GEBCO Centenary Conference

Technical Developments in Depth Measurement Techniques and Position Determination from 1960 to 1980

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Outline

- Evolutionary sequences
  - Enabling technology
  - Position determination
  - Depth measurement
- Bookend snapshots
  - 1960
  - 1980
- Impact on GEBCO

Enabling technologies

Transistor

- Invented 1947
- By 1960 computer logic used transistors, core memory
- During 1970’s IC memory replaced cores

Shipboard computer

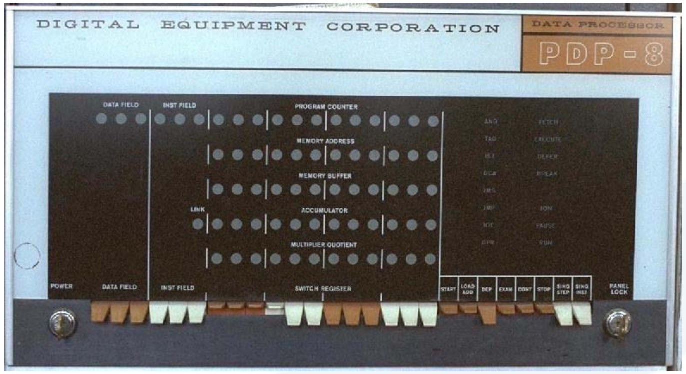
- Seaworthy “minicomputers” by 1965

Integrated circuit

- Invented in 1959 at Texas Instruments
- Logic density doubling time:
  - 12 months, 1962-late 1970’s (Moore’s Law)
  - 18 months, since late 1970’s (Modified Moore’s Law)

1966 DEC PDP-8 Computer

BIO Metrology:
Reg Gilbert
Clive Mason
Andrew Bennett

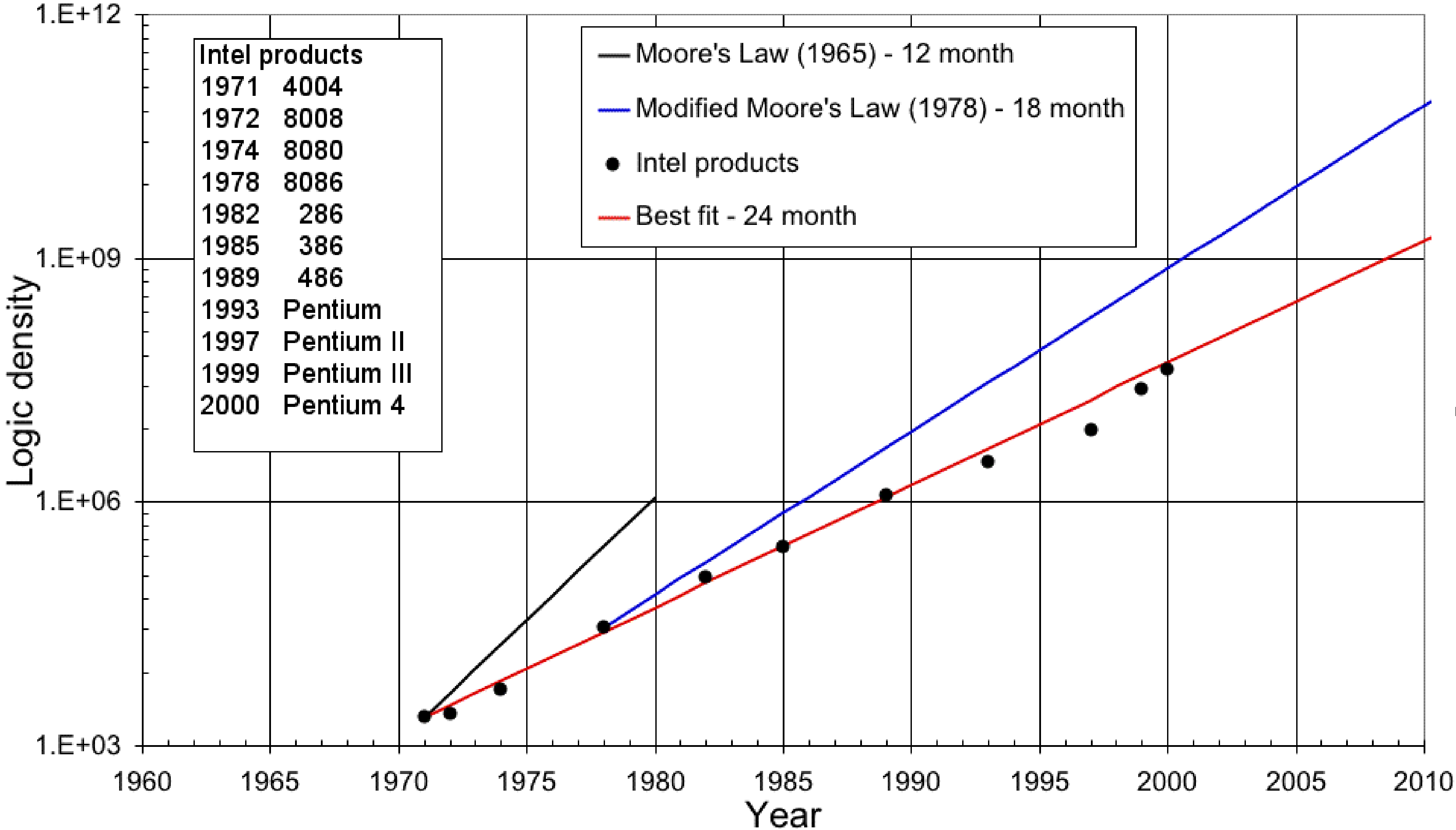


Introduced in 1965
BIO bought s/n 132 & 198 in 1966

World's first Minicomputer (less than $25,000)
4096 12-bit word 1.5 µsec core memory
Only I/O device - 10 cps teletype
Storage medium - punched paper tape
Programming language - PAL III
50,000 sold before PDP-11 arrived in 1970

Gordon Moore,
Intel co-founder

Logic density increase



Computer memory

40 year trend

- Memory cost cut in half every 20 months
- Memory capacity doubled every 24 months
- Memory (and computer) size cut in half every 36 months

PDP-8 vs this laptop

- Laptop has 150,000 times more memory
- PDP-8 memory cost 5,000,000 times more (per bit)
- PDP-8 core memory occupied 3,000 times more space

