

# Technology Review

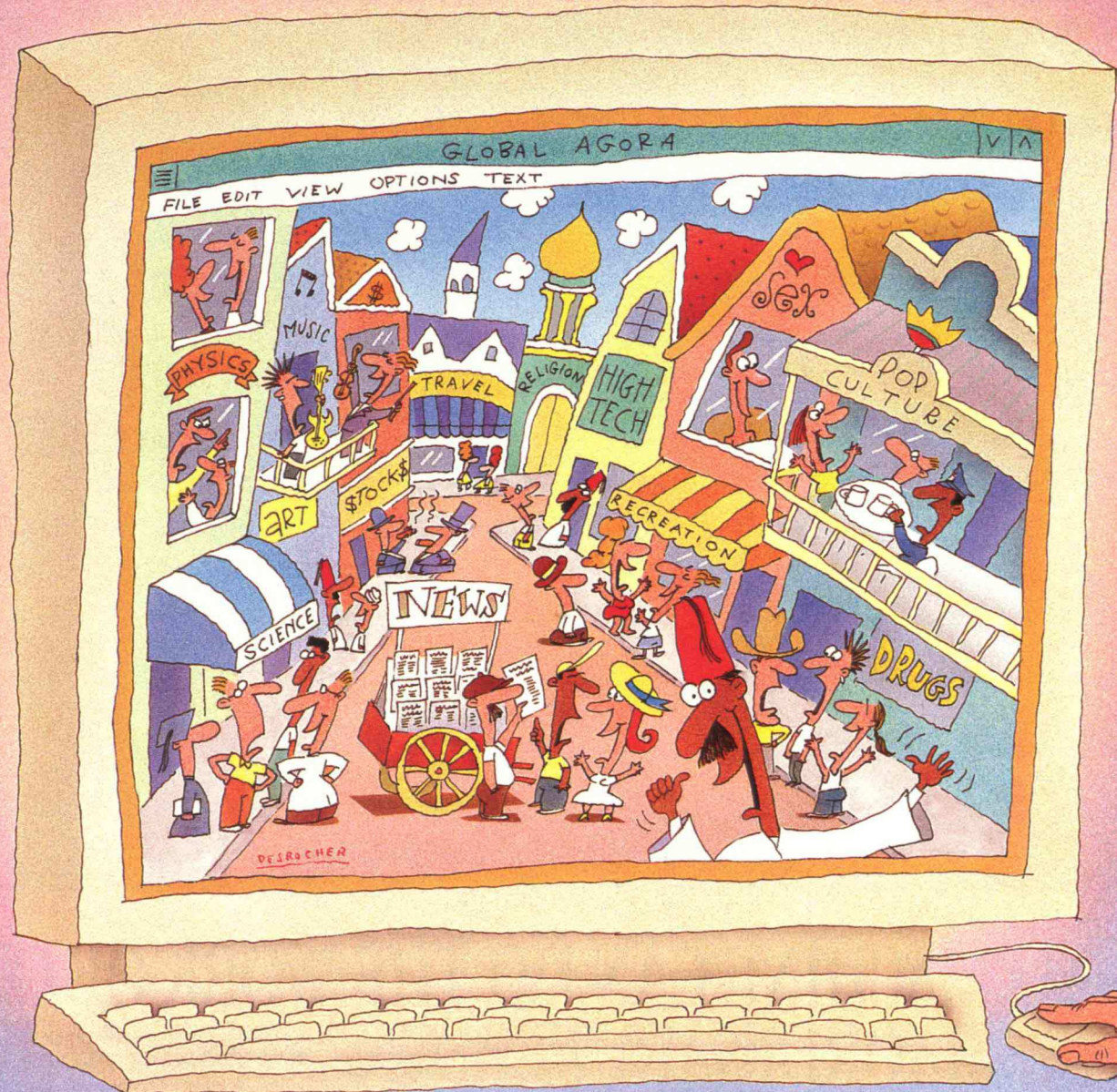
EDITED AT THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

