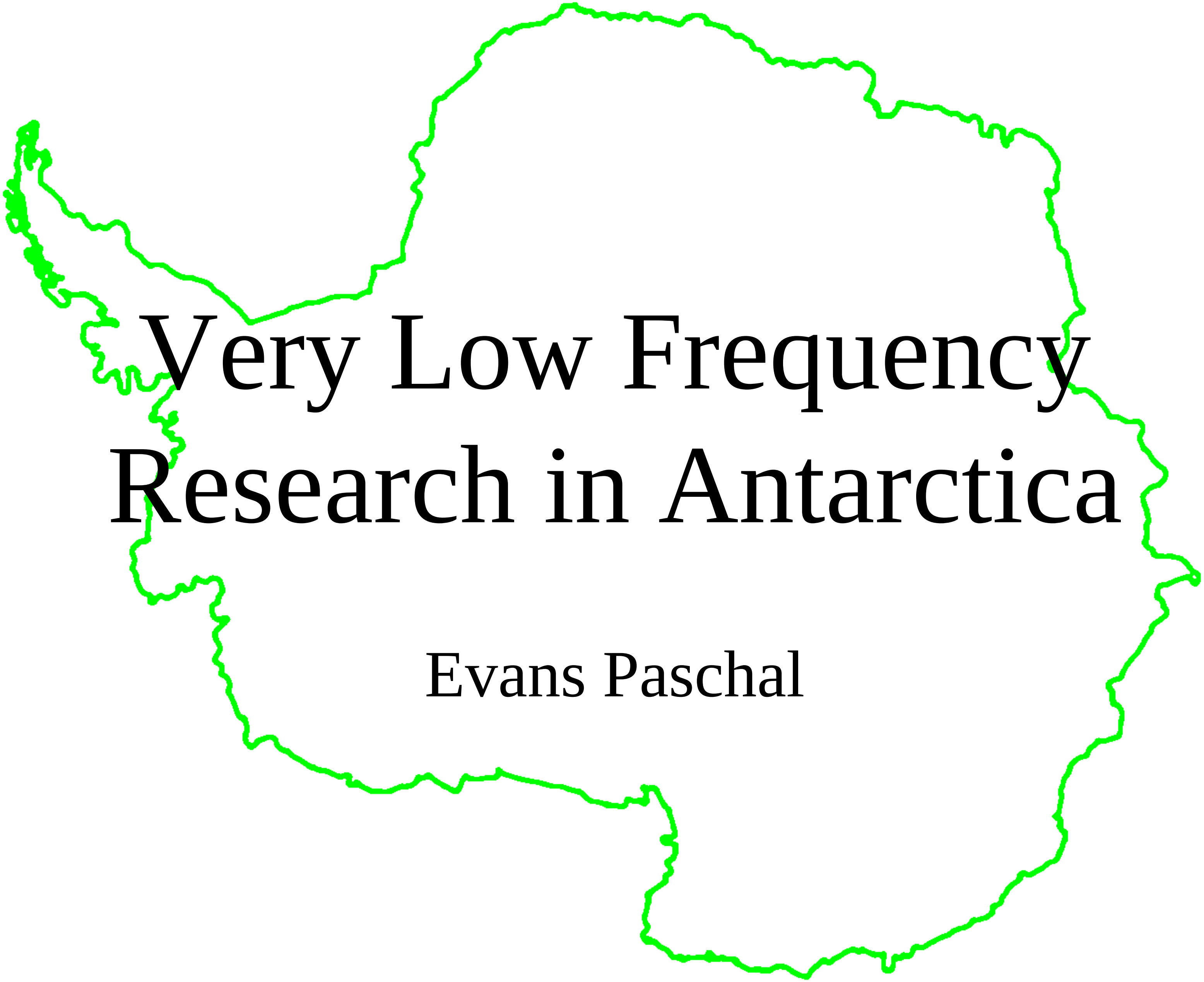
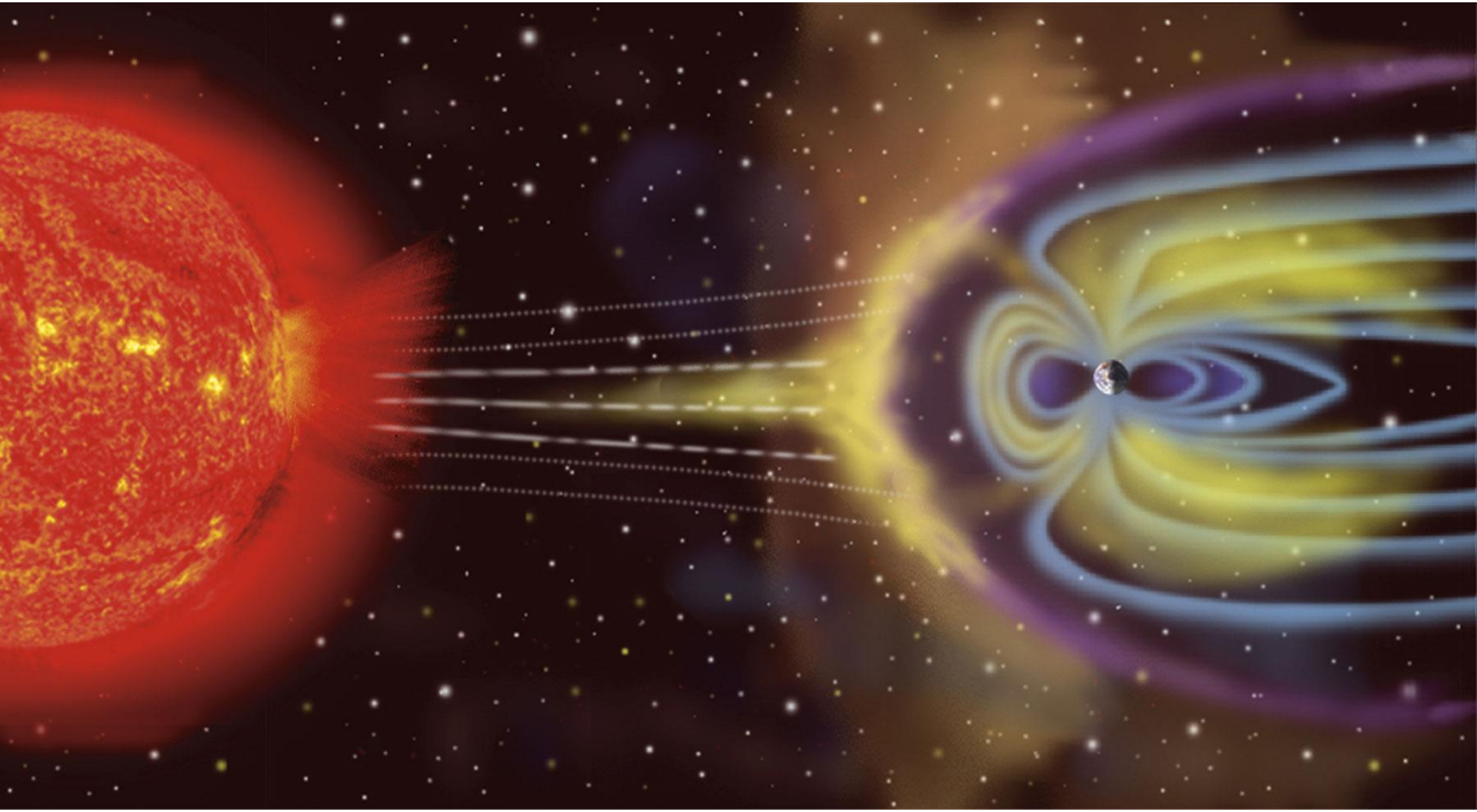
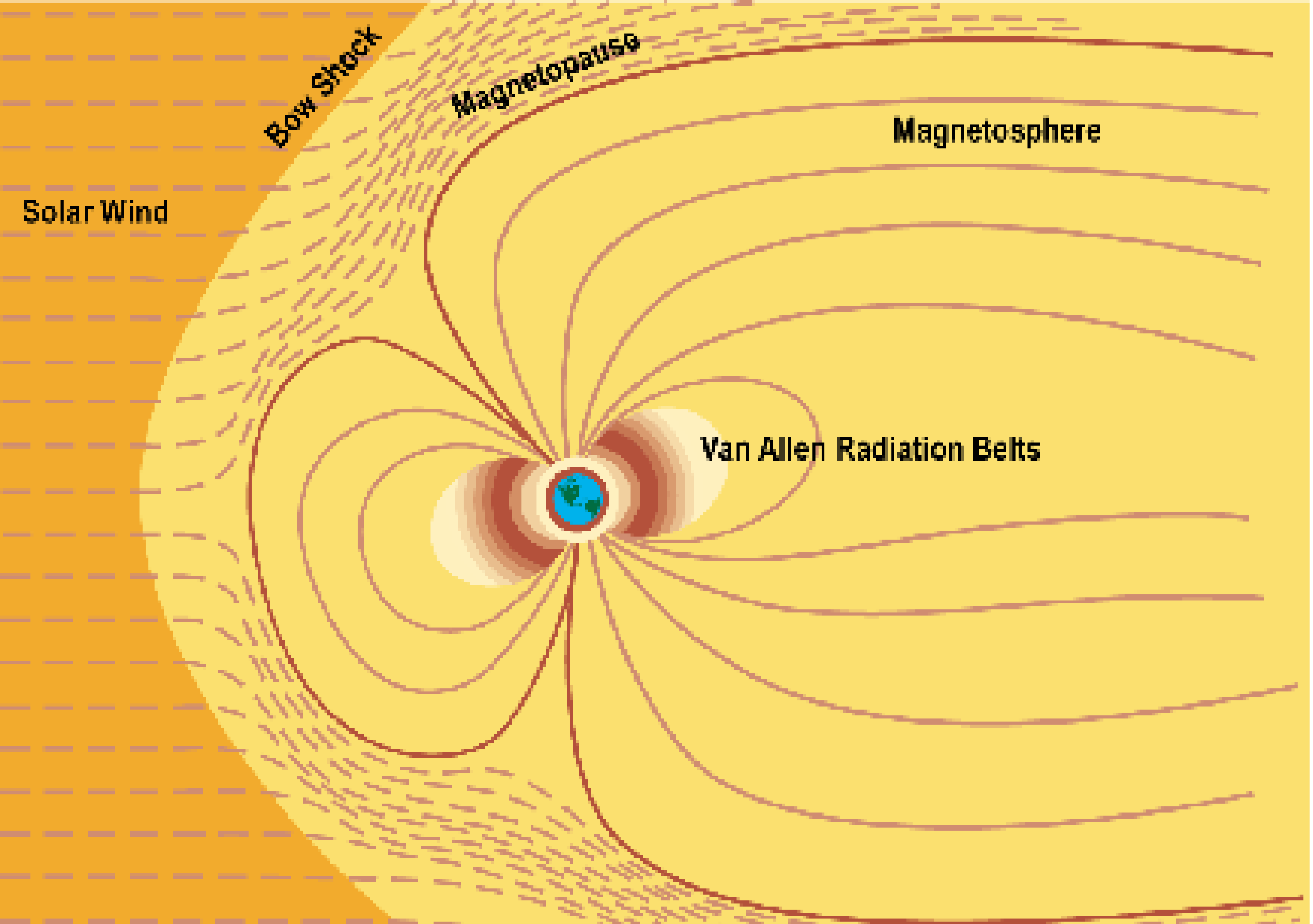


# Very Low Frequency Research in Antarctica

Evans Paschal

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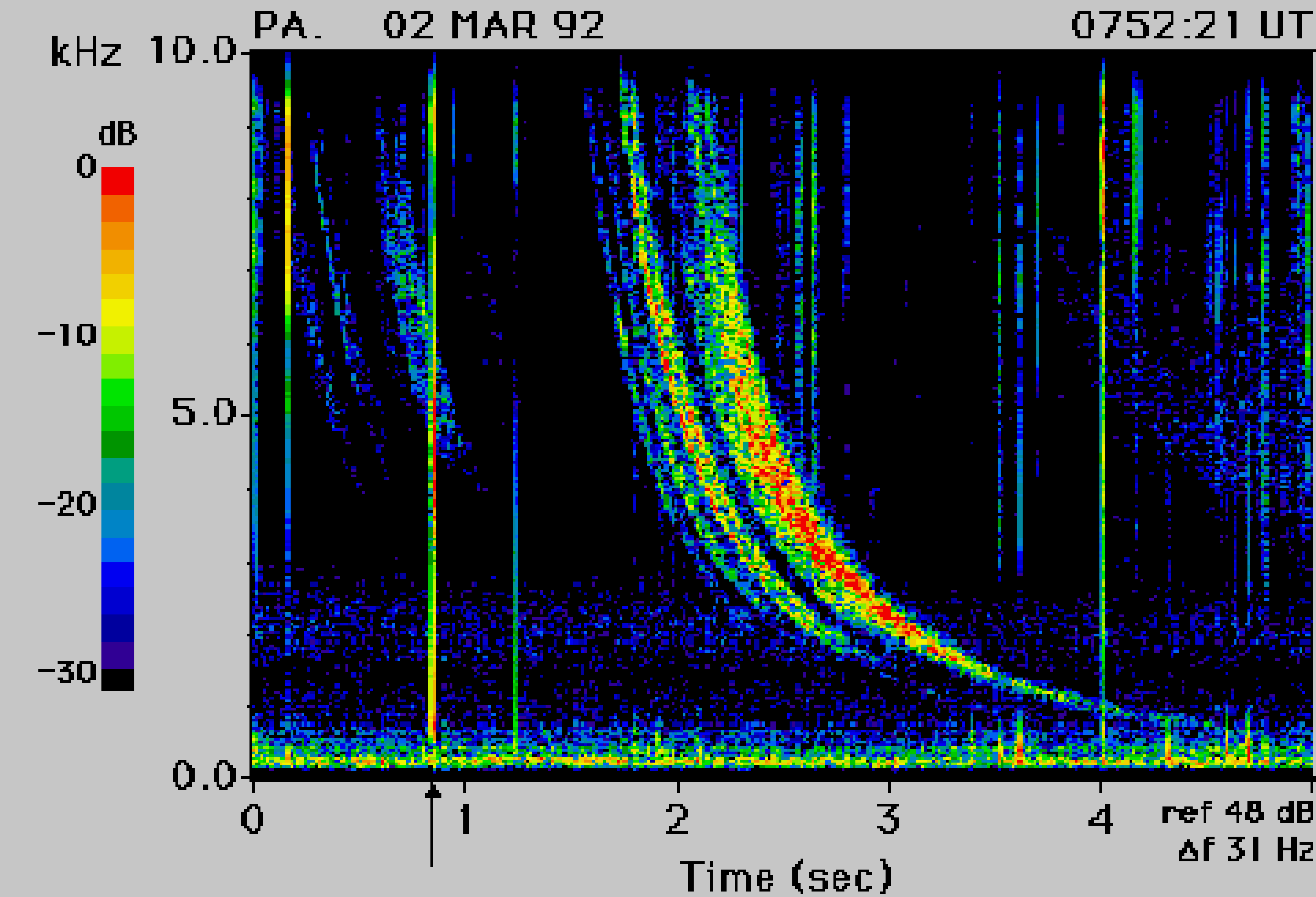
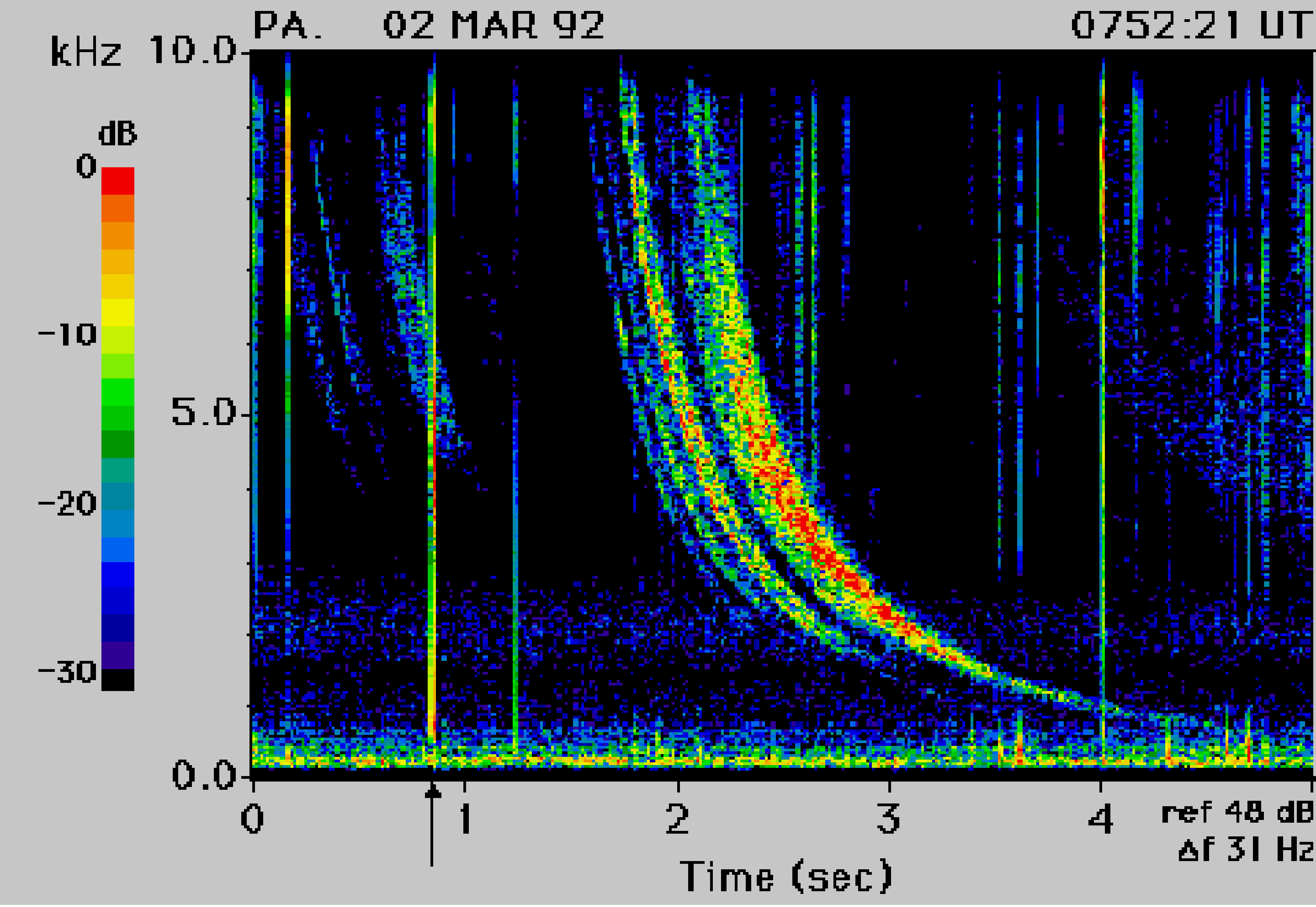
Magnetopause
Magnetosphere
Solar Wind
Van Allen Radiation Belts


