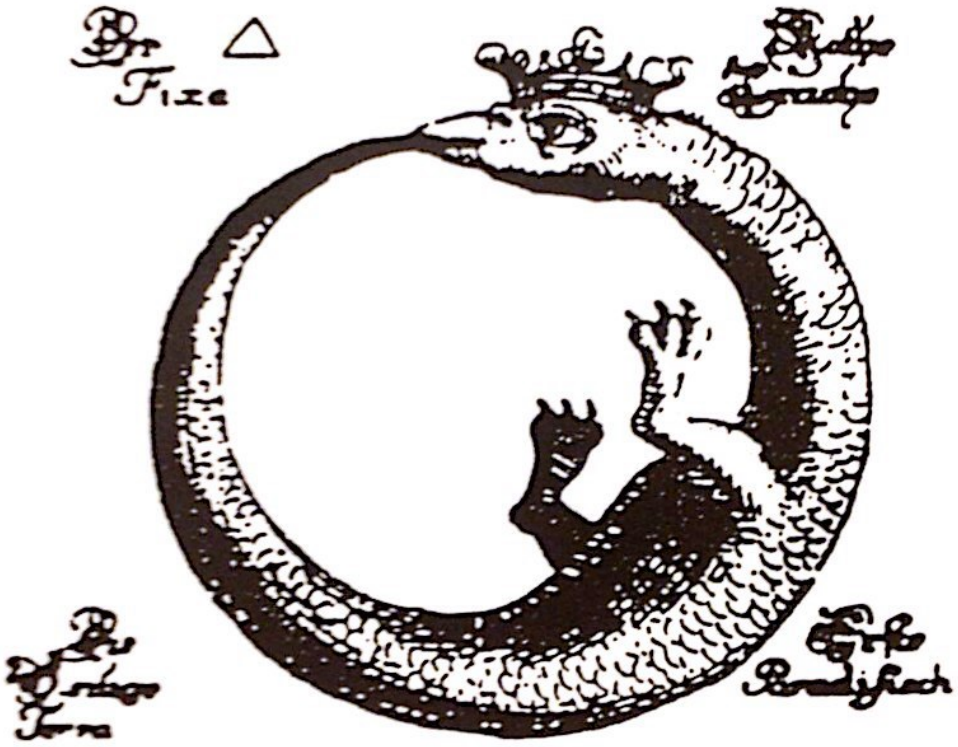
PERSISTENT MODELLING

Extending the role of architectural representation



EDITED BY PHIL AYRES

ROUTLEDGE

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Edited by Phil Ayres

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Chapter 2

The persistence of faith in the intangible model

Mark Burry

There are many dialectics that make architectural modelling less clear-cut than one might first imagine. Modelling *for* (design models) as opposed to modelling *of* (models of the design),[1] for instance, and modelling (active engagement with the designing) *versus* model making (engagement of the model maker working for the designer). The architect may make many models to assist the development of a design without ever showing them to the client just as the finished model that shows the client a scaled representation of what they are commissioning may, in fact, hold little decision-making value to the architect: they 'know' what their design will look like.

Such dialectics have been around for as long as there have been models, but since the digital design revolution, we now have the potential for steady state modelling – a persistence in the evolutionary roles models can play, regardless of context. Curiously digital design and rapid prototyping have provided models with a wider role but at the same time makes the status of models even less clear-cut than previously; they have not necessarily freed the designer from traditional modelling frameworks.

This chapter looks at three case studies that highlight the dialectic between design model as clarifier, and design model as signifier. It will propose that there are concerns around modelling that will not be resolved easily, and that this is ultimately helpful to the designer. The first case study will refer to practice, and the increasing challenges of modelling the unfamiliar. This will be done by outlining a brief history of modelling at Gaudí's Sagrada Família Church (now a basilica) in Barcelona, probably unique in spanning analogue and digital modelling environments. The second will look at the difficulties encountered in design studio for a project where the positive effects of aging were positioned as a design driver, and how the proposed building and its model can become synonymous. The final case study looks back on an interactive wall surface and will discuss the dilemmas encountered when modelling performative

architecture: the designer has to become technical expert *manqué*, and the prototype the architectural outcome.

Learning from the Sagrada Família Church

Barcelona's new Catholic basilica, the Sagrada Família Church, was consecrated on 7 November 2010. Although the interior is complete, the exterior still has an estimated 15 years of construction towards completion including the two sacristies, six great towers that reside over the apse and crossing, and four towers over the main front. The project commenced in 1882 under the architect Francesc de Paula del Villar (1828–1901). He resigned a year later, and his plans for a modest neo-Gothic parish church were subsequently passed onto the young architect Antoni Gaudí (1852–1926). In his hands, the project grew from a modest place of worship to a basilica of such generous proportions and artistic expression that it became worthy of a papal visit in order to enact its consecration.

