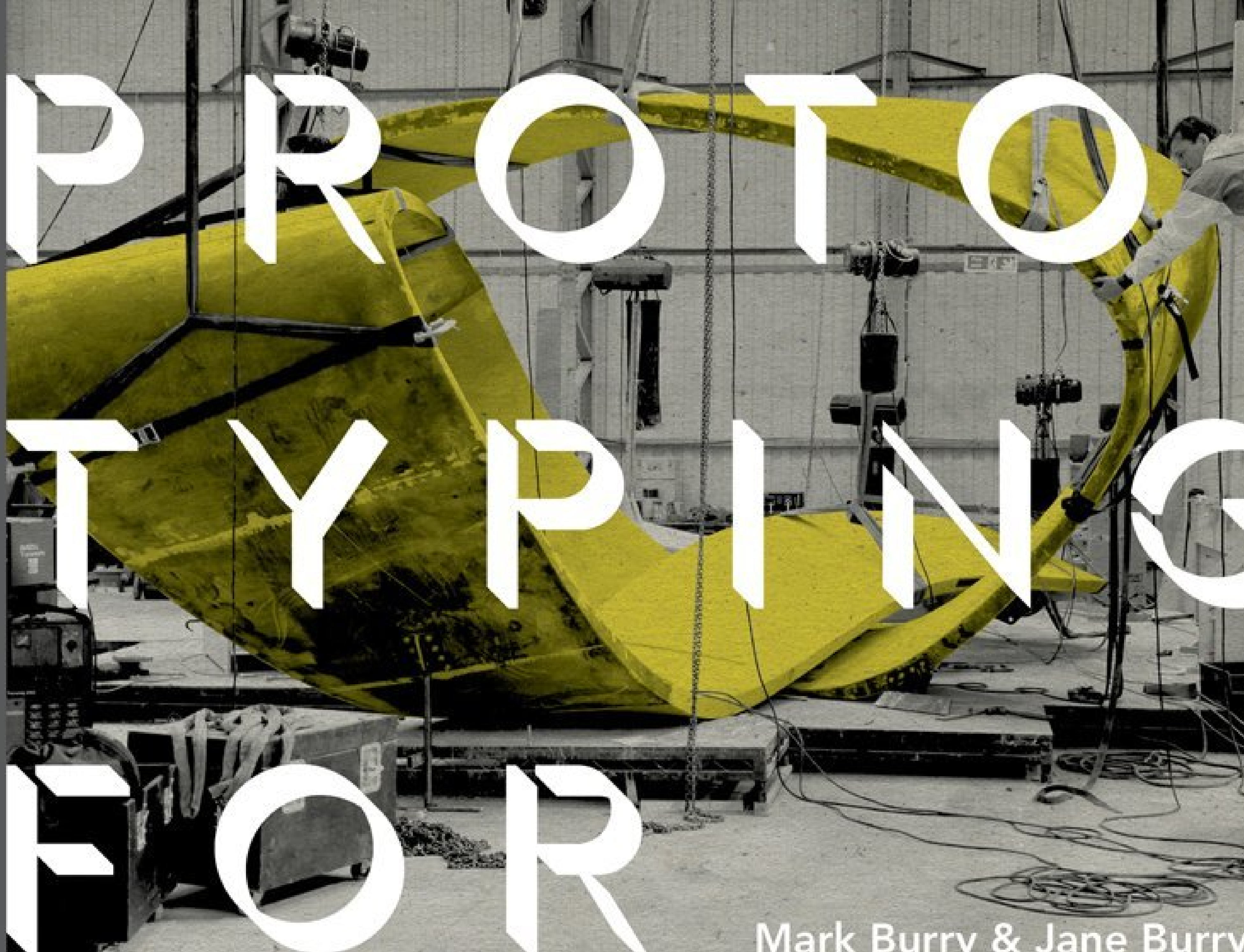