PA. 02 MAR 92
0752:21 UT
kHz
10.0
5.0
0.0
dB
0
-10
-20
-30
0
1
2
3
4
Time (sec)
ref 48 dB
Δf 31 Hz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0752:21 UT
kHz 10.0
5.0
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0
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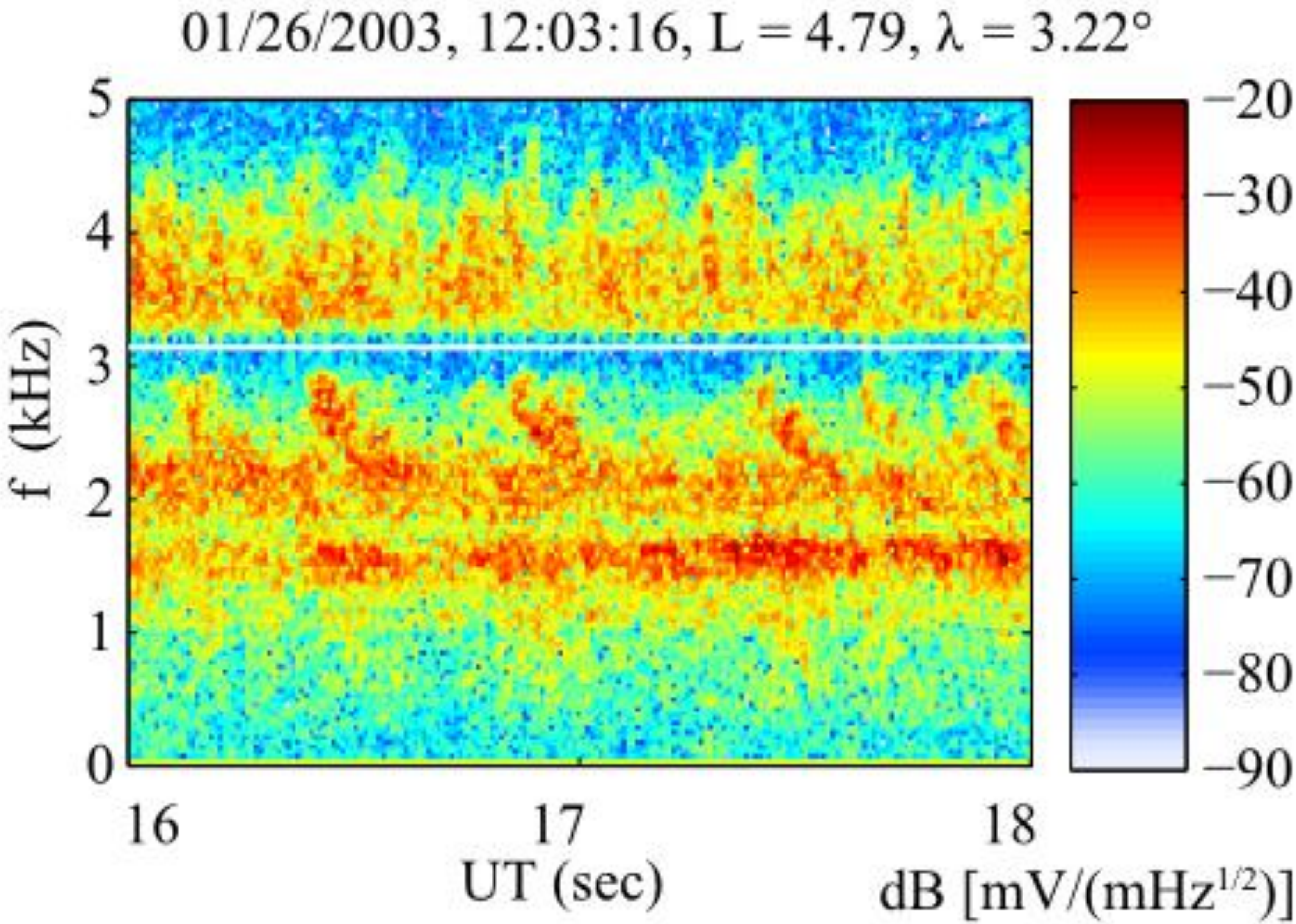
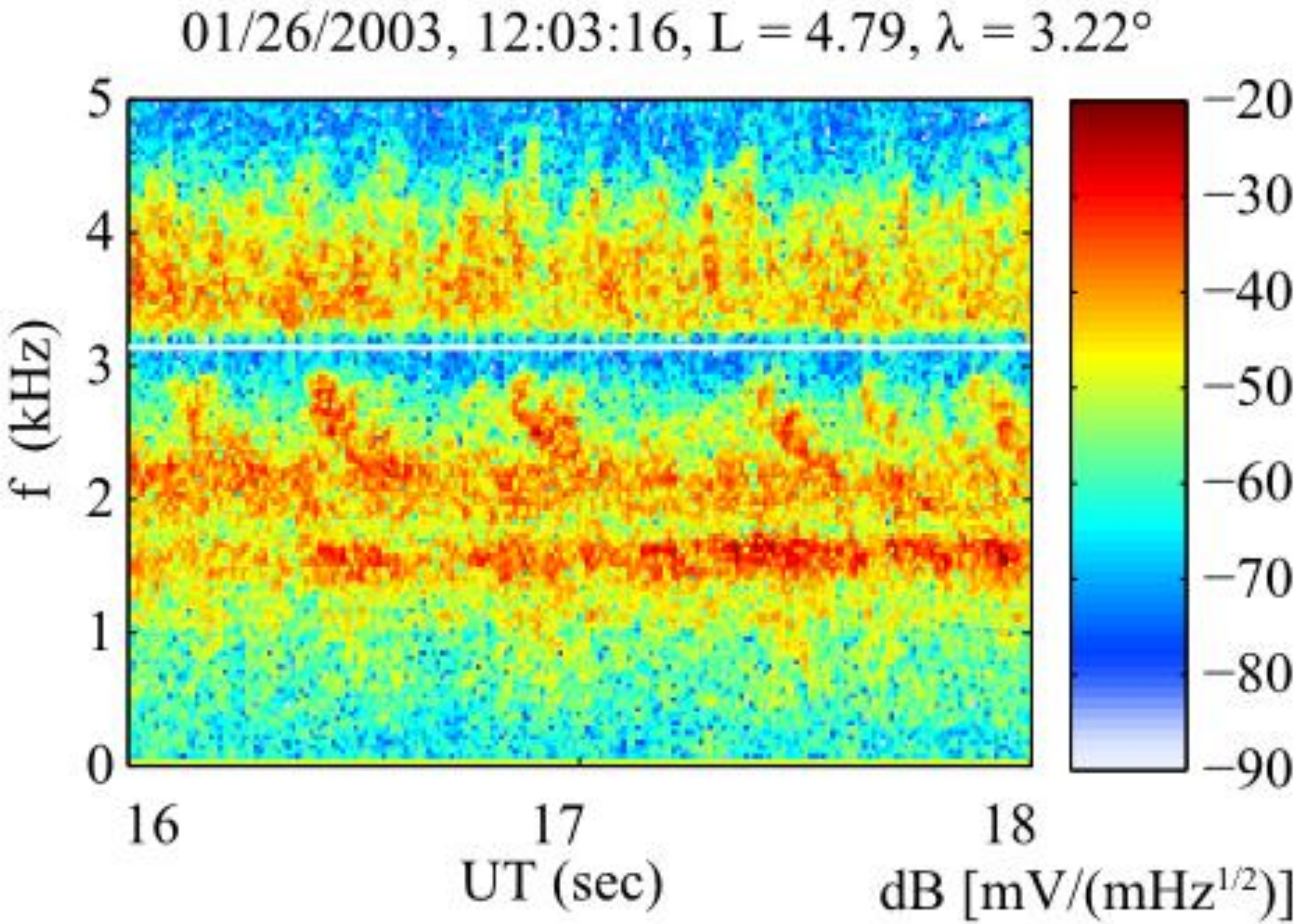
Time (sec)
ref 48 dB
Δf 31 Hz


01/26/2003, 12:03:16, L = 4.79, λ = 3.22°
f (kHz)
5
4
3
2
1
0
16
17
18
UT (sec)
−20
−30
−40
−50
−60
−70
−80
−90
dB [mV/(mHz^1/2)]



01/26/2003, 12:03:16, L = 4.79, λ = 3.22°
f (kHz)
5
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UT (sec)
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−90
dB [mV/(mHz1/2)]

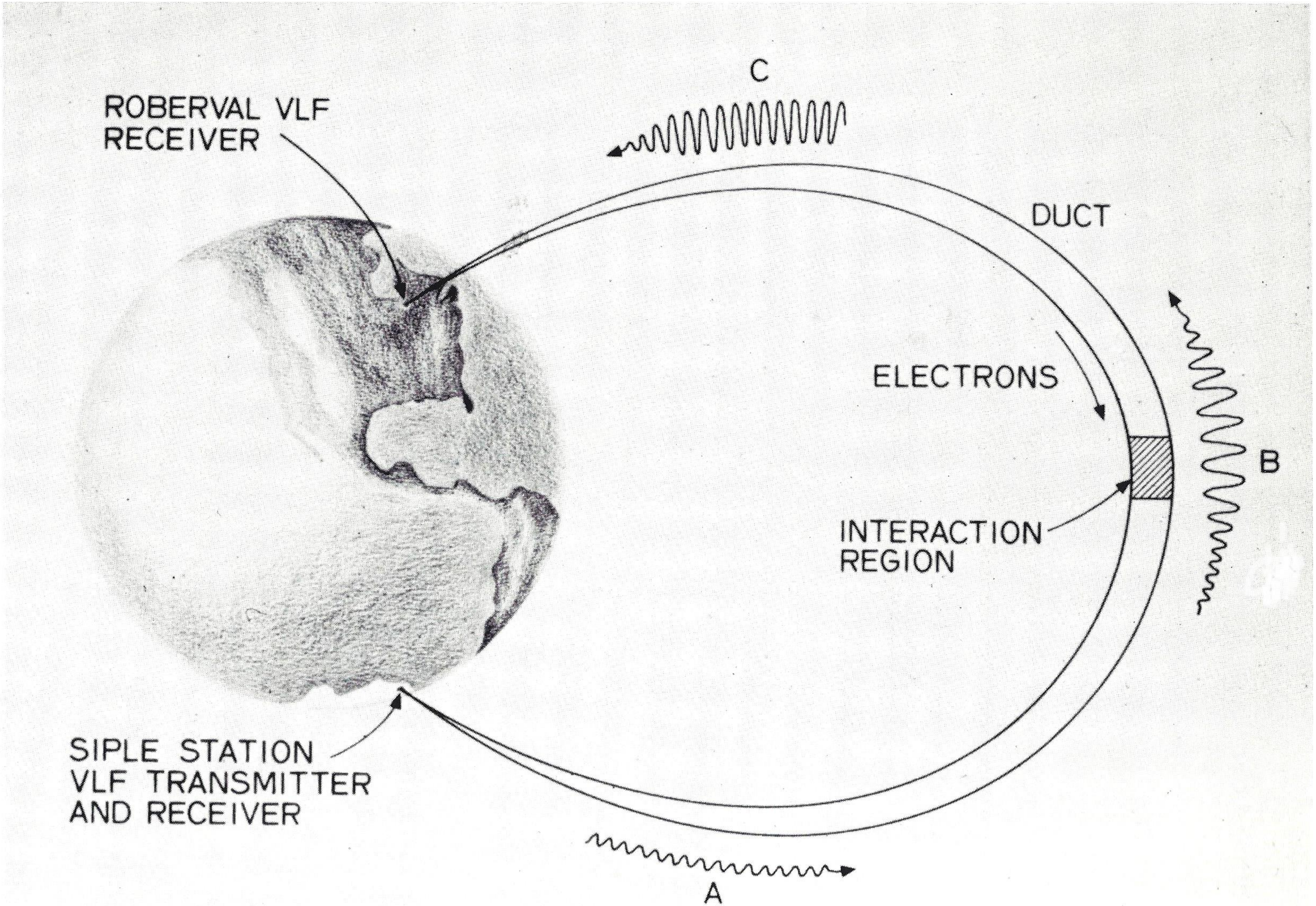
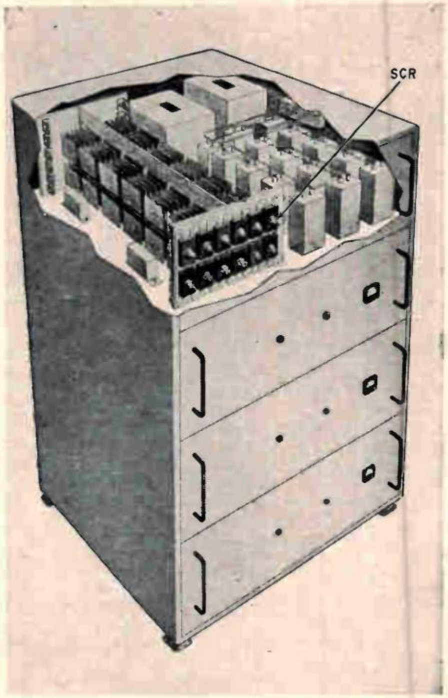



Figure 1. Sketch of field-aligned duct connecting Siple Station, Antarctica, to its conjugate point, Roberval, Quebec. Coherent signals, trapped in the duct, are amplified through cyclotron resonance with electrons in an interaction region centered on the magnetic equator.

the transmitter are grouped into sections which are triggered in sequential order by precisely timed, low-power gate signals. A simplified block diagram of a four-section scr transmitter shown below illustrates the basic scheme. By the time the last section is triggered by the exciter, the first scr section has recovered and can be triggered again.

The current pulses are portions of a transient oscillation that occurs when the scr begins to conduct. By making the pulses exactly one-half cycle of the desired frequency and by combining the outputs of the four sections in a common load, the resultant waveform closely resembles a continuous wave. Filtering this signal removes the distortion components and yields the desired sine wave. Because the sequential method of firing the scr's suggests the fire-and-recover principle used in early machine guns, Westinghouse engineers refer to this triggering scheme as the gatling gun technique.

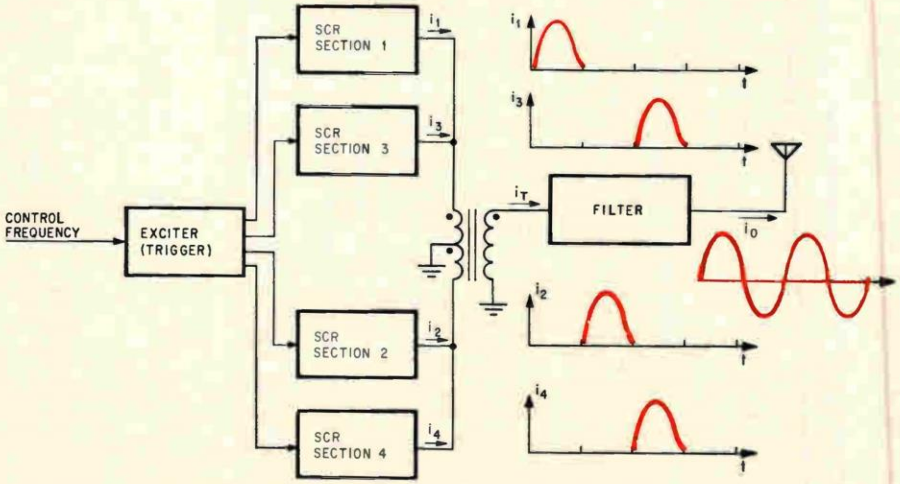



Transmitter consists of four sections, each with 24 scr's mounted on water-cooled heat sinks. This is an artist's conception of a packaged transmitter.

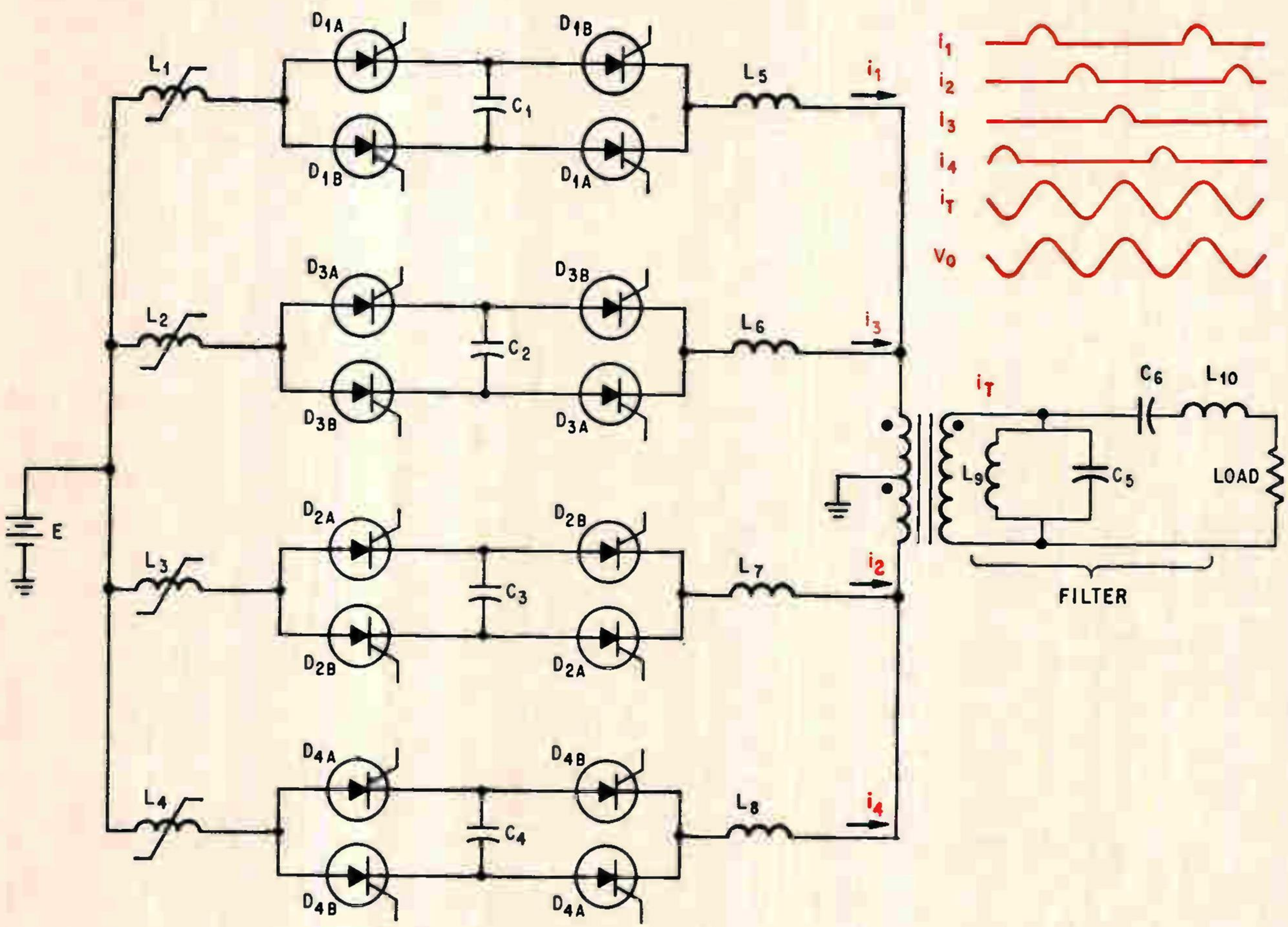
## Basic circuits

The basis of the technique employed in the scr amplifier is illustrated by the simple series-resonant circuit in the top diagram on page 121. When the switch is closed, the transient current, i(t), is an exponentially decaying sine wave. The voltage, v(t), appearing across the capacitor has a similar transient, but it oscillates about the supply voltage, E.