Gaudí led the project for 43 years until his death and in terms of constructed fabric, he had managed to complete the crypt beneath the apse – commenced by del Villar, the apse walls and most of the four svelte towers that close the transept to the east: the Nativity Façade. Despite being such a small proportion of the proposed whole when he died, the project dominated his œuvre, being led by Gaudí for almost his entire career finally becoming his sole project for the last 12 years. His accidental death truncated such intense directorship, and it has been in the hands of several generations of successors ever since. In this last period – when it must have been increasingly obvious to Gaudí that the project would not be finished in his lifetime, he moved from looking at the building in detail as an *object* and considered it from an entirely different perspective, more as a *system*. This is to say, from representing the building as a scaled version of what it was to become (model *of*), he moved to an innovative framework representing how the building would be continued by his successors with his continued authorship nevertheless assured. He affected this by offering a model *for* instead of a *fait accompli*. To this end, he guided rather than directed future unknown collaborators by setting up a procedural roadmap, an applied geometry that exploited the properties of a special class of surfaces: doubly ruled surfaces.[2] I will discuss these in more detail later in the chapter, but first I will provide a little more context to give this account of a persistent model in action more traction.

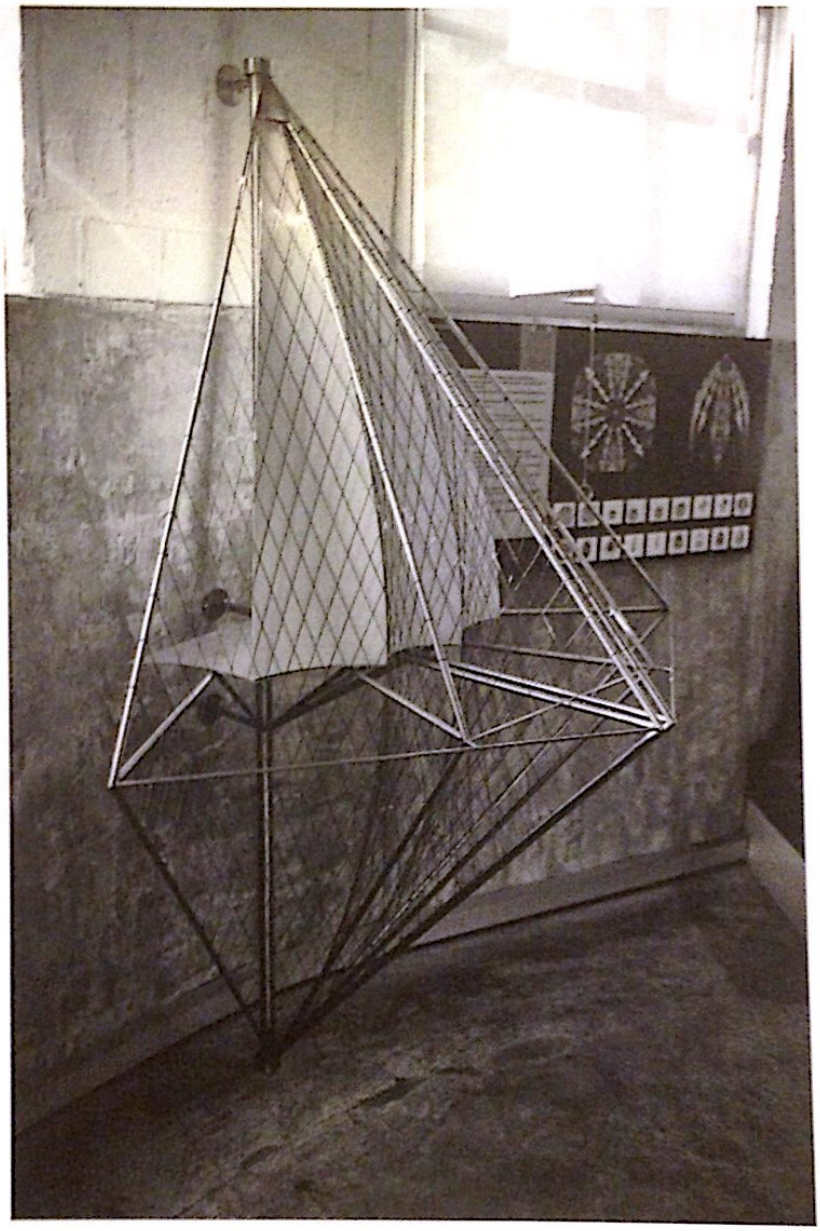
When we critically evaluate Gaudí, we can do so on far more framework dimensions than most other great architects. He can be evaluated 'stylistically', for instance, with bold attempts to align him with progressive movements of the day both at home and abroad; or he might be shown to have been one step ahead all the time; or even working beyond the fringes of such movements to the point that they might have been irrelevant for him – these are matters of conjecture as Gaudí wrote nothing about his work during his entire career. Quite a different analysis of his œuvre might be made that examines his work from a cultural perspective in order to position it within the many turbulent shifts taking place in society during his lifetime: Gaudí's architecture as a potential force for

change. Studying his work technically also offers yet another set of rewards for the commentator as his various innovations can be contradictorily pitted against the many instances of his apparent conservatism. Once Spain became more open to the world following the death of the dictator Franco in 1975, many more opportunities presented themselves to the fascinated wishing to investigate the strands of originality that appear to make Gaudí a unique architectural figure from any of the lenses that might be applied to his portfolio of projects, albeit modest in number but extraordinary in detail.

