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The Electric Acid Test

On the Isle of Man, the beginnings of a marketable electric motorcycle.

By Adam Fisher

The Isle of Man is a small British possession in the Irish Sea. Inland, a native breed of four-horned sheep graze in verdant fields. On the coasts, castles touch the sea. The Manx have their own (albeit dead) language, their own money, their own laws, and--tellingly for this story--no national speed limit. This quirk of governance makes the place a natural host to a bloody ritual that has taken place nearly every spring for a century: the Tourist Trophy. The TT is not a motorcycle race but the motorcycle race: the first, the most famous, and by far the deadliest.

It's also a party: 40,000 bikers invade the island determined to scare the wool off the sheep while screaming through the Snaefell Mountain Course, a winding circuit of public roads cordoned off for the event. The circuit climbs from sea level to 1,380 feet, snaking for almost 38 miles through 200-some turns on country roads that cut through village, hamlet, and farm. Much of the track is hemmed in by dry-stacked fieldstone walls topped by spectators drinking their pints. There is no safe place to crash. Racers die or are maimed every year.*

As in warfare, the carnage is accompanied by technological progress. Soichiro Honda came to the race in 1959 having declared five years earlier that it was time to challenge the West. Less than a decade later, his company won the world manufacturer's title in every class: 50cc, 125cc, 250cc, 350cc, and 500cc. Not long after that, the British motorcycle industry was itself conquered, wiped out by mismanagement and superior Japanese technology. Ironically, the technical advances that made racing bikes so fast led the Fédération Internationale de Motocyclisme (FIM), the sport's governing body, to decertify the race in 1976, calling it too dangerous. Thus, pros no longer ride the TT. However, the race's bloody reputation makes the TT, if anything, even more prestigious than FIM-sanctioned events. To compete in it, in the words of the legendary FIM rider Valentino Rossi, "you need to have two great balls."

This year, the Manx government added a futuristic new event to the June race schedule. The TTXGP, for "Tourist Trophy eXtreme Grand Prix," was billed as the first zero-emissions motorcycle race. While any technology could enter, as a practical matter zero emissions means electric. Even the FIM got on board, making the TTXGP the first FIM-approved TT race in over 30 years and the first officially sanctioned electric-motorcycle race ever. "It is either going to be the most important day in the next hundred years of motorcycling or a complete debacle," said Aaron Frank, an

editor for Motorcyclist magazine who traveled from Milwaukee to watch the race. "But either way, it's worth watching."

As the day arrives, everyone watching knows that the TTXGP will be slower than the "real" motorcycle race, the TT, because the TTXGP is an energy-limited race. In effect, the "gas tank" of an electric bike is minuscule, so to win the TTXGP the bikers must mind their energy consumption. In contrast, the gas bikers in the TT run with their throttles wide open. However, batteries' energy density has been improving at a rate of about 8 percent a year, which means that even without any other technological progress, electric bikes should run head to head with gas in about 20 years. The TTXGP is intended to make the future arrive sooner. The winner will not just be the fastest in an esoteric class but the front-runner in the greater challenge ahead: creating an electric bike that can compete in the \$50 billion world motorcycle market. In that sense, the TTXGP is the proving ground for the next Honda.

**This year is no exception, claiming the life of a racer named John Crellin--the 226th TT fatality.*

Green Machines

Twenty-two electric bikes show up to compete. While many of the entries are experimental one-offs from technical universities or obsessive hobbyists, three entrants are so-called factory teams: Brammo, Mission Motors, and MotoCzysz. All of them hail from the West Coast of the United States. Brammo is in Ashland, OR, Mission Motors in San Francisco, and MotoCzysz in Portland. And all are entering the consumer market with an electric bike. Brammo is set to sell its motorcycle off the floor at Best Buy: it's a \$12,000 runabout with a top speed of 55 miles per hour. For the TTXGP, Brammo has upgraded almost every component in its bike to create two 100-mile-per-hour crotch rockets, both entered in the race. The Brammo racers are fast, light, and nimble but under-spec'd compared with what Mission and MotoCzysz trailer in: full-size race bikes heavy with batteries, capable of reaching 150 miles per hour. The Mission bike will sell for \$69,000; the MotoCzysz will probably sell for slightly less.

