

Making the impossible possible

The roadside is colourful and bright in spring when driving down the Hume Highway from Sydney to Melbourne, as you pass through countryside rich with yellow fields of canola backed by the olive blue hue of the hills of gums.

After nine hours of driving, the countryside gives way to the northern suburban sprawl of Melbourne. In those last 30km into the city, the striking encroachment of suburbia on the countryside is noticeably tamed by great sculptures that decorate the roadside, starting with the blue poles that rise alongside Craigieburn Bypass, a freeway completed in 2005.

Flashing by in the corner of the eye, the sculpture was specifically conceived to be experienced at a freeway speed

of 110km/h. It was designed by architectural firm Tonkin Zulaikha Greer in association with landscape architects Taylor Cullity Lethlean, while artist and sculptor Robert Owen was involved in the concept design and modelling.

The project won the 2006 Australian Institute of Landscape Architects Award for Excellence for Design in Landscape Architecture, with the judges saying the bypass is “a sophisticated transit project which integrates art, landscape and infrastructure ... creating a 5km gateway experience which is at once dynamic, sequential and memorable”.

The judges also noted that the client, VicRoads, “should be applauded for setting the framework in which a project of this calibre and significance could be realised”.

items such as panel attachments, side connections for beams or bracing, and upload attachments for acrobatic purposes,” Duchesne said. “Most of the time, considering the final width of the beam, the modulus of the beam itself is greater than required, which allows us to remove material and keep the weight as low as possible.”

The stage set also features a unique fibreglass wall, rising some 7m high, known as the “antigravity wall” where acrobats run up and down, perpendicular to others who climb nimbly across. The wall is constructed on the ground before being raised using two hydraulic rams that only have two functions in each location – raising the wall during the build and lowering the wall during the bump out.

“In terms of risk management – when we were considering shipping the set across to Australia, the wall was the only item that couldn’t be easily replicated, if for example containers washed off ships,” Brown explained. “Because the wall is made out of a mould that gets destroyed in the manufacturing process, we carried out a 3D image scan so I now have a digital image scan of the entire wall and can now replicate it when required.”

In response to the merging of disciplines between stage set design and engineering, the National Institute of Dramatic Arts (NIDA – www.nida.edu.au) will start a new degree next year to specifically target the technology of staging events. The

course will be aimed at providing event managers with the technical expertise of engineers braced with an understanding of the performing arts.

The Bachelor of Dramatic Arts (Staging) will be the only course of its kind in Australia.

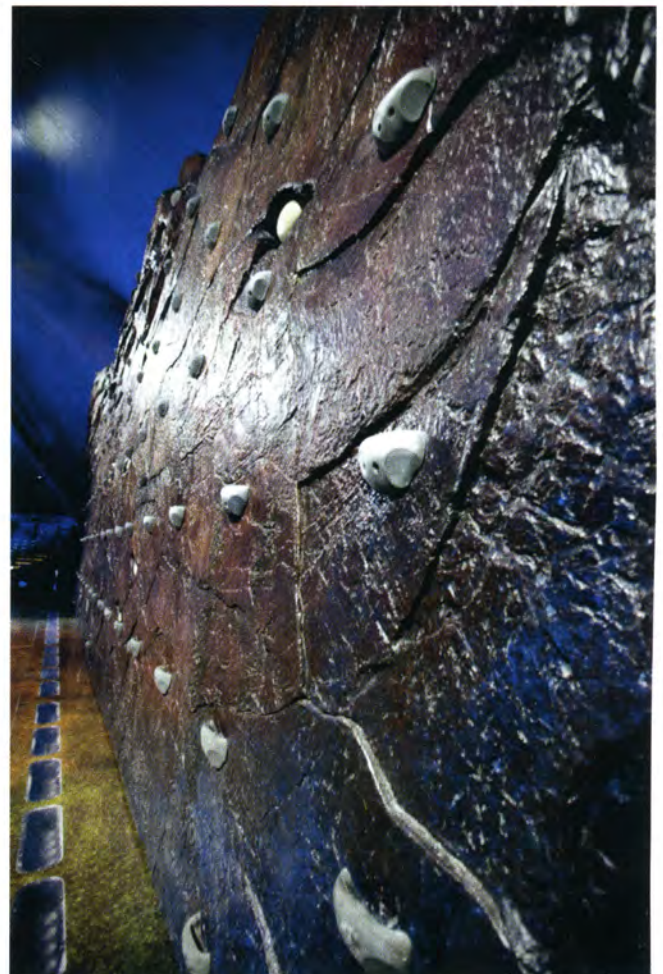
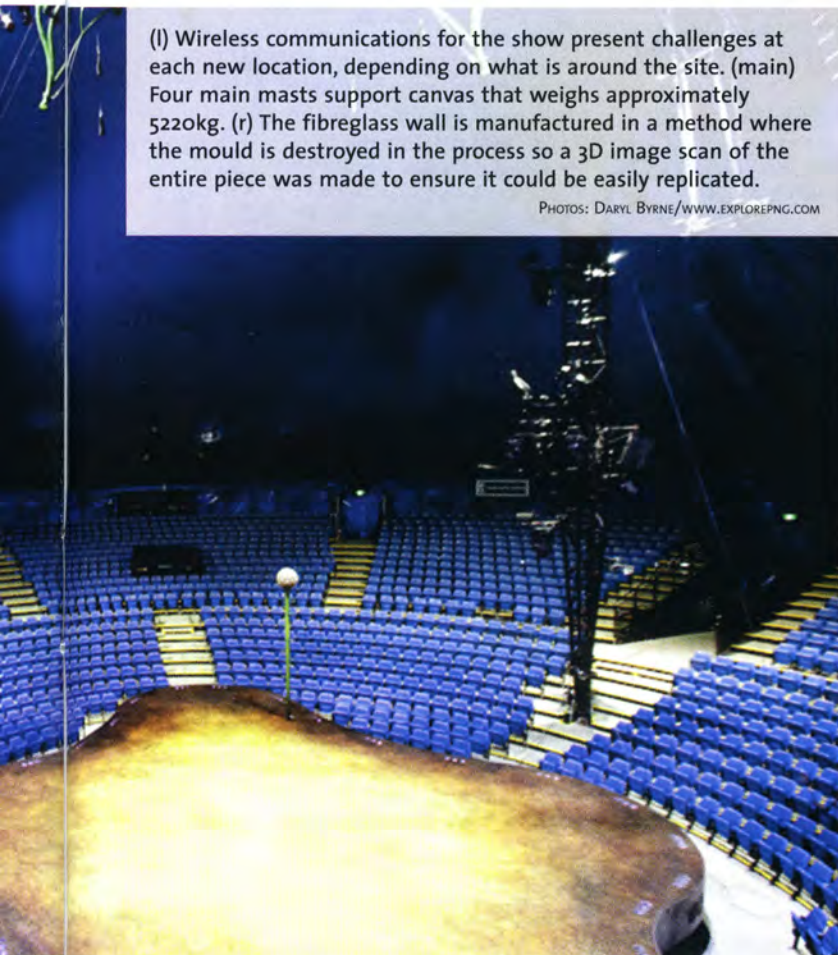
Partridge Event’s Sparks said: “The degree will utilise the expertise and high achievements of leading Australian technical specialists in the international events, arts and performance industry. The industry will embrace this staging degree.”

