen. Again, if anybody could squeeze plasma ... into one of these, or something, you could sell them enormously. You could feel the machines are starting to get a little bit smaller, but again only in the office of Richard Meyer are you really forced to wear a white shirt like this. But at that time it indicated ... this sort of corporate look of this sort of civilized architect. There is no longer a window for you to have the light pass behind, because, of course, any kind of light that's not coming from the screen is an interruption – anything from the outside world. So you're in this world, this very neatly organized, again, no mess, no calm, no quiet, nobody too old, nobody too young, everybody's sort of floating there in this kind of area of American optimism, in a certain way. Interestingly, probably more women seen in images of architectural production in that moment then in almost any other moment of architectural history. One might want to do another lecture on why that happened and why it disappeared. Why the boys were very quick to get back with the toys. And it has something to do with the secretarial function of drawing. That if the drawing is no longer coming behind you ...you are the privileged gatekeeper of the glories of the universe, something that only a man could be trusted to do, since surely that which is "she," the woman, would bend, distort, and twist anything coming through because that's the nature of "she."

So that figure of the architect suddenly changes when the drawing is a kind of work product within a cultural environment that is, as it were, managed into existence. In this little moment of management, you get these kinds of figures appearing. Basically, you know the story: when this guy, this is Sutherland again, starts with his first drawing program, he's working with a 22 cm monitor surrounded by a hundred square metres of computer. This computer is not in a room, it *is* the room. He just enters into the computer, and one part of the computer allows him to be there facing it. By 1982, the first mini-computers come out, that is to say, computers affordable by medium-sized architectural offices. Very, very important to know, of course, that the computer is not in the hands of the architects. The computer is in the hands of the military, then of aerospace, then of automation, then of city infrastructure, then to the most enormously large engineering firms, then to corporate architectural firms of global scale, and then slowly, slowly, slowly, it's disseminating to a wider and wider group of the community, and not by chance, that coincides with the machines getting smaller.

So in 1982, the first official mini-computers come out, that is to say, medium-sized offices could afford some. One could again ask, let's say, in a city like Montréal, when did that happen? It would be very interesting to see which firms received them first. That's also the year in which AutoCAD is released, that is to say, the first generic, what will become generic software package for computer graphic design comes out in that same [year]. And there is something of AutoCAD buried beneath almost all of the software still used today, and importantly, of course, AutoCAD starts with a default black background. ... Even if you decide that you're going to draw on white, that becomes a decision, that is to say, you draw the white background. If you don't touch it, you're drawing white on black. So already by 1982 the default setting of the black had been accepted, and by the 1990s every architectural studio was fully computerized. Then, and only then, a new generation of experimental designers [testing] the limits of software were able to develop new forms of software. When you speak about architects and the computer, everybody thinks of this new generation of experimental design, but frankly, the young generation of architects was never allowed to touch a computer until everybody else had finished with it. So you could imagine the architect at the very, very bottom of an enormous family tree. By the time the computer comes down, everybody else has gone on to other things and we are just totally thrilled with it and excited.

And this is, of course, crucial to the story I am telling – that our ability to not see the black background has to do again with this sort of instant Alzheimer's approach, this very convenient way in which architects are able to forget their own history, which allows everything they do to seem so unbelievably new. And if you're at the bottom of the line, that is, not really getting a chance to do anything new at all, the only way to do this is to make sure it's clear that you are the first. So we have a lot of architects who were the last actually acting as if they were the first. This is not at all a bad thing, and, in fact, I would argue in another lecture that architecture is a strictly rearguard phenomenon. That's what's absolutely fascinating about architect – it's not avant-garde and it offers this unbelievably subversive rearguard action. Your pop-up toaster is considerably more sophisticated than the house in which you live. No architect would ever be trusted to do the inner workings of a pop-up toaster, so remember, we are living in a field in which high tech is considered to be large pieces of stainless steel bolted together. (laughter) When people discuss high tech in architecture, there is never any laughter. I don't know why you laugh now, because it's absolutely fantastic work, which is more or less unchanged since the 1960s. And still, even in its own terms, what was ludicrous to call high tech in the sixties, what is it now, almost half a century later, to do the same thing?

So for us, what it is that we do is much more interesting, much more reflective, much more thoughtful, much more analytical, much more the work of an intellectual, I would argue. And what I so deeply admire about the work of the so-called digital architects is that they're carrying out essentially an intellectual labour on the history of certain technologies in relationship to thinking about space, and so on. That's precisely why it's subversive work. Not because it's somehow breaking new ground, but it's quite the opposite – reassessing, and reimagining, and reconsidering an entire generation of research. And this has always been the role of the architect to, as it were, provide some kind of coherent way of thinking about things, heterogeneous forces that simply don't belong together. Any force that could be (another lecture), any force that could be naturally, as it were, or easily or efficiently combined, would make the architect irrelevant. An architect is only invited in when nobody knows what to do. So it's a figure of trauma, it's the figure of last resort. You can also be the figure of last resort, in cultural terms, that is to say, you would be the last person in to call to clear up an entire mess that would include discussions about computers, networking, multitasking, social shifting, and so on. In other words that’s our role, reflective, and if drawing is the way that we reflect, the way we have changed our drawings becomes very, very important.

So the visionary architects – and this is the title of a number of exhibitions in the 1960s including one at the Museum of Modern Art – are already in 1960 throwing up a huge challenge to the Museum of Modern Art about how to handle this kind of drawing, and by the way, the way they did that was to put the drawings in a black room and have the most transparent images with light behind them, that is to say, the work of *Archigram* and so on, could only be exhibited, as it were, by way of this reversal. But these visionary architects, let’s say like *Archigram*, were the absolutely the last to use the computer. I mean, these guys couldn’t afford their lunch, let alone a computer, but they were the first, perhaps, to fantasize about the real impact of the computer, not only on architecture, but let’s say on life.

Now what’s interesting, then, for me, is that exactly in the year 1964 architectural discourse is washed with images of these new dark images – architects start drawing white on black…. Architects who don’t have computers, like Cedric Price, start drawing this kind of image, which is here in the collection. Peter Cook, Instant City; David Greene, Pod House: 1964. It’s all the same year…. And what’s happening then, you’ve got a group of people who are thinking about what the computer means for architecture and have started, as it were, to simulate the drawing style that’s now possible as a result of the computer. And remember, these are people who are not trying to understand what the role of computers in architecture would be – *Archigram*, of course, famously, and Cedric Price, understanding the computer itself as the architecture that we will live in. In other words, literally arguing through a lot of the basic positions that still seem, let’s say, urgent, for us to consider. So basically, we could sort of stop there and say, oh, that’s interesting. Architects, who are visionary, who can see ahead, can see what technologies would do before they are allowed to use them, how already, as it were, are simulating the effect of those technologies in their drawing style. But in fact, there had been a genre of white-on-black drawings that had already emerged in the 1950s and early 1960s by architects who absolutely had no interest in computers, and even [by] architects whose work was entirely opposed to them. So, here’s Aalto’s … 1958 [project] as published, Kahn’s City Hall Project, 1952–57, and [??] Crematorium. And again, you can see even in the way this is positioned, a white-on-black drawing, as a sketch positioned below a model, the model now reading as if it’s a drawing, in a sort of soft focus image. And again, just in case you didn’t think that we’re systematic – is everything systematic in architectural publications? So with incredible care this kind of argument is being made by which a model is being treated as if it’s operating as a drawing, and then you get these kinds of images.

Now, a small number of these countless drawings that you can find, which are white on black, in the late fifties, early sixties – a lot of them, I mean, a very, very small number, actually draw with white material on a black background; they are almost all photographic negatives…. You just take a drawing and reverse it. And again we have to be careful about that. Some drawings are drawn to be flipped. So this is David Greene, 1965, Living Pod. He draws it above, he photo-collages the figure in order to have it published immediately in that form. And he’s the one doing the publishing, so we know this is the intention. Others were published one way and then flipped another way. So Yona Friedman in 1958, Spatial City, then below, as it was, republished in 1964 in *Form Magazine*. And that is to say, by 1964, in order to be cool you had to look like this, which is important because

Friedman was super cool…. He’s at the centre of all those discussions, and that’s a very cool, biodynamic system that he’s describing. That’s his city working as a self-organizing system. You can’t imagine it, but even by ’64 it simply wouldn’t be cool if it was black on white; it has to become white on black. Again the same thing happens. You can systematically go through Friedman again. Spatial City, ’59.

Some architects are retrospectively flipped.… So a famous image of Mies’s Barcelona column, and then as it’s flipped – Mies himself never doing such a flip, but interestingly, his disciple Craig Ellwood always flipping. And I would argue in this case (we’d have to do some more homework), but this is a typical publication of Craig Ellwood’s houses: Rosen House on the left, ’65, [Johnson House?] ’52 on the right. Somebody who is a disciple of Mies developed a style that made this Miesian architecture seem even more appropriately white on black, even more abstract, if that was the goal. And retrospectively, this seems to have then produced this; in other words, it just now seems obvious that one could do that to Mies. So many other aspects of Mies’s drawings would be considered a violation of the spirit. Nobody more in control, so beautifully in control of his representations than Mies. Arguably, it’s some kind of sacrilege to do anything to any of his images; we have gotten to the point where you can flip one of his drawings and it even seems like perhaps it was always that way. There are a number of famous Mies images, which people treat with great affection, not knowing that it’s a photographic reversal of an image that was never drawn that way. And I think, again, we could speculate at great length on Mies’s relationship to, on the one hand, paper, and also to the materiality that’s so obviously part of the pleasure he takes in his collages.

Some architects did their own flip…. So this is Le Corbusier, Three Human Establishments, 1946, on the top, then edition of 1959 on the bottom. So he himself reverses every single image in his book to do this. Many of the flipped images also appear in the same context with the reverse. These are typical pages that start to appear in the sixties … so white on black at the bottom, black on white at the top. This is Curran, of course: black on white at the bottom, white on black at the top. And, of course, each of them is given exactly the same territory on the page, so you’re asked to treat both of them the same. And in so doing, you are being asked to treat white and black as the same thing. Which means if you move your eye from the bottom of the page to the top, you’re crossing over a line, a line between the end of the white surface, which, remember, was invisible) to a black surface, which is now invisible – so you’re basically crossing a line between one form of invisibility to another. But in order for the whole thing to remain invisible, you have to do a little flip as your eye goes across that line.

Of course, in more detail you could argue that on the right the white is really the default background because it goes all the way around, but then I’m showing it to you on a black wall, which was white when the lights were out…. So we took a white wall, we turned the lights out, it made it black, then I throw a black image on it, the black background of my Power Point in order to give you a white frame within which a black square appears with a white circle in it inside which is a dense interior of a building, which you recognize because you think it’s a building. I haven’t given you any information that suggests it’s a building, but you just guess it’s a building because it looks like a plan. And then the reverse happens on the bottom, and you just digest all of that like nothing happened … which is a neat trick. And actually, if it’s as weird as I just said to you, maybe it’s understandable that we just look at this and kind of gaze through it.

This is the kind of work – basically what's going on is that in the late fifties, early sixties the images are starting to flip backwards and forwards, literally on the same page – which, of course, has the effect of making the background visible as a background for the first time, and then having it go invisible again, so there's a kind of a flicker of the background. The background, that is, becomes a sort of mark, even if it becomes a trace of the photographic medium in which architectural drawings primarily circulate…. Obviously, if one image is a photographic negative of the other and you are asked to flip backwards and forwards, actually what you are experiencing is, of course, photography.

Now this is in my mind clearly associated with the postwar rise of the technologies of light lines against dark backgrounds. And again we can go through the whole history of radar and so on, and how that related actually to the development of computer graphics and how that particular MIT lab is part of that military history. But what I am, of course, interested in as a historian are the precedents, and what is quite shocking is how few examples there are of such behaviour as we move back in time. The great exception, the exception that proves a couple of rules, I hope, is of course this guy Ivan Leonidov. Leonidov is, of course, somebody whose images are almost always seen in this form, as white on black. So here we are: Workers' Club, 1928, in its different forms. And again, you know these images very well, so I am just asking you to concentrate, let's say, on the black background. But it's not simply a photographic flip here. What's interesting about Leonidov, he actually is drawing with white ink on black paper or cardboard or even on the table, and there was a table that was found with his drawing underneath. And you see here two images of the same project: one drawn white on black and the other black on white. And in both cases, the material is not so good on Power Point, but the materiality of the support system, the weave of the black paper and the weave of the white, is very visible as such. So there's really somebody working, let's say, with pre-photographic media but treating them in a photographic way, and of course, the intention is to publish them exactly like that.

