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Prototyping is
the Shorthand of Design

Tom Kelley, *General Manager, IDEO*

Prototyping is the shorthand of *innovation*

by Tom Kelley

It was the pathway to discovering the structure of DNA. It was an early approach to understanding supersonic flight. It was the design source for Apple's first computer mouse. Taking on the role of storyteller, Tom Kelley narrates parables that joyfully share his insights on the value of prototyping. He offers many lessons that together make it abundantly clear that creative epiphanies and model building go hand in hand.[1]

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The problem seemed insurmountable. We'd designed some new goggles for snowboarders, but weren't sure if our sleeker, face-hugging style would stay fog-free in the freezing conditions found on most ski slopes. We needed to test the goggles in the wild. But it was the middle of summer in sunny California. Our client at Smith Sports Optics didn't have the time or the budget to fly us down to New Zealand, where it's winter in July.

We couldn't wait five months for winter to come around, but there was another possibility. Two blocks south of IDEO's Palo Alto offices stands a classic family-run ice cream factory. The folks at Peninsula Creamery thought us a bit crazy when we floated our wild request for a nontraditional use of their indus-

trial-size freezers, but as long as we didn't eat all the ice cream, why should they care?

Industrial design studio head Paul Bradley and a handful of team members bundled up in parkas and long johns. The exercise bike and fan (to simulate wind) were found by tapping out an e-mail (the way all sorts of unusual requests get filled at IDEO). Since nearly everyone at IDEO is a bike enthusiast, it wasn't hard finding volunteers to pedal for an hour in an ice cream freezer, as observers snapped photos of their perspiring faces and,

1. This article is an excerpt from *The Art of Innovation*, copyright 2001 by Tom Kelley, reprinted with permission of Doubleday, a division of Random House.

fortunately, not-too-foggy prototype goggles.

Prototyping is problem solving. It's a culture and a language. You can prototype just about anything—a new product or service, or a special promotion. What counts is moving the ball forward, achieving some part of your goal.

Not wasting time.

The water's rising

Prototyping is a state of mind. Think of the best moviemakers. We don't idolize them just because they strike us as glamorous players in a profession filled with beautiful people. They're also people who *get things done*. People who make movies prototype every day, just to get by. Consider the following story. Larry Shubert of IDEO worked for a few months on the set of the underwater thriller *The Abyss*. If you haven't seen it, all you need to know is that most of the movie happens beneath two thousand feet of water. That critical fact forced the *Abyss* team, led by *Titanic* director James Cameron, to seek out a gigantic body of water to film the action. A pool wouldn't do, but what about a half-finished nuclear power plant in South Carolina? The main containment vessel was a tremendous 250 feet in diameter and 50 feet deep. Cameron turned it into the world's largest freshwater tank—almost 7 million gallons. This being a film, there wasn't time to plan. There was also no time to build scaffolding, so parts of the interior set were created literally as the water poured in, with workers in rowboats furiously painting the walls as the water rose.

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That's the right metaphor. No matter your business, no matter your experience, odds are the water's rising. You don't have time, and if you don't act soon, you—or your project—will be underwater. There probably isn't time to do things the regular way—to do them by the book.

When Shubert and a couple of other IDEO folks were told they were flying to South Carolina to work on *The Abyss*, they suddenly realized they'd be working underwater and needed to be scuba-certified. One problem: The scuba course was going to take weeks. "We said,

'There just isn't enough time,'" Shubert recalls. "'We'll go through the books on our own.'" After a little negotiation, they made a deal with the scuba instructor. Shubert and the others read the books, did the dives, and passed the test—in a couple of days instead of a few weeks.

Kid stuff

Many of us first learned about prototyping as kids, doing class projects or finding ways to help pass those long summer afternoons. My brother David, for example, has been building things and then trying to make them better for as long as I can remember. We had a snowy Ohio winter the year I was six years old, and David started a series of increasingly complex snow construction projects in the backyard. He started with the basics—three-tiered snowmen—but soon progressed to whole forts by lining up snowmen shoulder-to-shoulder to form four walls.

