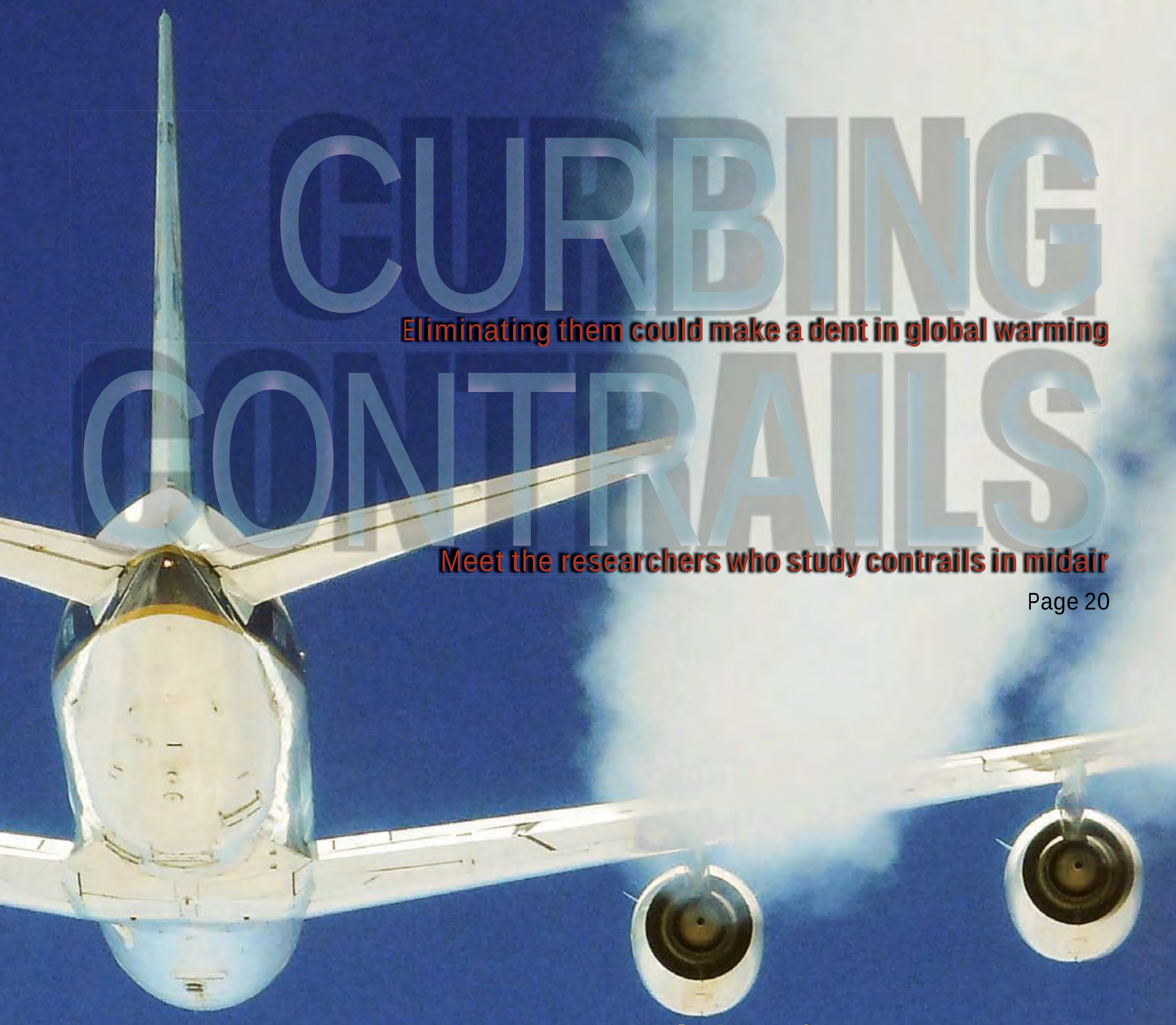

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Keeping TIME in deep space

NASA is looking for new ways to sharpen deep space navigation and give scientists more flexibility. Debra Werner looks at an upcoming orbital experiment that could point the way.