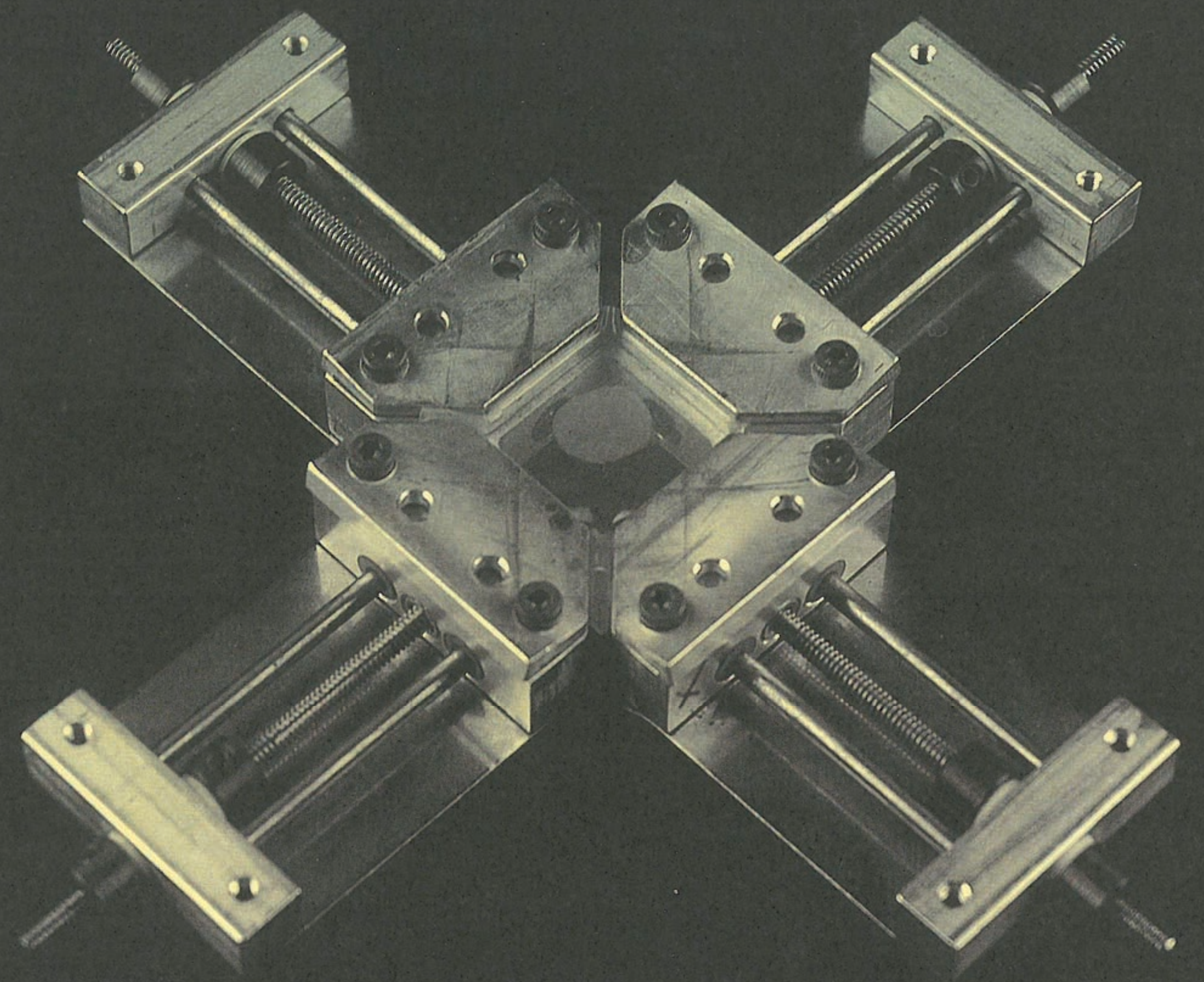
PROTO-TYPING FOR ARCHI-TECTS