Against the enquiry into his work that blossomed post Franco and 50 years after Gaudí's death there is the backdrop of the continuation of the Sagrada Família Church itself in the absence of its originator. Many very prominent architects have railed against the continuation of the building during the decades after Gaudí's death, their concerns exacerbated by the presumption that the building suffers from three major deficits. The first is that Gaudí himself is not available to continue the design and direct the work, and for such a unique architect, this deficit is insurmountable. The second is that in the presumed absence of coherent and definitive instructions from the master himself on what to build (as opposed to how to go about completing the building), even if an exceptional architect of Gaudí's calibre presented him or herself in that role, in itself their contribution would vitiate the small proportion of the project actually built by Gaudí, which means that the building was best left as a ruin. The third presumed deficit is that Gaudí's working method was obscure and whatever plans he left were burnt during the destruction of his workshop based on site by vandals during the 1936–1939 Spanish Civil War. Although the models were trashed at the same time, it is the burning of the drawings that are always emphasised as the final impoverishment of opportunity for any would-be successors. It is the role of the models, the modelling, and their survival as remnants that I wish to platform here, as an additional and far richer framework with which to evaluate Gaudí's architectural contribution than could ever be served by drawing for such an architect. For not only do his models survive as intelligible fragments today, their production reveals a design process which, in the light of the inevitability of the construction going way beyond Gaudí's lifetime, offers a completely different perspective on Gaudí's way of working, and the idea of the persistent model that works alongside the building, evolving itself as the building evolves as a constructed project (Figure 2.1).

This point does not need to be laboured, as a condensed explanation of how the models were made in Gaudí's time and how they have functioned subsequently reveals new ways to scaffold design development through modelling that employs a *lingua franca*, in this case, doubly ruled surface geometries. There are only three such surfaces: the plane, the hyperbolic paraboloid (Figure 2.2), and the hyperboloid of revolution. In Gaudí's last 12 years, he worked exclusively with this set and complemented it with the helicoid, a singly ruled surface, and the more egregious ellipsoid, among others. The doubly ruled surfaces offer many practical advantages for they perform well technically: they facilitate the alignment of reinforcement, for example, in straight lines that coincide with the surface rulings. The surfaces are easy to describe spatially and the same process used to make the models both as scaled or full-size prototypes is also used by stonemasons to cut stone and the mould makers to make their moulds.

2.1
The model makers' studio: in terms of design process very little has changed since Gaudí's time despite the incursion of digital design



2.2
The underlying geometry for the sacristies: vertical hyperbolic paraboloids th intersect vertically giving fluted profile at base level and the elegant curved ed up to the meeting point a top of the tower

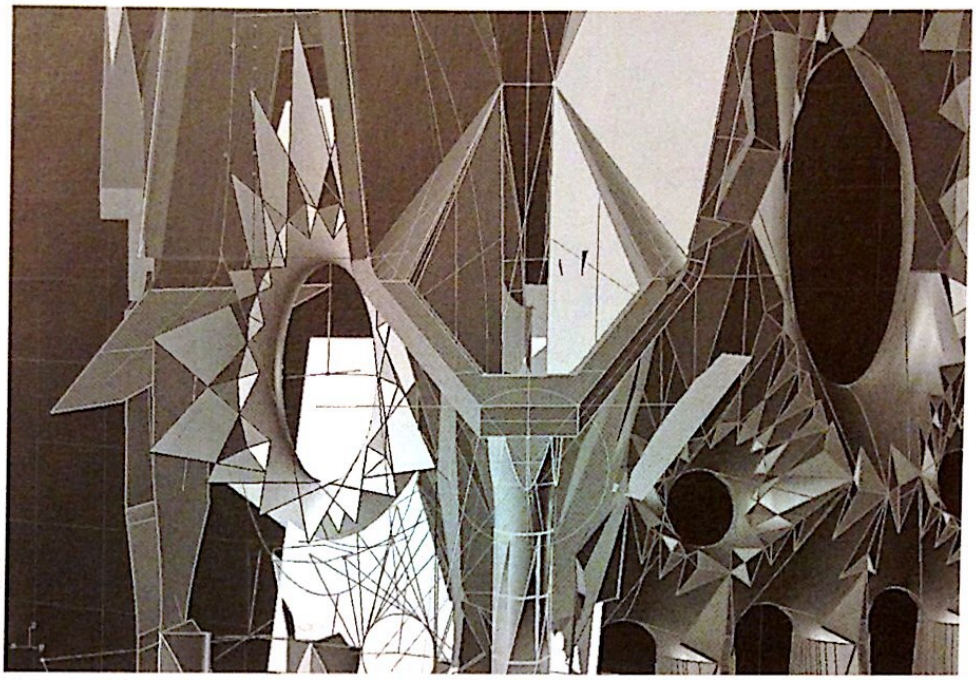
The surviving model of the sacristy tower (Figure 2.3) encapsulates the persistence that such a modelling tactic offers for design development to be in tandem with actual construction. There are two roles being played here for the persistent model. The first is the introduction of a parametric design approach, for Gaudí conceived of this model as the genotype for all the remaining towers for the building. The strategy is simple. He has selected two hyperbolic paraboloids that intersect vertically giving a fluted profile at the base of the tower with an A–B–A rhythm around the perimeter resulting in 12 concave surfaces intersecting at a point above the centre of the model. By varying the parameters of the hyperbolic paraboloids, the resulting silhouette for the towers can range between being tall and needle-like and the characteristically squat form of a pumpkin. Obviously the height is a parametric variable as is the number of component hyperbolic paraboloid surfaces and the surfaces' geometrical characteristics.

