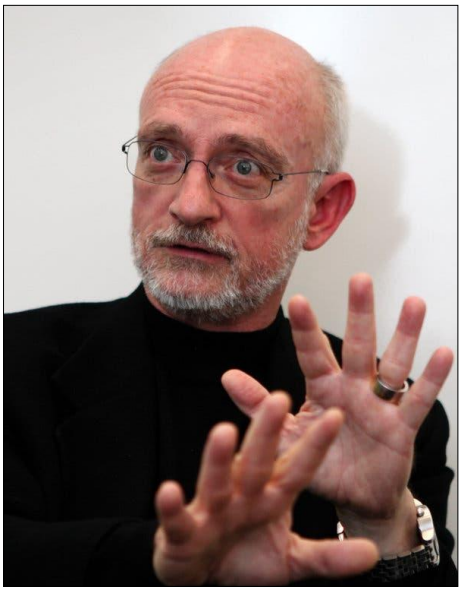
Mark Fuller

Born 1951. Designer of spectacular fountains.
Available online at www.livesretold.co.uk

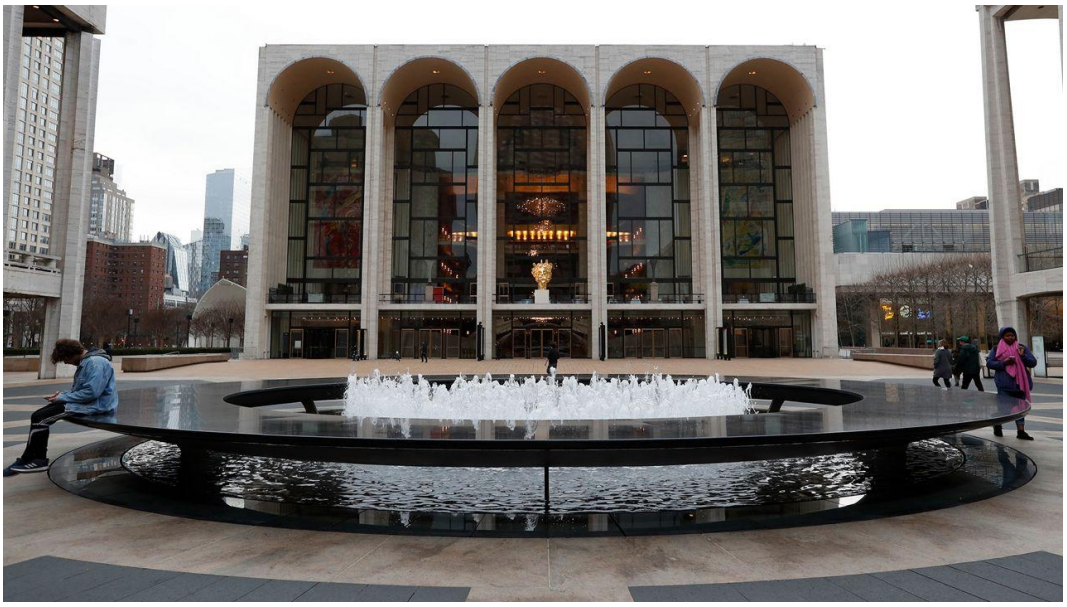


Contents

1. The Story of Mark Fuller

This chapter was archived in 2021, with acknowledgement and thanks, from the website of the New Yorker magazine at www.newyorker.com. The article was written by John Seabrook, and was published on January 3rd 2010.

The renovated Revson Fountain, at Lincoln Center, can fire water as high as sixty feet into the air.Photograph by Eve Sonneman.



The Lincoln Center Fountain at rest.

When Philip Johnson designed the main plaza at Lincoln Center, in the early sixties, he imagined a glowing, pulsating column of water at the center, a feature that would give the modernist piazza, he once said, “the focal point a fireplace gives a home.” The result was the Revson Fountain. When it opened, in April, 1964, it was the most technically advanced fountain New York had ever seen; the Times thought it might be “the most sophisticated blending of light and water in this country,” noting that the nozzles and the lights were controlled by “computer programmed tapes.” In the fountain’s signature move, a six-foot-wide column of frothy water rose

into the air, brilliantly illuminated from below. When the pumps were abruptly shut off, the water appeared to float in the air. If architecture is frozen music, as Goethe said, then the Revson was liquid architecture. It quickly became an icon of the city.

But over the years the fountain's powers diminished. In hydraulic terms, it lost "head"—vertical thrust—mainly as a result of leaky valves, which is the way fountains, like people, tend to fail. The movies document this sad decline. In "The Producers" (1968), one can see the Revson in its prime, when Gene Wilder celebrates his new partnership with Zero Mostel by prancing around the watery eruption, but from "Manhattan" (1979) to "Ghostbusters" (1984) and "Moonstruck" (1987) there is an observable loss of potency. By the time of its appearance in "Sweet Home Alabama" (2002), the fountain looked ragged, and was out of commission for stretches of time—just another clever modernist idea that didn't last. The drained basin of the fountain, with its exposed plumbing, gave the plaza the focal point that a toilet gives a bathroom.

In 2006, Lincoln Center launched a $1.3-billion redevelopment project, and among the many improvements to the arts complex—two additional restaurants, a roof garden, two groves, and a new approach from Broadway—was a plan for a new fountain. There was never any serious discussion about trying to fix the old one, Reynold Levy, the president of Lincoln Center, told me recently. "It was like the decision to replace an old mainframe computer with a P.C."—a no-brainer. There was, however, "a great deal of discussion about what the new fountain should be." The firm Diller Scofidio + Renfro, the lead designers of the redevelopment plan, came up with a number of options, including moving the fountain off center and, instead of a circular fountain, creating a linear strip of water. But in the end, Levy told me, "everyone agreed that the fountain was properly placed, and was the right size, and people should still be able to sit at the edge, on the granite pedestal." Diller Scofidio did replace Johnson's monolithic granite base with a thin granite disk that rests on slender steel supports—a significant improvement—and lower the water level in the fountain's basin to match the level of the pavement.