So here we are: he's again writing for publication and you are again being asked as you look at this, which is the original pages of the magazine, you're being asked, as it were, to flip backwards and forwards. The fact that the geometric figure is almost the same in both cases is reinforcing exactly what I'm describing – that in your mind, perhaps, there might be a figure that is relatively stationary, but the background is flipping black, white, black, white, black, white. And, of course, the page of the magazine, kind of yellowish in this case, is itself coming up and made visible, because if you make the background visible, well, then backgrounds in general become visible, and you start to get this weird kind of effect. This, of course, is a …bird's-eye view and elevation, white on black. But there's something …the drawing at the top is assuming a status not exactly like a line drawing, not exactly like a photographic reversal – there's something creepy going on, I would like to suggest. And you see it here: those are photographs of a model, which don't seem so different than the drawing. So in other words, he's taking a model and making it look like a drawing. But it's a photograph of a model, so you're making a photograph of a model look like a drawing. But in this case you're making the building look as if it's white on black, with a black background, and you see it again, this is a double-spread, typical of Leonidov. And this is not by accident…. So this key project of Leonidov, the movie studio, you can see when he's producing the drawing, he's actually using photographs as the plans and now it's the reverse. Now it's the photograph used as an element within the plan – of course, the purpose of this building is a movie camera runs up and down that long strip, there, and these are a series of sites in which movies can …

It’s a place for photography to occur, so it’s not by chance he’s using photographs in it. But again, if you look more closely at the pages, you’ll see, for example, he’s using photographs again in the plan element. Again we go up to the top, now in reverse. A garden is represented, not by a photograph of a garden, but a photograph of a sky with trees in the front, which is then reversed to appear dark on white. And then below, interestingly, he publishes the model upside down, so it floats in space. But if you look at the roof of the model, it has photographs on it. So you take a photograph of a model, which is trying to look like a drawing – and the way it does this is to have photographs on it – so you’re photographing a photograph suspended with a model, and so on and so on.

This is very, very calculated work. And I would suggest actually the fact that this “P” is upside down is not an accident at all. Of course, if you know anything about the Suprematists that would make a hell of a lot of sense. We end up in 1930 with the famous Linear City Scheme, and it doesn’t read so well. But you’ll see that in the plan. Again, sections of the plan are configured as photographs, so you’re looking at a photograph of a plan with photographs in it. And perhaps even more interestingly, on the top you have a model of the Linear City, but the model itself has been constructed as white on black, and there are photographs embedded in the model…. And it goes on and on and on. That’s just basically to say that Leonidov is extremely cool, with photography, but also calculating, reflective, intensive…. Now the question is, in this sort of magnificent exception to the rule somewhere between 1926 and 1930 Leonidov is producing this kind of essay, this kind of intellectual commentary on the relationship between architecture and photography. The question then is, what are his sources? …  Of course, you can imagine that his sources are Suprematists, primarily Lissitzky and Malevich. Malevich, of course, the high priest of black and white…. So, of course, you say to yourself, yeah, no problem, of course, of course, of course. But if you look at the Suprematists’ work, of which there is an unbelievably large archive, the black background is actually quite rare.

And let’s sort through some of the possibilities. Of course, this is Malevich’s Architecton, and it’s … a white figure floating against a black background. You could say, yeah, it’s floating against a black background because Malevich thought of these things as spaceships, which he did. Therefore, the black is representing … eternal space and so on. But the black has been carved into a clear territory. The black square, of course, everybody knows, but lesser known is the black circle and the white on white. So if you look at the black square in its two variations, the black circle and the white on white, what you’re looking at is really an attempt to make the difference between white and black irrelevant. Strategically, polemically, with time, and what happens is the key images are probably these ones: this is Klucis’s “Dynamic City,” which is arguably, and certainly, he argued that, the first photomontage. And, of course, this is something highly disputed, particularly by Hannah Höch and Raoul Hausmann … who claimed, in exactly the same year, to have come up with the same technique. What’s important for us is that circle has now become a building site. That is to say, it’s not just a collage of architecture, and architecture is, as it were, coming out of that disc.

Continuing with the work again, here is Klucis’s electrification – you can see that now the circle remains a building site, but has assumed a kind of a grey colour. So actually the blackness of the circle is not really the key to the circle itself – and at that time, this is very, very polemical. This is Rodchenko

Line Compositions, 1920 … a year after Klucis's. And you can see that the clear impression is black is white, white is black –doesn't matter. You can systematically follow it through in Lissitzky. Going from the left, interestingly blacks … marked by white line against a black background with some kind of architecture coming out of it to his project, of course, which now is something again, a similar twist…. I don't have time to analyze in detail to 1930, where a catalogue of an exhibition making the architecture occupying the centre of this black disc. So there is this sort of evolution of black, the concept of black as a building site, as a site for building production, and, of course, the famous image of the Hanover Room by Lissitzky. And what I want to point out to you, of course, is this: they couldn't have a more polemical commentary on the equivalence of black and white background…. The images identically split between both and the fact that the man is upside down again is continuous with that idea that we're no longer in a space of gravity in a normal way.

So we can do some sort of history of why it is that it was possible for Leonidov to do these kinds of images starting in 1926 with this skyscraper plan, which he reverses like this. And then ends in 1930 with the linear city scheme on the right, which looks like an image maybe drawn not by a person but by a machine – which, of course, is the idea. And the idea of a city produced, let's say, in a line, so a series of lines to communicate a city that would be constructed in lines. But actually, even though we can explain why, and the precedents for Leonidov doing this, the rareness of his images is absolutely astonishing given how easy it is to flip a drawing from negative in the publication process and the fact that almost all experimental architects wanted to be cool, wanted to do dramatic visual things. And so all of them collaborated intimately with the most experimental graphic designers of the day. In other words, it was a piece of cake to flip your images white on black. Anybody could have done it, and instantly become cool. Nobody was doing it because actually it was not cool, and that's my point – that there's a moment in time in which it becomes cool and Leonidov is not dead. Leonidov, though, is letting us know what the issue is.

Of course the issue is photography itself. It's not until the 1950s that publishing an image like the one on the right starts to turn into something like a recognizable genre, that is to say, an architect would look at an image like that and feel some familiarity with it as a technique. And by the early 1960s we could argue that the reader of an architectural magazine might not even notice an image that's white on black even if the majority of the images are still black on white. Now there are lots of possible explanations for this, but one of the effects of it is that computer images could be later extremely easily absorbed by the discourse – in other words, there's a history of us, as it were, absorbing these images. Computer drawing was seamlessly naturalized with a photographic legacy and, of course, this is entirely consistent with McLuhan's argument that the only effect of a medium is, as it were, is the effect of seeing the previous medium. In other words, just as this kind of drawing is revealing the photograph and so on, the computer will then reveal these drawings.

From that point of view, then, this huge revolution in architectural drawing from white to black is maybe not such a rupture in the history of architectural drawing, but something like an extension of the longstanding although usually recessive photographic sensibility in architecture. But perhaps the negative photographic flip had itself only become visible in the 1950s because it's precisely in that moment that there is the demise of an even earlier form of white line on a dark background, which is, of course, the blueprint. And in this case, of course, the Villa [Savoye?] of Le Corbusier seen in plane and elevation.

The blueprint, of course, is an image applied to linen or paper – it's invented in 1842, mass-produced in 1860s for architects and engineers, and by the end of the century hand-tracing, which is the single biggest activity of any architect or engineer's office, became redundant. In other words, the office was transformed. The blueprint took over from the hand, the blueprint mechanized the discipline, and you can make an argument (another lecture) that it is the blueprint that made possible modern architecture because you can't have a modern architecture if you don't have a modern office. And it's the blueprint that industrialized the production of architectural drawings themselves.

Blueprint is, of course, a photographic process. In fact, it begins at the very beginning of photography. More than that, it was invented by William Herschel, who played a key role in the invention of photography by his friend William Henry Fox Talbot. Now I could understand that if I am in Montréal, you may well think that the French invented photography. Coming from New Zealand, I side with the British. Never mind. No matter who you think won the fight, it was Herschel that even coined the word photography, drawing with light, "photographie," and later even coined the photographic use of the words negative and positive. That is to say, the entire language comes from this guy who invented the blueprint. It's important to note that Herschel and Talbot explicitly invented photography as an improved form of drawing and upgraded their own landscape drawings with a camera … and technically can be more precise.

Talbot's wife was incredibly good at making drawings that way and he was not. And he was infinitely jealous and he literally designed the machine to deal with the fact that he couldn't handle his wife being better at this thing. Talbot's book on his invention of photography is called *The Pencil of Nature*. Drawing is not understood as the technological substitute for the pencil. It is understood as an improved pencil, an upgraded form of drawing. But blueprints in the world of architecture were always treated as secondary negative copies rather than drawings per se. Construction documents rather than artworks. They were almost never published…. Despite being the one form of drawing that the architect was symbolically identified with in the consciousness, let's say, of the client, the architect being the one who provides the blueprints. In that sense, blueprints were the hidden ghost image of architecture, only seen in engineering magazines and advertisements for architects, interestingly. Popular magazines like *House Beautiful* and *House and Garden* in the 1930s developed a genre of a kind of simulated blueprint; they just basically published plans in sections and so on in reverse.

The only exception to this repressed tradition of the blueprint as was so often the case – and if you're dealing with repression, of course Vienna is the right place to start with – was Kiesler, who was the first to exhibit and publish blueprints as final projects. So these are from 1925, these are from the collection of the Museum of Modern Art. It occurs to me actually now for the first time – I wonder if they consider them drawings or not? They are not originals – in a sense, they are on paper…. This is the Endless Theatre from 1923-25 – a fantastic project, of course, but they are blueprints, produced as blueprints. There's no other drawing available of these images – Place de la Concorde project, 1925; Spiral Plane, 1925. So this is a real exception: an architect using the blueprint as [his] primary mode of communication. And, of course, Kiesler having a very, very special relationship to the dark black surface. But it's precisely only in the mid 1950s when blueprint as a transfer technology is made redundant by the success of the so-called whiteprint or [diazo?] machine that the ghost image was brought to the surface in the form of the photographic negative.

In other words, what happens, in my view, is that the blueprint is actually the backbone of the architecture and architectural production and even modern architecture, but is buried as the antithesis of the classic image of the shadow drawing…. It's all about technical production, it's not about reflection and thinking, therefore, it's buried. It suddenly comes up to the surface in the fifties precisely because at that moment it becomes redundant. Just at the moment it's going to die, it comes up and [is] brought to the surface, and architectural magazines are very slow to pick up on it. Again, *Arts and Architecture*, which is not a professional magazine, I think that's the key, was aimed towards a sort of artistic, cultural audience on both coasts of America, and absorbed the white on black pseudo-blueprint style of popular magazines. They absorbed it in the 1940s and in the 1950s perfected it as a graphic style. Look at *Arts and Architecture* … and I'll show you quickly three examples … so you get a sense of the genre. So basically, what happened is, in the 1950s the pseudo-blueprint was absorbed into architecture exactly at the moment that the blueprint died out. To rush to the finish – in that moment that colour starts to appear, the colour of the blueprint starts to appear in publications all over the world…. So it's the sort of death throes of the technology that comes up, and Kiesler is doing this kind of image … and this kind of image, 1949 – oh, it's not Kiesler, it's Ben van Berkel, oh! So something keeps going, something is allowing us to absorb these new kinds of images in this way.

