

Incoherent Scatter Radars Past, Present, Future

Bob Robinson

National Science Foundation

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

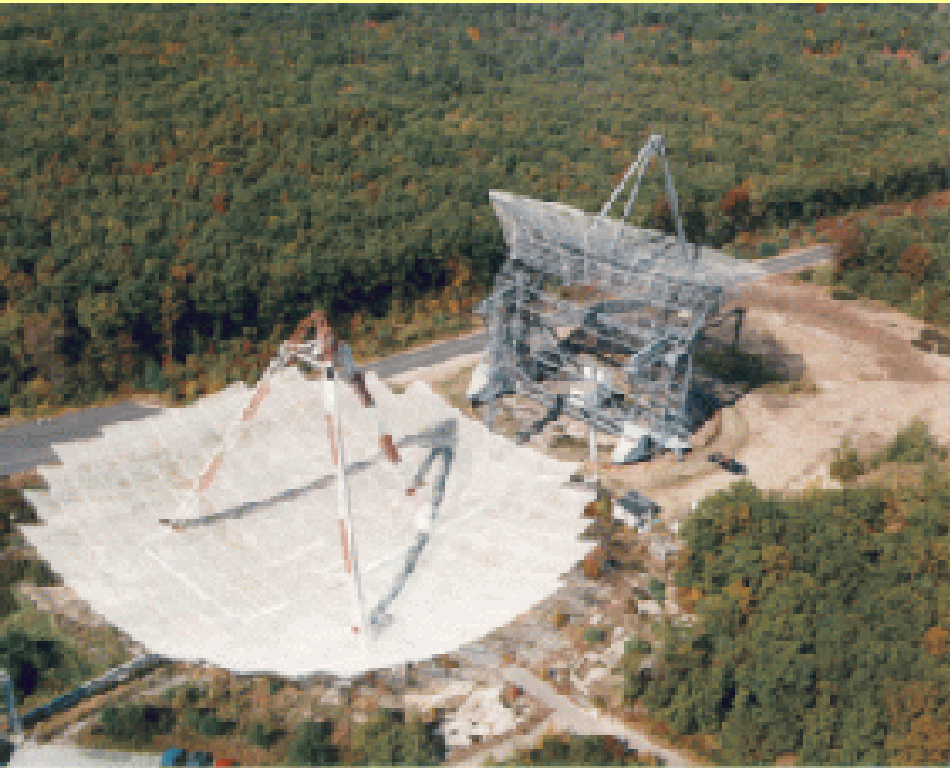
A timeline of incoherent events



**Bill Gordon
conceives of
incoherent
scatter**

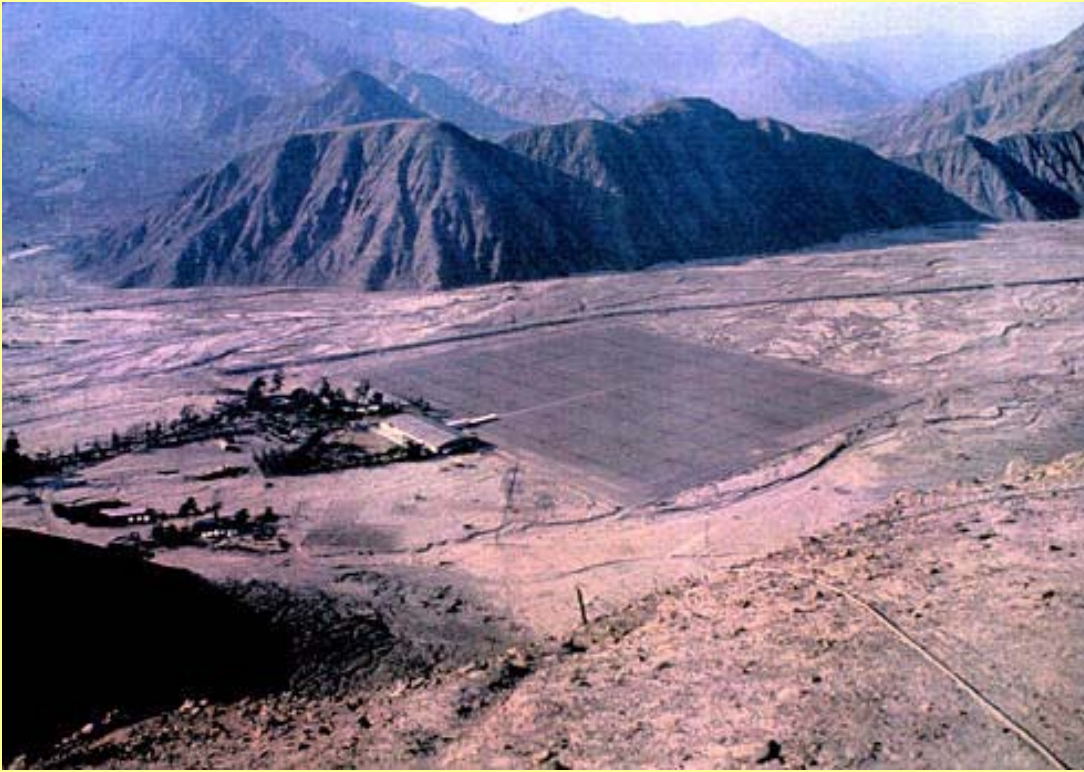


1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010



**Millstone built
by MIT Lincoln
Lab**





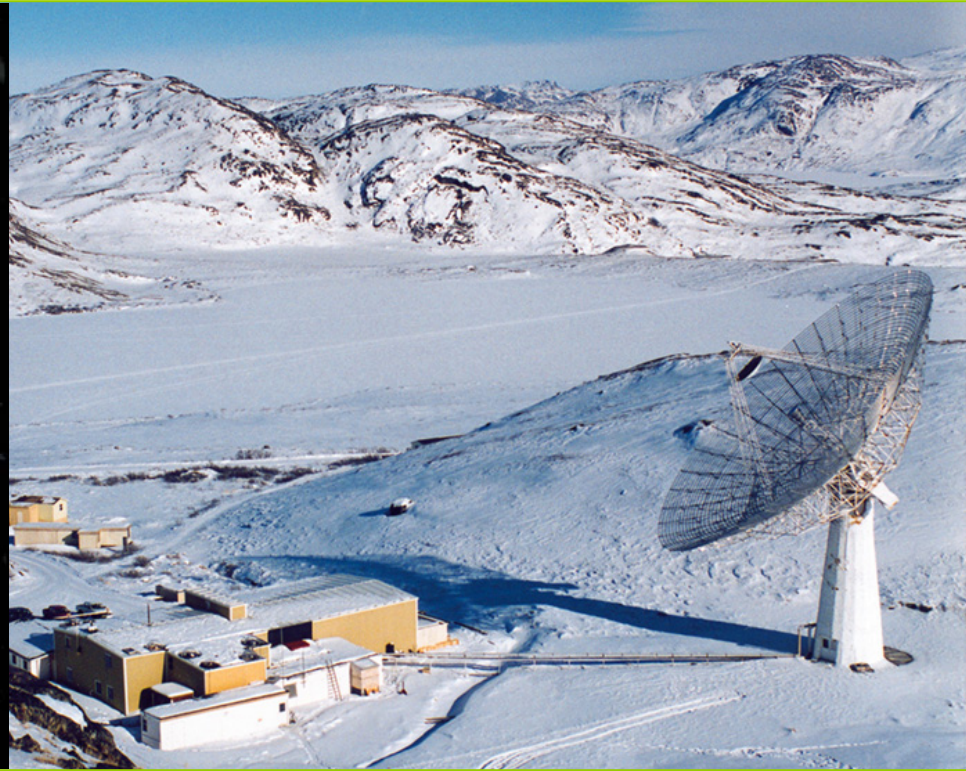
**Jicamarca
built by
NBS**





**Arecibo
built by
DARPA**





**DNA builds
ISR at
Stanford**

**Stanford
radar
moved to
Chatanika**

**Chatanika
Radar moved
to Greenland**

1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010



A timeline of incoherent events

**NSF takes
over Arecibo
from DoD**



1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010

A timeline of incoherent events

**NSF support
of Millstone
Hill Radar
begins**

1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010

A horizontal timeline bar with a blue background and white text. The years 1955, 1960, 1965, 1970, 1975, 1980, 1985, 1990, 1995, 2000, 2005, and 2010 are listed from left to right. A red arrow points downwards from the year 1975 to the text 'NSF support of Millstone Hill Radar begins' located above the timeline.

