

The Future of the High Frequency Active Auroral Research Program (HAARP)

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- **62.39 deg (North) lat; 145.15 deg (West) Gakona, AK**
- **Phased array HF transmitter; 2.8 to 10 MHz; 33 acres; 5 x 3600 hp diesel engines; 3.6 MW; \$290M**
- **Air Force Research Lab, Space Vehicles Directorate (AFRL/RV) Kirtland AFB, NM**





HF Ionospheric Heating



ELF, VLF

**Radiation Belt
Remediation**

Magnetic Field Lines

**Ionosphere
90 – 2000 km**

**Ionospheric
Irregularities**

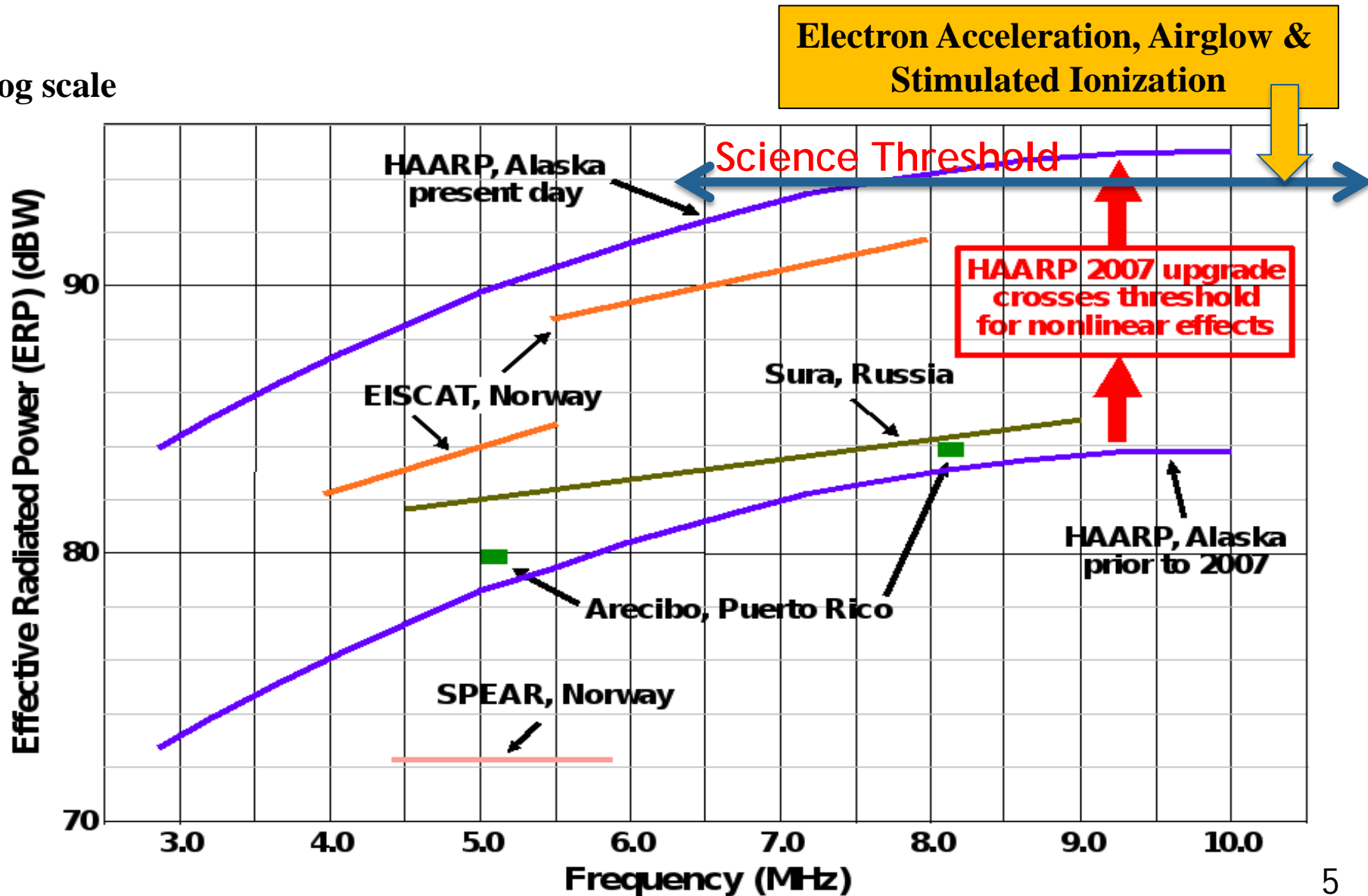
**HF Energy
2.8 – 10 MHz
3.6 MW**

**Submarine
Communication**



HAARP Compared to EISCAT, Sura & Arecibo

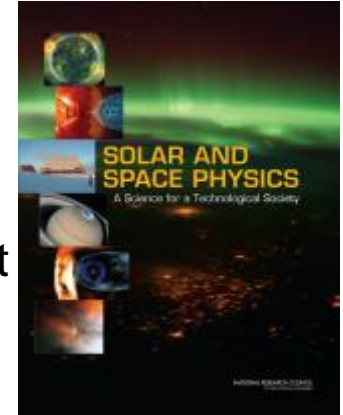
Log scale



2013: Two National Research Council Studies Involving HAARP

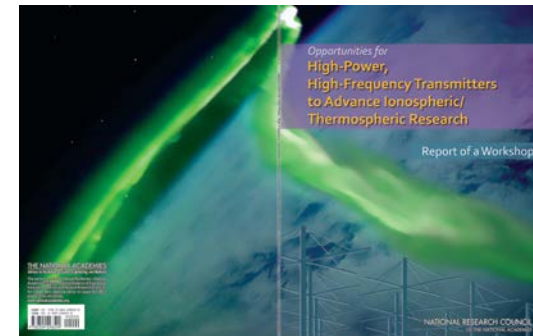
