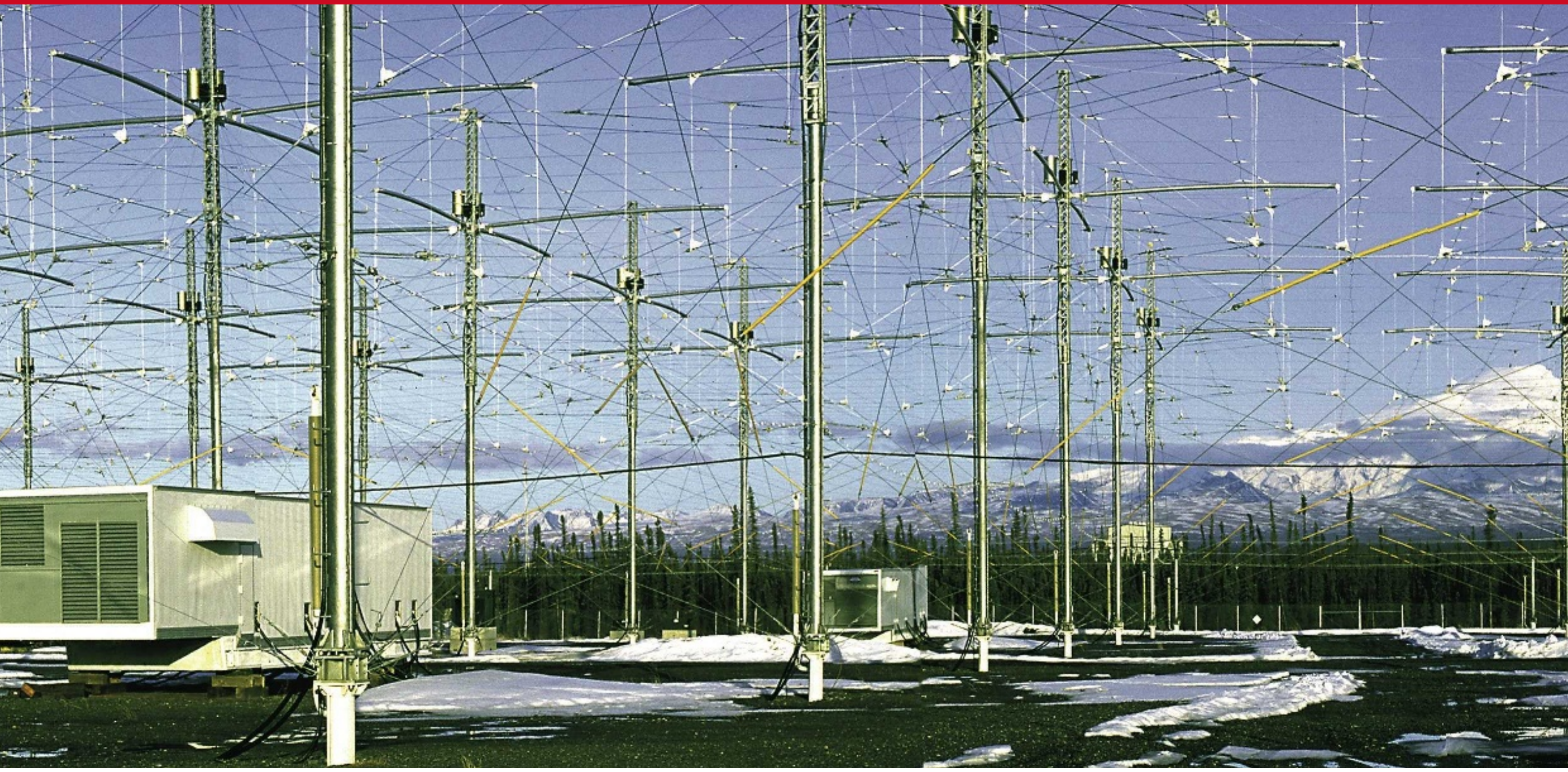


HEATING UP THE HEAVENS

Battling rumours of death beams and mind control, an ionosphere research facility in Alaska finally brings science to the fore. **Sharon Weinberger** reports.

It's a Strangelovian scenario that only the Pentagon could dream up: North Korea, in the throes of a military coup, launches a nuclear weapon that explodes 120 kilometres above the Earth. The blast fills the atmosphere with 'killer' electrons that would within days knock out the electronics of all satellites in low-Earth orbit. It would cause hundreds of billions of dollars of damage, and affect military, civilian and commercial space assets.

