

Surveying with light

Land surveys (at least ~3000 BC)



- Nile flooded annually, need to remark farms
- Taxes
- Construction (canals, roads, pyramids, etc.)

Great Pyramid of Giza; $1/15^\circ$ alignment



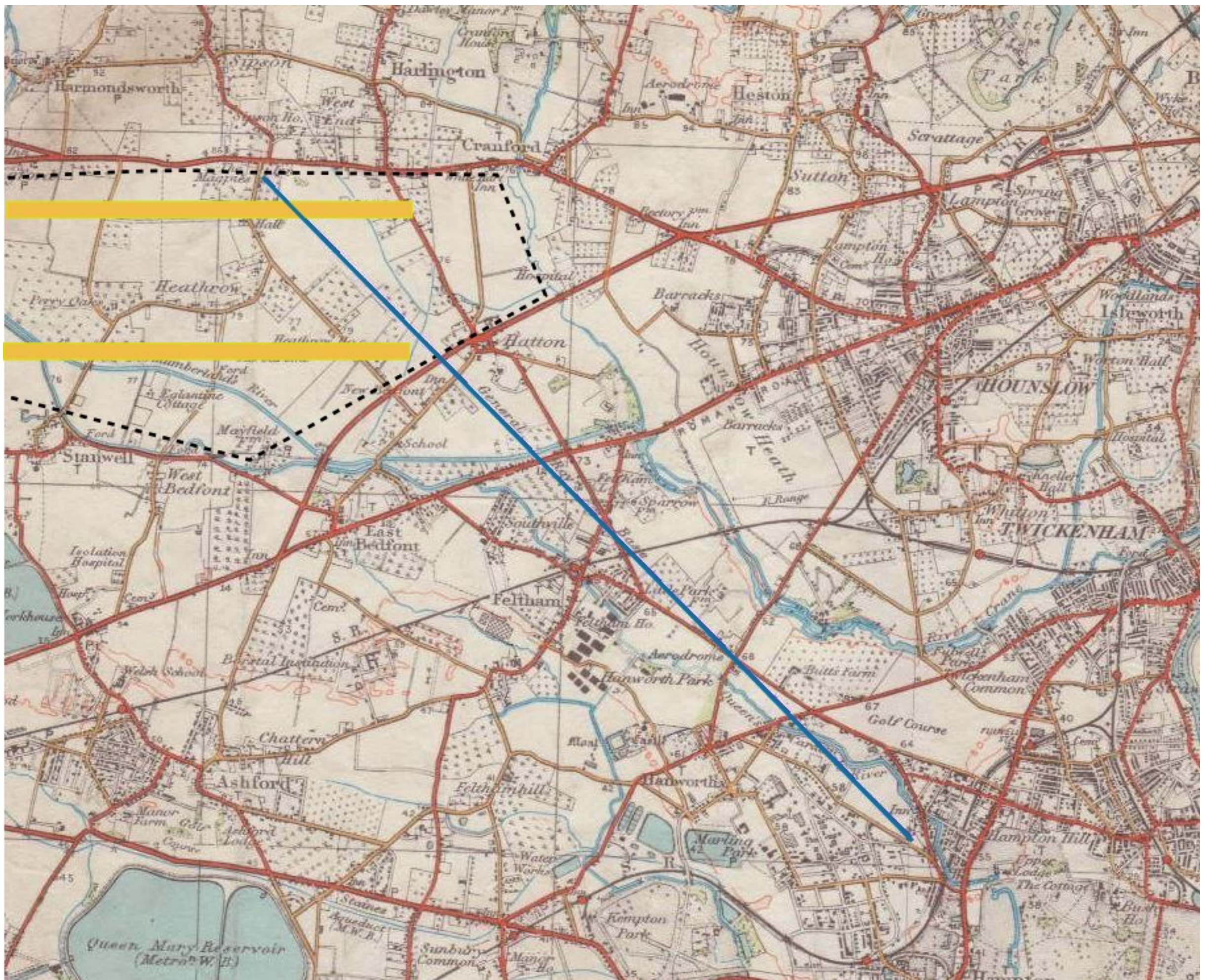
Greeks & Romans — Segovia, 15 km aquaduct



