Experts' Roundtable on Sustainable Climate Management Strategies

Introduction

In 1997, the Getty Conservation Institute initiated a project to investigate preventive strategies to preserve collections in regions characterized by hot and humid climates. At the time, biodeterioration was considered the major conservation-related issue in these regions, far more critical than either chemical aging or mechanical deterioration. Although some ventilation-based climate control approaches had been attempted, the majority of climate improvement strategies were based solely on standard air-conditioning systems, which produced not only less than satisfactory preservation climates, but also presented technical and economical sustainability challenges. It became evident that economical and sustainable climate improvement strategies (i.e., effective alternatives to air-conditioning systems), primarily for controlling biodeterioration, merited further study. The GCI spent the next ten years researching climate management strategies. During this time the GCI also offered a series of courses on preventive conservation aimed at the management of the environmental conditions under which collections are housed and used.

In April 2007 the Getty Conservation Institute organized the Experts' Roundtable on Sustainable Climate Management Strategies in Tenerife, Spain. The objectives of the roundtable were to exchange knowledge and experiences, to identify areas in need of further study or new research, and to identify opportunities for education and training in this subject.

Based on the growing need to adapt to global climate change, along with a call for more sustainable strategies, the GCI believed that it was time for an interdisciplinary dialogue about the museum environment, specifically the indoor climate. An international group of experts—including architects, engineers, conservators, and conservation scientists with established records in the fields of environmental research, management, or control—were invited to participate in a discussion on sustainable climate management strategies and alternatives to conventional air-conditioning systems for cultural institutions. Topics addressed during the two-day roundtable included current climate management strategies and emerging trends; the meaning of sustainability in relation to the preservation of cultural heritage; and whether cultural institutions *such as museums, archives, and libraries can or should play a role in the debate about energy consumption.*

Here follows the edited transcript of the discussion that took place over the course of the two days. The proceedings were edited by Foekje Boersma, GCI Education, with input from Education and Science department staff.

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Welcome

DARDES: During the last decade, the GCI offered a series of courses on preventive conservation [Preventive Conservation: Museum Collections and Their Environment].[i] Although the courses were designed for conservators, they aimed to cover more than just monitoring and control of the environment at the level of the object or at the level of the collection itself. The courses invited people to step back to look at the museum envelope as a container for the collection and as a factor in the environment that affected the collection. We looked at how the museum actually functions, the dynamics of materials and fabrication of buildings. We looked at mechanical systems and at how museums go through the renovation design and implementation process. Conservators who were employed in museums that were undergoing very large expansion projects often found that they needed to talk to architects and engineers in a language that architects and engineers could understand. And they were, in some cases, giving specifications for the museum environment that were not achievable and not appropriate. The GCI offered this course over a period of about six years in North America and in Latin America, and we put together a team of teachers that included architects, engineers, and conservators.

This roundtable takes that approach to environmental management a step further. The GCI's Preventive Conservation course attempted to create a transdisciplinary dialogue about the museum environment that would include a range of specialists. I think this roundtable is very much that kind of dialogue. We have at this table conservators, architects, and engineers. I think we need to come together again in this discussion about what we're trying to achieve for the environment.

It is important for this roundtable to look at the state of the art of our environmental research and how we are implementing museum environmental controls. But also, what are the emerging issues? What are the trends that we need to be thinking about? Are we making the impact that we need to make? We will all be talking about our research agendas and the directions we are taking with research in our institutions; I think it is equally important to think about our educational role and the role that we have to influence how the profession uses the results of our research. That is where we can make the greatest impact.

Global Climate Change and Cultural Heritage

DARDES: Maybe we can start by considering whether there is any sort of agreement on what the challenges are for the field as a whole, whether we see things the same way. And, if we agree that there are problems for the heritage field related to climate change, how we are prepared to meet those challenges. For some people, dealing with climate change may be a high priority. To others it may not even be on the radar at all.

ORESZCZYN: Certainly in the UK, climate change is a major issue, and there is a lot of concern in the government. In particular, this focus is on energy use, and the concern is not only about climate change, it's also actually a concern to do with security of supply. In Europe we rely quite heavily on fossil fuels from Russia and from the Middle East, and even if they don't run out, there is concern about actually getting reliable supplies of those. So I think there's a general view that the world in the future is not going to stay the same as it is now.

In the UK we're all looking forward to a Mediterranean climate—less rain, more swimming pools in the people's back gardens—but it is going to have potentially major impacts. For many places, the average conditions are going to be the same as they previously were in some other parts of the world. Some parts of the world will already have had to deal with the environment that we are now going to have to deal with in the UK. So on one level, you can say that it's not an extreme problem. However, there is going to be an increase in extreme weather events, and we have some evidence of that happening already, and how we cope with those is an issue that this sector will probably have to come to terms with.

It is the indirect effect that is probably going to be more significant, because energy is used in everything we do. It provides us with a phenomenal service. Developed countries are going to have to significantly reduce their consumption of energy. That is going to change the way people behave. It's going to change the way we move around in the future. It's going to probably change the cost of energy, or else energy is actually going to have to be controlled some other way, through rationing. This will probably change our behavior in similar ways to the changes that we've had due to the introduction of electronic components and wireless and mobile phones and computers over the last fifty years. I would predict that we will have similar social changes that will occur through trying to tackle these issues, and these will have serious impacts on the ways that people use buildings, the sorts of conditioning that people use, and so on. The way that people are charged for energy is going to be changed. In the UK, the government has set all of the energy utilities the challenge that they will not make money by selling more energy; they will have to find a market mechanism for making more money by selling less energy, and they are going to radically change the whole way in which energy is charged. The utilities are going to start controlling when we use appliances in our buildings in order to solve this very problem of how many power stations we actually need in the country.

STANIFORTH: I think that one can summarize the actions that the museums and heritage sector may need to take in two ways. One is mitigation of climate change by reducing the amount of carbon dioxide added to the atmosphere through energy efficiency and considering the type of energy that we use. And the other aspect is adaptation. And adaptation has two aspects. In the day-to-day maintenance of the building, the lesson that we are already learning is that climate change will find out poor standards of preventive conservation. But the other aspect is the way in which we adapt buildings to cope with these extreme weather events.

So I think that helping our colleagues in museums and the heritage sector to understand the sort of adaptation methodologies that they may need to apply to their buildings would be something that we may want to talk about further.

CHIARI: Excuse me—what time frame are you talking about for this climate change, and how severe will the climate change be?

ORESZCZYN: It depends on what action we take as to how large those changes are predicted to be. The slightly worrying thing is, and I'm not a climate change scientist, but the little I know about the science is that the predictions seem to get worse rather than better as the models develop. They seem to be finding more positive feedback mechanisms—meaning that the change is happening more rapidly.

STANIFORTH: We need to plan for a hundred years, the end of the twenty-first century, which may seem a long time in the future, but for an organization like the one I work for [National Trust, UK], we have thirty thousand buildings that we look after. So if we're thinking about proofing against climate change, then it takes a long time to do all the maintenance on those buildings, the work on the roofs, for example, so we have to start now.

CAMUFFO: There isn't any evidence that natural weather events have increased in frequency, but it is clear that the impact has increased because of the population growth. Compared to earlier times, now houses, buildings and people are everywhere, increasing the probability of being hit and causing disasters. However, for indoor cultural property the main challenge is not climate change, but the increasing demand for thermal comfort. From past centuries, we have simultaneous indoor and outdoor measurements that show that the indoor temperature was kept between three to eleven degrees higher than the outside temperature, resulting in a slight lowering of relative humidity. Today, the indoor temperature exceeds 20°C and the relative humidity is around 30 to 35 percent. And in the future, what will be the demand for comfort? If we want to use a historical building, a very high standard of comfort is nowadays requested. Churches cannot be unheated any longer—as the number of churchgoers decreases, the Church wants to make it more comfortable. Winter heating is not considered enough; people may also need summer cooling. Is all this sustainable?

We would also face the enormous problem of the pollution from developing countries, such as China and India. What can and should be controlled is some amount of pollution, but we will be unable to control the whole system, beginning with the water vapor that is the most efficient greenhouse contributor. Global warming will expand oceanic waters and the rise in sea level is the most important challenge. In Venice, for example, the sea level rose in the last three centuries by more than seventy centimeters (sixty centimeters when corrected for the waves of motorized boats and the works made in the lagoon). Half of the local sea level rise is due to land subsidence, and half is due to thermal expansion of seawaters. You can imagine that in one century

KOZŁOWSKI: The European Commission supported the Noah's Ark project on the effect of global climate change on cultural heritage. The project looked at the impact of a climate change that was modeled over the coming hundred years on various cultural heritage materials, and it came to this conclusion: that the picture is not so clear in terms of adaptation and mitigation. When you look at the deterioration function and risk factors for materials, some regions will be better because they will be drier and there will be less corrosion; some regions will be worse. Preventive conservation becomes more important with climate change.

Cost of Climate Control

The expected increasing costs of climate control as a result of global warming was a topic discussed by the group as one of the main challenges facing the cultural heritage sector. The *group explored this topic further by discussing a potential research topic into the cost of degree of control.*

MICHALSKI: Museums can't afford more capital costs, and even when they are provided money for capital costs by some layer of government, they find within a few years that there's no other layer of government that's providing maintenance and operating costs. So we're seeing with museums that in the seventies and eighties put systems in—those systems are coming up for replacement, or they are dying, or they were simply never operated past the first two or three years, because they ran out of money to run them. So the question that we get asked is, "Do I need to replace these or continue down the same path?" So a lot of what we're looking for is reasons to reduce their energy costs, which is consistent with somebody who is approaching this issue from a global warming perspective. So if museums can stop spending so much money on maintaining climate that tends to be energy consumptive and instead move that budgetary item to something else like labor, education, and so on—which tend to be more constructive for people and less energy consumptive—then it's going to be beneficial from both perspectives. I think if we can rebalance the budgets of many museums away from energy costs toward any other kind of cost, it's beneficial both for the museum's operations and for global warming.

KERSCHNER: Global warming aside, most medium and small museums simply cannot afford to put in any type of major system, and the very existence of some of these museums is at stake. We [at the Shelburne Museum, Shelburne, Vermont][ii] couldn't do a program without significant help from the U.S. government National Endowment for the Humanities, and although I'm completely in favor of doing everything we can about global warning, the competition for funds at museums is just so severe that we have to get simpler.

PADFIELD: Air-conditioning is not the purpose of the museum. The purpose of the museum is to have curators, to have active people researching in archaeology and history. Therefore, I regard the purpose of this meeting as an opportunity to address the balance, to see how far we can go without having engineers sleeping with beepers under their pillows. There are museums that are spending three-quarters of their income just on the air-conditioning, the engineers, the people who go around calibrating instruments, and so on.

What's going wrong is that museums allow for competitive architecture. The idea that [museum buildings] should be good containers has simply vanished. We have a rather urgent business to bring some sanity into museum design.

MICHALSKI: The problem we have in my country [Canada], and I think in many nation-states, is that funding systems for museums' operation are compartmentalized. The architectural budgets are certainly compartmentalized, compared to operating and maintenance. So [climate control systems] get put in when people have a lot of money. They get put into the flagship organizations, which then set the standard. There's a tendency for people who spend the most money to become the de facto standard, even if it's not rational. And they put it in because they have a big capital grant, and it takes them years to discover that they're spending a lot of money that they can't afford.

CONRAD: One of the things that we do when we design systems for clients, we kind of end up being facilitators and educators. One of the rules we've always used is that we will never design a system that they cannot afford to turn on. The client has to know what the needs of their materials, their building are. Next, what is their budget? What can they afford? So many times, a conservator and curator don't have a clue what their financial capabilities are, and so they want the best. And I absolutely refuse. Instead I will predict for them: this is what their annual operating costs are going to be.

HENRY: We have to be able to tell stewards what the implications are in capital costs, in operation, for the decisions they make about [temperature and relative humidity] fluctuations and the necessary degree of control. We cannot sit in an ivory tower and say it has to be the best of all situations. We have to understand the trade-offs that are going to be made, because those trade-offs might not be whether or not they install tight environmental control or not, the trade-offs might be whether they have fire protection or fluctuations, which goes back to risk management.

STANIFORTH: It would be very helpful in future publications about environmental control systems if energy consumption were one of the standard bits of data that are always included.

ORESZCZYN: I would like to strongly support the fact that we really ought to be collecting this sort of data on a regular basis for a range of different types of museums in different countries.

HENRY: I would like to refer here to the research of one of my graduate students, David Artigas,who looked into the efficacy and costs of different approaches to climate management in historic buildings and museums.[iii] The data he used came from several historic house museums and historic buildings operated as museums that had a range of monitoring programs. What we did in this analysis was to look at the heating season, the cooling season, and then the mixed season, in which we transition between heating and cooling. We often find that the mixed seasons are the most problematic from the standpoint of degree of control. Two standard deviations were used for the temperature and relative humidity data, so that we were operating with about 95 percent of the data set, with 5 percent being set aside as extraordinary excursions and not necessarily informing the question of degree of control. This is just a basic numeracy issue when we're comparing data from one location to the other. And [the findings] necessarily have to be populated by more data, but with curve fitting, we begin to see a pattern here, and my hope is that we can explore this further. I would add this to the research agenda.

In David's thesis, the energy consumption was based primarily on metered electrical energy or delivered fossil fuels, whether it's natural gas or fuel oil for heating. The issue that he was faced with in looking at the energy consumption was how to take out or adjust for the consumption for lighting and other baseline uses. If we get serious about looking at this, we almost have to look at the consumption through the equipment for buildings that are so equipped—but, at the same time, recognizing that lighting can be a significant contributor in the interpreted museum environment (not so much in the archives environment or storage environment). But we do have to factor that in, because then that adds to the load.

CONRAD: I might just touch on that. Every time we do work in a historic building—in fact, in any building for that matter—we always try to get one year's worth of energy bills. I calculate it on a unit basis, so I have my dollars per square foot or dollars per square meter. And we constantly do that because the energy costs change so rapidly.

PADFIELD: About this matter of pricing that you've applied to the fuel costs: More interesting perhaps is what's called the total cost of ownership or total cost of running. Fuel is still cheap, and wages are going up faster still. In my experience, the total cost of ownership of high-performance air-conditioning is colossal. And it goes into retainer contracts for twenty-four-hour guaranteed one-hour response. And I would be really interested—I realize that it's a more complicated calculation, but it would be very striking if one could add this statistic.

ORESZCZYN: I totally agree with you that cost is the thing that people understand. But if you're trying to use information across different countries, cost varies so much that you really do need to know what the actual delivered energy is and not just the cost, in order to be able to utilize the information.

HENRY: The one thing that I would add to the idea of looking into the total cost of ownership is that it probably requires a longer-term study. The intervals of repairs as well as maintenance are not necessarily—the repairs in particular—going to occur in the observed year if we only do a one-year increment.

ORESZCZYN: I think it would be useful too, but I think the important thing is, if you're planning to share this information, that you come up with a standard way of recording so that the information can be useful. There's a whole host of decisions that have to be taken, such as volume versus floor area, whether you use delivered energy or primary energy. It's also useful to have what the external climate is and, obviously, what the internal climatic conditions are. You need to be able to have all that information there, so that people can process it in a way that's most useful for them, which means that there needs to be almost a pro forma for what information needs to be collected in order to be able to share this information. At UCL [University College London], we've run simulation models to predict theoretical energy costs, but there's nothing like real costs. We've used Energy Plus, but there are other models.[iv] The only reason we use Energy Plus is that it's a public domain piece of software, and you can add extra algorithms to it. It's not so much which software you're using, it's more about getting access to the real data, which generally is more accurate, because that's what actually has happened. So the models have a lot of assumptions behind them, which means that there are very often quite large differences.

The other thing that I was going to add was that the potential access to this sort of information should become easier in Europe. We're about to have something called the European Directive on the Energy Performance of Buildings, which means that all public buildings are supposed to display their energy consumption, so there are mechanisms coming that should make it easier to collect this sort of information[v]. But I think it's only really of use if you have other sorts of associated information. You need to know something about what plazas are in that building; you need to know something about what the external environment is. So if we're going to do this sort of exercise, you do need to start getting into the detail.

STANIFORTH: I think it would be very useful to have a standard unit that we all agree on for energy monitoring. I must say that for many years, we have been specifying the need for energy metering and also for meter subcircuits. You know that if you've got gas and oil supply to a building, that's generally being used for heating, so you can identify that part of the energy usage. Then we submeter the electrical circuits so that you can distinguish between the lighting circuits and the conservation heating circuits. The technology is all out there and available to have this sort of monitoring alongside the other monitoring that we do.

PADFIELD: The SI unit of energy is the joule, and you can measure it by putting an induction loop around the cable that goes to your air-conditioning apparatus. So that's very simple, except that I've never, ever been able to do this, because nobody knows which cable it is. The frustrations of the real world compared to our cozy discussion here is a subject for another meeting altogether. But there are a thousand and one little details that would make analysis and testing better, and one is, for instance, that the standards should in fact insist on measurement, both of the climate and of the energy consumption. It has to be built into the specification, and then you know where to put the induction loop. Natural measurement is trivial but impossible at the same time.

Sustainability and the Cultural Heritage Sector

The discussion about global warming and the cost of degree of control led the group to look at sustainability and what it means for the cultural heritage sector. An introduction to the subject was provided by Sarah Staniforth.

STANIFORTH: I will start with reminding us of what the definition of a museum is. In 1998, the Museums Association in the UK said, "Museums enable people to explore collections for inspiration, learning and enjoyment. They are institutions that collect, safeguard and make accessible artifacts and specimens which they hold in trust for society." Just looking after the collection isn't enough—they have to have meaning for people. And sometimes the interaction of people and collections can be an issue, and we've had many debates over the years about the potential for conflict of between conservation and access.

The National Trust's definition of conservation is, "the careful management of change. It is about revealing and sharing the significance of places and ensuring that their special qualities are protected, enhanced and enjoyed by present and future generations. first and foremost recognizes that conservation is the careful management of change.[vi] It accepts that we can't keep things the same but that what we can do is to influence the rate at which they change. And for the National Trust, we're not just looking after collections, we're looking after everything—from coastline, countryside, woodland, agricultural land, as well as gardens and parks and historic buildings. It's all about understanding the significance of those places and sharing that with people and ensuring that the special qualities are protected, enhanced, understood, and enjoyed both by people today and people tomorrow. And that's really in a nutshell actually the definition of a museum, and the definition of conservation is stating what sustainability should be.

Sustainability has three elements. It has the economic elements, the environmental elements, and the social elements. And if we think about the economics, I know that all of you who work in small museums face the same issue that the National Trust faces, four out of five of our historic properties run at a loss. And the only way that we stay afloat is through the membership subscription from our 3.4 million members. So the central funding comes from our membership subscriptions, which now is our largest stream of income and is over one hundred million pounds a year. For all of those small museums that don't have the cushion of membership, staying financially viable is extremely problematic. Our economic business model for our properties is based on high visitor numbers. But what if visitor numbers drop off—and there's already signs that they're leveling off, because there's so much competition for use of people's time. Actually, having a business model that relies on high visitor numbers is, I would suggest, going to become increasingly problematic in the twenty-first century, particularly when energy costs go up and make it less affordable for people to come to these places. Most people come to National Trust properties by car because our houses are in the country. It is very difficult to get to them by public transport, however much we push green transport.

Potentially our economic model will not hold up as we go through the twenty-first century. Farm rents—which were the traditional way that these country houses were sustained—are relatively low now. We look for alternative sources of income including events like weddings, dinner parties; people can become tenants and live in the properties. They film films at National Trust properties. But for most properties, the largest source of income is when visitors come and pay for entry if they are not members and spend money to get in and spend money in the shop and the restaurant.

The second aspect of sustainability is the environmental role that museums can have in influencing people through good example. And so it's important not just to have good environmental practices but to tell people about them, because it's an opportunity when visitors visit sites to actually explain about good environmental practices—our careful use of energy, that we're minimizing water use, and we're minimizing waste production. For the next three years in our strategic plan, we are committing or targeting to reduce our energy use by 10 percent for each of those three years, which may be problematic. And we're doing that by a combination of reducing energy use and also of increasing use of renewables.

For example, Gibson Mill in Yorkshire, which originally was a water mill, a cotton mill powered by water.[vii] This property is entirely self-sufficient. The following measures are used at Gibson Mill: we've restored the water turbines, we've got solar thermal panels, and we've got photovoltaic panels. The heating comes from a wood chip boiler, and of course we've got good energy conservation practices with insulation. The water supply is from natural spring water. We try to minimize water consumption—we reuse the gray water to flush some of the water toilets—we recycle waste. We've only recently opened it to the public, and the whole purpose of the visit is to explain sustainability. And we encourage people to come by green transport—so, by bicycle or to walk there—because it's in a very beautiful part of Yorkshire.

And the final aspect is social sustainability, and this is all about the ways in which we can find benefit for people with the aim of enhancing their quality of life. And we do that through those three museum functions of providing access, providing learning, and giving enjoyment. I believe that preventive conservation is one of the roots to sustainability through enabling sustainable access—so, minimizing the impact of visitors on places and also welcoming the benefits of increasing access, which enhances or helps the financial bottom line and also helps people to see authentic objects in the context for which they were made. And the whole route to that is through risk management and the use of the preventive conservation framework.

HENRY: Well, first of all, I would like to thank Sarah [Staniforth] for clarifying the issues and presenting them so logically and systematically, including the definitions. But one thing that I noticed on the social sustainability—and I don't know if I'm reading into it or if it's an omission—does social sustainability involve inclusion of the community, either through employment or engagement of local services? Is that implied in your mandate?