So here's what I am arguing. The medium rose to the surface, the medium being the black background itself, rose to the surface only in the moment of its death – the death of the blueprint, as if to hand over the tradition of the ghost images to a different form of photographic negative before it would then be turned over to the computer screen. So I am basically saying digital drawing is deeply imbedded in the history of architectural drawing, the history of drawing with light, a history of the ghost image that extends back to Vasari. After all, the traditional black-on-white drawing is itself already a negative if you think about what's dark, and a drawing is, in fact, what will be light in the end.

So here's just one, let's say, conclusion, in the terms of collection. We have to remember that paper itself, that thing which was turned into the privileged site for original production by an artist and made possible the very idea of the architect as an artist. Paper was at that time, first and foremost an expensive technology of transfer. The only permanent drawings were contract drawings. Mainly, we were dealing with cartoons made of pieces of paper glued together, which were pricked in order to transfer an image from one surface to another. The purpose of the paper being white was only to facilitate their transfer. Drawing on paper in the sixteenth century was just a technology for imitation, a kind of early form of Xeroxing that was gradually turned into the centre of the emerging art world. The … the artistic original actually emerges right out of the heart of systems of copying, but architectural drawings never quite survived this.

But we might argue that the same thing will happen with digital architectural drawings. Just as with paper and then with photography, this will require institutional shifts and redefinitions, but what are we going to collect? Are we going to collect the files or the prints in architectural design departments? Where will we keep these things? In drawing collections, photography collections, print collections? Should we keep the file, or do we need to keep the software, or do we need to also keep the computer, but especially the printer, since obviously the printer affects the quality of the image? I don't accept the point that was made earlier that there's a fundamental difference between the calculation and the printouts. There is, in my mind, never a possibility to completely separate the algorithm from the printout. In fact, it's in the particular form of printout that one can sense what it is that's being defined as an algorithm by the architect. Therefore, we cannot just simply say, let's just keep the formulas, and we don't need the examples. Secondly, I think it will be a question of preservation and all of the arguments about preservation will be extremely relevant. And I think emulation is probably the key area in this regard: that there was a growing expertise in the area of emulation and we could consider the ways in which drawings in one media can be emulated by another and we would have to develop systems of sampling. We could make the argument that we should just be systematic: we just collect every tenth drawing no matter what it is, no matter who does it – that would be a reasonable argument for detecting movements. We could also do it randomly: just send a machine to randomly collect anything, any program, any machine, any software – and that would actually be scientifically a very thorough way of collecting digital material. We could curate it by obsessively collecting those things that we think are the right things to keep, but it's the old form of collection. If you know it's the right thing to keep, you've already got it in your head. How to collect those things whose meaning you don't yet know requires other kinds of strategies. Anyway, for all the talk about computers, I don't think we really ever got to talk about the things that we claim that we want to collect, and I would say that's where we have to start. And maybe if we could, just for a moment, hesitate and look in at that kind of black screen somewhere between there and there. Thanks. (applause)

DERRICK DE KERCKHOVE: I guess I was calling for "screenology" this morning: we've got a "screenologist" right here. Thank you very much, Mark.

We're now going to have a chance to listen to Bernard Cache, architect of a company called Objectile from Paris, and Bernard will talk to us about non-standard folding software, after Jean Prouvé. Bernard. (applause)

## Bernard Cache
## Après Jean Prouvé : le pliage numérique non-standard

Good afternoon, everybody. By respect of the bilingual nature of this country, I was the one designated to speak French, so I will do it. And so, I will make a presentation symmetric to that of Peter Galison, which means I will make a short introduction in English and then the bulk of the exposé in French. And then when it comes to questions, I can take them in English. So after Mark's brilliant presentation, I cannot resist the pleasure of opening a new file here on the software – it has to warm-up – and to show you that all the exposé is about this.

[…] mais dessiner cette pièce, je pense qu'il faut à peu près une bonne journée de travail. Cette journée de travail se fait en quelques clics. Tout cela vient en fait avec, par exemple, les moyens de contrôler le dessin, c'est-à-dire que si je rends ce repère courant, je zoome ici, je peux vérifier que la pièce correspond exactement à ce dont j'ai besoin et surtout qu'elle comporte déjà tous les problèmes d'arrondi, de pliage, de déformation de la tôle et toutes ces choses-là.

Bien entendu, à ce stade, je peux continuer de modifier la géométrie de la pièce, c'est-à-dire que ce n'est pas parce qu'elle est insérée qu'elle devient un objet qui a perdu son intelligence. Je vais retourner dans une vision plus conventionnelle. Voilà. Je vais zoomer sur la pièce de connexion et maintenant, je vais demander la modification d'un des paramètres. Donc, je vais choisir la largeur de la pièce et je vais rentrer, par exemple, 150 mm. Donc, la pièce s'est recalculée. L'ensemble des trous de perçage sont [est] déplacé[s]. Enfin, tout fonctionne.

Maintenant, on a beau travailler dans un environnement digital, nous ne sommes pas encore dans l'utopie, c'est-à-dire qu'il reste des rapports de négociation et des rapports de conflit entre entreprises, et l'utopie de la chaîne continue de l'information depuis le concepteur jusqu'à la machine est quelque chose qui n'est pas près d'arriver. Donc, il reste nécessaire de générer des plans en deux dimensions pour discuter avec les entreprises. Je vais faire ça sous vos yeux.

Je vais ici dans une autre fonction. Je montre le composant. Je valide le facteur d'échelle et, si tout va bien, voici le plan de la pièce qui a été automatiquement généré. La seule chose qui n'est pas gérée correctement d'une manière associative, c'est la mise en page du plan. Donc, voilà. En particulier, maintenant, si je zoome sur cette partie, je vois cet angle de 74,88 degrés, qui est l'angle gamma dont on a besoin sur le pliage.

Mais les ouvriers ont besoin d'avoir un plan 2D de manière à savoir comment tenir la pièce quand on la tient dans la plieuse. Donc, je replie cette pièce et maintenant, on va générer le programme à la fois pour la machine de découpe laser et pour la plieuse. Donc, je vais aller dans une autre fonction. Je prends ceci <inaudible>. Je vais ouvrir un fichier entièrement vierge qui va être mon fichier de fabrication. Je mets ces deux fichiers l'un à côté de l'autre. Maintenant, je vais demander de déplier la pièce qui est ici, sur la base de cette phase de référence, sur le repère qui est ici. Voilà. Ça, c'est fait. La pièce a été entièrement étalée. Vous voyez ici la valeur de l'angle que nous avions vue sur le plan ainsi que le rayon de courbure du pli qui est le paramètre technique dont ont besoin les ouvriers pour savoir quelle est la force qui s'imprime sur le métal.

Donc, là, ce plan part en usine. Si les problèmes de rapport économique sont résolus, c'est automatiquement recevable par la machine Bystronic que vous avez vue, pour le laser et pour le pliage. Maintenant, le fait que ce soit associatif signifie que si je reviens au tout premier fichier et que je le mets à côté du plan de fabrication, je vais maintenant prendre de nouveau une de mes hypothèses de départ – il faut que je rentre pour 11 fichiers. Je vais saisir le point, je déplace et vous allez voir que toute la chaîne va se reproduire. Vous voyez que l'angle, maintenant, ici fait 68 degrés et que la pièce est donc entièrement actualisée. Pour ceux qui font des plans sur AutoCAD […]
<brève interruption dans l'enregistrement>

[…] que nous voudrions développer de façon à être capable de produire un bâtiment comme le Musée Senn-Foulds (?) que je vous ai montré, qui est une forme… une structure d'entrelacs, suivant des méthodes qui soient véritablement associatives et numériques. Pour cela, je vais maintenant vous expliquer comment ça se passe au niveau géométrique.

J'ai fait, tout à l'heure en anglais, une toute petite démonstration du calcul d'un point d'intersection entre deux lignes. Évidemment, on peut aller vers des choses beaucoup plus compliquées. Je vais vous expliquer maintenant que toutes ces variations sont, en fait, possibles parce que, par derrière, nous avons des invariants géométriques.

L'associativité. Je pense que ce qui est important d'un point de vue culturel dans l'associativité, et ce qui fait qu'il se passe vraiment quelque chose, c'est qu'au lieu de concevoir un objet comme un archétype unique, un objet fini, on conçoit en fait des séries de variations. Et ça, ce n'est faisable que parce que derrière la géométrie que nous mettons en œuvre, il y a des invariants; et l'un des invariants les plus simples et les plus classiques est celui du théorème de Thalès, c'est-à-dire que – je zoome un petit peu sur mon écran – si je change l'orientation des parallèles qui sont ici, évidemment les distances entre les points A, B et C varient, mais le rapport que vous voyez ici, c'est-à-dire RC1 égale 2,18 et RC2, 2,18, qui sont les ratios calculés pour cette ligne et pour cette ligne, restent égaux(?) [reste égal] quelle que soit la position de ces parallèles.

Maintenant, rendons la chose un petit peu plus difficile pour vous expliquer comment tout ça n'est pas du tout limité à une géométrie toute simple, mais peut évoluer vers des choses qui deviennent extrêmement compliquées d'un point de vue topologique. Mais, au lieu d'aller tout de suite aux entrelacs, je vais passer par la géométrie projective qui est déjà à un étage assez significatif.

On va prendre ce paramètre qui règle le parallélisme des droites, on le modifie et vous voyez que, cette fois-ci, le ratio ici vaut 1,96 et de l'autre côté, 2,12. Puisque mes deux lignes ne sont pas parallèles, je suis sorti du théorème de Thalès et j'ai brisé le ratio proportionnel entre ces deux lignes. Mais rassurez-vous, il existe d'autres ratios et, en particulier, des ratios projectifs, qui sont des ratios de ratios – donc des choses plus compliquées – et qui, elles… enfin lequel rapport va rester égal et invariant quelle que soit la position de ce qui devient maintenant l'équivalent d'un point de fuite. Vous voyez que les deux ratios en jaune ici font 1,27 et 1,27, quelle que soit la déformation que j'apporte à cette géométrie.

Une incidente comme ça… dans l'histoire de l'art, les gens ont buté contre ce ratio avant qu'il soit inventé à la suite de la géométrie projective de

Desargues, mais en fait, un petit peu plus tard surtout, par Michel Challe. Souvenez-vous, Alberti se posait la question de savoir quelle était la loi de diminution de la représentation de carreaux sur un pavage, de carreaux qui sont dans la réalité égaux et qui doivent être rendus en perspective par une diminution constante à mesure de l'éloignement. Donc, la loi de diminution de cet éloignement est donnée par le birapport que je vous ai montré ici.

Tout ça en fait pour vous faire réaliser que les tables et le modèle que j'ai utilisé pour les manipuler est [sont], en fait, un modèle de géométrie projective qui a été inventé par Desargues et dont on voit une représentation ici sur une gravure d'Abraham Voss. Je vous rappelle que Desargues n'était pas seulement un géomètre, mais un réel architecte, c'est-à-dire que Desargues a construit. Une des seules réalisations de Desargues qui ait été conservée jusqu'à l'âge de la photographie est celle-ci, et malheureusement la maison a été détruite peu après la prise de la photo. Desargues se posait plus concrètement en termes d'architecture le problème général de la rencontre d'une cage d'escalier avec une voûte devant rencontrer un mur oblique comme on peut en voir dans les remparts de fortifications.

Donc, vous voyez ici la solution de Desargues. Si vous la comparez à toutes les autres solutions proposées par les gens qui l'ont suivi immédiatement après, vous voyez que Desargues est celui qui a trouvé la solution qui fait appel au plus petit nombre de plans.

La géométrie projective qui, en fait, n'a la perspective que comme une des applications possibles, était en fait pensée pour la production pour la taille de pierre et la production d'ouvrages d'art relativement complexes. Je pense qu'ici vous voyez comment la géométrie projective permet de créer ce qu'on pourrait appeler « a free form surface » où chaque pierre est différente et a été calculée précisément. Donc, les logiciels que nous utilisons aujourd'hui ne font, en quelque sorte, qu'automatiser le mode de raisonnement qui était celui de Desargues à l'époque.

