Eye-Controlled Machines

Software that translates eye movement into commands to control devices could be a boon for motion-impaired people

2015 WORLDCHANGINGIDEAS

- Earlier this year when Erik Sorto, a quadriplegic man, used his thoughts to direct a robot arm to bring a beer to his lips, the media went wild.

- It was an impressive feat.

- The catch is that the technology behind it—an electrode-laden chip implanted in Sorto's brain—is expensive and invasive and often requires months of training.

- Worse, few paralyzed people have the psychological and physical profile the technology requires.

- There could be a better way.

- Rather than creating a direct link between the brain's electrical activity and machines, Aldo Faisal, an associate professor of neurotechnology at Imperial College London, wants to use eye movements to control wheelchairs, computers and video games.

- With off-the-shelf video-game cameras, Faisal and his colleagues built goggles that record the user’s eye movements and feed those data to a computer.

- Software then translates the data into machine commands.

- Almost anyone can use the technology, including amputees, quadriplegics and those suffering from Parkinson’s disease, multiple sclerosis or muscular dystrophy.

- The system costs less than $50 to build.

- At a science exhibition, the vast majority of thousands of volunteers grasped the technology well enough after 15 seconds to play the game Pong, no instructions needed.

- Scientists have long known that the eyes can reveal people’s objectives—where they want to go, what they want to do, who they want to interact with.

- Drawing on 70 years of research into the neuroscience of eye movements, Faisal and his colleagues wrote algorithms that turn a glance into a command for a wheelchair, a wink into a mouse click or the dart of a pupil into the swing of a game paddle.

- To predict intention, the algorithms depend on training from real-world data, acquired by recording volunteers’ eyes as they drove a wheelchair with a joystick or operated a robotic arm.

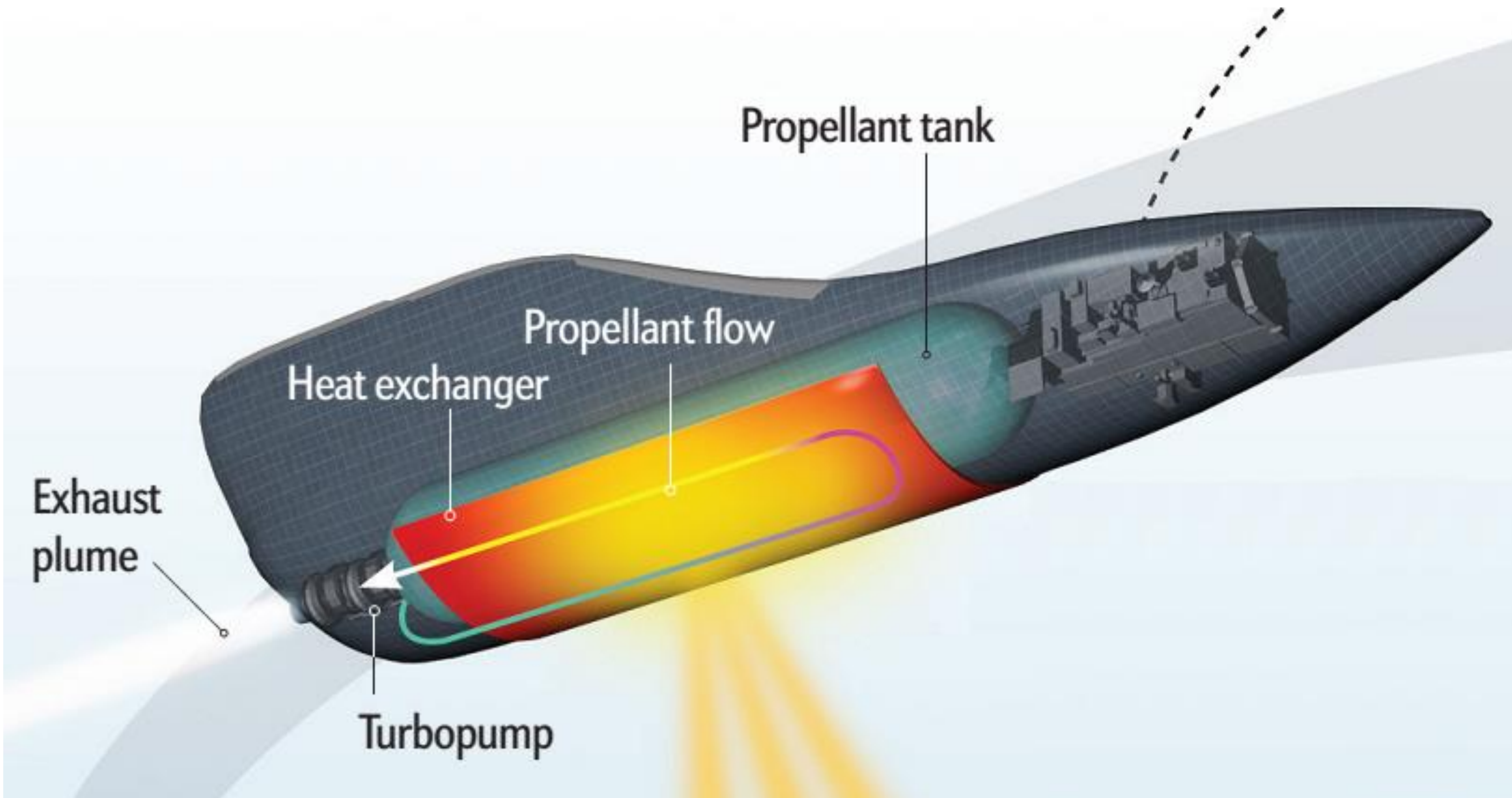
- Gradually the software learned to tell the difference between, for example, the way people look at a cup when they are evaluating its contents and when they want to pick it up and take a drink.