STANIFORTH: Very much so. Even to the point that in evaluating the significance of a place, we would involve the local community in writing a statement of significance, because very often the traditional practice for understanding significance was for the experts to say, "This is significant because it's the best example of Georgian architecture" or "It's got the finest collection of eighteenth-century portraits." And then you miss that significance that it may be, for the local people, the place where they walk their dogs. So the community is involved in everything from helping us evaluate significance to volunteering. We have forty-eight thousand volunteers, so we couldn't open a single National Trust property without volunteers who come from the local community.

HENRY: And also recognizing that you may be able to create an economic opportunity for a village where folks might be underemployed, so that there could be things like the tearooms in the village.

STANIFORTH: We've done quite a lot of work on public value, so that's both social value and economic value. And there are very interesting economic multipliers for the impact of heritage attractions on the loyal economy. And we've looked at it in the southwest of England, East Anglia and in the Lake District. And the economic multiplier is between four and five. So for every pound that we're turning over as a visitor attraction, the community is turning over four or five pounds.

PADFIELD: To go back to fundamentals, Sarah's [Staniforth's] definition of sustainability is actually change. Your mill was using water power originally, now it's generating electricity. Your solar power never existed. So what you're doing, in fact, which you have called sustainability, seems to me, in fact, to be change or survival. And I'm not criticizing it, I'm just trying to define it. And it's true that the houses that you maintain now have, in fact, had their own history, where they have changed—so there's nothing new in this. I just want us to realize that sustainability is here being moved a long way from the dictionary definition, which is to keep going "what is." And here we're talking about how to adapt. There's no criticism implied, but there are other ways of defining sustainability: the traditional one is to keep going what is; in other words, it's a fossilization process.

STANIFORTH: I was trying to reflect it back to museums and conservation, because I think that what we do as museums and what conservators practice actually are ways of demonstrating sustainability. Another definition of sustainability would be to not use more resources than are needed, not to steal resources from future generations.

PADFIELD: The point I want to make is that sustainability, as we have been discussing it, appears to me to be the economic sustainability of the institution that owns the national treasure. Sustainable in the now-fashionable sense of saving energy and therefore saving the planet comes into direct contradiction with sustainable ancient building preservation. I thought when we were going to discuss sustainability that it would be, for example, how the [Hali Saflieni] Hypogeum in Malta works, which is in effect an underground temple that is very sensitive.[viii] And so the management doesn't try to maximize their profit; they allow twenty-eight people in a day in two guided tours with very short light exposure. And it's well documented that this is a thoughtful management plan. To me, that's sustainability. Putting solar heaters onto a historic mill in order to persuade the public to change their ways may be admirable, but in fact, it's a completely different attitude to historic things. Again, to use this as a basis for propaganda, people can argue that that's a good way of getting people to change their minds, but to me it is not sustainability.

ORESZCZYN: I'd quite like to support Sarah's [Staniforth's] definition of sustainability, and I think managing change is very important. There are a few buildings that you can probably mothball and keep or try to keep exactly as they are, and people will pay enough money, but if you want to try and keep the large number of properties, which certainly in the UK we have, you've got to make sure that they are, among other forms of sustainability, economically sustainable, and using them in exactly the same way that they were originally intended is just not an option. You have to somehow manage a change of use in them, which will involve changing certain elements of them. So I think that managing that change in a way that keeps the essential elements, whatever you decide those are, is very important.

HENRY: Not to put too fine a point on it, but I think the definition of sustainability has been given to us. We've been preempted on that. It's a question of how we apply that definition to cultural heritage. The EU [European Union] has pretty much spelled it out, among other institutions and agreements and charters, and in my mind, it's a question of how do we apply the principles in cultural heritage.

STANIFORTH: I could put up a straw man and show you what the National Trust sustainability principles look like. These are written specifically to fulfill the National Trust's 1907 statement of purpose, "The National Trust shall be established for the purpose of promoting the permanent preservation for the benefit of the national of land and buildings of beauty and historic interest. To deliver our core purposes, we need to understand what sustains our own places in the wider environment in society, globally and locally. We must act sustainability in all our decision making and exemplify this to others. We shall enable our staff, volunteers, and supporters to continually learn and use our experience of sustainable practice to benefit others. We have three sustainability principles which are fundamental to our work.

"#1, Public benefit. The National Trust will seek to meet the real needs of society for health and welfare, for equality of opportunity for learning and for skills and ways which do not compromise the environment, natural and human, now or in the long term. We shall seek to act with integrity in the long-term interests of society and heritage within the capacity of the environment to sustain them.

"#2, Planning for change. The Trust will think and act long-term and wide scale. We shall seek to anticipate environmental and societal changes foreseen and unforeseen and so minimize our negative impacts on the environment and on people. We shall seek to work with natural processes and use our knowledge of the past to determine our present actions so as not to create future problems.

"#3, Resource stewardship. The National Trust will promote the wise use of natural resources, operating frugally and minimizing waste, safeguarding the quality of air, water, soils, landscapes, and ecosystems on which all life depends. We shall respect cultural resources of all types and celebrate diversity and distinctiveness. We shall care for our staff, volunteers, and supporters and shall seek to act in everyone's best interest." [The National Trust Sustainability Principles 2005 {internal document}]

MICHALSKI: I find myself being sympathetic this time toward Tim [Padfield], in his points. Especially when *sustainability* is used incorrectly as an adverb, but we know it's become code for "in a manner which is consistent with bureaucratic current definitions of sustainable as a concept." And it's easier just to turn it into a floating adverb.

We had a long discussion at a recent APT [Association for Preservation Technology International] workshop—there was a whole day on sustainability—and what came up is that sustainability within the international arena is very much defined by the United Nations bureaucracy and terminology, and they refer to the three pillars of sustainability, which are, as I recall, financial, ecological, and social. Not cultural. Some of the people at the meeting said, "Well of course, cultural is under social." If you actually look at the way social is used in the UNESCO thing, it's not at all clear that they intended cultural to come under social. So there was a proposal to add a fourth column, which is heritage or culture. We certainly, from our perspective, are advising our clients that if we can get them economically sustainable and sustainable from the broader perspective of the planet, then that would be a real advance in progress.

KOZŁOWSKI: I think that there are several definitions of sustainability, and one that is very important is energy conservation—it's a kind of radical definition of that term because you're saying you should save energy not as a by-product of conservation. The second is environmental sustainability—that cultural heritage properties should not use environmental resources. But there is this older meaning of sustainability, which in my mind is kind of dominating: to manage change of cultural heritage objects in a sustainable way means that we start from a past use or past historic climate, historic conditions of the object, and try to maintain the object in the modern society with different demands, maybe changing its use with minimum intervention. So we profit as much as possible from the past, changing as little as possible. And I have two examples of that narrower meaning of sustainability. The first one is churches. We have some two thousand wooden churches in Poland, many medieval. When we advise the local community on preservation, we advise them on how to use these churches, and how they can try to improve comfort by bench heating, for example. In this way we implement the principle of sustainability—because the other solution, very often, would be to abandon that church and build a huge new one of concrete. The second example is Sarah's [Staniforth's] paper in the Ottawa book on preventive conservation produced by the IIC in 1994,[ix] where she said that to sustain abandoned country houses in England, it's enough to put some heat in, avoiding mold formation, deterioration, and so on. So in this narrower sense, sustainability means we are trying to use the patterns of past use, of past historic climate, and try to adapt to modern times. But there is a link between the concept of the energy-saving definition of sustainability and that concept of using historic climate and conditions. If we conserve the buildings as much as possible, profiting from historic climate, historic conditions, and adding something like conservation heating or little energy input, we at the same time save energy. So, saving energy and avoiding the use of environmental resources is a by-product of proper conservation and preservation, and it's not contradictory.

CONRAD: It seems that there are some key things that are all reversible. *Reversible* is a wonderful word that we can use in managing change. These kinds of things start to fit together when we talk about what's happening on this planet, and as time goes on, the dimension—if we take our wonderful treasures and hide them so nobody can ever seen them, what are we doing? The whole thing of balance, the people, the comfort, that whole deal.

There's another buzzword. It's a thing called "embodied energy." I'm a LEED [Leadership in Energy and Environmental Design] Accredited Professional,[x] and we've been tossing this LEED process around at APT in a couple of different committees. It's a process where you get a silver or gold star for a certain number of points—actually it's a silver star. And what we wanted to do, where we wanted to take this system to—and when you take a building, an existing building, and you tear pieces of it apart for adaptive reuse, we want to give negative points. We want to take points away from the person who is destroying this building. We've been turned down by the U.S. Green Building Council, but the thought is there.

One of the things on the shopping list of sustainability items we have not touched on yet is recycling, reusing materials. I'm curious about things we've been doing all along for thirty years, and we didn't realize we were doing green things.

PADFIELD: You can invent fine words in many languages, but usually they're just fine words. What we could perhaps do is be much more modest in our intentions and certainly decide what is missing in our base of knowledge, which will allow us in fact to function as a profession that is well regarded and respected. For me, authenticity, sustainability, all of this is something much simpler than words about global warming and carbon footprints. It has to do with a much simpler attitude of respect for old things. And it comes from a lifetime of seeing the elegance of construction with poor materials. Lately I've concentrated on houses. One of the interesting things about old houses is that they were built rotten from the start. And that's because the people were too poor, so they reused rotten wood where it didn't matter, and they put in new wood when its load-bearing properties were needed. And I'm saddened in my retirement to see how buildings listed for preservation are being destroyed by restoration, renovation, adaptive reuse. All these things that appear as positive buzzwords in our discussion—I simply don't agree with that. I think that respect [involves] leaving old things as evidence for cleverer people in the future to find out how things were done and how we can learn from it. The amount that I've learned from looking at old buildings, to the credit of old buildings and the clever way the intelligence of a poor society went into building a comfortable house. It's been a revelation to me.

STANIFORTH: My experience of buildings not being used is that they are neglected, and that's the sort of place where you have fires and complete destruction of the building. So one of my sort of watchwords for sustainability would be to ensure that everything has a use.

PADFIELD: Yes, I quite agree. I try to be brief, so naturally I aim for the punch line rather than the detail. But what will happen, in fact, is you have the further choice when you decide to turn your historic property into, for example, a hotel. You have the choice that you can charge more if you have an *en suite* shower, toilet, and new piping. Or, alternatively, you can offer it as, for instance, the public school experience, where you wake up in the morning to ice on your washbasin. And this is the problem. It's a slippery slope. I'm not saying that everything should be fossilized. What I'm saying is that you choose what to fossilize. And what I see disappearing is in effect the heritage of humanity in the clever ways that people managed to make their life comfortable.

MICHALSKI: I think other, more direct issues are how to deal with Tim's [Padfield's], issue about what are the risks to the cultural heritage of having a uniform franchise approach toward solutions. For example, when I think about light damage to collections, this notion of rotation and spreading the damage out is a false moral solution that, in fact, in the long run is incorrect. We need sacrificial lambs, or at the very least, we need to encourage diversity of approach, and that seems to me one of the global lessons from the planet—that uniform generic solutions are generally dangerous, whether it's monocultures of agriculture or monocultures of restoration. We can have historic houses that are truly authentic in their sustainability and have very limited visitorship, or we can address explicitly what the costs and perils of visitorship are, which has not been done well.

STANIFORTH: I think that we're going to struggle with thinking about all aspects of sustainability. I don't think we're ready for that as a group. And therefore we could pick out the environmental bit, which is, after all, our mandate for being here, and I think that the final section in Michael's [Henry's] article in the *GCI Newsletter* absolutely captures not only a sort of introduction that explains where environmental stewardship sits within the whole sustainability framework, but it also suggests some actions that people can take.[xi] And if one is being useful for the profession, providing an action plan is the most useful thing that we might be able to do as a contribution.

HENRY: Thank you for the compliments, but a fundamental question that we might want to put forward to the profession is, do we or do we not embrace the question of sustainability? It's already happened in some corridors or corners, the Centre for Sustainable Heritage, the National Trust, but I think it has not been completely or uniformly embraced. Certainly there are people out there who view it as "not my job." And so question number one is, do we want to make a statement that we have an obligation to embrace this and account for it in some way, not giving people direction as to how, but do we have a responsibility to include this in our sense of stewardship? And if we answer that question, then where do we go forward? Going forward, where are the friction points? Friction points are between conservation and environmental cost or energy cost. The friction points are between authenticity of the site and economic sustainability and adaptive reuse. And at least identify where we see those friction points being, and the fact that we have to address them.

Several years ago, when May Cassar [director of the Center for Sustainable Heritage at University College London[xii]] first spoke to me about the application of sustainability to cultural heritage and conservation, I really didn't have much trouble accepting the principles or the application of the principles to what we were doing, because it struck me as a common-sense and responsible path to stewardship, balancing a variety of things that ethically we should be thinking about. The one thing that I fault architects and engineers and even some objects persons in our field on is that, while we call ourselves stewards of cultural heritage and stewards of history, we don't do a very good job of understanding history of applying history to what we do. If we could understand how heritage buildings worked in the past and relate that back to how we might use them in the future, employ them to help modify the interior climate, I think we would be taking a great step forward in sustainability, particularly with respect to energy conservation.

PADFIELD: My feeling is that if we are the custodians of the world's heritage, then that's our primary job, and even if we use very inefficient methods of air-conditioning, that's a drop in the ocean compared to the energy consumption of the world. In other words, we're guilty of tokenism. I have a two-forked argument. One argument is that that's a meaningless humility. That's the first point. And my second point is that in any case, we can save energy even if there were no global warming; even if there were no pressure, there are very good reasons for simplifying our air-conditioning. And they have to do with sustainability. We should ensure that every museum, maybe not historic houses—they're a slightly different case—but every museum should be able to endure for one thousand years of total neglect. A power cut lasting five hundred years. That's actually the most likely thing to happen. And this is not to say that there's no such thing as global warming, I'm not saying that at all.

TOLEDO: I can't help thinking: What if we run out of energy? What would we do with our museums? How could they remain open? How could they survive without energy? The only way I see forward is by dealing with the environment and problems passively, either by the building or by enclosures. I would like to remark that we don't slow down our pace. We keep on going and trying to find other ways of having energy. We are not able to step back and say no, it's enough, let's go back to the basics. It's unbelievable.

MICHALSKI: My sense is that what we're looking for here as an output or a goal for consensus is in the practical issues of saving energy, which is not necessarily driven by either belief in global warming or something else. It can be a point where people get to the same place, which is a desire to reduce energy consumption for quite different motivations, whether it's sustainability or something else. To what extent cultural heritage and historic buildings are really important trendsetters or elements of setting good examples, I don't know. Maybe I'm being too skeptical. But there are some technical issues that it would be useful for us to reach an agreement on and to look at what those risk-risk tradeoffs are, how they can be most clearly expressed. We have to learn to give our best sense of the technical issues without subtly throwing in interpretation, which is the role of all stakeholders who have different value systems. So at least if we could clarify transparently where we see the technical issues for sustainability and cultural heritage lying, then it would be up to other people to make use of that in their decision making.

STANIFORTH: I think you're right, and I think that the contribution of this group is very much in the technical environmental area, and obviously we're talking about that in the context of trying to make museums more sustainable.

ORESZCZYN: In the UK now, the general understanding is that there is no way that you will tackle the problems that we're trying to tackle simply by a technological fix. That as quickly as we build new, renewable wind turbines and as quickly as we install insulation, we also find new ways of using energy. Energy provides us useful things. It's great. We always do something useful with it. And we are going to have to change people's behavior. That's totally understood, certainly in the UK now. The problem with that compared to the technological fix is that politically it is far more difficult to talk about changing people's behavior. But it is now understood that that's what's going to happen.

MICHALSKI: I think we need to use sustainability in global warming. I would see it as an opportunity. If the propaganda from the global warming movement has been successful—

and it apparently has in virtually every nation-state except the most powerful one, and that's just a question of time and maybe an election or two—we can piggyback on that. There are a lot of granting programs in the U.S. that depend on certifying your project as green under various measurement systems that are out there for being green, which includes things like whether or not you have bicycle stands and so on, so they play the game of getting the right score. But, be that as it may, that's the direction it's going, and it's a good thing, and I think we need to coordinate our information and efforts with that kind of pressure, because they support what we want to do and we support their objectives. But coming at it just from our professional perspective within the museum operation doesn't seem to work for various reasons.

Climate Requirements for Collections

In the discussion about sustainable climate management strategies, the climate requirements for collections and for human comfort, as well as the effect of climate control on buildings were addressed. The discussion on the climate requirements for collections began with an introduction by Stefan Michalski.

MICHALSKI: Climate requirements for artifacts—I remember writing something for the National Trust for Historic Preservation [U.S.]. I provided a table on what I thought were artifact "needs" versus artifact "wants." The conservators, who felt that they were the advocates for the requirements of the collection, generally would give a list of what they wanted, which, if one looked a little skeptically at it, was a much longer list than what the artifact needed, especially when trying to negotiate it with the wants and needs of the building and the wants and needs of the occupants. I found that if you tried to look at all the traditional wants of the building, the collection, and the occupants, there was no hope of finding any kind of middle ground. They would always be in conflict. If you got relatively skeptical and talked about the needs, you could reduce the number of conflicts. What I really mean by *needs,* of course—because it's all relative—is looking at it from a risk perspective: what are the big needs of the collections and the people and the building, and then each one of those three becomes more flexible. And it's not so much flexible; I think it's important to break out of the sense that it's flexible. We spent years trying to stop conservators from thinking of the revised climate recommendations as somehow relaxed, softer, all of those things that mean we lost: we're losers in the negotiations, somebody else won. Many of these modifications to the traditional climate specifications, I think, are at the very least neutral; nothing was lost in the safety of the collection, and in many instances, they can be shown to be beneficial. So it's important to get out of the assumption that if we change from what used to be called ideal, that it's a loss. We're still stuck, however, with most of our clients, most of our profession, very much thinking about ideal and believing the word *ideal.* It makes people in our profession very defensive, because they feel that they are negotiating a loss rather than trying to negotiate a win-win situation for cultural heritage and the globe. So that's the philosophical perspective.

I think there is work to be done; there's disagreement about what is exactly known about the science. I don't think the science is completely finished or completely known with certainty. But even the stuff that we're relatively certain about, we have not effectively put into practice.

These are some of the issues within climate control: damp is pretty well understood. There are some interpretations of some of the mold data and studies that we can argue about: exactly where is the line; what role does hysteresis play; how do we interpret contaminant colony forming units in terms of what's happening in actual growth. But overall, we can all characterize where the danger zone for mold is. But in terms of characterizing where the region of humidity and temperature is that is the boundary for mold growth, it still seems to be remarkable the extent to which in the field people will pick a fixed value for relative humidity rather than work with what we know about the combined parameters of temperature and humidity. We don't have to assume 60 percent universally around the world. But I don't think there's much controversy there. The controversy clearly arises if one uses humidistatically controlled heating in a hot climate to reduce the relative humidity, considering the doubling of the rate of degradation with every five degrees centigrade increase. So the issue really is, what's the risk-risk trade-off in terms of reducing damp versus elevating the temperature? I don't think there's any need to argue that dilemma in terms of whether the issues are real; it's just quantifying them. And I think that quantifying them is going to have to be a value judgment and not just a material science judgment. Most of the risk-risk tradeoffs we have in low-tech sustainable climate dilemmas have to do not only with material science but also with curatorial and societal judgments about what's the worst form of damage. We're talking about different degrees of noticeable damage, so the question is, which damage does the community prefer to some other damage? So sooner or later, we have to get out and speak to the community to resolve those low-tech issues.

That leaves fluctuations as the hazard that we're still hung up on. We were hung up on it thirty years ago, and it doesn't seem to have gone away. Until a few years ago, I thought we were reaching a consensus that the fluctuation issue had been exaggerated universally and that universally we could back away from very tight fluctuations. And then our colleagues in Poland demonstrated with a more sensitive technique that you can perceive, measure, monitor degrees of damage from short-duration fluctuations to a surface of an object—which, I have to admit, was, from my perspective, bad news, because what seemed to be a straightforward move toward less obsession with fluctuations had been reinvigorated by a different direction in terms of data. So I think there is a real debate there. There is a degree of uncertainty, currently, if we go to the scientific literature on the role of short-term fluctuations. My sense in reading the texts is that we all agree on long-term fluctuations as an issue in large wooden objects and in furniture. That's the dominant kind of wooden objects I generally advise on. Short-term heating and short-term fluctuations are a low risk.

On the temperature fluctuation side, if we knew we could refine the temperature fluctuation issue, we could probably save the most energy, if we lower the uncertainty in the role of temperature fluctuations rather than humidity fluctuations. From my experience, allowing museums to consider much wider ranges of temperature fluctuation, especially as long-term slow fluctuations such as seasonal setbacks, I think, certainly in cold-climate countries, would have huge impact for energy conservation. There is currently not good certainty on the role of temperature fluctuations for fracture of painting materials. Personally I think that some of the computer modeling that has been published on oil paintings implies a greater role for temperature fluctuations in causing fractures than is warranted. I certainly think that a cold painting is very vulnerable to poor handling, but I am skeptical about whether the temperature fluctuation in a completely quiet painting drives the fracture. I haven't seen direct evidence.