A timeline of incoherent events

**NSF takes
over
Chatanika
from DNA**

1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010



A timeline of incoherent events

NSF takes
over
Jicamarca
from NOAA



1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010



**EISCAT
UHF radar
built**



1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010



**EISCAT
VHF radar
Built**



1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010



**EISCAT
Svalbard
Radar built**

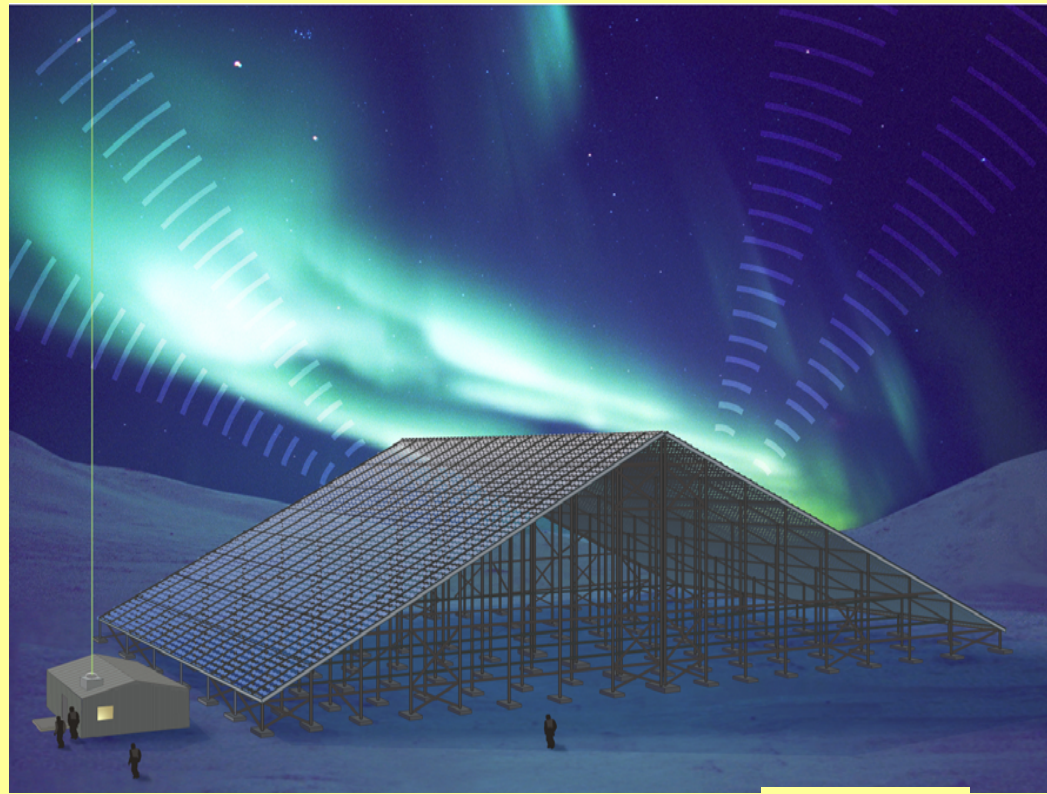


1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010



**AMISR is
built in
Alaska**





**AMISR is
built in
Canada**

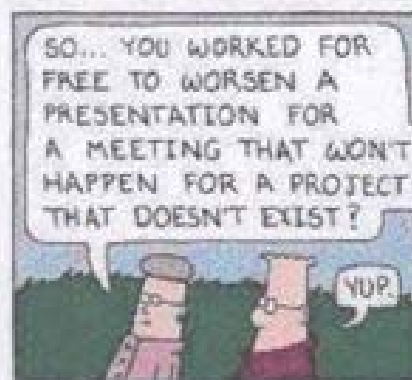


History of AMISR

- 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

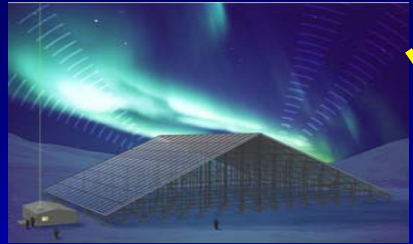
BY SCOTT ADAMS



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**

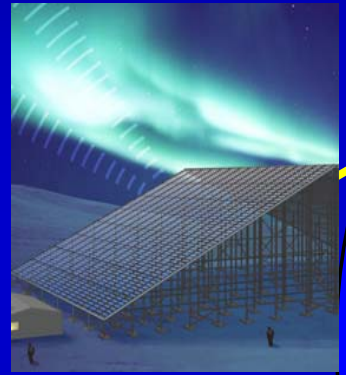
The NSF Incoherent Scatter Radar Chain-2008



AMISR-
Resolute Bay



Sondrestrom (SRF)



AMISR-Poker
Flat



Millstone Hill
(MH)



PFR
2007

RBR
2008

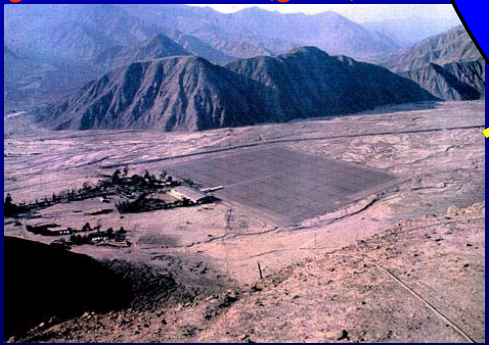
SRF
1982

MH
1962

AO
1962

JRO
1963

Jicamarca (JRO)



