

Geoscientists seek to save HAARP

With ionospheric modification, scientists can do plasma-physics experiments that are impossible in the lab.

Prospects for the continued operation of the US High Frequency Active Auroral Research Program (HAARP) became dire last June, when its owner, the Air Force Research Laboratory, switched off the lights. HAARP is the world's most powerful high-frequency (HF) transmitter. A few experiments are planned this spring by the Defense Advanced Research Projects Agency (DARPA). "If no one pulls a rabbit out of the hat, that will probably be the end," says David Hysell, a Cornell University atmospheric scientist who is part of DARPA's HAARP collaboration.

On 26 February, the White House Office of Science and Technology Policy (OSTP) hosted a meeting for federal agencies to consider HAARP's future. Representatives attended from the Department of Defense, NASA, NSF, and Los Alamos National Laboratory. The aim was for the agencies jointly to either seek a solution to keep HAARP open or purposefully shut it, rather than let the Air Force Research Laboratory alone kill it. HAARP cost nearly \$300 million to build; keeping it open hinges on someone coughing up about \$5 million a year in operating costs.

The meeting was private, but by the next day, word was out: No rabbit—but maybe a fighting chance. A US Air Force spokesman told PHYSICS TODAY that no decision was reached. Still, after being briefed by the OSTP, Robert McCoy, the director of the Geophysical Institute at the University of Alaska Fairbanks, came away hopeful: "The guys [at OSTP] were optimistic. We may have two or three years to build a business case." McCoy is working to bring in funding from domestic and international sources.

Powerful, flexible, steerable

The HAARP facility consists of an array of 180 crossed-dipole transmitters for heating the ionosphere, plus instruments for analyzing the response. Located in Gakona, Alaska, about 375 km south of Fairbanks, the facility began operating at low power in 1993, but the full array was not completed until 2007. It transmits frequencies in the range of 2.8–10 MHz and can pump 3.6 MW up

to the ionosphere. The signals can be shaped.

Ionospheric heaters work like short-wave radios, explains Brett Isham of Interamerican University in Puerto Rico, who has used HAARP and other HF facilities. "It's the same way that Voice of America, Radio Moscow, and Deutsche Welle work. But in those cases [the signals] bounce from the ionosphere to go from one continent to another. We take exactly the same transmitters and point them straight overhead." Instead of just reflecting, the waves interact nonlinearly with the ionosphere. The simplest response is heating, but with high enough input energy density, more complicated interactions can be induced. "And because HAARP can focus the unprecedentedly high power densities," says Utah State University's Herbert Carlson, "we see an entirely new, rich variety of effects."

Earth's atmosphere is dilute, so things happen slowly, Carlson continues, "whereas in laboratory plasmas, things happen much faster—you can see before and after, but you can't see things while they happen. In the ionosphere, things happen slowly enough to watch as it's changing." Ultimately, says Cornell's Hysell, "people are interested in ionospheric modification because they are interested in radio wave propagation—to facilitate or disrupt

communications. And to study basic plasma physics."

The Office of Naval Research has used HAARP for studies in which very-low-frequency (VLF), ocean-penetrating signals are generated in the ionosphere to communicate with deep-sea submarines. The air force has looked at nudging high-energy electrons out of radiation belts as a means to lessen degradation of satellite electronics and disruptions in satellite communication due to solar activity or nuclear explosions in the atmosphere. The facility has been used to explore other issues related to GPS and satellite communications. Basic science at HAARP includes such efforts as sustaining high-density plasma layers and creating artificial aurorae to learn about wave-plasma interactions. In addition, summer schools at HAARP provide hands-on training for graduate students.

"HAARP is the most capable of any HF facility, and it can do a few things that others can't," says Isham. As an example, he cites the creation of artificial plasma layers. Ionization occurs just below where a plasma layer reflects the HAARP beam, increasing the electron and ion densities at the lower altitude. "The beam then reflects from the new, slightly lower layer, creating new ionization below the new reflection point, and so on, causing the artificial layer to descend," Isham explains. "People had thought of this, but didn't expect that HAARP's energy density would be



The High Frequency Active Auroral Research Program in Alaska is the world's leading ionospheric heater; with it, the ionosphere can become a plasma-physics laboratory.