by Debra Werner
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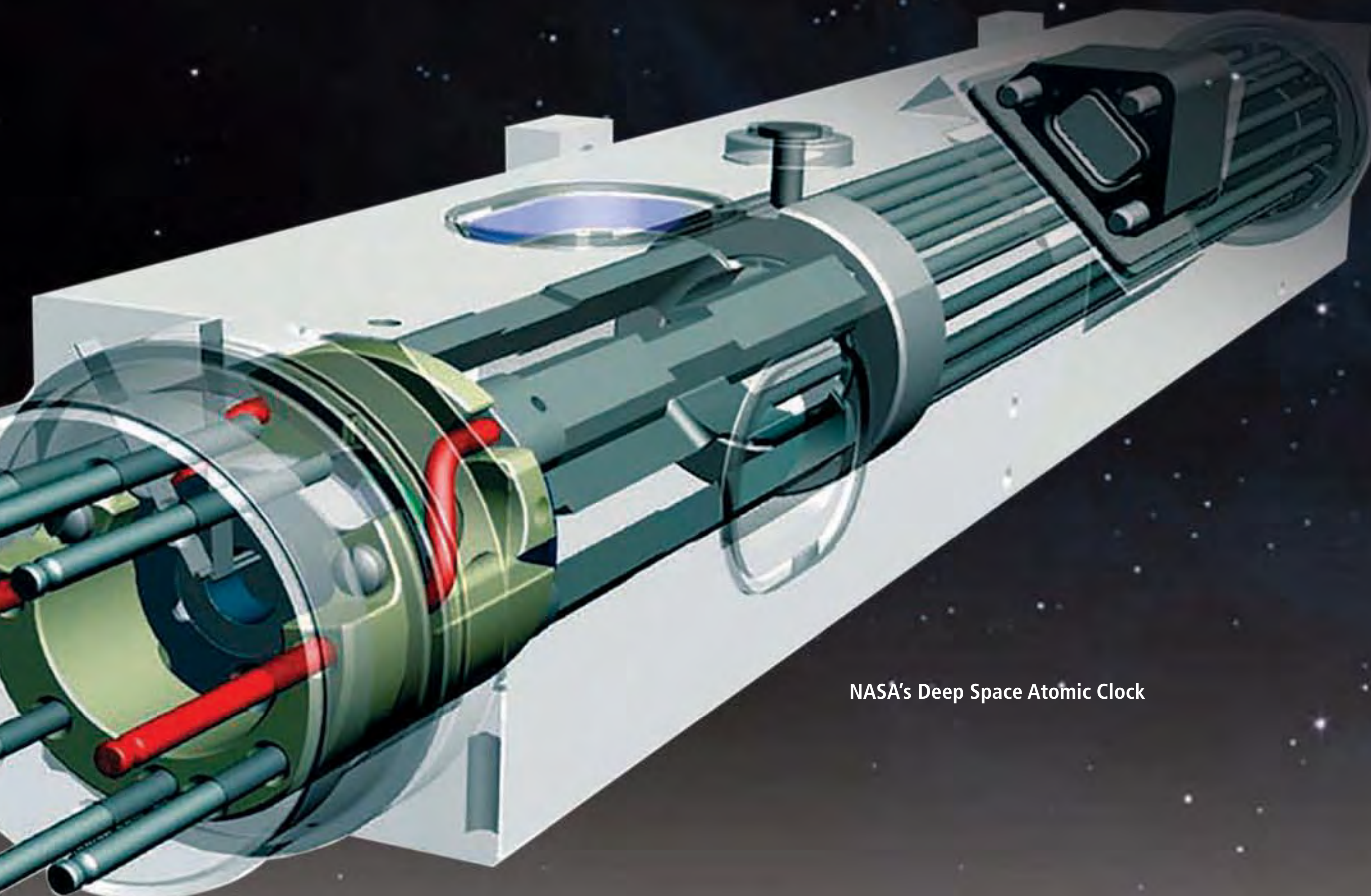
NASA is preparing to send an experimental atomic clock into orbit, and if all goes as planned, the mission will demonstrate the potential for installing atomic clocks on future spacecraft bound for deep space. That would be a big breakthrough, because the locations of unmanned probes or crew vehicles bound for Mars could be calculated in a manner that would take up less of the communications time between a spacecraft and Earth. Scientists are already thinking about how they might use the extra antenna time.

NASA currently calculates the location of a spacecraft outside Earth's orbit by uplinking a radio signal to it from the Deep Space Network's antennas in California, Spain and Australia, each of which has an atomic clock. The spacecraft downlinks the signal to a DSN site, and with some math, the spacecraft's distance from Earth can be determined from the transit time of the signal. The atomic clock is crucial, because a nanosecond error in mea-



NASA's Deep Space Atomic Clock

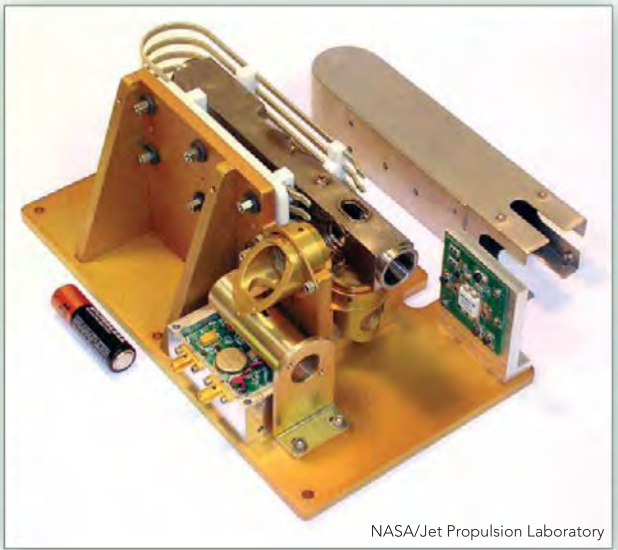
NASA/Jet Propulsion Laboratory

suring when the signal left and when it returned equates to a 30-centimeter error in locating the spacecraft.