- **2013 Decadal Survey in Solar and Space Physics**

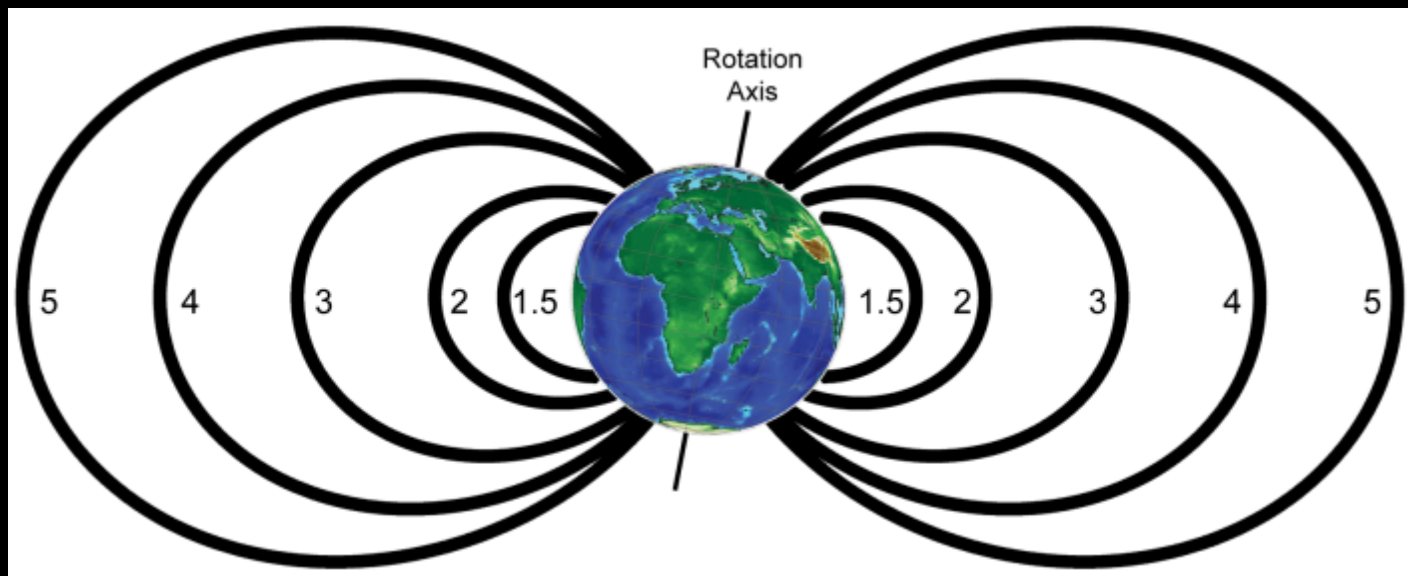
- Priority - Fully realize the potential of ionospheric modification techniques through collocation of modern heating facilities with a full complement of diagnostic instruments including incoherent scatter radars. This effort requires coordination between NSF and DOD agencies in planning and operation of existing and future ionospheric modification facilities.



- **Mar 2013 - Workshop: Opportunities for High-Power, High-Frequency Transmitters to Advance Ionospheric/Thermospheric Research**

- NRC Workshops do not provide recommendations but report contains 72 pages of HAARP science
- Themes: Geospace and space weather; Stimulated emission and radiation belts; radio science, communications, and radar
- Strong recommendation to co-locate incoherent scatter radar

