Data Crunching in the International Geophysical Year (1957-1958)

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IM2025 *Slide Rules and Other Historic Computing Instruments*

Massachusetts Institute of Technology

October 25, 2025

What was the IGY?

- A scientific success with international funding;
- New discoveries and proof of cooperation amid conflicts
- A political and social artifact of its times—Cold War tensions never far away (US/USSR; PRC/ROC; Antarctic)
- An oasis of optimism for humankind
- Today's topic—a turning point for gathering, preserving, and ***calculating with big data***

Origins

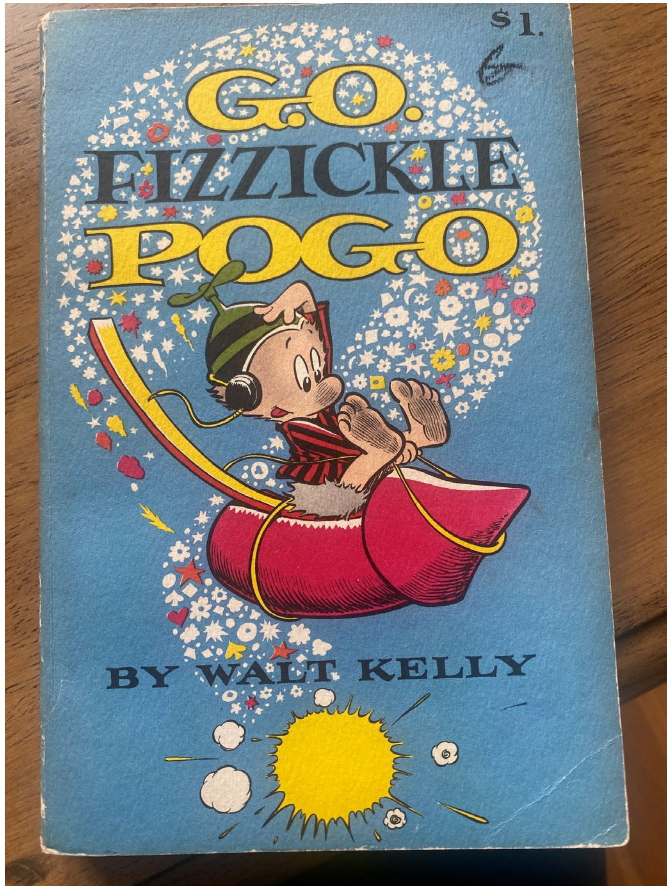
- Francis Bacon "experiments in concert," European and maritime weather data, 1761 and 1769 transits of Venus, magnetism studies
- First International Polar Year (1882-3) rings of Arctic/Antarctic stations, despite Ellesmere disaster; helped to debug undersea cables. 20 volumes published
- Second International Polar Year (1932-3) delineated multiple ion layers explaining short-wave radio wave propagation; data suspended and lost in WWII
- Fabled 1950 Maryland Van Allen dinner: Berkman and Chapman propose a Third Polar Year
- July 1957-December 1958 high sunspot intensity
- Proposal works way through ICSU; becomes IGY; CSAGI formed at Uccles, Belgium
- USSR joins; PRC objects to ROC; 67 countries, 60,000 scientists, countless others

Rollout

- “History’s greatest science research project…”
- “Single most significant peaceful activity of mankind since the Renaissance and the Copernican Revolution”
- “For the first time the peoples of the earth have joined to study their common and fundamental scientific problems together” (UNESCO)

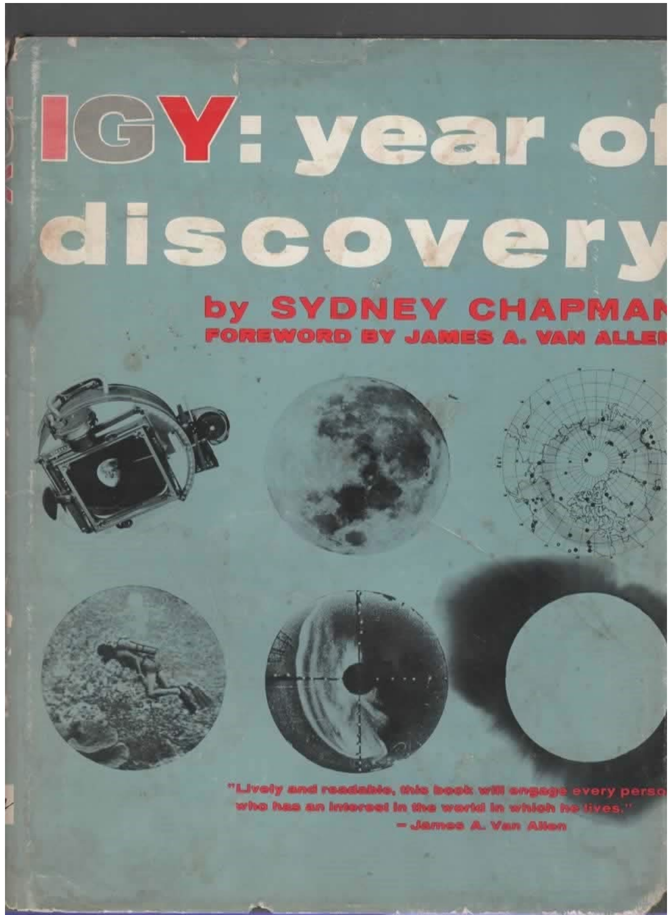
IGY in popular culture

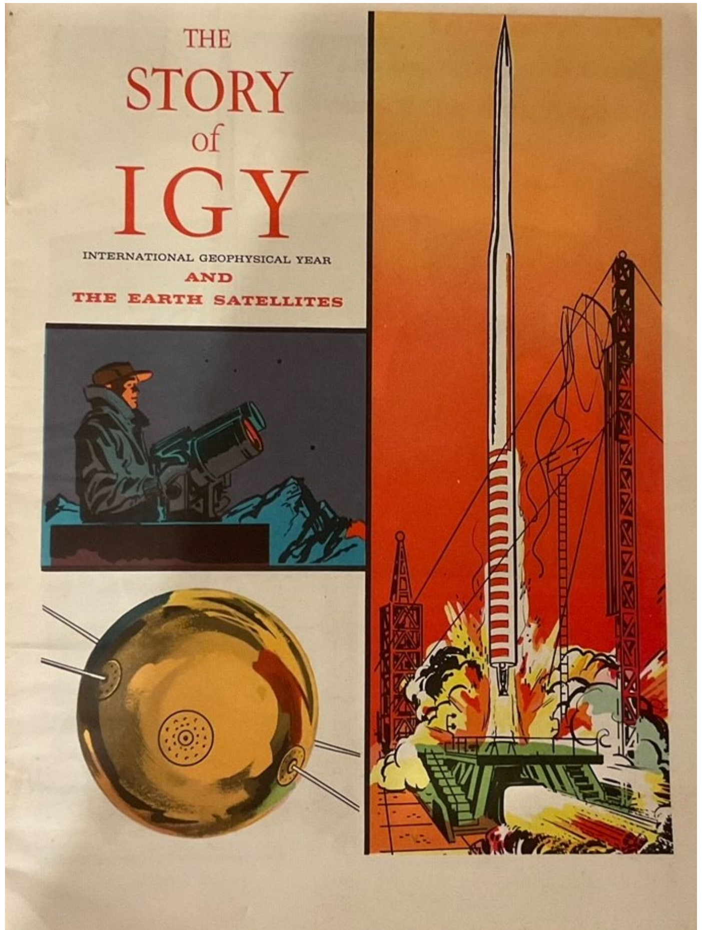
- Walt Kelly, *G.O. Fizzicle Pogo* (1958): the sardonic swamp critters ponder an 18-month "year," shooting men to the moon, and nuclear war

