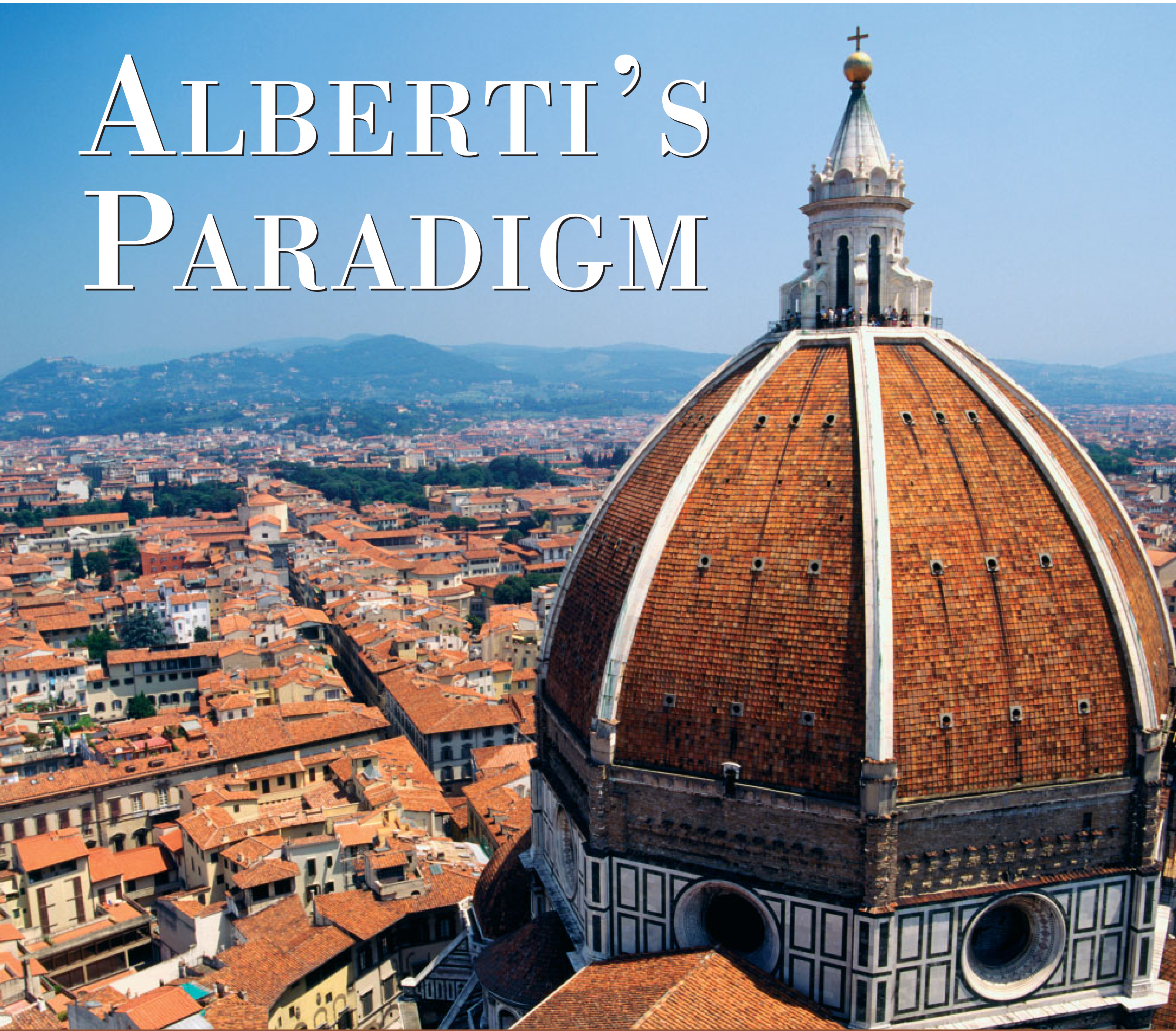
Alberti's Paradigm



Could the advent of building information modelling (BIM) see the architect's status return to that of his medieval counterpart, the master builder? Guest-editor **Richard Garber** examines the work of Filippo Brunelleschi, who did the seemingly impossible in early 15th-century Florence by spanning the massive opening of the dome of Santa Maria del Fiore, the city's cathedral, through an adept use of physical models.

