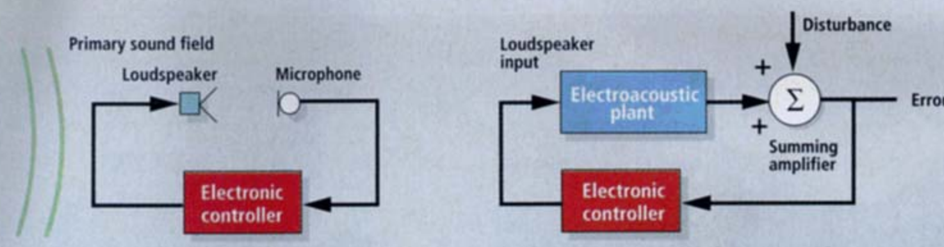
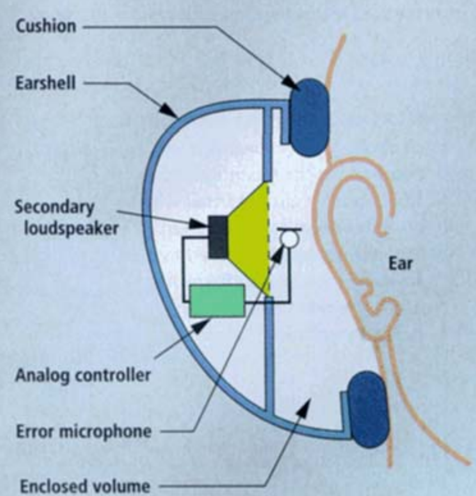
Advanced Applications of Control and Automation

Professor Günther Schmidt
TU München

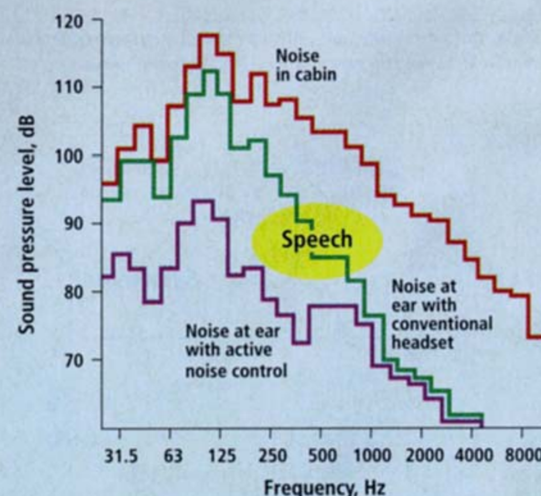
Active Noise Control in Vehicles or Buildings



[7] An active noise control system using feedback includes an electronic controller, loudspeaker and microphone [far left]. An equivalent block diagram [left] shows a closed feedback loop, designed to minimize the error between the disturbance (the noise to be canceled) and the output of the loudspeaker (the secondary, or noise-canceling source).



[8] A headset with active noise control based on feedback includes a loudspeaker, a microphone and an (analog) controller. This last sits against the listener's ear, inside the earshell.



[9] Noise levels in the cabin of a military vehicle may reach 120 dB, close to the pain threshold. A conventional headset (without active noise control) attenuates the sound at frequencies upward of 125 Hz by 10–20 dB. A headset with feedback-based active noise control, however, reduces the sound level at low frequencies—below 300 Hz—by 15 dB or so.

SOURCE: P. WHEELER, ROYAL AERONAUTICAL SOCIETY

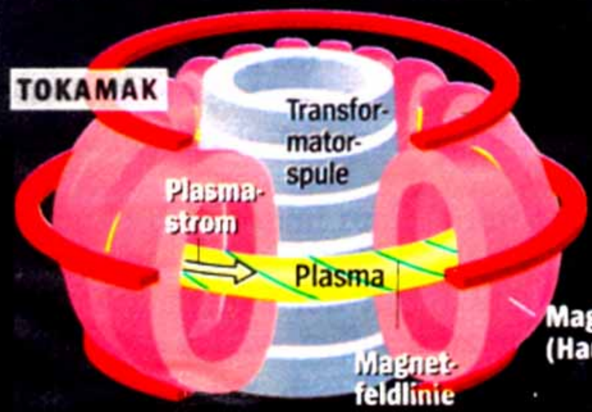
Acoustic Noise Cancelling Headphones

Stabilization of 2 DoF Plasma Position in Tokamak: Energy Source of the Future: *Nuclear Fusion*

Stabilisierung der Plasmalage (radial / vertikal)

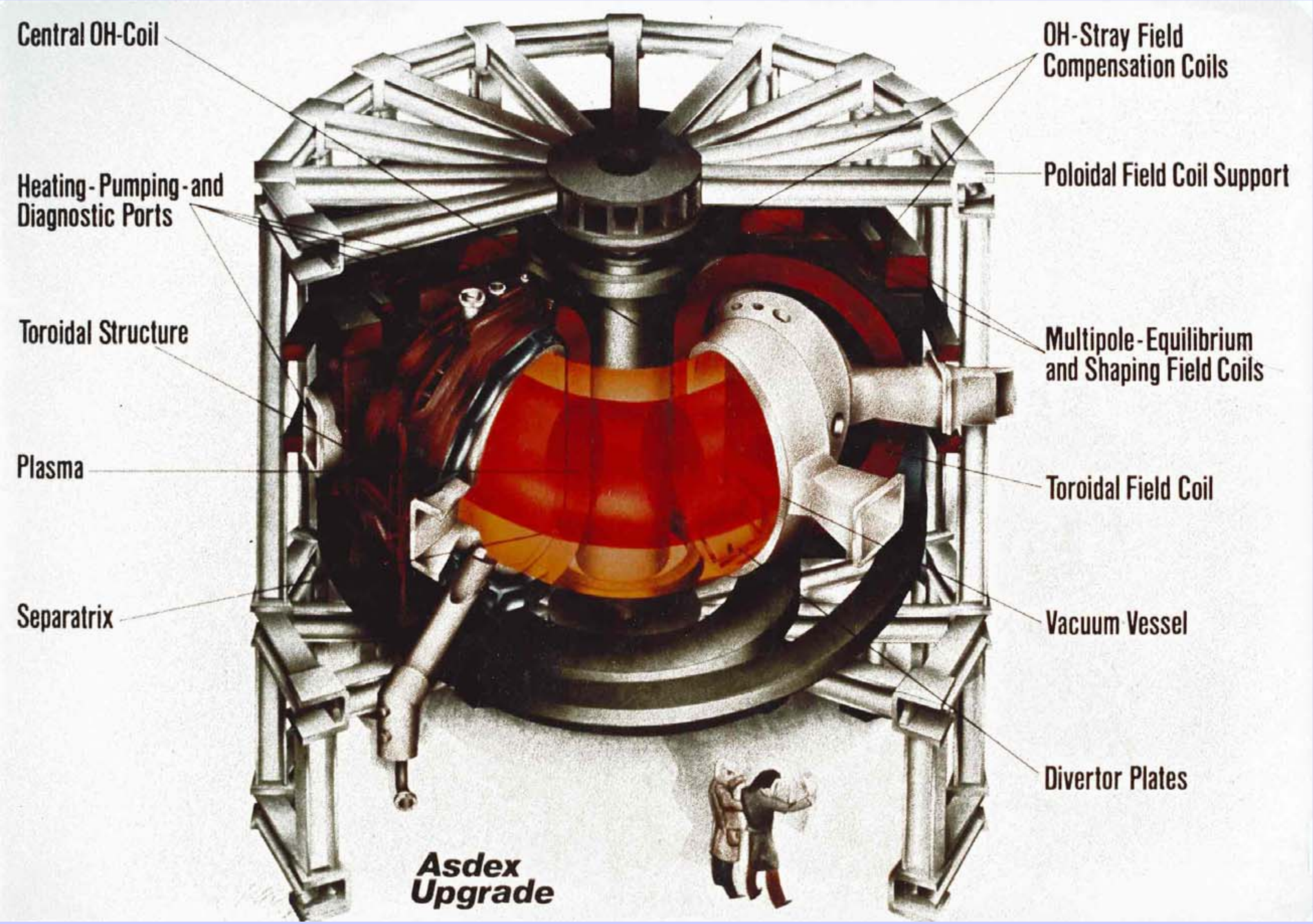
Sternenfeuer im Labor

Bei der Verschmelzung der schweren Wasserstoffkerne Deuterium und Tritium zu Helium wird nutzbare Energie freigesetzt. Um die Kernfusion zu zünden, müssen höchste Temperaturen – ähnlich den Bedingungen in der Sonne oder bei Wasserstoffbombenexplosionen – erzeugt werden.



Magnetischer Einschluß Ein dünnes Gas aus Deuterium- und Tritiumkernen („Plasma“) kreist in einer Vakuumkammer. Mächtige Magnetspulen halten das Plasma in einem kreis- oder spiralförmigen Magnetfeldkäfig in der Schwebe und heizen es auf über 100 Millionen Grad auf.

- Im Tokamak stabilisiert, neben den umschließenden Spulen, ein von einem zentralen Transformator erzeugter Strom im Inneren des Plasmas den Magnetfeldkäfig.


Central OH-Coil
OH-Stray Field
Compensation Coils
Heating - Pumping - and
Diagnostic Ports
Poloidal Field Coil Support
Toroidal Structure
Multipole - Equilibrium
and Shaping Field Coils
Plasma
Toroidal Field Coil
Separatrix
Vacuum Vessel
Divertor Plates
Asdex
Upgrade