Mission and MotoCzysz are both targeting the high-end superbike market, and both promise to ship products in the next year or two, but that is where the similarities end. Mission's charismatic young CEO, Forrest North, is a computer geek who likes to speculate on the future of software design: he fantasizes about a wheelie-popping autobalancing "Segway app" for a bike's control computer. (Though he hastens to say that Mission itself is not working on such an app.) MotoCzysz founder Michael Czysz is a designer--and his bike is a looker. Exposed battery packs protrude from each side, a fresh take on the naked-sportbike style of the insanely popular Ducati Monster. The packs are modular and swappable, and the bike is "green," Czysz explains, "because it's upgradable." Even Infield Capital's David Moll, one of the investors behind Mission Motors, is impressed when he sees the battery-as-engine design. "I've got a dog in this fight, but if that doesn't excite you," he says of the MotoCzysz entry, "then there's something wrong with you."

Brammo, Mission, and MotoCzysz are directly competing for the capital that's needed, in enormous quantity, to introduce a new vehicle to the American market. Brammo has the early lead in the money race: a \$10 million investment from Best Buy's venture fund and Chrysalix Energy Venture Capital, as compared with Mission's \$2 million in seed capital. Bringing up the rear is MotoCzysz, a company essentially funded out of Michael Czysz's back pocket. While both Mission and Brammo hope to win the TTXGP in order to generate publicity and thus orders, MotoCzysz *needs* to win, or at least place, in order to woo enough capital to enter the marketplace. It's anyone's race to win, of course, but in most motor sports, the factory teams with access to deep corporate pockets are the first to cross the finish line. Behind them come the privateers--scrappy dreamers and shade-tree mechanics who are short on resources but long on heart.

So it's all the more surprising that in the week before the race, a dark horse emerges, freaking out all the factory teams. The fastest bike in the TTXGP prelims--two qualifying runs around the island--turns out to be from Team Agni, a total unknown, a mere privateer. Millions of American research-and-development dollars find themselves chasing the tail of a no-money ratbike engineered in India.

"Bloody Simple"

Cedric Lynch and Arvind Rabadia are the two halves of Team Agni, and their tent is the smallest in the pit area, a 10-foot-by-10-foot red E-Z Up. Their kit is equally minimal: an assortment of hand tools, a halogen work light, and a few copies of the latest issue of Battery Vehicle Review to pass out to curious visitors. The zine, which is the journal of the U.K.'s Battery Vehicle Society, is a hand-stapled, Xeroxed affair; the cover story, "Living with the G-WIZ," features one owner's evaluation of his electric quadricycle.

In their tent the day before the big race, Lynch positions the hot halogen light over a custom fiberglass battery tank that Rabadia has built by hand. The toxic smell of polyester resin fills the air. "Bloody hell, Cedric!" exclaims Rabadia from his lawn chair. "Are you trying to kill us, man?" Rabadia sports a Mohawk and a gold hoop earring, giving him an all-purpose air of menace. Lynch, on the other hand, has the otherworldly demeanor of someone who has spent the past 20 years meditating in a cave. He's barefoot, ponytailed, and dressed in little better than rags; it is unclear whether he even hears Rabadia's outbursts. Right now, Lynch is bent over double, fashioning a part from a piece of scrap metal by holding it with his bare feet and boring a hole in it with a mechanical hand drill. They're quite a pair--the pirate and the pauper. "I do all the talking and Cedric does all the working," Rabadia says. "Swearing at Cedric is my way of calming myself down."

At the center of the Agni tent is the machine that's blown through the two qualifying laps and set the pace to beat. If the factory-made machines look like the future, the Agni entry looks like Frankenstein's monster. The bike is a Suzuki GSX-R with a lopsided stack of lithium-polymer batteries where the internal-combustion engine and gas tank would normally be. Twin DC motors, each the size and shape of a stack of

pancakes, are mounted outboard of the frame and drive the rear wheel by way of a chain. The engineering is primitive, the craftsmanship nonexistent. The whole bike seems to be held together with zip ties and duct tape. Instead of a dashboard, the rider reads from a battered yellow voltmeter jammed between the handlebars. After the fiberglass tank dries, the paint job comes out of a spray can, and the stickers of Agni's sponsors--mainly Kokam, a South Korean battery company--are slapped on so haphazardly that they flap in a breeze. But Team Agni is ready for the main event.

