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Bob Sheil | ***55/02*: A manufactured architecture in a manufactured landscape**

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Design and manufacture are integrated in the fabrication of a shelter for Kielder Water & Forest Park. Dialogues between design and making, and between object and landscape, are outlined.

55/02: A manufactured architecture in a manufactured landscape

Bob Sheil

The spectacular surroundings of Kielder Water & Forest Park, in Northumberland, England, are a confluence of opposing states: the man-made and natural; the utilitarian and recreational; the beautiful and isolated; shaped by weather converging from east and west. Kielder Castle was built in 1775 as the Duke of Northumberland's hunting lodge. In recent years the territory has gained notoriety for a series of innovative art and architectural commissions including *Belvedere* by Softroom Architects (1999), *Kielder Skyspace* by the American artist James Turrell (2000), *Minotaur* by architect Nick Coombe and artist Shona Kitchen (2003), and *Kielder Observatory* by Charles Barclay Architects (2008). This paper outlines one of Kielder's most recent additions – a shelter entitled *55/02* – the result of a collaboration between sixteen*(makers) and manufacturers Stahlbogen GmbH.[1] The work rekindles the symbiotic relationship between design and making once central to the production of architecture. The reawakening of this tradition has been stimulated by the mainstream adaptation of CAD/CAM as an industrial and disciplinary medium which binds the protocols of drawing with those of fabrication.[2] However, as this account of the project shows, the relevance of an increasingly digitised world extends beyond the production of *55/02* as an artefact – it forms the basis of the architecture's relationship with its locality as an industrial, historical, social, cultural and manufactured landscape *[1]*.

Evolution of a digital landscape

Kielder Water & Forest Park is a highly managed landscape. It is centred on the largest man-made reservoir in Northern Europe, surrounded by what is now England's largest forest. The reservoir, which primes England's largest hydro-electric plant, was planned in the 1960s to satisfy demand for water by the industrial economies of Tyneside, Wearside and Teesside. By the time of its opening in 1981, however, the reservoir's purpose was frustrated by a steep decline in heavy industries and their replacement by more water-efficient industries engaged in new technologies. Many came to regard the government-backed project as a white elephant,[3] failing to

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1 The entirely prefabricated shelter *55/02* settles into its new surroundings, June 2009

2 Looking north–west towards the site at Cock Stoor prior to installation, 10.34 hrs, 21 April 2009

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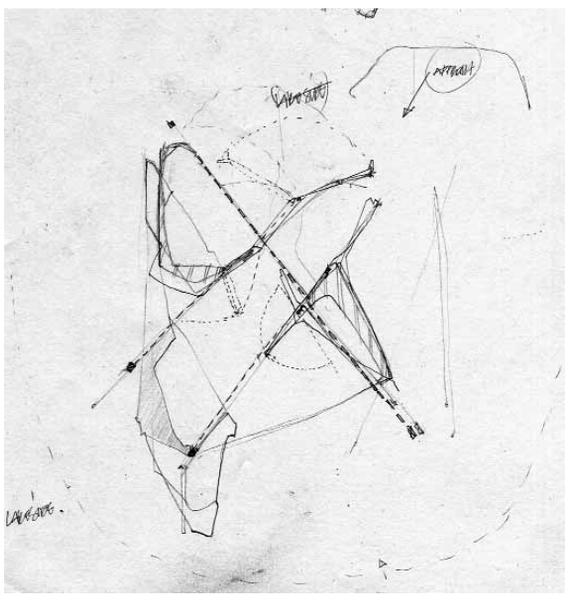
anticipate how valuable the plentiful supply of fresh water would be for a globally-warmed world. Upon completion of the dam, designed by Sir Frederick Gibberd & Partners,[4] the reservoir took two years to reach its capacity of 200 million litres. Much of the building stock in the valley was dismantled prior to construction of the dam although fragments of the valley's history remain in evidence among the shoreline ruins of abandoned settlements, roads, viaducts and railways.[5] The reservoir is owned and managed by Northumbrian Water who lease the hydro-electric plant to NPower, a UK energy supplier in German ownership operating the plant from Dolgarrog in Wales.[6] The reservoir exudes an eerie atmosphere of abandonment and incarceration; a quality eloquently captured within *Wave Chamber*, a shoreline camera obscura by artist Chris Drury.

The 650 square kilometres of forest surrounding Kielder are owned and managed by the UK's Forestry Commission. In line with the government's policy to establish a strategic reserve of timber for the nation, the first plantings took place on its open moorland in the 1920s. Most of the present forest is planted in coniferous trees, with 75% of the area planted in Sitka Spruce, 9% in Norway Spruce and Lodgepole Pine and the remaining 16% in Scots Pine, Larch, Douglas-Fir, Birch, Rowan, Cherry, Oak, Beech and Willow. Some 550,000 cubic metres of timber are harvested annually for processing into construction-grade timber, and timber for pallets, packaging, fencing, chipboard, pulp and fuel.[7] The trees provide a wildlife habitat that varies from woodland to marshy grasslands and bogs, supporting a diversity of wildlife including badger, roe deer, otter, shrew, bat, birds of prey and 50% of Britain's red squirrel population.



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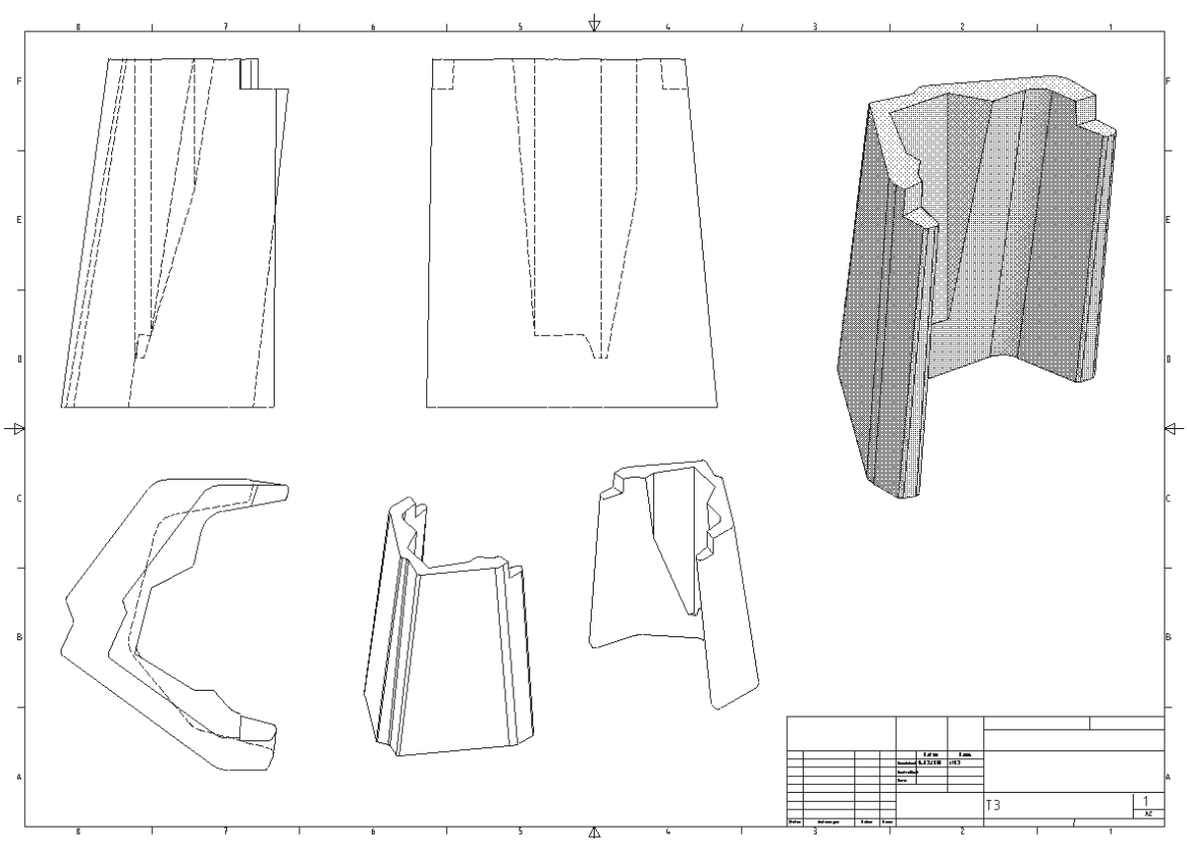
3 Freehand sketch plan by Emmanuel Vercruysse, defining dynamic spatial tactics

