

## The High Frequency Active Auroral Research Program

# HAARP

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## HAARP Fact Sheet

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HAARP Cam



HAARP Cam 2



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### What Is HAARP?

The **H**igh frequency **A**uroral **R**esearch **P**rogram (HAARP) is a program focused on the study of upper atmospheric and solar-terrestrial physics and Radio Science. The HAARP program operates a major Arctic ionosphere research facility on an Air Force owned site near Gakona, Alaska. Principal instruments installed at the HAARP Research Station include a high power, high-frequency (HF) phased array radio transmitter (known as the Ionosphere Research Instrument (IRI), used to stimulate small, well-defined volumes of ionosphere, and a large and diversified suite of modern geophysical research instruments including an HF ionosonde, ELF and VLF receivers, magnetometers, riometers, a UHF diagnostic radar and optical and infrared spectrometers and cameras which are used to observe the complex natural variations of Alaska's ionosphere as well as to detect artificial effects produced by the IRI. Future plans include completion of the UHF radar to allow measurement of electron densities, electron and ion temperatures, and Doppler velocities in the stimulated region and in the natural ionosphere using incoherent scatter techniques.

### Is HAARP Unique?

Ionosphere research facilities have been in continuous use since the 1950s to investigate fundamental physical principles which govern the earth's ionosphere, so that present and future transmission technologies may take into account the complexities of this highly variable medium. In addition to HAARP, the United States has operated two other ionosphere research sites in recent years, one in Puerto Rico, near the Arecibo Observatory, and the other (known as HIPAS) in Alaska near Fairbanks. Both of these facilities were built with both active and passive radio instrumentation similar to those at the HAARP facility. Interest in the ionosphere is not limited to the US: a five-country consortium operates the European Incoherent Scatter Radar site (EISCAT), a premier ionosphere research facility located in northern Norway near Tromso. Facilities also are located at Jicamarca, Peru; near Moscow, Nizhny Novgorod ("SURA") and Apatity, Russia; near Kharkov, Ukraine and in Dushanbe, Tadjikistan. All of these installations have as their primary purpose the study of the ionosphere, and most employ the capability of stimulating to a varying degree small, localized regions of the ionosphere in order to study methodically, and in a detailed manner what nature produces randomly and regularly on a much larger scale. HAARP is unique to most existing facilities due to the combination of a research tool which provides electronic beam steering, wide frequency coverage and high effective radiated power collocated with a diverse suite of scientific observational instruments.

### Who is Building HAARP?

Technical expertise and procurement services as required for the management, administration and evaluation of the program are being provided cooperatively by the Air Force (Air Force Research Laboratory), the Navy (Office of Naval Research and Naval Research Laboratory), and the Defense Advanced Research Projects Agency. Since the HAARP facility consists of many individual items of scientific equipment, both large and small, there is a considerable list of commercial, academic and government organizations which are contributing to the building of the facility by developing scientific diagnostic instrumentation and by providing guidance in the specification, design and development of the IRI. BAE Advanced Technologies (BAEAT) is the prime contractor for the design and construction of the IRI. Other organizations which have contributed to the program include the University of Alaska, Stanford University, Cornell University, University of Massachusetts, UCLA, MIT, Dartmouth University, Clemson University, Penn State University, University of Tulsa, University of Maryland, SRI International, Northwest Research Associates, Inc., and Geospace, Inc.

### What is the Value of Ionosphere Research?

The ionosphere begins approximately 35 miles above the earth's surface and extends out beyond 500

miles. In contrast to the dense atmosphere close to the earth, which is composed almost entirely, of neutral gas, the thin ionosphere contains both neutral gas and a small number of charged particles known as ions and electrons. This ionized medium can distort, reflect and absorb radio signals, and thus can affect numerous civilian and military communications, navigation, surveillance and remote sensing systems in many varied ways. For example, the performance of a satellite-to-ground communication link is affected by the ionosphere through which the signals pass. AM broadcast programs, which in the daytime can be heard only within a few tens of miles from the station, at night sometimes can be heard hundreds of miles away, due to the change from poor daytime to good nighttime reflection from the ionosphere. A long-range HF communication link which uses multiple hops or reflections from the ionosphere and ground, often experiences amplitude fading caused by interference between signals which have traveled from the transmitter to the receiver by two (or more) different ionosphere paths.