If the switch is replaced with an scr, as in the second diagram on page 121, gating-on the scr will result in the same current and voltage waveforms. However, the scr will conduct only until the current returns to zero and attempts to reverse its direction. At this time the scr will automatically turn off. Because of the characteristics of the oscil-

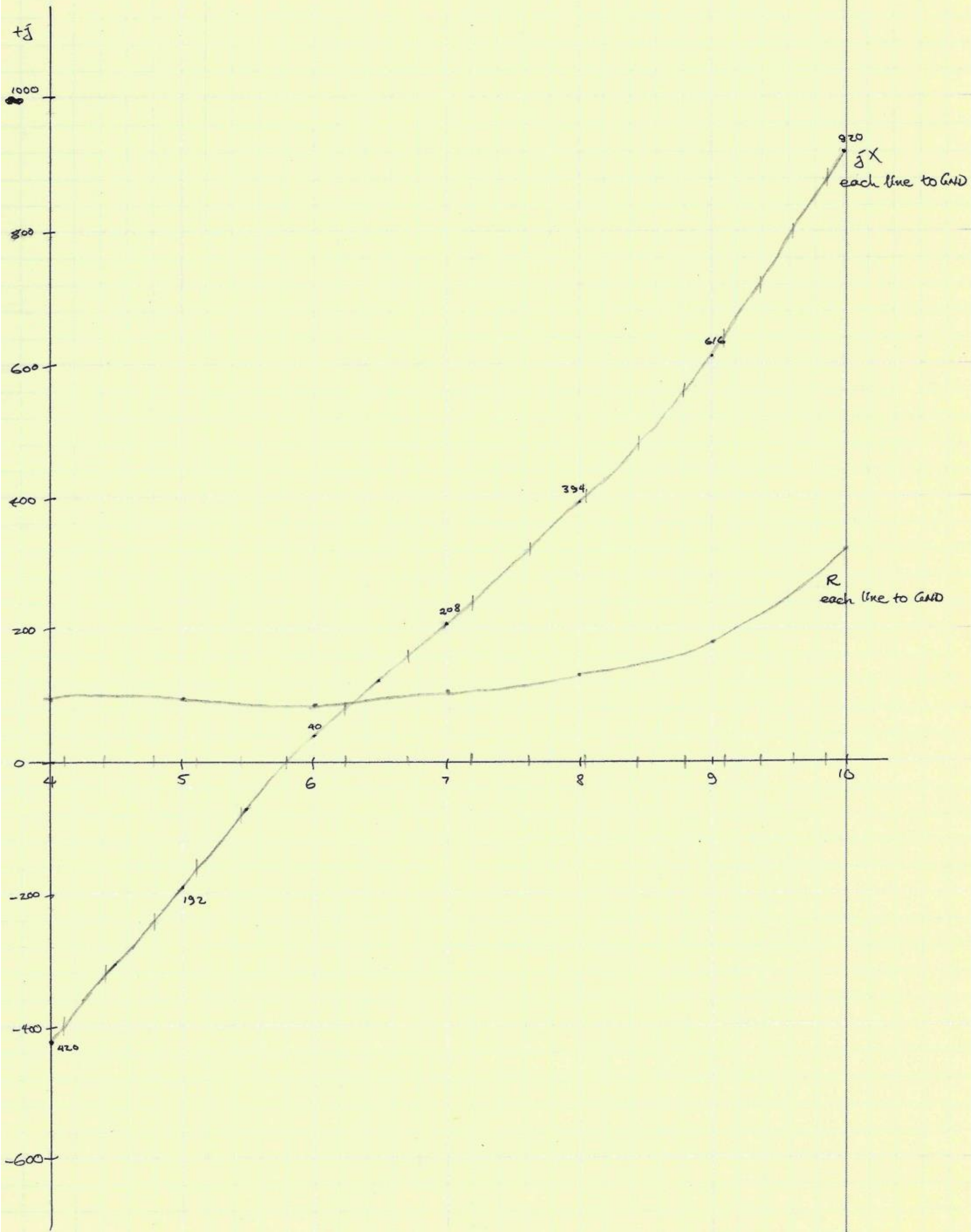



High-power current pulses developed in each scr section are combined in the load to produce a sine wave. The trigger, or exciter circuit, controls the firing of the scr's and determines the load frequency.




Power amplifier represented by four scr sections combines the current pulses through a center-tapped transformer that inverts the pulses from the two bottom sections. Scr's are fired alternately on either side of the transformer. Saturable reactors $L_1$ to $L_4$ protect the scr's during turn-on by preventing sudden current surges that might burn out scr junctions. To obtain a sinusoidal waveform scr's are triggered in the sequence $D_{1A}$, $D_{2A}$, $D_{3A}$, $D_{4A}$, $D_{1B}$, $D_{2B}$, $D_{3B}$, and $D_{4B}$. In the actual transmitter, six scr's in series are used for every scr in the diagram.

Antenna reactances (each leg to GND)



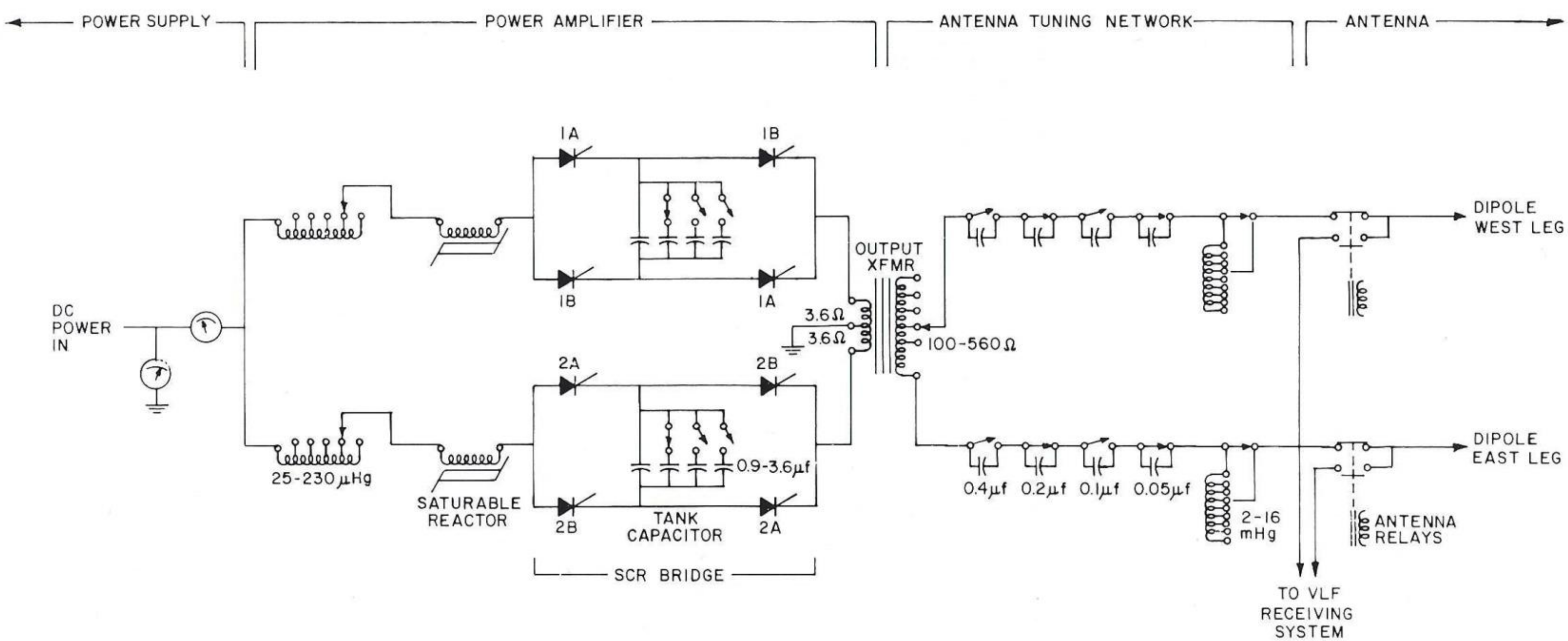



Fig. 4.4. Transmitter diagram of the VLF transmitter power supply, power amplifier, and antenna tuning network.

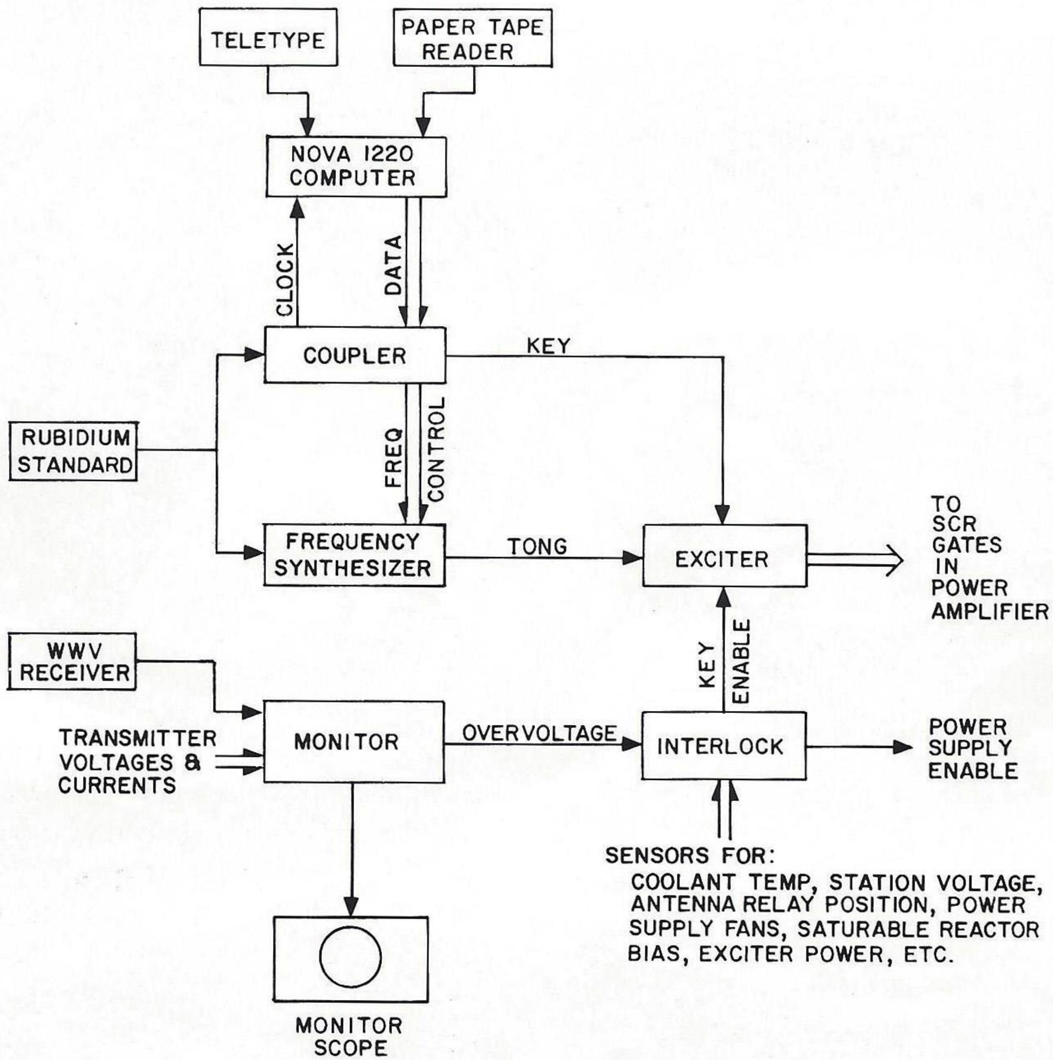



Fig. 4.5. Transmitter control system diagram. The circuits control times and frequencies of transmissions and also monitor the operation of the transmitter.

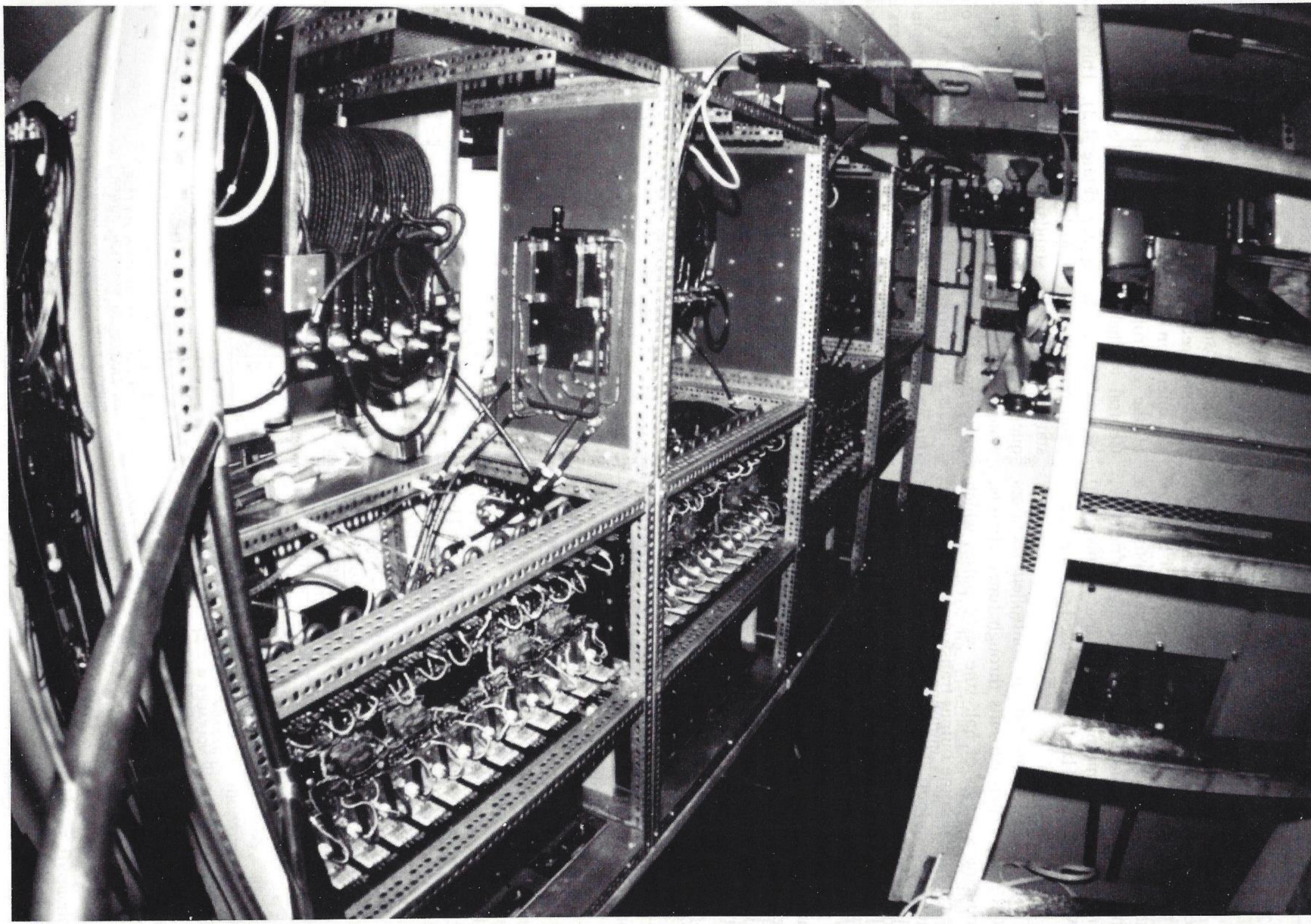


Plate 4.1. View of the VLF transmitter showing the power amplifier on the left and the dc power supply and auto transformer on the right.

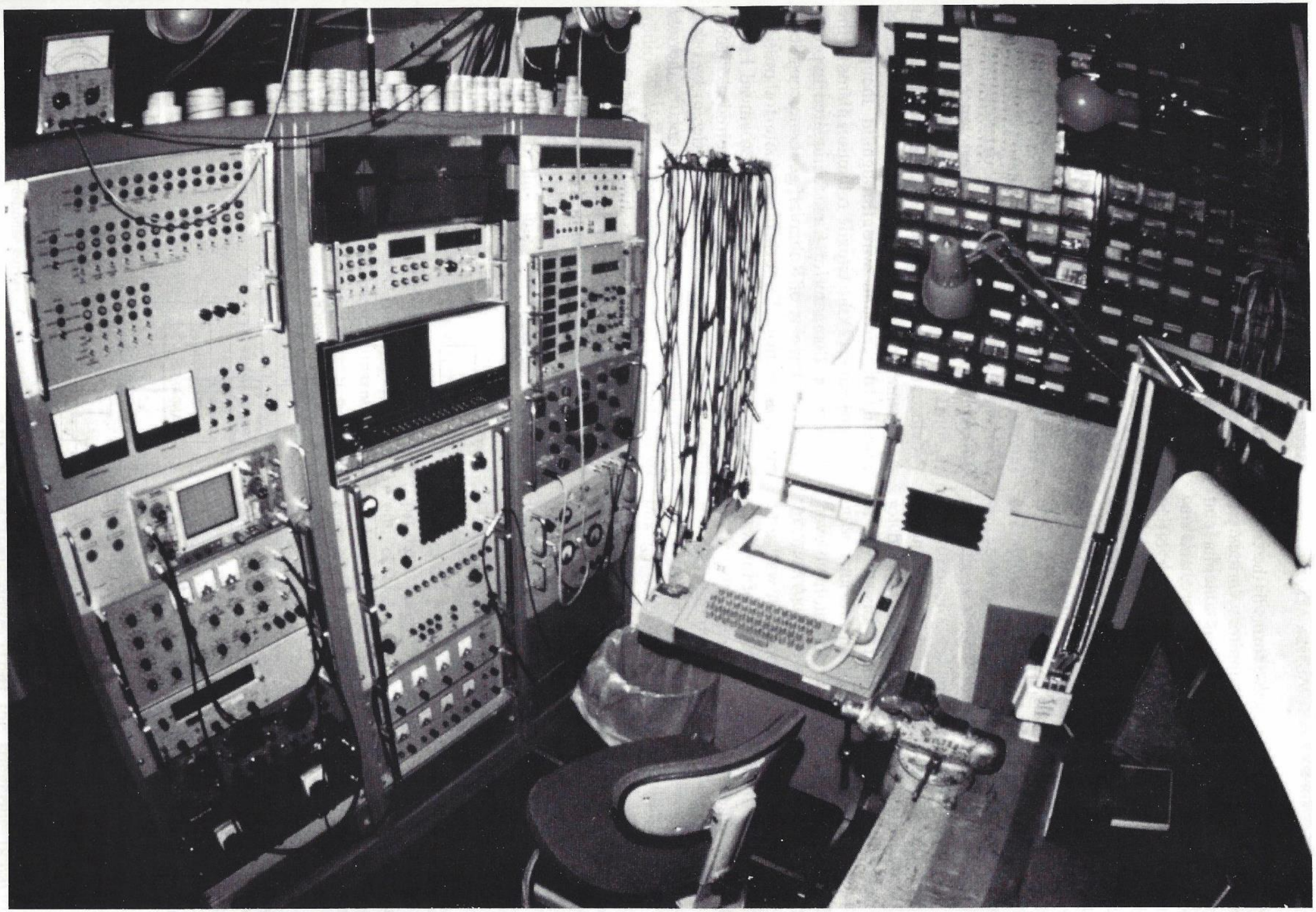


Plate 4.2. View of the transmitter control modules. A Data General Nova 1200 minicomputer is the central instrumentation of the control system.

