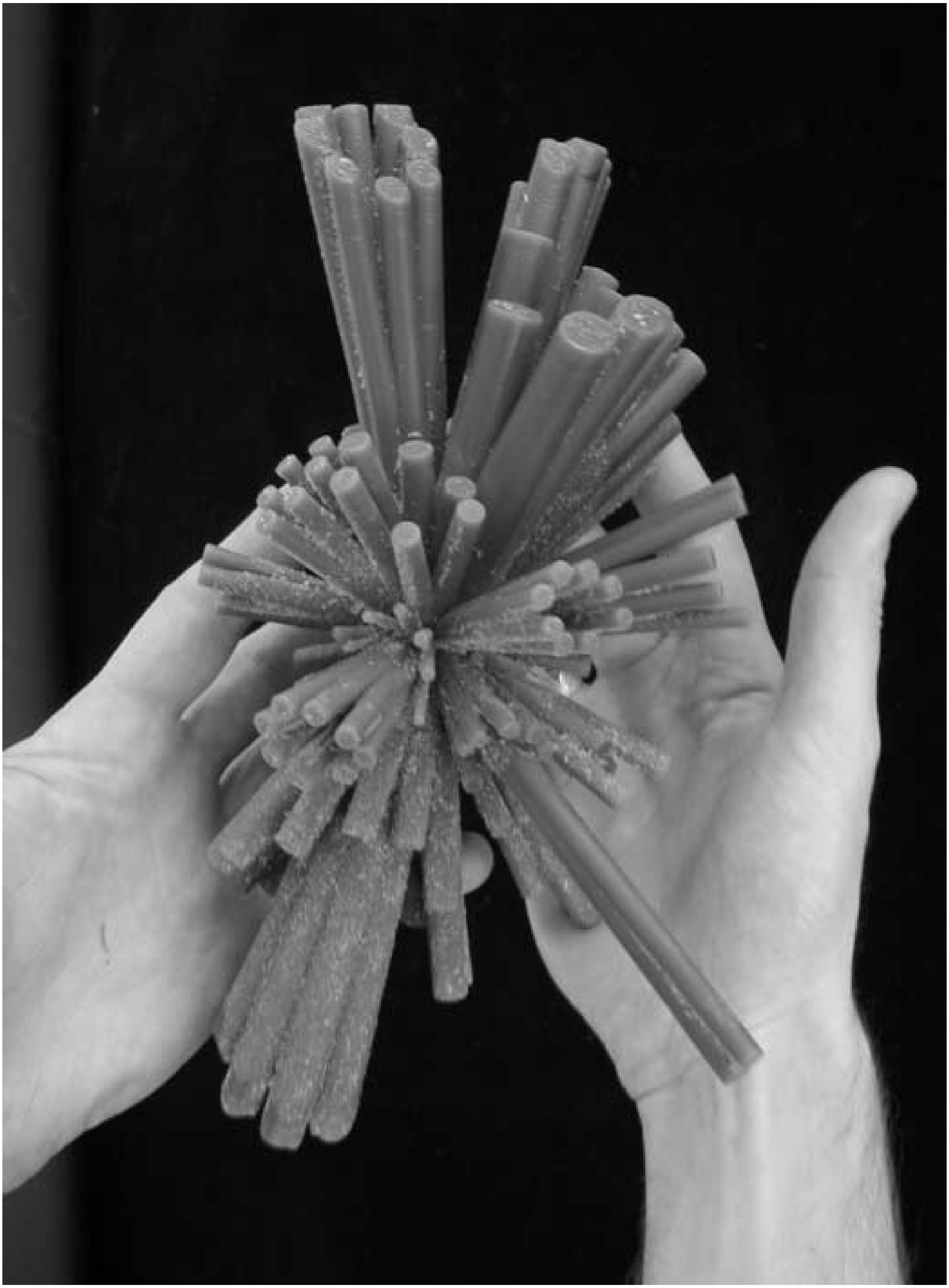

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Developments in computer-aided design and manufacturing are breaking down divisions between designing and making, opening up radical new opportunities for the practice of architecture.

Transgression from drawing to making

Bob Sheil

Design: *'v. to make a detailed plan of the form or structure of something ... v. to contrive, devise, or plan something. n. a drawing or other graphical representation of something that shows how it is to function or be made. n. the way in which something is planned and made.'*

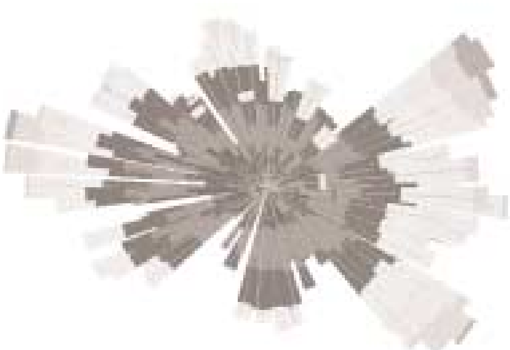
Make: *'v. to assemble something from constituent parts. v. to form something by performing the movements that it requires. n. the process of making something... n. the way that something has been made ...'* (Selected from *Encarta* dictionary: English online version, 2005)

For almost 500 years the role of the architect has been defined by the status of the drawing, and hence by design:[1] first, as a visionary medium that could represent the three-dimensional world through ideas; then as a process that developed and projected intellectual meaning; and finally as a document that conveyed information sufficient to translate these ideas into matter. It is drawings of the latter kind, their association with the architect's expertise in making and evolution towards present-day digital formats, that I wish to discuss (Harbison, 1994). In doing so, I will address the interdependency between design and making in architecture, and identify why this connection has become critical and inseparable as design information becomes a means of control in contemporary manufacturing processes.

Within the past ten years, the architectural drawing has changed its status more fundamentally than at any time since its inception in the Renaissance – and therefore so, too, has the role of the architect. As a designer, this change has caused a basic shift in the positions I would normally have occupied in the sequence of events that take ideas into the world. Whereas in the past I developed particular information for purposes of negotiation, my work now transgresses the frontier between representation and the generation of physical artefacts. In the era of CAD/CAM (Computer-Aided Design, Computer-Aided Manufacturing), embedded within my representations are codes that can choreograph the behaviour of manufacturing machines. Design representations that were open to negotiation and reliant on the expertise of others may now be read as direct instructions to make. As a result, whether I have the appropriate expertise or not, I am engaged in a process of 'Design through Making' (Sheil, 2005). I can either embrace this as an opportunity only dreamt of by my predecessors, or I can ignore it and forgo any direct influence my craft might have upon the nature of making things.

