Surveying with light

Land surveys (at least ~3000 BC)

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

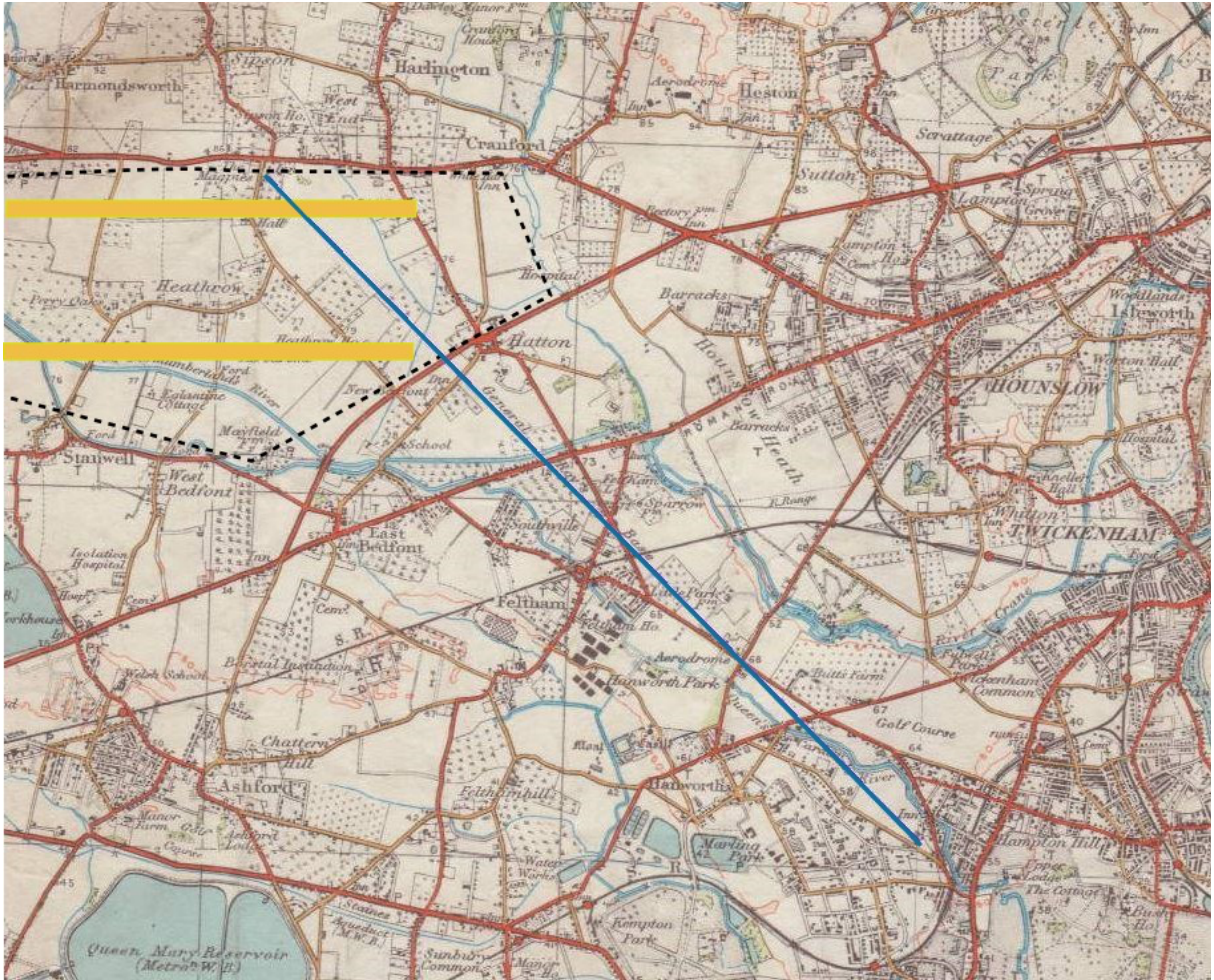
Great Pyramid of Giza; 1/15° alignment