JULY 1994

\$3.75/CANADA \$4.95

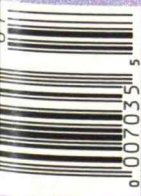
## *Life on the Net*

CHAOS AND COMMUNITY ON-LINE

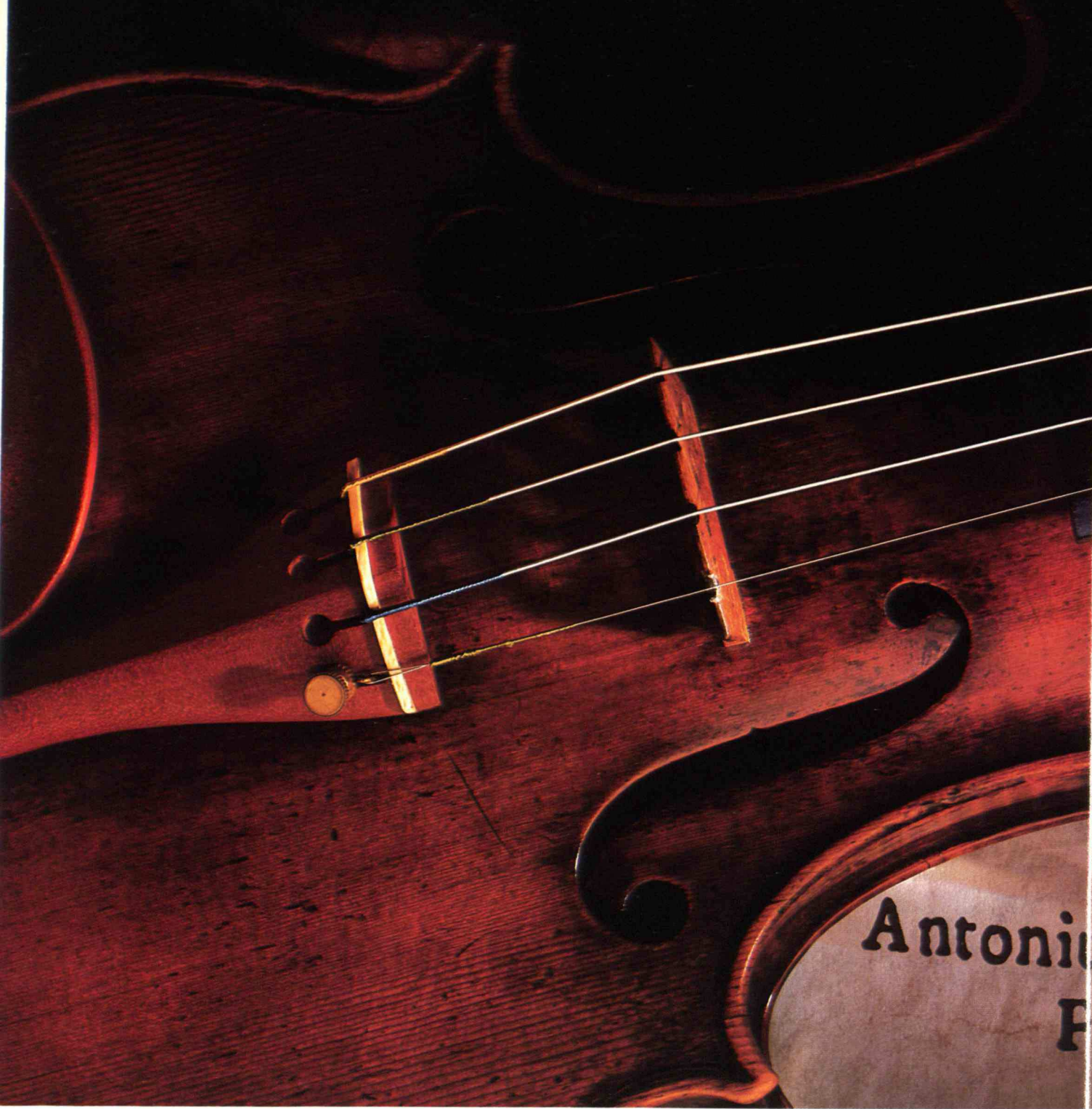


ALSO IN THIS ISSUE:

- ◆ WHY DEFENSE CONVERSION WON'T WORK ◆
- ◆ THE SECRETS OF SILICON VALLEY'S COMEBACK ◆
- ◆ BUILDING THE MACHINE THAT TOOK US TO THE MOON ◆
- ◆ ORDER WITHOUT LEADERS: THE POWER OF DECENTRALIZED THINKING ◆