Filippo Brunelleschi, Vaulting of the Dome of Santa Maria del Fiore, Florence, Italy, *c* 1420–36
The completed dome soars over the Florentine skyline and can be seen for miles. A series of external apertures in the exterior cavity bring light and air into the central cavity, which it is possible to walk through, while others were used to accept the armature of exterior scaffolding used by masons and bricklayers during construction. The total height of the dome and lantern is approximately 114 metres (375 feet). The dome's diameter is about 42 metres (138 feet). It is estimated that it weighs 37,000 metric tons (81,571,037 pounds), and the number of bricks used in its construction was more than four million.

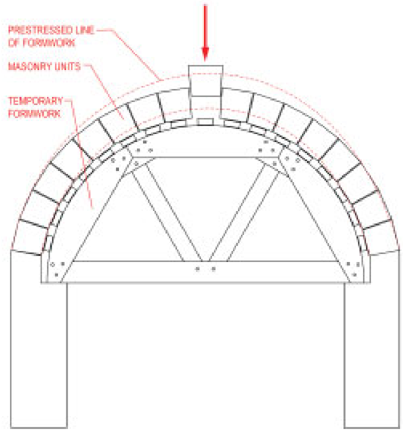
As design processes more fully make the transition to the digital, there has been an increased interest in drawing parallels with the analogue counterparts to such processes, in some instances stretching back as far as 600 years. One of the comparisons many have made in the advent of building information modelling (BIM) is that these new technologies will somehow return architects to the status of the master builder of the pre-Renaissance – that the strict division, or gap, between architects who design buildings and the builders who construct them is being closed. It was the *capomaestro*, or master builder, who facilitated the smooth flow between design and construction in many of the notable projects of the late Middle Ages. Unlike today's practitioners who graduate from the many dedicated architectural schools, the master builders of this period were most likely exceptionally talented craftsmen or artisans, still trained in guilds, who crossed over into architecture from an allied art. Their knowledge of making not only allowed them to conceive the design of buildings, but also gave them the opportunity to specifically formulate the construction sequence and engineer building practices.

Among the several notable projects of the 15th century was the vaulting of the massive dome of Santa Maria del Fiore (*c* 1420–36) in Florence by Filippo Brunelleschi. Brunelleschi was a trained goldsmith[1] who won prominence and acclaim for his daring and untested plan to construct the dome without the wood scaffolding traditionally used for centring. According to most interpretations, as the project's *capomaestro* he designed and engineered many innovative tools and techniques in the process that would form the basis for many of the built successes of the Renaissance.

Brunelleschi and Early Information Models

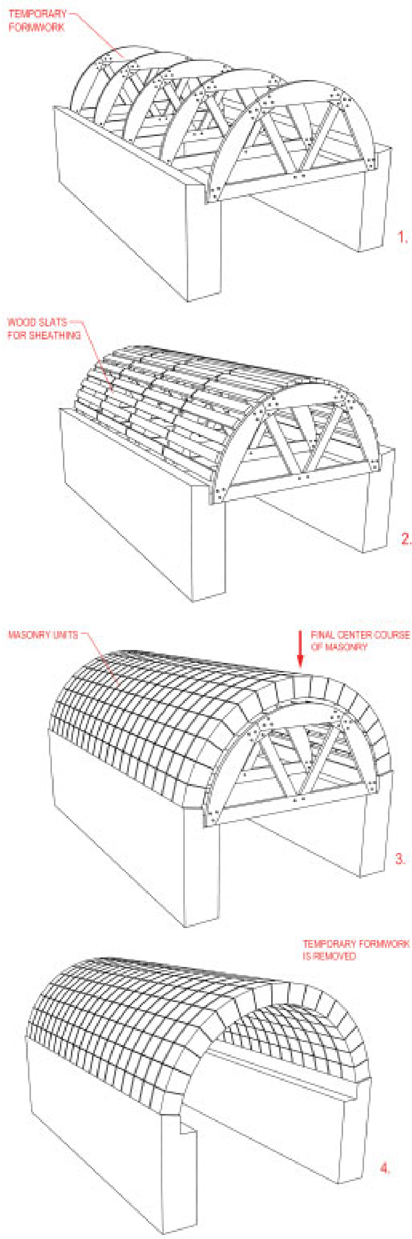
The most significant way new ideas about building and construction technologies could be examined during this period was through the making of large physical *modelli* crafted by designers to convey their intentions. These were in many ways similar to today's information models. They were usually large enough to be entered and inspected by clients, and they conveyed spatial organisation as well as information about materials and construction techniques. In the largest of these, craftsmen from the various guilds who would oversee the actual building were employed to construct the portions of the scaled model they would ultimately be responsible for in the field.