Mark Burry & Jane Burry

Thames & Hudson



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Prototyping Performance

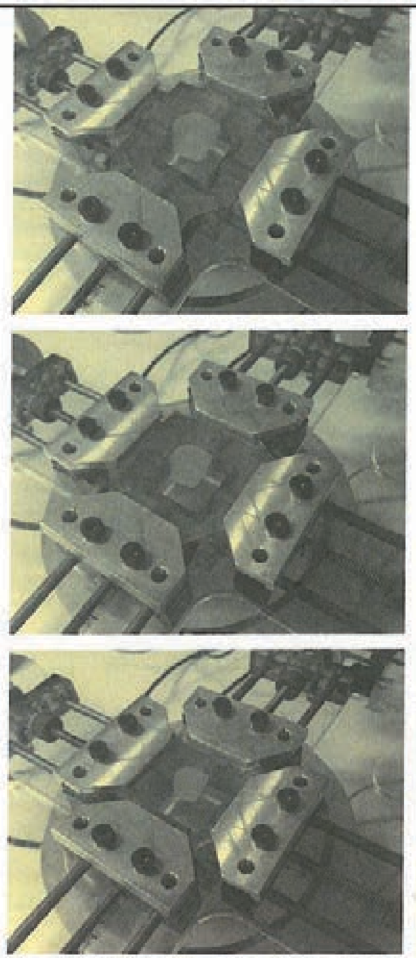
As the adoption of digital and parametric modelling has become more widespread in both the practice and the teaching of architecture, so too has the recognition that such technologies provide a very tangible opportunity to link architectural models directly to the structural and environmental performance of the finished article through computer simulation – the ability to alter design parameters and observe their impact on design performance. This has simultaneously increased the value of analogue and mixed (i.e. physical and digital) performance prototyping, taking advantage of the increased accessibility of microelectronics for sensing and actuation to link the two.

For multi-criteria optimization, and the exploration of multiple performance criteria and their simultaneous interaction, the level of fidelity and applicability of prototypes – digital, analogue or mixed – is still relatively low. The behaviour of the natural environment is inherently complex; the interaction of light, heat, humidity and air movement, for instance, can have a dynamic and volatile impact on the conditions experienced in a building. Generally speaking, architects use prototyping to gain feedback and information with which to inform the design process, particularly in the early stages, and are not engaged in the lengthy process of developing more generalizable knowledge about the performance of particular construction systems under particular conditions. Here, we deal briefly with a few examples of prototyping for select performance criteria.

1 (opposite). CASE RPI, Electropolymeric Dynamic Daylighting System (EDDS): Biaxial strain engineering jig.

Light and kinetic prototyping

One of the many ways in which the light entering a building can be modulated by means of design is through the introduction of responsive kinetic façades. Kinetic architecture has to be prototyped just to develop robust working kinetic systems. Accurately predicting its environmental performance, in terms of controlling light levels, heat gain and energy use for cooling, and incorporating this into the detailed design of the architecture, adds another complex layer of experimentation and simulation. A well-known example of a building with a kinetic façade designed to respond to and modulate natural lighting and reduce the amount of energy needed to cool the interior



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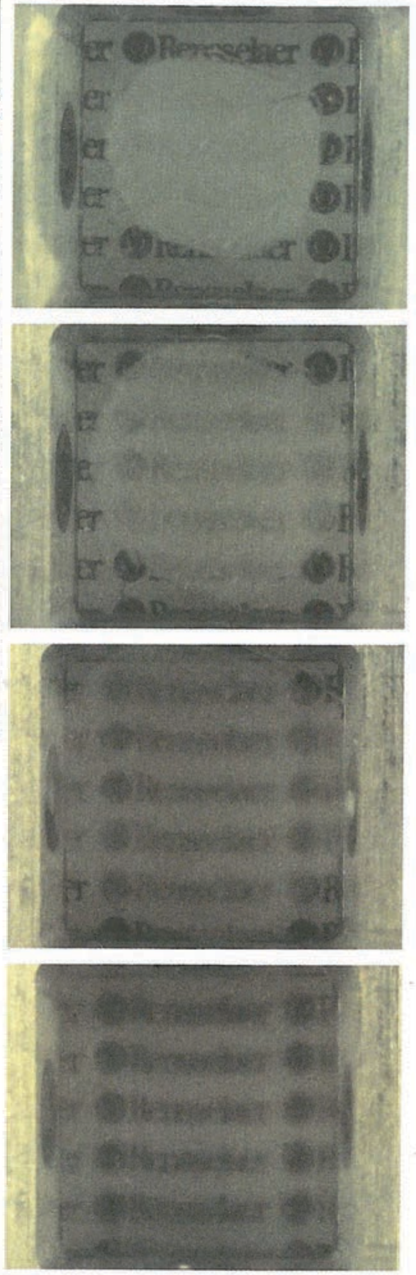