Which brings me to part of the evidence and data that I think we have been weak on collecting (including myself), but it's the part of the evidence that I favor most strongly, which is not from the laboratory. My experience has been, over and over, that laboratory research has refined estimates that were benchmarked by what we observe in the real world, and I don't think that's going to change. One of the things we can certainly learn from climate modeling is that modeling itself is extremely uncertain, and that most models are benchmarked to existing historical data, and we need to encourage our community to systematically collect or process observed data on the role of fluctuations. It could be because I'm from a cold climate and I've seen collections in gorgeous condition that I know have been to minus twenty degrees centigrade every winter, and that includes paintings. I find it difficult to believe that the temperature fluctuation itself is a big issue. I have less experience in elevated temperature. I think [the effects of] elevated temperatures, though, have also been exaggerated, until you reach the melting points of adhesives, polymers, waxes, at forty to sixty degrees centigrade.

Within that climate and historical approach, I think the proofed relative humidity fluctuation or the proofed temperature fluctuation is great. The idea has been around loosely, but we haven't really leaned on it as a strategy to move forward in advising other people. I think that it is a relatively powerful and novel concept that has not been part of common knowledge until recently. It's an intellectual tool in our field, in order to get out of certain impasses that relate to historic buildings and sustainability. So it's a microaspect of sustainability, in terms of risks to the object from fluctuations; and although fluctuations are not the most important aspect of climate for real risks to collections, in my opinion, it does seem to be the biggest issue as far as what I think are wrong decisions for climate control in cultural heritage and buildings. It's actually using history and what happened in the past to make some prediction about the future, and it's global.

"Locally proofed" is a concept that allows each museum to make a rational risk assessment, and it has a huge advantage, which is that it doesn't need material science, so it doesn't need that kind of expert, it just needs a local historical record. In the end though, I think we will also need the material science to discover the remaining small risks to the collection. And we're not going to find zero risk. I think that we're going to find very large numbers of very low risks from climate. And then we'll find a few that are high, most of which I'm still convinced are mold, the one big risk from climate. So we're in this messy business now of still relatively uncertain science, some of which is taking us back to being worried about fluctuations that we thought we could walk away from worrying about. But it will become a question of quantifying them. And not just quantifying them with material science.

It brings me full circle that in this issue, the question will be, how disfiguring is it? So if we hear acoustic emission, if we model that it may reach the stress, the question becomes in my mind, so what? The question is, what's the condition or state of the polychrome after five thousand of these cycles, and supposing there is a change, how important is that change compared to saving the planet, saving energy? There never was in the past any truth to the sense that the perfect ideal climate was preventing all forms of damage. And that's one assumption we really have to try and get our colleagues and users and clients to get away from. It's all about reducing the change and loss of value over time, and those are trade-offs, because some of that loss of value is loss of access or the museum closing down.

And I don't think that it's too extreme to say that, certainly with the clients I deal with, there's a huge amount of the kind of middle-of-the-road cultural heritage that is really at risk. The major museums will go on wasting energy for the foreseeable future, as far as I can see. It's the next tier of cultural heritage that is, I think, the real fabric of our cultural heritage, not the iconographic things. How much do we want to preserve of that, and how much do we expect them to stay minimally changed over time?

ORESZCZYN: I think that was an excellent summary of the views, and I strongly agree with many of the things you were saying. I think education has an incredibly important role to play in this. It's interesting that most of us originally came from quite a hard-science background. And I actually wonder whether part of the problem is this quite hard-science background, where we can understand things very well theoretically, but actually, the real-world problems are not just the theoretical ones. I think this area of optimization—rather than trying to avoid discomfort or major catastrophes—is really problematic. We have it in [the area of] thermal comfort, where everybody wants to go for twenty-one degrees centigrade, because that's where theoretically the optimum would be expected. But in reality, it's impossible to achieve in most buildings anyway, and people can actually tolerate a much larger range of conditions, just as objects do. So I think it's not only a problem in terms of this particular area but also a problem in general, in terms of how we control the environments in buildings for a whole host of reasons, and we ended up [working] toward optimization, where actually what we want is a whole series of robust solutions.

MICHALSKI: This term *robust* certainly comes up when we are trying to develop databases and so on, and robustness is really important for things working. I think it's consistent with a risk management approach, because it addresses the really large risks, such as a mold event, over the next fifty years. Time scale becomes so important, because we do have a tendency to slip into thinking only about what will happen the next year, the next two years. But after being at it long enough, you start to hear stories about people who had terrific climate control for twenty years and then the humidifier failed, the designer had not built in redundancy, nobody had told the operators what to do in the event of this kind of failure. Something that goes wrong every ten or fifteen years for a few days can erase all the risk control you've done with the high-tech system by, in fact, creating climate that is completely novel historically. A mechanical system can do two things: it can make novel climate that's good, and it can make novel climate that's bad. And in terms of risk management, it's the second one that's much more important, even if the probability is quite low. Robustness is equivalent, from my perspective, to truly avoiding intermittent high-impact climate events, which seem to be at least as much due to malfunctioning equipment as to global warming over the last thirty years.

CONRAD: As the engineer in the crowd, we have to understand that the engineering community is not a leader in mechanical systems; we're a follower. Our mechanical systems are a result of what the conservation community tells us to do. Regarding the choices of your mechanical systems, I remember twenty-five years ago, when energy was dirt cheap, the most important thing was to maintain relative humidity. So we designed precision climate control systems. And then it starts to get expensive, and so people said, "Oh, let's change our priority. How about stability?" So we moved into the world of stability. And what stability says is that we can have gradual drift, that seasonal fluctuation, which had two purposes: one, it saved energy and money, and two, it saved us some condensation damage to the building. But now we're being told that we have to control fluctuations. The only problem is, we don't have any rules. We're in a bit of a vacuum when it comes to being told to control fluctuations, and we are the ones who have to design the systems that are energy efficient and actually produce a product that matches the requirements of fluctuation.

HENRY: What I see as a practitioner when I go into a site is an overemphasis on environmental management, and I suspect it's solely because it's the one risk that people can naively easily quantify. And they don't really quantify the risk; they just measure the conditions. Temperature and relative humidity are the only things that a curator or a site director can get a meter for and measure. They can't measure security; they can't measure fire risk; they can't measure any number of other things that put their collections at risk. I've been called into institutions, and they're worried about temperature and relative humidity, and yet their storage facilities are atrocious because they have the greater potential for physical damage from just moving things around. As we discuss what's appropriate for environmental management, appropriate goals, I think it's incumbent on us to put it into the context of other risks and to address that there are other risks that institutions have to deal with that are less easily quantified. This ability to measure is a forcing function that drives back to the granting [agencies], because they can measure it.

STANIFORTH: I quite agree about that real importance of knowing what your priorities are. But I would disagree with attributing the tightness of temperature and humidity specifications to the ability to measure them, compared with our ability to measure or record and document other things that happen to buildings and collections. Our real resources over time are the condition reports or the quinquennial surveys. Quinquennial surveys—I don't know if it's something that's practiced in North America, but in building conservation in the UK, we would have a practiced building surveyor undertake five yearly surveys, and we'd then have a list of maintenance jobs for the next five years. We also keep insurance records for major events like theft and fire damage to buildings, and therefore all of those results of poor attention to risk management are documented, and that is your real documentation of the effectiveness of your risk management. So what I'm saying is that I think that the Canadian

[Conservation Institute's] preventive conservation framework has been extremely influential and in many ways has articulated in its expression what is good common sense.[xiii]

You undertake the implementation of risk management for the things that are going to cause the most serious damage first. For example, when you open a new museum, the first thing that you would spend money on, I would suggest, is a security system and fire prevention and fire detection systems. You would then prevent water getting into the building, and then you would go down that preventive conservation framework for that particular collection in that particular building and implement the remedial action in order of risk. It then becomes very logical, and very often you will find that doing anything about the climate will drop off the bottom because it is so much less urgent than other risk management tasks that need to be undertaken.

HENRY: I would just like to respond to that. I agree with you 100 percent. We don't have the routine physical surveys of buildings in the United States; we're more episodic. And I agree with you about looking at risk holistically. But I am speaking from the experience of going into small institutions and [noting] where they see the risks, and they see the risks where they can measure things. We can tell them about what CCI [Canadian Conservation Institute] and what GCI have done, but their emphasis is on what they know, and what they know is what they are able to measure. And so that may emphasize that we have an education problem.

MICHALSKI: Just to defend the museums. They are also frequently looking at requirements of granting bodies that routinely will begin with the climate control specs. And they will have other issues like fire and security, but it's remarkable how much vague advice about risk management, about the other big issues, are in the granting body's documents and how specific they are in climate and light. So they've got numbers for the climate and light and are quite specific. So I don't think necessarily the initiative is coming from the museum, but as a profession, we were incredibly successful in that part of propaganda. We sold that idea on climate control and fifty lux and the magic numbers, and it stuck. Now the question is, how do we unstick it, because it's stuck?

CAMUFFO: To come back to the concept of proofed fluctuations that Stefan [Michalski] introduced: We measured microclimates in several European museums, and we found that in most museums, the heating or the cooling system is on during the day and is off during the night, so this introduces a strong variability day by day and season by season.

So, if we want to improve this situation, the best is to keep an even level day and night, and this means to reduce costs, because twenty to twenty-four degrees centigrade in winter are too much, as people may have coats on. Keeping the winter temperature at fifteen or sixteen degrees centigrade is very advantageous for conservation. Artworks in churches remained for centuries in the same place, in the same natural microclimate—good or uncomfortable, whatever it was; that is, the so-called historical climate.

In past decades, some heating was introduced in many churches. Objects that are vulnerable to heating change have a certain way of adapting to the microclimate variability. If the microclimate remains at the same average level with the same variability, these objects have adapted in some way, and they can remain and survive. Permanent heating may lower the internal relative humidity to a level that may be dangerous. Another negative factor is due to fluctuations in temperature and relative humidity that may return before the material has relaxed. If weather changes continually for a week with a continuous decrease of relative humidity, and after this cumulative effect we have an additional drop due to a short-term fluctuation, for example, heating, the synergy of the two may be dramatic. In the European standard that we are drafting [CEN prEN 15757, Conservation of cultural property—Specifications for temperature and relative humidity to limit climate-induces mechanical damage in organic hygroscopic materials], we are considering the idea of keeping the climate within the total variability of the historic climate in order to avoid any risk for the object. If we go outside this variability, we enter a totally unknown area that may be risky. If the object is in good condition, it can experience new damage. But if the object already shows some signs of deterioration, if there are some cracks and microcracks, these will continue to develop and the object will continue to accumulate damage.

STANIFORTH: I think that what Dario [Camuffo] is talking about I picked up in what I wrote about the dangers of international standards for loan exhibitions, because the scenario you suggest is that of an object that becomes acclimatized to the environmental conditions in the museum where its home is, as it were. And then you take it to this so-called ideal environment that is specified internationally for loan exhibitions, and it's very tight. It might be 50 percent plus or minus 5 percent [relative humidity] and twenty degrees plus or minus one degree centigrade, and it's extremely damaging for an object that has come from a church in Italy which is acclimatized to maybe 65 percent or a National Trust house that's acclimatized to 60 percent. The damage that we see that is related to relative humidity tends to be when objects go to loan exhibitions and the microclimates that we specify, and the exhibition cases to create the home environment, rather than the ideal environment, fail. So my question is about these loan exhibitions, and if we can continue with loan exhibitions—because if we're going to move toward a climate that will closely reflect the external environment of the home museum in order to reduce the amount of energy that's required to keep the object in good exhibition at its home museum, what's that going to mean for these loan exhibitions which do depend on a uniform standard internationally? So are we actually coming to the end of blockbuster international loan exhibitions?

KOZŁOWSKI: I want to comment on loaning objects, transferring from one climate to another. I know several conservators who have experienced a disaster with objects that were brought from churches to their ateliers to be treated. These objects were moved from churches in Poland, where the relative humidity would be above 70 percent, especially if they were taken during the wet period. These objects cannot be loaned, or there must be a very careful adaptation strategy for normal museum conditions. But I think that the reason why most objects on loan survive very well is because—if you look at data—usually 50 to 60 percent [relative humidity] is a natural average. So maybe this is the reason why we are lucky, because the historic natural climate is usually around 60 percent average.

CHIARI: I can give a recent example. The Getty organized an exhibition of the icons from Mount Sinai's Saint Catherine Monastery, and the monks imposed the requirement that the relative humidity would not change. Their conditions are something between 20 and 30 percent RH, a level that probably would not be considered good for an icon. But they were all sealed in with that condition, brought to the Getty, and brought back. And of course, that was the only possibility for anyone to see those icons, because I went to Santa Catalina as a tourist, and I couldn't see them, because they don't let you go. So that's just one example, but it's in favor of what you are saying.

STANIFORTH: I think it is very possible, for smaller objects, to make these climate display cases for exhibitions, and that's a very good solution, but I guess that I get more involved in loaning bigger objects, pieces of furniture, and given that the point of a decorative art exhibition is very often to see the object in context—so you create a room setting, and then to put them in boxes is more problematic. Something we may want to debate here is, is it more sustainable to take the object to the person than to bring the people to the objects—and arguably it is—but then how do we square that with the need to have more variable climate control in different parts of the world?

Since Michalski in his introduction indicated that there is still a lack of understanding of material behavior with regard to fluctuations, the discussion continues to focus on this.

HENRY: Outside continental Europe, when we're looking at passive measures, nonmechanized measures for dealing with collections conservation, the question of fluctuations comes to the fore. It's not driven by engineers. It's trying to avoid engineers. And in trying to avoid the engineering solution—and I say that as an engineer—the question comes up, what can we tolerate, what can we accept as the level of risk, versus what we can provide in a stable building in an aggressive climate?

PADFIELD: There are fluctuations in relative humidity and in temperature. From the point of view of historic buildings, if you allow the temperature to follow as closely as possible the temperature outside, you eliminate a lot of damage to the building. There is not very much work on the effect of temperature fluctuation. There has been perhaps an overemphasis on relative humidity as the vital thing. And this has, in fact, resulted in destroying a few buildings for the sake of the collection. However, there is some evidence, it comes up scattered in the literature, that temperature—perhaps we have been neglecting it and assuming it hardly matters. So I would say that we're a bit short of experimental evidence on the influence of temperature. Marion Mecklenburg has produced some very interesting and provocative results on the effect of temperature on even oil paint: very ancient materials that one would think would have been researched to extinction, but his results were actually quite startling, and therefore they bear repetition.

STANIFORTH: As far as the size of the fluctuations over what period, I think that the concept of the proofed extremes that an object has survived is very important, and therefore you could define for a particular object with a certain proofed range that it will be the short-term fluctuation of less than a day to the limit of those ranges. So if you have an object that has been proofed to survive without cracking at a range of between 40 and 75 [percent relative humidity], you could be going along quite nicely, as stably as possible, using conservation heating or conservation ventilation or whatever method, and then you could perturb that stable condition.

MICHALSKI: But overall, from my experience of trying to pull together advice for small museums, the shorter time fluctuations are not crucial to damage. They don't provoke large amounts of damage, or we would have seen it.

STANIFORTH: Stefan [Michalski], how would you define a short-term fluctuation? How many hours?

MICHALSKI: It depends. The "short" is relative to the collection.

STANIFORTH: Mixed collection of organic materials.

MICHALSKI: I find anything less than a day falling into "short." I think the diurnal fluctuation is still the most important—not just because it's naturally fairly guaranteed in most climates to some extent. Yes, we can say, "Well, the initial hour represents the skin changing" and so on, but as soon as we put a layer or wax or varnish or paint, then we have a system which first of all tends to have a much smaller gradient under the paint, and then the question becomes the paint's response. As soon as oil paint is one hundred microns, it's many hours for its response time. The short answer is, anything under a day. Something between one hour and ten hours is roughly short for most mixed collections.

STANIFORTH: And just putting that into practice, the question of comfort heating which applies in churches is in theory, therefore, comfort heating for people during a service in a church, and it would be shorter than that short-term fluctuation that might cause damage. So I now look at Dario [Camuffo] and say that in practice, when you have been into churches which have heated up the whole space rather than using the Friendly Heating, has damage been observed in practice?

CAMUFFO: Yes. Absolutely. For a church, the most typical short-term fluctuation is one of hour heating for Mass. Many churches show evidence of damage after heating has been installed. In the case study of the European projects Friendly-Heating and Sensorgan, altarpieces and organs were in excellent conditions before the installation of heating; now there are some cracks in several parts of the wooden structures. Roman [Kozłowski] mentioned that his research showed that cracks widen and shrink during Mass. The problems are so numerous that we risk causing some confusion if we do not distinguish what happens in different climatic areas. In most Mediterranean countries, no heating is best for conservation. However, Henk [Schellen] was right in saying that in the Netherlands or in other parts of Europe, for instance in Scotland, the rain is very frequent, and there is dampness. The main topic we have so far discussed has been low humidity generated by winter heating and cracks resulting from microclimate variability. A different, important problem is dampness in humid regions that can be mitigated with some heating; however, heating should be carefully applied because it may cause the formation of salts and salt mobilization, maybe hydrolysis.

SCHELLEN: I have a remark about what Dario [Camuffo] was saying about the heating of churches. One could have the idea that not heating a church at all would be the optimal solution for objects. There is evidence in favor of slightly heating a church compared to no heating at all. So when you look at the temperature difference between the walls and the dew point, then it is better to slightly heat the church.

CONRAD: The decision of temperature control and humidity control in a church is the preservation of the organ. The organ is worth more than the building. If you don't maintain a reasonably good relative humidity environment, the organ goes out of tune.

SCHELLEN: There's another interesting item regarding organs in the church. Normally, temperature is not an important factor for collections, but for organs it is, because the organs are tuned at the specific temperature. And when you use it at another temperature, it will be mistuned. So normally in the Netherlands, they are tuned at fifteen degrees Celsius, so you have to keep up fifteen degrees Celsius also during wintertime or you have a mistuned organ. The other way around is that you tune your organ every season.

KOZŁOWSKI: Just to remark on short-term fluctuation. I would like to correct an idea that is emerging in the room. In our work, what we try to say about fluctuation is not as a restrictive but, rather, that you can have a fluctuation that is quite large. Why? Because if people want to heat a church which has these beautifully preserved objects, if you say to them, "You can't do anything because this will be against stability," then they will do something on their own, without any guidance or rational conservation approach. If you tell them, "Your objects, your sculptures can survive an RH fluctuation of plus or minus 25 percent because modeling or acoustic emission or the laboratory supports that", that's giving them freedom to introduce something to improve the comfort without endangering the objects if they stay below a certain variation. I would not like it to be seen that our research is bringing a warning.

In Poland we are sometimes looked at as dangerous because we say that it is okay to work with priests at a church to install a system that brings fluctuation to plus or minus 15 or 20 percent—the objects will survive that. The conservators don't like this. They think that one shouldn't touch the issue, because stability is so important. So they prefer not to be involved with the heating of the church, rather than saying something positive. So we wanted to produce a CD with this kind of national data about historic climate, natural fluctuation, short-term fluctuation caused by appropriate heating like infrared or bench heating. But we are blocked by conservators because they said, "You are dangerous people who don't understand conservation." We are from the other side, which says that short-term fluctuation is not dangerous. Allow it. But in a rational limit.

PADFIELD: I'm getting a little bit depressed, because everyone's talking about how much one can allow things to vary, and I want to put in a plea for constancy, and if we look at this church affair, it all stems from the 1960s, when Herr Künzel said that the way to heat a church is to catch the woodwork by surprise, and then it won't notice, and then it will cool down again.[xiv] And we have some evidence that this is complete nonsense. And that evidence has been available for a long time in the way of flaking, particularly with wall paintings, where we have really rather good investigations of how much relative humidity affects it. So this is the danger of setting a standard for seventy years, and yet all the evidence is there against it. And this makes me wonder that we're perhaps heading toward the same sort of thing.

And therefore, I'm putting in a plea for constancy. And supposing one says, "We're not going to relax the standards. It's going to be 50 percent, twenty degrees, or at least constant"—what are the consequences? And the first thing is, you can achieve it, and we've done this in the admittedly rather simple example of archives. We have built archives that, in effect, hardly vary at all, ever. And we've done it by passive means, by looking at building materials and constructions and putting in round corners instead of square corners. It's not my question to you but my urging to you is, don't give up so easily. The other thing is that times change without one noticing. Once we were all terribly worried about acid rain. Do you ever remember that? Well, now we're worried about fluctuation. But at the same time, there are more vandals, bombers, and thieves around in museums, so everything is put behind glass anyway. So we just come in and say, okay, we design the showcase for stability and constancy. So my plea is that we don't get off into the sideline of how much variation you can allow; we keep hold of the idea that when you first opened Nefertiti's tomb, it was perfect. And the question is, was that because it was constant?

MICHALSKI: This is a point where I really have to depart from Tim's [Padfield's], perspective. And constancy as expressed as a goal—but with the word itself unqualified, for me it is too much of slipping into an absolutist position, and we need to quantify all of these issues, and we need to quantify the risk involved. I'm very glad to hear that Roman [Kozłowski] is coming from the other perspective. I have to say that when his colleague gave the paper[xv] at an ICOM-CC [International Committee for Conservation of the International Council of Museums] meeting, the perspective was the opposite. There were people leaving that talk feeling justified that any fluctuation is dangerous, because his paper was, "Look, we measured acoustic emissions with even a short-term interval, and the object is not capable of reaching equilibrium," and so it was for many people there who were not aware of the direction of the paper, which had a different spin on it. The message [in the paper] was, we have a subtle technique which is showing that this is a very low risk, and maybe even zero risk, even if it responds. So it's another example of how it's really important to present the same information carefully to an audience of practitioners because they will pick up on—the same data obviously can be interpreted from two very different directions. The cup is half full or the cup is half empty.