Brunelleschi's model for the dome of the Santa Maria del Fiore was some 18 metres (60 feet) in length and was constructed by four bricklayers lent to the architect by the Florentine Building Commission.[2] A series of wooden (and possibly stone) tension chains were set at equal distances



TYPICAL SCAFFOLDING FOR CENTERING A MASONRY ARCH

The timber formwork required in vault or dome centring was typically stressed into place by the weight and fit of masonry units. Masonry units were applied from each side and culminated in a centre course that locked the units into their final location. As the units were installed, stresses on the temporary timber frame caused it to deform, thus it was critical to make the timber frame as rigid as possible to minimise such damage. Drawing based on illustrations by John Fitchen in *Building Construction Before Mechanization*, MIT Press (Cambridge, MA), 1989, pp 100–05.



TYPICAL SCAFFOLDING FOR CENTERING A MASONRY ARCH

Traditional Vaulting Drawings, 2008
The conventional method of vaulting an arch or dome prior to Brunelleschi's plan to vault the dome of the Florence cathedral was by first constructing and erecting a temporary support structure, usually of timber frame members, that was hoisted into place (1). Not only was the erecting and decentring, or removing, of these heavy members dangerous work, but deformation due to the settling of either the timber frame or masonry members also needed to be considered. Masonry was installed on top of a series of wooden slats that formed sheathing on top of the timber frames (2). Once the final centre course of masonry was installed, the centring could be removed (3). In many cases, the size of the dome or arch meant that the only practical way to remove the timber frame was to dismantle it piece by piece, high in the air – a daunting process in itself (4). Drawing based on illustrations by John Fitchen in *Building Construction Before Mechanization*, MIT Press (Cambridge, MA), 1989, pp 100–05.

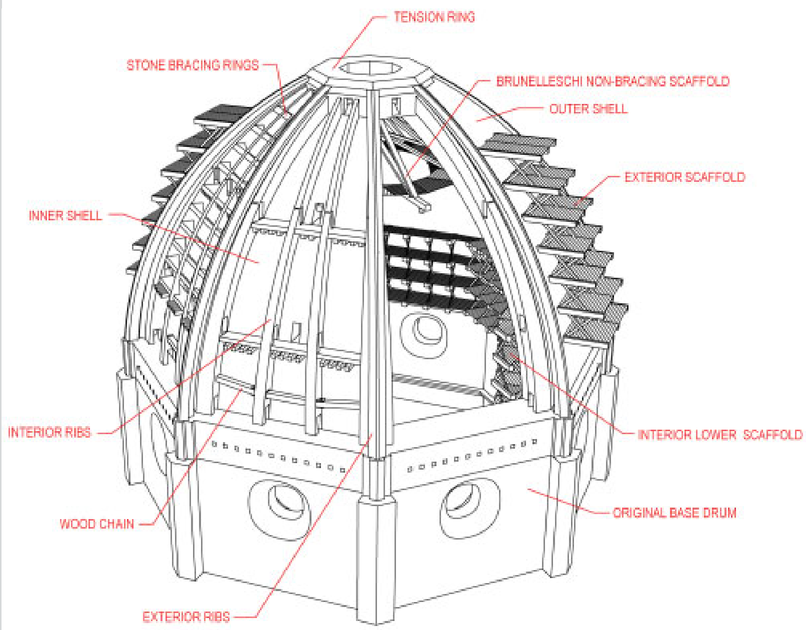
within the interior cavity of the dome itself so as to invisibly support the structure, using neither buttresses, as seen in the Gothic cathedrals of the previous century, nor internal armature or scaffolding. The model thereby fostered a productive discussion and the opportunity for feedback from the various trades before the vaulting of the dome itself, and helped to ease the concerns of Brunelleschi's employers, the wardens of the Opera del Duomo,[3] as to whether such construction techniques would actually work. There is a clear correlation between the ability of such a working model to systemically test construction techniques and sequencing as opposed to simply representing a designer's intentions. In fact, some speculate that these models became more sophisticated as a more three-dimensional awareness emerged in the guilds. Similarly, virtual sequencing is made possible by information models today.