The fountain's innards would be gutted and rebuilt. To accomplish that, the architects proposed bringing in wet Design (wet stands for Water Entertainment Technologies), the Los Angeles-based water-features firm, led by Mark Fuller. Fuller, who is fifty-eight, may be the closest thing the world has to a fountain genius. He and his colleagues at wet, which he co-founded in 1983, have brought a new language to fountain architecture by giving the water itself a voice: playful, mischievous, sometimes bombastic, sometimes serene. In the United States, wet's projects include Fountain Place, in Dallas, in which water squirts from tiny holes in the pavement, draining through narrow slots into a "vanished pool" below the surface; the

Grove at Farmers Market, in Los Angeles, a sort of liquid cornfield, in which the stalks are made of water; the kinetic water-sculpture fountain in the McNamara Terminal at Detroit Metro Airport, which emits water sparks; and the double row of water plumes outside the Brooklyn Museum. Among other things, wet has extended the tradition of the fountain as trickster, a player of water games, which the Italian Renaissance fountaineers mastered, and which they employed to great effect at Villa d'Este, in Tivoli, outside Rome.

But wet is best known for the fountains at the Bellagio hotel and casino in Las Vegas, which Steven Spielberg has called "the greatest single piece of public entertainment on planet Earth." These fountains, which occupy the better part of an eight-and-a-half-acre lake, are programmed to dance to particular tunes—"Singin' in the Rain," which was created by the choreographer and director Kenny Ortega, is a crowd favorite. wet also did the spectacular water features that are part of the volcano at the Mirage, just down the Strip from the Bellagio. More recently, wet built the Dubai Fountain, which opened in May, and is the biggest fountain in the world. It can project painted images on its water forms, and blast water fifty stories high.

Lincoln Center wasn't in the market for a fountain like that. "We made it clear that we were not looking for a thirteenth art form at Lincoln Center," Levy said. "And we are not Las Vegas. We didn't want something that would take away from the 8 p.m. curtain." Was there any interest in making the fountain musical, like those at the Bellagio? "No music," Levy said firmly. "Because that wouldn't have been appropriate."

Diller Scofidio presented some renderings of tasteful waterworks that reassured the board, and, Liz Diller, one of the firm's principals, said, "we went to see wet's headquarters, in California, and we were very impressed. It was obvious they were the best qualified for the job." The Revson Foundation contributed four million dollars to the cost of the renovation. In early 2007, Lincoln Center decided to get wet.

Mark Fuller is compact and energetic, and has a worried air about him; it often seems as if he's working out a problem in the back of his mind, even as he's talking about something else. He has stocky fingers that twitch sometimes when he talks, as if he were itching to take something apart, and his posture is slightly stooped, as if from years of leaning over a workbench. In demeanor and appearance, he looks like an engineer, but there's a showman inside Fuller, and his alter ego comes out in his dancing fountains.

He grew up in a family without much money, on the outskirts of Salt Lake City. In the spring, when the snow began to melt, water would rush down the sloped streets, and Mark would make elaborate networks of snow dikes,

sluices, and spillways for the water to flow through. Disneyland opened in Anaheim, California, in 1955, and Mark made his first visit, with his parents, when he was fourteen. The park made a lasting impression on him; he was particularly enchanted by the underwater submarine ride and the Jungle Cruise. As a teen-ager, Fuller built a miniature jungle cruise in the back yard for the family's goldfish, complete with lagoons and underwater tunnels, using an old washing-machine motor to propel the water through the system. He even constructed his own underwater lights. "Here I was, fooling around with a hundred-and-twenty-volt current, in water, but nobody seemed concerned," he said.

In high school, Fuller was interested in theatre and, recognizing that in "appearance and stature I was not Charlton Heston," he channelled his theatrical impulses into sets and props. At the University of Utah, he studied civil engineering while continuing to do set design—for Aeschylus' "Agamemnon," he created an altar that breathed fireballs—in an effort to unite his seemingly disparate interests. An opportunity came after one of his professors showed the class a 16-mm. film that demonstrated laminar flow, a well-known principle in hydraulics.

In an ordinary garden hose, the water flow is turbulent. Water molecules bounce off one another chaotically, moving at different velocities, under changing pressure. When the water is projected out of the nozzle, it splinters into spray. In a laminar stream, the molecules all flow in the same direction, and surface tension binds the water as it emerges from the nozzle into a glassy rod that holds together, like a laser beam, and looks heavier, ropier, and wetter than water in a turbulent-flow stream. "How cool is that," Fuller recalled thinking as he watched the film in class.

For his senior honors thesis, Fuller decided to build a laminar-flow fountain. He and two other seniors engineered it by running water from a garden hose through a large plastic cylinder that was stuffed full of drinking straws. As the water passed through the straws, the turbulence diminished, and was further quieted as it passed through first one small mesh screen and then a smaller one, so that when it emerged from the nozzle it flowed in a smooth rod. A friend's father agreed to install the thesis fountain—the world's first permanent laminar fountain—in the atrium of his new office building, the Conquistador, in Salt Lake City.

After two years of graduate school at Stanford, Fuller applied for a job at Disney, and for his interview he took along slides he had made of his laminar fountain. "They looked at it and said, 'We definitely want to hire you—we're just not sure as what,' " Fuller recalled. He became an "Imagineer," charged with developing new ideas for Disney's theme parks. After a year of working on rides at Disneyland, he moved to Epcot Center, in Orlando, the park intended to embody Walt Disney's dream of science,

technology, and design working together to create a better world. Fuller designed the first “leapfrog fountain,” in which laminar streams jump from one raised planter to another. In order to complete his work in time for Epcot’s opening, Fuller did not sleep for the last four days. Later, his colleagues had buttons printed that said, “I kept up with Mark Fuller at Epcot.”