Matters of transgression 1

Taking the place of the pre-Renaissance architect – whose tacit knowledge, close association with the craft guilds, and largely verbal instructions, honoured him with the status of master builder – the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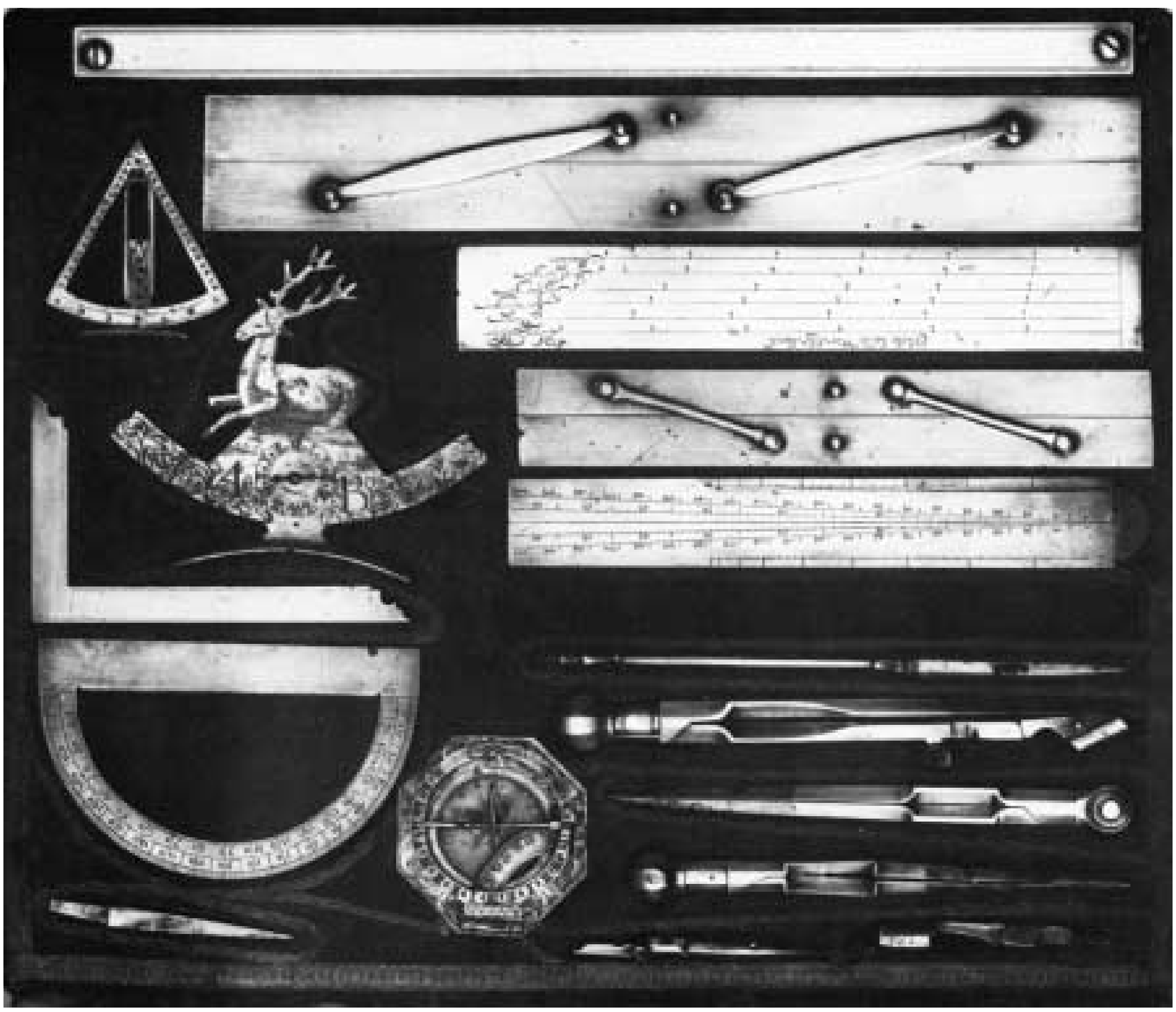
1 Design and manufacture of the 'B of the Bang'. Designers: Thomas Heatherwick Studios. Structural consultancy: Packman Lucas. 3D solid modelling was critical in determining the method and sequence of fabrication. *a*, 3D wax print of core configuration (1:100); *b*, wind load analysis; *c*, fabrication (see Sheil and Packman, 2005).

post-Renaissance architect sought a superior position through the comprehensive nature of drawings that projected both imaginative and material meaning. This instilled a distance from the physical act of building by distinguishing an architect's expertise as something more than a matter of prowess in construction, placing architects in the position they occupy today: a profession whose expertise in design is called upon in the making of buildings. Architecture came to be regarded as something more than building – as an idea, typically making its first appearance as a drawing, the product of the architect. So the authorship of ideas for buildings could be claimed, and the template from which to build the idea was generated.

Drawings of the pre-digital era were made with tools that had altered little through centuries of use: the compass, the ruler, the set square, the pen, and so on *[2]*. Conveying expertise in building fabrication, geometry and draughtsmanship, architects' drawings attempted to impart authoritative information in such a way as to provide content essential in the costing and making of buildings. It was the particular manner in which these drawings informed skilled craftsmen and labourers, and displayed knowledge of fabrication parameters that determined the architect's claim upon expertise and authority in the design and making of buildings (Saint, 1983).

Following the introduction of standardisation and mass-production in the nineteenth century, when divisions of responsibility and specialisation established formal distinctions between the professions of building and architecture, the drawing evolved into a document of legal status and restricted content. As raw materials were mass-manufactured into products such as roof tiles, glass plate and ironmongery, architects were offered a palette of standardised elements from which to select, thereby gaining valuable time to expand their repertoire of work. The need for knowledge in artisanship waned, to be replaced by a need for ingenuity in the utilisation and adaptation of 'ready to use' components. Hence, architects' face to face contact with craftsmen and builders became less frequent, non-verbal and less collaborative, and the exchange between drawing and making was altered.

The establishment of the General Contractor and Site Agent gave rise to a strictly defined relationship between the designer and the builder, and drawings became increasingly contractual and specialised in their purpose. Nevertheless, unlike the innovations that led to the cultural and technological ideals of the twentieth century, methodologies and disciplines in architectural design had altered little in their medium of communication since the days of Alberti. Although a vision for a profession of integrative design leaders in an increasingly



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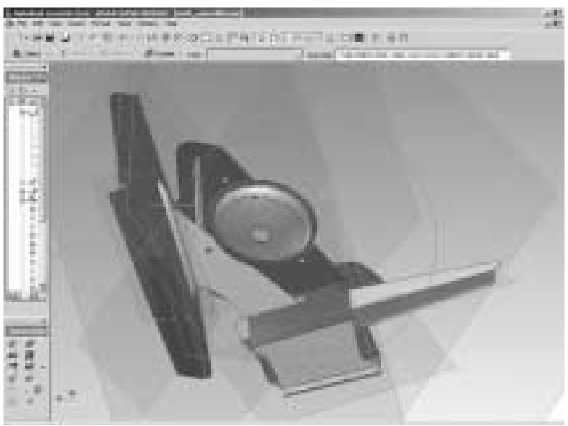
technological and complex society existed (Gropius, 1935), necessary interdisciplinary mechanisms did not. Architectural drawings of the last century reflected properties similar to those of the nineteenth or eighteenth. In parallel, a disparity also existed between the relative disorganisation of the building industry and the efficient industries of manufacturing that supplied its components. Subsequently, although it was constrained by contractual limits and the diminishing tacit knowledge of the architect in making things, the architectural drawing continued to perform the role of translating knowledge for application in making buildings. As a result, it would still have been common for many practising architects, from as recently as the mid-twentieth century, to have a working knowledge of the majority of materials, processes and details inherent in their proposals.

