BRAIN POWER WORKOUT: BUILD MENTAL ABS OF STEEL!

POPULAR science

WHAT'S NEW REAL VIDEO FROM DIGITAL STILL CAMERAS, P. 16

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FEBRUARY 2004 VOLUME 264 #2

"High on DARPA's wish list: mind-controlled battle robots, and airplanes that can be flown with nothing more than thought."
MIND OVER MACHINE p. 48


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ON THE COVER: JOHN B. CARNETT; SHADOW DEXTEROUS ROBOT HAND COURTESY THE SALLY AND RICHARD GREENHILL PHOTO LIBRARY; INSET PHOTOGRAPH, CHARLES MASTERS. THIS PAGE, CLOCKWISE FROM TOP LEFT: BRIAN FINKE; JOHN RETTIE; LUIS BRUNO; DAVID BARRY; COURTESY LOCKHEED MARTIN, BACKGROUND IMAGES COURTESY EARTH SCIENCES AND IMAGES ANALYSIS LABORATORY, NASA JOHNSON SPACE CENTER; HUGH KRETSCHMER; BRENT HUMPHREYS; JOHN CLIETT, DIA ART FOUNDATION.

Mental Abs of Steel: Got 'Em?

MCKENZIE FUNK'S FEATURE IN THIS ISSUE, "MENTAL MUSCLES of Steel," is an homage to all those muscle-building regimens found in men's magazines: the washboard-abs, lats-of-iron, pecs-of-stone workouts designed to make a man more mighty than he already is. Evidently, the thighs-of-titanium, glutes-of-depleted-uranium research is always turning up new breakthroughs, because fresh routines are published every month to considerable hoo-ha.

But is it possible to exercise the *brain*, beyond the workout it already gets as the mainframe and server for body and mind? Does sitting in traffic and meetings, watching TV, and processing hamburgers not already keep the IQ organ in peak shape? Funk's research says more can be done, and his piece offers intriguing tips and exercises, both mental and physical (*you* try brushing your teeth with the wrong hand for a week: not easy).

I especially like the section on fine-tuning the mind as a b.s. detector for arguments about science. Beware, he says, the mushy use of terms like "paradigm shift" and "theory." Our own letters department frequently observes "theory" deployed as a term of disparagement by people who oppose absolutely the ideas and evidence used in the construct of complex explanations. The word serves to cut an argument off at the legs, not enrich it: "That's just a theory. It's not proven." As if the state of being unproven is not the precondition for a theory to be, well, a theory. Of course one shouldn't cite theory as absolute fact. But neither should one dismiss well-established theory for not being fact—that's like ridiculing a very fit set of biceps for not being steel: a mark of conceptual flabbiness, and likely to get you roughed up if you're in a tough bar in a nerdy part of town.

The brain's function, rather than its fitness, is the subject of another feature in this issue, "Mind over Machine," by Carl Zimmer. The prospect that scientists will be able to use brain signals to operate machines—indeed, they have already made significant progress toward doing this—is hugely important. Imagine a prosthetic arm directed by the thoughts of a quadriplegic. Although spinal-cord regeneration may be the long-term vision of those who seek to restore body function to the terribly injured, the ability to forge a man-machine connection would open new worlds of experience to both the injured and the well. Science isn't stranger than science fiction, but in areas such as this it is altogether more marvelous.

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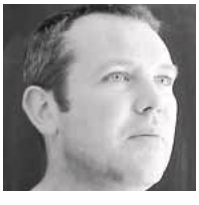
Never let it be said that CONSTANCE ADAMS shies away from a challenge, whether it be moving to Japan without speaking the language, dealing with a dodgy landlord in Berlin ("I swear he was a Bulgarian weapons trader"), or trying to parse the lingo of NASA bureaucrats. We asked Adams, a space architect who has worked on several NASA projects, to suggest how the agency might remake itself to regain its footing in the wake of the Columbia fiasco.

After working on large-scale urban design projects in Japan and Germany, including the area along Berlin's famed Friedrichstrasse, Adams moved to Houston in 1997 to work at the Johnson Space Center. Her assignment: help design the TransHab, an inflatable module that would serve as living quarters for astronauts during a long voyage, such as one to Mars. Initially Adams was stunned to find that the talented engineers who were her collaborators had never given much thought to the physical or mental discomforts that might be endured by space travelers. Over time, though, a healthy dialogue led to mutual respect—and to a better product than either architects or engineers could have created in isolation. "There are no good guys and bad guys in this field," she says. "We're all trying to get to Mars."

CARL ZIMMER has brains on his mind. Monkey brains. Human brains. In "Mind over Machine" [page 46], he writes about a research effort in which monkeys are learning to control robotic arms with their thoughts. "What struck me most about brain-machine interface research," says Zimmer, "is that in the past, people were speaking hypothetically: *If, if, if.* Now the tone has shifted to *when.*"



"I'm interested in the interpretation of symbols by different cultures—like half-remembered British symbols that turn up in African art," says **BRIAN CAIRNS**, an illustrator based in Glasgow, Scotland, whose work accompanies Zimmer's feature story. "In the new age of the machine, the [cursor] arrow is a powerful symbol." Cairns's illustrations have also appeared in *The Atlantic Monthly* and *Mother Jones*.

The surreal images, such as the unnerving torso-face hybrid on page 66, that photographer **HUGH KRETSCHMER** created for "Mental Muscles of Steel," our brain-building regimen, are the photographic equivalent of Magritte paintings. He spent 14 hours on the photography alone. "The lighting, skin tones had to be exactly the same," says Kretschmer, whose work has appeared in *Vanity Fair* and *GQ*.

While **McKENZIE FUNK** was bulking up on science to write "Mental Muscles of Steel" [page 56] he found plenty to raise his skeptic's ire, including undue claims to "revolutionary" research. But Funk, a contributing editor at *National Geographic Adventure*, couldn't get too smug: He realized he'd believed some doozies, like that a penny dropped from the Empire State Building would kill a person below.

FROM "ANOMALY=DISASTER" TO "ZEBRAFISH"

Your guide to this month's POPSCI

CONSTANCE ADAMS PHOTOGRAPHED BY BRENT HUMPHREYS

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Best of the Best Ofs

I'm a regular subscriber to POPULAR SCIENCE, and I'd say the December Best of What's New issue is your best yet. The great innovations you showed convince me that now is truly the golden age of engineering—an era in which laser systems guide cars, the Internet is accessed wirelessly, and entire music collections fit into minuscule MP3 players. I'm currently studying to be an electrical engineer; your magazine motivates me to work harder and go further into the ever expanding field that I love.

Bill Stubler
Webster, N.Y.

I just finished reading your excellent Best of What's New issue. In the engineering section you gave the Grand Award to the Shanghai Transrapid, built, you said, by the Chinese. The Chinese did build the track from downtown Shanghai to Pudong Airport; however, the Transrapid maglev was designed, developed, built, and tested by the German consortium of Siemens & Thyssen. The testing alone, at the Transrapid Test Facility in northwestern Germany, took almost 25 years. The Shanghai maglev was transported by a heavy-lift ship from Hamburg, Germany, to Shanghai Harbor and was installed under the supervision of Siemens & Thyssen engineers and technicians. From your article your readers might incorrectly get the impression that the Chinese invented the Transrapid.

I rode the Transrapid myself in Germany at the Hanover World's Fair in 2000. Totally awesome. No sound. Just a swoosh . . .
Hoke Mueller
Montreal, Quebec, Canada

What's New editor Scott Alexander responds: You are correct. The Shanghai Transrapid uses German-developed technology. The Chinese, however, were the first to put it into commercial use (and foot the bill for same). We felt they deserved credit for making that kind of commitment to a technology we've been waiting for decades to see in everyday use.

Making Burt Rutan's Tier One the Best of What's New Grand Award winner ["Best of Space and Aviation," Dec. '03] was a great decision. Rutan is going to succeed at building the first private spaceship, just as he has succeeded with every other of his aeronautical enterprises. Please, God, after he launches this vessel, let there be a billionaire out there who will fund him to build a private manned orbital spaceship. Many of us space enthusiasts are sick of NASA spending huge amounts of money to bore 200-mile orbits around the Earth.
Roger Brannon
Austin, Texas

Your article on Tier One says that at a height of 60 miles the craft would be in "the realm of zero gravity." Actually, the force of gravity at this height above the Earth is only slightly less than it is at the surface. If you were able to stand on the top of a structure that extended to 60 miles high, you wouldn't notice much change in your weight. Your author appears to have mixed up the concepts of zero-gravity weightlessness and apparent weightlessness due to free fall.
Sandra Kayser
Austin, Texas

Aviation editor Eric Adams responds: Ms. Kayser is absolutely right. Though the terms "weightlessness" and "zero

(LETTERS, CONTINUED) ▶

CORRECTION

The photo of the *Nimitz*-class carrier on page 95 in the December '03 issue was courtesy Jeffrey G. Katz/ Northrop Grumman Newport News.

POPULAR science

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gravity" are often used interchangeably in the shorthand of space travel, the distinction is nevertheless critical.

The Nanny-Car Diaries

Bless Stephan Wilkinson for affirming my pent-up frustration over how each new car I buy takes more authority over me ["Warning! Here Comes the Nanny-Car," Man & Machine, Dec. '03]. I've had this wacky idea that I'm supposed to be the one in charge and doing the thinking. Manufacturers, however (no doubt driven by their liability lawyers), are putting me more and more into a position of being dictated to, and I don't like it! Being babysat behind the wheel brings a whole new meaning to "My Mother the Car"—or should we say "Big Brother the Car."
Ron Taylor
Black Diamond, Wash.

Thank you for your marvelous article on nanny-cars. I've wondered how far you could get if you introduced a genuinely low-tech line of products, designed to perform their function and stay out of your way. Don't test my water for chemicals, just brew my coffee!
Dave Oatley
Canal Winchester, Ohio

I respect your article on bossy automotive technology but question its focus. Do trivial convenience features such as rain-sensing wipers and timed headlights deserve so much criticism? I have faith in Mr. Wilkinson's ability to evaluate the quality of his different bells and whistles; however, did he consider testing the features on various makes and models before poking fun? I was amused, but as the proud owner of a reasonably priced C-Class Benz, I will vigorously defend the functionality of all its convenience and safety equipment.

But, hey, I'm a Jersey driver—what do I know?
Jason G. LaCorte
Cherry Hill, N.J.

Yes, Nuke the Sun

I don't think the idea of sending our nuclear waste into the sun should be dismissed so quickly ["The Bad Things That Would Happen If We Launched Nuclear Waste into the Sun," FYI, Dec. '03]. I agree with the author's assessment of the problems that may occur with rockets during transport, but that doesn't mean these problems will persist. Advances in rocket tech will continue as they have for several decades. What's the alternative to getting nuclear waste off the planet? Burying it under a mountain in Nevada and "hoping" that no one will disturb it for several thousand years?
Nathan Reggish
Plano, Texas

_FROM THE BLOGS

Last month, over 300 Web logs linked to *popsci.com*. A sample:

PopSci 2003 Best of What's New_
Really nice 2003 Best of What's New list. Exceedingly cool, with something novel for everyone, something clever for everyone, and at least one product that every type of reader will want. Seriously, this is the broadest and best list of cool stuff that I have seen in many years.
posted by Bill Cockayne, Future Now
blogger.ifff.org/future

Best of General Innovation: Discovery Kids Ultimate Labs DNA Explorer_
All right, I'm officially scared. Talented kids can now discover who their daddy is in the privacy of their own bedroom. When I'm older, my kids will be splicing a firefly and a goldfish or cloning the cat while I tootle away on my computer.
posted by CodePoet, Code Poetry
codepoetry.net

I'd suggest keeping your junior Einstein away from small pets and younger siblings.
posted by Jodi Red Wolf, Opinions of the Wolf
redwolf.com.au/column/opinion

Überpainfully awesome DNA Explorer kit. So cool it hurts. *lust*lust*lust*
posted by Angyl Bender, Flug auf dem Glücksdrachen
livejournal.com/users/being_angyl

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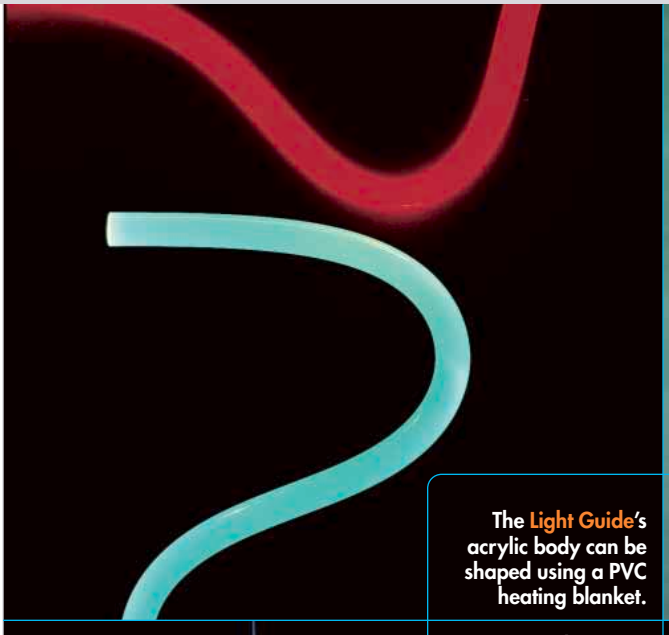
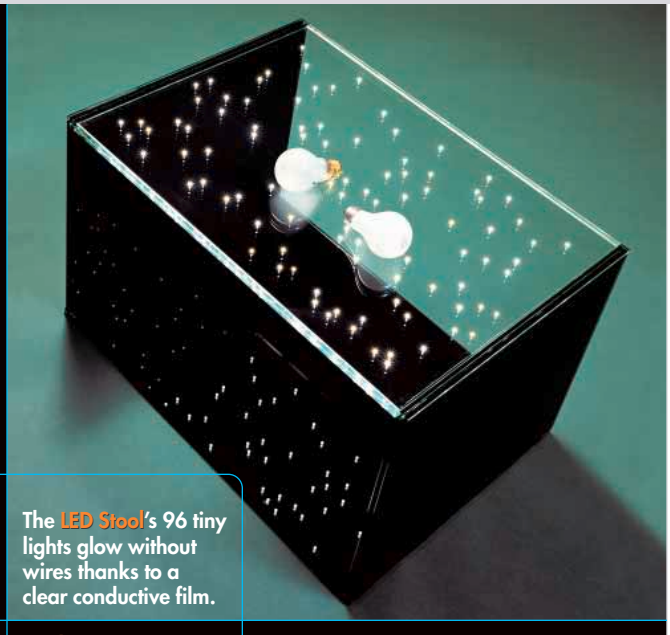
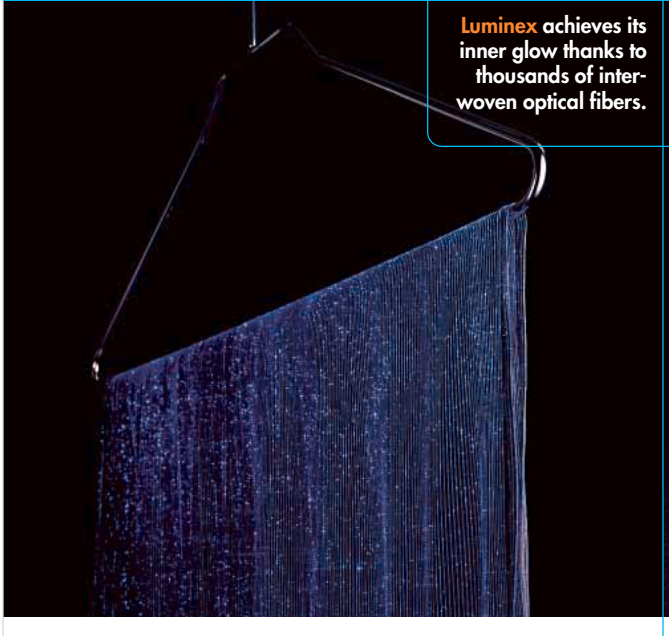
What's New



The Light Guide's acrylic body can be shaped using a PVC heating blanket.



The LED Stool's 96 tiny lights glow without wires thanks to a clear conductive film.



Luminex achieves its inner glow thanks to thousands of interwoven optical fibers.

EL Phenomenon provides enough light to read a map or signal your presence.

BREAKING THE BULB

NEW TECH TAKES LIGHT NEW PLACES.

The traditional globe-and-filament bulb turns 150 this year. Not a bad run for a device invented in the horse-and-buggy days. But new material and conduction technologies are set to break lighting out of the bulb, weaving and embedding illumination right into everyday objects, art, even clothing. Here's to a future that emits more light than heat. —ELIZABETH SVOBODA

STRONGER NEON Luxaura's shapable and tough Light Guide offers neon effects in a solid-acrylic LED-powered light conductor. $30 for a 21-inch length; *luxaura.com*

FREE YOUR LIGHTS Durable, low-heat LEDs can be embedded in objects using a clear conductive film, as in Ingo Maurer's LED Stool (which is actually more of an end table). $4,600; *ingo-maurer.com*

SAFETY MATERIALS Flexible electroluminescent panels on Marmot's EL Phenomenon jacket prototype glow on command. Not yet for sale.

FIBER OPTICS The sparkle in this Luminex fabric comes from woven optical fibers illuminated by LEDs. $330 per yard; *luminex.it*

JACKET AND SCARF STYLING BY KIRSTY MOGENSEN

PHOTOGRAPHS BY LUIS BRUNO

Now Still Cameras Shoot Real Video

Full-motion video comes to the compact digicam.

Until now, digital still cameras have produced shoddy video (with only 240 lines of resolution and 15 frames per second). Now, thanks to faster and cheaper chips, digital shooters are starting to boast VGA full-motion video (that is, 480 lines of resolution at 30 fps). You won't get DVD-quality video out of these units—most lack image stabilization, lights and the ability to zoom, and all use MPEG-4 compression, which degrades images somewhat—but the quality is very respectable, and the ability to shoot an hour of video on a 1GB flash memory card is not to be underestimated. Dedicated camcorders offer better quality, but if you want a single device for stills and video, these new hybrids' balancing act will definitely impress. —SUZANNE KANTRA KIRSCHNER

▼ **THEN** [320x240]

▼ **NOW** [640x480]

1. THE ONE-HAND SHOOTER

FISHER FVD-C1 CAMERACORDER

The most versatile (and most expensive) pocketable imager in the group, the FVD-C1 combines a 3.2MP digital camera and VGA recorder in a comfortable pistol-grip housing that feels more like a camcorder than a camera (though it comes with an impressive 5.8x optical zoom lens for stills). $900; *fisherav.com*

2. THE SERIOUS IMAGER

FUJIFILM FINEPIX S7000

Perhaps assuming that someone who cares about top-quality stills is likely to be equally picky about video quality, manufacturers have shied away from putting video on their high-end digital cameras. The S7000, however, offers great stills (thanks to a 6.3MP sensor and 6x optical zoom lens) and strong video capability. $800; *fujifilm.com*

3. THE FASHION ACCESSORY

PANASONIC SV-AV50

The SV-AV50's deck-of-cards size belies the powerful video recorder hidden inside. In fact, small hands are a bonus when getting a grip on this model. Bear in mind, though, that its diminutive size comes at the expense of still-picture quality—its 2MP stills are barely acceptable these days. Style-wise, however, it's one of the sexiest we've seen. $400; *panasonic.com*

4. THE NO-BRAINER

KODAK EASYSHARE LS743

A 4MP sensor, Schneider lens and trademark Kodak ease of use make the LS743 a great all-around camera. Throw in this model's high-quality video as a bonus, along with a very reasonable price, and it's quite the compelling package. $400; *kodak.com*

FROM TOP: HYLAH HILL (2); CHARLES MASTERS

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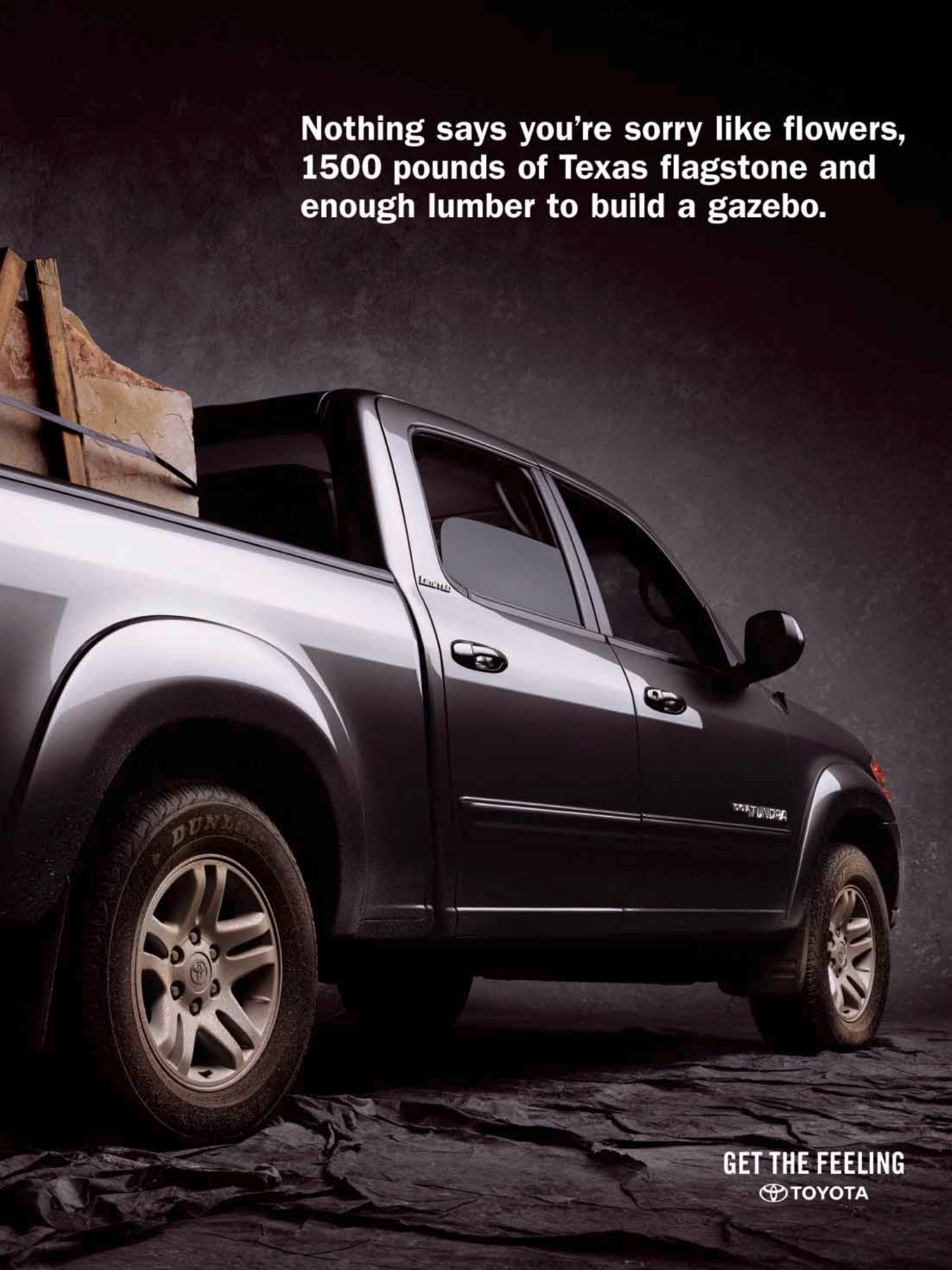
toyota.com 2004 Tundra Double Cab Limited 4x4 shown with available equipment. *43.88 cu.ft. for 2004 Tundra Double Cab 4x2 and 4x4 vs. 43.42 cu.ft. for Ford F-150 SuperCrew 4x2 and 4x4. Comparison data from ford.com 12/10/03. 38.66 cu.ft. for Chevrolet Crew Cab 1500 4x2 and 4x4 based on manufacturer's press release 7/1/03. **1,875 lbs. for Tundra Double Cab SR5 4x2 4.7-liter V8. Including the weight of occupants, available equipment and cargo; limited weight distribution.


Nothing says you're sorry like flowers, 1500 pounds of Texas flagstone and enough lumber to build a gazebo.
TUNDRA
GET THE FEELING
TOYOTA

A DARK AND STORMY DRIVE, 2025

THERE ARE LIMITS TO HOW CAREFUL YOU CAN MAKE A DRIVER, BUT WITH CARS WE'VE ONLY JUST BEGUN.

There are two approaches to making safer cars: The brain approach and the brawn approach. In the case of collisions, the evolution toward ever brawnier vehicles has made driving safer for the people who drive these monsters—and more dangerous for everyone else. The best way to save all the lives in an accident is to prevent it from happening in the first place. In recent years safety-smart technology (such as traction-control systems and the like) has evolved to enable drivers to better control their cars; now the focus is on systems that will allow vehicles to take control when drivers fail to do so. In the coming years expect to see a long list of integrated active cruise control systems, vision aids and collision avoidance sensors. Here those systems combine as Joe Commuter takes a drive in 2025. —DAN LIENERT

1 **Tired after a long day, Joe begins to nod off soon after hitting the cruise control. His car's alertness monitor beeps him awake, only to have him execute an ill-advised swerve as he exits the freeway.**

Active cruise control systems, which use traditional or laser-based radar to detect your distance from the car in front of you, then adjust the throttle and brakes to keep you from hitting that car, are now available on a variety of luxury models. Nissan also offers a **lane-keep system** in Japan, which detects lane dividers and keeps the car on track. Many other companies are researching along similar lines.

BMW and Mercedes are working on ways to **gauge alertness** by monitoring metrics such as the driver's blink frequency, pupil dilation, and how much he looks around. An infrared camera mounted just above the windshield determines whether the driver is falling asleep at the wheel, and sounds an alarm as necessary.

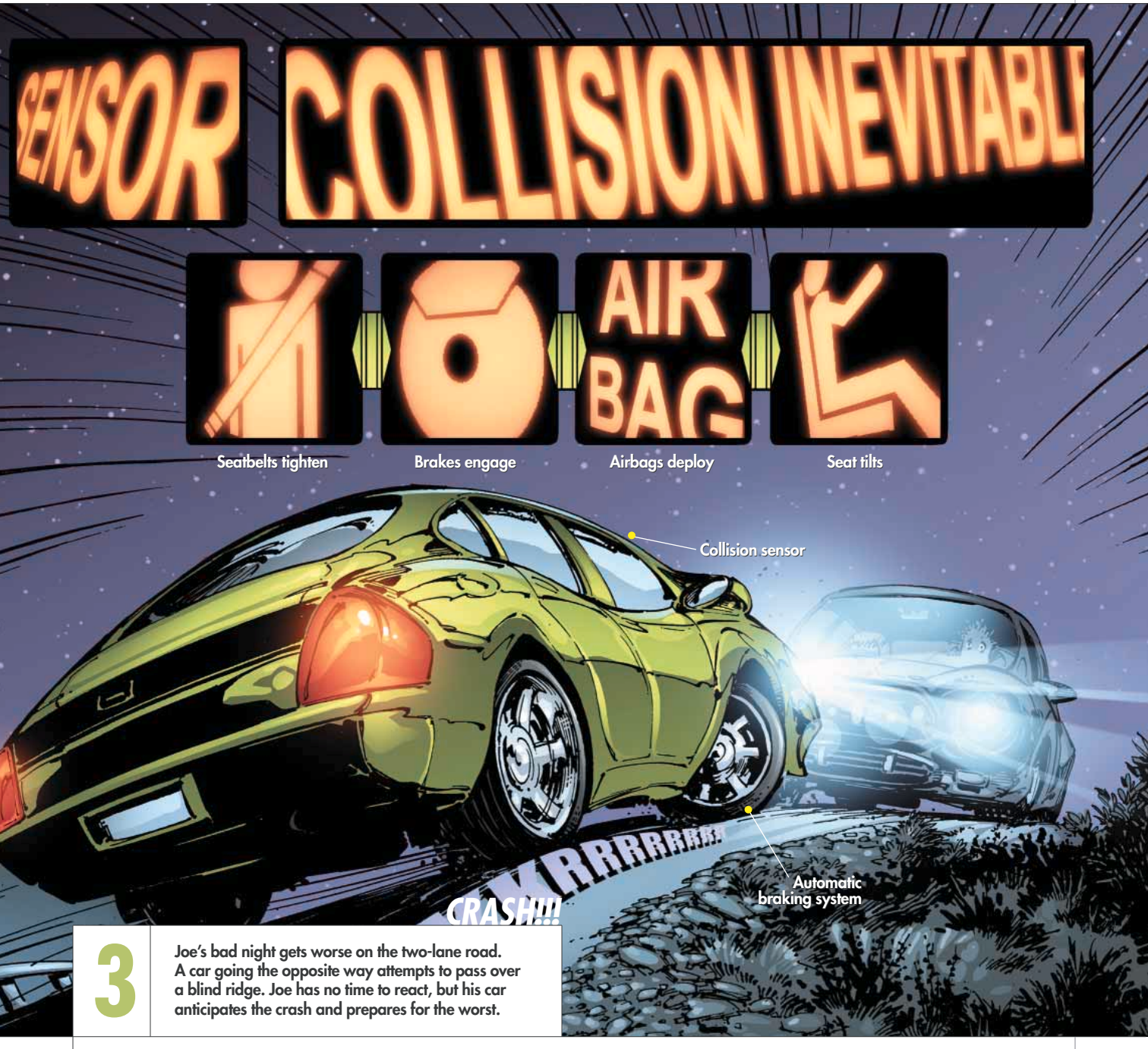
Valeo Raytheon is working on a **blind-spot detection system** that emits radar beams from each side of the car, and uses them to detect when another vehicle is in your car's blind spots. When a vehicle is in a blind spot, a small red light on the side-view mirror on that side of the car lights up, letting the driver know that there is something there. Look for systems like this to be on the market by 2006.

2 **After his near miss, Joe pulls off to grab a coffee, but the dark side road is just as perilous. While his night vision and adaptive headlights help, only his accident avoidance sensor prevents him from hitting a deer.**

Adaptive headlights increase visibility by aiming into turns, which illuminates more of the road. They were first available in the Lexus RX 330 in the spring of 2003. BMW also offers adaptive headlights in their 2004-model 5- and 7-Series sedans.

Head-up night-vision systems act like infrared headlights: A **laser** shoots a beam of invisible infrared light from the grill. As it reflects, it is captured and projected visibly onto the car's windshield. Cadillac introduced this feature as an option on its 2000 DeVille.

The most promising upcoming devices are automated collision warning sensors. The systems, under development by a variety of manufacturers, including the Big Three, use an **accident avoidance camera** and radar to detect and track "potential collision partners"—that is, things you're well on your way to hitting. The hardest task for these devices is classifying objects—for example, determining if that thing rolling across the road is a harmless plastic bag or a kid on a skateboard. Once your car identifies that you're on track to hit something better avoided, the next step is to stop you from doing it. Motorola, in partnership with DaimlerChrysler, is integrating these systems with automatic braking. "Once we gain confidence in these, we'll stop the car before it bumps into something," says Don Remboski, director of the Motorola Automotive Innovations Center.

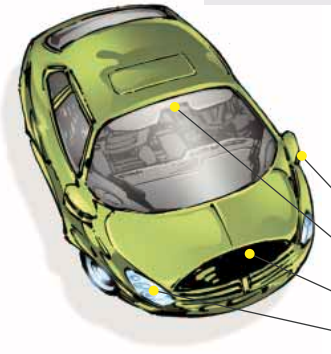


3 **Joe's bad night gets worse on the two-lane road. A car going the opposite way attempts to pass over a blind ridge. Joe has no time to react, but his car anticipates the crash and prepares for the worst.**

Most safety systems available now and in the near term avoid taking control of the car—unless it's already too late to avoid a crash. For years Mercedes has featured a rollover sensor and pop-up roll bar in its SL-Class convertibles. In 2003 it introduced the Pre-Safe system in S-Class Sedans, which **tightens seatbelts** and **adjusts the passenger seat** to an optimum safety position (backrest raised, seat bottom lowered and moved rearward) when it **senses a crash is imminent**.

Other systems under development from Honda, BMW, Toyota and others use a combination of data both from the vehicle itself (for example, the stability control system may sense if understeer is uncontrollable) and from radar-based systems in the grill. Just before a crash, the car will cut the fuel pumps, adjust the seats and seat belts, and **hit the brakes**. Honda's system is available on the Japan-only Inspire, and Toyota's should be introduced in the U.S. within the next model year.

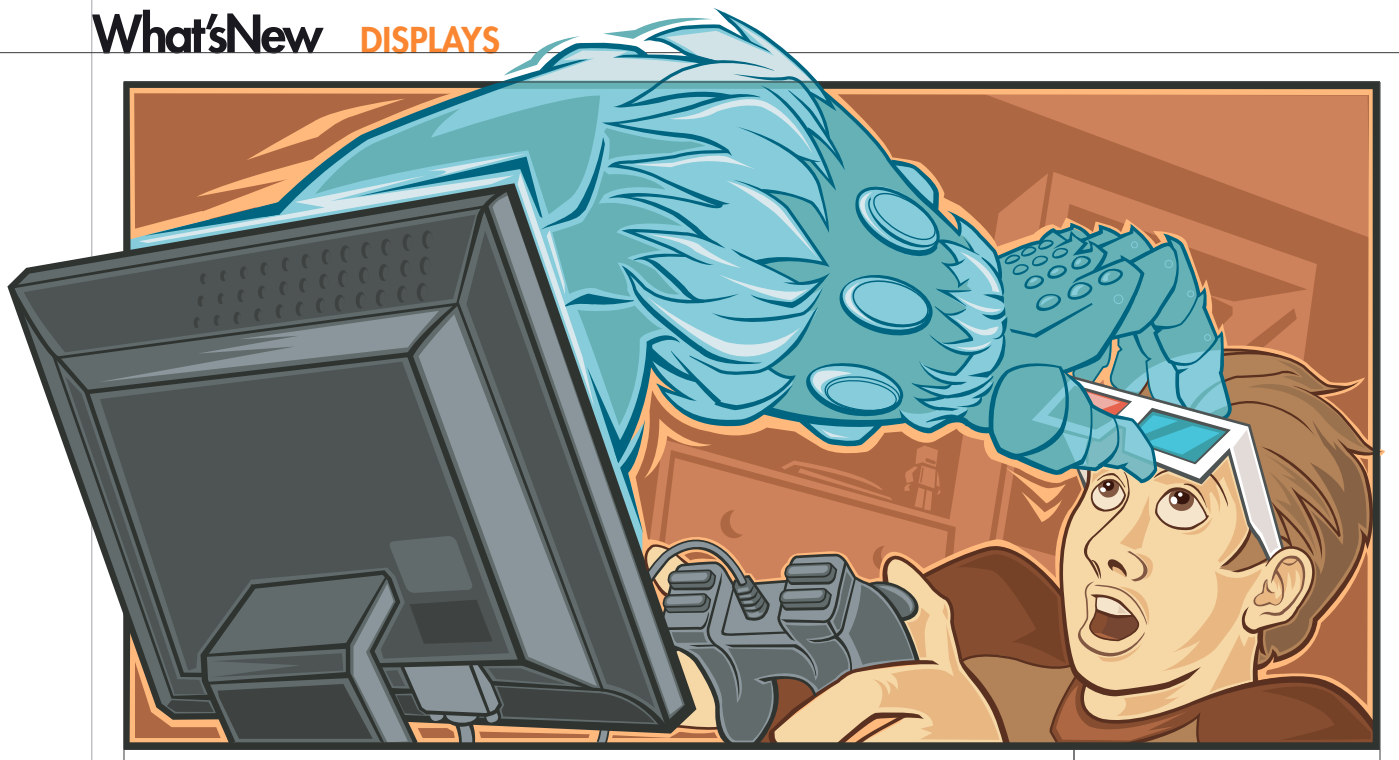
THE ALL-SEEING CAR



For the most part, active safety systems will remain invisible—to both driver and onlooker. But a close eye will be able to spot the myriad sensors in upcoming designs.