HENRY: So the question actually is, what is the time interval, independent of range, that we want to use to define short term?

MAEKAWA: Well, most of the time scale usually comes from the material. It really depends on the material—whether it is material density or material thickness.

MICHALSKI: The practical answer to your question about time constants is that we have to partition the problem into its simplest components and then work up toward the most complex ones. The proofed fluctuation, I think, is at its simplest when we refer to time spans long enough for an object to reach equilibrium. I certainly feel comfortable advising people that objects have been proofed seasonally, and by that I mean, if a small museum says, "We know from the last full year . . ."—and the first thing you would do, if you don't know what happened in the past, is at least collect one year of data, and that year is at least more accurate. It may be a peculiar year, but it's more certain than nothing. And then you work from that. So if it goes to 10 percent humidity for three months in the winter, I'd feel safe to say to people that whatever damage is possible from that in a single cycle has happened already. You will still see movement.

A disagreement I actually had with Marion Mecklenburg over the years was his emphasis on a very conservative estimate of yield point as a definition of damage. That always seemed to me excessively cautious, although it gave us a plus or minus 15 percent RH had wider limits than that, because for me, the definition of really significant or perceptible damage culturally is usually fracture—delamination fractures, straight fractures, things cracking. So the fact that it's a slightly different shape (due to deformation beyond the yield point)—one can call it damage, but for me, it's a very different degree of damage. So if we back away from that into short-term fluctuations, the duration and the peak height are both important if you're trying to predict how much of a surface gradient will appear in an uncoated material. And it is a question of either modeling it or finding it empirically. Whatever pattern happened in the past is unlikely to form damage if that pattern is repeated. Whether or not you can feel certain in making that judgment, of course, is difficult, but that's a way of capturing all of the mathematics—just to say, as long as the future is not different in terms of its pattern from the past, then it's a low-risk situation, except for damp and mold and archival issues. Again, we're just talking about fracture of wood and paint essentially.

CHIARI: Do you feel like we have enough tools to really evaluate the deterioration of objects as a function of individual variables, and can you suggest some that can help us, the conservation scientist, not climatologist, to provide perhaps the tools, the scientific experiments to do it?

MICHALSKI: We need experimental studies on real systems that are constructed. We desperately need that middle ground. Right now I talked about anecdotal or historic evidence, which can be incredibly powerful when you find a good example. Whatever your approach is to the strengths or weaknesses of inductive reasoning, it's still all we've got, and if you find a counterexample to a current model which is real and well documented, it's very powerful in checking models. I certainly use them to correct generalizations that are made, and it's generalizations that have been biting us, in terms of climate control specifications.

If we as a group could reach a consensus on what are the most useful examples to look at—I think, for example, humidity fluctuations on polychromes or oil paintings. We've got virtual modeling ever since Marion Mecklenberg's models, and certainly the climate modeling being done by the building physics people is, I think, much more advanced and sophisticated, because you have a critical mass, you have universities around the world doing it. We don't have people around the world modeling the response of objects. Dario's [Camuffo's] paper [see "Church Heating: A Balance between Conservation and Thermal Comfort"], which was very sophisticated in terms of the climate modeling of the organ pipes—when you actually look at the virtual modeling of stress in the organ pipe itself, it's like a Mechanics 101 approach to modeling fractures. None of the time constants are taken into consideration. In fact, as far as I could see, the model, which was a block, was then extrapolated to a square cylinder, which was a different system. So we need better modeling, but I think what we need at least as much is the kind of experimental work done on systems which are applied to fluctuations. What's really important is to look at complex objects.

[The other side to] your question is, what parameters should we be having as failure models? What's a failure criterion in an object that we're modeling? I can't think of anything that isn't fairly straightforward. First of all, it would be fracture. The difficult thing about fracture is that for long periods of time, these materials are viscoelastic, viscoplastic, so we have to modify the fracture criterion for the time constant. So we know in wood that fracture along the grain can occur after much longer elongation before it breaks, if the time constant goes longer than one day to thirty days. So we need to adjust the failure criterion for fracture substantially with the time constant. We have to recognize that fracture mechanics tells us that the scale of the object is very important for the likelihood of fracture, in order to get enough elastic energy to grow the crack. We need to use large samples. And I think the modeling has to include that; it has to take a fracture approach. The next layer below that is going to be deformation, and deformation will be yield point. Yield point, again, is viscoplastic in most materials we're interested in, and we have to separate recoverable viscoelastic yield from nonrecoverable viscoplastic yield, and that won't be easy, and they're both time dependent. And between those two, I think we will be busy for modeling. So I think it's just fracture and yield—but recognizing that they are complicated by viscoelastic and viscoplastic behavior.

CONRAD: Would you add into that delamination?

MICHALSKI: Delamination for me is a form of fracture. It's just fracture between planes rather than fracture across, but yes, and there's a lot of terrific FEM [finite element modeling] that's been done in composite materials, especially delamination from an edge on graphite, epoxy, composites—all of the sophisticated FEM modeling of hygrothermal stresses in layered materials is in the high-tech graphite epoxy literature. It's certainly where I found, some years ago, the modeling of the last couple of points at the crack. It's really important to get lots of elements in the FEM model, in order to represent the peeling stresses at the edge of the crack correctly, and so we need to look at that. But I think it's just fracture and deformation. That sounds simple enough, but actually, when you look at it and look at time in organic materials, it's going to be quite different from metals and ceramics. Some people who work in this field who have been trained as metal or ceramic engineers, inorganic material engineers, bring quite a different perspective from that of the plastics polymer mechanical engineers to failure.

KOZŁOWSKI: I would like to discuss or to ask your opinions about the common statement that all objects are different, and that, really, no research is pushing us forward. Whatever research I present, the conservators will usually say that this is not representative because each species [of wood] is different. But if you look experimentally, it's not true. I think we should be more courageous if we feel that the reality is not so complex. For wood you can make some general statements. It is a quite uniform material, the response of which is predictable, even if there are some differences. We are currently researching twenty species of wood from the workshop of the National Museum in Kraków. We measured the adsorption of moisture and dimensional change as a function of RH and are now processing this data to try and produce a sort of universal relationship for museum woods. This will be a kind of ideal relationship and we'll investigate what the impact is on the modeling if one uses such general data instead of one specific for a given type of wood.

MICHALSKI: The notion that everything is distinct gets used to defeat any kind of general advice, and it can be very frustrating. And I hear the word *complex* being used frequently here. The response of woods is not particularly complex, as far as a sufficient model goes. I think we can accept from conservators that situations that we're trying to model are both variable and complex. But sometimes the fact that they're variable can be handled reasonably well by most modeling. The modeling tool that we're using to build a general collection risk model, for risk analysis [Analytica] accepts a distribution between the middle, the highest, and the lowest—or more elaborate distributions, if you know more information—which is very different from saying that the system is complex. That really does defeat models fairly quickly, if it's too complex a system. But if it's highly variable in some parameters, like the species of wood, then that's more manageable, and that allows us to accept the conservators' concern. So the reason I'm mentioning this is [to propose] the way politically and diplomatically to accept part of what conservators mean when they say that every situation is different. They don't mean that every wooden polychrome artifact is a different complex model; what they mean, I think, is that there's a great variation in each of the key parameters, and that we need to recognize that.

PADFIELD: You were correctly modest about science contributing much to predicting the effects of fluctuation. The other contribution comes from anecdotes. And my experience of anecdotal condition reporting is that it's simply useless. And this casts doubt on all the risk analysis and all these elegant concepts of proofing, because you can't ever find out what has happened before.

KERSCHNER: I think it's really important to get the word out to the field and out to the conservators, to get them to look at their collections. Especially with the idea of proofing and what the collections have sustained in the past, as well as what they haven't sustained in the past. And then also to get the idea through that it's okay not to do big systems. In fact it's okay to do absolutely nothing, based on data and measurements. But my main question still remains, how wide can the fluctuations be before they're dangerous to a particular collection, and for how long? And I think there's still research needed on that.

The discussion on the use of simulation tools will continue later. The group took a side track in discussing the impact that current standards have on the decision making process for the control of indoor climate in museums, archives, and libraries.

CONRAD: Recently we've done a lot of work in libraries and archives. Some states are developing standards, and no two states are the same.

PADFIELD: I actually have a list of things that would do a lot to improve the standards. Standards are written into contracts; everyone works to a standard, because they're scared of the lawyer's fees if they don't. And the standards are a whole mixture of right and wrong and ignorance. We identify the bits where we're ignorant, and to find those bits, you need the standard—whenever it says something shall be adequate or convenient or anything like that. What it means is, we haven't a clue, and we're just passing on conventional wisdom.

To give a particular example, the standard for archives says you should have ventilation. That's an air-conditioning issue. But as far as I can see, there's no need for ventilation, but it's in all the household books and has been for a thousand years. Well, maybe we do need ventilation, but I've never found any evidence.

The other one I've identified as essential, which is still ventilation, has to do with internally generated pollution. Imagine what happens: you have a photographic collection, and it's got acetate negatives, and you're worried sick about this vinegar syndrome. I haven't seen any evidence of the fundamental thermodynamics and kinetics of what happens to an acetic acid molecule that is liberated from a decomposing negative. Then it wanders around by Monte Carlo methods, and it's likely to react again very close, at the same negative or the next one. And then it can escape into the room or not, and then it escapes to the outside. Now, if you ventilate the room a lot, does it do any good at all? And it's to do with the rate of the reaction of the acetic acid. There are good scientists working on air pollution and museums, and as far as I can see, they all utterly miss the point, which is that it's a kinetic process. The self-destruction is spatially limited, so what happens if a book is decomposing? Does it just decompose itself, or does it decompose the whole library? We don't know about these things.

So for archives to say you should have ventilation, which in fact means there should be temperature uniformity, that's an architectural issue. Therefore, our standards are based historically on the concept that engineers can fix anything. And that's true if you've got infinite resources: they can fix anything.

MICHALSKI: Somebody comes up with a number in the 1940s and '50s. It goes into some professional code; it goes into a federal code; it goes into the state codes; and after about twenty years, it's in so many layers of codes that even though building science comes along and shows that it was completely—well, sort of a half-intelligent guess, but it's really wrong. To undo that, to actually put a new code in place, is a huge struggle and can take another twenty to thirty years. So we're not different in that respect. And one of the worst layers of government for perpetuating those codes are the granting agencies, because they have no incentive to take risks. They are risk averse in their operation. It is not in their nature to adopt codes that they perceive to involve more risk. So we have to present it as new code that has the same risk or even lower risk, rather than trying to say that we're asking you to accept more risk, because I don't think that's true. But we certainly need to have credible science in order to demonstrate that.

I used to think that showing them other correlated risks, like saving energy, saving budget, other things that will go right—the argument against that is, we're not a granting body that actually influences all those other things. Just because you save money on mechanical systems doesn't mean that the money is transferred magically through the government so it reappears in some other part of your budget from some other granting thing. And again, the risk analysis field is familiar with this. They actually talk about opportunistic options—where the biggest risk may not be addressed, but if the money exists there and you can get access to that pot, you go for it.

CAMUFFO: Conservation is in line with energy saving. There is a basic distinction between climatic areas that are too dry or too wet. If relative humidity is too low we cannot heat, if too high, we should proceed with some heating. In general, I would recommend passive systems that use no energy and are safe for conservation. In cases where the environment is too wet, it is not so easy to control only with passive methodology; there is need for some heating. Important objects should be preserved looking at their actual needs, which can be known from their past history. Their past climate history is fundamental, because the damage they have, or don't have, is a consequence of their past life. The study of their historic microclimate and its variability is the key to preserving them.

The museum in Tenerife and the collections in storage we visited have another problem. There is a mixture of various objects coming from different places, without a documented past climate history. Nothing can be said about them.

PADFIELD: There really is no way of producing permissible variation. The more you vary, the more the risk goes up with our particular infinite range of items that we have to preserve. And therefore, the aim should be to have no variation. And what I disagree with fundamentally is this coupling of economy and permitted variation, and it comes from air-conditioning engineers who say, "Well okay, we can run the thing cheaper by having less variation." We have to come back to consider why architecture is left out of the standards.

Human Comfort

When deciding on a climate management strategy (especially for historic houses), the issue of human comfort and visitation should also be addressed. In heating climates, the most demanding season is winter. Some institutions close their doors during this period, including the National Trust (UK), which operates a conservation heating program. However, for many institutions, winter closure is not an option. On the other end of the spectrum, hot and humid climates pose very different challenges to visitation.

KOZŁOWSKI: I would like to start with a crucial question for countries such as Poland—that is, countries situated in cold areas—and it is the question of visitation of historic properties in the winter. We know that the National Trust closes for the winter. My question to Sarah [Staniforth] is, to what extent has this been stipulated by low visitation during the winter? Or is it based on the principle that you don't want to heat your properties in winter, even if you have a certain percentage of properties that people would like to visit in winter? In Poland the visitation of almost all properties in the winter is low. But when you talk to the managers about limiting the visitation (maybe by closing), in order to save energy and to create a better indoor climate, to make a property more sustainable, then you meet with huge resistance. Most of the management will say, “No, we must be open, we must show everything, and the rooms must be heated because our staff is guarding the rooms."

STANIFORTH: We started from a position, when I joined the National Trust, that the houses closed at the end of October and reopened at the end of March. So at that stage, we hadn't started with conservation heating or anything. But we started conservation heating in the knowledge that the houses were closed in the winter. Now, because of our economic model that relies on visitors, there is more demand for opening during the winter.

We're now beginning to experiment with opening weekends up to Christmas, and they would be focused around events that could be things like a carol concert or Christmas decorations. How are we responding to that? First of all, I think we are finding from last Christmas, which was the first time we made a real effort to open properties in the winter, that actually it made a huge difference economically, and it did pay, because the shops were open, the restaurant was open, so our retail and catering operations had a very good end of the year economically, and we were able to do it very selectively, so we didn't open the whole of the house. The housekeepers were doing their winter cleaning, so part of the experience was seeing conservation in action. And in some of the houses, we could use this limited comfort heating for the hours when the house was open. At the other end of the winter, we brought the opening forward to the seventeenth of March this year, but we've had the most fantastic spring in England, so the cold temperatures weren't such an issue this year. But in most years, the houses have become cold over the winter, and actually opening earlier could be quite uncomfortable, particularly for the volunteer room stewards who sit in the rooms.

CAMUFFO: Our EU-funded Friendly-Heating Project, which was aimed at churches but can be generally applied to historic buildings, is aimed at heating strategy. It is against the concept of heating the whole building volume and is devoted to heating just people. In the case of a historic building, we should consider that people come from the outside well dressed, walk inside, and need only a small amount of heat. It may be strategic to have a heating carpet for people to walk on. For the building's guardian, a possible solution is to have localized heating with a lamp or heating carpet, but still there is no need for heating the whole building. This is not conservation heating, of course, just comfort heating for people. In this case, you can reduce the need for energy and have sustainable use.

STANIFORTH: We have experimented with heating mats for the visitors, and I agree that the volunteers, if they feel that there's a warm surface near them, then it makes them feel more comfortable. And the other thing is to ensure that there's a room that's properly heated where they can go to have a cup of tea, so they can warm up somewhere. So it's not an issue for the visitors, I agree; it's an issue for the people who have to stay in the room for security.

KERSCHNER: We've also based ours on an economic model, and our economy from Vermont just says that we don't get people once the leaves fall off the trees in October. We close at the end of October, and we don't open again until the middle of May. We are a relatively small private institution [Shelburne Museum], and we're just responding to when people come or not. We've tried many things. We've tried the shoulder season, where we're open through Thanksgiving or through Christmas and then closed for January and February. We've tried single tours, where once a day we have maybe ten or fifteen people at the very most come on weekends, and we only bring in one guide—but then they only get a limited experience of the museum. When we come right down to it, we need to have a certain volume just to hire the guides for our twenty-five or twenty-six buildings, and strictly based on economics, it doesn't make sense. On the other side of that, in the months that we are open, we are increasing special exhibits to bring more people in, and we're increasing loan exhibits. This is putting more stress on the collections, certainly. So when we talk about having wider humidity and temperature standards, that's great for most of our artifacts, but we're sending more out on loan to institutions that use these very narrow standards.

HENRY: Up until now, we have been talking about visitor load as sort of what the minimum threshold is to open up for visitation. In the United States, particularly in the Southeast—and I suspect this is the case in some hot climates where there's air-conditioning—there's also a question of peak load capacity. We've looked, for a couple of institutions, at the cooling load calculations for air-conditioning and what they want to populate the museum with in terms of number of people. Our problem in these climates is that the peak load of visitors is usually coincident with the peak exterior cooling load. We questioned, rather than having that peak load coincident with 2:00 p.m., when we have the highest solar heat gain and the highest outside temperature, is there a way to manage visitor load so you encourage people to come in the morning and the late afternoon?

And I found that institutions are dead resistant to this, whether it's managing the tour groups or the walk-in visitors. And so you end up designing systems, if you're putting systems in, that are exaggerating their overcapacity. And I've been unsuccessful in getting people to think about this as an alternate strategy for load management and [to understand that] there would be big paybacks. So I would like to ask Sarah [Staniforth] if you have this issue of peak loads, overcrowding and overloading in buildings? And I don't mean structurally, but just the contribution to discomfort and overheating, if you will.

STANIFORTH: It's very, very unusual for us to see in our monitoring data any peaks that you can relate to thermal load from people. The only time we sometimes see it is if we have a function of a lot of people in one room for a length of time. Just for ordinary visiting, we hardly ever see a rise in temperature and rise in humidity as a result of people. But we absolutely have other issues about carrying capacity of the houses, and we've developed what's called a Conservation for Access Tool Kit, which enables our property managers to evaluate the number of visitors a property can take, the number of cleaning staff that they need to service that number of visitors because of the relationship between visitor numbers and dust deposition on the objects, and to look at the economics of it—because understanding where the payback is or where the costs are when you open for longer, it can be a difficult relationship to understand. You can't take it for granted that if you open for longer, you're going to make money.

MAEKAWA: We've been working on the Our Lord in the Attic project in Amsterdam,[xvi] and we've seen the impact of visitors in terms of increase of temperatures and humidity. But so far, the house has been leaky enough that that effect did not accumulate. Before that happens, outside air just dilutes the environment. It seems to be working right now as is, but our question is, what happens if tourism continues to grow, which is the trend anyway. We are experiencing similar issues in our projects in China [Mogao grottoes] and Egypt [Valley of the Queens].[xvii] Probably the worst case in Egypt is with tourists coming into the Valley of the

Kings between 1100 and 1600—just busloads and busloads of tourists come in and go through the tombs. And there's no question about the impact there. There is very limited air change happening within the tombs. So the question is, shouldn't we start thinking about how to deal with this increasing trend of tourism in historic houses?

HENRY: I would agree, and I like what I heard from Sarah [Staniforth] about the National Trust's philosophy to look at Conservation for Access, and my only suggestion would be that we include the environmental management component in that. Now, in the UK climate, perhaps in the climate at the Our Lord in the Attic, it's not as critical, because you don't have the coincident cooling loads that you do in other locations in the summertime when you have peak tourism. But the problem that I face as a practitioner is getting property stewards to embrace the idea that there is some sort of ceiling—not necessarily in terms of environmental management but in terms of site capacity—for parking, for traffic. There's a tipping point for the visitor experience, where the quality declines because they're standing in line. And I think part of the sustainability—and, as a subset, the environmental management—should be that we ask property stewards to begin to think about what their capacity is, and then there are other derivative benefits, whether they're conservation or energy use or land impact or water runoff on the soil and so forth, as well as their relationship with the community. And maybe the tool kit is a good starting point.

TOLEDO: In Brazil we also do not have an impact of visitors on our hot and humid museums, but then we have problems with visitors' comfort. People rush in the rooms and try to get out as soon as possible because of the heat. Historic houses are leaky, so there is no impact, because the heat disperses. But when their windows are closed you have this uncomfortable visitor who doesn't enjoy visiting very much because of the heat in these historic houses.

CAMUFFO: We had a problem with a number of highly visited historic buildings—for example, the Sistine Chapel, which had from seven thousand to seventeen thousand visitors a day. The real problem was not the actual number of visitors but the number of visitors multiplied by the time spent by each visitor inside—the integral effect. It was strategic to shorten the time that each visitor spends inside and not reduce the total number of visitors and in addition, to produce some service to visitors before they enter the chapel. For example, an exhibition to explain the history of the frescoes will reduce the time for explanations inside.

SCHELLEN: The impact of the visitors can be quite confusing, because, when you are introducing a lot of people, they bring in heat and also humidity. So when you look at the relative humidity inside a room, you don't see any specific relative humidity effects. But the relative humidity effects near outside walls can be significant. Another impact is the carbon dioxide level, which has nothing to do with conservation in principle. But when you have a lot of people, you have a very high CO_2 level, and you have a public health risk.

STANIFORTH: To monitor carbon dioxide, we have done spot checks and found that we have never been anywhere near the limit. We've just got such leaky houses. The way that we calculate the carrying capacity is to identify the pinch points in a visitor route and then work out how many people per five minutes can go through that pinch point, which sets the limit for visitor numbers for the day.

CONRAD: We had to do a yearlong monitoring program once at the Louisa MayAlcott House up in Lexington, Massachusetts.[xviii] The lady who lived there wrote a book called *Little Women.* They made a movie of the book and what happens when you do this is that, all of a sudden, everybody from everywhere shows up. They open up at ten in the morning; the buses are there. They had to build a new parking lot. The monitoring data showed that from ten to four, a basic disaster was going on. What happened was not so much the temperature and relative humidity as a problem, but the actual wear and tear on stairs, floors, and wall coverings was absolutely disastrous.