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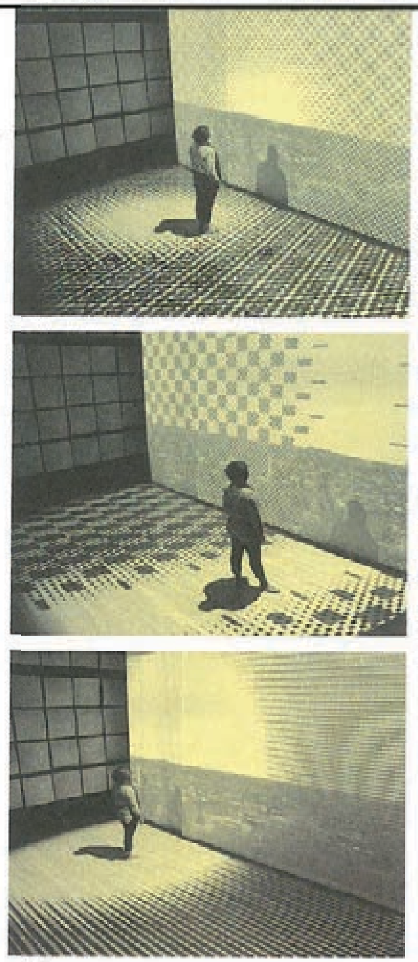

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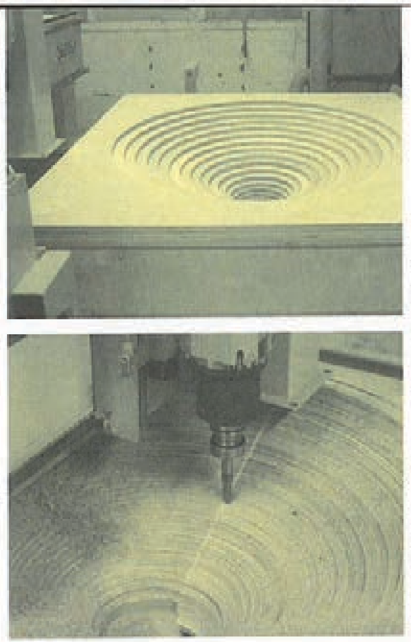
2–8. Electropolymeric Dynamic Daylighting System (EDDS): Dynamic strain stage, with a thin sample of film on a transparent elastomer.

9–11. Sequence of stills from the full-scale mock-up of the EDDS. The visual effects are a consequence of user interaction and environmental energy modulation.



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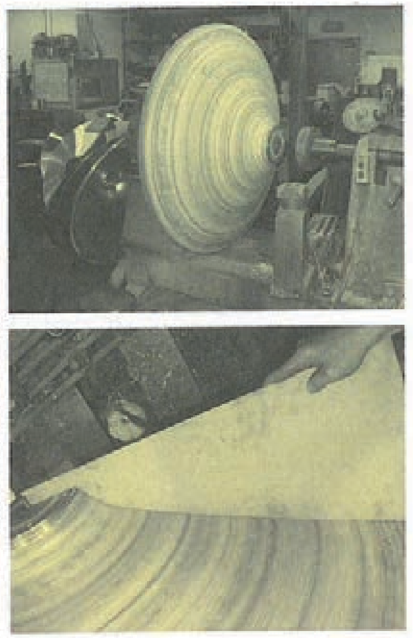