Semi-modern methods

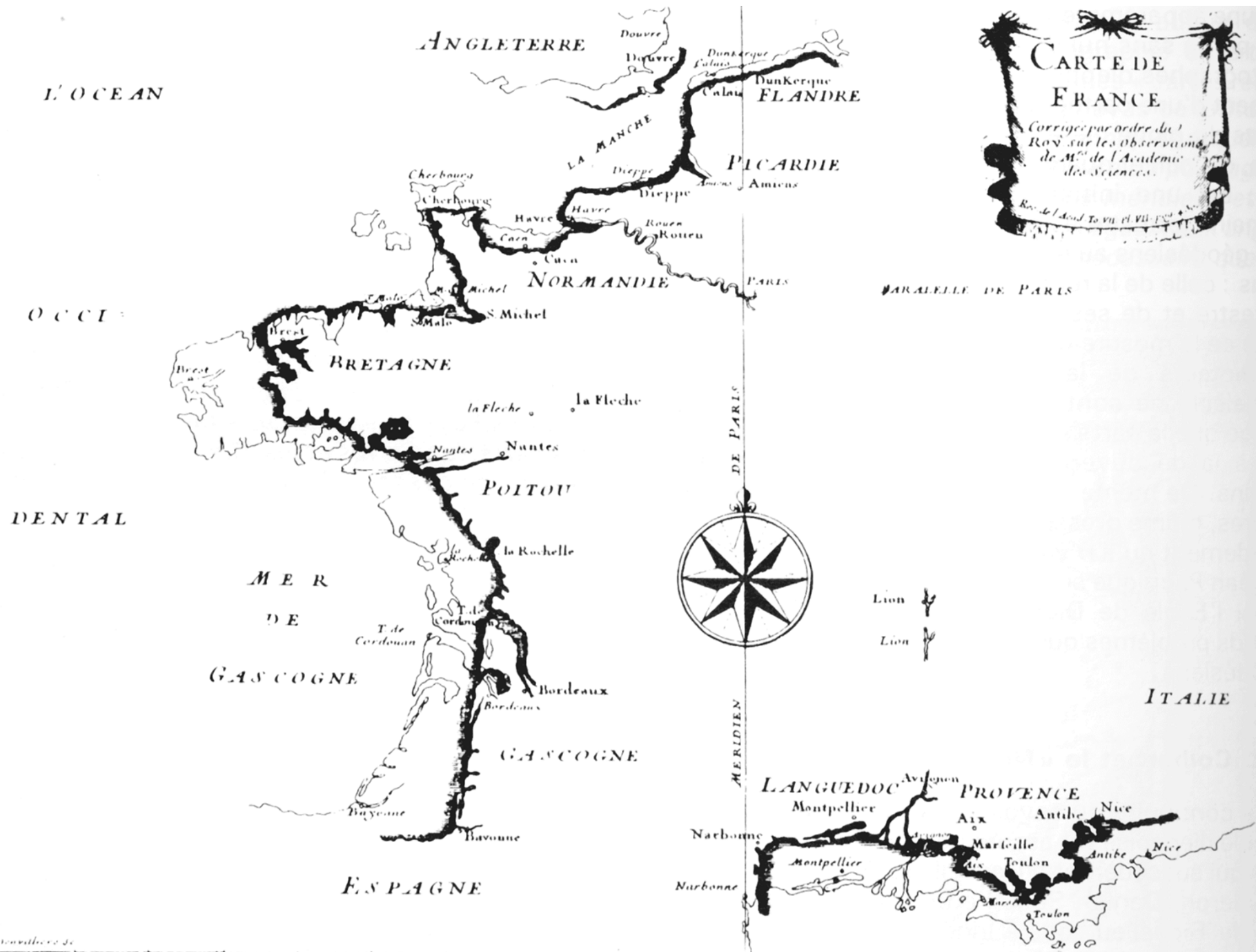
- Need to know one distance 'baseline'