Sparks himself only finished a Masters of Engineering from UTS in 2009, after more than 20 years working as a highly acclaimed and accomplished set designer. He said the highlight of doing his masters was getting a whole new appreciation of risk management in the arts.

Danny Cameron is an avid supporter of the arts and has previously worked as a stage manager of temporary venues, often using his engineering skills as part of his artillery. In researching and writing this article, he saw the production and participated in a back stage tour of *Ovo* as a guest of *Cirque du Soleil*. He visited *Halo* with Partridge shortly after it was unveiled and attended the launch of *Sculpture by the Sea* in mid-October.

(l) Wireless communications for the show present challenges at each new location, depending on what is around the site. (main) Four main masts support canvas that weighs approximately 5220kg. (r) The fibreglass wall is manufactured in a method where the mould is destroyed in the process so a 3D image scan of the entire piece was made to ensure it could be easily replicated.

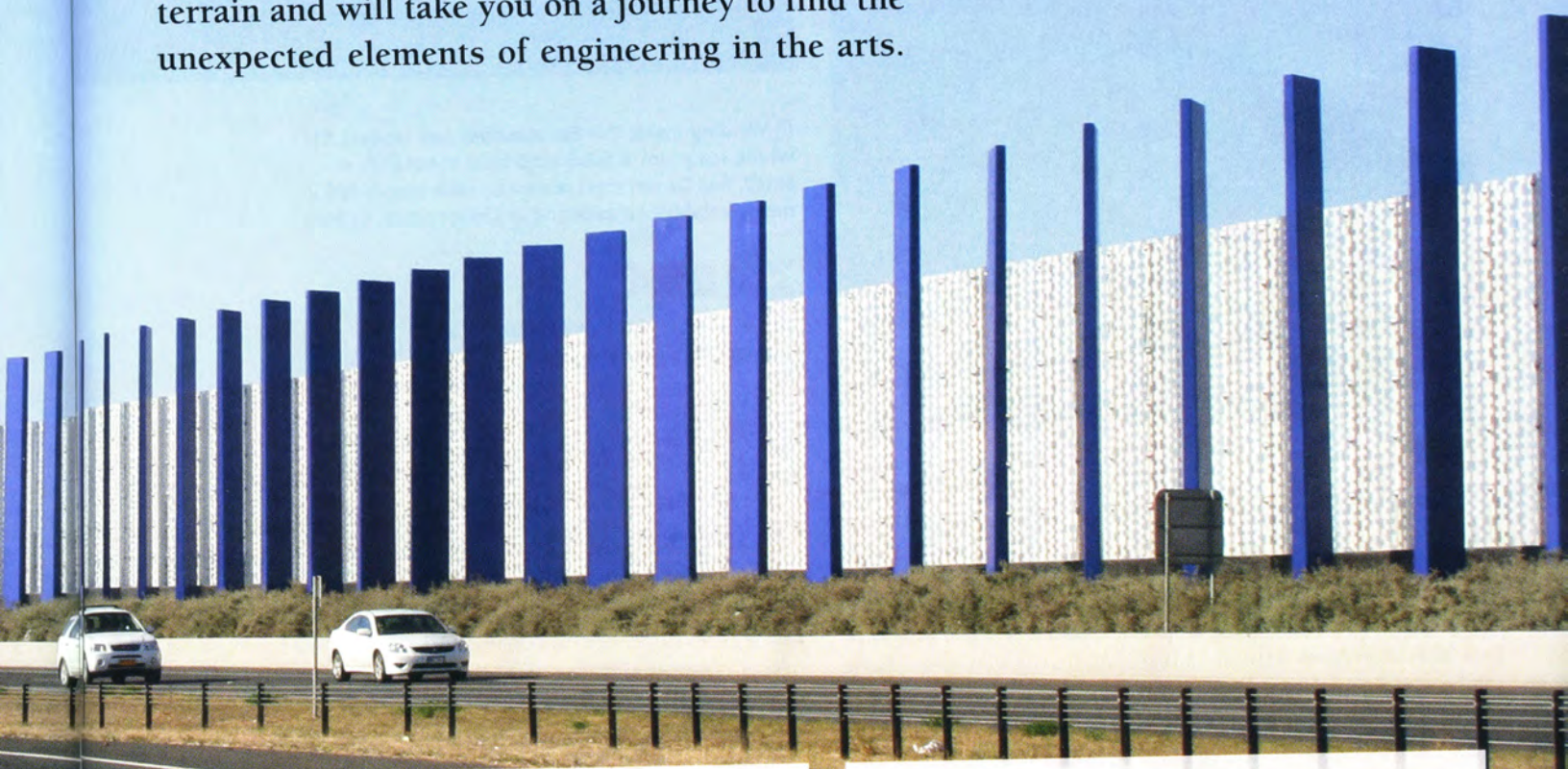
PHOTOS: DARYL BYRNE/WWW.EXPLOREPNG.COM



Danny Cameron explores engineering in the arts, first by driving along Melbourne's freeways, before visiting one particular new sculpture in Sydney called *Halo*, which has involved complex engineering to bring the artistic vision to life. The engineers involved in the production of *Halo* use similar guiding risk management practices in performing arts, and this is the third direction of the piece – extending from film set design, into massive staged events like the Olympics and Cirque du Soleil. The article crosses a wide terrain and will take you on a journey to find the unexpected elements of engineering in the arts.

Flashing by in the corner of the eye, the Craigieburn Freeway sculpture was specifically conceived to be experienced at a freeway speed of 110km/h.

PHOTO: BILL STRONG/FUCKR.WILLIEWONKER



Since then, the Melbourne freeways have continued to become a veritable art gallery.

On the latest major road project under construction in Melbourne, three new sculptures will be installed early next year. Linking Melbourne Authority, the specialist statutory authority overseeing the delivery of the Peninsula Link project on behalf of the Victorian government, stated that though it does not have a specific policy for urban design and public art, during the competitive tendering process the winning tender by the Southern Way consortium made “a strong commitment to provide an integrated, high quality urban design solution”.

The Southern Way consortium, comprising Abigroup, Bilfinger Berger and the Royal Bank of Scotland, has