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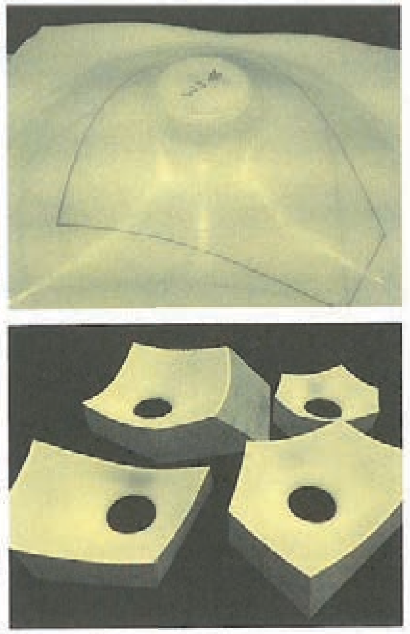

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12–13. SIAL, FabPod meeting room, RMIT University, Melbourne, Australia, 2012–13: Milling a hyperboloid mould using a CNC machine. The doubly curved, ruled hyperboloid surface performs well as a sound diffuser, scattering sound waves.

14–15. Hyperboloid mould for creating spun-aluminium cells for the FabPod.

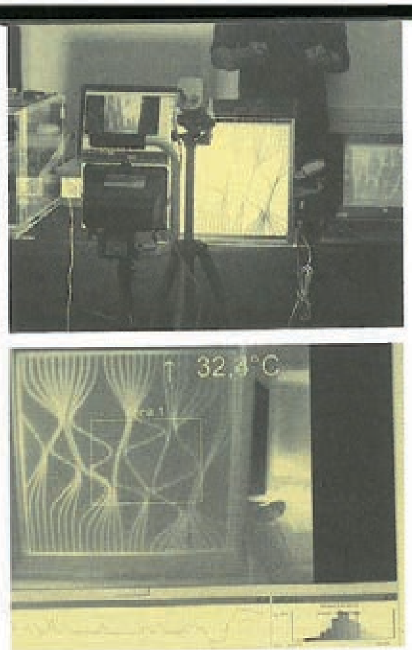
16. Cutting boundary on hyperboloid in formed acrylic.

17. Unique cells for the assembly of the FabPod. Each cell has the same hyperboloid shape, but the varied boundary shapes and sizes introduce sound-scattering potential, as well as 'organic' visual variety.

is the Institut du Monde Arabe in Paris by Jean Nouvel (completed 1987), with its distinctive, southern-facing brise-soleil grid of camera-shutter oculi. Other examples of kinetic façades include Charles Hoberman and the Adaptive Building Initiative's four 'Intelligent Surfaces' – Tessellate, Permea, Strata and Adaptive Fritting – and the umbrella-like shading system on the Abu Dhabi Investment Council Headquarters by Aedas architects and Arup (completed 2012). While each of these designs is undoubtedly the result of extensive prototyping intended to create a novel working kinetic system, questions remain regarding how to prototype effectively and accurately the actual lighting effects and impact on heating and energy use in the finished buildings.

Acoustics and prototyping

The use of prototyping to evaluate acoustic performance has a long tradition in the design of concert halls and theatres. In the case of such buildings, both large-scale physical (traditionally wooden) models and full-scale wall panels are tested in acoustic laboratory conditions to check predicted reverberation times, clarity and loudness. But such physical models and full-scale mock-ups are expensive and time-consuming to build; moreover, they tend to be employed only once or twice late on in the design process for the purposes of verification or minor refinement. For iterative testing in the more volatile stages of the design process, digital simulation is more affordable and better able to provide the fast analysis turnaround times needed in order effectively to tune the geometry, materiality and mass of a highly acoustically controlled space through trial and error. Computer models for acoustic simulation still need to be simple in shape and polygon count. Such details as the surface shape and materiality of the architecture are approximated by applied digital textures with given attributes – a coarse-grained approximation. There are, however, such initiatives as Arthur van der Harten's Pachyderm plug-in for Rhino 3D (a commercial CAD application) that allow architects to complement the use of costly software packages by expert consultants with more accessible tools, cutting down the analysis time between design iterations in early architectural design.