- Before Faisal can commercialize any medical devices based on the invention, he must secure funding for clinical trials.

- In the meantime, a €4-million grant from the European Union will support his group as it develops robotic exoskeletons that paralyzed people could control using the eye-tracking software it developed.

Microwave Rocketry

Beamed power could create a low-cost paradigm for access to space



- Humans have been riding rockets into space for more than 50 years, and for all that time, the cost of reaching orbit has remained astronomical—$5,000 to $50,000 per kilogram, depending on which rocket is used.

- The problem is that none of our rockets is very efficient.

- About 90 percent of a rocket's weight is fuel and propellant, leaving little room for payload.

- If it could lose some of that weight, a rocket could lift more cargo, reducing the cost of putting a given kilogram of stuff into orbit.

- In 1924 Russian scientist Konstantin Tsiolkovsky proposed a way to make this happen, suggesting that beams of microwaves from ground-based transmitters could power a rocket's ascent.

- Tsiolkovsky proposed using parabolic mirrors to aim “a parallel beam of electromagnetic rays of short wavelength” at the belly of a rocket, heating propellant to produce thrust without the need for large amounts of onboard fuel.

- This, he wrote, was the most attractive method available “to acquire cosmic velocity.”

- The idea languished until recently, when technology finally caught up with Tsiolkovsky’s vision.