Arecibo (AO)

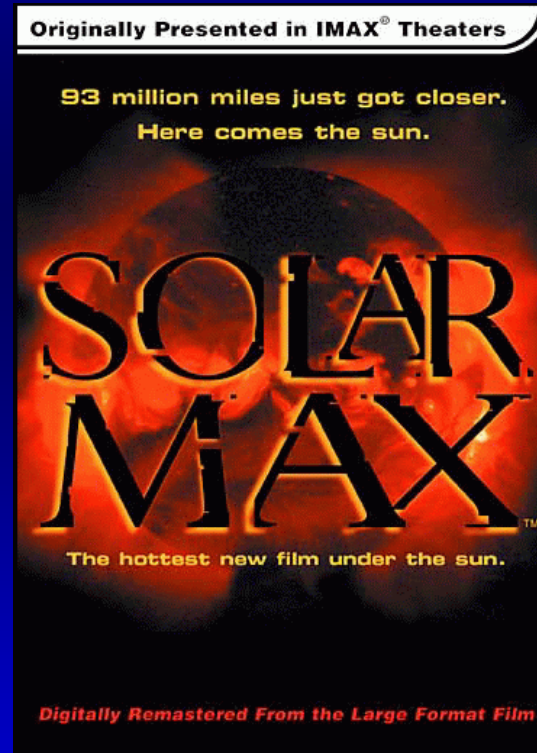
How much does NSF pay annually to operate the four incoherent scatter radars?

- **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?





the University of Florida
National Center of Students
at Michael J. Scott
Florida, Gainesville, FL 32611 USA
http://www.ionm.ufl.edu/