À côté de Desargues, il y a un autre mathématicien français qui s'appelle Pascal qui, lui, s'intéresse aux hexagones. Voilà un hexagone qui est un peu quelconque et, si je zoome ici, vous découvrez une droite qui est, en fait, la droite d'intersection de chacune des paires de côtés opposés, c'est-à-dire que si j'ouvre ici le capot du moteur, je vais donc éditer le point qui est celui-ci. Vous voyez que c'est aussi un point d'intersection entre cette ligne-ci, celle qui apparaît en rouge – peut-être que je vais zoomer un petit peu, on verrait mieux – vous voyez, c'est l'intersection entre cette ligne-ci et celle-ci. Donc, si on prend les trois paires de côtés opposés, on obtient ces trois points d'intersection. Cette relation reste constante quel que soit le mouvement, enfin, la disposition, vous voyez, des points de cet hexagone.

Je vais vous montrer maintenant à quel point on peut manipuler cette géométrie. Je vais le mettre dans une configuration qui est exprès beaucoup plus visible pour ce que je vais faire ensuite, c'est-à-dire je prends le point A, je le mets là; je prends le point F que je mets là; et je prends le point E que je mets là. Vous voyez que les trois points L, N et M restent alignés et, en quelque sorte, j'ai fait une figure d'architecture déconstructiviste, mais qui a une invariance par derrière et une régularité qui me permet, en fait, d'automatiser après tous les processus qui vont aller derrière. Ça, je pense que c'est fondamental. Et, en particulier, puisqu'il s'agit de programmes, je pense qu'il est très important de constater que les fonctions les plus importantes maintenant ne sont plus des fonctions de modélisation, ce ne sont plus des fonctions de transmission géométrique, mais ce sont des fonctions de substitution parce que, évidemment, pourquoi tout ceci fonctionne, c'est que cet hexagone n'est pas tout à fait quelconque. Cet hexagone est appuyé sur un cercle et, parce que ce cercle est une conique, je peux le remplacer par une autre conique.

Je vais, sous vos yeux, faire l'opération de substitution du cercle par l'ellipse d'à côté qui explique bien, je pense, le mécanisme fondamental de l'associativité et qui n'est autre que celui qu'on utilise dans l'insertion de composants comme la pièce de connexion sur la table tout à l'heure. Je vais dans cette fonction qui est « Éditer/Remplacer ». Je montre le cercle. Je vais demander de le remplacer pour tous les éléments du dessin. Vous voyez que l'ensemble du dessin s'est transféré sur l'ellipse et surtout que j'ai conservé la relation d'alignement entre les points M, N et L. Évidemment, tout ceci reste associatif.

On peut même aller vers quelque chose d'encore plus compliqué, c'est-à-dire passer une conique dégénérée. Vous savez que si on coupe un cône, à un certain moment, on va se retrouver avec un plan de coupe qui sera parallèle à celui de l'axe du cône et à ce moment-là, l'ellipse se sera transformée en une paire de droites. Je vais faire une opération de remplacement qui va être beaucoup plus compliquée, c'est-à-dire je vais être obligé d'affecter cette fois-ci les points à l'une ou l'autre des droites du dessin. Je le fais déjà pour les trois premiers. Voilà. Vous voyez, bien entendu, qu'ici on est dans une phase intermédiaire du dessin. Donc, les points M, N et L ne sont plus alignés. Vous voyez que la ligne est brisée, mais je vais continuer le travail pour affecter d'autres points à l'autre droite : voilà pour ce point, voilà pour le cinquième et voilà pour le sixième.

Normalement, ça marche. Je vais donc recommencer une dernière fois. Et c'est peut-être parce que je zoome (?)<inaudible> pas assez bien. Voilà. En même temps que nous avons fait cela, je vous signale que nous avons remonté le temps, c'est-à-dire que nous sommes passés du théorème de Pascal au théorème de Pappus qui a été écrit quelque 150 années après Jésus-Christ. Ça, c'est un aspect très important et très intéressant de la géométrie, à quel point la géométrie projective est une espèce de mur contre lequel des gens comme Vitruve ont buté avec les corrections optiques, contre lequel Platon avait déjà buté avec le problème de la bonne et de la mauvaise copie – je vous rappelle que c'est un problème architectural, c'est-à-dire la nécessité pour les artistes de déformer les proportions des statues de façon à ce que vues d'en bas, les déformations de proportion réapparaissent comme bien proportionnées. C'est donc un problème qui est fondamentalement lié à la culture de l'architecture. Ici, nous sommes en 150 après Jésus-Christ et vous voyez que ce théorème reste valable.

Donc, on a commencé par un invariant proportionnel. On est passé à un invariant projectif. On va maintenant passer à des invariants topologiques plus complexes. Pour vous montrer que tout ceci s'applique aussi à une architecture plus proche d'un esprit que certains pensent contemporain, je vais dessiner un graphe. Pour ça, j'ai besoin de simplement une série de segments. Voilà. Sur ce graphe, je vais créer un entrelacs en 3D. Je vais ici, je prends ma fonction d'entrelacs. Je vais changer de couleur pour que ça soit plus visible. Je vais donner une hauteur maximale à mon entrelacs. Maintenant, je lance le calcul. Rassurez-vous, ça n'est pas de la géométrie 2D. On est bien parfaitement en 3D. D'ailleurs, ça se verra plus si on vous montre les quatre vues. Il s'agit bien d'un objet tridimensionnel dont je peux continuer à modifier la géométrie en déplaçant les points qui le pilotent.

Vous imaginez bien maintenant que ce que nous allons continuer à développer, c’est l’application de ce que je vous ai montré pour des pièces de connexion à ce type de géométrie. Il faut bien comprendre que l’écriture de ce type de logiciel est relativement complexe et que tout ça va prendre encore au moins cinq ans. Les noyaux doivent changer. Il y a toute une épaisseur du travail sur l’écriture de logiciel qui est importante et ce n’est pas quelque chose qui se fait comme ça du jour au lendemain.

Pour conclure, je vais vous montrer maintenant un embryon de projet architectural, c’est-à-dire que j’ai [je suis] passé de l’échelle du composant à celle d’un embryon d’architecture. Nous testons régulièrement nos techniques sur des espèces de pavillons de démonstration. En voici un qui avait été présenté il y a maintenant au moins quatre ans. Les murs sont entièrement courbes. Les entrelacs suivent aussi ces courbes. Nous attachons beaucoup d’importance à la texture – vous voyez que même les panneaux qui sont lisses ont une certaine texture qu’on tient à pouvoir maîtriser. Voici le contraste d’ailleurs entre l’entrelacs et la texture.

Maintenant, je vais passer à une version, je dirais, un peu simplifiée du problème. On va s’attacher à dessiner la structure de cet embryon de pavillon. Je retourne sur le logiciel et je vais ouvrir une représentation purement symbolique de ce pavillon. Vous voyez que si maintenant je prends un point de contrôle ici, je peux le déplacer et tout se recalcule.

Maintenant, ce qu’on va faire, c’est que je vais générer un des portiques qui sert de structure au pavillon. Pour ça, je retourne dans un rendu simplifié et, comme d’habitude, c’est la même chose que l’insertion de la pièce de connexion, la même chose que l’opération de substitution que j’ai faite dans le théorème de Pascal pour le transformer en théorème de Pappus. Cette fois-ci, je vais aller chercher un composant qui est beaucoup plus lourd – c’est celui-ci – et vous allez voir que… ne serait-ce que le temps de chargement de l’ensemble du composant n’est pas négligeable. Ce que j’ai à faire maintenant, c’est de montrer une vingtaine de points à l’écran. Je commence par celui-ci. Vous pouvez voir comme la question d’efficacité est toujours un problème parce qu’on a beau réduire le travail – ce que je vais générer maintenant prendrait probablement trois jours de dessin, mais pour finir – on trouve que désigner 20 points c’est encore trop long. Dans le nouveau noyau qui va sortir d’ici deux ans, on pourra éviter de désigner ces 20 points pour chacun des portiques. Donc, la notion d’efficacité est très importante.

Vous voyez, comme je parlais, le portique a été généré. Bon, j’étais dans un rendu un peu mauvais, mais je pense que vous voyez bien à l’écran. Au total, il y a 58 pièces qui ont été calculées avec leur programme d’usinage en place. Je vais vous montrer un peu mieux la géométrie; la voici. Là, il faut bien vous dire que, par exemple, si je zoome ici entre la plaque orange et la plaque jaune, il y a exactement 0,2 mm qui est le joint dont on a besoin pour tenir compte des tolérances d’épaisseur des planches de bois livrées par l’industrie.

Maintenant, il ne nous reste plus qu’une seule chose à faire, c’est d’envoyer tout ça sur la machine. Je retourne à un rendu simplifié et je cherche une fonction. Je montre le composant et, en ce moment, toutes les pièces qui sont disposées sur le projet comme elles devront l’être dans la réalité vont être prises une par une positionnées sur la machine suivant une stratégie d’optimisation pour minimiser le nombre de planches qu’on va utiliser et le programme d’usinage de l’ensemble des perçages, des contournages, des vidages de poche va être généré automatiquement. C’est pour ça que ça prend un tout petit peu de temps parce que je suis sur un portable, mais voici ici une vue générale. Attendez, je vais mettre ce fichier courant. Voici une vue générale où vous avez les 58 pièces.

Si maintenant je demande une vue en perspective et que je zoome sur un des éléments, vous voyez la trajectoire où l’outil va venir descendre ici, il va faire le tour de la pièce, va se lever ici pour laisser un ergot pour que la pièce reste connectée à la machine, va retourner là, va faire le vidage de poche, etc. Tous les problèmes d’usinage ont été résolus de manière automatique et associative. Associative, ça veut dire que si je remonte maintenant à l’esquisse initiale, que je redéplace un point, ces programmes vont être régénérés à leur tour. Voilà, ça sera tout pour aujourd’hui.

## Greg Lynn
## Going Primitive

[beginning was not recorded]

A primitive is based on a whole set of procedural operations within a set of instructions. So: a primitive is a thing which is yet to be determined, let's say, or yet to be specified, but nonetheless it has qualities of holism, of completion, of closure. That would be very familiar to classical architecture, I think, and this is one of the kind of tricky ideas I'm trying to work through. And this morning there were some discussions of thinking about classical issues like enthasis and all kinds of things, that maybe it might be fun to try and hook up at the conversation.

But one of the things that a primitive is not, is a primitive is not some whole that gets subdivided into parts – a lot like what Mario was talking about this morning; it's not something based on fractions and subdivisions of discrete components. It's also not based on something which is iteratively reduced to some ideal. The primitive replaces both of those models: of the whole, which is subdivided in a fractional or modular way, or the ideal form, which is reduced.

I have to admit, you know, five or ten years ago, like a lot of architects, I started using the computer, and started to think about architecture in terms of big shapes. And started to think the problem of architecture was the problem of producing big shapes, and the discourse in question should be about big shapes. And consequently I spent a lot of time looking around for large computer-controlled machines that could build a piece of architecture or a building in one piece at a giant scale as a single shape.

Now I have to say as a field, I think we should be embarrassed by that ambition. I'm embarrassed that I had that ambition, only because I completely forgot what architecture is about, which is the assembly of large numbers of components to produce a single object or multiple objects. And I'll talk a little bit in terms of numbers of components, but architecture is really – the questions that we should be talking about are not questions of massing or overall shape. We should be talking about assembly of massive numbers of components to produce scales and hierarchies of spaces and volumes, of which the big shape is one question, but I think it's probably not the most critical one.

Also just to make a comment: I like this term *device* a lot. It's the first time I've really thought about this term. It's usually techniques, or diagrams, or some other term, but I like the term *device* because it kind of connotes some kind of intricacy of components that assemble. So a *device*, like a watch, is a thing which is made out of small, fine-grain, interacting components. And in that sense, I think architecture is more like a device than it is a shape. Also the term "to devise" implies a kind of innovation through reconfiguration of existing systems. So I think this is a very good term, and nobody's really mentioned it. I just wanted to make sure that this idea of *devising* is – in terms of applying some innovative approach to existing systems – is important. I think it's no accident, the kind of interest in Renaissance and pre-Renaissance architecture, because I think the approach to devices would make us have to think about previous architecture rather just some kind of break and a newness.