Christoph Frommel has noted that 'the architectural model must have evolved because of the same need for material and spatial quality and could have even been the response of the master builders to the illusionism of the painter-architects'.[4] The model also ensured a sort of architectural precision about the whole volume of the proposed building, if not its construction details. As the rise of the contemporary architect-designer separated the architect from the building site, models would have ensured a three-dimensional understanding of the scope of the work at a time when drawings did not figure prominently in the planning of buildings.

Trained in the guilds, Brunelleschi was a secretive and competitive man, and his architectural models of buildings and details were rarely finished so as to keep his design intentions covert. They lacked ornament, and only showed relationships between walls and other principal elements.[5] As many of these models initially served as competition entries for various parts of the dome, it is apparent why Brunelleschi wished to keep information from rivals such as Lorenzo Ghiberti who were also working on the project. In addition, it seems in keeping with his role as the master builder that Brunelleschi also kept information from workers on the site as a way of maintaining control of nearly every aspect of the construction. It was common for competition presentation models to eventually be used as guides for construction. As such, these models were routinely updated and added to as new technologies were developed and the construction of specific projects progressed.

Brunelleschi's use of such information models is consistent with their further employment in the 16th century, when a better understanding of construction technologies and higher degrees of craftsmanship meant that fewer changes to models were required once construction had begun. In contrast to the 15th-century

Filippo Brunelleschi, Vaulting of the Dome of Santa Maria del Fiore, Florence, Italy, *c* 1420–36
Model of the dome and apse of the Florence cathedral exhibited at the Palazzo Grassi in Venice in 1994. The exhibition, organised by Henry Millon and Vittorio Lampugnani and titled 'The Renaissance from Brunelleschi to Michelangelo: The Representation of Architecture', called attention to the importance of models in the design and construction of late-medieval and Renaissance works. Models were typically large enough to be entered by clients or tradesmen, and the master builder often employed the latter in their construction to ensure coordination of design intent with construction methods. Such models are generally thought to be more useful in the study and understanding of early Renaissance construction projects than drawings.



CONSTRUCTION OF THE DOME AT SANTA MARIA DEL FIORE, FLORENCE

The vaulting without centring of the Santa Maria del Fiore was a complex undertaking. Brunelleschi employed information models in order to better organise and convey his intentions to the masons and bricklayers who carried out this work. The numerous innovations in the construction of the dome included a two-shell system between which a series of wooden chain (and possibly stone) tension rings were installed within the cavity to resist the outward pressures of the form itself. This allowed construction of the dome without external buttressing or internal structural centring frames. In addition to the interior scaffolding, a series of exterior platforms were designed to fit into the exterior masonry of the dome. Drawing based on illustrations by Frank D Prager, in *Brunelleschi: Studies of His Technology and Inventions*, Dover Publications (Mineola, New York), 2004, p 35.