Looking for the next revision of his prototype fort, David briefly considered a two-story model, which he—luckily for us—abandoned when he hit upon the idea of using a cardboard box to make snow "bricks." We were industriously building snow fort 2.0 with our adobe-style construction techniques when David hit upon an idea for revision 2.1: adding water to each brick so that it would freeze to a solid (and incredibly heavy) block of ice, which David hoped might help the fort last until Memorial Day.

You're probably coming to the conclusion that my brother was incredibly driven from an early age, which may be true but is not the point. With our little team, we built the mother of all snow forts that year, and we did it by building a bunch of prototypes and then figuring out how to make each one better than the one before. David's gift was his faith in the process. He knew that if he kept trying out new techniques, he'd make dramatic improvements.

I think a lot of us understood this intuitively as children and lost it gradually as we matured. David's influence has made this childlike curiosity and enthusiasm second nature at IDEO. A playful, iterative approach to problems is one of the foundations of our culture of prototyping. It can be part of your workplace too.

Build to learn

Veteran IDEO studio head Dennis Boyle approaches client meetings like mini shows. He

often says, "Never go to a meeting without a prototype," which we now jokingly refer to as Boyle's Law. In fact, Dennis often brings *several* prototypes, as well as interesting materials to spark the muse. It's part of the iterative process. "We kind of shock people by how many things we'll build sometimes," he says. When a project's just getting off the ground, client meetings may be weekly. Dennis wants to make his mistakes—and discoveries—as soon as possible. As he puts it, he looks for any opportunity to make models, sitting down with his team and saying, "OK, what are we going to build for next week and the week after and a couple of weeks out?"

There's always something that wasn't clear at the last meeting that you can clarify by offering distinct choices, such as showing how you might implement a hinge or mount a display or control a specific mechanism. When the project is especially complex, prototyping is a way of making progress when the challenges seem insurmountable. "In engineering, if you have more variables than equations, you normally have an unsolvable situation," explains Dennis. "But on the other hand, if you just take some good guesses and fill in the blanks on some of them, you'll get some answers."

Focused prototyping helps to resolve small but critical problems one by one. IDEO studio head Sean Corcorran's mantra is "build to learn." When he was working on a chair for Vecta, for example, his team reached a point at which a height adjustment lever that tilted with the chair became critical. They didn't build the whole chair. They didn't even build the whole tilt mechanism. They just built the little lever and its interface with the release mechanism. It only took a couple of hours. The finished prototype fit in Sean's hand, and it quickly demonstrated that the principle would work.

How Amazon did it

After reading about prototyping movies and goggles and snow forts, it's understandable if this process seems undefined. "All well and good," you may say, "but how does this help me if innovation isn't a daily ritual at my company? And how do I prototype a new service or business?"

Quick prototyping is about acting before you've got the answers, about taking chances—stumbling a little, but then making it right. Consider Jeff Bezos's story of the birth of Amazon.com. A business rookie, he launched one of the Internet's first multibillion-dollar behemoths, literally on the run.

Bezos's saga put wings on the Silicon Valley cliché of starting your company in a garage. His e-commerce juggernaut began with one startling statistic. In spring 1994, he happened upon a prediction that annual growth of the World Wide Web would ramp up at an astounding 2,300 percent. Inspired by the market potential of such explosive growth, he madly scratched out a list of things he could sell online—everything from music to clothing—before settling on books.

Within weeks, Bezos quit his cushy Wall Street job and called a moving van. Incredibly, he hadn't yet figured out where to cast his e-commerce seeds. His short list included Boulder, Portland, and Lake Tahoe. Unable to make up his mind, he instructed the van driver to simply head west. The next day, Bezos phoned and told the driver he'd decided on Seattle, a city with plenty of high-tech workers.

Bezos was doing exactly what innovators do every day: breaking a problem down into its parts, making on-the-fly decisions in parallel. The ordinary thing to do would have been to stay put until he had decided upon a city. How could a moving van begin its journey without knowing a state, let alone an address?

But Bezos gained a day of Internet time by launching his ship before he'd charted his New World. As his moving van rolled westward from New York on the interstate, Bezos flew to Texas and picked up a beat-up car from a family member. While his wife, MacKenzie, drove, he sat in the passenger seat, pecking out a business plan on his laptop and punching out calls on his cellular. Think of it: nothing on paper, no place to land his imagined company, yet he was already hurtling toward his destiny. He took a detour through Northern California to interview potential vice presidents of development, and he retained a Seattle attorney by phone to incorporate his online venture with the unlikely name of Cadabra. He still had no idea

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where he was going to live or how he would fund his scheme, but he had no time to waste because "when it's growing 2,300 percent a year, weeks are important."