Greeks & Romans — Segovia, 15 km aquaduct

Semi-modern methods

Basic

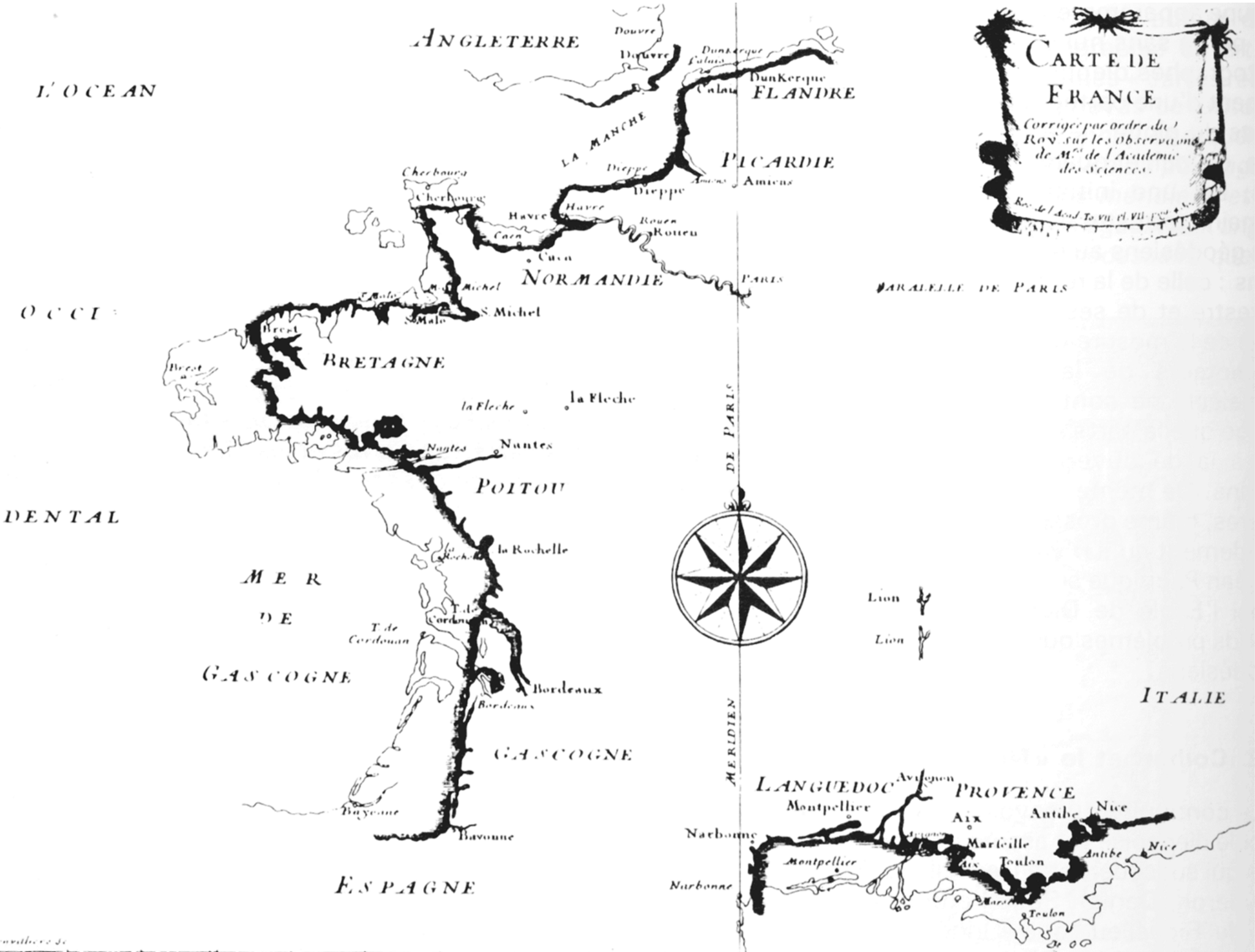
- Triangles
- Need to know one distance ‘baseline’