ATIONAL ASTRONOMY AND
Cornell University

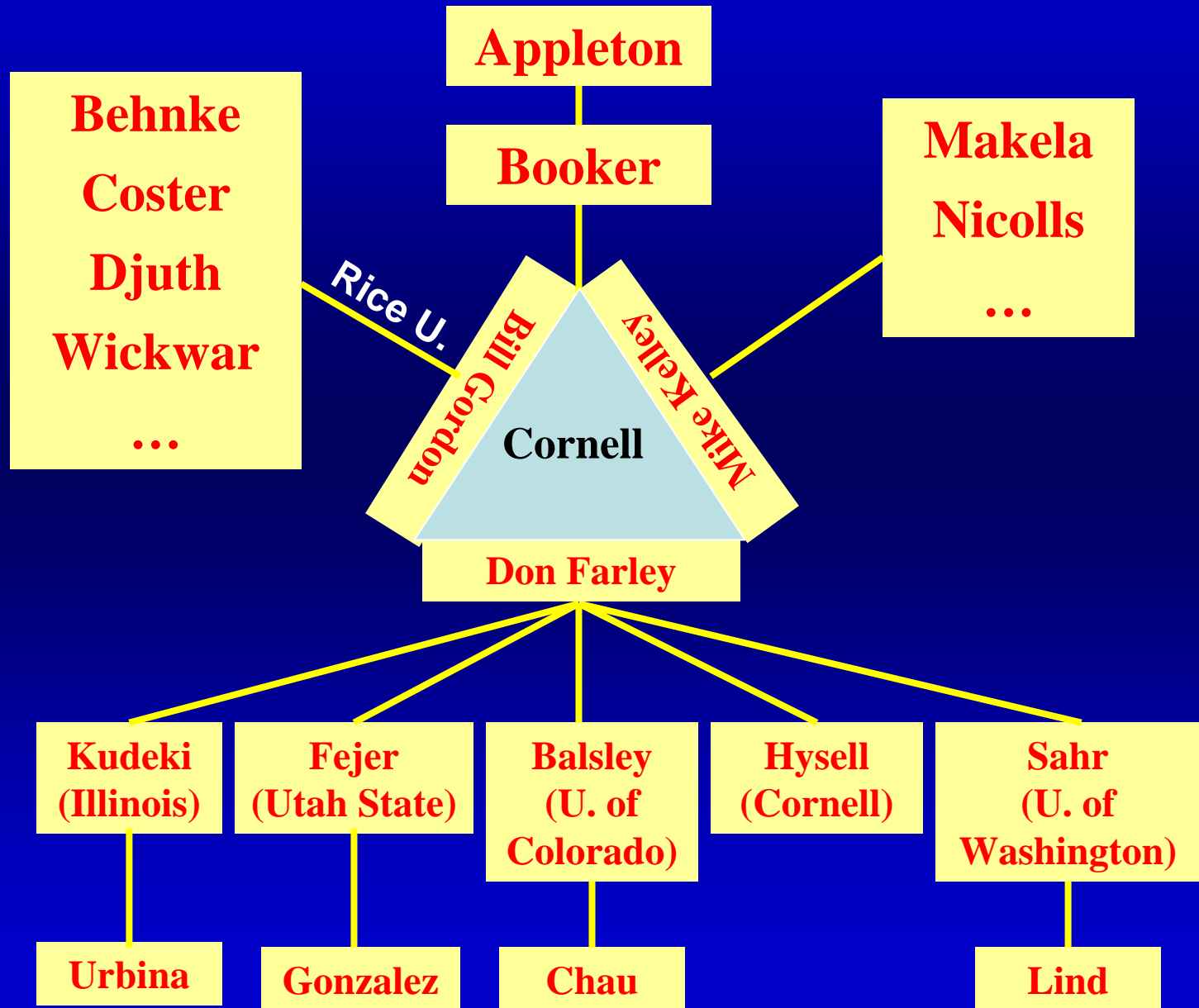
4



In the National Science Foundation's Long-Range
Strategy, and the advancement
of science and technology

BioComplex

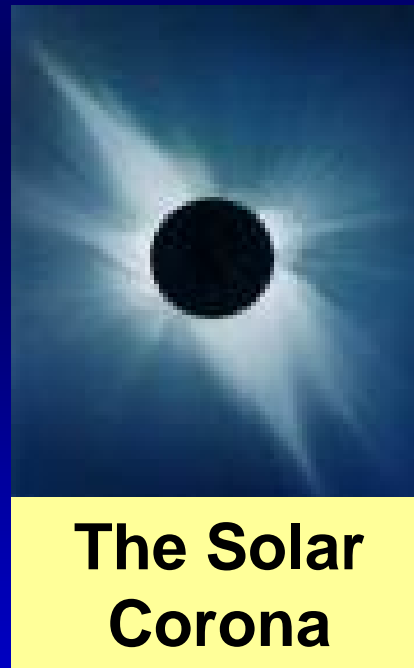
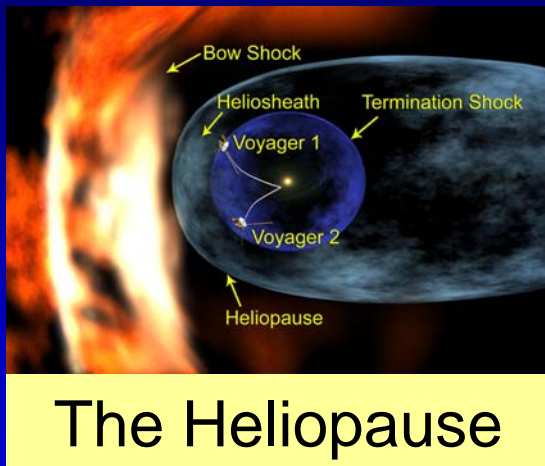
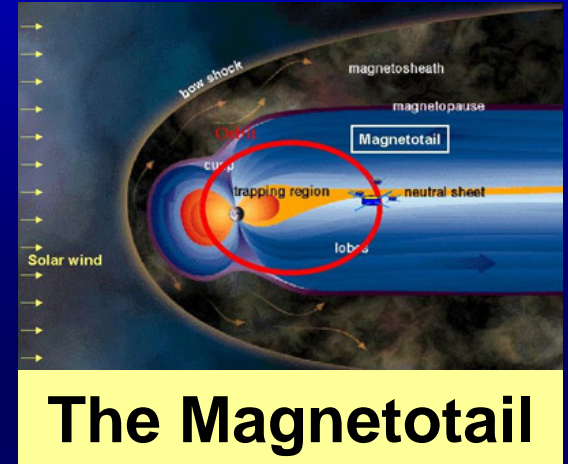
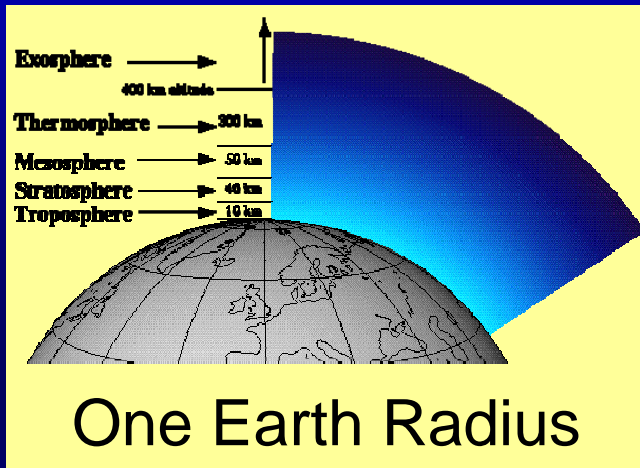
Where do incoherent people like Sixto come from?



