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Manufacturing Bespoke Architecture

Abstract. At the disposal of today's architect is an evolving array of interoperable tools and processes that allow the fabrication of design propositions to be increasingly complex, non-standard and adaptive. How are we equipped to deal with such a growing breadth of new potential, and how are the philosophies that underpin this potential being defined? This paper attempts to address what is something of a contemporary dilemma in architecture, as the constraints of industrial standardisation are relaxed. Have the roles of designers and makers changed in a way that we've not experienced before, and is a new approach to making architecture emerging?

Part One

Over the past decade, conventional protocols of exchange that focused on the key relationship between design and making have been thoroughly redefined by digital technology [Sheil 2005a]. For centuries, the construction of prototypes, artefacts, buildings and structures has operated on a rolling tradition of visual and verbal communication between designers, consultants, makers, clients, users, regulatory bodies and contractors. In making buildings, roles were defined by where individuals and disciplines were located on a chain from concept to execution. All were reliant on its links being successfully forged, not only to achieve results, but also to underpin their status within their respective professions and trades. Prevailing over the entire process was the design, an assemblage of cross-referenced visualisations, specifications and quantities forming the templates and instructions for making. Given the numeracy of complex transfers from one step to the next, constructs in architecture have evolved as negotiated translations; the most engaging are those that have recognised this in a creative and informed way from the very outset.

The redefinition of these historic protocols was initially led by the gradual adoption of computer-aided drawing in the early 1990s by practice and academia. As three dimensional modelling and rendering became more available and sophisticated, a frenzy of liberated experimentation ensued. Speculative design looked to the weightless and scaleless domain of digital space as the new terrain for innovation and speculative discourse and as the means to compositionally define spatial and formal complexity.¹ The gap between the designer's vision and operations of the construction industry widened as fabrication processes remained largely analogue in how they were driven and delivered. A defining example of this challenge was Future Systems' Media Centre at Lord's Cricket Ground (competition winner 1995, opened 1999), in which the primary enclosure was entirely prefabricated by the Pendennis Shipyard in Falmouth, Cornwall, as theirs was the only industry both familiar and experienced in extrapolating design information for the fabrication of such forms.

Concurrently though, news tools of computation, means to capture and analyse the performance of buildings, built environments and the behaviour of users, brought a fresh understanding of the complexity and density of dynamic contexts in architecture.

Geometry was re-ignited as a great organiser, only now it was adaptable and smart, as developments in design software far outstripped those in the world of how such forms could easily be made; more significantly, the means to communicate from one realm to the other was restricted. In the first decade of the new millennium this restriction started to lift as CAD/CAM (computer-aided design and computer-aided manufacture) entered the mainstream. Subsequently, a vast expansion on the remit, scope and potential of the designer was released, allowing for their direct engagement and control of fabrication processes. Likewise, the capability of manufacturing and construction to fulfil design intent was expanded, and a creative dialogue between design and fabrication began converging once more.

Size Matters

The term 'bespoke' is said to have originated over one thousand years ago from the old English 'bespeak', meaning 'to request', 'to order in advance' or 'to give order for it to be made'.² Tailors of London's Savile Row claim that the term was in common use on their street from the seventeenth century, when tailors kept their cloth on the premises and customers would 'bespeak' a particular length of fabric to be fitted as a suit or uniform. The first recorded use is thought to have occurred in C. Clarke's *A Narrative of the Life of Mrs Charlotte Clarke* (London, 1755) on the life and experiences of an actress, cross-dresser and famous playwright's daughter in eighteenth-century London. In this instance, the term was used in reference to the performance of a 'bespoke play', in the sense that it was a one-off.