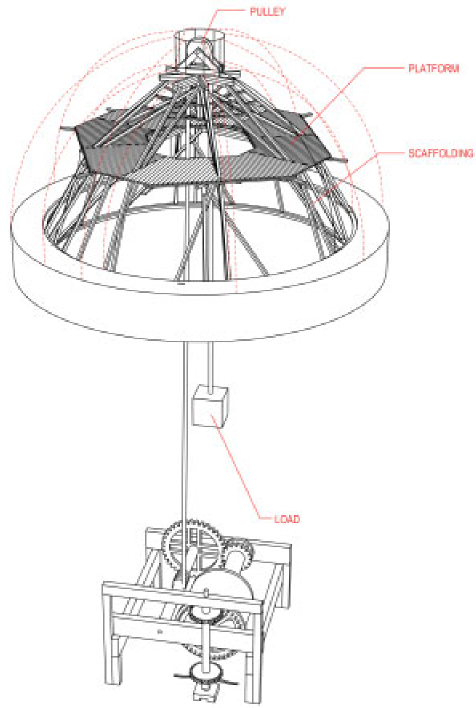
modelli, *modani*, or full-scale copy models (representations), of building profiles in wood were now used as a basis for the fabrication of details such as lintels or cornices.[6] These were like jigs, used for the replication of architectural features. It is interesting to note that *modani* began to emerge following the establishment of Gutenberg's printing press in Europe (1465), which helped to further codify architectural orders and disseminate knowledge about construction techniques through published treatises. They also seem to have been the precursors to 'mock-ups'.

Among Brunelleschi's most important inventions that revolutionised the construction of the dome was his oxen-driven hoisting device.[7] This machine was used to deliver materials several hundred feet in the air to the masons laying the dome's complex brickwork, and was significant because none of the previous pulley systems, driven by men, had ever reached such heights. At its retirement, it was estimated that the hoist had lifted 31.7 million kilograms (70 million pounds) of building materials to the masons and bricklayers.

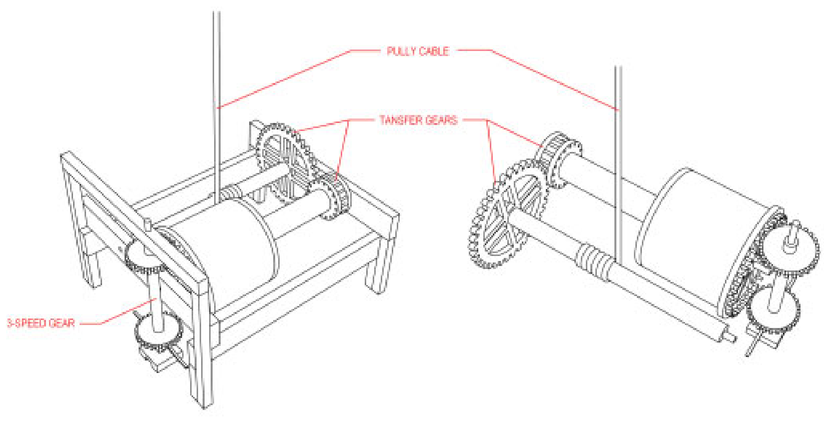
Alberti and the Codification of Architecture

While Brunelleschi was working through the problem of vaulting the dome in the field, using scaled models and his advanced construction technologies, the theorising of such a scientific concept of art and building for the time was concurrently being undertaken by Leon Battista Alberti. In his treatise 'Della pittura', he wrote of Brunelleschi and his accomplishments: 'Who is so dull or jealous that he would not admire Filippo the architect, in the face of this gigantic structure, rising above the vaults of heaven, wide enough to receive in its shade all the people of Tuscany; *built without the aid of any truss work or mass of timber* – an achievement that certainly seemed impossible?'[8] It was also in this text that he would define modern principles of representation by geometrically defining the instrument of perspective and its use in architecture and design.