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?



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

Radar pulses affected by sunspots

By Mike Bolzeng

A correlation between the annual pattern of coronal activity and the degree to which the sun's corona will reflect radar pulses has been found through long-range radar studies of the sun from El Campo, Texas.

Averaged out over a year, the more active the sunspots are the more readily will the sun's corona reflect radar pulses back to earth. The finding was reported by Dr. Jesse C. James in a paper presented before the Northeast Electronics Research and Engineering Meeting (NEREM) in Boston, Friday, Nov. 8. Dr. James is director of the world's largest solar radar facility which is operated at El Campo by MIT's Center for Space Research, under support from the National Aeronautics and Space Administration.

Supports theory
The proportional annual correlation, Dr. James said, does not come as a particular scientific surprise since theory would indicate that such violent solar eruptions as associated with sunspots should influence the radar reflectivity of the corona. But it is the first experimental data obtained so far that the otherwise theoretical correlation should be helpful to scientists in determining the properties of the various sections of the sun.

Direct proportional correlations cannot be observed with El Campo equipment over short periods such as day to day or even week to week, Dr. James noted. Only when data for an entire year is compiled and analyzed can the sunspot-reflectivity correlation be seen. Dr. James and his associates at the field site have been

studying the sun's corona with radar since April, 1961. The corona is sometimes thought of as a sort of solar atmosphere surrounding the visible solar disk, except that it is proportionally far larger than the earth's atmosphere, extending out into space several solar radii. The turbulent corona is composed of charged, high-energy hydrogen nuclei, electrons, and other particles released from the continuous hydrogen explosions that regenerate the sun's source of energy.

Vast clouds of charged particles that streak away from the sun and through interplanetary space are speeds near that of light—clouds that are sometimes called solar winds—come from the turbulent corona and make up what is called the "extended solar corona."

The El Campo solar radar antenna is a fixed array of 1,024 dipoles, small metal crosses, arranged out over a nine-acre field in eight orderly rows. The power source is a 500,000 watt radio transmitter, operating at a frequency of 38.26 megacycles per second (784 meters wavelength). The antenna's view of the sky is

a fan, shaped one—15 degrees wide east and west and $\frac{1}{2}$ of one degree north and south; the latter is slightly larger than the angle subtended by the sun's disk as seen from the earth.

Operated daily for 30 minutes every day around noon while the sun moves through the 15-degree antenna field of view. For the first 15 minutes—the time it takes a burst of radio energy to travel from earth to sun and back—the MIT scientists transmit coded radar pulses. For the last 15 minutes, they shut down the transmitter and receive the echoes. A computer is used to analyze the data and select the true signals from background noise from the sun and from elsewhere in the sky.

Dr. James informed the NEREM meeting that the echoes always exhibit "doppler spreading," shifts in frequency which indicate that they are being reflected by rapidly moving material in the corona. Exactly what these rapid motions are, he said, is still a mystery. "But they are thought to be wave motions of some sort that are responsible for the heating of the corona," he concluded.

Letters to The Tech

(Continued from Page 5)

rician, Nemitt confused the plan of action Mr. Thomas proposed—the original called for a Geneva conference before the withdrawal of the G's.

Jackie from Los, the tone of the review implies that opposition to the war in Vietnam is based on pure opinion, whereas only (or rather "cold-hearted") logic supports it. This has been debated many times before now, and has never been "proven" one way or the other.

As a final note, it was interesting to see that this article appeared in The Tech as a "factual" review, whereas Ted McGraw's article on the growth of the "anti-communists" appears in America was prefaced by "This article does not necessarily reflect the opinion of . . ."

Lee Sedon '67
Grumpy Tools
To the Editor:

In the light of your note in the last issue of The Tech on the status of the Empire Fashion Center, I would like to point out something. The same you must know by now. Most of the petite outfits you listed were obtained by suit up on a jute-fiber on the floor which I know personally

RACQUETS RESTRING
Fresh Service
Tennis & Squash Pads
37A Mt. Auburn St., Cambridge
(Opp. Lowell House)
FR 4-5417



A man whose taste has grown up.
A man with a thirst for a manlier brew.

Graduate from beer. Graduate to Ballantine Ale. It's light like beer, but what a difference. Real tangy. Bolder. Keener. More to the point. Try Ballantine Ale... you'll be an Ale Man, too.

(Planning a party? Call your local distributor for Ballantine Ale. He'll be happy to serve you.)



BALLANTINE Ale
B. BALLANTINE & SONS, NEWARK, N.J.