The young Mark Fuller.

In 1983, Fuller and two partners started wet. Fuller was still at Disney, but he left the following year to work full time on creating Fountain Place, in Dallas. The company struggled at first; at one point, Fuller had maxed out thirteen credit cards. In 1995, he got a call from Steve Wynn, the casino developer. Wynn was planning the Bellagio, and he wanted it to be a place that would “make you forget you were in Vegas,” he told me recently, in a hoarse voice, during an early-morning phone call. “I thought an incredible fountain could do that. My landscape guy, Don Brinkerhoff, said, ‘You got to look at this fountain that this kid did at Disney.’ So we went down there and looked at it. It wasn’t a big thing, but Mark figured out how to do the laminar streams, and how to light them, and I was pretty impressed with that. So I flew him to Vegas and took him to dinner, and I said, ‘Can you build me something that’s never been seen before?,’ and I told him the scale I wanted it on, and that it had to all be coördinated with music—the sound, light, and water all together, a perfect union. Fuller said he could do it. He said he could make the lake dance and throw water up two hundred feet in the air.”

“I assured Steve that it would be like nothing else on earth,” Fuller told me. He got the job.

Mark Fuller.

To create the Bellagio fountains, Fuller employed water cannons he had invented that use compressed air to fire shots of water—"Shooters," he called them. They were far more efficient than mechanical pumps at lifting large amounts of water into the air. He also realized that he needed to invent a new kind of nozzle, with a broad range of motion. To visualize the shapes that such a nozzle would make, he had one of his engineers put on a raincoat and hold a hose in different positions above his head, while he twirled around on a spinning chair.

Fuller came up with an underwater robotic arm that was attached to a nozzle and could move in three dimensions. The nozzle could sweep forward and back, creating fan shapes, and it could twirl, creating cones; the engineers, by changing the position of the nozzle and the velocity and acceleration of the water, could create countless variations. Fuller called the units "oarsmen," because of the rowing motion the nozzles made.

A robotics company called Sarcos, in Salt Lake City, agreed to build the oarsmen for twelve thousand dollars apiece, but, after unforeseen design and engineering challenges, they ended up costing more than twice that amount. Fuller borrowed as much money as he could to make up the difference. When it looked as if he might go bankrupt, Wynn loaned him the two million dollars it would cost to finish the job, on condition that

Fuller refrain from building a fountain for any other casino in Las Vegas until he had repaid him. (Fuller paid back the loan several years ago.)

A wet designer named Claire Kahn choreographed one of the first programs, to Aaron Copland's arrangement of "Simple Gifts," and Ortega did another, to "Singin' in the Rain." Ortega told me, "You try to make the water hear the music." The Shooters fire to the staccato beats in the music, and the oarsmen sweep through the legato movements. The choreographers first worked up short sequences on the computer, using a program called Virtualwet, and then "put it on the lake," Ortega said. Unlike dancers, he added, "fountains don't talk back, but they do break down sometimes."

When Wynn saw the fountain for the first time, in 1998, performing Ortega's piece, he was overcome: "I'll never forget that moment. Within sixty seconds I knew—this is it. It was the most incredible feeling." Since then, millions have been similarly moved by the Bellagio fountains. "There's something extraordinarily emotional about that fountain," Ortega told me. "The water is so alive—it is life. And people get very emotional around it. You see people crying—just overwhelmed by the spectacle."

The wet campus comprises eleven buildings in an industrial section on the border of Burbank, near the airport. The building that houses the wet design staff looks like any busy architect's office: the designers, many of whom trained as architects, are seated before computer screens, using software to produce geometric forms and shapes, which will be rendered not in concrete and steel but in water. wet designers often visualize the individual nozzles in a fountain, Fuller told me, as pixels. "We work with basic forms," he said. "Lines and circles, mainly. We don't make, say, cloverleafs. Out of these simple geometries we create complex patterns, but it always starts with simplicity." It is up to the engineers and the fabricators to design and build the plumbing, wiring, circuitry, and software that will sculpt the water into the shapes the designers have conjured up. And because a Fuller fountain isn't a sculpture with water—the water is the sculpture—everything else in the fountain is hidden, usually under the water itself, which adds immensely to the engineering challenges.

In the Idea Playground, wet's R. & D. lab, men in white lab coats try to make water do things it has never done before. Water is heavy, and fountain designers through the ages have been preoccupied with finding ways to counter the effects of gravity. The ancient Romans figured out how to use gravity to their advantage, by forcing water into fountains from high aqueducts; the weight of the down-rushing water created the head. During the Renaissance, the ancients' hydraulic innovations were rediscovered, and the Popes restored and embellished the fountains of Rome, commissioning the great sculptors of the day, who used water to give their figures the liquid glue of life. In the nineteenth century, mechanical water

pumps began to be used in fountains, which made fountaineering easier, and today anyone with an electrical outlet can run one in his back yard. But in form and function mechanical fountains didn't change much until wet came along and invented the compressed-air cannons to conquer the problem of gravity. wet makes five standard sizes—NanoShooters, which have a range of up to six feet; MicroShooters, which can go up to sixty feet; SuperShooters, a hundred and twenty feet; HyperShooters, two hundred and forty feet; and XtreamShooters, which can fire water five hundred feet into the air.

Outside the lab, I saw a demonstration of a SuperShooter. Its barrel was about twelve feet tall, held upright by metal supports. One of the lab workers used a remote control to fire the Shooter, while we stood back. A shuddering boom was followed by a crackling sound, as the water flew high overhead.