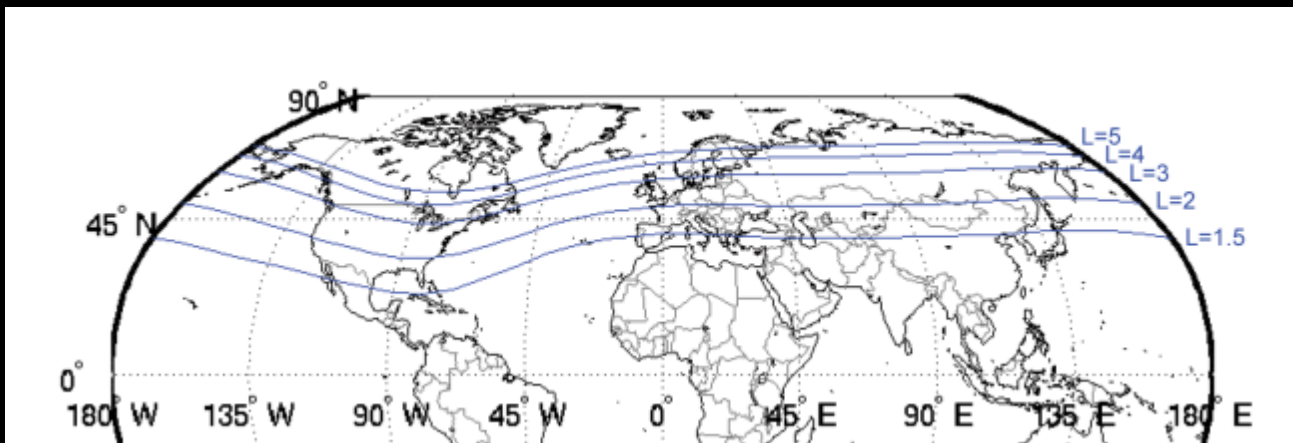
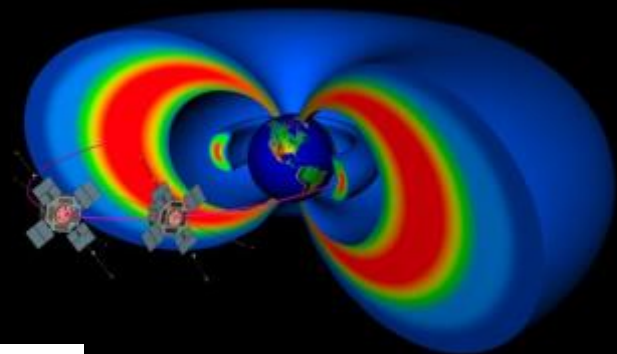




Van Allen Radiation Belts

L-Shells

NASA Van Allen Probes

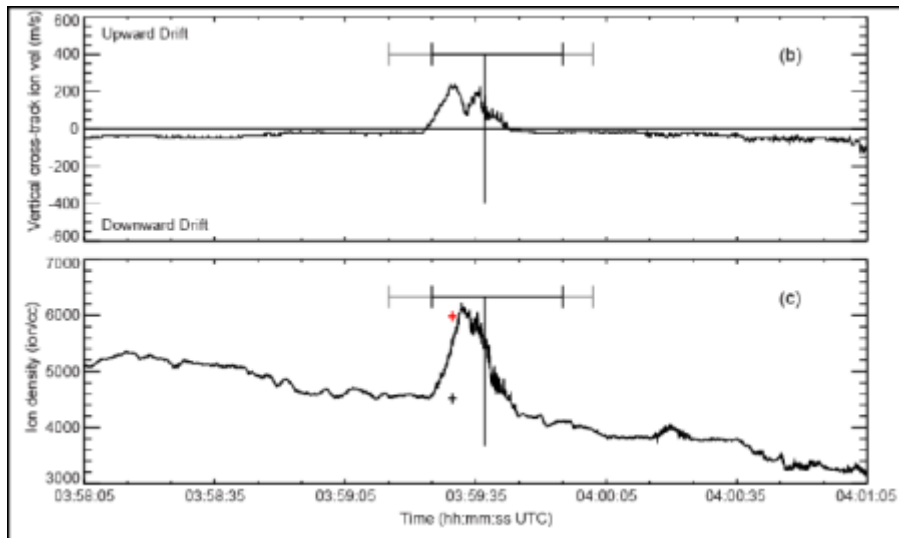


New HAARP Results Related to Radiation belt Remediation and VLF Propagation

DMSR satellite data over HAARP

During heating experiments observe enhanced upward plasma flux and electron densities