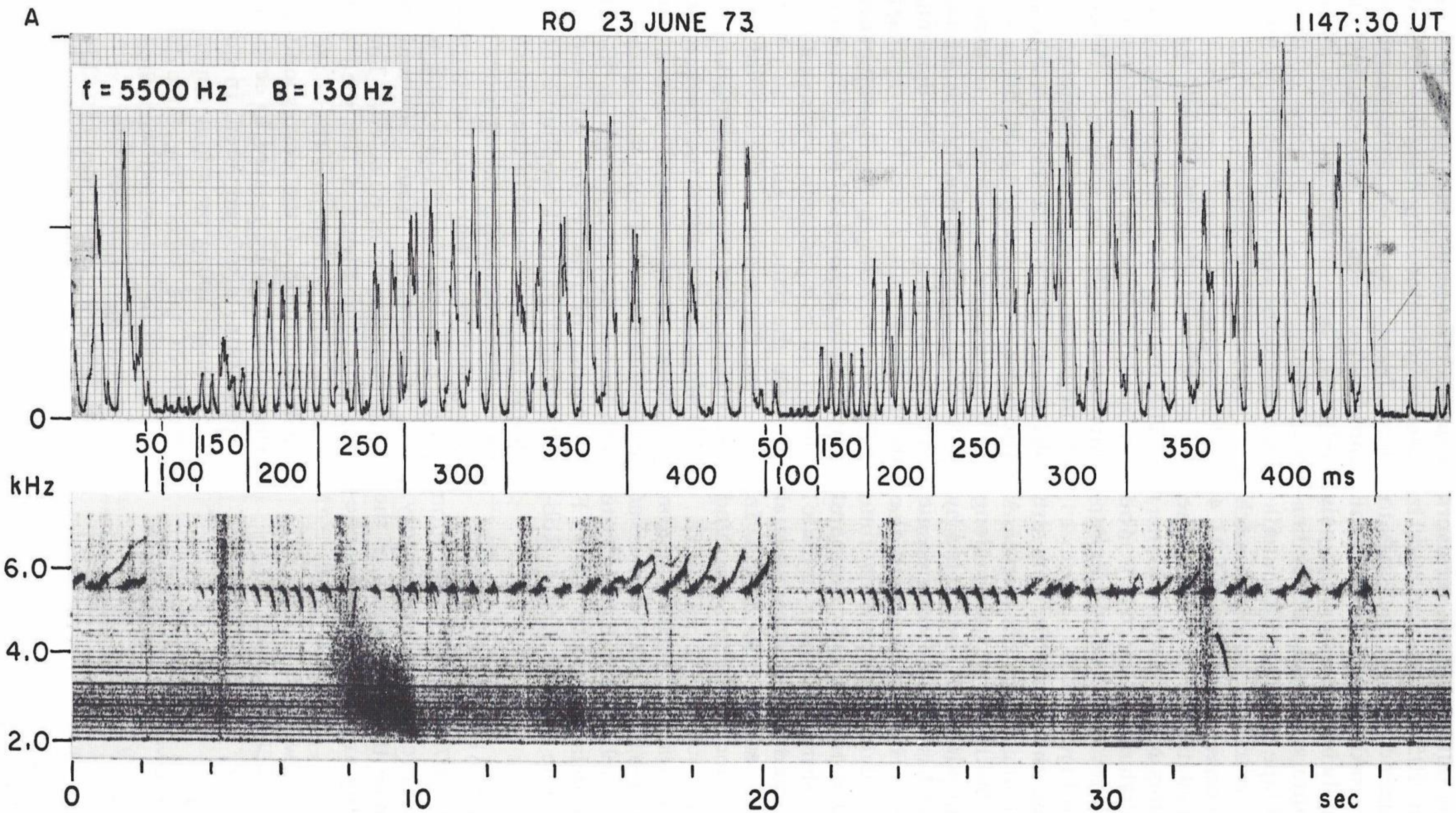



Fig. 5.1. Variable pulse length sequence received at Roberval. The lower panel shows the spectrum, and the upper panel shows the amplitude in a 130-Hz bandwidth centered on 5.5 kHz. Pulse lengths vary from 50 to 400 ms in 50-ms steps, as is indicated by the numbers between panels. A two-hop whistler, with echoes at ~3 kHz, appears at 8–10 s and originates in the sferic at 4.2 s. A strong well-defined two-hop whistler component extending up to 5.5 kHz is seen at about 8.2 s and corresponds to the one-hop delay of the Siple pulses.

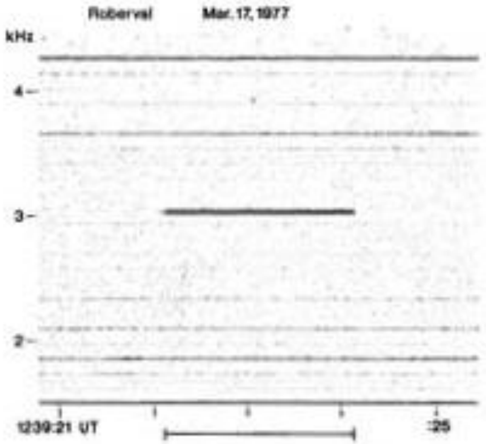



Fig. 1. Spectrogram of a 2-s pulse from Siple to Roberval at 3030 Hz. The pulse is constant in amplitude, showing neither temporal growth nor emission triggering.

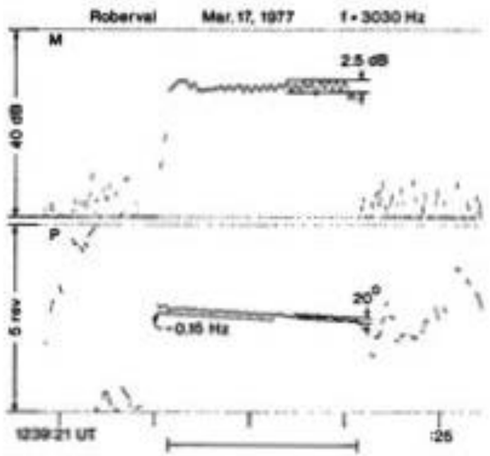



Fig. 2. Plot of the magnitude M and phase P of the pulse in Figure 1. Two plateaus on the leading edge of the magnitude plot indicate two additional paths of propagation. Pulsations in amplitude develop toward the end of the pulse. The phase plot shows that the received frequency is 0.15 Hz below the transmitted frequency due to an increase in path length during the pulse.

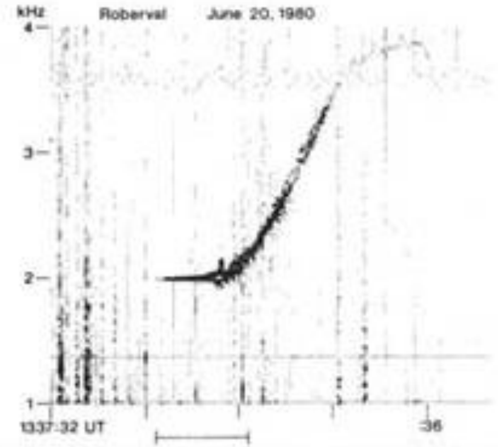



Fig. 3. Spectrogram of a 1-s pulse at 2000 Hz showing growth in amplitude with time and the generation of an emission.

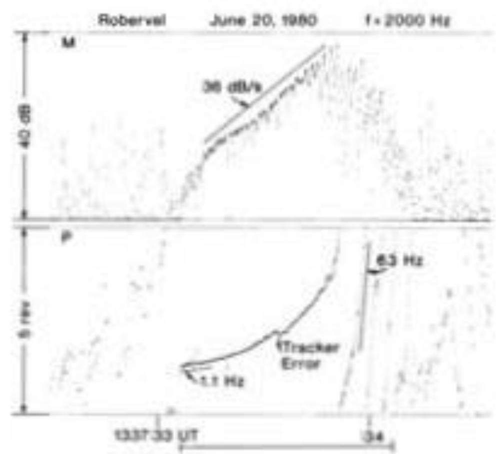



Fig. 4. Magnitude and phase plot of the pulse in Figure 3. The growth rate is 36 dB/s before saturation. The phase plot shows that the pulse is offset by +1.1 Hz from the transmitted frequency at the start, and the frequency offset increases with time. When the emission starts to separate, the received signal is 63 Hz above the transmitted frequency.


ATLANTIC OCEAN
PRINCE EDWARD ISLANDS (S. Afr.)
SOUTH GEORGIA (UK)
SOUTH SANDWICH ISLANDS (UK)
CROZET IS. (Fr.)
SOUTHERN OCEAN
FALKLAND ISLANDS (UK)
South Orkney Is.
Scotia Sea
ARGENTINA
Weddell Sea
KERGUELEN (Fr.)
South Shetland Is.
Larsen Ice Shelf
Ronne Ice Shelf
HEARD & MCDONALD ISLANDS (Austr.)
CHILE
Antarctic Penin.
Alexander I.
Berkner I.
Amery Ice Shelf
ANTARCTICA
Vinson Massif 4897 m
South Pole
INDIAN OCEAN
Thurston I.
Mt. Kirkpatrick 4528 m
Ross Ice Shelf
Roosevelt I.
Ross Sea
SOUTHERN OCEAN
Balleny Is.
PACIFIC OCEAN
MACQUARIE I. (Austr.)
CAMPBELL IS. (N.Z.)
AUCKLAND IS. (N.Z.)
ANTIPODES IS. (N.Z.)
AUSTRALIA
NEW ZEALAND
40°
20°
0°
20°
40°
50°
60°
70°
80°
60°
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100°
120°
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160°
160°
140°
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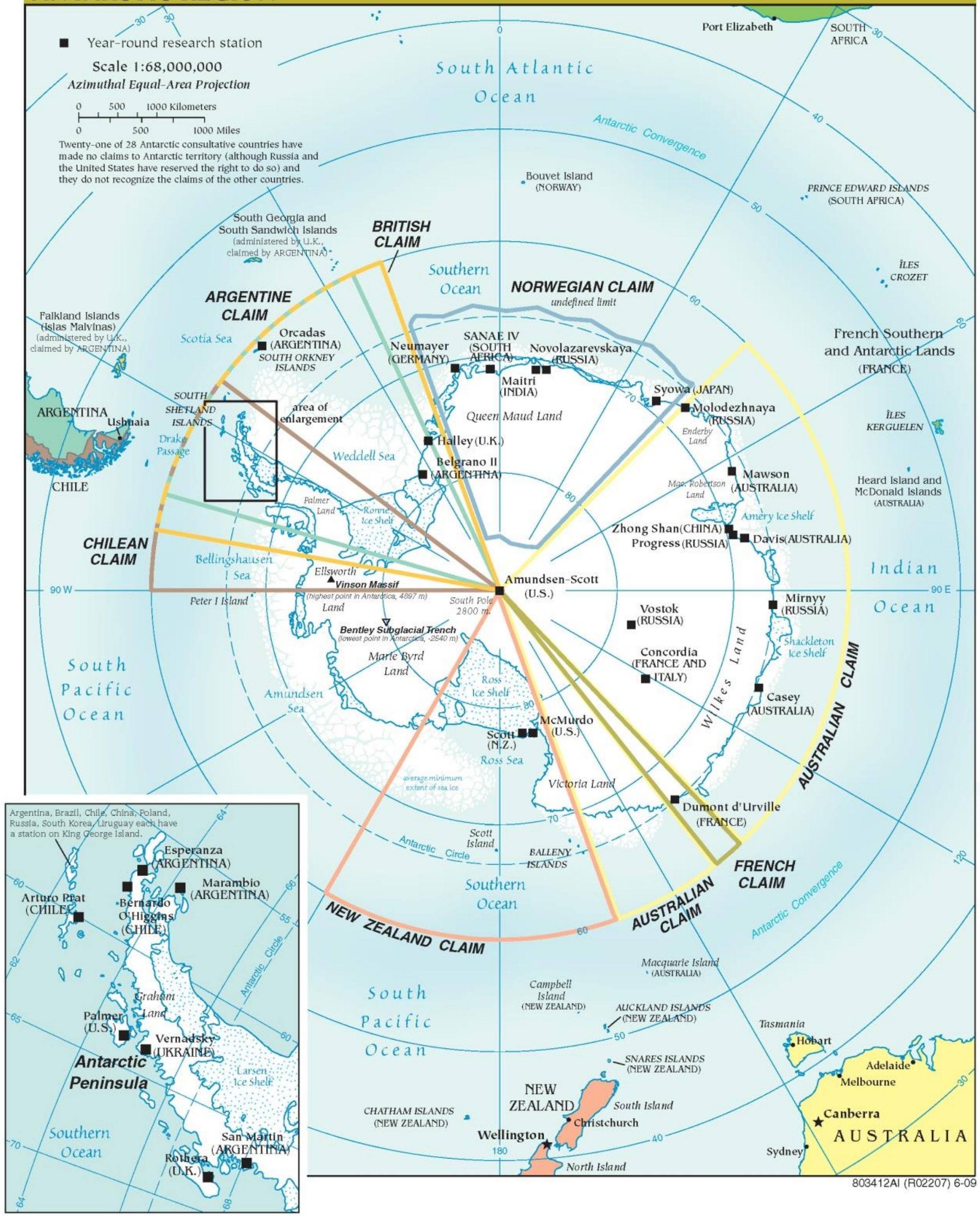
60°

**Antarctic Digital Coastline: Antarctic Digital Database, 2000**
**US Digital Outline: ESRI**

# ANTARCTIC REGION




803412AI (R02207) 6-09

SOUTHERN OCEAN
KONG HÅKON VII HAV
Antarctic Circle 66°34'S
South Orkney Is
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ANTARCTIC PENINSULA
WEDDELL SEA
BRUNT ICE SHELF
Halley (UK)
FIMBULISEN
Fimbulheimen
DRONNING MAUD LAND
Thorshavnheine
ENDERBY LAND
Scott Mtns
KEMP LAND
Anvers I.
Palmer (USA)
GRAHAM LAND
LARSEN ICE SHELF
COATS LAND
Dome Fuji (Valkyrie)
Adelaide I.
Rothera (UK)
PALMER LAND
FILCHNER ICE SHELF
Berkner Island
Shackleton Range
MACROBERTSON LAND
Prince Charles Mtns
AMERY ICE SHELF
Prydz Bay
RONNE ICE SHELF
Alexander I.
EAST ANTARCTICA
Pensacola Mtns
PRINCESS ELIZABETH LAND
BELLINGSHAUSEN SEA
Vinson Massif 4892m
Ellsworth Mtns
Dome Argus
4000
90°W
South Pole
Amundsen-Scott (USA)
Thiel Mtns
WILHELM II LAND
90°E
Davis Sea
Peter I Øy
ELLSWORTH LAND
ABBOT ICE SHELF
Whitmore Mtns
Transantarctic Mountains
WEST ANTARCTICA
Queen Maud Mtns
Queen Elizabeth Range
Subglacial Lake Vostok
QUEEN MARY LAND
SHACKLETON ICE SHELF
AMUNDSEN SEA
80°S
Queen Alexandra Range
Executive Committee Range
MARIE BYRD LAND
ROSS ICE SHELF
GETZ ICE SHELF
WILKES LAND
Dome Circe
2000
McMurdo (USA)
VICTORIA LAND
Mt Erebus
70°S
TERRE ADÉLIE
GEORGE V LAND
ROSS SEA
OATES LAND
Dumont d'Urville Sea
Balleny Is
180°
60


Seattle
San Francisco
Honolulu
Pago Pago
Christchurch
McMurdo
Station


32 11 4


BLDG 7

# Antarctica


Palmer Station
Siple
South Pole
Vostok
Byrd
McMurdo Station
Digital Coastline:
Antarctic Digital Database, 2000
Polar Stereographic Projection
Central Meridian 0, Base Latitude 71 S


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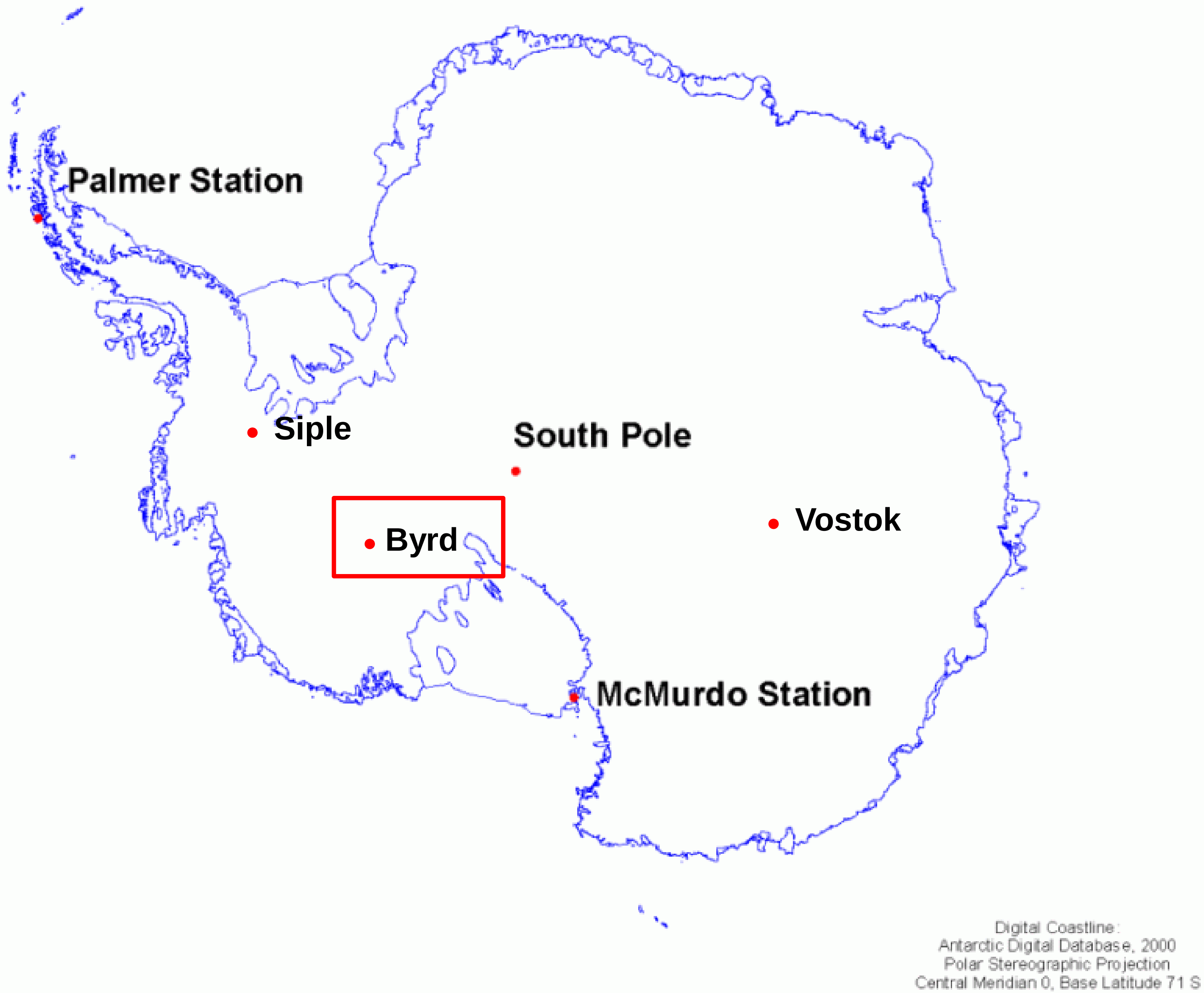
# Antarctica