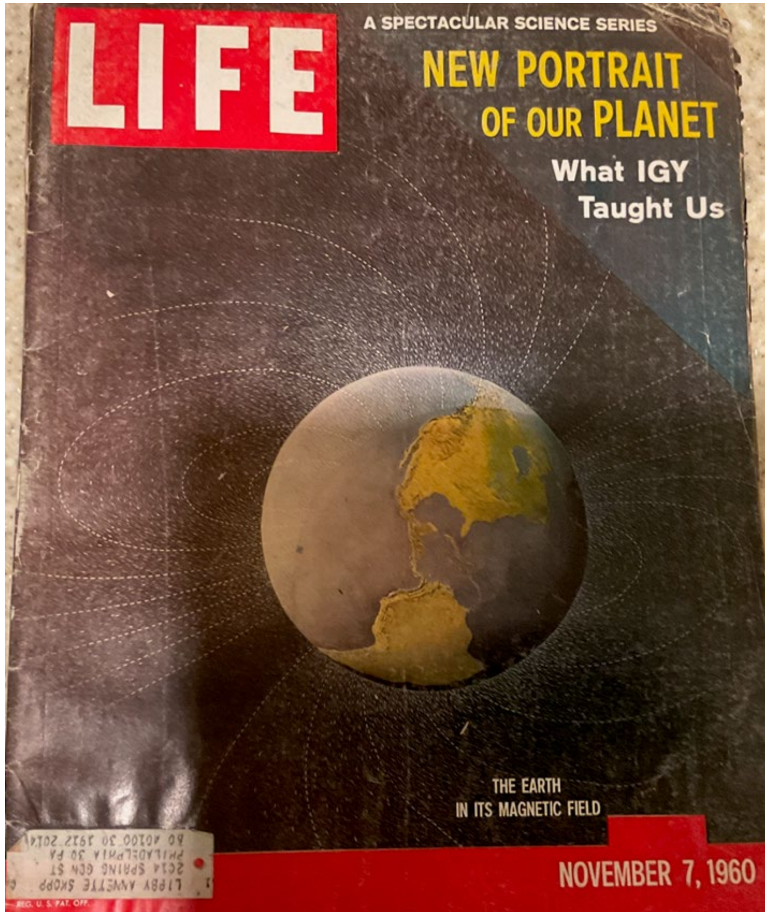


IGY in popular culture

- Many popular books and articles

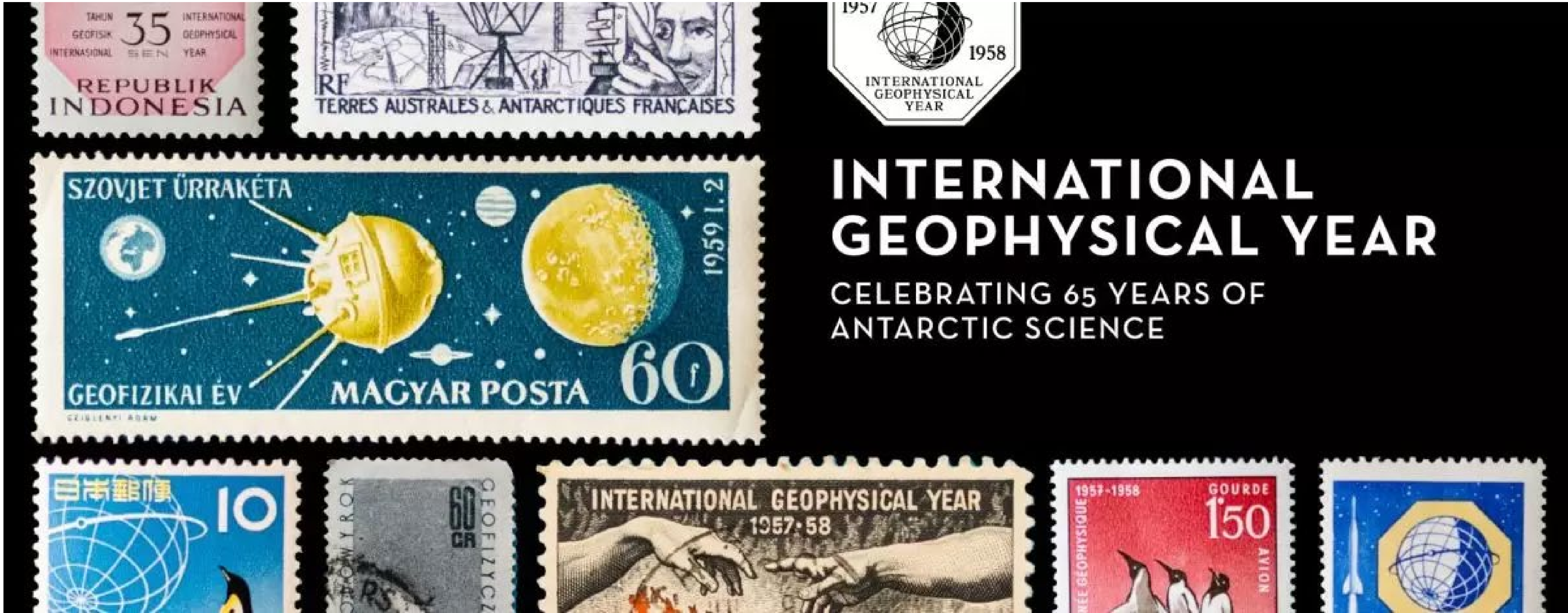






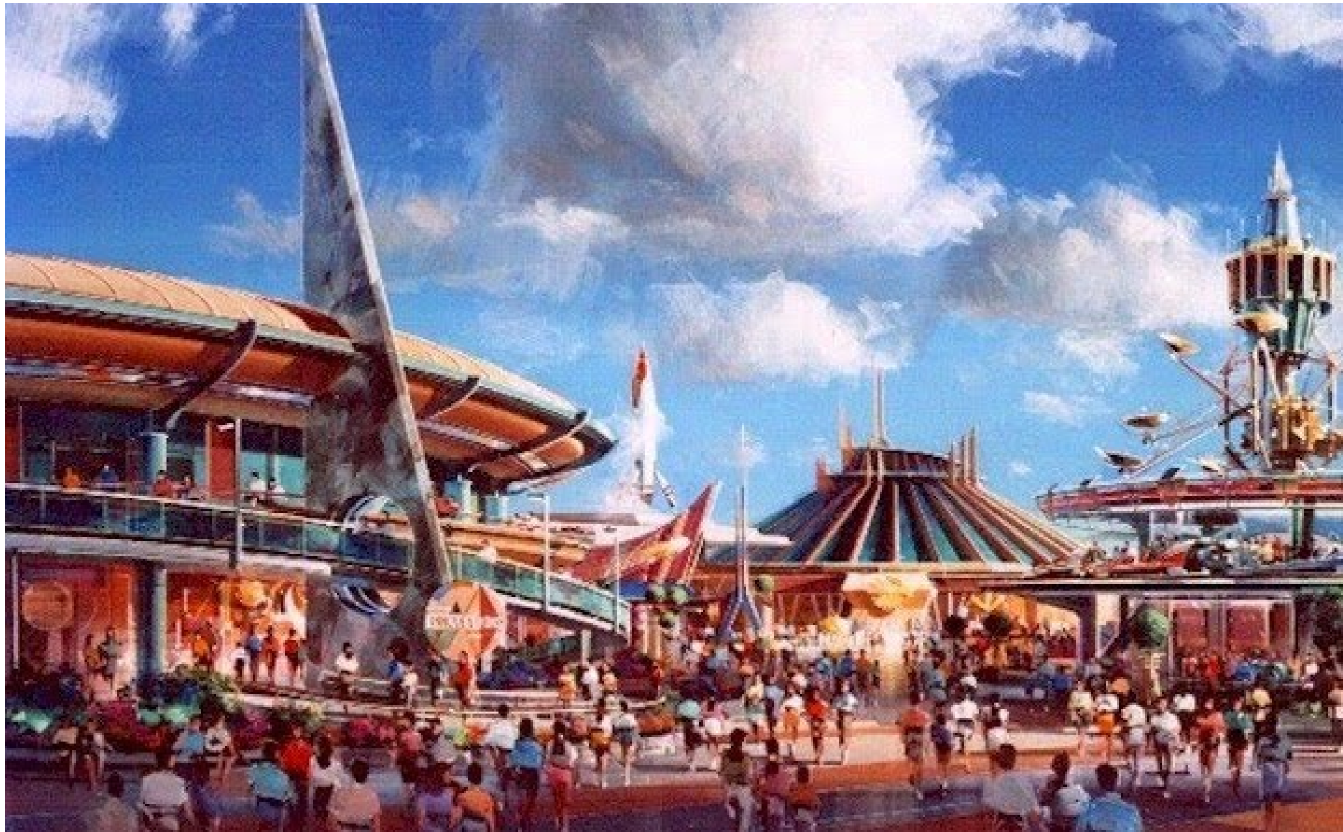
IGY in popular culture

- A philatelist's dream



IGY in popular culture

- Disney, 1964 World's Fair, Tomorrowland



IGY in popular culture

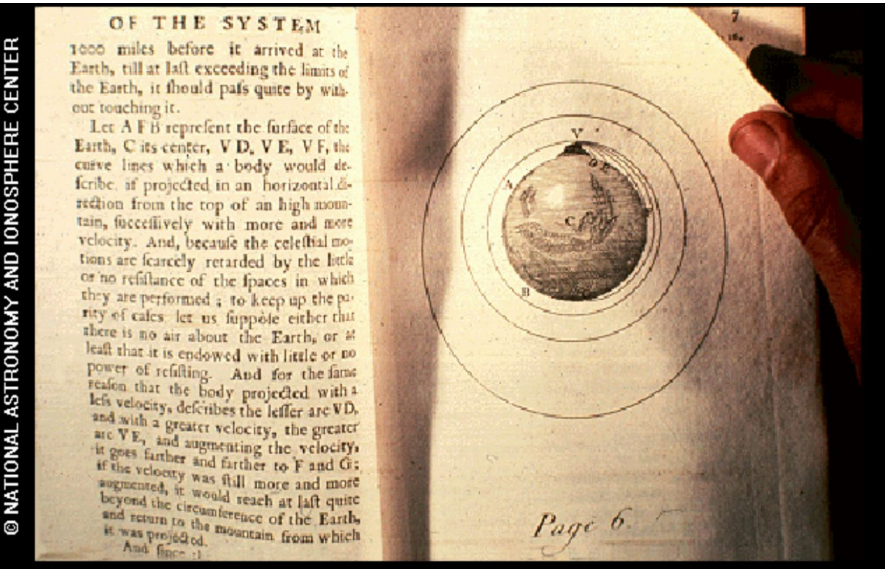
- Donald Fagen, *I.G.Y.* (1982)

    A just machine to make key decisions
    Programmed by fellows with compassion and vision

IGY objectives

- Focus on synoptic observations in real time;
  global meteorology v. local historical geology
- Data exchange fixed 1957. Three World Data Centres:
  A (US), B (USSR), C (Europe & Japan), weather in Geneva
- 14 divisions: atmosphere, oceans, earth, sun
- Will focus today on satellites, ionosphere, and the Antarctic

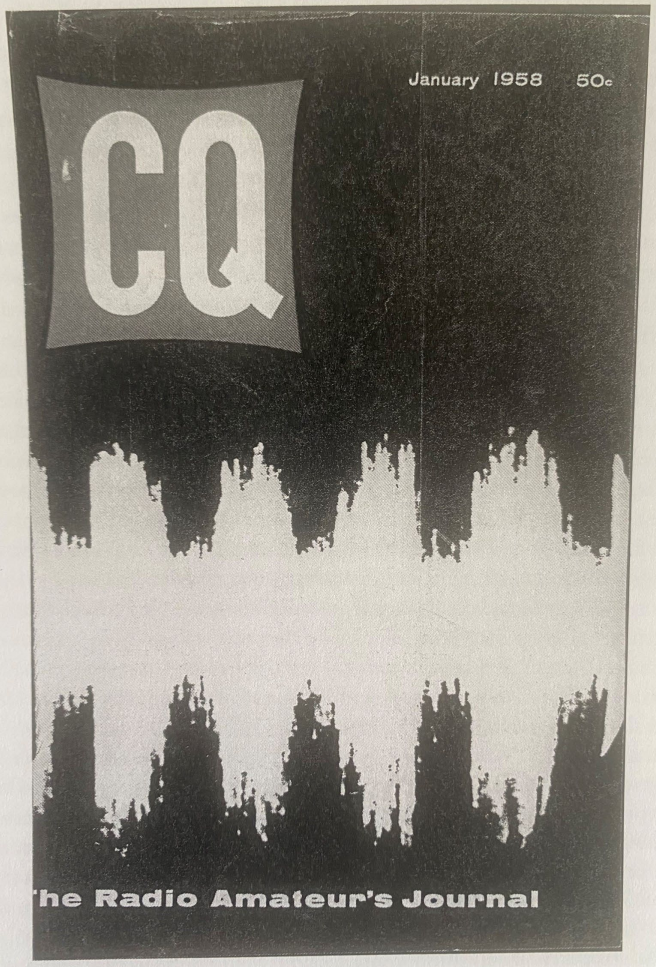
October 4, 1957



Veronica della Dora

From the Radio Shack to the

…e 2. Sputnik confirmation (QSL) card sent to the listeners of the satellite, 1957. Court…



…ure 3. Graphic rendering of Sputnik's signal on the cover of the popular *CQ* ham radio

The road to Sputnik

- “Endlessly falling object” concept known since Newton; rocketry advanced by Tsiolkovsky, Goddard & Oberth
- “V is for vengeance”—3600 von Braun V-2s rained down on London and Antwerp
- Both US and USSR known to be active since 1940s—twin 1955 reports; July 1957 Russian notice to ham operators
- US riven by military vs. civilian dilemma and military vs. military rivalries

The reaction to Sputnik