Wind Turbine + Generator

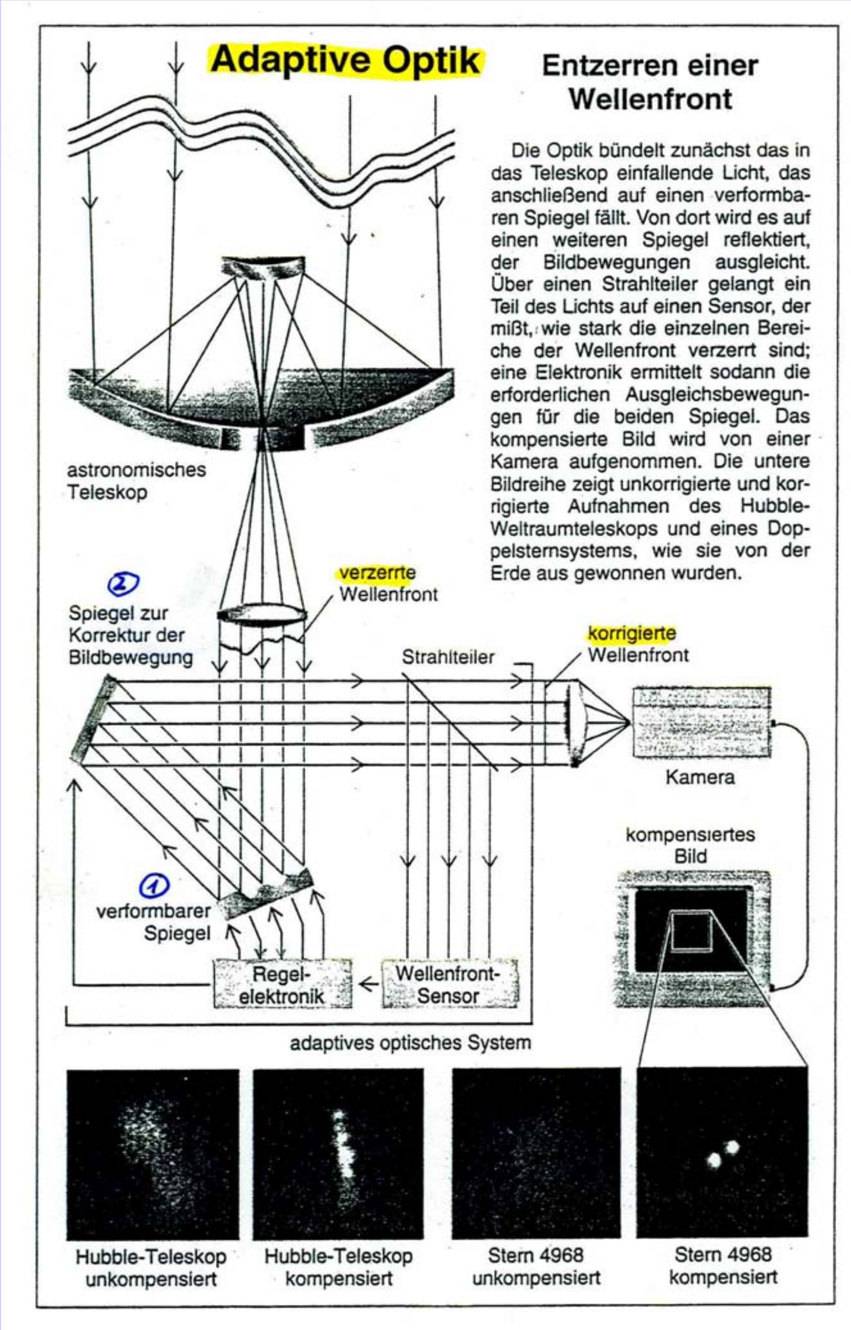
***Repower 5M*, largest worldwide**

Power: 5 MW

Rotor diameter: 126 m

Height: 90 m on land

120 m at sea



Adaptive Optik

Entzerren einer Wellenfront

Die Optik bündelt zunächst das in das Teleskop einfallende Licht, das anschließend auf einen verformbaren Spiegel fällt. Von dort wird es auf einen weiteren Spiegel reflektiert, der Bildbewegungen ausgleicht. Über einen Strahlteiler gelangt ein Teil des Lichts auf einen Sensor, der mißt, wie stark die einzelnen Bereiche der Wellenfront verzerrt sind; eine Elektronik ermittelt sodann die erforderlichen Ausgleichsbewegungen für die beiden Spiegel. Das kompensierte Bild wird von einer Kamera aufgenommen. Die untere Bildreihe zeigt unkorrigierte und korrigierte Aufnahmen des Hubble-Weltraumteleskops und eines Doppelsternsystems, wie sie von der Erde aus gewonnen wurden.

Adaptive Optics:
Wavefront Equalization

Transatlantic Tele-Surgery by Visual Feedback: Strasbourg – New York

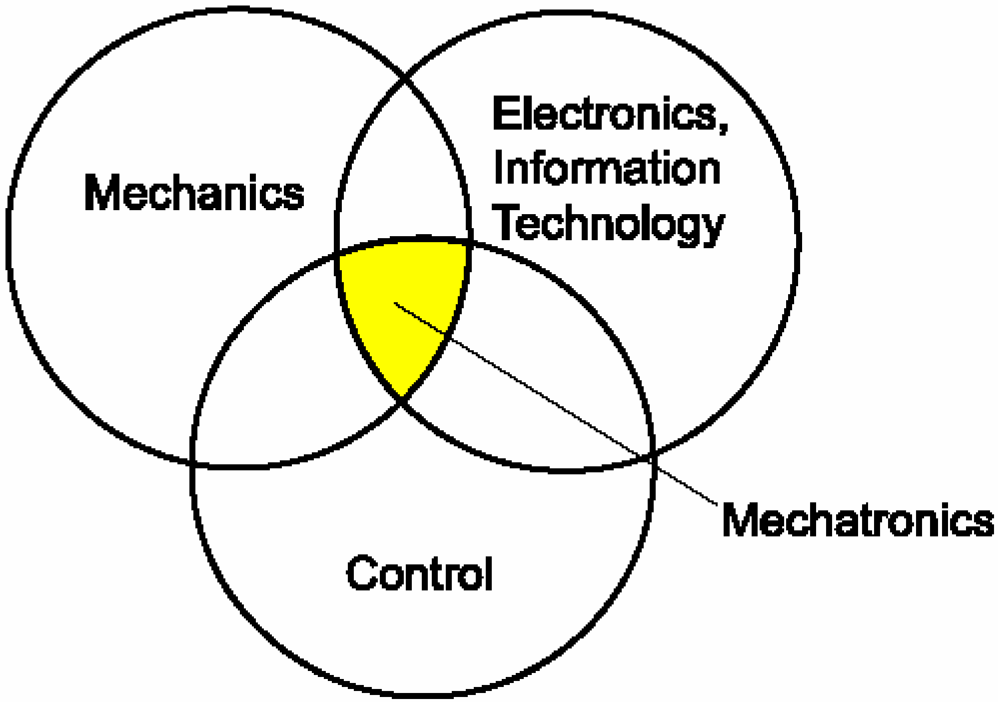


Figure I.13: CE and mechatronics

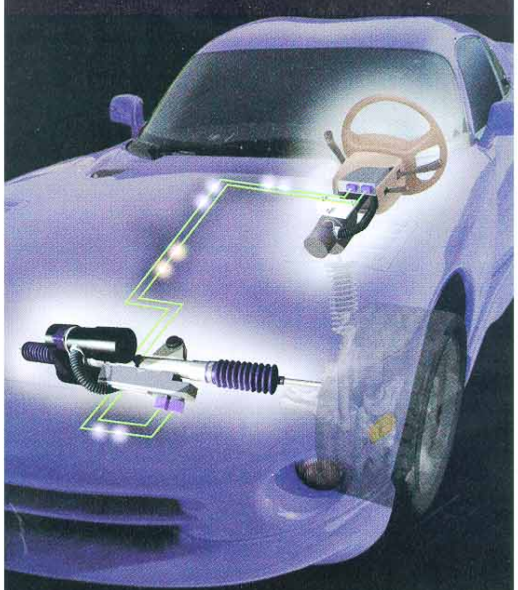
"There is no piece of mechanics
that can be made smarter by electronics"

By-Wire Cars Turn the Corner

Replacing a car's hydraulic systems with wires, microcontrollers, and computers promises better safety and handling—but will drivers buy it?

Steer-By-Wire Enhances Car Wheel Control

Only wires [green] may relay signals from a car's steering wheel to its front wheels in a front-wheel steer-by-wire system. And an electrically actuated motor, not a mechanical link with the steering wheel, turns the front wheels.



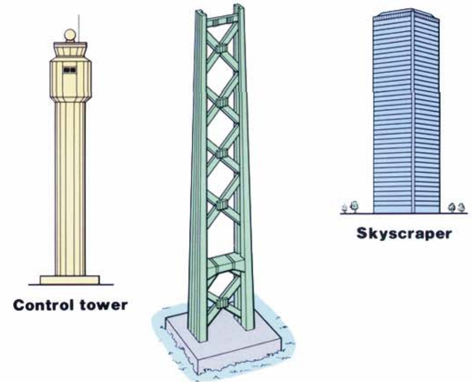
Active Damping Control of Civil Engineering Structures

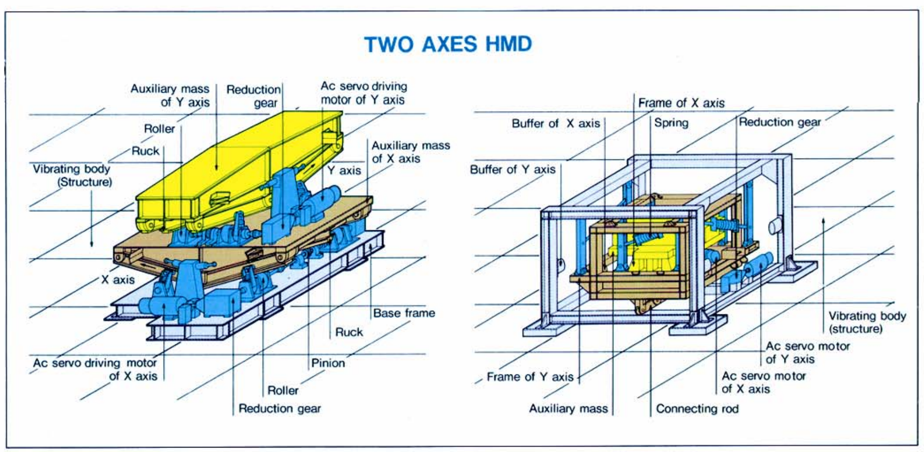
Aktive Gebäude-Schwingungsdämpfung IHI

Hybrid Mass Damper (HMD)

Computer controlled hydrid mass dampar reduces the vibration induced by wind and earthquake excitation on large bridge towers and high-rise buildings.

The hydrid mass damper system provides high damping performance to secure the amenity of living spaces in structures.





Ishikawajima-Harima Heavy Industries Co., Ltd.