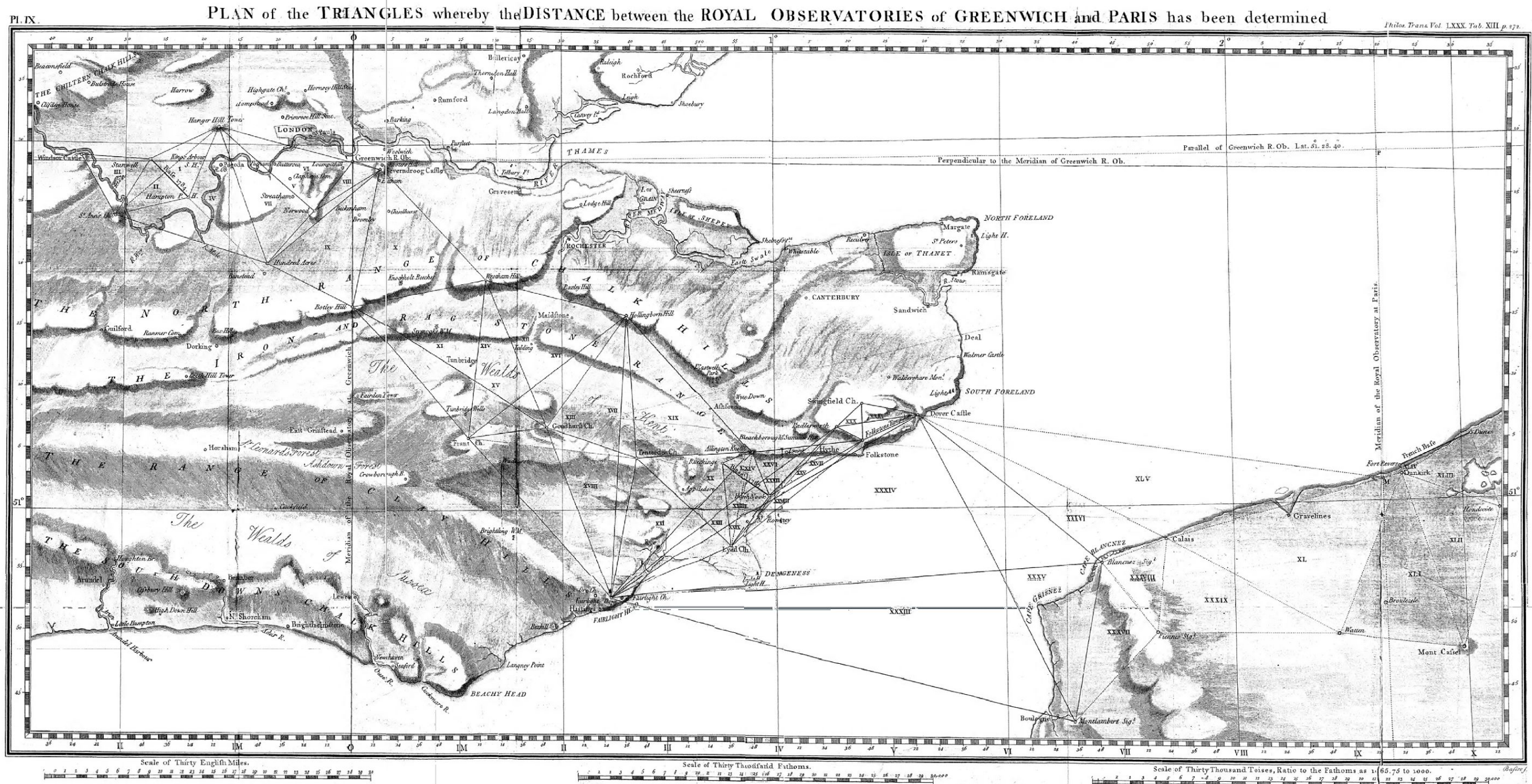


Baseline measurement

- Glass or Metal rods
- Chain

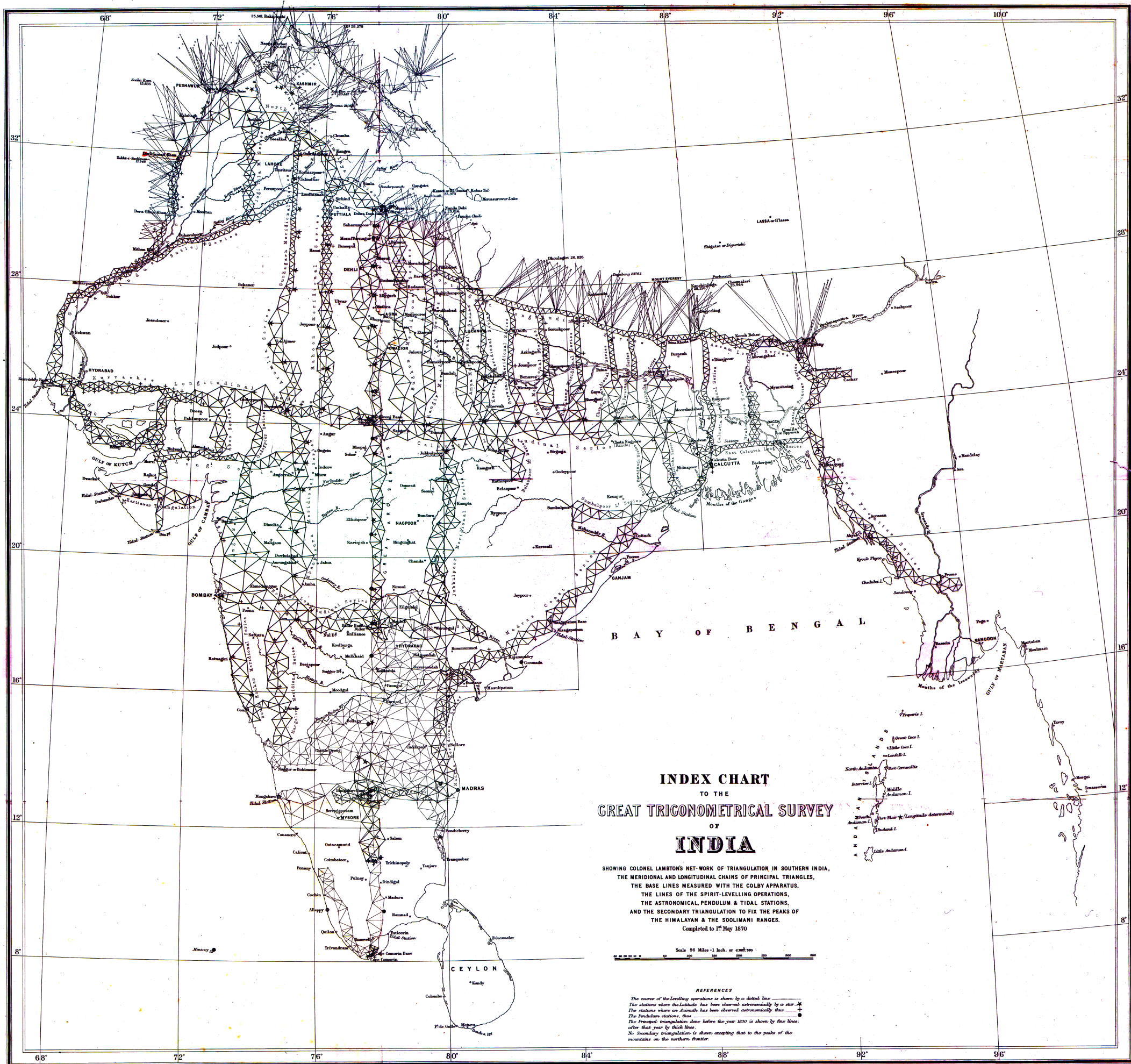


Anglo-French survey 1790



Great Trigonometric Survey of India

- 1802–1871
- George Everest was second supervisor

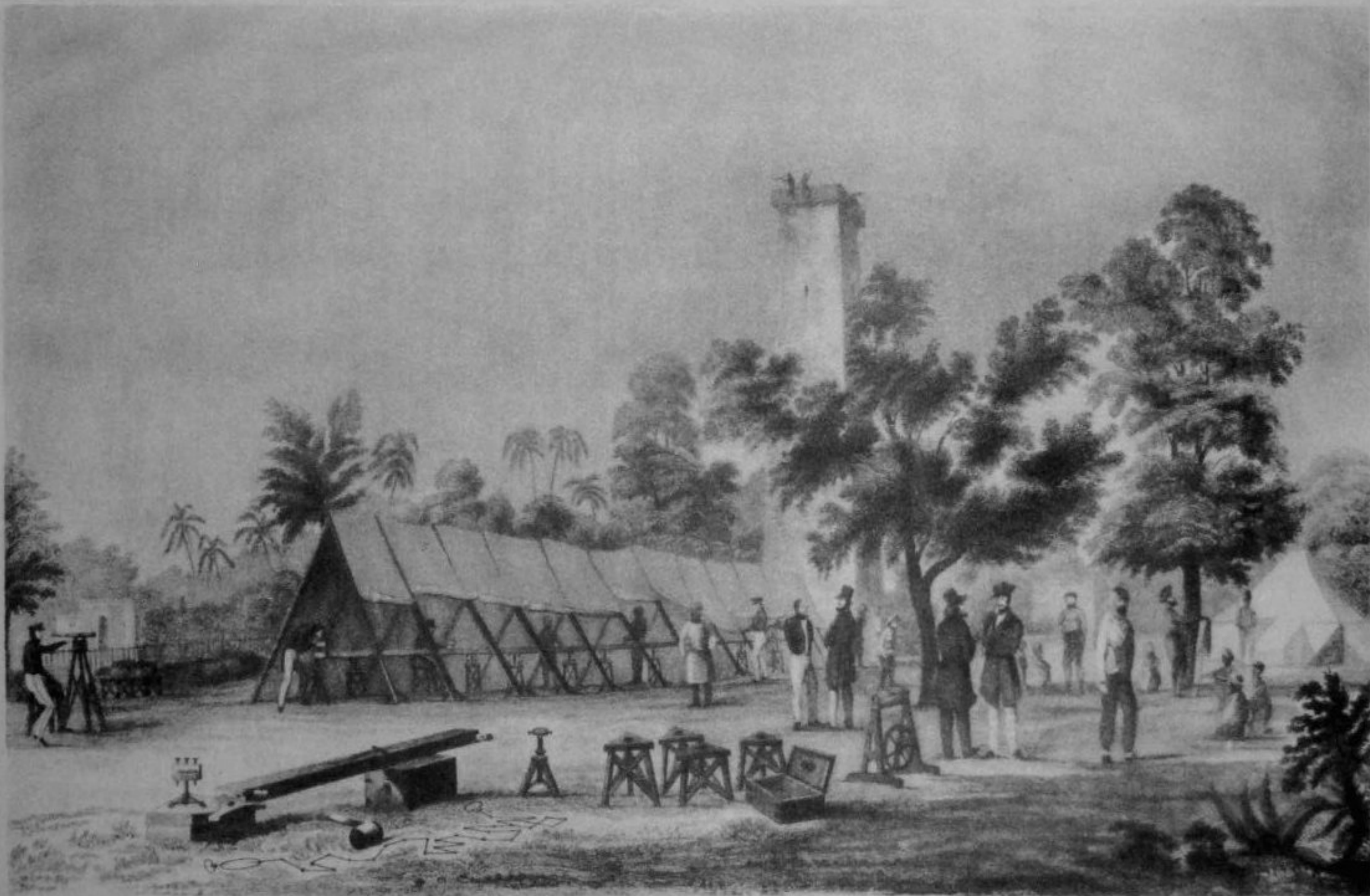


INDEX CHART
TO THE
GREAT TRIGONOMETRICAL SURVEY
OF
INDIA

SHOWING COLONEL LAMBTON'S NET-WORK OF TRIANGULATION IN SOUTHERN INDIA,
THE MERIDIONAL AND LONGITUDINAL CHAINS OF PRINCIPAL TRIANGLES,