Hyperbolic positioning evolution

Concept developed during WWII
Systems developed between 1950 and 1980

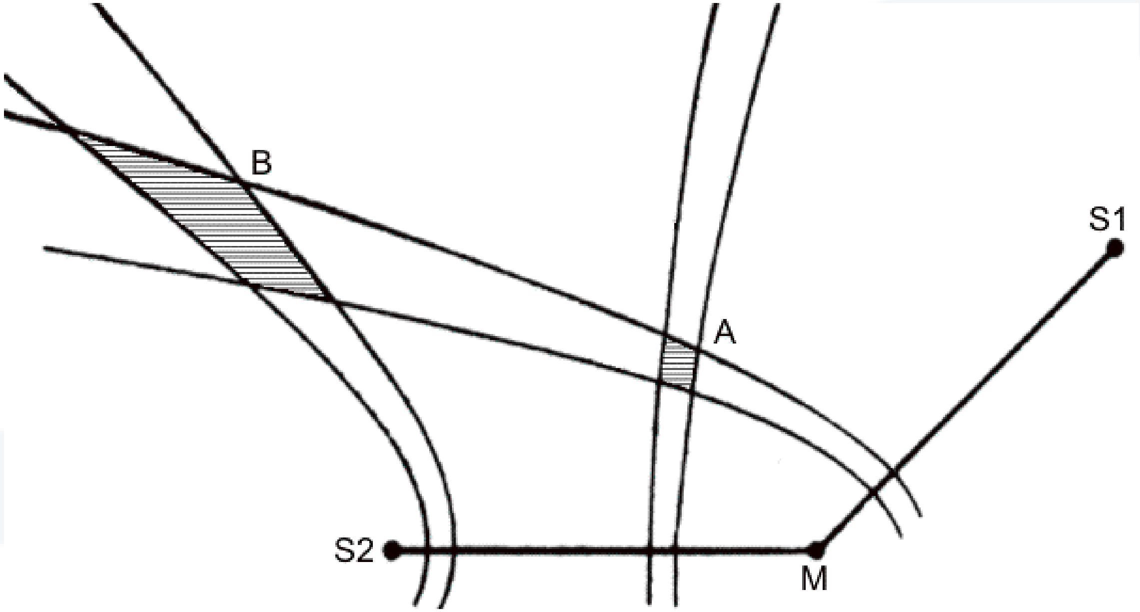
System	Principle of Operation	Baseline Length (n.m.)	Frequency Band (kHz)	Range (n.m.)	95% Position Accuracy Good - Bad
Omega	CW phase comparison	5000 - 6000	10 - 14	Global	2 - 6 n.m.
Decca	CW phase comparison	60 - 120	70 - 130	240	30 - 1200 metres
Loran-A	Pulsed Time difference	200 - 400	1850 - 1950	800	1 - 15 n.m.
Loran-C	Pulsed time difference and phase comparison	150 - 800	90 - 110	1200	200 - 600 metres

Lane ambiguity resolution methods developed
Skywave elimination a priority for Loran-C