アクティブ制振システム—AVICS-1（アビックスワン）

OBAYASHI

■概　要

アクティブ制振システム-AVICS-1は、高層ビルやペンシルビル、タワーの、中小地震や強風時の揺れを抑制・吸収し、居住環境向上を図るシステムです。
「制振システム」は、制振装置（付加質量、駆動部）、制御用コンピュータ、センサーから構成され、地震動や建物の揺れをセンサーが感知すると、その情報を制御用コンピュータで瞬時に解析・判断して、その結果を動作指令として駆動部へ出力して付加質量を動かし、時々刻々の建物の揺れが常に最小になるように最適制御するシステムです。
この制振システムの採用により、相対変位・絶対加速度応答ともほぼ1/3程度に低減でき、強風による"船酔い現象"を防止し、また、地震時の後揺れをなくします。

■特　長

- 最先端の制御理論のソフトへの組込み
- ボールねじ駆動方式による高精度の制御
- より少ない付加質量で、より大きな制振効果の実現
- 強風や、日常よく起こる中小地震による揺れを大きく低減
- フェイルセーフ機構による安全性の確保
- 装置がコンパクト

■開　発

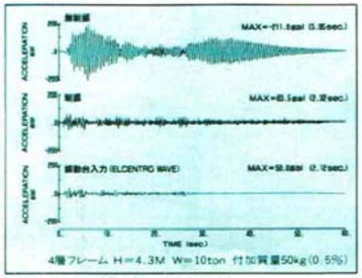
慶応義塾大学 理工学部 下郷教授、吉田助教授の指導を受け、トキコ㈱との共同開発

- 平成元年12月　基本的なフレーム実験について、実証実験完了
- 平成3年2月　制振装置の実機について、実証実験実施

■用　途

高層ビル、ペンシルビル、塔状構造物

- オフィス　●マンションなど居住施設　●病院
- 老人ホーム　●タワー　　　など

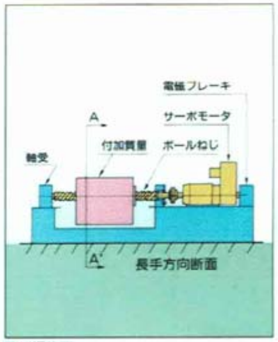


■制振実験結果（最上階の応答加速度）

■リバーサイド隅田プロジェクト

適用建物：事務所・住宅棟（設計：当社）
構造・規模：S造一部SRC造、B2F、33F、軒高133.3m
制振装置：AVICS—1 マス重量15t×2基、一方向制御

■アクティブ制振システムの概念



■制振装置

■高性能を実証したAVICS-1システム

■制振効果の比較（15階建ビルの場合）

Semi-Active Control System

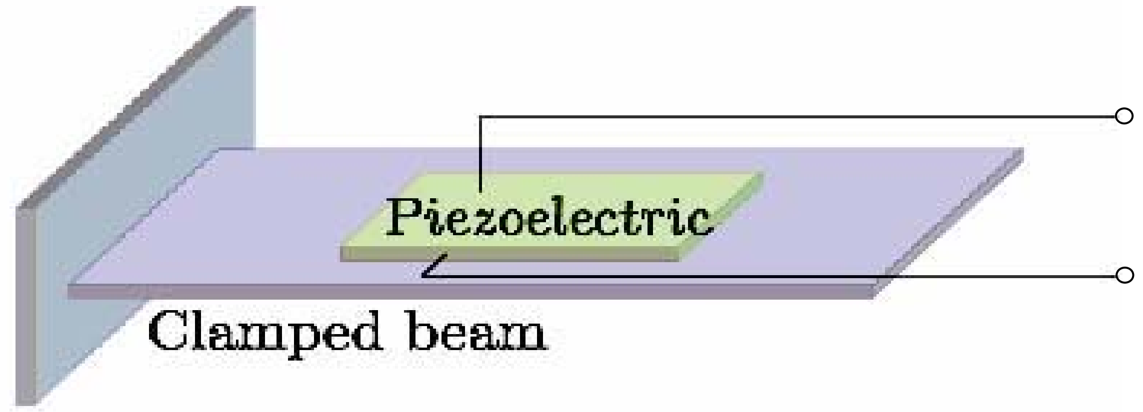


Fig. 1. Shunt Damping

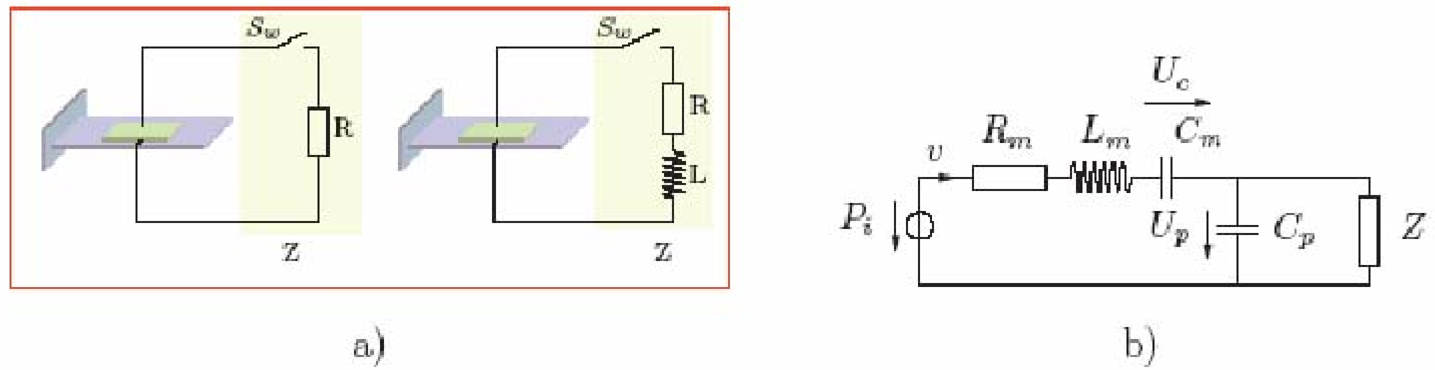
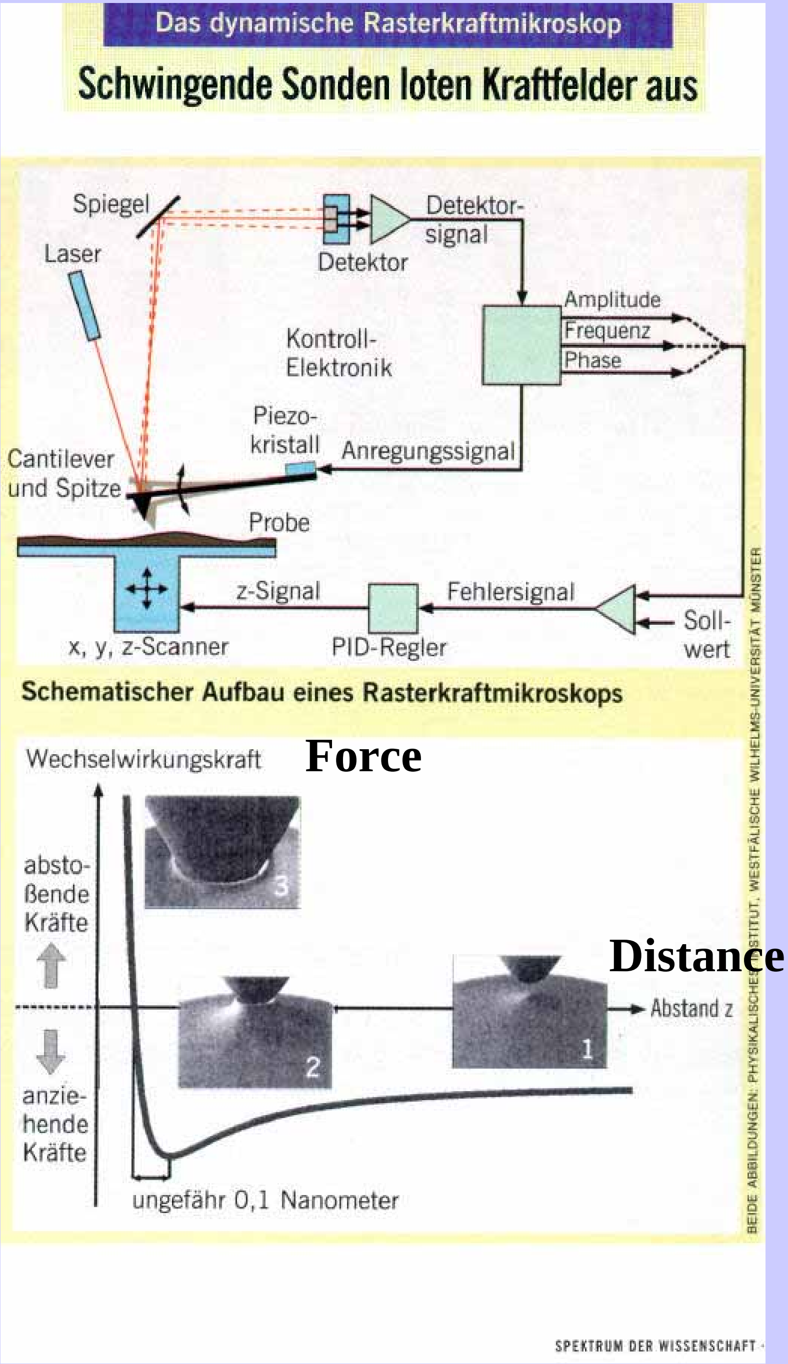
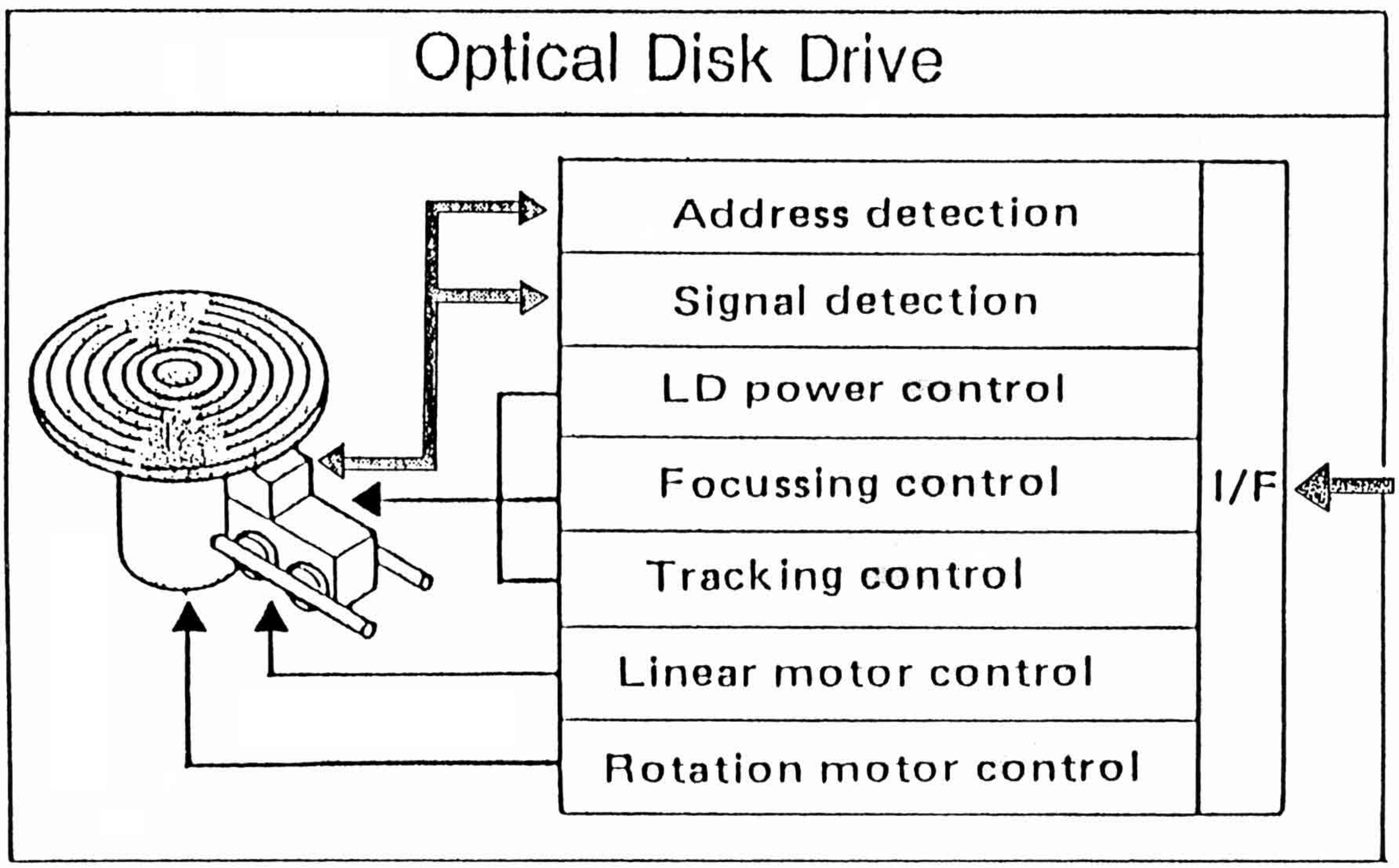


Figure 6.1: a) Different switching shunt topologies b) Electrical equivalent model of the shunted piezoelectric composite structure.