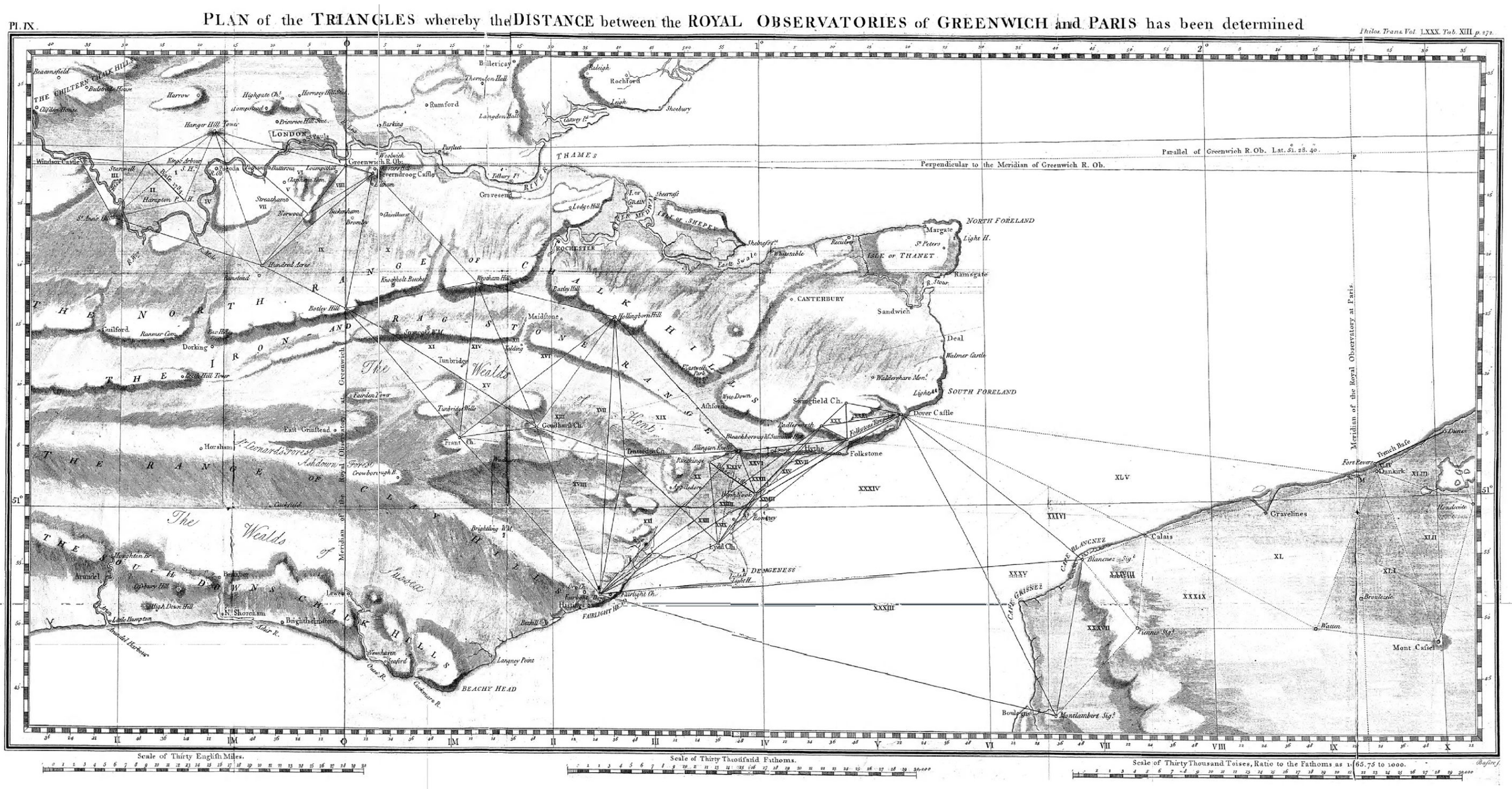
Harmondsworth
Harlington
Heston
Cranford
Aerodrome
Sutton
Scrattage
Lampton
Heathrow
Perry Oaks
Hatton
Barracks
Isleworth
HOUNSLOW
Hounslow Heath
Stanwell
West Bedfont
East Bedfont
Southville
Feltham
TWICKENHAM
Whitton
Isolation Hospital
Feltham Ho
Aerodrome
Hanworth Park
Borstal Institution
Welsh School
Twickenham Common
Golf Course
Butts Farm
Chattern Hill
Ashford
Hanworth
Felthamhill
Marling Park
Hampton Hill
Water Works
Kempton Park
Sunbury Common
Queen Mary Reservoir (Metro W. B.)
Staines Aqueduct (M.W.B.)
Hampton