CHIARI: I just wanted to mention the damage that visitors do to other visitors, in the sense of personal space. At a certain point, you lose the pleasure of visiting a site.

HENRY: I would just like to continue along that line. There is a house museum in North Carolina, up in the mountains, called the Carl Sandburg Home, which is naturally ventilated.[xix] And the museum has made a commitment that they will naturally ventilate that house through the summertime. They have figured out a way to avert collections problems with very close monitoring. Implicit in that is that they have to manage the visitor level—not so much because there's no equipment, but it's visitor experience and visitor-experience quality and discomfort—not thermal discomfort but discomfort from proximity, just being too close. So in that regard, they manage the population within the building so that people are not too close on the tours, that they're not too bunched up, and that they don't get uncomfortable just because of personal space issues.

STANIFORTH: I'll tell you how I'm going to spend the May Day bank holiday in England: I'm going to go and volunteer at one of our houses where one of these carrying capacity studies is done. The bank holiday, particularly if it's good weather like we've been having—that's when the houses are most crowded, and then you can evaluate subjectively the number of people in a room before you feel that it's uncomfortable and your personal space is invaded. And we're just going to have a volunteer in each of the rooms in the houses and say, "Okay, the carrying capacity of this room is no more than fifteen people," and that's another way, apart from the pinch point way, of evaluating what carrying capacity is.

Climate Control versus Climate Management from an Architectural Point of View

In addition to the collection needs and visitors' comfort, the building itself plays a major role in an indoor climate management strategy. This discussion was introduced by Michael Henry.

HENRY: Nominally, what we're supposed to talk about in this session is the [building] envelope. The envelope provides both constraint and opportunity, particularly when we're dealing with historic buildings. It's easy for us—in the context of sitting around the table as scientists, stewards, engineers, architects—to think in the abstract. We can think about the envelope as liability or asset, as constraint or opportunity. From the field come the following issues. This is what we have to deal with when we're looking at buildings and envelopes.

1. Interior microclimates as a result of humidification in cold climates. The discontinuities in the building envelope such as window openings, shutter pockets, boundary layer, etcetera, affect where we're getting condensation. Overcooling buildings in hot, humid climates leads to condensation on windows and to high moisture content in exterior materials, especially in the case where we try to improve thermal performance by adding exterior storm sashes or exterior glazing.

2. Intrawall microclimates—within window glazing systems and between layers of materials in the wall section.

3. Envelope singularities. Singularities are penetrations in the building envelope that result in exfiltration and infiltration, whether they're active chimneys, gaps around doors, or cracks and crevices where layers of materials join. These all pose problems for us when we're trying to predict, assess, or maintain an interior climate.

4. Moisture control. We all know that most moisture entering the building by volume comes in as bulk water. But it has to leave by drying, and the rate of drying versus bulk water entry is huge. So the drying time takes much longer than the wetting time, and yet very few institutions deal with bulk moisture control fundamentally, before they deal with climate management in the interior.

5. Use and authentic interpretation. Going back to understand how we can manage the building envelope so that we can manage the interior climate. Understanding what that means in terms of opportunities for interpretation of a building.

6. Systems accessibility and maintenance. We can talk all we want about climate management and maintaining conditions in buildings, but until we have buildings that have adequate space for these systems or we understand the implication of asking for those systems to be installed in existing buildings, we really don't confront the problems that we're faced with. So sustainability really has to look at the institutional capabilities for maintaining what they've got, even in the most basic measures.

7. Cost of temperature and relative humidity control. If we look at chapter 21 of the *ASHRAE Handbook* and we look at the degree of control, you can see that the cost, either in energy or in dollars, of the degree of control goes up exponentially. This isn't new. And the economics do play into this, because sooner or later an institution has to deal with it.

And those are the thoughts that I'd like to leave you with as we move into this discussion further. What are the opportunities for the envelope? How do we manage this with minimal systems? And yes, how do we deal with it in a cost-effective manner?

Effective passive management is a thoughtful application of passive management while knowing the building and the philosophy.

KOZŁOWSKI: How realistic is this kind of manual operation of the building envelope? How can you rely on people? With electronic heating for conservation, we are on a safe side because we have automatic systems. How should you train or encourage them, because after one month, when it's not a novelty, is it functioning very well?

CONRAD: I think Rick [Kerschner] has the same problem, too. When we try and have things done manually, the question is, who does it? The security people do not want to do it—it's not their job. The guy cleaning the floor: "Not my job." It ends up being our job as conservators, because nobody else wants to do it.

HENRY: Roman [Kozłowski], you're quite right—it is an issue. If we go to operating protocols or operating regimens for a building, the implementation requires a considerable amount of thought and design, because you have to answer the question, who's going to do it, how are they informed as to when it's to be done? At Drayton Hall[xx] [Charleston, South Carolina], we tried a more sophisticated approach, with real-time measurement of exterior and interior dew point in wind speed and when it was appropriate to open the windows and doors—and, quite frankly, it was a failure. And it was a failure because we neglected to include the docents, and the docents, the guides in the building, wanted to show the building with the doors open, and when they saw the building with the doors closed, they came up with excuses, from tripping hazards to lawsuits. Quite frankly, the building was never lived in with the doors open at seven o'clock in the morning and the damp moist southern air coming in. But that's the way they've typically historically presented it, and they were resistant to change. So even with the best of intentions and the best design and good technology, there can be human resistance—not just disinclination but outright resistance to implementing these things. So it's a human factors design problem, as well as a monitoring and technology and building envelope operation problem.

KOZŁOWSKI: In his introduction Michael [Henry] touched upon the problem with repair to buildings with wet cellars. The measures to control microclimate cannot deal with infiltration of groundwater before your building is healthy. If the original historic building didn't have a good system to stop infiltration of water but the cellars are used for cafeterias or for offices, would you advise a very severe intervention to the building to lay water protection barriers? This happens a lot in my hometown of Kraków, where old houses have medieval cellars, and there is now a strong tendency to use them as restaurants. But people are caught between making a very severe intervention to the envelope, or they introduce a new function and then suffer from terrible salt problems, disintegration of the fabric because of water penetration. I think it's an interesting problem if you consider sustainability of building envelopes.

HENRY: It's a good question. In my example what has happened on that building is that the drying is to the inside surface of the occupied rooms as a result of the attempt to dehumidify and as a result of an inappropriate response on the exterior, where they have sealed the exterior masonry so thoroughly against vapor migration that the only moisture path left is to the inside. And so there is no drying on the exterior, and it speaks to the issue of symptomatic treatments that then have unintended consequences, as opposed to dealing with source moisture control. So source moisture control has to be dealt with independently of change of use of different spaces. And then the question of appropriate use of the space comes into play, looking at other aspects of the comportment of the building.

PADFIELD: I want to thank Roman [Kozłowski] for bringing up a subject which quantitatively is huge, because we have been concentrating on the big prestige buildings, but many preserved environments are whole environments, they're whole cities, and they do tend to have cellar restaurants. So I find this a fascinating corner of our trade where you have to discuss compromise. And this brings up some possibilities for preventive conservation that is reversible. And the one that we use frequently is the concept of a sacrificial mortar, where we say that this change of use will drag salt through the wall and we collect it in a sacrificial mortar. And this is a far more effective, nondestructive, and long-term action than the usual one, which is to put an epoxy varnish on the newly cleared brickwork.

HENRY: I agree with Tim [Padfield] wholeheartedly, and actually, in building preservation I advocate that we look at the mortar as *the* sacrificial material in the wall, because from an embodied energy standpoint, the high-value material or component is the brick or the stone, and it's the mortar that was intended to be ultimately sacrificial and renewable from a maintenance standpoint. An area of research that I think would be helpful would be to expand our base of building materials' properties in terms of hydrothermic properties, so that we can do more effective modeling. We haven't even scratched the surface, either for historic materials or alternate new building materials that provide for humidity buffering. And for those of us who are doing new archives or new storage facilities, there's great promise in humidity buffering materials, but I find that there's not a lot of data or research that helps us from the design standpoint.

MAEKAWA: When you start to talk about controlling a moisture problem in a basement, certainly gutters and water drainage are important, but in addition to this, the surrounding landscape has to be maintained.

KERSCHNER: In fact, we had to increase the storm drain system of the Shelburne Museum, not just around the building—but then, where do you put the water? And it was hundreds of thousands of dollars to improve the storm drain system to get it off the site.

HENRY: I think what we end up saying here as we talk about the building envelope is that we're not just looking at the slice of construction materials with an exterior climate and an interior climate, but we're also looking at the building in terms of where it's founded, whether we've got appropriate soil properties, what the hydrology is in the much larger exterior context and, I would submit, the ecosystem that's going on around that.

STANIFORTH: I'd be interested to know what colleagues' experiences are of preventive maintenance of buildings in other countries, because traditionally, building maintenance was something that was practiced very assiduously, and gutters were cleared and roofs were checked. I find now that actually having the people who on a day-to-day basis will look after buildings is one of the areas of budgets that are cut. For example, most of the cathedral workshops have been disbanded in England, and conservation work on cathedrals is done by major contract now. And I think that there is a case to be made that the building profession needs to relearn preventive maintenance in the way that the museum profession has learned about preventive conservation.

HENRY: When I do an assessment at a historic house museum and go through the organization and staffing, I often find that the person who is nominally identified as in charge of building maintenance, on a percentage basis, the time that they spend on the building is quite small, and that the reality is that they spend a lot of time on groundskeeping or setting up chairs in pavilions and tents for the rental events, weddings and so forth. I think that there are three areas of roadblocks to preventive conservation of buildings that we really need to confront. One is the philosophical. We don't have a strong philosophical statement about it, although it has been around for a while. Two is the organizational capacity, meaning that where are the people that are trained in the multiple skills that are necessary if one is to replace slates, do mortar repointing, do wood repairs, and so forth. This is really a multiskilled person on a small site. And then last, it's the resistance to fund this. Funding organizations in the United States are typically looking at the episodic restoration. You talk about small ongoing repointing projects—they won't fund it. And we really have to overcome that, and we have to overcome the resistance of the board of trustees, the board of directors to looking at ongoing maintenance as a continuum as their responsibility.

TOLEDO: Let me throw some doctoral knowledge that I have on hot and humid environments in old buildings, traditional naturally ventilated buildings. So they are built to prevent heat and moisture buildup inside, so we use long eaves to avoid direct sunlight on the facades. When we don't have the long eaves, we have other measures, such as ceramic tiles to prevent driving rain from outside from getting into the building. We also have ventilated ceilings and ventilated roofs—again, just to get rid of the heat, the hot air that tends to settle up there. We have very high ceilings to allow heat stratification, so the higher the ceiling, the better for human comfort. And then we have cross-ventilation all the time, and this can apply to lightweight buildings and heavyweight buildings. Although we are now comfortable inside, we have dust soiling of the surfaces. This is visible if the collection is not protected by a showcase or some sort of frame. And then we have, of course, fading, because we open the windows and then light comes in as well. Maintenance is not a strong point in these buildings. Nowadays when we restore or intervene in a building, we try to fix the tiles with copper iron. But it's a problem when the rainy period comes and there is nobody to go up and put the tiles in the right place, so water infiltration is a serious problem. So maintenance is a serious problem.

HENRY: Trying to bring this back a little bit—I mean, we've drifted off into maintenance of the building envelope, which of course is necessary for its function as a climate moderator, but I'd like to go back to one of the themes that I touched on in the paper prepared for the roundtable—this question of operability of the building envelope to maintain an interior environment, which can be a hybrid approach. It's not necessarily to say that it's in the absence of systems. But in many climates, there are days that are quite favorable to collections' conditions, but because we've sealed the building up for the system, we can't take advantage of those, except through the system if we have free cooling, or free heating, or free ventilation. But one of the obstacles that I encounter when I'm looking at how to operate a building envelope is the lack of knowledge about how it was traditionally operated. This is not in the purview of the historic architect, because the historic architect is typically looking at fabric or stylistic issues, but not necessarily at the more fugitive aspects of occupancy, shades, screens, things that are going to be discovered in letters, correspondence, other areas of research. And it's not hard science. But it is an area of research into the history of how buildings were managed for what was then considered comfort and how they were operated, and the physical evidence is literally thin and missing. And I think it would be worthwhile if we could encourage some research in that area.

TOLEDO: In line with this, I would like to learn more about the performance of the two types of buildings that coexist in a hot and humid environment—e.g., the northeast part of my country [Brazil]. Very lightweight buildings that coexist with very heavy buildings like churches, our Baroque churches. I would like to see the performance of these two types of buildings regarding their protective role for collections.

The discussion then moved into the field of building design.

HENRY: On the issue of building design, I think we have to recognize that we're talking essentially about three building types: one is historic buildings, which we actually have to design for adaptively, because they already exist; archives and storage, which are not occupied and offer tremendous opportunities for inherent stability; and then contemporary or new construction for museums, which have to balance this question of signature building, public appeal, thermal comfort, and a host of activities that are unrelated to object conservation.

CAMUFFO: In the last few years, new museums have been built with glass and metal; the appearance of the building is much more important than the exhibits within. So what is the trend? Historical buildings have a lot of problems, but with their thick walls they provide a natural microclimate with a large inertia that is good for conservation. The new buildings are very attractive, certainly, but less appropriate for preservation. It should be useful to have some general statement that a museum should be primarily made for preservation; this seems obvious, but things are sometimes different.

PADFIELD: Historic houses are museums in themselves if they have their original furniture, but more often they are turned into museums. Now, if one has to make a global statement and put punch behind it and try and get publicity for it, one should never make a historical building into a museum that contains objects that don't belong to it. In terms of energy use, damage to objects, and general discomfort for visitors, you cannot beat a museum in a historic house. And what tends to happen is that museums, or collections that are looking for museums, they are usually offered a very cheap house; usually it's a military barracks that's been abandoned or something like that. So it is essential—if you want to save energy and be sustainable and all that, you should ban putting new museums into old houses. Museums should be built for the purpose.

But having said that, you've then got to notice that most modern museums are even worse than historic houses for exhibiting things in. And so if I were to pick out my own personal hobbyhorse, it is that museums are very badly designed technically because they are simply showpieces for the architect. They are in fact sculptures. If we want to make a statement, we should say that architects and those who judge competitions should both specify and judge on suitability for preserving and exhibiting the collection.

MICHALSKI: I agree that we create many problems unnecessarily by turning historic houses into museums, but I don't think the converse is true. It's not that the problem will go away if we stop putting objects that are historic into buildings that are historic, because some of those systems are truly authentic systems.

ORESZCZYN: In terms of new buildings, I think there needs to be some work done to find out why people are commissioning the buildings they are commissioning. There is a whole host of reasons why people end up with the signature buildings that they do, buildings that don't necessarily deliver what in operation they need to deliver, and why people don't understand the implications of some of the decisions that are taken.

Architects will design you anything you want. There are some architects that would design you black boxes with no windows in them—that can provide very stable conditions—and there are other architects that will design you other things that are very sexy and exciting and probably not very useful. It is up to the clients to decide what they want and what they're trying to achieve. And obviously it's a balance. And I'm glad that over the last several thousand years, we have not built boring boxes that provide ideal environments and nothing else. There is a compromise that needs to be achieved, and at the moment, the people who are taking these decisions are not looking in the longer term for cost of maintenance, and there can be small compromises which don't sacrifice completely the look of an exciting building. We just need to make sure and realize why this is. Is it because the people who are commissioning the building see their own future as being, in part, the signature building?

MICHALSKI: Purpose-built museum buildings will always be the flagship organizations or benchmarks, and people in historic houses feel, "If only we weren't stuck with a historic building, we could do that." I think we need to give people tools rather than encouraging them to come out with a design target, which is the pressure from engineers and architects. One has to ask, why are we intervening at all, and that means we've assessed that we can reduce some risk that we've measured or perceived or predicted. And if that's not there, then the basic rule is, if it ain't broke, don't fix it. So we need to encourage people to have tools which are more sophisticated sounding than that, or keep it simple, stupid. We're trying to find what the essential rational basis is of those commonsense intuitions. Risk management sells as a phrase much better than preventive conservation does to the kinds of bureaucrats who listen. And it reflects for me a commonsense approach, which is to begin with the status quo and then assess it for risks—which is quite different from, "Let's virtualize the ideal and then express it in our concrete world somehow," which has got us into trouble over and over.

Climate Control versus Climate Management from a Mechanical Point of View

Having looked at collection needs, human comfort, and the use of the building as an envelope of the indoor climate, the discussion moved on to look at technological solutions, a topic introduced by Ernest Conrad.

CONRAD: So what I'm going to talk about is engineered systems within a building, which are mechanical, electrical, fire protection, security. I first want to give you some information about when we design the systems we design, what makes them be what they are, because they're generally not our choice. As engineers we have alternatives. There's pros and cons, but generally it's a team process, and we are actually the followers. So our mechanical systems follow the demands of others. It is very rare that a mechanical system drives what a building is going to look like.

When we talk about climate control systems, there are six elements that make a system be what it is. The first one is sunlight, solar. We have skylights, windows—the heat coming through that glass, solar energy, is a major component in the design of that system. Next is the heat from lights, which are sensible heat loads. The third one is people. If you have people in the space, you have both sensible and latent heat loads. Latent heat loads are the moisture that your body gives off. The fourth one is the heat through a wall, called transmission. If it's hot on the outside and you have to cool it on the inside, there's a heat flow through that wall. The fifth one is called infiltration. Infiltration is air that leaks in one end of the building and goes back out the other. And last but not least is mandated ventilation. If we have people inside the building, most countries have laws that mandate that you take air from outside and you put it in that building, whether you like it or not. Lots of times we don't like it, because it's dirtier, but we're mandated by code to introduce this air.

These six are the entire list of the things that influence your environment inside. The more you look at these six, the more you can eliminate. We talked about a storage facility. A storage facility, if it's narrow, if it's underground, there's no sun, there's no people, there's no lights, the transmission is almost zero, there's nothing there, but the one thing that always ends up being there is infiltration. And of all these six elements, the thing we don't know much about is infiltration. We have almost no data.

What are the impacts on engineered systems? One: public access. When a facility has a demand for public access, we have mandates to have indoor air quality for the people; it means that the heat load of people has to be compensated for with systems. Two: light control, of both natural light as well as the lights we have within the space that generate heat. Three: risk management. This is a money issue, and it's an evaluation. You have to look at each individual collection and make the decision, as part of the stakeholders, as to how far to go, how do we manage the cost, what can we afford? Four: preparedness. It's fire protection, it's security, it's flood, it's all those kinds of things. It's all different types of emergencies, and we need to have disaster plans that can react to them. And that all becomes a part of our design. We now design HVAC systems where we will close all the outside air dampers upon an emergency. Five: environment responsibility. This is where sustainability comes in. I believe that sustainability is a very important issue, but so too is preparedness. Six: research. The more we have good data, the better I can design a system that's going to match the needs of the collection. Seven: measurement. Measurement is a very important tool. It's monitoring. If you don't get the feedback of how well a system is doing, how can you make adjustments? So we need to measure and verify to find out if we are doing it right. Preventive maintenance is to fix it before it breaks. Eight: education. Education involves the stakeholders. It's the owner, it's the architect, it's the engineer, it's the conservator. It's the entire team.

I see all the above basically as the primary things that drive what you're going to end up within a system, whether it be opening windows, just working with the wind, having ventilation, having humidistatic heating, heating, cooling, dehumidification, active humidification. And one thing I'll mention is the cost. The cost of installing a heating system, the cost of installing cooling systems, the cost of running both of them compared to the cost of humidifying. The cost of humidifying is the cheapest, the lowest cost of all those elements and the one that does the most damage. When a humidifier fails in the "on" position, you've got about an hour before you've destroyed all your fine art. So we try very hard to educate a client if we're going to have active humidification, that you need to have all kinds of redundancy measurements. It's a very dangerous piece of equipment, and we try very hard to avoid this unless we have a purpose-built building. This is type 5 of my building classification system[xxi], new buildings for the most part; it's specifically built to accommodate active humidification.

The other thing that's important is that it's either all or nothing. All or nothing means that if you open the windows, there's no sense in running the mechanical systems. If you're going to run a basic ventilation system, don't try to do other things at the same time, because you're just burning up energy. You're not gaining anything for it.

I also want to touch on heating. When you have an active source of water within a building and you're trying to do conservation heating, you absolutely have to get rid of your active sources of water, or else you're going to do more damage than you're going to do good. Divergence is disaster.

The other thing is tightness of a building. People want to make a building tighter. The tighter we make a building in its envelope seal, the more and more that we have to rely upon mechanical systems. If I don't have infiltration, the natural mixing with outdoors, we have to rely upon more and more of the mechanical systems to do filtration, pollutant removal.

I also want to mention maintenance. Generally when machinery is put into a building, it has a useful life on the order of about twenty years. When we try to budget for repair costs, we use a straight-line method. Every year I budget 5 percent of the original cost of the system: that will cover on a straight-line basis my repairs to broken parts— labor is in there too. The other piece of it is in the controls. The amount of cost to take care of the control systems. The more sophisticated the controls are, the more money we have to spend to maintain those and calibrate them. Generally what we'll see will be, depending upon the size of the institution, a quarterly process, where an outside contractor puts the building through a kind of minicommissioning. They check the points to make sure they work right. You're paying the labor of a technician for one or two days every quarter, plus whatever parts have to be put into it. And this can be substantial.