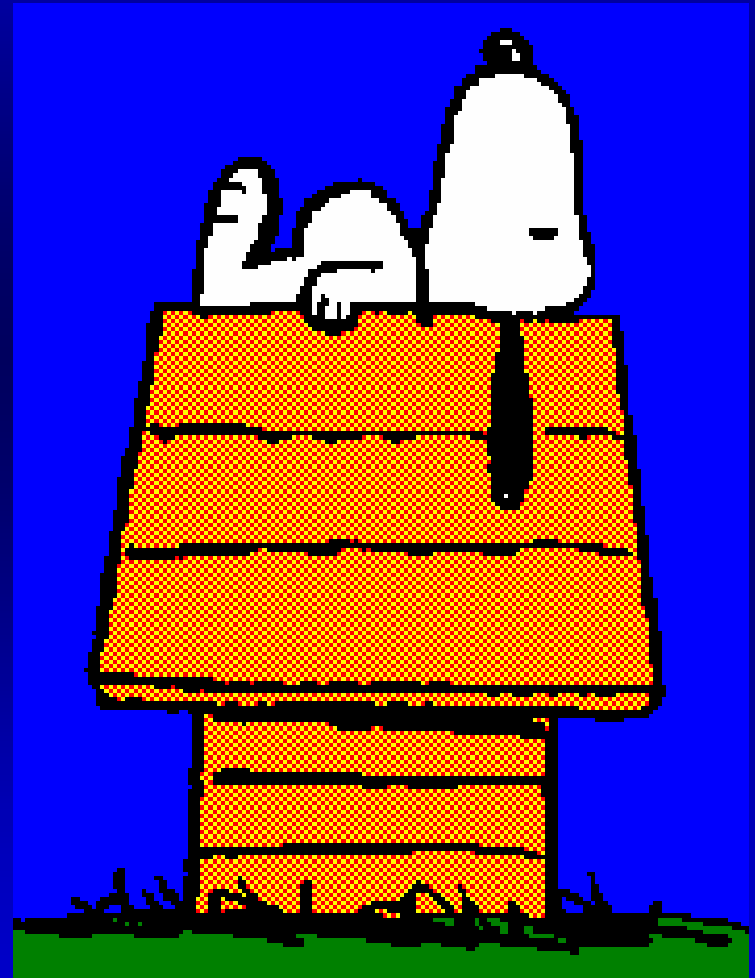
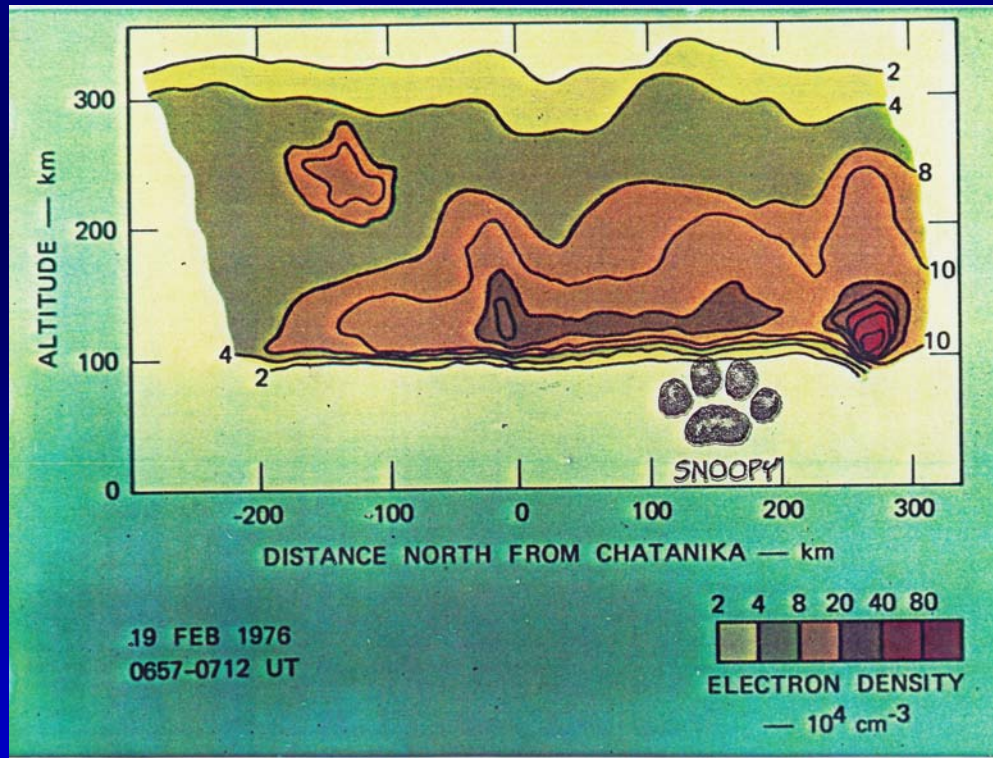
WE GOT SO
ALICE
"CAUSE WE CHARGE SO LITTLE"
Means why Econo-Car is the Big New Step in rent-a-car. We feature the most complete line of cars, vans, and trucks. We include gas, oil, insurance, and tolls. We provide a 24-hour delivery. When you want a car try it!