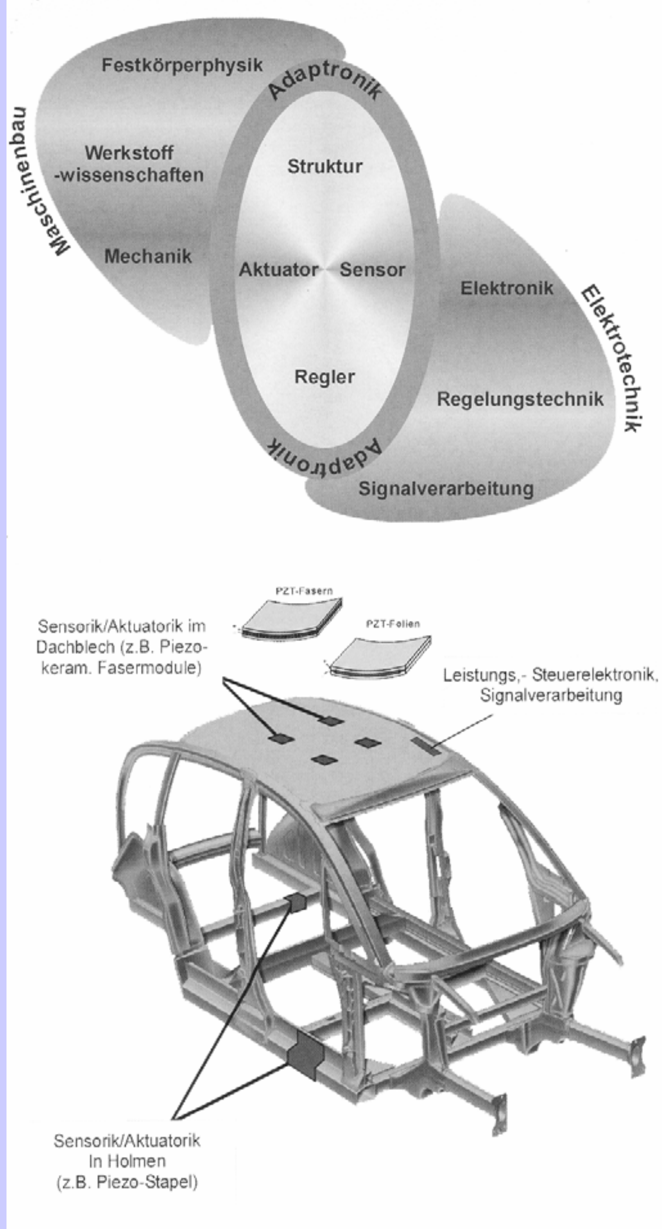
Vibrating Atomic Force Microscope (AFM)




Optical Disk Drive
Address detection
Signal detection
LD power control
Focussing control
Tracking control
Linear motor control
Rotation motor control
I/F

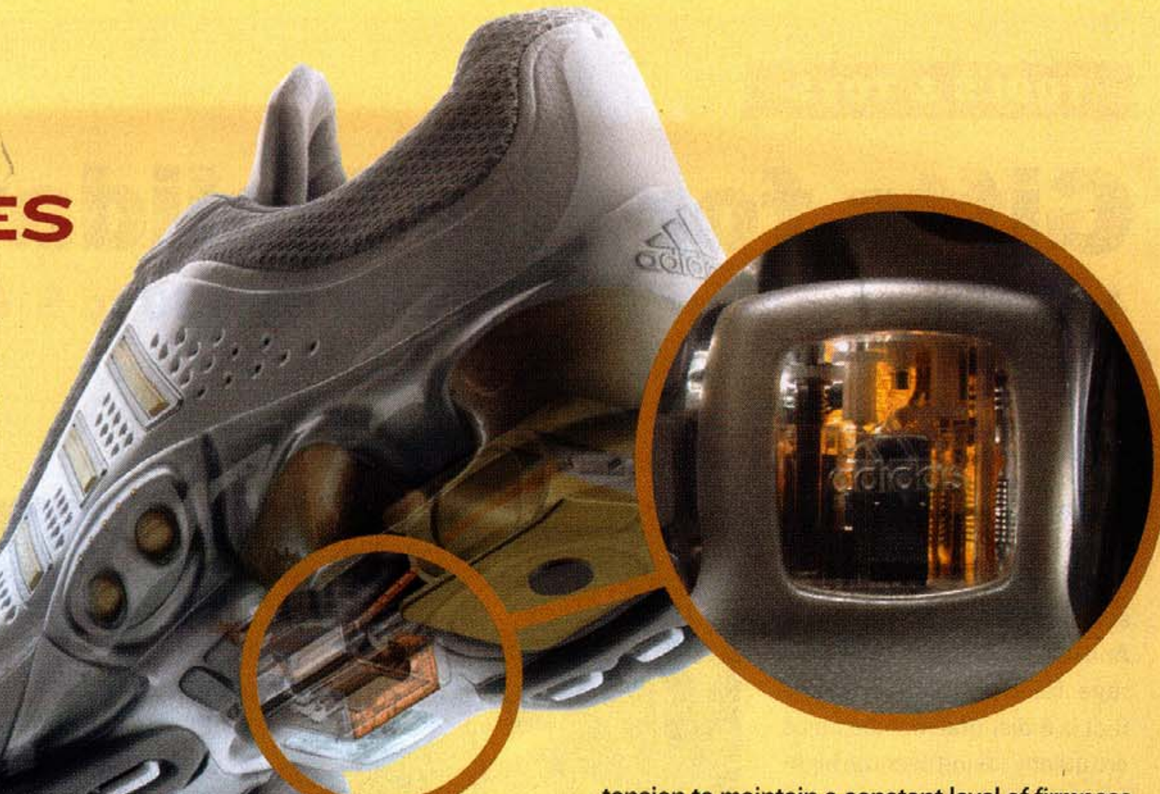
Adaptive Structures:

Active Car-Body



Adaptive Struktursysteme: Aktive Karosserie

SMART SHOES



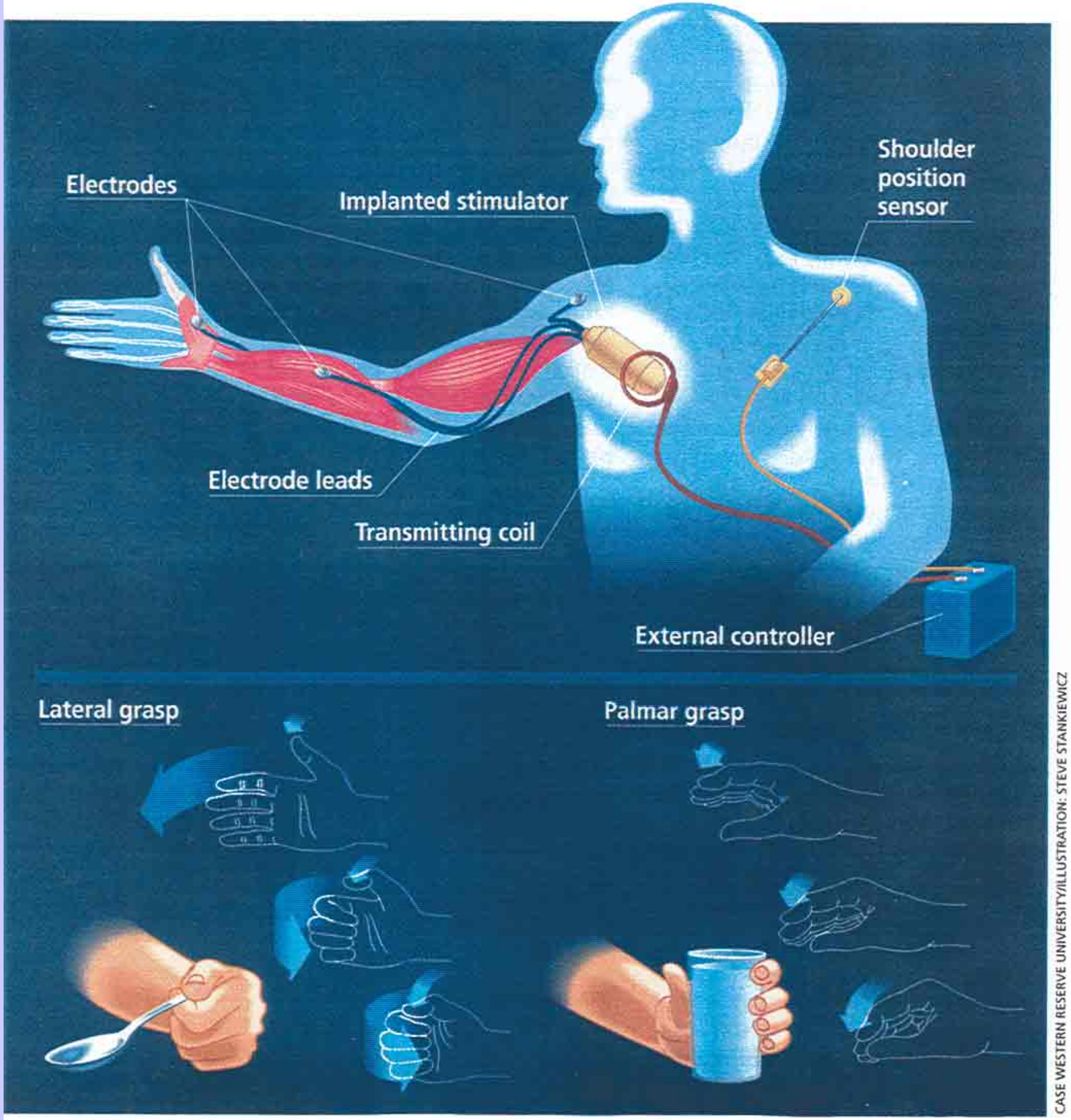
Are your running shoes too hard for running on asphalt? Too soft for a dirt track? No matter, because, according to Adidas-Salomon AG, in Herzogenaurach, Germany, the Adidas I running shoe will continually adjust the firmness of its heel to make sure it always feels right: softer on concrete, firmer on grass, for example. (Test shoes were not available at press time.)

