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ENGINEERING THE ART OF ANISH KAPOOR

ESSAY BY CHRISTOPHER HORNZEE-JONES

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Design and engineering firm Aerotrope's work on Anish Kapoor's Deutsche Guggenheim commission is the latest in a series of close collaborations with the artist that began almost ten years ago. Over this period, we have contributed our technical expertise to the realization of his increasingly ambitious artworks in both public spaces and galleries, working with a diversity of materials from steel and wax to water and air, each of which has presented specific possibilities and challenges.

I have been drawn to working with artists due to my long-standing passion for creativity that spans the arts, design, engineering, and science. In our work outside of the art world, our role is often to evolve new designs and technology in the fields of renewable energy and experimental low-energy vehicles. We see our work with artists as an integrated and enriching part of our practice, not as an interesting sideline to "real" work. The process of critically reexamining our received assumptions of what is possible and then formulating bold new expressions of vision is as vital to making compelling artworks as it is to adapting our society to the challenges of climate change and the limits of global resources.

During each project with Kapoor, we may go through periods of relatively independent parallel work, which are linked by sessions of closely interactive review. Our objective, especially during the initial phase of realizing a new work, is to keep the creative options as open as possible rather than to let premature decision making, often driven by technical or production concerns, constrain or deflect Kapoor's artistic judgments. For the technical team, this is of course not the simplest path, but it is certainly the most rewarding, and our experience shows that it allows the strongest work to prevail.

The first of Kapoor's works to which I contributed was *Turning Water into Mirror, Blood into Sky* in 1999. This work, composed mainly of fluid, which nevertheless gives the appearance of a solid concave object, was being developed with the structural engineers Atelier One, who also engineered *Taratantara* (1999). As part of his exploration of voids and negative space, Kapoor was interested in ways in which a hollow or depression could be formed in the surface of water and had started experimenting with submerged propellers to draw the surface downward. Together we decided to use centrifugal forces to spin the water into a negative parabolic form. The first low-tech experiments using a record player and a cooking pot full of water proved the concept surprisingly well. The key technical challenge in *Turning Water into Mirror, Blood into Sky* was to ensure that the vessel rotated very smoothly so that the surface of the spinning water settles into a parabolic form without ripples, which would disturb the appearance of it being a static concave mirror. The full-size work, commissioned by the Lisson Gallery, London, was developed using the insights gained in those first tests. We subsequently engineered a larger version of the work for the 2003 exhibition *Anish Kapoor* at the Museo Archeologico Nazionale, Naples. Looking back, it seems that even in this first project developed together, we were able to successfully integrate artistic and technological concerns in the final work.

We generally become involved on projects with Kapoor when his ideas demand the input of some fairly sophisticated technology. However, the employment of highly technological methods is

seen by both of us as a means to an end (the production of a successful artwork), not as an overt display of technical prowess. The works are concerned with the relationship between art and technology only to the extent that we seek to find solutions or uses for materials, construction methods, and details that follow rationally from their place within the overall conception. In some works, such as the Deutsche Guggenheim commission *Memory* (2008), every structural element is made visible. In others, such as *Cloud Gate* (2004), the work is expressed as a purity of polished form and the complex technical systems which make it possible remain unseen.

For Kapoor's conception of *Cloud Gate*, it was crucial to achieve the effect of an apparently massive object just having landed softly on the plaza in Chicago's Millennium Park. To convey a weightless presence demanded specific attention to the nature of the contact between object and ground. This determined the design of an internal structural framework mounted on two compact steel towers that pass unseen through the small areas of actual connection between the sculpture and foundation structure below. Although *Cloud Gate* gives the impression of a solid object, its stainless steel skin is only a quarter of an inch (6mm) thick. In order to maintain the purity of the surface reflections, we needed to devise systems to suspend the skin elements during assembly and the whole sculpture once it was complete. Working closely with the fabricators Performance Structures Inc. of Oakland, California, we arrived at the approach of balancing the weight of each of the 169 skin tiles individually by springs. This allowed them to fit together collectively without the distorting effects of gravity. Once welded together to become a complete shell, we transferred the sculpture onto thirty-two custom-made suspension units, which bear its eighty tons while allowing it to respond as a whole to external conditions such as wind, snow falls, and the wide seasonal temperature changes that are characteristic of Chicago.

Another of Kapoor's works that employs principles of fluid dynamics, and in which we have had a deep involvement, is the series of vortex installations titled *Ascension*, originally commissioned by Galleria Continua and first built in San Gimignano in 2003. The work consists of a central fog-filled vortex extending from floor to ceiling, accessed by the public through curving, tapering passageways. It has since been shown, each time incorporating site-specific adaptations, in Rio de Janeiro (2006), Brasilia (2006), São Paulo (2007), and Beijing (2007). The artistic possibilities for employing a vortex in an artwork were explored by first using experimental rigs that were not directly related to any particular artwork context. These initial trials showed that we could produce the structured yet immaterial forms Kapoor was seeking. Furthermore, through fine-tuning the flows of air, we could establish the vortex at the boundary of instability where its character is constantly changing under the influence of tiny disturbances such as drafts and movements of people.