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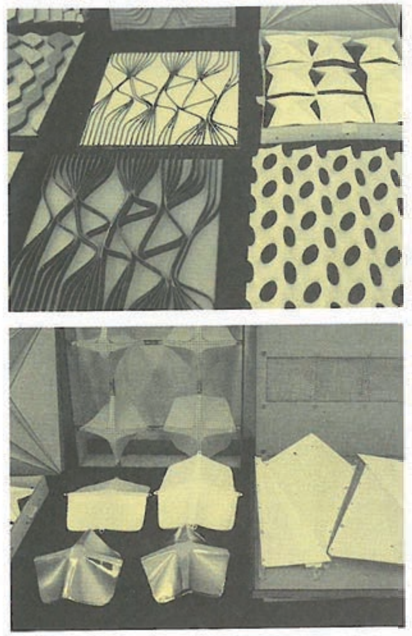

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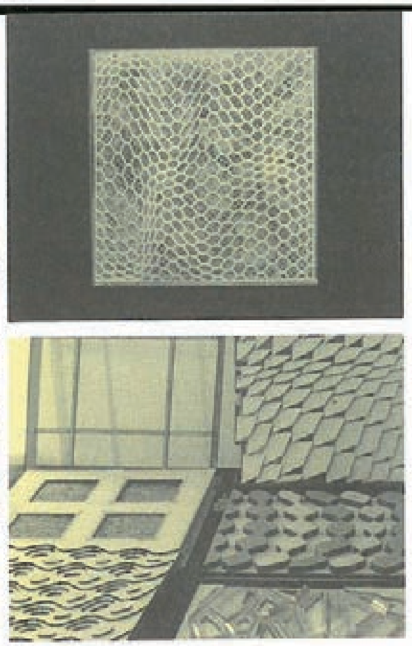

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18–19. Thermal Reticulations research cluster, Smartgeometry, The Bartlett/UCL, London, 2013: Recording the thermal performance of different façade patterns. Thermal imaging shows the way in which the pattern and materials influence how the surface heats up and cools down, while thermal sensors monitor how heat passes through the façade sample and is distributed in the space behind it.

20–23. Some of the many façade designs, including kinetic systems, that were tested for their thermal performance.

Other sites of acoustic interest for architects include outside high-end performance spaces and the increasingly common phenomenon of open-plan commercial or educational work environments, with their need to accommodate both noisy, collaborative activity and more focused, solitary pursuits within the same space. Using a smorgasbord of media and techniques, the FabPod project (see page 158), for example, was a prototyping exercise intended to investigate the use of geometry and materials to tune the acoustics of a semi-enclosed meeting area.

Air and prototyping

Architecture modulates and controls the temperature and movement of air, shapes internal and external climates, and provides shelter from the extremes of weather. However, although prototyping the interaction between architecture and air is fundamental to architectural design, it is a complex proposition, whether using wind tunnels or computational fluid dynamics. All air is turbulent, even apparently still air in an internal room, and understanding the subtle, site-specific dynamics of wind and the behaviour of external and internal air in architectural contexts – which is coupled with thermal performance, humidity and air quality in and around buildings – is a complicated business. To really influence the architecture, some understanding is needed through prototyping in the very early stages of design. Fortunately, there is a range of new fluid and thermodynamic simulation software with visualization that architects may find simpler to use than engineering analysis packages. However, each of these applications has limitations that need to be very well understood in order to get any meaningful feedback.

The Tangible Transdisciplinary Table (TTT) is an example of prototyping in 'mixed reality', combining physical modelling and interaction with background digital sensing, simulation and visualization. A so-called demonstrator project, the TTT brought together architects, landscape architects, local planners and engineers around a table on which they could move and interchange building blocks on a city plan and observe changes in a wind simulation projected on to the table in real time. The mixing of physical and virtual prototyping, to provide rapid or near real-time feedback on the impact of design changes, has also proved a powerful way to design for passive thermal and ventilation performance, for instance in the design of building façades.