# NO MACHINE CAN DO THE WORK OF ONE EXTRAORDINARY PERSON.

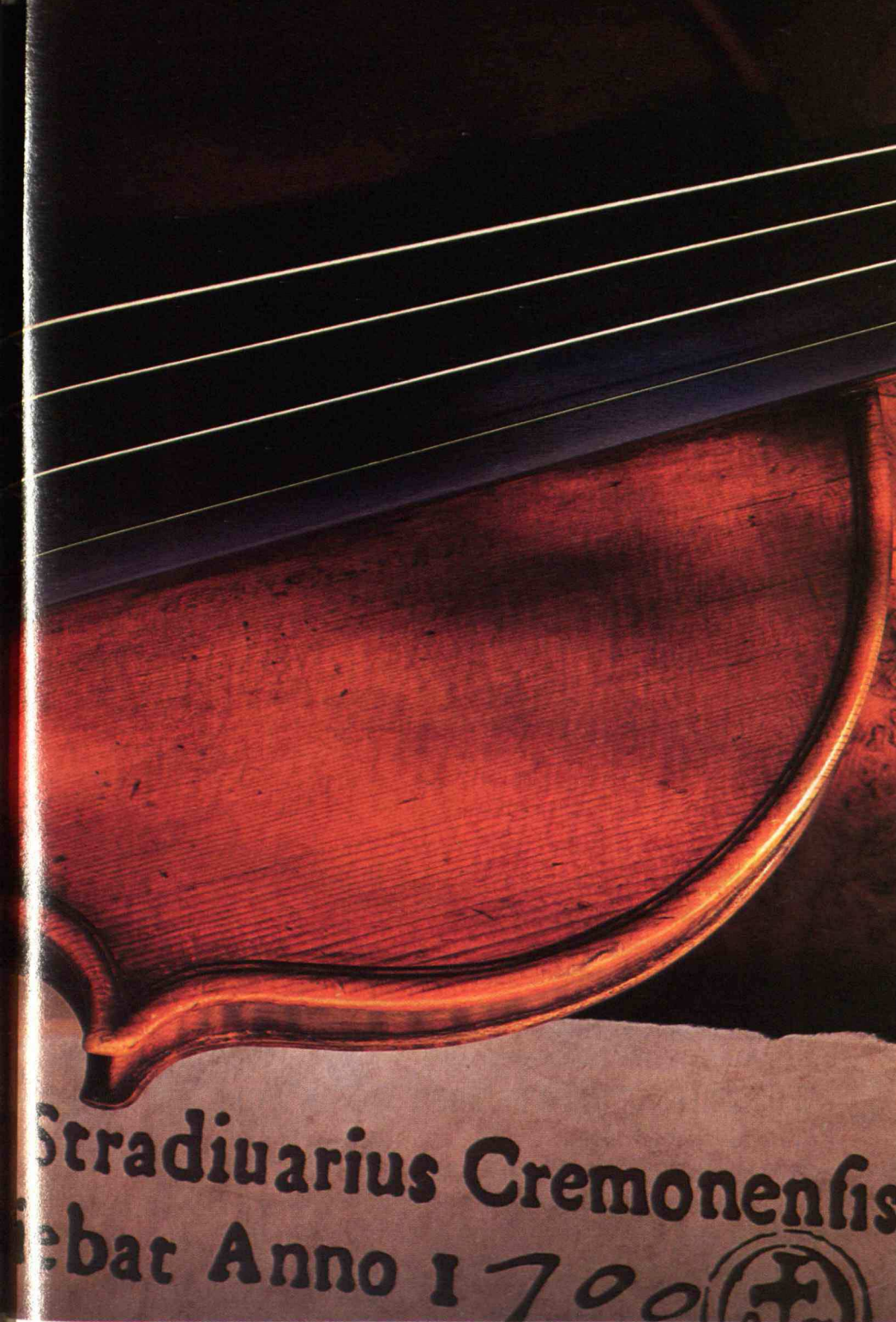
On a late summer's evening in 1700 Antonio Stradivari worked by candlelight to finish a violin. A violin that would become the quintessence of perfection.

A Stradivarius is legendary not because Antonio had access to

special technology, but because of his passion for his craft.

No tool or machine can take the place of such passion. At Lockheed, the Robert E. Gross Award is given to those exceptional engineers who also have a passion to be the best. The award is named after the creator of the modern-day Lockheed,





Dr. Suzanne Cornelius  
Lockheed Space  
Operations Company

D. F. "Dan" Glover  
Lockheed Aeronautical  
Systems Company

John E. Gulley  
Lockheed Fort Worth  
Company

Donald B. Henderson  
Lockheed Aircraft Service  
Company

Dwight Janoff  
Lockheed Engineering  
& Sciences Company

Dr. Stephen Mende  
Lockheed Missiles  
& Space Company

Tsun Ng  
CalComp Inc.

Dr. Robert J. Norbutas, Sr.  
Lockheed Missiles  
& Space Company

Dr. Ramon A. Olivero  
Lockheed Environmental  
Systems & Technologies  
Company

Dr. Herbert E. Rauch  
Lockheed Missiles  
& Space Company

Dr. Donald B. Reid  
Lockheed Missiles  
& Space Company

Joel Thompson  
Lockheed Advanced  
Development Company

Dr. Joseph Vadyak  
Lockheed Advanced  
Development Company

Elliott Willner  
Lockheed Missiles  
& Space Company

Paul A. Zank  
Lockheed Sanders

who knew that as long as he had people with such passion, all else would follow.

The extraordinary accomplishments of this year's award winners include advances in everything from maneuvering jet fighters to the development of a new alloy and maritime stealth.

It is because of these remark-

able individuals and their teams that Lockheed remains one of the most innovative, technically advanced aerospace companies in the world today.



Watch Nova on PBS, Tuesdays at 8 p.m.





# Contents

## FEATURES

### 20 TRAVELS ON THE NET

BY STEPHEN STEINBERG

The communities springing up along the Internet and other computer networks provide a harbinger of life on the evolving information highway. Log on to Internet services like Usenet, IRC, and MUDs and you'll see the raw and ungainly beginnings of a world with vast possibilities for communication, learning, and entertainment—one that looks nothing like 500-channel TV.

### 32 CHANGING THE CENTRALIZED MIND

BY MITCHEL RESNICK

Contrary to popular belief, complex phenomena like economic trends, the body's immune response, even bird-flock formations are not the result of careful direction by a central authority. In fact, they arise from simple individual behaviors and occur without any leader at all. The study of such intricate patterns can provide new insights and new tools for all who plan and design.

### 42 LESSONS FROM SILICON VALLEY

BY ANNALEE SAXENIAN

Both known as leading centers of innovation, California's high-tech epicenter and Boston's Route 128 embody two radically different approaches—the former based on networks of companies, the latter on independent firms. Silicon Valley's recent rebound shows that the network approach has clear advantages.