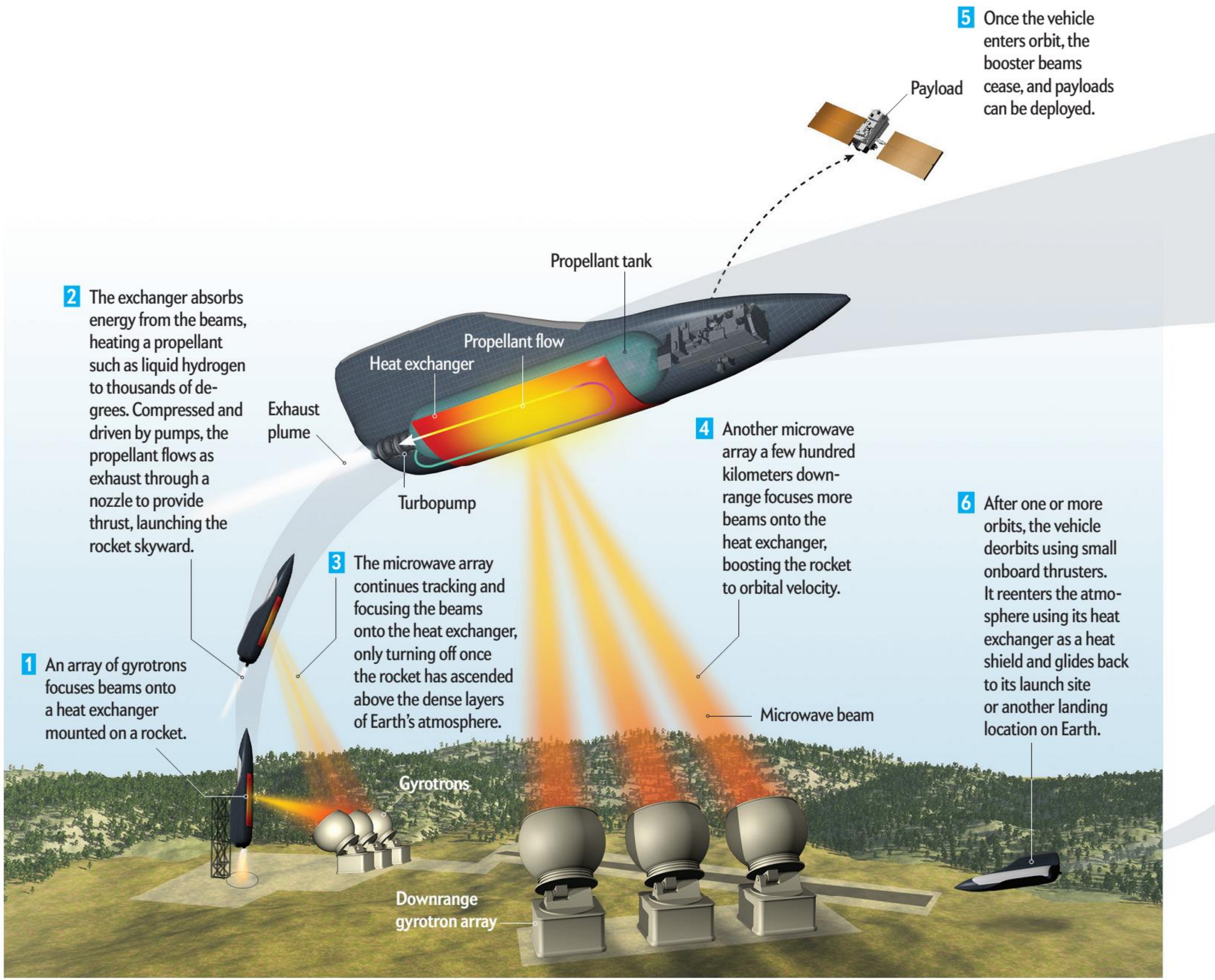
- Microwave lasers—masers—were invented in the 1950s, but it was not until the advent of better, more affordable generators called gyrotrons that masers could reach the megawatt-scale power levels required for space launches.

- Recent advances in batteries and other energy-storage systems have also made it possible to power sufficiently large gyrotrons without straining the electrical grid.

- Today researchers around the world are investigating the concept, including Kevin Parkin, who led a pioneering study in 2012 while at the California Institute of Technology.

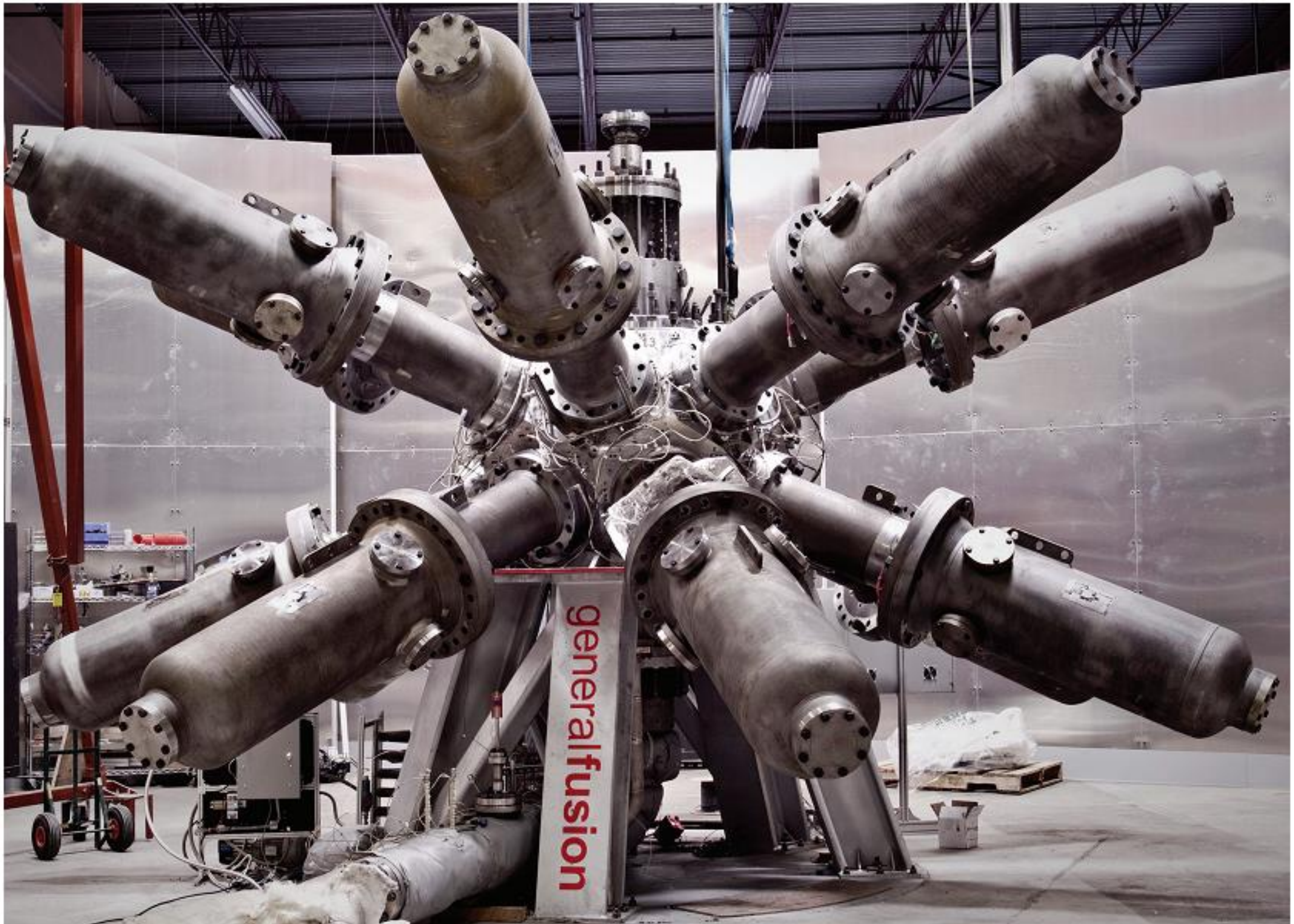
- Based in part on Parkin's work, one private company, Escape Dynamics, is now conducting tests to develop a microwave- powered, reusable system that could launch satellites—and eventually humans.