- BLIND-SPOT RADAR
- INFRARED CAMERAS
- LASER RANGE FINDER
- ADAPTIVE HEADLIGHTS

ILLUSTRATIONS BY GREG CAPULLO, TODD MCFARLANE & JAY FOTOS



Into the 3rd Dimension

Display innovations make 3-D imaging a reality. No glasses required.

3-D technology has traveled a long and sometimes ugly road. In recent years, red-and-blue glasses and bulky LCD headsets made moving images pop off the screen, but fashion-wise landed somewhere short of fabulous. The Holy Grail has always been true 3-D without extra eyewear, and now several companies are bringing headgear-free 3-D displays to market, for applications ranging from gaming to medical imaging to battlefield simulations. Here's a look at the leading contenders in the race to get us out of flatland. —SUZANNE KANTRA KIRSCHNER

	SHARP ACTIUS RD3D NOTEBOOK	IO_2 TECHNOLOGY HELIODISPLAY	PERSPECTA SPATIAL 3D SYSTEM
STAGE OF DEVELOPMENT	**Available now**	**Prototypes available**	**Available now**
PRICE	$3,000	$22,500	$40,000
WHAT IT LOOKS LIKE	**3-D pictures appear to float in front of or inside this laptop's 15-inch flat-panel display.**	**A 3-D image, from 5 to 150 inches diagonally, seems to float in midair above a projection box.**	**3-D models, up to 10 inches in diameter, enclosed in a glass dome.**
HOW IT WORKS	A switching LCD attached to a normal LCD panel creates a barrier that controls the direction of each pixel's light, aiming it at one eye or the other. 3ality is working on a similar solution that can be applied to CRT monitors.	Heliodisplay agitates air to create a surface upon which it can project a 2-D image. Since the image does not appear on a physical object, the eye interprets it as a 3-D image (although it has only a single viewable side).	One hundred ninety-eight layers of 2-D images are projected onto a rotating screen at 5,940 frames per second to create depth. The viewer's eye merges the 100 million data points into a 3-D image that can be viewed from all sides.
WHAT IT'S USED FOR	**Videos, games, molecular modeling, computer-aided design. The technology has been sighted on PDAs in Asia.**	**Not yet in products but will likely be seen in both home-entertainment and teleconferencing devices.**	**Medical imaging, air traffic control, battlefield visualization. You can even see plays performed inside it.**

BRIEF HISTORY OF 3-D

- ***1838:*** Charles Wheatstone invents the stereoscope. The device uses two slightly different drawings to create the illusion of three dimensions.
- ***1858:*** Joseph D'Almeida creates the anaglyphic process, which uses red and blue lenses to make 3-D images.
- ***1859:*** Mass-marketed handheld stereoscopes become a national obsession. Viewers sell for $1. Pictures for 10 cents.
- ***1922:*** The first anaglyphic feature film, *The Power of Love*, debuts, using two projectors to create the effect.
- ***1939:*** The View-Master, a souped-up stereoscope, goes on sale, featuring seven 3-D images on a single disc.
- ***1947:*** Hungarian scientist Dennis Gabor develops holography.
- ***1952:*** A single-projector anaglyphic film, *Bwana Devil*, premieres, sparking a new 3-D film craze.
- ***1953:*** Three Dimension Comics No. 1, the first 3-D comic book, hits newsstands, starring Mighty Mouse.
- ***1960:*** The laser is invented, allowing scientists to create far better holographic images.
- ***1983:*** Mastercard is the first to put a hologram on a credit card.
- ***1986:*** *Captain Eo*, one of the first films to use LCD shutter glasses to create stunning, true-color 3-D, debuts at Epcot Center in Orlando, Florida.

JOSHUA ELLINGSON

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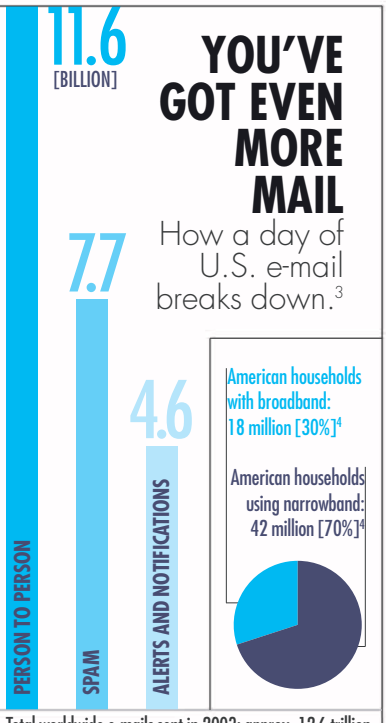
STATS
Numbers that count.

10%
of the world's population is on the Internet.[1]

65%
of Americans are on the Internet.[2]

YOU'VE GOT EVEN MORE MAIL
How a day of U.S. e-mail breaks down.[3]



American households with broadband: 18 million [30%][4]

American households using narrowband: 42 million [70%][4]

Total worldwide e-mails sent in 2003: approx. 12.6 trillion

Nokia 3650

TV TO GO. KINDA.
Streaming video makes an underwhelming debut on cellphones.

For the true info-junkie or sports nut, no screen is too small for getting caught up on the news or watching highlights of the game. But while diehards might put up with the new video services available on select Sprint PCS and AT&T Wireless cellphones, for the rest of us it's really a stretch to even call them video.

Although AT&T's RealOne performed best in our tests, it served up only four to seven frames per second (full-motion video is 24 fps). The resulting footage is painfully jerky, with sound akin to crackly AM radio. Sprint's MobiTV delivered just one frame per second (as did Sprint's RealOne service), playing like a slide show with FM-quality audio.

Viewing programming from the Learning Channel or Toon-World TV Classics at such low frame rates may be masochistic, but MobiTV's and RealOne's decent audio quality redeem them for news and sports, with clips available from CNN, MSNBC, FOX Sports, and more. However, it would have been nice to be able to recommend these TV services with higher praise than "they work well as radios."—SUZANNE KANTRA KIRSCHNER

FIRE-RESISTANT GERM FIGHTER
A California couple build their safe house.

Wildfires came within a mile of Madeleine Landry's Simi Valley, California, home last October, but she and her husband, Ed, weren't budging. "When I asked the firefighters what to do if the fire came closer, they said, 'Go inside, close the windows and doors, and let it go by,'" she recalls. Unconventional advice, perhaps, but then again, this is not just any house. The Landrys' 11,000-square-foot homestead is equipped with vacuum-sealed doors, a steel frame, and an exterior clad only with steel and concrete—that is, it can survive the odd brush with fire.

The home protects against more than just heat. In an effort to reduce the need for cleaning chemicals (Madeline became extra-sensitive to them after the Landrys' previous home was treated for termites), the steel used for the home's touch surfaces—doorknobs, handrails, refrigerators—is coated with an antimicrobial compound, called AgION, intended to inhibit mold, mildew, bacteria and yeast. Silver ions in the compound kill microbes by disrupting their respiration.

The coating also does something else well: It masks the fingerprints that are usually so visible on stainless steel, a quality that may get it into stores sooner rather than later. Take a full, multimedia tour of the house at *akconcepthome.com*.
—CHARLES WARDELL

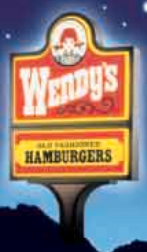
NEED YOUR HD FIX?
A new satellite-TV service for starved fans.

For all the hype about HDTV, there's been a dearth of high-def programming on the dial. This month, however, satellite-TV start-up Voom (*voom.com*) will begin delivering 39 channels of HDTV (competitors DirecTV and DISH Network have six and seven HD channels, respectively). Voom will supplement the usual HD fare with 21 exclusive commercial-free channels devoted to music, sports, movies and more. The service also includes 88 regular channels. Monthly costs are competitive ($40/month), but the setup is a killer—$750 for a dish, receiver and installation.—SUZANNE KANTRA KIRSCHNER

CLOCKWISE FROM TOP: COURTESY AK CONCEPT HOMES (3); COURTESY VOOM; COURTESY AT&T WIRELESS

1 UN Conference on Trade and Development, Nov '03; 2 Nielsen NetRatings Oct. '03; 3 IDC, Oct. '03; 4 Gartner G2, Oct. '03

A late night oasis on the highway of hunger.



Wendy's Late Night Pick-up Window is open 'til midnight or later. So, you can get a *hot 'n juicy Classic Single, Classic Double with cheese or Classic Triple with cheese,* and eat great, even late.

THE GO

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Q1 Digital

CD Player? No.
A cross-dressing digital
Camera. Nice curves.
£100 (U.K only); *fujifilm.com*

Reverse Pivot Ergo Pruner

Reversed action lets
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LEGEND

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Athlete's Foot
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As a plush toy, sure.
$6; *giantmicrobes.com*

kiloWatt Game Controller
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By playing PS2? Now
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$700; *powergridfitness.com*

Nokia 5140
Tough walkie-talkie
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Price not set; *nokia.com*

HRX Mower
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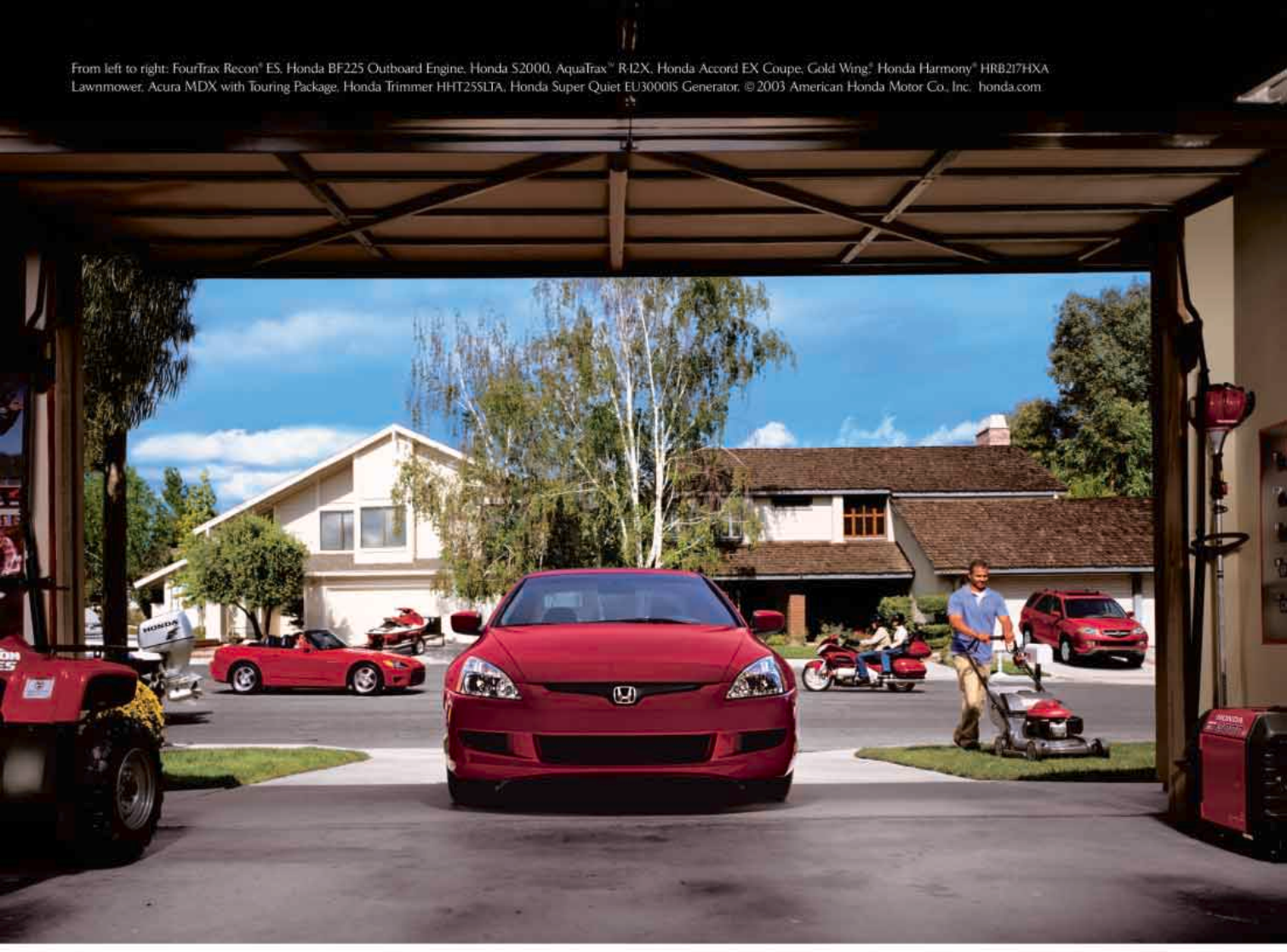
◀ SEE PREVIOUS PAGE FOR ICON LEGEND

ICONS BY AARON PILAND

From left to right: FourTrax Recon® ES, Honda BF225 Outboard Engine, Honda S2000, AquaTrax™ R-12X, Honda Accord EX Coupe, Gold Wing,® Honda Harmony® HRB217HXA Lawnmower, Acura MDX with Touring Package, Honda Trimmer HHT25SLTA, Honda Super Quiet EU3000IS Generator. © 2003 American Honda Motor Co., Inc. honda.com



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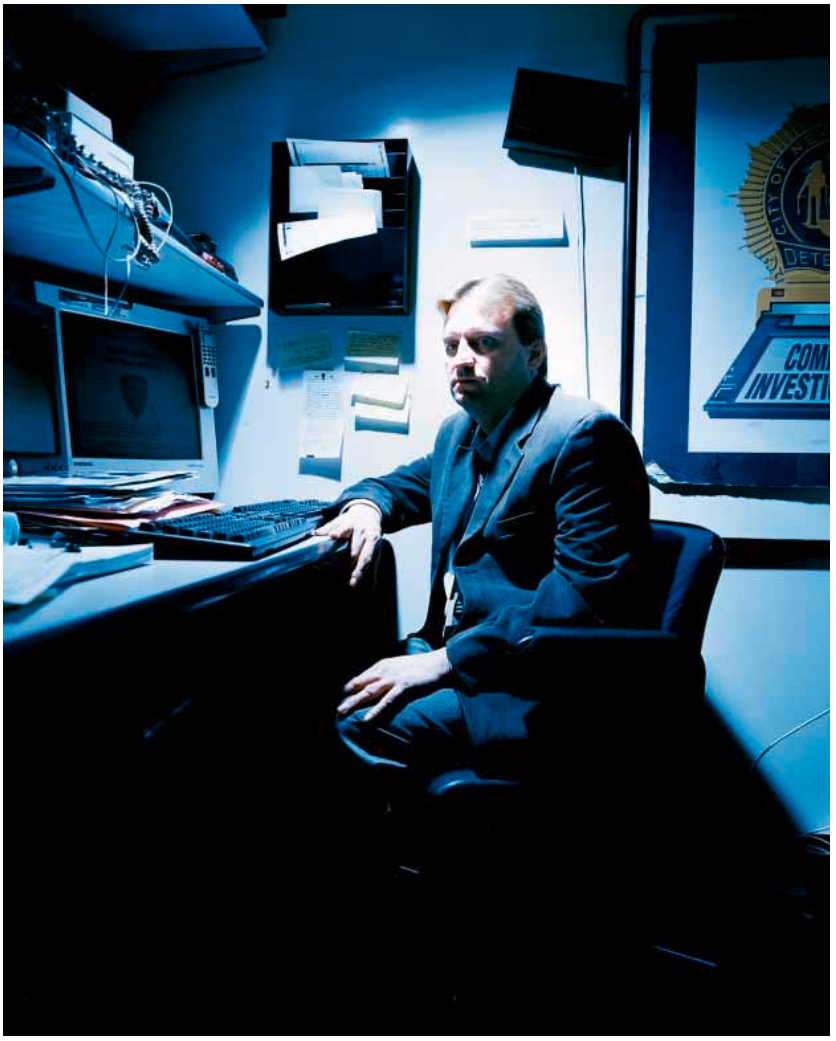
CRIME SEEN
BY JESSICA SNYDER SACHS
AT THE INTERSECTION OF SCIENCE & CRIME

Hi, Pedophile…! Meet Yur Worst Nitemare :-)

In the dark and chatty world of avatars and assumed identities, this cybercop is a virtual Sybil, trolling for creeps and thieves.



CALL ME MR. S **Detective Mike Smith, of the New York City Police Department computer-crime squad, in his lair. Smith prowls Internet chat rooms, hunting for online criminals. Virtual drag is one of his specialties. "He talks well to men," says a fellow officer. Often that means consulting women in the building for the little details that count, like ring size.**

DAVID BARRY

AUGUST 14, 2003: ON THE NIGHT of the great blackout, as the last waves of New York City workers walked over East River bridges and those with no way home settled down to sleep in lobbies or on sidewalks, a faint computer glow emanated from an 11th-floor window of One Police Plaza in downtown Manhattan. The light was barely noticeable, filtered as it was through the smoked-glass door of a tiny room that is nestled like a *matrioshka* doll inside the larger space that houses the NYPD's computer-crime squad.

If you'd followed the light to the door and stood outside it on that remarkable night, you would have heard the tapping of a keyboard, the periodic sound of a wheeled office chair moving about within the small room, and the occasional mutter. If you'd gone inside, you would have found one man, Detective Mike Smith, working long after his usual daytime shift had ended, because it seemed to him that the blackout offered a perfect opportunity to engage in a solo, marathon, 24-hour sweep for pedophiles, drug dealers, identity thieves and scam artists.

"I had backup power," Smith says. "I had coffee. Where else would I want to be?" The 18-by-14-foot room is filled with computers, webcams, caller-ID machines, VCRs, boxes overflowing with case files, and empty Starbucks Venti cups, all the gear a cop needs when he moves into an almost unbounded universe crowded with millions of people—and their multiple avatars—who deal and file share and chat and date and, yes, hunt for prey in the virtual universe.

One reason the door to the cyber-crime unit's little room is always closed, Detective Smith explains, is that "for all we know, there are times when I'm chatting with someone in this very building."

Over the past eight years, most major metropolitan police forces have begun fielding online investigation units. But the breadth of Smith's criminal

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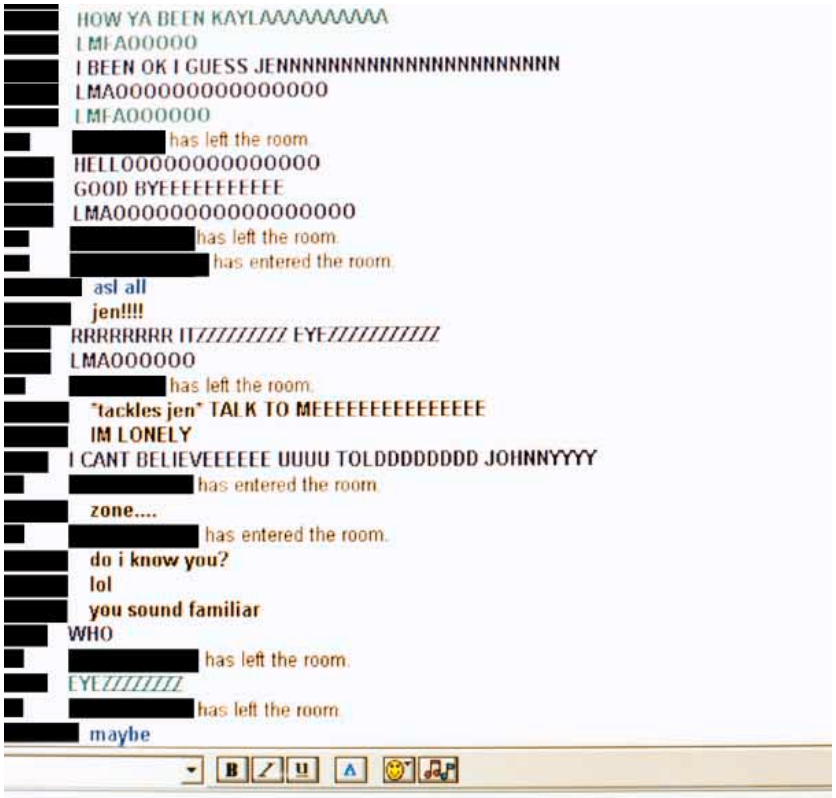
investigations and the range of his online personas make him something of a virtuoso in the cyber-gumshoe world. "I am an Internet Sybil," he says. While Smith's two partners, Travis Rapp and Michael Gischner, tend to concentrate on cracking online identity-theft rings, Smith is just as happy to spend his days in the chat rooms, juggling multiple online identities, bumping into naive little girls, and coaxing information from young women, drug dealers, insecure teenage boys and, of course, no shortage of predatory men.

Smith's pedophile cases have in recent months included a prominent rabbi, an Army MP, a four-star chef and the owner of a multimillion-dollar manufacturing company—each of whom found himself in trouble when he engaged in sexually explicit conversation, sent pornographic photos, or arranged a sexual tryst with a 9- to 17-year-old who turned out to be Detective Smith.

A 10-year veteran of the NYPD narcotics squad, Smith retains something of the towheaded, surfer-boy good looks that no doubt proved a bit of a hindrance in his years working undercover on the streets of upper Manhattan. Smith discovered the appeal of virtual identities in 1994, when a bad case of chicken pox contracted from a teenager he had arrested sent him home.

"After 102 hours playing computer hockey—I won the Stanley Cup four times—I discovered the Internet," he says. Specifically, Smith began reading postings on electronic bulletin boards and newsgroups, and uncovered a public forum for soliciting, marketing, and smuggling illegal drugs—a forum that was, at the time, largely unmonitored. "I came back to work telling them this is where we need to be."



TALK 2 ME **Going undercover online requires that Smith and partners master the Web equivalent of street talk, a strange mix of emoticons, stuttering letters, CAPS for emphasis, and lingo peculiar to the passions of chat-room participants. Then, the cops build trust.**

Smith's online drug busts often involve impersonating men—a gay stud boasting of all-night orgies, for example, who received offers of black-market Viagra; that case led to the arrest of a college student who was smuggling mass shipments from India. One challenging impersonation involved assuming the online identity of a real drug dealer he had just sent to prison. The masquerade culminated in the arrest of a major online supplier. "People dealing drugs on the Internet knew this guy like you or I know Derek Jeter," says Smith.

Still, Smith admits, he is at his best in virtual drag.

"Mike talks to men well," says Rapp of Smith's special role within the unit.

As a 160-pound blonde named Ingrid, he recently helped nail a financial scam artist preying on plus-size women in a BBW (big beautiful women) newsgroup. As a 30-something female marketing rep for a New York sports team, he gathered evidence that sent Internet ecstasy king Wagner "House of Beans" Bucci to Oneida State Prison in June 2000.

In none of his cases, claims Smith, does he solicit any of the criminal activity he encounters online. "I don't have to," he says. "Guys love to brag to women." The anonymity of screen names only greases their bravado.

But of course that anonymity is an illusion. After a Web user has crossed a legal line, Internet service providers cooperate with police by supplying the real name and address behind a screen alias. And Smith and partners generally have an easy time fleshing out their pen pals' dossiers: The tools that make the Internet a handy aid to criminal activity also help the police; Google is as useful to them as it is to anyone. "Before the guy is sitting in front of me in handcuffs, I usually know more about him than I do my best friends," Smith says.

Turning back to a monitor, he scrolls down a seemingly endless list of chat rooms. "Pick one, any one, it doesn't matter," he says. "I can find

DAVID BARRY

crime in any of them." Selecting a discussion on the illegality of marijuana, he enters as a 30-year-old, part-time topless dancer ("just for college, ya know") who hates her life:

"I am in a lousy mood today. . . just got a summons . . . jt in the park on my lunch hour."

Smith backs up repeatedly to correct typos. If he were impersonating a kid, he says, he would leave the misspellings—maybe even play with the type fonts, make some letters bigger, others smaller, all quirks he's picked up while watching the children of friends as they chat online.

Although Smith likes the fact that online undercover work is physically safer than the street variety, he finds it a greater mental strain. "On the streets, if you trip up on your story, you can deny having ever said something, claim the guy heard you wrong," he explains. "But now my guys have everything in writing. And if they catch me, they can get out the word to a thousand people, real fast."

As a 160-pound blonde named Ingrid, he recently helped nail a financial scam artist who preyed on plus-size women.

And they do try to catch Smith, of course. What kind of mascara does he use? Panty size? How many tampons in a box? Name a brand of makeup remover. "They're always testing me," he says.

But female officers and workers at One Police Plaza provide cover, feeding him data. Recently, for example, he interrupted an online chat that he was conducting in the persona of a 14-year-old girl to run across the office to ask a petite detective her ring size. A sketch of her hand now sits on top of Smith's computer monitor, every finger labeled as to size.

As for the challenge of keeping his identities straight, Smith disdains the conventional filing methods taught in law-enforcement seminars for online pedophile investigators: "Can you see me keeping track of index cards in this mess?" Instead, Smith bases each of his online personalities on an actual friend or acquaintance—morphed down in age and size as needed.

"When you leave, I may even base one on you," he teases.

Meanwhile, Smith is convinced that his new buddy in the marijuana chat room is a man, despite the slinky, open-blouse picture he just received via instant messaging.

"yur a guy," Smith types. "pantyhose size quick . . . name one brand of nail polish . . . ok lipstic . . . bra size."

Smith cracks his neck left and right, then rests his chin on his hands in front of the keyboard to stare at the monitor, waiting for a reply.

After a long pause comes an unconvincing offering: "34C."

"He just wants a nude picture of me," says Smith. Nothing illegal about that. But if Smith can get the guy to come clean, it could be the start of a less guarded conversation.

Drug cases take weeks to months to cultivate, and often go nowhere, he says. By contrast, Smith says, trolling for pedophiles is "like shooting fish in a barrel." Three out of five guys will continue chatting with Smith even after he tells them he's an underage girl, he says. One in five if he's an underage boy.

Given the number of online predators Smith encounters, does he get depressed or discouraged? Just the opposite, says Smith. "Every time we put one guy away, we may be stopping his contacts with hundreds of kids." In fact, investigators found contacts with over 300 children recorded on the computer hard drive of a recently arrested suspect. And, Smith adds, "if the guy's wife stays with him once he gets out of prison, we know he'll have a parole officer for life." ■

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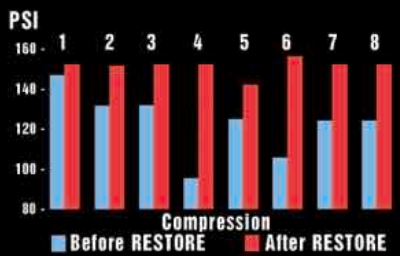
Cylinders
(1988 Chevrolet 4-cylinder with 242,104 miles)

Cylinders
(1989 Dodge V-6 with 120,903 miles)

Cylinders
(1976 Cadillac V-8 with 111,937 miles)



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INSIDE

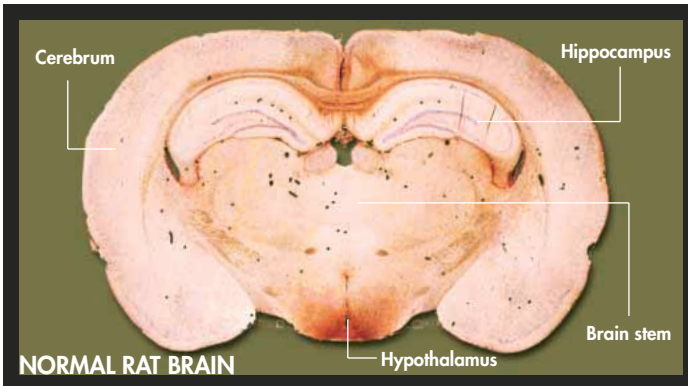
NEUROSCIENCE

FRESH FEARS OVER CELLPHONES

A Swedish study links mobile phones to brain damage. In rats, anyway.

The safety of cellphones has been called into question, again. This time the scientific community is paying very close attention.

Last summer neurosurgeon Leif Salford and colleagues at Lund University in Sweden published data showing for the first time an unambiguous link between microwave radiation emitted by GSM mobile phones (the most common type worldwide) and brain damage in rats. If Salford's results are confirmed by follow-up studies in the works at research facilities worldwide, including one run by the U.S. Air Force, the data could have serious implications for the one billion–plus people glued to their cellphones.



COURTESY EHP

CAN YOU HEAR ME NOW? Researchers at Sweden's Lund University say these rat-brain cross-sections show first-ever evidence of brain damage from cellphone radiation. While the controls (example, top) appear healthy, the test subjects (bottom), which were exposed to a 2-hour dose of cellphone radiation of varying intensities, are heavily spotted with proteins (dark patches) leaked from surrounding blood vessels, and show signs of significant neuronal damage.

The findings have re-ignited a longstanding debate among scientists and cellphone manufacturers over cellphone safety.

Many of the hundreds of studies performed during the past decade suggest cellphone use may cause a host of adverse effects, including headaches and memory loss. Other studies, however, have shown no such effects, and no scientific consensus exists about the effect of long-term, low-level radiation on the brain and other organs. A comprehensive $12 million federal investigation of cellphone safety is currently under way but will take at least five years to complete.

Meanwhile, the research world is scrambling to replicate Salford's surprising results. His team exposed 32 rats to 2 hours of microwave radiation from GSM cellphones. Researchers attached the phones to the sides of the rats' small cages using coaxial cables—allowing for intermittent direct exposure—and varied the intensity of radiation in each treatment group to reflect the range of exposures a human cellphone user might experience over the same time

TICKER /// 11.03.03 A DRY SPELL FURTHER GLOBAL WARMING COULD DAMAGE GRAPE HARVESTS IN ALREADY HOT REGIONS SUCH AS ITALY'S CHIANTI, ACCORDING TO A >

period. Fifty days after the 2-hour exposure, the rat brains showed significant blood vessel leakage, as well as areas of shrunken, damaged neurons. The higher the radiation exposure level, the more damage was apparent. The controls, by contrast, showed little to no damage. If human brains are similarly affected, Salford says, the damage could produce measurable, long-term mental deficits.

"THE CELLPHONE IS A MARVELOUS INVENTION," SAYS NEUROSURGEON LEIF SALFORD. "BUT GOVERNMENTS SHOULD BE SUPPORTING MORE RESEARCH."

The cellphone industry so far has been quick to dismiss the data, saying emissions from current mobiles fall well within the range of radiation levels the FCC deems safe (body-tissue absorption rates of under 1.6 watts per kilogram). "Expert reviews of studies done over the past 30 years have found no reason to believe that there are any health hazards whatsoever," says Mays Swicord, scientific director of Motorola's Electromagnetic Energy Programs. Dr. Marvin Ziskin, chair of the Institute of Electrical and Electronics Engineers' Committee on Man and Radiation, is similarly skeptical. "The levels of radiation they used seem way too low to be producing the kinds of effects they're claiming."

Salford is the first to admit that it's too early to draw any conclusions, but contends the unusual results deserve a closer look. "The cellphone is a marvelous invention; it has probably saved thousands of lives," he says. "But governments and suppliers should be supporting more autonomous research." Meanwhile, Salford advises users to invest in hands-free headsets to reduce radiation exposure to the brain.—ELIZABETH SVOBODA

ENGINEERING

RISE OF THE REPLICATORS

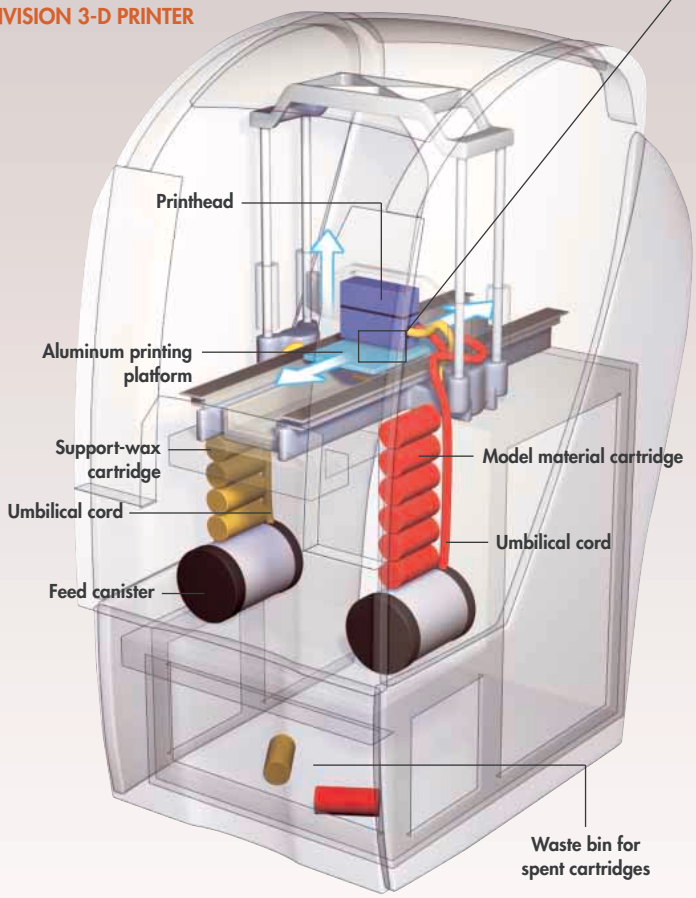
From car parts to coffee cups, faster 3-D printers make it all.