FINAL

DAILY NEWS

NEW YORK'S PICTURE NEWSPAPER ®

5¢

Vol. 39. No. 88 New York 17, N.Y., Saturday, October 5, 1957

SIGHT RED BABY MOON OVER U.S.

Cambridge, Mass., Oct. 4 (UP)—The Russian satellite was seen for the first time in the U. S. tonight at Columbus, Ohio, where Larry Ochs, manning a Moonwatch observation station, reported sighting a steady light that crossed his telescope. It definitely was not a meteor, he said.

Ochs, stationed at one of the 150 Moonwatch observatories set up throughout the world, told the Smithsonian Astrophysical Observatory here that he first noticed the light at 11:28 P. M. It was traveling from west to east. Ninety-five minutes later it was sighted again.

Also Seen in Indiana

At Terre Haute, Ind., farther west, another watcher, Nunn Addaldo, reported sighting the satellite at approximately the same time.

Meanwhile, American scientists disagreed on whether the satellite, which circles the globe every 95 minutes will be visible in the U. S. to the casual observer, but all agreed that if it is, the best viewing time will be at dawn and dusk.

Dr. Fred L. Whipple, director of the Smithsonian observatory, said Americans might be able to see the satellite at twilight hours, but Prof. W. J. Luyten of the University of Minnesota said viewing the sphere would be "extremely difficult if not impossible."

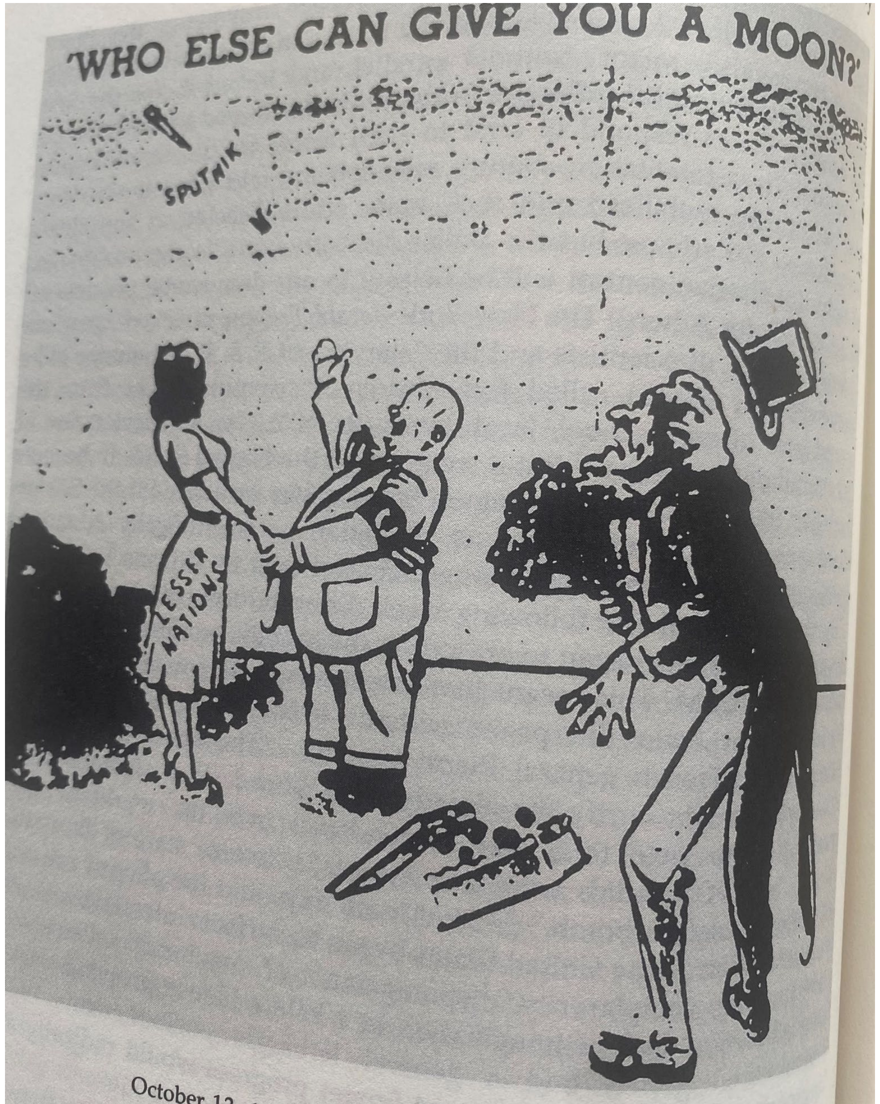
Astronomer J. Allen Hynek and his staff prepared to receive at the Smithsonian observatory reports from the specially equipped observation points around the world.