Almost 275 years after suits and uniforms were first made there, the Savile Row Bespoke Association was founded in 2004, and within three years they trademarked the term 'Savile Row Bespoke' which defined a two-piece bespoke suit as 'crafted from a choice of at least 2,000 fabrics, be made almost completely by hand, and requiring at least 50 hours of hand-stitching'. To qualify, Savile Row Bespoke suits must also be 'derived from a paper pattern, individually cut and produced by a master cutter, and subsequently undergo personal supervision by the master cutter in the course of production'. In June 2008, the association lodged a complaint under the truthfulness rule at the UK's Advertising Standard's Authority (ASA) against the international firm Sartoriani who had recently opened a nearby store where machine cut suits were promoted as bespoke.³ The ASA noted the complainants' argument that 'the advertised suits were machine-cut abroad[(in Germany at the time)] to a standard pattern after initial measurements were taken and adjusted at the end of the process' and that the suits 'at best' should be described as 'made to measure'. Sartoriani claimed that the initial machine-cut fabric pattern was a 'working frame' that could be individually adjusted if the customer's measurements did not match a standard pattern size, and that this occurred in some cases.

The ASA concluded that, following recent changes to the industry, the use of the word bespoke to describe the advertised suits was 'unlikely to mislead'. They went on to say, 'both bespoke and made-to-measure suits were "made to order"', in that they were made to the customer's precise measurements and specifications, unlike off-the-peg suits". The ASA did not rule on a fuzzy distinction between hand-made or machine made, nor the particular differences of approach either method adopts in making or fitting, nor even where the suit was made; they ruled on the rather neater and universal principle of measurement.⁴ Whether the artefact is made to order, made on the premises,

made to measure, made by hand, or manufactured by machine, our recent understanding of the centuries old term 'bespoke' has undoubtedly been altered.⁵

Designer as maker

Today, the bespoke is referred to in the context of personalised stationary, customised software, pharmaceuticals, wines, cars, financial investments, even biscuits, suggesting it is increasingly common for everyday and mass produced artefacts to be made to order. Bespoke is also a term associated with architecture, and in the first instance through the idea that most buildings are in some sense unique to their location, the time they were designed and built, who they were designed and built by, how they were built, and the circumstances that surround their occupation and use. More specifically, the architecturally bespoke has associations with craft, ornamentation, materiality, fit, uniqueness and the unrepeated. However, as with the core productions of Savile Row, and for many of the same reasons, the meaning of bespoke in architecture in recent years has shifted on methodological grounds. Key to this are two primary issues: first, radical changes in how architecture is designed and made; second, a vast expansion in what might be regarded as materials for architectural specification – from the deployment of nanotechnologies to choreographing four-dimensional behaviour.

With regard to the background of the former, one of the key properties of the bespoke is the involvement of the maker as the designer. Unlike tailors, most architects do not make the things they design; they make design information, the equivalent of making the pattern, not the suit. Architects, however, also make space, an immaterial substance, and the equivalent of forming the host upon which the pattern is draped. The architecturally bespoke is therefore associated not only with the ability to establish rules for the 'made to order', but with the generation of a design that understands and anticipates the challenge and consequences of making that particular order, and its role within a construct that is greater than the sum of its parts. Equally, the subsequent bespoke artefact reveals the manner in which this commission has prompted a skilled craftsman or specialist to respond, and how the overarching construct fits together. At its best, this collaborative dialogue has the capacity to transcend the drawing as a literal template and goad the maker and the material into new territories. Since the introduction of digital fabrication technologies, profound changes have been brought upon this relationship and the habitual protocols between design and making. Through the progressive elimination of craftsman and skilled machine operatives, the expertise that designers relied upon to translate their work has diminished and in many respects transgressed into their domain.

A further ingredient of the bespoke is how an intimate knowledge of materials and their performance in use informs design, and relate to its method. Cutting fabric on the bias and incorporating ease within a garment each have their equivalent at architectural scales, such as the imprint of shuttering on cast concrete, or the deflection of steel under load. In tailoring a bespoke suit, drawing and making are synthesised from the outset where graphic and illustrative representation dissolves as the final artefact appears. Processes of measurement, pattern-making, cutting, forming, and joining components progress through three stages of fitting and fabrication known as the 'Skeleton baste',⁶ the 'Forward' and the 'Finish bar finish'. Such intimacy between drawing and making is rare in the practice of architecture, and the architectural drawing must therefore anticipate and understand the difference between the simulated and the actual and adapt accordingly. Clearly, the range of materials specified in architecture is substantially

broader and more complex than that of tailoring, not least as it also incorporates strategies for immaterial qualities such as context, light, reflection, temperature, sound, culture, meaning, memory and emotion. In this regard, both the tools and the palette of the twenty-first-century architectural designer are rapidly expanding as they provide the ability to approach design as a strategic act with novel outcomes.