THE BASE LINES MEASURED WITH THE COLBY APPARATUS,
THE LINES OF THE SPIRIT-LEVELLING OPERATIONS,
THE ASTRONOMICAL PENDULUM & TIDAL STATIONS,
AND THE SECONDARY TRIANGULATION TO FIX THE PEAKS OF
THE HIMALAYAN & THE SOOLIMANI RANGES.
Completed to 1st May 1870

Scale 90 Miles = 1 Inch, or 1:10,800,000

REFERENCES
The course of the levelling operations is shown by a dotted line
The stations where the latitude has been observed astronomically by a star *
The stations where an azimuth has been observed astronomically by a cross +
The pendulum stations, thus ●
The principal triangulation done before the year 1830 is shown by fine lines,
after that year by thick lines
No secondary triangulation is shown excepting that to the peaks of the
mountains on the northern frontier.



CALCUTTA BASE LINE

from a sketch by James Prinsep, Jany. 1832
[III, 495 ; IV, ch. iv].

Distance with light

Light travels 299,792,458 meters/second

Dr Erik Bergstrand

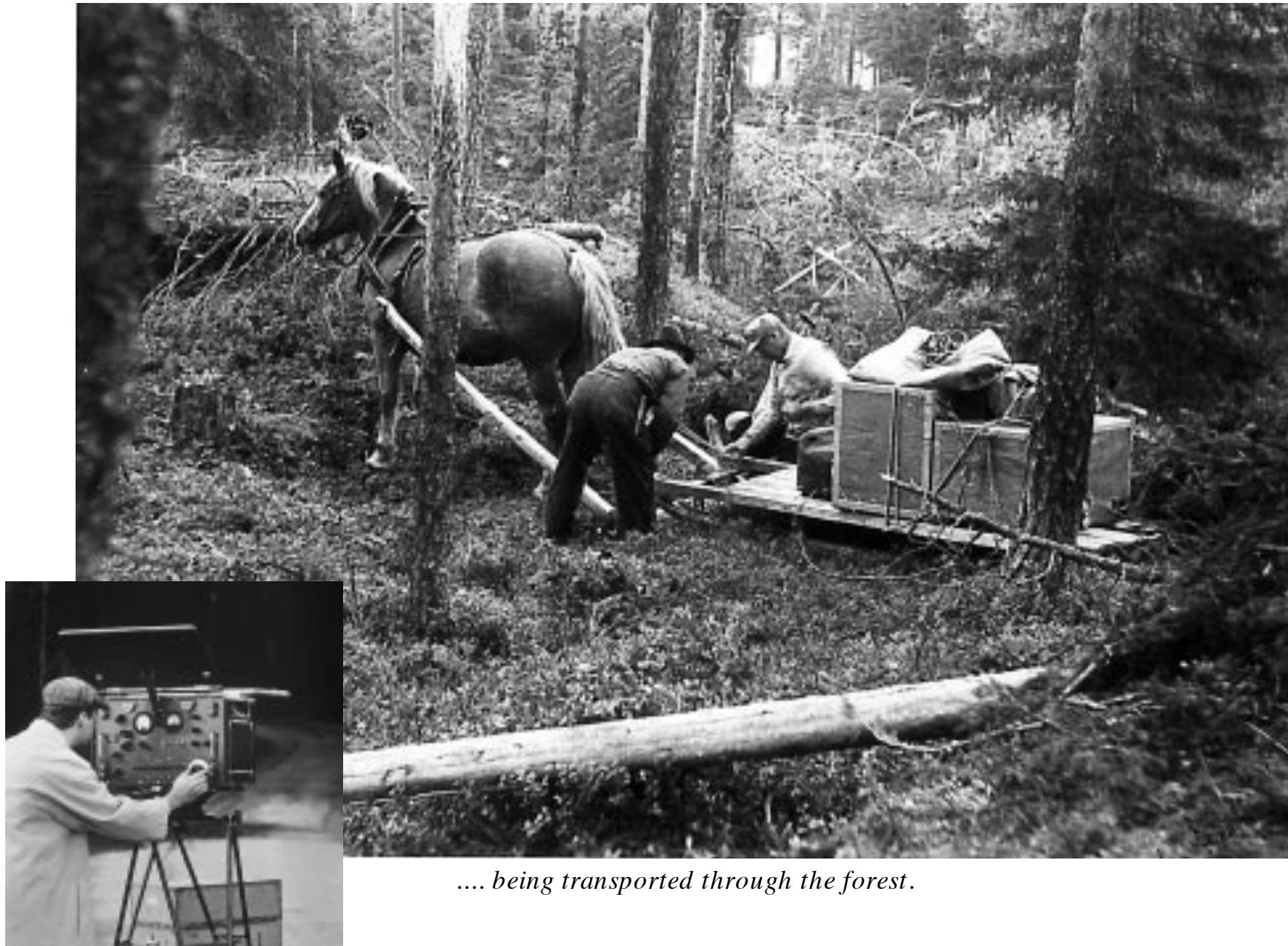
- Measuring the speed of light in 1940's