2.3
Restored gypsum plaster model, one of the two sacristies that Gaudí planned for the Sagrada Família Church in Barcelona. The 1:25 scale model is for a cupola that is more than 40 metres high. Gaudí made this model in 1922, four years before he died. Crucially it is the 'parametric model' for all of the 12 towers that remain to be built including the two sacristies. This image not only reveals the extent to which the models were destroyed, as relatively few fragments can be seen physically contributing to the restoration, it also reveals the success of Gaudí's strategy of using doubly ruled surface geometry to describe the whole project as a schema from which others could follow, given the manifest success in rebuilding the model from the fragments

Very few pieces of the model survive, but Gaudí had also committed the design to stone with a detailed engraving of the horizontal (plan) section of the tower which has survived beyond the torching of his studio in 1936 (Figure 2.4). An understanding of the theory of the composition combines with the material evidence – Gaudí was delighted to give impromptu lectures on site to his many young admirers (disciples) some of whom went on to advance the project after he died – so there has been a clear instructional legacy for his successors. The combination of the base profile and the surviving fragments of Gaudí's model (clearly distinguishable in the restored model) and the broader explanation of his theories by Gaudí during his impromptu lectures to visiting architects has ensured a continuity to the project that flies in the face of the unremitting clamour from ill-informed critics. Those who seriously question the validity of the efforts to continue the construction, in the main, have not troubled to visit the museum on site where even a cursory glance reveals the richness of Gaudí's framework for posthumous design progression. The completed interior, however, has prompted a pause for thought with at least one prominent senior Catalan architect, Oscar Tusquets, to exclaim in a major daily through the title of his article, 'How Wrong Could We Be?'.[3] Tusquets does not effect a full recant, but he acknowledges that the spatial aspects of the Sagrada Família Church interior are such that had the works been stopped as he and his fellow detractors wished upon the project three decades earlier, Gaudí's legacy would have been greatly impoverished as a result. This extraordinary and scrupulously honest admission is testament to the pudding ending up well in the eating; I argue that the making too provides further evidence of Gaudí's genius, in the way that he helped manage the process decades ahead of its enactment.

Working on the parts of the building that Gaudí did not specifically detail is, on the one hand, straightforward for the reasons given above – Gaudí's persistent model, but taking advantage of digital technology has clouded

2.4
Scale plan of the sacristy engraved onto a stone slab showing the horizontal section of the intersecting hyperbolic paraboloids

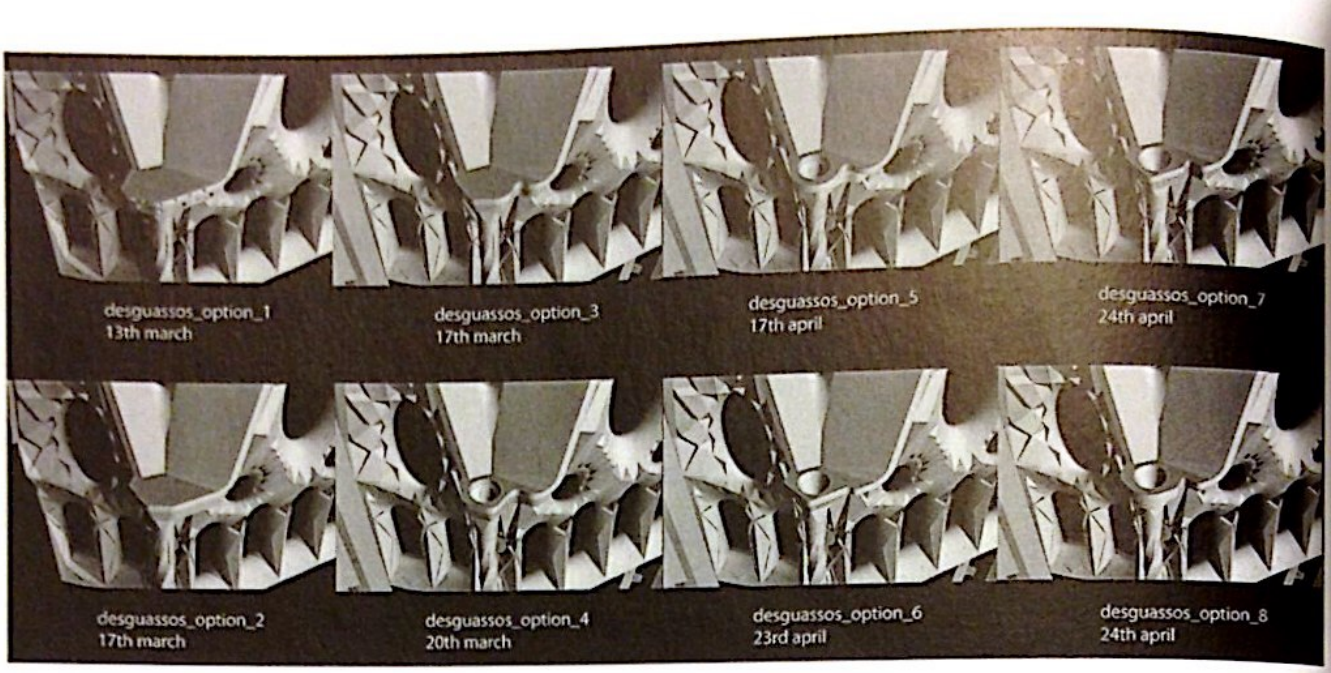


2.5
Sorting out the underlying geometry for the rainwater hopper collecting water from the *Sala Creuer* roof. Model: Mark Burry and Barnaby Bennett

matters somewhat. Looking at the design development of the *Sala Creuer*, the space 70 metres above the crossing (where the transepts and nave intersect or 'cross'), a number of persistent modelling dilemmas emerge that are counter-intuitive, at least to conventional digital design rhetoric. We do not have to go much further than reviewing the modelling of the rainwater hopper (Figure 2.5) to appreciate the limitations of parametric design, or 'flexible design' as we refer to it in our labours.