"That's the sound of water breaking the sound barrier," Fuller said, looking pleased.

Nearby was a mockup of an ice fountain, one of the water features that wet developed for the Las Vegas CityCenter, an $8.5-billion hotel and entertainment complex that opened in December. Out of an opaque black pool, columns of ice up to two feet wide appear, illuminated by colored lights, rising at varying speeds until they are as high as fifteen feet. "It's supposed to be somewhere between the column in the Stanley Kubrick movie '2001' and a big Popsicle," Fuller told me. As the ice columns emerge from the pool, they are sculpted by tiny, high-powered water jets. "It's like a dot-matrix printer," Fuller said. "It lets you create all these complicated shapes." Every so often, the ice columns are retracted and extruded again, and sculpted into different shapes.

Some of the most beautiful effects I saw in the lab were the quietest. I watched a three-quarter-inch-wide laminar tube of water transcribe a fifteen-foot arc without breaking up, lit from within by a colored beam of fibre-optic light that bends with the water. When that stream obliquely struck another stream, a shower of colored water sparks bloomed.

Although water is wet's stock-in-trade, the firm dabbles in fire, too. "There is a lot of demand for fire in the East," Fuller said. I saw several fire-and-water mockups, including a twister of water in a large glass tube, which had fire running through the middle of it. Another fire feature sprayed a mixture of natural gas and water. One of the lab technicians put his hand into the plume, explaining that as long as you kept your palm perpendicular to the floor you wouldn't get burned, because the water carries the fire over your hand. "But if you put it flat you'd fry," he said.

The new Revson Fountain was constructed entirely on site at WET, as are all the company's fountains, with precision German steel-cutting tools operated by wet employees. "Outsourcing wouldn't make sense for us," Fuller said, "because with this kind of work there are so many small changes to make along the way." The fountain has three hundred and seventeen computerized jets, some of which produce turbulent, frothy water, and others glassy waterspouts. Jets are arranged in two rings around the perimeter of the fountain, with radial arms leading to a central circular mass of more jets. These are run by twenty-four water pumps. (The old Revson had a total of three pumps.) Distributed evenly among the jets are thirty-six MicroShooters.

WET also designed the new pump room, which is beneath the plaza, and which contains, among other things, huge air tanks for the MicroShooters, built of high-grade steel in order to contain the air inside, whose pressure is a hundred pounds per square inch. "If one of these blew, you wouldn't find much more than a teaspoon of us," Fuller said, during a tour of the facility. The windowless area, which takes up twenty-two parking spaces in the underground garage, feels like a submarine, and if you're down below when one of the MicroShooters goes off you feel as if you were in battle. (The fountain technicians wear ear protection.)

A wet choreographer named Peter Kopik designed two programs for the fountain. There is a daytime program—a sedate, ninety-minute sequence of slowly morphing geometric shapes—and a shorter, more dramatic evening program, in which the MicroShooters are deployed along with the jets. The daytime program will run most of the time, and the dramatic program is intended to run later, as the plaza begins to fill with ticket holders.

Fuller seems a little frustrated at the constraints Lincoln Center placed on him to insure that the fountain wasn't too "Vegas." "Whatever that means," he said. "You know the expression 'sugarcoating the lemon'?" he asked me, with a somewhat rueful expression. "I feel like we're lemon-coating the sugar." Neither his oarsmen nor the big Shooters had made it into the final design; incorporating the thirty-six MicroShooters had required a certain sleight of hand. "No one told us we couldn't use them," he said.

The new fountain débuted on October 1st, and the daytime program has been running since then. When the jets are all on, they produce a mighty column of water that slowly rises to a height of twelve feet. When the column is at its greatest height, there are four hundred and seventy-five gallons of water in the air, all of it recycled. The glossier streams in the middle can be glimpsed through the stalks of froth on the outside. Especially after dark, people are drawn to the column of water, mesmerized by the two hundred and seventy-two L.E.D. lights that make the water glow

white (colored gels could be added to the lights, but that would presumably be considered inappropriate) and hushed by the sound of the cascade.

The dramatic program, however, has not gone off nightly. Adjustments needed to be made to the wind sensors that had been installed around the plaza. While wet has mastered water, and is working on fire, it is powerless against the effects of wind. With so much water propelled so high in the air, even a slight breeze could push some of it beyond the rim of the Revson's basin. A dousing might feel good on a hot summer day, but it would probably not delight an elderly couple dressed for the ballet on a chilly fall evening. The fountain as trickster is one thing; the fountain as potential lawsuit is another. It seems that Lincoln Center, in spite of its best efforts, might have got more fountain than it bargained for.

I was finally able to see the dramatic program on a cool, almost breezeless evening at the end of October. Kerry Madden, Lincoln Center's taciturn vice-president of concert halls and operations, whose responsibilities include overseeing the fountain, met me in the plaza. He was on his cell phone, surrounded by three cops, and they all scrutinized the fountain as though looking for signs of suspicious intent. Finding none, Madden and I went upstairs to the outdoor balcony of Avery Fisher Hall, while, below, a guard steered people away from the downwind side of the fountain, just in case.