Baseline measurement

- Glass or Metal rods
- Chain

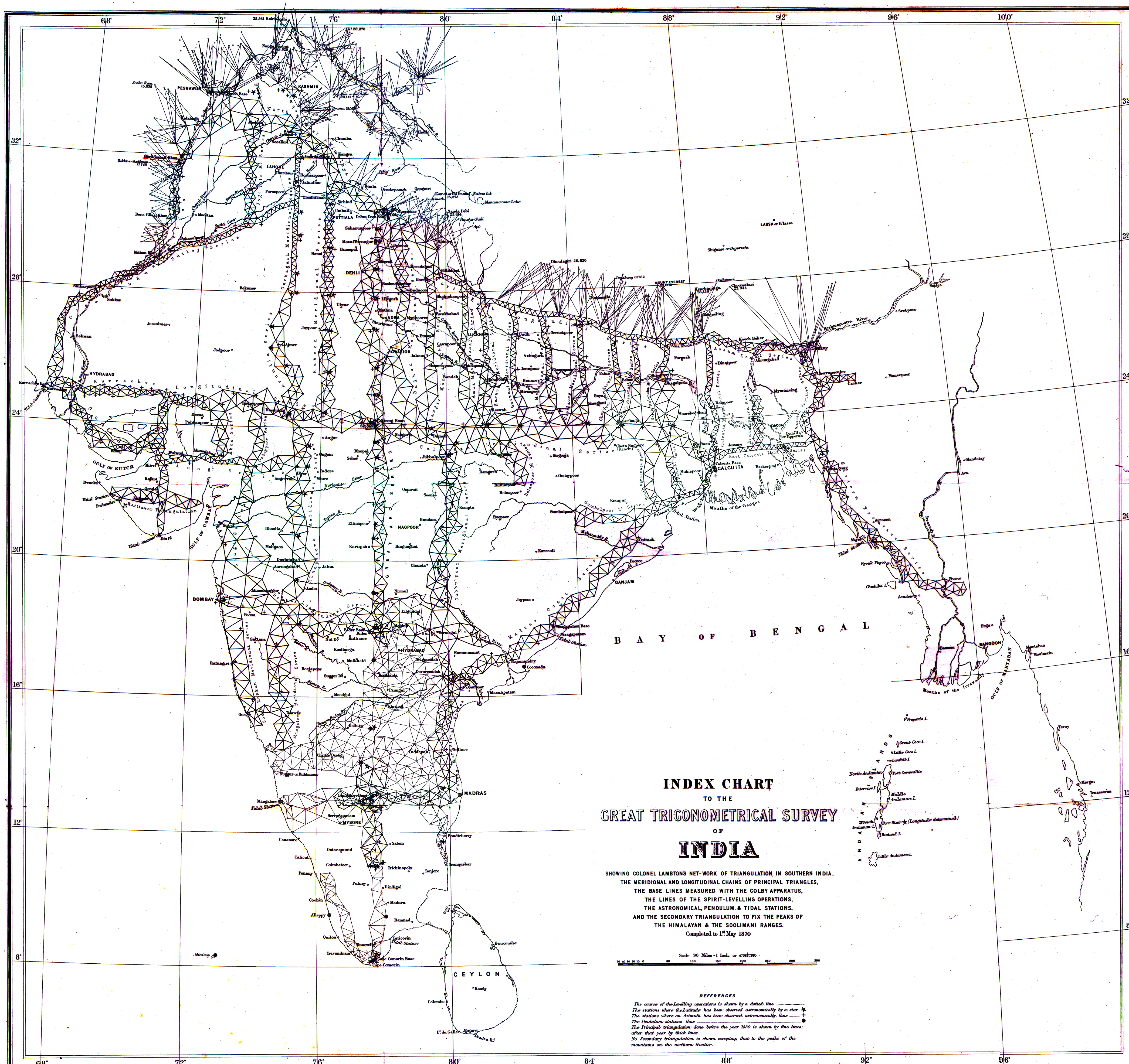

CARTE DE FRANCE
Corrigée par ordre du Roy sur les Observations de Mrs de l'Academie des Sciences.
ANGLETERRE
L'OCEAN
OCCIDENTAL
MER DE GASCOGNE
ESPAGNE
LA MANCHE
FLANDRE
PICARDIE
NORMANDIE
BRETAGNE
POITOU
GASCOGNE
LANGUEDOC
PROVENCE
ITALIE
PARALELLE DE PARIS
MERIDIEN DE PARIS
Douvre
Dunkerque
Calais
Amiens
Dieppe
Cherbourg
Havre
Rouen
Caen
Paris
S. Michel
Malo
Brest
la Fleche
Nantes
la Rochelle
T. de Cordouan
Bordeaux
Bayonne
Montpellier
Avignon
Aix
Marseille
Antibe
Nice
Toulon
Narbonne
Lion