Alberti held various official posts with the papacy in Rome during his lifetime, while practising architecture and authoring his own *Ten Books on Architecture* (*De re Aedificatoria*) among other texts. *De re Aedificatoria* (1452) was a projective document in contrast to Vitruvius' *Ten Books* (*De architectura*), and sought to refine and develop the idea of architecture as a humanist art, the architect as an intellectual, and the practice of architecture as the loftiest of professions. The treatise is based on Alberti's survey of Classical orders and led to his calling for a more theoretical understanding of the use of these orders. Through his work with the papacy, Alberti was well travelled and had the opportunity to survey



The relationship of the oxen-driven hoisting device invented by Brunelleschi and the scaffolding that was erected at the level of the dome's cupola was carefully coordinated. The scaffolding was not required to centre the dome – this was achieved through a series of chain rings and patterns of bricklaying, and as such was constructed of much lighter elements than the more conventional scaffolding of the period. At the top was a pulley that brought materials through the scaffolding to a series of levels where the tradesmen were working. At the base of the hoisting device were gears that allowed it to be moved forward or in reverse without changing the direction of travel of the oxen that were tied to it. Drawing based on illustrations by Frank D Prager, in *Brunelleschi: Studies of His Technology and Inventions*, Dover Publications (Mineola, New York), 2004, p 28.



HOISTING DEVICE AND GEAR DETAIL

Powered by oxen, Brunelleschi's hoisting device involved a set of gears that moved differentially and in both forward or reverse by way of a reversing clutch and screw-controlled load positioner. It has been estimated that the hoist had lifted 31.7 million kilograms (70 million pounds) of building materials to the masons and bricklayers by its retirement. Frank D Prager suggests that the device was worked on by Antonio Manetti Ciaccheri, who was to become *capomaestro* after Brunelleschi. Drawing based on illustrations by Frank D Prager, in *Brunelleschi: Studies of His Technology and Inventions*, Dover Publications (Mineola, New York), 2004, p 71.

Classical works first-hand, which prior to the diffusion of the woodcut or the arrival of Gutenberg's printing press in Italy, was the only way to see such buildings. Interestingly, however, even contemporary translations contain very few illustrations, and as such are in keeping with the late-medieval practice of only verbally describing a work of architecture or construction process. For Mario Carpo: 'Alberti … tries in the *De re Aedificatoria* to emulate through plain alphabetic writing the expressive potential of the images whose use he rejected.'[9]

De re Aedificatoria is perhaps one of the first examples of the early Renaissance desire to both establish architecture as a profession and disseminate information about its practice – a task made relatively easy by Gutenberg's press.[10] This is in direct opposition to the operations of the late Gothic guilds, from which Brunelleschi was born, which sought to keep construction practices as highly guarded secrets and translate them mostly verbally.

In writing his treatise, Alberti became an advocate of those architects engaged in design but not in construction. This codified a split, or gap, between design and making that still exists today, more than 600 years later, and frequently puts architects at odds with those who build their work. Alberti's 'disinterest in the actual realization of his designs may have been a consequence of the *forma mentis* (mindset) he acquired in the cautious, reserved circles of the Curia. Or it may have been the result of a natural preference for the purely theoretical aspect of his art.'[11] In fact, this tendency towards broader intellectualism, as opposed to trade specialisation, 'comes to the fore again and leads to the cult of a type of versatility which is more akin to the dilettante than the craftsman'.[12] This is not to suggest that Alberti's vast contributions, both theoretical and pragmatic, are not significant to the contemporary practice of architecture; rather, that the framework within which he sought to position that practice of architecture was rooted in the discourse of making, and not in making itself. 'It is evident from the disdain with which Alberti refers to building masters that he imagined them capable only of execution and not of conception in architecture.'[13]

Interestingly, though Alberti most famously advocated this separation of the design profession from the building trade, documentation exists that suggests this division already existed. By the early 15th century, late medieval Gothic builders in Europe were, unbeknown to them, already working according to what has come to be known today as the Albertian Paradigm.[14] As early as the mid-14th century, construction officials were formally adopting the title 'architect' or '*archititector*', and working remotely – and even internationally.[15]