Since the sun's radiation creates and maintains the ionosphere, sudden variations in this radiation such as those caused by solar flares can affect the performance of radio systems. Sometimes these natural changes are sufficient to induce large transient currents in electric power transmission grids, causing widespread power outages. Lightning is known to cause substantial heating and ionization density enhancement in the lower ionosphere, and there are indications that ground-based HF transmitters, including radars and strong radio stations, also modify the ionosphere and influence the performance of systems whose radio paths traverse the modified region. Perhaps the most famous example of the latter is the "Luxembourg" effect, first observed in 1933. In this case a weak Swiss radio station appeared to be modulated with signals from the powerful Luxembourg station, which was transmitting at a completely different frequency. Music from the Luxembourg station was picked up at the frequency of the Swiss station.

The continual growth in the number of civilian and military satellite systems whose performances can be affected by changes in ionosphere conditions stimulates research on characterizing and understanding those effects, whether they be natural (solar related) or the result of controlled local modification of the ionosphere, using ground HF transmitters. The HAARP facility is capable of supporting research in both these areas of interest, by utilizing its flexible HF transmitting array and its suite of radio and optical diagnostic instruments for active experimental research. Effectively, the diagnostic instruments alone constitute a space-weather observatory (on the ground), which provides real-time data on the state of the dynamic ionosphere over much of Alaska.

#### **Why is the DoD Involved?**

The Department of Defense (DoD) conducts Arctic research to ensure the development of the knowledge, understanding and capability to meet national defense needs in the Arctic. Interest in ionosphere research at HAARP stems both from the large number of communication, surveillance and navigation systems that have radio paths which pass through the ionosphere, and from the unexplored potential of technological innovations which suggest applications such as detecting underground objects, communicating to great depths in the sea or earth, and generating infrared and optical emissions. Expanding our knowledge about the interactions of signals passing through or reflecting from the ionosphere can help to solve future problems in the development of DoD systems, and could as well enhance the utilization of commercial systems which rely on the expedient transfer of real-time communications.

#### **Why Gakona, Alaska?**

During HAARP's environmental impact study, Gakona was identified as one of two DoD-owned, Alaskan locations which satisfied the site selection criteria of being within the auroral zone, near a major highway for year-round access, away from densely settled areas and their electrical noise and lights that could interfere with sensitive research measurements, on relatively flat terrain, of realistic and reasonable construction and operation costs, as well as minimal environmental impacts. On October 18, 1993 following the July 15, 1993 issuance of the Air Force's Environmental Impact Statement which evaluated potential environmental effects of constructing and operating the HAARP facility, a Record of Decision (ROD) signed by the Deputy Assistant Secretary of the Air Force for Installations selected Gakona as the location for the HAARP facility.

#### **Location of the HAARP Facility**

The access road is located at Milepost 11.3 on the Tok highway. The geographic coordinates of the HF antenna array are approximately 62.39 degrees (North) latitude, 145.15 degrees (West) longitude. The geomagnetic coordinates for the facility are 63.09 degrees (North) latitude and 92.44 degrees (West) longitude.