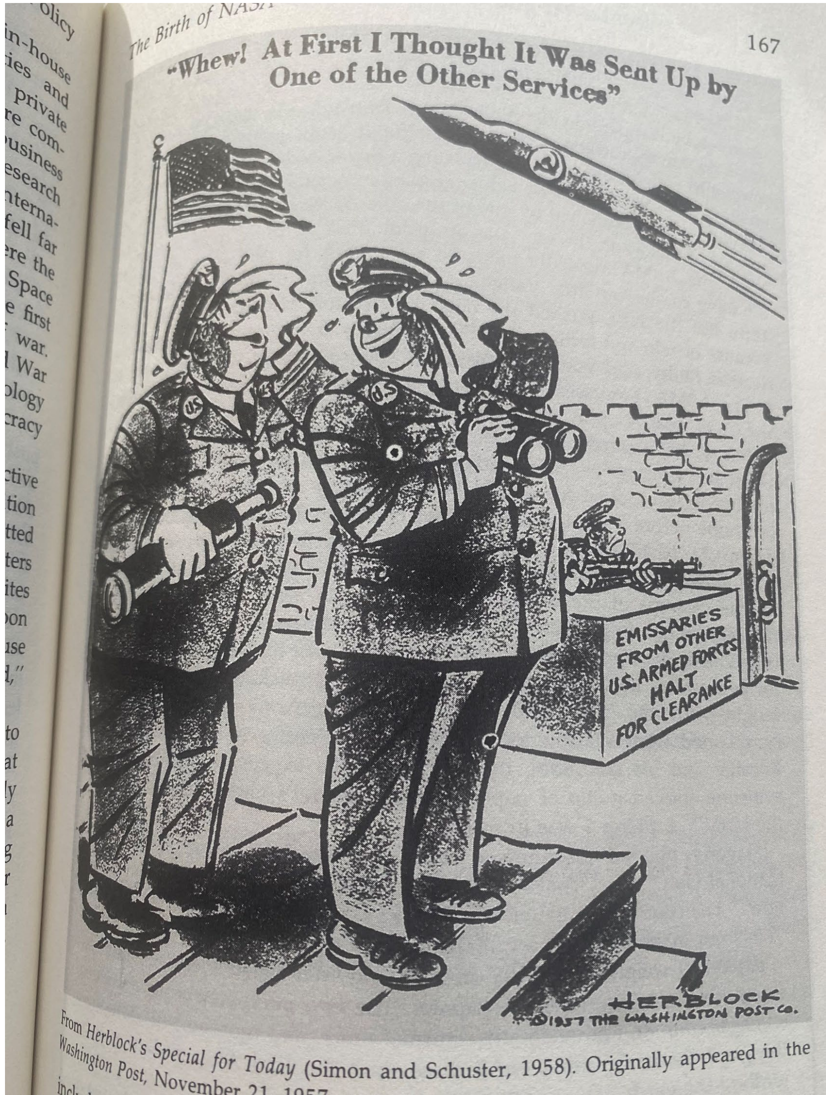
More than 40 Operation Moonwatch observatories west of the Mississippi River were activated first because they were the nearest U. S. stations in the band of twilight.

If the moon is in a north-south orbit—as the Russians once said they planned—it will pass over various points in the U. S. because the earth will be rotating under the satellite from west to east.

Moscow Moon—around the world in 95 minutes

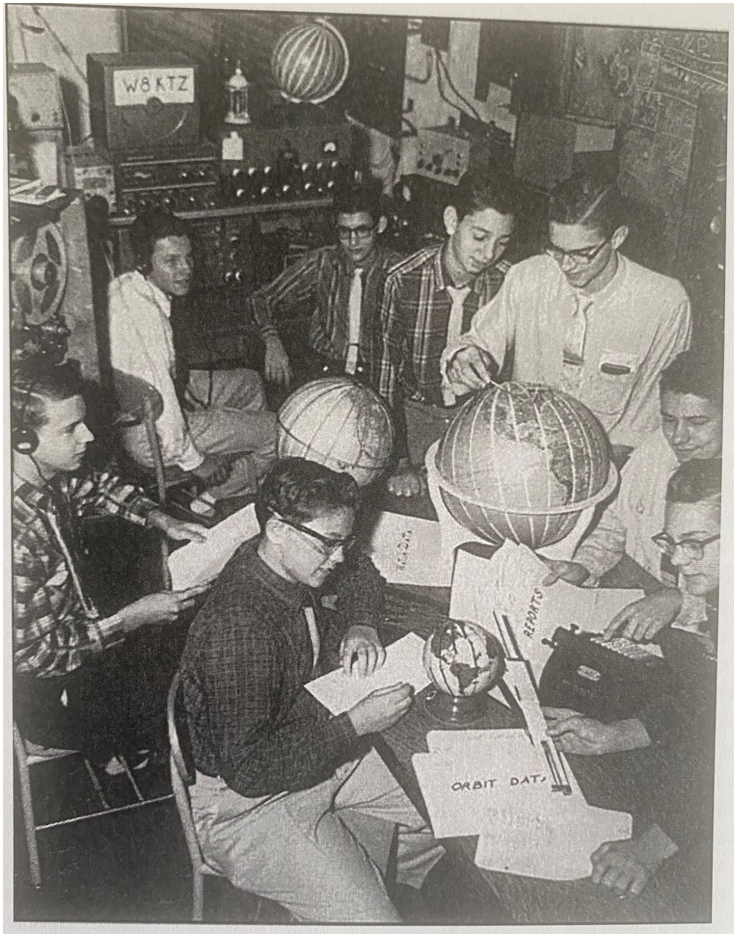
The reaction to Sputnik





The reaction to Sputnik

Figure 5. The American amateur radio operator Dick Oberholtzer and his wife listening to Sputnik I's radio signals. From *Life*, October 1957. Francis Miller, The LIFE Picture Collection Shutterstock. Used by permission.



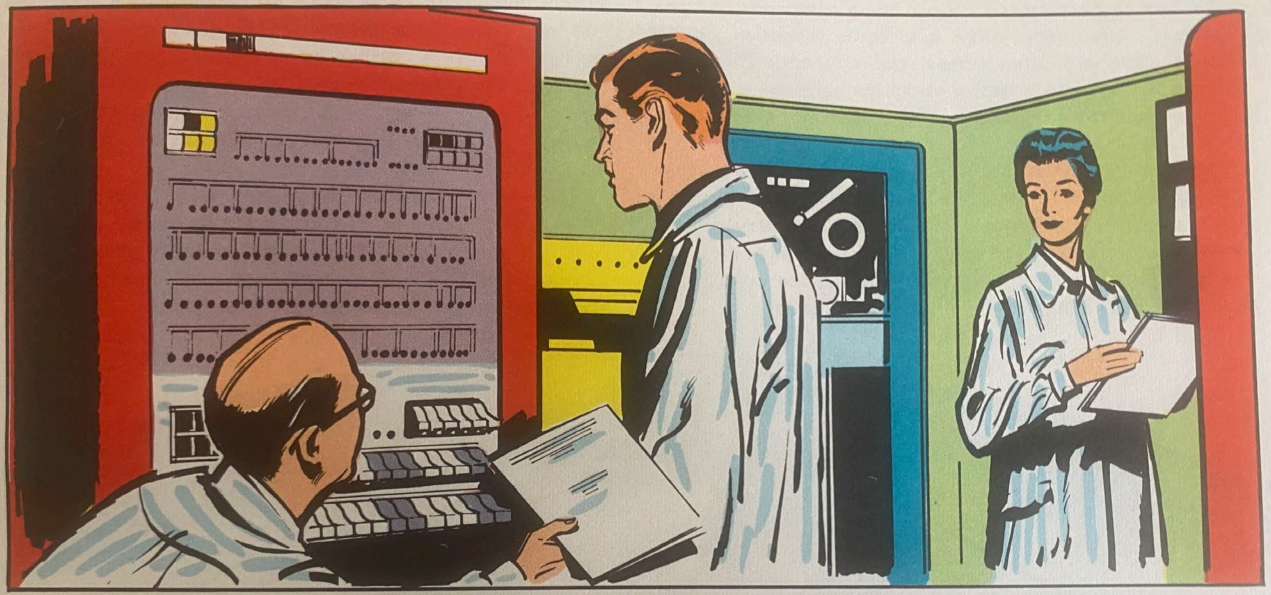
. Students of the St. Joseph High School radio club as they track Sputnik's orbit. Used by
on of *CQ Magazine*.