Palmer Station
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McMurdo Station
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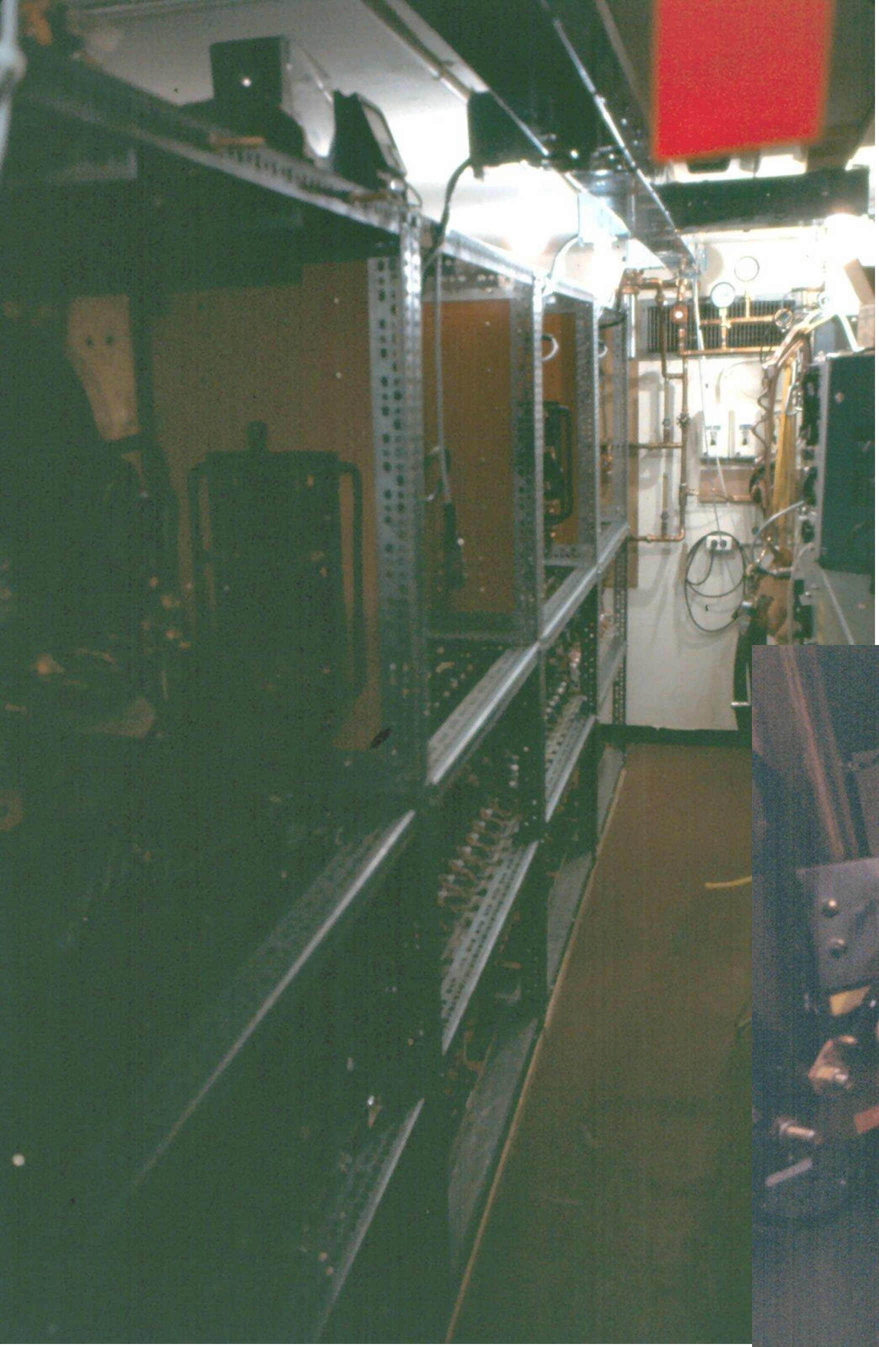
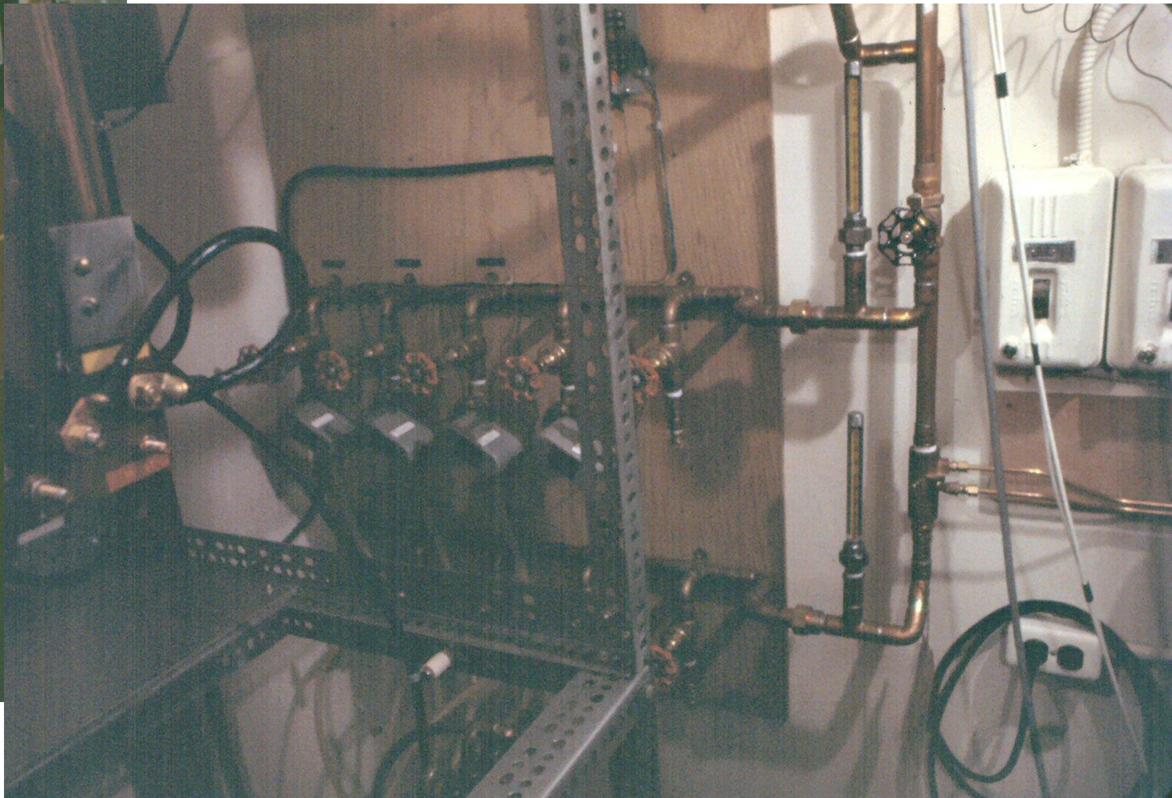
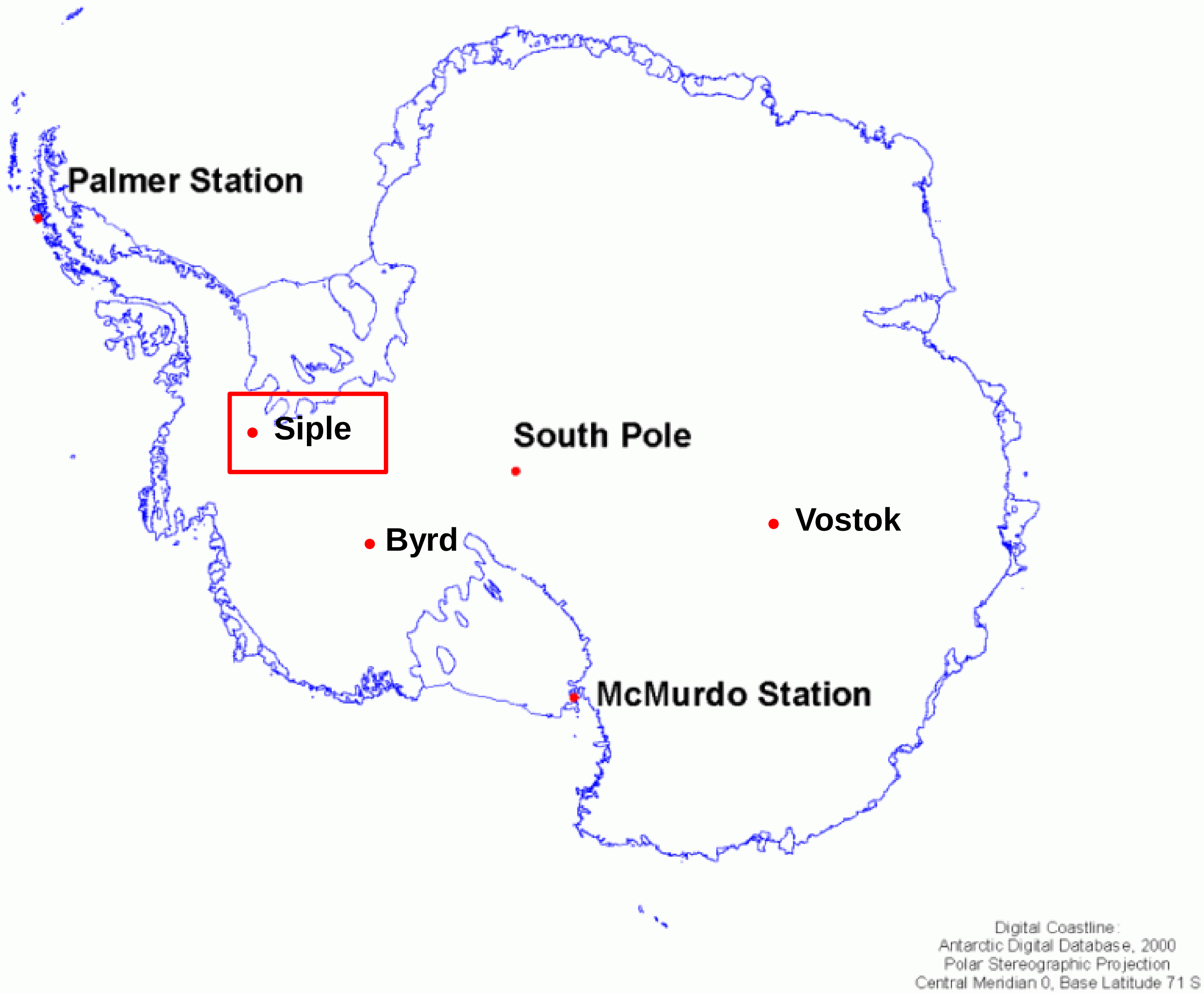
Polar Stereographic Projection
Central Meridian 0, Base Latitude 71 S


Bavaria
LAGER

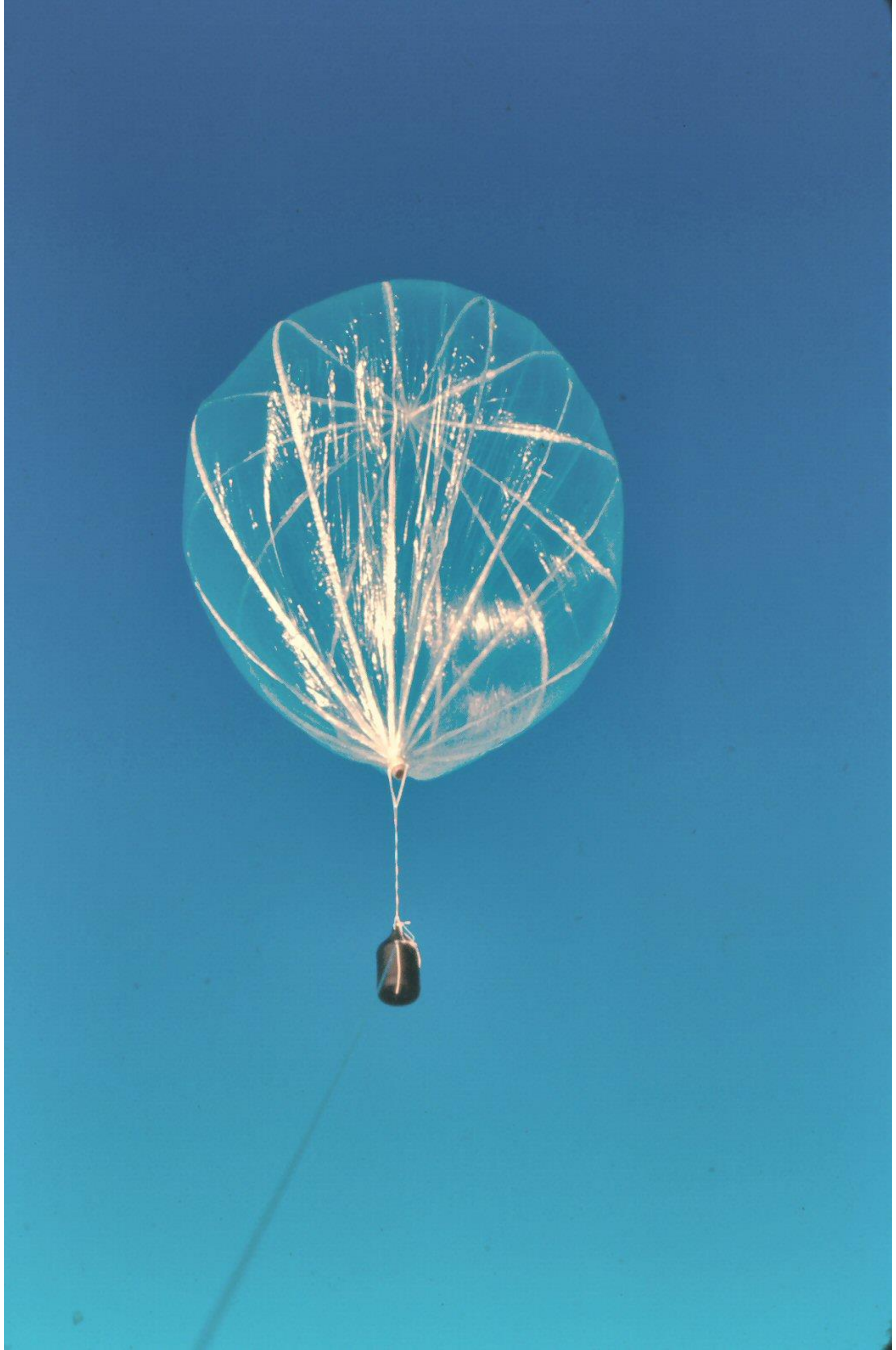

# Antarctica

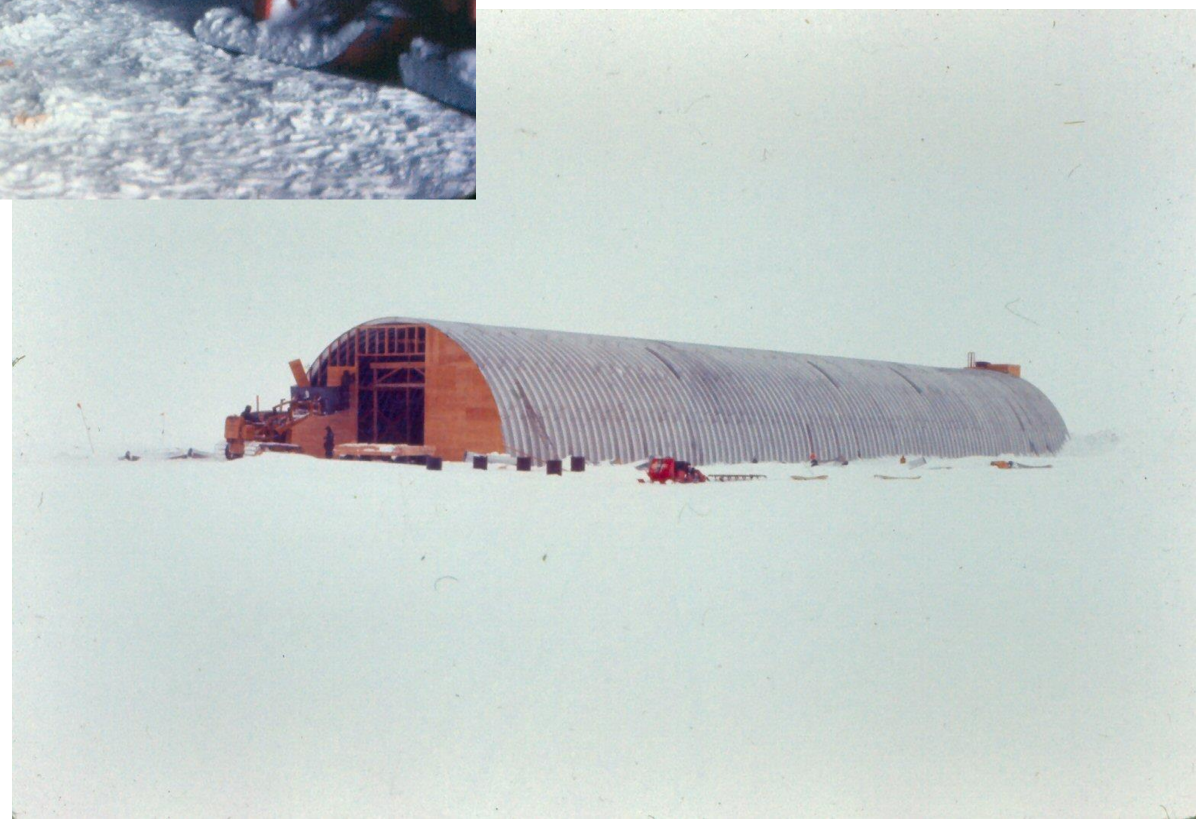

Palmer Station
Siple
South Pole
Vostok
Byrd
McMurdo Station
Digital Coastline:
Antarctic Digital Database, 2000
Polar Stereographic Projection
Central Meridian 0, Base Latitude 71 S