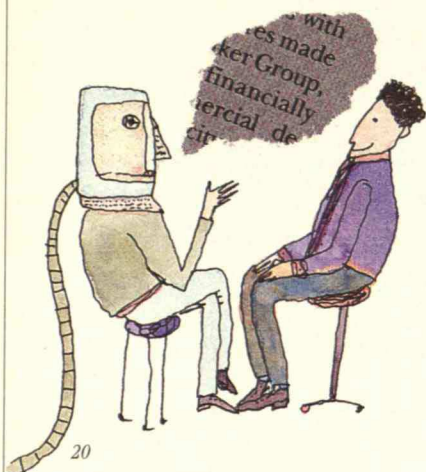
### 52 WHY DEFENSE REINVESTMENT WON'T WORK

BY BRUCE D. BERKOWITZ

The Clinton administration's effort to help ailing defense companies adapt to civilian manufacturing is astute politics but bad economics. The elephant simply can't dance. A more effective approach would be to help liberate these firms' valuable talent and capital for enhancing new or established companies.

### 61 FLY ME TO THE MOON: AN INTERVIEW WITH JOSEPH G. GAVIN, JR.

Twenty-five years ago this month, Neil Armstrong took his historic "giant leap for mankind." The leader of the team that developed and produced the lunar modules—the series of spacecraft that landed astronauts on the moon—describes the historic engineering project's agonies, ecstasies, and legacies.



20



32



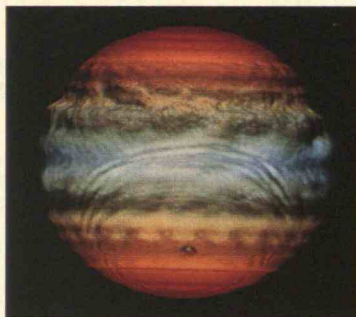
42



61

COVER ILLUSTRATION: JACK DESROCHER

## DEPARTMENTS



10

### 5 FIRST LINE

### 6 LETTERS

### 10 MIT REPORTER

Modeling Big Hits; How Cells Die for Us

### 13 TRENDS

Space-Age Divining Rods; Have Antimatter, Will Travel;  
A New King Cotton; A Greener White House; Reading the Silver Screen

### 69 THE HUMANE ENGINEER

*SAMUEL C. FLORMAN*

In response to record levels of unemployment, engineers are applying their problem-solving skills to a wide range of new fields and endeavors.

### 70 THE ECONOMIC PERSPECTIVE

*BENNETT HARRISON*

Networking, computer-based and otherwise, is expanding the reach of economic-development organizations. They can share information and expertise that help attract new investment and jobs to poor communities.

### 72 FORUM

*MARTIN HART-LANDSBERG*

By harassing North Korea for its alleged nuclear ambitions, the U.S. is pursuing an unproductive policy that reflects an unresolved war.

### 74 REVIEWS

Robert J. Crawford on persistent Japanese-management myths.  
Will Warner on the blurring divide between humans and machines.

### 80 PHENOMENA

The High Art of Apollo XI



13



74

Technology Review (ISSN 0040-1692), Reg. U.S. Patent Office, is published eight times each year (January, February/March, April, May/June, July, August/September, October, and November/December) by the Association of Alumni and Alumnae of the Massachusetts Institute of Technology. Entire contents ©1994. The editors seek diverse views, and authors' opinions do not represent the official policies of their institutions or those of MIT. We welcome letters to the editor. Please address them to Letters Editor.

Editorial, circulation, and advertising offices: *Technology Review*, Building W59, MIT, Cambridge, MA 02139, (617) 253-8250; FAX (617) 258-7264. Printed by Lane Press, S. Burlington, VT. Second-class postage paid at Boston, MA and additional mailing offices. Postmaster: send address changes to *Technology Review*, MIT, Building W59, Cambridge, MA 02139.

Subscriptions: \$30 per year. Canada add \$6, other foreign countries add \$12. Contact *Technology Review*, P.O. Box 489, Mount Morris, IL 61054, (800) 877-5230 or (815) 734-1116; FAX (815) 734-1127.

Advertising representatives: Mark E. Lynch, Eastern Sales Manager, 9 Salem Drive, Saratoga Springs, NY, (518) 583-6086; The Leadership Network: Kiki Paris, 200 Madison Ave. New York, NY 10016, (212) 686-1734; Albaum, Maiorana & Associates, 418 W. 5th St., Royal Oak, MI 48067, (313) 546-2222.

Printed in U.S.A.





# THE MOST POWERFUL COMPACT RADIO IN THE WORLD!



**NEW!**  
Just  
arrived  
from  
Europe!

## THE GRUNDIG YB-500 FM/AM Shortwave Receiver

Listen! Here is the BIG BREAKTHROUGH in powerful performance and design. Not in stores... Now available to you in the U.S.A. from Willabee & Ward. No other compact radio packs all these powerful features.

▲ **POWERFUL RECEPTION.** The Grundig YB-500 **does it all:** pulls in AM, FM, FM stereo, **every** SHORTWAVE band, even aviation, military and ship-to-shore. All with lock-on digital precision.