Bezos's story would make a great movie about how rapid prototyping can give you a business edge. The dynamo entrepreneur was sorting out the pieces of the puzzle as he sailed west, trying to figure out what his Web site would do, where he'd be, who he'd hire—and what he'd call the darn thing.

Bezos could make an early blunder—like the clunky name of Cadabra—because he was carving himself out so much extra time. Once he'd rented suburban Seattle digs to house his venture in the proverbial garage, he applied the same "time is precious" logic to Amazon.com. Get it up, get it out was the order of the day. Function preceded style and editorial content. Low on graphics and animation, Amazon.com loaded fast and excelled at the basics—making it easy to find and buy books.

Good prototypes don't just communicate— they persuade

By the time the dust cleared, the bricks-and-mortar booksellers were playing catch-up. The next time you kick off a project, try sparking your engines with a little New World Amazon-style energy. Think about tackling problems when you don't have the answers. Once you get in gear, you'll be surprised how easily some of the solutions appear.

Make your luck

Prototyping doesn't just solve straightforward problems. Call it serendipity or even luck, but once you start drawing or making things, you open up new possibilities of discovery. It's the same method that has helped scientists unlock some of the greatest secrets of nature.

"I decided that no harm could come from spending a few days building backbone models," said 1962 Nobel Prize winner James Watson, referring to the metal prototypes he and fellow geneticist Francis Crick used to model and test their hypotheses. "Perhaps a week of solid fiddling with the molecular models would be necessary to make us absolutely sure we had the right answer."[2]

Although their academic colleagues were skeptical of the approach, Watson and Crick's freethinking style and openness to two-dimensional and three-dimensional prototyping helped guide them toward the momentous discovery of the structure of DNA. Even Watson sometimes wondered if he were floundering. "My doodling of the bases on paper at first got nowhere. Not until the middle of the next week, however, did a nontrivial idea emerge. It came while I was drawing the fused rings of adenine on paper."

Doodling, drawing, modeling. Sketch ideas and make things, and you're likely to encourage accidental discoveries. At the most fundamental level, what we're talking about is play, exploring borders.

Some of the bravest prototypers in the world are the people who build experimental aircraft—and the test pilots who fly them. The Bell X-1 aircraft flown by Chuck Yeager to break the sound barrier in 1947 was sometimes referred to in news stories as "a bullet with wings." What's less well known, however, is that the first prototype actually was a bullet. When you're creating something new to the world, you can't look over your shoulder to see what your competitors are doing—you have to find another source of inspiration. During development of the historic aircraft, designers at Bell examined a 50-caliber bullet flying at supersonic speed. The bullet was aerodynamically stable even as it broke the sound barrier, so Bell's engineers created a 31-foot-long fuselage in the shape of that bullet, adding some stubby wings and a powerful rocket engine. Thanks to the brave prototype testing by men like Yeager—the X-1 didn't even have an ejector seat—we gained knowledge about supersonic flight that led to the creation of production aircraft like the Concorde and modern jet fighters.

Of course, we don't pretend to be Chuck Yeager or Nobel Prize winners, and IDEO makes no claim to discovering anything remotely as important as the structure of DNA. But the process of prototyping can spark little innovations, the sort that can be the difference between a product's success and its failure.

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2. James E. Watson, *The Double Helix: A Personal Account of the Discovery of the Structure of DNA* (New York: Scribner's, 1998), p. 116.

When designing a new video game controller for Logitech, we sent drawings to IDEO's machine shop to have them knock out a prototype steering wheel, to be made of rigid ABS plastic with a black rubber coating. But the shop was completely out of black rubber, which, with a deadline looming, seemed like a potential disaster. So they molded the steering wheel out of red rubber, the only kind they could lay their hands on in time. By chance, the client loved the brightly colored wheel, and the little accident spun the product in a new direction, inspiring Logitech to introduce a line of fire-engine-red steering wheels.