Alberti and the Advocation of Models

In the second book of *De re Aedificatoria*, subtitled *Materials*, Alberti discusses the use of models in architectural design. Like Brunelleschi, he also suggests that models should remain incomplete, proposing that 'the presentation of models that have been colored and lewdly dressed with the allurement of painting is the mark of no architect intent on conveying the facts; rather it is that of a conceited one, striving to attract and seduce the eye of the beholder, and to divert his attention from a proper examination of the parts to be considered, toward the admiration of himself'.[16] What is remarkable about this section of the work is how Alberti articulates the use of models, and how these uses are similar to the purpose of BIM systems in contemporary practice. This is an interesting contradiction: Alberti's call for the separation of design and making would seem consistent with architects making representations of their designs with models (for example, renderings), but instead he recommends more operative uses.

Alberti suggests that the use of models to examine, in an iterated way, the relationship of a design proposal to its site and district, its overall form as well as the internal relationships between its components, is paramount to understanding how appropriate a proposal is. Further, the adequate size and shape of such components leads to a proper selection of materials and orders, and quantity of columns: 'their thickness … extent, form, appearance, and quality, according to their importance and the workmanship they require.'[17] This suggests the model can be used to investigate construction sequencing and techniques as well as costs of materials, and that the number of elements can be counted so that a budget can be arrived at in a similar way to how Brunelleschi studied the vaulting of the dome of Santa Maria del Fiore through his models and inventions, including the wood (and possibly stone) chains that lent tensile support. Likewise, the digital information models of today simulate construction sequencing over time to allow for a better coordination of trades, and are linked to live databases to calculate real-time construction estimates.

Differences Between Alberti's and Brunelleschi's Uses of Models

While both Alberti and Brunelleschi employed models in their advocation or execution of architectural design, there exist between them telling differences that speak to their own understanding of architectural practice and are of interest for discussions about BIM today. For Alberti, an architectural idea, or *disegno*, is conceived in the mind, but is only realised through a model.[18] The model is a mechanism through which an architectural idea unfolds. Alberti is less concerned with the model's ability to convince a client of the appropriateness of the proposal; whether it is appropriate or not is determined through the intellectual development of the proposal itself. He makes the clear distinction that a model is used firstly to fulfil the creative dimension of a design proposal, and secondly in the pragmatics of construction.

Brunelleschi thought that a model was a representation of an idea already formed in the mind, hence his secrecy about fully disclosing his intentions to others, especially workmen on site. For him, the model served as a virtual construction of an actual building. How specifically

Brunelleschi's ideas were formed prior to the construction of the models we will never know. However, it is clear that the making of models for the various parts of the Santa Maria del Fiore dome (for example, its lantern and scaffolding) and some of his inventions were critical to the successful completion of that project. In contrast to Alberti, for Brunelleschi intellectual development and construction process or method were comprehensively integrated in the model.

Both of these positions seem to overlap and contrast with contemporary discourse in the adoption of BIM as a new paradigm for the design process. Through simulation and the ability to form/fabricate materials directly from digital models, writers such as Sanford Kwinter and Manuel DeLanda have posited that information models have allowed us to enter a new paradigm: 'the virtual to actual'. Here, a building is already fully real and simply needs to be actualised via translation from virtual to actual matter. This is contrasted with the 'possible to real', a paradigm advocated by Alberti that has existed for the last 600 years. In this approach, the possible (an idea) has no measured relationship to the real because it is necessarily interpreted by a third party – in the case of construction, a builder who interprets a set of architectural drawings (representations). DeLanda writes more specifically that the former is a design philosophy that takes into account materials (both virtual materials simulated within the computer, and actual materials used in building), while the latter is purely cerebral and as such has no relationship to matter or materials.[19]

Though there is no reference to either of these paradigms in the work of Alberti or Brunelleschi, they are helpful in tracing the impact of their ideas about the practice of architecture. For both, there is an important distinction in the utility of models as devices to work through the problems of construction. In advocating the separation of design from making, Alberti's use of the model in this capacity was to arrive at a subjective appropriateness of a design proposal. Brunelleschi, his secretiveness and desire to control the site notwithstanding, used the model as a collaborative apparatus to virtually work through the problems of construction – ideally with those who would be responsible for the actual construction. He was known to carve details for his workmen in wood, clay and wax. This notion of enhanced collaboration, as opposed to separation, forms the essence of information modelling technologies.