By the end of the twentieth century this was no longer the case. The medium of drawing and organisation of the building industry underwent the first phase of a revolutionary change. With entirely new tools and working relationships, making drawings evolved into a complex discipline of generating and managing multi-media information. The drawing was no longer a static document, but an evolving bank of parametric data from which multiple subsets were extracted. Constructing buildings involved a repertoire of knowledge in products, techniques, environments and legislation, tied with extensive levels of liability that were beyond the scope of the individual (Groak, 1993). The building came under increasingly stringent regulation, necessitating specialist fields of expertise. Consequently, as architects' skills in the design of information expanded, their loss of individual expertise in making buildings accelerated. Their link with making was almost severed and so too their conventional position as leaders in the building design process. Concurrently, the terms 'design' and 'build' were seen and practised as separate entities, the connections between them as negotiable, and supervised by independent professions.

Questions of expertise and protocol

Below this simple outline lie questions that challenge the scope of architectural expertise and, for the purposes of this paper, its relationship to making. For while they have grown apart for centuries, within the past decade circumstances have emerged that challenge this separation at a fundamental level. The source of this challenge is the integration of digital fabrication technologies (CAD/CAM) into mainstream design protocols. Those who make drawings are now capable of simultaneously making information that is directly used in making things *[1]*. This information not only



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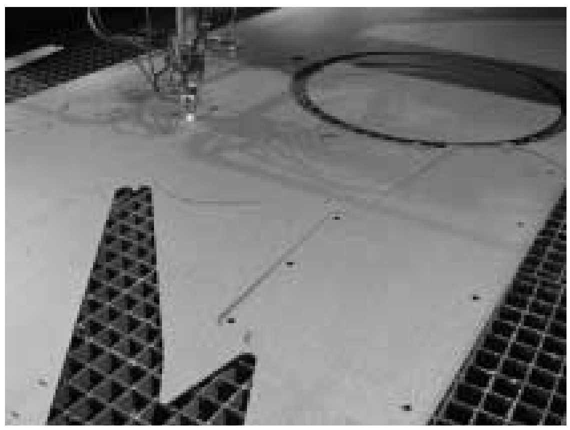

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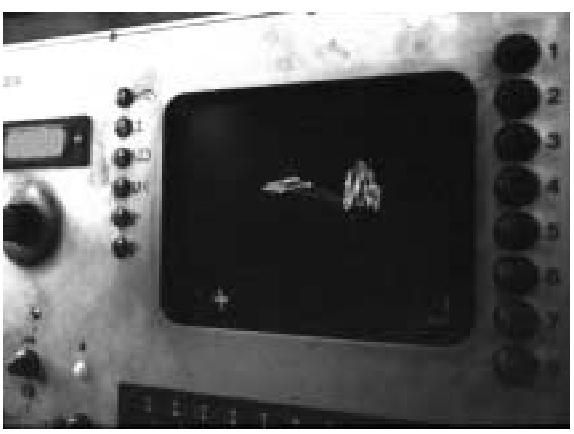

3b

3d

2 c1600 set of brass instruments in green leather case (see Hambly, 1982: 42).

3 Making in the machine, a preview of fabrication. Design and fabrication of architectural components by sixteen*(makers) and Nick Callicott at Ehlert GmbH, Weinerode, Germany 2004 (see Callicott, 2005).

determines the exact geometric coordinates of the component, but dictates the behaviour of the selected manufacturing tool. As an everyday matter of design consideration, the maker of the drawing can now view a simulation of the fabrication process, and assess the machine's ability to perform the task *[3]*. So the maker of the drawing is sharing a territory that was hitherto the exclusive realm of manufacturing experts: forming judgement on the basis of fabrication feasibility. As a result, the evolution of divisions in expertise and labour between designer and maker is being reversed. In short, while the discipline of architecture continues in the realm of generating ideas for buildings, the drawing is no longer a document where content is entirely dependent upon translation by others, but forms a direct code to make. The maker of drawings has become an operative in the making of things, and will therefore require appropriate interdisciplinary expertise – not a specialised practice, but a generalised one.

In Norman Potter's stirring, deeply political book *What is a Designer: Things. Places. Messages* (Potter, 1968), simple answers are shown to be elusive without reference to social, professional or methodological context. While the words of this skilled cabinetmaker are addressed to students and practitioners of all kind of design, Potter singled out architects as embroiled in work that is 'exceedingly difficult and subject to every conceivable restriction', and challenged the extent to which their expertise bridged the gap between 'promise' and 'fulfilment'. Potter's observations were made when the gap was widening to the point of being unbridgeable but, as outlined above, significant means to do so are now embedded within design media. What remains open to question is the architect's knowledge and experience of the vast array of manufacturing disciplines involved, some advanced and specialised, others centuries old. Making buildings requires knowledge not only in the world of information exchange, but in the world of making things. Such an endeavour requires critical traits that are not only familiar with the tactile and the physical, but also the analogue and the digital *[4]*. This is a tacit expertise that designers must reacquire to fully engage with the opportunities of digital fabrication. The post-digital architect needs hybrid abilities and occupies a place between the analogue and the digital world, where design and making are synthetic activities in practice as well as intention. It recalls a colloquial term that inverted its meaning in a previous period of revolutionary change.

A Jack of all trades

It is thought that the phrase 'Jack of all trades' came into popular use sometime before 1600 (Morris, 1988). Jacques, the French colloquial term for tradesmen, was also the name associated with the leather jerkin they wore, hence the term 'Jacket' in English. Since the late nineteenth century, when the expression 'master of none' became attached, the phrase has commonly been associated with disparagement and superficiality. A person labelled in such a way may be recognised for a range of abilities, but lacks a distinct specialisation that marks them out. This negative slant is contrary to its earlier meaning, which was coined as a term of praise and admiration in recognition of people who had the talent, creativity and will to perform a broad scope of work. In the 1600s a 'Jack of all trades' was admired for his appetite to learn, acquire and practise new skills, for his flexibility and diverse experience. The multi-tasking, cross-disciplinary and, for all we know, highly innovative Jack of all trades was valued by context, not by comparison to the extraordinary achievements of dedicated specialists in practice at the same time.