Brendan Boyle, Dennis's brother, invents toys at IDEO's Skyline group and pitches them to the major toy companies. One of his more successful discoveries came while gluing together the prototype of a toy football. Brendan and his team had hatched the idea of creating a foam-rubber football with built-in tee-wings that kept the ball positioned so that you could automatically tee it up for placekicking. Charlie Brown would have loved the idea.

Brendan fashioned his first prototype the quick and dirty way. He simply took an existing football and set about gluing wings on it. But as he began applying the wings, he saw that it would be easier to follow the existing curved line of the football.

"Oh, this is kind of cool," Brendan remembers thinking, seeing that if his wings traced the curves, it would look like a propeller. He quickly "punted" on the idea of a self-teeing football. Once he started tossing balls around the office, it became clear that the curved wings had a more noble purpose—straightening wobbly throws into perfect spirals. And so the Aerobie football was born and became one of Skyline's most successful toys (figure 1).

Get into the habit of making stuff or airing trial-balloon ideas. Odds are you'll bounce your way to the insight that may inspire your next breakthrough.

Prototypes beat pictures

Prototypes aren't only about making giant discoveries like DNA or little ones like a hot-selling toy. There's also something wonderfully tangible about a prototype.

It's easy to reject a dry report or a flat drawing. But models often surprise, making it easier

Figure 1
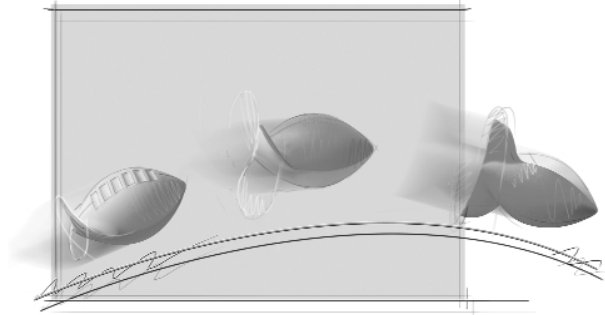
Failed prototypes opened the way to success for the Aerobie football.

to change your mind and accept new ideas—or make hard choices, such as forgoing costly and complex features. Years of experience have taught us that prototyping is also part performance. If the act isn't well orchestrated and substantial, the audience gets antsy. And executives, understandably, already have enough on their minds.

Give your management team a report, and it's likely they won't be able to make a crisp decision. But a prototype is almost like a spokesperson for a particular point of view, crystallizing the group's feedback, and keeping things moving.

We believe in that great old saying: A picture is worth a thousand words. Only, at IDEO, we've found that a good prototype is worth a thousand pictures. Somehow, you up the data rate. Give people two or three very concrete choices, create a situation in which audiences can hash out ideas, and you can run with them or show why they might not fly. Bring lots of hardware in that shows the size and shape of things, how parts fit and work together, and people will likely say, "Oh, I never thought of that."

What kind of prototype works best in different situations is itself a moving target. Good prototypes don't just communicate—they persuade. If you're developing a consumer product, you might prototype out of foam or plastic or wood. But there are many other ways to prototype. Sometimes, we quickly film what we like to think of as movie trailers, to show the highlights and essence of what a product, service, or business may become. If you're working on a project that has a service or human component, sometimes it helps to have team members—and even clients—express the project through archetypal characters in a little improvisational skit.

Living, moving prototypes can help shape your ideas.

The Palm V, from early prototypes in foam and machined aluminum to the final product with a stamped aluminum housing.

Bit by bit

All too often, we've seen how employees prepare presentations for upper management in large corporations. A group is given a few months to come up with a new product, service, or marketing campaign. More often than not, they don't solicit enough input or feedback early on—there are no incremental reviews. When the boss finally sees what they've been working on all these months, it's either a happy surprise or a total disaster. When you're starting on a new project, try getting in the mind-set of a quarterback facing a two-minute warning. Instead of the long ball, try to get a few yards, passing to the sidelines to stop the clock. Just keep the momentum going.

We pitch presentations in stages: Show the rough sketch, the cheap foam model, and use them to right the course before it's too late. As Dennis says, if you only have till next Thursday, you actually have to decide on some part of the product. You've got to cut and run and tell the shop to work up a model.