4 3D digital sketch by Nick Callicott, defining structural, material and envelope strategy

5 Testpiece, the 'exam' set by Callicott for his welding team at Stahlbogen

6 1:1 prototype of 'structural tank', this established choice of fold radius and exposed the need for a greater number of folds in later iterations. The same prototype was later used for colour testing



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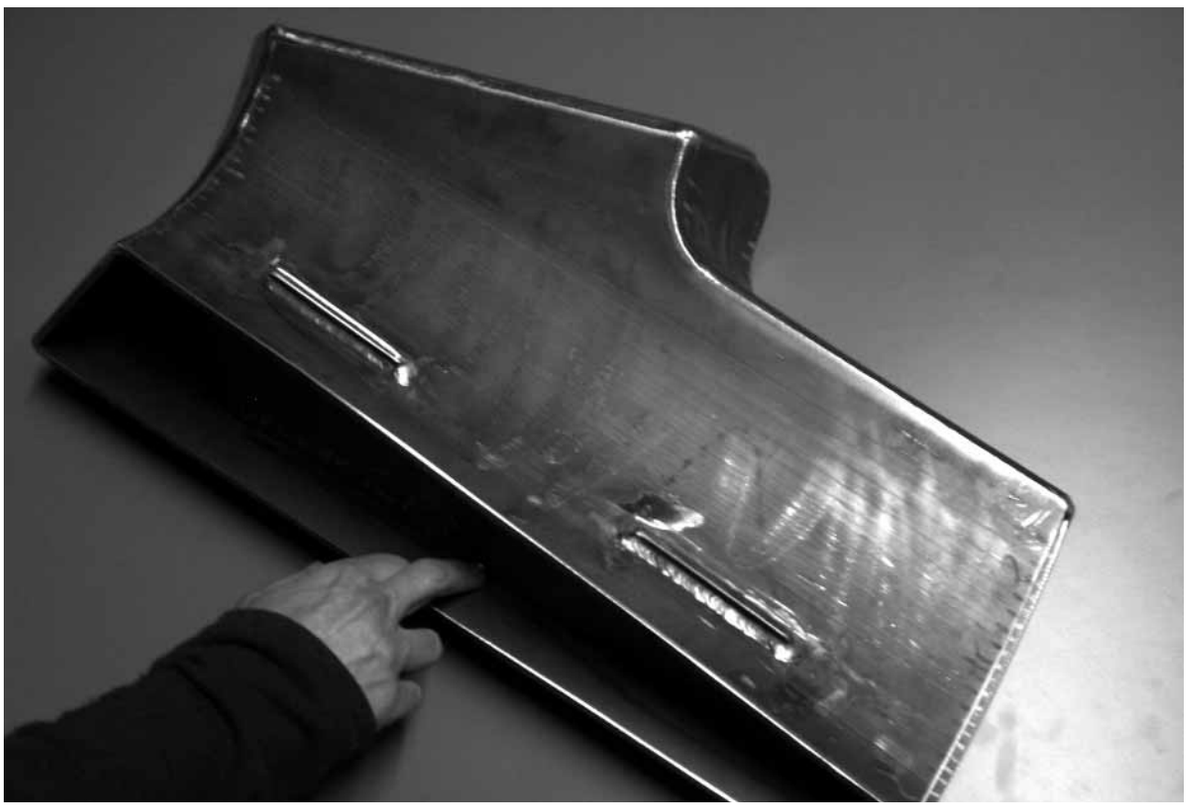
With industrial decline gathering pace in the North East in the mid 1980s, regional authorities set up a Tourism Development Action Plan 'to re view the future economic and social well being of local communities'.[8] Among other initiatives, this led to the 1994 establishment of the Kielder Partnership: a public, voluntary and private sector collaboration developing Kielder Water & Forest Park 'as an inspirational place for leisure, exploration and fun'. Income from tourism and leisure now competes with forestry as the primary economy of the area,[9] shifting the perception of the landscape from a utilitarian resource to an aesthetic commodity.



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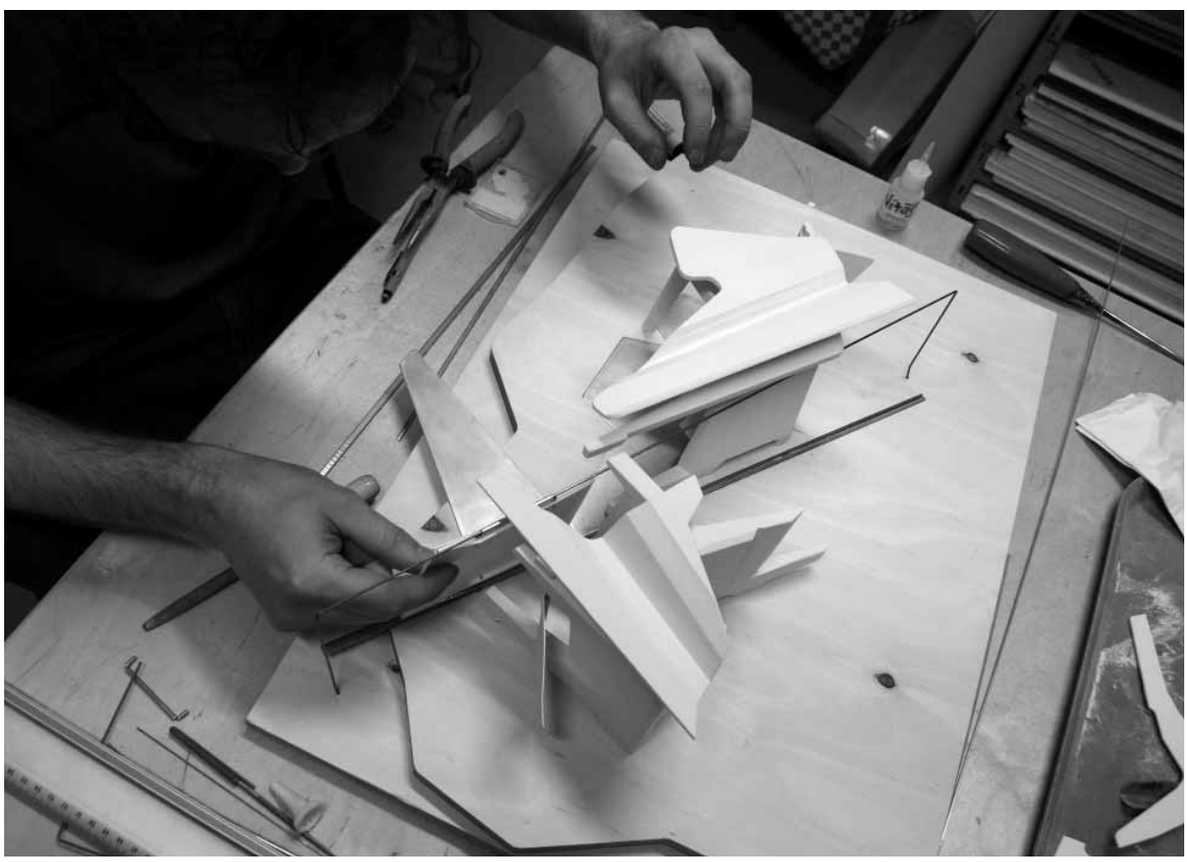
Forestry at Kielder was traditionally mapped and recorded through handmade drawings. Management techniques have changed since the 1920s when the first saplings were planted by hand. Operating on a 50-year cycle, bulk harvesting did not gather pace until the 1960s and '70s when, at its peak, the forest's chainsaw gang numbered seventy. Trees were cut in this fashion through the 1980s and '90s when the first generation of mechanised processors were introduced. Given the scale of the operation, management was approximate and harvesting/planting cycles were handled in units of one hectare. Since 2000, with the crop growing to include over 150 million trees, the management of Kielder Forest has become fully mechanised and digitised, sparking a revolution in the way trees are processed and opening a new way to regard the entire territory – as a landscape designed following a strategy for its visual appearance. A fleet of purpose-built harvesters with onboard computers for accurate product measurement now pluck the woodland crop tree-by-tree. These harvesters penetrate the forest to select, cut, process and transfer groomed lengths of trunk to forwarders. With their capacity to traverse marshy, rocky and steep terrain, these forwarders act as high capacity 'gofers' between the harvest site and the network of forest roads. Harvesting has become a form of manicure driven by an aesthetic and spatial strategy laid down by landscape designers. That strategy is controlled through 3D GIS and GPS information, both in the harvester cab and back at the station, allowing officers to accurately map, record and manipulate the forest mosaic pixel by pixel.[10]