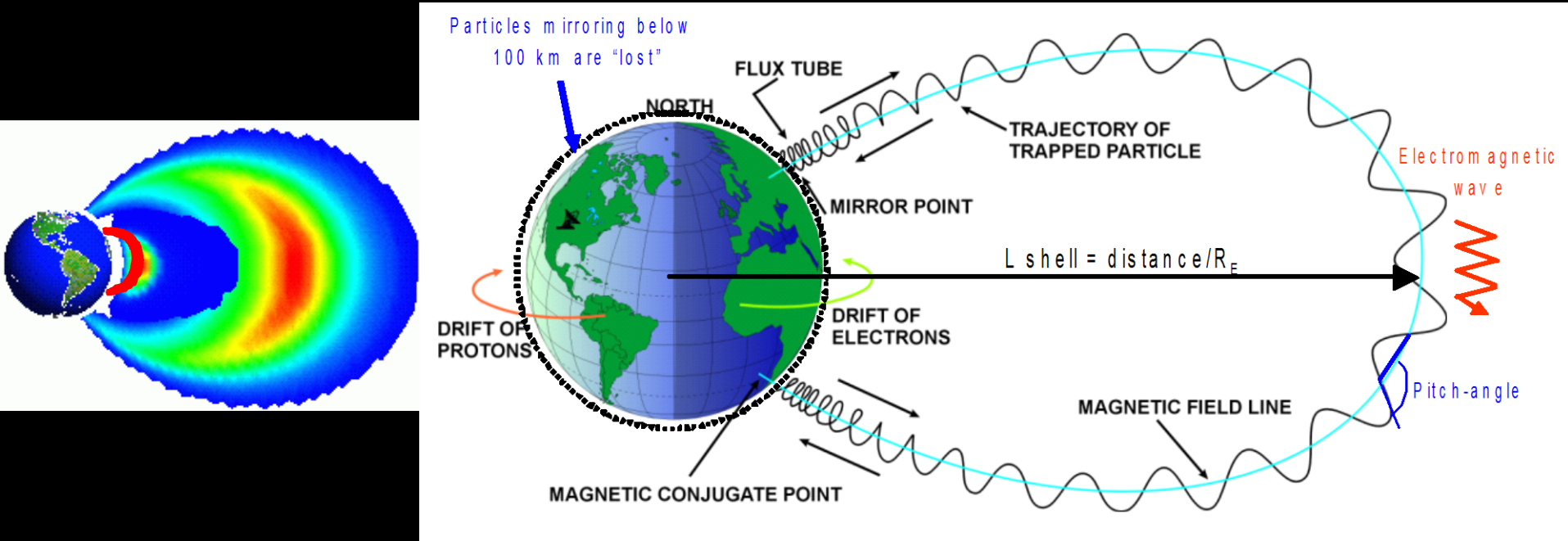
Chris Fallen et al., 2011



- **Recent results from DARPA campaigns at HAARP have demonstrated optimum heating techniques to continuously maintain upward field-aligned plasma flux, density and electron temperature enhancements in the topside ionosphere (about 400-800km).**
- **Structures may act as field-aligned waveguides for ducting VLF waves to the magnetosphere and possibly to the opposite hemisphere.**
- **VLF waves may be generated by HAARP itself or other ground-based transmitter.**
- **HAARP can be used to optimize the continuous formation of VLF ducts, and also to simultaneously generate VLF signals.**