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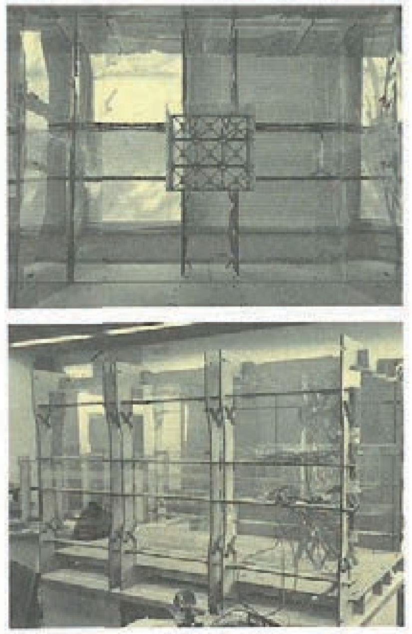

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24–27. Flora Salim *et al.*, Tangible Transdisciplinary Table, RMIT University, Melbourne, Australia, 2013: Simulated wind flow, projected on to the table, alters in real time as designers change the position and shapes of buildings in the model on the table.

28–29. Rafael Moya and Daniel Prohasky, Mini Airflow Tunnel Project: This project is aimed at providing architects with a low-cost platform for rapid wind analysis. Sensors inside a transparent, small-scale wind tunnel evaluate changes in wind speed and pressure, temperature, and humidity when architectural prototypes are placed in the airflow.

Prototyping performance in practice

Many of the architectural practices that outlined their use of prototyping for the third part of this book stated strongly that the nature of a prototype depends very much on what is being tested. Among the examples of real-world prototypes described, there are many that were intended to test one aspect of performance in particular, be it structural behaviour, lighting effects or acoustics. Diverse and often complementary means were employed to achieve this aim, some involving the testing of both physical and digital prototypes, some at scale – where it was possible to apply a scaling function to the particular mode of performance – and many at full scale.

Given that digital design is essentially data-related, it is possible to point to a bilateral relationship between data and design: the latter leading to the production of useful data that is highly relevant to the whole process and, conversely, the former being used to steer the design. This section includes several examples of this relationship, as well as instances where the prototype gives form to the invisible world of data not as a physical outcome, but rather as a powerful driver intended to get the best from the often multidisciplinary design team, as in the example of CASE RPI and aspects of SUPERSPACE.

The ongoing work at the Sagrada Família in Barcelona showcases the production of 1:1 prototypes using highly sophisticated data streams – in this case, those emanating from the essentially geometrical constructs that are the basis of Gaudí's 'codex' of doubly ruled surfaces. Such examples are clear manifestations of the possibilities of 'file to factory' data streaming: the sending of data from the digital model directly to the machinery used to produce the physical prototypes and, ultimately, the building itself.

Other examples in this section include the work of Franken\ Architekten and the ICD in Stuttgart, where the protagonists make a link between data, the algorithm and production. In such cases, there is the possibility of completely decoupling architectural design from all that might be regarded as 'traditional practice'. While this is not explicitly stated nor implied in this section, suffice it to say that the projects offer an insight into the cleanness of such a direct link between design, data and digital production. Prototypes emerge from the design and making processes that can be managed entirely as virtual manifestations of underlying data.

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Manifestation of Data

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CASE RPI [Anna Dyson]

Almost all of our prototypes go through testing protocols

According to its website, the Center for Architecture Science and Ecology (CASE) is 'addressing the need for accelerated innovation of built ecologies through the development of next-generation building systems'. Co-hosted by Rensselaer Polytechnic Institute (RPI) and Skidmore, Owings & Merrill (SOM), CASE is a multi-institutional research centre that bridges the gap between the university and practice to form a unique facility in the heart of New York City. Physically independent of both hosts, the centre feels more like an independent laboratory and, on entering the facility, the visitor is greeted by a tremendous sense of active experimentation, with an abundance of fascinating, working prototypes on display.

At the heart of CASE's work is the urgent need to address future cities' demand for water, energy and other resources. The technologies on which it is focused are therefore aimed at locally harnessing ecologically sustainable energy and improving the interaction between human systems and those in the natural world.