Exploring a role for architecture

With support from Arts Council England North East, the Kielder Partnership appointed Peter Sharpe as full-time curator in 1999 to lead and coordinate a programme of visual art and architectural commissions and residencies. In 2003, responding to a call for expressions of interest, sixteen*(makers) were awarded the first architectural residency.[11] Resulting research involved a fine-grained analysis of micro environmental fluctuations close to a remote test site. The work involved the installation of a series of 'smart probes' which responded to variations in temperature and humidity and demonstrated the potential for an adaptive architecture to become locally specific over time.[12] This research remains active through an ongoing doctoral project by Chris Leung into Design Instruments and a recently completed Ph.D. by Phil Ayres.[13]

The Kielder Partnership's latest endeavours are tied together by the Lakeside Way, a new 44km path tracing the reservoir's entire shoreline, which is open to walkers, wheelchair users, cyclists and horse-riders. Completed in June 2009 and funded by Northumberland Strategic Partnership and One North East, four out of five new shelter commissions are located on this path. *Specere*, a triangular timber enclosure by Adjaye Associates, overlooks the reservoir from Deadwater Fell – at 571m one of the highest points in Kielder Park. Others in the series include *Robin and Freya* by architects Studio Weave involving two structures on opposing sides of the reservoir which imagine fictitious inhabitants: on the North Shore, Robin's hut is clad in timber shingles while Freya's Cabin, to the south, facing



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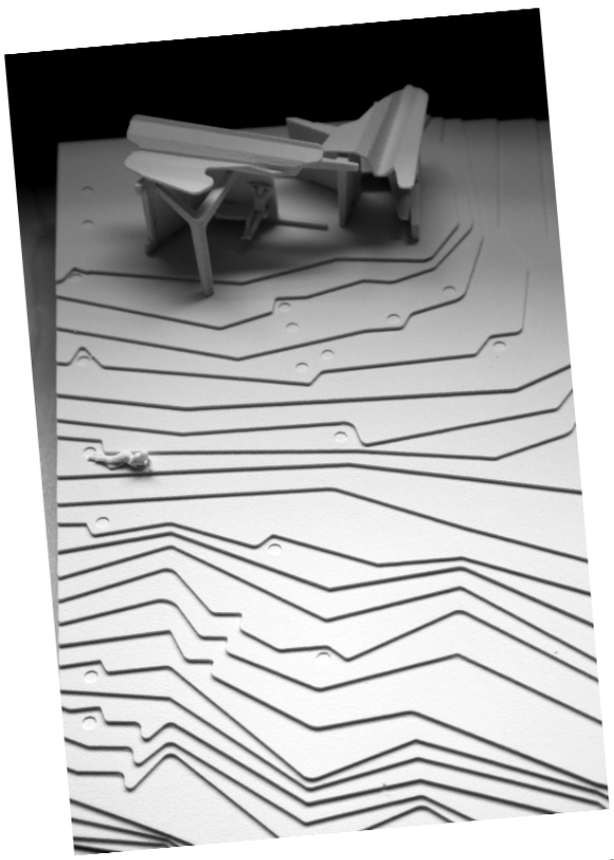
her partner, shines in gold. Nearer the shore, and positioned below the reservoir's highest water level, are *Janus Chairs* by Ryder Architecture, three over-scaled pivoting glulam and stainless-steel chairs. And *Silvas Capitalis*, a 6m high carved timber head by the American artists collective *SIMPARCH*, lurks in the woodland interior nearby.

55/02 is the fifth in this series of shelters. It marks the latest manifestation of many years' experimentation by its designers and fabricators, fuelled by a fascination with making and the synthesis of digital drawing and making. The project is named after its coordinates: 55° 11.30 N, 02° 29.23 W. In this regard, it has been conceived not as an imposed object but as a construct customised to fit the unique character of its place.

The structure is made entirely from steel and prefabricated by Stahlbogen at their works in Blankenburg, Germany. Its folded form orientates the visitor to key views, vistas, adjacent canopies and distant edges. Its fractured, incomplete envelope absorbs the variable spatial territory of surrounding trees and vegetation. Its undulating canopies are like giant gargoyles scooping rainfall and channelling it away from the seated areas below. Its tank-like, or maybe boulder-like, walls present barriers to the prevailing breeze that are sliced, modulated and framed by a sliding screen. Its monochromatic vermilion coat offsets the darkness of the woodland interior, but it is also an indirect and admiring reference to the Forth Railway Bridge luminous in its 'international orange', 130km to the north.