When his wife's coffee mug wouldn't squeeze into the puny cup holder in the couple's camper, engineer Mervyn Rudgley didn't buy a new mug. He simply printed out a new cup holder. And he just as easily could have printed out a new mug as well. Rudgley works for 3D Systems, a Valencia, California, maker of three-dimensional printers for rapid prototyping. These rudimentary *Star Trek* replicators spit out models of nearly anything an engineer can conjure in CAD software, shaving time and money from the design process. Motorola creates cellphone mock-ups with 3-D printers. NASCAR whips out model car parts. And Rudgley's wife now sips from her favorite cup on road trips.

Though commercial 3-D printers are still prohibitively expensive for consumer use, prices are plummeting. Five years ago most machines cost between $100,000 and $500,000, says Marina Hatsopoulos, CEO of Z Corporation in Burlington, Massachusetts. Last October, 3D Systems unveiled a $39,900 device called InVision (shown below) which squirts photosensitive acrylic plastic to build 3-D models. Z Corporation's ZPrinter 310, also unveiled last year, sells for $29,900, and can print out color models. And Hewlett-Packard has reportedly created a prototype 3-D printer that could sell for as little as $1,000.

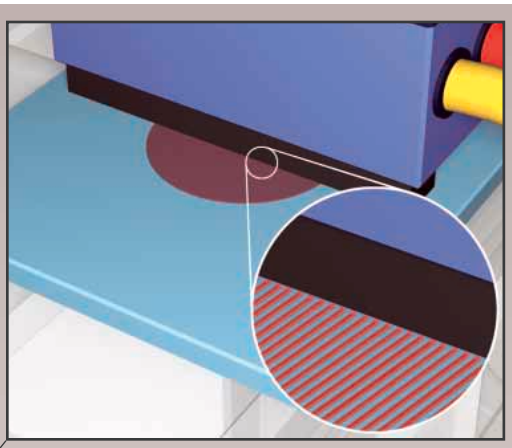
Like others in the industry, Rudgley thinks 3-D printers will eventually sit on everybody's desktop. "You want a kitchen implement and you'll buy the data rather than going to the store," he says.—MICHAEL STROH

INVISION 3-D PRINTER



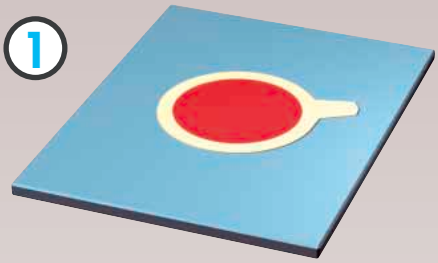
ILLUSTRATIONS: GARRY MARSHALL; FROM TOP: COURTESY Z CORP.; COURTESY 3D SYSTEMS; NICKODEMUS THE DRAGON, SCOTT CHRISTIAN SAVA, FROM THE COMIC BOOK SERIES THE DREAMLAND CHRONICLES, COURTESY ASTONISH COMICS; COURTESY Z CORP.

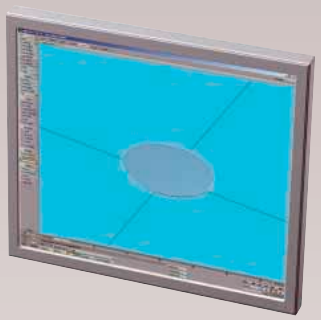
CLIMATOLOGIST AT SOUTHERN OREGON UNIVERSITY/// 11.10.03 VIRAL BIRTHDAY THE COMPUTER VIRUS CELEBRATES ITS 20TH YEAR /// 11.28.03 HEART ATTACK GENE FOUND



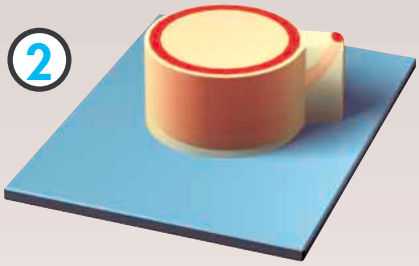
HOW TO PRINT A MUG

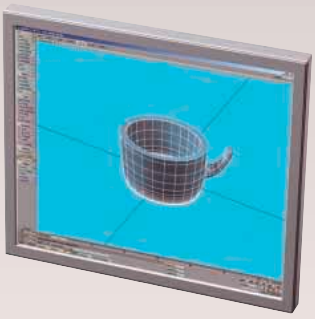
A 3-D printer works much the way its 2-D cousin does, though the process is far more impressive. The heart of 3D Systems' ATM-size InVision is the jet-studded printhead. Rather than ink, the head's 448 jets blast either photosensitive gel or purified wax onto a sliding aluminum platform. The platform can accommodate models up to 12 inches by 7 inches by 8 inches. One slick consequence: As long as they all fit, InVision can print several jobs at once. So while it's building your coffee mug, it can also print out a toy dragon.



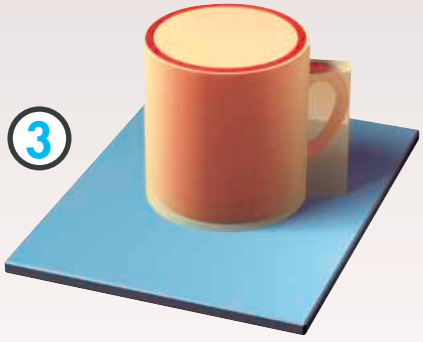


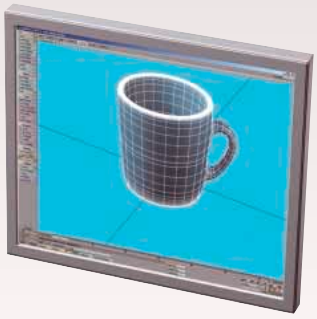
GROUNDWORK Guided by a CAD blueprint, InVision first lays down a thin wax pedestal to build on. The jets then spray one 0.0016-inch-thick layer of photosensitive gel on top of another.





FINE PRINT Each layer also contains areas made of wax, which support fragile parts, such as the mug's handle. As each layer nears completion, an ultraviolet light winks on to harden the gel.

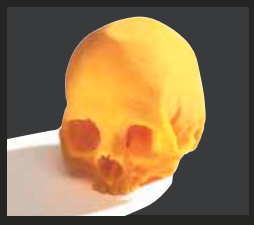




BUFF AND SHINE Six hours of printing later, the mug is complete. Almost. It still needs a quick bake in the oven to melt away the wax. Estimated cost: $12. Clearly, buying a mug at Wal-Mart is still faster and cheaper. But many in the industry think that won't always be the case.

HOT OFF THE PRESS

3D Systems' InVision uses UV light to solder plastic droplets. The process creates detailed models but takes longer than Z Corporation's ZPrinter, which sprays out starch or plaster powders and liquid binders to make low-cost, rough models. A sampling of the goods:



STARCH-POWDER SKULL
Z CORPORATION
PRINT TIME: 5 HOURS

PLASTIC MODEL BRIDGE
3D SYSTEMS
PRINT TIME: 7 HOURS

PLASTIC DRAGON
3D SYSTEMS
PRINT TIME: 7.5 HOURS

PLASTER-POWDER TRUCK
Z CORPORATION
PRINT TIME: 4 HOURS

AFTER STUDYING 100 MEMBERS OF A FAMILY CLAN PRONE TO CORONARY ARTERY DISEASE, SCIENTISTS AT CLEVELAND CLINIC REPORT THAT A MUTATION OF THE MEF2A GENE >

NASA

BACK TO THE FUTURE

Space-plane bidder puts winglets on vintage capsule design.

Retro tech is in fashion at NASA. As Congress and the White House debate the agency's future, NASA is pushing its big contractors to build a new "space taxi" as soon as possible, to get astronauts to and from the International Space Station more safely than the shuttle does [see "It Doesn't Take a Rocket Scientist," page 68].

"Safe," "soon" and "simple" are the watchwords, according to Mike Coats, the former shuttle pilot who leads the Lockheed Martin team competing to build the orbital space plane (OSP). NASA is expected to choose between Boeing and Lockheed Martin (which is working with Northrop Grumman and Orbital Sciences) this summer.

Don't expect to see OSP emerge as the "mini-shuttle"—a reusable craft that lands like an airplane—envisaged before the Columbia accident, says Coats. NASA's astronaut community is leaning toward a simple cone- or sphere-shaped capsule, like the Apollo or Russia's Soyuz. It's seen as the safest solution and the most likely to be ready by 2008, when NASA wants the OSP to be in service as a lifeboat for the space station.

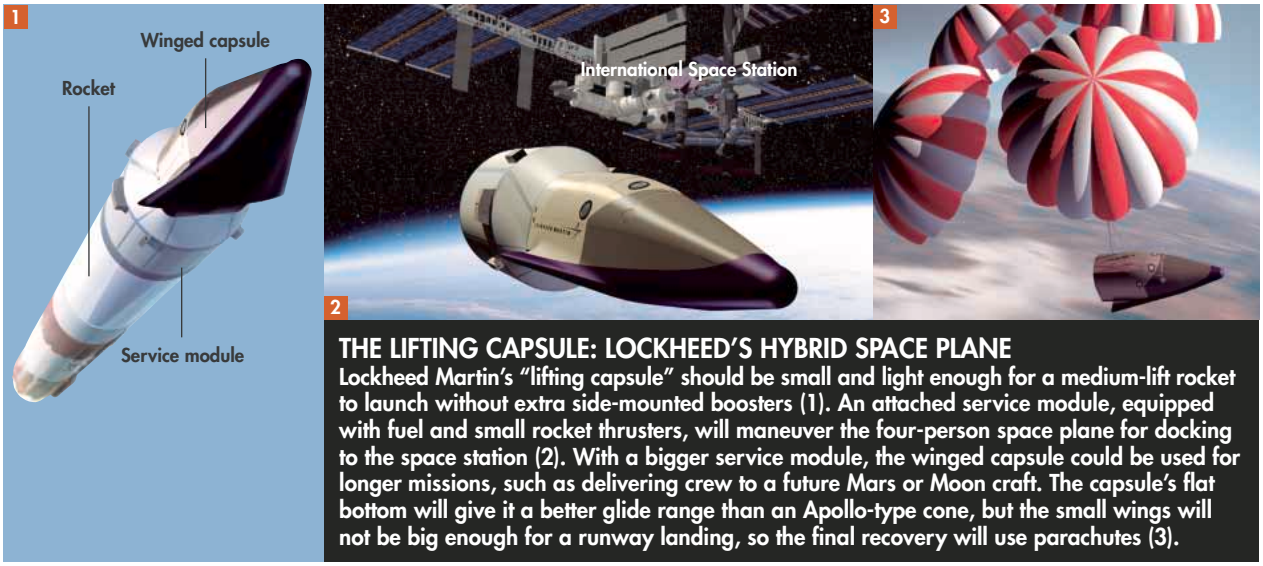
> MIKE COATS ADMITS THAT CAPSULES LOOK OLD-FASHIONED BUT ARGUES THAT THE MISSION IS TO GET PEOPLE INTO AND OUT OF ORBIT SAFELY.

But a winged spacecraft has its advantages, Coats says. NASA wants a vehicle that can get a sick astronaut to a U.S. hospital within 24 hours. Because a winged vehicle can glide when it hits the atmosphere, it doesn't have to wait until the space station's orbit takes it directly across the U.S. In the case of an aborted launch, the winged vehicle also has a better chance of finding a landing spot.

But a simple capsule is gaining favor, according to Coats, because it's stable and forgiving when things run amok. In May, when U.S. astronauts rode a Soyuz down from the station, the capsule's guidance system broke down. The Soyuz tumbled, putting the crew through loads equal to eight times the force of gravity, and landed about 300 miles off target, but what impressed NASA was that the crew survived a major failure. Another issue is the life span of the vehicle. A winged vehicle is too complex to be thrown away, but some at NASA like the idea of a one-shot or short-lived vehicle, says Coats, because it's possible to incorporate improvements on the production line, rather than periodically grounding a mini-shuttle OSP for upgrades.

Boeing is still studying both a capsule and a winged mini-shuttle and won't say which it will finally offer to NASA. The Lockheed Martin team is looking at both a capsule and a hybrid design that it calls a lifting capsule (see graphic below).

While Coats admits that capsules look old-fashioned, he argues that the mission is to get people into and out of orbit safely: "The sexy part of spaceflight ought to be what you do when you're out there."—BILL SWEETMAN



THE LIFTING CAPSULE: LOCKHEED'S HYBRID SPACE PLANE
Lockheed Martin's "lifting capsule" should be small and light enough for a medium-lift rocket to launch without extra side-mounted boosters (1). An attached service module, equipped with fuel and small rocket thrusters, will maneuver the four-person space plane for docking to the space station (2). With a bigger service module, the winged capsule could be used for longer missions, such as delivering crew to a future Mars or Moon craft. The capsule's flat bottom will give it a better glide range than an Apollo-type cone, but the small wings will not be big enough for a runway landing, so the final recovery will use parachutes (3).

COURTESY LOCKHEED MARTIN, BACKGROUND IMAGES COURTESY EARTH SCIENCES AND IMAGES ANALYSIS LABORATORY, NASA JOHNSON SPACE CENTER

WEAKENS ARTERIAL WALLS AND LEADS TO HEART ATTACKS /// 12.01.03 AN ANCIENT SCOURGE BASED ON DESCRIPTIONS OF ALEXANDER THE GREAT'S FINAL ILLNESS AND OF BIRD >

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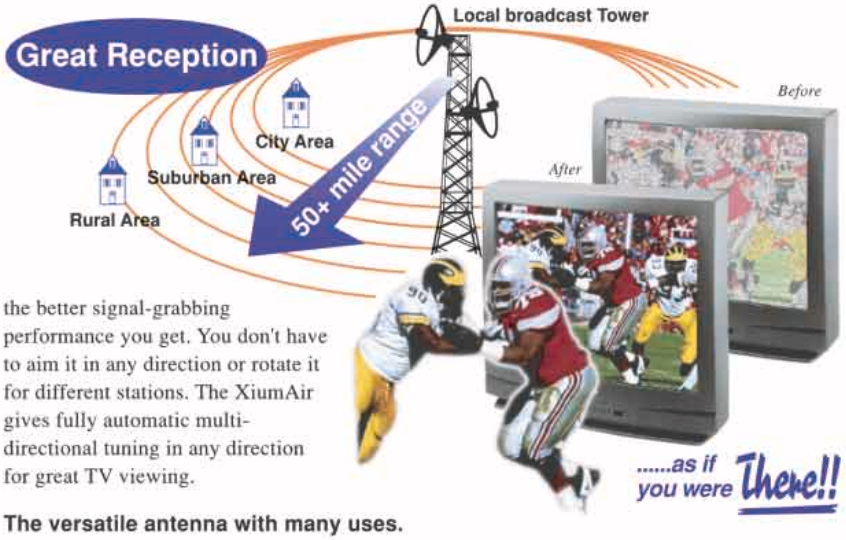

the better signal-grabbing performance you get. You don't have to aim it in any direction or rotate it for different stations. The XiumAir gives fully automatic multi-directional tuning in any direction for great TV viewing.

The versatile antenna with many uses.
If you have a DSS satellite system, the XiumAir is the ideal complement for receiving local channels without monthly fees. And when high definition broadcast TV arrives in a few years, you will be ready. Plus you can use the antenna now for AM / FM stereo, home-based CB systems, and shortwave radio. The XiumAir Antenna features compact, modern styling that will blend in with almost any decor. The UV-protected housing is made of impact-resistant copolymer, making the exterior resistant to weathering and color change. It includes a standard cable connector for any cable-ready hookup. The XiumAir Antenna delivers maximum local broadcast reception to any television, stereo or any other audio or video receiver, without the use of unsightly, ugly or 'wind damaged' antennas.

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This unique design is the result of years of research and testing, and now you can try it for yourself risk-free. Each XiumAir Antenna System is handcrafted and individually tested for high quality performance. With the XiumAir Antenna, you'll eliminate those unsightly antennas for good. The XiumAir Antenna comes with a 30-day manufacturer's limited warranty and Xium's exclusive risk-free home trial. If you are not satisfied for any reason, just call us for free expert installation assistance, or simply return it within 30 days for a full refund, less S&H.

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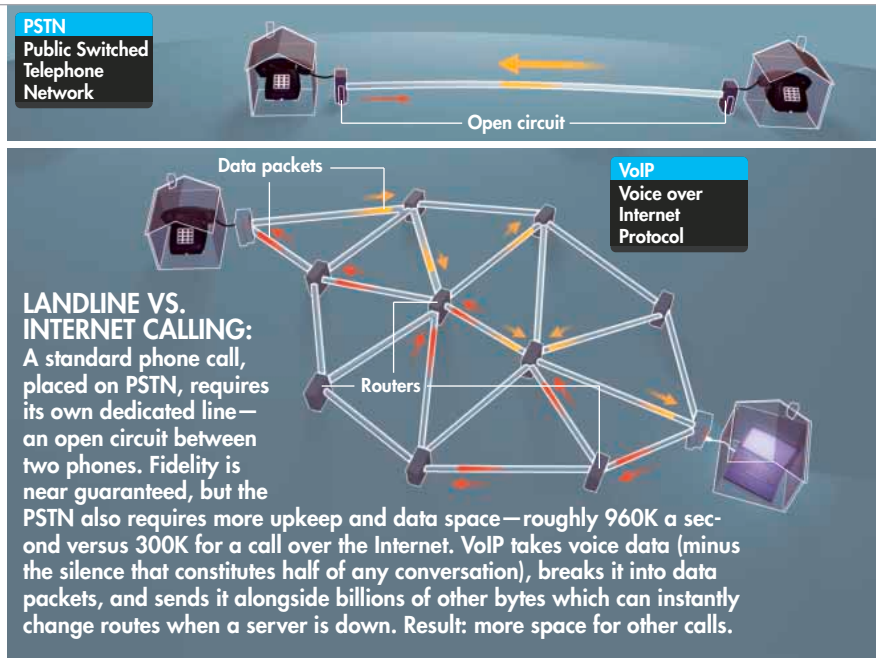

LANDLINE VS. INTERNET CALLING: A standard phone call, placed on PSTN, requires its own dedicated line—an open circuit between two phones. Fidelity is near guaranteed, but the PSTN also requires more upkeep and data space—roughly 960K a second versus 300K for a call over the Internet. VoIP takes voice data (minus the silence that constitutes half of any conversation), breaks it into data packets, and sends it alongside billions of other bytes which can instantly change routes when a server is down. Result: more space for other calls.

Could the landline be going the way of the telegraph? To find Web-tech enthusiasts who think so, just ask any one of the two million–plus people who have downloaded Skype, peer-to-peer software that allows users to make calls anywhere in the world, for free, over the Internet. "I'm speaking to you through a headset connected to my regular telephone, connected to my laptop, which is wireless," says Skype CEO Niklas Zennström, calling an ordinary phone in New York from Sweden. "Like a very big cordless telephone."

That "very big cordless" is threatening to further rock the already battered telecom industry. Thanks to today's critical mass of broadband connections, Voice over Internet Protocol (VoIP), the nine-year-old technology behind Skype, is finally going mainstream. So much so that some experts predict that 40 percent of the world will be using VoIP within the next five years, a prospect that has telecom giants scrambling to keep pace, and profits. Already MCI, AT&T and SBC offer some type of VoIP calling plans to their customers. And while the big guys play catch-up, smaller players like Packet8 and Vonage are winning over callers at breakneck speed with long distance Internet calling plans as low as $20 a month.

Skype plans to cash in as well. This winter the company will introduce a new fee-based service that will allow users to make and receive calls over the Internet from regular phones.

But there are still a few technical hurdles on the road to ubiquity. The extra equipment VoIP requires—at minimum, an analog-to-digital converter to patch your phone into the Internet—feels cumbersome, and service can be spotty. From his oversize "cordless," Zennström is barely audible as he speaks about becoming the leading player in VoIP. "VoIP is notorious for poor quality," says Andrew Odlyzko, director of University of Minnesota's Digital Technology Center. "But in the long run, it has the potential to transcend the limitations of telephony."—NICOLE DAVIS

OPINION

IN DEFENSE OF THE FIRST GENETICALLY ENGINEERED PET

Last month pet stores began selling genetically engineered fluorescent zebra fish, called GloFish, and I was first in line. Never mind that California has banned transgenic pets, and animal-rights activists nationwide cry foul: *What's the point?* The fish are technological marvels—that's the point. Scientists began adding fluorescence genes plucked from jellyfish and coral to zebra fish during the late '90s to make them glow in the presence of toxins, and thus help keep our waterways clean. The $5 gen-mods also happen to look spectacular beneath a black light; they fluoresce neon red. In this case, environmentalism delivers a bankable fringe benefit.—JENNY EVERETT

FROM TOP: GARRY MARSHALL; COURTESY SEGREST FARMS AND 5-D TROPICAL

BEHAVIORS AT THE TIME, SCIENTISTS AT THE VIRGINIA DEPARTMENT OF HEALTH AND COLORADO STATE UNIVERSITY SAY THAT THE CONQUEROR MAY HAVE DIED OF WEST NILE VIRUS

PERSPECTIVE

DESIGNER STEROIDS, BY THE NUMBERS

For a stealthy boost, athletes turn to the bathtub chemists.

2,000	Estimated number of substances banned by the International Olympic Committee (IOC)
30	Percentage of banned substances that are steroids
THG	The only designer steroid ever detected
4	Number of hydrogen atoms added to known steroid gestrinone to make THG
0	Advanced science degrees held by accused THG developer Victor Conte
100	Number of athletes suspected of consulting "Dr." Conte
1	Number of U.S. testing labs accredited by the IOC
219,500	Annual number of U.S. teens who use steroids
17	Age of recent steroid-linked suicide victim Taylor Hooton
$2 MILLION	Annual research budget for the U.S. Anti-Doping Agency
$2.5 MILLION	Average annual salary for major-league baseball player

SOURCES: International Olympic Committee; Don Catlin, professor of pharmacology, UCLA; National Institute on Drug Abuse; U.S. Anti-Doping Agency; National Household Survey on Drug Abuse

INNOVATION

URBAN FIREFIGHTING GETS A KILLER EDGE

A new rapid-fire gun could save lives rather than take them.

Metal Storm, an Australian-made weapon in development for the U.S. military, is notorious for its terrifying rate of fire: a million rounds per minute. When you press "fire" on the weapon's laptop computer, sequenced electronic signals are sent to shells preloaded into a grid of 24 projecting barrels, and the mayhem begins. With no clumsy moving parts—ammo feeders, breeches, firing pins—Metal Storm can blast out bullets much like an inkjet printer sprays dots on a page. The gun's primary purpose is "to kill, stop, destruct, harm the target," says Arthur Schatz, Metal Storm's senior vice president of operations. But now the company is working on a peacetime application: to fight high-rise fires. Swap out the ammo for Pyrogen, a novel flame suppressant that is far lighter than other chemical agents, and Metal Storm guns "could be a valuable adjunct to existing firefighting methods," says Captain Larry Collins, a helicopter operations specialist for the Los Angeles County Fire Department. Firefighters reach a blaze by scaling stairs, averaging a minute per floor, precious time in which the fire above them can spiral out of control. Crews equipped with Metal Storm guns mounted on trucks or on the skids of a helicopter could shoot Pyrogen canisters through the skyscraper's windows—a hundred into Window A, Floor 34, 50 into Window B, Floor 46, and so on—thus buying time for the crews on foot.—JAMES VLAHOS

BALLISTICS: KOOPMAN/CORBIS; FLAME SNUFFER: COURTESY METAL STORM

THE POPSCI OPINION POLL

BASED ON 18,743 VOTES POSTED TO POPSCI.COM FROM 10/1 TO 12/3

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THIS MONTH'S OPINION POLL:

IS HOMELAND SECURITY DOING ENOUGH TO GUARD THE NATION AGAINST BIOCHEMICAL TERRORISM?

WHAT DO YOU THINK? POPSCI.COM/OPINION

/// 2.01.04 REMEMBERING COLUMBIA TODAY MARKS THE ONE-YEAR ANNIVERSARY OF THE SPACE SHUTTLE COLUMBIA'S DISINTEGRATION ON RE-ENTRY, WHICH KILLED ALL SEVEN >

AVIATION

DEFENSE INFLATION

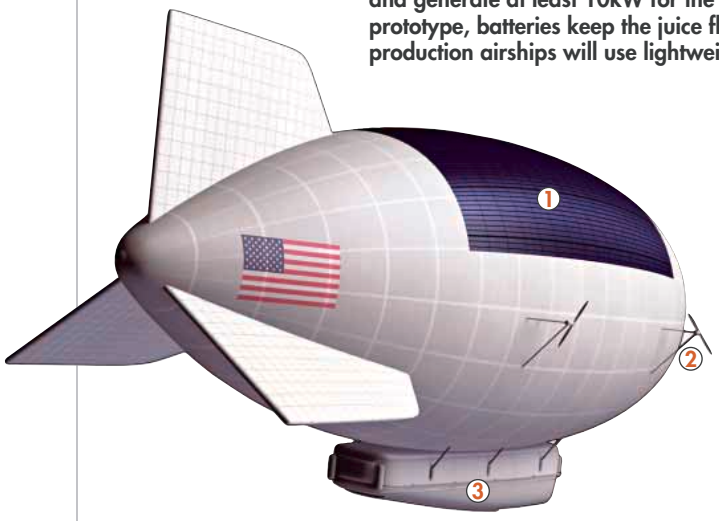
Meet the homeland security blimp, flying high by 2006.

Being oversize has its advantages. Just ask researchers at the U.S. Missile Defense Agency, which recently dished out $40 million to arms maker Lockheed Martin to design what could soon be the world's largest pilotless airship. Measuring 500 feet long, with a volume of 5.2 million cubic feet, the prototype high-altitude airship, or HAA, will be 25 times larger than the Goodyear blimp.

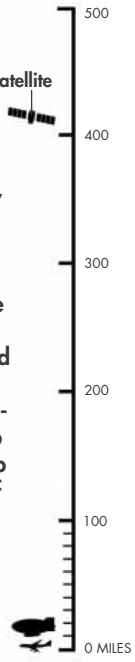
From a military perspective, such an XXL craft may seem like an inviting target, especially since its top speed is only 80 mph. However, parked 12 miles up, it will be immune to most ground-launched missiles, and its onboard sensor systems will "see" at least 350 miles in any direction, allowing it to spy most incoming military threats. A fleet of 10, says the MDA, could provide an early-warning curtain for the continental United States.

Compared to high-altitude unmanned aerial vehicles, such as NASA's ill-fated Helios, the airship should be able to carry a heavy payload; its 4,000-pound capacity makes it ideal for toting heavy surveillance and communications equipment. Another big advantage: HAA's solar panels and fuel cells will allow it to loiter above the jet stream in a geostationary position for up to a year, something no drone or spy plane can do.—MATTHEW STIBBE

1 POWER SUPPLY
The helium airship will generate enough electricity from thin-film photovoltaic solar cells to power the engines and generate at least 10kW for the payload. On the prototype, batteries keep the juice flowing at night, but production airships will use lightweight fuel cells.



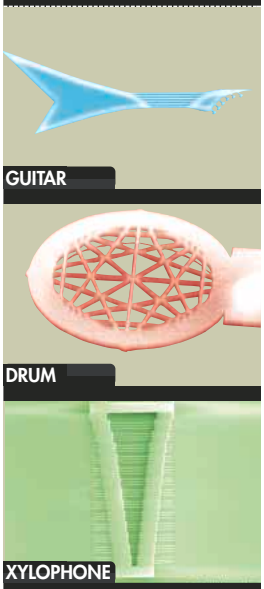
2 ENGINES
Four electrically powered engines, each driving two 30-foot-wide blade propellers, will provide forward thrust. The "steerable" propellers will help keep the airship within a mile of its assigned location.



3 PAYLOAD
The missile-defense airship might carry laser radars for pinpointing ballistic missiles or relay mirrors to extend the range of the 747-derived airborne laser. Other possible payloads: radar systems to detect low-flying cruise missiles, weather sensors, communications relays and cellphone base stations.

SHRINKAGE DEPT.

RESEARCH UPDATES ON THE QUEST TO MAKE REALLY TINY THINGS



SHRUNK ROCK

Strumming the strings of the world's smallest guitar requires more than just nimble fingers. Better factor in some deft laser work and a very attuned ear. Cornell University scientists crafted the blood-cell-size Stratocaster in 1997 using e-beam lithography on silicon wafers. But it took them seven years, and a new Gibson Flying V, to actually play a note. To do it, the scientists bounced focused laser light on the guitar's silicon "strings," causing them to vibrate and alter the light they reflect. The resulting "tunes" were screeched out in Es and As, 17 octaves above what a normal guitar produces. A wee xylophone and drum now round out the band. Scientists say these clever little research tools may help improve electronics: Energy-efficient nanorods, similar to the Gibson's "strings," could replace power-hogging quartz oscillators in wireless devices.—MARTHA HARBISON

FROM LEFT: GARRY MARSHALL; COURTESY CCMR/CNF, CORNELL UNIVERSITY

ASTRONAUTS ABOARD /// 2.02.04 CHASING A COMET THE NASA STARDUST SPACECRAFT, LAUNCHED IN 1999, IS SET TO BE THE FIRST PROBE TO COLLECT DUST PARTICLE SAMPLES >

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- **LEVITRA works the first time, time and again**
  Some men may require additional attempts
- **LEVITRA works to improve the quality of erectile function**
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It doesn't matter if the challenge is on the field or off – I always strive to be the best. For ED, I found something that works for me, LEVITRA.†

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† Individual results may vary.

Please see adjacent Patient Information for more about LEVITRA (2.5 mg, 5 mg, 10 mg, and 20 mg) tablets.

LEVITRA is a medicine that may be used up to once a day to treat erectile dysfunction (ED). LEVITRA is for use by prescription only. Men taking nitrate drugs, often used to control chest pain (also known as angina), should not take LEVITRA. Men who use alpha-blockers, sometimes prescribed for high blood pressure or prostate problems, also should not take LEVITRA. Such combinations could cause blood pressure to drop to an unsafe level. The most commonly reported side effects are headache, flushing, and stuffy or runny nose. Men who experience an erection for more than four hours should seek immediate medical attention. You should not take LEVITRA if your doctor determines that sexual activity poses a health risk for you. LEVITRA does not protect against sexually transmitted diseases.

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Q&A

SPACE BOY

For $50,000, he could be the first kid in orbit.

In a bid to become the first teen in space, 18-year-old Justin Houchin has booked a berth on the Solaris X. Interorbital Systems (IOS) is building the rocket to compete for the X Prize, the $10 million jackpot for the first civilian team to put humans into space on a reusable vehicle. Even though IOS has yet to launch a rocket—let alone a human—higher than 10,000 feet, they're already selling tickets for 25-minute suborbital rides.

POPULAR SCIENCE: How are you preparing?

JUSTIN HOUCHIN: The ticket is $50,000, and I'm hoping to get cosmonaut training in Russia, so I need to raise a good amount of money.

PS: Are you nervous?

JH: The capsule can separate and land on its own if something goes wrong. And the people at IOS will be riding the rocket too. So it's in their best interest to make it safe.

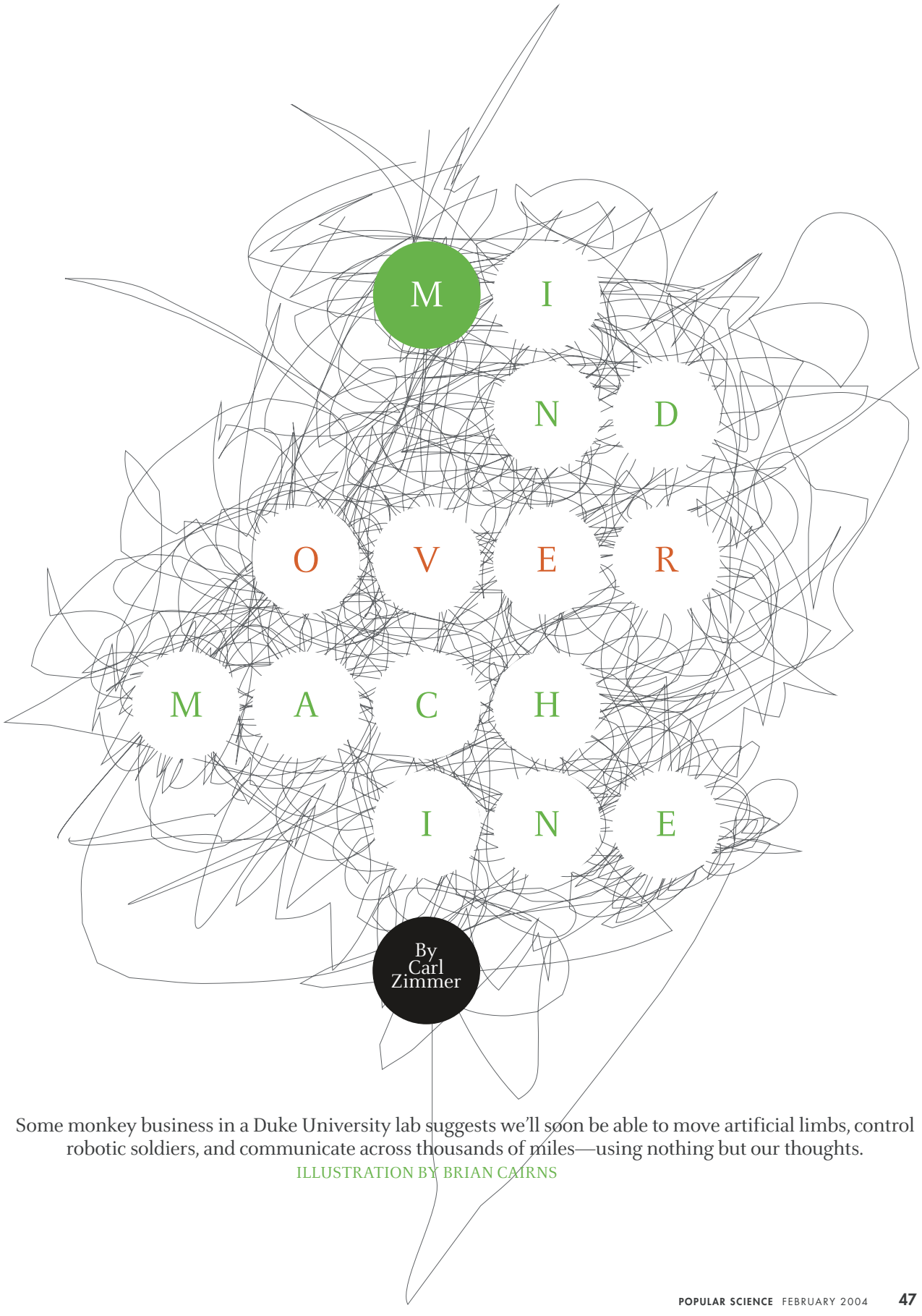
PS: What do you do for an encore after the space trip?