Part Two

Two co-authored design and make projects are examined here; a chair from 1995 (figs. 1-2) and a small building from 2009 (figs. 3-12). Both projects fit within the author's definition of protoarchitecture (see [Sheil 2008]), a self-coined term to identify experimental design that challenges the methods and role of the designer particularly in relation to how and why the work is made. Secondly, and central to the arguments presented here, both projects identify a key transition in the definition of the bespoke that spans a period of significant change in design and fabrication methodologies and tooling. In analysing these projects together for the first time, it will be argued that many of the strategies in designing and making a bespoke piece of furniture that went beyond the realm of the conventional drawing, and were exclusively developed by hand, are now adoptable through digital design and fabrication technologies. It will also be suggested that these new facilities must be seen as essentially hybrid disciplines that are practiced adjacent to the point of production. What is also being explored here is an underlying idea that integrated digital design and fabrication technologies have instigated a renewed relationship between the bespoke and the prototype, and that exploration of either presents opportunities for the other. What is new in this relationship is that these pursuits can be exercised mutually and synthetically; for those who wish to take advantage of this potential, there are significant implications for the way they might practice and learn [Callicott 2000].

Making the Bespoke

The chair shown in figs. 1 and 2 was sixteen*(makers)⁷ first commission and was made for a management consultant in 1995 who noticed the collaborative's experimental approach to design and making on projects 'plot 22' and 'Dartmoor' [Groat 1996]. The practice was established whilst Callicott and Sheil were students at The Bartlett School of Architecture UCL. Both were midway through their undergraduate studies when Peter Cook was appointed as the school's Professor of Architecture in 1990; under his charismatic stewardship the school became a vivacious and inventive forum for experimental ideas. The 'fee' for the chair was a 50% barter on our client's second-hand Macintosh Powerbook 100 (which was introduced on 21 October 1991). One handmade chair in part exchange for a laptop; it seemed the analogue and the digital were destined to be present in the history of our practice from the start. At the time of the commission our client was practicing the Alexander Technique, a method of focusing and developing controlled body posture and balance habitually and intuitively. The commission was envisaged as a means to address this practice routinely, and to design an everyday point of support for reading, typing, dining and relaxing. The particular movements and strains upon forearm, eye, head, neck and shoulders in relation to the gizmos of the day, such as the centrally placed traceball, a mouse, a 23 cm, 600 x 400 pixel resolution backlit LCD display with compact keyboard, were absorbed as essential but not exhaustive design criteria.

Fig. 1. 'Webb Chair' (1995), sixteen*(makers)' first design and making commission, developed through a series of conversations between authors and client. © sixteen*(makers)

Fig. 2. 'Webb Chair and Webb Table' (1995), Sixteen*(makers) first and second design and making commissions, developed through a series of conversations between authors and client. © sixteen*(makers)

Somewhat in the traditions of Savile Row, the client was surveyed, his frame and posture measured and noted, and other chairs and stools were commandeered as adaptable props. They were made higher, wider, more vertical, softer or cooler. Likes and dislikes of the function and form of chairs were identified and key objectives were agreed upon and marked on jigs, rulers, floors and walls. Issues of comfort and restraint were explored in relation to the chair's purpose and role, and environments where the chair would likely be located were noted for matters such as deflection and vibration. Materials from which to make the chair were also explored, not only for performance and visual preference, but also for their capacity to carry other narratives within the object. Lying about the studio in Shoreditch at the time were a number of speculative test pieces in mild steel, hardwood, acrylic, glass and rope, forming a haphazard library of experiments and assemblages in relatively simple techniques. Amongst these was an ongoing trait to customize materials, particularly steel, from their origin as extruded standard profiles, into ends, junctions, and limbs through abrasion and forging. Some of these traits had a highly graphic as well as tactile quality, portraying not dissimilar looks to those we once pursued in ink. However, it was their tangible properties, such as weight, surface quality, conductivity, resonance and reflectivity that were the predominant objects of investigation and value.