The shift that positioned narrow and deep expertise above that which is broad and shallow took place as the new twins of industrial standardisation and professional practice emerged in the 1800s. Following the Industrial Revolution, skills became more consistent, specialised and factory-based. Abilities in set, repetitive tasks were in greater demand than flexibility. Standardisation, which led to products that would perform with predictable results, informed not only the manufacturing culture, but divisions of labour and skill that were further reinforced by the new status of the professions. These developments continued to shape all manner of human preoccupations for a further two centuries and, as a consequence, the changes we are now beginning to see recall characteristics of pre-industrial adaptability. Across multiple activities in business, industry and artistic realms, strict boundaries that once determined the scope of knowledge and skills required are dissolving. Frequent use of terms such as interdisciplinary, multi-task and multi-service indicate that broad input and diverse experience is increasingly promoted as an essential asset in today's workforce. So we see in the early twenty-first century a shift away from specialisation to a world that recognises the virtue of hybrid skills, a Neo-Jack of all trades to be admired rather than disparaged.

Making by drawing

Digital fabrication (CAD/CAM) has been a resource of manufacturing industries for over 50 years (Callicott, 2001) but has only recently appeared in professional architectural practice, largely as a result of the interface afforded by advanced drawing techniques (CAD). G-code, the script required to guide computer numeric controlled (CNC) machinery is now generated by the ability to export geometric and binary data in the appropriate format within the software package. Command of a basic knowledge of the programming language is no longer a requirement to use CNC machinery to carry out common 2D and 3D subtractive tasks such as milling, cutting and folding. Together with new additive processes such as Stereolithography (SLA), Fuse Deposition Modelling (FDM), and Selective Laser Sintering (SLS),[2] digital fabrication processes also provide the means to fabricate customised objects of a complexity that would have been prohibitively difficult or costly to make in the past. The key to

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bridging the gap has been the incorporation of digital fabrication functions within the CAD interface. As CAD/CAM becomes a core tool in the construction industry (Kolarevic, 2004), it is core skills in the visual manipulation of this interface that will project designers into a primary position in the fabrication process.

The need for designers to understand manufacturing protocols is evident, but it must be emphasised that the requirement for skills in visualising ideas remains undiminished: interdependency between design and making is more essential and critical than before. Designers with hybrid skills can relocate to the centre of building production, with a powerful array of tools to convey propositions that are fused with the information to make them (Timberlake, 2003). As the distinctions between both disciplines become blurred, design will be understood as neither drawing nor making, but both. Design will transgress rather than merely translate the conversion of ideas into matter, and architects will design through making.

Nevertheless, difference as well as interdependence must be recognised. The disciplines of making and craft involve engagement with physical and tactile attributes that are inconsistent and variable. Real wood has grain and knots, and alters its behaviour long after it has been cut to shape. Plate steel distorts differentially where varied heat is applied, for instance by a concentration of the plasma cutters tool path in one area. A fold in a drawing is not made

4 Between the analogue and the digital. Investigation into the merger of traditional with digital fabrication techniques utilising cast pewter, laminated walnut and three axis CNC milling. Martin Xavier Perez Jensen Broby, The Bartlett School of Architecture, 2005.

in the same manner as a fold in a chosen material of varied ductile quality. It is a feature of early investigations into digital fabrication that they have been applied to relatively stable and uniform materials such as fibreboard and polymer composites. Some implications of this were explored by Patrick Harrop in his paper 'Agents of Risk', given at the 'Fabrication' conference held by ACADIA (Association for Computer Aided Design in Architecture) in 2004: 'When we make, instead of predetermining action, we discover a map of engagement. We play by challenging and resisting material. In turn, it reveals an intentional resistance that provokes yet another challenge, and on and on.' (Harrop, 2004)

Matters of transgression 2

Architectual research aimed at direct engagement with the physical and tactile process of design through making has to be reported in terms like that of any other research discipline. Even though the purpose of the work (the production of physical artefacts) largely involves a process of trial and error, which is followed by visual, tactile and behavioural assessment, the work is translated into another medium or place (text and image) for the purposes of documentation and sharing. In doing so, the purpose of posing design questions through the act of making is countered by auxiliary issues imposed by this translation: such as, how to convey the scope of the work when physical and tactile attributes are essential to its purpose and understanding? Or more fundamentally, by what means can the tacit aspects of design and making be quantified when practices of trial and error are essential to its evolution?

This matter of translation is central to the problem of how we define these aspects of architectural design as research. It is a model akin to the everyday experience of professional practice, where a process of hybrid and synthetic working is required in order to deliver the most complex assemblies of the artificial environment. Within architecture, fields of research such as theory, technology, history, materials, culture and sustainability are well defined and have a tradition, whereas design itself – the core activity of a practising architect – occupies little space on the research shelves of architectural libraries and a similarly small proportion of research funding. This may suggest that design is a somewhat intangible element that envelopes the other constituent parts of architecture and cannot be readily accounted for or assessed. This is perhaps an understanding that recognises how design strategies often lead to propositions that are based on what not to do, rather than what is usually expected, or what becomes a norm.

Design pursues the need to be different, novel, and responsive to change in all aspects of its meaning, and therefore involves a degree of risk-taking and experimentation. Furthermore, design is a live practice for which the primary documentary resource is either drawings or buildings in which there is little time for academic documentation on how one was translated into the other. Compounding this are influences familiar to all designers engaged in seeing their ideas through to artefacts: the role of conversation, acts of collaboration, and the ensuing acquisition of tacit knowledge that fuels an appreciation and command of trial and error.

Design through making

It is now possible to envision how some of these questions may be examined if we return to the prospect of design information that is digitally integrated with manufacturing processes. Leaving aside for a moment questions on expertise and skill, transgression from drawing to making via CAD/CAM methodologies is a process that is traceable. The translation of ideas into matter forms a dataset that determines rather than negotiates the means of how its content is altered from information into matter. In this sense, another evolution has occurred in parallel with the shift surrounding expertise. The process of design has become more transparent and therefore will provide evidence of its place as a central agent in architectural development. CAD/CAM will bring greater exposure to the value and expertise of the designer who, aided by powerful visual tools, will transgress into matters such as workmanship, skill and assembly, as well as innovative information design. On a large scale, building information models (BIM) are developing as virtual building sites where the designer is operating in collaboration with consultants, fabricators, suppliers, even crane operators, on live data that is adjusted as 'built' information. Valuable time and flexibility can be gained in this realm, but most important of all, qualities of conversation, information trail and the subsequent adjustment for error previously denied to the design team is also acquired.