It's a technique that has worked for decades, but NASA thinks it can do even better. As things stand, a spacecraft must intermittently stop downloading images and science data to receive and send the navigation signals. If an atomic clock were on the spacecraft in addition to the DSN sites, a one-way signal could be passed between the spacecraft and the ground, and scientists would not have to pause science transmissions for as long.

Proving that a small, accurate atomic clock can withstand launch and operate without someone at the ready to maintain it are among the goals of the Deep Space Atomic Clock experiment. The mercury ion atomic clock was built at NASA's Jet Propulsion Laboratory in California and will be launched as early as September on a yearlong demonstration aboard a U.S. military satellite.

Ground-based atomic clocks used for spacecraft navigation are the size of refrigerators. The Deep Space Atomic Clock demonstration unit measures 23 centimeters by 25 centimeters by 28 centimeters and weighs about 17 kilograms. NASA engineers plan to continue to shrink the design for future tests. Their next goal is to produce a 10-kilogram version that consumes 30 watts, compared with the current model's 45 watts.



NASA/Jet Propulsion Laboratory

The demonstration model of NASA's Deep Space Atomic Clock, which weighs about 17 kilograms. Ground-based atomic clocks used for spacecraft navigation are as big as refrigerators.

Jet Propulsion Lab engineers have been testing the mercury ion atomic clock on the ground for more than a year. By March 1, they plan to deliver it to the company building the host satellite, Surrey Satellite Technology US, the Colorado-based arm of the British company. Surrey is making the Orbital Test Bed satellite for the U.S. Air Force.

Atomic clock makers measure the accuracy of their products by how little they speed up or slow down, a factor called stability. "When [the Deep Space Atomic Clock] flies, it will be the most stable clock in space today," says Bob Tjoelker, the Deep Space Atomic Clock co-investigator at JPL. Deep-space probes don't carry atomic clocks, but GPS satellites do. "This first Deep Space Atomic Clock should be five to ten times more stable than GPS rubidium clocks," Tjoeker adds.

Science options, traffic management

If the Deep Space Atomic Clock works as predicted, future spacecraft would have more flexibility about how to use their high- and low-gain antennas for transmissions and science. Members of NASA's Europa mission team, for example, are considering the technology for their study of Jupiter's moon Europa sometime in the 2020s.

The Deep Space Atomic Clock also could alleviate some of the Deep Space Network's communications traffic jams. Because the network sends and receives tracking signals from all NASA satellites, some spacecraft wait hours to relay data.

"Usually there is a single antenna pointing toward Mars," says JPL's Todd Ely, the Deep Space Atomic Clock principal investigator. "So if one spacecraft is getting tracking another isn't."

With the Deep Space Atomic Clock, NASA could beam timing information toward Mars, and any spacecraft with access to the beam could collect the data and compute its location and trajectory with an onboard navigation system. This capability would be particularly useful for crews traveling beyond low Earth orbit.

"As humans begin to explore further, that makes a strong case to further develop the clock and navigation systems that would use it," Ely says.

Reliability

If Deep Space Atomic Clocks are to be widely used, engineers must show they can withstand the vibration of a rocket launch, temperature and magnetic extremes as well as harsh radiation — a significant challenge given the intricacies of the device. The clock uses electric fields to confine mercury ions to a radio frequency linear ion trap housed in a titanium vacuum tube. It uses an ultraviolet light source in a process called optical pumping to excite trapped electrons, moving them from one energy level to another. By observing ultraviolet light scattered by the trapped ions, the device steers the frequency output of an ultra-stable quartz oscillator to a value that is nearly constant.

The ground-based high performance clocks used for deep space applications typically operate in a tightly controlled environment. Plus, clock experts continuously monitor the devices and perform any necessary maintenance.

"It's a challenge to try to preserve performance in a less stable environment," Tjoelker says. "Some technology provides exquisite performance but requires human intervention for long life."

To meet the challenge of spaceflight, NASA engineers began by selecting the mercury ion for its low thermal and magnetic sensitivity. They also spent more than 20 years developing the ion trap technology to further reduce that sensitivity and make the clock durable.

While the Deep Space Atomic Clock is designed for a one-year demonstration, future versions will need longer lives. "The ultimate goal is to continuously operate for much longer, 10-plus years," Tjoelker says.

Still, getting the first version into space and proving it works will be a significant milestone. "New technology is a tough sell, but this demonstration definitely will retire a lot of risk," Ely says.

Would the U.S. consider using them on new versions of GPS satellites?

"Given the importance and the nature of GPS as a global utility, moving to new technologies requires extensive testing and demonstration of the capability," says Air Force Col. Steve Whitney, who leads the service's Global Positioning Systems Directorate, by email.

NASA/Jet Propulsion Laboratory

NASA plans to launch its experimental Deep Space Atomic Clock on a spacecraft in 2016. The device would have to be much tougher than ground-based atomic clocks in order to withstand extreme temperatures, vibrations and other forces.