JH: Make movies. I'm definitely not going to let this astronaut thing be the peak of my career.

—INTERVIEW BY PRESTON LERNER

FROM COMET WILD 2 DURING A CLOSE APPROACH. ■


FR



MIND OVER MACHINE

By Carl Zimmer

Some monkey business in a Duke University lab suggests we'll soon be able to move artificial limbs, control robotic soldiers, and communicate across thousands of miles—using nothing but our thoughts.

ILLUSTRATION BY BRIAN CAIRNS

SOMETHING INCREDIBLE IS HAPPENING IN A LAB AT DUKE University's Center for Neuroengineering—though, at first, it's hard to see just what it is. A robot arm swings from side to side, eerily lifelike, as if it were trying to snatch invisible flies out of the air. It pivots around and straightens as it extends its mechanical hand. The hand clamp shuts and squeezes for a few seconds, then relaxes its grip and pulls back to shoot out again in a new direction.

OK, nothing particularly astonishing here—robot arms, after all, do everything from building our cars to sequencing our DNA. But those robot arms are operated by software; the arm at Duke follows commands of a different sort. To see where those commands are coming from, you have to follow a tangled trail of cables out of the lab and down the hall to another, smaller room.

Inside this room sits a motionless macaque monkey.

The monkey is strapped in a chair, staring at a computer screen. On the screen a black dot moves from side to side; when it stops, a circle widens around it. You wouldn't know just from watching, but that dot represents the movements of the arm in the other room. The circle indicates the squeezing of its robotic grip; as the force of the grip increases, the circle widens. In other words, the dot and the circle are responding to the robot arm's movements. And the arm? It's being directed by the monkey.

Did I mention the monkey is motionless?

Take another look at those cables: They snake into the back of the computer and then out again, terminating in a cap on the monkey's head, where they receive signals from hundreds of electrodes buried in its brain. The monkey is directing the robot with its thoughts.

For decades scientists have pondered, speculated on, and pooh-poohed the possibility of a direct interface between a brain and a machine—only in the late 1990s did scientists start learning enough about the brain and signal-processing to offer glimmers of hope that this science-fiction vision could become reality. Since then, insights into the workings of the brain—how it encodes commands for the body, and how it learns to improve those commands over time—have piled up at an astonishing pace, and the researchers at Duke studying the macaque and the robotic arm are at the leading edge of the technology. "This goes way beyond what's been done before," says neuroscientist Miguel Nicolelis, co-director of the Center for Neuroengineering. Indeed, the performance of the center's monkeys suggests that a mind-machine merger could become a reality in humans very soon.

Nicolelis and his team are confident that in five years they will be able to build a robot arm that can be controlled by a person with electrodes implanted in his or her brain. Their chief focus is medical—they aim to give people with paralyzed limbs a new tool to make everyday life easier. But the success they and other groups of scientists are achieving has triggered broader excitement in both the public and private sectors. The Defense Advanced Research Projects Agency has already doled out $24 million to various brain-machine research efforts across the United States, the Duke group among them. High on DARPA's wish list: mind-controlled battle robots, and airplanes that can be flown with nothing more than thought. You were hoping for something a bit closer to home? How about a mental telephone that you could use simply by thinking about talking.

BRIAN FINKE

THE NOTION OF DECODING THE BRAIN'S COMMANDS can seem, on the face of it, to be pure hubris. How could any computer eavesdrop on all the goings-on that take place in there every moment of ordinary life?

Yet after a century of neurological breakthroughs, scientists aren't so intimidated by the brain; they treat it as just another information processor, albeit the most complex one in the world. "We don't see the brain as being a mysterious organ," says Craig Henriquez, Nicolelis's fellow co-director of the Center for Neuroengineering. "We see 1s and 0s popping out of the brain, and we're decoding it."

The source of all those 1s and 0s is, of course, the brain's billions of neurons. When a neuron gets an incoming stimulus at one end—for example, photons strike the retina, which sends that visual information to a nearby neuron—an electric pulse travels the neuron's length. Depending on the

signals it receives, a neuron can crackle with hundreds of these impulses every second. When each impulse reaches the far end of the neuron, it triggers the cell to dump neurotransmitters that can spark a new impulse in a neighboring neuron. In this way, the signal gets passed around the brain like a baton in a footrace. Ultimately, this rapid-fire code gives rise to electrical impulses that travel along nerves that lead out of the brain and spread through the body, causing muscles to contract and relax in all sorts of different patterns, letting us blink, speak, walk, or play the sousaphone.

In the 1930s, neuroscientists began to record these impulses with implantable electrodes. Although each neuron is coated in an insulating sheath, an impulse still creates a weak electric field outside the cell. Researchers studying rat and monkey brains found that by placing the sensitive tip of an electrode near a neuron they could pick up the sudden changes in the electric field that occurred when signals coursed through the cell.

The more scientists studied this neural code, the more they realized that it wasn't all that different from the on-off digital code of computers. If scientists could decipher the code—to translate one signal as "lift hand" and another as "look left," they could use the information to operate a machine. "This idea is not new," says John Chapin, a collaborator with the Duke researchers who works at the State University of New York Downstate Health Science Center in Brooklyn. "People have thought about it since the '60s."

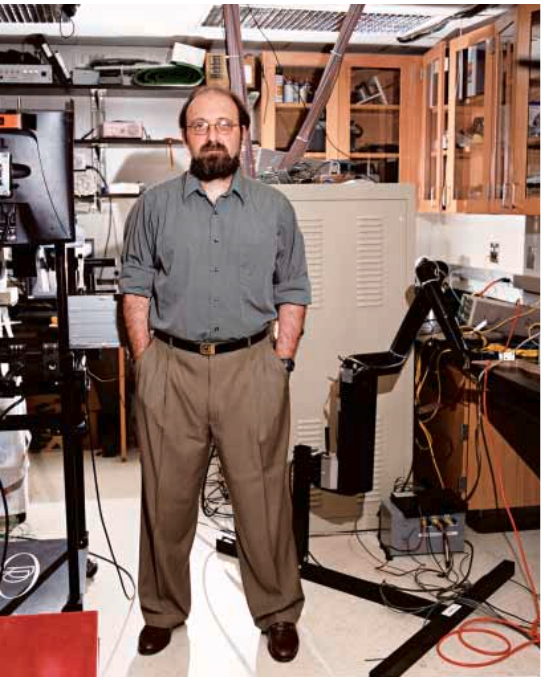
But most researchers assumed that each type of movement was governed by a specific handful of the brain's billions of neurons—the need to monitor the whole brain in order to find those few would make the successful decoding a practical impossibility. "If you wanted to have a robot arm move left," Chapin explains, "you would have to find that small set of neurons that would carry the command to move to the left. But you don't know where those cells are in advance."

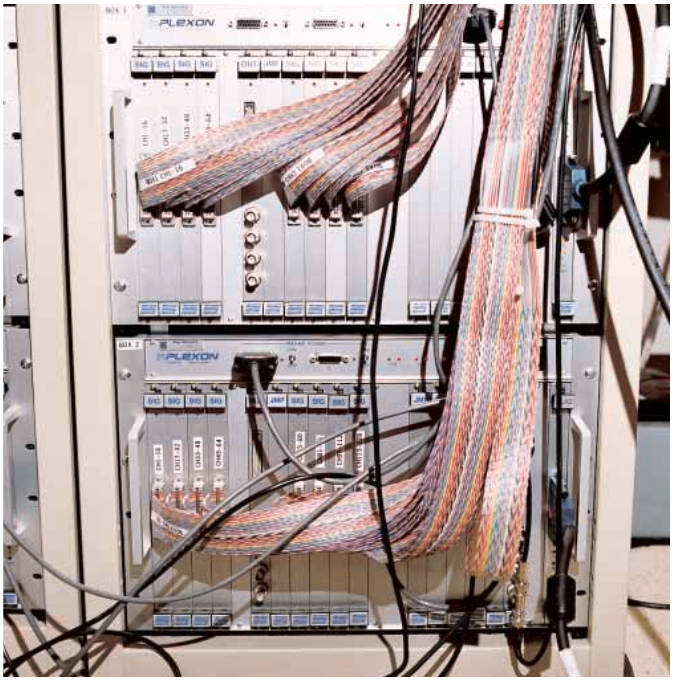
Thus everything that was known at the time suggested that brain-machine interfaces were a fool's errand. Everything, it turned out, was wrong.

IN 1989, MIGUEL NICOLELIS ARRIVED FROM BRAZIL at Hahnemann University in Philadelphia, intent on cracking the neural code, regardless of how complex it might prove to be. At Hahnemann he found the perfect collaborator in John Chapin, who had spent the previous decade working on a device that could take 12 separate recordings from the brain at once; if the two of them could perfect it, they'd be the first to be able to listen to more than one neuron at a time.

Every aspect of the project posed new challenges. To work adequately, the electrodes needed to be tiny enough to be safely inserted into the brain, and precise enough to send a reliable stream of data to a computer. Conventional electrodes would get covered in scar tissue. The problem, Chapin and Nicolelis found, was that the electrodes, designed as rigid spikes, were damaging the surrounding brain tissue—so the scientists subbed in electrodes with flexible tips. "They have to float around," Nicolelis says. "But if they are rigid and move around, the brain can be dissected."

By the mid-'90s, Nicolelis and Chapin finally were inserting their arrays of electrodes into the brains of living rats—and what they discovered instantly challenged the conventional





Sensors in the mechanical hand (left) register the force applied to a piece of foam (not shown) and match that with how hard the monkey thinks to squeeze. The center of operations: Miguel Nicolelis (middle) in his Duke University lab. The complex task of tracking all the brain activity falls to the Multichannel Acquisition Processors (right). Each of these records signals from roughly 150 neurons simultaneously.

BRIAN FINKE

wisdom on the way neurons send their messages. What they found was that the commands for even the simplest of movements—twitching a whisker, for example—required far more than just a tiny cluster of neurons. In fact, a whole orchestra of neurons scattered across the brain played in synchrony. And the neurons behaved like an orchestra in another important way. Beethoven's Fifth Symphony and Gershwin's *Rhapsody in Blue* sound nothing alike, even if many of the same musicians are playing both pieces, on many of the same instruments, using many of the same notes. Likewise, many of the same neurons, it turned out, participated in generating many different kinds of body movement.

With this discovery, the biggest supposed roadblock to making a brain-machine interface suddenly disappeared. Rather than needing to find the tiny handful of neurons responsible for a particular movement, scientists could, by listening to a small fraction of neurons in a brain, generate enough information to recognize many different commands. Think again of the brain as an orchestra: You don't need to set up a microphone next to every instrument to tell whether the orchestra is playing Beethoven's Fifth or *Rhapsody in Blue*. You could probably figure it out by listening to just a handful of musicians.

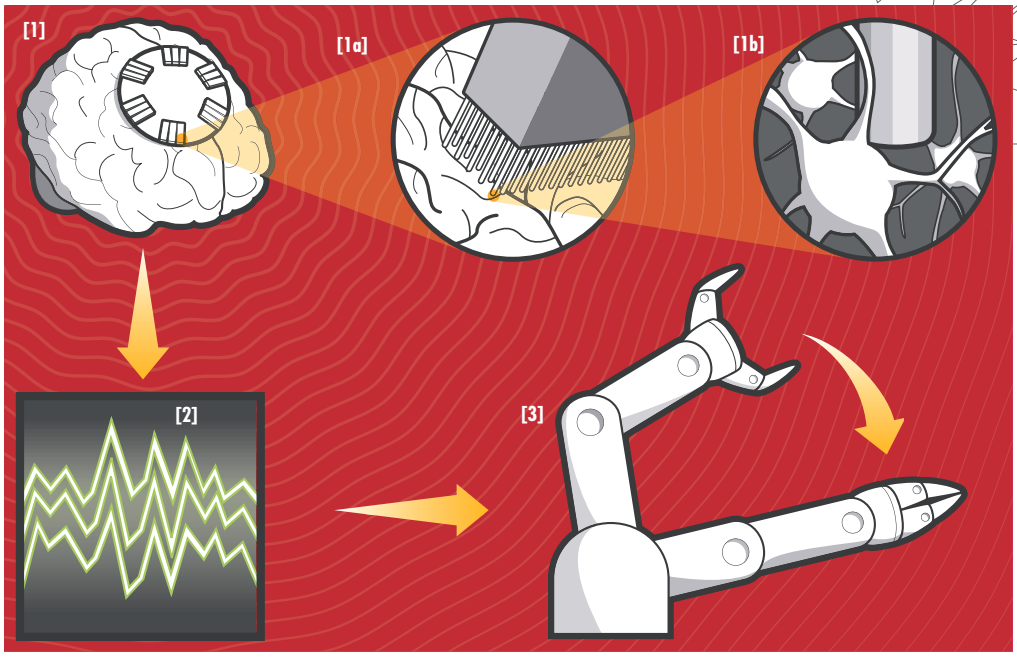
To test this supposition, Chapin and Nicolelis inserted electrodes into a rat's brain and began monitoring 46 neurons. They then trained the rat to press a lever to get a drink of water, and used the electrodes to record the pattern of signals the animal produced to move its arm. Then Chapin and Nicolelis disconnected the lever from the water supply, so that pressing the lever did nothing. The rat went on pressing the lever, but now the scientists gave the rat a drink of water when it simply produced the "press lever" command in its brain. After a while, the rat stopped bothering to lift its arm, and just thought about lifting it.

NOT LONG AFTER THE RAT BREAKTHROUGH, Nicolelis got a job at Duke and began setting up a new lab to take the research to a higher level. There he began to implant electrodes into monkeys instead of rats, hoping to get them to operate more complex equipment with their brains. Nicolelis teamed up with biomedical engineers at Duke to design new arrays of electrodes, along with high-capacity signal processors, that could handle the new challenge. "Miguel always wants more channels," says biomedical engineer Patrick Wolf with a grin. "It's like, 'More power, Scotty.'"

By 2000, Nicolelis and his colleagues had invented a system that could recognize patterns in monkey brains well enough to let the animals swing a robot arm to the left or to the right with their thoughts. The success gave the researchers the confidence to set themselves a goal: to design a system that would allow paralyzed people to operate a prosthetic arm with a set of implanted electrodes. The arm wouldn't let people play a piano sonata, but it would let them do simpler things like drink a glass of water. "That's a fairly complicated action," says Henriquez. "Going out, grabbing a glass, grabbing with enough pressure to not let it slip, raising it, drinking from it, and putting it back."

The next steps toward that goal would be to make the robot arm move in more intricate ways, and then to add a simple

[Monkey Mind Meld] How an animal's thoughts can move a robot



A multi-electrode cap [1] enables researchers to match a monkey's intentions—to manipulate a computer cursor by moving a joystick—with its brain waves. After recording which patterns of neuronal activity correspond to that action, researchers translate the monkey's thoughts into robotic motion. The cap holds five to 10 electrodes, each with 16 to 128 microwires [1a]. The electrodes are implanted in the brain at a rate of about 0.1 millimeters per minute, to a depth of only 2 millimeters. Once inside, each of the blunt-tipped microwires, which are only 50 microns wide, acts like a miniature antenna, capable of recording the electrical activity of one to four local neurons [1b]. The joystick is disabled. Now, when the monkey thinks, "Move cursor," the microwires record the electrical activity, then transmit it to a neural signal processor, which plots each neuron's impulses [2]. A computer correlates these patterns with the pre-recorded data on the monkey's actual arm motion: If the signals match, the robot arm moves down [3].

MCKIBILLO

hand that could also follow a monkey's commands. This is the system that's online today: A monkey learns how to use it by sitting at a computer screen and using a joystick to move a cursor across the screen. When a dot appears on the screen, the monkey drags the cursor on top of it in order to get a squirt of juice through a tube rigged up next to its mouth. The electrodes in the monkey's brain record the signals from its motor neurons as they form the commands that move its arm.

The signals are piped into a computer, which compares them to the joystick's movements and figures out how to predict the latter from the former. Once the computer has grown familiar enough with the monkey's brain patterns, it uses those signals rather than input from the joystick to move the cursor across the screen.

"After a while, like the rats before her, she realizes she doesn't have to move her hand," says Nicolelis. The monkey simply thinks the cursor across the screen.

Then the monkey learns to use its mind to control a robot. (The monkey, however, doesn't realize the robot even exists; it is simply focused on moving the cursor to gain rewards.) The monkey operates the joystick again, but the signals from the joystick go to the robot arm. The cursor still moves across the screen; now, however, it's responding to the robot's movements rather than the joystick's. The switch is awkward at first for the monkey—it's a bit like learning to type with the tips of two pens instead of your fingers. But by watching the cursor move on the screen, the monkey manages to control the robot with its brain signals alone.

When a monkey has learned this skill, it's ready for the third and final challenge: reaching plus grabbing. When the monkey moves the cursor to the dot, it now has to squeeze the joystick. Sensors measure how hard the monkey squeezes, and the computer screen displays the force as an expanding disc on the screen. By watching the disc expand, the monkey learns how to apply different amounts of force in order to get its reward. "She has to squeeze very precisely," says Nicolelis.

No one knew if a monkey could meet this challenge. Clearly, the electrode arrays could recognize commands to move the arm back and forth. But what if squeezing was controlled by neurons too far away from the electrodes to be monitored? Nicolelis put his faith in the orchestral nature of neurons—and he wasn't disappointed. The system could predict how hard the monkey was squeezing as well as it could predict where it was moving the arm. "The predictions," he says with pride, "are unbelievably good."

MUCH OF THE MONEY THAT FUNDS NICOLELIS'S research comes from DARPA, which in 2003 ratcheted up its long-standing interest in brain-related research to a new level by launching the Brain-Machine Interface Program (BMI) with an initial grant of $24 million divided among six different labs. "Imagine how useful and important it could be for a war fighter to use only the power of his thoughts to do things at great distances," says Tony Tether, the director of DARPA.

DARPA is famous for funding futuristic technology of all sorts, from the precursor to the Internet to the ill-fated terrorist futures market, which was attacked by Congress last summer. And according to former BMI program director Alan Rudolph, DARPA is well aware that there's no guarantee that the brain-machine interface research will ever make it onto the battlefield. "There's plenty of risk," he says. "If there wasn't a lot of risk, we wouldn't be involved."

In addition to the Duke research, DARPA's funding is helping other scientists pursue the linkage of brain and machine. At the University of Michigan, for example, it's supporting research that may eventually let humans control a more classic free-standing robot with their thoughts. The robot in question, known as RHex, can scurry around on six legs like a mechanical cockroach. Researchers are investigating how to teach rats to control the movement of RHex by pressing levers that steer the robot left and right. Then, in a process similar to the one employed at Duke, scientists will decode the brain patterns the rats use to press the different levers, and enable the rat to guide RHex by thought alone. Humans could someday use the same system to guide robots into collapsed buildings or across rough terrain on distant planets—or, DARPA hopes, into battle.

"YOU COULD IMAGINE THINKING ABOUT TALKING AND HAVING IT PROJECTED INTO A ROOM 2,000 MILES AWAY," SAYS CRAIG HENRIQUEZ. "I DON'T SEE THAT THAT WILL BE A PROBLEM."

Not all of DARPA's research is limited to manipulating machines. The brain does more than just move arms and legs—it also sends out complex commands that control muscles in the throat, tongue and mouth, creating speech. It's conceivable that a computer could learn to recognize those commands before they leave the brain and then translate them into words. "You could imagine thinking about talking and having it projected into a room 2,000 miles away," says Craig Henriquez. "I don't see that that will be a problem. It's very, very possible."

But Henriquez and other neuroengineers do see one particularly enormous roadblock in the way of DARPA's goal. According to Rudolph, it would be unethical to implant

electrodes in the heads of healthy soldiers. He's betting that future technology will be able to read brain signals without actually being inside the brain. Today the most common way to attempt this is with electroencephalography (EEG), in which electrodes are placed on the scalp. But EEG has a serious drawback: It can only pick up a blurry, weak signal compared to what electrodes nestled in the brain can record. People can learn to control a computer by altering their EEG patterns, but it takes months of training to type just a few letters a minute. That's not the sort of bandwidth you want for operating an arm. "To the best of our knowledge, that doesn't look very promising at the moment," Henriquez says.

Rudolph expects other approaches to pay off down the road. "Out at 20 years I have a lot of hope," he says. He points to a new kind of brain imaging known as magnetoencephalography, or MEG, that uses magnets to pick up electrical activity in the brain. MEG has the sort of speed and resolution that might make a brain-machine interface possible. In their current form, MEG scanners have to be protected by shielded walls and cooled with giant tanks of helium. But Rudolph speculates that room-temperature superconductors and other materials of the future will make MEG portable. "If you think about using superconducting magnets, maybe you could figure out how to make a helmet," he says. It might be possible in a few decades to design a helmet-like scanner that a soldier could wear along with a signal-processing supercomputer in his backpack. "At least DARPA's got some people looking at that," Rudolph says.

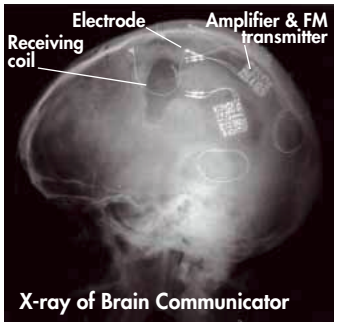
ONE OF THE WAYS YOU CAN tell that the monkey-controlled robot arms at Duke aren't science fiction is that sometimes they don't work. Some days the circuit boards fry, and other days the prospect of a reward of juice just isn't enough to motivate monkeys to play the game. For all the progress the researchers have made in recent years, the work is still hard, and there's a lot more hard work ahead before they see their research making a difference in people's lives.

Take the equipment itself. Wires sprout from the implants in a monkey's head and are jacked into a big signal processor, which in turn is plugged into a computer, which in turn is connected by cables to a robot arm. The Duke researchers will need to design a far more portable, unobtrusive system to make it practical for humans. They envision implanting an array of electrodes in key regions of a quadriplegic patient's brain. The signals detected by the electrodes would travel through a wire to a small processor embedded in the skull. From there, the processor would (CONTINUED ON PAGE 102)▶

More human-machine-interface research: **popsci.com/exclusive**

BRAIN-MACHINE BETA TESTING

Devices that harness brain or nerve impulses to help patients see, hear, move, and communicate are already available—though for now they remain relatively primitive.



FREEING "LOCKED-IN" PATIENTS

Neurologist Philip Kennedy has created a device to help totally paralyzed people control a computer cursor—and thereby communicate—with their thoughts. An electrode is surgically implanted into the patient's motor cortex, the movement-controlling part of the brain; the electrical signals it picks up are converted to software commands. Learning to use the device is a process of mental trial and error: Patients think about making various movements and watch how those thoughts affect the cursor; over time they learn which thoughts make the cursor move up, down, right and left. The brain data is sent to the computer via an FM transmitter, so no wires are necessary. So far six people have tried the $100,000 Brain Communicator, which is made by Kennedy's company, Neural Signals, in Atlanta, Georgia.

MACHINE-GENERATED VISION

Surreal-looking spectacles designed by ophthalmologist Mark Humayun of USC are helping blind people regain some sight. Artificial retinas are implanted in patients' eyes, then connected via wires to a small magnetic disc sutured onto the scalp. When a person dons the glasses, miniature video cameras pick up ambient light and turn it into electrical impulses, which are transmitted wirelessly to the magnetic discs and, from there, sent via the retinal implant to the brain's optic nerve, recreating the natural sight pathway. The device offers patients only fuzzy spots of light in a limited field, but Humayun hopes to improve resolution by determining which patterns of electrical pulses most effectively stimulate the optic nerve.

ELECTRONIC EARS

Cochlear implants, small electronic devices implanted under the skin behind the ear, have helped 59,000 people worldwide regain some hearing. In a healthy person, the inner ear converts sound waves into electrical impulses, which activate a nerve that sends sound signals to the brain. A cochlear implant mimics this natural process. The device's speech processor turns sounds picked up from a microphone into electronic bursts, which stimulate the auditory nerve to create the perception of sound in the brain.

BIONIC ARM

Three years ago utility-line repairman Jesse Sullivan touched a live wire, burning his arms so badly they had to be amputated. But a technique devised by biomedical engineer Todd Kuiken, director of amputee services at the Rehabilitation Institute of Chicago, enables Sullivan to control his artificial left arm with his mind alone. Kuiken grafted nerve endings from Sullivan's shoulder onto his chest muscle. When Sullivan thinks about raising his arm, his brain sends signals to the nerves that once initiated this function; the nerves spur his chest muscle to contract; and electrodes on the graft pick up those twitches and translate them into prosthetic-arm movements.—ELIZABETH SVOBODA

FROM TOP: COURTESY NEURAL SIGNALS; COURTESY COCHLEAR LIMITED

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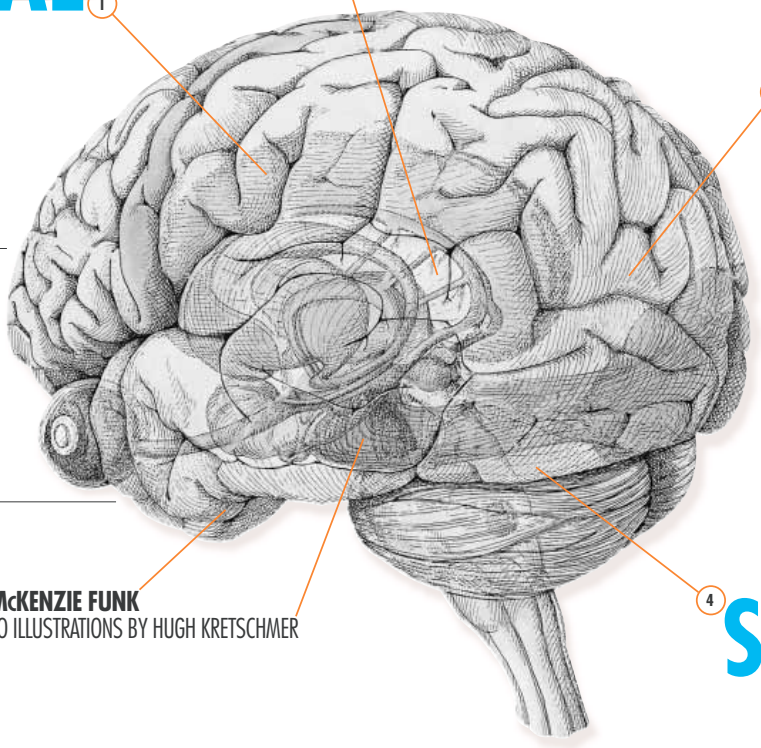
MENTAL MUSCLES OF STEEL



BY McKENZIE FUNK
PHOTO ILLUSTRATIONS BY HUGH KRETSCHMER

If you want to go from scrawny to brawny in 30 days, there is no shortage of miracle shape-up programs. But as impressive as beefy pecs and triceps may look, they won't help you cite the evidence for Einstein's special theory of relativity, rattle off pi to the 20th decimal place, or liberate yourself from the mass delusion that a penny dropped from the Empire State Building will gather enough speed to kill a hapless pedestrian. We at POPSCI believe the body part most worth stretching and toning—not to mention showing off—is the brain. You need to ensure that yours is flexible enough for creative problem solving, strong enough to run the occasional intellectual mini-marathon, and most of all, free of pseudoscientific flab. • You say the brain isn't really a muscle? Irrelevant. Recent studies indicate that it *can* bulk up: The hippocampus, a brain region responsible for thought and memory, produces new cells throughout a person's life, and some neuroscientists believe other parts of the brain also regenerate. The trick to keeping those new neurons? Use 'em or lose 'em. So take our scientific-aptitude quiz, learn the mental muscle groups, and get pumping.

ADDITIONAL REPORTING BY RENA PACELLA

(Step#)

1: HOW FIT IS YOUR BRAIN RIGHT NOW?

The first step in your regimen is assessment. It's time to apply the fat calipers to your gray matter. Gauge your mental conditioning with this PopSci quiz.

1

Which of the following could you hold in your hands, were it not inside a swirling cauldron of liquid helium that would freeze them off within microseconds?

a] A quark
b] A SQUID (superconducting quantum interference device)
c] A quasar
d] A phonon

2

The most contentious scientific debate surrounding global warming concerns:

a] Whether Earth's atmosphere is getting warmer
b] How much Earth's atmosphere is warming
c] To what degree man-made, not natural, causes are responsible for the warming of the atmosphere
d] Whether the consequences of significant global warming would be severe

3

Which is the most important tool currently used to enforce the nuclear test ban treaty?

a] Oscilloscope
b] Imaging satellite
c] Geiger counter
d] Seismometer

4

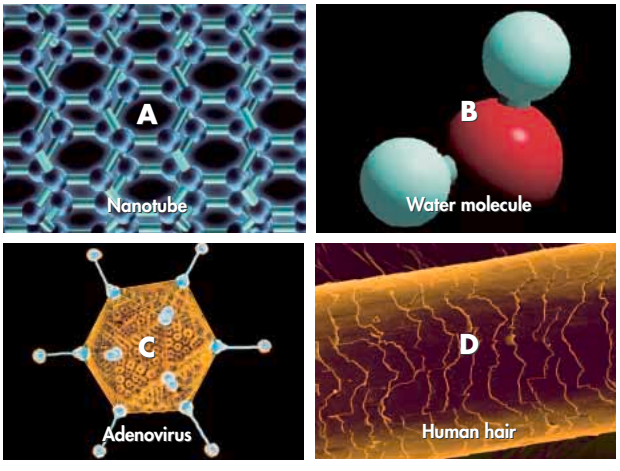
Which is true of *all* life on Earth?

a] It either takes in or emits oxygen
b] It watches reality TV shows
c] It consists of one or more cells
d] Its cells have distinct nuclei

5

Rank the images below in size order, from smallest to largest.

a] B, A, C, D; b] B, C, A, D; c] C, B, D, A; d] A, C, B, D



6

Which of the following has been found?

a] A tachyon
b] A bozino
c] Dark energy
d] A room-temp. superconductor
e] Element 118

7

Your wife is a guinea pig in a double-blind experimental drug trial. Who knows if she is getting the actual drug or a sugar pill?

a] Your wife
b] Your wife's doctor
c] Researchers overseeing the trial
d] b and c only
e] a and b only
f] None of the above

8

The most effective weather satellites continuously monitor one part of the Earth to track atmospheric changes. Engineers place them in _____ orbit.

a] Polar
b] Geostationary
c] Low-Earth
d] Sun-synchronous
e] Elliptical

9

If a Texan oil baron drilled through the center of the Earth and out the other side, then jumped into the hole, what would happen to him?

a] He would travel through, gathering speed; upon reaching the other side he'd launch hundreds of feet into the air
b] He would get enough of a boost from his Earth "fly-through" to launch into the outer solar system
c] He would speed up, slow down, then stop just as he reached Earth's center
d] He would speed up as he approached Earth's center, and slow down going away from it, forever oscillating between the two ends of the hole

10

Scientists scanning your genome find three mutations, in areas associated with Huntington's disease, alcoholism and a tumor-suppressor protein. This means:

a] You are predisposed to cancer and alcoholism, and you'll definitely get Huntington's disease
b] You'll end up a cancer-ridden alcoholic suffering from Huntington's disease
c] You have a predisposition to all three conditions
d] Nothing

11

Why does one bad apple spoil the barrel?

a] Bacteria migrate from the spoiled apple to the others
b] The spoiled apple releases a gas, ethylene, which causes the others to spoil
c] The spoiled apple attracts flies, which cause the others to spoil
d] That's just an old wives' tale

12

What is the relationship between the distance and the speed (redshift) of a distant galaxy?

a] Planck's constant
b] Hubble constant
c] Einstein's constant
d] No relationship at all

13

The Möbius strip pictured here has _____ side(s).

a] 1
b] 2
c] 4
d] 6

ANSWERS

1] B; 2] C; 3] D; 4] C; 5] A; 6] C; 7] C; 8] B; 9] D; 10] A; 11] B; 12] B; 13] A

WEBLINK: For expanded answers to quiz questions: *popsci.com/exclusive*

PREVIOUS SPREAD: MAKEUP BY ROBERT MOLTON; PROP STYLIST: MANUELA AMZALLAG; THIS PAGE, CLOCKWISE FROM TOP LEFT: KENNETH EWARD/BIOGRAFX/PHOTO RESEARCHERS; SCOTT CAMAZINE/PHOTO RESEARCHERS; JAMES CAVALLINI/PHOTO RESEARCHERS; GARY D. GAUGLER/PHOTO RESEARCHERS; BOTTOM RIGHT: AARON HAUPT/PHOTO RESEARCHERS

(Step#)

2: MIND GAINS: EXERCISES FOR THE IQ ORGAN

The first lesson from your neurobics instructor: Like any muscle, the brain can be limbered, shaped, and expanded. Here's a smart workout routine.

Train Your Cranium

Eight activities that build beefier brains.

COMPETITIVE SPORTS

In 2003, University College London researchers found that middle-aged people who regularly engaged in logic and memory games such as cards, bingo and chess performed better on short-term memory, mathematical reasoning and vocabulary tests than those who did not. Animal studies have shown that mentally enriching environments increase the likelihood that new brain cells will survive.

GYMNASTICS

After training rats to cross rope bridges and pencil-wide balance beams, and to master the see-saw, University of Illinois researchers found in a 1990 study that the coordinated rodents' neurons possessed 25 percent more connections to other brain cells than did those of treadmill-running rats.

BRAIN BREAKS

Duke University neurobiologist Larry Katz suggests getting up from your desk every hour for a change of scenery, even if it's just a trip to the water cooler. Unfamiliar sensory stimulation can increase the production of brain chemicals called neurotrophins, he says. In a 1996 study, Duke University researchers found that neurotrophins increase the size and complexity of dendrites—the tendrils on a neuron that receive and process information.