Geodimeter model 1 (1953)



Geodimeter model 2 (1955)



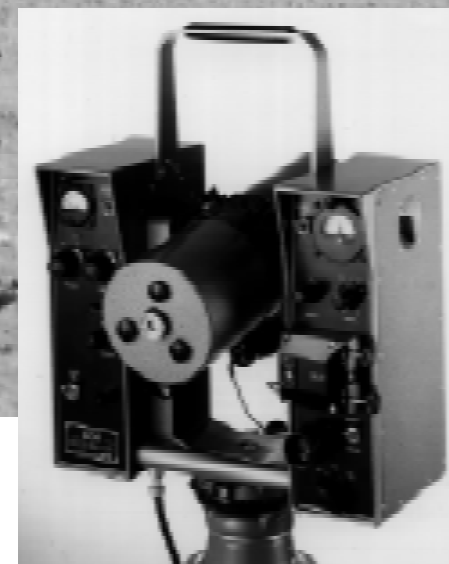
.... being transported through the forest.

Geodimeter Model 2

Geodimeter model 6 (1964)

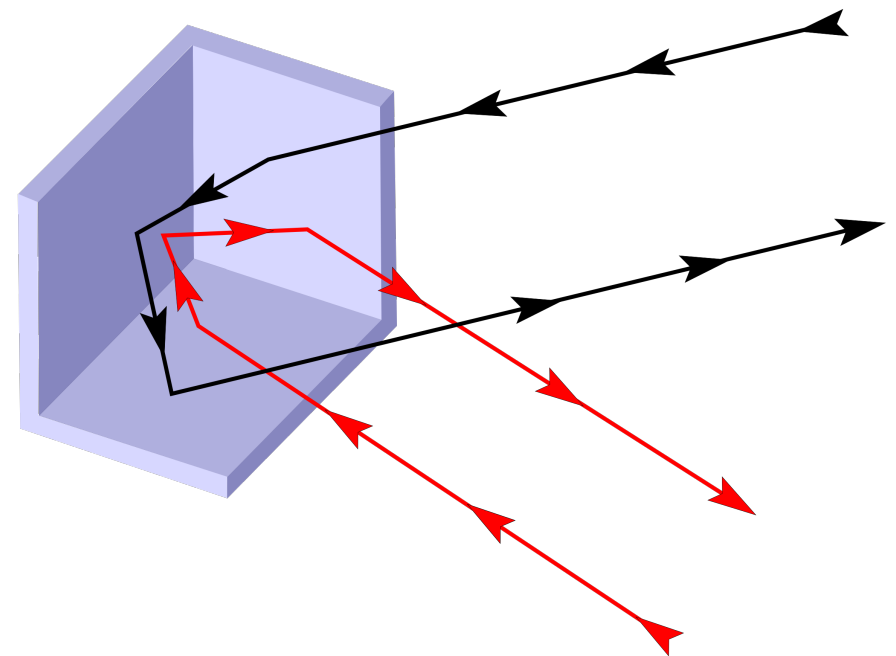


*Geodimeter Model 6 in front of the Pyramids in Giza.
A control measurement of the 4700-year old Cheops pyramid
showed that the north side measured 231.434 m and the east side
231.379 m - a difference of only 5.5 cm from a perfect square!*