### **What is the IRI and what does it transmit?**

Basically, the IRI is what is known as a phased array transmitter. It is designed to transmit a narrow beam of high power radio signals in the 2.8 to 10 MHz frequency range. Its antenna is built on a gravel pad having dimensions of 1000' x 1200' (about 33 acres). There are 180 towers, 72' in height mounted on thermopiles spaced 80' apart in a 12 x 15 rectangular grid. Each tower supports near its top, two pairs of crossed dipole antennas, one for the low band (2.8 to 8.3 MHz), the other for the high band (7 to 10 MHz). The antenna system is surrounded by an exclusion fence to prevent possible damage to the antenna towers or harm to large animals. An elevated ground screen, attached to the towers at the 15' level, acts as a reflector for the antenna array while allowing vehicular access underneath to 30 environmentally-controlled transmitter shelters spaced throughout the array. Each shelter contains 6 pairs of 10 kW transmitters, for a total of  $6 \times 30 \times 2 \times 10 \text{ kW} = 3600 \text{ kW}$  available for transmission. The transmitters can be switched to drive either the low or high band antennas. Electric prime power is provided from an on-site power plant housing five, 2500 kW generators, each driven by a 3600 hp diesel engine. Four generators are required for operation of the IRI and the fifth is held as a spare. From a control room within the Operations Center, the transmission from each of the 180 crossed-dipole antennas is adjusted in a precise manner under computer control. In this manner, the complete array of antennas forms a narrow antenna pattern pointed upward toward the ionosphere. The transmitted signal diverges (spreads out) as it travels upward and is partially absorbed, at an altitude which depends on the transmitted HF frequency, in a small volume several tens of miles in diameter and a few hundred meters thick directly over the facility. The remainder of the transmitted signal either reflects back toward the earth or passes through the ionosphere into space, continuing to diverge as it does so. By the time it reaches the ionosphere, the intensity of the HF signal is less than 3 microwatts (0.000003 watt) per  $\text{cm}^2$ , thousands of times less than the Sun's natural electromagnetic radiation reaching the earth and hundreds of times less, even, than the *variations* in intensity of the Sun's natural ultraviolet (UV) energy which creates the ionosphere.

### **How safe are these transmissions?**

Because the antenna pattern of the IRI array has been tailored to transmit its signal upward rather than toward the horizon, radio field strengths at ground level, including areas directly under the antenna array, are calculated to be smaller than Radio Frequency Radiation (RFR) standards allow for human exposure. This is possible because the individual transmitters are spaced apart over 33 acres so that the concentration of radio fields never exceeds these nationally recognized safety standards. Electromagnetic field strength measurements have been made throughout the development of the facility, beginning in 1994 and regularly thereafter. Measurements on the ground, directly under and around the array and at multiple points on-site and off-site have verified compliance with RFR standards as well as with all requirements for safety mandated in the EIS Record of Decision. At the point of closest public access on the Tok Highway, for example, the measured fields are ten-thousand times smaller than permitted by the RFR standards and hundreds of times smaller than typically found near AM broadcast station antennas in many urban areas. The strength of these fields continues to decrease in a rapid manner at greater distances from the facility.

### **What about aircraft?**

While the signals along the ground are well-below adopted safety levels, the signals transmitted above the antenna array may have sufficient strength to interfere with electronic equipment in aircraft flying nearby. Therefore, to ensure the safety of all flight operations in the vicinity of HAARP, the facility employs an [aircraft alert radar](#) (AAR) to automatically shut off appropriate transmissions when aircraft are detected either within or approaching a defined safety zone around the facility. Flight tests are conducted regularly to demonstrate the capability of the HAARP radar to detect even very small targets. Research operations are not conducted unless the AAR is operating satisfactorily.