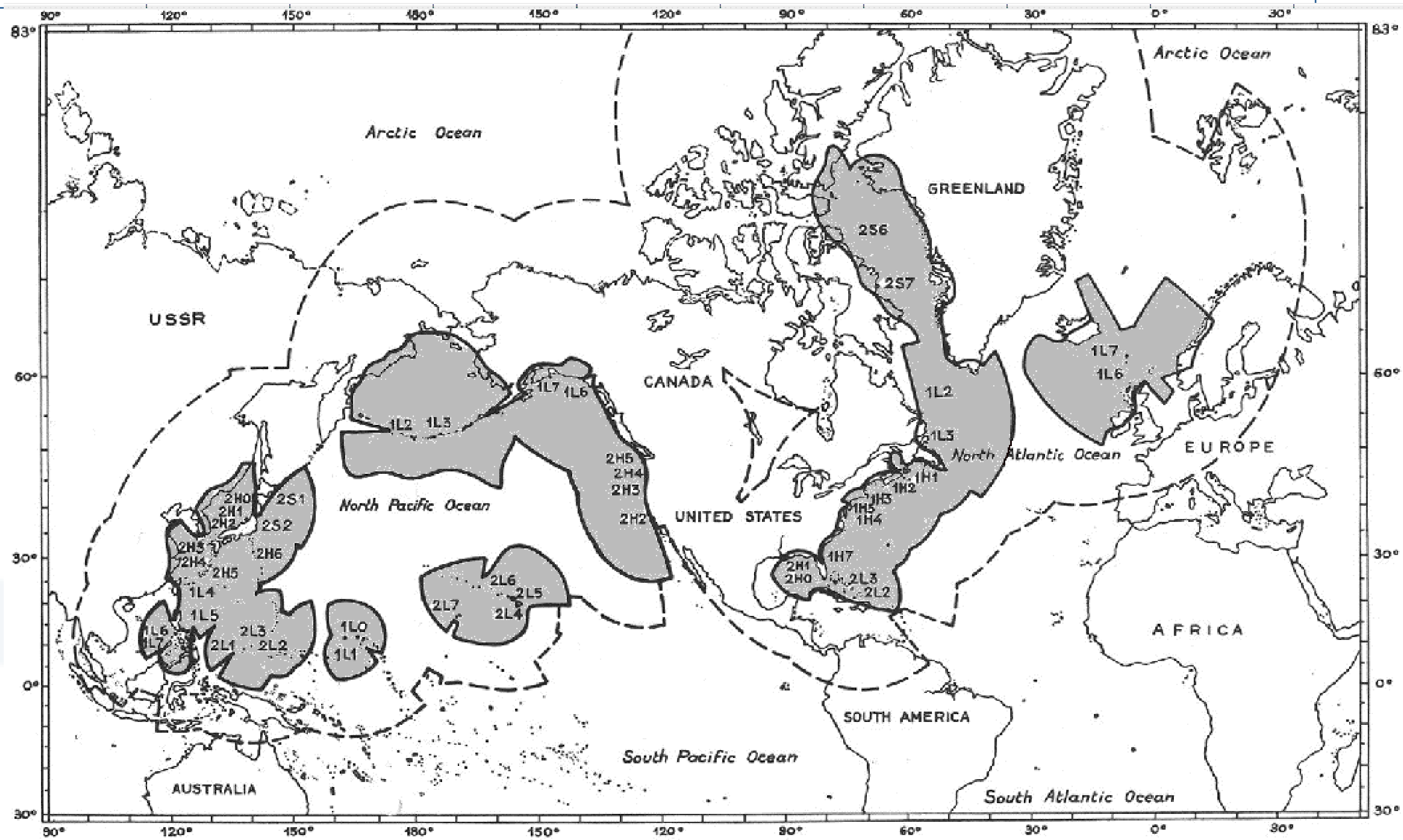
Hyperbolic radiopositioning

Bad geometry

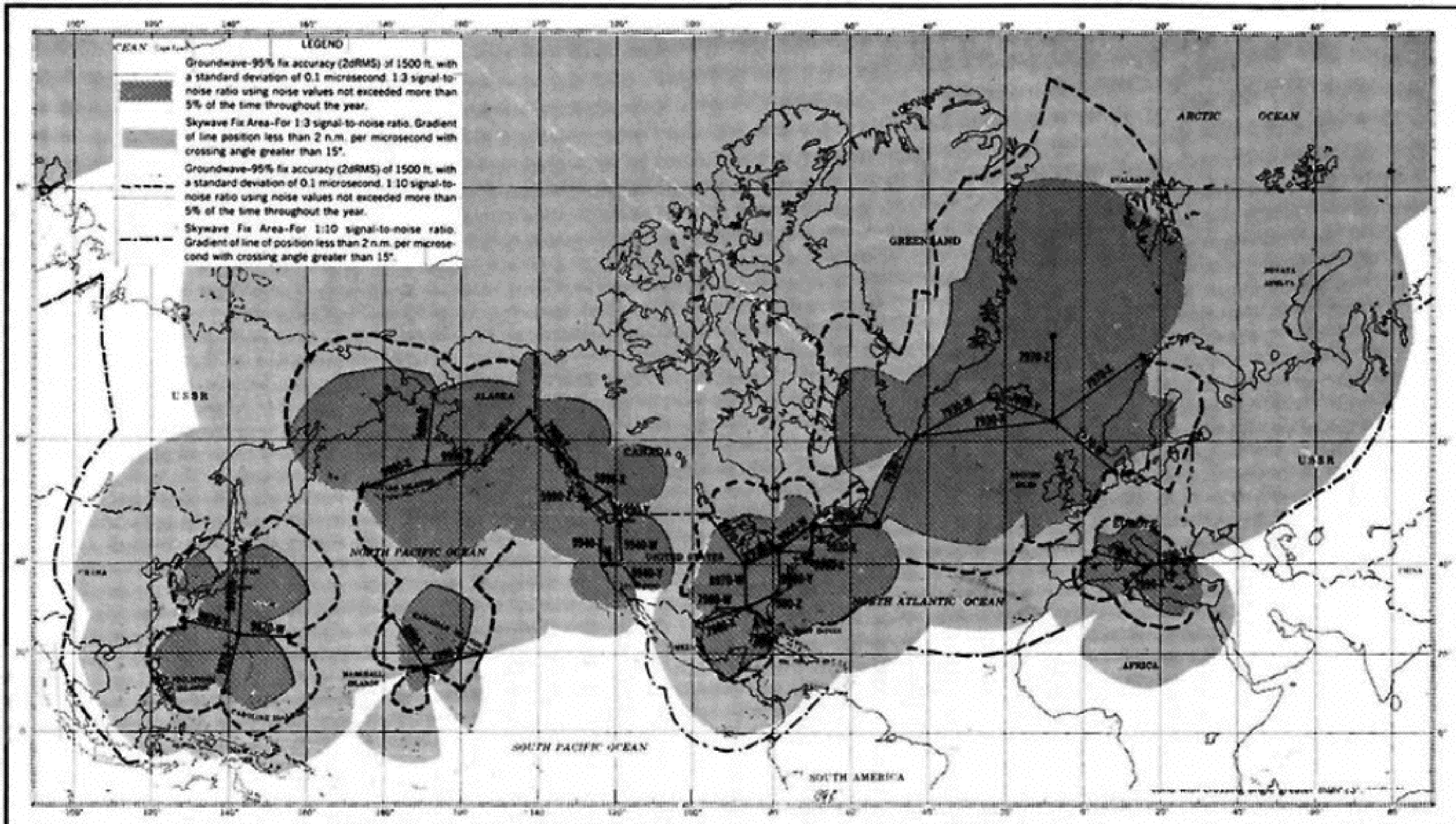
Good geometry



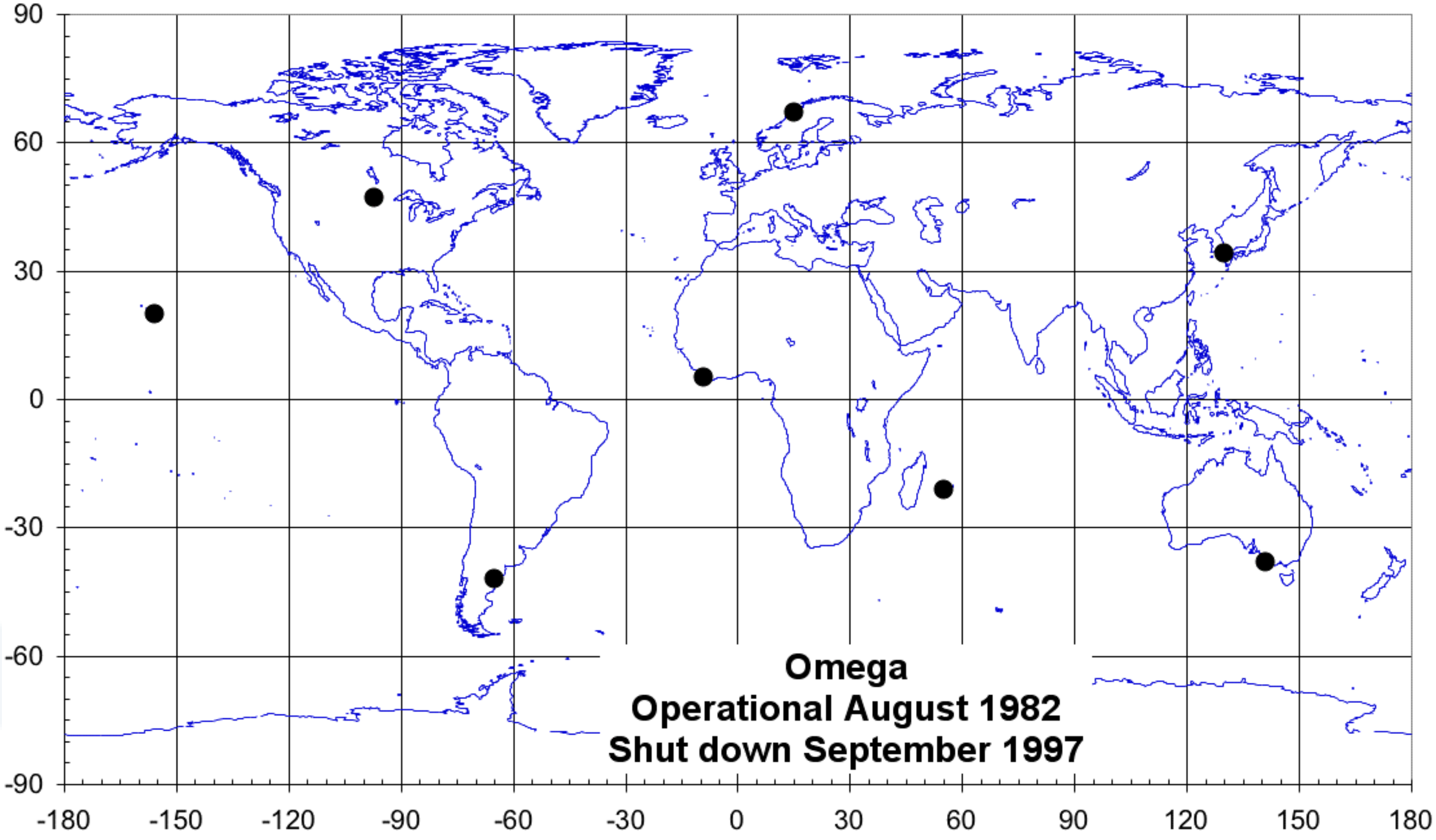
Loran-A coverage in early 1960s



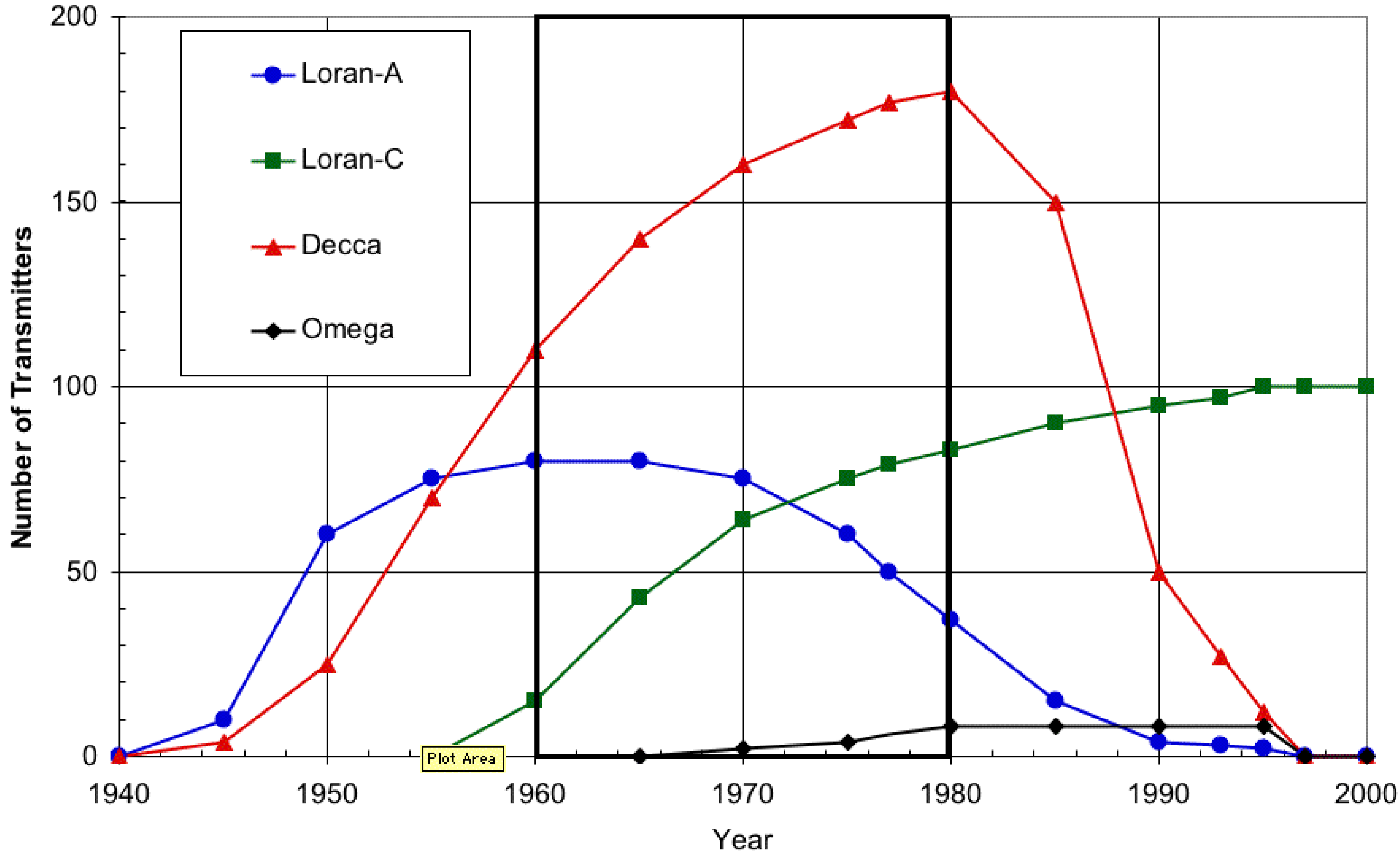
Loran-C coverage in 1980



Omega network



Hyperbolic system evolution



Satellite positioning evolution

Navy Navigation Satellite System (Transit)

- Concept in 1957,
- Operational in 1964
- Publically available in 1967

Passive ranging (“rho-rho”)