So one of the things – the dominant theme that I'll talk about, and Mario mentioned this already – is that I see the computer as ushering in an era of calculus-based design systems for architects. I think calculus has been around … for three hundred years. The computer was first thought of in terms of a machine that would be able to calculate calculus equations, and I think it's just recently that we're able to think about it. And so what I'll really do is a kind of of high-school-level description of calculus principles and talk about how in architecture, specifically, those principles can affect the way we think about space.

The kind of three major shifts in the principle of calculus is the loss of the zero and the loss of the privilege of the whole number. So if you're dividing things fractionally in the way Mario was showing us, or even if you're dimensioning things in a modular way, it's not only that it's more complicated to think of variable units, it's also metaphysically problematic, because the whole number has a greater value in some mathematical systems. But the whole number in calculus has no value; it's actually a shift towards infinitesimal subdivisions. Second thing about calculus is that it's a system of continuous calculation, so you're dealing with not only curves, but curves which are vectors in the sense of how they're being described positionally in space. So the introduction of curve-based tools, the introduction of infinitesimal modules, and the loss of the kind of symbolic and real value of whole number systems are all things you have to think about when you're using these tools.

Again, the idea of a primitive is trying to think through these issues of a thing which can be infinitely subdivided, a thing which can be endlessly modified with all of its parts and components modifying continuously. It's not necessarily a whole that gets subdivided, but it's a collection of components which can endlessly be unfolded in different organizations, and it involves setting up hierarchical definitions of systems. And architecture systems tend to be structure, envelope, panelization, windows and apertures, massing – these kinds of issues – so the multiple systems in architecture can be thought of in relationship to one another with a kind of flexible primitive.

One thing, just as a kind of aside, is that architectural theory for some amount of time was looking toward the natural sciences, and was trying to come up with bottom-up methods of design. I have to say this concept of a primitive does not imply bottom-up design. This is not a way of writing algorithms and having algorithms give you results, and then like a breeder or a kind of omniscient aesthete or functionalist picking those variations. The primitive does use algorithms, it does use procedural modelling, but it actually thinks the problem of the whole, and the problem of the collection, at its outset. So when you begin with an approach to building primitives, you have to think of the part and the whole at the same time. You don't just get some kind of emergent whole or some kind of magic moment where it turns into a collection.

So to show you now a couple of examples:

[slide]

Going primitive:

- Curve is infinitesimally divided segments
- Modulation of whole and parts in unison
- Seperatrix: continuity and differentiation
- Monolithic fusion across scale
- Non-modular seriality
- Complex variation, not simple variety

- Undulation of details with surface
- Fusion of form, panel, relief, aperture, and colour
- Continuity through disparate morphologies
- Intensive surfaces

These are basically the themes that involve a calculus-based system of modelling, but within architecture. I mean, I think there's a difference between disciplines, and some of these problems are specifically architectural problems. But the idea of the infinitesimally divided module, and the fact of calculus where even a straight line is defined as a curve – it's just defined as a curve without any inflection – means that when you're drawing curves, curves are actually line segments of an infinite subdivision, and the module of that subdivision is one of the issues of how you define them. Again, I mentioned the modulation of whole and parts in unison, in some continuous way; the idea of continuity is a model of defining shape. Non-modular seriality, I think, is very similar to what Mario and Bernard both referred to as non-standard components, and then as we'll go on, [there are] more architectural issues, like issues of detailing, which instead of thinking of large planes, connect points that are frozen in space with details that resolve those intersections. In a system like this with a primitive, details are ubiquitous. I mean, everything is a detail and detail is absolutely everywhere distributed all over a form.

[slide]
Modulation of whole and parts in unison

The first example of this – I've kind of broken it up, there are things going on other than this – but the best example of modulation of whole and parts in unison

[slide]
Plan of Bijlmermeer project

is in this housing project that I'm doing just to the south of Amsterdam in the Bijlmermeer….

[slide]
Exploded three-dimensional digital drawing/diagram of Bijlmermeer project broken into irregular masses (the discrete neighbourhoods)

So I'm not going to go into any depth on any of these projects, but let me just say this is a building that was built in the seventies. It's roughly a kilometre long if you walk it, and there are five hundred apartment units in it. We're renovating them, and trying to, while keeping the structure of the building, break it up into discrete neighbourhoods of fifty apartments. And one of the things that we did – and this is how we won the competition, I believe – is we gave each neighbourhood of fifty apartments a distinct position and a distinct shape in that block, so that instead of being divided by the length of the building, they're divided into these chunks.

[slide]
Section / Excel spreadsheet

The way we did it – the project – I mean, I'll mention a few of the kind of nerdy things – since Mario put it on the table – we designed the whole thing in Microsoft Excel, where we would take each one of these apartment types, could get all kinds of information and a database associated with it, so we could do all kinds of cost models and all kinds of studies of how to organize a neighbourhood. So this is an Excel document where this edge would merge with that, and it's a section view of all these neighbourhoods and apartment types. But the way we were able to get these uniquely shaped apartment types is by using escalators, so that we rewired the circulation of the building so that every neighbourhood has an elevator at one end and an escalator at the other.

[slide]
Facade – digital aerial perspective showing trusses (grey), escalators (red), stair verticals (red)

Now to support – and this is where this issue of modulation comes in – to support these escalators we have a 120-some trusses that clip onto the existing building. And because of the diagonals of the escalators and the structure of the building to which these trusses attach, every single one of these trusses is unique in its shape and in its size, but to take advantage of manufacturing …

[slide]
Facade – digital elevation showing truss pattern

and also take advantage for the aesthetics of the project, they're all built out of the same number of components. So there's a little over 1,100 pieces that go into every one of these trusses, and there are over 120 trusses, and they're all defined initially by these escalators.

[slide]
Two sets of four trusses (digital model)

Now like the problem of enthasis, where you modulate the curves, we spent a lot of time trying to work out the mathematics of the curvature of the edges of these elements. They have to attach for at least five and a half metres of distance where they touch each other. The bays of the existing building vary – there are two different bay dimensions – and the diagonal of the elevators as they pass through is the third variable. So we wrote and we had a lot of support from a company called Microstation, and a specific person named Robert Aish, who has written a software plug-in called Generative Components, where you basically make each one of these separators a discrete algorithmic component, which gets arrayed along the face of the building. And each one of those components looks to the escalators to determine its specific shape. After doing that we got something like this,

[slide]
Facade – perspective view showing truss undulations (digital model)

modelling it interactively. But one of the problems I had is that every time an escalator stops – like here – there's an abrupt transition from one truss to another. But I wanted to temper the facade so that it was "synthesized," let's say, along the entire length of the building. So we then wrote – this group of eleven components is then bundled together into another component – and each one of these looks at seven neighbours to the right, and distributes its shape across those seven, and looks at seven neighbours to the left, and distributes its shape along those neighbours. And then we calculate the whole facade from the left end of the building to the right, and then back again from the right to the left.

[slide]
Facade – perspective view showing truss undulations (digital model)

[slide]
Facade – perspective view showing truss undulations (physical model)

So – I'm not positive about my math – something like ninety million calculations go into every change in any one point in the building. So it's kind of like the old days when we used to sit around with a Silicon Graphics machine, and try to make something move, and then go away and have a coffee and come back and see the screen frozen. It's the first time in a long time that we're crashing basically kind of supercomputer-scale machines. But as we – so it's not interactive is what I'm saying – but as we make decisions, this entire facade, which is made out of a little bit less than a million components, every one of those million components is looking at every other component to determine its size and shape. It's doing it through a hierarchical chain of procedures. It's exactly what Bernard was showing you … every one of these pieces is looking at every other one of the pieces.

[two slides in quick succession]
Facade – perspective view showing truss undulations (physical model)
Perspective view from roof (physical model)

It's very – I have to say – I'm not totally convinced, because it's a very cumbersome operation, but it does produce a continuity and, dare I say, elegance of the whole system. So what's really driving this is an acceptance of structural and circulatory parameters, but more than anything it's an aesthetic. It's an absolute aesthetic predilection I have that I want all of these components to be of the same family and connected with each other so that they all have continuity and variation at the same time. And that's really part of an aesthetic discourse rather than anything else.

[three slides in quick succession]
Perspective views of facade (physical model)

[slide]
Curve is infinitesimally divided segments

OK. The second idea, that the curve is really just the infinitesimally divided component –

[slide}
Photograph? or digital image? – interior perspective of (Korean) Presbyterian Church of New York – from balcony

In the housing project, some of those are actually rolled steel curves, but most of them are built out of linear components. And the challenge is really detailing the connections between the components, and getting something which has the right degree of both smoothness, but also articulation. Another kind of anecdote is that when I started using computers – still, in fact – I don't, our office doesn't do very convincing renderings. Our renderings tend to look like wet, shiny metal things with no articulations. And as I would show these things at lectures and in the world, everybody started assuming that I wanted to make wet, shiny, unarticulated buildings. And I have to say that was never an agenda of mine, because I think architecture is about exploiting the expression of the multiple systems of structure and panel and interior. It's also about exploiting components and the relationship of components. So in this church in New York, we produced a single volume which oriented you toward the altar and brought light in from behind, and did all the things that make a space look spiritual. But we did it through components that all varied, but they varied in calculus sequence.

[slide]
Photograph? – interior perspective of church – looking the other direction

So the kinds of rhythms of variation are very important, and some degree of iteration, like a kind of repetition with a difference, is just a principle of the mathematical system, and it's an aesthetic.

[slide]
Photograph – exterior view of church facade

So to say that the aesthetic and the machine and the mathematics are disconnected, I think is just flatly incorrect, because this is a calculus shape – anybody would know that.

[slide]
Fusion of form, panel, relief, aperture, and colour

The (check this) look at a little bit of an over-the-top project,

[slide]
Plan(?)  Predator installation

but a project that I think produces a new genre of object. What I'd like to do is try a little bit of a musical interlude. I was on an airplane a few years ago and saw a documentary on The Who, and learned that it was Pete Townshend … the first rock band to use a synthesizer. And they pulled apart all the tracks of this one song, "We Won't Get Fooled Again," and played each one of the tracks to show how they were working with each other. And it was very clear that in this band – they were one of the first bands where the drummer Keith Moon would be playing drums over the vocal track. Most rock bands, the singer would stop singing and the drummer would drum. Keith Moon always just played rhythm while nobody was singing, but every time Roger Daltrey started singing, he started going crazy. So that was one thing, and I thought, here's a new model of symphonic interaction going on between the drummer and the singer. They then showed the sound of the synthesizer and showed how Pete Townshend started mimicking the sound of the synthesizer with his guitar. So I went back and listened to some of The Who, and I have to say this is kind of a canonical band for me, personally, and I don't think that these things are accidental. I think there's a sensibility that goes with design that you can't deny. I realized that Pete Townshend was imitating the synthesizer before the synthesizer was even invented.

So I've come up with a few principles for integrating new technologies into existing fields. The first is the field has to be ready to integrate the new technology. I mean, you just saw Mark do it with the white lines on black backgrounds; the computer was already being drawn – the aesthetic – before the computer was even there. And I think in architecture there has to be a kind of concept for the equipment – and by the way, all this calculus stuff is over three hundred years old. So architecture has had the opportunity to think [about] the problems for a while. So Townshend is already playing his guitar in a way that makes him be the logical place that the synthesizer's going to first get played. Second thing is that he spent a lot of time in a very simple way just tapping on one note, and you'll hear it just over and over again – dudududududu. And he was learning at the simplest level the principles of that new tool. And then the third thing he did is he took his existing instrument and learned to make it play in a way that it could enter into a kind of symphonic relationship with the new technology. So first having – articulating the problem and the need before the invention of the tool, understanding the principles of the tool on its own terms rather than constantly telling the tool what you want it to do, and then third, being able to take your discipline and play it as an expert in such a way that you integrate with the new tool, you produce a new genre of music, and I think you produce a new genre of architecture as well. OK. So bear with me; I've only tried to do this once before –

[sound]
Introduction to The Who: "Won't Get Fooled Again"
This is obviously the synthesizer … I'll let this go for about thirty seconds [sound drops and rises again] That wasn't me …

[inaudible behind music]

OK. So I hope you get the idea, but (laughter) here's an artist who's integrating this new tool, getting his guitar to sound like it, and producing what is basically a kind of symphonic and operatic sound that now is – has become a genre in and of itself. Now I'm not going to bore you with all of the examples of it, but because I was just, I have to say, kind of "on the fly" sitting here, if you listen to somebody like Beck, four years ago … I get the right spot …

[sound]
Introduction to Beck: "Loser"

[obscured by music] … you can hear him now working with a Macintosh laptop and an acoustic guitar, doing something very similar. I think the thing about this is that the technology is expanding so he's integrating hip-hop, he's integrating [inaudible].