- NASA is taking notice: in July the agency added beamed rocketry to its road map for future technology development.


5 Once the vehicle enters orbit, the booster beams cease, and payloads can be deployed.
Payload
Propellant tank
2 The exchanger absorbs energy from the beams, heating a propellant such as liquid hydrogen to thousands of degrees. Compressed and driven by pumps, the propellant flows as exhaust through a nozzle to provide thrust, launching the rocket skyward.
Propellant flow
Heat exchanger
Exhaust plume
Turbopump
4 Another microwave array a few hundred kilometers downrange focuses more beams onto the heat exchanger, boosting the rocket to orbital velocity.
6 After one or more orbits, the vehicle deorbits using small onboard thrusters. It reenters the atmosphere using its heat exchanger as a heat shield and glides back to its launch site or another landing location on Earth.
3 The microwave array continues tracking and focusing the beams onto the heat exchanger, only turning off once the rocket has ascended above the dense layers of Earth's atmosphere.
1 An array of gyrotrons focuses beams onto a heat exchanger mounted on a rocket.
Microwave beam
Gyrotrons
Downrange gyrotron array

Little Fusion

After decades of slow progress and massive investment, some fusion power researchers are changing tactics



- You can accuse fusion power advocates of being overly optimistic but never of thinking small.

- Fusion occurs when two elements combine, or “fuse,” together to form a new, third element, converting matter to energy.

- It is the process that powers the sun, and the fusion world’s marquee projects are accordingly grand.

- Consider the International Thermonuclear Experimental Reactor (ITER), which a consortium of seven nations is building in France.

- This $21-billion tokomak reactor will use superconducting magnets to create plasma hot and dense enough to achieve fusion.

- When finished, ITER will weigh 23,000 metric tons, three times the weight of the Eiffel Tower.

- The National Ignition Facility (NIF), its main competitor, is equally complex: it fires 192 lasers at a fuel pellet until it is subjected to temperatures of 50 million degrees Celsius and pressures of 150 billion atmospheres.

- Despite all this, a working fusion power plant based on ITER or NIF remains decades away.

- A new crop of researchers are pursuing a different strategy: going small.

- This year the U.S. Advanced Research Projects Agency- Energy invested nearly $30 million in nine smaller projects aimed at affordable fusion through a program called Accelerating Low-Cost Plasma Heating and Assembly (ALPHA).

- One representative project, run by Tustin, Calif.-based company Magneto-Inertial Fusion Technologies, is designed to “pinch” a plasma with an electric current until it compresses itself enough induce fusion.