- Concept in 1957
- Timation I launched in 1967

Global Positioning System

- Concept in 1970
- First satellites launched in 1978

LOREX

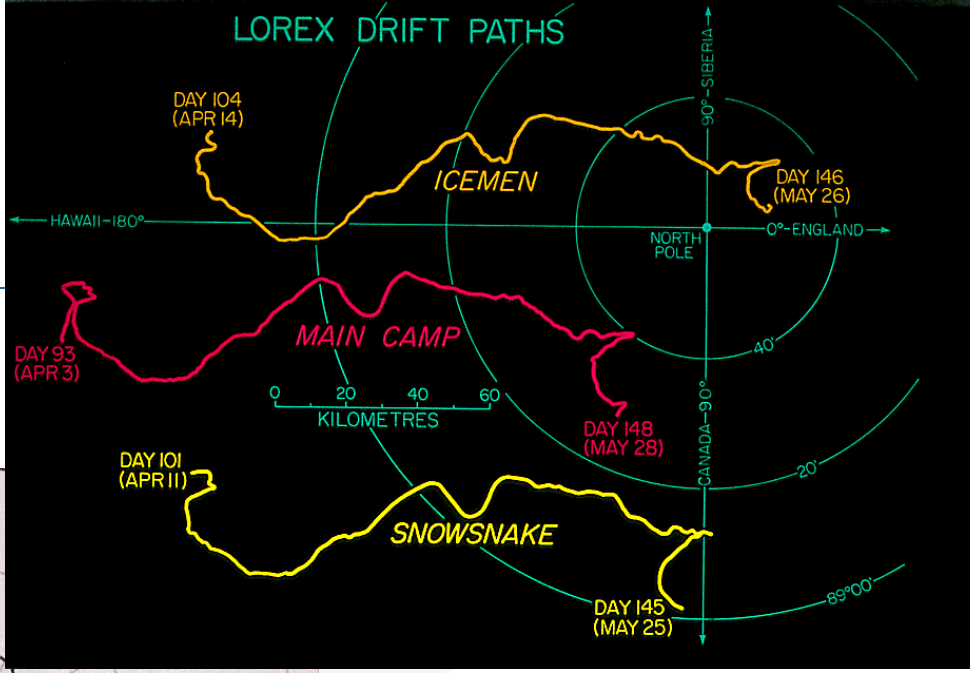
16 x 250-ton LAPES drops in 7 days

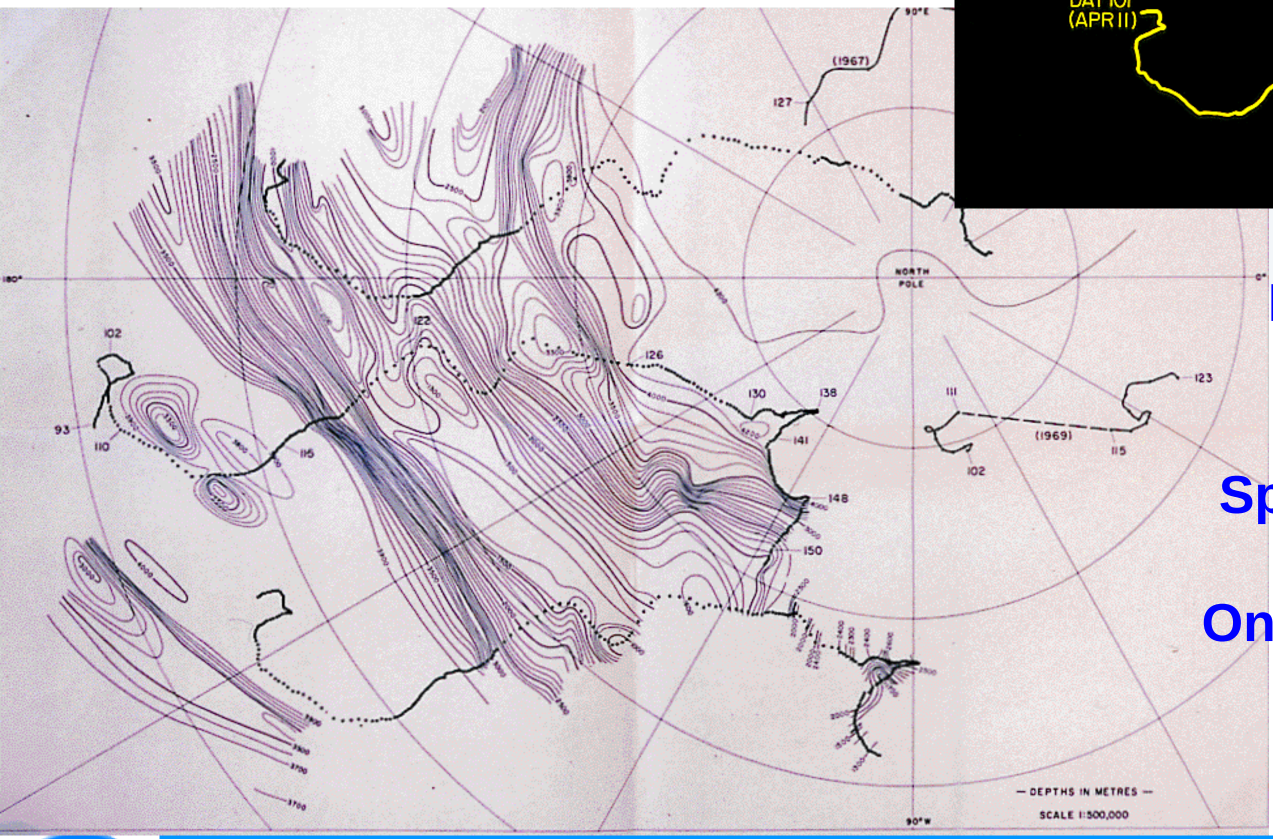
Transit antenna

Camp building

Navigation centre

002



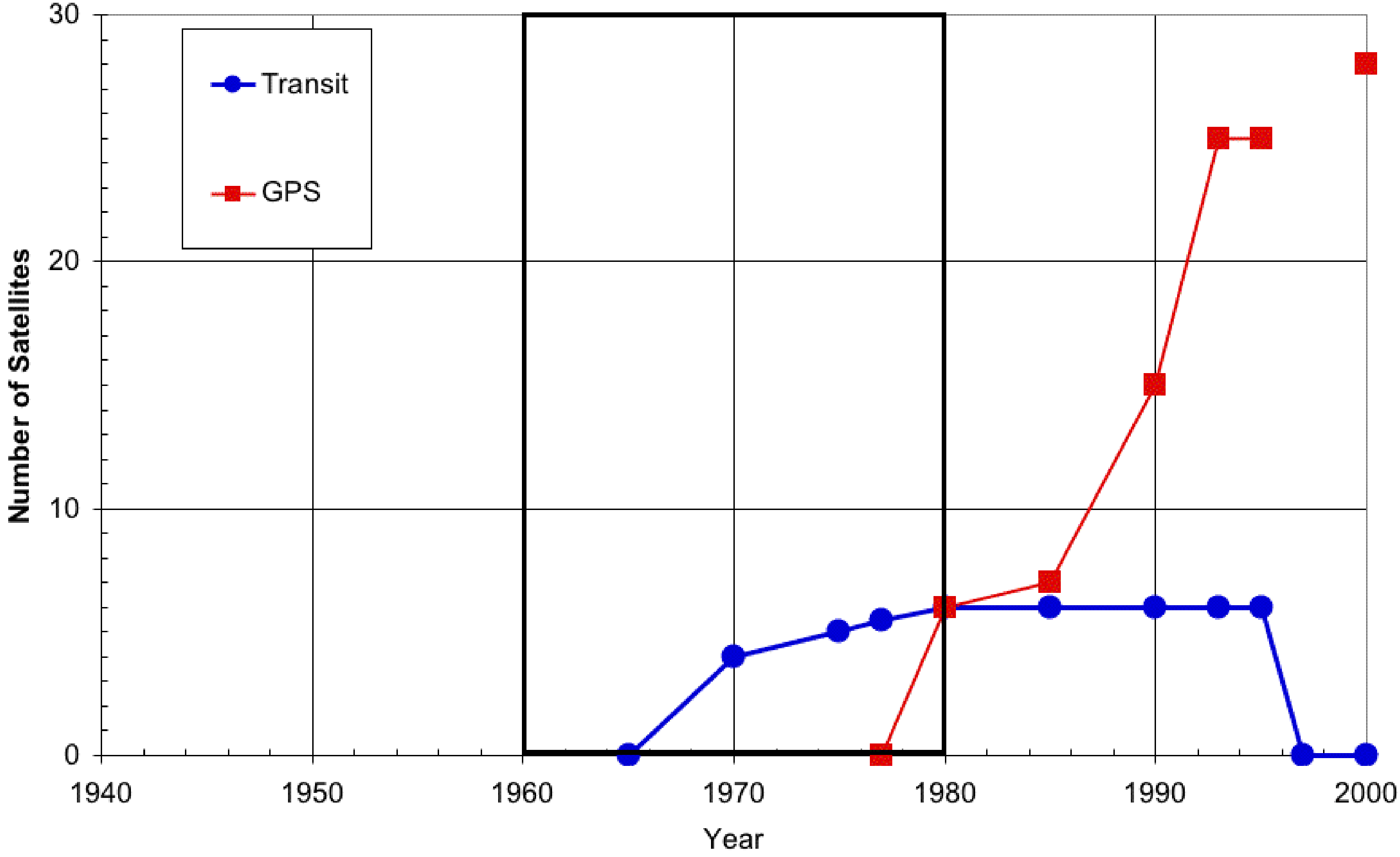