REFLEX TUNING

In 2003, researchers at Hong Kong's Chinese University concluded that playing the piano or another instrument significantly ➡

THE MENTAL MUSCLES

BICEPS 1

The prefrontal cortex does the heavy lifting: planning, and the control and storage of working memory.

ABDOMINALS 2

Broca's area, which gives language its syntax, is your intellectual core.

HAMSTRINGS 3

A seat of strength and flexibility, Wernicke's area imbues words with meaning.

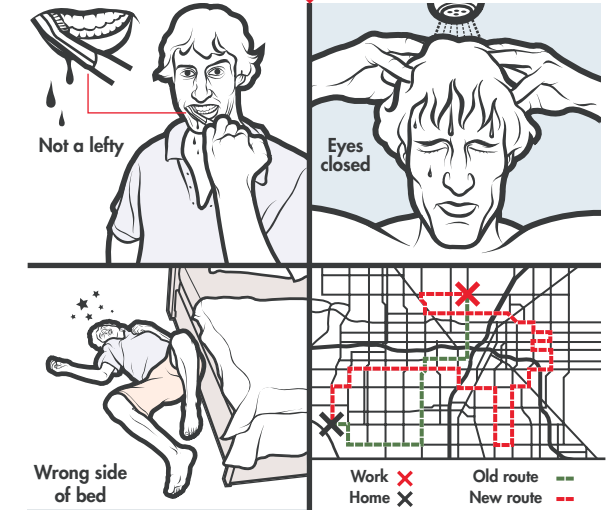
GLUTEALS 4

Cerebral power is found in the hippocampus, which processes information so it can be stored as memory.

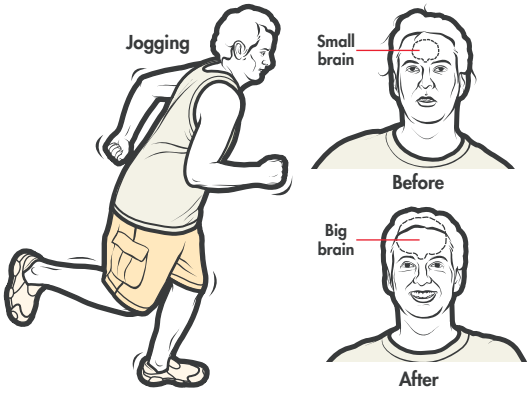
QUADRICEPS 5

For scientific sprints, the inferior parietal region provides mathematical, visual and logical reasoning.

MORNING WARM-UP Brush your teeth with the wrong hand. Take a new route to work. "Rarely activated pathways in your brain's associative network [will be] stimulated, increasing your range of mental flexibility," says Larry Katz, a Duke University neurobiologist.



AEROBICS Jogging may boost your ability to produce and maintain new brain cells. Researchers at the Salk Institute for Biological Studies reported in 1999 that running doubled the number of new brain cells that survived in adult rodents.



WEBLINK: For a brain-building diet menu, go to *popsci.com/exclusive*

INFOGRAPHIC BY JASON LEE

Illustrations by JAMESON SIMPSON

improved subjects' verbal memory. And after studying the leisure activities of almost 500 subjects over the course of 21 years, researchers at New York's Albert Einstein College of Medicine reported last year that playing a musical instrument is associated with a reduced risk of dementia.

BELLY CRUNCHES

"Two hydrogen atoms are walking down the road. One says, 'I've lost an electron.' 'You sure?' the other asks. 'Yes,' the first answers, 'I'm positive.'" Silly joke? Yes, but jokes are not *just* silly. A 1999 University of Toronto study showed that processing a verbal joke exercises cognitive abilities such as abstract reasoning and the use of long-term memory to reinterpret information in working memory. "If solving math problems in your head is like doing sit-ups, sharing jokes is like playing Frisbee," explains linguist David Gamon, coauthor of *Building Mental Muscle.*

REST BETWEEN WORKOUTS

Many studies suggest that when people fall into rapid-eye-movement (REM) sleep soon after learning something new, they are more likely to retain the new knowledge. And non-REM sleep may give inactive neurons a chance to repair damage caused by free radicals.

(Step#)

3: BOOST YOUR B.S. METER

Any trainer will tell you bad technique leaves you vulnerable to injury. Assess data with a healthy dose of skepticism, or you might pull a conceptual hamstring.

Spot the Junk

Words are powerful. Know how to use them correctly—and how to recognize jargon abuse.

RELATIVE VS. ABSOLUTE RISK

In 1995 thousands of women shunned oral contraceptives altogether after a study showed users of a recently introduced form of "the pill" were twice as likely to develop blood clots as were women taking older versions. Yet though the relative risk had indeed doubled, the increase in absolute risk was still tiny: Mortality reportedly climbed from 1.5 to 3 women per million. Meanwhile, in the months following the "pill scare," pregnancy rates in England and Wales jumped 7 percent over those for the same period the previous year.

WHO'S AN EXPERT?

Though a Ph.D. doth a doctor make, it doesn't always make an expert. Someone with a degree in oceanography is not automatically an authority on other topics. If people were more aware of the distinction, Nobel Prize–winning chemist Linus Pauling might not have gotten so much attention for recommending massive (and, it turns out, unhealthy) doses of vitamin C to treat everything from the common cold to cancer.

THEORIES

A disclaimer appeared in the biology textbooks of Cobb County, Georgia, in 2002: "Evolution is a theory, not a fact, regarding the origin of living things." In an absolute sense, this is true: Theories are proposed or accepted explanations based on assembled evidence. But in science, many theories—the theory of gravity, for example—enjoy near universal acceptance, based on the preponderance of evidence and the success of the model. The term "theory" does not imply doubts about a phenomenon's fundamental existence.

NANO-THIS, NANO-THAT

The boom in nanotechnology has led to a corresponding boom in nano-babble, rendering the prefix virtually meaningless. Take the recent fad of "nano-reefs" for small home aquariums: If they were actually sized in nanometers (billionths of a meter, or 10^{-9}), they'd be invisible to fish and their owners. What's next, pico-reefs? (Pico: 10^{-12}.)

NATURE VS. NURTURE

Is human behavior genetically predetermined or is it a result of environmental influences? Dogmatism on both sides of this "debate" has led to innumerable wrong turns, such as social Darwinism on one side and Soviet-era training programs on the other. The correct answer: We are products of both genes and environment, and understanding their complex interactions remains beyond our limited ken.

THE UNCERTAINTY PRINCIPLE

Werner Heisenberg's uncertainty principle, formulated in 1927, states that a small bit of matter—an electron, for example—cannot have both a well-defined position and a well-defined momentum at the same time. What's more, measuring one of those properties inexorably disturbs it—you can never know what an electron's position was before you measured it, because the act of measurement changes its position. Dime-store philosophers have had a field day with this

Werner Heisenberg

concept, using it to explain all manner of things. Pundits have been known to maintain, for example, that since the presence of a reporter exerts an influence on the people being observed, the journalistic endeavor is an example of the uncertainty principle. But in practice, Heisenberg's principle only applies to the subatomic world.

HULTON ARCHIVES/GETTY IMAGES

CLEAN YOUR FILTERS

Adhere to these basic principles at all times.

FALSIFIABILITY 1

In the 1930s Viennese philosopher Karl Popper stated that for a claim to be considered scientific, it must be conceivable to prove it wrong by observation or experiment. For instance, the statement "All elephants are gray" would be falsified by a single sighting of a pink elephant.

OCCAM'S RAZOR 2

When choosing between two competing theories to describe a phenomenon, medieval philosopher William Occam said, the simplest explanation is the best. Sure, maybe dachshunds exist on Earth not because of selective breeding but because aliens brought them here, but why make more assumptions than necessary?

SAMPLE SUFFICIENCY 3

The smaller the sample size, the less believable the findings. It's not enough to know that one in 10 study subjects developed adverse reactions to a medication; you must find out how large the pool was. If there were just 10 subjects and one fell ill, the significance is unclear. But if 100 out of 1,000 people got sick, you should avoid that pill.

PARADIGM-SHIFT PRINCIPLE 4

Philosopher of science Thomas Kuhn coined the phrase "paradigm shift" to describe rare, profound shifts in the way the world is understood by science: Earth at center of universe, Earth not at center of universe, for example. Paradigm shifts are rare, but use of the phrase to pump up an idea's importance is frequent. When a theory is trumpeted as revolutionary, part of a paradigm shift, this is usually a red flag for half-baked ideas; be skeptical. Everyday science is more evolutionary than revolutionary; established ideas are upended less often than media reports would have you believe.

DON'T BE A CARRIER

FIVE MISCONCEPTIONS EVEN YOU (YES, YOU) HAVE BEEN KNOWN TO SPREAD.

Are insidious tidbits of folk science lurking in the dark corners of your burgeoning brain? Begone!

FALSE: Toilets and bathtubs drain counterclockwise in the Northern Hemisphere, clockwise in the Southern Hemisphere. The Coriolis effect, caused by the rotation of the Earth, can be seen in the spin direction of weather systems such as hurricanes and cyclones. But in the short-lived flush of a toilet, the force is far too weak to have an impact; the direction of the water's rotation depends on the toilet's design.

FALSE: No two snowflakes are alike. Snowflakes are six-sided crystals composed of about 10^{18} water molecules, giving them unimaginable—but not infinite—potential for variation. In 1988, Nancy Knight, a meteorologist at the National Center for Atmospheric Research, discovered two identical snowflakes that had been collected from clouds above Wisconsin. The snowflakes apparently formed as conjoined twins.

FALSE: Humans use just 10 percent of their brains. MRI and PET scans show that a much larger portion of the brain is engaged during complex thought processes. And biologists scoff at the idea that we would evolve such an oversize brain—it eats up 19 percent of the fuel in our bloodstream—only to use but a fraction of it.

FALSE: A penny dropped from the Empire State Building would kill someone below. A few calculations tell us that a penny falling edge-on from the 1,050-foot-high observation deck on Floor 86 of the 102-story skyscraper would fall 500 feet before reaching maximum velocity: 57 miles an hour. This is about 1/10 the speed of a low-caliber handgun bullet—fast enough to hurt but, except in freak circumstances, not to kill. It's a moot point anyway: Thanks to updrafts, coins tossed from the observation deck generally land on the setback roof of Floor 80.

FALSE: The Moon appears larger when it's on the horizon because it's magnified by the atmosphere. This is an optical illusion. You can confirm that fact by taking photographs of the Moon as it tracks across the sky: It will appear the same size on the negatives, no matter where it is. The cause of the illusion is the subject of considerable debate, but the leading theory is that it's a classic Ponzo illusion: The brain mentally magnifies objects near the horizon because it interprets them as far away; thus the Moon appears larger to us when it is closer to the horizon.

(Step#)

4: BEEF UP ON THE FUNDAMENTALS

You've shed counterproductive and backward notions. Now it's time to absorb some of the basic knowledge that distinguishes the science literati from the ignorati.

Know the Major Milestones

The worldview-shaping experiments everyone should understand.

FLYING CLOCKS

The most celebrated experimental backing for special relativity came in 1971, when four cesium atomic beam clocks were flown around the world. Einstein's theory predicted the clocks would lose 40 ± 23 nanoseconds compared with reference clocks on the ground when circling the globe eastward, and gain 275 ± 21 nanoseconds when traveling west. The results: a loss of 59 ± 10 nanoseconds eastbound and a westbound gain of 273 ± 7 nanoseconds—evidence that time is not absolute but dependent on frame of reference.

PRIMORDIAL SOUP

Could life have emerged from the conditions on early Earth without divine intervention? In 1953 chemists Stanley Miller and Harold Urey of the University of Chicago filled a glass bulb with hydrogen, methane, ammonia and water to simulate the early atmosphere, then heated it with a Bunsen burner "sun" and battered it with electric "lightning bolts." After a few weeks, the bulb held a reddish-brown soup containing amino acids—the key building blocks of life. Scientists now believe ammonia may not have been present in the Earth's early atmosphere, but updated studies conducted sans ammonia have yielded similar results.

THE DOUBLE SLIT

In 1801, British physicist Thomas Young decided to test whether light is a wave or a stream of particles. He cut two slits in a screen, put a second screen behind it, then shone light through the slits. If light was a stream, it would appear as two dots on the second screen. But if it was a wave, it would spread out as it traversed the slits, creating an interference pattern—a series of light and dark bands—on the second screen. Young observed an interference pattern. More than a century later, researchers found that electrons also create an interference pattern, and concluded that particles can also act like waves.

"IT TAKES A COMPUTER SECONDS TO MULTIPLY TWO 400-DIGIT NUMBERS. RUN THE PROBLEM BACKWARD—ASK IT TO FIND THE TWO FACTORS—AND IT'LL TAKE MILLIONS OF YEARS."

MANJUL BHARGAVA,
MATHEMATICS,
PRINCETON UNIVERSITY

OH, THE PESKY QUESTIONS YOUR CHILDREN ASK

OF COURSE YOU KNOW THE ANSWERS. STILL, HERE'S A REFRESHER.

Q: Why is the sky blue?

THE SHORT ANSWER: Because of the way sunlight scatters when it hits the air.

THE FULL ANSWER: The sky appears blue because of a phenomenon known as Rayleigh scattering. When sunlight passes through the atmosphere, the longer yellow, orange and red wavelengths (in the 570-to-700-nanometer range) pass through air molecules virtually unobstructed. But blue (475 nm) and violet (400 nm) light is scattered by air molecules in all directions.

Q: Why is the ocean salty?

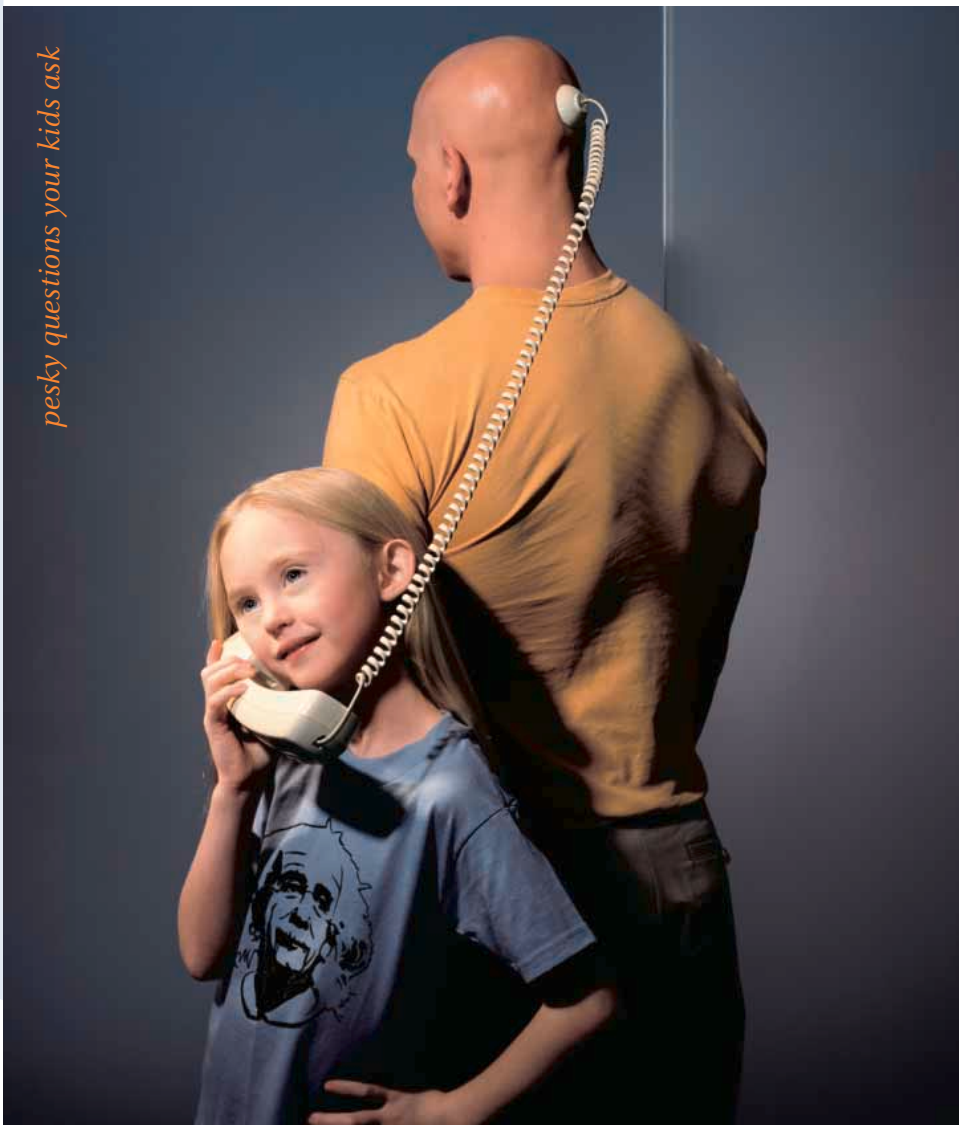
THE SHORT ANSWER: Because sodium and chloride, the two ingredients in salt, flow into it.

THE FULL ANSWER: Rivers erode sodium-containing rock and carry it out to sea; undersea volcanoes spit up chloride. Sea creatures absorb many of the other minerals found in the ocean, such as calcium and sulfur, but have little use for sodium or chloride, so the salt gets concentrated.

Q: Is it hot in the summer because the Earth is closer to the Sun?

THE SHORT ANSWER: No.

THE FULL ANSWER: The Earth is actually farthest from the Sun in July, closest in January. Seasons occur because of the 23.5-degree tilt of Earth's axis. In summer the axis is pointed toward the sun, so days are longer and the energy hitting any one spot is more concentrated.



pesky questions your kids ask

BUGSTUNT

Here's a trick that's guaranteed to wow your camping buddies: Listen for a cricket, count the number of chirps the insect makes in 15 seconds, then add 40, and—voilà!—you've got the ambient temperature in degrees Fahrenheit.

(Step#)

5: SHORTCUTS TO MENTAL SHARPNESS

Feeling sore and achy? Ready to bag your workout regimen? Wait! These exercises will help you reach your fitness goals with the barest minimum of effort.

MNEMONICS

The cheater's guide to scientific erudition.

1. **MY VERY EASY METHOD: JUST SET UP NINE PLANETS**

   The first letter of each planet's name, in increasing distance from the Sun: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune, Pluto.

2. **CHNOPS**

   From this alternate spelling of a favorite liqueur, the six elemental building blocks of life: carbon, hydrogen, nitrogen, oxygen, phosphorus, sulfur.

3. **ROY G. BIV**

   The name of this nonexistent person holds the first letter of each color in the visible spectrum, in order: red, orange, yellow, green, blue, indigo, violet.

4. **OH, BE A FINE GIRL, KISS ME!**

   The first letters of these words provide the stellar classifications, from ultrahot O stars to cool M stars. More PC version: Oh, Be a Fine Guy, Kiss Me! Better yet: Only Boys Accepting Feminism Get Kissed Meaningfully.

5. **SIR, I SEND A RHYME EXCELLING / IN SACRED TRUTH AND RIGID SPELLING / NUMERICAL SPRITES ELUCIDATE / FOR ME THE LEXICON'S DULL WEIGHT**

   Encoded in second-rate poetry: the transcendental number pi to 20 places. Just count the number of letters in each word: three, one, four, one, five, nine . . .

Couch Potato Science

Seven movies for the, er, passive learner.

The Fly (1958)

This outlandish story of a human-fly hybrid is not beyond the pale: Scientists have injected multiple human genes into flies to study diseases, and strange "mosaic" creatures have been created, including a sheep-goat with wool and hair interspersed in its coat.

2001: A Space Odyssey (1968)

A team of astrophysicists helped director Stanley Kubrick add gravity to his sci-fi fantasy. The sound of silence is overpowering, as it should be—in the relative vacuum of space, there's no medium to transmit sounds. And the movie's space station rotates on its axis, capitalizing on centrifugal force to keep its astronauts' feet on the floor—an idea first proposed by Russian scientist Konstantin Tsiolkovsky in 1920.

Jaws (1975)

Real sharks don't hold grudges, and they certainly don't make repeat assaults on specific boat captains, no matter how crusty. But biologists celebrate *Jaws* because a bearded Richard Dreyfuss acts and talks like a true scientist, clinical even when contemplating the shredded body of the first victim: "It indicates the non-frenzied feeding of a large *Squalus*, possibly *longimanus* or *Isurus glaucus* . . ."


Gattaca


2001


Jaws


The Fly

Boys from Brazil (1978)

This sci-fi classic, featuring an army of Hitler copies, paints a remarkably accurate picture of cloning methods for the time. A hitch: Just because the clones are genetically identical to Hitler doesn't mean they'll act like him.

Contact (1997)

Based on the book by Carl Sagan, this film hews reasonably to fact. At Sagan's request, astrophysicist Kip Thorne conceived the story's greatest conceptual leap: Ellie Arroway's 18-hour, 26-light-year wormhole journey to Vega. Thorne then published a *Contact*-inspired paper about these theoretical tunnels in space-time in the prestigious journal *Physical Review Letters*.

Gattaca (1997)

This futuristic vision of genetic segregation is both far-out and near at hand. Already, human embryos that are created in the lab can be scanned for genetic defects so that only healthy ones will be implanted in the mother's womb. But it'll be years before we can build security systems that grant or deny entry based on an instantaneous DNA test.

Titanic (1997)

OK, so Leo's motor skills are impossibly intact after sloshing through a ship full of ice water. But director James Cameron compensates for that with near-perfect physics in his depiction of the sinking vessel. Realistically, gravity's downward force is barely larger than the upward-acting buoyancy of trapped air pockets, causing a gentle descent, not the typical Hollywood maelstrom.

FROM TOP: EVERETT COLLECTION; MGM/NEAL PETERS COLLECTION; UNIVERSAL/NEAL PETERS COLLECTION; 20TH CENTURY FOX/EVERETT COLLECTION

BRAINFOOD?

U.S. consumers spent more than $210 million on supposed brain-boosting supplements in 2002.

GINKGO BILOBA:
$130 million

MULTIVITAMINS:
$33 million

COMBINATION HERBS:
$22 million

PLANT AND FISH OILS:
$14 million

OTHER SINGLE HERBS:
$12 million

Source: Nutrition Business Journal

"THE OZONE LAYER IS ONLY AS THICK AS TWO STACKED PENNIES. A 'MINOR' CHANGE IN THE SYSTEM CAN HAVE A MAJOR EFFECT."

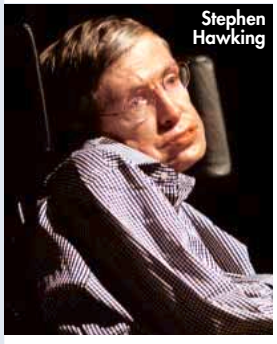
AZADEH TABAZADEH
ATMOSPHERIC SCIENCE,
NASA AMES RESEARCH CENTER

SCIENCE: THE CLIFFS NOTES

HOW TO FAKE IT WHEN THE CONVERSATION GOES OVER YOUR HEAD.

SUBJECT: **TIME TRAVEL**
WHAT TO SAY: **"I think Stephen Hawking's chronology protection conjecture is dead on."**
WHAT YOU JUST SAID: **Time travel into the past isn't impossible according to classical physics and the general theory of relativity, but Hawking proposed that quantum-level effects conspire to always prevent it and its associated paradoxes. His most famous science-fiction-writer-befuddling question: If time travel is possible, why haven't we been overrun by tourists from the future?**

SUBJECT: **SUPERSTRING THEORY**
WHAT TO SAY: **"The problem is, no one's ever seen a supersymmetric particle."**
WHAT YOU JUST SAID: **Superstring theory—the leading candidate for a "theory of everything" that can describe gravity, electromagnetism and the strong and weak forces with a single set of rules—posits the existence of a slew of undiscovered "supersymmetric" particles, such as selectrons and squarks. But physicists still haven't seen evidence of them.**


Stephen Hawking

SUBJECT: **EXPANDING UNIVERSE**
WHAT TO SAY: **"Isn't it wonderful that after all these years, Einstein's greatest mistake may not have been so great?"**
WHAT YOU JUST SAID: **Straining to balance equations in his relativity theory, Einstein decided in 1917 that an unknown cosmological force was counteracting gravity—an idea he later called his greatest blunder. Then in 1998, two studies showed that the universe is accelerating—and hence that some new force (now called dark energy) must indeed be acting against gravity.**

SUBJECT: **TACHYONS**
WHAT TO SAY: **"But wouldn't tachyons violate causality?"**
WHAT YOU JUST SAID: **This putative class of faster-than-light particles has never been observed experimentally, but physicists keep looking. And there's another problem: According to special relativity, tachyons would turn time on its head. If you used tachyons to send a message from Point A to Point B, certain observers would see the message being received before it had been sent. Effect would precede cause: a violation of causality.**

SUBJECT: **HUMAN GENOME PROJECT**
WHAT TO SAY: **"30,000 genes can't be enough to generate the complexity of a human being."**
WHAT YOU JUST SAID: **Before the Human Genome Project published maps of the human genome in early 2001, researchers expected that the full complement of human DNA would contain as many as 100,000 genes. The surprise figure—roughly 30,000—means that humans possess only slightly more genes than the lowly wall cress plant (25,000).**

// THE BASIC WEB //

WHERE TO TURN ON THE NET FOR SCIENTIFIC BOLSTERING.

howstuffworks.com: A great basic resource for everything from car engines to CAT scans.
math.ucr.edu/home/baez: This physics reference covers everything from quarks to kinetic energy. But the real gem is the Crackpot Index, useful for evaluating "revolutionary" physics.
nap.edu: Dull? Perhaps. But with browsable online editions of more than 3,000 books from the National Academy of Sciences and its ilk, this is a dense Web cluster of trustworthy science.
quackwatch.org: Dedicated to fighting medical frauds, Quackwatch identifies misleading health information on the Internet—and provides a handy, seven-step method for spotting bogus science.
scienceworld.wolfram.com: The self-proclaimed "best resource for math and science" on the Internet is a simple and reliable quick-reference guide that doesn't gloss over details.
wikipedia.org: Collaborative, open-source Wikipedia is the encyclopedia equivalent of a peer-reviewed journal—except that *anyone* can post a definition, or correct an existing posting.

AFP/CORBIS

(Step#)

6: STRUT YOUR STUFF

Before you got fit, you wouldn't have dared meet geeks and eggheads on their own turf. Now these are your people. So chat, flirt, and don't forget to flex.

"OVER BILLIONS OF YEARS, EVEN PLANETS DEFORM AS IF THEY'RE FLUIDS—IT'S A QUESTION OF TIMESCALE."

MICHAEL MANGA, EARTH SCIENCE, UC BERKELEY

Top Nerd Bars

Science abs pumped? Here's where to show them off.

MIRACLE OF SCIENCE, CAMBRIDGE, MA

GEEK FACTOR: Harvard and MIT profs and local biotech workers lounge at fireslate tables surrounded by microscopes and other lab paraphernalia. A giant, wall-mounted menu is modeled after the periodic table of elements.
GUARANTEED PICK-UP LINE: "Want to experiment with coupled-wave theory?"

OUTPOST TAVERN, HOUSTON, TX

GEEK FACTOR: Johnson Space Center astronauts have been knocking back brews here for more than 20 years. Every April 12 is Yuri's Night—celebrating cosmonaut Gagarin's historic jaunt into space.
GUARANTEED PICK-UP LINE: "Ever wonder what Earth looks like from the back of a Ford Explorer?"

AMIGO'S, PASADENA, CA

GEEK FACTOR: Every other Wednesday is Quantum Margarita Night, when physicists from Caltech and NASA's Jet Propulsion Lab meet to drink strawberry margaritas and talk shop.
GUARANTEED PICK-UP LINE: "What's a nice girl like you doing in an *n*-dimensional space like this?"

DNA LOUNGE, SAN FRANCISCO, CA

GEEK FACTOR: A "no Microsoft zone," this dance club equipped with Linux-based Internet kiosks and live webcasts offers its source code to patrons for free.
GUARANTEED PICK-UP LINE: "Every now and then two numbers meet, link, and become forever binary."

CELTIC BAYOU, REDMOND, WA

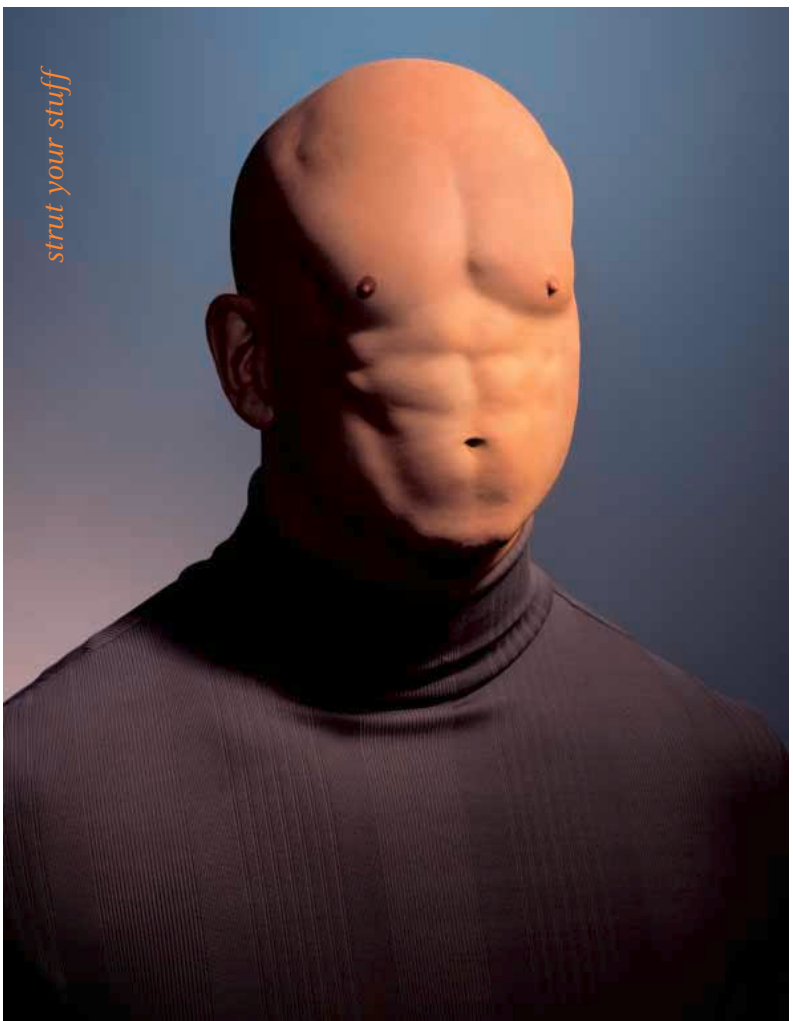
GEEK FACTOR: This Irish pub features a wireless network and lunch discounts for Microsoft employees.
GUARANTEED PICK-UP LINE: "Hey, nice GUI. Want to integrate our matrices?"

SCI-FI CAFE, NEW HAVEN, CT

GEEK FACTOR: Yalies meet here to sip Hale-Bopps (a nonalcoholic mix of cranberry, orange and lime juices) or Saturn Hemisphere martinis.
GUARANTEED PICK-UP LINE: "If you were a phaser, you'd be set on 'stunning.'"

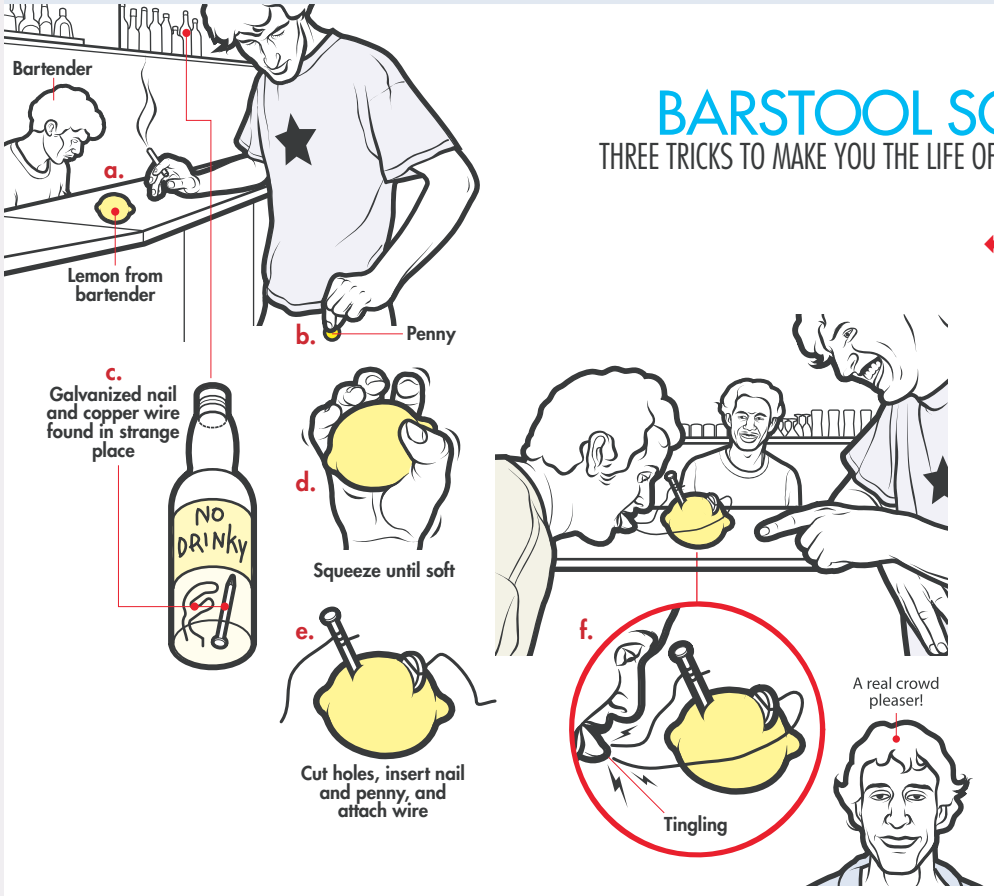
KOA HOUSE GRILL, KAMUELA, HI

GEEK FACTOR: The Koa House is so close to the W.M. Keck Observatory that local astronomers refer to its lounge as the Koa boardroom.
GUARANTEED PICK-UP LINE: "I've heard Uranus rotates on its side. True?"



BARSTOOL SCIENCE

THREE TRICKS TO MAKE YOU THE LIFE OF THE NERD PARTY.