- The approach has pedigree: scientists at Los Alamos National Laboratory used the pinch technique in 1958 to create the first sustained fusion reaction in a laboratory.

- Companies unaffiliated with the ALPHA project are also working on alternative fusion schemes. British Columbia-based General Fusion has built a device that uses shock waves propagating through liquid metal to induce fusion.

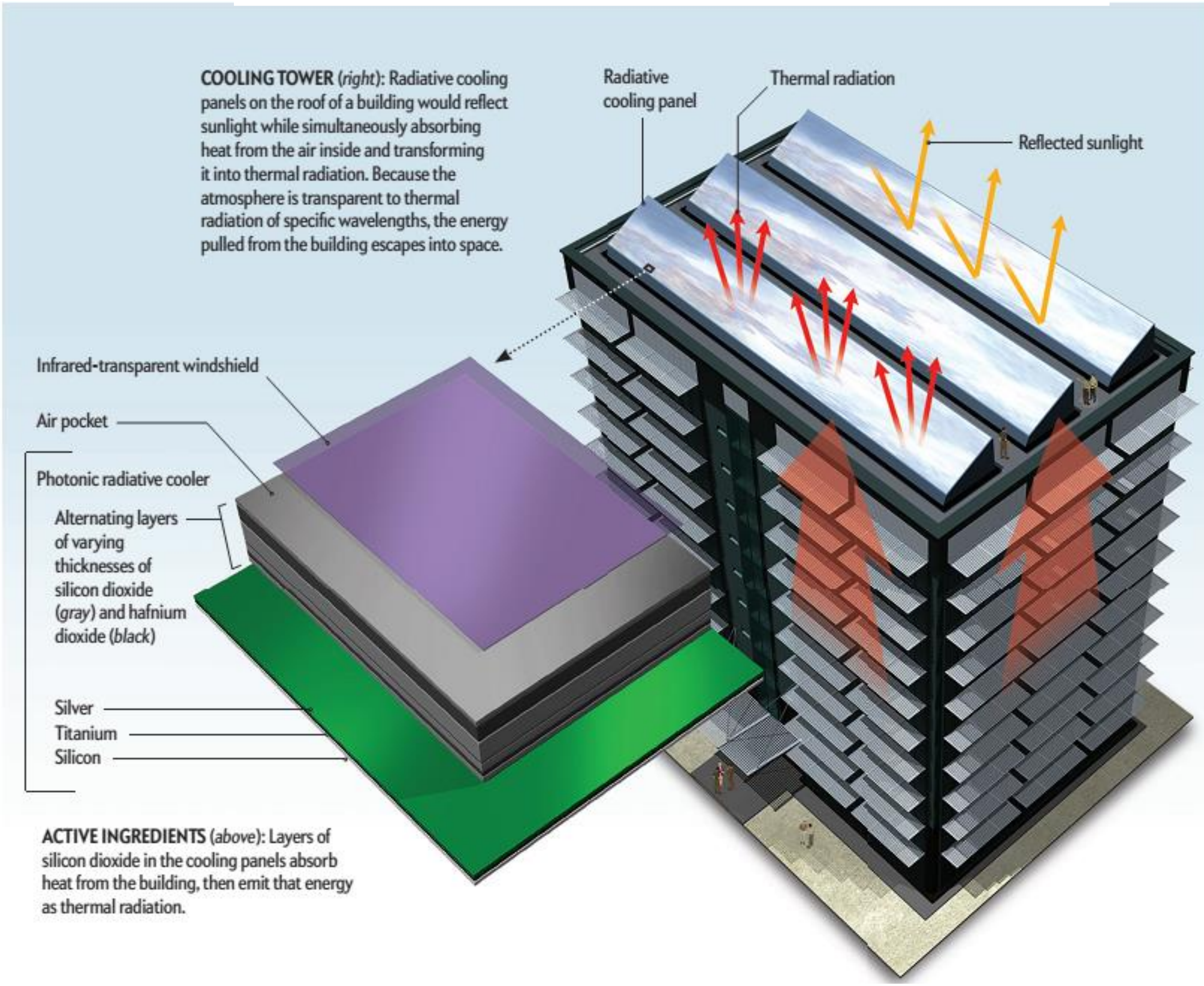
- Tri Alpha Energy is building a colliding beam fusion reactor, a device just 23 meters long that fires charged particles at one another.

- And defense giant Lockheed Martin has claimed to be working on a magnetic fusion reactor the size of a shipping container that will be commercially available within a decade.