If this doomsday scenario sounds outlandish, then the possible response may sound even more improbable: injecting radio waves into the atmosphere to force these energetic electrons out of orbit. Yet this is exactly what the US Department of Defense is looking at in a major ionospheric research facility in Alaska.

The High Frequency Active Auroral Research Program (HAARP) has been entwined with controversy since its birth. Originally envisioned as a way to facilitate communications with nuclear-armed submarines, HAARP took almost two decades to build and has incurred around US$250 million in construction and operating costs. It consists of 360 radio transmitters and 180 antennas, and covers some 14 hectares near the town of Gakona about 250 kilometres northeast of Anchorage.

With 3.6 megawatts of power at its command, HAARP is the most powerful ionospheric heater in the world. At its heart is a phased-array radar that emits radio waves that are partially absorbed between 100 kilometres and 350 kilometres in altitude, accelerating electrons there and 'heating' the ionosphere (see graphic). In effect, HAARP allows scientists to turn the ionosphere, the uppermost and one of the least understood regions of the atmosphere, into a natural laboratory.

It is one of several ionospheric heaters scattered around the world. The facilities create unique opportunities to study the fundamental physics behind how plasma and electromagnetic waves interact. Researchers have already used HAARP to create an artificial aurora and otherwise study the basic physics of how charged particles behave in the ionosphere.

Experiments have been ongoing for several years, but the facility didn't reach full power until last June. As yet it may be too early to assess whether its research potential has been worth the time and money invested in it, particularly given the ever-changing justifications for building it. The facility, which has been passed around varying military agencies, including the Office of Naval Research, the Air Force Research Laboratory and the Defense Advanced Research Projects Agency (DARPA), is perhaps the only research facility that has had to justify itself as being neither a death beam aimed at Russia nor a mind-control device. So prevalent are the conspiracy theories that HAARP has even been referred to in a Tom Clancy novel, in which a fictional facility is used to induce mass psychosis in a Chinese village.

In fact, HAARP is a unique case of cold war-era military goals meshing with scientific research, and then maintaining that linkage even after the end of the war. If the conspiracy theories surrounding HAARP draw on fantastical ideas of death beams, then the real history of the facility is almost as colourful.

Death beams and submarines

HAARP traces its origins back to cold war-era concerns over nuclear annihilation, when US and Soviet submarines prowled the deep seas, engaged in an elaborate game of hide and seek. By staying underwater, the submarines avoided detection, but they also couldn't communicate well — the deeper they went, the weaker the contact signal became. Then, in 1958, Nicholas Christofilos, a physicist at the Lawrence Livermore National Laboratory in California, proposed using extremely low frequency (ELF) waves to communicate with submarines underwater. His idea, adopted as Project Sanguine, eventually led to the development of operational facilities in Michigan and Wisconsin. But these were mired in controversy. They were huge — needing 135 kilometres of antenna wire to transmit the signal — and many took exception to their goals and to the possible detrimental effects on the health of people living nearby. The Navy eventually

E. KENNEDY/NAVAL RES. LAB.

The HAARP facility includes 180 antennas.

closed them down in 2004, saying that they were no longer needed.

Another approach to ELF submarine communication was to take advantage of electrojets — currents of charged particles that flow through the ionosphere and could act as a virtual antennas, transmitting messages to submarines. Once this idea was proven experimentally[1] in the mid-1980s, physicist Dennis Papadopoulos, then of the Naval Research Laboratory in Washington, DC, began trying to drum up support for a new facility.

At the time the Pentagon was shutting down over-the-horizon radar sites that had been designed to detect Soviet bombers attacking the United States — including one in Gakona, an ideal location because it is underneath an electrojet. So Papadopoulos, who is now at the University of Maryland in College Park and has served as a scientific adviser for HAARP since the project's inception, argued for building an ionospheric heater there. The facility would help the Navy to study ELF waves, it would provide scientists with an ionospheric heater and it would guarantee continued life for the military site in Alaska, something that Alaskan Senator Ted Stevens, famous for steering congressional dollars to his home state, also liked. "That," says Papadopoulos, "was the genesis."

But even before construction began, people started to speculate about what the facility could be used for and why it was being built. In a news conference in 1990, Stevens talked about bringing energy from the aurora borealis "down to Earth so it could be used" to solve the world's energy crises, earning him the mockery of physicists. Others such as Nick Begich, the son of another Alaskan lawmaker, began claiming that HAARP was really intended as a missile defence weapon. According to Papadopoulos, these claims, although far-fetched, were based on a sliver of truth: Bernard Eastlund, a consultant to one of the firms building HAARP, had filed a series of patents making extraordinary claims that HAARP-like technology could be used as a defence shield by transforming natural gas into microwaves, which would knock out incoming Soviet missiles. The idea, jokingly dubbed the "killer shield", was even reviewed by the JASON defence advisory group, but was dismissed as "nonsense", according to Papadopoulos.