From this catalogue of references, the design's first move was established in the form of a foot adapted from a short section of heavy rolled T-bar in mild steel. To the central web of the T-bar, a flat bar the same thickness and width as the central web was beveled and arc welded. The joint was ground, filed and sanded until seamless and the shiny surface was reheated with an oxy acetylene torch until black again. Overgrinding was always something to be mindful of, for as soon as the weld surface dipped below the adjoining sections, the only course of recovery was to break the weld and start again. The inner and outer radii of the rolled T-bar and the feathering of its tapered flanges, set a geometric tone for key positions where the chair's limbs would end or meet others. The length of this first element, about 1m, far exceeded what was required, and so it remained as the key datum from which to strike the seat's horizontal axis until the remaining substructure of the chair's legs and spine was complete. Both front legs also stemmed from the same flat bar, but here they were jointed to a parallel square section of the same thickness. The heavier elements connected vertically to form the seat's substructure, whilst of the lighter, one swerved away on the left hand side to receive a rigid arm, and the other tapered to finish short of a cantilevered right hand arm with some give.

When our client returned for his 'skeleton baste' fitting, the chair's key dimensions and alignments were tested and adjusted. Movements and postures were simulated and marks were made on the chair's steel carcass in chalk. Rough boards were fashioned as jigs to form seats, and various blocks and wedges were positioned to judge the thickening of various elements such as arms and the spine. The torch was re-ignited and geometries of the frame adjusted before the client departed. As the chair passed through two more fittings, a small pile of reclaimed tongued and grooved oak strip flooring was rescued to form the seat and subsequently jointed to form two panels tied to the subframe with a leather thong. The rigid left arm of the chair was filled out with a further section of jointed and reclaimed oak and the flexible right arm was wrapped in leather from a local upholstery merchant. Our studio was located at the western end of Sunbury Workshops in London's historical quarter of Shoreditch. In the two units beneath us were a shopfitter and an octogenarian wood turner. Next door below were silversmiths working above a frame gilder, and further along a prestigious upholsterer, and a team of

glassblowers. Although, not formally organized, the range of skills being practiced was highly influential and complimentary to our aims as architectural graduates. We could witness at close proximity the vibrancy and vulnerability of an urban micro-industry, and realise how little our education did to make us aware of how direct engagement with its potential could inform our design strategies. As the project of a fledgling experimental design practice, these acts of meticulous production informed many of the foundations of our attitude to repositioning the designer as maker. However, it was clear that in terms of a critical place in our chosen industry, they resembled more the world of the nineteenth-century artisan than the contemporary professional.

Bridging the gap

Resolving the bridge to this divide would take us back to our exchange fee for the chair and the presence of a new realm for workshop tooling, that of the digital. As an indication of how fast changes in related technologies took hold in this time, Nick Callicott's *Computer Aided Manufacturing in Architecture: The Pursuit of Novelty* [2000] was published just five years and numerous operating system and hardware upgrades later. The subsequent portfolio of sixteen*(makers) increasingly addressed the evolving relationship between digital design and making through a series of speculative projects and publications, including 'Cut and Fold', 'STAC', and 'Blusher' (all 2000-01), *Design through Making* [Sheil 2005b] and *Protoarchitecture* [Sheil 2008]. In parallel, their work shifted further towards a directed stream of academic research on both digital and analogue practices, with Ayres and Leung embarking on related doctoral studies with particular focus on responsive systems, persistent modelling [Ayers 2012], and environmental analyses. Greatly facilitating further opportunities for academic collaboration with industry, Callicott left UCL in 2005 to set up Stahlbogen GmbH in Blankenburg Germany, with partner Kris Ehlert. At the time, sixteen*(makers) were establishing speculative proposals as architects in residences at Kielder Water and Forest Park Northumbria, on behalf of The Kielder Partnership. With an open brief, the appointment provided an extended period of speculative investigation on the difference between digital modelling (as the 'ideal') and physical installation (of the 'real'). On the basis of a series of built installations on remote sites, the work, which led to a solo exhibition at The Building Centre in 2007 entitled 'Assembling Adaptations', presented the potential for real-time monitoring of microenvironmental change to drive the design of a bespoke dynamic architecture [Sheil and Leung 2005]. Whilst this research remained ongoing and formed the core of both Ayres's and Leung's doctoral research, the practice was approached by The Forestry Commission to design a public shelter on a proposed perimeter walkway to the reservoir. The additional brief carried a set of performance requirements and budget that would restrict many of the immediate possibilities of the residency. However it offered the first opportunity to collaborate with Stahlbogen GmbH from the outset of a new project, and a fresh set of investigations were embarked upon.