OK. And then finally, a kind of even better example of it, just like a couple of months old. This guy is Simple Kid, with a much more sophisticated synthesizer track, but nonetheless bringing in acoustic guitars, drums, keyboards, all these things, to produce what I think is a very kind of rich and layered sound. But this is literally like that Who song:

[sound]
Introduction to Simple Kid: "Drugs"

Here comes the synthesizer part … [obscured] You'll hear how the synthesizer starts to –For his kind of symphonic arrangement, previous techniques and new techniques are really important. So the idea that the computer is now a thing that has its own aesthetic, which excludes all previous aesthetics, which needs a new machine to make it and which we forget everything we previously knew about the discipline, I think, is a mistake. I think it's only recently that we're getting out of that mode of thought, but I'm glad we are. But anyway, I think popular music has been much more … savvy about the integration of previous sounds and new sounds.

So in the spirit of creating a new genre of object, I've collaborated a fair amount with a painter named Fabian Marcacchio, and this is a project we did called the Predator. It's called the Predator because when we were trying to think about what we were going to do, the *Predator* film with Schwarzenegger had just come out. And I said – and we'd had a problem integrating architecture and painting – and I said, "Well, in this movie the special effect is a faceted stealthy alien over a jungle. And the shredding of the alien, and the fronds of the palm trees in the jungle produces a space which has both image and form in it. Why don't we do something like that?" And Fabian said, "Oh, I love that movie. I've been doing Predator paintings for the last six months." And he was doing basically jungle paintings, so we wanted to produce something that had – and again, this isn't like a competition between Richard Serra and Frank Gehry, or Donald Judd and John Pawson or something – I had my own issues as an architect, and he has his as a painter. Architecturally – the architectural issues were to produce a translucent form that squeezed you against the gallery walls, and that had panelization and apertures that worked with the geometry of the surface. Fabian's concerns were producing a painting which was intensively connected to the form, and to produce a painting that had a front-side/back-side effect.

[slide]
Photograph – large blue model of Embryological House, wall hung

To do that, the real task, and this is that thing from five years ago I was telling you about, where I was looking for a big machine to spit out a big form,

[slide]
Photograph – view of CNC machine from outside sealed room

but to do that I realized we couldn't build it in one piece … we had to think about panels. And it was at this point that I bought a CNC machine for my office, a laser cutter for the office. And we used these machines for their ability to translate surfaces into the path of a tool.

[slide]
Photograph – view of cutting machine being operated

And we discovered a few things about that step of translation.

[sequence of four slides]
Digital model of objects to be fabricated on CNC machine – axonometric view

So the basic principle is you take a geometric file that's defined as curves that make a surface mesh, and then you translate those things into the movement of the tool in space that removes material.

[slide]
Photograph – close-up of CNC machine fabricating model

You can also make a thing that cuts, like a laser cutter, or plasma-jet cutter, or water cutter – the principles are all the same. I have to say almost the entire industry of architectural manufacture already uses these things. So if you want to live in a Victorian house with gingerbread ornament, it's cut with a CNC mill and it's all designed on a computer – because they don't have people with jig saws; they can't afford to do that.

[slide]
Plan view of two-and-a-half-dimensional model: undulating, sculpted green surface

So the translation of the surface into the form gives you the opportunity to make decorative effects by intervening and actually designing those tool paths.

[slide]
Three-dimensional view of white form (Embryological House) generated by folding a two-and-a-half-dimensional surface, resting on a similar surface

I won't go into all of that, but the principle is basically we would mould plastic on two-and-a-half-dimensional forms, so that each one of these panels comes from one of these pieces of form work. This is another project, the Embryological House, which is actually here at the CCA, I'm real happy about.

[two slides intercut rapidly]
Photograph – several curved and cut, comb-like fragments of surface
Photograph – cut metal model of Embryological House (CCA's)

So – and again, you can cut in 2-D – which, actually this mistake, in water-jet cutting steel, and folding it up and welding it, I realized that these gaps, which were inaccuracies, were actually good systems for thinking about windows and apertures.

[six slides intercut rapidly]
Photograph – mould for Predator
Close-up view of mould
Photograph – mould for Predator
Close-up view of mould
Digital model of Predator – multicoloured
Digital model of Predator – blue

So the first step was kind of the massing of this. And we cut little models and would FedEx them to Fabian every two days, and he would paint them up and send them back to us. The second issue was designing some kind of texture, so the tool path actually had paint information on the skin.

[slide]
Diagram of Predator strips
Diagram of Predator strips – close-up
Diagram of Predator assembly

And then finally the problem was cutting up two hundred and fifty two-metre-by-three metre panels, and dividing Fabian's painting up, so that we could reprint plastic sheets, and then mould those plastic sheets onto custom forms, and then assemble all those custom forms together to produce a single surface.

[three slides intercut rapidly]
Digital model of Predator assembled
Physical model of Predator strips assembled
Digital model of Predator strips assembled

And again this is the kind of window apertures we were playing with.

[slide]
Photograph – Predator installation

And so we ended up building this self-supporting vaccu-formed plastic skin that for us produced a new genre of work, in the sense that it wasn't a painted sculpture. I mean, you can read it as a painted sculpture, but the fact that the surface pattern, the printed painting, and the literal paint collaborates to produce a new kind of a surface was only possible out of the collaboration. So bringing together the kind of digital approaches in both of our fields, it let us work together,

[two slides in succession]
Photograph – Predator installation close-up
Photograph – Predator installation

but it also let us produce an object which had qualities that for us constitutes a new genre of type – of spatial type. It's not architecture and it's not painting, it's something in-between.

[slide]
Non-modular Similarity

[four near-identical slides in succession]
Array of digital images of curved form

OK, just to run through a few of these principles. The principle of non-modular seriality – this is a coffee set that I did for Alessi with – twenty other architects did these, and what I did was I took some of those curves off of the housing project and started to rationalize the curves as a system because that was a project that had already tempered all of the shapes, so they were already compatible and connected. So we started to modify those for gripping and ergonomics and to do studies, and we kind of resolved it so there were eight different types of curve which were mutually compatible. And we didn't use Excel this time – we tried – but we wrote a script that would remodel surfaces out of those eight types in combinations of five curves, and we came up with something like fifty thousand coffee pots,

[slide]
Digital study models of Alessi coffee pot

and then started to look for a way that we could produce that kind of variation industrially. And we had the luxury of knowing that these things were going to sell for $35,000. So production costs were an object, but we could basically go to aeronautics to make them.

[sequence of five slides]
Digital study models of Alessi coffee pot

So these are the studies we did in my office to just look at ergonomics and how we wanted them to look,

[slide]
Photograph – vacuum-formed casts of four coffee pots

and the real issue is I wanted the tooling path to be on the surface. And I wanted to eliminate all the handles and spouts and make it functional without adding components to it, so the surface needed to be grip-able. So we found – and this is the great thing about southern California – we found a company that produced vaccu-formed titanium for the aerospace industry,

[two slides intercut]
Digital image – Alessi coffee pot in "open" position
Digital image – Alessi coffee pot in "closed" position

and the principle is just that you take two graphite blocks and cut the shape out of the blocks. And then you put two sheets of titanium in between those blocks, and put it in an oven with no oxygen in it, and heat it to a thousand degrees until the titanium gets soft. And then you blow argon gas in it with a little bit of oxygen, and detonate it, and it drives the soft titanium into the mould, and so you get a uniform surface but you also get texture like it's a cast object. So it has a kind of pre-industrial texture to it. And then to colour it we built a special jig, because we found that colour was the voltage of an ionized bath that you would soak it in. And so as we pulled it out of the bath we kind of changed the voltage, so it goes from this burgundy down to this green colour. In the surface there's a tray that's reversible, so when they're empty you can lay them on their backs. There's coffee, tea, hot water, and cream [pots], and then you flip that tray over and they stand up for when they're full. So it has kind of two positions built into the surface geometry so all these curves are used to model all the curves of the tray.

[slide]
Photograph – completed coffee pot set

[slide]
Seperatrix: Continuity and Differentiation

But anyway there're fifty thousand of those that get industrially produced.

[sequence of six slides]
Physical model of Geode Block, Sociópolis, Valencia, Spain
Plan of individual apartments
Plan of block
Plan of block
Elevation of block
Section of block
Perspective rendering of block

We've experimented a little bit with monolithic massing. I'll just show these two projects very quickly. It's a housing complex with artists' studios in Valencia, Spain, that we're working on. And the studios and the apartments share a single set of curves, so that every one of the apartments is unique floor-to-floor. But they're al connected into a monolithic mass. So that the separatrix is – you know, the kind of classical definition of a separatrix is a curve that unites and divides at the same time, so it's the thing that brings them together but also distinguishes between the two spaces.

[slide]
Monolithic Fusion across Scale

[slide]
Three photographs of urban skylines captioned:
Socialist Skyline
Homogeneous fabric
Capitalist Skyline
Independent towers
Skyline of Social Capital
United towers

Similar approach with United Architects for our World Trade Centre competition…. United Architects is a kind of coalition of designers that I'm very good friends with that are in my generation, like Ben van Berkel, Caroline Bos, Foreign Office Architects, Kevin Kennon Architects, Jesse Reiser, and Nanako Umemoto, and a motion graphics firm called Imaginary Forces. And the one thing we all agreed on was that we wanted sloped towers. And we also wanted to produce a mass which was both individuated and single at the same time, so there was a kind of multiplicity of towers. And on the skyline it wouldn't be like a legislated fabric, but that it would have qualities of fabric, but at the sixtieth floor. And that it would have both skyline qualities like the Manhattan skyline, but it would also be a single building – so it was one and many.

[slide]
Digital images of sloped towers: three-dimensional views, plans

We looked at colleagues' work like Philip Johnson, Eric Owen Moss, Zaha Hadid, Rem Koolhaas – there are any number of architects that have proposed sloped towers, and we found the problem was always what Larry Silverstein told us at the beginning of the competition, which is if we didn't have from forty-five to fifty feet from our core to our skin all the way around the building, it would never get built in New York. So we had to somehow solve the problem of a sloping mass with a vertical elevator, because in all these schemes you get sometimes twenty feet and eighty-five feet, or all kinds of odd variations floor-to-floor.

[slide]
Digital images: massing/circulation diagrams in elevation and plan

So we needed variegated massing with totally serial floor plates. So we used the Sears tower model, where we located an elevator as a vertical core, and then spiralled uniform office plates all the way round that core.

[slide]
Digital rendering: perspective view of WTC proposal

So it would give us sloping profiles, where we could produce these kinds of cathedral-like vault spaces around the memorial. But at the same time we had a vertical elevator. And the one thing you can bend in a tower is the exit stair.

[slide]
Digital model of exit stairs

So we also had this very robust safety and exiting network.

[two slides in sequence]
Sections
Sectional diagrams

But this is another – this is an example of a multiplicity of components, where it's one and many at the same time.

[two slides in sequence]
Photographs of crystalline physical model, lit, night view

[slide]
Aerial perspective (digital) of European Central Bank

A second project we did for the European Central Bank, where Ben really wanted to make a thing like a big piece of money, which actually I kept saying was like the Sudbury Nickel, if you guys know that.

[slide]
Schematic plans of floor plates

So the way it works is there are three elevator cores, with towers that pinwheel off those elevator cores. So exactly the same principle as the World Trade Center, only a totally different massing. So as these uniform office plates pinwheel around these elevator cores, they produce a spherical profile.

[slide]
Plans and 3-D models of floor plate iterations

So again, it's all serial, repetitive plates, but organized in an iteration where they change. So you get these open spaces and then also these closed atrium spaces between the office plates.