From annihilation to defence

With the breakup of the Soviet Union, submarine communications no longer seemed as crucial, and HAARP needed a new *raison d'être*. Supporters proposed new tactics, such as studying ELF waves' ability to map out underground bunkers like those found in North Korea, a goal that quickly drew scepticism.

> "Scientific research to better understand Earth's ionosphere is a worthwhile endeavour."
> — Philip Coyle

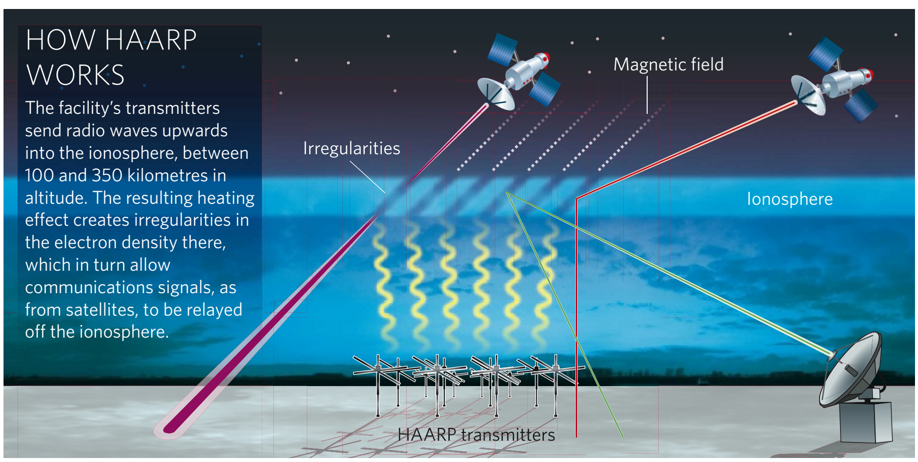
After the terrorist attacks of 9/11, however, the military found a new use for HAARP. In 2002, a panel headed by Anthony Tether, the director of DARPA, recommended that the facility be used to study ways to counter the effects of a high-altitude nuclear detonation, which would release energetic electrons that could cripple low-Earth satellites.

Electrons are produced naturally in this region when the solar wind, a stream of energetic particles flowing from the Sun, slams into the magnetic envelope that protects Earth. The planet has its own self-cleaning mechanism to rid itself of the particles: it eventually dumps them lower into the atmosphere through natural auroras and lightning. Scientists are now looking at whether they can accelerate this process by creating 'whistler' waves, which would kick the electrons into low enough altitudes — around 100 kilometres — where they would rain out naturally.

No one knows for sure whether it will work. "It is what we call a data-starved area — theory is ahead of actual observations," says Paul Kossey, HAARP's programme manager at the Air Force Research Laboratory at Hanscom Air Force Base, Massachusetts. Several experiments are being done to look at this possibility. Stanford University in Palo Alto, California, for example, is involved in the One Hop Experiment, which uses HAARP to inject very-low-frequency waves into the magnetosphere to create whistlers. The investigators use a buoy and ships in the South Pacific, where the waves fall back to Earth, to measure the presence of whistler waves[2].

Mitigating the radiation from an atmospheric nuclear detonation would require an entirely new facility, and the technology would be daunting. In 2006, a New Zealand-led group of scientists published a paper[3] arguing that any attempt to remediate radiation could lead to worldwide blackouts of high-frequency radio waves, disrupting communications and navigation. And some say that countering such high-altitude nuclear detonations is simply unrealistic. "I think scientific research to better understand Earth's ionosphere is a worthwhile endeavour," says Philip Coyle, a former associate director of the Livermore laboratory who served as the Pentagon's chief weapons tester during the administration of President Bill Clinton. But, he adds, they don't know how much energy they would need to flush the electrons, or how, ultimately, injecting this much energy would change the ionosphere.

In the meantime, there are plenty of straightforward science questions for HAARP to look into. The ionized part of the atmosphere has



SOURCE: AFRL/ONR

long captivated researchers, going back to the days of Nikola Tesla, who dreamed of using it to send electricity around the world. In 1933, scientists found that changing the electron density in the ionosphere could alter the propagation of radio signals[4]. That discovery eventually led to the development of ionospheric heaters to study these and other effects.