Radiation Belt Dynamics and Energetics

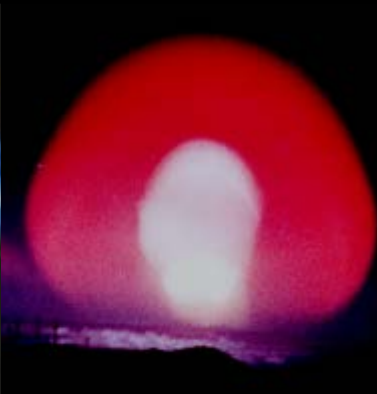
2007 ONR MURI Topic



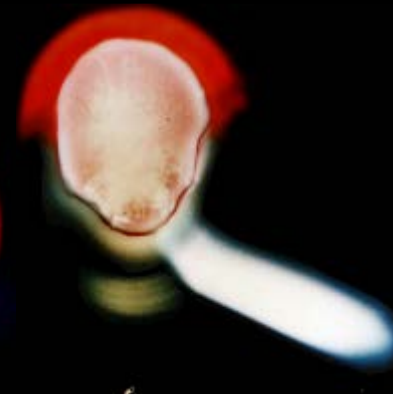
ORANGE
3.8 MT at 43 km



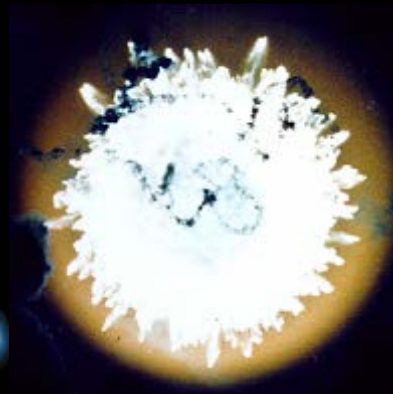
TEAK
3.8 MT at 76.8 km



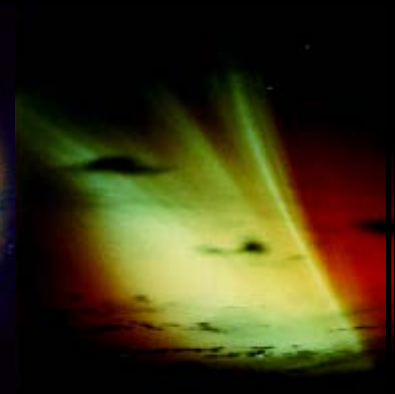
KINGFISH
__ MT at __ km



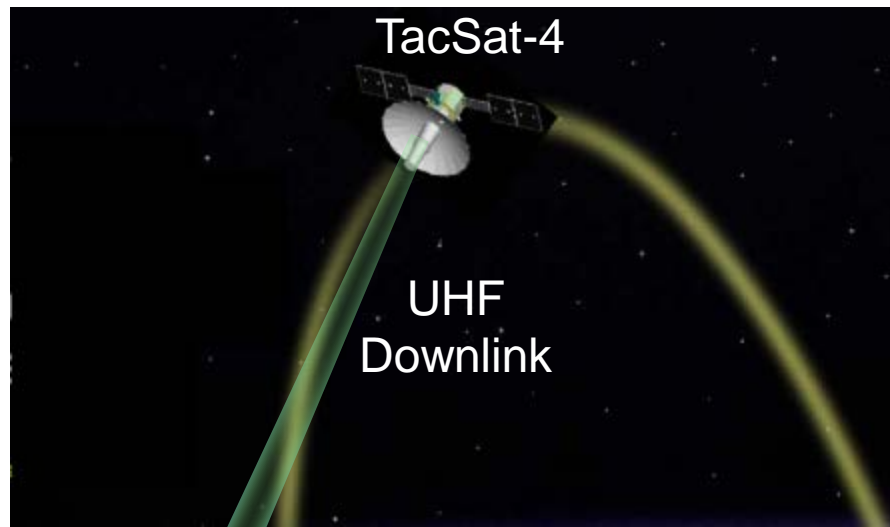
CHECKMATE
__ MT at __ km



STARFISH
1.4 MT at 400 km



COMMX Working with HAARP