combined with the McClelland Gallery and Sculpture Park to commission a number of sculptural pieces to adorn the roadside. While one of the pieces will be permanent, every two years until 2037 a new sculpture will be commissioned as part of the Southern Way McClelland Commission – alternating between the other two sites on the Peninsula Link. In total 14 sculptures will be commissioned over the next 25 year period.

Multidisciplinary engineering practice AML Consultants is working on two of the sculptures that are to be installed on the Peninsula Link next year. The sculptures are called *Rex Australis* by Dean Colls and *Panorama Station* by Louise Paramor. The latter will become the permanent sculpture on the freeway.



(l) Welding inside the *Rex Australis* and (above) the whole sculpture is fabricated from thousands of small, flat Corten steel plates. (r) *Halo* stands tall in newly established parkland in Chippendale, Sydney.

View  online

To see a short video of *Rex Australis* in construction, read the magazine online.

Colls' *Rex Australis* (<http://deancolls.com>) is now complete and assembled at his workshop awaiting installation. The sculpture is fabricated from thousands of small, flat Corten steel plates, all welded together and onto a framework to give its form, a ram skull. From an engineering perspective, AML Consultants worked with Colls to understand wind and seismic loading, as well as the live loading of the sculpture. The consultants also provided loadings for the footings, determined section properties and stresses at critical locations in the sculpture and provided advice regarding bolting together the components.

On Paramor's *Panorama Station* (<http://www.louiseparamor.com>), the concept is based on a previous work titled *Stupa City* – a series of sculptures which are architecturally inspired and assembled from “found objects” such as lamp shades, storage boxes, children's toys, and more. *Panorama Station* is an upscaled version, 14 times the size of the original components. It is 16.5m high at its highest point and has a footprint of 11.5 x 4.5m.

AML Consultants mechanical engineer Noam Olshina said they began with a small-scale model, from which they had to estimate the weight and wind area of each component and use this to estimate all possible loadings and their combinations (including wind, seismic, dead and live loads).

“Working closely with the fabricator, the method of construction was developed and materials selected in order to meet several design objectives, including hiding the support structure from view while maintaining the final appearance in line with the sculptor's vision,” Olshina explained.