Satellites and data

- 20/40 MHz versus 108 MHz—heard by many worldwide
- November 3—*Sputnik 2* and Laika
- Vanguard failures, Explorer successes, and Van Allen belts
- Calculate Sputnik weight from implied air resistance
- Calculate time and manner of Sputnik disintegration from change in WWV signal strength

Sputniks and data

- Computers were remote and input was slow
- Irregular orbits, so need to recalibrate as often as every passing



All observations must be sent immediately to Washington, because it is on the basis of this information that the precise path of the satellite on its next trip around the earth is predicted. The satellite path is never twice the same, since during its 90-minute round trip the earth itself will have rotated. This means that other observers must be alerted as each new trip begins, so that they do not miss the speedy, tiny sphere in its flight.

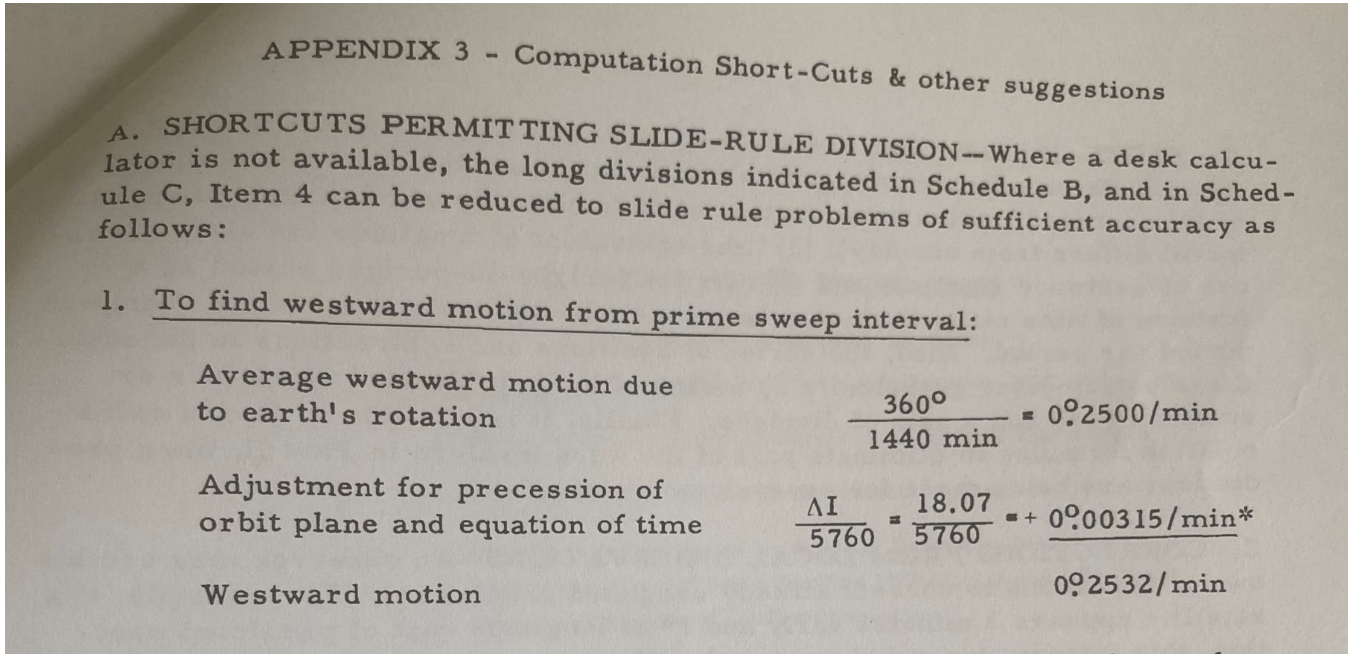
Large electronic computers are used to solve a huge number of mathematical problems within this short span of 90 minutes. These devices fill a room and require many highly trained people to operate them. The computers do the mathematical problems so quickly that there is enough time left to notify the next stations that the satellite is coming their way.

Sputniks and data

- Operation Moonwatch

Sputniks and data

- Specialty tables prepared, along with nautical and logs
- Slide rule vital for "close-enough" calculations at remote field locations



APPENDIX 3 - Computation Short-Cuts & other suggestions

A. SHORTCUTS PERMITTING SLIDE-RULE DIVISION--Where a desk calculator is not available, the long divisions indicated in Schedule B, and in Schedule C, Item 4 can be reduced to slide rule problems of sufficient accuracy as follows:

1. <u>To find westward motion from prime sweep interval:</u>

Average westward motion due to earth's rotation	$\frac{360^\circ}{1440\ \text{min}}$	= 0°.2500/min
Adjustment for precession of orbit plane and equation of time	$\frac{\Delta I}{5760} = \frac{18.07}{5760}$	= + 0°.00315/min*
Westward motion		0°.2532/min

A slide rule for a single frequency

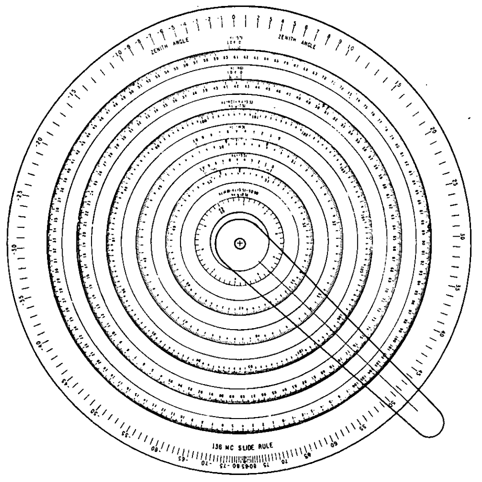


Figure 2-14.–Minitrack ambiguity resolver: 136-MHz circular slide rule.

RESETTING INSTRUCTIONS

NORTH—SOUTH

A. Lay cursor arm hairline along 0.5 on the drift scales.

B. Rotate 57 λ equatorial scale until NSF(E) K_c from new calibration lies under hairline. Mark an NS arrow on equatorial scale pointing to new NSF(E) K_{s1} on equatorial drift scale.

C. Repeat Step B for the 46 λ polar scale using new NSF(P) K_c and K_{s1}, the 4.0 λ ambiguity scale using new NSM K_c and K_{s1}, and the 3.5 λ ambiguity scale using new NSC K_c and K_{s1}.

EAST—WEST

Repeat Steps A, B, and C, using EWF(E), EWF(P), EWM, and EWC $K_{c'}$, and $K_{s1'}$.

AMBIGUITY RESOLUTION

NORTH—SOUTH

SETUP:

A. Rotate the 57 λ, 46 λ, 4.0 λ, and 3.5 λ annular rings until the NS arrow on each ring points to current K_{s2} value on corresponding drift scale.

B. Read $K_c(4.0)$ value below arrow on 4.0 λ ring. Add 50.00 to this value. Read $K_c(3.5)$ value below arrow on 3.5 λ ring. Subtract $K_c(3.5)$ from $K_c(4.0)$ + 50.00 to compute $K_c(0.5) = K_c(4.0) - K_c(3.5) + 50.00$. Rotate 0.5 λ ring so computed $K_c(0.5)$ lies under $K_c(0.5)$ arrow.

C. Use above values of $K_c(4.0)$ and $K_c(3.5)$ to compute $K_c(7.5) = K_c(4.0) + K_c(3.5)$. Rotate 7.5 λ ring until computed $K_c(7.5)$ lies under $K_c(7.5)$ arrow.

OPERATION:

A. Using outermost scale, rotate cursor arm to zenith angle given in prediction. Hairline on cursor arm should now be near proper 3.5 λ baseline and 4.0 λ baseline Minitrack NS readings on 3.5 λ and 4.0 λ rings.