From 3 April to 25 May, all three camps drifted across the ridge

Speed varied from 100 to 1000 m/hr

One camp came within 12 km of the Pole

Number of active satellites



Acoustic depth measurement

Single-beam echosounders
- Invented in 1920s, widely used from 1930s

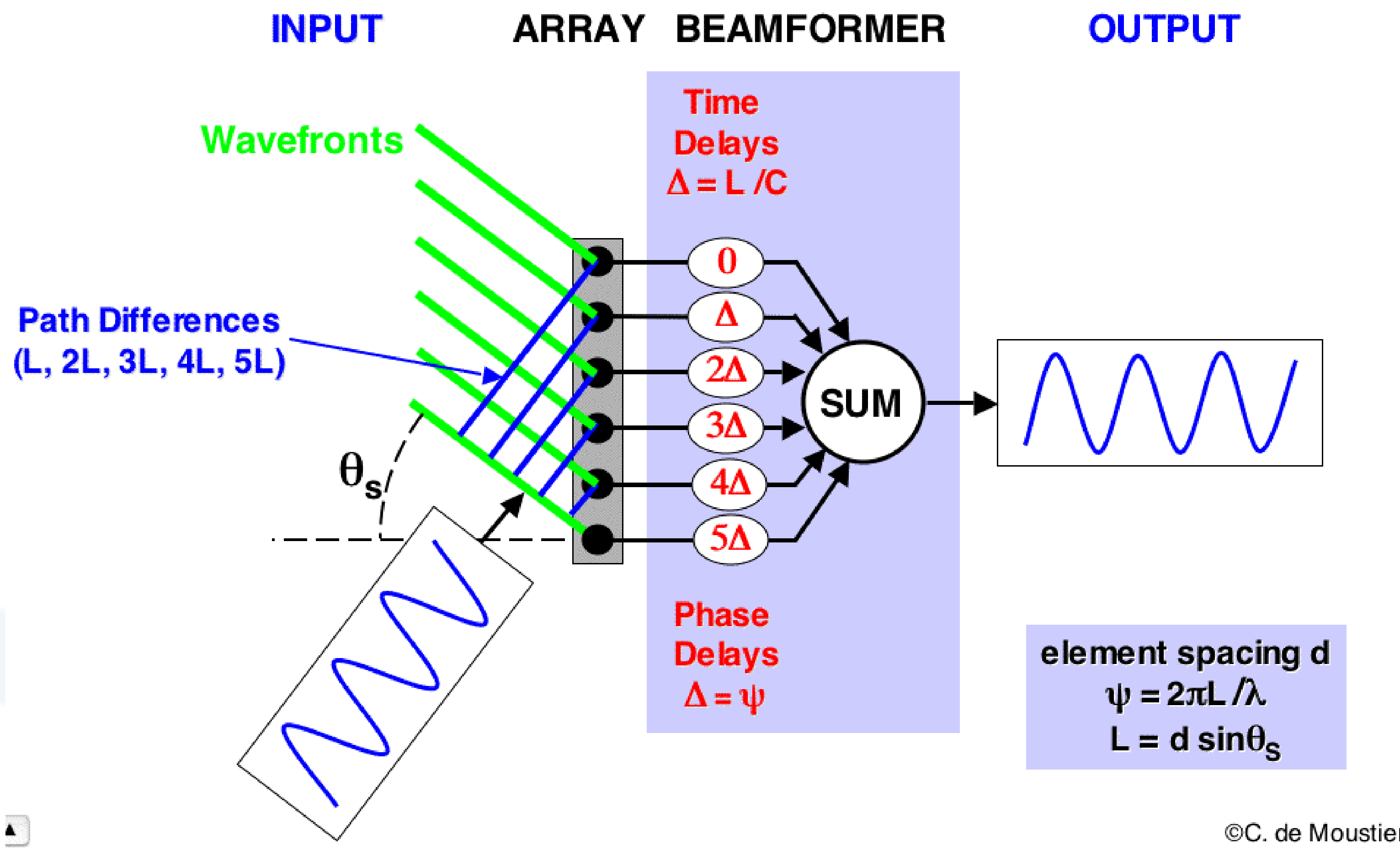
Digital echo-sounders
- Chart scalers and signal digitizers developed during 1960s