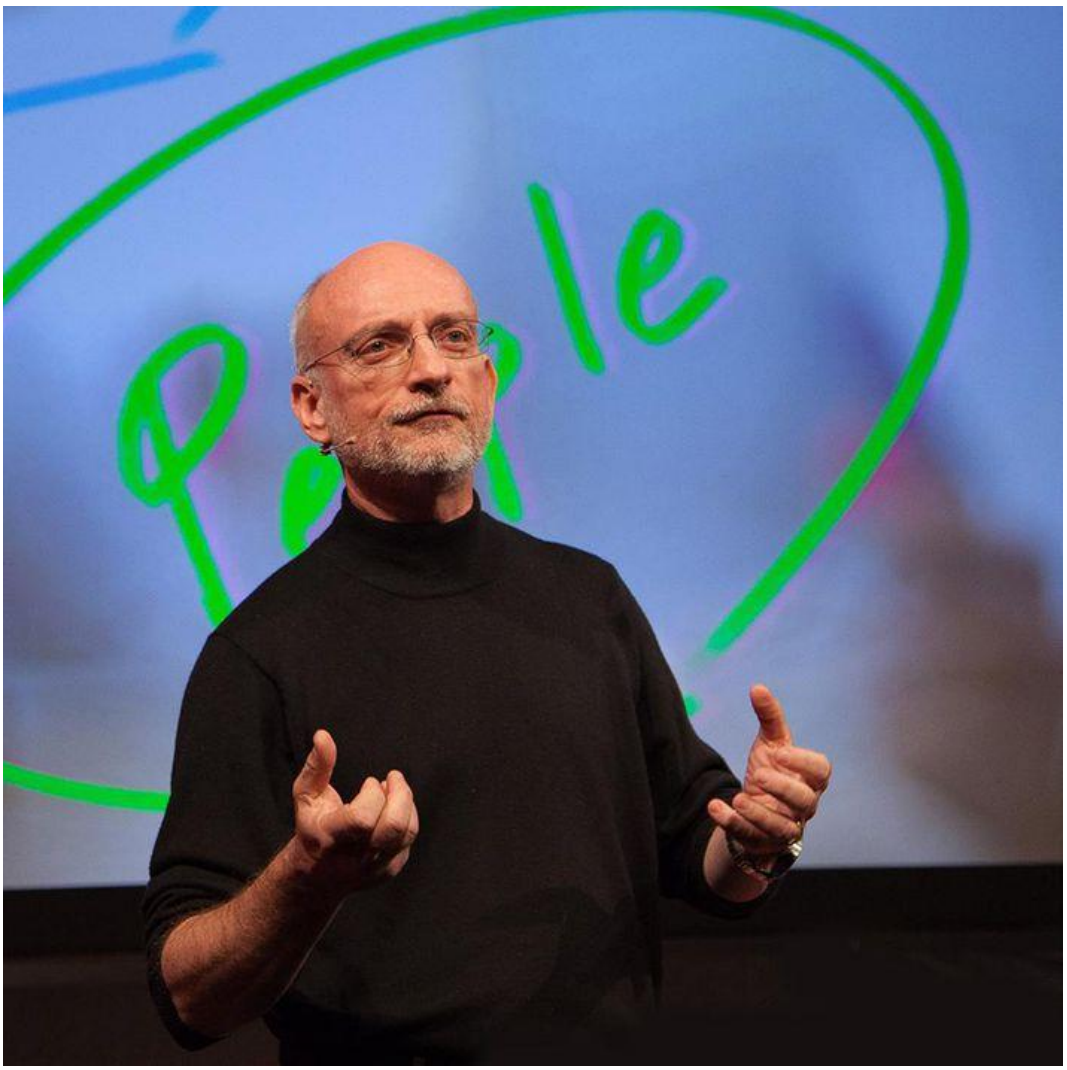
"Let's go with the show," Madden said tersely into his phone, speaking to the operator in the pump room.

The show began with the rising column seen in the daytime program, but soon the first shots appeared, and the booming of the air cannons was heard, faintly at first, and then louder, as the shots climbed higher. As the crest of one shot began to fall back to earth, it struck the next shot, on its way up, and created globes, like Japanese lanterns made of water, momentarily suspended in the air.

"That's about twenty feet," Madden said, when the first shots went off. Down in the plaza, a crowd was gathering. "That's about forty," he said, excitement breaking into his no-nonsense tone.

Then there was the biggest boom yet, and all the Shooters went off at once, sending water sixty feet into the air—almost as high as the surrounding buildings—and as the main plume arced down there was a loud slapping sound of water landing outside the basin, on the plaza itself.

But nobody minded. When the volley ended, and the fountain's waters abruptly disappeared, there was a short, stunned silence, followed by bellows of approval from the crowd, which were, under the circumstances, entirely appropriate.



2. Visiting WET

The following chapter was archived in 2021, with acknowledgement and thanks, from the Wired magazine website at www.wired.com. The article, by Daniel Oberhaus, was published on 6th March 2020.

The headquarters of the world's leading water design firm, Water Entertainment Technologies, or WET, is best described as a cross between a machine shop, a research laboratory, and a movie studio. At one end of the sprawling complex in North Hollywood, California, technicians weld together giant sheets of steel and pull plastic parts from injection-molding machines.