▲ **POWERFUL SOUND.** Exclusive Audio Power Boost — found on no other world band radio — gives the YB-500 big, rich, room-filling legendary Grundig sound.

### Powerful Features.

Power scan! The YB-500 has continuous power scan on shortwave — stops at every signal and lets you listen. When you hear a broadcast you want, you tell the radio to stop. Only Grundig has this feature.

Power timing features! The YB-500 can send you to sleep on FM, wake you with weather on AM, then switch you to BBC shortwave. Even shuts itself off. Elsewhere, you'd pay \$500 for these features.

### Powerful Memory.

The BBC and *all* major world broadcasters are pre-set for instant retrieval. You can add

40 more stations on any band and display call letters for reference. No other radio at this price offers such powerful memory.

Also has instant keypad access to all frequencies. Illuminated, adjustable LED display for bedside use. Advanced RDS FM station information display. It will be years before other makers catch up with the YB-500. But it is available today from Willabee & Ward.

### Powerful Value.

The Grundig YB-500 is only \$299 (plus \$9.50 shipping and handling), payable in eight monthly credit card installments of \$38.56. Includes 4 AA batteries, deluxe travel pouch, stereo headphones, owner's manual, and Grundig's shortwave listening guide. **INTRODUCTORY OFFER: ORDER NOW AND GET A FREE DUAL-VOLTAGE INTERNATIONAL ADAPTER!**

Grundig 1-year warranty on parts and labor. 30-day money back guarantee. Grundig is to radios what BMW and Mercedes are to cars. European look! European sound! European quality! Order now!

**Phone orders normally shipped next business day.**

**Call Toll-Free: 1-800-367-4534**  
**Extension 697-413**

First and **ONLY** world band with award-winning vertical design. Measures approximately 7½" x 4½" x 1½" with built-in stand and retractable ferrite antenna.

© 1994 MBI

#### RESERVATION APPLICATION

Willabee & Ward  
47 Richards Avenue • Norwalk, CT 06857



**Call Toll-Free: 1-800-367-4534**  
**Extension 697-413**

Please send me \_\_\_\_\_ Grundig YB-500 Digital All-Band Shortwave Receiver(s). For each receiver, charge eight installments of \$38.56\* to my credit card:

☐ VISA ☐ MasterCard ☐ Discover ☐ Am. Ex.

Credit Card No. \_\_\_\_\_ Exp. Date \_\_\_\_\_

Name \_\_\_\_\_ Please Print Clearly.

Address \_\_\_\_\_

City \_\_\_\_\_

State/Zip \_\_\_\_\_

Signature \_\_\_\_\_

(Orders subject to acceptance.)

☐ I prefer not to pay by credit card and will pay by check. Enclosed is my check for \$299 plus \$9.50 shipping/handling, a total of \$308.50\* for each receiver.

\*Any applicable sales tax will be billed with shipment. Higher shipping/handling outside U.S.



# First Line

## Turning Missiles into Chevrolets

**I**N the first few days of my first engineering job out of college, at an aerospace firm near the Boston area's Route 128, my boss sat me down with a bunch of Air Force manuals so I could begin learning the jargon and culture. But while I soon realized that our project's technical aspects would provide interesting challenges, I also started worrying about what it all meant. Sanitized terms like "close air support," "air interdiction," and "counterair," for example, essentially referred to engineered destruction and death.

Why not apply the firm's resources, I thought, to uses that *enhance* life instead of compromise or destroy it? I was naive enough to say so to the department head—my boss's boss—when he dropped in to see how I was doing. "This warlike stuff really bothers me," I told him. He chewed on his pipe, deep in thought, for what felt like an hour, and just when I concluded he'd soon be showing me the door he answered: "It really bothers me, too. But I've been in this business all my life, and it's all I know."

In this post-Cold War era, "conversion" of aerospace firms is finally one of our country's major goals—and many in the defense industry are now trying to apply "all they know" to the direct civilian/commercial good of the nation. But it clearly won't be easy.

For one thing, companies don't readily switch fields or working styles. For another, while some military products may conceivably be "dual use" or yield spinoff, others defy such fortuitous revival. "There are some things you cannot convert," said Dennis J. Picard, CEO of Raytheon Co., at a seminar at MIT last fall. "It's very hard to convert a missile to domestic use."

Yet even missiles are being considered in our current attempt to wring broader benefit out of defense-oriented ventures. "Hoping to find a peaceful, commercial use for relics of the Cold War," a recent

story in the *New York Times* began, "the White House is considering recycling dozens of nuclear-warhead missiles and selling them to American industry for launching commercial satellites."

But these missiles, while they might find niche applications in some fields of scientific research, were built to deliver relatively light payloads (massively destructive, but small), and to carry them only through low-earth orbit. Communications satellites—the main application of commercial launches—are typi-

*Defense companies  
can indeed be converted,  
but mostly through  
reincarnation.*

cally heavier and require placement in much higher orbits.

A bigger problem, however, is the cost and complexity of such products, built to exacting military standards. The missiles can in fact serve as a metaphor for the limited commercial prospects of the companies that make them. What complicates, even bedevils, these firms' conversion is the very set of powerful and refined capabilities that have long enabled them to provide yeoman's service to their customers at DOD and NASA.