Manufacturing the bespoke

Completed in June 2009, the shelter known as 55/02 is named after its coordinates: 55° 11.30 N, 02° 29.23 W, otherwise known as Cock Stoor, Lakeside Way, Kielder Water and Forest Park, Northumberland, UK.⁸ Key issues to recall from theses accounts relate to:

1. winning the commission on the basis of strategic information rather than an illustrated design visualisation, to clearly posit an underlying intent to develop the built design on highly specific qualities of the final and 'real' site;
2. making it clear in the award of the commission that the built design would explicitly evolve in collaboration with Stahlbogen GmbH.

Qualities of the selected site that informed the primary aims of the work included the intersection of distant harvest lines, trenches, gouges and trails, and the atypical qualities of the site that overlooked the reservoir from a raised mound on the north shore. They also included orientation to prevailing weathers and sunlight, relationship to key views and distances from other resting points, and the particular spatial qualities of the surrounding plantation of preserved Scotts pine and their array of geometric intersections through the loose grid of straight and bare tree trunks, each between 5° and 15° off plumb. These, and the rich matrix of adjacent layers and nodes of orientation, generated a dynamic field of variable spatial depth and quality of light, sound, temperature and enclosure for the design to acknowledge. Collaboration with Stahlbogen GmbH was initiated from the very outset of the commission, with the manufacturers in attendance and taking part in the site analysis and selection visit. In this respect, access and manoeuvrability of plant and personnel was also considered, and it was thereby possible to renegotiate the proposed route of the Lakeside Way and determine the position of a planned temporary road spur for the supply of materials to build the new pathway. At the conclusion of the site visit it was agreed that the shelter should have no obvious boundary between its material edges and the rich constellation of its environment, and that in response to its exposed position it should offer substantial shelter to the north, with a greater degree of openness to the south.

In recognition of unnegotiable budget constraints, a key early decision was to ensure that the design took account of Stahlbogen's existing tooling and expertise, that the number of materials be limited, and that Stahlbogen's established knowledge in sheet steel fabrication be exploited and stretched. On this basis, the design progressed through simultaneous speculative exercises in drawing and making which flowed between the factory in Blankenburg and studios in London and Copenhagen (from where Phil Ayres collaborated). Flowing from one workstation to the next were images, drawings and comments on 1:1 physical prototypes produced by Stahlbogen, spliced with sketches, hand-made models, 3D drawings and 3D prints emerging in London and Copenhagen. This sequence led to the evolution of the projects distinctive 'tank-like' walls, the idea for which was led by a series of 1:1 test pieces at Stahlbogen. These units not only distinguished much of the project's formal character, but also informed the development of speculative design drawings and models, and established the unconventional order of exchanging design information between the drawing makers and the manufacturer. Once primary decisions on how to approach the fabrication and design of the enclosing walls was established, an entirely fresh CAD model was constructed through which every resulting form was assessed for potential conflict with the dimensions and limitations of the equipment and processes that would produce them.

Fig. 3. 'Shelter 55/02' (2009) by sixteen*(makers) in collaboration with Stahlbogen GmbH. The illustration shows the first test prototype unit in manufacture at Stahlbogen's works in Blankenburg Germany. © sixteen*(makers)

Fig. 4. 'Shelter 55/02' (2009) by sixteen*(makers) in collaboration with Stahlbogen GmbH. The illustration shows Nick Callicott inspecting the work and refining the design prior to completion at Stahlbogen's works in Blankenburg Germany. © sixteen*(makers)

Production design evolved by constant shuffling between fabrication, drawing, animation and assembly. Once information for the tank walls was fully developed, the steel was cut, folded, capped, welded, and connected as a structural unit in a few days. Assembled in the factory in the same configuration they would finally be placed on site, they became, for a period, models upon which to judge and test propositions for overhead roof elements. Strategies for these elements were visually developed upon the CAD file, and cross-referred to both 1:20 physical design models and the 1:1 partially built shelter of tank walls.