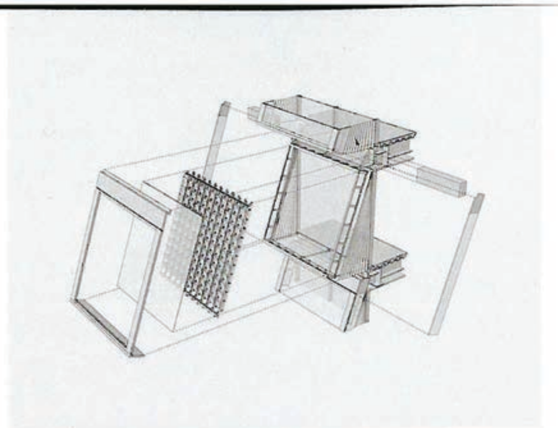
The motivation for establishing CASE as a research lab based partly on practice and partly on academia was to get the best from the applied research environment offered by a practice with the scale and history of SOM and, at the same time, bring the next generation of researchers through RPI and its advanced-degree programme in built ecologies. In particular, CASE uses an interdisciplinary approach to facilitate the coming together of architectural and engineering practices, other research institutions, manufacturers and related consultants, all of which are striving for the same thing: performance-driven building technologies that offer a cleaner and self-sustaining built environment.

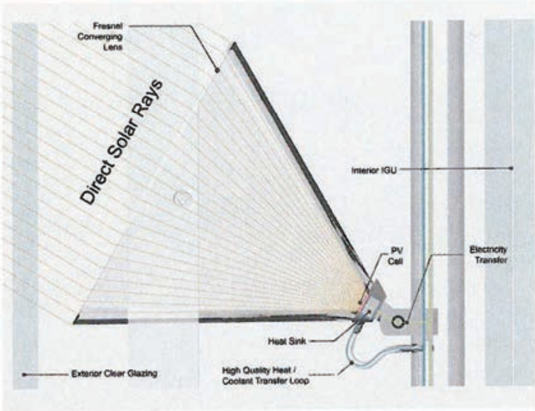
The link to RPI is a fortuitous one as, from CASE's perspective, the institution has a 'visionary administration', offering an intellectually wide-ranging and rigorous collaborative environment. In working within a transdisciplinary (as opposed to cross-, inter- or multidisciplinary) framework, the contributing disciplines do not become subsumed in the scientifically creative team. CASE's distinctive methodology, combined with the in-between status of being a university-practice, has been contrived deliberately to ensure that academics can still have their contributions recognized within their disciplines and not feel as though their endeavours are moving them away from any tenure-track priorities. For the practices and industries involved, the research environment offers an entrepreneurial workspace with the potential for spin-offs. This is not a done deal, however: CASE maintains an internal discussion questioning the extent to which the team should be developing new knowledge as opposed to new research frameworks.

As the work at CASE is grounded in both biophysics and the physics of energy, prototypes for the centre are usually conceived in relation to physical behaviours – a test of protocols on the pathway to invention. There is also a strong sense that, as a deeply committed research partnership, CASE is, in itself, an ongoing prototype for academy–practice–industry hook-ups offering codependence without any loss of independence.

1. Integrated Concentrating Solar Façade (ICSF), CASE RPI, New York, NY, 2005–: An early prototype of the ICSF (2007).

2. Prototype installed at the Syracuse University Center of Excellence for operational, performance, and daylighting experimentation.





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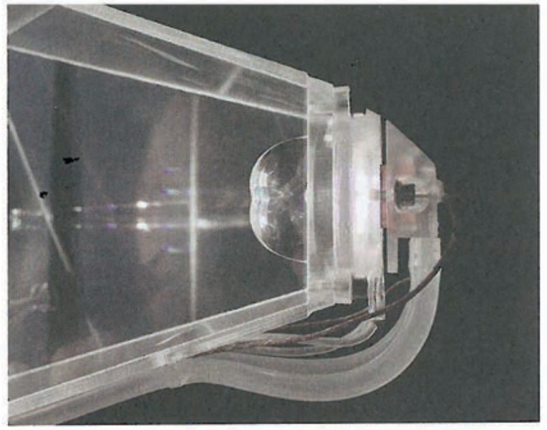

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3. Integrated Concentrating Solar Façade (ICSF).

4. Section view of an ICSF module showing solar concentration and components.

5. A receiver assembly during solar tracking, including secondary optical element, multi-junction solar cell and water-cooled heat sink.

6. Proposal for retrofitting an ICSF curtain-wall unit into an existing building façade.