The preferred firmness of a cushion in the heel is selected when you push either of two buttons on the side of the shoe, one carrying a plus sign, the other a minus. These in turn activate a motor that tightens or relaxes a steel cord to give the heel its variable firmness. Five light-emitting diodes on each shoe indicate the firmness levels.

The hollow plastic cushion in the heel contains a Hall Effect sensor, which reads the strength of an electromagnetic field created by a magnet near the bottom of the heel. As the runner's foot strikes the ground and the plastic cushion is compressed, the sensor measures the change in field strength. It sends this data to an embedded 20-megahertz microprocessor in the shoe's arch, which calculates to within 100 micrometers just how much the cushion has been compressed, and adjusts the cord tension to maintain a constant level of firmness no matter what you're running on. This cycle of sensing, measuring, and adjusting happens 10 000 times a second. You won't notice the cord's tension changing until you start moving, because the motor is activated only when the foot is in the air. This ensures that it is not wasting energy by fighting against the runner's weight.

The Adidas I is expected to hit stores in December. ■

ADIDAS I RUNNING SHOE • US $250 • http://www.adidas.com



[2] The user of the Freehand System controls a paralyzed hand with a sensor supported on the opposite shoulder [top]. Its position is calculated with reference to the position of the chest. The sensor's signal is sent outside the body to a microcontroller, which digitizes the signal and sends it to a transmitting coil over the implanted stimulator. By shrugging a shoulder in different ways, the user can choose between a palm grip or a pinching grasp [bottom].

Hand Neuro-prosthesis

C-Leg® Microprocessor Knee

The Otto Bock C-Leg® and Otto Bock Compact™ microprocessor-controlled knees are designed to deliver the best in stability and reliability. Both knees utilize easy-to-charge lithium ion batteries with 40-45 hours of power.

The Technology that offers Day-to-Day Stability

Otto Bock's highest priority when developing the C-Leg® was to provide optimal stability during the gait cycle. Using unique algorithms developed from studying how thousands of people walk, combined with input from multiple built-in sensors, the microprocessor determines the phase of gait. Then, automatic adjustments are made to the knee's function to provide stability -- right when it is needed.

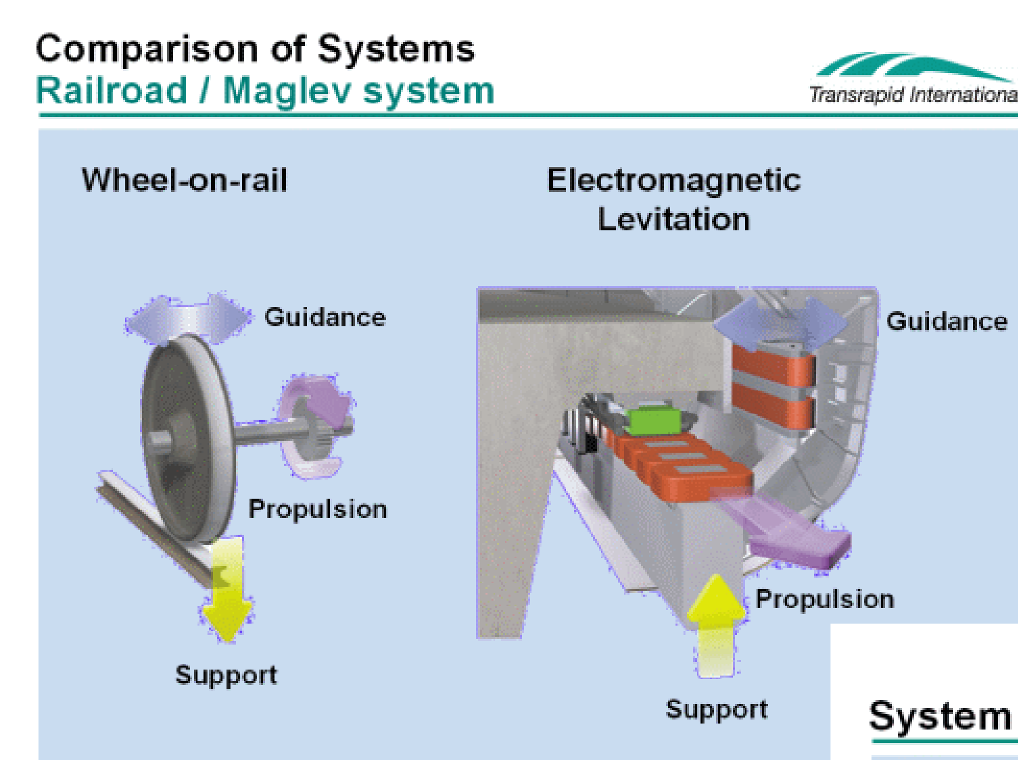
Here's how it works:

Force sensors in the pylon detect loading of the foot and ankle.
Additional sensors read the precise angle of the knee joint.
This data, along with swing speed input, is read 50-times per second by the on-board microprocessor
The result is increased stability, ease of swing, and greater efficiency with every step! There's even a knee-disarticulation version available.

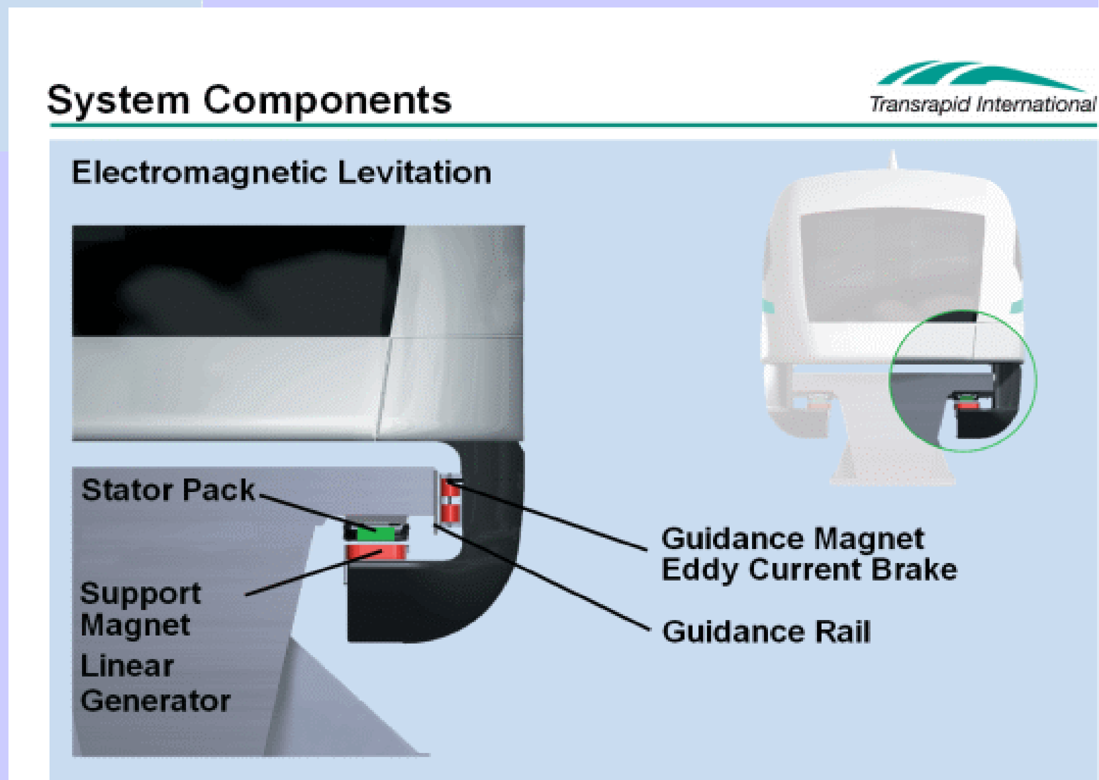
EEG-based Brain-Computer-Interface (BCI)

EEG = electroencephalography (brainwaves)

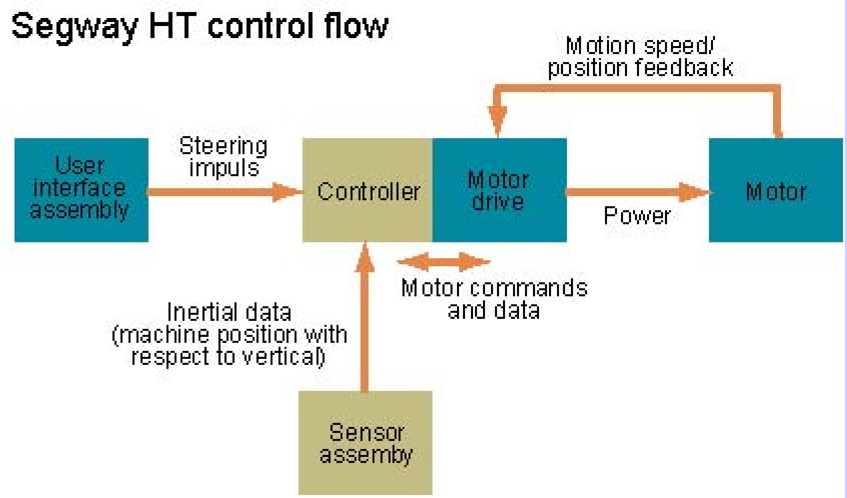

Innovative Transportation Technology
for the International Market
Transrapid International