Pursuing this, I may now refer to work that has explored this territory of transgression, that of sixteen*(makers),[3] a research group at The Bartlett School of Architecture. Our work explores questions surrounding design, fabrication, use and adaptability in architecture. Initially, the group was formed in the early 1990s out of a motivation to engage as designers with the physical and tactile aspects of production without a dependency upon drawing. In the course of the subsequent transition from analogue to digital practices, the tacit experience we gained by learning how to make has become a valuable foundation upon which to understand and exploit the implications for design practice of digital fabrication techniques. Approaching this shift from 'the other side' has informed us about how the implementation and adaptation of digital manufacturing processes is a bi-directional transgression. It is not merely an efficient new facility to enable innovative design, but implies that questions of fabrication design may be considered and tested at a far earlier stage than we have become accustomed to in recent decades. In other words, sixteen*(makers) investigate questions on how we design, as well as what we might design.

Works of transgression

The first and second stages in the work I am going to describe have been discussed in Nick Callicott's *Computer-Aided Manufacture in Architecture – The Pursuit of Novelty* (2001). 'Shorting the automated circuit' ('STAC', 2000) and 'Blusher' (2001) were early attempts to reposition design input in the context of emerging hard and soft technologies. In 'STAC', the work exists as object, system and event, where the overlap creates an opportunity to develop extensions to existing design practices through a direct relationship with the manufacturing medium. Consisting of a hemispherical sensor array fabricated in FDM (Fused Deposition Modelling), the assembly constructs an interactive relation between site, audience and representation, which is fed back to the manufacturing process. The sensor array is a tool informing subsequent mutations of itself, as the data it gathers on local environmental conditions regenerate the code of the original design file.

In 'Blusher', the loop from object to manufacture and back was expanded to include modifications generated by the less predictable and somewhat erratic presence of a human audience. Where the previous work was sited for only a short

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5 Kielder Park, Northumbria, UK, sixteen*(makers) 2005.

time on one location, 'Blusher' was developed for a touring exhibition with the purpose of being reconfigured in each venue according to context. It comprised an array of adaptable folded steel plates forming a scaffold structure upon which a network of sensors was housed. Although the plates could have been a set of repeating modules, they were designed with unique formal qualities around common attributes of having to stand up, lie down, or fix together, so that ideas of difference were imbued within the components of its figurative character. 'Blusher's sensory data was used to drive an active component of polycarbonate leaves which would flutter and blush in various ways according to the proximity and behaviour of inquisitive observers. By managing the history of this data, the object could begin to recognise familiar patterns of behaviour, suggesting that over time it might respond with greater certainty and thus inform its redesign for another location. The third work in this series, which I will discuss in more detail, is an ongoing project that responds to our appointment as architects in residence by the Art and Architecture Partnership at Kielder (AAP@K) in Northumbria.

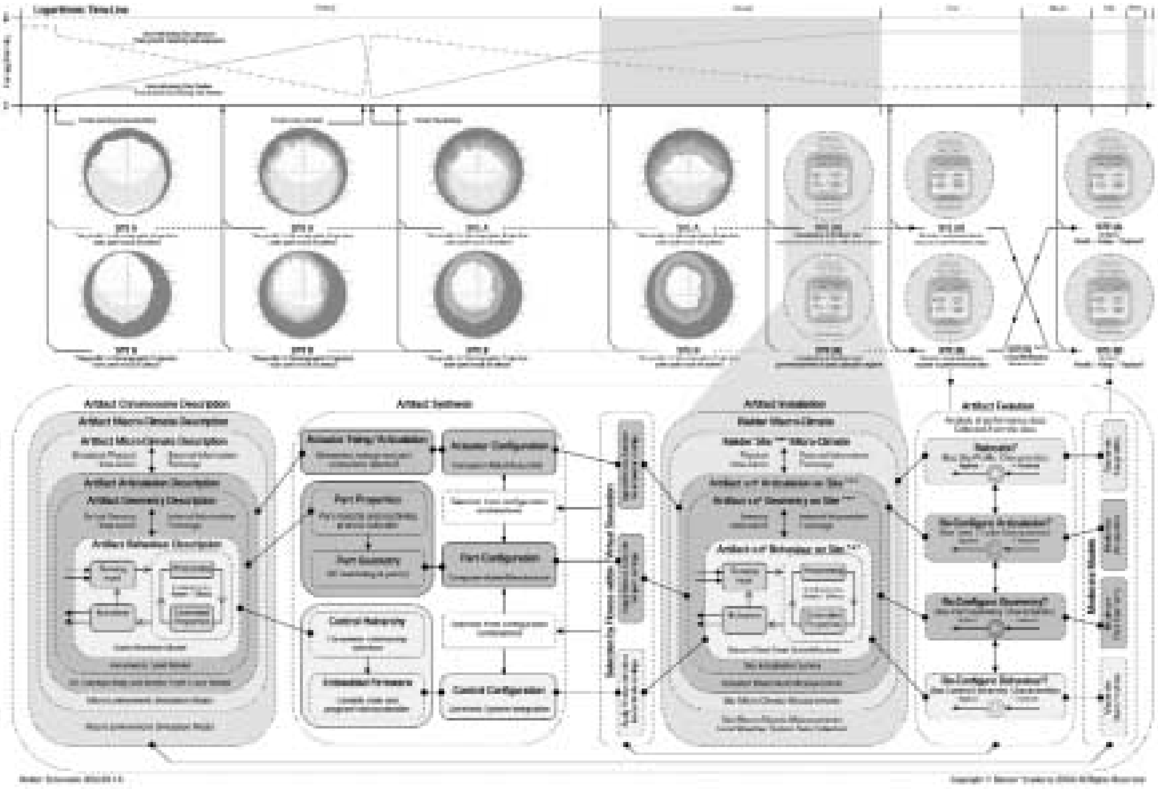
Architects in Residence

AAP@K is known for commissioning works such as the 'Belvedere' by Softroom and the 'Skyspace' by James Turrell. Coordinated by curator Peter Sharp, it is supported by several local bodies, including The Forestry Commission, Northumbrian Water and Tyndale District Council, and together they share interests in 62,000 hectares of land centred on the UK's largest reservoir and surrounded by one of Europe's largest managed forests *[5]*. For over a decade, AAP@K has organised residencies for artists, but to date all architectural appointments have been commissions for specific works. Ours is the first architectural residency, held jointly with the practice London Bloc Architects. A specific outcome did not have to be identified early on, but rather the outcome was to remain entirely open. Constructed in such a way, the residency implies we should start by revealing what it is that we do, and following on, explore the role for architects and architecture in such a place. Practising architects are rarely if ever afforded such an open-ended position. Without a specific brief or a defined group of users, our starting point became the site itself, a vast rolling landscape that has been the source of a significant proportion of Britain's timber for construction over the past 50 years.