"At first it might seem as though the same U.S. companies that built sophisticated guidance systems capable of sending a smart bomb through the air shaft of an Iraqi bunker could certainly retool and make consumer electronics to compete with NEC or Panasonic," says Bruce D. Berkowitz in "Why Defense Reinvestment Won't Work," in this issue. The problem, he maintains, "is management and organization. The specialized structure, procedures, and culture that defense contractors have developed over the past 40 years to survive in the defense economy make them hopelessly ill-suited for competing in commercial markets."

John M. Deutch, now deputy secre-

tary of defense, spoke in a similar vein in the April issue of *Technology Review*. "The defense procurement system," he said, "was designed for a different world—a world of large-scale systems and defense-unique items."

Though a few companies "might find useful commercial application for widgets built to military specifications," says Berkowitz, "these will likely be the exceptions." In an interview also in this issue, Joseph G. Gavin, Jr., former president of Grumman Aerospace Corp., agrees, noting that "the products of the 'converted' aerospace company need a top-of-the-line aura. . . . When you're betting somebody's life on the outcome, you get into a methodology that is too expensive for commercial products—unless you want to create a Mercedes. You cannot compete by trying to produce a Chevrolet."

Gavin maintains that "people who say 'convert the defense industry' don't really understand what they're proposing: it's more accurate to say that there's much there that can be directed to some useful commercial purpose." But in many cases, Berkowitz and other analysts argue, we should cut to the chase. "Instead of attempting to prop up defense firms that are no longer needed," he says, "it would be more efficient—and, in the long run, more humane—to let them die a natural death."

Those aerospace firms that remain will likely continue to play a major role in maintaining the nation's defense and its powerful, though reduced, defense industrial base. In some cases, modest adaptations will enable them to serve specific Mercedes-like commercial functions. But the true "recycling" of whole companies, in the usual sense of reclaiming the essence, say, of used aluminum and paper products, will require decomposition and reconstitution. The country's awesome engineering talent previously constrained by defense needs and procedures may thereby be unleashed with a vengeance, in the form of new or enhanced commercial enterprises. ■

—STEVEN J. MARCUS



*Publisher*  
WILLIAM J. HECHT

*Editor*  
STEVEN J. MARCUS

*Managing Editor*  
SANDRA HACKMAN

*Senior Editors*  
DAVID BRITTAN, HERB BRODY, SANDRA KNIGHT,  
SUSAN LEWIS, PHILIP LOPICCOLO, LAURA VAN DAM

*Associate Editors*  
SUSANNE FAIRCLOUGH,  
BETH HORNING, FAITH HRUBY

*Copy Editor*  
LUCY McCaULEY

*Editorial Assistant*  
SHERRIE SAINT JOHN

*Office Manager*  
CHRISTINE DESMOND

*Design Director*  
KATHLEEN SAYRE

*Senior Designer*  
NANCY L. CAHNERS

*Assistant Designer*  
LORI NOLLET DAMON

*Production Manager*  
SCOTT GLAZIER

*Design/Production Assistant*  
VALERIE KIVIAT

*Columnists*  
SAMUEL FLORMAN, BENNETT HARRISON,  
ROBERT M. WHITE, LANGDON WINNER

*Contributing Writers*  
DEBRA CASH, ANN MARIE CUNNINGHAM, DAVID GRAHAM,  
TOM KIELY, STEVE NADIS, WADE ROUSH, SETH SHULMAN,  
P.J. SKERRETT, STEPHEN STRAUSS

*Associate Publisher*  
PETER D. GELLATLY

*Circulation Director*  
BETH BAROVICK

*Associate Marketing Manager*  
MARTHA CONNORS

*Subscription Service Manager*  
LINDA MANION

*Accounting*  
LETITIA A. TRECARTIN

*Technology Review Board*  
ROBERT W. MANN (Chair)  
Department of Mechanical Engineering, MIT  
PETER D. GELLATLY  
Associate Publisher, Technology Review  
BARBARA GOLDOFTAS  
Program in Writing and Humanistic Studies, MIT

WILLIAM J. HECHT  
Publisher, Technology Review

RICHARD A. JACOBS  
Richard A. Jacobs Ltd.

STEVEN J. MARCUS  
Editor, Technology Review

VICTOR K. McELHENY  
Knight Science Journalism Fellowships, MIT

ROBERT M. METCALFE  
InfoWorld Publishing Co.

R. GARY SCHWEKHART  
Washington Biotechnology Funding

EDWARD T. THOMPSON  
Publishing consultant

G. MEAD WYMAN  
Dataware Technologies

*Editor Emeritus*  
JOHN I. MATTILL

# Letters

## A NEW DAY AT DOD

In "Reforming the Pentagon: An Inside Job" (*TR April 1994*), John M. Deutch provides insightful comments on the changes occurring within the Pentagon and the defense industry. More important, he is in a position to do something about it. If the Pentagon can overhaul its



cumbersome, overregulated, and costly procurement system to allow nondefense companies like Motorola to sell their products to the government, that will also help companies like the one I serve, Martin Marietta, to integrate commercial products into the many defense systems we produce.

