Incoherent Scatter Radars
Present, Past and Future

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3. **It is difficult to imagine an area of space science research that does not benefit from the data provided by the incoherent scatter radars.**

2. Because the incoherent scatter radars are able to measure height profiles of the most fundamental ionospheric properties, data from these instruments are used for a broad range of research studies pertaining to the upper atmosphere, ionosphere, and magnetosphere.

1. The Geospace Facilities (GF) Program in the Division of Atmospheric and Geospace Sciences at the National Science Foundation (NSF) was created in 1983 to oversee the scientific operation of a network of incoherent scatter radars used to probe the upper atmosphere and ionosphere.
NSF Hierarchy

Barack Obama

NSF Director

Computer Sciences

Education and Human Resources

Math and Physical Sciences

Geosciences

Biological Sciences

Social, Behavioral and Economic Sciences

Engineering

Ocean Sciences

Atmospheric and Geospace Sciences

Earth Sciences

NCAR and Facilities Section

Atmospheric Section

Geospace Section

NCAR and Facilities Section

Solar Physics

Magnetospheric Physics

Geospace Facilities

Aeronomy
Goals of the GF Program

• To ensure that the science undertaken at the GF-sponsored facilities is of the highest quality and is coordinated with the university community to produce a synergistic effect in the advancement of upper atmospheric science; and

• To ensure that the facilities are maintained as state-of-the-art, cost-effective research tools available to all qualified scientists, and that the data and services provided by the facilities are adequate to meet the community’s short- and long-range scientific objectives;

• To educate the next generation of space scientists in the development, operation, and use of multi-user facilities, leading to the maintenance of a diverse, highly-qualified user base for upper atmospheric research data.
The NSF Incoherent Scatter Radar Chain-2006

- Arecibo (AO) 1962
- Jicamarca (JRO) 1963
- Millstone Hill (MH) 1962
- Sondrestrom (SRF) 1982

The NSF-supported ISRs--2011

- AMISR-Poker Flat (PFISR) 2007
- AMISR-Resolute Bay (RISR) 2008
- PFISR 2007
- RISR 2008
- SRF 1982
- MH 1962
- AO 1962
- JRO 1963
Bill Gordon conceives of incoherent scatter. Arecibo built by DARPA. Jicamarca built by NBS. Millstone built by MIT Lincoln Lab.

EISCAT UHF radar built by EISCAT. EISCAT VHF radar built by EISCAT. EISCAT Svalbard Radar built by EISCAT.

A timeline of incoherent events:
- 1955: NSF takes over Arecibo from DoD
- 1960: NSF takes over Jicamarca from NOAA
- 1965: NSF takes over Millstone Hill Radar from DNA
- 1970: Chatanika Radar moved to Greenland from DNA
- 1975: NSF takes over EISCAT Radar from NSF
- 1980: Chatanika Radar moved to Greenland from NSF
- 1985: EISCAT Svalbard Radar built in Norway
- 1990: AMISR is built in Alaska
- 1995: AMISR is built in Canada
- 2000: NSF support of Millstone Hill Radar begins
- 2005: NSF takes over Chatanika from DNA
- 2010: NSF takes over Jicamarca from DNA

ISR Starts and Stops

- UK: Malvern, (multi-static) 1968-1975
- MISCAT, Aberystwyth, UK, 1972 (multi-static--first ISR to measure three-dimensional drift velocities)
- The Upper Atmosphere Observatory (U. S.), planned 1969-1975
- The Polar Cap Observatory (Canada), planned 1987-1997
ISR Deployment Strategies for the future

- Global coverage
- Ease and cost-effectiveness in ISR operation
- Interoperability and commonality in ISR scheduling, operating modes, and data access
- Global leveraging and coordination
How do we know how many observatories are enough?

![Graph showing the relationship between the number of observing sites and the knowledge of the system.](image)
Where do we need ISRs?

- Within the polar cap (Resolute Bay)
- Around the auroral oval (Poker Flat, Sondrestrom, Tromso, Svalbard)
- Sub-auroral zone (none)
- Mid-latitude (Millstone, Kharkov)
- Low latitude (Arecibo)
- Equator (Jicamarca+one more)
- Low latitude southern hemisphere (Argentina)
- Auroral latitude southern hemisphere (McMurdo)
Meridian Ring of AMISRs
## ISR Global Operating Modes

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<tr>
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<th>Northern Hemisphere Science Mode</th>
<th>Southern Hemisphere Science Mode</th>
<th>Conjugate Science Mode</th>
<th>Equatorial Science Mode</th>
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What is the future of ISR?
Question

• What is the most important aspect of incoherent scatter radars that have kept them at the forefront of ionospheric and atmospheric research?