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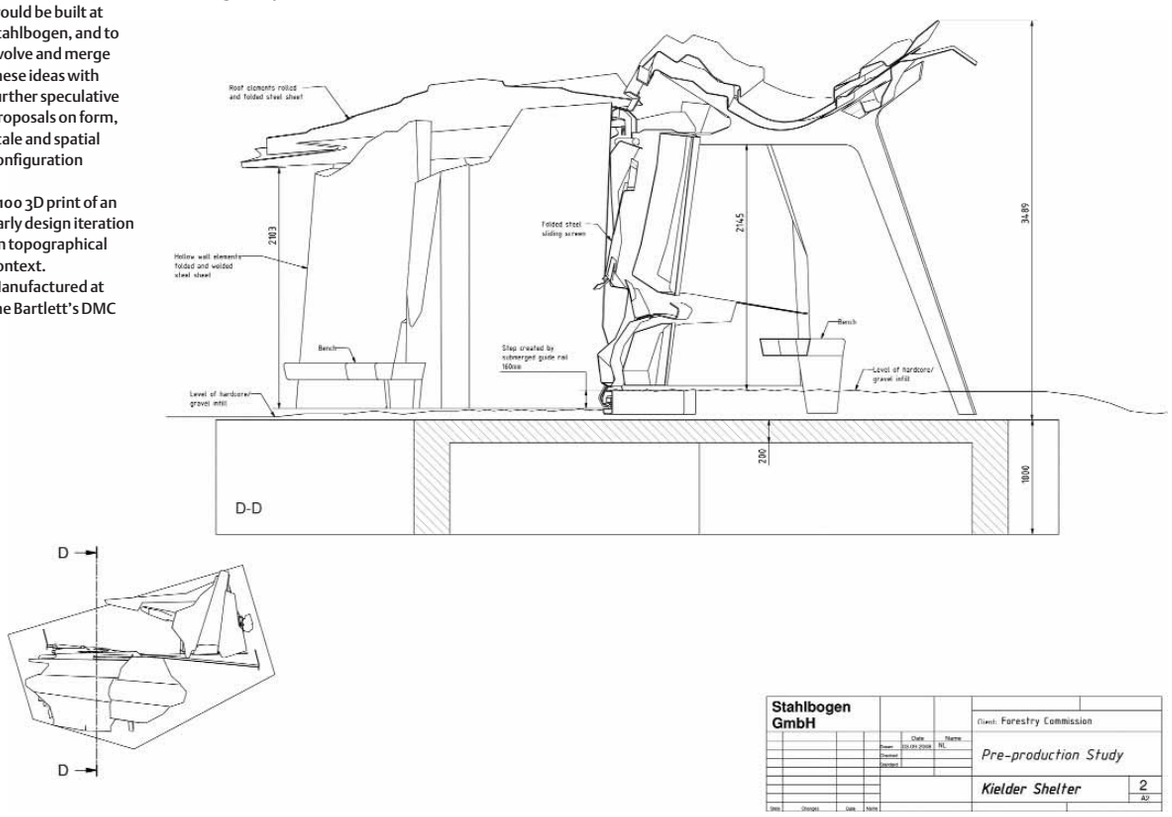
7 Hybrid digital and analogue model-making under way at the Bartlett's Digital Manufacturing Centre. This series had a twofold purpose, to take an overview on Callicott's proposals for how the project would be built at Stahlbogen, and to evolve and merge these ideas with further speculative proposals on form, scale and spatial configuration

8 1:100 3D print of an early design iteration on topographical context. Manufactured at the Bartlett's DMC

9 Section from Pre-Production Drawing set. The entire scheme was redrawn again on several occasions both prior to and during production. This set was developed for both structural and design analysis



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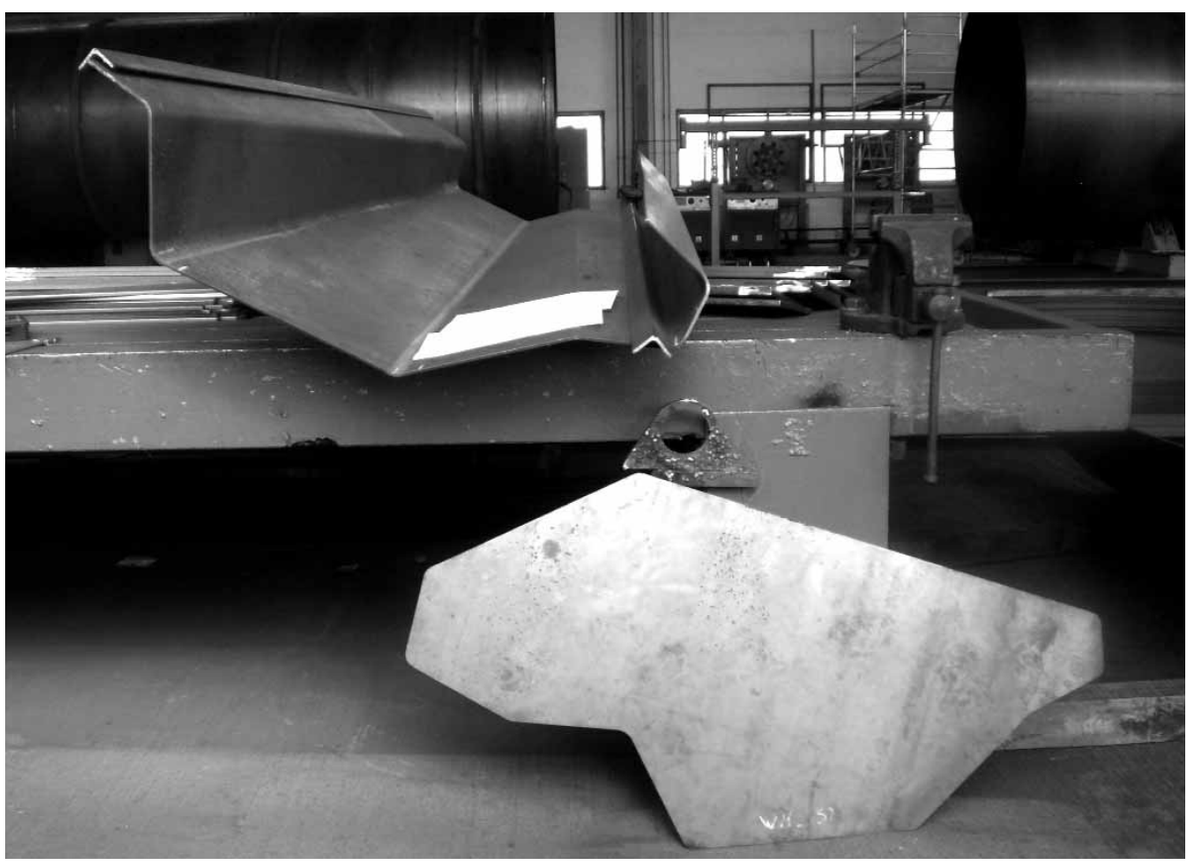

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10 55/02's design acknowledged that the budget could not justify investment in new tooling, thus folding geometries and folding sequences were calibrated by the limitations of the CNC press and Stahlbogen's stock of existing tool heads