[four slides in succession]
3-D glass model
Exterior perspective digital rendering
Exterior perspective digital rendering
View through building form towards city (digital rendering and collage?)

[slide]
Complex Variation, Not Simple Variety

[slide]
3-D digital model of blob (BMW factory, Leipzig)

This project was actually a kind of identity project. It's the first time I really tried to sell out with a corporate project to win a competition and it didn't go well – but it was a factory for BMW in Leipzig. We met with the designers and asked them about their forms and they said, "Well, a BMW always has five different characteristics, and we can turn any car into a BMW."

[twelve slides in succession]
Two blobs
Hourglass blob
Five blobs
Blob
Blob
Four blobs
Factory plan with blobs inserted – digital
Aerial perspective of factory model with blobs inserted (physical model, roof removed)

Photograph of underside of factory model – brushed steel?
Exterior aerial perspective – close-up (physical model)
Exterior aerial perspective (physical model)
Model detail

They all need double-kidney grills, they all need this … slash on the back window. And they went through and told us, and we ended up remodelling the program using these double-kidney formal vocabularies and came up with a design which had all of the enclosed elements in this factory working with BMW's signature forms. And I have to say the whole time the head of the factory was walking us into the job saying, "You're going to get the job, you'll get the job." and the CEO walked in and said "This is the most BMW-looking piece of architecture I've ever seen – this is the last thing we need – is something that reinforces our brand." But anyway, this is just to say that formal aesthetic qualities using surface modelling like a car is modelled on – they're not totally scientific or rational, but they're definitely aestheticized. They're aesthetic principles that you can tap into and use, and there's a whole discourse about them. I mean, they have secret curves they still use to make their clay, and to model their computer surfaces, that are proprietary.

[slide]
Intensive Surfaces

[six slides in succession]
Photograph: Vitra chair prototype – wood
Photograph: Vitra chair prototype – wood
Photograph: Vitra chair prototype – wood
Photograph: Vitra chair prototype – wood
Woman sitting in chair prototype
Back view, person sitting in chair prototype

And then finally, the principle of integrating components into simpler and simpler assemblies. So this is a chair that we're doing for Vitra, and here I wanted to integrate, like with the coffee pot, or like the skin of the housing project, all of the components into a logic of surfaces. So the legs, the arms, the back, the cushion – everything is integrated into two surfaces, and the two surfaces are really the expression of the chair. This is a wood model we did just in the office, to test it. The other interesting thing about this is that the Vitra Museum did a show of Issey Miyake's work about fifteen years ago,

[slide]
Twelve prototypes, perspective and plan view

where they showed the A-POC [a piece of cloth] system, where Miyake took a 1950s knitting machine and hooked it up to computers, so he could do variably knitted surfaces that you would then cut out your dress or your shirt. So Vitra now adapted that and almost all the Vitra furniture is knitted, like crocheted with kind of hook-and-weave systems. So we're working with – we've resolved all the manufacturing except the upholstery now – and we're working with this machine to give it tool code, so that we can come up with tens of thousands of variations of the knitting. Because every one of these things is knitted and the machine doesn't care if some of the yellow is here or if some of the yellow is there (pointing), as long as it's always the same amount of the two colours of thread, the machine can just give you the variation for free. So all of the upholstered surfaces will be one of a kind, but one of a kind in a sequence.

[slide]
Surface mesh diagrams: axonometric, side, front, plan views

These are the – this is actually literally called the “grandmother” crochet pattern – so this is the way that the knitted panels get made.

[slide]
Undulation of Details with Surface

[six slides in succession]
Plan of shop in Stockholm
Axonometric of shelving diagram
Photograph of grooved undulating wall surface – close-up
Photograph of grooved undulating wall surface with shelves
Photograph of undulating wall surface, woman in foreground
Photograph of undulating wall surface

And finally, this is a kind of version of what we did with the Predator. It’s a shop in Stockholm, and here we integrated into the surface all of the shelving and components for display. So you can see again here the idea that the surface can do more work, that it can produce decorative effects, that it can produce these kind of shelving locations, that it can produce the kind of spatial qualities that make up the space. Again, the idea of investing surface modelling with all these architectural qualities is a thing that’s very important. Thanks. (applause)

## Roundtable Discussion, 19 November 2004

## Jean Gagnon, Chair
## Introduction

I have been asked to not only chair this but to make a little introduction trying to somewhat frame the issues and to help us to focus on the right track. I would like to start by saying where I come from on these issues. Prior to being at the Foundation, I was Curator of Media Arts at the National Gallery of Canada for about nine years, and there I was responsible for the film collection, the video collection, the new media, and also contemporary artworks that are technologically based. And during those years, I realized how ill-prepared the museums are. I am not at all a specialist of architecture, I am not an architect, and didn't study architecture, but in terms of art museums, I realized how much there was a need to develop methods and approaches to deal with non-traditional media arts. These include ... film, video, new media, computer-based systems, installations, and so on.

So when I arrived at the Daniel Langlois Foundation seven years ago, my task was to create a program of the Foundation, and as I mentioned briefly this morning, we have created programs to help artists to produce new works using digital means ... [We are] also enquiring about how to preserve these works because it would be [irresponsible] to help people to produce all these works with no consideration for how we can access these works in the future. And based on my prior experience with the National Gallery, I knew that there was a little lack of expertise, but also research about these issues. So, since we started our activities in '99, we got involved in a few projects relating to research, relating to this question of preservation.

One of those projects was a two-year project we did in partnership with the Guggenheim Museum in New York called "Variable Media Networks" – and Alain later will give you more information about this – but this project was meant to start to reflect about how museums can deal with not only digital stuff ... but works of the [past] that used chemicals that don't exist anymore, resin, matters that don't exist anymore. So what do you with that, how do you approach that? And one key element of this was that artists should be involved in the process right at the moment of acquisition.... There was a questionnaire developed so that artists could eventually decide ... some parameters or up to what degree in the future the work can be modified or not modified in terms of technology that is involved ... Other projects we did, one was with an organization in Rotterdam called "V-2" Institute for the Unstable Media ... In New York they called it "variable media"; in Rotterdam they called those things "unstable media." But no matter how we call those things, they are certainly characterized by instability. Just as an example, two years ago we launched a DVD-ROM on the work of Michael Snow and two years down the road if you have a recent operating system like OS10 on a Mac our DVD doesn't work. OK, so it's an example of the kind of little problem that these raise even after two years. There are already problems for certain people to access this particular DVD-ROM.

Also, we got involved with the National Gallery of Canada this year. We gave them a grant so that they can access their collection of media arts and media works ... and eventually they will, out of this study, elaborate their policy about how to deal with these new media works. Strangely enough, the National Gallery, which has, you know, huge collections and one of the biggest video art collections in the world, has no policy concerning new media, media works, video, so hopefully by the end of this year, they will be able to start developing a new policy around those issues.

And all these projects [lead us to] a research project that we should launch next year that involves among others, the CCA. And we hope with the CCA to do a test case on Greg Lynn’s archives or work that is here, in the collections. But also it involves the Musée d’art contemporain here in Montréal, the National Gallery of Canada in Ottawa, plus many universities, McGill, Art History and Communication, the music faculty of McGill, which is very involved with music technologies, and also Queen’s University, which has the only program in conservation, art conservation in Canada. And this big research that would go on for five years aims at developing methods, vocabularies, descriptive vocabularies, typologies of technology ... It also involves test cases. I mentioned the possibility of test cases [with Greg Lynn’s archives], and we’ll find test cases for many of these other collections – [the] National Gallery’s, Musée d’art contemporain. And these test cases should involve also engineers, computer engineers, or other engineers, or electrical engineers, in order to develop expertise and with the educational [institutions like] universities. The point is also to form a new generation of future curators, future restorers, people who will eventually have to deal more and more with that kind of material.

And just to finish my intro, I’ll just give you an example of this ... We did one with the Guggenheim, actually we organized with them a little ... exhibition that took place in March this year at the Guggenheim, New York, called *Seeing Double*. And in this exhibition we showed two versions of each work – seven works were shown, and each of these works was shown in two versions: one was the original or the piece as created originally with parts of the technologies of the given time, and a new version that was adapted or arranged to work on present-day systems. And one of these test cases that the Langlois Foundation worked on particularly was that of a piece by Grahame Weinbren and Roberta Friedman called *The Erl King*, a piece from 1982, which is a film installation. Well, it’s an interactive video installation, but the original images were shown in 16 mm. So, this piece involved, originally, a computer that doesn’t exist anymore called a Sony SMC-70. For those who were around in the early ’80s, you may have seen those computers: you have two diskettes, Sony computer. And so, these don’t exist anymore. There were three videodisks on which film elements were – obviously these disks were analogue disks. There was one touch screen, and all this was programmed in Pascal. And Pascal, for those who know a bit, is passé now.

And so we hired a computer programmer in order to work on this. And our type of [approach] from which we started was that we would emulate this fast system. Emulation meaning, quickly, that you basically make a present-day computer behave as an ancient computer. So, the first thing was to research an emulator for the SMC-70 ... there’s a whole industry of emulators out there, mostly for games. We know some people like Atari, so they developed emulators so that they can play those games; or Pac-Man – they are Pac-Man fans so there are emulators that allow them to play Pac-Man on a G5, whatever. So we started by looking if such an emulator existed, and it didn’t ... so, obviously, we thought, OK, let’s do an emulator. But we realized that first of all it would be fairly costly in terms of time for programming, but also the question was that who else had a password in those years with that computer – is there any other use for us in emulating that particular computer? And in the context of that particular test case, the answer was no. It didn’t need to necessarily develop this emulator in view of future use, so instead ... of emulating the system, we decided, because we had access to the source code, to basically recompile the code, the Pascal codes, so that it can be workable on present-day systems.

There were also other issues, like what to do with the videodisks, and eventually one solution, the solution, was that the film was digitized frame-by-frame ... the most readable type of image files, so that in the future it's possible to access those ... quite easily. So, they are then played back 24 frames per second ... (the video rate ... is 30 frames per second, so we went back in reality to closer to the original film element, which is 24 frames per second). But then, in the original piece, when somebody would touch the screen, there would be a few seconds of live time, so that the disc would go to the next segment. But on the new system there was no live time, and the artists wanted the live time. So we had to programme in these [moments] ... A restorer or somebody to be in charge of this would have thought "Oh, gee, it's even better," but the artists wanted to keep this feature ... Obviously, here, we're dealing with an installation – it may not be the same thing as dealing with architectural works, and I am eager to hear some of your experiences, because we think that also this research has to include different art practices, and we think that we can learn from each other...

Just as a quick anecdote that also demonstrates some of the problems. We have [had] recently a conference by the Head of the Restoration Department of the Cinemateca di Bologna, and this cinématèque is one of the most active cinématèques in the world in terms of digital restoration of films, and actually they do both ... chemical restoration and digital restoration. And so the guy explained all the process, and everything else, and in the end he said, "And then we restore the films, and then we try to get the new 35 mg." And this is the case for archivists ... film is still the best preservation medium. They know how it behaves over time, it lasts over one hundred years, and its condition of storage and everything else is pretty much known. So even after digital restoration, they still [keep the] film copy, film negative, and obviously they don't throw away the final film, digital file, because you can imagine these are huge files and eventually they are the unknown things in that process.

And finally, the last example, you may know, some of you, that the National Research Council in Ottawa, they ... developed years ago, a scanning system that uses laser, and it's very extraordinary ... For instance, they can use it to scan paintings, and you can see the brushstrokes, and you know, the details, and everything else. And now they can also [do this] with grottoes in Italy, I don't know which one, but they scan the space, a 3-D space. And I had a demonstration, so you can move in the space and you can have ... users with different points of view, and at some point the people who were demonstrating it to me said, "Oh, we're just using 4 percent of the backup because our computer today cannot use the rest of the backup – the files are so big that they use about 4 percent of the backup." And he said also that in the long run they don't really know how to keep these big files. Again, that's the only factor. So today, I think that the issue is not so much how to digitize images, or how to digitize your collection – really, I think the question is what to do with ... digital archetypes, and yesterday we saw with the presentation of Bernard Cache a good example of [this]. Do you preserve, for instance, one instant of this table, which seems to reflect really what this thing was about or do you keep the software and everything? But if you do that, how do you guarantee future access to this particular software in, say, fifty years.