Anglo-French survey 1790



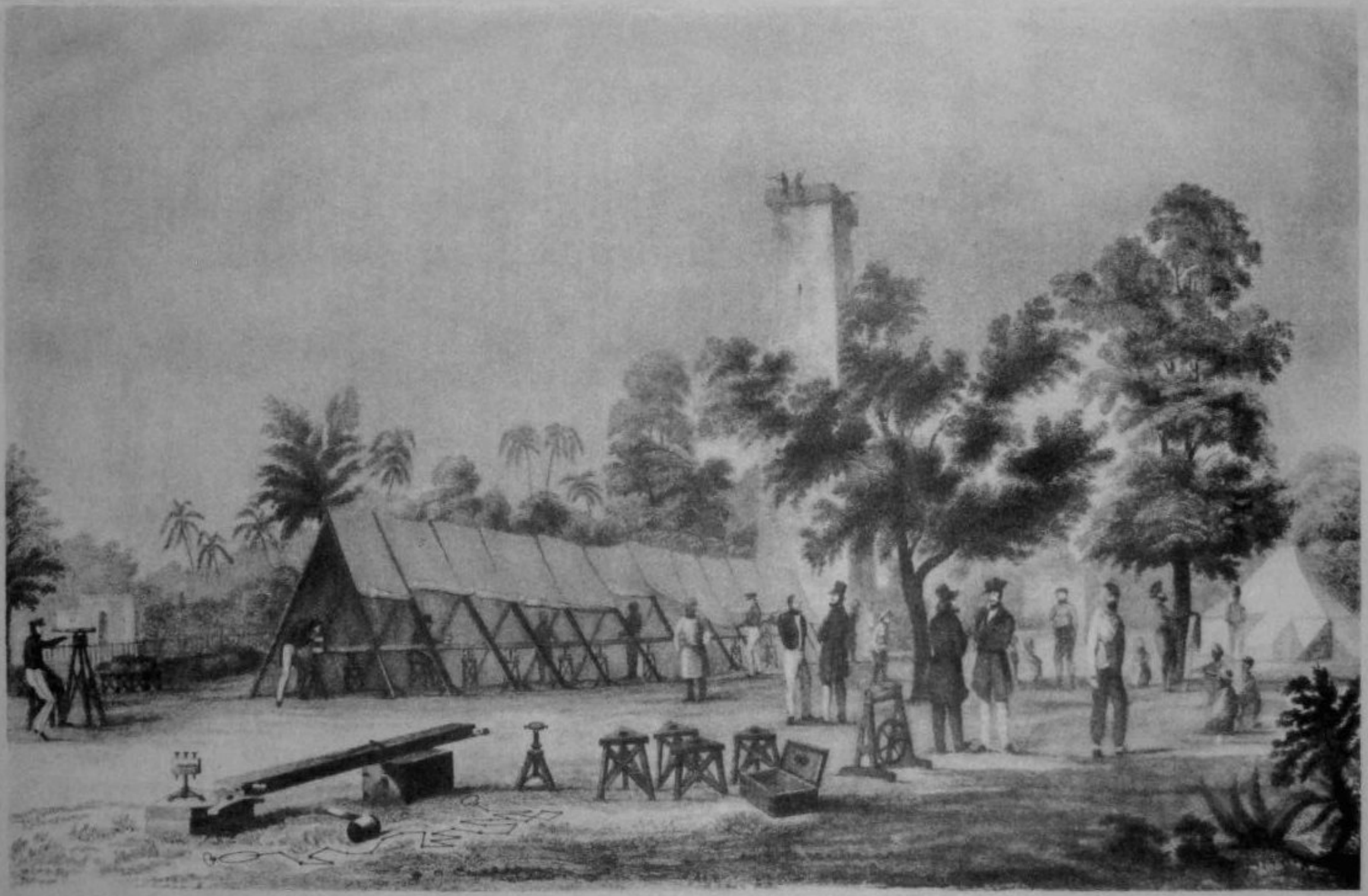
Great Trigonometric Survey of India

- 1802–1871
- George Everest was second supervisor



COMPILED UNDER THE ORDERS OF COL. J. T. WALKER, R.E., F.R.S. &c. SUPERINTENDENT GREAT TRIGONOMETRICAL SURVEY OF INDIA AT DEHRA DOON, AUGUST 1870.

