Incoherent Scatter Radars
Past, Present, Future

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Outline

1. Wonder why I agreed to give this talk
2. Try to convey the impression that I know what I’m talking about
3. Desperately search audience to see if anyone is still paying attention
4. Check the clock to see if I can wrap things up
5. Try to remember all the things I forgot to say
6. Summary
7. Stand awkwardly waiting for someone to ask a question and hoping it’s not a tough one
8. Sit down
A timeline of incoherent events

Bill Gordon conceives of incoherent scatter
Millstone built by MIT Lincoln Lab

Jicamarca built by NBS

Arecibo built by DARPA
A timeline of incoherent events

- 1955: DNA builds ISR at Stanford
- 1965: Stanford radar moved to Chatanika
- 1970: Chatanika Radar moved to Greenland
- 1975: 
- 1980: 
- 1985: 
- 1990: 
- 1995: 
- 2000: 
- 2005: 
- 2010: 

[Images of radar antennas]
A timeline of incoherent events

- 1955: NSF takes over Arecibo from DoD
A timeline of incoherent events

NSF support of Millstone Hill Radar begins
A timeline of incoherent events

NSF takes over Chatanika from DNA
A timeline of incoherent events

NSF takes over Jicamarca from NOAA
EISCAT UHF radar built
EISCAT VHF radar
Built 1955 - 2010
EISCAT Svalbard Radar built

AMISR is built in Alaska.
AMISR is built in Canada.
History of AMISR

1989: Workshop to develop technical requirements for an ISR in the Polar Cap
1995: Polar Cap Observatory proposal submitted by SRI
1996: PCO approved for funding by NSF
1997: Removed from NSF budget by Congress
1998: Second Workshop convened to discuss scientific justification for a portable incoherent scatter; highest priority locations were Alaska and Arctic Canada
2000: SRI submits proposal to build the Relocatable Atmospheric Observatory
2002: Project rescoped and renamed AMISR
2003: SRI proposal approved by the National Science Board
2004: Construction begins
DILBERT

AS USUAL, I WORKED UNTIL MIDNIGHT LAST NIGHT, MOM:

WELL, AT LEAST YOU MADE SOME EXTRA MONEY. I DON’T GET PAID FOR OVERTIME.

WELL, AT LEAST IT WAS IMPORTANT WORK.

NOT REALLY.

MY BOSS MADE ME CHANGE MY “POWER-POINT” SLIDES, BUT THE CHANGES MAKE THEM WORSE.

WELL, AT LEAST YOU’RE PREPARED FOR YOUR MEETING. IT WAS CANCELED.

BUT THAT’S OKAY, BECAUSE THE PROJECT ISN’T FUNDED ANYWAY.

SO... YOU WORKED FOR FREE TO WORSEN A PRESENTATION FOR A MEETING THAT WON’T HAPPEN FOR A PROJECT THAT DOESN’T EXIST?

OH... YOU MUST WORK FOR THE GOVERNMENT.

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AMISR Firsts

• The first incoherent scatter radar built by NSF
• The first U. S. incoherent scatter radar built for basic research
• The first phased-array, solid-state incoherent scatter radar
• The first incoherent scatter radar with no moving parts
• The first relocatable incoherent scatter radar
• The first reconfigurable incoherent scatter radar
The NSF Incoherent Scatter Radar Chain-2008

AMISR-Resolute Bay

AMISR-Poker Flat

Jicamarca (JRO)

PFR 2007

RBR 2008

SRF 1982

MH 1962

AO 1962

JRO 1963

SRF 1982

Arecibo (AO)

Millstone Hill (MH)

Sondrestrom (SRF)

AMISR-Resolute Bay

AMISR-Poker Flat

Jicamarca (JRO)
How much does NSF pay annually to operate the four incoherent scatter radars?

- A. $2.5 Million
- B. $7.0 Million
- C. $18 Million
- D. $100 Million plus tip
- E. The cost of building Arecibo
The Arecibo Observatory has been featured in two movies.

What other ISR has been featured in a movie?
Where do incoherent people like Sixto come from?

- Behnke
- Coster
- Djuth
- Wickwar
  - Rice U.
- Don Farley
- Booker
- Appelton
- Kudeki (Illinois)
- Urbina
- Fejer (Utah State)
- Gonzalez
- Balsley (U. of Colorado)
- Chau
- Hysell (Cornell)
- Lind
- Sahr (U. of Washington)
- Makela Nicolls
  - ...
AMISR Graduate Student Support

• Boston University, Josh Semeter
• U. of Colorado, Jeff Thayer
• U. of Michigan, Bob Clauer (Hampton U.)
• Cornell U., Mike Kelley
What is the highest altitude from which incoherent scatter returns have been detected?

- One Earth Radius
- The Heliopause
- The Solar Corona
- The Magnetotail
- The Crab Nebula
Who was Jesse James?

- The director of the world’s largest solar radar facility (in 1965) located at El Campo, TX, and operated by MIT for NASA
- Had to average over one year
What famous cartoon dog appeared in a data plot from one of the incoherent scatter radars?
AMISR "All-Sky" Mode
What is the future of ISR?

- **Sondrestrom**: DoD will decide to take it back and launch it on a satellite to search for Earth-colliding asteroids.
- **Millstone Hill**: Will be purchased from MIT by the Disney corporation, which will turn it into a theme park.
- **Arecibo**: Will be taken over by a local pharmaceutical company that discovers a rare “medicinal” herb flourishing under the dish in the presence of intense microwave radiation.
- **Jicamarca**: Will be used by NASA to convince the nation that it has successfully landed astronauts on Mars and found a race of ill-tempered, four-legged beasts looking amazingly like llamas.
The global chain of ISRs will continue to grow.

ISRs of the future will be lower cost, with the ability to run routinely for many hours.

Each ISR site will include a cluster of advanced radiowave and optical instrumentation for comprehensive observations of the upper atmosphere.

The ISR network will be fully integrated, with smart, interactive, autonomous operation.

Barriers between ISRs will disappear, allowing users and students greater versatility, flexibility and ease in conducting experiments.

Most importantly, the next generation of radar users will be knowledgeable and skilled in all aspects of ISR operation and data analysis, leading to new discoveries and improved capabilities.
The meaning of incoherence

• Dictionary: Lacking coherence
  – Rambling, random, disconnected, incomprehensible

• Example 1: Incoherent scatter is the process by which radiowaves are randomly scattered by electrons in the ionosphere

• Example 2: This talk

• Incoherent scatter, like this talk, depends on the weak connection between its parts, and contains useful information when sufficiently sensitive detecting systems are applied
Conclusion

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