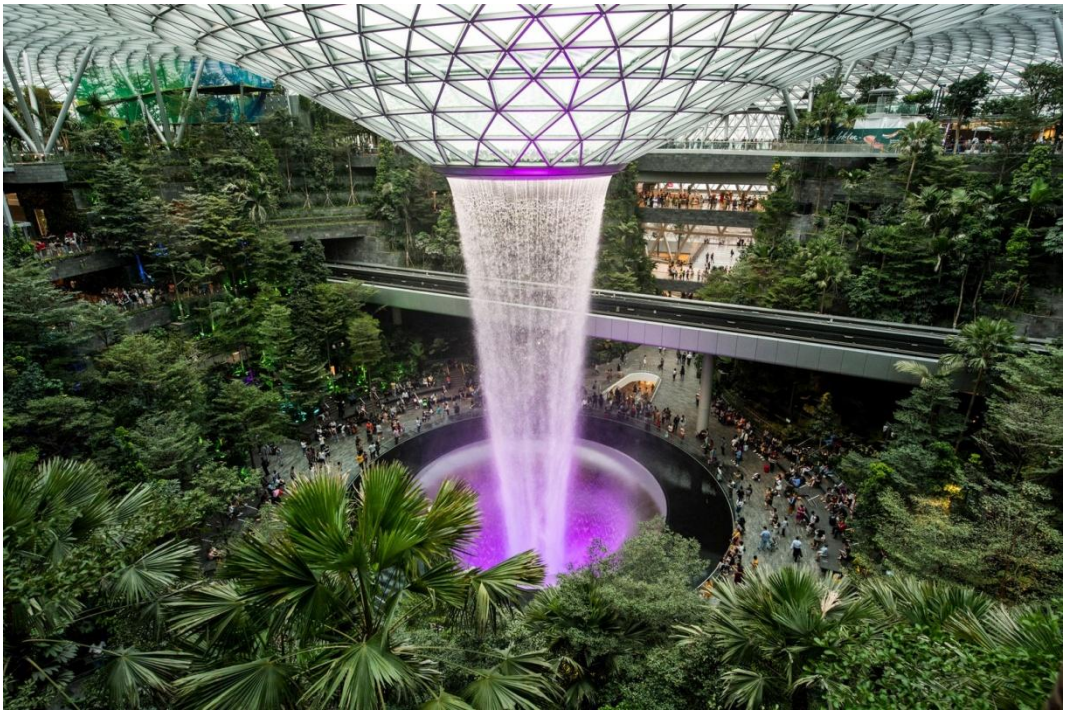
Just around the corner, scientists with PhDs in disciplines like plasma physics, optics, and chemistry run experiments in the company's four scientific labs. Out back, engineers build scale replicas of upcoming water features against photorealistic backdrops of their eventual homes, places like shopping malls, hotels, and office buildings. Spread through the facility there are pianos and drum sets, secret passageways, and a 20-foot robot that stands in the corner judging passersby.

The company's unusual digs are exactly what you might expect to spring from the mind of someone like Mark Fuller, WET's founder and CEO. As a former Disney Imagineer, Fuller honed his engineering skills in an environment where science, design, and entertainment were effectively treated as a single discipline. As the leader of WET, he takes the same approach to water. Many of the world's most iconic water features—the Bellagio fountain in Las Vegas, the massive waterfall in Singapore's airport, the dancing fountain in Dubai—were brought to life here in WET's surreal waterworks factory.

WET is in the business of creating massive public artworks, and to date it has built more than 250 installations around the world. Fuller says customers typically approach the company with a simple request: They want something that hasn't been done before. It's a blank canvas for Fuller and his team, but the final design of a water feature is ultimately informed by its environment—indoor features must meet a different set of requirements than outdoor displays.

Take the Rain Vortex in Singapore's Jewel Changi airport complex, which WET just completed last year. Singapore gets a lot of rain, so WET capitalized on this by designing the water feature to collect rainwater from the roof and funnel it into the building, creating the world's largest indoor waterfall. Water cascades in thin sheets from a hole in the glass toroidal roof over 130 feet above the Jewel's plaza, which is overflowing with plantlife. At night, an array of cinema projectors positioned around the

Vortex light up the waterfall with a customized light show. During a downpour, the vortex might be moving as much as 10,000 gallons of water a minute—enough to fill an Olympic-size swimming pool in about an hour.



Rain Vortex at Jewel Changi Airport, Singapore.

When it comes to engineering water features, “controlling turbulence is the name of the game,” says Garrett Young, who leads WET’s team of 40 engineers. In short, turbulence breeds chaos. It causes water to slosh, spill, and spray in ways that are difficult to predict. These effects are compounded by variables like air flow, temperature, or textured surfaces, which make it staggeringly difficult to get a large water feature to behave. To understand how water will move in such a complex system requires modeling water very precisely at the level of its individual particles—and that requires a lot of computing power. The environments in some of WET’s upcoming water features are so chaotic that the company is renting time on a supercomputer at Oak Ridge National Laboratory just to make their simulations.

“What we do is very simulation intense,” says Young. “But it allows us to give the illusion that we’re breaking physics.”

You know those plaza fountains that shoot up thin streams of water that then disappear underground through cracks in the tiles? They’re now a mainstay of corporate plazas everywhere, but that was originally WET’s idea. When they first floated the design for a client in Texas back in the 1980s, Fuller says no one outside the company thought it would work. The cracks in the tiles seemed too narrow to let the water drain fast enough.

But if you work through the math, it’s the total lengths of the cracks around the tiles that matter, not their width—so there was more than enough space to move water off the plaza and into the underground collection pool.

WET Mock-up for Seminole Hard Rock Hotel & Casino, Hollywood,

“I made a couple of bucks betting all the stonemasons that the water would get out of there,” says Fuller. “It just seems like magic because all the water disappears before your eyes.”

But even with all the theory in the world, things don’t always work as planned. The Bellagio fountain in Las Vegas was WET’s first major project and arguably its biggest claim to fame. Steve Wynn, the hotel magnate building the Bellagio, wanted the largest fountain in the world, complete with thousands of dancing water jets, some of which would send water over 300 feet into the air. But to blast water that high, traditional pumps just aren’t going to cut it. They would require an obscene amount of energy that would have to be dumped into the system all at once.

So instead, Fuller and his team developed what they refer to as “shooters,” giant water cannons that use highly pressurized air to blast water through a nozzle. These reduced the fountain’s energy needs to just a fraction of what they would have been had they gone with pumps. But when they installed the shooters in the Bellagio pool, there was a problem. The valves in the water cannons would get stuck open at random, sending a torrent of water streaming into the air. “It looked like Old Faithful,” says Fuller.