11 Folded structural skin awaits base plate fitting

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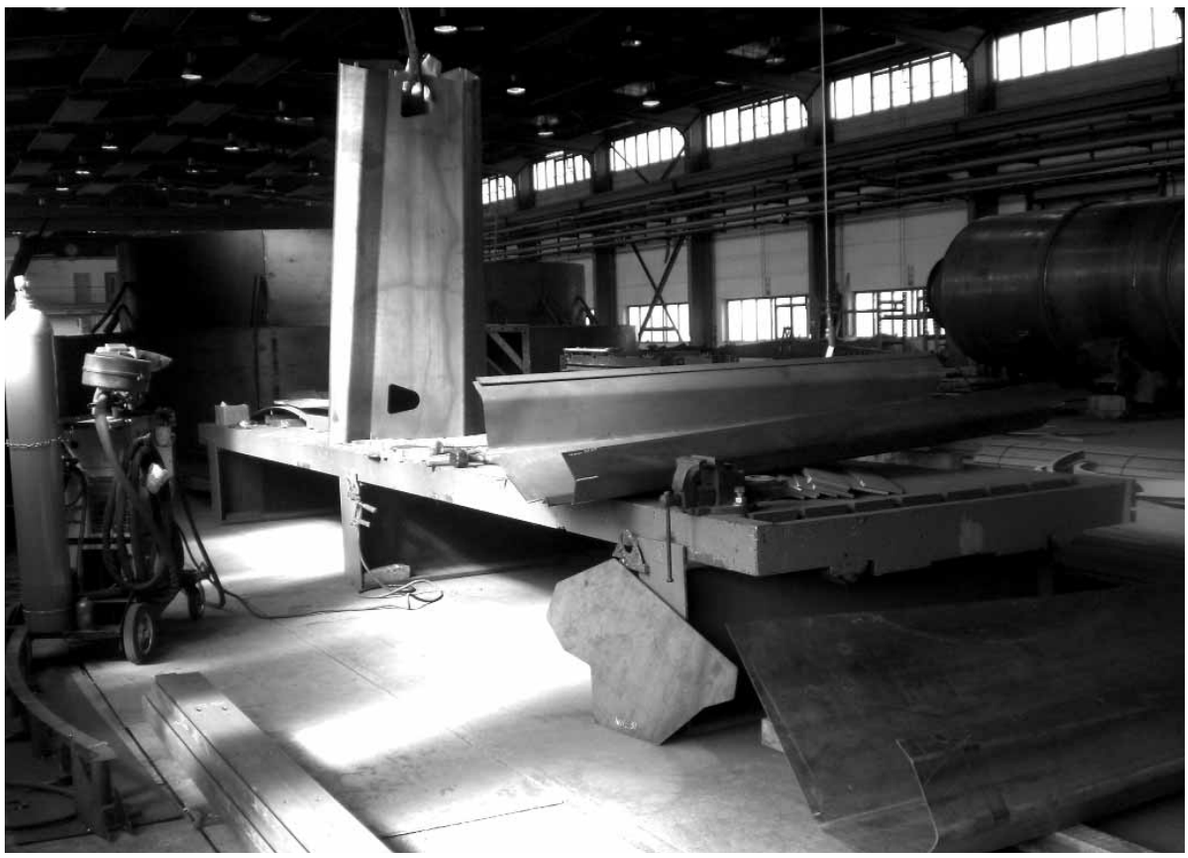

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12 *55/02*'s first series of elements take shape at Stahlbogen, Blankenburg, Germany

13 Master welder, Klaus Leineweber, operates Stahlbogen's semi-automatic welding tractor to stitch one of the longest seams. All such welds were left exposed rather than ground flat to preserve the shelter's manufactured blueprint

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An architecture to engage with the landscape

55/02 began in January 2008 as a sketch proposal off the north shore of the Lakeside Way. The brief called for 'some form of shelter for up to four people, with seating', and 'some form of engagement with the Kielder landscape', on a hypothetical site. A shortlist of potential candidates was given two weeks to respond to an outline brief, and a construction budget of £35,000 excluding fees and installation costs. The project presented an opportunity for sixteen*(makers) to team up with a founding partner, architect Nick Callicott, author of *Computer-Aided Manufacture in Architecture: The Pursuit of Novelty*[14] who had in 2003 left London for Blankenburg to set up and run Stahlbogen, specialising in steel fabrication using digital techniques.[15]

In line with the other submissions, sixteen*(makers)' pitch was selected on the basis of a sketch proposal submitted on two A3 sized boards – a common approach in selection processes of this kind. However, this convention presented a challenge to the practice which has established much of its reputation through process-driven methods, evolving projects through making from concept to completion, where often the final outcome bears only a tentative resemblance to early iterations. Established in 1994, much of sixteen*(makers)' preceding work had been developed in workshops with few drawings. Conclusions derived from physical prototypes, material testing, experimentation with tooling and methods, examination of behaviour, intuition, and conversation between designers and makers. In an age where drawings are reconfigurable and malleable in real time, anonymous paper-based sketch designs are a difficult medium to pitch the flexibility and potential of digital design and digital fabrication.[16] They risk confusing, irritating or denying the jury; and they risk becoming a hostage to fortune. With this in mind, our attention returned to the phrase 'some form of'; into which we read that the built work should provoke interpretation on notions of 'shelter' and 'engagement with the landscape'. Further, we wished to draw upon aspects of our residency at Kielder which investigated how architectural constructs might adapt and change in response to immediate fluctuations of temperature and humidity. Our January 2008 submission presented a design strategy to the jury: a brief to answer the brief.

Contrary to the common practice of submitting a rendering which simulates reality, our outline drawings were entirely diagrammatic and drawn in two dimensions. The A3 panels indicated, upon an outline of the hypothetical site, various zones and forces of influence that would act on the plot and inform the shelter's design. These included sun paths, topographical features, key views, prevailing weather patterns, proximity to access, etc. Diagrammatic plans indicated a construct with variable spatial potential and alternating degrees of enclosure and permeability. They also suggested a complex geometric form reminiscent of the man-made cuts and trenches in the Kielder landscape, the wayward edges of its formal planting grid and the intersection of aircraft vapour trails in the overhead sky. The panels also illustrated additional contextual qualities that would inform the work. These included images of dew, vegetation and ground textures. In addition, the panels contained an array of images from previous works, which illustrated experimentation with digital craft and manufacturing techniques, and offered a short descriptive text:

> *A Shelter of Reflection and Response*
> *The illustrated proposal is schematic and devised to present design principles and preliminary ideas for a small enclosure surrounded on 3 sides, to the east, south and west, by fixed and pivoted screens. The shelter sits on a prepared ground plain offering users scope to sit within the shelter's core or relax nearby. Depending on the time of day or year, the screens would offer additional scope for visitors to frame immediate spaces, or the reservoir and landscape beyond. The screens would have variable transparency from solid sheet to perforated mesh. The shelter will be prefabricated and installed with minimum disturbance to the environment. It will be constructed in folded steel and timber as a durable assembly requiring minimal maintenance. Potential for the pivoting screens to be activated by wind and temperature controlled mechanisms is also indicated* [...].

Cock Stoor [55° 11.30 N, 02° 29.23 W]

The jury selected the proposal as a 'wild card' and curator Peter Sharpe invited the team to visit the region in February to select a site from two options on the North Shore. Located on an intersection of distant harvest lines, trenches, gouges and trails – and overlooking the reservoir from a raised mound – a plot at Cock Stoor was selected. In comparison to the hypothetical site for the sketch scheme, the plot at Cock Stoor featured a steeper topography and a more varied relationship to sun path, views and key lines of approach. Water levels in the reservoir not only fluctuate in accordance with seasonal and annual rainfall, but also in response to various controls by Northumbrian Water. This has a significant impact on Cock Stoor which, at highest levels, is almost cut off from the surrounding forest when a shallow trench to the north is submerged. Consequently the small promontory, capped with Scots Pine,[17] is a rare clump of woodland excluded from harvesting. Vertically, the woodland also presented an array of geometric intersections through the loose grid of straight and bare tree trunks standing between 5° and 15° off-plumb. Their pattern generated a dynamic field of variable spatial depth, having a pronounced effect on light and acoustic properties *[2]*.