If no prediction is given, take the 4.0 λ baseline Minitrack NS reading as 00.XXX and add 50.000 to this. Then subtract from this sum the 3.5 λ baseline Minitrack NS reading as 00.YYY to obtain the hypothetical 0.5 λ baseline Minitrack NS reading as 49.ZZZ or 50.ZZZ = (50.XXX – 00.YYY). When the hairline is rotated to this computed value on the 0.5 λ ring, it should then be near the proper 3.5 λ baseline and 4.0 λ baseline Minitrack NS readings on the 3.5 λ and 4.0 λ rings.

B. Adjust hairline to fall halfway between proper 3.5 λ and 4.0 λ ring readings. This step is the mechanical analog of mathematically adding the 3.5 λ baseline Minitrack reading to the 4.0 λ baseline Minitrack reading to obtain the proper reading for the hypothetical 7.5 λ baseline. Both techniques should give the same 7.5 λ baseline reading to which the hairline should be adjusted.

C. The hairline should now be adjusted to the nearest 46 λ or 57 λ ring reading having the same value as the corresponding Minitrack 46 λ or 57 λ baseline NS reading. The correct lobe number for this reading may now be read directly off the proper ring scale.

EAST—WEST

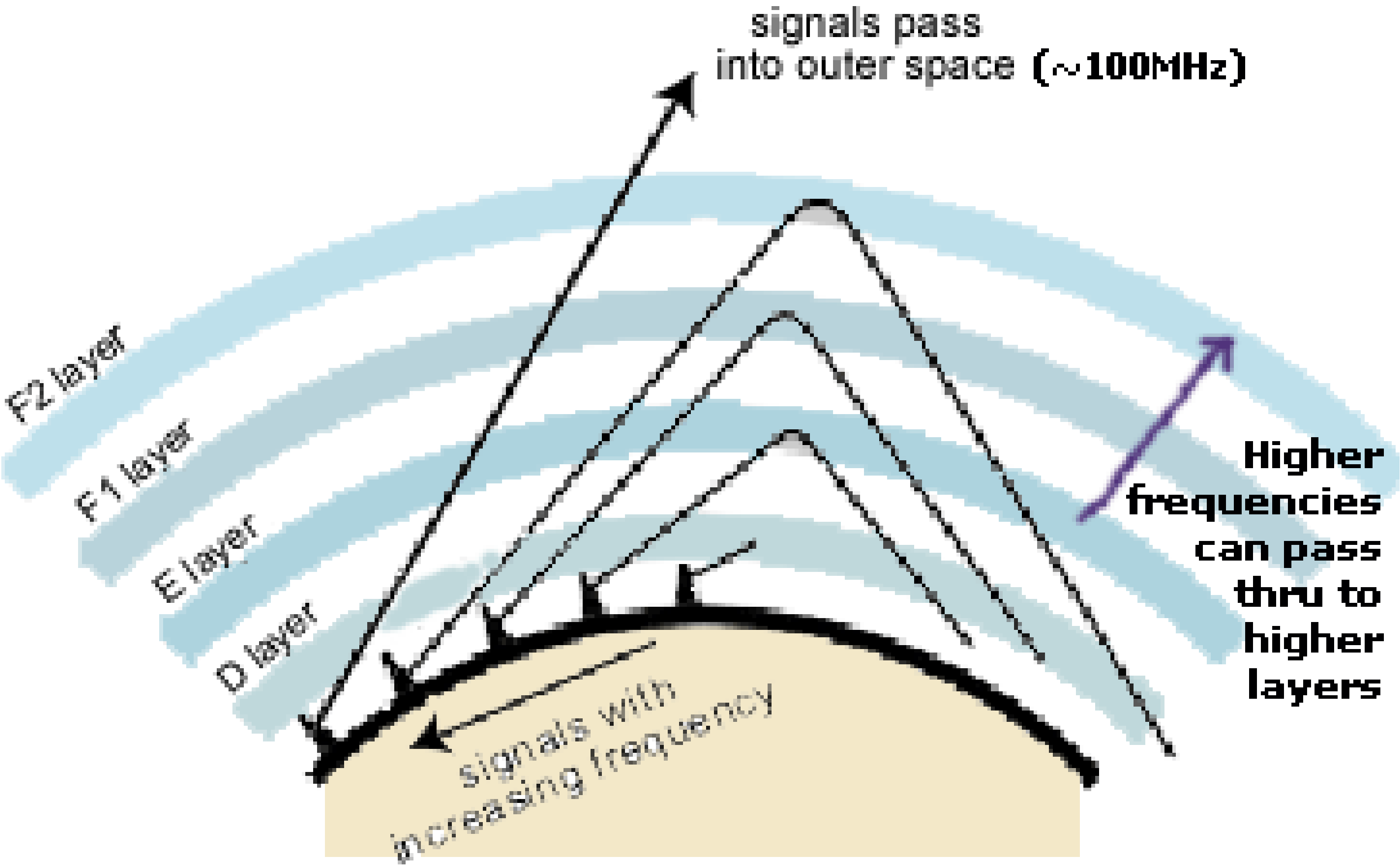
Repeat above using EW readings and arrows.

Figure 2-15.–Ambiguity resolver instructions printed on rear of slide rule.

After Sputniks

- By 1961 the score was US 31 USSR 7,
  but the early damage of 1957-1959 was done
- American recriminations and the space race
- Soviets would not share data on booster vehicles—
  it was a military secret
- Civilian agency NACA then NASA in US

The ionosphere



The ionosphere and data

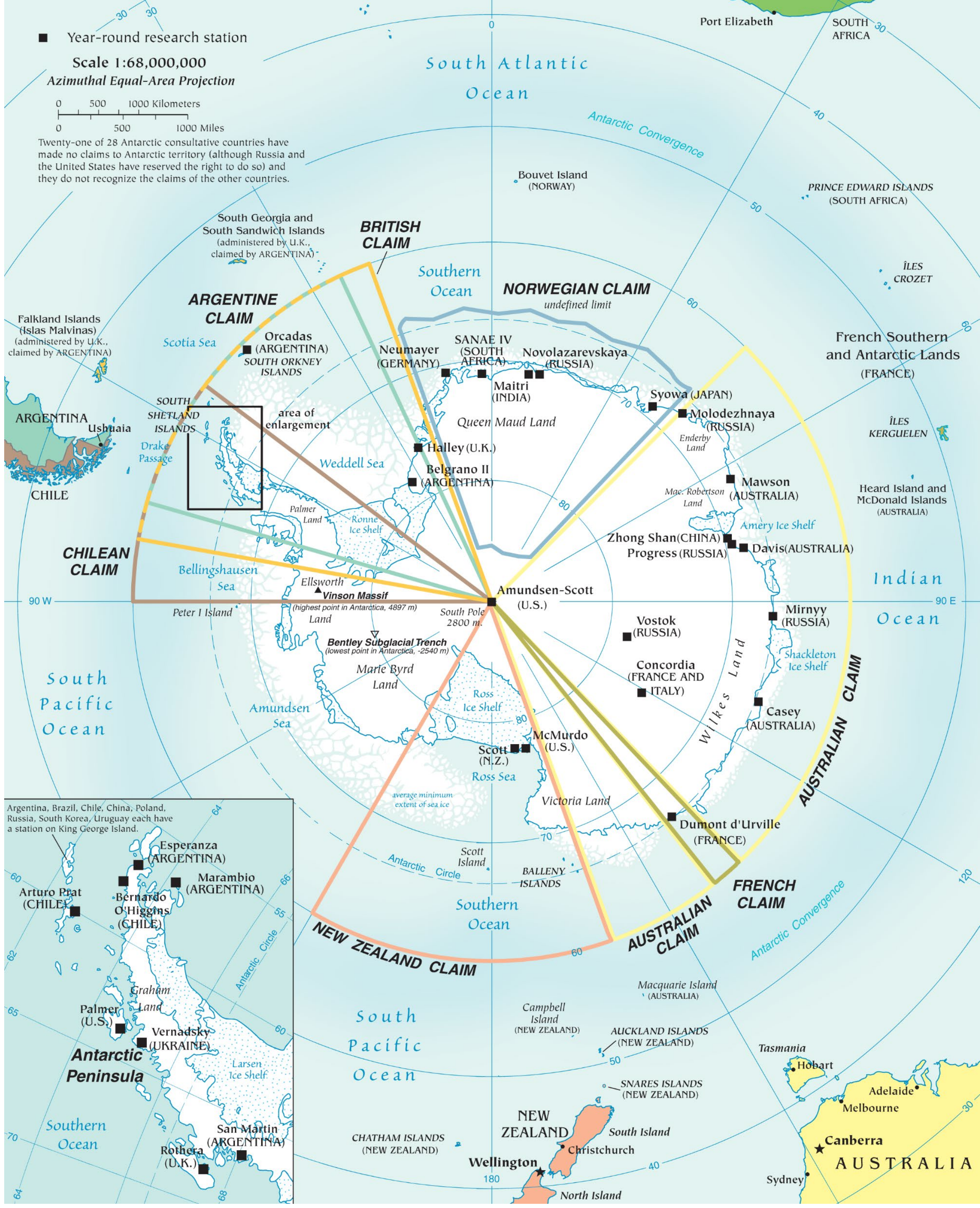
- "Seven veils": two Van Allen belts, D, E, F1, F2, and ozone
- Argus: why not detonate three H-bombs?
- Ionospheric sponder measured layers from rebound
- Rockoons with timed grenades, tell mean temperature of air the sound passed through. Use slide rule to gauge the content of these layers