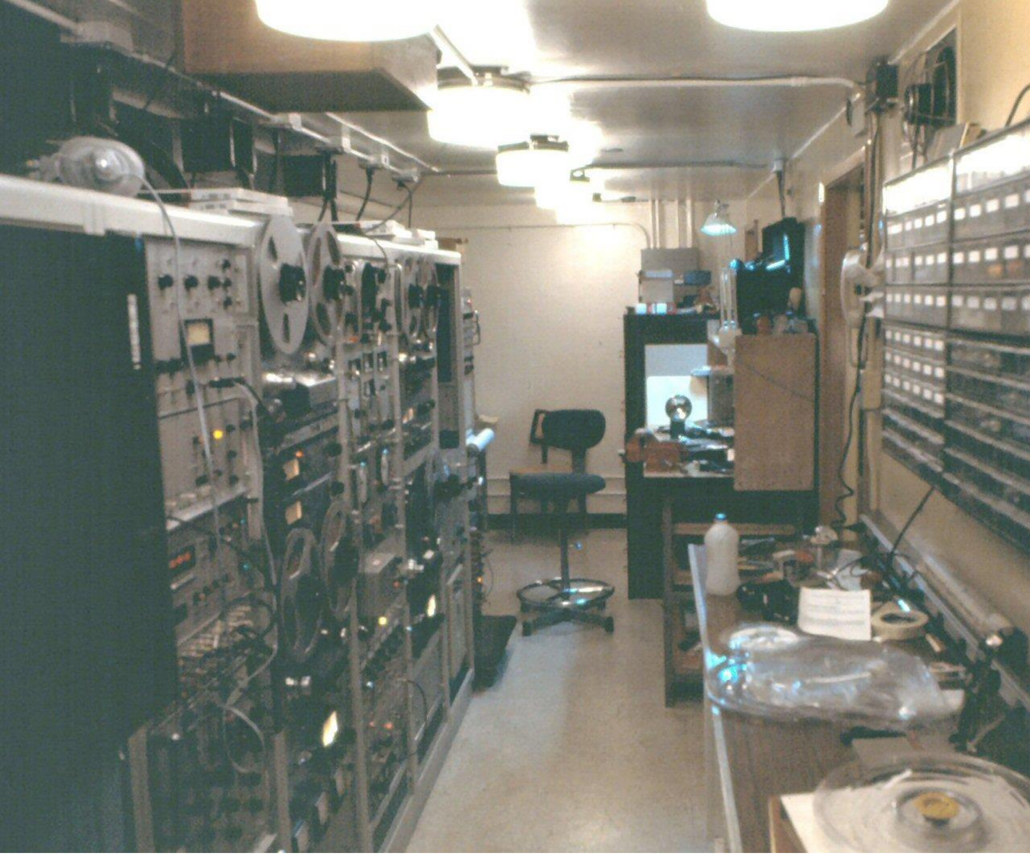

SIPLE STATION
ELLSWORTH LAND
ANTARCTICA
49
BOOSTER CLUB
75°SOUTH 84°WEST

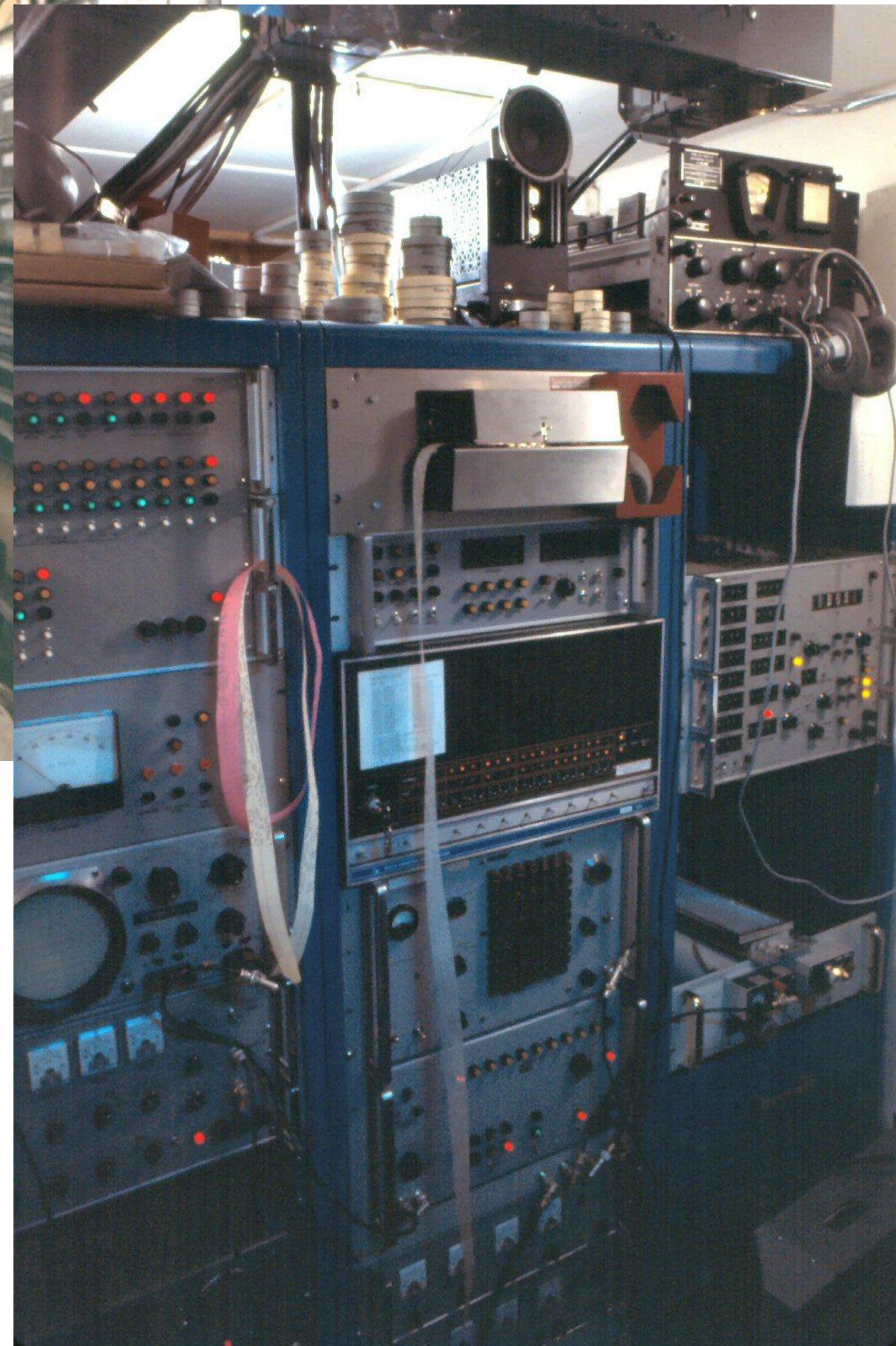

HANDLER
TRIMPI
U.S. ARMY

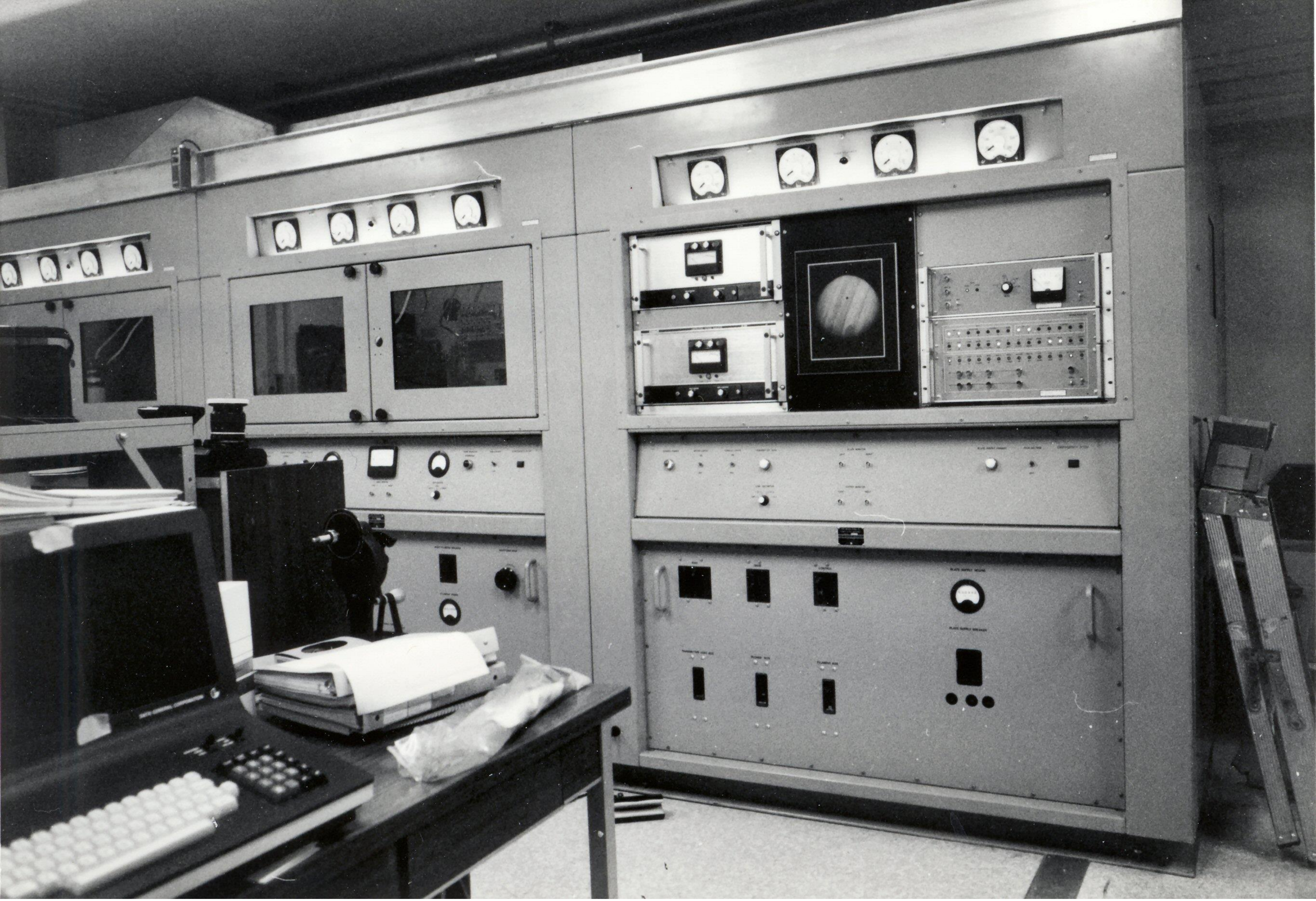

SALT

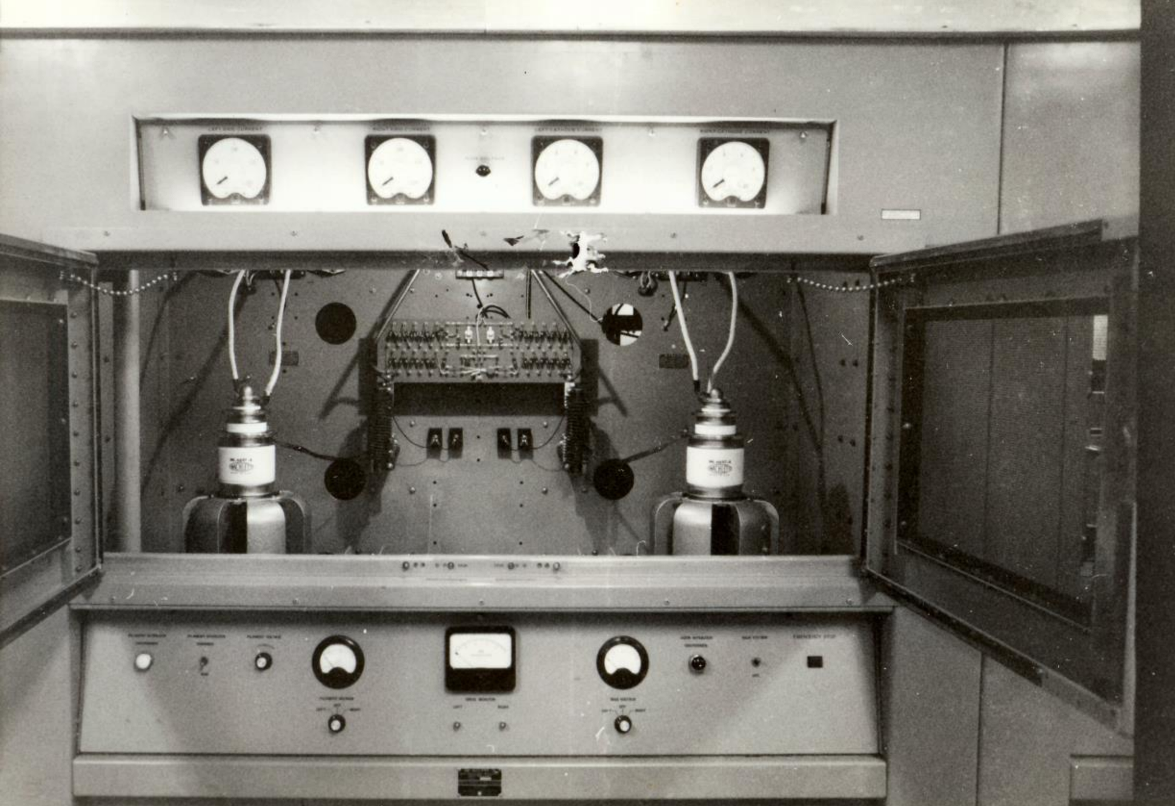


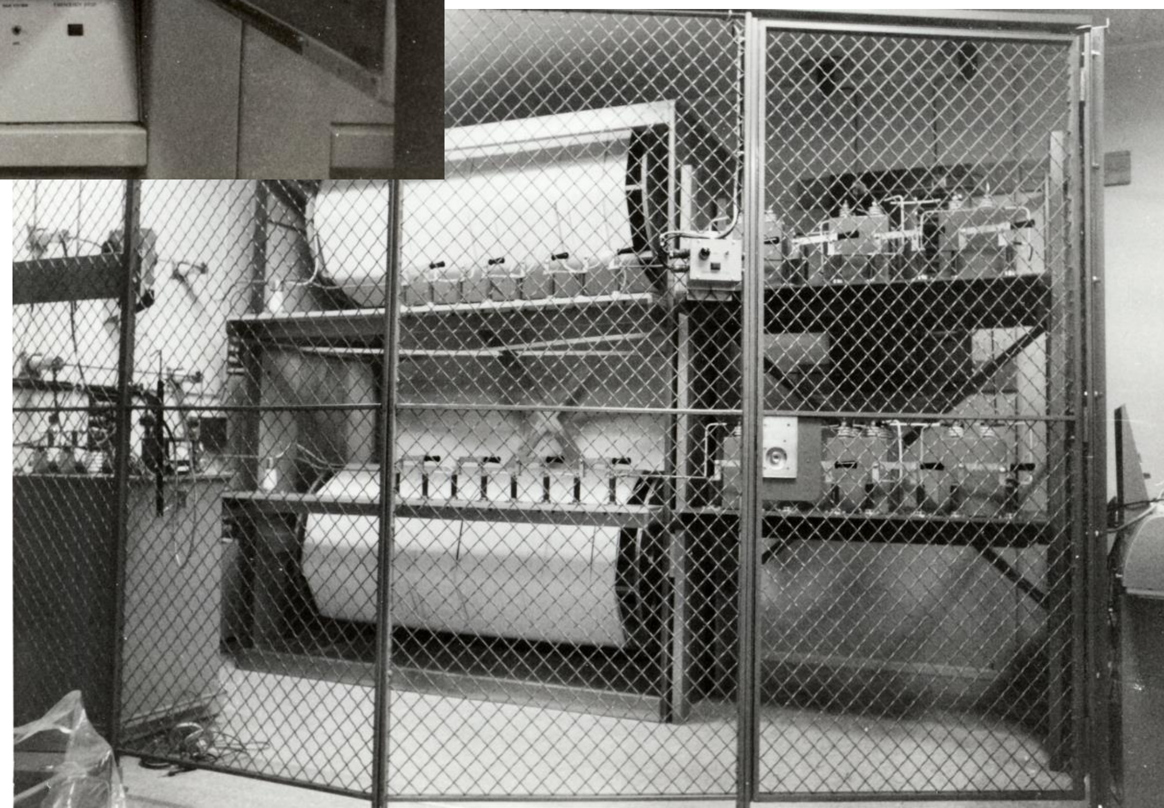













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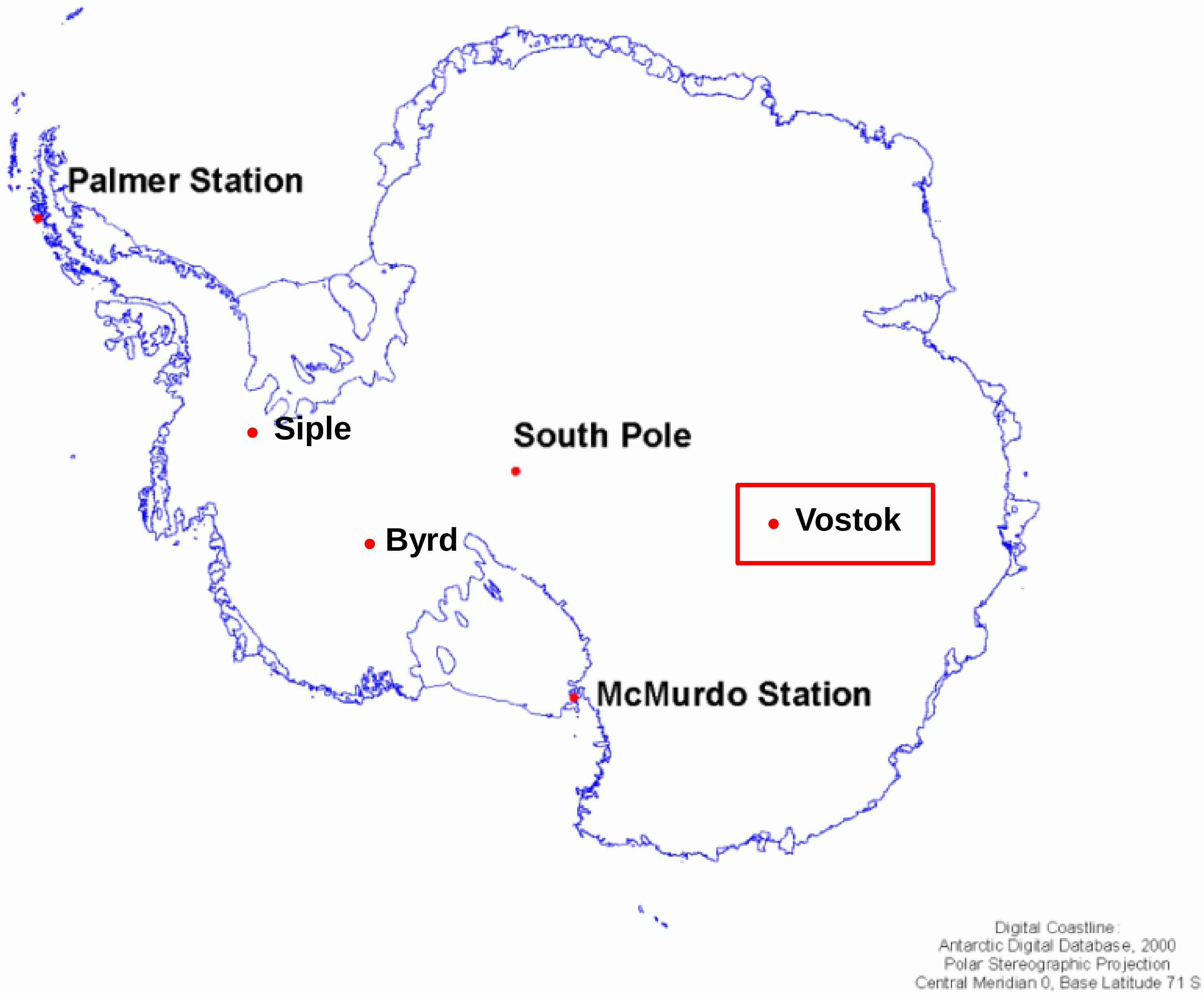
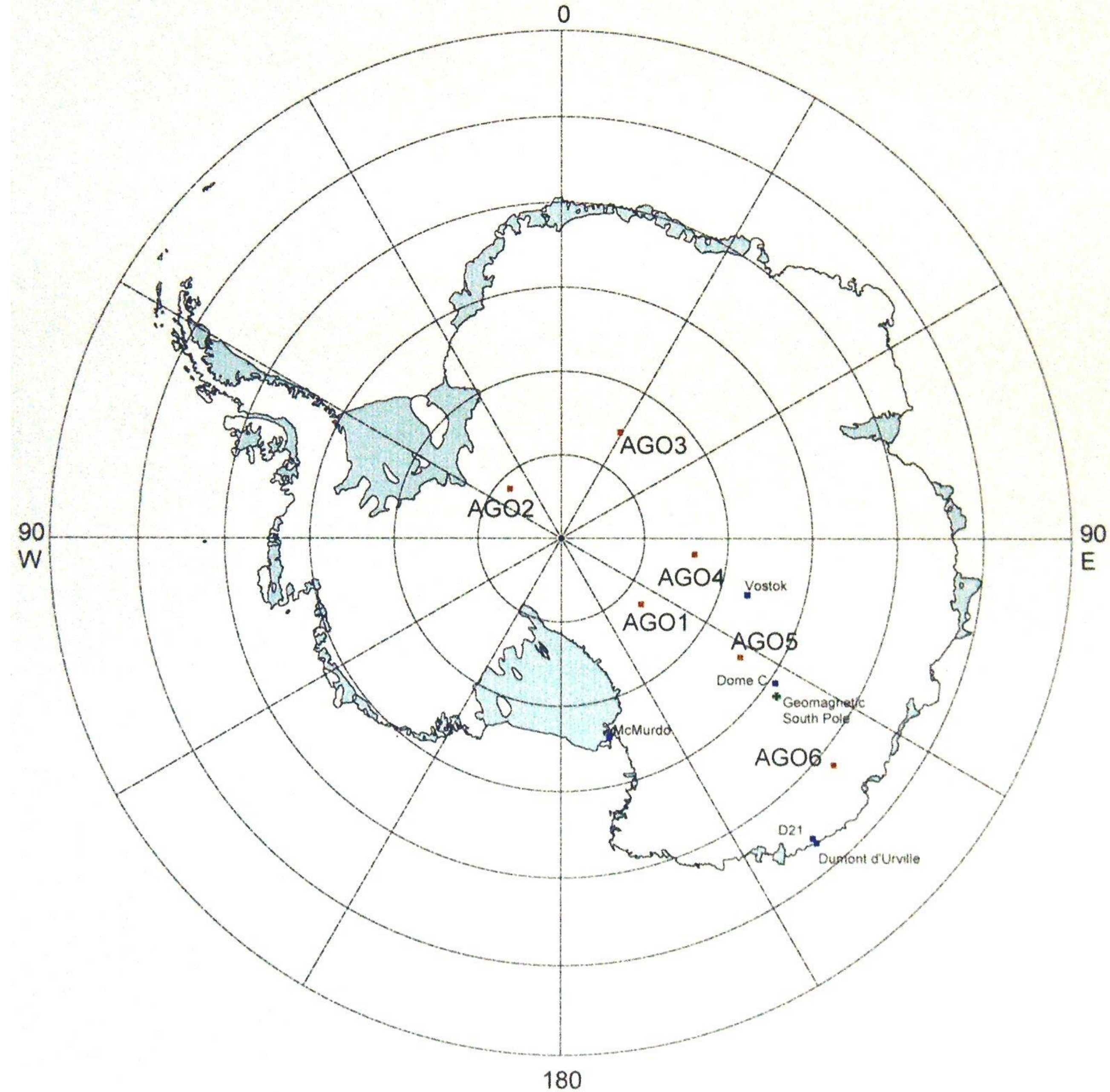