Magnetic Levitation and Guidance



Stabilization of Unstable 1-Axis Vehicle

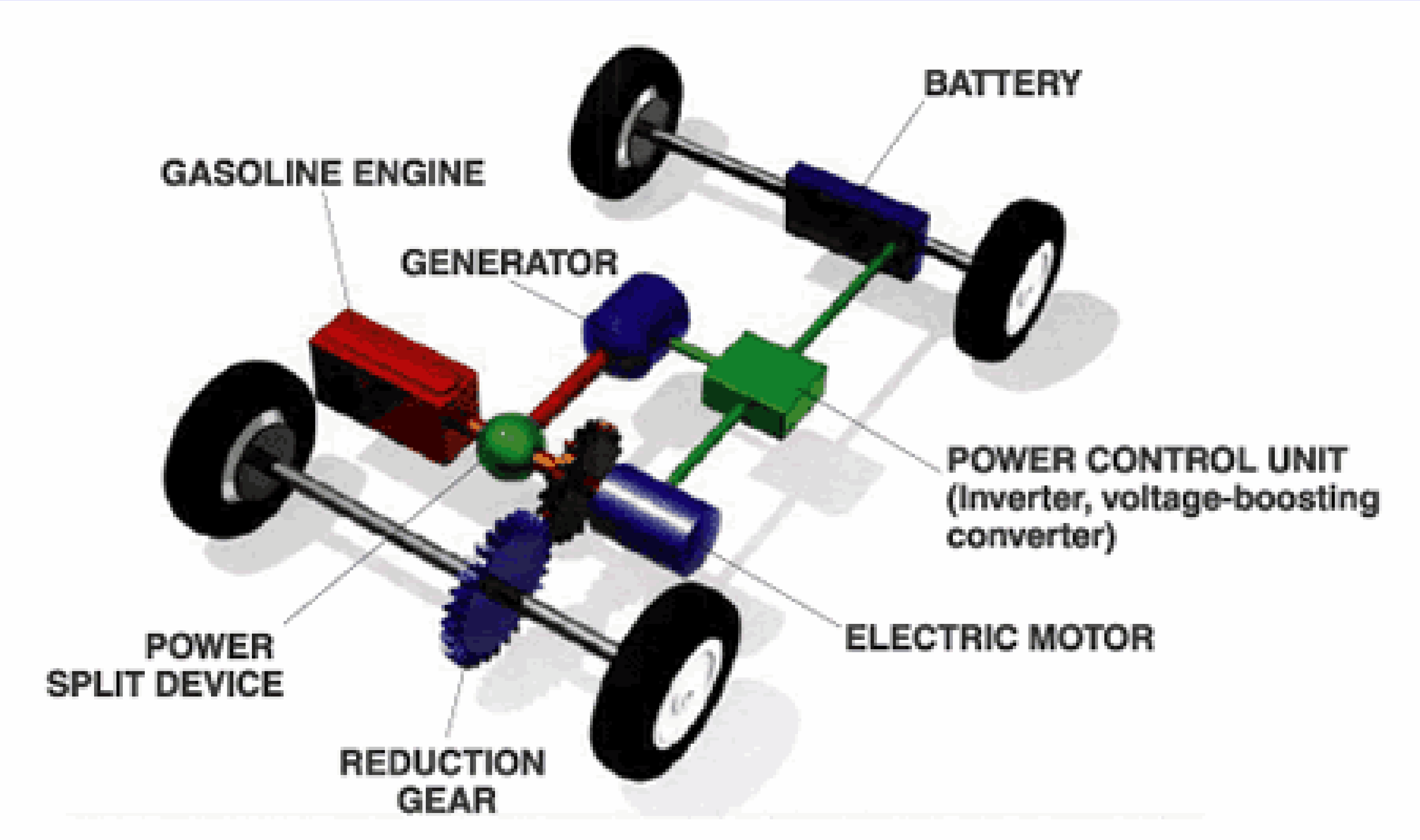


Segway Roller (Dean Kamen)

Hybrid Engine System

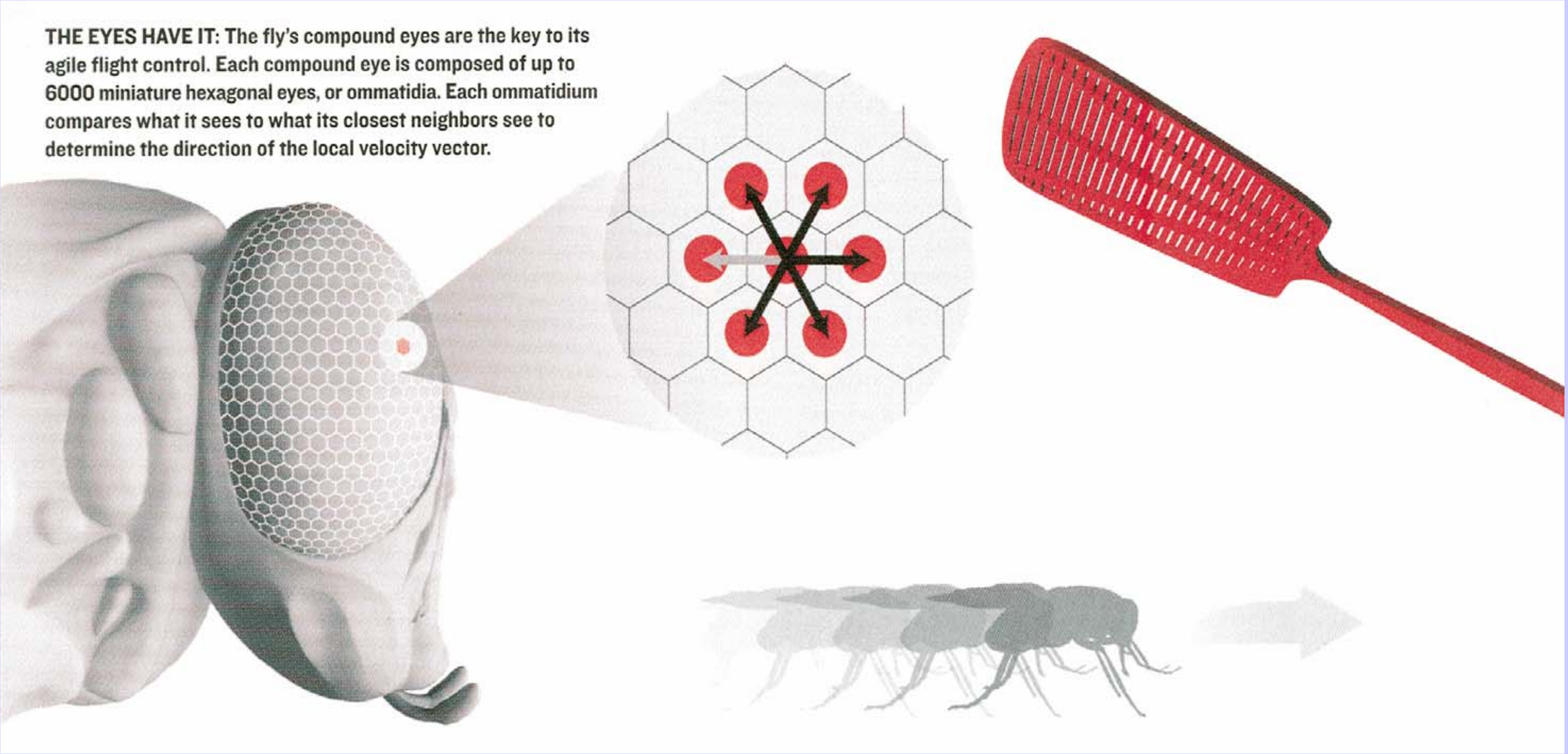
Operational Modes:

Start and low speeds, driving under normal conditions, sudden acceleration, deceleration and braking, battery recharging, at rest



Bionics: The Housefly's Flight Control System

Example of Reverse (Control) Engineering



The Housefly's Flight Control System

A Comparison

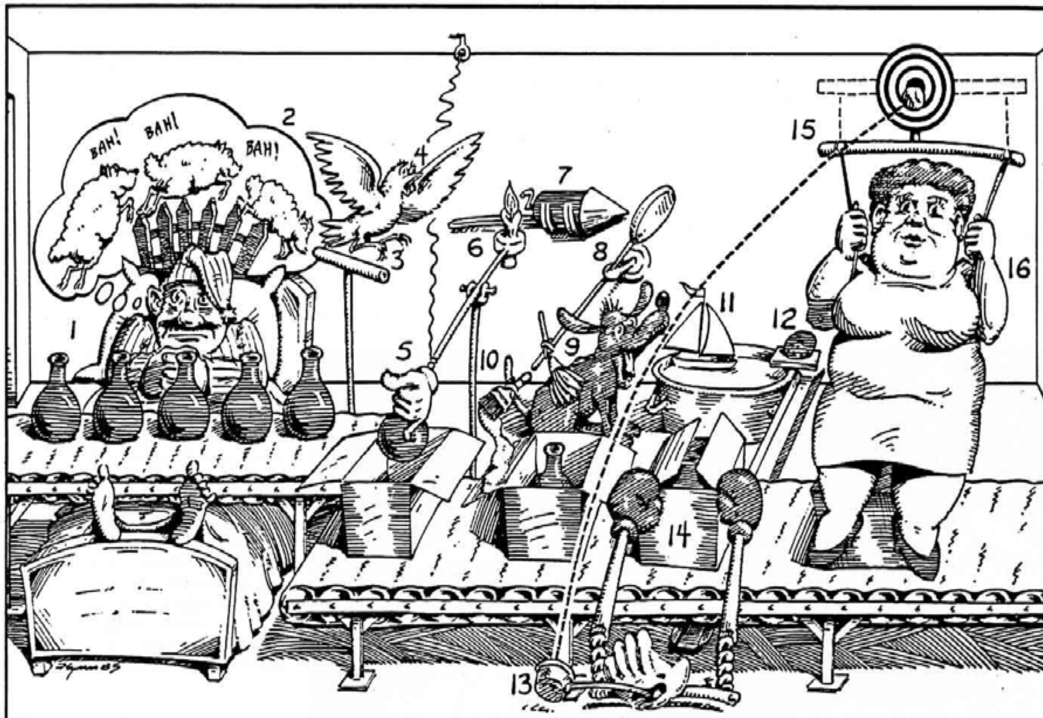
	Housefly	S/VTOL-Aircraft, e.g. F-35
Sensors	80,000 sensory inputs (distributed on body) • 6,000 from compound eye (optical flow) • hairs for airflow • rotation sensors (halteres)	• Pitot tube (airspeed) • altimeter, height & rate • gyroscopes, vanes (sideslip, angle of attack)
Processing	300,000 neurons (most for vision) 300 neurons (for flight control)	1.1 million lines of code in Power PC
Actuators	12 muscles for 2 wings & 2 stabilizers (halteres)	Control surfaces: flaps, ailerons, rudders
Power-efficiency	3 Joules/sec / 100 mg	3 to 5 times as much (aircraft, helicopter)
Maneuvering capability	High (up, down, backward, somersault, ...)	low
Evolution	300 million years	100 years
Feedback control	***Sensor-rich***	***Processing intensive***