Side-scan sonar
- Shadowgraph developed during 1950s

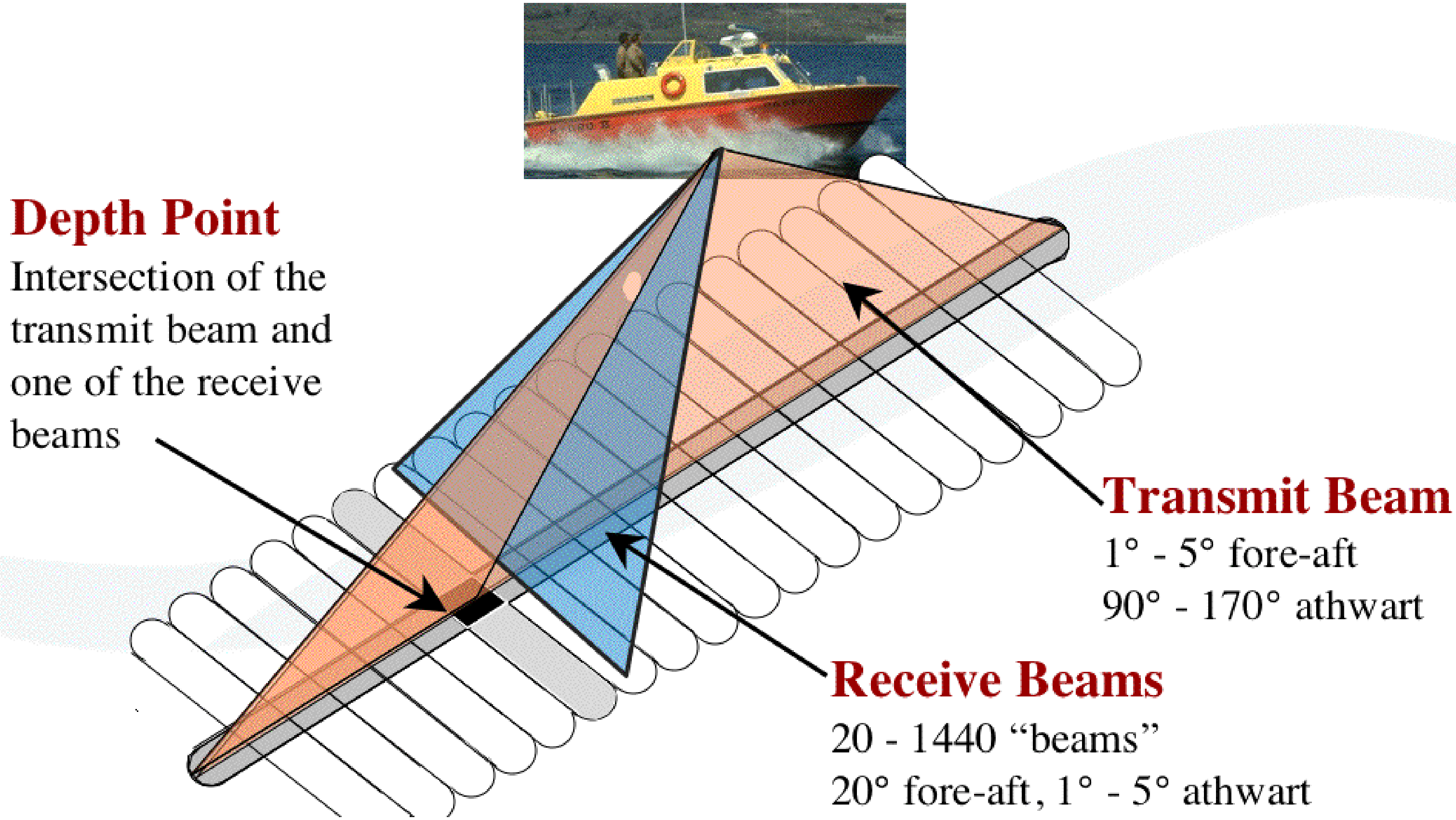
Two-row sidescan interferometry
- GLORIA operating by 1965

Electronic beam steering
- NBES 1964, SASS late 1960s, Seabeam 1976

Beam steering concept



Multibeam concept



1960 snapshot

Vertical single-beam (mostly analog) echo-sounders were the universal tools for depth determination.

Decca and Loran-A hyperbolic systems were well established, however they did not provide coverage very far from shore transmitters, and no southern hemispheric coverage.

Much mid-ocean positioning still depended upon celestial methods.

1980 snapshot

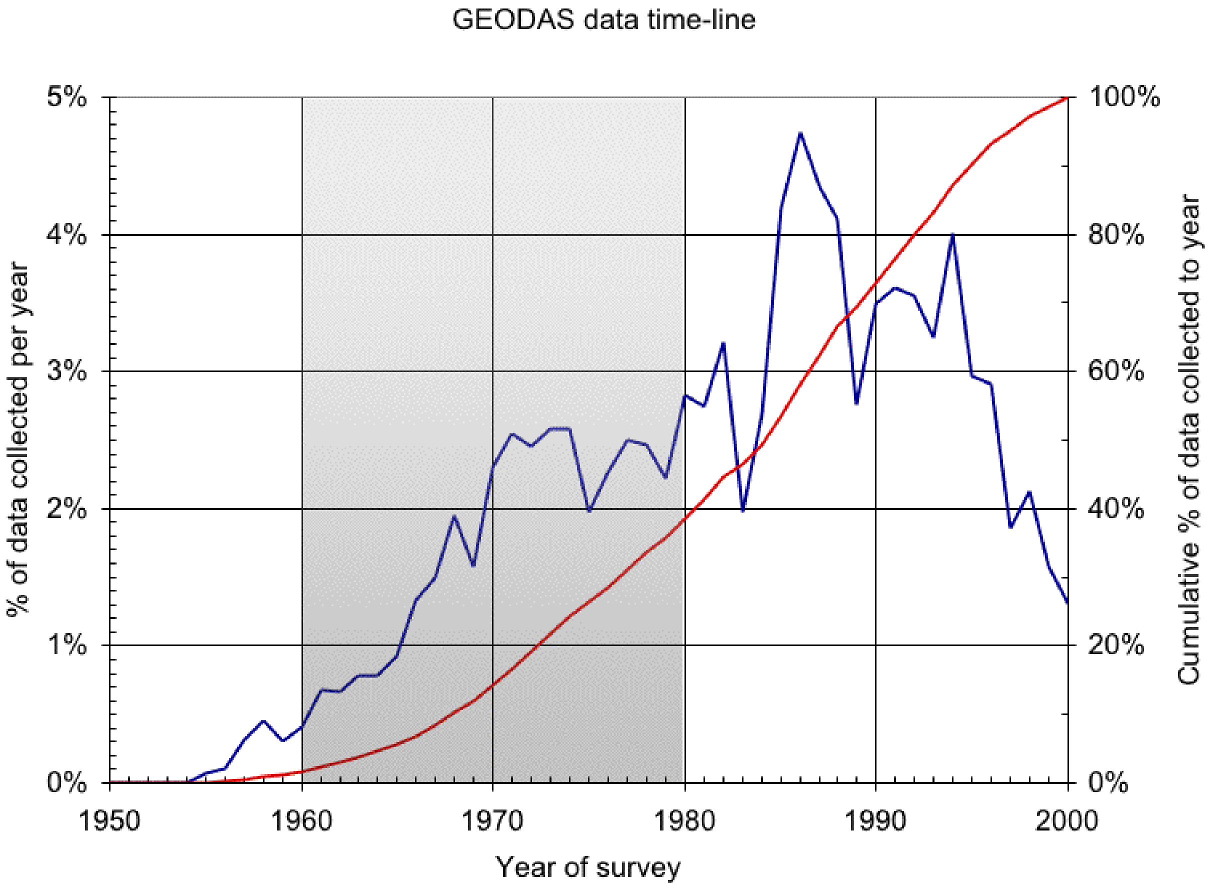
Multibeam and GLORIA sidescan data had begun to flow into the GEBCO database. Almost all depth data was collected in digital form.