- Fusion’s track record suggests that these projects should be viewed skeptically. Yet if any of these approaches succeeds in delivering clean, abundant power with no radioactive waste, it could solve ills ranging from energy poverty to climate change with a single innovation.

The Heat Vacuum

A multipurpose mirror sucks up heat and beams it into outer space



- Air-conditioning accounts for nearly 15 percent of building energy use in the U.S. today.

- The number of days with record heat could soar in the coming decades.

- These two facts present a difficult problem: In a warming world, how can we cool our homes and workplaces while reducing energy use?

- Researchers at Stanford University say part of the solution is a material that sucks heat from sun-drenched buildings and radiates it into outer space.

- The basic concept, known as radiative cooling, originated in the 1980s, when engineers found that certain types of painted-metal roofing pulled heat from buildings and radiated it in wavelengths that pass through the earth's atmosphere unimpeded.

- Radiative cooling never worked during the day, however, because no one had made a material that both radiates thermal energy and reflects sunlight.

- Reflection is critical: if a material absorbs sunlight, heat from the sun negates any cooling that thermal radiation might achieve.

- To solve the problem, the Stanford team created what amounts to a very effective mirror.

- In trials on the roof of its lab, the material, made of layers of hafnium dioxide and silicon dioxide on a base of silver, titanium and silicon, reflected 97 percent of sunlight.

- The silicon dioxide atoms behave like tiny antennas, absorbing heat from the air on one side of the panel and emitting thermal radiation on the other.

- The material radiates primarily at wavelengths between 8 and 13 nanometers.
- The earth’s atmosphere is transparent to these wavelengths, so rather than warming the air around the building, the heat escapes to space.
- Even in direct sunlight, the group’s 20-centimeter-diameter wafer is about five degrees Celsius cooler than the air.
- Shanhui Fan, an electrical engineer at Stanford and senior author of a 2014 Nature paper describing the work, imagines panels of the material covering the roofs of buildings.
- With its roof continually expelling heat, a building’s air-conditioning can relax and consume less energy.
- There could be other applications. Remove the mirror component and pair the material with solar cells, for example, and it could cool the cells while allowing light to reach them, making them more efficient.

Slow-Motion Cameras for Chemical Reactions

Infrared spectroscopy and computer simulations reveal the hidden world of solvent-solute interactions

- The hydrogen bonds that hold together the molecular base pairs of our DNA form in intra-cellular fluid.
- Much of our planet’s environmental chemistry occurs in oceans and other bodies of water.
- Most drugs are synthesized in solvents.
- Yet chemists generally study the bond-by-bond mechanics of chemical reactions only in the gas phase, where molecules are relatively sparse and easy to track.
- In a liquid there are more molecules and more collisions among them, so reactions are fast, messy and complicated.

- The process you want to observe will look like an undifferentiated blur— unless, that is, you can take snapshots of the reaction in a few trillionths of a second.

- Andrew Orr-Ewing, a chemist at the University of Bristol in England, uses lasers to study chemical reactions.

- He knew that reactions in liquid catalyzed by heat create vibrations that can be observed in the infrared spectrum.

- In experiments conducted between 2012 and 2014, Orr-Ewing and then Bristol doctoral student Greg Dunning shot an ultrafast ultraviolet pulse at xenon difluoride molecules in a solvent called acetonitrile.

- The laser pulse acted like a scalpel, carving off highly reactive fluorine atoms, which in turn stole deuterium atoms from the solvent molecules, forming deuterium fluoride.

- The speed with which the telltale infrared vibrations appeared and then vanished after the first laser pulse—observed using a standard technique called infrared spectroscopy—revealed how quickly bonds formed between atoms and how quickly the reaction reached equilibrium.

- The experiments were a proof of concept for observing the split-picosecond details of reactions in liquids.

- Most chemists, however, use computer simulations to observe and refine chemical reactions instead of expensive lasers and detectors.

- For them, Orr- Ewing’s Bristol colleagues David Glowacki and Jeremy Harvey wrote simulation soft ware that predicted the results of Orr-Ewing’s spectroscopy experiments with an extraordinary level of accuracy.

- “We can use these simulations to peer more deeply into what’s going on,” Orr-Ewing says, “because they tell us more precise information than we can get from the experiments.”

- Together the experiments and simulations provide the best insights so far into how a chemical reaction actually happens in a liquid.

- Developers are already starting to incorporate the team’s methods into computer simulations for academic and industrial use, which could benefit scientists doing disease research, drug development and ecological studies.