How it works

- Chops light very fast (30 meter pulses)
- Bounced off a corner reflector
- Calculate how much extra length is needed to match with outgoing pulse
- Run at a different frequency



GEODIMETER MANUAL

Form 23
(8-6-54)

U. S. DEPARTMENT OF COMMERCE
COAST AND GEODETIC SURVEY

GEODIMETER OBSERVATIONS

State New Mexico Locality Cuba Date 8/31/58
 Station Lybrooks to Station Union Geod. No. 114
 Observer G. B. Lesley Height Geodimeter 1.10 Meters
 Mirror Tender J. D. Rigney Height Mirror 1.75 Meters

Time Heater on 1820 Chief of Party C. W. Thorson
 Time Plate on 1822 Recorder C. W. Thorson
 Lamp Voltage 3.6 Focus, Transmitting 10.3
 Heater Voltage 6.3 Focus, Receiving 8.4

Frequency	EL D1	No. 1 Lt. Cond.	Mirror	No. 2 Lt. Cond.	Frequency	EL D1	No. 1 Lt. Cond.	Mirror	No. 2 Lt. Cond.
1		1-60		1-50	2		9-65		9-55
Phase					Phase				
1	8	-	57.1	+	63.2	-	50.1	1	7
2		+	58.5	-	51.1	+	51.4	2	
3		-	59.1	+	52.0	-	52.4	3	
4		+	56.4	-	63.1	+	51.1	4	
Sum			231.1		229.4		205.0	Sum	
Mean			57.78		57.35		51.25	Mean	
Mirror					Geodimeter				
Time					Time				
Temp.					Temp.				
Press.					Press.				
R.H.					R.H.				

Eccentricity, Geodimeter +0.0790 Meters Mirror -0.1930 Meters
 Reduction of Electrical Length to Physical Length:
 LC: Light Conductor, course. lc; Light Conductor, fine. m; Mirror, fine
 F1
 Correct lc LC₁ 60 -lc₁ 57.78 -m 57.35 LC₁ 60 -LC₂ 50 = 59.34
 lc₁ 57.78 lc₂ 51.25
 F2
 Correct lc LC₁ 65 -lc₁ 22.90 -m 22.45 LC₁ 65 -LC₂ 55 = 64.23
 lc₁ 22.90 lc₂ 17.02

Weather: Partly Cloudy, Clear, Haze, Smoke, Sharp
 Thermometer: 2 Meters above ground at Geodimeter
 : 2 Meters above ground at Mirror
 Wind: Calm, Light, Moderate, Hard
 Remarks:

Arrow in wind direction:

FIGURE 17.—Geodimeter observations, Form 23.