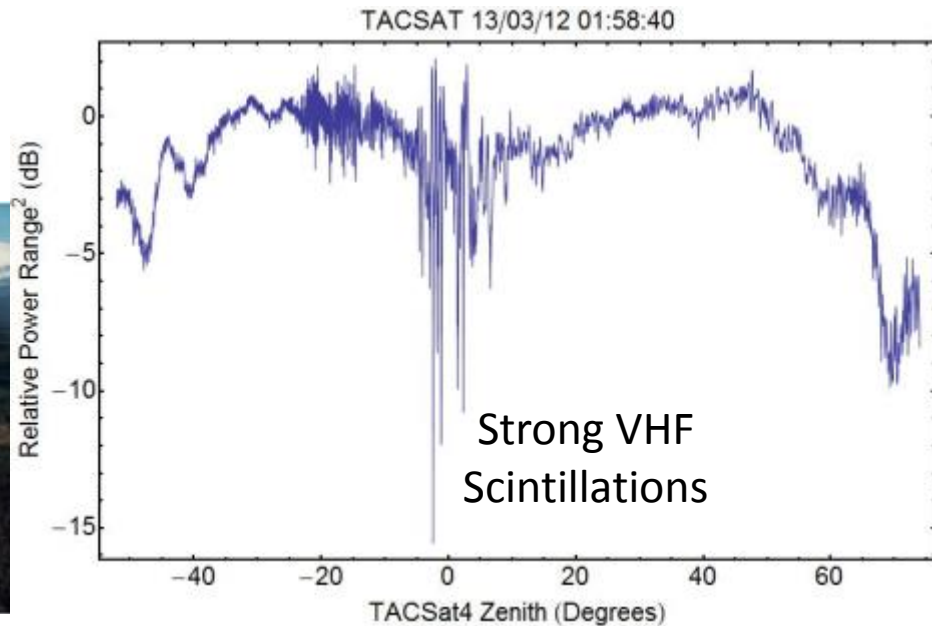


TACSat4
Actively
Pointed to
Ground
Receiver

Modified
Region

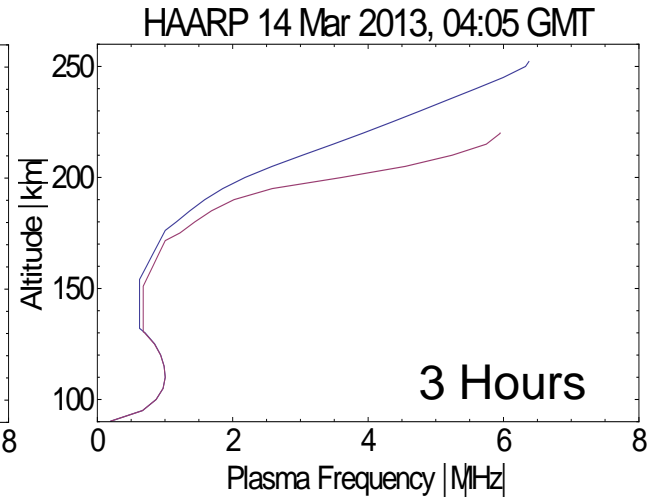
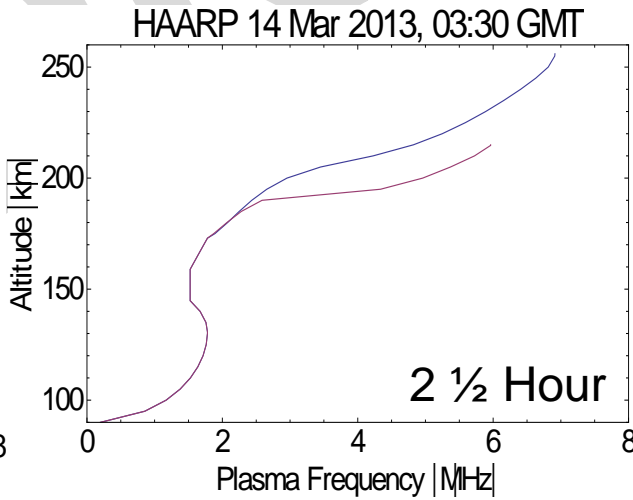
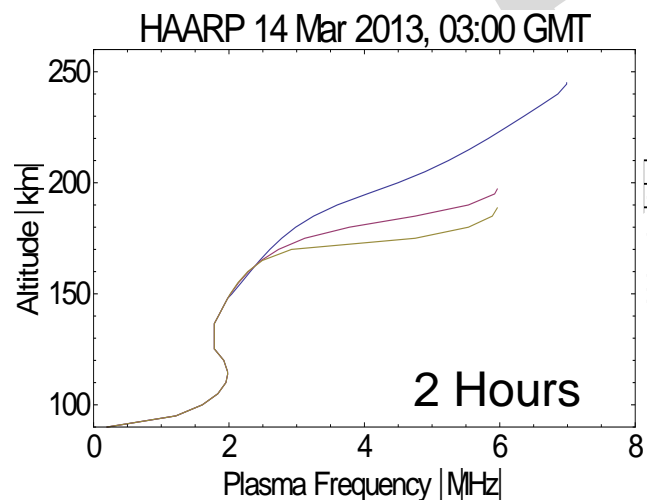
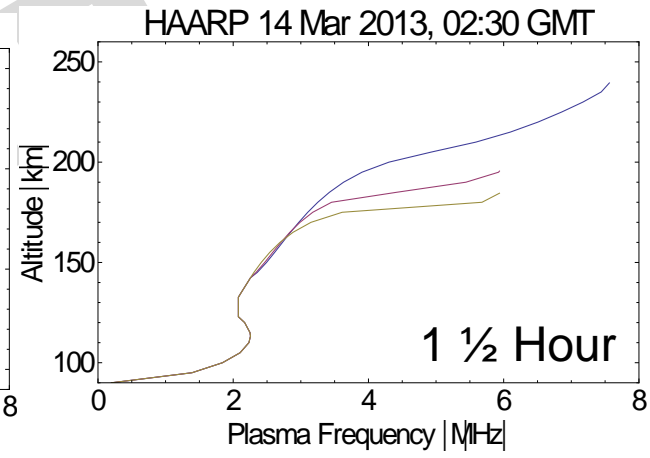
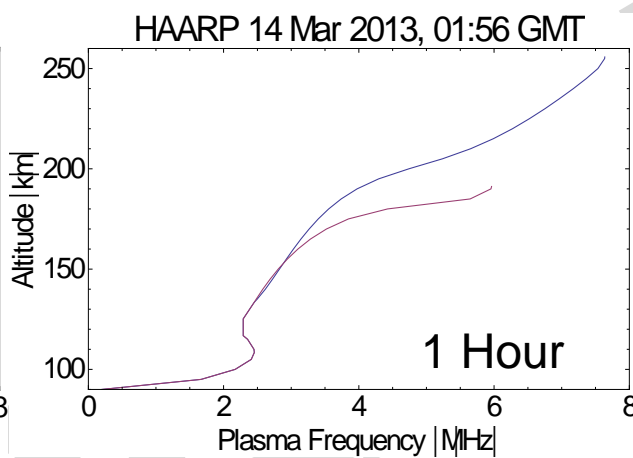
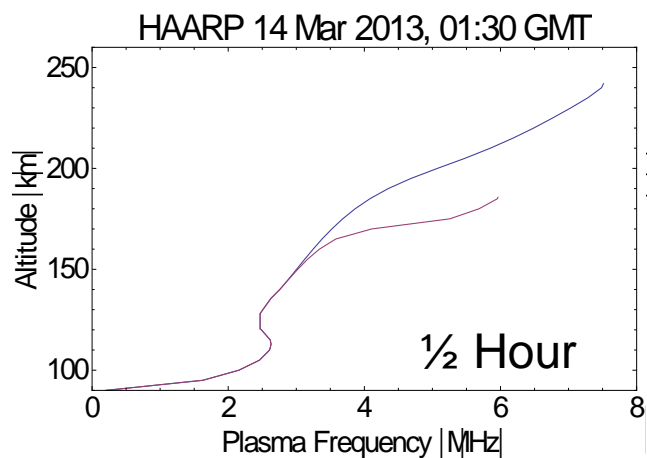
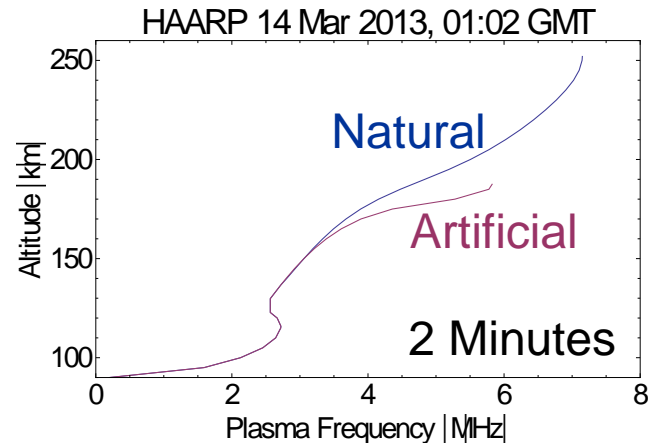
F-Layer Ionosphere