Wynn, who was spending $40 million on the project, was less than pleased, Fuller recalls. But when the WET team sent divers out into the pool to look for a problem, everything seemed fine. At the time, WET was still a small company and didn’t have its own research labs to use to figure out what was happening. So Fuller turned to a friend of his who worked as a scientist at Caltech to do a root cause analysis. Soon he had an answer: When air expands, it sucks thermal energy out of a system, which is why cans of compressed air like hairspray or computer dusters get cold when you use them. When pressurized air was fed into the shooters at the Bellagio, it caused temperatures to drop to -50 degrees Fahrenheit. This made large balls of ice build up in the valves and hold them open. The solution was simple: WET added a component to the pipe that caused the ice to form in a different section of the shooter rather than in the valve. But without getting into the fundamental science, the problem would have been difficult, if not impossible, to solve.

The team’s job is to limit technical surprises as often as possible. By the time WET installs its water features, they need to work flawlessly. When you’re working on water features that cost tens of millions of dollars, there are no do-overs. This requires a rigorous troubleshooting process that straddles the divide between analog and digital. When WET engineers begin designing a fountain, they will start with simple physical models that they can easily tweak. Once they’re satisfied with the overall design, they render it as a computer model so they can interact with the design in 3D space, sometimes as a VR or AR experience. Finally, they’re ready to

build a scale replica in WET's back lot, complete with a detailed scenic backdrop, to see how it will look in situ.

WET Optics Lab.

Bellagio Fountain, at the Bellagio Hotel, Las Vegas, cost $40 million. It has 5,000 water jets and 4,000 lights, all individually controllable. It can throw water 500 feet in the air.

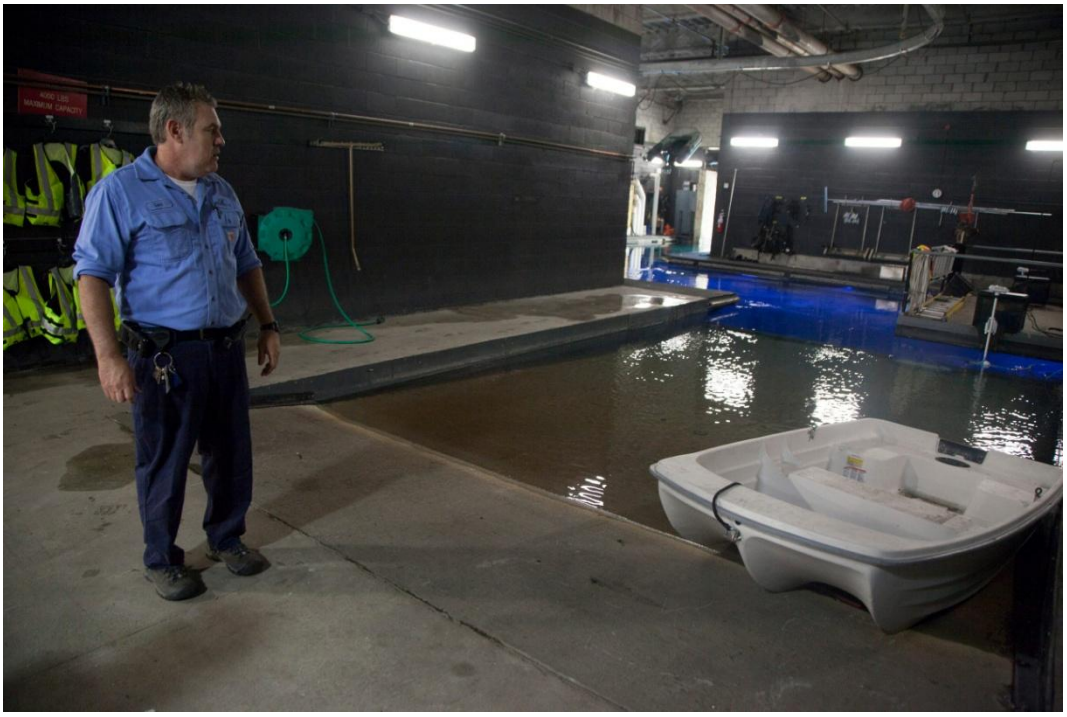
This year, WET will install six water features around the world. At the same time, its engineers are working on new technologies that they hope to incorporate into features in the near future. Fuller compared one of these to a rocket engine that blasts out ionized particles or plasma to create pyrotechnic effects. They are also developing water jets that can move autonomously around a fountain, but Fuller declined to go into details about where a water feature using this technique will be installed.

The role of pools and fountains in public spaces is always in flux. While they once served utilitarian functions like bathing or drinking, they are now almost entirely about aesthetics. But through it all, Fuller says, they've served as a point of human connection. At a time when people spend a lot of their day staring down at screens, WET's water features still have the power to stop people in their tracks and make them look up.

---

3. Maintaining the Bellagio Fountain

The following chapter was archived in 2021, with acknowledgement and thanks, from the Las Vegas Review-Journal at www.reviewjournal.com. The article, by Andrew Taylor, was published on May 2nd 2017.



Inside the Batcave.

The Compressor Room beneath the Bellagio fountain.

Deep in what's dubbed the Batcave, about 30 staffers quietly toil with one-of-a-kind vehicles, masks and skin-tight outfits to ensure the Fountains of Bellagio keeps running.

"It was named the Batcave before we even opened," said Curtis Briggs, manager of the Fountains. "We don't have a Batboat; we have a Bellagio barge."

One of the Bellagio Fountain maintenance boats.

The Batcave has several boats, two of which the staff built to serve the attraction's very specific needs. One serves as a mobile filtering system and the other is a barge with a winch for moving the fountain's water cannons, which weigh up to 1,800 pounds each, to the maintenance area. Because of the challenge of moving the huge pieces, staffers prefer to do the repairs in the lake whenever possible. Every member of the staff is scuba-certified.