Closing the Gap *Due*

It is in fact impractical to suggest that the architect's return to the role of master builder would discourage those architects working remotely today. Although it is clear that the success of such a mode of practice was in part due to the proximity of the designer-builder to the building site, and access to workers and indigenous building materials (such as the use of Carrara marble from in and around Florence for the Santa Maria del Fiore dome), the ubiquitous nature of information has allowed for a change in the architectural delivery process. In the Albertian Paradigm, interpretation was necessary to mediate between an architect's intentions and the realisation of the building – a 'possible to real' relationship that could not ensure precision in the translation from drawing to building.

Certainly, one of the advantages of information models being advocated here is that they have the ability to translate and actualise data from the virtual state. In both the pre-Renaissance and immediate contemporary condition, the collaborative aspects of this notion – that the designer/architect and builder/tradesperson could physically work on a scaled construct testing ideas, building techniques and construction sequences – seem to indicate that the gap between design and building, conceptualised by Alberti and which existed throughout the 20th century and into the 21st century, will finally be closed. AD

Notes

1. See Ross King, *Brunelleschi's Dome*, Penguin Books (New York), 2000.
2. See Frank D Prager, 'Brunelleschi's Inventions and the "Renewal of Roman Masonry Work"', *Osiris*, Vol 9, March 1950.
3. These wardens were themselves members of Florence's largest and most powerful guild – the Wool Merchants.
4. Christoph Luitpold Frommel, 'Reflections on the early architectural drawings', in Henry Millon and Vittorio Lampugnani (eds), *The Renaissance from Brunelleschi to Michelangelo*, Bompiani (Milan), 1994, p 102.
5. Henry Millon, 'Models in Renaissance architecture', in Millon and Lampugnani, op cit, p 22.
6. Ibid, p 72.
7. See Prager, op cit, p 509.
8. Leon Battista Alberti, *On Painting*, revised edition, Yale University Press (New Haven, CT), 1966, p 40.
9. Mario Carpo, *Architecture in the Age of Printing*, MIT Press (Cambridge, MA), 2001, p 124.
10. See ibid, p 9, where Carpo suggests that the 'modern print format' afforded by the printing press affected the transmission of architectural theory in the 1530s.
11. Franco Borsi, 'The themes of Alberti's life', *Leon Battista Alberti: The Complete Works*, Rizzoli (New York), 1986, pp 10–11.
12. Arnold Hauser, 'The Social Status of the Renaissance Artist', in *The Social History of Art*, Vol 1, Knopf (New York), 1952, p 335.
13. Franklin Toker, 'Gothic Architecture by Remote Control: An Illustrated Building Contract of 1340', *The Art Bulletin*, March 1985, p 88.
14. This term should be credited to Mario Carpo, who has used it in several texts including 'Nonstandard morality: Digital technology and its discontents', in Anthony Vidler (ed), *Architecture Between Spectacle and Use*, Yale University Press (New Haven, CT and London), 2008, p 131.
15. See Toker, op cit, pp 67–9.
16. Leon Battista Alberti, *On the Art of Building in Ten Books*, trans Joseph Rykwert, Neil Leach and Robert Tavernor, MIT Press (Cambridge, MA), 1988, p 34.
17. Ibid.
18. Henry Millon, op cit, p 24.
19. Manuel DeLanda, 'Philosophies of Design: The Case of Modeling Software', *Verb: Processing*, Vol 1, No 1, 2001, pp 132–42.