### **What is the potential for Radio Frequency Interference (RFI)?**

Every radio transmitting facility has the potential to interfere with other radio spectrum users. To determine the potential for HAARP's transmissions to interfere inadvertently with other spectrum users such as Alaskan TV, AM/FM radio, ham radio, or even with HAARP's own sensitive radio receiving equipment, a comprehensive RFI study was conducted during the environmental impact study phase. Theory predicted that in several worst-case scenarios, interference may be encountered by some nearby users sharing the RF spectrum. On the other hand, the real world experiences of similar ionosphere research instruments and radar diagnostics employed elsewhere in the world have shown that compatible operations are practical. Included in HAARP's Spectrum Certification from the National Telecommunications and Information Administration (NTIA) are commitments to a mitigation program that includes the use of state-of-the-art transmitters with stringent requirements for

minimizing out-of-band transmissions; proper orientation of the HF antenna array and adoption of operating procedures, including beam steering, to minimize array side-lobes; employing special techniques such as waveform shaping, filtering and antenna null placement; and working with affected spectrum users, if any, to reach mutually agreeable solutions. A local phone number (907) 822-5497 permits anyone believing they have interference from HAARP to contact the Gakona site operations center. In addition, an automated spectrum monitor is installed to allow the HAARP control operator to monitor nearby spectrum usage to assist in frequency selection for avoiding potential interference.

### **What is the RFI Resolution Advisory Committee?**

The Record of Decision stipulated that an RFI Resolution Committee ("Committee") would be formed with local representation, to help mitigate potential RFI issues. The local community-appointed resident would serve as an ombudsman to ensure community satisfaction with the RFI mitigation approaches undertaken by HAARP. The purpose of the Committee is to provide a forum for the thorough review of confirmed RFI reports. This Committee has met at least yearly since December 6, 1994. Committee members are from the following organizations (one from each): Community-appointed resident, Aircraft Owners and Pilots Association (AOPA), ALASCOM, Alaska Department of Environmental Conservation, Alyeska Pipeline Service Co., American Radio Relay League (ARRL), Coast Guard, Federal Aviation Administration (FAA), Fish & Wildlife (Federal), Fish & Game (State), National Park Service, HAARP Environmental Liaison Officer, HAARP operational staff (site supervisor or delegate), HAARP Program-appointed chairperson, National Park Service, Naval Research Laboratory (NRL), and the combined Alaska military command (ALCOM) frequency coordinator.

To ensure that all concerns, including aircraft safety as well as radio frequency interference issues, are addressed completely, a Developmental Prototype (DP) was completed in 1994. The DP consisted of a 6 x 8 (48 antenna element) array of crossed dipole antennas. A 3 x 6 (18 antenna elements) subset of these antennas was energized by 18 pairs of 10 kW transmitters contained in three separate shelters, thus supplying up to a maximum of 360 kW. Prime power for this initial array was obtained from three portable 350 kW diesel generators.

During 1998, the DP was upgraded to include transmitters for all 48 of the antenna elements that were originally installed. This Filled Developmental Prototype (FDP) was capable of producing 960 kW of total transmitter power. Measurements of the HF fields in the vicinity of the FDP antenna array showed that field intensities everywhere, including within the FDP beam, were below recommended international safety limits for fly-by-wire aircraft. Nonetheless, the FDP was only operated in conjunction with the aircraft alert radar, to insure that no high power transmissions occurred when there was local flight traffic. Operation and test of the FDP verified the system engineering design and helped develop interference mitigation procedures that are now integrated into all research operations involving the IRI.

### **HAARP Diagnostics**

HAARP has developed an extensive set of diagnostic instrumentation to support ionosphere research at auroral latitudes, to characterize the processes produced in the upper atmosphere and ionosphere by high power radio waves and to assess the potential of emerging ionosphere/radio technology for DoD applications. While some of these scientific instruments are collocated with the IRI at the research facility, others, due to geometrical considerations, are located off-site at various distances from the facility. One of the primary active on-site instruments is the HF ionosonde, which transmits in the 1-30 MHz band and is used to provide scientists with information about the electron density profile in the ionosphere. Another is the UHF ionosphere radar which transmits radio wave signals in the 430 - 450 MHz band and which will eventually be expanded to provide incoherent scatter capability.