Individual components needed to be easily and quickly assembled on site and the fabrication costs kept to a minimum.

After this was all defined, Olshina said: “We were then able to check and ensure the stresses in the various components, the underlying support structure and the connections between each component were all within acceptable limits.

“The design of several of the connections was particularly challenging. Where it was not possible to have these hidden from view, we sought methods that would blend them into the form of the overall sculpture, thus making them ‘invisible.’”

The works will be installed in early 2013 to coincide with the opening of the freeway.

In an openly symbolic way, the sculptures along all the roadways help Melbourne realise its ambition to become the cultural capital of Australia.

Another major Australian capital, the City of Sydney is echoing similar sentiments.



City of Sydney lord mayor Clover Moore said: “The value of art is plain to see in great cities like Barcelona and Chicago – in shaping and enlivening the experience of city life.”

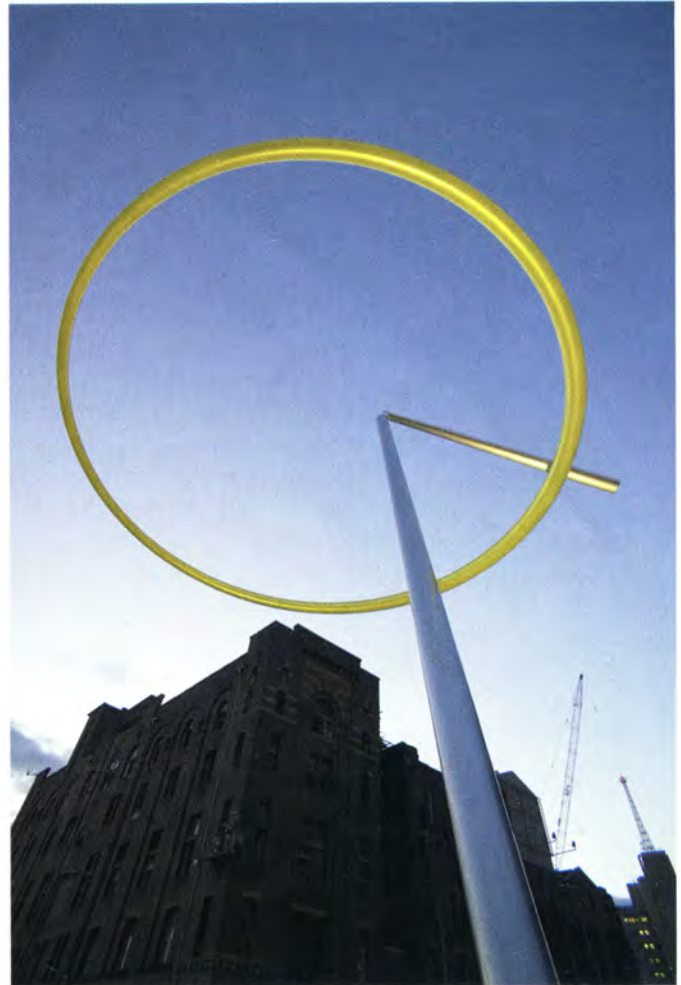
The City of Sydney is currently calling for experienced curators to develop and deliver major new public art programs in the city centre, and in Australia’s largest urban development site, Green Square.

In the case of the city centre, the City of Sydney has committed \$180 million to support George Street’s transformation into a light rail and pedestrian boulevard. New public artworks are an important part of the council’s plans for the precinct.

The development of these new public art initiatives build on the success of recent public artworks commissioned by the city – including *Halo* at Central Park.

Halo is quite a structure. From the original line drawings of artists Jennifer Turpin and Michaelie Crawford, engineering consultant Partridge Event has spent the past three years with the artists bringing *Halo* to life, under the direction of Partridge Event director Jeremy Sparks.

Blazing yellow against the blue sky, a 12m diameter ring sits 13m in the air atop an angled and tapered mast, and is set off-centre on a single cantilevered arm that rotates on a central bearing.