The *Sala Creuer* connects the six towers above the crossing to the main body of the basilica space below. Concretely it is the first drum of the main tower that acts as a gathering point for visitors emerging from the surrounding four towers dedicated to the evangelists, all in positions 45 degrees to the four cardinal axes, the adjacent tower over the apse, and the cross at the top of the main tower itself – a principal draw card for the non-vertiginous visitor. All the water falling onto the main tower drains into eight hoppers and thence into down-pipes. The hoppers, *desguàs* in Catalan, are simply stone funnels sitting in front of the major and minor window gable intersections into which the water drains invisibly from behind the parapets that connect the gables.

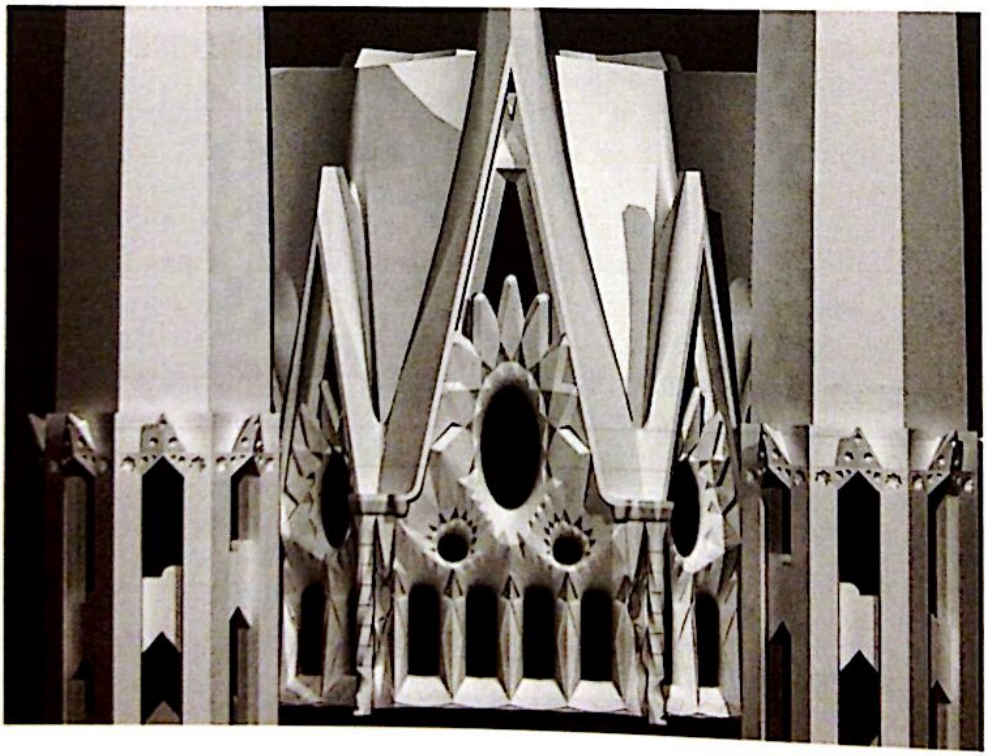
The whole of the *Sala Creuer* was modelled parametrically. It is unavoidably a very complex space approximately 25 metres both in height and diameter, but the limitations of the software tools have never been made more apparent than with the hopper design development. These elements, the hoppers, were not designed by Gaudí specifically for this location, but as with the sacristies, their presence elsewhere in the building provided us with a working model if not an actual archetype. It was not so much the continual time-intensive design refinement of each new version of these hoppers (Figure 2.6) and the inability of the parametric design schema to accommodate each iteration that surprised us, but the resulting workflow issues. We were modelling the unfamiliar, and each version revealed its deficiencies in steps along the way that were



2.6
Eight iterations of the design development for the *Sala Creuer* rainwater hopper – time-consuming variants with little possibility of exploiting parametric design software. Model: Mark Burry and Barnaby Bennett

different from each other. Typically we would agree that a particular version rendered in 3D met all the design criteria, not least inconspicuously performing its task. On that basis, a model at 1:25 would be made and with the advantage of parallax and binocular vision, a deficiency would typically reveal itself that had not been apparent in the rendered images. Some iterations would work at 1:25, however, only for a subsequent 1:10 scale version to reveal a visual problem that was not apparent at a smaller size.

The full-scale version, no doubt, could yet prove troubling, but we are still a year or two off seeing the built hopper *in situ*, but my point here is a



2.7
Rendered external view of the *Sala Creuer* showing the definitive version of the rainwater hopper. Model: Mark Burry and Barnaby Bennett

straightforward one. This design element is constrained to a geometrical approach that is used consistently throughout the building, but despite this, we had to construct each iteration from a primitive seed, not simply relax each new version from the previous by tweaking the odd parameter value. The model for the hopper persists, then, as a general description, not as a set of parametrically variable relational geometries (Figure 2.7). Arguably it is this set of decision-making criteria that ensures that Gaudí's final design for the Sagrada Família Church cannot fully 'self-design'. This is why completion of the building will continue to oxygenate its opponents' critique as artistic treatment overlays the geometrical schema, but this will remain at the level of detail rather than interfere with Gaudí's overall spatial narrative.