Lemon Battery

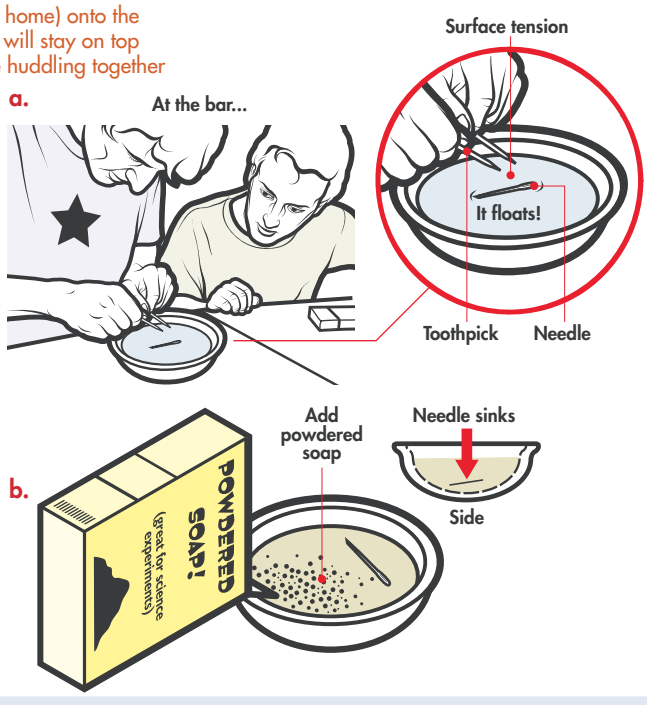
Grab a penny, bum a lemon from the bartender, and wrassle up a galvanized nail and some copper wire. Squeeze the lemon until it's soft, then make two small cuts. Insert the nail and penny in the holes, attaching separate lengths of wire to each. Make the guy next to you touch his tongue to the free ends of the wire. It'll tingle. **The science:** In this makeshift voltaic battery, the zinc-coated nail is the negative electrode and the copper-coated penny the positive. The electrolyte is lemon juice, whose positively charged hydrogen ions react with zinc: $Zn + 2H^+ \rightarrow Zn^{2+} + H_2$. The penny helps channel electrons through the circuit and your neighbor's tingly tongue.

Möbius Strip

Mark the bottom-right and top-left corners of a long, thin strip of paper with X's, and the other two corners with O's. Twist and roll the paper such that X meets X and O meets O, and tape the ends together. Ask the drunk next to you how many sides this strip has. If he says two, draw a line along the middle of the strip until you're back where you started to show him that a Möbius strip is one-sided. Now punch a hole in the strip and ask: "If there's only one side, where does the hole lead?" Raise your eyebrows meaningfully. **The science:** Welcome to the weird mathematical field of topology. The hole in the strip suggests how wormholes—hypothetical shortcuts between distant points in the universe—could work.

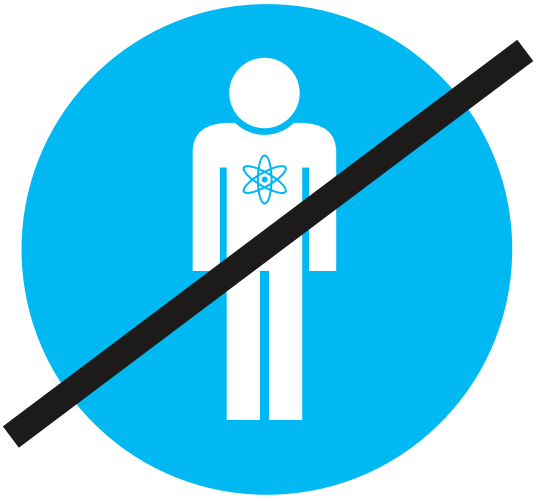
Floating Needle

Using a couple of toothpicks, lower a steel sewing needle (brought from home) onto the surface of a bowl of water. It will stay on top thanks to surface tension, the huddling together of polarized water molecules due to hydrogen bonding. Next, get some powdered soap from the bathroom, sprinkle it into the bowl, and watch the needle sink to the bottom. **The science:** Soap has an electrically charged carboxylic-acid structure at one end of each molecule. These structures vigorously attract water molecules, pulling them from their mutual attractions and thereby breaking the surface tension.



Illustrations by JAMESON SIMPSON

It Doesn't Take a Rocket Scientist



Architect **Constance Adams** was a certified outsider within NASA's classically hardcore engineering culture when she started working there in 1997. In the seven years since, she has taken a whirlwind tour through the worlds of Mars exploration, mission science, space "human factors engineering," and the conceptual design of vehicles like the X-38 and the Orbital Space Plane. And she's developed a unique perspective on what NASA—and the country—need to do to set the space agency back on the right course. Here's her prescription. • Photographs by Brent Humphreys

Good news/bad news: The Columbia disaster has brought renewed attention to spaceflight, but so far, much of that attention lacks any real clarity of understanding. Rather than train the spotlight on our space program's fairly desperate need for both funding and vision, Columbia seems to have ushered in open season on NASA. Congressional hearings rehash hoary old debates about the value of our space program, chastizing the agency and calling for hastily conceived reforms. Many people with whom I've been privileged to work closely inside and around NASA share my concern that we may be on the verge of making irreversible decisions that future generations will regret. The Bush administration's announcement of a redirection of the space program, which was pending at press time, may address some issues raised by the Columbia investigation, but it's sure to miss some more fundamental problems, problems that are deep, structural and, if you believe in the value of space exploration, critical to our place in the 21st century.

THE "KNOWLEDGE CAPTURE" PROBLEM

In a decade of professional practice in large-scale urban, medical and institutional architecture, I have always started any new project with an investigation into institutional memory. I need to know how previous programs arrived at their final designs before I feel qualified to propose next-generation solutions. But almost immediately after I arrived at NASA in 1997, I learned that trying to gather such information in the 18,000-employee, 16-facility agency was tough going. The standard response when I requested data on old projects was a quizzical stare. As I began working on the design of the TransHab, an inflatable habitat for long crew expeditions like a Mars mission, I realized I needed solid dimensions for Skylab interiors and furnishings. Those drawings always seemed archived somewhere beyond reach. Eventually I just went over to the Skylab 1G Trainer at Space Center Houston's visitor center with a tape measure and some gum-soled shoes. I'm sure it gave a few tourists a real thrill to come into the Trainer exhibit and find me dangling from the ceiling.

In its collective knowledge and in the individual history and experience of its employees, NASA is a unique, living national treasure of know-how. But the know-how is frustratingly hard to access. Think of NASA as a computer with virtually no interface and rusty hard drives. Furthermore, its storage media are getting old: The only American men and women who have ever successfully designed and flown a spacecraft are retired or retiring; many others are no longer with us. Without a conscious program of mentoring within the organization, this knowledge is only intermittently and imperfectly transmitted to new generations of engineers and scientists. The result is that young engineers constantly redesign programs without being aware that previous designs for the same item already exist. They may thereby introduce a new problem or layer of risk, and this gets to the heart of the matter: As has been pointed out with regard to the Columbia disaster, there is within NASA a creeping lack of interest in real expertise. When any bureaucracy supports its mandarin culture over real intellectual capital—precisely what the board that investigated the Columbia disaster accused NASA of doing—it becomes stagnant rather than productive.

What NASA needs to do is establish an active mentoring program, whereby new hires are apprenticed to senior technical staff for a certain period of time; allow real engineers (not a recruiting team) to select graduate students for internships; and open a direct line between each project office and the central archives so that records of a team's decision-making process and detailed information on the final product are readily available.

But even these measures won't fully address the squandering of hard-won expertise, because the problem isn't confined to a failure of archiving. Any team that takes on a project is going to amass some truly valuable information. What happens then? At NASA, more often than not, project teams get disbanded and people with unique knowledge get poached away. Whereas other industries actively encourage the capture of knowledge in team environments—where the sum of knowledge is measurably greater than any individual effort—NASA seems unaware of the value of a stable, successful team and its ability to store, transmit, and use accumulated knowledge.

Our TransHab project team was ultimately able to get far enough in our testing and design to warrant what NASA calls an Independent Technical Assessment. In our case, this meant that NASA invited some of the old guard (including Charlie Feltz, chief engineer of the X-15; Chris Kraft, Mission Control pioneer and former Johnson Space Center director; George Jeffs, chief engineer on the space shuttle; and Johnson Space Center director George Abbey) to come out of retirement for a few days and formally assess the project. Such events seem relatively rare, yet in their intensity, methods and relentless pace, they hearken back to the early days of human spaceflight. The panel picked apart our reasoning and process just as surely as they tackled the technologies we had developed, and in so doing taught us how they themselves had pulled off the feats that made NASA great. Finally earning their approval after three days of vigorous work felt like the greatest achievement of my life.

Our final task, a six-week feasibility study on a different vehicle, was particularly exhilarating. By then we had absorbed all the questions and critiques from our advisers, and we started using their assessment tactics on one another. Now able to anticipate how our teammates would work, we came up with solutions that produced a truly elegant spacecraft.

And then we were disbanded. The dissolution of a project team that could produce a vehicle like TransHab on a shoestring budget is a great loss to the space program, not necessarily because any one of us is particularly special but because the team's accumulated knowledge represented nearly 40 years of spaceflight, the results of thousands of failures large and small. As Charlie Feltz told us, "engineers learn by failures. We've had a lot of failures."

Here's an idea: Why don't we borrow a pattern from design disciplines like architecture and industrial design, and develop "studios" populated by specialists from different fields—and when one project is done, *try keeping the team together.*

ICON: CHRISTOPH NIEMANN

OUTSIDER IN
Constance Adams stands before the Lunar Landscape section of Johnson Space Center's Starship Gallery. "I am one of the people who live in the boundary world between the space 'insiders' and the general educated public," she says.

THE "VISION CAPTURE" PROBLEM

NASA has a bigger problem than the knowledge-capture failure noted above: It has an institutionalized inability to capture vision. Post-Columbia, more Americans than ever have sensed this. "The space shuttle is unsafe, and we should stop flying it now," they say. "Why hasn't NASA developed anything to replace it?" It's a question that insiders ask as well. Most folks I've talked with in advanced engineering at NASA agree that the United States should have started building a next-generation shuttle in the mid-1990s, when Columbia and Discovery, the oldest shuttles, had reached their 10-year minimum life span. Max Faget, the chief engineer on the Mercury, Gemini and Apollo capsules, told the press last spring that it's a shame we haven't built a new spacecraft. With today's technologies and materials, we could make something much lighter and cheaper to fly and maintain than the shuttle.

It's not that NASA hasn't taken first steps toward developing a meaningful shuttle replacement—it's just that those steps invariably ended in a stumble. In the past three years, we've seen three separate programs proposed: the Second Generation Reusable Launch Vehicle (2GRLV), the Space Transportation Architecture Study (STAS) and the Space Launch Initiative (SLI). Each set forth overarching new strategies and architectures for human spaceflight that differed only slightly in scope. And each took a few toddling steps before the rug was pulled out. (Just three months before the Columbia accident, NASA diverted the SLI's $4.5 billion budget to help cover the needs of the shuttle and International Space Station programs.)

Now NASA is pushing a new program dubbed the Orbital Space Plane, which is widely touted as the plan to replace the

space shuttle. There is some confusion in this, since not one of the specifications of the Orbital Space Plane as currently envisioned could match the shuttle's capacity for crew support, nor its sheer power as a high-tonnage launch system.

To be sure, the OSP's requirements have descended directly from aspects of the three major initiatives mentioned above. But the OSP inherited just three components—for crew return, crew transfer, crew rescue—from complex systems that included launch platforms, light- and heavy-lift capabilities, vehicles for science payloads, cargo and exploration support, as well as the more ordinary, everyday support features for the ISS and its crew.

The inherited crew-transfer component had originally been conceived as one element of a broad, upgradable, long-term system, capable of carrying up to 10 passengers for full-up missions, and of active docking and orbital operations. As the OSP emerged last spring, it had fewer and fewer of those characteristics, until it became the pint-size version of a passive-crew-rescue vehicle envisioned today. A competition that was already under way—and from which several potential bidders had been eliminated—had been radically rescoped to meet immediate political goals within soaring budgetary shortfalls.

Why? Probably because there wasn't enough vision or commitment behind the shuttle-replacement plans to begin with.

What should have happened? NASA should have continued to develop the architecture for a true shuttle-replacement system and requested that the crew-transfer part of the program be fast-tracked; or, if that approach didn't seem responsive enough to the needs of the day, the table should have been swept clean and the process started afresh with a new set of problems on the boards.

One result of the retrofitting rush that gave us the OSP initiative is that the smaller, more risk-taking and often more dynamic companies were knocked out of the bidding before it even got going. Now that the OSP only need accommodate four people and ride atop an expendable, commercial launcher, it's beginning to look to me an awful lot like the various vehicles being developed by the contenders for the X Prize. Yet by the nature of the bidding, none of those 25 teams has any chance of bringing its space-plane concepts to OSP. What would be the result if NASA were to enable this sharing of ideas by inviting competition and reopening the field of design solutions? Most likely cost savings and superior design.

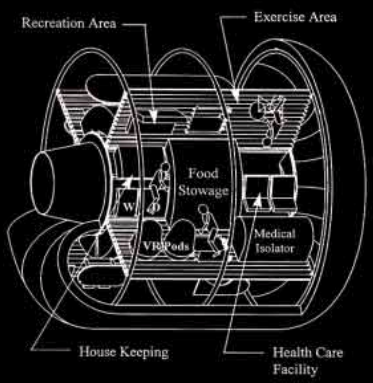
Here is the recent history of shuttle-replacement systems in a nutshell: Propose and study a succession of systems, then fight to keep a single subcomponent going when the budget is slashed—without considering its long-term compatibility with the rest of the human spaceflight program. All these separate pieces somehow need to be made to fit the next wave of big-picture plans. And the Big Plan bogey keeps shifting—it's anyone's guess how the OSP will fit into the Bush Administration's new space initiative. When the components' utility in a new scenario is hard to prove, they get shot down—no matter how much effort has already gone into their development. They become ideas that go back on the shelf, only to get reinvented by future generations.

More TransHab redesign sketches at **popsci.com/exclusive**

1 PRE-EXISTING DESIGN

A group of structural engineers had drawn up the initial designs before the architects got involved. There was no up or down in these plans—astronauts in different areas would be inverted relative to one another. Besides being disorienting for the crew, this design also constituted an inefficient use of the total volume.

ADAMS:
"It was clear that the horizontal variation really wasn't going to do it. They were having a hard time even drawing a picture that showed both sides, where one person would be upright and the other would be upside down. If you can't imagine it, don't design it."

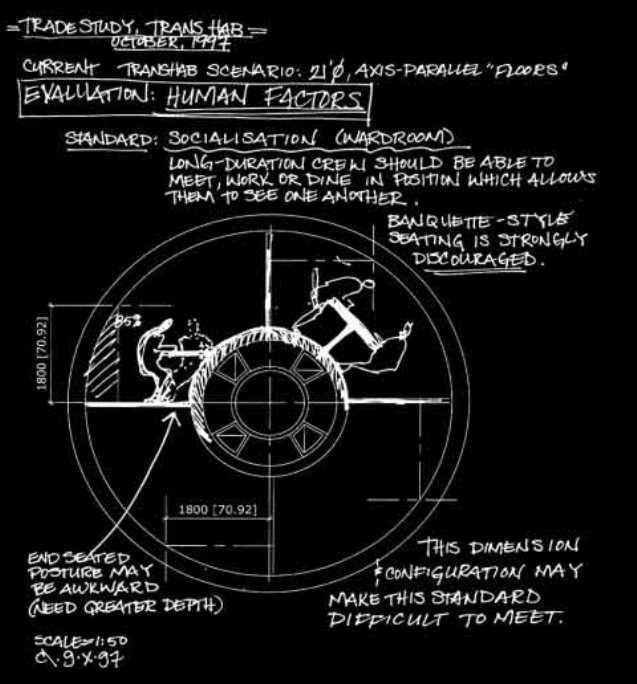


Crew Support Quadrant

2 ADAMS'S CRITIQUE

Adams first worked to improve the original proposals, rearranging certain elements to suit the crew. Here, she shows two potential seating arrangements meant to enhance socialization. Even these layouts, however, would be too cramped and awkward.

ADAMS:
"When you're buying a family home, you don't want one where the dining room is only four feet wide."



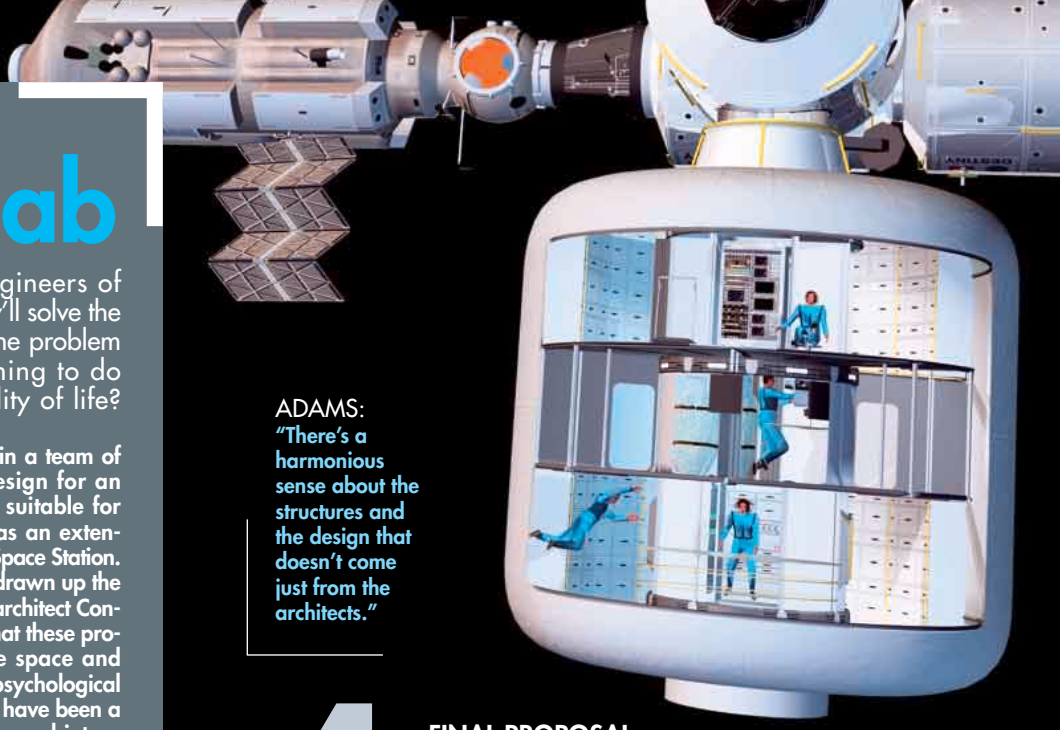
CLOCKWISE FROM TOP RIGHT: BOB SAULS/FRASSANITO & ASSOCIATES; COURTESY NASA (3)

A CASE STUDY

TransHab

Give the crackerjack engineers of NASA a problem and they'll solve the hell out of it. But what if the problem they're solving has nothing to do with the astronauts' quality of life?

In June 1997 NASA brought in a team of architects to work on the design for an inflatable habitation module suitable for long-duration spaceflight or as an extension node on the International Space Station. NASA engineers had already drawn up the initial plans for TransHab, but architect Constance Adams demonstrated that these proposals made poor use of the space and would likely have a negative psychological effect on the crew. What could have been a devastating clash of cultures turned into a smooth marriage: The architects respected the engineering constraints, and the engineers began considering the critical human factors. In the end, the collaboration led to an ingenious space module and a model for future projects.—GREGORY MONE



ADAMS: **"There's a harmonious sense about the structures and the design that doesn't come just from the architects."**

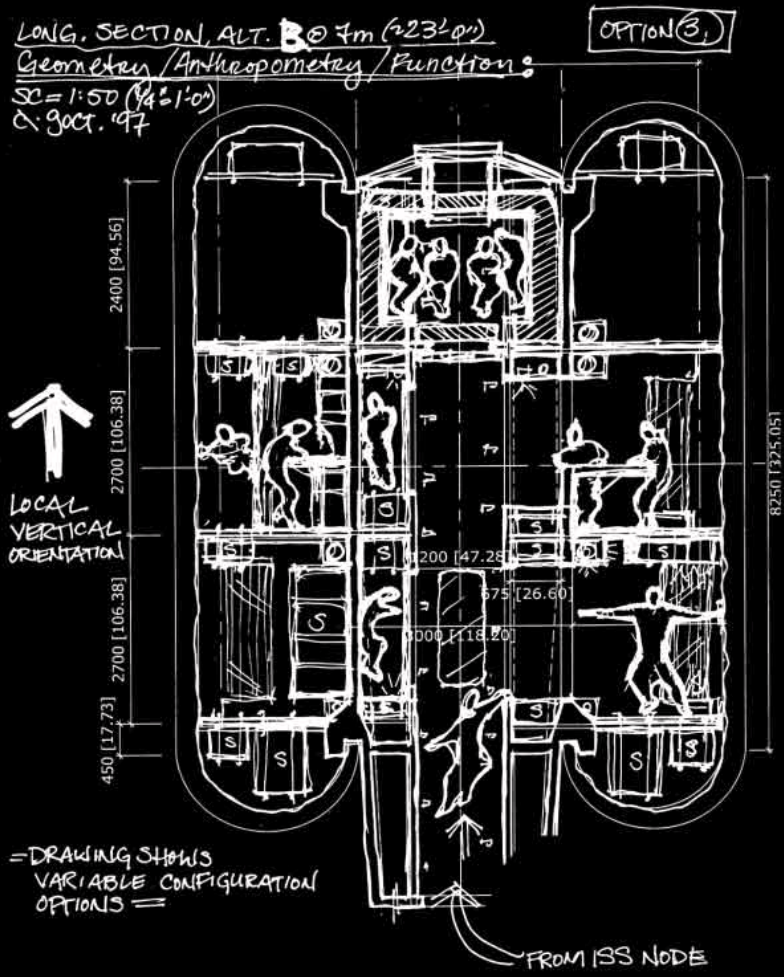
4 FINAL PROPOSAL

The final design incorporated the changes suggested by the architects—the astronauts can move, work, exercise, sleep, and socialize freely—while also adhering to the engineering requirements. Adams contends that the final product was a success because each team internalized the guiding principles of the other.

3 REDESIGN: ROOM TO MOVE AND BREATHE

Adams factored in the two possible roles for TransHab: as a long-duration spacecraft and as an ISS extension node. She included a central core in which crew would travel to and from the ISS, a radiation shelter surrounded by potable water for a Mars flight, social and meeting rooms, vertical sleeping quarters, and enough space within the rooms for astronauts to stretch out their arms. Another of Adams's goals was to design a space that could house a total of 12 astronauts—six ISS and six Mars-bound crew—for the pre-mission periods when TransHab is docked.

ADAMS: **"What are these guys going to need to do during their six-month trip to Mars? With a horizontal scheme, you couldn't draw all these people doing all these things. Here, every single cubic meter of the volume is being utilized."**



THE "GREAT PROJECTS" PROBLEM

As many wise space pundits have said in recent times, NASA needs a challenge. Without a broad, external challenge backed up by consistent support and political will, it seems unlikely that the kind of heroic effort and vision that characterized the first decade and a half of NASA's existence will re-emerge.

What these pundits are really bemoaning is the lack of *consistent* vision, which ultimately stems from an issue that is much larger and older than NASA, and whose nature is of profound interest to architects and master planners, because it has a powerful effect on the kind and scale of projects we may build. Simply put, undertaking what we call Great Projects—projects of a large, public scope whose completion will require 10 years or more—is very difficult in a democracy.

In an autocratic society, it is common for rulers to make their mark by commissioning massive works such as roads, fortifications, elaborate religious or magisterial structures. And once the order has been given, it becomes a goal of the government to see that the works are completed, and in such a way that they stand to the glory of the rulers who brought them into being.

Under our democratic system, it is inherently impossible to ensure that any long-term program will receive funding, or remain consistently funded, from year to year. From this perspective, the four terms of FDR's nearly unchallenged administration may well have been critical not only to the establishment of the Works Progress Administration but, more important, to the completion of many individual WPA projects.

Certainly in today's politically polarized environment, a shift from a Democratic to a Republican administration (or vice versa) often portends the cancellation of many unfinished public projects—for example, the several major human spaceflight programs axed before the end of February 2001, less than a month after George W. Bush's inauguration.

When budgets are cut, the public needs to be aware that this will result in the loss of valuable programs and personnel. But for those losses to matter to the American people, a truly inspiring vision for NASA must be articulated. And when politicians announce new NASA initiatives, whether to the Moon or Mars or beyond, the public must listen hard within the announcement for a coherent plan and a powerful commitment—including, of course, the funding—to deliver the mission itself and not just the *idea* of mission.

On this point, the Columbia Accident Investigation Board's report is very clear: "It is the view of the Board that the previous attempts to develop a replacement vehicle for the aging Shuttle represent a failure of national leadership."

NASA proved a long time ago that it can answer a profound and improbable challenge, as it did with the great Moon mission announced by President Kennedy in 1961. But it is not up to NASA to supply the vision itself. That falls to our leaders. If they do supply the vision, it's a safe bet that a truly renewed NASA will do an extraordinary job of bringing it to fruition. ■

NASA: Snapshot of a Bureaucracy

"To understand and protect our home planet. To explore the universe and search for life. To inspire the next generation of explorers . . . as only NASA can." That's the avowed mission of the U.S. space agency. But to understand what NASA actually does on a day-to-day basis, you need to look at the agency's organization and budget.

Established in 1958, the National Aeronautics and Space Administration has grown into a sprawling enterprise with research centers and flight facilities across the country. NASA employs more than 18,000 civil servants, and that's not counting people on the payroll of aerospace contractors hired by the agency.

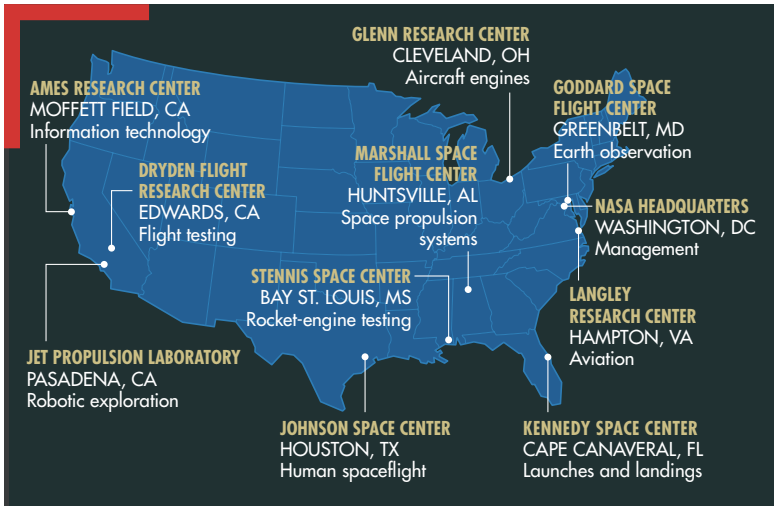
Most of the work is done at 11 centers, each of which has a particular focus and expertise (see map below). NASA also has field-testing facilities at Wallops Island, Virginia, and at Las Cruces, New Mexico.

President Bush's budget for fiscal year 2004, which began on October 1, 2003, earmarks $15.5 billion for NASA, about 3 percent more than in 2003. If that sounds like a lot of money, consider this: It's less than 1 percent of the total federal budget, and less than the Department of Defense will spend on space this year.

The agency's budget seems even more modest once you realize that the lion's share goes to the International Space Station and the space shuttle (see chart). Together, they consume more than NASA's entire budget for exploring Mars and our solar system, for searching for extraterrestrial life, for studying the structure and evolution of the universe, and for observing Earth with remote-sensing and weather satellites. —DAWN STOVER

NASA 2004 BUDGET REQUEST*

Spaceflight (space shuttle, space station and flight support) $6,110
Space science (including solar system exploration, the search for life, and space-based telescopes) $4,007
Crosscutting technologies (including the development of new launch vehicles) $1,673
Earth science $1,552
Biological and physical research $973
Aeronautics $959
Education $170
Inspector general $26
TOTAL $15,470
*(in millions)



GUILBERT GATES

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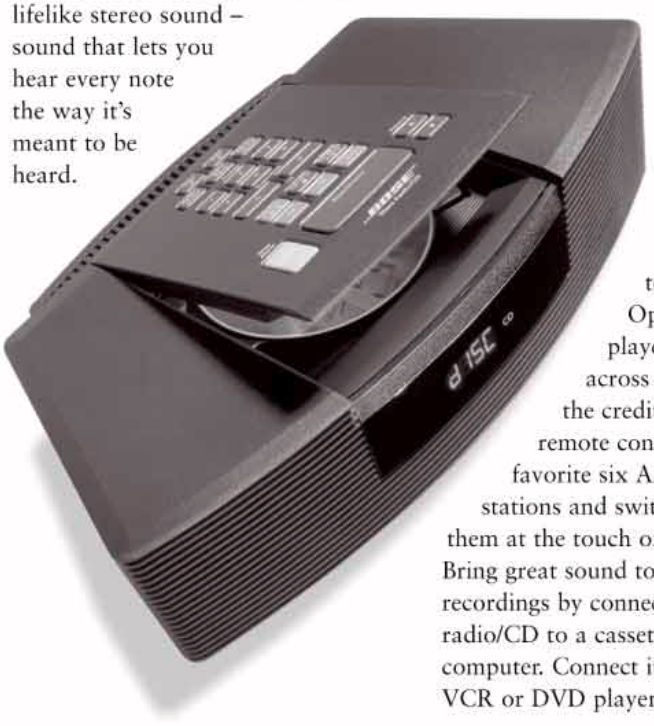

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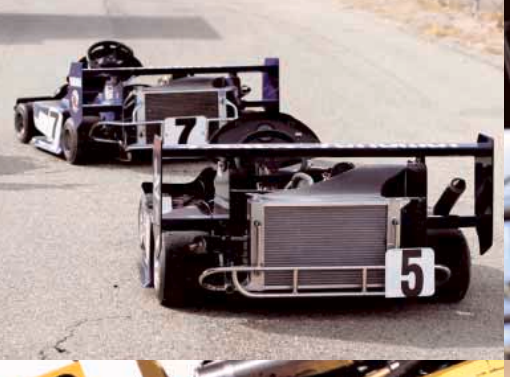
ULTIMATE!! RACING!! MACHINES!!

They look like lawnmowers on steroids, but superkarts can keep pace with million-dollar Ferraris—150 mph on the straights and crazy Gs in the turns. The best value in racing is starting to get respect.

By Preston Lerner // Photographs by John Rettie



SCENES FROM A RECENT RACE AT LAGUNA SECA

Superkarts are miniature marvels of performance engineering, featuring metal-matrix-compound brake rotors and carbon-fiber rear wings.

START

Ken

Frankel is a mechanical engineer whose company machines implausibly complex aerospace components to improbably precise tolerances. So it's surprising to find him in the paddock of Mazda Raceway Laguna Seca wrenching on an earthbound vehicle whose puny wheels wouldn't look out of place on a clown car and whose engine is no bigger than the ones powering garden mowers. He carefully maneuvers the vehicle onto a set of scales—one for each low-profile tire—that have been leveled with a laser to within 30 thousandths of an inch. Accuracy is critical; the chassis responds to differences in corner weights of as little as 2 pounds. The ride height, meanwhile, is adjusted in increments of 1/16 of an inch.

"You're looking at the convergence of the highest imaginable performance in the smallest possible package," Frankel says. "This is *not* a go-kart."

Actually, it's a *super*kart, and it's not to be confused with the putt-putt-mobile your father slapped together out of leftover steel tubing and a misfiring chainsaw motor. Powered by a race-proven 250cc motorcycle engine with a sequential-shifting six-speed gearbox, a superkart has as much in common with an amusement park ride as an F-22 has with the *Wright Flyer*. Carbon-fiber bodywork is commonplace. So are aluminum components, titanium fasteners, disc brakes, electronic engine management and onboard data-logging computers. What we're talking about is the most bang for the buck in the motorsports universe—racetrack performance that costs less than a minivan but makes a Lamborghini look lumbering.

"It's such a rush to drive. In fast corners, you feel like your head is going to be ripped off," says Eddie Lawson, who races the superkart Frankel is preparing. "If I could afford it, I'd have my own Indy car to play with. But that would cost a couple of million dollars, and I'd need a whole team of guys to work on the car. With the superkart, I can head out to the track by myself, and it stops, goes, turns in, and corners just like a proper open-wheel racecar. In some respects, it's even *more* fun than an Indy car because you can really toss it around without losing control, and a good driver can make up for a bad ride. It's a real kick in the butt to drive."

This isn't some Mario Andretti wannabe blowing smoke. Lawson, 45, is a four-time 500cc motorcycle World Champion who raced Indy cars for a season before retiring from professional motorsports. He now scratches his racing itch by trouncing the competition at selected amateur events in his state-of-the-art superkart. He's here at Laguna Seca, in Monterey, California, in early September to compete in the most prestigious international event on the superkart calendar. This race—which is interspersed with more traditional automobile race events over a three-day weekend—is the crown jewel of the five-part World SuperKart Series, which southern California kart builder J.R. Clasen founded in 2001 to raise the sport's lower-than-low profile in the United States.

Despite a top speed of nearly 150 mph, superkarts don't get much respect. "Considering how much fun they are, they aren't as popular as they ought to be," Lawson says. "For the big-time sports car guys, a superkart is less than their tire budget for the year. But when they fly into town in their private jet with their girlfriends, they don't think the superkarts look as cool as their Ferraris."

ALTHOUGH THE RACE THIS WEEKEND is officially known as the World SuperKart Challenge, it could be billed more properly as the Beat Eddie Lawson Invitational. More than 50 drivers from England, France, Australia, Canada and all over the United States are here to see how they measure up against the sport's living legend. Most of them are well-heeled middle-aged thrill-seekers out for a good time. "This is like having sex all week long," jokes Bill Busacca, a dentist who drives for Old Farts Racing. (Team slogan: "The older we get, the faster we used to be.") Only a handful of drivers have a legitimate shot at defeating Lawson. Even reigning European champ Damien Payart has his doubts. "He is very fast," the sad-eyed Frenchman says ruefully.

THE LAST LAUGH After winning four motorcycle world championships in the 1980s, "Steady Eddie" Lawson turned to superkarts for kicks. "The sports car guys look down on us, but we're way faster."