rent a car from
ECONO-CAR

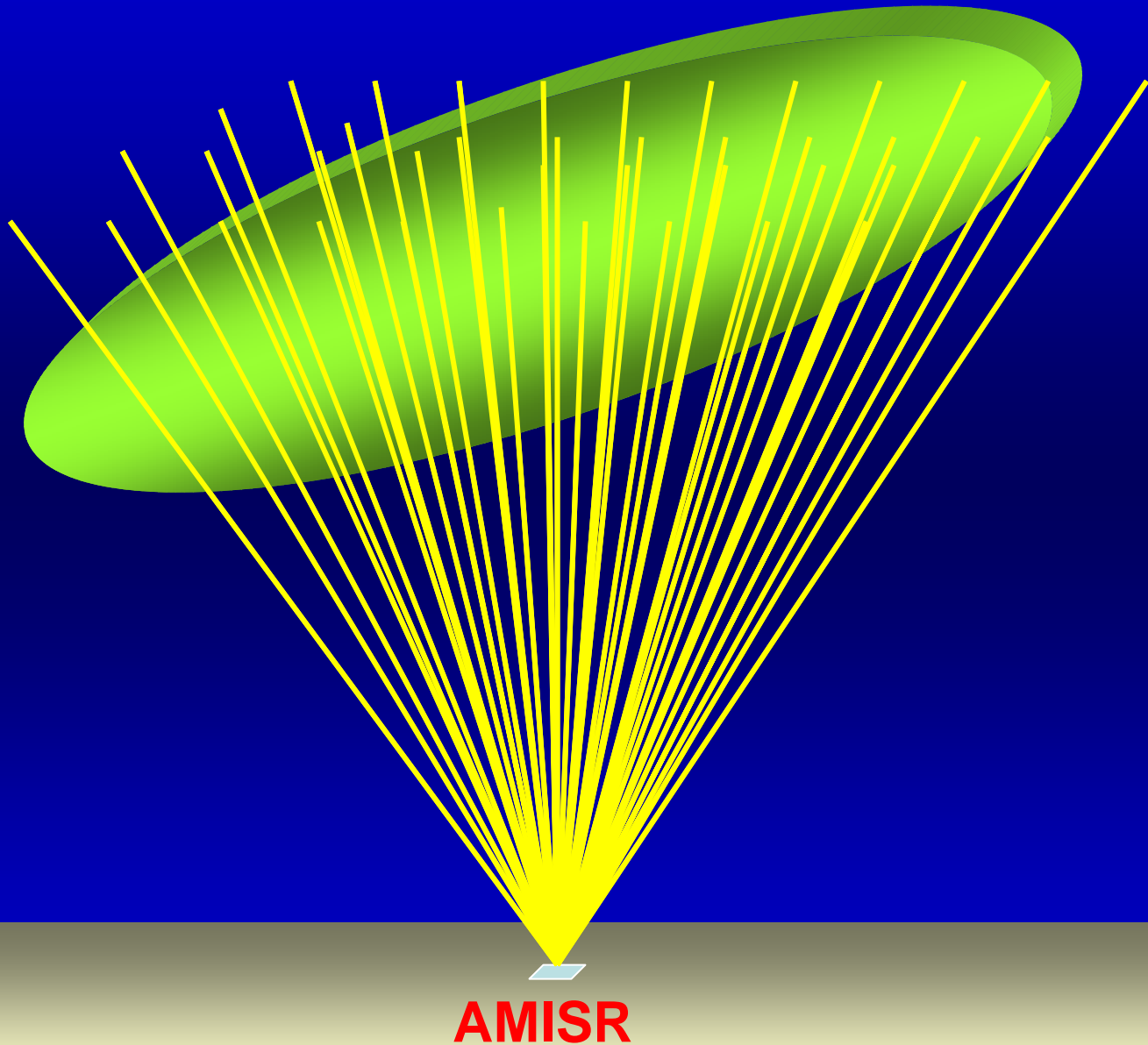
from **3.99**
per college day plus tax and a mile

"Dial DEBBIE"
LI 2-4229

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

Or:



- 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?