Ascension requires conditions of air movement analogous to a natural tornado. The vortex forms when a strong suction, which is provided by a powerful remote extraction duct mounted in the ceiling, is combined with a slow, smooth rotation of the air in the space. In these conditions, the air begins to spin with increasing speed as it nears the center of the system where a hollow core forms, exactly analogous to the eye of a storm. The third essential technical element is the introduction of a small amount of artificial fog into the vortex, which is required to make the air movement visible.

There is a subtle but crucial distinction between Kapoor's successful integration of a physical phenomenon in an art context and, for example, an exhibit in a public science center. *Ascension* does not seek to explain how a vortex works, but to communicate on spiritual and metaphorical levels. Despite, or perhaps because of, its unexpected placement in an interior space, *Ascension*'s vortex is

perceived as being entirely real, and in that sense the work is not theater. Its exact means of formation is intentionally left to the viewer's imagination, thereby implying the existence of a mythological cause behind its creation, which, however, remains unknown.

We set about developing *Ascension* using fluid dynamic theory and air-test models, in a manner similar to the use of wind-tunnel testing for new designs of vehicles and buildings. Most commonly, the smooth rotation of the air in the space is created by the flow of air entering through curved passageways. The viewer must also walk through such passages to reach the vortex, engendering a rich experience of being in the work. The experimental process with air-test models provided Kapoor with uncannily realistic visualizations, allowing him to be confident that his artistic intent would be expressed in the full-scale installations. This is essential, because the works usually required large-scale constructions and air duct systems that were not amenable to adjustment once built. In particular, we worked closely with him on resolving the forms of the passageways and their relationship to each exhibition space to find the best aesthetic and technical solutions. For the installation in the thirty-five-meter-high rotunda of the Centro Cultural Banco do Brasil in Rio de Janeiro, we even used banks of fans installed behind existing columns to turn the air.

We have also worked with Kapoor on his series of works using pigmented wax, namely *My Red Homeland* (2003), *Past, Present, Future* (2006), and the installation *Svayambh* (2007). In these works, the final form and texture of the wax was determined by the motion of a mechanically driven object which cut its surface or on which it was propelled through the gallery space. Kapoor's desire had been for these works to genuinely form themselves during the exhibition, as most clearly illuminated by the title of the work *Svayambh*, whose Sanskrit-derived meaning is "to be created out of itself." His vision for these works was for the movement to be barely perceptible, visually and audibly, engendering the sense that the object was continually coming into being of its own accord. This project involved us in experimentation with the specific compounding of the wax in order to achieve the most versatile balance between stability and plasticity. We built test rigs and quantified the forces required to cut and form this material. We designed the customised drive mechanics for each work. The effect achieved, for example in *Svayambh*, is that an eight-ton block of wax progresses through the gallery spaces silently and without apparent effort.

Memory presented us with some new challenges: of finding an adequate form and of its subsequent structural engineering. The sculpture's form needed to establish its own coherence, yet was also governed by Kapoor's requirement that it fit tightly against the physical constraints of both the Berlin and New York Guggenheim galleries. This led to the creation of a work that can only be seen through a series of partial and spatially-separated views; a work which never reveals its form completely.

We started the process of form refinement by taking Kapoor's maquette and digitizing its form into computer coordinate data. From there, we began working toward the final geometry by applying increasingly fine adjustments of form—each stage was assessed by the use of physical models machine-cut by a computer-controlled milling machine from foam plastic to replicate the digital model. We have found that the use of physical models is essential in the form-finding process. It is simply not possible to make these subtle judgments only by viewing images of the sculpture on-screen, no matter how sophisticated the technology used for its visualization. Our objective is always to provide Kapoor with the means to continue sculpting the work within the digital form-finding process, and to resolve the most delicate issues of form and detailing right up to the creation of the

final data for fabrication.

Memory presents structural engineering challenges for Aerotrope and for the building's engineers in both cities. Neither gallery space is configured to easily show such a large and heavy work. This has dictated the modular construction of the Cor-Ten steel sculpture, which is assembled from 154 tiles, each of a different shape. The maximum size of the tiles is dictated by the need to bring them into the buildings through standard street doors, and in the case of New York, via an elevator. The tiles are bolted together through the raised pattern of stiffening ribs, which are visible on the outside of the form, to become a complete structural shell. The darkened void of the inside is also made visible through a precisely square aperture approachable through an adjacent gallery.

The visibility of both exterior and interior surfaces has had a profound effect on the structural realization of the work, since the concealed support systems we developed for *Cloud Gate* are not possible here. Instead, engineers at Aerotrope have designed the sculpture's shell to bear directly on the floor and be stabilized by its contact with the walls. The geometry and thickness of the ribs has been calculated using computer analysis methods more commonly applied to the shell structures of ships and aircrafts, whose so-called "monocoque" hull and fuselage structures behave in a similar way.

Once again, Kapoor's vision is for the form to achieve an apparent weightlessness by having minimal glancing contacts with the floor, walls, and ceiling. The intended emphasis is on the work's volume, dividing and shaping the space, as opposed to giving the impression of a great mass planted heavily on the floor. For us, as engineers, this encapsulates the central challenge. We must satisfy all the criteria of strength, safety, and manufacturing, and yet also reach the point where the manifestation of a steel fabrication can be transcended by the viewer's experience of the object as art. The nature of this endeavor is the thread I can trace most clearly through the years of our involvement in realizing Kapoor's works, and also the fundamental stimulus for our ongoing collaboration.

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