The bike's shabbiness is, for Rabadia, a badge of honor in what he sees as a class struggle between the factory teams and the privateers. "We thought we were the underdogs," he says. The Agni bike was thrown together in only six weeks. "It could have been half that," he says. "I told Cedric 'two weeks,' but then I wasn't around to crack the whip." For Lynch, the bike's evident ugliness is not a class statement but, rather, the fruit of his rigorous antimaterialist philosophy. To Lynch, it's what inside that's important, and nothing else. There's not much to an electric bike--just a battery bank, controllers, motors, and the wiring that connects them. But unlike all the other designers, who hide their circuit boards inside aluminum cases, Lynch showcases his wiring under Plexiglas right on top of the main battery stack, enabling his competitors to examine exactly what makes the thing go. There's not a microchip to be seen, but that's exactly the point. "Anything that's not there can't go wrong," Lynch explains. He races as he lives, on the barest minimum. "Bloody simple, it is," Rabadia adds. "Nothing to it."

Team Agni may be a study in minimalism and eccentricity, but it also has something formidable: more than 50 years of experience. Lynch recounts how he first became interested in electricity. "I left school when I was 12 because I couldn't stand it, and I went home to read," he says. "Mostly theoretical treatises and that sort of thing." For fun, he pattered around in a workshop with his father, one of the engineers who had built the Colossus computer and broken the Nazis' war codes. As a young man, Lynch made a career of entering electric-vehicle races. The first one was in 1979, when his poverty proved to be no disadvantage. "DC motors were very expensive then," he recalls, "so I made one of my own design out of tin cans." Lynch came in second, as his tin-can design proved to be more efficient than that of the factory-made competition. In the 1980s and '90s he would come to dominate the Battery Vehicle Society races. "We won most of the things we entered," Lynch says. "It was good fun." Back in the BVS days, Rabadia was Lynch's protégé, but now it's Lynch who works for Rabadia. The latter set up Agni in his native India to commercialize his mentor's design: the so-called pancake motor. He's brought Lynch to the TTXGP "because our motor is the best, and we need to get the respect we deserve."

"Just a Miscalculation"

Meanwhile, on the opposite side of the island, Team MotoCzysz has rented out a small test track to get some last-minute performance data. Things are not looking good for the best-looking bike. In the first qualifying lap around the island, MotoCzysz blew two of its three motors, and in the second, the rider had to cross the finish line under human

power, paddling with his feet like a duck. "Humiliating," Czysz admits, "but just a miscalculation."

Like Agni's machine, the bike has no software, no onboard data-logging computer, no odometer. The bike is smart enough to know how much charge it has left, but the state-of-charge meter--the "gas gauge," in essence--had yet to be calibrated. To make sure that the bike has enough juice for the race, the rider has to know what's left in the "tank." And without a dynamometer, the only way to get the calibration information is to ride the bike in a circle for a few miles and then hook it up to a digital multimeter. Czysz makes the best of it while climbing onto the bike. In full leathers, highly styled hair, and designer sunglasses, he looks like the Derek Zoolander of electric-vehicle racing. He even speaks with Zoolanderian opacity: "Other teams have data acquisition," he boasts. "We have rider acquisition."

Adrian Hawkins, the lead MotoCzysz engineer, sheepishly holds up his stopwatch and ledger. "Our acquisition system," he says.

Just before launch, the owner of the track--a practical joker--suggests to Czysz that Imperial miles and U.S. miles are different.

Czysz turns to Hawkins, and asks how long each lap is.

"One point five miles," answers Hawkins.

"U.K. miles or U.S. miles?" Czysz quizzes.

Hawkins is stumped: U.K. miles or U.S. miles?

"U.K. miles or U.S. miles!" Czysz demands, more forcefully this time. Czysz has a reputation as a screamer, and his voice is rising.

"U.S. miles," Hawkins stammers, gently telling Czysz that miles are consistent across borders.

A voice from the small crowd that's gathered to watch comes to Hawkins's rescue, politely informing Czysz there's an Imperial gallon and a U.S. gallon, and perhaps that is the source of his confusion.

"It's gallons that are different?" says Czysz to no one in particular, "Okay, I didn't know." And with that, he zips off.

The Breakdown Lane

Mission has even bigger problems. Like MotoCzysz, its bike completed one of the qualifying laps and broke down in the other--but the team has no idea why. It's the night before the big race, the one that counts; the bike is busted, and all Mission really knows is what its rider Tom Montano can describe. The bike was feeling really good--fast, even, he says. He was passing other riders left and right, and then the machine just gave out. "All I can compare it to," Montano says, "is when a gas bike

starts lugging and then binds up."