Or then again, you might buy your prototype from a dime store. Twenty years ago, IDEO veteran Jim Yurchenco bought part of a key prototype for the first Apple mouse off the discount shelves of the Walgreen's store across the street. A butter dish bought for a couple of bucks was just the right size to hold the mouse's rolling ball. That isn't to say that we didn't make dozens of subsequent prototypes. It just shows that what counts is expressing the idea quickly—and cheaply.

This isn't a concept that works only for start-ups. A few years back, Wells Fargo Bank was struggling to find the solution to a feeling we're all familiar with. If someone shadows you while you're tapping away at an ATM, you probably

get uncomfortable or even fearful, especially if you're withdrawing a couple of hundred dollars and the streets are deserted. So when IDEO took on the bank's project, we observed how people behave at ATMs and began brainstorming all kinds of ideas, including expensive add-ons like video cameras and periscopes. But it turned out that sticking a $1.80 fisheye mirror (the kind that truckers stick on their big side mirrors) above the ATM worked just fine. Sure, we could have pushed them toward more high-tech, expensive solutions. But prototyping can also remind you that the most obvious, simplest solution may be the best.

Shoot the bad ideas first

Prototyping is a dance. Sometimes, the music doesn't move you or your steps fail. But that's no reason to stop. Just as writer's block happens when writers stop writing—so, too, does innovation grind to a halt when prototypes stop being built. When the muse fails you, don't mope at your desk. Make something.

"I just prototype a bad idea and maybe shoot the hell out of it," says one of our Silicon Valley-based engineers. He'll often know it's not the solution he wants, but if he prototypes it, he can shoot it down faster and then find out what doesn't work, or perhaps discover something new. Prototypes can be a source of creation and insurance. When all else fails, prototype till you're silly.

How Apple did it

It's easy to rhapsodize on the value of modeling. But sometimes, only a real-life story can show you how the process actually works. And few products better demonstrate the importance of quick prototyping than the Apple Duo Dock. The time was the early '90s. Apple wanted to introduce a portable that could easily dock in a home base with a standard monitor and keyboard. The portable had to be small and thin, and the company initially anticipated some sort of mechanical dock, using levers they'd already seen.

It bears remembering that for decades—long before the debut of the iMac—Apple had been a leader in industrial design. In the Silicon Valley of the early eighties, the profession almost wouldn't have existed without Apple. PC clones were manufactured, not designed, and we owe a debt of gratitude to this colorful company,

which always recognized that behind every transaction was a real person.

But with the Duo Dock, Apple had the usual pressures. It's natural to be skeptical of new ideas, especially when they're likely to cost more and increase risks. We imagined that the laptop would dock mechanically, but we tried not to let that constrain our brainstorm. We were searching for a metaphor. At the time, Dennis Boyle had a three-year-old who'd already figured out how to pop a video into a VCR. If the TV was already on, it would just start up and play his cartoon. Didn't that kid-friendly experience fit perfectly into the tradition of the Mac graphical interface, the wonderful, playful simplicity that was Apple's trademark?

What if we could do something that direct— that powerful? What if you could just pop the Duo into the dock like a video—and it would sweep in effortlessly and play like a movie? Though the idea sounded promising, Apple at first was reluctant to take any chances. The company preferred a traditional mechanical eject system. The VCR approach sounded expensive, like something that might delay the launch date.

But the VCR metaphor stuck with the IDEO team. Dennis and company brainstormed again. They quickly hatched (and later patented) their key innovation, which involved combining a toy motor with a clever gear mechanism. The other option, using traditional scientific motors, was pricey—anywhere from $10 to $30. If they'd used the sort of precision motor that people expected them to use, cost alone would have killed the idea. But toy motors are dirt cheap— about $1.25—and surprisingly reliable.

Dennis gambled. He temporarily suspended work on the mechanical lever and told the team to make the dock with the toy motor. A couple of weeks later, he brought in a working model to Apple. They were so excited they took it around to everybody and got instant buy-off. Sure, it cost a little more and would take a few weeks longer. But Apple recognized that the simplicity and smoothness of the VCR-like approach would give it a competitive advantage. And more data protection. A risk with mechanical docks is that users often try to eject their computers before files or the operating system software are ready. Since the motorized approach was software-controlled, the Duo would only eject when ready.