I would make a plea to halt the turbulence in the acquisition process. The principle cause of its inefficiency is the perpetual motion of requirements, people, scheduling and funding. Each funding cycle does not start until the slate is wiped clean from the previous year and new priorities are set. What is needed is common agreement—in Congress and the executive branch—on mechanisms that make it harder to start new programs, that authorize only a few people to change a program once it is started, and that establish multiyear budgets for the Pentagon and its programs. In other words, the time has come to appropriate funds by project, not by the year. Many of us in the industry are encouraged that the Pentagon is facing up to the need for a thorough overhaul of its procurement process.

Finally, I would note that Deutch is also right on the mark in discussing the need to downsize government-run defense facilities to balance the downsizing taking

place in the private sector and take advantage of the inherent flexibility of contractor-operated labs and industry R&D. As he correctly states, today's defense infrastructure was largely designed to deal with yesterday's military problems. We are now in a different world, one that requires innovation and change.

If fundamental cultural change starts with leadership at the top, the Pentagon is well served in having the services of John Deutch and Defense Secretary William Perry.

NORMAN R. AUGUSTINE  
Chairman and CEO  
Martin Marietta Corp.  
Bethesda, Md.

## UNFAIR R&D COMPETITION

In "A Strategy for the National Labs" (*TR February/March 1994*), Robert M. White suggests that DOE laboratories be subsidized while they attempt to penetrate the private-sector contract R&D business. How fair is such a strategy to existing contract R&D organizations, which include large institutions such as Battelle, SRI International, SAIC, and Southwest Research Institute as well as hundreds of smaller corporations, including mine? All these organizations, both for-profit and not-for-profit, have gradually built their capabilities by investing capital and earnings in laboratories, instruments, computing facilities, and staff. It seems to me that if federal laboratories have outlasted their mission, they should be closed—not subsidized in the hope they will take R&D business away from existing institutions.

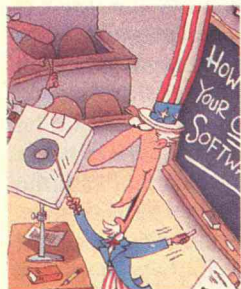
CHARLES E. KOLB  
President, Aerodyne Research  
Billerica, Mass.

## HIGH COST OF SOFTWARE

In a letter to the editor (*TR February/March 1994*) that appeared in response to "Subduing Software Pirates" (*TR October 1993*), A. Kerim Kar maintains that U.S. software companies should cut the high costs of programs sold in developing countries. This situation applies equally well to developed countries in



Europe, where U.S.-originated program packages sell for double to triple their neighborhood-software-shop prices in the United States. When I ask distributors here in Belgium about the price differences, the answer is always: they are needed because of the copying. (High European prices cannot be explained by the cost of intermediaries or local taxes, since the European offices of U.S. firms offer upgrades at multiples of prices I'm offered for the same software in ads mailed to my address in the United States.) The European office of a U.S. firm told me that "we pay more to our U.S. parent for upgrade kits than



its retail price in the U.S." Ironically, the result is rampant copying through "rental clubs," less formal trading among friends, plus institutionalized violations by even large companies.

U.S. software houses are injuring themselves (and the U.S. balance of payments) by their wildly high pricing.

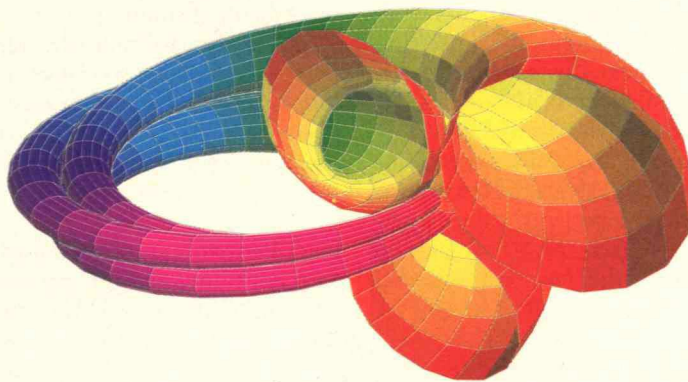
Unlike Kar, I don't think U.S. software should sell below its actual (not list) U.S. price; there are antidumping laws here, too. Just realistic pricing would cause a sales boom and reduce copying, both casual and institutional, to "reasonable" levels. Most people would prefer to obtain the manufacturer's package that includes the many-hundred-page users' manual rather than stand at a photocopying machine.

LESTER A. GIMPELSON  
Brussels, Belgium

#### CORRECTION

"Simulations on Trial," in the May/June 1994 issue, reported that Honeywell hired computer animators at Forensic Technologies, Inc. (FTI), to help prove that Minolta infringed on Honeywell's patented autofocus camera technology. The article also said Minolta hired FTI's rival, Z-Axis. Actually, the reverse is true: Honeywell hired Z-Axis and Minolta hired FTI.