Palmer Station
Siple
South Pole
Vostok
Byrd
McMurdo Station
Digital Coastline:
Antarctic Digital Database, 2000
Polar Stereographic Projection
Central Meridian 0, Base Latitude 71 S


USSR-USA hut
SKILSAW


# AGO and Related Sites

(1995-1996)

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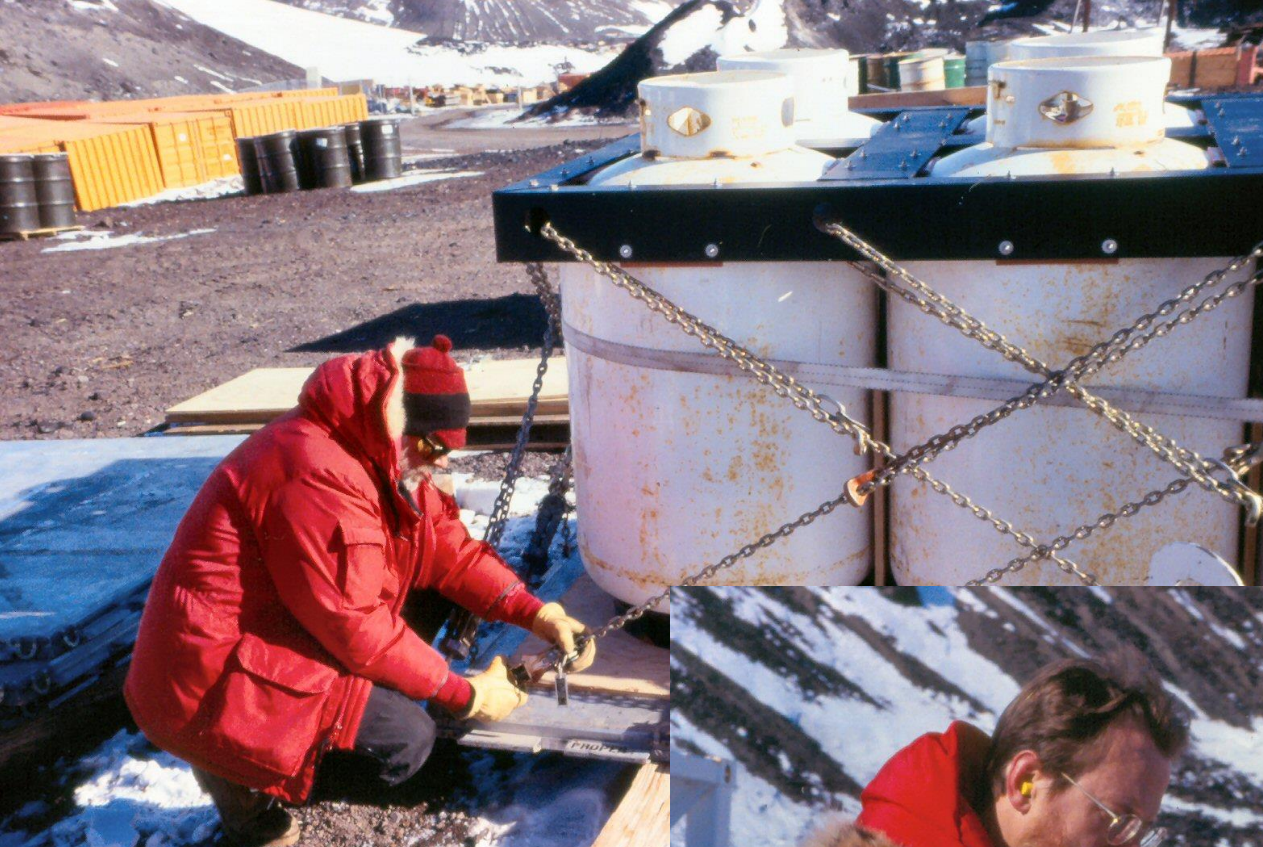


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VXE-6
UNITED STATES OF AMERICA

VXE-6


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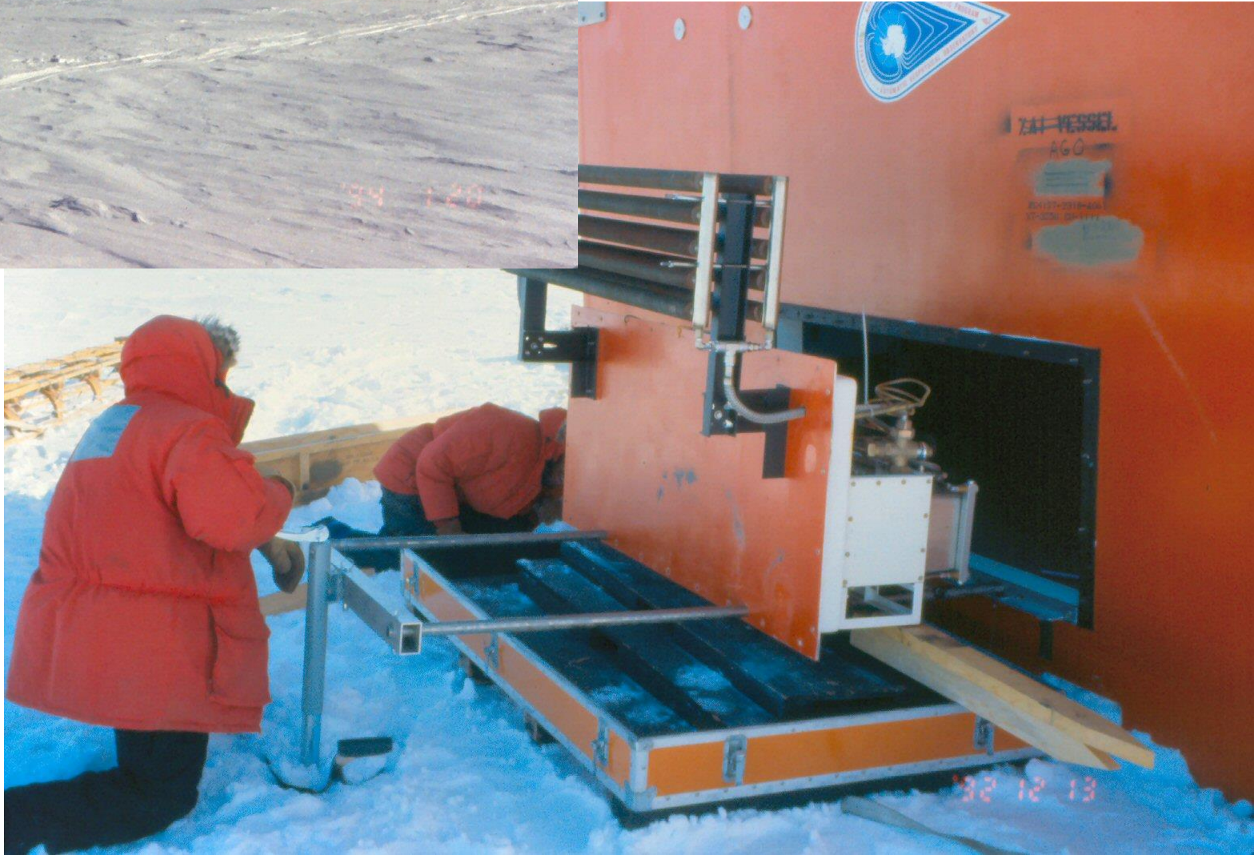
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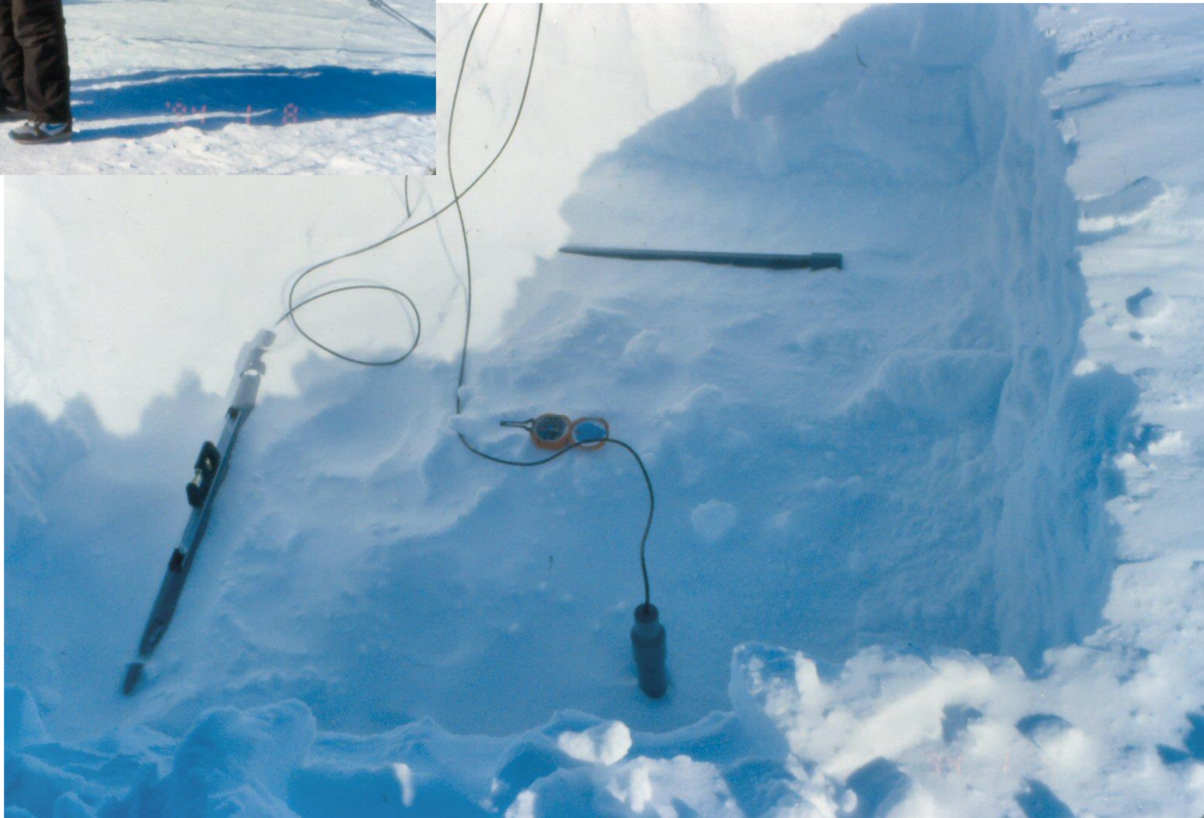
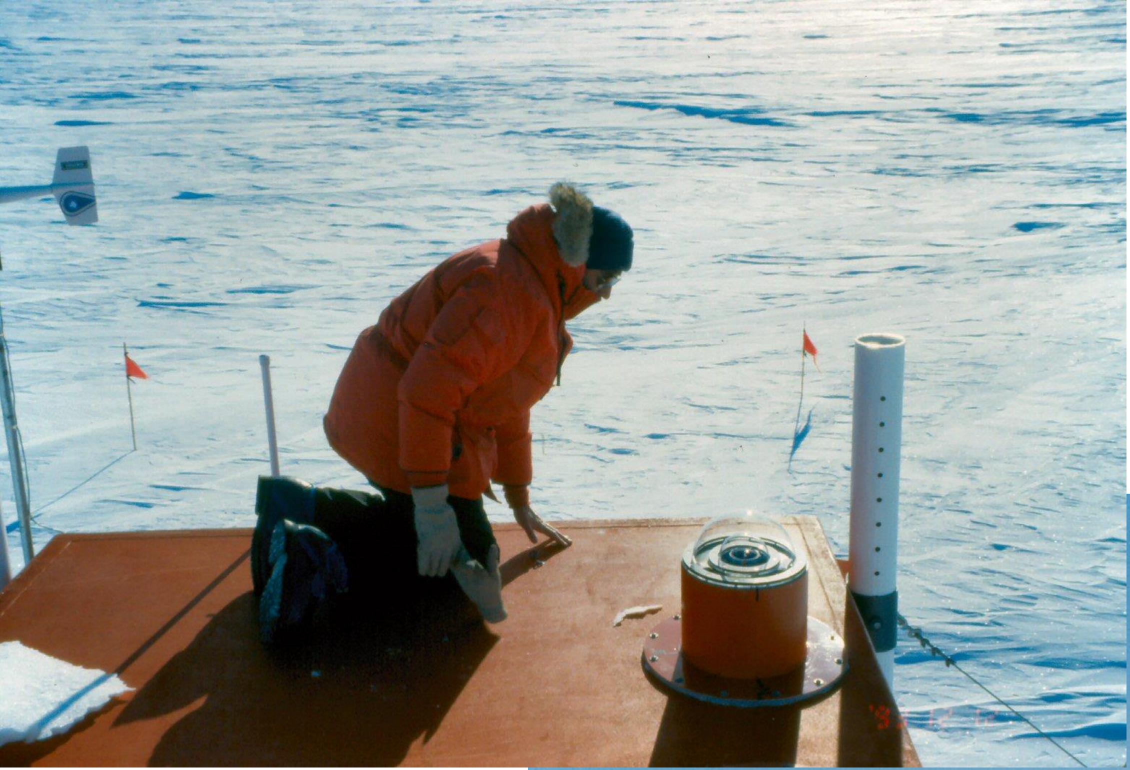
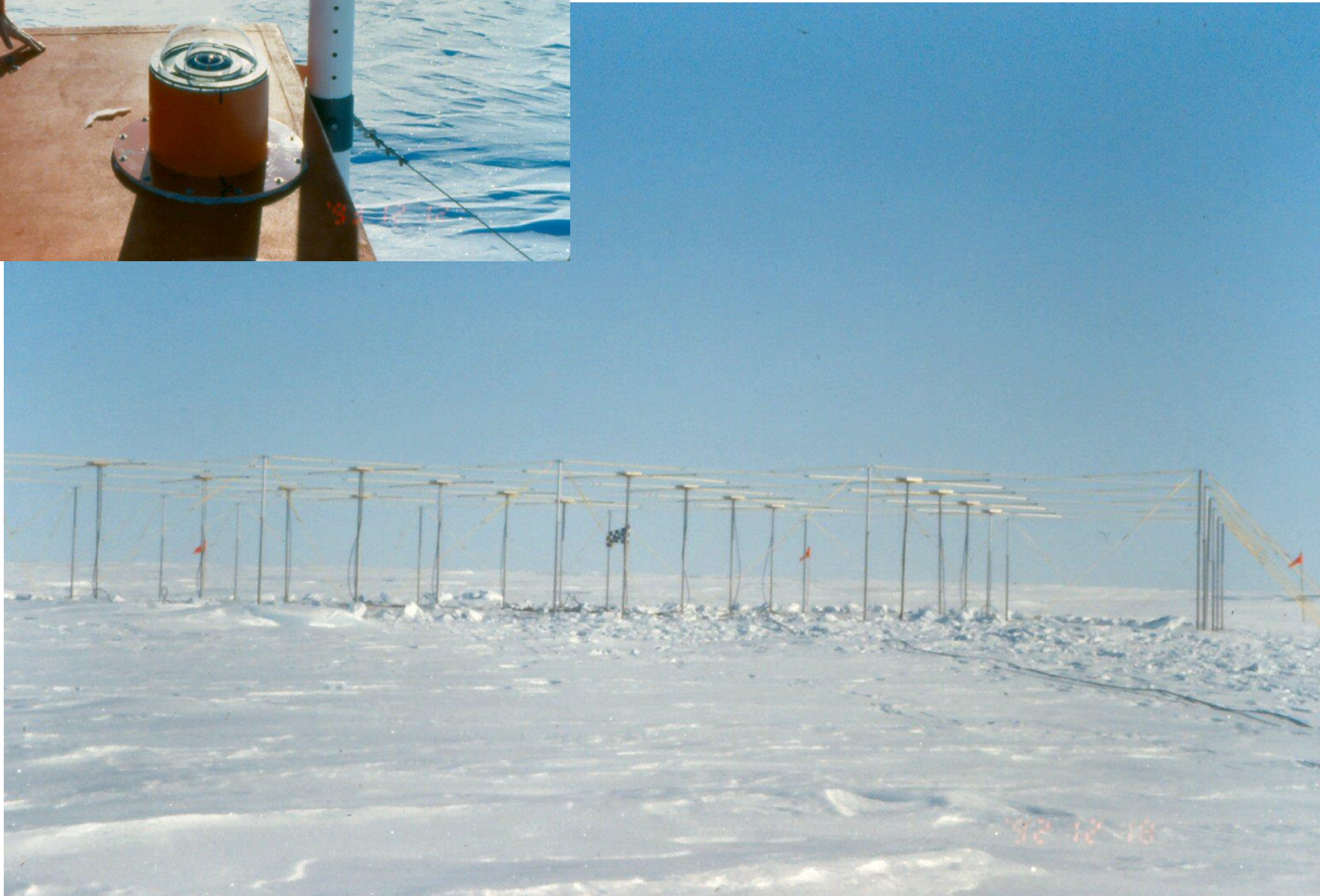
BFC