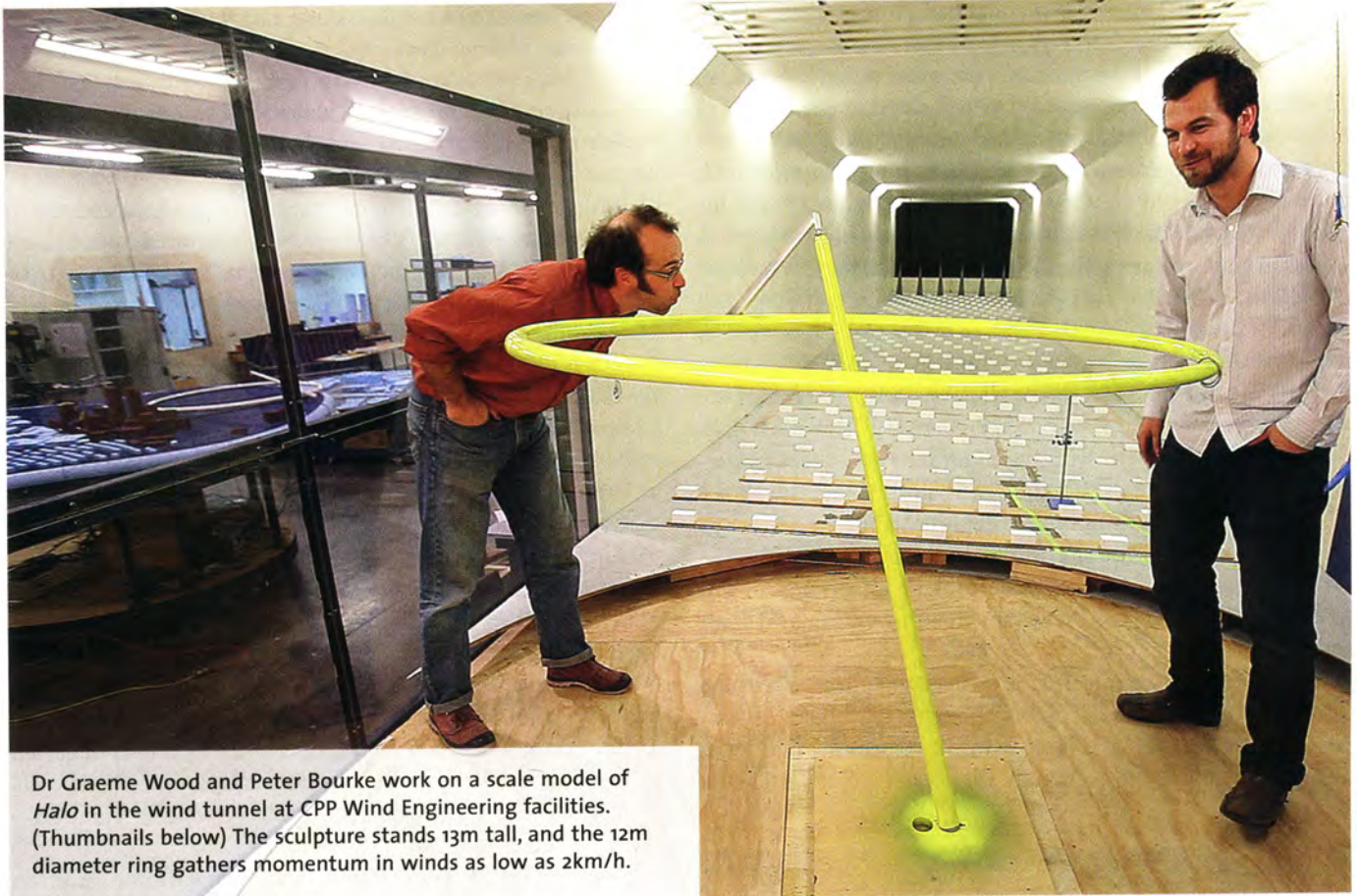
The ring turns with the energy of the wind, and as it is off-centre, it also tilts as it turns in a finely tuned counterbalance. Set in newly established parkland, the sculpture is spectacularly lit up at night and seemingly hovers in the sky as it spins in a tipsy motion.

The ring is tapered, allowing the changing diameter, and hence increasing surface area, to pick up kinetic energy from wind in any direction. Seemingly effortlessly, *Halo* creates a swaying momentum in winds as low as 2km/h.

The sculpture itself is a combination of advanced carbon fibre manufacturing processes and finely-machined stainless steel fabrication, all revolving on an advanced ceramic bearing. Its design and construction process has involved extensive modelling and numerous scale models tested multiple times in wind tunnels.

The structural analysis team at Partridge designed a stiff and stable structure that could be freely activated by the wind, and used extensive finite element analysis to design the smallest and lightest steel connections.

Partridge mechanical engineer Arran Gordon developed a design for the bearing unit that delivers almost frictionless motion, using an innovative small 12mm-diameter ceramic



Dr Graeme Wood and Peter Bourke work on a scale model of *Halo* in the wind tunnel at CPP Wind Engineering facilities. (Thumbnails below) The sculpture stands 13m tall, and the 12m diameter ring gathers momentum in winds as low as 2km/h.

ball. Cyclic load tests on the bearing system were carried out at SPFX Australia, confirming that even under extreme loading and maximum movement, the bearing performed perfectly, ensuring low future maintenance and no risk to the public.

Sparks said the geometry of the whole design needed to be very accurate and have a very finite point of connection. The fixed point has a capacity designed for a one-in-400-year wind event. The ceramic ball bearing allows it to have three axes of movement achieved at a single time, and it has been given an off-centred pivot point so that as it rotates, the ring sweeps a greater area than its actual diameter.

Extensive visual, dynamic and quantitative load testing of numerous scale models was carried out in the wind tunnel at CPP Wind Engineering in the Sydney suburb of St Peters. CPP Wind Engineering developed customised software to model *Halo's* predicted movement, and this software was recalibrated after a fully assembled pre-commissioning process and testing in real wind conditions at the yard of the fabricator, Innovation Composites, on the south coast of NSW in Nowra.

Sparks said: "The model making and wind tunnel testing were really critical in the process. The mechanical engineers viewed it as a buckled wheel and said it would always self-dampen, but they were unsure at what rate it would. Then when it came to testing, the wind engineers were always re-evaluating exactly how fast the ring would spin."



But a lot still came down to the installation process, and Sparks said the design still allowed a great amount of adjustment capacity onsite as the team raised the full-scale sculpture.