The plot centred on a pronounced NW/SE vista which, to the north, ran almost parallel to the edge of a mature sector of trees towards Whinney Hill and, to the south, ran for 2km across the reservoir towards Tower Knowe. This axis is chilled by northerly winds which overwhelm the plot's small potential for solar gain. Likewise, any southerly breeze would be cooled by its route across the reservoir, marking this plot as one of the Lakeside Way's cooler stopping-off points. Immediately to the north, a small cove occupied a quiet corner of Belling

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14 The first cluster of elements are assembled and reviewed. The welding tractor can be seen in the lower foreground

15 Track for the central sliding screen is laid. To the left in this image, Nick Callicott, to the right Bob Sheil

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16 Nick Callicott inspects work in progress. On account of his unique role as co-designer and manufacturer of *55/02*, Callicott refined and altered production drawings while simultaneously managing fabrication. A significant factor in its final resolution was the decision to assemble *55/02* on the factory floor in a direct line of sight from Callicott's drawing position

17 Working by eye and jig against the same tolerances as digitally manufactured elements, a 40 x 40 MS bar is forged into shape as a frame component to the sliding screen

18 Eight weeks from first fold to first full assembly

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Inlet, and to the east, across the mouth of the inlet, stood Belling Crags. To the south-west, through three to four layers of woodland, Leaplish could be made out some 3km away. Each of these nodes presented a deep matrix of views which would become driving elements in the design. In addition, the surrounding field of Scots Pine would incorporate a further layer of the architecture's dynamic envelope. It was decided that *55/02* should have no obvious boundary between its material edges and the rich constellation of its environment. It was clear that, in response to its exposed position, the structure should offer substantial shelter to the north, with a greater degree of openness to its leeward side.

The location would have been an unlikely and difficult site for construction were it not adjacent to a proposed temporary service road installed to deposit hardcore, gravel and topping for construction of the Lakeside Way. It was possible to engage with the Forestry Commission when planning the localised route of the Lakeside Way to determine the position of a spur for the site at Cock Stoor and prepare its groundscape. With the manufacturer in attendance, the decision to select Cock Stoor not only took into account aesthetic and contextual qualities but also the feasibility of delivery and assembly. This established the beginning of the collaborative design process, which would transgress disciplinary boundaries throughout the project's development.[18] Precise placement and orientation of *55/02* would alter again by responding to detailed GIS data on the position of all trees immediately adjacent to the plot, of which the minimum were felled.

Liminal design strategies

Following site selection, we were instructed to draw up an outline proposal for client approval within three months, to be followed by a coordinated application for planning consent alongside the other six schemes *[3–6]*.

The design progressed through simultaneous speculative exercises in drawing and making which flowed between Blankenburg, 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, handmade models, 3D drawings and 3D prints emerging in London. Both avenues cross-referred at regular intervals; exchanging and superimposing data in order to select changes and retreating to calculate the consequences. The glue in this fragmented workflow was online video conferencing. As many drawings and experiments were produced in designers' shorthand, a parallel set of representational drawings were developed to convey ideas in context. Given the project's limited resources and modest budget it was agreed that Stahlbogen should proceed with production design using their default solid modelling software Autodesk Inventor. While this emerged as the most influential and effective design tool, other approaches were explored in London using Rhino and Vectorworks for representational modelling and the communication of ideas. It was decided early on to explore dynamic qualities in the design, so animations were generated in Autodesk Inventor to simulate behaviour and assess potential conflicts.

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These animations gave credence to the idea of a sliding and tipping screen, and were also used to reassure Health and Safety Officers at Northumbrian Water.

Initial conversations about the procedure of the project raised a tentative cloud of formative, literary and technical ideas. These conversations were separated into autonomous categories of design, construction, procurement or logistics. All were regarded as design speculation whether the question under review was manufacturing technique or aesthetic language. Thus sixteen*(makers) worked between art, craft, architecture and building, drawing from works by Fabrizio, Lewerentz, Matta-Clark, Pichler, Prouvé, Rural Studio, and the collaborators Chareau, Bijvoet and Dalbet. Likewise, soundings were taken on the paintings of Anselm Kiefer, the drawings of Lyonel Feininger, the sound of John Cage and the coachwork of Sir David Brown. Through this process, the A3 panels from January's speculative pitch were revisited and picked apart. What emerged was an interest in alternating spatial enclosure and openness, in developing the fragmented and dynamic language suggested by the plan, and in dispersing key seating positions as pivots for reading the landscape's mosaic of cuts and folds. New sketches were produced and a conceptual jig was formed from these to begin factory experimentation.

Design for production

Stahlbogen GmbH is a subsidiary of Ehlert GmbH, a firm established in Güsten specialising in the fabrication of industrial structures such as bridges, vessels, formwork and frames for the chemical, petro-chemical and mining industries. A large proportion of Ehlert's output involves shaping plate steel in thicknesses from 2 to 40mm. The firm has 40 employees and a range of facilities including a 400 tonne 6m wide CNC press, a 10 x 2.5m plasma cutter and an 8 x 2m laser cutter. Ehlert works mainly in mild steel but also fabricates elements in aluminium and stainless steel. Nick Callicott, once Director of Computing at the Bartlett School of Architecture, UCL, set up Stahlbogen with fellow Bartlett graduate Kristina Ehlert in 2003 to pioneer a hybrid business model tapping their backgrounds in design and making and their expertise in 3D digital drawing and fabrication. So Stahlbogen is distinctively placed to exploit boundaries between design as a representational tool and making as a means of realisation. Production ideas for *55/02* were sketched out in the office and sent to the factory floor for immediate fabrication and review. It was during this phase that the project's structural envelope of 'tanks' evolved *[7–9]*.

A primary consideration in this phase was to ensure that the design took account of existing tooling. It was understood at Stahlbogen that there would be no possibility, on a project of this scale, to acquire new plant, equipment or tools. This factor was as significant as any other in shaping the final iteration of *55/02*, challenging designers and makers to reverse the conventional design process by working with the inventory of tooling. A further consideration involved limiting the project's base material to sheet steel. This offered the broadest scope to form the complexity of integrated architectural and structural elements. In combination with the CNC press and plasma cutter, a design strategy based entirely on sheet steel would control costs and place an appealing constraint on design. So, as the scheme evolved from sketch to proposed form for manufacture, all 3D shapes were designed to ensure that the form could be generated easily from a flat pattern with minimal wastage of material.

As early as the initial drawings prepared in January, spatial envelopes were characterised by cranked and softly folded non-linear forms. To inform the debate, Stahlbogen produced a 3D drawing portraying a folded 'tank' wrapped through a series of internal and external folds, open at both ends. Much of the geometry was a speculative response to conversations on site at Cock Stoor, but it also took into account the physical limits of the CNC press, variable options for fold radius, and the standard dimensions of flat plate. Folding would, of course, add essential stiffness to the sheet steel. It was suggested that the form could be made in no more than two sheets butting against two continuous exposed welded seams. Over 2m in length, such seams are not difficult to weld to a high standard, but would be a considerable task for any experienced welder to lay perfectly straight. For this reason, it was decided that these seams would be stitched by the factory's semi-automatic welding tractor. It was clear, however, that elsewhere it would only be possible to weld by hand and for this reason Callicott devised a test artefact to identify an employee who could be dedicated to this task. While this exam was under way, sixteen*(makers) printed the 3D 'tank' drawing from a '.stl' file on a ZCorp 310 at the Bartlett School's Digital Manufacturing Centre,[19] and the idea of forming the shelter around a series of vertical tank-like folded structures took hold.