Transit satellite positioning was the standard survey mid-ocean positioning method. Omega was almost complete, and was also used.

Loran-C was well-developed (in the northern hemisphere), and was used within its coverage area.

The first GPS satellites were in orbit.

GEODAS database history



Cumulative content	
1960 <	2%
1970	14%
1980	40%

GEODAS positioning allocation

Generalized Navigation Category	Navigational Fix Accuracy (m) [Mayer et al 2002]
Unknown	10000
Celestial	10000
OMEGA	7300
Pilot	2000
LORAN A	1200
LORAN	1200
TRANSIT	500
LORAN C	500
DECCA	500
GPS	100
Survey	50
STARFIX	50
GPS P-CODE	20
DGPS	20

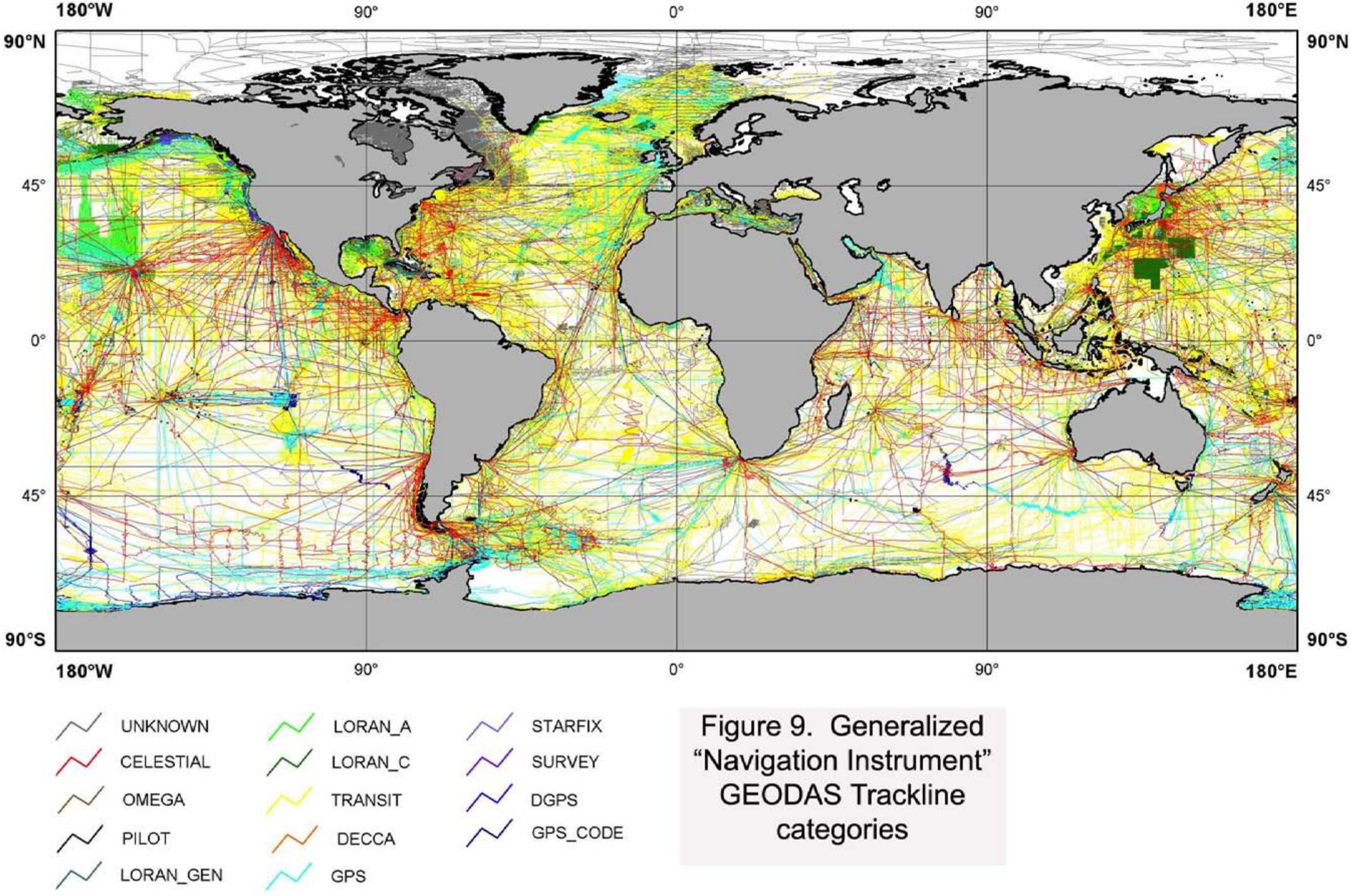


Figure 9. Generalized "Navigation Instrument" GEODAS Trackline categories

Thanks to Martin Jakobsson