Atmosphere and attrition

The fact that even in modern times a building like the Sagrada Família Church can be more than five generations old before its inauguration, inspired us to run a transdisciplinary design studio taking up this point for senior students of architecture, landscape architecture, and industrial design at RMIT University in

2.8
Attrition: sea-worn boulder made from a former brick construction

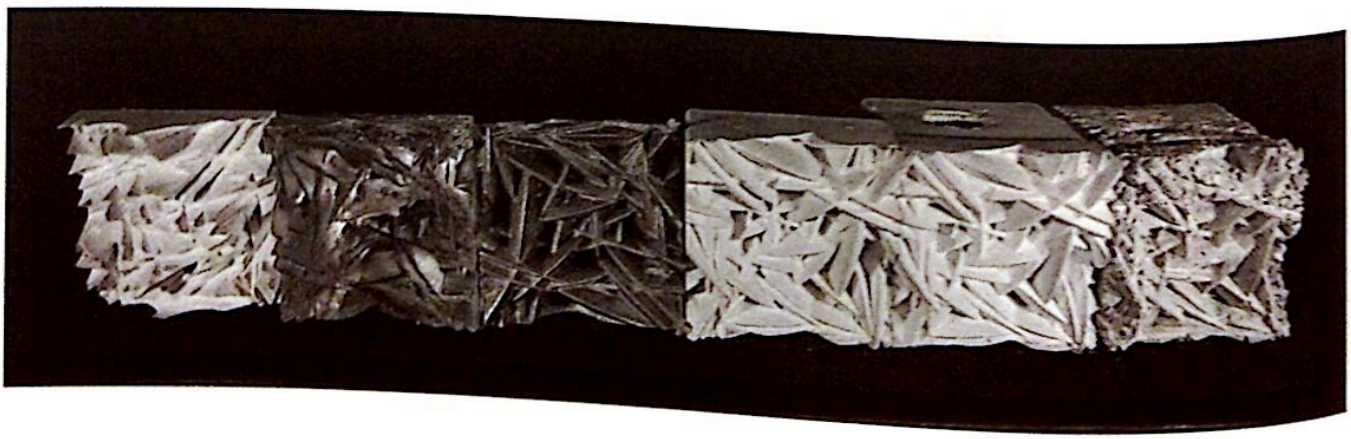
Melbourne, Australia (where I teach).[4] Could a model transcend the crystallisation of a building's perfect state the moment it is finished as universally captured by the media with scant deference to the vicissitudes of climate, season, time of day or age? Why presume the project's maximum value as being its condition on opening day, when as a capitally intensive outcome, buildings must comport equally well when not necessarily bathed in sunlight (*atmosphere*), and still wear their age with dignity (*attrition*)?

Students first introduced themselves to each other and us as teachers by seeking out and photographing examples of atmosphere and attrition to share as a class drawn from three distinctive design disciplines seeking to define a shared set of sensibilities. Among examples of 'atmosphere' one student included an exquisite image of smoke captured as the highly expressive but intangible descriptor of volume within space, a quintessentially fleeting impression of a unique moment as the shutter blinked open. 'Attrition', for example, was presented as a sea-worn boulder formed not from stone but from brick masonry lying almost as an equal among its naturally occurring peers (Figure 2.8). The students went on to design a public library in transdisciplinary teams. Following review, their infant project was wrested from their creative grasp and passed on to a different group while they went on to inherit a project from a different group. As a means to promote the status of the persistent model ahead of the vexed issue of authorship and ownership, each project sought to establish its own credentials ahead of any of its progenitors.

An example of a project that successfully transcended its 'owners' to the extent that I am so drawn to write about it here was *Sandy Toes*.[5] The group's model reigned beyond the group itself. The Sandy Toes library was set on the St Kilda shoreline, a seaside suburb of Melbourne. Looking at the proposal in detail, desert rose was the *partí* for a wall tiling system created for the project; desert rose is an unusually configured mineral with lens-like protrusions that sit upright from the plane of the crystal, arrayed in patterns not unlike the petals of a rose, hence its name, it offered a fascinating foil to the sand-filled blasts of wind (Figure 2.9). Depending on the tile locations, it was envisaged as being materialised from concrete, aluminium, silicone rubber, plaster and glass influenced by where and how it was being used (Figure 2.10). Curious in the extreme as a naturally occurring mineral, its digital modelling was a *tour de force*, in our view, and the circumstances by which it was designed to contribute to the aging of the building compellingly inspired (Figure 2.11). The desert rose tiles were

2.9
Desert rose, a mineral composed of gypsum, barite and sand, found in various arid locations around the world after the evaporation of a low-lying inland sea

2.10
Alternative materials used for digitally fabricated desert rose tile: from left to right, mould master, then glass, aluminium, silicone, gypsum plaster and finally, concrete. James Goscinski and colleagues