Before convening a design meeting at the factory, two folded tank prototypes 2m tall were assembled and here a further revision was made. Standing side by side, with a 50mm gap between, it was apparent that the folds only worked visually up to a point beyond which the sensation that the surface was undulating became too subtle. At full scale, the 50mm gaps also suggested potential for more visual perforation and transparency in the scheme's envelope. Options for the radius of internal and external folds were also reviewed, and choices made according to the quality of light traversing opposing surfaces through the fold. At 50mm the transition was soft and subtle, whereas tighter folds appeared too sharp and more open folds indistinct. When the design team converged at Blankenburg, the prototype tank was examined for structural stability, fabrication feasibility and visual quality. From here, project design continued along two parallel routes: through drawings exploring the context and relationship of ideas; and through test pieces and prototyping. Both modes were representational in

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the sense that, although the test pieces were physically made, they were regarded, like drawings, as speculative explorations into materiality, form, structure and weight.

Design for approval

Sixteen*(makers)' early works in the 1990s were primarily furniture commissions. Projects evolved in ways not dissimilar to the tailoring of a bespoke suit. Clients would elaborate the brief by suggesting materials, forms, references, scale and budget, and sixteen*(makers) would respond with a drawn or made sketch. The project would proceed on an advance of a proportion of the budget, usually enough to purchase materials. At the halfway stage of manufacture, the client would be invited for a 'fitting', where the final direction of the design would be agreed and a further advance required. These often tense meetings relied on mutual trust, focused on resolving the final made object. The last phase of completion was then undertaken at the risk of both client and designer. If the former was unhappy, they were not obliged to pay costs but they lost their investment. Likewise, sixteen*(makers) would finish up with a bespoke work with unpaid costs and a damaged reputation. Unconventional as these methods were, all projects undertaken in this way reached a satisfactory conclusion.

Although it is difficult to exercise such agreements in projects of a larger scale, the practice remains committed to exploiting the manufacturing phase as a period rich in potential for design evolution. Drawings produced for client and planning approval prior to fabrication must retain sufficient scope for manipulation. In May 2008, a 1:25 model was designed and assembled for this purpose. It incorporated 'translated' components from Stahlbogen's interim design package, printed on the Z310 and assembled alongside handmade components for the roof and sliding door. The translated elements subdued some of the detailed information in the production design files to emphasise overall formal qualities at this scale. At this stage of design, conventional roles, protocols and schedules for architectural production were almost entirely reversed as the architects caught up with the manufacturer. Representational models made by sixteen*(makers) were largely generated by Stahlbogen's production files. As a result, the 1:25 model had a peculiar hybrid status. It remained speculative and representational while its constituent parts were already based on advanced data ready for fabrication. Both modes proved complementary, offering valuable ideas for testing towards feasible realisation. With the support of Kielder Partnership, the next step was to submit a planning application to Tynedale District Council; a task that would challenge the project's evolutionary approach to design.

Experimentation and testing at Stahlbogen slowed during this period while sixteen*(makers) generated a set of planning drawings summarising the proposal. This included 1:100,000 and 1:10,000 contextual plans, a 1:1,000 site location plan, site photographs, 1:100 ground level and roof level plans, and a 1:100 section. A 3D contextual model at 1:100 was also printed and photographed, and four perspectives drawn to show the scheme in its immediate context. For a number of reasons, including coordination with the four associated proposals and changes taking place in the structure of the regional authority, the projects were not called to committee until 26 October 2008 at which hearing all but *55/02* received approval. Objections were raised about the project's 'harsh geometric aesthetic' and its 'visual intrusion into the open countryside'. Fortunately, Kielder Partnership remained supportive and, after consultation with Tynedale District Planning Department, a revised application was submitted and approved on 17 December 2008. The resubmission placed a greater emphasis on immediate context and the visual experience of encountering the building. Emmanuel Vercruysse developed a series of collage-based images made by merging the 3D model with site photography, emphasising the work's central ideas on space and place. The hearing was positive and councillors who had previously lodged objections offered praise. Stahlbogen were immediately informed and progress resumed.

19

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19 May 2009. *55/02* is taken to site in 21 pieces

20 The ground slab is marked out using factory prepared sheet steel jigs, seen here either side of the sliding screen lower rail

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Design in production

The building now on-site results significantly from its final phase of production, which began at the Stahlbogen factory in January 2009. Stahlbogen revisited the digital model and began an entirely fresh model in Autodesk Inventor driven by production and cost considerations. Components were built in the CAD model as solid objects, which were then converted to hollow forms with a skin. After this phase, each were folded and unfolded as developable shapes and assessed for potential conflict with the dimensions and limitations of the CNC press. In folding sheet, not only is the thickness of material and geometry of fold a consideration, but also the feasibility of that series of folds in respect of their sequencing through the press. As a task set for the project was to minimise seam welds on each tank, most tank sides contained six to ten folds. The production design model had to ensure that each piece could be made without posing an obstacle for the press. As a result, the tanks were reduced in size and increased in number. This complemented an earlier interest in developing more transparency in the shelter's envelope. The number of folds was also increased at this stage, to increase stiffness in response to engineering queries and also for aesthetic reasons. Folds in the CAD model had a far more severe appearance than those on the 1:1

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21 Nick Callicott supervises and leads on-site assembly with the same team he chose to fabricate *55/02*

22 Temporary strapping to adjacent trees was deployed in assembly

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23 Local contractors D. G. Walton assist in positioning of components

24 Stahlbogen's assembly and fabrication team, from left Reinhard Schumann, Klaus Leineweber, Nick Callicott. Redundant setting out jigs can be seen in the foreground

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prototype. In CAD, the model displayed a line to delineate the beginning or end of a radius while, on the prototype, the 25mm radius of each fold conveyed a soft and seamless turn. In addition, the distance between folds on the 1:1 prototype appeared too great and more were required to emphasise movement, alignment and fracturing *[10–13]*.

An additional external factor arose at this time affecting design. Severe rainfall throughout the region over winter had delayed construction of the Lakeside Way and saturated the site at Cock Stoor. In previous iterations, the proposed foundation layout for *55/02* was a series of concrete pads, with hardcore and gravel on the surrounding groundscape. However, as conditions made this too difficult, contractors for the Lakeside Way laid a single slab. While this was not the preferred approach, the provision of structural support over a wider area offered additional scope for manoeuvre. Subsequently, the seating position in the south shelter was placed centrally under the canopy and, as we later discovered, assembly on site was made easier. Sheil, Ayres and Vercruysse met Callicott at the factory four times to exchange views on progress. At the last gathering, a final decision was made on the hue and saturation of the painted finish. It was also decided to eliminate a seat placed on the external face of the north-east corner as one too many *[28]*. A trace remains, where the overhead roof connection piece drops to a level where it had been intended to connect with the absent seat *[14–18]*.

Over the next three months, *55/02* evolved through fabrication, drawing, animation and assembly. Guided by engineering calculations provided by a local consultant in Blankenburg, the tank-like wall elements were formed in 4mm mild steel sheet, giving the work its defining scale and configuration. Roof components were formed in 8mm plate steel, selected not only for its strength and stiffness but also for the visual weight of its exposed edge. Roof elements were subdivided into more components than had been indicated earlier. This was initially prompted by ensuring that pieces were transportable and manoeuvrable on site but also, as the project's individual language became defined, a need for layering and complexity in the canopy became apparent. Among the roof elements is one that appears rolled but, on close inspection, is obviously folded. This came about as multiple close folding was the only way that the tapered and conical belly, which had appeared in sketch models early on, could be fabricated in respect of adjacent connecting elements. Once the tanks were complete, the roof was fitted twice. On the first occasion, it was suspended from the factory crane to assess visual qualities and identify the location of intermediate connector pieces. Later, the exercise was repeated to assemble the shelter under full load *[19–24]*.