The management of industrial forests is increasingly concerned with the visual impact of harvesting strategies on the landscape. The integration of onboard global positioning systems and 3D mapping data allows the forest to be farmed on a highly granular level. Micro-environmental conditions of topography and soil condition are tracked against historical and projected weather and growth data. Forestry management has entered a realm of 'designing' harvesting patterns beyond utilitarian or pragmatic needs. So the manufactured landscape has begun to lose its industrial aesthetic and become concerned with questions of the picturesque. What were once ad hoc conditions of the forest territory, such as edge, canopy, ground, and density, are recognised as qualities that may be continually redefined by an architectonic management strategy. It is in this shift in the nature of how the landscape is planned, constructed, developed and managed that our residency has sought a beginning. Furthermore, overarching the context of a change in technique, it is on change as an environmental presence and force that the project has become focused. To this end, the work has involved designing and making a series of bespoke surveying instruments or 'probes' to explore how change is measured and taken into account in forming architectural strategies. As an everyday task in practice that typically resides within three dimensions, our survey-in-residence asks if design can be directly informed by, and respond to, dynamic conditions. The probes therefore perform another purpose: as well as monitoring change they will themselves respond to change and evolve as architectural interventions.

Making design tools

The design of the probes is driven by two principal factors of the site. First, the qualities that interest us are constantly changing and require surveying tools to measure difference rather than the static characteristics of any given instant. Second, change varies in time-scale and speed, so the tools must be embedded for a sufficiently long period of time to capture those changes, during which they must be remotely accessible, both to collect data and possibly to re-programme them. These criteria necessitate the design and fabrication of new instruments that seek out rather than simply measure. Their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Artifact Installation
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Part Geometry
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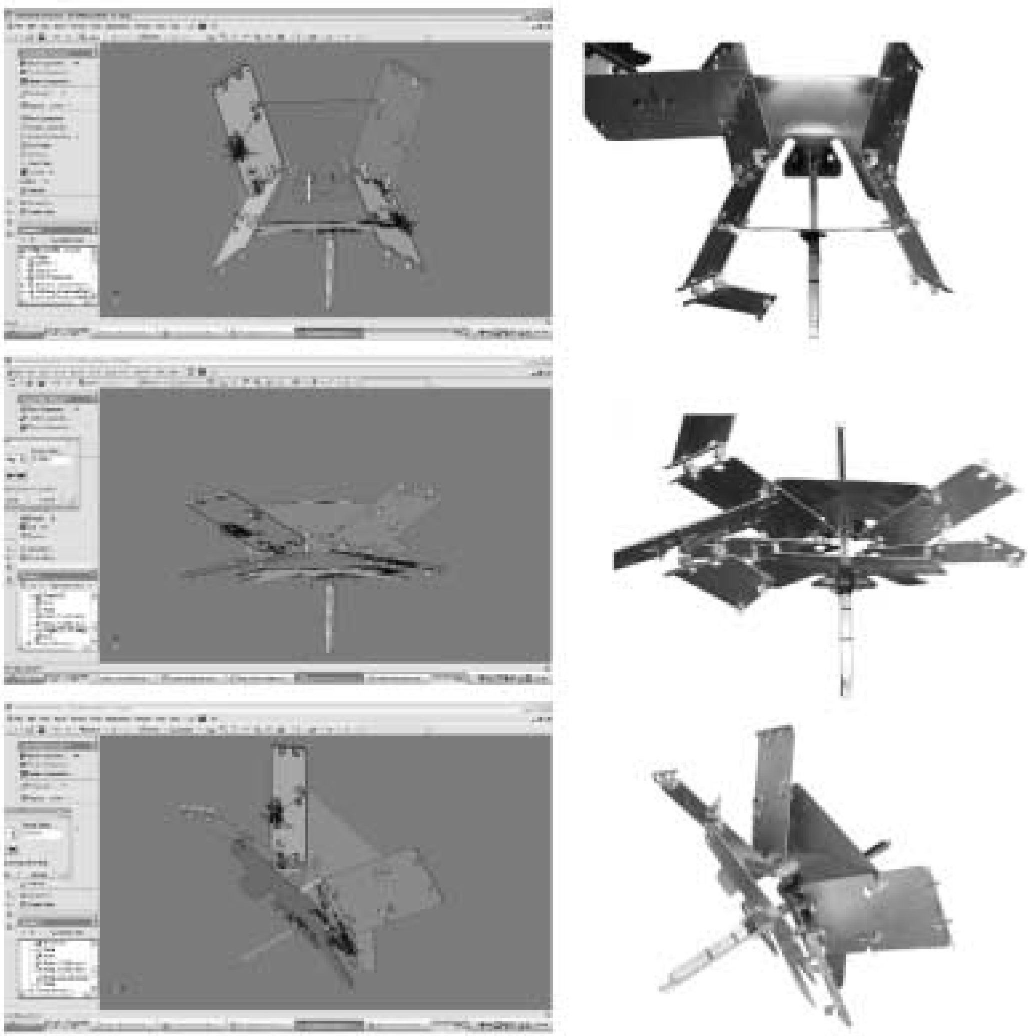

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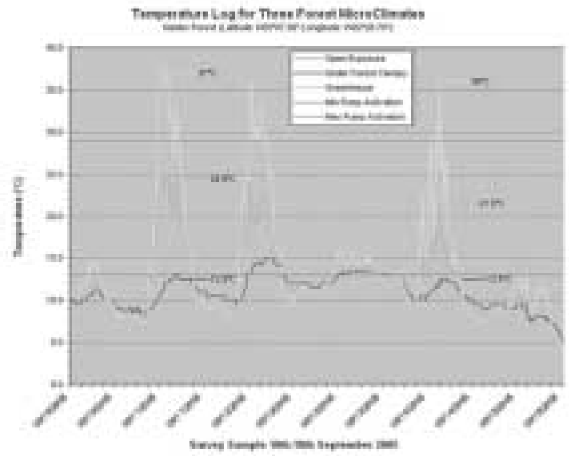