"The first summer, the lake got up to 87 degrees, but in the winter it can drop as low as 38," Briggs said. "That's why we do most of our preventative maintenance. When it gets cold, you have to limit your time in the water."

About half of the staff has been in place since the fountains were built, maintaining equipment that has been underwater for 19 years. The dancing water show's cannons includes Oarsmen, which move back and forth, and Minishooters, Supershooters and Extremeshooters, all of which fire straight up.

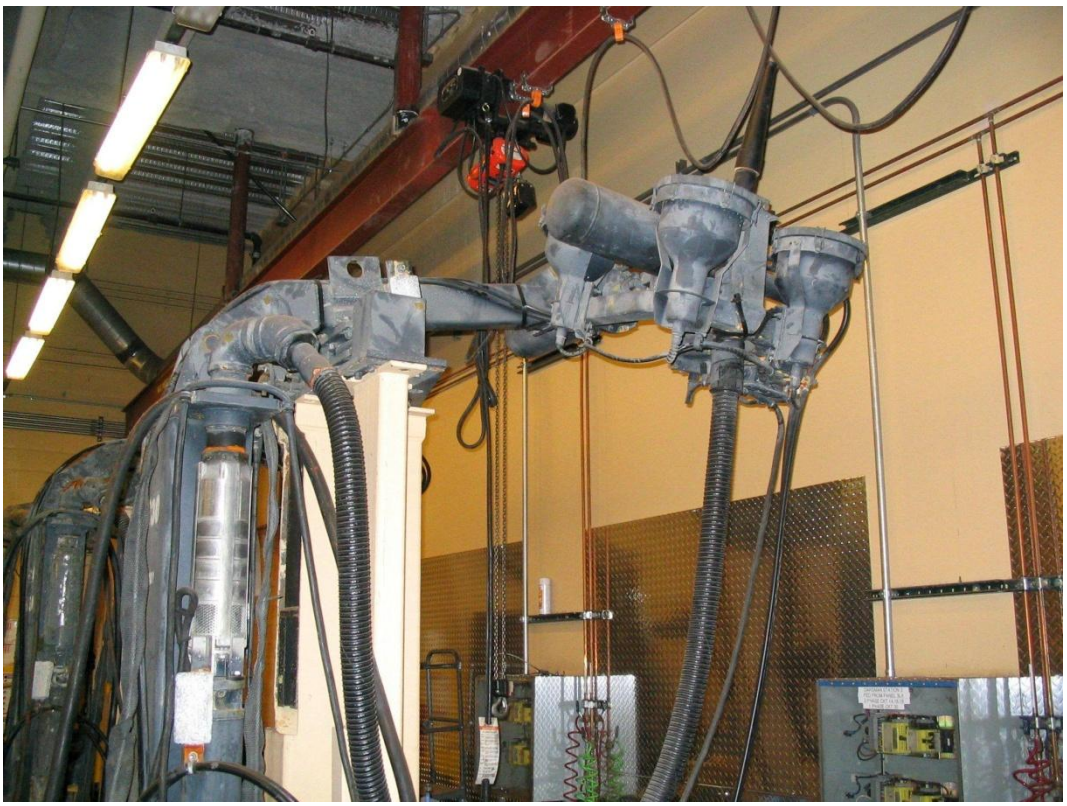
“The static devices launch the water at different pressures,” said Arnold Cabrera, a longtime member of the maintenance staff. “Generally, they go up a foot for every pound per square inch, so the Extremeshooters, which are set at 460 PSI, go up about 460 feet, nearly as tall as the hotel.”

When the water goes that high, it comes down as a mist. Water from the other canons comes down in column form, which the crew feels looks more dramatic. The show system also includes fog manifolds — structures that come out of the water with approximately 5,000 nozzles.

“We like to say we can turn Paris into London in five minutes,” Briggs said. “When we first opened, every time we had a show that used the fog, people called the fire department.”

The lake had been open for a year before the ducks found it, and initially, crew members made the mistake of feeding them. When they realized they had 90 ducks, they saw their mistake and moved them off-site. The number of ducks is down to a manageable average of 15. As far as Briggs knows, no duck has ever been launched from the lake by a shooter or hit by a column of water.

“I’ve seen ducks turn 90 degrees to avoid the water column,” he said. “When the show is getting ready to go, compressors turn on and you can hear that. It takes about two minutes for shields rise out of the water, and the ducks seem to know to get out of the way then.”



An Oarsman device under maintenance in the workshop.

WET Design conceived of, designed and built the attraction in two years. It was budgeted at $4.5 million, but as more features were added, the cost skyrocketed to $50 million. To meet the time frame, portions were subcontracted and less expensive materials were used. The company that built the Oarsmen has gone out business, creating challenges for the crew that keeps it all running.

"The Oarsmen are mostly built with mild steel and coated with a tar-based paint that wore off in about a year," said Fountains of Bellagio engineer Rod Botelho. "We took them all out, sandblasted and powder-coated them. They were designed to last five years. We've kept them running 19, and we should be able to keep them going for quite a few more."

Keeping the water clean involves complex engineering and hard work. The filtration system's pumps can move 5 million gallons a day — about a quarter of the lake's contents.

"There just wasn't a filtration system available that was large enough," Briggs said. "Ideally the water should all be turned over every 24 hours, and it takes four days for the lake water to get turned over. Because of that, we have a cleaning barge."

The barge separates heavy objects found at the bottom of the lake, such as coins, which are filtered through 52 pool filters mounted to the barge. The coins are placed in an account that distributes money to several charities.

"It takes a lot of manpower to do it, but we've got to get the coins out of the water anyway," Briggs said.