So … for now, and I guess from this point, we will do another round of the table so that maybe you can say what is your experience, what is the sort of approach you've favoured so far or maybe you have not yet found any approach at all, or whatever, but it would be interesting to see the different elements that you may have in your respective institutions, and after that, we will have a presentation about our "variable media" project with the Guggenheim….

**Discussion**
**Summary**

"Don't throw away your old tractor until you find a new one."
– Ford Peatross

The lively roundtable discussion on digital media focused on the issues framed by Jean Gagnon, including: access; preservation and conservation by emulation, migration, or other means; the importance of involving artists in the process at the moment of acquisition; the necessity of developing policies to deal with new media work; copyright or trademarks in terms of long-term preservation; selection strategies; and collecting the design process itself.

## Alain Depocas, Daniel Langlois Foundation
## Presentation of *Variable Media*, a project by the Daniel Langlois Foundation and the Guggenheim Museum, New York City

**Summary**

The Variable Media Network proposes an unconventional new preservation strategy that has emerged from the Guggenheim's efforts to preserve its world-renowned collection of conceptual, minimalist, and video art, which is supported by the Daniel Langlois Foundation for Art, Science, and Technology. The aim of this affiliation is to help build a network of organizations that will develop the tools, methods, and standards needed to implement this strategy.

The variable media paradigm pairs artists with museum and media consultants to provoke comparison of artworks created in ephemeral mediums. The initiative aims to define each case study in terms of medium-independent behaviors and to identify artist-approved strategies for preserving artwork with the help of an interactive questionnaire.

For artists working in ephemeral formats who want posterity to experience their work more directly than through second-hand documentation or anecdote, the variable media paradigm encourages artists to define their work independently from medium so that the work can be translated once its current medium is obsolete. This strategy requires artists to envision acceptable forms their work might take in new mediums, and to pass on guidelines for recasting work in a new form once the original has expired.

More information on this project is available at http://www.variablemedia.net

The publication *Permanence Through Change: The Variable Media Approach* can be downloaded in PDF format from the website. It presents viewpoints, methods, and case studies concerning the preservation of art created with non-traditional materials, tools, and technologies, and includes texts by such authors as Bruce Sterling, Steve Dietz, Jon Ippolito, John Handhardt, and Nancy Spector, as well as excerpts from the 2001 "Preserving the Immaterial" conference.

# Greg Lynn
# The *Embryological House*

I thought what I would do is to just go through some things very quickly to give you an idea of the scope of material and the concept of the project. It was – this project kind of came from, there were some grant sources and exhibitions that went for about two years; I worked intermittently on it. The Graham Foundation and the Wexner Center and several institutions funded it as a pure research project, so although it's called the Embryological House, it really wasn't about making a house. It was more a study of envelopes, and it was an attempt to look at all of the manufacturing and construction techniques available in the aeronautics industry and car industry and in the building industry, and to use only techniques of construction that existed, but with no concern whatsoever for cost. At the end I'll show you we went through a little cost exercise to figure out how much each house would cost. And we even set up a little database which we never got to work on the Web. The idea was you could see how much one would cost, and the cheapest we ever got was a little over six million dollars for a very small house (laughter), but it was more of an exercise.

The idea of it was like Alberti's dictum: to make a villa to which no piece could be added or subtracted, without jeopardizing the integrity of the whole. It's made out of a fixed number of components in the end, but to make them variable, the first thing we did is we set up this controlling geometry where we would unfold … There are twelve points that control two thousand points on the surface, and you can manipulate the object by any one of these points, and hierarchically it'll affect all of the others.

This was all initially modelled in a drafting package that I like with very good curve control called MicroStation. We took this geometry – you'll see basically each one of these points unfolding into twelve points, so it was really a study in how to make an envelope that could capture spaces inside its surface. From this geometric primitive, which was a kind of hierarchically organized set of points, we then started to move it into surfaces and into manufacturing, and we did it step by step. We first came up with a set of possible configurations. We then mixed those configurations together, which you can see. Each one of those twelve types or sixteen types would get mixed and we came up with tens of thousands of possible volumes. The data set now has grown from a kind of parametric model of curves, to a data set of tens of thousands of three-dimensional forms.

We then started to study how to take those surfaces and manufacture them at progressively larger and larger scales. At one scale we would fold these surfaces flat, and we cut with a robotic water jet steel plates and assembled those steel plates into models, which were about the size of the model that's over here. We took these elements and exploded them into panels. Here we actually automated the process where we could take one of our ten thousand volumes, of which there are an infinite possible number, and we would drop that into an Excel file. It would generate all of the machine code for all of the panels so we could automate the process for manufacturing.

We went through several variations of this at different scales, and you know from the scale of objects that were about this big, to – and every form has a corresponding tool that it was made from. So, for instance, this object right here: there are six blocks of wood that have a cut pattern in them, that we formed plastic on, and each one of these panels is formed on that plastic, cut away, and assembled. So corresponding to this object, there are six panels, that are maybe, you know, if you line them all up end to end they're about a metre by six metres, and these are some of those elements. And again, these are completely reproducible, so this is a tooling path. They're all cut by machine. The only labour involved is gluing the wood together and setting it up on the machine, so it's an industrial process. Gluing them together is not an industrial process. So I can show you some examples of that. We did studies of the fenestration and the skin, of which there are several thousand. This process of putting windows in them was also automated, so we have several thousand files that were all rendered, of all these elements. We built a couple of large site models and started to develop the elements into construction systems. So elements of structure are blue. So we started to break them down into elements of structure which could be manufactured out of aluminum tubes, skin elements where we actually built some tests of aluminum skins which were fabricated with a, it's called a *shot peen* process. Flexible photovoltaics – we looked at how they would meet the ground, and what the foundations would be. And so along with these renderings there are also technical kinds of working drawing type descriptions of these things. And again, this was all also automated, because I used this as kind of research to find out how a geometric database could automatically produce construction drawings. And then finally, there were, I think, three very large models, the biggest of which is this one, which is one-third of the scale of one of these actual volumes. And these were all discarded. We built these out of foam, which I thought would be very lightweight, but it turned out to weigh almost two tons. So archiving it would be like archiving a small building. But so this was the finished element for the Venice Biennale, and we hung it off a wall. We built three models like this for installations of various scales. This one's the biggest.

And then finally, as an exercise, we came up with a set of options that you could pick in terms of the type of, the colour of the aluminum skin, always with different, selected different figures. And you could go through and pick what kind of cladding it had – if it would have photovoltaics, what kind of glass would be used – and this is a kind of exponential table. We set up the rendering engine and rendered tens of thousands of images and then linked them all up, so that as you would make the selections you would kind of cascade through the choices. But this is – it was unrealistic to make something that would render these images on the fly, in a Web browser, so there's also a database of options that you would pick. And we ended up hooking some of these up to a database that would give you costs at the time, but we never actually got that to work online. And then to give you an idea of the numbers of objects we produced during that time – and this is not now the digital information, which was more what I just showed you – this is actually the physical information we produced. I'm not sure of the exact number, but something like fifty or sixty small models like this, which are stereolithography prints. So you take a three-dimensional file, and you put it into a machine that draws with a laser in photosensitive resin, and you pull out an art object at the end. There were also the CNC machined surfaces, like this; these are also now maybe the size of the palm of your hand. We did, well, maybe fifty of those. We did larger versions of them, but I don't actually know the inventory. But I'm sure – how many objects are there? Do you know? (inaudible) 130. How many? So, OK. And they go from the scale of these kinds of smaller objects, and again, every object is always mated with the panel that it was formed with.

But what's kind of, what was a significant discovery on my part in this project is the idea of not designing *a* building, or using this tool to come up with *a* building, but designing an ensemble of objects where the real task is the series. And so it wasn't really about making all of these and then picking one, it was about coming up with a range where they were all identifiable as coming from the same generic information, let's say, and that they were all controlled with the same components. So these elements always had 64 panels, for instance; we never had to add or subtract a panel. The bigger ones always had 128 panels, so it was really a study in how to manufacture or design something that had regulating principles, but variety, so it's why it's at the CCA. I mean, to be honest, I could have taken the thing apart and given, you know, one to everybody, which is kind of, a lot of museums were interested in just one or two, but it's really important that it all stayed together in all of its variations and its breadth. So these are the panels that go with these larger volumes.

So, but again, all of the material I'm showing you, it gets glued together, but basically, it's industrial material. I mean, there's machine code here that could be reused, and there's geometry here which could get reused, and the model building tended not to be so artisanal. You know, the one exception [is] these steel, laser-cut steel plates, which then get assembled into these volumes.

And there's one kind of large model with landscape that has a stereolithography element inside a wood CNC landscape. Another large one. So also we didn't give you guys that –there's a model there that still exists if you want it, we never shipped it to you (laughter). And so anyway, in there is also (inaudible) [from the Venice?] Biennale, there are prints of instances of all of this that are digital prints, that also they could be thought of as an addition or whatever. I don't know exactly how you approach the genetics of the geometry, as well as the different scales of manufacture of it, but there various prints and drawings that came through the process as well as renderings, kind of step by step. So, hopefully, that gives you an idea of the kind of the work you have to think about archiving. (laughter)

**Discussion**

SPEAKER: That's supposed to be now our test case, isn't it?

SPEAKER: Exactly.

SPEAKER: So we'll have fun.

SPEAKER: Thank you, Greg. Now, do you have questions for Greg?

SPEAKER: (inaudible) … series … produced automatically or do you intervene in each individual?

GREG LYNN: Well, more or less once we get it to work, well, once we had it working in one instance, we would then apply it to six or so iterations to just see if our assumptions were correct. But there's a lot of design, like in the patterning of the surface and things, there's a lot of design decisions, but once those decisions are made we would then automate that process, so almost – I don't know if you guys use Photoshop or something, but the idea of *actions* where the computer records certain steps, you know, would be our approach to programming. So we would save certain steps; sometimes we would just cut and paste those, and automate them literally with a program like Excel, and then just run the geometric operations so they – I actually don't remember the exact numbers, but … tens of thousands of volumes, you know. I've never even seen all of them. I mean, nobody's ever seen all of them. But because we could see a few hundred, we would automate the process, and generate the database, and then instead of picking things to make, we would all pick things out of it. But we've never systematically gone through and physically modelled them, so it's a mix of design and automation.

SPEAKER: What I find interesting about what you just said, this approach – it's very interesting that it's a new development that's coming from digitization, that external machines are now capable of almost the same flexibility of the thinking process itself. A kind of – when you modulate a shape in your own mind, in fact you go further than we can, so that is going to multiply by infinity all that content we have to worry about.

GL: Yeah, and these objects were by two or three people working for a total of four months. And I would say just the volume of production – it's automated, it's very automated – you know, in machine time, it's thousands of hours of machine time so…

SPEAKER: How did you decide how many models to make … and what was the function of those in the process, and why make twenty or thirty or forty?

GL: Well, I mean, when we first did this … these very first geometric diagrams, you know, they were set up, this grid of, I guess, twenty-five were set up to go from the most generic one-room space, which then got elongated into different configurations. But then it grew in this direction, which had an indentation to divide the space, and a bulb to make a room off of the space – two bulbs, then three bulbs … so out of that we got a matrix of twenty-five kinds of very generic spatial types. And so whenever we were manufacturing these, we would tend to try to take, you know, from that catalogue of formal problems of the envelope. So you know, we were always taking four or five, because there were four or five basic configurations in there. But you know, really, all the time I was looking for problems in the surfaces…. This model, the one that's out here, was a failure, but I was interested in how big a failure it would be, because of the resolution of the panels, and the tightness of these curves. I just wanted to see if the surface would work … this edge for me, it didn't work, so we would – I would always take a range, to just basically test architectural problems. It depended on the scale of the – that we were building – as to how the problems would go down. But it wasn't … a logical thing; it was more of a … kind of pragmatic, intellectual issue, case by case.