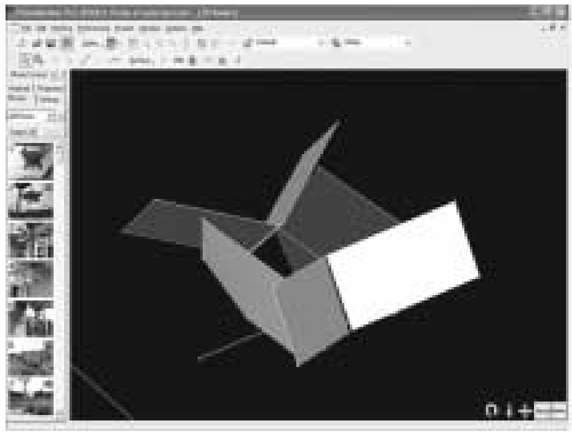

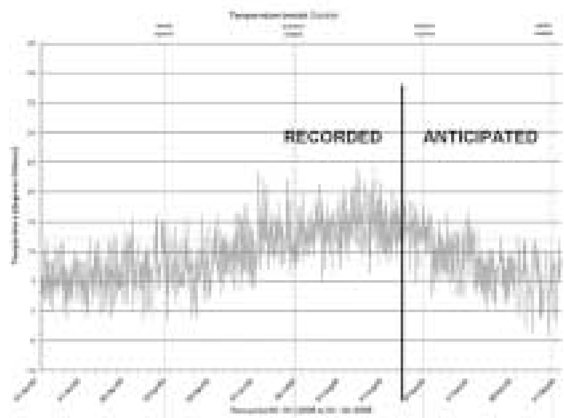

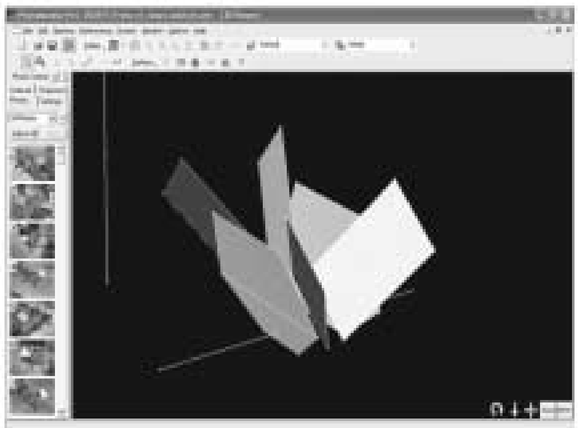

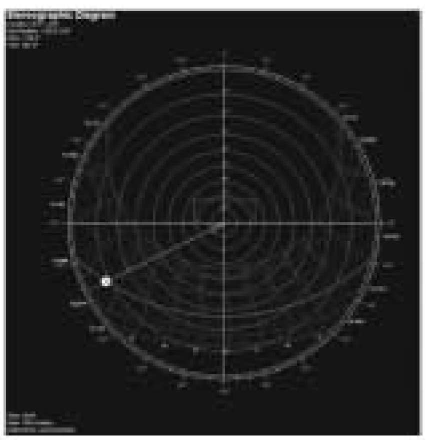

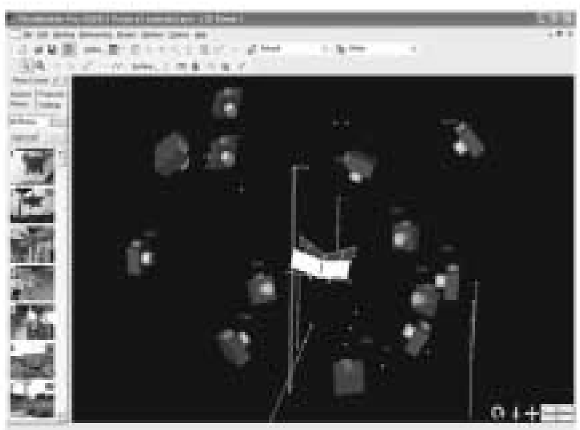

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6 Kielder Probes/Design methodology. Artefact description, synthesis, installation and evolution. Diagram by Chris Leung, sixteen*(makers) 2005.

7 Kielder Probes/Synthesis. First generation artefact manufacture. Testing of sarrus linkage and thermo-hydraulic pistons, sixteen*(makers) 2005.

8 Kielder Probes/Installation. Photogrammetry readouts and data gathering of real object behaviour, sixteen*(makers) 2005.

data-acquisition strategy is a balance of opportunity, possibility and time with which to observe, measure, log, store and transmit site-specific data as information that can usefully inform a future architectural strategy.

Exactly how the balance is weighted will only become apparent once the probes are settled on the site. Kielder is an exposed and isolated environment, demanding some self-sufficiency for those that live and work there. The probes must therefore be robust and occasionally exercise autonomy, and to this end their operating system will be delegated a degree of decision-making needed to balance work with 'survival'.

Unlike a conventional architectural survey, the probes will embody a formal response to their respective sites, articulated by passive thermo-hydraulic pistons that move the probe's body. The piston's actuation is proportional to temperature within a specific range. There are two arrangements of the piston, one responds primarily to ambient (dry-bulb air) temperature and will be similar wherever the probe(s) are sited at a particular point in time – in some ways this will be deterministic because of the average temperatures experienced. The second is solar-heated using a parabolic reflector, which is more unpredictable as it is at the mercy of the site-specific characteristics of shade or exposure in the forest, minute-by-minute changes in cloud cover and self-shadowing by elements of the probe itself. There will be unpredictable availability and timing of the energy source(s) that drive the thermo-hydraulic pistons as conditioned by the weather and site microclimate, in addition the probe's operating system will be programmed to have different responses (for and against) to harness the available sunlight.

Their presence as customised objects designed and made for specific surroundings will present the first evidence of a design process. Connections with local conditions such as ground, vegetation, exposure and so on, will recognise uniqueness. It will be apparent they are made for Kielder and the dense repertoire that forms its identity and sense of place. In this sense, transgression from design to making is made evident as the probes appear in a sequence of prototypes that become increasingly affected by what they 'learn'. Sites to position the probes will also be chosen for varied character, aspect, proximity to a location of interest, and so on. So not only will they function as survey instruments, they will also perform physical interventions, enclosing a territory and altering its status from a seemingly random plot of topography into a place that anticipates future action.