Still, there were problems to solve. Early models spat the Duo out so forcefully that the expensive laptop appeared precariously close to crashing to the ground. We added an oil-filled damper to soften the movement. More than a dozen different prototypes were made. Early models were fashioned of particleboard and ABS plastic, the testing levers, and the toy motor mechanism. They were often cobbled together in an afternoon.

The working prototype itself became a celebrity, like a popular exhibit at a science fair. These were the days when Apple CEO John Sculley would stroll through Apple's labs to get a firsthand look at the latest projects. This particular day, he was supposed to review five projects in about half an hour, but once he spied the Duo Dock prototype, he didn't budge. The other projects had static charts or simulated things on screen. The Duo Dock was entertaining. You could open it up and see its clever mechanisms working away. Sculley wanted to know all about it.

Apple ordered a couple dozen copies of the next prototype so that it could demonstrate the concept to customers and partners before the real ones rolled out of the factory. In the few weeks before the new prototypes arrived, the original became so popular that it required its own conference room. You had to schedule a meeting if you wanted to see the prototype. The Duo Dock earned great reviews, but we're equally proud of how cheaply Apple was able to manufacture the innovation. Fear of added expenses nip countless innovations in the bud. But the toy-motor–powered mechanism embodying the VCR approach required less than $7 in parts—roughly comparable to the cost of some purely mechanical solutions.

To me, the Duo Dock is a classic case study of why an iterative approach works. Prototype with energy and enthusiasm, and you've got a good chance of hitting upon the very feature or product that resonates with your customer.

> *Prototype with energy and enthusiasm, and you've got a good chance of hitting upon the very feature or product that resonates with your customer*

Forget Congress

Okay, so maybe you don't make products and are having a hard time seeing the value of prototyping for your business or service. You don't believe the shoe fits for every industry. What about a national park? If the federal government can prototype on the fly, isn't that a good sign that even the most daunting bureaucratic obstacles are no excuse, that with the right energy and ideas, anyone can innovate?

In 1997, the Golden Gate National Recreational Area was struggling like a geriatric multinational corporation, unsure of its identity and future. A patchwork of roughly two dozen sites strewn along 70 miles of rugged Northern California coastline, the parks lacked funding and volunteers, and—despite crown jewels like Muir Woods and Alcatraz—many of its riches were barely known to the public.

Board member Mickey Drexler, chairman of the Gap, knew they had a problem. Nobody, not even fellow board member and advertising guru Rich Silverstein, knew exactly what the GGNRA was—or what it was selling. "We can't even define it ourselves," Drexler declared during a key powwow. "We can't even put it on a T-shirt."

The t-shirt idea set Silverstein (famed for his celebrity-studded Got Milk? campaign) to thinking. He brainstormed with his partner, Jeff Goodby. They quickly recognized that the recreational area's run-on name stank. Why not just change it? Well, for one thing, that kind of change requires an act of Congress.

Unless you break the rules. So they hatched the Golden Gate National Parks, earned the ire of federal bureaucrats, and forged ahead.

Following the Gap chairman's logic, they hired the gifted illustrator Michael Schwab, who created the marvelously simple brand look for the first of many icons—a sweeping image of the Golden Gate Bridge and the parklands on either side (never mind that the bridge itself technically wasn't part of the park). The icons were so hot that when they premiered in bus shelters, people actually stole them, and a barrage of phone calls from consumers made clear that plenty of others were dying to buy them. Thereafter, the name—and numerous classic images—went forth and multiplied on T-shirts, sweatshirts, coffee mugs, and calendars. In just two years, the park raised $26 million in charitable contributions, launched a couple of profitable retail stores (you've gotta like a federal agency that invents profit centers), and recruited 15,000 new volunteers, helping to put the shine back on a national treasure.

The entrepreneurial, rule-bucking Golden Gate National Parks are now the poster child of the national park service, and the same bureaucrats who bemoaned its shoot-from-the-hip style now come to study the masters, treating the park like a living Harvard Business School case study. The best irony of all is that if they'd waited for Congress, they wouldn't have gotten past Go. The feds still consider the original, cumbersome "Golden Gate National Recreation Area" the official and legal name.

They can keep it. ■   *Reprint#01123KEL35*

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