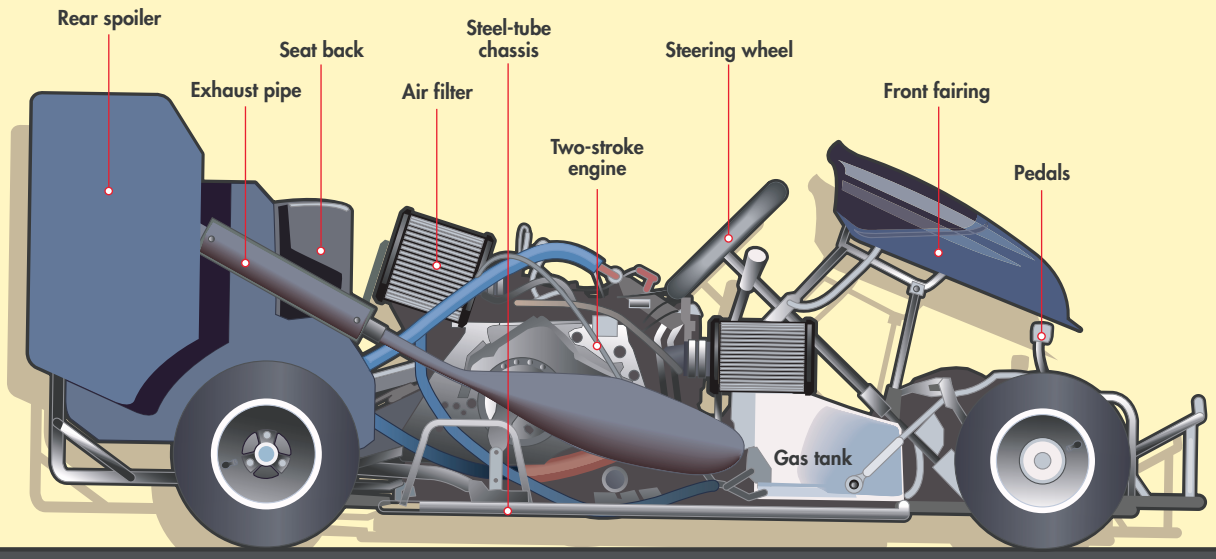
Lawson's most formidable opponent appears to be Mark Owens, a Brit who, at 29, is already a hard-bitten veteran of the kart wars. His crew chief (and father) Paul Owens worked for decades designing open-wheel racecars, and helped develop the first carbon-fiber chassis to be used in anything other than Formula 1. "I'm here to knock [Lawson] off his pedestal," the younger Owens says.

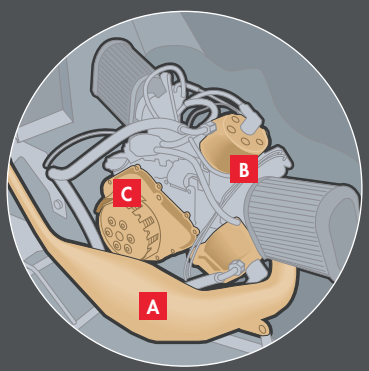
Laguna Seca begins Friday with a qualifying session. Today, Saturday, there's a preliminary race whose results will determine the starting grid for Sunday's 30-minute main event. Lawson and Owens start 1-2 and run that way until Owens falls back with a gearbox problem. Lawson wins, averaging 97.89 mph around the 11-turn, 2.38-mile road course; Payart is second, Owens third. Twenty-three-

JOHN RETTIE

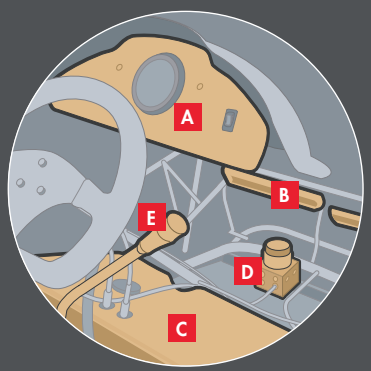
The Superkart: Stripped & Streamlined for Speed

The premise of the superkart is simple: Throw maximum power into the lightest package possible, and watch it go. In addition to an intrinsically high power-to-weight ratio, the superkart also features a low center of gravity and rigid, wheels-bolted-to-chassis suspension, both of which help it rip through corners. The final touch: carbon-fiber body panels for efficient high-speed aerodynamics.

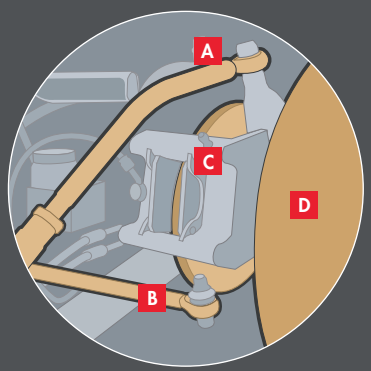




ENGINE As there's no exhaust valve, engineers tune the shape of the exhaust pipe [A] to create optimal pressure in the two cylinders [B]. A sequential manual gearbox [C] sends power to the wheels.



COCKPIT Carbon-fiber dash with tach [A] sits above the brake pedal [B]—operated with driver's left foot—and gas tank [C]. The brakes' adjustable master cylinder [D] is within reach, as is the shifter [E].



SUSPENSION This is nonexistent, really, just the wheel assembly bolted to the chassis [A] and the steering arm [B]. Four-wheel disc brakes [C] make for efficient stops, and slicks [D] hold on during turns.

year-old American tyro Ron White is a fighting fourth; his kart, made for him by Los Angeles dentist-cum-racer Pat Yoshikane, invokes envy from rivals ("many of the parts are *magnifique*," says Payart). Fifth goes to Lawson's close bud and teammate Wayne Rainey, 42, a three-time 500cc motorcycle World Champion who races a superkart with hand controls developed after he was paralyzed from the chest down in a 1993 bike crash.

The results aren't unexpected. But the speeds are mind-boggling. Jaw-dropping. Awe-inspiring. Although the superkarts max out at about 130 mph on the relatively short uphill front straight, they carry an insane amount of momentum through the sweeping turns, generating lateral cornering loads of 2 Gs. (That's half the G-load of a Champ car but twice that of most sports cars.) The chassis are so light and nimble that drivers dart around like badly spooked squirrels on a caffeine high. "The first [practice] session on Thursday was really frightening," says 24-year-old Kyle Martin, a perennial champion in smaller 125cc shifter karts who's getting his baptism of fire in a superkart.

The headline attraction this weekend is the American Le Mans Series, which features sports cars racing on the same track as the superkarts (though at different times). The stars of this series are multimillion-dollar thoroughbreds known as Le Mans Prototypes, or LMPs. But the Audi R8, winner of three consecutive 24 Hours of Le Mans, is only 7.6 seconds, or

MIKA GRONDAHL

10 percent, quicker than Lawson's superkart over a 76-second lap. And Lawson is just as fast as the ex-F1 studs driving Ferrari 550 Maranello racecars—machines that go for $1 million a pop—in the GTS class behind the Audis. As for the less exotic Ferrari 360 Modenas and Porsche 911 GT3s, they seem to wallow around the track like pregnant cows.

The crowd can't believe what it's seeing. Neither can the sports car drivers. After a session in his comparatively monstrous BMW M3, Boris Said comes over to gawk at Lawson's kart. Said, the reigning Trans-Am champion, is accustomed to honking 650-horsepower pony cars massive enough to reduce a superkart to roadkill. *"Awesome!"* he says, shaking his head. "Yep, one of these days, I'm going to get one of these things for myself."

THE COMMONLY ACCEPTED CREATION MYTH of the go-kart is set in Glendale, California, a suburb of Los Angeles, in 1956. Here, in the shop of the mighty Kurtis-Kraft company, birthplace of the roadsters that dominated the Indianapolis 500 during the 1950s, a fabricator by the name of Art Ingels spotted a surplus lawnmower engine in one corner and steel tubing in another. He put the two together and fashioned the world's most inexpensive high-performance wheeled vehicle.

Go-karts developed along much the same lines as racecars. The need for speed spawned more complex technology, which cost more money, which funded better gizmos, which generated higher speeds, which is how we got from Ingels' crude contraption to Lawson's high-tech rocket ship in less than 50 years. "In terms of training, I could jump directly from a superkart to an LMP car," says 24-year-old Alan Rudolph, who's competing at Laguna Seca in both a superkart and an open-wheel racecar called a Star Mazda. "But in the eyes of car sponsors, a superkart is just a go-kart, so I have to drive the Mazda to be taken seriously."

Whereas in the United States go-karts are generally dismissed as toys, in Europe and South America they've long served as stepping-stones to careers in auto racing. For many years, the preferred model was a single-speed, direct-drive 100cc machine that raced on special kart tracks that were much shorter and twistier than auto-racing circuits. Karts with bigger engines—the first generation of superkarts—were introduced in Europe in 1969, but their popularity waned. Then, about 15 years ago, in the never-ending quest for speed, enterprising karters in southern California started stuffing motocross engines and gearboxes into their chassis. These 125cc shifter karts were such a hit that it was just a matter of time before somebody decided that bigger was bound to be even better.

But the twin-cylinder 250cc shifter karts that resulted proved too powerful for kart tracks. Moving to full-size car circuits was a no-brainer, but the higher speeds achieved on these longer racetracks spotlighted several deficiencies in existing kart chassis: The short wheelbase made the machines diabolically

Pitting the Superkart Against Rivals

Hail to the superkart! It leaves a standard sports car like the Mazda Miata in the dust, and even a muscle car like the Corvette, with its beefy hp and flashy top speed, is a pokey 25 seconds slower per lap. The superlight superkart (just 462 pounds) accelerates faster than the Corvette and is nimbler in the curves. The Champ car bests the kart, but there's no shame in that: It costs 20 times more and requires an entire support crew.


CHAMP CAR


CORVETTE


SUPERKART


MIATA

	CHAMP CAR	CORVETTE	SUPERKART	MIATA
Price	$600,000	$50,000	$30,000	$25,000
Engine type	Turbo V8	V8	Two-stroke	Inline-4
Displacement	2.65 liters	5.7 liters	0.25 liter	1.8 liters
Peak power	700 hp	350 hp	90 hp	142 hp
Hp/liter	264	61	360	79
Weight	1,565 lb.	3,100 lb.	462 lb.	2,400 lb.
Hp/pound	0.45	0.11	0.19	0.06
Lateral acceleration	4 Gs	0.92 G	2 Gs	0.88 G
0-to-60	2.2 seconds	4.8 seconds	4 seconds	8.1 seconds
Quarter mile	10 seconds	13.2 seconds	12 seconds	16.3 seconds
Top speed	240 mph	175 mph	150 mph	121 mph
Lap time (2.38 miles)	1:10	1:50	1:25	2:00
Cost per				

Performance data for production models from Car and Driver. Some performance data for Champ car and superkart are estimates.
**The additional amount of money driver must spend to gain each second on the racetrack, using the Miata as a baseline.*

CLOCKWISE FROM TOP LEFT: COURTESY PAUL WEBB/MOTOR SPORT IMAGES; COURTESY GENERAL MOTORS; COURTESY MAZDA; JOHN RETTIE

twitchy, and their width added scads of drag. As a result, the Commission Internationale de Karting, based in Switzerland, developed a formula for 250cc shifter karts designed to race on automobile circuits, and the modern superkart was born. Superkarts have longer wheelbases than conventional karts (for better stability through high-speed corners) and heavier minimum weights (to promote more robust chassis), and they are narrower (to generate higher straight-line speed).

In many respects, a superkart is a car writ small. One fundamental difference is that superkarts don't have springs to suspend the wheels or shock absorbers to dampen them. Instead, the chassis serves as the suspension. While a lot of racecars are built around carbon-fiber tubs designed to minimize chassis flex, kart frames are still welded together the old-fashioned way out of steel tubing, because a certain amount of chassis flex is required. Driver flex, too, is par for the course.

"One thing that makes the racing experience so exciting is that you feel like you're part of the kart," says J.R. Osborne, a 36-year-old real estate developer and ex–Formula car racer who drove 26 hours straight from his home in Denver to make the race at Laguna Seca. "The downside is that karts are much more extreme than cars, much more violent," he adds, referring to the formidable G loads and molar-rattling vibration. "If the track is too rough, you literally can't see."

The other big point of departure between automobiles and superkarts is the powerplant. The four-stroke engine technology that is found in virtually all street cars is used mostly in slower karts. The hot setup is a two-stroke engine. That's right, the annoyingly whiny, smelly, smoky buzz-boxes that power many lawnmowers, chainsaws, dirt bikes, even radio-controlled model airplanes. Two-strokes spew out a lot of pollutants, suck down a lot of fuel, and don't last very long. But they sure go like stink.

For example, Lawson's Yamaha TZ250 develops 90 horsepower from a 250cc engine: That's 360 horsepower per liter. A stock Corvette makes less horsepower—350—out of close to *6* liters. Even Jeff Gordon's Nextel Cup stock car produces only 130 or so horsepower per liter. And with the Yamaha engine shoehorned into a container not much larger than a

JOHN RETTIE

A BRUISED & DIZZY DRIVER

When Eddie Lawson told me his superkart was "a kick in the butt," I didn't think he meant it literally. My mistake. After driving it for 90 minutes, my body was dotted with ripe purple bruises—though I was having too much fun to notice. The only reason I called it quits was that all the lateral Gs I was pulling had my head flopping around like a newborn baby's. Not to mention that I couldn't focus my vision on the road in front of me—no small concern when you're zipping along at better than 110 mph with your keister two inches from the pavement.

Lawson had generously arranged this test session at a racetrack carved from the Mojave Desert a few miles west of Edwards Air Force Base. The first order of business was to warm up the high-strung engines, which tend to explode if not romanced properly. Before long, the air was redolent with the aroma of burnt castor oil, which is mixed with 110-octane race gas to lubricate the internal moving parts of the two-stroke motors.

After Lawson turned a few shakedown laps, I squeezed into the formfitting seat. He gave me a push start; once rolling, I shoved the shift lever forward to engage first gear, goosed the gas pedal, and the kart scooted forward like something out of a Road Runner cartoon. After about, oh, two seconds, it was time to upshift. When I pulled the lever, second gear engaged with a satisfying thunk. Downshifting was easier still: I banged the lever forward and—voilà!—no muss, no fuss, no clutch and no need to master the tricky racecar technique of heel-and-toeing to match engine and gearbox revs.

At low speed there was nothing to it. But when I nailed the throttle, I was like, "Holy horsepower, Batman!" Third gear, fourth gear, fifth, sixth and still pulling strong. I was too overwhelmed to scan the digital tach on the steering wheel, but I later realized that the power-band began around 8,000 rpm, and the screaming little engine didn't run out of steam until closing in on 13,000 rpm.

Approaching a corner, I squeezed the brake and the superkart slowed so dramatically I lurched forward in my seat. Emboldened, I went deeper into the next turn and hammered the brakes. The rear wheels locked and the tail started to come around. No problem: I made a quick steering correction and the kart snapped smartly back into line. Soon I was sliding around like a stunt driver on a frozen lake. Nothing I'd ever driven responded so intuitively. There were no springs or shocks or complex aerodynamics to muddy the conversation: I felt a direct, almost telepathic connection between my nerve endings and the contact patch where tires met pavement.

Superkarts come with awkward baggage: Limited racing opportunities. Minimal sex appeal. Zero driver protection. They're also hard on the wallet (by kart standards) and even harder on the body (by car standards). But short of spending hundreds of thousands, if not millions of dollars, a superkart is as close as most of us will come to the experience of driving a Formula 1 car. By the way, I was a full 12 seconds slower than Lawson. Talent, unfortunately, doesn't come with the kart.—P.L.

breadbox, Lawson's superkart boasts a power-to-weight ratio better than virtually every production car in the world short of the $670,000 Ferrari Enzo.

A two-stroke engine is less-is-more philosophy in motion. A cylinder in a four-stroke requires two revolutions of the crankshaft to complete its four distinct cycles—intake, compression, combustion and exhaust. In two-strokes, intake and compression are combined in one cycle and combustion and exhaust in another, so each cylinder produces power with every revolution of the crank. Also, two-strokes don't have conventional intake and exhaust valves, which means they don't need camshafts to actuate a complicated (and often fragile) valvetrain.

Top-of-the-line superkarts are motivated by twin-cylinder 250cc two-strokes, some of which spin faster than 13,000 rpm. Typically, an extra carburetor jet enhances top-end performance, while the exhaust port stays closed longer at slower speeds to produce low-end grunt. Special attention is paid to the shape of the exhaust pipe, which is technically known as an expansion chamber. "You can put on bigger carbs and you can run higher compression," says longtime engine builder Sandy Rainey, Wayne's dad, "but the pipes are where most of the power comes from."

Superkarts stop as well as they go, thanks to disc brakes front and rear. (Frankel fabricates Lawson's rotors out of an aluminum-based metal matrix compound to save weight.) They also generate oodles of mechanical grip through wide, treadless tires. Aerodynamically, though, superkarts are relatively primitive, because the drivers must punch a huge hole in the air. (Sure, you can run fully enveloping bodywork, and some racers have, but that's problematic too—"It stiffens the chassis too much," says Paul Owens.) Still, superkarts are very sensitive to aero tuning. The standard practice is to adjust the nose of the kart, lowering the ride height to increase downforce, and balance the aerodynamics by trimming the angle of the rear wing.

A good superkart costs about $15,000; figure 30 grand for one with every option known to man. It ain't cheap, obviously, but it's a bargain by motorsports standards. "I hate to say it, but it comes down to ego," says Randy Taylor, 47, an American Airlines Boeing 767 pilot who's another car racer turned superkart fanatic. "If everybody had zero ego, everybody would be racing superkarts."

Become a superkarter. Go to **popsci.com/exclusive**

FORTY-NINE SUPERKARTS STREAM ONTO THE TRACK Sunday morning, forming what appears to be a long, multicolored snake as they buzz around on their warm-up lap. By virtue of winning yesterday's prelim, Lawson starts the race from the pole—the inside position of the front row. But when he sees the green flag and floors the throttle, his Yamaha sputters and his kart bogs down. (He finds out later that the fuel line had come loose, allowing gasoline to spray out.) White, a 125cc-shifter-kart ace, surprises everybody by barging into the lead, and he, Lawson and Owens run in feisty formation. Then Owens slices past both of his rivals with a bold move, and White falls back as his engine loses power.

KARTS ARE MORE EXTREME THAN CARS, MUCH MORE VIOLENT.

Owens leads despite another gearbox problem. Lawson can't take advantage because every time he buries the gas pedal, his engine stumbles. He resorts to feathering the throttle, which compromises acceleration and top-end speed, so he makes up for it by pushing harder in the corners. Racers often rate their effort in terms of tenths, with nine-tenths being an aggressive race pace and ten-tenths a banzai lap. As he and Owens scythe through lapped traffic, Lawson's going eleven-tenths. At one point, he draws alongside the Brit, but Owens hangs tough, and Lawson can't make the pass stick.

With two laps to go, Lawson's kart runs out of gas and rolls to a stop at the end of the front straight. By this time, Payart is second, but he's too far behind to challenge for the lead. Owens wins by 17 seconds. Back in the paddock, he's hailed like a conquering hero. His father hands him a cellphone; his brother is calling from England to congratulate him. Owens pronounces himself well satisfied. "Eddie Lawson has never ever been beaten—until now," he says.

Over in the Lawson pit, the atmosphere is surprisingly upbeat. Rainey is stoked after finishing fourth after a race full of slicing and dicing. And Lawson is pleased with his performance even though he's disappointed by the result. "If I'd had a wide-open throttle, I think I would have had [Owens] covered," he says. "After all, we were quickest through the whole weekend. Then again, if my aunt had balls, she'd be my uncle."

Owens may be king for a day, but Lawson's got nothing left to prove. He's out here strictly for grins, and for a racer, life doesn't get much better than Laguna Seca in a superkart. "Try one yourself," he says, "and you'll know what I mean." ■

Preston Lerner, a contributing writer for Automobile, *races his own Nissan 240SX in amateur events. He's looking forward to his next chance to drive a superkart, as soon as his bruises heal.*

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Who are the Great Teachers? They are gifted scholars, explainers, enthusiasts, communicators—and, yes, entertainers. Everyone who has ever experienced the sheer pleasure of learning from just one great teacher knows what we mean.

There are nearly 500,000 college professors in America. Since 1990, we have identified the top 1% of college professors based on teaching performance. Our list is based on teaching awards, published evaluations of professors, newspaper write-ups of the best teachers on campus, and other sources.

Each year, our recruiters travel the country—Harvard to Stanford, UCLA to UNC—listening to hundreds out of the top 1%. Of those, about one in 20 are selected to give an audition lecture. The audition is then reviewed by hundreds of our customers. Those who get a high score from our customers make The Great Courses. More than 15,000 of our customers have voted on audition lectures to select our faculty.

In the end, we and our customers select about one in 5,000 professors. We've been searching for more than a decade and, with our customers, have chosen about 100 professors to make our courses. Why only these? Because we want only those professors who will make your time in the world of ideas a daily pleasure. Members of our faculty have won many honors including the Pulitzer Prize, the Carnegie Foundation's Professor of the Year award, and Fulbright and Guggenheim Scholarships. But what matters is that they are clear, devoted scholars with a passionate zeal to teach others what their disciplines have discovered.

"The Teaching Company offers only brilliant teaching... lectures by the best that Harvard, Yale and other top universities have to offer."

—The Wall Street Journal

The average Great Course scores 8.97 out of 10

Once a professor is selected, each course is *crafted*—not merely recorded—for the customers of The Teaching Company with the needs of intelligent, engaged adults foremost in mind. Every course is designed to be comprehensive, richly detailed, and extremely well-presented.

Recently, an outside service surveyed 3,600 of our customers and asked them to rate the course they had most recently completed on a ten-point scale, where 10 is "extremely satisfying." The average course scored 8.97.

Lifelong Learning That Fits Your Life

Where do our customers find the time to become "renaissance" people in this time-pressed age? Often, they have enriched their lives by taking back "lost" time with The Great Courses. You can use The Great Courses when you commute, exercise, or work around the house.

We once asked a heart surgeon who had watched hundreds of hours of lectures how he found the time in his career for The Great Courses. He answered, "I skip the first half hour of junk TV each evening and watch a Teaching Company lecture instead."

Another customer echoes what we have heard many times: "Since I've discovered The Teaching Company, I look forward to my driving time. Thank you for changing my commute from frustrating to fascinating." And many of our customers have made The Great Courses the cornerstone of a rewarding retirement.

"Why the Guarantee?"

The price for shipping and handling of our products includes a lifetime satisfaction guarantee. What does this mean? It means that if a course is ever less than completely satisfying, you may exchange it for another or we will refund your money promptly.

Most publishers and booksellers do not guarantee that you will be completely satisfied with their product. We do. And we guarantee your satisfaction for a lifetime because we want you to be our customer for a lifetime of learning.

One customer published his view of our guarantee, which we have reproduced below:

"It was just a plain jane mailer from The Teaching Company. They offer taped lectures by prominent professors on subjects that get my heart racing. I remembered receiving mailers from this company before, though I had never purchased anything. As I glanced at this one, though, something caught my eye. They offered a lifetime satisfaction guarantee on every tape in their catalog.

What? I had to read that again. But there it was right on the front page and again on the order form:

LIFETIME SATISFACTION GUARANTEE.

To understand how powerful this is, keep in mind what this company sells. These aren't little audio tapes with 30 minutes of fluff, they're HUGE, in-depth taped lectures from some of the best minds in the country.

When I saw the guarantee, I was sold. Where's my credit card?

But there's another reason for the guarantee - ethics. Thomas Rollins, president of The Teaching Company, said his company values clients so much, he simply doesn't want them to have any product they don't absolutely love. In our lively phone conversation, he said, "We call our lectures The Great Courses, and if we don't deliver great courses, we don't deserve the money."

Wow! Most people think of customer loyalty as customers being loyal to a business. But how about a business being loyal to customers?"

—Dean Rieck,
Direct Marketing magazine
April 2000

About Value

The best college professors in America teach The Great Courses, but you don't pay anything like private school tuition to hear or see their lectures.

Compare The Great Courses to any other product available: when on sale, our average compact disc (CD) course is

$49.95 for 12 CDs, 12 hours. That's only $4.16 per CD. Compare $4.16 for each CD to what you pay elsewhere—$10? Or more?

In fact, in any format, these courses are much less than most audiobooks or any other video you can buy. And, with each 6-hour segment of The Great Courses, you receive 50- to 80-page Course Guide Booklets with an in-depth course outline, bibliography, and course summary authored by the professor. This is an exceptional value in educational material, taught by the best professors in America.

About Pricing

Every course is offered to our customers at its sale price at least once per year; many are offered on sale even more often. Frankly, most of our courses do not sell in large numbers; only a small percentage of Americans are interested in higher learning. To make our courses available at exceptional values, we put a fraction of our courses on sale at a given time, they sell in larger numbers than usual, and we can make large batches of them economically. We then pass those savings on to our customers by putting those courses on sale for up to 70% off.

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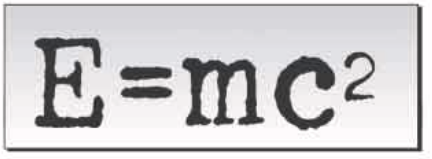

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Richard Wolfson (Ph.D., Dartmouth College) is Professor of Physics at Middlebury College in Vermont. Decades of teaching at Middlebury, with its strong emphasis on the humanities, have made him an expert at demonstrating the logic and significance of physics to students from many fields. His writings have appeared in *Scientific American*, and he is the author of *Physics for Scientists and Engineers*.

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1923WATCH.COM

So rare that only a handful were made in 1923

In 1923, a Swiss watchmaker crafted the most advanced watch of its time. After 80 years, the Steinhausen watch has finally been "reborn," preserving its mastery of technology and classic design. Once only displayed in high priced collections, this rare timepiece from history can now be yours .

Imagine a Swiss watchmaker's shop in Steinhausen, Switzerland circa 1923. A master watchmaker is huddled over his sturdy wooden table, the tools of his trade neatly arranged to either side. For countless hours, the craftsman dedicates himself to his trade. He creates the perfect watch - the first of its kind to display the date, day, and month, and the only one to designate AM/PM. From such humble beginnings came one of the most sought after watches in the world - now recreated.

Rarest of Rare

With only a handful of these distinctive handmade timepieces in circulation, this exquisite wristwatch could only be found in the collections of the world's most distinguished gentry. That was, until now. Reborn with the same classic styling and updated with the kinetic automatic movement, this handsome watch has once again become the envy of modern society. In fact, it is estimated an original kinetic timepiece could command a price in upwards of $300,000.

Not Lost in the History Books

Painstakingly reproduced in its original form for you, the Steinhausen is as unique today as it was 80 years ago. Still manufactured by hand and put through two weeks of rigorous testing before delivered to your door, this 21st-century reproduction carries the same graceful styling and sweeping second hand movement as the original. The scratch-resistant glass is made of polished mineral crystal and comfortably rests in a surgical grade stainless steel case and bezel, which provides the ultimate in precision and protection. The ageless ivory face with Roman numerals and brushed stainless steel crowns complete this masterful portrayal of perfection.

Automatic Kinetic Movement

Developed in the 18th century, automatic movements use kinetic motion wound by the motion of the wearer's arm. On the basis of terrestrial attraction, a rotor turns and transmits energy. The kinetic movement consists of precision crafted gears and has 185 parts, which are assembled entirely by hand. As a result, the Steinhausen **never needs winding or batteries!**

One of the Worlds Most Accurate

The most elite Swiss names in automatic movement allow for an accuracy of +25/-27 sec. per/day. The Steinhausen movement has been fine tuned for a rating of +5/-7 sec., making it one of the most accurate in the world. The testing for flaws and accuracy is so strenuous that only 6% of movements made ever end up in a Steinhausen.

To prevent wear on gears, fine watches use tiny gemstones to reduce friction. A number of the world's most elite watches consists of upward of 20 jewels and cost thousands of dollars. Steinhausen watches contain up to 35 jewels.

THE STEINHAUSEN REBORN

Old world craftsmanship & new world technology

- Transparent rear crystal displays movement.
- Kinetic movement – requires no battery or manual winding.

- 185 precision parts assembled by hand.
- Interchangeable 8.25" leather black or brown bands.
- Mahogany Storage Case.
- Polished stainless steel construction.
- Water resistant to 50 meters.

Kinetic movement...never needs batteries... never needs winding!

Adapted from Swiss Technology

A Swiss engineered movement comparable to the Steinhausen has never been produced at this low price. By combining the hand made craftsmanship of the Steinhausen with the latest watch making technologies, this masterpiece is now within your reach.

Today, some 80 years after its creation, you can once again enjoy a replica of the Steinhausen masterpiece reborn in its original glory. Each watch comes housed in a mahogany storage case and includes two interchangeable leather wristbands in black and brown.

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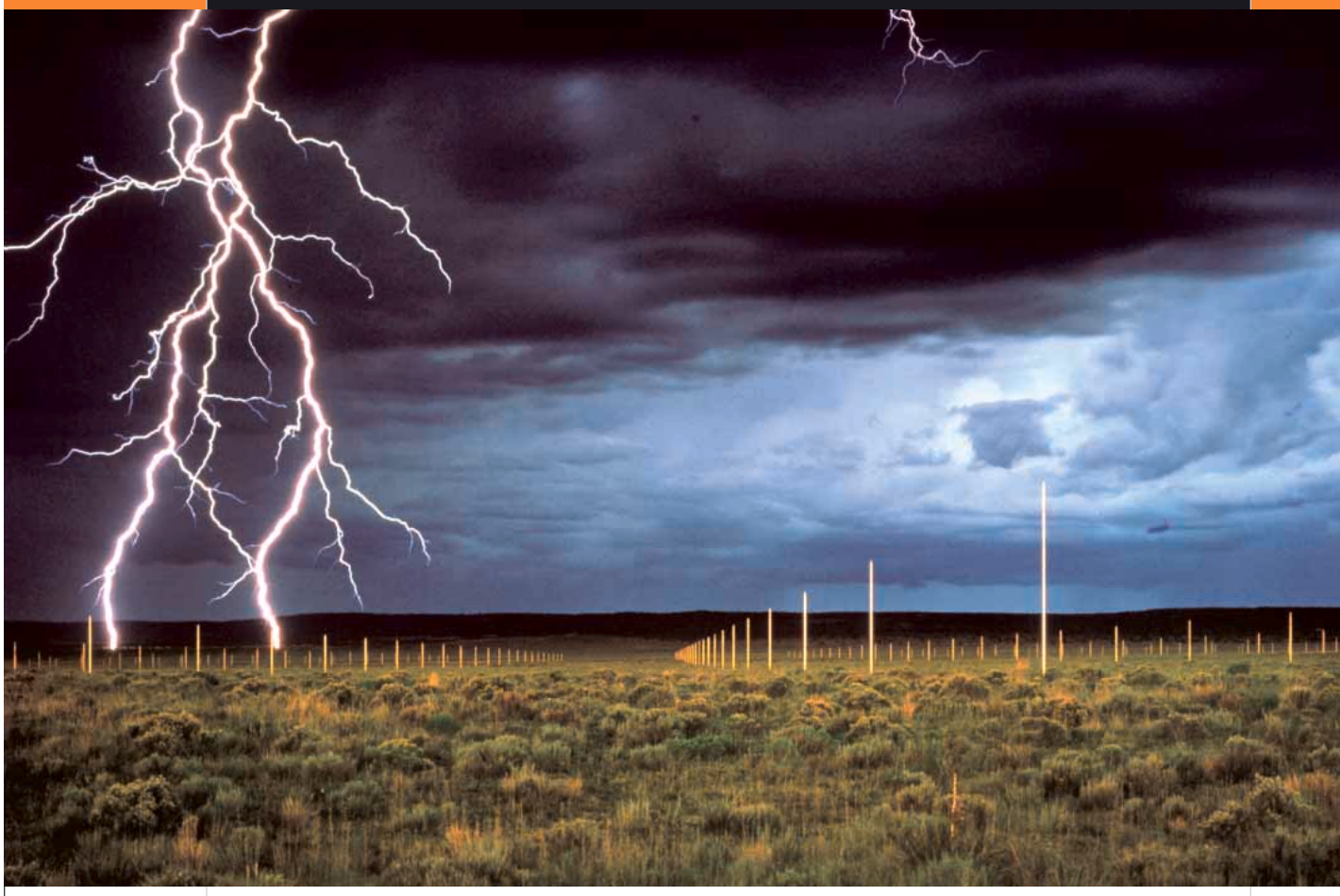
"ANY INDIVIDUAL BETTING SESSION MAY BE 90 PERCENT LUCK, BUT WHEN YOU PLAY 500,000 HANDS A YEAR, IT'S 90 PERCENT SKILL." **PAGE 92**



JOHN CLETT, DIA ART FOUNDATION

ELECTRICAL ART ***The Lightning Field,*** **Walter De Maria's "earthscape installation," draws thousands of art, science and extreme-weather tourists every year.**

Ben Franklin Slept Here

New Mexico's high desert is a hotbed for electrical storms. Where better to camp among 400 lightning rods? By Charles Graeber

_FIRST PERSON

INSIDE THE LITTLE WOODEN CABIN IN A VAST OPEN FIELD, on the wooden desk by the wooden chairs, you'll find a list of suggestions for your stay. And at the bottom of that list you'll find one simple fact, underlined for emphasis: The invisible is real.

See for yourself. Step beyond the table to the back porch, out into the blazing sunshine. Now look around. All the way around. It's a beautiful nothing, 360 degrees of scrub brush and sage framed by distant mountains and a robin's-egg sky. You could be anywhere—the Sahara, the Moon—but in fact you're somewhere outside the town of Quemado, New Mexico, a dozen or so miles from the Continental Divide. You've been dropped here to spend the night at this remote desert cabin with four perfect strangers, and to wait for the lightning to strike.