## CAN THE MOST POWERFUL AND RELIABLE MATH SOFTWARE REALLY BE THE EASIEST TO USE?



Engineers and scientists who use Macsyma consistently describe it as more powerful and more reliable than any other mathematics software. Reviewers agree that Macsyma's on-line help system is the best in the field. IEEE Spectrum calls Macsyma "a national treasure" and says:

"Users with heavy mathematics needs should insist on Macsyma."

And, the most recent PC Macsyma runs fully three times as fast as earlier ones on PC Magazine's 1992 benchmark tests.

**Call 1-800-macsyma for a free demo disk today.**

# Macsyma®

**A quarter century of software development is hard to beat.  
\$349\***

\* For PC version in U.S.A. and Canada. Academic and quantity discounts are available.  
Macsyma is a registered trademark of Macsyma Inc.

Macsyma Inc.  
20 Academy Street  
Arlington MA 02174-6436 / U.S.A.

tel: 617-646-4550  
fax: 617-646-3161

1-800-macsyma  
1-800-622-7962



## TREATING THE WHOLE PATIENT

My experience attending medical school and working in the health-care field is vastly different from that portrayed by Adriane Fugh-Berman in "Training Doctors to Care for Women" (*TR* February/March 1994). At my alma mater, the University of Kentucky, breasts were studied in anatomy, female orgasm was recognized, patients were informed of the potentially upsetting nature of their sexually transmitted diseases, and female medical students did examine male patients' prostates. Furthermore, during my residency in family practice, doctors delivered fewer than 15 percent of their patients' babies surgically—nowhere near the 50 percent the author cites. Of the women I followed personally from beginning to end of pregnancy, none went to Caesarean section, and less than 15 percent required (or received) episiotomies.

I also take issue with the author's use of inflammatory language, such as when she labels as a "misguided study" the experimental use of estrogens in men for possible cardiovascular benefits. The study was not misguided, simply negative in its results. In science, we do studies because we do not know all the answers or potential outcomes. At least the researchers did not falsify positive data to "get published" at the expense of progress.

If we want to create yet another branch of medicine, perhaps a specialty in men's health could reduce the current disparity in men's life expectancies. This would do much to alleviate the suffering and loneliness at the end of many women's lives. But what we really need are more good family doctors.

BRUCE KINZINGER, MD  
Joppatowne, Md

Adriane Fugh-Berman overlooks the fact that the specialty of family medicine provides comprehensive care for women. A residency-trained, board-

certified family physician will spend three years in postgraduate training that includes work in internal medicine, surgery, obstetrics, gynecology, orthopedics, pediatrics, emergency medicine, geriatrics, behavioral medicine, and other subspecialty areas. Residency programs are also incorporating a curriculum of women's health into those three years of training.

Is there room for improvement? Always. Do we need another specialty? I believe we should perfect what already exists.

SUSAN Y. MELVIN, DO  
Associate Clinical Professor of Family Medicine  
University of California, Irvine

Fugh-Berman's view of women's health care continues the separation of men and women into opposing camps

that regard each other with distrust and some hostility. The author's medical-school experience was unfortunate, but even with that dismal start she was able to rise above it and view women with respect. The goals she promotes have been incorporated into graduate medical programs in obstetrics and gynecology. Many men, including myself, embrace these ideals within this specialty. We don't need more division; we need caring physicians who treat patients with respect and as partners in their health care.

H. J. NUSBAUM, MD, PhD  
Albany, N.Y.

## A GRAND DESIGNER?

Thank you for publishing Kenneth Miller's balanced review of the latest creation/evolution controversy ("*Life's Grand Design*," *TR* February/March 1994). People on both sides of the debate too often take non-negotiable positions and either misrepresent science or twist Biblical scripture.

Using evolutionary theory to explain biological change over time does not contradict the Bible. According to the Big Bang theory, all matter in the uni-

verse, as well as space and time, began with a single spontaneous flash of creation that evolved in stages until the present. The first chapter of Genesis agrees. Whether these events occurred over one week is debatable. Time is relative to the observer on a cosmic scale, and the Bible clearly states that God exists outside human time.

By trying to sway public education through expensive legal tactics instead of genuine debate, the creationists fail both science education and Christian education.

TOM MORROW  
St. Petersburg, Fla.

Scientists and educators are greatly indebted to Kenneth Miller for his energetic and effective defense of evolution against creationist attacks during the past decade.

The "intelligent design" (ID) thesis does have some advantages. One of the irritating features of the 1980s debates was the refusal of creationists to commit themselves to any specific hypothesis that could be analyzed and tested. But as Miller shows, ID does allow such analysis and testing; his discussion also shows clearly what Darwinian theory assumes and what it rejects. Thus, in a classroom free of outside pressures, there might even be some pedagogical value in presenting ID when teaching evolution. College biology teachers should also consider using Miller's article in courses for mature students who know enough about science to follow the argument. And all science teachers could profit by reading the article to understand the issue.

But we must resist attempts to inject ID as an alternative to evolution in public-school pre-college science classes. Unfortunately, teachers face tremendous pressure to avoid trouble by opting to teach *neither*. That's just what fundamentalists want—getting evolution out of the schools is better for them than having their own flimsy alternative presented by skeptical teachers.

STEPHEN G. BRUSH  
Professor of History of Science,  
University of Maryland  
College Park, Md.