Hearing this, Jon Wagner, Mission's CTO, gets on his hands and knees and opens the bike's power plant. It sits low in the bike's frame just forward of the swing arm. "I'm getting a sinking feeling that we've got a janky motor," Wagner says. Placing the two probes of a digital multimeter to the motor's guts, he takes three measurements of internal resistance: .018 ohms for the first and .021 ohms for the second two. The measurements are consistent with a short in one of the three windings. "We may have to take this thing apart and relacquer the coils," he concludes.

Wagner has found the failure, but that doesn't explain why the motor quit in the first place. Mission was counting on its custom software to give it an edge, but forget stunts like "Segway mode"--the Mission bike didn't even have brains enough to shunt current away from an overheating motor. Even worse, when data-acquisition tech Ray Shan downloads the race log from the bike, he finds that Mission would have been better off if it hadn't used a race computer at all. "We completed 31 percent of the track before we broke down," says Shan, in disbelief, "but we used 40 percent of our total power." Even if the motor hadn't blown, the bike would have run out of juice before the end of the qualifier.

It's Seth LaForge, Mission's lead software engineer, formerly of Google, who starts to connect the dots. What if the software loaded on the ride computer was not updated to account for the larger sprocket that was swapped onto the back wheel before the race? Then the bike would be running faster than its speedometer would indicate--and this would explain why Montano reported passing other riders left and right.

To test LaForge's hypothesis, Shan recalculates the bike's speed by extrapolating from the tachometer data. Since electric bikes generally don't have gearboxes, the relationship between rotor speed and actual speed is fixed. The revised speed calculations indicate that the bike was topping 100 miles per hour for the first seven miles of the course--an energy-guzzling pace, for sure. But why didn't the bike just run out of charge before the finish, like the MotoCzysz bike? Why did it break down instead? The answer comes when Shan superimposes the corrected speed data onto a motor efficiency map. "One hundred miles per hour is right at the edge of the chart," says LaForge, gasping a little when he sees the graph. The bike was redlining the entire way, dumping energy in the form of heat. A faulty setting in the motor control software was feeding the motor too much electricity. The bike just cooked itself.

LaForge would be a hero, except it's his code that didn't account for the larger gear in the first place. Garbage in, catastrophic motor failure out. The team works all night to replace the motor.

"Over the Moon"

On Friday, race day, the spectators at the start/finish line are in a jocular mood. They've come to the Isle of Man to see the afternoon's Senior TT, the "real" race, in which the boys with the biggest balls race thundering liter bikes at speeds of up to 180

miles per hour. Although the fastest TTXGP bikes can hit 150 miles per hour, they can't sustain that pace for the whole course, because even the biggest, heaviest battery bombs in the field--Mission and MotoCzysz--have the energy equivalent of only about a quarter of a gallon's worth of gasoline in their tanks. The electric racers must carefully modulate their throttles to conserve energy. For the TT traditionalists, that fact makes the electric race little more than a mildly amusing morning diversion. Voices from the crowd crack jokes:

"That isn't the warm-up area anymore, then, is it?"

"No more 'Gentlemen, start your engines!' I suppose."

"They'll need some pretty long extension cords for this track."

And then, with a wave of a green flag, the electric bikes take off, not an extension cord in sight. The motors wind up, accelerating the bikes with a steadily rising whirl: mix, chop, blend, crumb, aerate--until, finally, puree. They're so quiet that some spectators camped out on the sides of the road aren't even aware the bikes are coming until they're already past.

It's a good show, especially when some of the field start blowing parts under the strain. MotoCzysz is the first casualty: two of its three air-cooled DC motors disintegrate, throwing chunks of metal through its vent holes. The machine, perhaps fittingly, comes to rest in front of one of the oldest churches on the island--St. Runius. Back at the start/finish line, Michael Czysz realizes that he's a goner when the radio announcers at the first checkpoint fail to note his bike. "That's it, that's it, it's over now," he says under his breath as the meaning of failure sinks in. One of Brammo's two hopped-up race bikes is the next casualty, victim of a bump taken at 100 miles per hour that pops the rear wheel in the air ever so slightly. Suddenly free of the earth's bite, it spins even faster, the motor's RPM skyrockets, and the overclocking sensor inside does what it was programmed to do: cut the power to protect the engine. The bike eventually gets to within one mile of the finish line before giving up the ghost completely.