Telling temperature from speed

Air - Speed of Sound vs. Relative Humidity									
Temperature *(°C)*	Speed of Sound *(m/s)* Relative Humidity *(%)*								
	10	20	30	40	50	60	70	80	90
0	331.5	331.5	331.5	331.6	331.6	331.6	331.7	331.7	331.7
5	334.5	334.6	334.6	334.7	334.7	334.7	334.8	334.8	334.9
10	337.5	337.6	337.7	337.7	337.8	337.9	337.9	338.0	338.0
15	340.5	340.6	340.7	340.8	340.9	341.0	341.1	341.2	341.2
20	343.5	343.6	343.7	343.9	344.0	344.1	344.2	344.4	344.5
25	346.4	346.6	346.8	347.0	347.1	347.3	347.5	347.6	347.8
30	349.4	349.6	349.9	350.1	350.3	350.5	350.8	351.0	351.2

$$v=20.05(273.16+t)^{1/2}$$

Antarctic



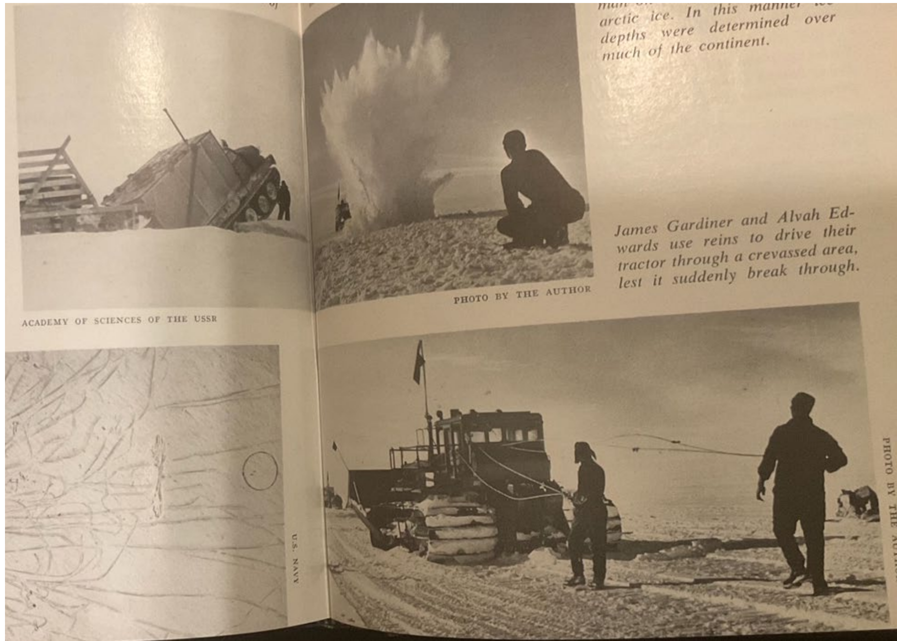
Year-round research station
Scale 1:68,000,000
Azimuthal Equal-Area Projection
0 500 1000 Kilometers
0 500 1000 Miles
Twenty-one of 28 Antarctic consultative countries have made no claims to Antarctic territory (although Russia and the United States have reserved the right to do so) and they do not recognize the claims of the other countries.
South Atlantic Ocean
Antarctic Convergence
Port Elizabeth
SOUTH AFRICA
Bouvet Island (NORWAY)
PRINCE EDWARD ISLANDS (SOUTH AFRICA)
ÎLES CROZET
South Georgia and South Sandwich Islands (administered by U.K., claimed by ARGENTINA)
BRITISH CLAIM
Southern Ocean
NORWEGIAN CLAIM
undefined limit
ARGENTINE CLAIM
Falkland Islands (Islas Malvinas) (administered by U.K., claimed by ARGENTINA)
Scotia Sea
Orcadas (ARGENTINA)
SOUTH ORKNEY ISLANDS
Neumayer (GERMANY)
SANAE IV (SOUTH AFRICA)
Novolazarevskaya (RUSSIA)
Maitri (INDIA)
French Southern and Antarctic Lands (FRANCE)
Syowa (JAPAN)
Molodezhnaya (RUSSIA)
ÎLES KERGUELEN
ARGENTINA
Ushuaia
CHILE
SOUTH SHETLAND ISLANDS
area of enlargement
Drake Passage
Queen Maud Land
Enderby Land
Halley (U.K.)
Weddell Sea
Belgrano II (ARGENTINA)
Mawson (AUSTRALIA)
Heard Island and McDonald Islands (AUSTRALIA)
Mac. Robertson Land
Palmer Land
Ronne Ice Shelf
Amery Ice Shelf
Zhong Shan (CHINA)
Progress (RUSSIA)
Davis (AUSTRALIA)
CHILEAN CLAIM
Bellingshausen Sea
Ellsworth
Vinson Massif
(highest point in Antarctica, 4897 m)
Land
Amundsen-Scott (U.S.)
South Pole 2800 m.
Indian Ocean
90 W
90 E
Peter I Island
Mirnyy (RUSSIA)
Vostok (RUSSIA)
Bentley Subglacial Trench
(lowest point in Antarctica, -2540 m)
Shackleton Ice Shelf
South Pacific Ocean
Marie Byrd Land
Concordia (FRANCE AND ITALY)
Wilkes Land
Ross Ice Shelf
Amundsen Sea
Casey (AUSTRALIA)
McMurdo (U.S.)
Scott (N.Z.)
Ross Sea
AUSTRALIAN CLAIM
average minimum extent of sea ice
Victoria Land
Dumont d'Urville (FRANCE)
Scott Island
Antarctic Circle
BALLENY ISLANDS
FRENCH CLAIM
Southern Ocean
NEW ZEALAND CLAIM
AUSTRALIAN CLAIM
Macquarie Island (AUSTRALIA)
Campbell Island (NEW ZEALAND)
AUCKLAND ISLANDS (NEW ZEALAND)
South Pacific Ocean
Tasmania
Hobart
SNARES ISLANDS (NEW ZEALAND)
Adelaide
Melbourne
CHATHAM ISLANDS (NEW ZEALAND)
NEW ZEALAND
South Island
Christchurch
Canberra
AUSTRALIA
Wellington
North Island
Sydney
Argentina, Brazil, Chile, China, Poland, Russia, South Korea, Uruguay each have a station on King George Island.
Esperanza (ARGENTINA)
Marambio (ARGENTINA)
Arturo Prat (CHILE)
Bernardo O'Higgins (CHILE)
Graham Land
Palmer (U.S.)
Vernadsky (UKRAINE)
Antarctic Peninsula
Larsen Ice Shelf
Southern Ocean
San Martín (ARGENTINA)
Rothera (U.K.)