What does all this mean in practice? I'll give you two examples. We designed a system on an island out off the coast of Maine. It was a Coast Guard island, which shuts down in wintertime. The local historical society picked up the lighthouse. So there is this museum at the top of a hill on Monhegan Island that has all of about thirty amps of power in the wintertime for the entire island. An art colony wants to have a storage facility for their collections while they're closed down in the wintertime. We looked at what this lighthouse used to look like in old photographs, and it had buildings around it. We re-created another one of the buildings, and it has no power. If you look at the geography of the island, the top of the hill has a little dip in it, so when it rains the water goes into the groundwater there. Under the foundation we used a clay base, and you can roughly calculate moisture migrations through clay. We put different insulation in different places. Underneath we used foam glass, little glass bubbles which produce insulation, but it also lets moisture move through it. We put one type of insulation on the sides and a different type on the top of the building. With absolutely nothing but the sun on the building, the insulation on the sides, and a very small amount of moisture moving into the building all winter long, it works pretty well.

Most recently we have dived into the world of geothermal—for example, at George Washington's sister's plantation, called Kenmore , in Fredericksburg, Virginia.[xxii] These plantations would have a main mansion and, on either side, dependencies. One dependency would be for cooking, and the other dependency would be for the servants to live in. We butt up against one of the dependencies, dig a hole in the ground, and we do a geothermal system, which is wells and tie into climate control equipment, so all this machinery is outside these buildings. From this vault we will actually bore underneath the foundations of these buildings and pop up into the basements with ductwork and distribute the climate control into these spaces. What these systems do is that they tend to take on the massive heat loads in the daytime and kind of coast on through as they try to take care of the building. You don't really worry about the people so much. So it kind of works twenty-four hours a day trying to maintain the building.

ORESZCZYN: I was very glad that you mentioned about educating the client, because I was slightly concerned when you started off talking about engineers being followers. The worst examples of buildings, I think, have been where you have the client who commissions the building, gets the architect in, and then the engineer comes in and follows what the architect has done, tries to put that right, asks the client questions like "What's the maximum number of people you're ever going to have in this building?" And they say, "Well, when we get a really big exhibition, we're going to have one thousand people," and the engineer says, "Right." This is going to be a really massive system, but the engineer never gets back to the client about how much this is really going to cost them, the implications of what they've just asked for. That question is so absolutely massive in terms of the plant, the fact that the plant will cost more to maintain and operate in the building, and the cost of building in the first place. It's got to be an interactive process. Without that interactive process between the engineer feeding back all of these things—and there has to be a responsibility, I think, on the engineer to do that in a sensible way.

CONRAD: You noticed I said that the engineer is just as much a stakeholder as all the other players. It's the system that follows; it's not the engineer that follows. The engineer is as much responsible to be a teacher, a facilitator, as everybody else, because the end result, the system, is going to follow whatever all those things are.

SCHELLEN: Ernest [Conrad] was talking about influential impact factors and mentioned eight. And I think you forgot one, one very important one. And that's the thermal mass of the building.

CONRAD: Transmission is that envelope, and you're very right. Once that heat transfer gets inside the building, thermal mass is the interior. Another thing just to touch on is that organic materials do the same thing from a humidity standpoint. If I take this room and pack it full of hygroscopic materials, you can find that fluctuations start to disappear, because the paper and wood itself will absorb and release and start to take care of itself. And so I can have smaller systems that can operate that don't have to work against big fluctuations.

HENRY: I'd just like to continue with what Henk [Schellen] said, and my comment doesn't apply to Ernest [Conrad] as an engineer, but I've encountered mechanical engineers who will go to the handbook and look at the thermal resistance or thermal conductivity of a building material and not realize that that is under equilibrium interior and exterior conditions, and they calculate heat loss or heat gain, and then they size the equipment accordingly, without realizing that they've got a diurnal fluctuation on the outside. So what they end up doing is that they don't see it as a potential benefit, they see it as a liability.

PADFIELD: I just want to revisit this matter of infiltration. In order to understand how air pollution affects things and how much is absorbed compared to how much is generated internally, one has to have always a measurement of the infiltration rate. In order to interpret the data for temperature and relative humidity of a building inside and out, you have to have the air infiltration rate. What we have been doing for a century or so is measuring inadequately. In other words, we measure temperature and relative humidity, and we give up because it's difficult to measure infiltration. Therefore, we have a whole pile of data that in effect is completely useless except for quality control. As a research tool, our body of historic data is, in my opinion, useless, because we don't measure what's difficult to measure. And so I want to put on record that what we need is an air infiltration monitor.

This also has a very profound effect on exactly these portable solutions, because what happens is that the pattern of air movement through a building is interestingly complex, and the result is chaos in terms of the climate as you measure it from point to point. And the biggest problem with any air-conditioning on wheels is controlling the movement of the air. It's very important—there are many small museums that do have air-conditioning on wheels, and it's extremely unreliable. It's not unreliable in the mechanical sense; it's unreliable in the sense that the pattern of air movement between rooms, when you open doors and close doors, can cause serious variation in the relative humidity. And basically so much so that we generally advise that it's better not to bother, because you generate so many artificial variations. That's caused by human action. I'm not talking about the building envelope in this context.

MICHALSKI: There are linked chapters in the *ASHRAE Handbook* being rewritten. There are signs that infiltration is being addressed—finally after thirty years, the research is saying it ain't diffusion, it ain't diffusion, it ain't diffusion, it's *infiltration*. Infiltration ain't so easy to model; it's a complex system; we need empirical results. And by empirical results, I don't mean results to calibrate models. So I disagree a little bit with Tim's [Padfield's] perspective on infiltration. I think it's one of those complex, almost noncomputable systems. It will always be useful and necessary to monitor your own real system, because it's noncomputable from fundamentals, and you just have to see how it behaves, much like climate globally. But infiltration seems to be, even if it were computable, you'd have to destroy your building to find the parameters to put into your model, so it's either pragmatically or theoretically (or both) noncomputable. So it does need a different strategy, and again, that's not something that engineers are comfortable with.

PADFIELD: Moving air around could be said to be a threat to sustainability. And the reason air-conditioning moves air around is actually to move heat around, mostly. And air is a very inefficient transporter of heat. The *ASHRAE Handbook* strikes me as both very good and also very dangerous, because as far as I can see, it assumes air-conditioning and then says, "This is how you do it properly." And I would add a chapter to the *ASHRAE Handbook* that goes before the air-conditioning, which has to do with designing a building not to need it, and until ASHRAE ceases to be a trade journal and becomes a scientific body of sound advice, then we have to wait for that.

KERSCHNER: You have to look at the different buildings and cater to them. With our barn with all the carriages in it [at the Shelburne Museum], humidistatic ventilation worked very well, and one of the main things it was supposed to do was to bring down humidity during the summer when it was drier outside. It did that to some extent. But one of the main things it did was that it prevented condensation right against the surface when we had a really warm spring day and it was coming in on the cold artifacts. By mixing the air beforehand, it prevented that. It was working so well that we took it into a new building that was mainly a steel and cement structure, very well insulated; we tried humidistatically controlled ventilation. I couldn't pump the air in fast enough during the winter to get the building cold enough, at which point we shut everything off, and it just settled down completely. So you try to model one building and take it to the next, and a lot just comes down to experience as well.

SCHELLEN: I would like to talk about introducing displacement ventilation in museums. Displacement ventilation is a way of ventilation that is very effective in office buildings. The idea is that you bring in cool air into the building at a low level, and then it will be heated up by the sources of heat that are inside the building. The idea is that the air will arrive at your body level and then climb up to the ceiling, where it's sucked off. That's the idea. When you look at a museum in a cold climate, you normally would have to heat during wintertime. When you are bringing in air by displacement ventilation, you bring in cold air, but you need heated air. So it won't work the opposite way, because when you are bringing in air to heat the building, it will go up immediately to the ceiling. The displacement idea won't work. The other fact is that displacement ventilation only works because of the temperature stratification. I think it is a completely idiotic way of ventilating.

CONRAD: That's a very good point. Actually, the displacement ventilation concept has been tied into the world of sustainability, believe it or not. These engineers are LEED certified engineers who try to save energy. The idea is that when you supply air at floor level and it comes up, it makes the person comfortable. It saves a little bit of energy, because it makes the people comfort cost lower. But if I have a historic building and I'm going to do this, after the heat goes past my head and keeps on going, it goes up onto the building fabric, up on the top ceiling. In a cooling mode, you now talk about very high temperatures on surfaces. It's very high, it's hot, it's dry, and I don't necessarily recommend doing that in a historic building. From the wintertime standpoint, there's a tremendous controversy.

But what happens when we look at a historic building—sometimes, if we have to conceal everything, we're at a loss as to where we can do things. I'll give you a perfect example. Saint Patrick's Cathedral—here's a building where all the pews have grilles at the ends. Years ago in the 1800s, they had a one-pass system. They'd bring in air from outdoors, they'd run it through heating coils, there's ductwork, there's no fans, there's just natural heat, natural hot air rises, it would come in, and all the heat would be dispersed at the pews, and then way up at the top, 175 feet up in the air, they have exhaust. So now we want to air-condition this place. So they took what is called a triforium. About eighty feet, thirty or forty meters up in the air, they put air-conditioning that takes cold air and it throws it out into this space; it falls down onto the people, and that makes them comfortable. The problem is, there's no return. The return is up there too, so it goes out, comes back in again, out, back in again. There's no efficient circulation path of airflow.

ORESZCZYN: The example that Henk [Schellen] gave, I think, is a very good example of the fact that there are actually very few building services engineers who specialize in museums and understand them. We've got some of the best people around the table, but it's a fundamental problem that if you have a large section of the museum population starting to get engineers who are not familiar with the particular requirements of museums, they provide systems, and most of the systems—certainly in the UK, 90 percent, 99 percent of the air-conditioning systems offer human comfort. And the requirements are quite different, and unless you understand those differences, then you can end up with a system which really is totally inappropriate. And that doesn't happen in the top museums, which can afford to get the specialists in, but for those other museums that try to go down this route, it can be really quite devastating.

HENRY: Two comments. One on the issue of sizing. In one of the engineering trade journals, there was an interesting article about the layering of conservatism in design and how the client will ask for something that has its own built-in conservatism. The design engineer specifying the performance—or the architect, if it's the architect taking the lead—will put in an additional layer of conservatism. The design engineer actually responsible for selecting the equipment will apply some conservatism and margin, and then the manufacturer himself will have some conservatism in the performance data and so forth, so that they don't run into problems. And then you layer that, looking also at electrical capacity and all the other systems that come into play, and we end up with considerable capacity in the systems. The problem is that it's all in one system rather than a layered system, so that we have some real inefficiencies, and things are not operating at the optimum point of operation.

And my second comment. Ernest [Conrad] mentioned designing for preparedness for disasters, and one of the issues is the question of passive survivability and what happens when we lose utility infrastructure, and if we do have a system-based climate management, how long we can operate in a passive mode and what are the optimum protocols for operating in that passive mode. Often when we think about disaster preparedness, we're thinking of short-term events like fires and short-term power interruptions. But what we're seeing down in New Orleans is that these postdisaster events can last for weeks or months before there's any element of recovery of critical infrastructure. And even backup systems don't operate that long. So passive survivability is probably something that we should look at as a design goal when we're evaluating environmental management.

When discussing technical solutions to sustainable climate control, it is important to reflect on conservation heating, which has been a recognized strategy for climate control in historic houses in heating climates.

MAEKAWA: We had some discussion about the use of conservation heating and its ineffectiveness, in a sense, because a lot of heat is lost, and heating is very expensive—I mean energy intensive. What about using another approach, instead of conservation heating? Is there a way?

CONRAD: The technique of conservation heating has really been a great way, at least in the heating climates, that we've been able to do dramatic improvements to preservation. In historic buildings with collections inside and not that many people around in the wintertime, we can keep relative humidities to a point by lowering temperatures, where if we didn't have any heat in the building at all, you would see mold all over the place in springtime. To heat the place even more would drive the relative humidity down to 10 percent and split half the wood in the building. So conservation heating is a middle ground. You can't add humidity to these buildings. They never were capable of withstanding—they have single-pane glass; there's no insulation. If you do anything to these buildings to improve the thermal characteristics, we're basically taking them apart and putting them back together again, and they don't even look like what they used to be.

One of the weaknesses of conservation heating is its controllability. What happens is there's not enough demand for private industry to create stuff for us. So we have to pick out stuff from other places, and the controls we put on these things are put together piecemeal. It's been a struggle to take these types of systems and have them operate in such a fashion that they don't go beyond the realm of keeping that balance.

SCHELLEN: In a way I think it's quite unnatural that on a warm sunny day, when you have a problem with too-hot temperatures, that you are introducing electricity to reduce the relative humidity at a moment when you have a lot of energy from the sun. So I wonder if you couldn't think of a way of using this sun energy at that time.

CONRAD: I'm all for these photovoltaics, wind and other types of things. We could buy green power, and what you've done is that you've financed windmills and other types of things out there on the planet that give us that reusable energy. And if there's ways we can do that within these buildings, that's a great step.

PADFIELD: May I respond to that? We've been looking into conservation heating and dehumidification. There is a very important difference. Conservation heating generates a temperature gradient between outside and inside. In our experience of mold growth, it is a consequence of a temperature gradient or of temperature nonuniformity inside. And therefore, all other things being equal, conservation heating is not to be preferred over straight dehumidification. But then the other balance that applies is that conservation heating will work in a very nonairtight, a very open building, as most historic buildings are, and by the time you try dehumidifying instead, you either have to alter the building by making it more airtight or, alternatively, you can actually use the dehumidifier to come halfway toward conservation heating. And this is actually thermodynamically attractive. It's very fundamental that the electricity that goes into either your heater or your dehumidifier—that electricity finishes up as warmth in the house. Therefore, if you've got a very leaky house, you can install a dehumidifier. You'll have hardly any effect directly on the RH, but the by-product, which is heat, will in fact reduce the relative humidity, which raises an interesting possibility which I think you, Richard [Kerschner], actually referred to in your paper [see "Providing Safe and Practical Environments for Cultural Property in Historic Buildings—and Beyond"]—that by carefully balancing the measured leakiness of the house and dimensioning your dehumidifier, you can actually make a compromise where you're both removing water and heating slightly. And this is probably the optimum way of treating a building.

SCHELLEN: I have a question about the risk of introducing conservation heating in the houses of the National Trust, for example—problems with computer control and the risk of fire because there are no people inside the house.

STANIFORTH: I'm afraid that we would have very seriously lost the plot if our wiring were so dangerous that there was a fire risk. It's all installed with specifications from electrical engineers, and the first thing we certainly would spend money on is to ensure that the fire precautions are in place. So that would be ensuring that there weren't things that were going to start a fire but that if the worst happened, there are compartments in place to stop it spreading and a very good detection system—plus, we always have people living in the houses. So someone would be on duty, not awake and patrolling the house, but in the house if an alarm went off.

And on the issue of how reliable the systems are. We use, if it's for the scale of a whole building, a building management system, and we've found control engineers who understand the philosophy of conservation heating. And on the scale of a room, we use Hanwell humidistatic controllers, which were developed for our particular requirement. We find there's nothing to go wrong with them because they're electronic; there are no moving parts. Of course, the things that are very important are the calibration of the humidistats and that the heaters work.

ORESZCZYN: Can I just pick up on "there's nothing to go wrong with. . ."? I think all experimental systems never perform as you had hoped they would, and I think the important thing is to learn the lessons and feed those into the next versions of the systems that you're going to come up with and then refine out the problems that inevitably happen. I think the number of experimental systems that have been put in—even ones that in theory can't go wrong—always do have something in practice that you can learn from, and it's very important to do that.

STANIFORTH: We've been doing this for, fifteen-plus years now, but I agree with you that there were all sorts of hiccups to start with.

KERSCHNER: When we were developing our systems, we were looking for something very simple that would operate and that could be transferred to small institutions such as historical societies that maybe are run by a volunteer—and not even a professional museum person, let alone a conservator. We haven't found that it transfers yet to the very small institutions, even though it's a relatively simple system. And now there's one organization in the U.S., called the Image Permanence Institute, that developed a datalogger and Climate Notebook software. They're actually going to the next step and providing the advice—you can call them out. And they're making the monitoring equipment. But there's a whole system there that you need to put in place. CONRAD: There's been a lot of talk about conservation heating, and I wonder how far can we go in this range? Have we gone too far with raising temperature to start an effect on collections that we probably should not have done? I think it's on the upside as opposed to the downside of temperature. And I wonder if that is something that should be revisited, and are there others?

STANIFORTH: Increasing the rate of thermal deterioration—that is, assuming that one is using conservation heating rather than no heating, but in my experience, and certainly in our application, one is using conservation heating instead of comfort heating, and therefore it is actually a reduced level of temperature. I think there's a bit of a win-win there. Most people are using conservation heating in the winter as an alternative to comfort heating and humidification.

MICHALSKI: All the knowledge I've been able to accumulate between anecdotal and theoretical modeling suggests to me that the temperature fluctuation issue, as far as mechanical damage to materials is concerned, is a much, much lower risk than relative humidity fluctuation for the same numbers. If we're talking percent humidity and degree centigrade, then 5 or 10 [percent fluctuation] of either one—the humidity one globally across mixed collections—is a much, much bigger risk. That's not to say that a small risk is zero risk or that it might be unacceptable to some collection managers, but that has not been my experience.

PADFIELD: If you look at it chemically, it works out that relative humidity is much less effective as a chemical agent than temperature, and therefore you should raise the temperature as little as possible, because the upper limit for relative humidity is usually, by common consent, at the point of biological danger. Then there comes the point that when talking about mechanical damage, the minimum gradient of mechanical damage is around the middle of the 50 percent relative humidity mark, and one unsung reason for settling for 50 percent, apart from the fact that it's an easy number, is that it's the point where mechanical movement is smallest for a given relative humidity change. So it's a sort of stable region. But unfortunately, another factor comes in—that as the relative humidity goes up, many materials become more compliant, so there are modulus changes, and therefore, if you combine these two effects, one would say, "Okay, it would be nice to be at 50 percent, but going up is less dangerous than going down, and going up requires a smaller temperature rise, and therefore that's better chemical stability."

So you can consider using the biological limit and saying that we do conservation heating only to reduce the RH to below the biological limit, which itself depends on temperature. And since this is a winter exercise in most places, you can actually heat very little. So my feeling is that conservation heating can be done in a very gentle way and also that it can be done in a sustainable way—if instead of controlling by the relative humidity, you just inject a constant power that brings you pretty close to the required temperature excess. It's to some extent self-regulating. And your RH won't be totally stable, but on the other hand, the control gear is unbelievably simple. It just consists of one fixed resistor in your electricity supply though there are more efficient ways to control power!

So I think that there are variations on conservation heating that are worth exploring. In particular, I'm very skeptical of the use of any feedback mechanism. I feel that there's a fundamental danger in feedback mechanisms—by which I mean a sensor that sends a signal to a computer that controls the heater or the humidifier. They're basically not sustainable, because they break, and my experience, especially in rural areas, they're simply not maintained. So things like a constant wattage system— which you install and then you allow it to run for one hundred years with no attention at all—are worth exploring.

MICHALSKI: In terms of feedback mechanisms, I think probably a hybrid would be best. The fixed wattage has the risk of simply being badly calculated when it's done. I would see an operational or implementational risk there, whereas feedback mechanisms are well understood. And one of the simplest ways of implementing that typically is redundancy. If you have two things controlling and each one has a probability of failure, then the probability of both failing at the same time follows a square law, and that's a huge reduction in risk by a quite simple increase in the cost and design. So redundancy, I think, perhaps is not used as often as it might be.

CONRAD: To add to that, the other thing we do is that we do fail-safe, and so if our system is going to fail, we look to make it designed so it fails safely, to fail on, fail off, fail as is, so all that gets built into it, as well as the redundancy.

MICHALSKI: I think it's fair to say that we should be able to design to get the advantages of both approaches—something that's essentially following a load approach to design but at the same time using some kind of intelligent feedback. The fact that we can add much more intelligence now to the feedback is a double-edged sword, but we can keep some of these older, fundamental design principles in mind at the same time we use a smarter system, like enthalpy controllers, in conservation heating and so on.

KOZŁOWSKI: A short comment on the discussion about the constant input of heat into the building. For cold climates like Poland, it brings the relative humidity too low during very dry, frosty periods, but it has the element of simplicity, and it's better than, of course, heating for comfort. But we could maybe call it background heating, not to confuse it with conservation heating, which would be, rather, the system with feedback and tuned to constant relative humidity? I think it's a very good approach. A colleague from English Heritage was telling us that this is often used in English churches, but England has mild winters, so it can be very effective if there is no risk of very frosty periods. because it's very simple.

KERSCHNER: We've been using humidistatic heating for control of humidity three seasons a year [at the Shelburne Museum], and during one season of the year, about three months long, it's pretty hot and humid, and we use conservation ventilation. Ventilation can be a problem in that it's quite loud with the fans. And so recently, we've been looking at using conservation cooling with a DX [direct expansion] unit, a little window air conditioner, and it seems to work pretty well in relatively tight buildings. Right now we're building a new structure. It's only about a thousand square feet, and we don't want to put supercooling and reheating in, because it's way too expensive to do it; it's probably not necessary. But we do want to keep humidity below about 65 or 60 percent in the summer. So we're looking now at what's been used in Europe for the last ten years—and we're just starting to use it in the United States—which is called mini-splits, or modulating air conditioners that run at a very low level; they have a special cycle, it's for drying also, and they're very inexpensive, and it's supposed to be very efficient. Now, what I don't know is how the cost of running one of these things would be compared to running fans for a large amount of time. Do you have any ideas?