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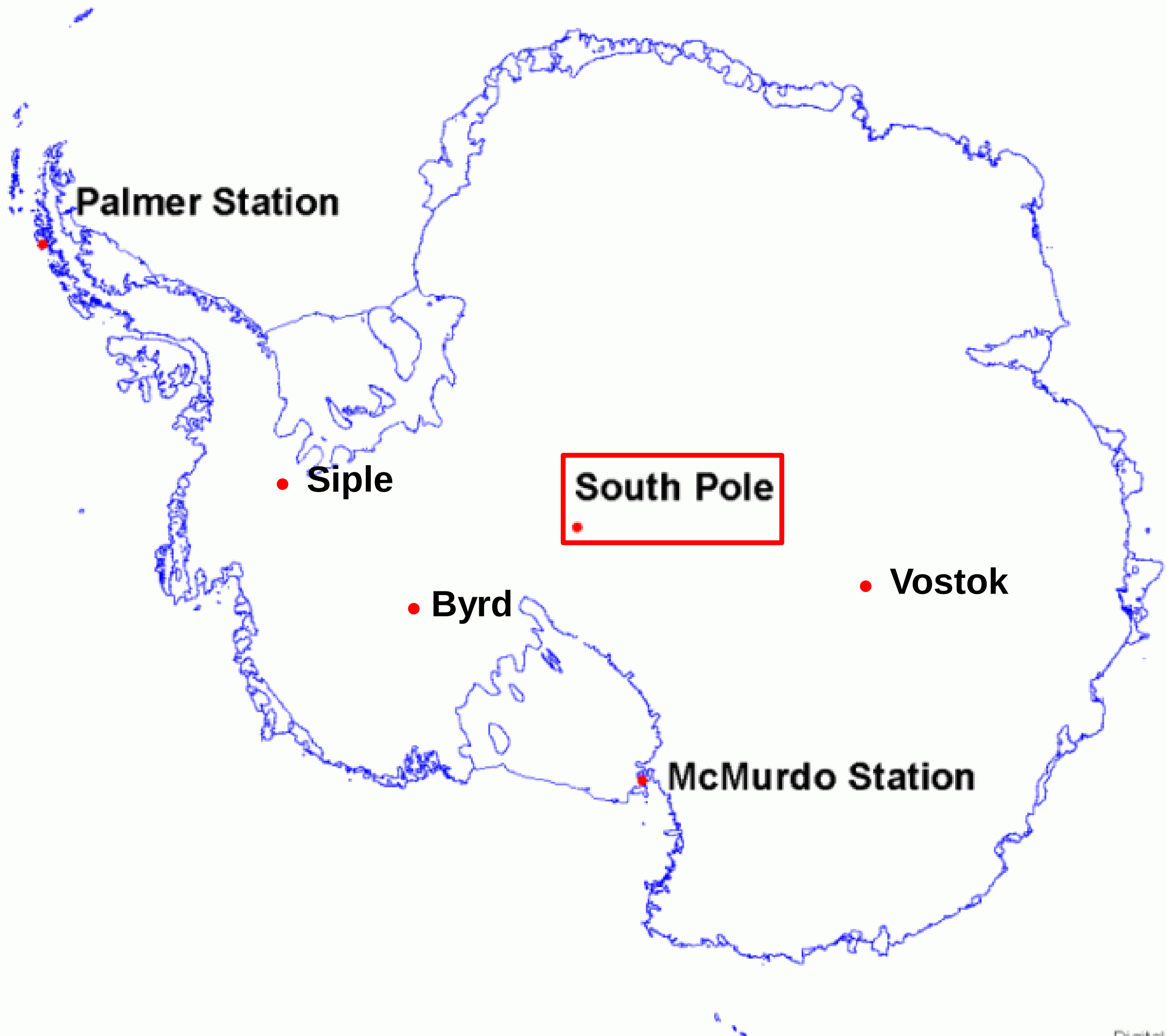
# Antarctica

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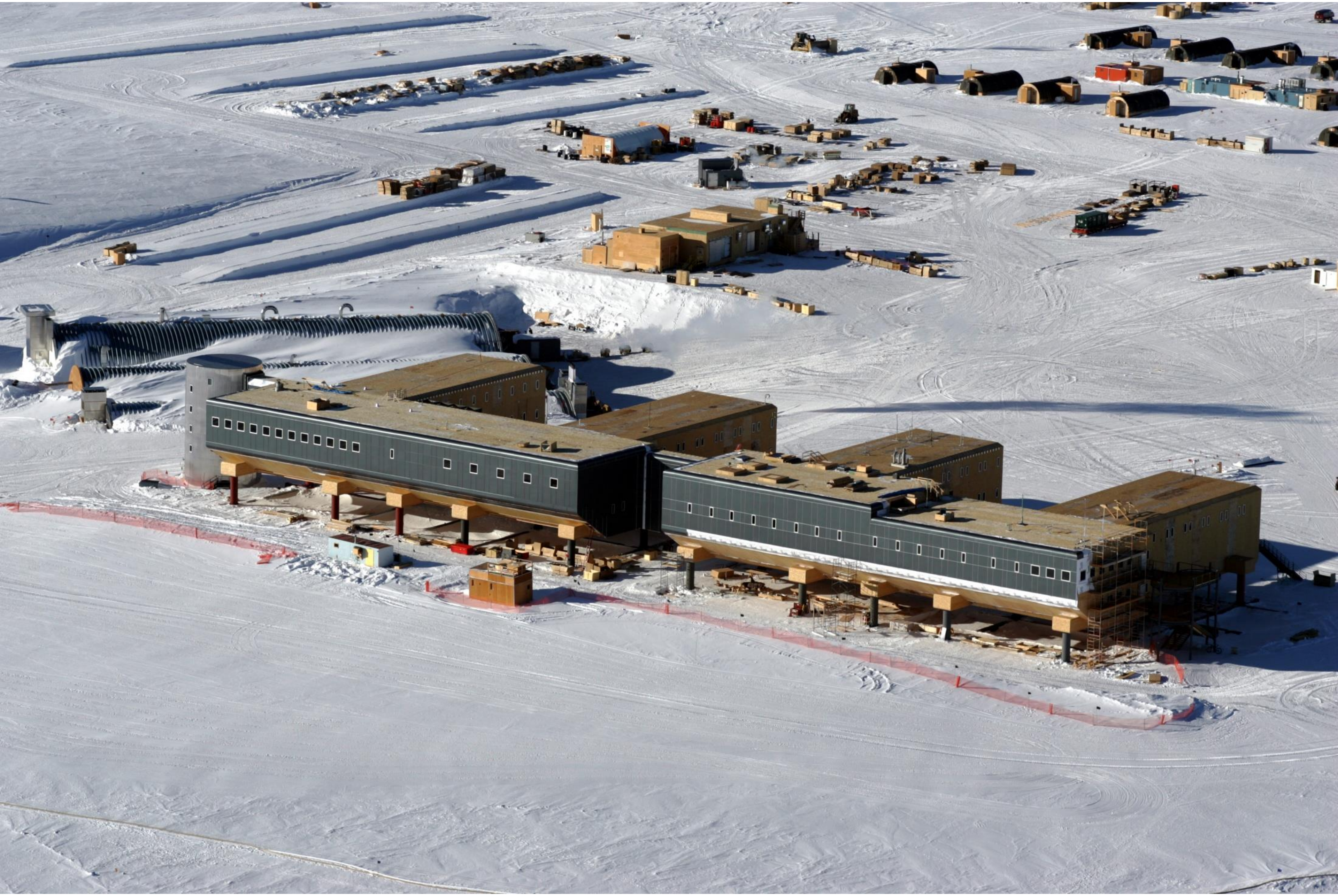
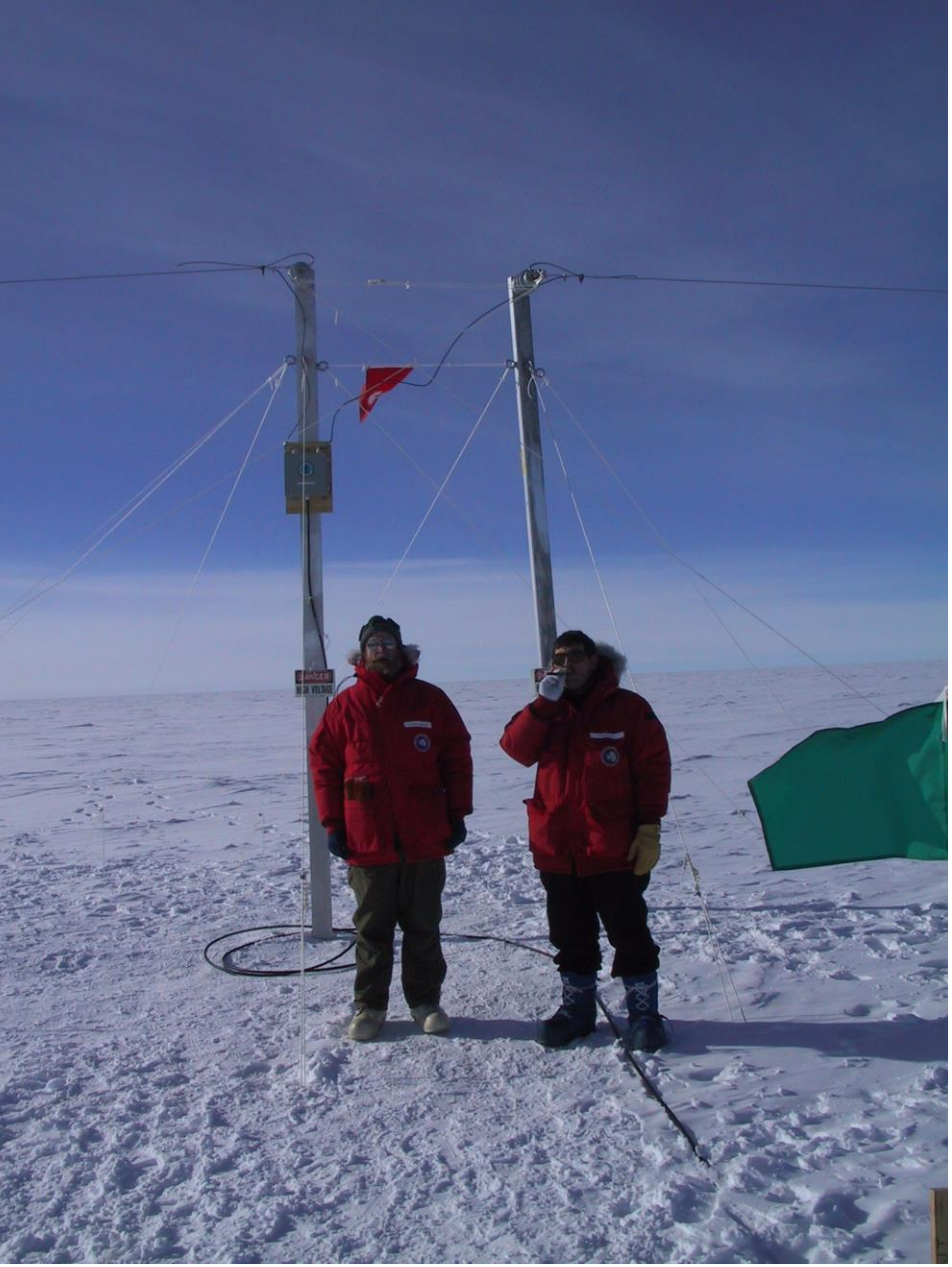


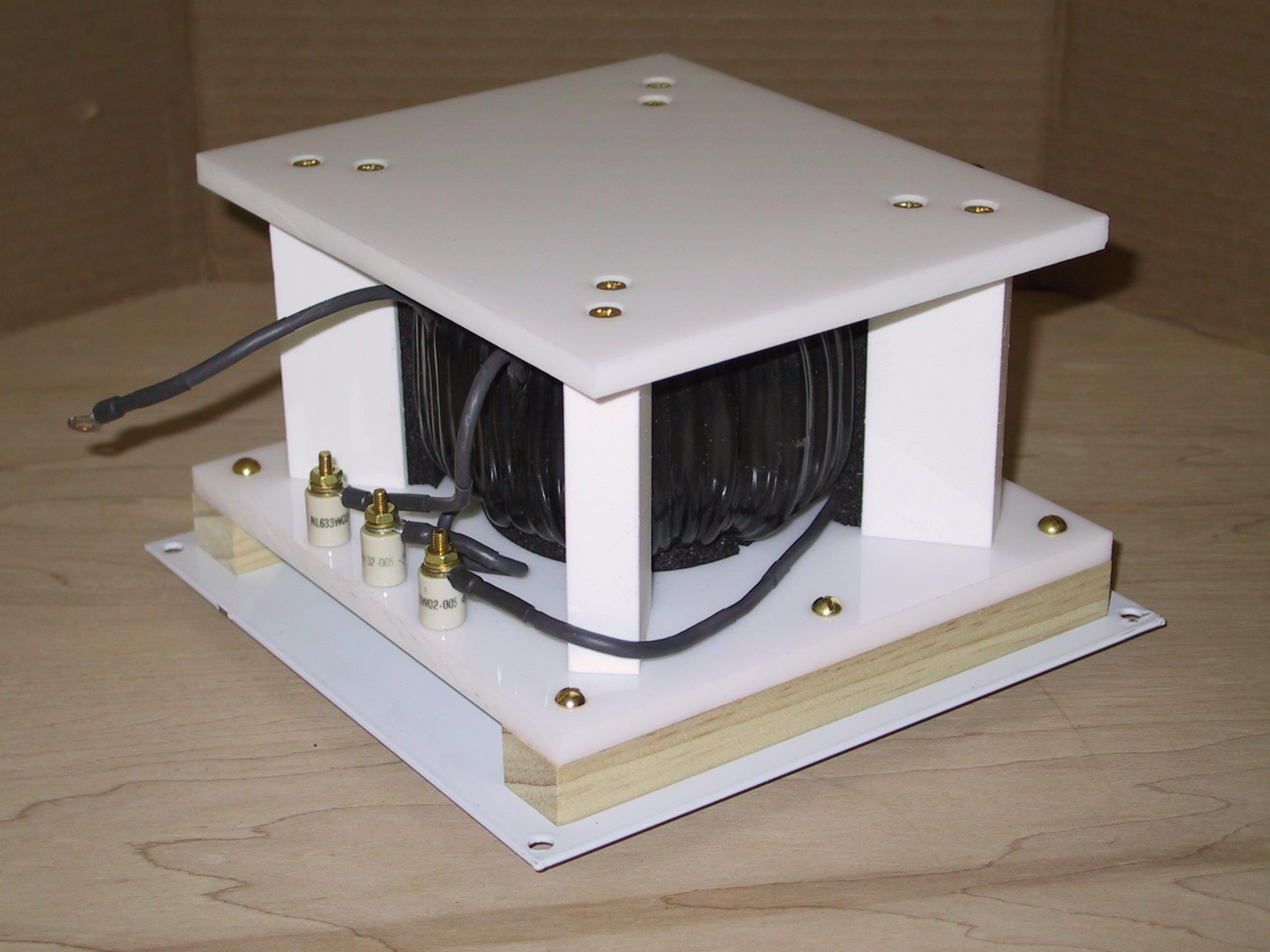

GEOGRAPHIC
SOUTH POLE
ROALD AMUNDSEN
DECEMBER 14, 1911
"So we arrived and were able to plant our flag at the geographical South Pole."
ROBERT F. SCOTT
JANUARY 17, 1912
"The Pole. Yes, but under very different circumstances from those expected."
ELEVATION 9,301 FT.
Toyoda Sushi


DANGER
HIGH VOLTAGE


I KAN
108


model 1500A amplifier
Industrial Test Equipment Co., Inc.
Port Washington, NY
OVERTEMP
POWER ON
A.C.
VOLTS
Input Level
Signal Input

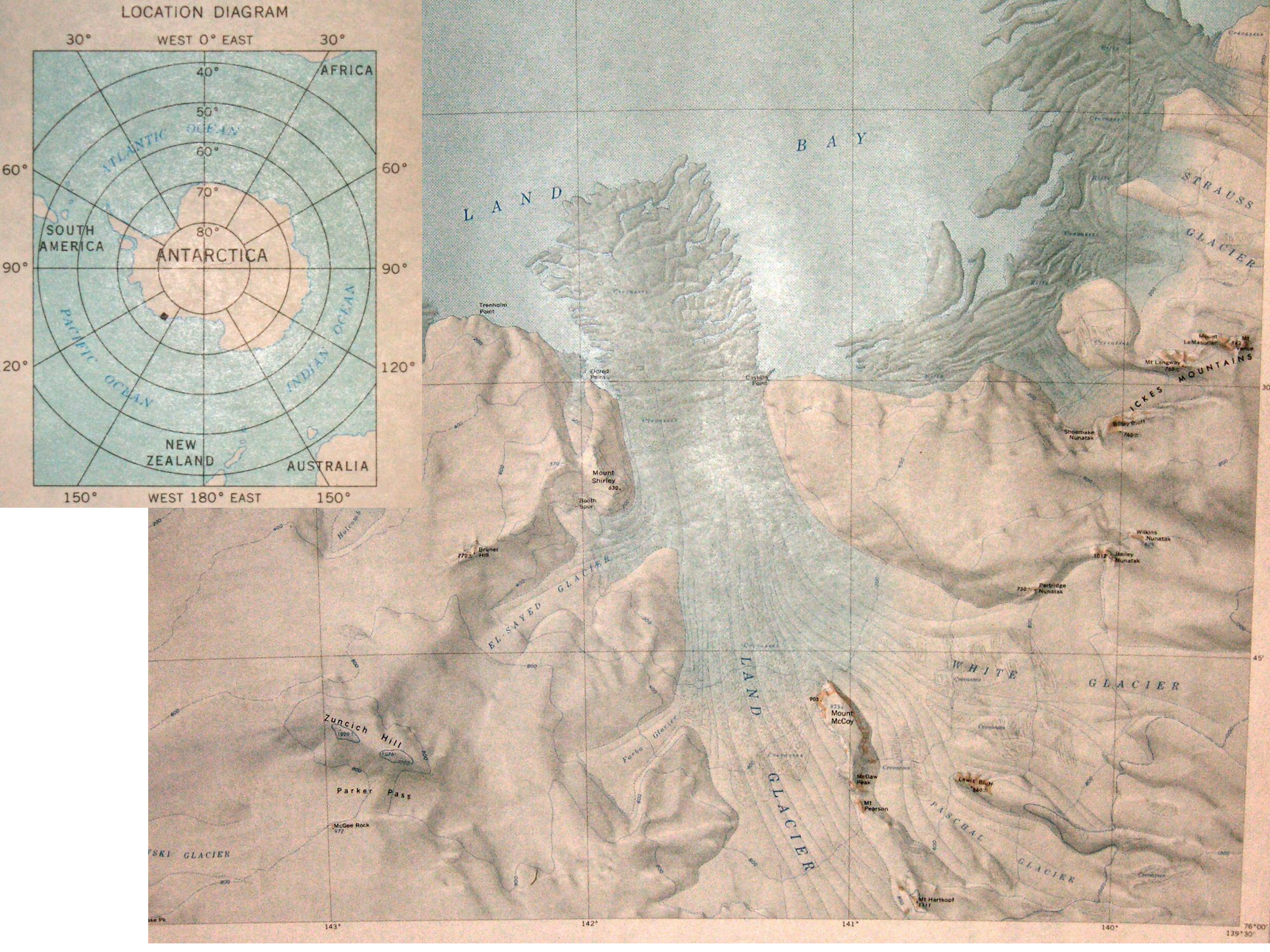

INVERTER 1
DR Series Power Inverter/Charger
Trace
BATTERY 1
DC Disconnect / Overcurrent Module
INVERTER 1 OUTPUT
CIRCUIT 1 CIRCUIT 2
INVERTER 3
BATTERY 3
POWER TO INVERTERS
KIRKLAND
STARTING / DEEP CYCLE
Marine • RV




Central Brass


OUTPUT PANEL
AMPLIFIER 5
AMPLIFIER 4


DR Series Power Inverter/Charger
Trace
DC Disconnect / Overcurrent Module
BATTERY 1


LOCATION DIAGRAM
30°
WEST 0° EAST
30°
40°
AFRICA
50°
ATLANTIC OCEAN
60°
60°
60°
70°
SOUTH AMERICA
80°
ANTARCTICA
90°
90°
PACIFIC OCEAN
INDIAN OCEAN
120°
120°
NEW ZEALAND
AUSTRALIA
150°
WEST 180° EAST
150°
LAND
BAY
STRAUSS
GLACIER
Trenholm Point
Mount LeMasurier
Mt Vance
Mt Longway
ICKES MOUNTAINS
Shoemake Nunatak
Billey Bluff
Mount Shirley
Booth Spur
Bruner Hill
Wilkins Nunatak
Bailey Nunatak
Partridge Nunatak
EL-SAYED GLACIER
WHITE
GLACIER
Zuncich Hill
Parker Pass
McGee Rock
Mount McCoy
LAND
GLACIER
McGaw Peak
Mt Pearson
Lewis Bluff
PASCHAL
GLACIER
Mt Hartkopf
SKI GLACIER
143°
142°
141°
140°
45'
76°00'
139°30'