Flock of Birds

Formation Control
for a Group of Agents, e.g. Humans, Animals, Vehicles, …

Swarm of Fish

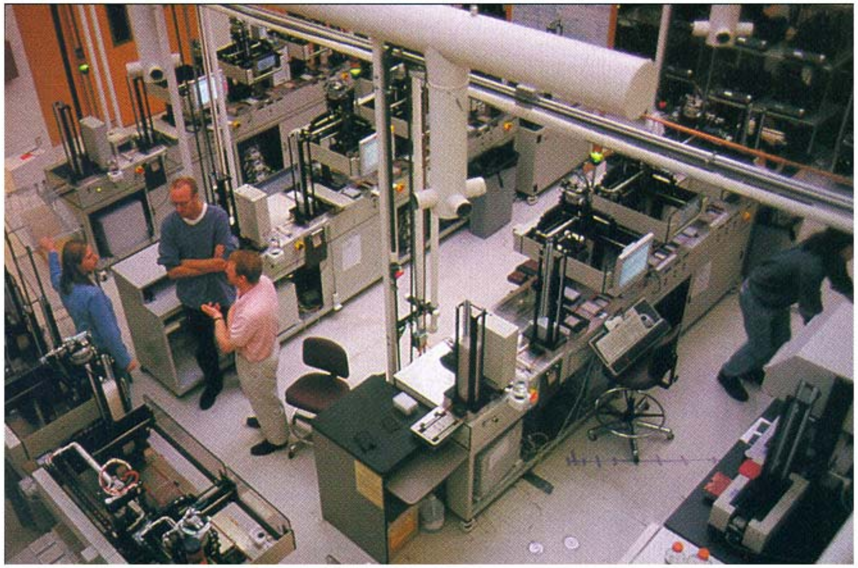
Automation:

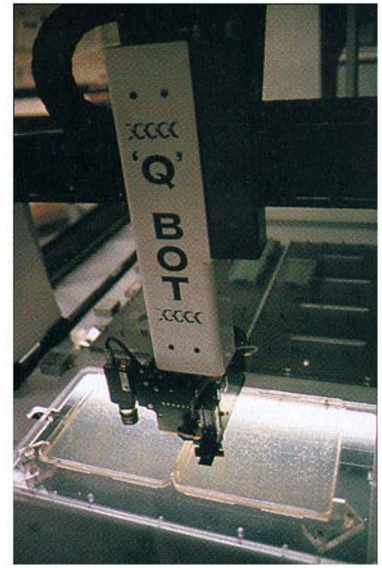


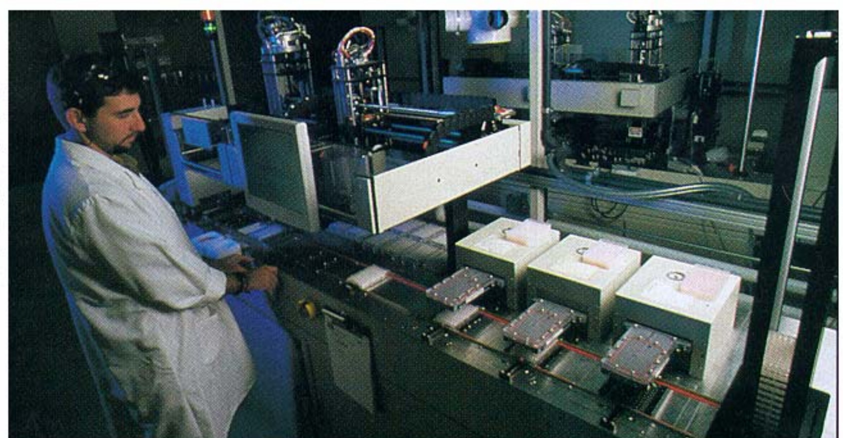
As bottles move down belt, insomniac (1) counts them pretending they're sheep. Bleating of sheep (2) scares canary (3) which flies off perch singing and cuts the string (4) dropping glove that grabs bottle and lowers it into box (5) and raises candle (6) that ignites rocket (7) that hits feather duster (8) that tickles dog (9) who wags his tail with glue brush (10) and barks (11) blowing sailboat against coconut (12) which rolls down gutter into catcher's mitt (13) that sends boxing gloves up to hit box flaps (14) and throws baseball at target (15) that lowers stout lady on trapeze (16) to seal box.

the hard way.

How Automation Made Decyphering the Human Genome Possible

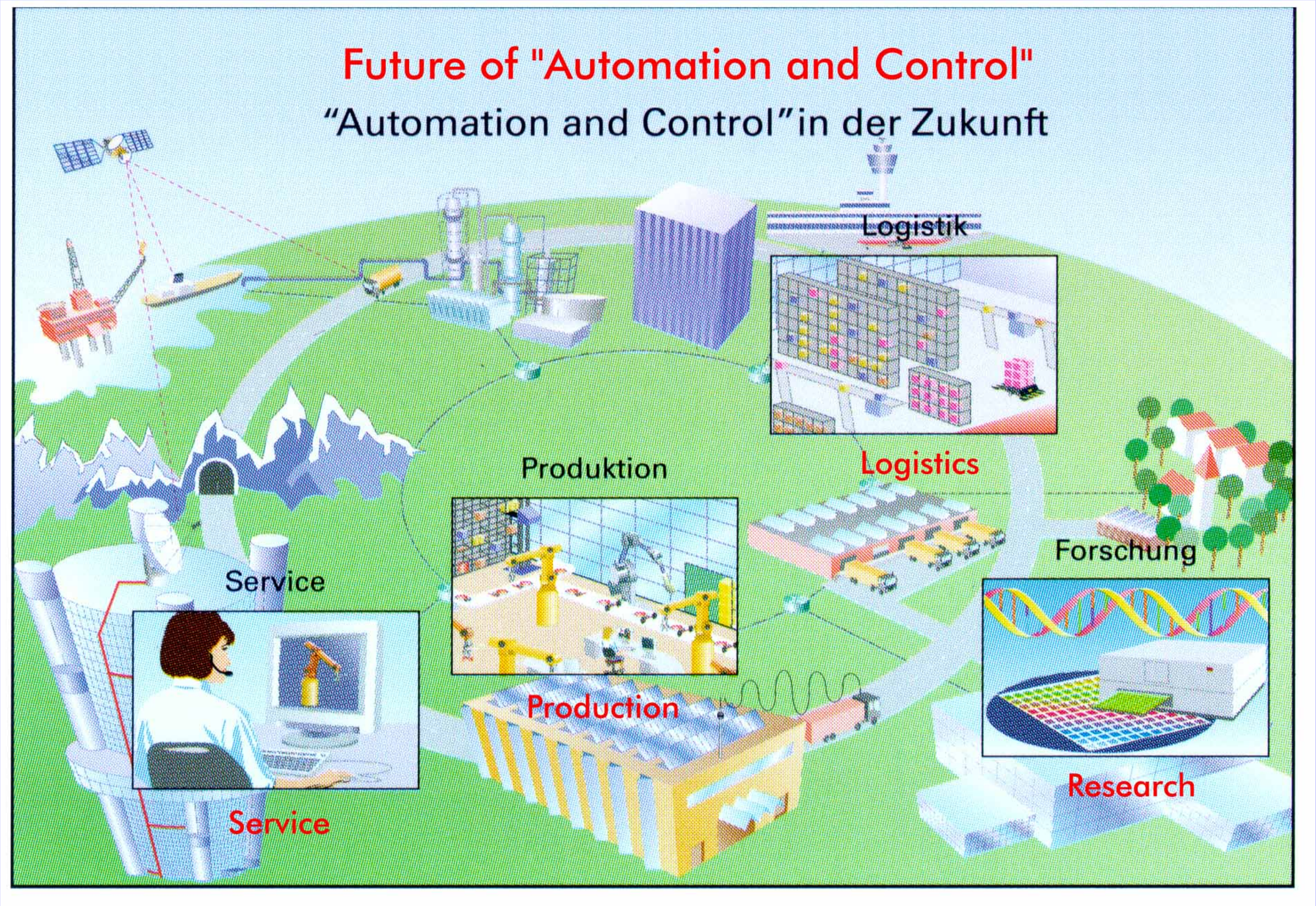


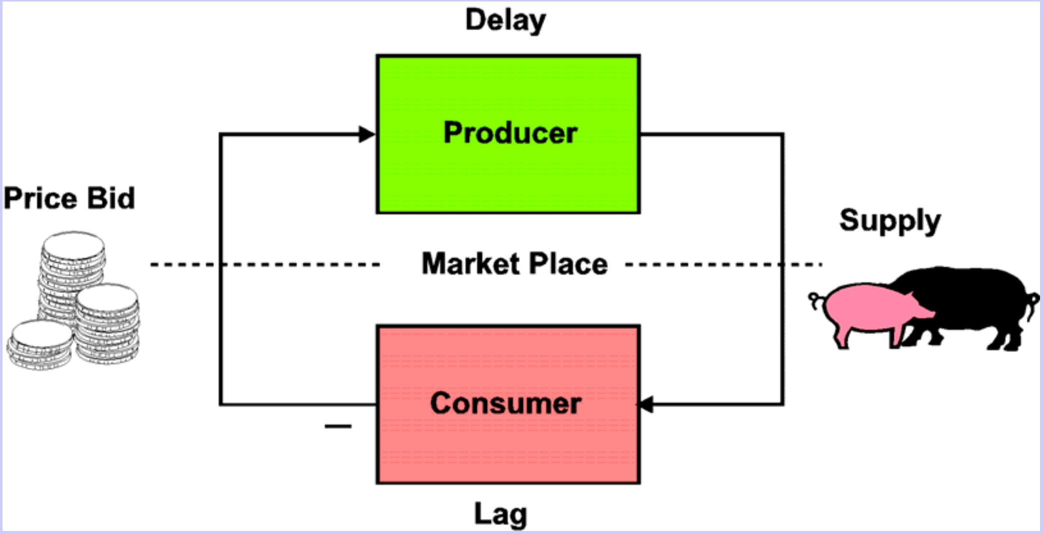


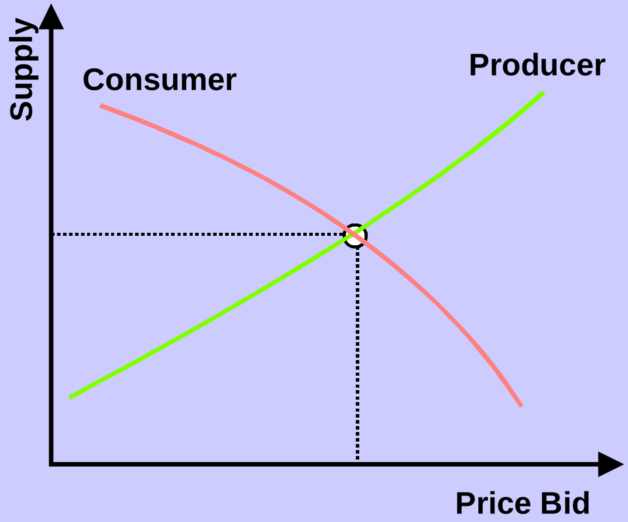


[3] The sequencing laboratory at the Whitehead Institute [above] in Cambridge, Mass., uses a number of automation advances. For instance, the Q-bot [above, right] picks thousands of bacteria colonies from agar-coated plates and places them in wells filled with liquid growth media. DNA purification [right] has also been automated by a process invented at Whitehead.