Among the passive on-site instruments are two magnetometers for the measurement of the earth's magnetic field and its variations, and two riometers (relative ionosphere opacity meter) to sense ionosphere absorption of the celestial background electromagnetic radiation. The radio spectrum from 100 kHz to 1 GHz is being recorded to determine frequency of usage and to monitor HAARP transmissions to ensure adherence to FCC and NTIA requirements. Other passive on-site instruments include sensitive optical imagers and photometers, ELF/VLF receivers, and Total Electron Content receivers. Data obtained from these scientific instruments are **readily accessible** on the internet in near real time, allowing scientists to observe and participate in the investigations directly from their laboratories. In addition to the instruments specifically developed by HAARP, a number of diagnostics potentially are available through other federal agencies and the University of Alaska's Geophysical Institute.

### Use of Local Resources

The Geophysical Institute of the University of Alaska Fairbanks (UAF) has played a major role in the development of diagnostics and coordination of Arctic programs with the US scientific community. UAF led a consortium of universities and industries which provided support in the design and development of the Gakona facility and its associated scientific instruments. BAE Advanced Technologies, the prime contractor for the IRI, utilized Eric Goozen for initial site survey work. Ahtna Construction, Inc., a Glennallen based contractor, has contributed very extensively to the development of the facility. Ahtna currently provides housekeeping and security services. Anchorage-based engineering firms Duane Miller & Associates and USKH prepared the civil and pad design work and conducted the on-site testing and evaluation. Arctic Foundation of Anchorage designed and manufactured, and Kiewit Pacific Company installed thermopiles in the pad, using Amtec, Inc. to survey the thermopile locations and Tester Drilling and EBA Engineering to provide drilling support. Acme Fence Company installed fencing, using the services of Mark Lappi to survey the fence lines and B&B Plumbing to steam thaw the ground for drilling. City Electric, Inc. erected the towers, antennas, and ground screen. Pacific Detroit Diesel and Valley Diesel refurbished and installed the 2.5 MW diesel generators which are used to power the HF transmitters. Service Oil provides fuel oil. Copper Valley Telephone installed the telephone lines, and Copper Valley Electric supplies commercial housekeeping power. Bishop & Sons Enterprises supplies water, while CBS Service provides trash removal and sewage disposal. Harley McMahon flew sorties to test the capabilities of the aircraft alert radar and provide the opportunity for aerial photography.

### Current/Future Operations at the HAARP Research Facility

Construction of the full IRI was completed in early 2007. In the near term, emphasis is being placed on validating the performance of the complete IRI to include compliance with all specifications for interference mitigation and safety of operations. Initial IRI testing began during March 2007.

Both on- and off-site scientific, observational instruments are now providing data on the natural high latitude ionosphere. A **complete listing** of these scientific instruments is available.

### Environmental Process

In accordance with the National Environmental Policy Act (NEPA), an environmental impact statement (EIS) evaluated the consequences of constructing and operating the HAARP research facility in Alaska. The EIS discusses impacts on such diverse topics as electromagnetic and radio frequency interference, vegetation, wetlands, wildlife, air quality, subsistence, cultural resources, atmosphere and others.

State and federal environmental regulatory agencies were consulted to identify issues, and additional input was solicited from the public during scoping meetings held in Anchorage and Glennallen, Alaska in August 1992. A draft of the EIS was prepared and distributed to the public and to specific organizations on March 12, 1993. Public hearings were held in Glennallen and Anderson, municipalities close to the sites under consideration. The final EIS was released to the public on July 15, 1993 and the Record of Decision selecting Gakona, Alaska as the site for the HAARP Ionosphere Research Facility was signed on October 18, 1993.

In addition to the NEPA process described above, the HAARP facility complies with all applicable state and federal regulations that are appropriate for its construction and operation.

### Additional Information

An updated version of this fact sheet will be issued as often as program changes warrant to keep interested parties apprised of significant developments in regard to HAARP. Any individual seeking additional information about HAARP, or wishing to provide comments regarding HAARP, may contact:

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*Pioneering Ionospheric Radio Science Research for the Twenty-First Century*



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