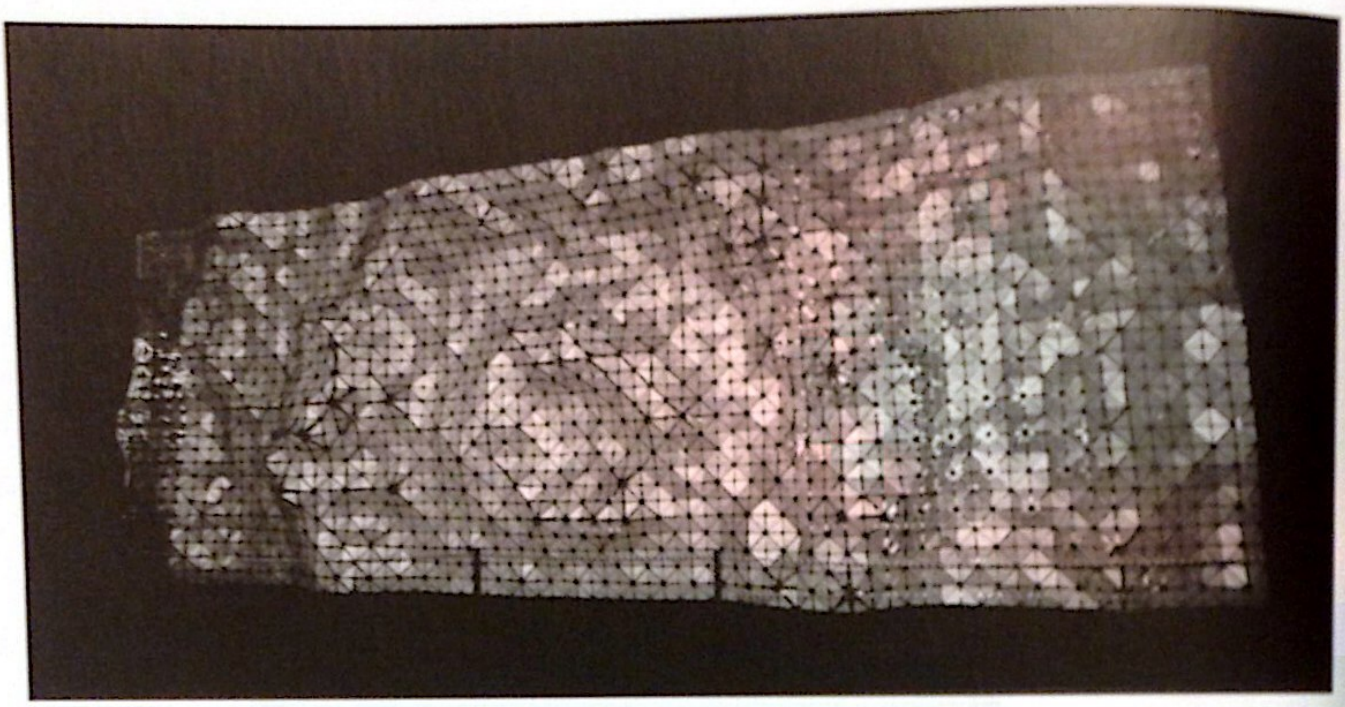
2.11
Digitally modelled desert rose, composed as a tessellating tile for a library project wall. James Goscinski and colleagues

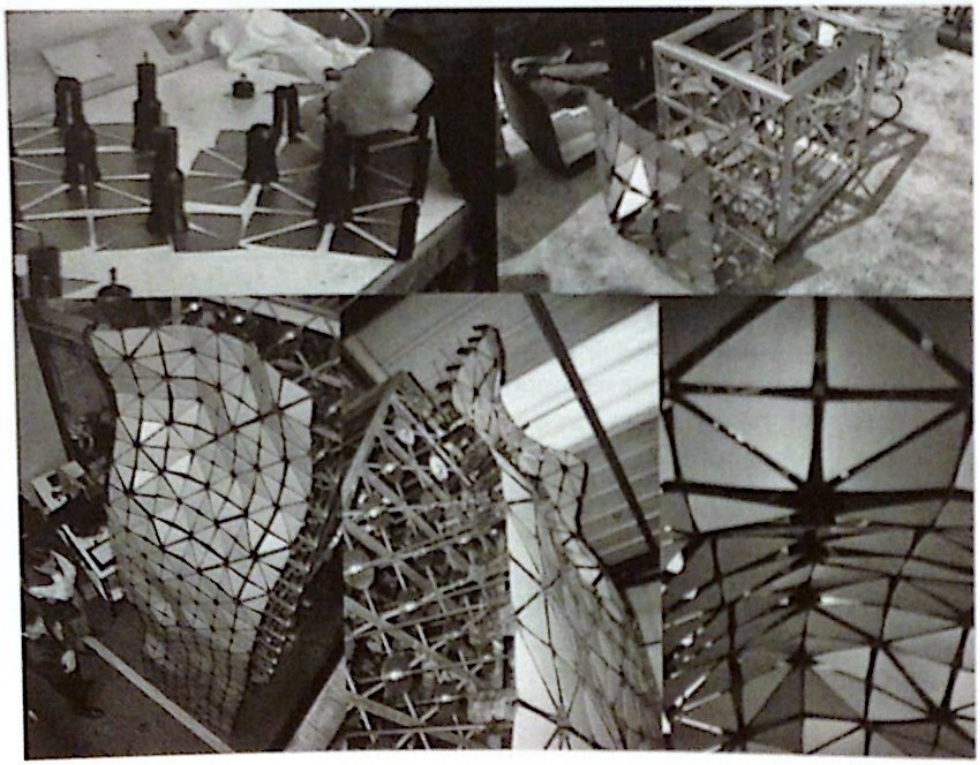
deployed as the perfect substrate for a plaster render in such a way that on opening day paradoxically the walls would be smooth with no sign of the underlying mineral lenses. Only through the action of decades of windborne sand would the specially mixed mortar be eroded sufficiently to allow the mineral behind the surface to manifest itself – the 'best days' of the building might not appear until several generations of library users have passed through the doors.