CONRAD: It's about equivalent to a refrigerator. Twenty-five dollars per month.

KERSCHNER: That may be about the same as running the fans.

CONRAD: A dehumidifier is no different than a refrigerator. It's no different than a window air conditioner. It's all the same stuff. It's arranged a little bit differently, but its electric bill is the same. So fans, motors, dehumidifiers, window air conditioners— there's not a big difference in the dollars you spend to use your electricity. One of the things we do, though—in some of these dehumidifiers, they have heat recovery. Heat recovery gives you, on the average, about 70 percent reduction.

PADFIELD: May I just interject there a little bit of chemistry. Actually, you're leaving out the whole group of absorption dehumidifiers, which have to be used at low temperature.

There were two techniques. One was to have a wheel of silica gel and the other wheel of some sort of matrix for lithium chloride. Now one of the strange things about lithium chloride dehumidifiers is that they lose lithium chloride. Lithium chloride is hygroscopic under almost any conditions. If you have lithium chloride in some sort of aerosol, then it will contaminate the entire collection with hygroscopic surface film, which vastly accelerates corrosion because you've got an ionizing solvent. I'm not too sure; I haven't seen too many warnings about this, and maybe silica gel has taken over. In the case of silica gel, one tends to lose the silica gel, and so one wonders, where does that go? And that, presumably, also finishes up as a fine powder because silica gel is a nondurable material. So my worry about these low-temperature dehumidifiers is that they are chemically unsafe. Now I don't have research experience of this, but I thought it would be a good thing to bring up in this distinguished collection of people, who should among them have a lot of experience of these matters.

MICHALSKI: Point of information: Both of those technologies have pretty much gone out of the marketplace ten or fifteen years ago. What's replaced them is an aluminum honeycomb wheel, like the old lithium chloride, but it's been coated with silica gel in a compact diffused form. They clearly had loss problems with those technologies that Tim mentioned, and they solved them by going to this. So the advantage of that is that it has a much higher pass-through and much less resistance, much less fan power required than the silica gel beds, and on the other hand, the advertisers note that you can take them out and wash them with a hose without losing anything that is embedded on the surface. The cleaning problem was impossible with the previous ones.

CONRAD: I might also add that when we look at the new use of silica gel in the wheels, many times when you start going through the economics, the wheel, if you look at the psychrometric chart, what it's doing is removing water at the same temperature right on down. So I don't have in the refrigeration cycle "cool it way down and heat it back up again." And if we look at the cost to reheat the wheel to drive the moisture out, many times we start to find that the silica gel process is an economic process for removing moisture in large volumes.

MAEKAWA: In your paper, Sarah [Staniforth], you mentioned the use of portable air-conditioning units for providing human comfort during especially hot summer days [see

"Conservation Heating to Slow Conservation: A Tale of the Appropriate Rather Than the Ideal"] How effective are they?

STANIFORTH: I only mentioned them theoretically, because it's very unusual to have the sort of hot, humid conditions in the United Kingdom that require using them. We've only used them experimentally, and I think Richard [Kerschner] was probably doing it in practice, and we were just looking at them in theory. Actually, we never got beyond the stage of realizing that all the machines that we could buy commercially had a cutoff at 18 centigrade, so once the temperature came down to 18 centigrade, then they ceased to have any dehumidifying effect, and because it wasn't a big issue in the UK, we never took the work any further. But I know Richard has looked much more at that.

KERSCHNER: Yes, we've used window air conditioners, especially in storage, where there's not a lot of people going in and out. The trick is to undersize them so that they don't turn off, so they don't make the building too cold. But calculating that undersizing is not easy, because engineers tend to oversize for comfort, so you've got to just keep coming down and down, and we're still experimenting with that. We also started in storage, and now we're considering moving it to a gallery, which is our next thought. We'll probably need more, because of people going in and out. So there aren't a lot of ways to calculate that I know of yet.

CAMUFFO: We measured in several European museums what happens near a humidifier or an air conditioner. In general, these devices are placed close to the most vulnerable, important artifacts with the idea of protecting them, but in practice they generate clouds of moisture that are absorbed and then released by the artifacts, producing expansion/shrinkage cycles. In addition, the HVAC equipment is not so easy to control. I also saw some humidifiers that were so powerful that they had a dehumidifier working parallel to counteract the actual humidifier.

Computer Modeling

Since computer models are increasingly used in the design process of buildings and systems, the group discussed the pros and cons of this practice.

ORESZCZYN: We have moved from a situation of scientists using models and understanding everything, to these models being used by many people who previously didn't have access to these models at all. Because computers have become so easy to use, you can very easily slip into a situation of getting almost anything you want out of these models, and although I'm sure all the people around this table understand those limitations, there are lots of people out there commissioning buildings who also get people showing them computational fluid dynamics data coming out of it, lots of pretty graphs, and been convinced by that. They are being used in different ways now from the ways that scientists have traditionally used these techniques, and I think it is something that probably needs to be exposed more to the outside world.

MICHALSKI: It's very useful to start with modeling. I understand that modeling starts at the fundamentals and builds up. I would, however, suggest that we need to be careful about the way we present it to our conservator colleagues. There is a history in our field of very limited results being presented and stretched beyond their implications for practical advice within the conservation community.

SCHELLEN: One of the questions I have about fluctuations is how they interact with the time constants of objects. Stefan [Michalski] made a remark that it is extremely uncertain. I think we should improve the modeling, and there's only one way to improve them, and that is to make and compare measurements and to fine-tune the modeling. What I see in general is that people are introducing climate systems, and then they have to deal with some kind of control—for example, how and when to ventilate, when to heat, and if a ventilator device is needed to mix the air. I think this requires modeling. Modeling is also useful for studies on control strategies, studies on the effect of time constant, and so on.

MICHALSKI: Time constants are really important. In our modeling, three time constants are important: the response time of the object, including the gradient that Roman's [Kozłowski's] group is looking at; the stress relaxation time constants, which means that seasonal fluctuations are less stressful than short ones; and the time constant of the fluctuations themselves. I think there's a model there that we can work out.

ORESZCZYN: I think anecdotes are probably as important as theoretical modeling, in that neither of them explains what's actually going on, but both of them are probably helpful in trying to understand what's happening. I'll pick up on building physics modeling, which supposedly is far in advance of all the other modeling. There's no doubt that over the last thirty years in building science, the biggest sort of innovation has been in the development of these building physics models. And there's been very little monitoring work going on over those thirty years, largely because it's far cheaper to model than it is ever to monitor. And models always give you the answer you want, which is particularly good for policy makers, because if they ever fund any monitoring, it never gives them the answer they want. I do think there is a time to redress that balance, and it is probably easier to do now, because monitoring is actually far cheaper, and in fact, buildings are generally collecting data much more than they ever used to.

And I'd like to finish that by just giving you two examples of how building physics models don't explain things. We've been doing a lot of work; a lot of these models have been developed for energy predictions in buildings, and the simplest buildings to predict energy in are houses. In the UK we've recently built some houses that were modeled to have a certain heat loss and to use so much energy, and when they were built, they ended up using twice the amount of energy that theoretically they should have. And a lot of our houses are semidetached; they're joined together. And the assumption has always been that there's no heat loss between one building and the next building, because they both have the same temperature on either side of the wall. But what happens is that actually the wall between the two buildings loses three times the amount of heat that the external walls do, because they have cavities, and those cavities take air up into the loft space, into the roof space, and so there's a mechanism that we've never actually been modeling correctly, which means that actually a detached house, a single house on its own, loses less energy than one that is adjoined, a semidetached house.

So there are fundamentally some quite big things that we often forget in our modeling. And unless somebody's gone in and actually measured it—we've been building these houses for thirty years like this, and we've completely ignored this thing. It cost about ten dollars to fix this very significant heat loss issue. And just to give you an overall example, in the last thirty years in the UK, we have improved the theoretical efficiency of our houses by 30 percent, and yet over the same time, we have increased our energy consumption by 30 percent, so it's not a matter of simple physics modeling.

CAMUFFO: The problem is that a model is a very powerful tool to represent a mechanism, a mechanism we already know, because the model is based on an equation written by us, based on our state-of-the-art knowledge. The model responds simply by reflecting our knowledge, not adding new knowledge. If the model result is wrong, or different from experience, this simply means that we need more experimental observations and better equations.

SCHELLEN: When you are modeling, you have to distinguish between the quality of the model and the quality of the boundary conditions. When you don't know the boundary conditions and you have to base them on what's there, the outcome is rubbish. A simple infrared thermographic measurement can solve the issue of the neighbors and of losing some energy from the connecting wall. I plead not only for modeling but also for measuring boundary conditions, and then I think the modeling could be better. The way we use these kinds of models is that we fine-tune them with measurements, and then one can do a variance study of what will happen if something changes.

HENRY: And I would second that for another reason, because when we do modeling, we have to assume some homogeneity in the wall construction and the roof construction, and having worked on a lot of buildings, you find out as soon as you open them up that there are voids, there are places where there's brick instead of stone, and there are a lot of inconsistencies there that would only be revealed by some sort of imaging where you can see the inconsistencies.

ORESZCZYN: I totally agree with the idea that every building is different. And that's part of the problem. I just want to give one example. A lot of the building physics models are not too dissimilar from the models used to model the climate and, in fact, the weather. I'm not sure if this actually was ever true or it's an urban myth, but thirty years ago our weather models, certainly in the UK, were very bad. We'd watch the weatherman, and the weatherman would say, “Tomorrow it’s going to rain,” and the next day it was always sunny. Now we still haven’t gotten perfect models for the weather, but actually, most people, certainly in the UK, will watch the weatherman to decide whether to take their umbrella or not, and he will be right whether it’s going to rain or not. And why is that so different? What have we done to the models? The physics of the models is actually very similar. But we have just grounded them; every single day we ground those models in real data. We have weather stations measuring the weather all around the world, and that data is fed into the models, and every day we start again from the real situation, and we move forward and we improve the algorithms.

In building physics models, that’s hardly happened at all. The number of cases where we have been able to ground these quite sophisticated models in what has really happened has been quite small. And that’s one of the reasons we can improve these things. Now we have measured in this cavity. We can move on, and we can get rid of that error, which was in the way we used the models. There wasn’t an error in the physics; it was the way we applied the physics to that particular building construction. But that will carry on until we educate ourselves through real data.

MAEKAWA: Modeling seems to have a limitation in terms of verification at this point. Maybe there will be an opportunity among us to get together and beat the model? I’m interested in Energy Plus and other programs that UCL has been using, in looking more at the fluid dynamic model, what Henk [Schellen] has been doing. It’s nice to be able to see both measurement and experiment on one same plot.

SCHELLEN: What I think is interesting are combined models. For example, to have a model on the indoor climate of a building and to combine it with what happens to the structure or to combine it with CFD [computational fluid dynamics] or to combine it with control and simulation.

MICHALSKI: Henk [Schellen] mentioned CFD models; my sense was that most of the models that people are using are transmittance models. But do we really know what happens in terms of convection within the space using CFD? Unless I missed something, I haven’t seen anything within our field that is using that kind of models. When I went through the CFD literature five, ten years ago, there were certainly interesting things happening in terms of natural convection. How does air between two rooms really mix in a diurnal cycle—just with natural convection, without force? It seemed to me that that eventually would be very informative for us, and we would be able to truly model what we call microenvironments. But at the moment, we haven't actually modeled truly the boundary layers (some of these models have a mass transfer for the boundary layer, and they characterize the boundary layer in terms of an equivalent thickness, and that's an estimate) and the velocities, in the sense of natural convection and CFD modeling that's been applied. But that would certainly be powerful.

SCHELLEN: I think this world is developing very quickly, and so when you look at a Building Simulation Congress and note the contributions, more than two hundred to three hundred papers are on CFD, thermal network, and moisture. I think it would be a good idea to look at what's happening in this world.

PADFIELD: There are two sorts of models. There's the production model that's used by the engineering industry to design warehouses and their heat capacity. And the other is the research model, and we're, in fact, talking about the research model. Our experience of the production model—even of such well-established ones as thermal performance of buildings without even adding moisture—is that they are very inaccurate. And for the two most recent buildings we've designed, we have subcontracted the thermal modeling, because these computer programs are priced for very large consultant firms. In spite of that, the archive model that's actually been built is, in fact, a full three degrees different from the prediction. Now the other interesting thing is that it doesn't matter, because it works anyway. So what one can do is use a model to act as a primer for intelligent design, rather than as something that will produce accurate parameters. So I think the hope of getting production models to work on historic buildings with the sort of concealed faults that these buildings have is very small indeed. But the use of models as a trigger for developing new concepts and advancing concepts in climate control—there I think they indeed serve a role.

KOZŁOWSKI: We're collaborating with UCL in the recent EU project on global climate change, and UCL was modeling the indoor climate knowing the outdoor climate—for example, modeling a wooden building for which we had monitoring data (indoor and outdoor for one year). Then the model was fine-tuned, and there was striking agreement between the experimental observation from reality and what the model produced. This was very convincing. We could now introduce any type of flooding or drastic climate change and see what happens indoors. Then to that indoor climate, we could couple the model of objects, such as a wooden cylinder or a panel, and we could model the deformation, stress and so on. But I would like to say these are just the tools, and of course, it is very important that you check the model. We as researchers distrust our own modeling if we don't check its predictions by experiments tracing damage in materials or objects. I think that our group, should really concentrate on the question of to what extent the allowable climatic variations predicted by modeling can be used.. Maybe modeling and experiments should improve and give a broader set of the allowable thresholds because they are object dependent. I would like to have more discussion on the final product of modeling and experimental work rather than on modeling itself. At the end, we want to see criteria and tolerable allowed variations.

PADFIELD: Can I say about models that we don't get the input right, and before combining models into ever bigger models, perhaps we should return to the fundamental physics. And in particular, in the case of moisture modeling, nearly all the models assume Fick's law, which basically means that moisture moves under a proportionate gradient, and it's an exact analogy to the movement of heat. The only problem with applying Fick's law is that it is not right, and it's not right to quite a serious degree. But the interesting dynamic is that you can say this to a meeting, and people will nod and say, "Yes, that's right," and then they go back and use the same model, because it's a huge job changing the basic algorithm of their model. And similar ones apply to air pollution in museums, where we have this bizarre concept that perhaps five people in the world understand, called the deposition velocity—which isn't a velocity; it just has the dimension of velocity.

So my feeling is, as a slightly cynical observer of the modeling scene, where every PhD student, including myself, has to do a heat and moisture model in order to get through the physics exam, that we actually need some research. When you see these validations where reality appears to coincide with the model, what's missing from them is what's called sensitivity analysis. If you deliberately make a mistake by putting in a wrong parameter, you probably still get the same agreement. And a good deal of modeling can, in fact, be done on a much more naive level, with the security that you can write the code, whereas computational fluid dynamics basically is moving away from science. The point about science is that when you publish something, it's repeatable. Someone else can do the experiment. But nowadays you say, "We use a computer model for this." There is no chance ever of being able to repeat that experiment. My main point is that there is still some fundamental research to do before you launch into your computer.

SCHELLEN: On that point I do agree, but I don't agree on the point that, in a way, you can't imagine what's happening in the model. When a model is described well—and most of the models should be—then it's clear what the physics are behind the model. For someone who is not familiar with models, it's difficult to have trust in the model, because it's difficult to understand. I think it's better to have some kind of model that isn't perfect at the beginning but will become better when you compare it with experiments.

ORESZCZYN: There are also things like the LAA [Local Area Agreement] Annex that are actually trying to get some agreement between the various models as well, doing some model comparison. But we have to bear in mind that there are limitations with all the models, and it's also very important to apply the right model to the right situation for the right application, and there isn't any model that will answer all the questions that you ever want to answer. And so you have to choose the appropriate one, and computational fluid dynamics, in many situations, is completely inappropriate for some of the things that we're looking at, particularly if you are in a historic building and you don't really know where the air is coming in or going out anyway. Then what are you going to put into your boundary conditions? But there are other situations where it is very appropriate. I think that's one of the skills.

MAEKAWA: What about much more basic stuff like certain change of material characteristics over time or even different ranges of temperature and humidity? Do we know enough? In terms of model elasticity or expansion coefficient and so on, it's not so simplistic in the real world.

MICHALSKI: In terms of the pragmatics of getting research done, I think there's really just two paths that arise with using modeling. One is whether or not we think that as a group, or the institutions we represent, we can initiate the kind of research that uses modeling as its tool, for which I think we have very limited resources. Or, more realistically from my experience, whether we try to influence that huge group of thesis researchers working in engineering programs and other applied research areas, who are quite grateful, in fact, to get a suggestion when somebody says to them, "You know, this actually has a useful application." There are a couple of people around the table who actually represent institutes that have a long-term commitment.

We will always want more information; we will always research. The end of research is not in sight for any field, let alone ours.

STANIFORTH: Knowing 80 percent is good enough, as far as I'm concerned, because we know we can iterate and iterate and iterate research, and we've got to draw the line somewhere and make this useful for people.

I just want to mention in this discussion the work that the Bartlett [Bartlett School for Graduate Studies, University College London] did on trying to work out what environments were in libraries in the past, and they were taking books that had been printed at the same time but had then been exposed to different environments in different libraries, and they were looking at the difference in condition of one book compared with another and relating that to its environmental history in those libraries. And boy, was that work difficult in modeling what the history of conditions might have been in those libraries—one of which was a National Trust House, so I was quite familiar with that. But we got a lot of data, so there was good information to do exactly what you've recommended, Henk [Schellen], to be able to compare the theoretical model of the history of the environment in that library with the real data. It was an awful lot of work—and just for one book in one library. It is a big task to extrapolate from that sort of research to whole collections.

MICHALSKI: My main foreseeable project for the next couple of years is to do a risk analysis model in a project with the ICN [Netherlands Institute for Cultural Heritage] and ICCROM [International Centre for the Study of the Preservation and Restoration of Cultural Property] to develop a user-friendly risk assessment tool that's Web based. Behind the Web page will be what's loosely a modeling tool, Analytica, that's used in risk analysis a lot. The model would take the user from straightforward questions like What kind of building do you have, and Where are you in the world, so it would look up expert opinion and data. And then, What kind of artifacts do you have? And it would have some estimates of their vulnerability, and then it would crank out what the risks are and how you might reduce those risks by changing your answers. And if we put prices on different answers, then we've essentially got a cost-benefit tool.

It's not that we're imagining that we have a fully explicit synthetic model for each of those elements. We will be doing what's called a hybrid model, which mixes synthesizing models where possible, where they're reliable and usable with black boxes that are essentially matrices of expert judgment. We tried to use analytic expressions, and we moved, under the consultant's advice, to "discrete state" expressions or vectors—which essentially boils down to: we have a ladder for expressing degree of damage, from none to total. Then we can generate ladders for people's estimates of how much loss of value that represents. And it takes care of various issues. We will be dealing with uncertainty explicitly, because one has to in risk analysis models. We're currently using the simplest kind of distribution that you can elicit from experts, which is called triangular. You essentially ask them for their most probable or expected value and ask them for their possible highest and possible lowest. And already, that can be quite powerful if it's not symmetric, because then averages are not the same as the most probable value, and in risk analysis that becomes really significant in making decisions. The realistic footnote to it is that we recognize that it's not a complete computational model. It's a mix of providing an encyclopedia of expert judgments that have been put into a form that allows a software tool like this to manipulate them.

I think we have to keep in mind with modeling that it's not qualitatively different from what science models have been about before. The word model existed before computers. It essentially meant some simplification of the real world. And we always understood the advantages and disadvantages of reductionism. What computer models are really good at is something the human brain is really bad at, which is tying together many little models that have come to us historically, like fluid dynamics of the nineteenth century, and stringing together a cascade of effects. Computer models are simply addressing two practical problems: how do you cascade lots of little models, and how do you do dynamic systems we couldn't find the solution to mathematically?

CHIARI: Stefan [Michalski], do you see your system also like sort of a checklist?

MICHALSKI: I'm trying to get away from guidelines and best-practice and benchmarking checklists, which have come to dominate every aspect of how we make decisions, and I think they're frequently misleading, inefficient, and wrong. I think there are about ten or twelve things that you can reliably tell every museum with mixed collections in every part of the world that should be on their checklist of preventive conservation issues, like a reliable roof and doors that lock. Those aren't small things, but it's a very limited list, and what we're trying to develop is a tool that will make checklists no longer essential.

Dissemination: Education, Training, and Resources

Finally, the group discussed the need for the dissemination of existing knowledge and experience in technologies appropriate for museums.

STANIFORTH: I don't hear any of us saying anything different today from what we have been banging on about to each other probably for the last fifteen or twenty years, yet the word isn't getting out there, so we're doing something wrong or we're not leading enough on this subject. I think that the research idea is very valuable but we might want to push in a second direction, which would be about actually taking this as an opportunity to disseminate more widely those ideas about appropriate technology for small museums and museums in historic buildings.

I'm very disturbed that after all this time, when we've known a lot of these things, we're still struggling with getting these messages across. Why? Why is it so difficult? So I'd like really to pin down how we disseminate this knowledge, how we champion this sustainable form of conservation, what our advocacy role is. And I think the one word people haven't used this morning, although we did skirt around it yesterday, was training—the training aspect of it. And I think that schools are doing a very good job in raising children's awareness of environmental issues, and therefore energy conservation is going to be a concept that is much more familiar to them. So how can we transfer this huge wealth of knowledge and experience in this room into other practitioners' day-to-day work?