Effective radiated power (ERP) of existing high-frequency ionospheric heaters

Facility	Transmitter Power (kW)	ERP* (MW)
HAARP	3600	3600
EISCAT	1000	1260
Sura	750	300
Arecibo	600	240
SPEAR	110	17

*The ERP is the total power transmitted multiplied by the antenna gain.

HAARP, High Frequency Active Auroral Research Program; EISCAT, European Incoherent Scatter Scientific Association; SPEAR, Space Plasma Exploration by Active Radar.

enough. It has potential for controlling the ionosphere for applications such as enhanced over-the-horizon radar and tailored radio communications links."

Diagnostics

Although HAARP is unmatched in terms of power, frequency range, and beam-shaping ability, the 1.2-MW EISCAT (European Incoherent Scatter Scientific Association) heater in Norway outperforms HAARP in some studies thanks to a superior diagnostic tool: incoherent scatter radar. With ISR, a separate radar beam scattered off electrons in the ionospheric plasma can probe HF heater-induced perturbations; the return signal provides measurements of ion and electron temperatures and of plasma density and velocity. The diagnostics presently at HAARP include an HF ionosonde, magnetometers, HF and VLF receivers, a low-power radar, and optical instruments.

The diagnostics deficit is noted by the National Research Council (NRC) in an 11 February report of the proceedings of a workshop held last year. The report highlights the science potential of HAARP but says that it would be greatly enhanced with an ISR and with better satellite coverage.

Resonance, a pair of satellites that Russia plans to fly in a year or so, would follow the magnetic field lines above HAARP for up to 45 minutes at a time, says Dennis Papadopoulos, a University of Maryland physicist. "That's an eternity for our experiments. We will ask such questions as, How can we optimize the signals [from HAARP] to precipitate electrons in the radiation belts? How can we stimulate emissions that affect the radiation belt? It's like a lab experiment, except in space."

And NSF is keen to move its portable

ISR array to HAARP from Poker Flat, Alaska, for about a year of joint experiments, says Robert Robinson, who oversees geospace facilities for the foundation. Longer is unlikely, he explains, because other sites are already in line for the ISR. Although NSF's budgets "do not allow for us to support the operations at HAARP, we are interested in it as a scientific research facility," he says.

Besides HAARP and EISCAT—whose users are musing whether it could buy the HAARP transmitters if the facility is shuttered—Russia has a smaller ionospheric

heater, called Sura, near Nizhny Novgorod (see table above); and one is near completion at Arecibo Observatory in Puerto Rico (see story on page 24). Late last year, the University Centre on Svalbard (see PHYSICS TODAY, July 2013, page 20) mothballed its small ionospheric heater, SPEAR (Space Plasma Exploration by Active Radar).

"A national question"

The HAARP facility has always been under the wing of the Department of Defense, with participation and funding by DARPA, the Air Force Research Laboratory, and the Office of Naval Research. It also got pork-barrel funding through Alaska Senator Ted Stevens. That genesis got HAARP off the ground and also likely landed it in its current difficulties. The NRC report states that "some participants at the workshop cited the unusual history of the HAARP facility as a contributor to its underutilization by a broader community of researchers."

At the 26 February meeting, says McCoy, "I kept holding up the NRC report and saying, 'This is the scientific community talking.' We made our case that this is not an air force question. It's a national question." McCoy says that the air force will likely pull the plug this summer, although parts of the service continue to do research related to ionospheric heating. "But NASA and NSF are sympathetic." McCoy is aiming for a pay-per-use model that would cost about \$6000 per hour. For a typical two-week campaign, running 12 hours a day, that amounts to selling about \$1 million of time to each agency, he says. Japan, Russia, and Sweden have expressed interest in buying time at HAARP.

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