Probably the fastest and most hybridised element to be designed and made was the sliding screen. Proprietary rolling gear was sourced in Denmark early on, as configuration of the screen was debated and assessed for safety through approximate drawings and animations. Its track was one of the first elements laid out in the factory, but the screen was one of the last elements to be designed and assembled. Its outer frame is forged from 40 x 40mm solid sections while its inner panels consist of 2mm folded sheet. The screen was always imagined as a modulator of spatial and volumetric qualities

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25 Cluster of roofing elements assembled and installed

26 *55/02*'s installation was completed in three days

27 June 2009. *55/02* settles into its new surroundings

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28 The abandoned seat. Once fully assembled it was agreed there were sufficient seating positions and this element was unnecessary

between the north and south enclosures but, by saving its final design to near the end of fabrication, it evolved as a unifier of the project's experimental character and, peculiarly, its elevation resembles some of the early sketch plans. Further ideas emerging in this period include the manner in which the rhythm of vertical folds alternates to horizontal folds on the wall section that bridges the south-west enclosure. This was prompted by an urge to break the monotony of only vertical folds, and express a response to the location of the horizontally sliding screen. The flip to a horizontal emphasis altered the character of the envelope at that point from 'wall condition' to 'beam condition'. It also generated a more expansive view of the ground surface below and emphasised the potential to view in silhouette the presence of someone seated under the southern canopy. Likewise, the components for connecting the roofing elements with wall elements were designed to continue the notion that primary structures of the shelter would be separated by gaps offering views to its interior and beyond, or above to the tree canopy. Their splayed configuration was led by a need to spread load across a wide surface area, but also in their profile to augment the shelter's distinct language. At such points of connection, flush fitting access panels were designed for ease of site assembly, a matter of constant consideration *[25–27]*.

A manufactured reality

Completion of *55/02*'s design coincided with its fabrication and assembly in the factory. Its status as a project evolved out of tacit knowledge, conversation and the craftsmanship of its makers. This process is reflected in the absence of a complete set of drawings. As Stahlbogen had also been contracted to install the work on site, full assembly was not only necessary for testing and assessment but became in itself a dress rehearsal for installation at Cock Stoor. Once disassembled and packed, *55/02* consisted of 21 independent parts totalling 8.1 tonnes, which arrived on site on 14 May 2009. The work was assembled by the Stahlbogen fabrication team between 19 and 23 May, with help from the Forestry Commission and local contractors D. G. Walton who supplied plant, lifting gear and valuable consultation on shaping the surrounding groundscape.

One of the ironies in the project is that, on account of its remote location, it is likely to be known more through photography than experience, presenting an expected but nonetheless odd conflict with its 'real' intentions. Some have already remarked how certain photographs make *55/02* appear like a digital rendering superimposed on a real background. This will fade as *55/02* beds in and its newness is overtaken by due wear and tear. This is a landscape laden with scars of use – it is a manufactured landscape and this a manufactured architecture *[28]*.

Notes

1. Founded at UCL's Bartlett School of Architecture sixteen*(makers) include Phil Ayres, Nick Callicott, Chris Leung, Bob Sheil and Emmanuel Vercruysse. Callicott has since gone on to establish Stahlbogen GmbH a subsidiary of Ehlert GmbH in the Harz region of Germany, while 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 where more details may be found at www.sixteenmakers.com.
2. Bob Sheil, 'Transgression from Drawing to Making' in *Architectural Research Quarterly*, 9.1 (2005), 20–32, 26. See also various publications on the Kielder Residency by Sheil, Ayres and Leung at <www.sixteenmakers.com/publications.htm> [accessed 11 November 2009].
3. See C. S. McCullough, 'The Kielder Water Scheme, the last of its kind?' in *Improvements in Reservoir Construction, Operation and Maintenance*, ed. by H. Hewlett (The British Dam Society; Thomas Telford Publishers, 1994).
4. In consultation with engineers Babtie Shaw & Morton.
5. The dismantled Border Counties Railway line ran coal, timber and miners to and from nearby Plashetts Colliery from 1862 to 1964.
6. NPower are owned by RWE of Essen.
7. As of August 2009.

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8. From *Art and Architecture at Kielder*, a Tynedale Council publication, 2005.
9. Annual turnover for forestry at Kielder is c.£9m.
10. A geographic information system (GIS) captures, stores, analyses, manages and presents data that is linked to location. Technically, GIS is a system which includes mapping software and its application with remote sensing, land surveying, aerial photography, mathematics, photogrammetry, geography and tools that can be implemented with GIS software. The Global Positioning System (GPS) is a US space-based global navigation satellite system. It provides reliable positioning, navigation and timing services to worldwide users on a continuous basis in all weather, day and night, anywhere on or near the Earth.
11. P. Ayres, 'Getting Specific', in *Design Through Making*, guest issue of *Architectural Design*, 176, ed. by B. Sheil, 58–65.
12. B. Sheil and C. Leung, 'Kielder Probes – bespoke tools for an indeterminate design process', in *Smart Architecture* – ACADIA (Association for Computer Aided Design in Architecture), ed. by O. Ataman (Savannah: Savannah College of Art and Design, GA, USA), pp. 254–59.
13. P. Ayres, Ph.D. thesis entitled 'Adopting an Adaptive Architecture – enlisting digital technologies for the acquisition of local specificity over time' is held at Aarhus School of Architecture Library, Denmark.
14. N. Callicott, *Computer-Aided Manufacture in Architecture: The Pursuit of Novelty – Changing the Craft of Design* (Oxford: Architectural Press, 2000).
15. M. Stacey, 'Folding into the Landscape' in *Building Design*, 1880, 14 August 2009, pp. 16–17. Illustrated article on the role of Stahlbogen in designing and building 55/02.
16. B. Sheil, 'Time to be Real', in *Quality: Abstracts,* ed. by A. Dutoit, J. Odgers and A. Sharr, Welsh School of Architecture, Cardiff, July 2007, p. 72.
17. Scots Pine, as the most widely distributed conifer in the world, can grow to 36 metres in height. But on Cock Stoor most are about 20 metres tall with an average girth of 5 metres diameter. Left alone, Scots Pine usually lives for 250–300 years. Among those on Cock Stoor are survivors of the initial 1920s plantation.
18. In The Royal institute of British Architects' Plan of Works it is assumed that the contractor or specialist supplier might only become involved at stage C or beyond. In this instance, manufacturers and co-designers Stahlbogen were involved in project development from the outset. Later and closer to completion, those roles would revert to conventional boundaries of professional responsibility for contractual and legal purposes.
19. STL is a file format native to the stereolithography CAD software created by 3D Systems. This file format is supported by many other software packages; it is widely used for rapid prototyping and computer-aided manufacturing. STL files describe only the surface geometry of a three-dimensional object without any representation of colour, texture or other common CAD model attributes. The STL format specifies both ASCII and binary representations. Binary files are more common, since they are more compact. An STL file describes a raw unstructured triangulated surface by the unit normal and vertices (ordered by the right-hand rule) of the triangles using a three-dimensional Cartesian coordinate system.

Illustration credits

arq gratefully acknowledges: sixteen* (makers), all images

Biography

Bob Sheil is Senior Lecturer and Director of Technology at the Bartlett School of Architecture UCL. He has worked as a designer and maker in architecture, furniture, exhibition and web design. Following ten years in practice, 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 is a founder member of the workshop based practice sixteen*(makers) with Nick Callicott, Phil Ayres, Chris Leung and Emmanuel Vercruysse. He was guest editor for two issues of *Architectural Design*: *Design through Making* (2004) and *Protoarchitecture* (2008).

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