Bells and whistles

Radiation from solar flares is one area of interest. "These things are really important because it is the radiation coming off the Sun that is the main cause of satellite failure or potential death in human space exploration," says Michael Kosch, the deputy head of the communication systems department at Lancaster University, UK. Other areas include looking at the processes that cause an aurora — when electrons in the magnetosphere collide with the uncharged particles of the atmosphere, creating the optical emissions often seen as brilliantly coloured lights in the night sky. One of HAARP's most cited accomplishments is the creation of the first artificial aurora visible to the naked eye[5]. On zapping the ionosphere, HAARP created a green aurora between 100 and 150 kilometres high — in the middle of a natural aurora. "That was something you couldn't predict," says Michael Kelley, a physicist at Cornell University in Ithaca, New York, who has been involved with HAARP.

Other ionospheric heaters around the world include a lower-power US facility in Arecibo, Puerto Rico, which has been offline since a flood several years ago (although plans are under way to refurbish it), and one in the Russian city of Vasilsursk, which has struggled with funding issues. HAARP's closest peer is a powerful ionospheric heater at the European Incoherent Scatter (EISCAT) Scientific Association in northern Scandinavia. EISCAT's heater has cost roughly $24 million to build and operate to date, and was the first to create

an artificial aurora, even before HAARP.

HAARP, though, has the highest power as well as the most advanced optics and diagnostic equipment. But most of all, its phased-array radar means that the signals can be steered and controlled digitally. It can also create multiple beams, which can be shaped, or changed instantaneously to sweep north, south, east and west. "I think the main thing that makes it unique is that it has a much wider frequency operating range," adds Kosch, who has also worked extensively at EISCAT. HAARP operates between 2.8 and 10 megahertz, whereas EISCAT operates between 3.9 and 8 megahertz. "It can operate in a much lower frequency range than the one we can use here in Europe," Kosch says.

> **"HAARP can operate in a much lower frequency range than the one we can use here in Europe."**
> — Michael Kosch

As HAARP was only finished in 2007, scientists and Pentagon officials involved in the project concede that management issues, such as allocating time at the facility, are still in the formative stages. In fact, one of the most recent HAARP experiments is something that's not likely to show up in the scientific literature at all: an experiment done in January that involved sending radio waves to the Moon and then having amateur radio enthusiasts and a receiving antenna in New Mexico measure the reflected signals. But Papadopoulos says that the experiment was more for the amateur radio community than for scientists.

At the moment, time at the facility is divided between researcher-directed work, which takes place during 'campaigns' of two to three weeks, and military needs. "It's a fairly complicated situation in which we support new researchers, and new people, by getting them involved in the campaigns, which is relatively cheap," says Kossey. "Then of course we also fund [military] proposals and contracts that come in under broad agency announcements, in which researchers propose research that is of interest to the various organizations."

And even though HAARP is a military-owned facility, academics say that access has not been a problem. Umran Inan, the lead scientist for the Stanford work, says that Stanford has been one of the most frequent users, with numerous graduate students and foreign scientists working at the site. "Obviously, there are security arrangements, because it's a US Department of Defense facility," says Kosch. "I'm a foreigner — escort required — but I am already so familiar to the people there, and so familiar with the facility, that it's not really a major problem."

HAARP's evolution may not have been straightforward, but it is, in the minds of many scientists who work there, a success. "HAARP has been a boon to science in this area, and I think the managers that run HAARP, from the very beginning, have involved the community," says Inan. So unlike many other Department of Defense facilities that are built before there is a clear rationale, "in this case the community was involved from the very beginning, so the properties of the facilities were all defined with the involvement of the community. Now, I think it's a thriving success," he says.

As for HAARP's original legacy, as an antenna to send signals to submarines, that era has come and gone with the end of the cold war. "The communications for submarines is not as important any more," says Papadopoulos. "There are," he acknowledges, "no submarines from the other side." ■

Sharon Weinberger is a freelance writer in Washington DC.

B. MARTINSON/AP

Scientists want to better understand the processes involved in creating auroras.

1. Barr, R., Rietveld, M. T., Kopka, H., Stubbe, P. & Nielsen, E. *Nature* **317,** 155–157 (1985).
2. Inan, U. S. *et al. Geophys. Res. Lett.* **31,** L24805 (2004).
3. Rodger, C. J. *et al. Ann. Geophys.* **24,** 2025–2041 (2006).
4. Tellegen, B. D. H. *Nature* **131,** 840 (1933).
5. Pederson, T. R. & Gerken, E. A. *Nature* **433,** 498–500 (2005).