For its involvement, Partridge Event was awarded the President's Prize at the Engineers Australia Sydney Division Engineering Excellence Awards in September. Division president Brendyn Williams said: "This is a real feat of engineering – drawing on innovation, risk engineering and project management to deliver a clever and beautiful design for the community to enjoy for many years to come."

Halo was commissioned by Frasers Property and Sekisui House Australia in collaboration with the City of Sydney, as part of the development of Central Park on the old Carlton United Brewery site on Broadway in Sydney. Central Park is a \$2 billion development of an "urban village", with 11 build-

ings, around 2000 apartments and a collection of shops, cafes, restaurants, laneways, terraces and offices.

Halo is one of a number of pieces commissioned in an Artists in Residence program that will develop \$8 million of public art during the life of construction of the development to celebrate “the alchemy, flux and distillation that once took place inside the old brewery that occupied the site”. Partridge Event is responsible for structural and mechanical design as well as project managing the development of all these art works.

Halo artist Jennifer Turpin said: “The public art strategy will elucidate the soul of Central Park’s past and give expression to the spirit of its future.”

For *Halo*, the diameter of the ring represents the size of the vats that were on site at the former brewery. The story goes that brewery employees’ working conditions gave them entitlements to four beers onsite after each shift. Thus, the tilting counter-balanced motion of the ring reflects the employees of the brewery leaving the site after work being a bit tipsy.

Turpin said *Halo* was an extraordinary integration of art, science and engineering: “It’s as much an invention as it is an artwork.”

“Sculpture and engineering are closely aligned,” Partridge group managing director Eamonn Madden explained. “Artists have an understanding and an intuitive respect for materials, and want to make the seemingly impossible possible. That is

why you need engineers. It is quite exciting for an engineer to work with these people.”

With any invention comes an intersection of disciplines where standards and building codes do not cater for all eventualities, so Partridge Event implemented a strong risk management approach across all aspects of the project.

It is something the company has had experience with. Back in the 80s the company’s founder Harry Partridge worked on the set of *Mad Max: Beyond Thunderdome*, creating the massive Thunderdome cage the actors, lighting rigs and cameras were all to sit upon. For risk management purposes, Partridge Event provided George Miller (the film director) with a graphic of the load limitations on each section of the cage, thereby controlling the loads and enabling a more economical structure to be built on set.

Partridge Event is currently working on the set design of *Wolverine*, in production in Sydney, and Sparks has been supervising the construction and fabrication of structural steel using the same principles developed by the company’s founder on *Mad Max*. Sparks’ team is producing all the workshop drawings for the fabricators, as well as modelling and calculating loads on all the steel being used. He said to build the set to building codes equivalent to a fully permanent structure would be too expensive and simply infeasible when it is only required for such little function. Instead, his team design the film set structures fit-for-purpose, and specify operating conditions that must be controlled.

Madden said: “You can’t be thinking about anything being too risky, rather, you think it as a situation where you can introduce controls. Engineers introduce controls to make it all safer.”

He also said there is plenty of opportunity for engineers to get involved in arts and events, as engineers are increasingly recognised for adding value by controlling risks.

Pointing to one obvious advantage for engineering involvement, Madden said: “By having risky structures properly controlled, we can bring down insurance costs dramatically.”

This methodology for engineering within static, kinetic and performance arts has had a strong history, including involvement in the Sydney Olympics where Madden told the story of how certain artistic set pieces for use during the Opening Ceremony had specific wind load limits due to their economic design.

“On the night of the ceremony, Dr Graeme Wood (CPP Wind Engineering) and his colleague had a booth on site, and anemometers set up all over the stadium. We knew the wind speeds and which pieces could run and which couldn’t, and right up until an hour before the show, a great number of the pieces couldn’t have gone out – the wind speed was too great. And then, the wind just stopped.”

He smiled: “And that is a discipline where you wouldn’t normally think engineers are involved, but there they were, being able to dictate the whole show.”

That same approach to risk engineering for temporary structures, particularly in the events industry, is on display in the operation of *Cirque du Soleil*.

Sydney-born *Cirque du Soleil* production manager Derrin Brown said: “It is just a control of risk all the time. For example, there is a weather vane on the top of the Grand Chapiteau (big top) and there are a number of managers who all have a



The team celebrate the unveiling of *Halo* in Central Park, Sydney.

responsibility for monitoring conditions. We have a system of shutting things down once we get a sustained wind speed of 50km/h, and site evacuation is at a 100km/h constant wind speed (defined as a sustained wind speed of 10min or more duration). I wouldn't allow anyone to be onsite with sustained wind speeds over 120km/h."

Brown has been touring with the company for the past 18 months and is currently touring Australia with the production Ovo (www.cirquedusoleil.com/ovo).

Cirque du Soleil builds a temporary village at every city, complete with a 2583-person temporary theatre, as well as all the facilities to host an audience of this size.

Cast and crew facilities are also established onsite, including numerous workshops, offices, kitchens, dining hall, bathrooms, laundry, and even three schools with three teachers, all to support the cast and crew and their families.

The site operates on four generators that can produce 2MW, but Brown said there was multiple redundancy and spare capacity built in to control risk of a generator failure. Further, emergency sound and lighting exists on its own uninterrupted power supply (UPS). The fuel cell and the four diesel generators are supplied to Cirque du Soleil by Aggreko.