Antarctic

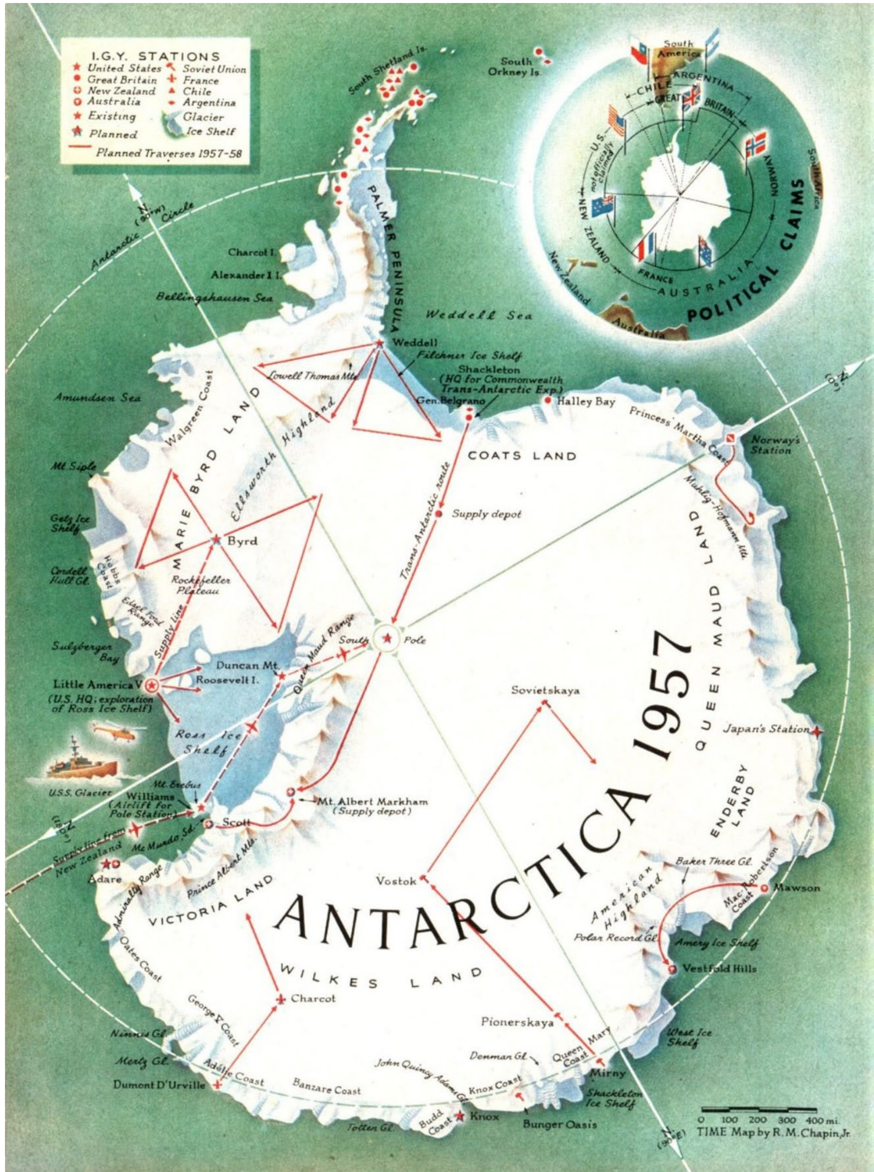
- The classic IGY laboratory—not only *synoptic* but *collective* science
- 14 stations by a dozen nations—the seven territorial claimants (UK, NZ, Australia, Chile, Argentina, Norway, France) plus US, USSR, South Africa, Japan and Belgium
- UK and Argentina long fought over peninsula
- US secured South Pole, USSR the "Pole of Inaccessibility"

Death on the ice

- At least 50 IGY fatalities
- Planes crash, ships sink, tractors plunge into crevasses
- Eventually use reins for bulldozers—pace as slow as Scott's



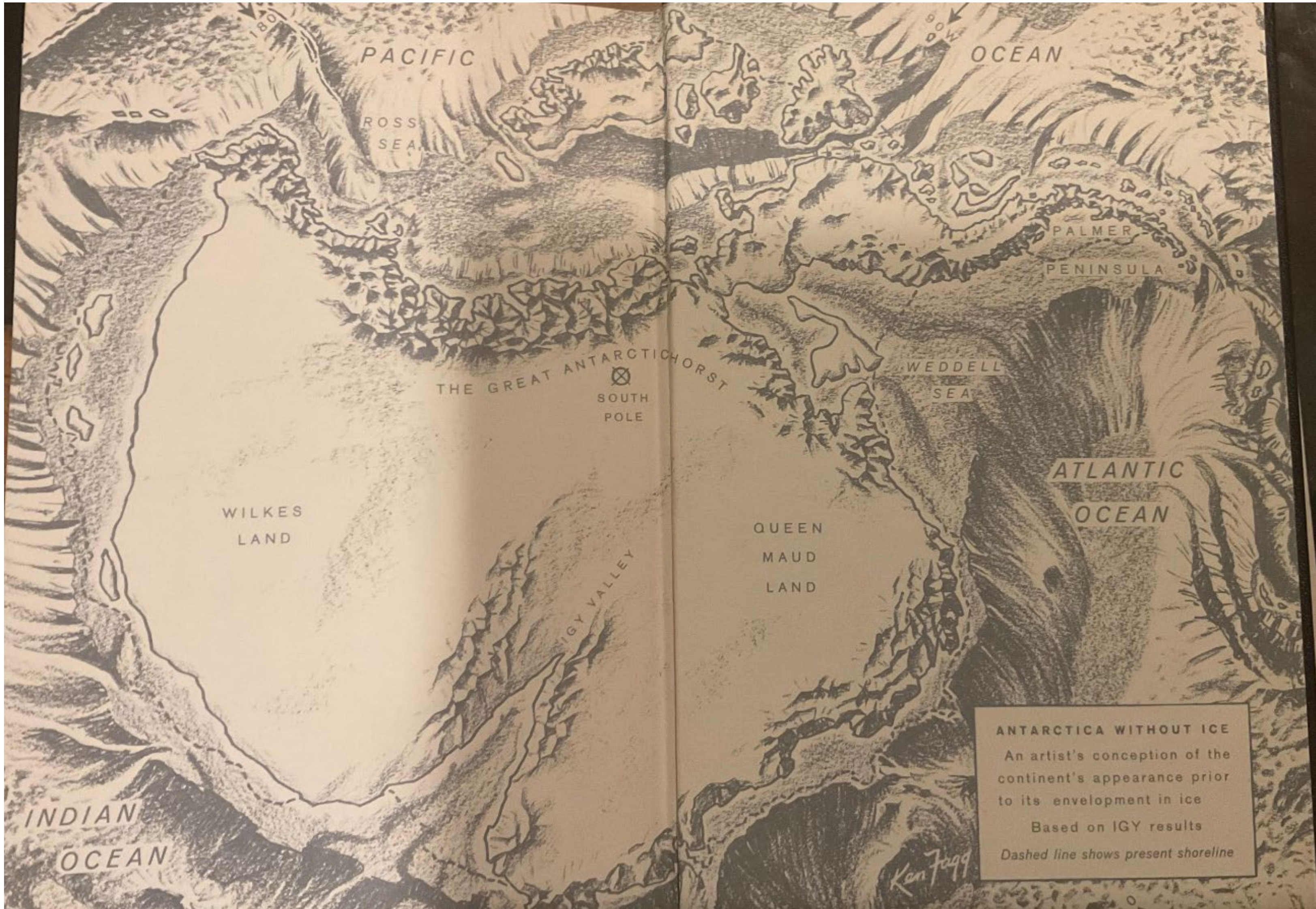
The Antarctic traverses



A continent or an archipelago?

- Resolved by traverses—linear expeditions to shoot seismic
- Sno-Cat teams measured position of sun using theodolite, got time from WWV, and "calculated our position using a slide rule (pocket calculators did not exist) to better than 200 meters accuracy using a nautical almanac."
- Coal beds, tree trunks…still not sold on plate tectonics
- More ice than expected—West Antarctica an archipelago of island ridges, East Antarctica much older with IGY Valley

A continent *and* an archipelago



Cold—and heat—the common enemy

- Plenty of cooperation among national stations
- Shared hazards—station fires, USSR's Belgian rescue, Japan evacuation and surviving huskies
- Successful integration of scientific data
- Those 12 countries signed the Antarctic Treaty 1959
- Led to Outer Space Treaty 1967

Big data, 1958 style

- Millions of feet of microfilm, paper records, photograph negatives, ice cores; few punch cards retained
- Plastic film degrades in a few decades
- World Data Centres A, B and C a success. Distributed, preserved media, means of exchange. Later focus on North-South climate dialogue, not East-West military tension
- Replaced by ISC and World Data System 2008, digitization
- “We don’t want another Library of Alexandria”

After IGY

- Cooperation continued: International Geophysical Cooperation into 1960, UNFCC, International Polar Year 2007-8 & 2032-33
- Midocean spreading ridges: from Wegener's "crackpot" continental drift to "obvious" plate tectonics in a decade
- Global warming, but global action? Compare to CFC bans 1970s-1996, much easier owing to industrial alternatives
- Keeling curve took off with IGY data; climate change continues
- Antarctic cooperation leads to peaceful exploration there and beyond

Watch the skies for more data!

pillsbury

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Thanks for your kind attention!

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