Performative architecture and the model as prototype

Needing little introduction ten years on is *Aegis Hyposurface*, the world's first responsive architectural surface (Figure 2.12).[6] Designed to react instantly to external stimuli picked up by sensors such as video cameras and microphones, a forest of invisible pistons operating 15 times per second pushed and pulled Aegis into a conversation with whoever triggered a response: both player and hyposurface form a reciprocal dialogue of movement. Germane to this chapter is the situation of model = prototype and prototype = completed artefact, which disturbs the normal sequencing of idea, conceptual engagement, design development, prototyping, industrial strength testing, and production (Figure 2.13).

Notwithstanding continual and ongoing refinement, essentially *Aegis* remains the permanent adolescent: the ultimate persistent model. Its continued





2.12 (top)
Aegis Hyposurface: inaugural exhibition of the first ever interactive wall surface at full architectural scale, in this case, 10 metres long by 3 metres high. dECOi Architects, 2001, ongoing

2.13 (left)
Scenes from prototyping *Aegis Hyposurface*, the prototype. dECOi Architects, 2001, ongoing

existence, beyond being a testament to the staying power of its originator Mark Goulthorpe, also draws attention to the yawning gap between what architects presume is their legitimately super-wide area of interest and the limits of their training and experience. This project is a persistent model from many perspectives. As with Gaudí, the project models a system as much as it tries to offer material existentiality, and in any case the surface is deliberately unstable: it is always meant to be on the move: flaccid *Aegis* is no hyposurface, it is a dead

surface. Its existence persists as a driver of young creative minds drawn to the same challenge as was faced by the original design team. A decade on and driven by more practical imperatives, students model interactive façades and roofs that respond to any of several climatic drivers – short-term and immediate, diurnal, seasonal and climate change itself. In the typical university environment, how on earth are students able to transport their ideas beyond constrained architectural concerns when hardly any institution manages to offer meaningful opportunity for transdisciplinary engagement between artist, architect, technologists and scientists? The persistent model needs to keep persisting in helping drive the agenda beyond that of sole author, beyond discipline silos, and into open space whence creative teams can truly work to their collective capacity, beyond the sum of the constituent individuals. This might start with the student experience.

Concluding comments

Ultimately it strikes me that the 'persistent model' is the model of a *design system* and not merely the model constrained to the representation of prospective *artefact*. It is tempting to see this as a condition of digital design, virtual modelling, and animation – actual and simulated.

I have selected examples that cross the digital divide in order to demonstrate that this take on the persistent model, that is the system model, transcends the distinction between considerations exclusively constricted to analogue or virtual environments. In this way we can argue that digital design certainly facilitates the creative opportunities that the persistent model invites, but cannot necessarily be assumed as the sole propagator for this extension. The work emerging from Gaudí's final years demonstrates that not only can 'ideas' persist beyond their authors, the model can itself be an intangible agent for the persistence of the ideas. My selected examples offer a counter-argument for the exclusivity of the ephemeral that demands a special place in design culture for, inconveniently to the design taxonomist, the persistent model can be rudely tangible yet inclusively ephemeral all at once.

Notes

1 I am indebted to Ranulph Glanville for this distinction: see R. Glanville, 'Keeping Faith with the Design in Design Research', in Alec Robertson (ed.), *Designing Design Research 2: The Design Research Publication*, Cyberbridge-4D Design/drs2.html, De Montfort University, Leicester, 26 February 1998.

2 Ruled surfaces are those which for any point on the surface, at least one line passes through that point and lies on the surface in its entirety. Doubly ruled surfaces have at least two lines meeting that condition which, for the hyperbolic paraboloid and hyperboloid of revolution of one sheet, leads to curvature in two directions (convex and concave).

3 Oscar Tusquets, 'How Wrong Could We Be?', *El País*, 'Architect and designer Oscar Tusquets wishes to apologize for a controversial 1960s manifesto.' 5 January 2011, http://www.elpais.com/articulo/english/How/wrong/could/we/be/elpepueng/201101

05elpeng_3/Ten. While being unequivocally critical about aspects of the detailed treatment post Gaudí, Tusquets concludes his short but bold recant on a decades-long opposition to the Sagrada Família basilica's completion with 'I don't know if the completed work will be the best architectural project of the last century . . . but it will certainly be the greatest religious building of the last three.'

4 *Atmosphere and Attrition:* Senior student design studio, 2nd Semester 2008, RMIT School of Architecture and Design, Tutors: Mark Burry, Malte Wagenfeld, Juliette Peers, and Barnaby Bennett.

5 *Sandy Toes* project: Original Concept: Murray Cook (Industrial Design), Wie Mun Lee (Landscape Architecture), Marianna De Delas (Architecture), Developed Design: Simone Steele (Industrial Design), Luke Martindale (Landscape Architecture), Brahman Perera and James Goscinski (Architecture).

6 *Aegis Hyposurface*: Concept: Mark Goulthorpe of dECOi Architects 2000. Design Team: Mark Goulthorpe, Mark Burry, Oliver Dering, and Arnaud Descombes. Ten years later, the hyposurface is still undergoing development by Mark Goulthorpe at MIT.