The largest energy use onsite comes from the running of the HVAC system, also supplied by Aggreko, which is set up using a combination of direct expansion (DX) units and chiller units to run an inner and an outer ring that controls the thermal temperature inside the theatre at between 21°C and 22°C.

For a travelling show, it only takes eight days to build the venue and its supporting infrastructure, from the moment the first container of equipment arrives. This is in addition to 10

days of site preparations that typically occur prior to the arrival of the first container.

As part of the site preparation process, core drilling and ground penetration radar are both used to prepare a site report that includes information for the ground crew about what they can tie into. Ground preparation works are variable depending on the site chosen – in Sydney, Adelaide and Perth the site is grass, while in Brisbane and Melbourne the show is located on shipping docks.

"The biggest challenge we have is the changing environment," Brown said. "Underground utilities in these temporary locations particularly create a lot of challenges – here in Sydney, we have a 60kV underground power cable circling around and within the circumference of the whole site."

The site in Sydney on parkland in the Fox Entertainment Quarter, so the entire site needed to be covered in a geotechnical membrane. Sewer and plumbing services were first installed and the site was then covered in a road base. A layer of asphalt then levelled the entire site.

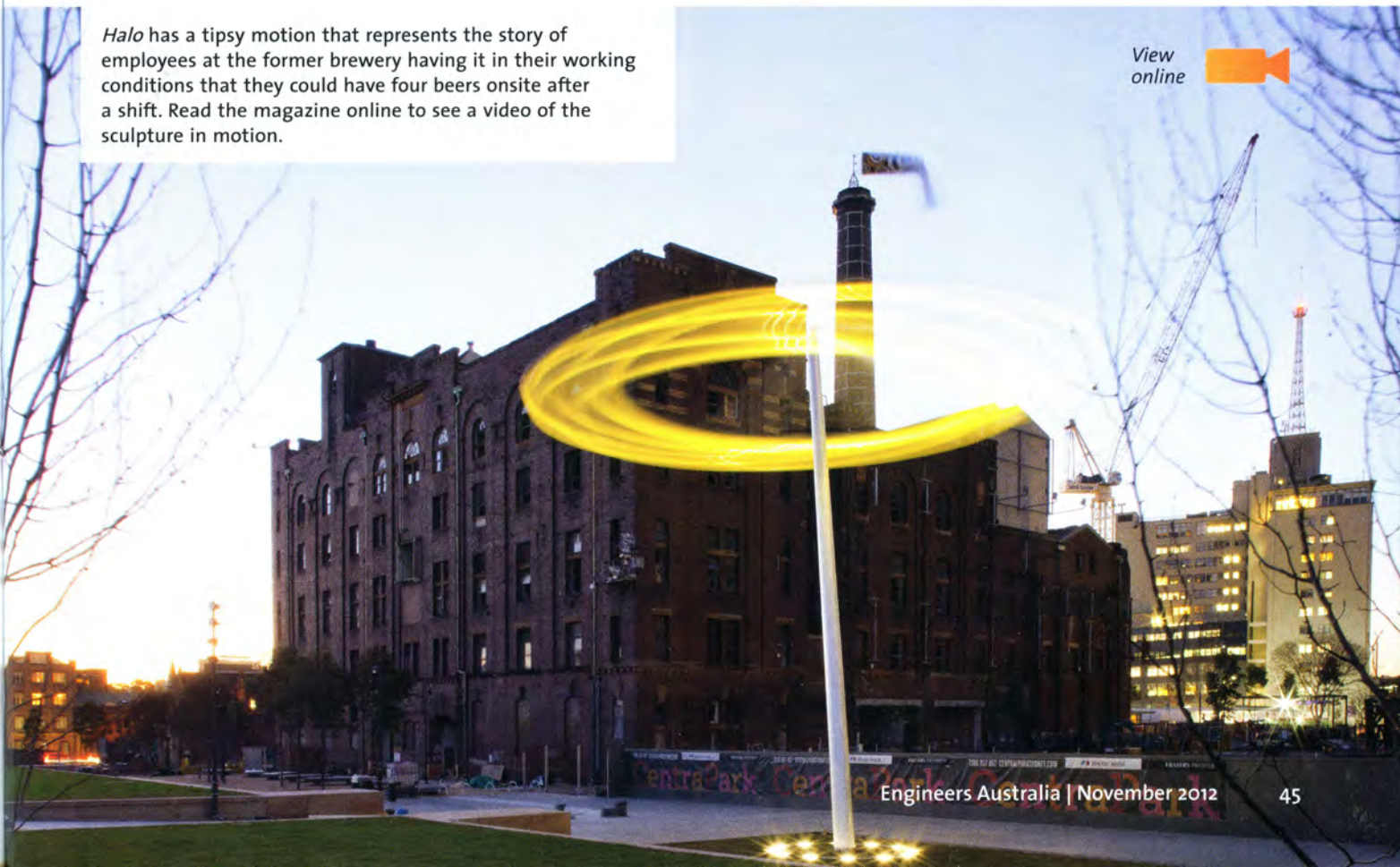
Brown said: "[For precision in an acrobatic stage arena] Critical areas like the stage floor can have no more than 3° variation in the surface."