DARDES: What we can think about now is, who are the audiences we need to target for training? I'm sure it's more than one audience. And the context for that training—whether it's within academic programs that already exist, whether it's short courses, whether it's in some combination of that.

The group identified several audiences: conservators, engineers, architects, heritage managers, heritage caretakers in the field (stewards, volunteers), and the general public.

Conservators

KERSCHNER: I think we have to get to the graduate training programs where they train the conservators. Preventive conservation is relatively new in the training programs and not well covered. There is a preventive conservation track finally now at Winterthur [Winterthur Museum/University of Delaware Program in Art Conservation], but that's only a few people. We need to get the conservators to learn about the idea of proofed conditions, because I don't think the word has gotten out at all on proofing and what we mean by it and how conservators should be looking at it, as opposed to 50 percent RH. It is more common to say, "Oh, this building has no climate control; we've got to do something about it." But when you go and look at the collection in that building, it may have been fine for the last thirty to forty years. So I think it's a whole reeducation at the graduate level.

PADFIELD: May I put in a plea for physics education in conservation schools? For historic reasons, conservation science has been chemistry, and it arises from the history of analyzing old masters for whatever purpose, and consequently everything is chemical. So therefore, there should be basic physics education, for which we can use Dario's [Camuffo's] book. For mature teaching you can have midlife courses, where you can bring in how air-conditioning works, and Henk [Schellen] can talk about all his modeling successes, and then it's much more focused. But this doesn't work with undergraduates, as I've discovered, because they're in the business of mending paper or mending textiles. That's so far away from museum climate that they're not ready for that. But they're ready for the fundamental physics, and then later on in life when they have a second chance to choose, then they can go for an additional course.

Engineers

MAEKAWA: Ernest mentioned a few differences between museum application and others. Yet when you try to work with local engineers, they have very little knowledge. Didn't the ASHRAE initiative try to disseminate all that information through creating a new handbook chapter for designing museums?

CONRAD: Up until 1999, the only thing an engineer had in the way of a text training for designing a new museum was his *ASHRAE Handbook.* The *ASHRAE Handbook* had one paragraph out of several handbook volumes—only one paragraph. So what can you expect? They had no knowledge of how the building wall in the envelope behaves. In fact, it was the architect's job to figure out the performance of the wall. And the architect's graphics handbook standards are incorrect. In 1999 a group of us got together and we produced an entire chapter, and I venture to say that since that time, I see a dramatic improvement in new museum construction.

MICHALSKI: I was told by a senior contributor to the ASHRAE publications that the *ASHRAE Handbook* is trying to change from recipe chapters to how to think. And we need to find better ways to teach people how to fish rather than to keep giving them the fish. And so the *ASHRAE Handbook* is changing in that way, but the reality is that it's an extremely painful process for the users to go through. They don't like to be told that now you have to think, analyze, be intelligent—all those things that various people around this table have said that we need to do in our particular subfield.

Which brings us back to another theme running through this, which is, how do you get people to deal with uncertainty? The fluctuation issue, the infiltration for engineers, the How do we do this? Why can't we just ask for constancy? And why do fluctuations keep coming back? So I think it's the uncertainty of complex systems, and one of the things we have to teach people—and this is certainly coming through in our approach to risk assessment—we have to teach people to be comfortable with uncertainty and not to have this drive to eliminate uncertainty from their design or professional lives. And that's really tough, especially in a culture in North America, where litigation is built on elements of uncertainty. And so people do become precautionary. I think what drives the fluctuation obsession is the precautionary principle, or risk aversion, and that's a tough one to crack.

HENRY: I'd like to comment just a little bit about this question of uncertainty. It's antithetical to the engineer's training to deal with uncertainty. We are graded on getting the right answer numerically. And we encounter this with historic buildings all the time, particularly with structural engineers, who are used to a certain precision and material properties. I teach for the [U.S. National Park Service] National Center for Preservation Technology and Training with another engineer and architect by the name of Sam Harris. I refer to this training program as teaching engineers to learn to sleep with ambiguity and be comfortable with it. And it's a really big step for them to do that, because it just runs counter to a lot of what we're talking about. There are so many chapters in the *ASHRAE Handbook*, and many of them are very specialized. The vector for getting to the engineers may not be directly training in the ASHRAE programs, because often the problematic museum is the small local museum that goes to the yellow pages in the phone book and looks up an engineer. And I find myself telling those engineers, look in your handbook for chapter 21, and here's how it works. They're not going to sign up for chapter 21 training when they go to the ASHRAE convention, if they even go to the ASHRAE convention. The vector for getting to the engineers is to make the conservators aware of chapter 21, so that they can sit down and, interactively in that design process, say, "We've heard about this tool, and we understand this is the way it's supposed to be applied, and let's have a conversation about this and head in the right direction that way."

CONRAD: There's two points on that. One is, when we go to a doctor, how many of us go to the yellow pages to pick a doctor? It's the same thing with professionals. We have great difficulty picking professionals who have a focus on a particular topic. The yellow pages just don't work. So it's word of mouth. And the other thing I want to touch upon, I do—not a fair amount but enough to scare me—work as an expert witness. I have such sympathy for architects, engineers, structural engineers who get taken over the coals by the legal program. Guidelines are very dangerous. The *ASHRAE Handbook* is a very dangerous piece of material, because lawyers grab onto this thing, and they will beat up the engineer, and they will make his insurance company pay. They could care less if they're right or wrong, because they're just going after your insurance company. And now your insurance rates are going to go out of sight, and so we have to be so careful and we'll end up overdesigning—not that we want to, but just for the sake of our own insurance premiums and the risk of being put out of business. I mean, this is a major issue.

SCHELLEN: We should educate our [engineering] students to think in a sustainable way. As an example, I asked my two hundred students how they would set their thermostat in summer and in winter, and all of them said they would set it to twenty or twenty-one degrees in winter and in summertime. They did not consider the way we dress. When these students become architects, then we will, for the future, always build buildings that need huge climate systems.

Architects

ORESZCZYN: Engineers often get involved too late in the day, or they see their role as handling the services but not the fabric of the building. There is an extra cost associated with doing these sorts of analyses which are not regularly done. Perhaps we have been guilty by suggesting that the fabric of the building—and using the fabric of the building is, necessarily, in the design part, a much cheaper solution. It takes more effort, and it takes more resources to look at these things in detail, to avoid some of the mistakes that get made.

There is no doubt that we cover these sorts of materials in both our environmental design course and sustainable heritage course. But those are not affecting the average practitioner; they are affecting people who are specialists, who want to specialize in these areas. However, I fear that that market tends to be very small and will always work with the top end of the profession. If you're talking about getting some of this information down to a larger, wider level, that's actually quite difficult, and unfortunately, the Bartlett has tried to compete very heavily with the AA [Architectural Association School of Architecture, London], and many architects see design as the thing that they should be trained in. I think it is different, though, once you get past the initial education, and once they're in practice, I think there is an opportunity for continual professional development. I was shocked when I went to an architectural school as a physicist. I found it very difficult to imagine how these people could work who were going to go out and design real buildings and never have drawn a picture of a real building. But then I thought about my own training, which was as a physicist, and I spent all my time doing quantum mechanics and relativity, which I never ever, ever use, and it's a similar sort of thing, and I think once you get into the real world, that's the opportunity to bring in some of these issues.

TOLEDO: Maybe we should shift the way we train architects. We are not trained to be low profile. We have to be artists with big egos, to be very inteventive, to push the limits. During our training, we don't have any sort of exercise such as how to build buildings with local materials, how to build earthen buildings. We are always trying to reach the highest technology possible. I think that if we take a more modest approach to buildings and how architects are trained, this would help as well.

Heritage Managers—the Clients

CONRAD: I would propose that we include the education of those stakeholders responsible for heritage preservation so they are educated to make the right decisions.

ORESZCZYN: I think what we have to bear in mind is that clients probably only ever commission one building in their life and get one air-conditioning system commissioned. In terms of things that need to be passed on, one is actually the whole issue of life-cycle costing. I think there is a real lack of understanding of what the life-cycle costing of different options are.

HENRY: And as a subset of that, I think that would be an opportunity to address preventive conservation of buildings, because there is a relationship there between life-cycle costing and building reinvestment as a way of preventive conservation.

CAMUFFO: I don't exactly know what happens in other parts of the world, but in Italy any responsibility concerning artworks is in the hands of the superintendent or the museum director. This person is always a valued art historian who studied art, history, and literature but missed adequate training in scientific disciplines, for example, physics, chemistry, biology, and conservation science. I think that this is very relevant, and we should recommend that any decision concerning conservation be scientifically supported by a well-trained, permanent staff member. Fortunately, some universities in Italy are now starting courses in conservation science.

MICHALSKI: That reminds me—we have two people [at the Canadian Conservation Institute] whose whole career has been being consultants in a building project for public museums, art galleries. They represent essentially the interests of the client, who is going to go through this once in his life, and they go through a different one every week or two. So we have a larger corporate memory of grants and modifications and upgrades that the museums have been through than the directors have that come in. It's a model that our federal government has followed, and it's been very successful. A lot of what we do in my section is to comment on design proposals that come forward. And we're perceived as objective. We're not necessarily as experienced or more experienced than some of the engineering consultants, but we don't have a conflict of interest. It's essentially two people servicing a country of thirty million, and it's made a huge difference. So it's how you pool and bring together those threads for the sake of the collection's sustainability. But we're five years away from walking out the door (or less), and they have not been replaced because our government has not seen fit to see this as incredibly valuable. So we're soon going to be experimenting with a very different system of delivering that information to Canadian museums. Hence, our current emphasis on developing "expert systems" to provide some of this advice.

Heritage Caretakers in the Field (Stewards, Volunteers)

STANIFORTH: This is a really major issue, and this comes back to the importance of training in preventive conservation. We are fortunate, because in the National Trust houses, we have at least four hundred housekeeping and conservation assistant staff, and we have a program of training courses for them which include housekeeping, emergency procedures, and environmental monitoring and control. They then take their training back to their houses where they work, and they train the volunteer room stewards who work there. Actually, the biggest issue for us is the opening and closing of the blinds and light control, rather than the open doors and windows. But light control is just as important a method of preventive conservation. Once they understand what happens when sunlight shines on an eighteenth-century carpet for one hour, then they understand the importance of using the blinds. So it's the training program, as always, that counts.

KERSCHNER: You have to train the people who are right in the room frequently, the docents or the guides. It doesn't take a lot of training, but at the beginning of each year, I'll go around and just talk for five minutes, show them how to do it, and then I'll check it up again in another month and the month after that, and some of them will never get it. But the majority will. So that's how we approach it.

General Public

CHIARI: Do you need to inform the public? For example, when you decide not to have air-conditioning in a historic building and there is a high temperature, do you inform the people to explain why you are doing this—the risks, the advantages, etcetera?

ORESZCZYN: I think that is a very important point. The reality is that we all spend a lot of money to go to climates that are incredibly hot as part of our holiday and then complain when we get back home. It's the same temperature, and it seems bizarre. So people do tolerate quite extreme conditions if they see a reason behind it. However, I think the biggest problem there is in trying to get this balance between comfort of people and comfort of objects, and there are very often regulations that cause problems.

STANIFORTH: I'm a huge fan of engaging with the public, because it raises people's awareness, and particularly when you're dealing in a country with a lot of historic buildings that people are living in, it's a very good form of leadership. We can set the example, and I think that that's a real function of museums—to inform and to educate, and we have a very, very good opportunity, because of the number of visitors who currently come to museums, to actually set a good example and to show the types of ways in which we can be energy efficient, that we think about our energy use, that we maintain the buildings, that we conserve the collections. And that's a great opportunity for people to learn about that and then take that back to their own buildings. In the UK, more than 50 percent of the population lives in buildings that are over fifty years old. People will have to practice those maintenance standards on their own buildings. Otherwise they will be filled up with water.

HENRY: Climate change is real and the impacts are real, and we're dealing with impacts that are in long time, slow change. So first and foremost is, we have to think long-term and we have to think ahead. The other thing is that while we're all here to conserve objects and buildings, there is a larger purpose to conservation, and that is to inform the public. And it's not just about the precious object or the important architecture, but it's about our impact on the world and on the environment around us. And what better vehicle do we have than our historic properties to inform the public about the effects of climate change, about adaptation to climate, human adaptation to climate, and human comfort? So it's not just about the threat, but it's about our impact and our lifestyle.

The group discussed several didactic approaches and teaching resources that could be appropriate in reaching the established audiences.

Didactic Approaches

DARDES: As far as the Getty is concerned, what we'd like to do, what we hope to do, is lead by example, rather than come up with the ideal curriculum that we think other people should follow. But I do see a real area where we can get involved in continuing education and hopefully reach those audiences through an approach that we can demonstrate in the courses that we give.

STANIFORTH: I completely agree about the continual professional development being the level to go in on, probably, because quite frankly, we tried for a very long time to influence the training courses in the UK to have more modules on preventive conservation, and it just hasn't happened. And I think that it would be very interesting to think not only about the mechanism that you've used in the past of actually bringing people together for a two-week total immersion course, and then you reach a limited but very loyal group of people—but I think now, with all the opportunities for distance learning and online learning packages, about actually developing some online-accessible material.

DARDES: I would be interested in knowing your opinion on whether you think interdisciplinary training is possible. We talk about interdisciplinarity within the field, but is devising a training program that would combine engineering students, architectural students, conservators—is that possible, or would that be too fractured an approach?

STANIFORTH: I was going to say that's very much the model of the Centre for Sustainable Heritage MSc in sustainable heritage. And interestingly, when we had the Dahlem conference in 1992[xxiii], that was one of the recommendations of one of the groups, and I think there's huge value in bringing together all of the professionals who work in heritage conservation museums, because that's how they're going to have to work when they're in practice.

ORESZCZYN: Can I just add to that? Again, I think you have to be very, very careful about what stage you introduce that. You need to have confidence in your own area first of all. You need to have a certain maturity to actually interact with the other disciplines, including appreciate the value of it.

HENRY: I think you really leverage the value of the training if you do it in an interdisciplinary context. There's much to be gained for everybody.

STANIFORTH: I think there's one other method—well, I don't know if you call it a method of training, but I think work experience is invaluable for people who are thinking about going into a preventive conservation or environmental speciality. And the internship, when people have just finished their training, they need to get their foot on the bottom rung of the ladder. We've just given up with the training courses in the UK, and we now have four three-year assistant conservator positions, which are to train and develop our own preventive conservators, because you can't get them off the shelf.

Teaching Resources

PADFIELD: I look up Wikipedia every now and again. But if you look up "conservation of art," there is absolutely nothing. Now, I thought about putting my bit in, but actually, I do my own, so that would be a bit repetitious, but I feel that if somehow—the Getty really is in a rather influential position here just to kick-start it. You've got the AATA abstracts, but quite frankly, I can't be bothered to get all those things from the library and read them. It's a completely different way of disseminating information, whereas Wikipedia is straight. Fill Wikipedia with environmental conservation information.

MICHALSKI: On the Wikipedia thing, I'd like to point out that the founder of Wikipedia is setting up a different, vetted Wikipedia, because many of the expert entries have imploded in ways that were predicted. Especially in an area like ours, which does not have an incredibly well-established profession, we have a certain amount of technical knowledge and a huge amount of dispute about which is valid and which is not. And those are the kinds of groups for which it just becomes a nightmare, from what I've seen in Wikipedia. And so what Wikipedia is setting up is a vetted site, where there will be a necessity for qualifications. It is essentially an intellectual elitist recognition. I would suggest that if we go the Wikipedia-type route, I would suggest that we go into that forum, which is not a populist approach to finding knowledge but an expert-driven approach to finding knowledge. Otherwise, I think it will implode.

PADFIELD: On the same lines, another useful thing would be a pledge for open access for everything published. It's basically because of the laziness and complacency of scientists that this continues, because all of us can publish with open access, and it doesn't cost anything.

ORESZCZYN: I think the move is happening toward that. Certainly in the UK, most research is funded by the government, and they're now increasingly insisting that everything is happening—so, for instance, all UCL publications now go on Eprints, which is a UCL publicly accessible site.

End of roundtable discussion.

Roundtable Statement

The experts' group formulated a statement at the end of the two-day discussion.

The Roundtable recognizes the need to manage environmental conditions in order to reduce certain incorrect climate-related risks to collections. It is important to accomplish management of environmental conditions in a responsible manner with respect to:

- "Proofed" conditions—an environmental management strategy for the preservation of collections should be based on risk assessment and an understanding of the historic climate a collection has been exposed to, in order to establish the proofed conditions. Within these conditions, damage to a collection caused by the indoor climate will be minimal.
- Building design and performance (thermal and hygroscopic mass)—understanding that collections may be housed in (retrofitted) historic buildings (n.b., the historic building may be part of the collection), in adapted contemporary buildings (often for storage), or in purpose-built, architect-designed buildings. The building is the first line of mitigation: in modern, adapted, or purpose-built buildings, the building should provide stable indoor conditions. In historic buildings, passive climate measures were often in place to mitigate the harmful effects of the outdoor climate and to create suitable indoor climatic conditions. Understanding the operation of these kinds of buildings is essential.
- Financial cost and energy consumption versus degree of control.
- Understanding the risks when an environmental management system is failing—this can be a mechanical system's failure or human failure.
- Social aspects.
- Human comfort.
- Global climate change.

The Roundtable identified areas of further research into:

- Object response to climatic conditions by:

    - Proofing of objects, in order to understand the impact of fluctuations (amplitude and frequency) in relative/absolute humidity and temperature.
    - Laboratory research into material response.
- Performance of HVAC systems, conservation heating, conservation ventilation, and low-level humidification and dehumidification.
- Energy consumption versus degree of control.
- Building design and performance.
- Historic operation of and performance of buildings.
- The use of climate simulations models—verification.
- Indoor microclimates (behind/in objects in rooms).
- Indoor pollution.

The Roundtable identified a role for education (interdisciplinary approach):

- Academic-level training and continued professional development to achieve better understanding of passive climate control measures and to improve communication and understanding among stakeholders (architects, engineers, conservators, conservation scientists, etc.):
    - Passive building solutions.
    - Monitoring/measuring.
    - Life-cycle costing of different options in climate management.
    - Proofing of objects as a means to understand the effect of the historic environment.
    - Fundamental physics in conservation.
- Work experience through internships/assistance.
- Use of new teaching technologies—e.g., distance learning.

Dissemination of information and new developments to the field is crucial:

- Web technology can be used to reach a wider audience:

- o Wikipedia entry on environmental conservation (expert/peer reviewed).
- o Publications made available: open access—creative commons.

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[i] www.getty.edu/conservation/education/prevent/index.html
[ii] www.shelburnemuseum.org/?flash=true
[iii] David John Artigas, "A Comparison of the Efficacy and Costs of Different Approaches to Climate Management in Historic Buildings and Museums" (master's thesis, Graduate Program in Historic Preservation, University of Pennsylvania, 2007); repository.upenn.edu/hp_theses/63/
[iv] www.eere.energy.gov/buildings/energyplus/
[v] www.epbd-ca.org
[vi] www.nationaltrust.org.uk/main/w-index.htm
[vii] www.nationaltrust.org.uk/main/w-vh/w-visits/w-findaplace/w-hardcastlecrags/ w-hardcastlecrags-gibsonmill_project.htm
[viii] whc.unesco.org/en/list/130
[ix] Sarah Staniforth, Bob Hayes, and Linda Bullock, "Appropriate Technologies for Relative Humidity Control for Museum Collections Housed in Historic Buildings" in *Preventive Conservation: Practice, Theory and Research. Preprints of the Contributions to the Ottawa Congress, 12–16 September 1994*, 123–28 (London: International Institute for Conservation of Historic and Artistic Works, 1994)
[x] www.usgbc.org/DisplayPage.aspx?CategoryID=19
[xi] "From the Outside In: Preventive Conservation, Sustainability, and Environmental Management"; www.getty.edu/conservation/publications/newsletters/22_1/feature.html
[xii] www.ucl.ac.uk/sustainableheritage
[xiii] http://www.cci-icc.gc.ca/
[xiv] H. Künzel and D. Holz, "Richtiges Heizen in historisches Gebäuden," [Correct heating of historic buidlings] VDI Beriche nr. 896, (1991): 121-137
[xv] Ł. Bratasz, S. Jakieła, and R. Kozłowski, "Allowable thresholds in dynamic changes of microclimate for wooden objects: Monitoring in situ and modeling," in *ICOM Committee for Conservation, 14th Triennial Meeting, The Hague: Preprints, vol. II*, ed. I. Verger, 582-9 (London: James and James, 2005).
[xvi] www.getty.edu/conservation/education/case/case_component1.html.
[xvii] Mogao grottoes, http://www.getty.edu/conservation/field_projects/mogao/index.html; Valley of the Queens, http://www.getty.edu/conservation/field_projects/egypt/index.html.
[xviii] www.louisamayalcott.org/
[xix] www.nps.gov/carl/
[xx] www.draytonhall.org
[xxi] For classification system, see Table 4, Classification of Climate Control Potential in Buildings in *2003 ASHRAE HVAC Applications Handbook*, Chapter 21, Museums, Libraries and Archives (www.techstreet.com/cgi-bin/detail?product_id=126084500).
[xxii] www.kenmore.org/kenmore_homepage.html
[xxiii] For futher information see, Krumbein, W. E., P. Brimblecombe, D.E. Cosgove, and S. Staniforth, eds. *Durability and Change: The Science, Responsibility, and Cost of Sustaining Cultural Heritage*. *Report of the Dahlem Workshop, December 6–11, 1992*. Chinchester, UK: John Wiley, 1994.