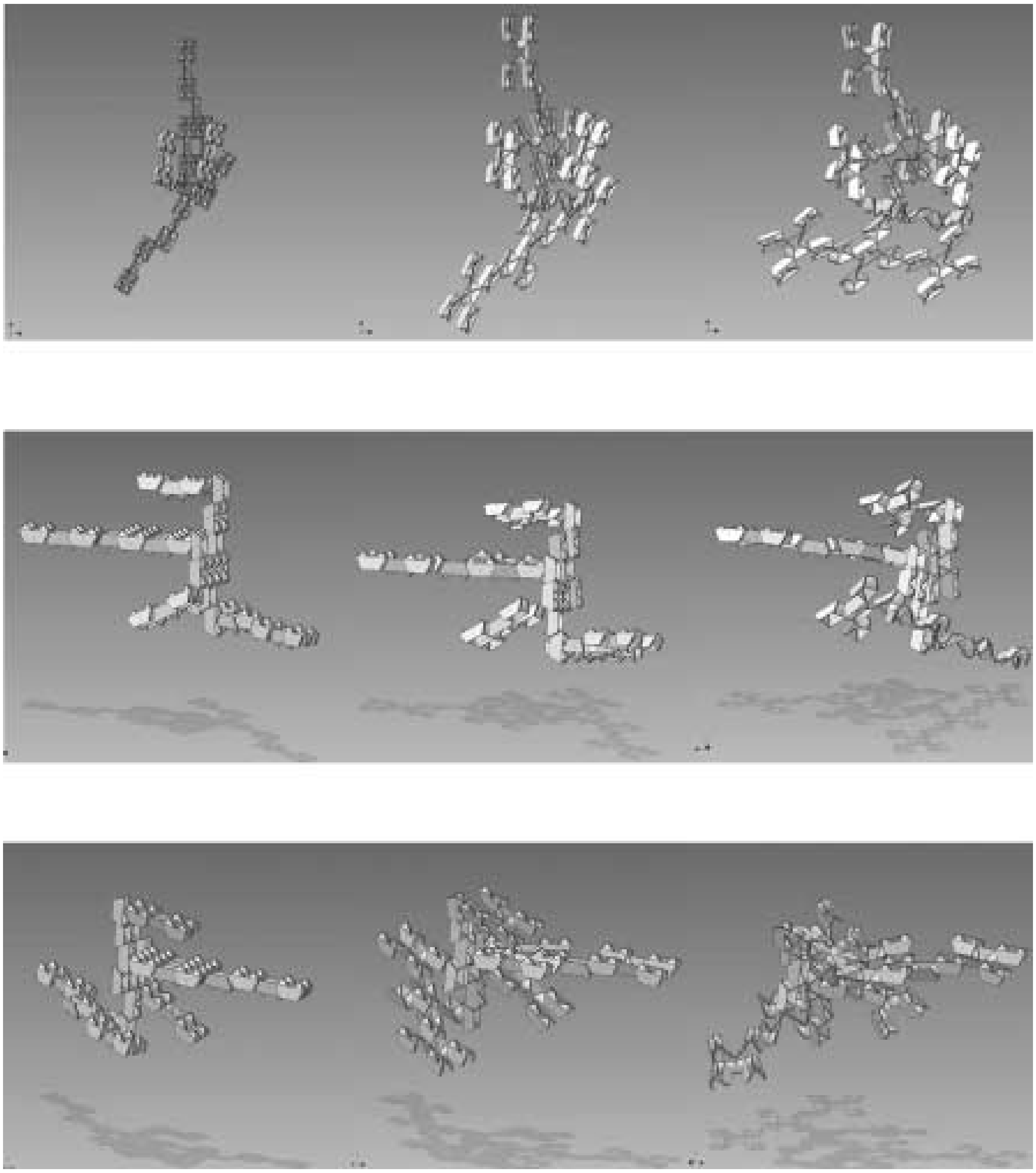
The probes are therefore proposed as instruments that evolve through generations from surveying tools into an architectural assembly. Their expressed genealogy, so to speak, exhibits a notion that propositions for architectural structures can emerge in response to change. Furthermore, with the potential to recognise patterns of change, each generation will have the capacity to reconfigure its own character in order to anticipate likely future conditions. There are two strategies informing development: first, to construct robust assemblies appropriate to their remote location; and second, to expand upon the idea of design as a process that is looped and non-linear *[6]*. The first of these strategies has informed ideas for the probes' behaviour.

Like their predecessors 'STAC' and 'Blusher', the probes are intended to respond to their locations. However, as they are likely to be encountered by only a few visitors, a more environmental response is proposed. Where previously a reconfigurable but ultimately static installation existed, in this instance, our interest is in generating a remote and responsive object with a capacity to move, even walk. Subsequently, we have looked at auxetic structures (ie, those that are capable of growth) and sarrus linkage principles. Such assemblies have the capacity to expand and enclose volumes from a relatively small amount of actuation, and in the appropriate configuration could generate a structure that could relocate itself, albeit slowly *[7]*.

The second strategy, to expand upon the idea of design as a process that is looped and non-linear, sees that the probes acquire greater formal specificity to site over time. Early representational models developed in paper and later MDF, were followed by 3D assemblies in CAD, later animated to represent movement. Once the required articulation appeared to be generated, and arrays tested, files for the first physical prototype in 3mm aluminium sheet were sent to the shop for cutting. This version is of course based on a virtual representation of the ideal which relies on settings of the control software, not necessarily the same settings found in microclimates across the territory of Kielder forest and reservoir.

To capture the characteristics of each site with individual spatial-temporal maps is the focus of the probe's design and will be the rationale for how each is sited. The study of the data they collect and the results of the virtual simulation will potentially inform their adjustment in situ, re-location within their vicinity, or replacement with a revised or entirely new intervention. For this reason, as the work evolves it will be monitored and recorded in photogrammetry, a means through which a 3D point cloud record of the work is stored at regular intervals *[8]*. This will permit us to download metadata of the probes' behaviour and experience of the site so that our survey informs us how to design a more site-specific and 'fitter' architecture *[9]*.

As a residency rather than a commission, our intention is to expose the raw process of generating and evolving ideas prior to the introduction of a programme. As the Kielder Forest and Reservoir present a territory of such scale that potential sites of interest can each have their own distinct character, our question on what role there is for architecture will come in part from the place itself. These are compelling reasons for rare and frequent visitors to expect and enjoy the sight of unique behaviour at any given time and location, as they ramble across and contemplate this extraordinary place. As a by-product of transgressing from drawing to making, the Kielder probes will open questions on how the moment when ideas transfer from the imaginary into the physical realm is chosen and determined.



9

9 **Kielder Probes/Evolution. Predictive behaviour analysis informing design modulation, sixteen*(makers) 2005.**

Notes

1. As Jonathan Hill reminds us: 'The term design comes from the Italian "disegno", meaning drawing, suggesting both the drawing of lines on paper and the drawing forth of an idea from the mind into physical reality' (Hill, 2005: 14).
2. Stereolithography (SLA) is a process of creating a solid physical object, normally no larger than approximately 350x350x400mm, directly from a 3D CAD file. A laser hardens a layer of liquid 0.1mm thick, and progressively builds up the layers to create the shape from the CAD data. Fuse deposition modelling (FDM) operates by extruding a bead of melted plastic filament through a thin nozzle. The plastic is laid down in layers that fuse together to form an ABS plastic part. This system can sometimes be more economical than laser-based systems. Selective Laser Sintering (SLS) operates in a similar way to SLA, but the resin is replaced by a fusible powder such as wax or thermoplastic.
3. sixteen*(makers) are Phil Ayres, Nick Callicott, Chris Leung and Bob Sheil.

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Biography

Bob Sheil is an Architect and Lecturer at the Bartlett School of Architecture UCL. His teaching career began in the Bartlett workshop in 1995 where his key interest and curiosity in the relationship between architecture and making evolved from practice to research. He co-founded the workshop-based practice sixteen*(makers) with Nick Callicott in 1994 and in 2004 was appointed coordinator of the Bartlett's Diploma Programme.

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