Surveyors then came in and marked out the asphalt according to the CAD plans.

The main arena, the Grand Chapiteau, is 51m across and seats 2583 people. The structure mainly comprises of four main masts that are all co-dependent, but also co-redundant. Conceived by a team of Canadian engineers, the canvas of the big top was produced by a French company who specialises in sails and big tops: Les Voileries du Sud-Ouest.

Halo has a tipsy motion that represents the story of employees at the former brewery having it in their working conditions that they could have four beers onsite after a shift. Read the magazine online to see a video of the sculpture in motion.

View
online





Cirque du Soleil builds a temporary village at every city it visits, complete with a 2583-person theatre, and all the facilities to support around 200 cast and crew, and their families. (Thumbnails below l-r) Linking tie-downs to the canvas, raising the canvas, the wind vane on the top of the mast, a number of 2m ground bolts bed down a steel plate, and local sewer and water services connect to the site.

PHOTOS: SUPPLIED/DARYL BYRNE

From the masts, primary wires extend down to steel ground plates that are bolted into the ground with 2m ground bolts, while plenty of other guide wires surround the perimeter of the big top. More than 1200 bolts are used around the site to tie the big top down. Pull tests are conducted on the primary wires and Brown said there can be no more than 1mm variation on each of the primary attachment points.

"I have absolute confidence in this structure," Brown said. "We have sustained floods in Cincinnati; snow in Houston, Texas; and in Mexico City we even had a 6.7 magnitude earthquake."

For a venue that travels around the world, Brown said almost every market has a different standard for temporary structures and precise definitions for what is "temporary" also varies. All around the world Brown said he ensures his crew work to some Australia/New Zealand standards, like high visibility work wear, because they are international best practice.

Cirque du Soleil also employs a local engineering consultant in each country it operates in to ensure local standards are satisfied. Brown said its importance is noted in the fact that it is one of the first three things the company does on arrival in each country.

"In each location we first set up the corporate structure, and then employ both the PR company and the engineer," he said.

Brown said: "For such environments like this, it is good to have someone with a lot of lateral thought."

In Australia, Cirque du Soleil contract TD&C, based in Melbourne (<http://tdceng.com.au>). TD&C has reviewed the Cirque du Soleil design and documentation and certified its compliance with Australian Standards. It has also monitored the site testing of tent anchors and inspected the full site installation for Ovo in Brisbane and Sydney.

TD&C consultant Doug Turnbull said the aforementioned underground services required an alternative ballast anchorage to be designed, using existing equipment transportation steel stillages loaded with commercially available concrete blocks. He said the sites for the upcoming shows in Adelaide, Melbourne and Perth have deep fill and alluvial soils, so the tent anchorages will require enhancing with either steel screw piles or sheet pile.

For its work with Cirque du Soleil, TD&C draws on its experience where it has consulted for Circus Oz for the past 17 years. This has included the design of tent supporting masts and tent anchorages, as well as seating and staging components. TD&C has also collaborated with Circus Oz in the development of various performance structures including trapeze, tight rope, sway pole and even a "flying double bass" item. Turnbull said



COVER STORY

the company also draws on experience consulting on other tension fabric structures, including reservoir covers, large hail protection structures and large commercial shade structures.

Local acoustic engineers are also contracted to monitor noise around the site to ensure neighbourhood noise conditions are met during a Cirque du Soleil show. In Sydney, there are eight different locations around the Moore Park/Entertainment Quarter/Paddington precinct where noise is monitored during performances.

Inside the big top, engineering can be found all around the stage, from the wireless communications to the advanced lighting and sound systems. Cirque du Soleil even has a “sensorama” machine by Melbourne-based Air Aroma Australia (www.air-aroma.com) that releases the smell of freshly mown grass at the start of the show, and the smell of a camellia when one of the sets is activated.

The stage itself is a feat of engineering. Designed and built by Montreal-based firm Scène Éthique Fabrication (www.sefabrication.com), it includes automated stage sections that can retract floor units during the show, thereby moving into place the backstage trampoline wall. The wall is made of two moveable components and is only supported on the sides to allow a floor with built-in trampolines to slide in and out beneath it, like an enormous drawer.

However, the structural components of the stage were the most impressive. Differing from the efficient use of structural capacity in film set design by the likes of Partridge Event, the structural steel used under the stage of Cirque du Soleil has been highly engineered to optimise its efficiency. The steel I-beams themselves are made by Scène Éthique Fabrication, whose engineers have found efficiencies can be found by laser cutting steel from within an I-beam in a pattern to maintain structural integrity and weight-bearing characteristics, while reducing a great deal of the weight. The beams are used throughout the stage structure and gangways.

“This is one of the most amazing things I have seen on this show,” Brown said. “I am able to save weight, which helps dramatically reduce crew labour requirements and transport costs, particularly in North America where truck capacity is actually bound by the weight of the load.”

Scène Éthique Fabrication project manager Sebastien Duchesne said each structural unit delivered for a Cirque du Soleil tour needs to be under 3m long and under 68kg. The Open Shell Truss (OST) I-beams the company supplies to meet these requirements were part of a structural system it patented in 2006.

“The way to determine the pattern of the cut is simply by considering the load applied on the beam against the accessories we need to integrate into the beam. Accessories can be