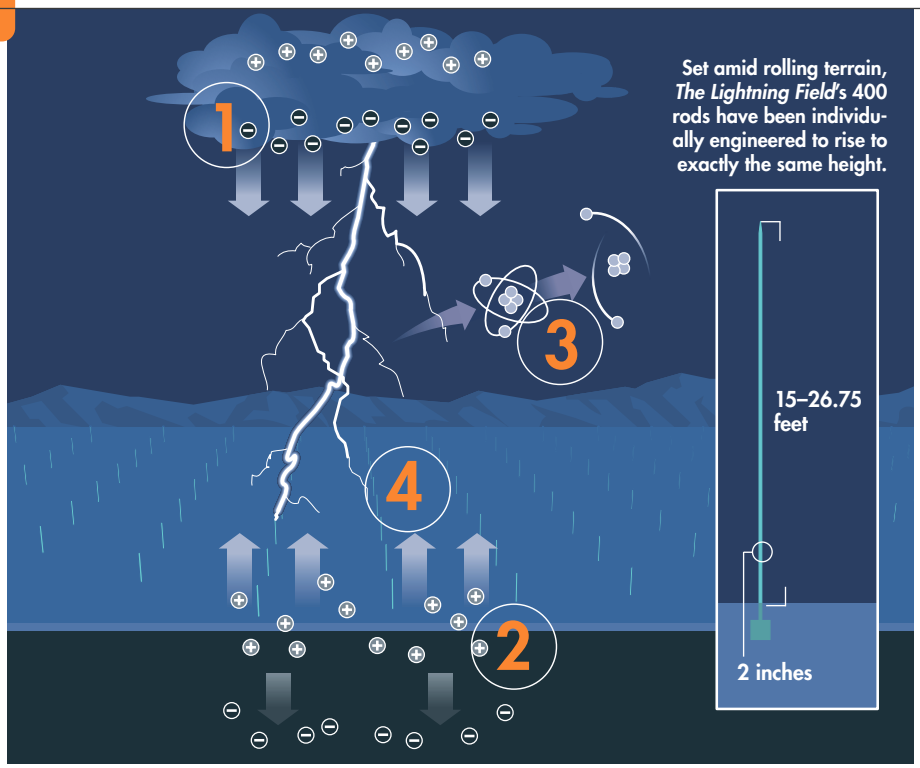
It happens, when it happens, just beyond the porch, along a grid of 400 equidistant stainless steel poles, extending a mile this way and a kilometer that. Despite the rough terrain, each pole has been

painstakingly engineered to reach to exactly the same height, such that a mile-long pane of glass might be rested evenly on their tips. These tapered tips point to the sky like the male ends of electrical plugs facing an enormous potential outlet. They are designed to attract the invisible, and make it explosively real.

At 7,200 feet above sea level, the high desert of New Mexico is one of the most frequently lightning-struck places in the country. Sometimes, when passing clouds get within 200 feet of the poles, they feel the tug of the steel and—*kaboom!* Sometimes the pole tips are surrounded by auroras of St. Elmo's Fire and blaze like plasma tiki torches in the desert. And sometimes nothing happens. Sometimes you sit here, in the middle of nowhere, thinking about what you can't see.

This is *The Lightning Field*, an installation by earthscape artist Walter De Maria. In the 27 years since De Maria's team first laid its computer-modeled grid on this high desert, the work has evolved from a boutique destination for a handful of art aficionados into a popular pilgrimage for a growing conglomeration of art, science and extreme-weather tourists. Reservations, booked up to a year in advance, are essential. The *Field* offers a rare opportunity to actively confront a phenomenon so deadly and majestic that it has become a universal metaphor for God's wrath. In the normal world, it's the sort of encounter that thinking people generally avoid.

At any given moment, our planet is being sizzled by an estimated 1,800 thunderstorms. In this country alone, lightning touches down 25 million times a year, along bolts extending up to 10 miles and carrying up to a hundred million volts. In the U.S. these strikes kill an average of 73 people a year; thousands more are injured, more than 700 seriously. Over your lifetime there's a 1 in 3,000 chance that you'll get struck yourself. It's not just for quaint rusticity that this little cabin is made of wood.



PLAYING WITH ZEUS'S FIRE

Lightning formation begins when condensation and freezing create a charge separation in storm clouds, with electrons clustered near the bottom of the cloud [1]. The electric field around the cloud repels electrons on the ground deep into the earth, creating a strong positive charge at the surface [2]. The voltage difference between the base of the cloud and the ground ionizes the surrounding air, making it much more conductive [3]. When the resistance of the air drops sufficiently, electrons race to the ground in a violent discharge we see as lightning [4]. *The Lightning Field*'s equidistant steel rods provide the lowest-resistance path to the ground for these massive jolts of electricity.

As luck would have it, my reservation coincides with a prediction for a stormy weekend, and sure enough, by 6 p.m. the horizon is promising, with a hard western wind pushing thunderheads across the vast desert space. Thin fingers of lightning stripe the distance. The five of us crowd out behind the house, staring in wonder. There's a feeling in the air—*something* big is coming. How can we be so sure? Maybe it's just intuition, or the clouds. Most probably, though, it's the ions.

Every schoolkid is taught that lightning is simply a discharge of potential electric energy, positive meeting negative between clouds and earth. The juice is generated in conditions unique to the upper reaches of the thunderheads themselves, which billow as high as 10 miles into the atmosphere. Low temperatures and violent winds conspire to mash microscopic ice crystals one against the other, shucking electrons, building a charge differential. The positively charged crystals gravitate to the top of the cirrus anvil, and negative crystals to the bottom, where they occasionally, violently, discharge to the ground.

But fewer people realize what is happening simultaneously on the ground, where masses of positively charged ions are flowing in from all directions, drawn to the negatively charged mothership above. To get closer, these particles climb whatever is handy—trees, steel poles, people. It's this movement of billions of positive ions up your head that causes your hair to stand on end just before a lightning strike. Well . . . that and the riveting fear.

In the distance, the storm clouds are like an advancing army of purple airships. I wrap a blanket around myself and start to walk into the field, between the poles, as a lasso of electricity flashes from one side of the heavens to the other. I'm not certain whether this is protocol, or safe, and without the protection of the cabin, I feel naked, exposed on all sides. Especially up. The lighting is now a *Close Encounters* light show, which makes it easy to forget to breathe. Steady pulses of heat and light burn toward the earth, hitting it, *bang*, and again, *bang-bang*, the

JASON LEE

electricity cutting the air over and over. The wind grows stronger, my ears are warm, the hair on my neck is standing up. I'm thinking of the science, the ionization, the cirrus anvil. But mostly I'm thinking: *holy s—*.

The storm gallops along the plain until what were electric saplings of distant lightning bolts are now thick trunks striking the desert beyond the poles, *bang, bang-bang,* filling the air with spasms of 50,000-degree air. This is an intimate weather moment, and I'm duly self-conscious. I find myself thinking about the metal in my watch, about my height, the fillings in my teeth. I think about standing on one leg, the way old-time electricians used to when testing new powerplants, to keep the voltage differential from crossing from leg to leg and frying their wedding tackle. And then I think about going back inside, to the cabin.

My new companions and I watch the show all night as it slowly approaches, rages, then sweeps back into the desert and behind the hills. It's dark then, and quiet. Then the moon rises, full and close, followed by a seamless desert of pinprick stars, each a burst of light from a place we've never seen—a stream of ancient wave energy, beautiful and, apparently, quite real. ■

_ADVENTURE GUIDE

WEATHER VEINS

LOOKING FOR a hair-raising experience? Don't know enough to get in out of the rain? Read on.

ELECTRICAL STORMS

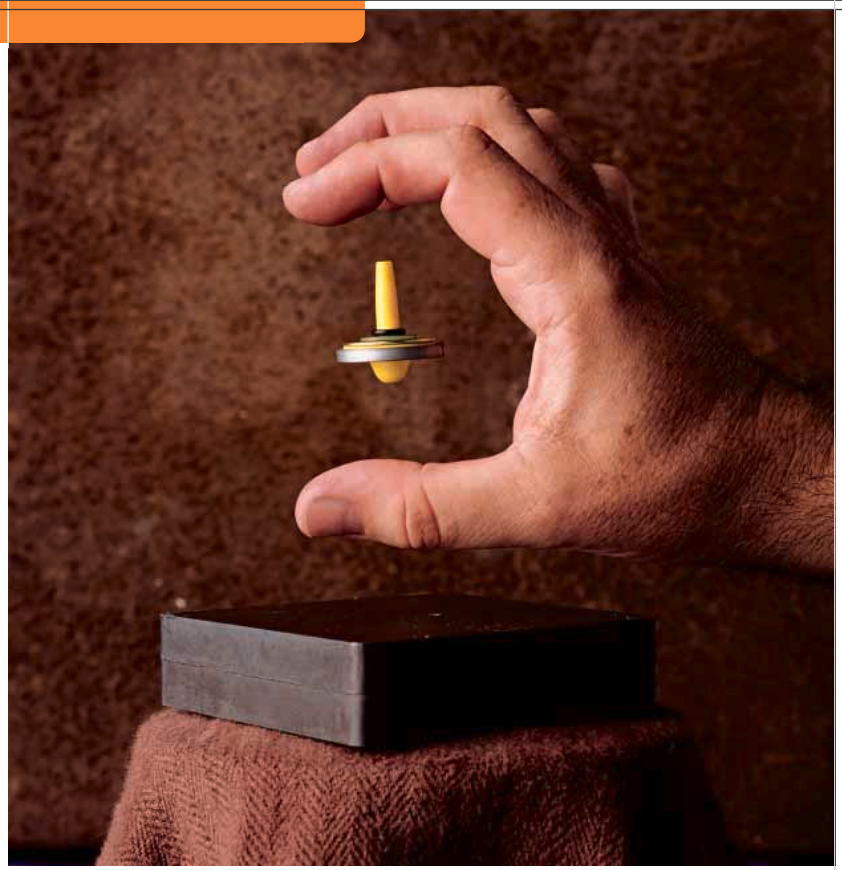
The Lightning Field, **Quemado, NM • A night of cabin camping amid nature's light show. May–October; $110 ($135 in July and August);** ***lightningfield.org***

TORNADOES

Storm Chasing Adventure Tours • Five- and 10-day tours through America's Tornado Alley between April and July. $1,700–$2,900; ***stormchasing.com***

HURRICANES

Hurricane Chase Safaris • Tag along with weather videographer Richard Horodner. $2,500; ***hurricanevideo.citymax.com***



THE RIGHT SPIN Harrigan's trial-and-error maglev wonder (left) showed that stable maglev is indeed possible. Above: A diamagnetic superconducting ceramic disc is another exception to Earnshaw's theorem.

Ignorance = Maglev = Bliss

For 150 years scientists believed that stable magnetic levitation was impossible. Then Roy Harrigan came along.

_GRAY MATTER

IF YOU'VE EVER TRIED TO FLOAT one magnet over another (and who hasn't?), you know that the stupid thing just keeps flipping over—an irritation formalized in 1842 when the Rev. Samuel Earnshaw published his famous theorem establishing mathematically that such magnetic levitation just can't be done. From that point on, any experimenter caught playing with magnets courted the derision of his colleagues: "Ha, ha, look at Fred over there trying to balance magnets! I guess *he* never heard of Earnshaw's theorem!" Physicists can be so cruel on the playground.

Well, not so fast. It turns out that Earnshaw's theorem is absolutely correct, but it has a couple of loopholes large enough to drive all sorts of stable magnetic levitation devices through, including one you can now buy in any novelty shop for about $30: the Levitron. (For more info go to *levitron.com*).

This spinning top, which hovers above a magnetic base, was patented in 1983 by a Vermonter named Roy Harrigan. Harrigan had one distinct advantage over all those scientists who had tried and failed to levitate magnets before him: complete ignorance of Earnshaw's theorem. Having no idea that it couldn't be done, he stumbled upon the fact that it actually can. It turns out that precession (the rotation of a spinning object's axis of spin) creates an island of genuine stability in a way that does not violate Earnshaw's theorem, but that went completely unpredicted by physicists for more than a century. (Though after spending half an hour getting the Levitron to work, I was willing to cut the blinkered physicists some slack. I can only imagine how Harrigan must have felt the moment he finally got the thing floating after *years* of effort.)

A second Earnshaw exception: diamagnetism. His theorem only applies to ferromagnetism, the common north/south pole type of magnetism found in most magnets. Diamagnetism is a purely repulsive magnetic force exhibited to varying degrees by all materials in the presence of a magnetic field. Simply drop a chip of graphite, for example, onto a block of magnets and it will float in midair forever. I've had some chips hovering in my office for six months. A superconducting ceramic disc is also a perfect diamagnetic material, and floating a magnet over it is so easy and stable that you can knock the magnet around with your fingers and it won't fall off. (Ten years ago this was new and exotic, but today you can buy a kit for $40.)

Chips of graphite, by the way, aren't the only diamagnetic objects you can levitate. Researchers in the Netherlands have successfully levitated water droplets, hazelnuts, frogs and even a hamster named Tisha. In theory, it should even be possible to levitate humans, although no one has actually done so yet.

How could people possibly have missed these maglev possibilities for so long? The power of negative thinking, simple as that. In my day job as a creator of the scientific software Mathematica, I remember Earnshaw's theorem whenever I'm told something can't be done. It's much better to assume that it *can* be done, then get to work on the possibilities. That's how breakthroughs are made.—THEODORE GRAY

Video evidence of stable maglev: **popsci.com/exclusive**

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NAME Bob Dancer AGE 56
JOB Professional video poker player and teacher. Dancer originally moved to Las Vegas to become a blackjack ace, but changed his name—Dancer is a pseudonym based on his other life passion—and his game when wary casino owners caught on to his card counting. Switching to video poker turned out to be a lucrative career move—during one six-month stretch in 2001, for example, he netted a cool million. (His greatest loss, $90,000, occurred during the same period.)
WORKPLACE Dancer holds free classes every Tuesday night at either the Fiesta Rancho Casino Hotel, or the Fiesta Henderson Rancho Hotel (see his Web site below for details). Otherwise, his workplace changes nightly depending on the promotions offered by individual casinos. A casino offering double points, for example, might pay him a cash-back bonus of, say, $600 rather than $300 for every $100,000 played. There is one place he never sets foot, though: The MGM Grand. After paying him $500,000 during his million-dollar run, it restricted his Slot Club benefits and removed the offending machine.
CRITICAL TOOL Math. Video poker is a numbers game, and the laws of probability bear out that there's a single best play for every hand. (See left for more.)
CURRENT PROJECT A series of six Winner's Guides that spell out strategies for such popular games as Full Paid Deuces and Jacks or Better. "There are 2.6 million different hands in a 52-card deck," says Dancer. "The guides group them into about 20 categories and give you rules to play each one perfectly."
GREATEST CHALLENGE New versions of video poker are constantly hitting the scene, and each one requires a different strategy to win. Plus, as successful players increase in number, casinos are lowering pay schedules (the amount they award for, say, a full house or a flush), cutting back on promotions, and reducing the number of machines. "It's survival of the fittest," says Dancer.
FINAL WORD "Any individual betting session may be 90 percent luck, but when you play 500,000 hands a year like I do, it's 90 percent skill."—DAVID SPARROW

For Dancer's class schedule, books and strategy guides, visit bobdancer.com.

GAMBLING MAN Bob Dancer puts on a video poker face at the Fiesta Rancho Casino.

THE PERFECT PLAY

Got a few hundred to blow in Vegas? Good, because even a video poker guru like Dancer loses more often than he wins. But by knowing the game and playing the odds, you might just walk away with a few extra grand in your pocket. Here are two hands commonly flubbed by amateurs in NSU Deuces Wild, and the strategy for playing them perfectly.

HAND NO. 1 DEUCE DILEMMA

YOUR INSTINCT IS TO Hold the straight flush you've been dealt, which pays out $50 on a $5 bet.

WHAT YOU SHOULD DO INSTEAD Hold only the three deuces, which are wild, and draw two new cards.

WHY? There are 1,081 different two-card combinations you can draw to the three deuces. In 819 cases (or 76 percent of those draws), this play will only result in a four-of-a-kind, which pays $20—a net loss of $30 from the straight flush you were dealt. But 156 combinations will improve your position. Forty-six of these combinations include a fourth deuce, which would give you a five-of-a-kind and light up the machine for $1,000. The average payoff for a three-deuce hand is slightly more than $72—only wimps settle for the sure-thing $50 straight flush.

HAND NO. 2 THE RIGHT HOLD

YOUR INSTINCT IS TO Hold the entire hand (a straight), or hold the wild twos and draw three new cards.

WHAT YOU SHOULD DO INSTEAD Hold everything but the six of diamonds.

WHY? A straight might give you bragging rights in your basement game, but here it's worth a measly $10. Tossing everything but the deuces is a better play, offering an average payoff of $15.37. But if you hold everything but the six—in effect, betting on either the three, four, six, eight or nine of clubs and a $50 straight flush—your average payoff jumps to $16.17.

FROM LEFT: JASON LEE; JAMES CHIANG

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FACTS,
ANSWERS,
ODDITIES &
ENTERTAINMENTS
FOR A MONTH
OF SCIENCE

NATHAN FOX

DEPARTMENT OF INADVERTENT ASTROPHYSICS

THE FALLACY OF THE BLACK HOLE IN SWITZERLAND THAT WOULD SWALLOW EARTH

A reader asks: "I heard that a new particle accelerator might create black holes. Won't these end up destroying Earth and everything on it?"

The planet is safe. (From particle accelerators, anyway.) While there is a *slight* chance that the Large Hadron Collider (LHC), a next-generation particle accelerator scheduled for completion in 2007, could produce black holes, they will certainly not be of the planet-swallowing variety. No, these would be about a million times smaller than the nucleus of an atom, and they'd "evaporate"—essentially disappear—in roughly 10^{-27} seconds. Apologies to the doomsday crowd, but the LHC won't be powerful enough to produce anything more threatening.

A quasi-controversy of this type first made the rounds through the news media and Internet in 1999, during the construction of Brookhaven National Laboratory's Relativistic Heavy Ion Collider (RHIC). In response to several alarmist, inaccurate news reports, Brookhaven commissioned four physicists to study the potential risk. The scientists concluded that RHIC posed no danger, but recommended that the question be revisited "each time a new facility opens up a new high energy frontier."

The upcoming LHC does just this, and so we called MIT physicist Frank Wilczek, one of the authors of the RHIC study, to revisit the question. We asked him if we had anything to worry about with the LHC. He laughed.

In a commendable spirit of thorough inquiry, Wilczek and colleagues' original study started with two different sets of assumptions. The first holds that our current estimate of gravity's strength is correct. The second maintains that our understanding of gravity is wrong, that there is "new physics" of a very specific type lurking at the extreme energies the new particle accelerator will create. Only in the second scenario would it be possible to create miniature black holes, either at RHIC (which had not yet, as we went to press, destroyed Earth) or at the LHC. "In standard theories of gravity, you can estimate what it would take to make a black hole, and that's just not going to happen," Wilczek says.

To create a black hole, the mass inside a certain volume has to cross a threshold. There needs to be so much mass in so little space that the force of gravity actually rips the fabric of space-time. Even though particle accelerators are designed to concentrate the maximum amount of mass (or energy) in the smallest space possible, the ones we can build now—including the LHC—are simply too weak to cross this threshold, provided that our current theories of gravity are correct. But if, as some physicists have proposed, gravity is actually stronger at very small distances (owing to the existence of unseen extra dimensions), we don't need to cram quite as much mass into the same confined space to create a black hole, and the LHC could produce more than 86,000 black holes every day.

Yet once these appeared, they would abruptly evaporate, thanks to an unusual black hole weight-loss program called Hawking radiation. "So, again, they wouldn't cause any

NAGGING QUESTIONS?
We answer 'em: **fyi@popsci.com**

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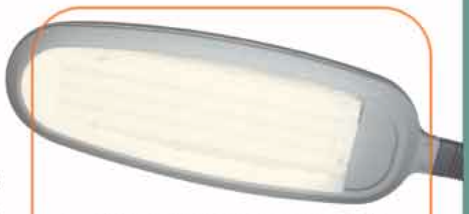

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danger," Wilczek says. "They would look not so different from unstable particles that we've been dealing with at accelerators for a long time."

Now, there are some arguments floating around the Internet that suggest we be more careful, because Hawking radiation, which would keep these mini-black-holes from growing, is unproven. True, but so is the far more hypothetical existence of extra spatial dimensions, which would be needed for particle accelerators to make the black holes in the first place. More important, these arguments seem to miss the point of a new accelerator, which is to explore the unknown. Hawking radiation will remain unproven until we witness a black hole evaporating. And though we may not see it happen at the LHC, wouldn't it be exciting if we did?—GREGORY MONE

BUREAUCRATIC TRANSLATOR

ANOMALY = DISASTER, AND OTHER HANDY NASA EUPHEMISMS

The U.S. space agency has a language all its own. NASA uses so many acronyms that the agency issues a book to its employees to keep track of them. And even when NASA uses ordinary words, they're often imbued with special meaning, generally designed to take the edge off graphic situations. "When you're inside," says one NASA spokesman, "it's not a problem understanding what we're talking about." It's the rest of us who need some help. Here are our translations of NASA's favorite lingo.—DAWN STOVER

anom•a•ly \ə-'nä-mə-lē\ *n*: a malfunction, sometimes serious
USED IN A SENTENCE: "Shortly thereafter, the X-43A began to experience a control *anomaly* characterized by a roll oscillation." (Press release, "NASA Mishap Board Identifies Cause of X-43A Failure," dated July 23, 2003)
WHY NASA USES IT: "Anomaly" turns catastrophes into irregularities.

con•tin•gen•cy \kən-'tin-jən(t)-sē\ *n*: a type of problem that may turn out to be a MISHAP (see below), and for which a response can be planned in advance
USED IN A SENTENCE: "A Space Shuttle *contingency* has been declared in Mission Control, Houston, as a result of the loss of communication with the Space Shuttle Columbia at approximately 9 a.m. EST Saturday." (Public statement, issued 12:10 p.m. EST on February 1, 2003)
WHY NASA USES IT: A "contingency" is an emergency but without all the negative connotations.

mis•hap \'mis-ˌhap\ *n*: an accident or catastrophe, such as a space shuttle breaking apart
USED IN A SENTENCE: "In the case of a high-visibility, mission-related Shuttle *mishap*, the NASA Administrator may activate an International Space Station and Space Shuttle Mishap Interagency Investigation Board." (Columbia Accident Investigation Board Charter, dated February 1, 2003)
WHY NASA USES IT: "Mishap" is blame-neutral, suggesting bad luck rather than error. "We just don't use the term

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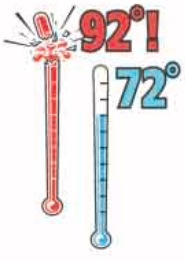

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8. After a year of using the ROM your friends admiring your good shape.
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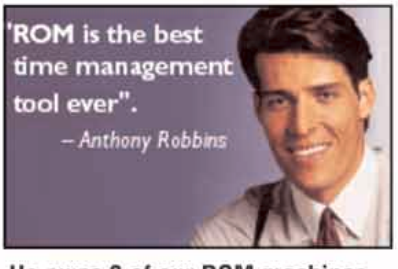

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'accident,'" says a NASA spokesperson. "I guess it's really not in our vocabulary." Not when they have so many other words for it.

nom•i•nal \ˈnä-mə-nᵊl\ *adj*: proceeding according to plan

USED IN A SENTENCE: "Telemetry from the Genesis spacecraft indicates that all spacecraft subsystems are reporting *nominal* operation." (Genesis Mission Status Update, posted November 26, 2003)

WHY NASA USES IT: "Nominal" sounds so much more scientific than "normal." Or, as one spokesperson explains: "It's spacetalk."

re–plan \ˈrē-ˌplan\ *n*: a new plan or program timetable, often resulting in increased costs, usually issued when NASA falls behind schedule

USED IN A SENTENCE: "The change order implements a *re-plan* to the JWST program to accommodate the planned launch date of August 2011, which was announced earlier this year." (Press release, "NASA Issues Modification to James Webb Space Telescope Contract," dated September 3, 2003)

WHY NASA USES IT: "Re-plan" sounds as if the agency is *making* a plan, rather than breaking one.

var•i•a•bil•i•ty \ˌver-ē-ə-ˈbi-lə-tē\ *n*: small fluctuations rather than a long-term trend

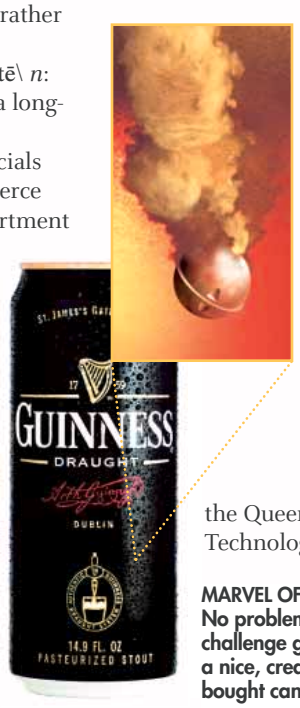
USED IN A SENTENCE: "NASA officials will join Department of Commerce Secretary Don Evans and Department of Energy Secretary Spencer Abraham to unveil the Administration's strategic plan on long-term global climate *variability* and change at a press conference tomorrow." (Press release, "NASA Joins Partners to Unveil Climate Change Initiative," dated July 23, 2003)

WHY NASA USES IT: "Variability" suggests a process that is natural, reversible and not out of control. The climate may be changing, but that doesn't mean we have to.

WORLD'S GREATEST INVENTION

THE INTERNET CAME IN A DISTANT SECOND

According to an online poll conducted by the British technology magazine *T3*, the greatest invention of the past 40 years was the beer widget, the small ball filled with nitrogen that is designed to release the carbon dioxide dissolved in a can of Guinness beer, giving it a foamy head. The device, introduced in 1989, previously won the Queen's Award for Technological Achievement.



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BOOK OF THE MONTH

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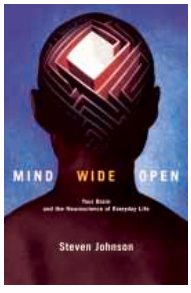

One of the more memorable commercials of the Reagan-era anti-drug campaign featured an egg sizzling in a frying pan, along with the ominous warning: *This is your brain on drugs.* Though the imagery was powerful, the problem with the message, as Steven Johnson points out in *Mind Wide Open* (Scribner, $25), is that your brain is always on drugs. Fear, love, depression, anxiety: Each of these corresponds to a rush of chemicals through your head.

In *Mind Wide Open*, Johnson explores how an awareness of the brain's workings can improve the way a perfectly healthy person thinks or controls his emotions. In this case, that healthy person is Johnson, who proves to be an enlightening guide to the workings of his own neurochemical wanderings. Interspersing explanations of the intricacies of neuroscience with personal reflections, Johnson picks apart his thoughts and emotions during intense periods, such as when he stood outside his Manhattan apartment and watched the towers burn on September 11, or following the birth of his first child. He also tours the strange world of companies like Braincare, which uses neuroscience tools to help children with attention-deficit disorder learn to focus, and teaches day traders how best to concentrate on their stock screens for long periods.

These odd adventures, their effect on Johnson, and, more generally, all this thinking about thinking, make for an often mind-bending read. Johnson presents a strong argument that we should all take advantage of the neuroscience boom, not just to satisfy our scientific curiosity, but for personal benefit as well. Go out and get your brain scanned today.—GREGORY MONE

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(CONTINUED FROM PAGE 52)

wirelessly transmit its signals out of the body. "It's like having an implanted cellphone," says Nicolelis.

These signals would be picked up by a portable computer, which would then generate commands for the artificial limb. Patrick Wolf has been aggressively tackling this part of the system, and has already built a wireless backpack computer for the Duke monkeys, with enough power to transmit their brain signals 100 meters through the air.

The researchers are also grappling with the fact that getting commands out of the brain is not the full secret to controlling an arm. The brain also needs feedback in order to make its commands more precise. Imagine trying to pick up a glass of water without a sense of touch: Instead of guiding your fingers around its side, you might simply knock it over. Or, once you'd managed to grab the glass, you might crush it accidentally as you tried to pick it up. Or, after passing those stages successfully, you might just splash your face with water.

John Chapin is working on ways to give people the feedback they'll need to make the Duke brain-machine interface a reality. He's experimenting with how to deliver information directly into the brain—particularly to the region of the brain that handles the sense of touch. But that's long-term research. In the short-term, a group at MIT is designing a cloth-like material that can be attached to a place on a person's body where he or she still has a sense of touch. Force sensors on the limb can then relay their signals to the cloth, which will turn that information into different vibrations. It's not the same thing as feeling a glass in your hand, but your brain can probably learn to take advantage of the information.

Learning, in fact, turns out to be the secret weapon of brain-machine interfaces. Nicolelis's latest studies have shown what is happening to the Duke monkeys on a neurological level as they use the dots and circles on the computer screen to alter the commands their brains generate. "Now we have plenty of evidence that the brain is changing, and in ways I didn't expect," says Nicolelis. "It happens in a matter of minutes." As the monkey trains, neurons in its brain begin to alter their firing patterns. More and more neurons get involved in producing commands—in fact, the number can triple. At the same time, a special set of neurons emerges that becomes active only when the monkey operates the robot directly with its brain, and not when it uses the joystick. Remarkably, these neurons switch on as soon as Nicolelis disables the joystick.

With this extra set of neurons, Nicolelis explains, "the brain is assimilating the robot. It's creating a representation of it in different areas of the motor cortex"—the part of the monkey's brain where movement commands are generated. As the brain carves out a special place for its representation of the robot, Nicolelis speculates, it's possible that the robot begins to feel as much a part of the body as the monkey's own arm.

If he's correct, this is very good news for people who might someday try to use his prosthetic limb. Their brains will reorganize themselves to master the limb, which will take on a natural feel. And since humans can be told what they should be learning—instead of figuring it out on their own as monkeys do—the training process may take even less time. "This could be done in a matter of a few trials, because you could instruct a human what to do," says Nicolelis.

The fact that the monkeys' brains adapt so readily gives the Duke researchers confidence in the face of all the challenges that lie ahead. While it's too soon to say whether brain-machine interfaces are going to turn up on the battlefield, they are almost certainly headed for the doctor's office. "We have a plan for every part of the puzzle," says Patrick Wolf, who strongly believes that the Duke team will meet its five-year deadline. "I don't see any showstopper." ■

Carl Zimmer is a science writer based in Guilford, Connecticut. His most recent book, Soul Made Flesh: The Discovery of the Brain—and How It Changed the World, *was published by the Free Press in January.*

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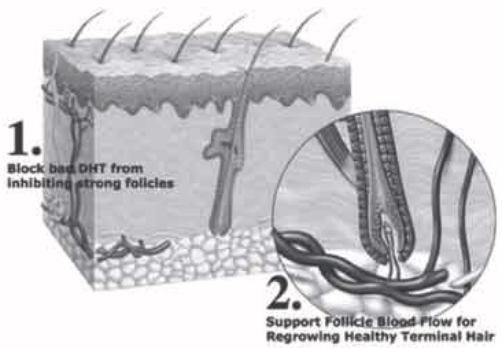

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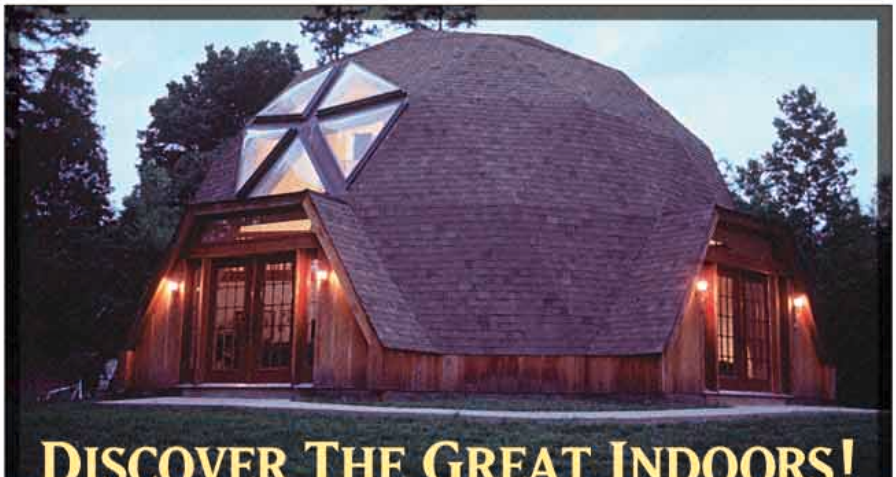

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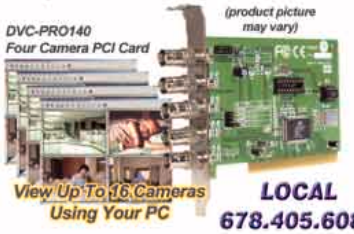

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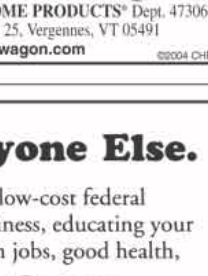

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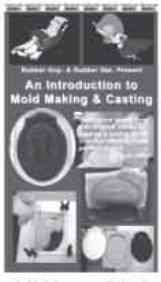

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SEPTEMBER 1923

FROM THE *POPULAR SCIENCE* ARCHIVES

50 HOURS AT INDY: THE CAR THAT REFUELED ON THE FLY

Auto enthusiasts envisioned high-speed tankers that pumped on the go. The idea did not catch on—except in the air.

Scattered among history's bright ideas are technologies that were doable yet not worth doing—like on-the-fly fill-ups for automobiles. In a 1923 cover story, we reported that a new supply car had enabled another auto to drive 3,155 miles in 50 hours at the Indianapolis Speedway without stopping to refuel (though it still had to pull over for tire changes). Why bother? Automotive and aviation developers alike were obsessed with setting endurance records, in part because at the time, places to refuel were few and far between. The same article described a breakthrough in which four army aviators transferred fuel from one deHavilland DH-4 to another while "rushing through the air at a speed of 90 miles an hour." Early systems were tricky, with tanker planes sometimes unable to haul the hose back in; in one test, a pilot was forced to land with a 48-foot hose "dangling under his machine." On-the-road refueling never caught on, but the inflight version became a staple of military strategy.

Other stories from the September 1923 issue:

THE WORLD'S MOST POWERFUL MACHINE GUN

The new .50-caliber Browning machine gun would see extensive action in WWII, Korea and Vietnam. It fired 500 rounds per minute and had an effective range of 6,000 feet.

INSULIN—A MIRACLE OF SCIENCE

Medical trials using insulin to treat diabetes were a great success. Frederick G. Banting, who discovered the hormone in 1921, won the Nobel Prize in December 1923.

A MODEL OPERATING ROOM FOR ANIMALS

The University of Pennsylvania Veterinary School boasted modern surgical methods as advanced as those used on humans.

BUCKING AUTO IMITATES A BRONCO

Before the mechanical bull, there was this: a car sporting a saddle bolted to its frame, and rear wheels mounted 3 inches off center. It gave thrill seekers a tooth-rattling ride.

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