Fig. 5. 'Shelter 55/02' (2009) by sixteen*(makers) in collaboration with Stahlbogen GmbH. A detail of the roof as installed on site at Cock Stoor, Kielder Forest and Water Park, Northumberland UK. © sixteen*(makers)

Fig. 6. 'Shelter 55/02' (2009) by sixteen*(makers) in collaboration with Stahlbogen GmbH. The illustration is created from a 3D LIDAR scan captured by Scanlab Projects at UCL. © sixteen*(makers)

In this sense, the design exercise became truly synthetic with making and the methodological strategies of the projects 1995 forerunner were resurfacing, albeit now equipped with considerably more adaptable and flexible design tools. Here, design decisions were being made and becoming available that would otherwise be excluded from the designer, who might only have provided an initial set of drawings to be followed as instructions for making. In this instance, such information provided by the team was only being regarded as a prompt and a guide, and final decisions were formulated on how the design implied in those drawings might operate both visually and feasibly at 1:1 on the shop floor. Crucially, this critical analysis and subsequent decision was being taken by a designer with ownership over the design and advanced skills in production.

Subsequently the design of each of the roof elements as built, evolved substantially from initial design proposals as developed in model or CAD form. A number of factors played into this outcome, including considerations on physical and visual weight, soffit qualities, complexity and physical geometry of surface in relation to vertical elements, and the feasibility of assembly, with very limited resources on site at Kielder.⁹ In addition, and perhaps one of the most surprising points to make, is how the final iteration for the design of the roof elements was informed by the visual language that was emerging from the preceding completed elements more than that which was conveyed in initial drawings. This point can best be understood by comparing the somewhat stark quality of the projects production drawings and the more fluid quality of the built works aesthetics. This is not to say that that a fluid aesthetic was found only through making, but that the production drawings that were necessary to construct the work were not being judged in this way.

Fig. 7. 'Shelter 55/02' (2009) by sixteen*(makers) in collaboration with Stahlbogen GmbH. The illustration shows the roof section in transit at Stahlbogen's works in Blankenburg Germany. © sixteen*(makers)

Figs. 8-9. 'Shelter 55/02' (2009) by sixteen*(makers) in collaboration with Stahlbogen GmbH. Left, View of the work part complete at Stahlbogen's works in Blankenburg Germany; right, Detail view of the work part complete at Stahlbogen's works in Blankenburg Germany
© sixteen*(makers)

Such drawings were made to provide the necessary digital information to feed the digital manufacturing process. In a sense, they partially equate to traditional shop drawings where in the past makers would redraw the designer's drawings at 1:1, and through the act of drawing the makeability of the design was established. However, in this instance, with the maker inhabiting and continuing the role of the designer, production drawings were constructed in order to facilitate a desired outcome in making, and if in view or in print the subsequent drawings were deemed to be aesthetically odd or unappealing, this was ignored in the knowledge of the results they delivered. This aspect can be understood globally in plan and section, which is a form of information on the project typically requested by publishers. Through the conventions of reading such literal projections, these interrogations struggle to capture the central qualities of the built work. The graphics that are generated greatly overstate gentle folds as harsh creases, and the resultant complexity of overstated lines and geometries are all that the eye sees. Little of the subtlety that easily transmits from the formed and assembled materials is conveyed, and it is very doubtful that had such drawings been presented to the client in the first instance, that the commission would have been awarded. By letting go of the design drawing as the primary instruction for making, and by reading such initial drawings solely as strategic intentions of spatial and material organisation, an otherwise unexplored architectural response is found in the place and process of production.