U. S. COAST AND GEODETIC SURVEY

GEODIMETER OBSERVATIONS

STATE: New Mexico LOCALITY: Cuba DATE: 9/1/58

STATION: LYBROOKS TO: UNION

OBSERVER: G. B. Lesley RECORDER: C. W. Thorson

GEODIMETER NO: 114 MIRROR NO: 1

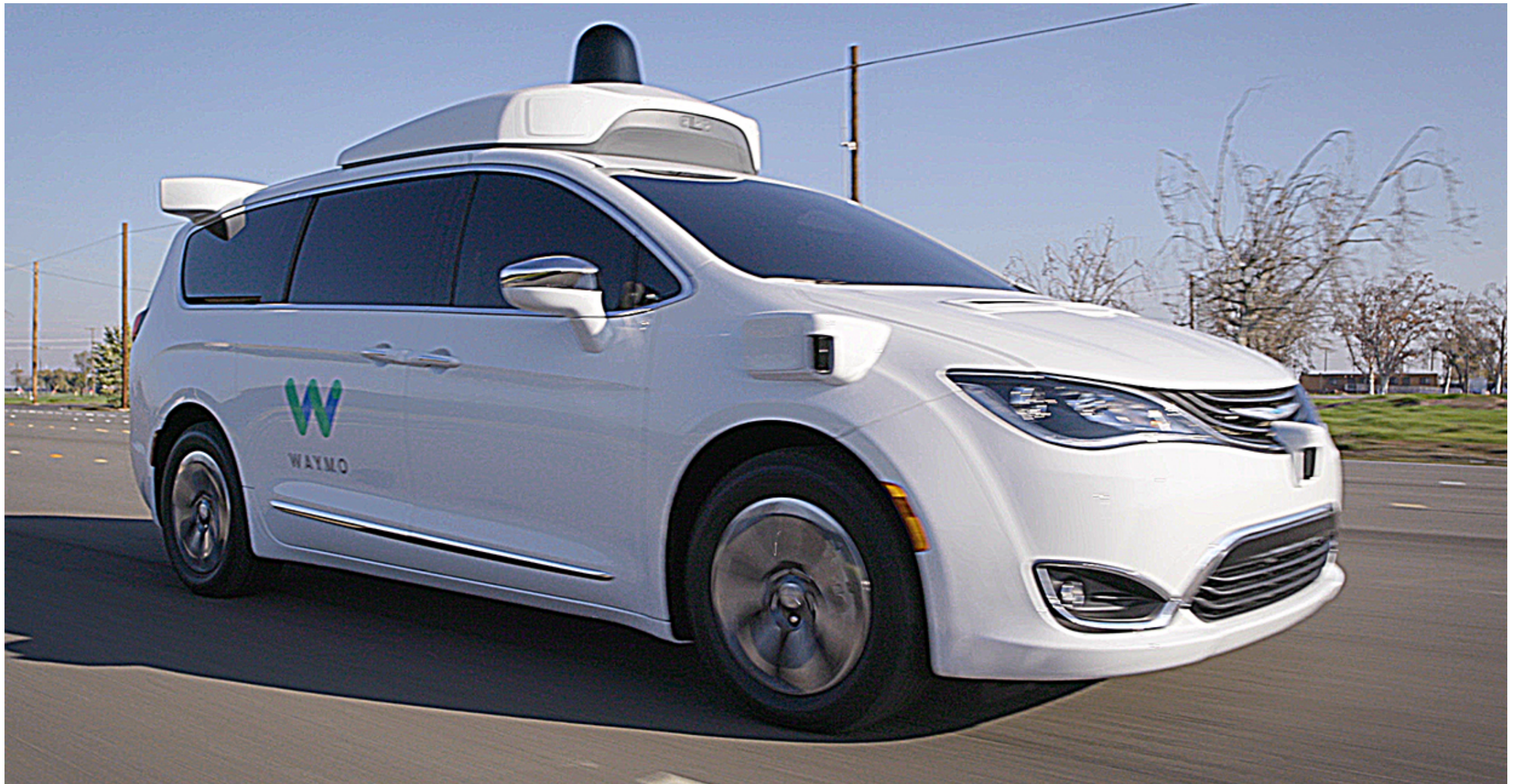
FREQ.	WAVE LENGTH COMPUTATION	QUARTER WAVELENGTH (meters)
1	$\frac{299,792,500}{4(10,000,003)(1.0002190)} =$	7.493 1692
2	$\frac{299,792,500}{4(10,049,853)(1.0002192)} =$	7.455 9996
3	$\frac{299,792,500}{4(10,299,792)(1.0002194)} =$	7.275 0678
3	$\frac{299,792,500}{4(10,299,792)(1.0002195)} =$	7.275 0671
2	$\frac{299,792,500}{4(10,049,853)(1.0002195)} =$	7.455 9974
1	$\frac{299,792,500}{4(10,000,003)(1.0002194)} =$	7.493 1663

COMPUTATION OF CONSTANTS	
GEODIMETER CALIBRATION CONSTANT	1.1288
GEODIMETER ECCENTRICITY	0.0810
MIRROR NO: 1 CONSTANT	-0.0088
MIRROR ECCENTRICITY	-0.1930
FOCUS CORRECTION	-0.0119
SUM OF CONSTANTS	+0.9961

COMPUTATION OF LENGTH			
FREQUENCY	1	2	3
NO. OF QTR. WAVELENGTHS (N)	(2780)	(2794)	(2864)
QUARTER WAVELENGTH X N	20831.0104	20832.0629	20835.7942
NO. OF LIGHT COND. X <u>0.7995</u>	7.9950	6.3960	3.1980
FINE DELAY READING	0.1175	0.6584	0.1338
SUM OF CONSTANTS	0.9961	0.9961	0.9961
SLOPE DISTANCE (METERS)	<u>20840.1190</u>	<u>20840.1134</u>	<u>20840.1221</u>
FREQUENCY	1	2	3
QUARTER WAVELENGTH X N	20831.0023	20832.0567	20835.7922
NO. OF LIGHT COND. X <u>0.7995</u>	7.9950	6.3960	3.1980
FINE DELAY READING	0.1351	0.6433	0.1360
SUM OF CONSTANTS	0.9961	0.9961	0.9961
SLOPE DISTANCE (METERS)	<u>20840.1285</u>	<u>20840.0921</u>	<u>20840.1223</u>
MEAN SLOPE DISTANCE	20840.1162		

FIGURE 22.—Computations of Geodimeter observations.

LIDAR for autonomous cars



Retro-reflector on the moon