Courtesy Paul Bernhardt
NRL



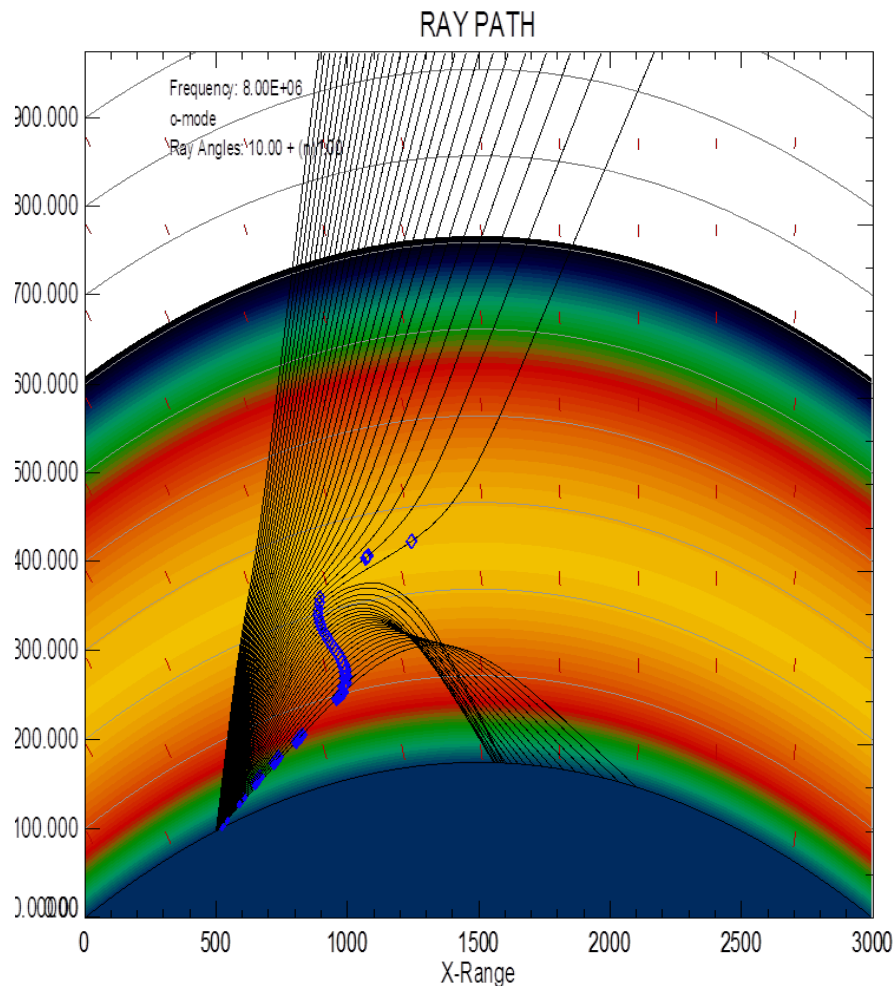
14 March 2013 01:30 to 04:00 GMT Extended Artificial Ionization with 5.8 MHz Twisted Beam