The rest of the pack zooms by, chains clicking furiously, on the way to their next checkpoint, the Sulby speed trap. A privateer team from Germany, XXL, pours on the juice to ring up the race's fastest recorded top speed: 106.5 miles per hour. XXL's English-speaking engineer, Marko Werner, laughs at the grandstand crowd's stunned reaction when they hear the figure over the PA. "It was easy," Werner says. There were no all-nighters or last-minute track days for him or his team, because instead of trying to reinvent the electric wheel, XXL spent its time and money--four months and 35,000 euros--sourcing the most trouble-free components it could find: a water-cooled motor and controller designed for a 10-year-old hybrid car, the Audi A4 Duo. "Siemens did all the verk," Werner confides.

The race is not won by top speed, of course--it's the fastest average speed that counts. And Agni is first over the finish line with a lap time of 25 minutes, 53.5 seconds. A cry

goes through the grandstand crowd: "India wins!" Three minutes behind, for second place, is XXL. Brammo's good bike takes third, the only factory bike to make it to the podium. Mission comes in fourth, and MotoCzysz and the second Brammo bike are DNF: did not finish.

If the TTXGP were a battle in which the biggest war chest determined the outcome, Brammo would have won. If it were a beauty contest, MotoCzysz would have taken the tiara and the sash. If it were chess with a crash helmet, then Mission would have had it. But in the end, reliability trumped all. Agni won the TTXGP by keeping it simple. XXL and Mission both used faster but more complicated liquid-cooled AC motors. But second-place XXL chose the tried-and-true design from Audi, while fourth-place Mission went all-out with a custom-built power plant. The experience of third-place Brammo is most telling of all: its one and only breakdown came *after* it bolted on an extra battery pack at the last minute.

As the Agni, XXL, and Brammo bikes glide one-two-three into the winner's circle, a scene of barely controlled mayhem erupts: the riders are draped with laurels, and shouts of "Motoguru!" go up for Cedric Lynch, who tells the television cameras that he is "absolutely delighted" with the result. Magnums of champagne are uncorked and sprayed across the crowd. TTXGP race organizer Azhar Hussain toasts Team Agni with a speech: "Today, a new company with no budget and no baggage came and won." The Indian ambassador to the United Kingdom is on hand to give Team Agni his personal congratulations. Arvind Rabadia receives him while wearing the Indian tricolor as a superhero-style cape. "First in the qualifier, first in the second qualifier, first in the race," boasts Rabadia, the Ashoka Chakra embroidered on his flag looking for all the world like a motorcycle wheel. "I'm over the moon, man!"

Lynch sees the race differently, as he does most things. In his mind, he didn't beat the rest of the field. Rather, he led it, earning a historic victory in an epic, ongoing struggle against internal combustion. "I can just imagine," Lynch muses, "what the petrol-heads would have said if we *hadn't* beaten the 50cc lap record set in 1966 by Ralph Bryans on a Honda works bike."

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[Lab to Market Workshop \(http://www.technologyreview.com/emtech/09/workshop.aspx\)](http://www.technologyreview.com/emtech/09/workshop.aspx)

Cambridge, MA

Tuesday, September 22, 2009

<http://www.technologyreview.com/emtech/09/workshop.aspx>

<http://www.technologyreview.com/emtech/09/workshop.aspx>)

[EmTech 09 \(http://www.technologyreview.com/emtech\)](http://www.technologyreview.com/emtech)

Cambridge, MA

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[Nanotech Europe 2009 \(http://www.nanotech.net\)](http://www.nanotech.net)

Berlin, Germany

Monday, September 28, 2009 - Wednesday, September 30, 2009

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[2009 Medical Innovation Summit \(http://www.ClevelandClinic.org/innovations/summit\)](http://www.ClevelandClinic.org/innovations/summit)

Cleveland, OH

Monday, October 05, 2009 - Wednesday, October 07, 2009

<http://www.ClevelandClinic.org/innovations/summit> (<http://www.ClevelandClinic.org/innovations/summit>)

[Optimizing Innovation 2009 \(http://www.connecting-group.com/Web/EventOverview.aspx?Identificador=6\)](http://www.connecting-group.com/Web/EventOverview.aspx?Identificador=6)

New York, NY

Wednesday, October 21, 2009 - Thursday, October 22, 2009

<http://www.connecting-group.com/Web/EventOverview.aspx?Identificador=6>
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