Fig. 10. 'Shelter 55/02' (2009) by sixteen*(makers) in collaboration with Stahlbogen GmbH. Installing the roof at Cock Stoor, Kielder Forest and Water Park, Northumberland UK. © sixteen*(makers)

Fig. 11. 'Shelter 55/02' (2009) by sixteen*(makers) in collaboration with Stahlbogen GmbH. Installing the roof at Cock Stoor, Kielder Forest and Water Park, Northumberland UK. © sixteen*(makers)

Fig. 12. 'Shelter 55/02' (2009) by sixteen*(makers) in collaboration with Stahlbogen GmbH. View of the work as installed at Cock Stoor, Kielder Forest and Water Park, Northumberland UK. © sixteen*(makers)

Part Three

A year to the month after 55/02 was assembled and installed on site, the building was captured as a 3D lidar scan using equipment on a loan to UCL by the international instrument and measurement manufacturers FARO.¹⁰ This technology has been developed for precision engineering and industrial applications over the last decade, but only in recent years, and coinciding with the evolution of point cloud modelling, has it entered the domain of the design and construction sector. With the potential to provide users with rapid and accurate feedback on existing structures in the form of exportable digital models, the capacity to exploit the resource of accurate and useable measured data is broad and deep. In this instance, it provided the authors of 55/02 with an asset from which to trace and record decisions that had not been developed through drawing. The scanned model may be overlaid on the CAD model and anomalies identified. In this instance such data would not be regarded as a fault, but rather as a difference that was not documented. One can easily imagine, however, that a less positive conclusion might be drawn in other circumstances. As in a world of increasing regulation and accountability, design differences that are undocumented tend to be labelled as 'faults' or at the very least 'disputes'. Drawing, whether digital or analogue, is without doubt an essential process and tool in the production of architecture. Both the act and the product of drawing are also central in defining the role of the designer, but as I hope this exploration has conveyed, in an age where we are bypassing the translation of drawings by those with the tacit skills in how they are realised, we might wish to consider their bearing strength in this great task, and what we can do to ensure their best intentions are fulfilled.

Acknowledgment

This essay has been adopted from the author's leading chapter in the publication *Manufacturing the Bespoke: Making and Prototyping Architecture* [Sheil 2012].

Notes

1. Seminal publications of this period that explore these themes include a number of guest-edited issues of *AD* including *Folding in Architecture* [Lynn 1993] and *Architects in Cyberspace II* [Spiller 1998].
2. See <http://dictionary.reference.com/browse/bespoke?s=t&ld=1032>.
3. See the ASA report on the judgement at: http://www.asa.org.uk/ASA-action/Adjudications/2008/6/Sartoriani-London/TF_ADJ_44555.aspx.
4. Recent developments in three-dimensional body scanning offer a route to broader and more perplexing questions on specific measurement [Treleven 2004]. Here, not only is the individual accurately measured in 3D, but the data may also be of assistance in monitoring their state of health, contributing to national welfare statistics and understanding their physical attractiveness to others [Swami and Tovée 2005; Tovée et al. 2002].
5. Shortly afterwards Sartoriani went on to open a store on Savile Row; however, at the time of writing the firm had ceased trading and existing orders had been taken over by online trader asuithatfits.com.
6. Skeleton baste is a term used in tailoring to describe the first and rough fitting of a bespoke suit. The second fitting is known as 'The forward', and the final as the 'Finish Bar Finish'.
7. Sixteen*(makers) operate between practice and research, and between design and making. Established at The Bartlett School of Architecture in the mid 1990s, the group includes Phil Ayres, Nick Callicott, Chris Leung, Bob Sheil and Emmanuel Vercruysse. Throughout its life, members of the group have remained independently active in academia, practice and industry, as they have worked together on a project-by-project basis from respective bases in London, Paris, Copenhagen and Blankenburg. Callicott has since gone on to establish Stahlbogen GmbH, a subsidiary of Ehlert GmbH, in the Harz region of Germany, whilst Ayres, Leung, Sheil and Vercruysse continue their ties with the Bartlett in design, research and teaching. The group now operate as an architectural consultancy at UCL. Further details may be found at www.sixteenmakers.com.
8. For a general analysis, with background information on local context and project sequencing, see [Sheil and Leung] and [Sheil 2009].
9. The site at Cock Stoor is 4 miles from the nearest car park and delivery point, is accessible via an unstable forestry road or by boat, and is without power supply. At the time of installation, it was also beyond the reach of a mobile phone signal.
10. The scan was carried out and post-processed by Matthew Shaw and Will Trossell of Scanlab Projects.

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