Courtesy Paul Bernhardt
NRL

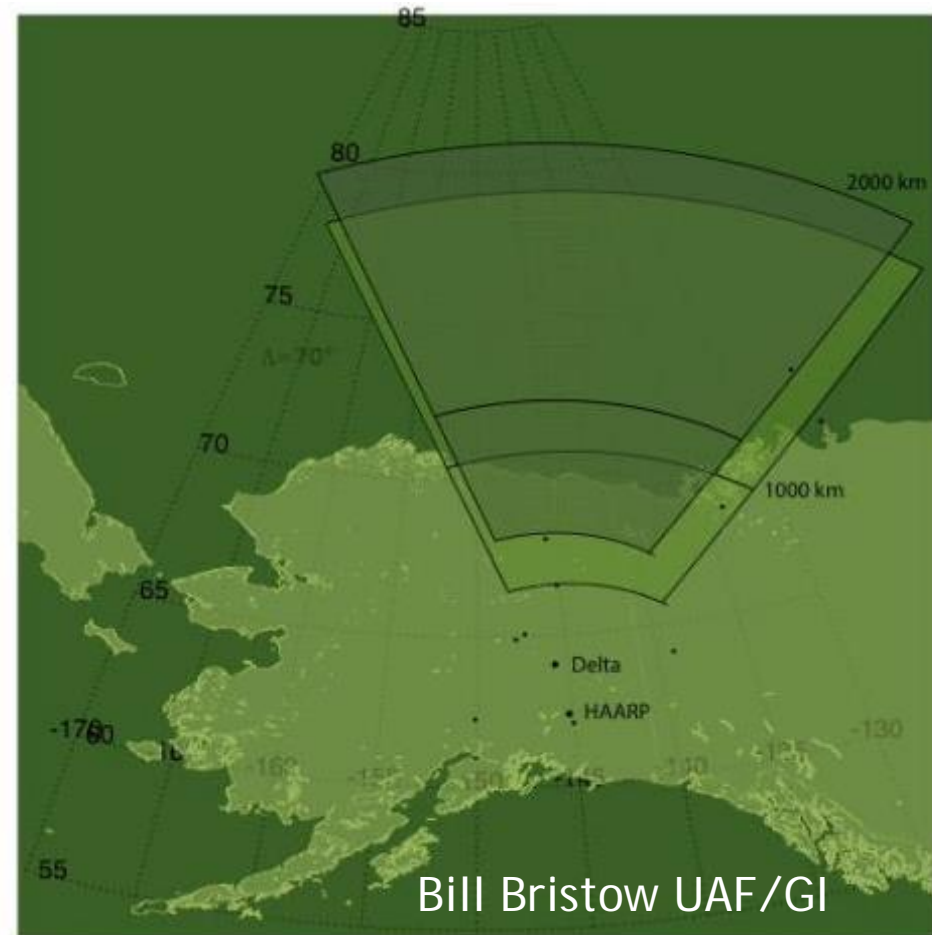


Over the Horizon Radar Experiments

8 MHz; Covers range of ~1100 km to ~1800 km from radar

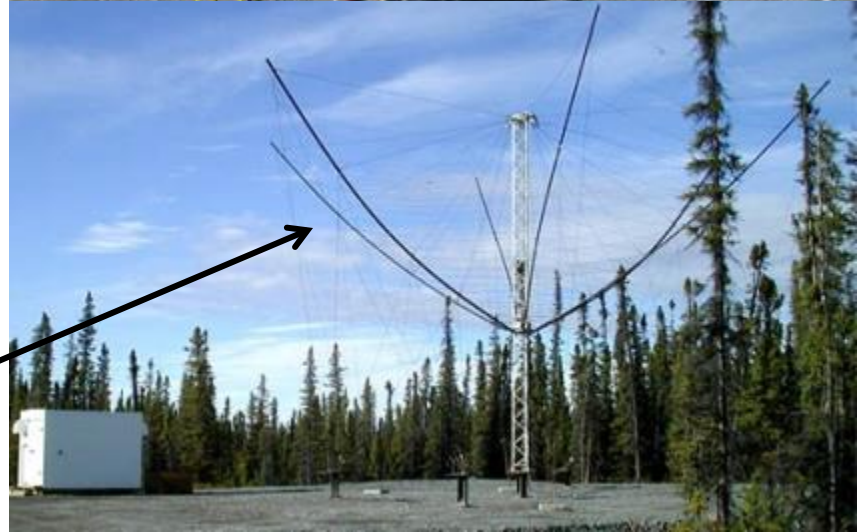
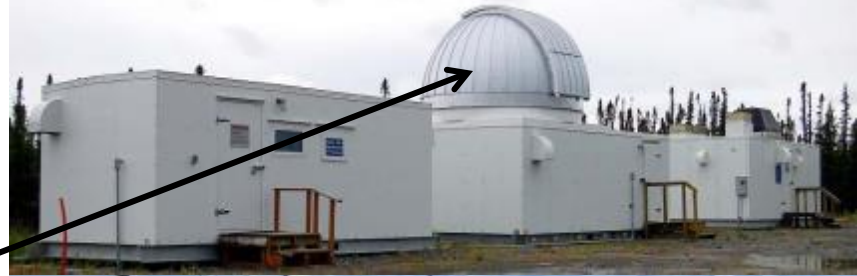


Offset of transmitter and receiver location; 2000 km range translates to about 80° latitude



Ionospheric Diagnostic Instruments at HAARP

- All sky Riometer
- Imaging riometer 8 X 8 Array
- Fluxgate Magnetometer
- Induction Magnetometer
- Digisonde
- Optics
 - All-sky imager
 - Telescopic imager
 - Photometers
 - 14 ft Optical Dome
- Tomography Chain (Cordova -> Kaktovik)
- VHF Radar (139 MHz)
- Modular UHF Ionospheric Radar (MUIR)
- Ionospheric Scintillation Receivers
 - SATSIN (offsite)
 - GPS-NOVATEL
 - Total Electron Content
- Radio Background Receivers
 - Broadband ELF / VLF Receiver network.
 - SEE Receiver string.
 - HF to UHF Spectrum Monitor
- HF 2-30 MHz High Angle Receiving Antenna
- Scanning Doppler Interferometer (SDI)



NSF Advanced Modular Incoherent Scatter RADAR (AMISIR)



Poker AMISR – (PFISR) located outside Fairbanks at the Poker Flat Research Range for auroral studies & NASA sounding rocket launches

HAARP Status May 2015

- **Owned by AFRL Space Vehicles Directorate (AFRL/RV)**
- **Currently in cold storage (Could be brought on-line in a few weeks)**
- **UA working with AFRL/RV to create a CRADA (2 years duration)**
 - **Allow access to HAARP & restore scientific diagnostics to HAARP**
 - **Plans to transfer equipment, facilities & land to UAF**
- **UAF-GI Activities:**
 - **Building Business Plan to operate HAARP**
 - **Reduce costs (use existing GI scientists & staff)**
 - **Identifying customers (DOE NNSA, DARPA, NSF, NASA, AFOSR, ONR/NRL, USNORTHCOM, International)**
 - **Explore new options for over the horizon radar for maritime awareness**
 - **Using HAARP to test space-to-ground communications – create scintillation**

Thank you, Questions?