PHOTOGRAPHS: STEPHEN ROSE/LIAISON AGENCY INC.

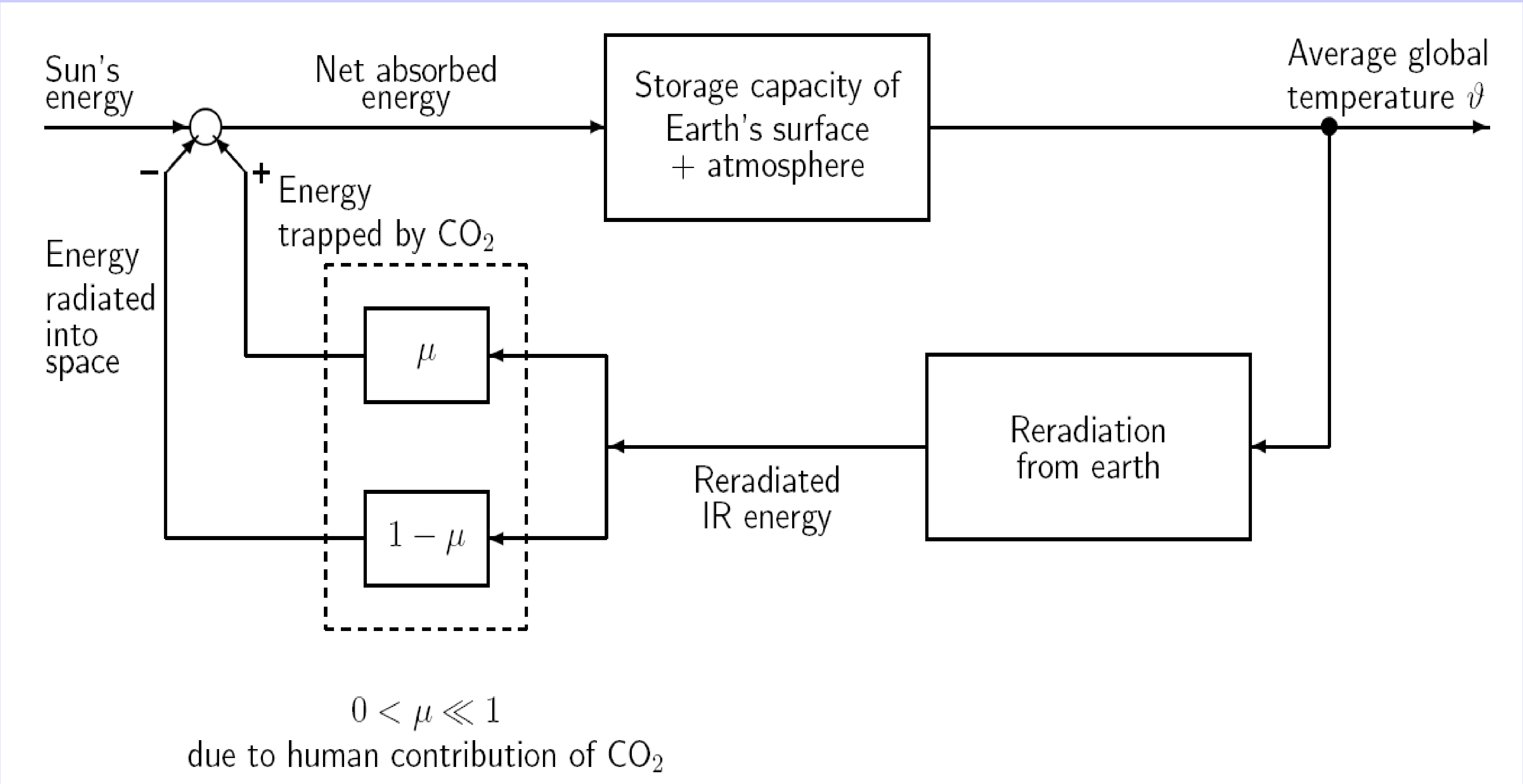

Future of "Automation and Control"
“Automation and Control”in der Zukunft
Logistik
Logistics
Produktion
Production
Service
Service
Forschung
Research

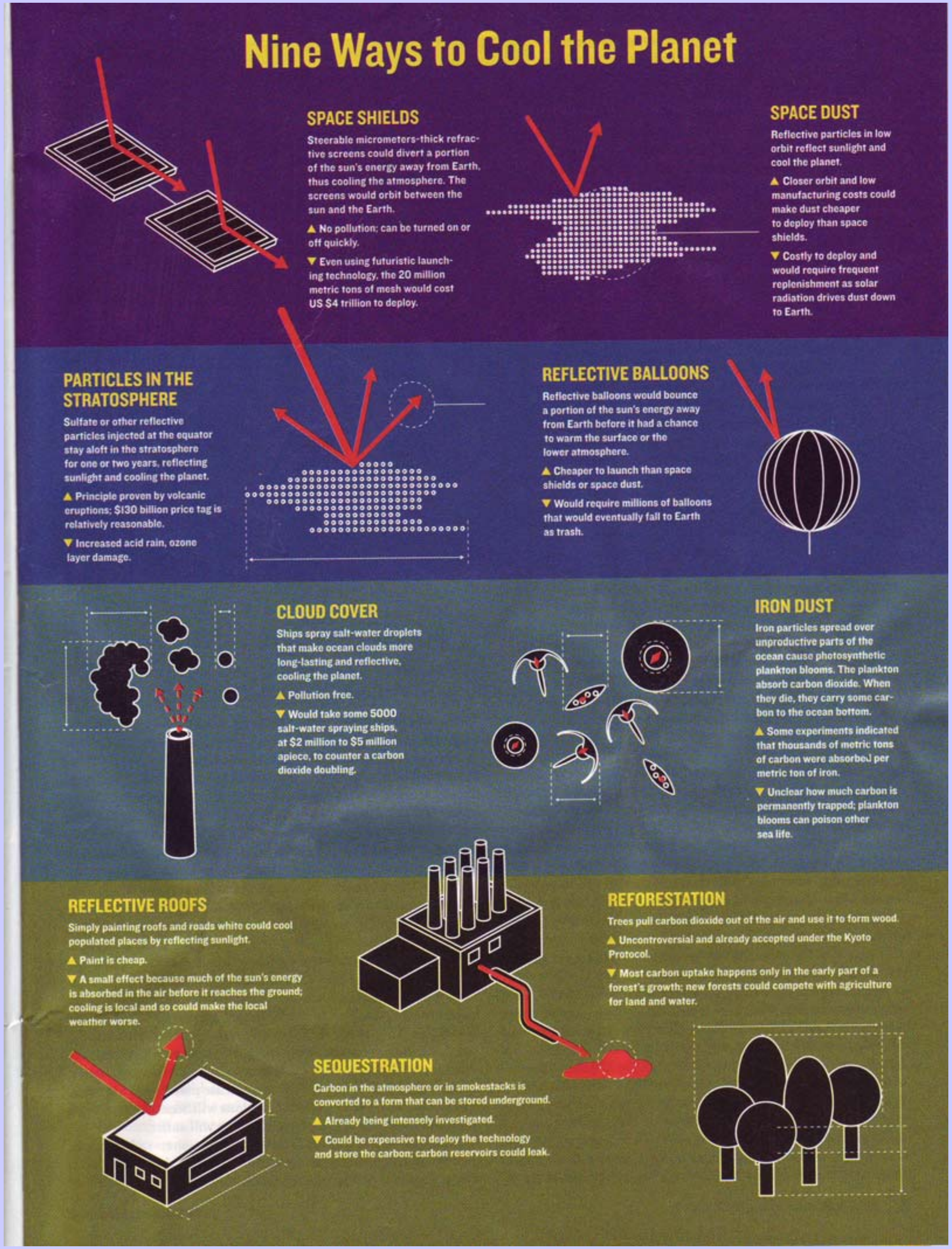




Market Mechanism - A Feedback System: Explanation of Business or Economic Cycles

Greenhouse Effect: Retention of Energy
A prominent example of a natural feedback process





Nine Ways to Cool the Planet

SPACE SHIELDS

Steerable micrometers-thick refractive screens could divert a portion of the sun's energy away from Earth, thus cooling the atmosphere. The screens would orbit between the sun and the Earth.

▲ No pollution; can be turned on or off quickly.

▼ Even using futuristic launching technology, the 20 million metric tons of mesh would cost US $4 trillion to deploy.

SPACE DUST

Reflective particles in low orbit reflect sunlight and cool the planet.

▲ Closer orbit and low manufacturing costs could make dust cheaper to deploy than space shields.

▼ Costly to deploy and would require frequent replenishment as solar radiation drives dust down to Earth.

PARTICLES IN THE STRATOSPHERE

Sulfate or other reflective particles injected at the equator stay aloft in the stratosphere for one or two years, reflecting sunlight and cooling the planet.

▲ Principle proven by volcanic eruptions; $130 billion price tag is relatively reasonable.

▼ Increased acid rain, ozone layer damage.

REFLECTIVE BALLOONS

Reflective balloons would bounce a portion of the sun's energy away from Earth before it had a chance to warm the surface or the lower atmosphere.

▲ Cheaper to launch than space shields or space dust.

▼ Would require millions of balloons that would eventually fall to Earth as trash.

CLOUD COVER

Ships spray salt-water droplets that make ocean clouds more long-lasting and reflective, cooling the planet.

▲ Pollution free.

▼ Would take some 5000 salt-water spraying ships, at $2 million to $5 million apiece, to counter a carbon dioxide doubling.

IRON DUST

Iron particles spread over unproductive parts of the ocean cause photosynthetic plankton blooms. The plankton absorb carbon dioxide. When they die, they carry some carbon to the ocean bottom.

▲ Some experiments indicated that thousands of metric tons of carbon were absorbeJ per metric ton of iron.

▼ Unclear how much carbon is permanently trapped; plankton blooms can poison other sea life.

REFLECTIVE ROOFS

Simply painting roofs and roads white could cool populated places by reflecting sunlight.

▲ Paint is cheap.

▼ A small effect because much of the sun's energy is absorbed in the air before it reaches the ground; cooling is local and so could make the local weather worse.

REFORESTATION

Trees pull carbon dioxide out of the air and use it to form wood.

▲ Uncontroversial and already accepted under the Kyoto Protocol.

▼ Most carbon uptake happens only in the early part of a forest's growth; new forests could compete with agriculture for land and water.

SEQUESTRATION

Carbon in the atmosphere or in smokestacks is converted to a form that can be stored underground.

▲ Already being intensely investigated.

▼ Could be expensive to deploy the technology and store the carbon; carbon reservoirs could leak.

Climate Control to Counteract Greenhouse Effect

IEEE Spectrum, May 2007