Engraved at the Surveyor General's Office.



CALCUTTA BASE LINE

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

Reg. No. 5521 HD'52-800'54

Printed at the Survey of India Offices (H.L.O.).

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.

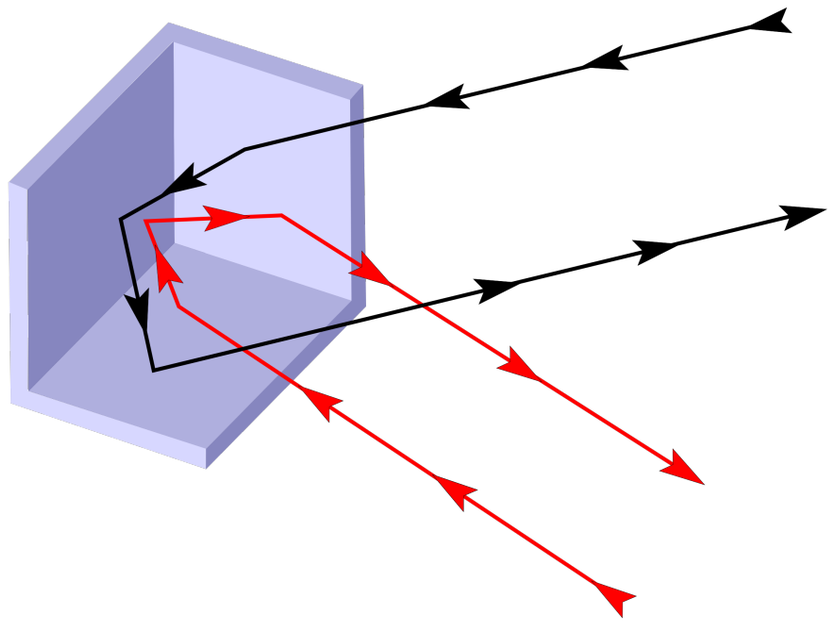
Geodimeter Model 2 ....

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



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	+ 22.0	+ 27.2	+ 16.2
2		+ 58.5	- 51.1	+ 51.4	2		- 23.9	- 18.0	- 17.8
3		- 59.1	+ 52.0	- 52.4	3		+ 23.7	+ 17.5	+ 18.0
4		+ 56.4	- 63.1	+ 51.1	4		- 22.0	- 27.1	- 16.1
Sum		231.1	229.4	205.0	Sum		91.6	89.8	68.1
Mean		57.78	57.35	51.25	Mean		22.90	22.45	17.02

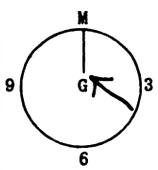
	Mirror	Geodimeter	Mirror	Geodimeter	Mirror	Geodimeter
Time		1917		1927		1940
Temp.	23.2°C	21.4	23.0	21.0	22.8	21.0
Press.	7520 FH	8228	7520	8205	7510	8180
R.Hu.	71°F 51°F	23%				

Eccentricity, Geodimeter +0.0790 Meters Mirror −0.1930 Meters
Reduction of Electrical Length to Physical Length:
LC; Light Conductor, course. 1c; Light Conductor, fine. m; Mirror, fine Mirror no. 1 constant −0.0088

F1
Correct 1c LC_1 60 $-\frac{1c_1\ 57.78 - m\ 57.35}{1c_1\ 57.78\quad 1c_2\ 51.25}$ LC_1 60 $-LC_2$ 50 = 59.34

F2
Correct 1c LC_1 65 $-\frac{1c_1\ 22.90 - m\ 22.45}{1c_1\ 22.90\quad 1c_2\ 17.02}$ LC_1 65 $-LC_2$ 55 = 64.23

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

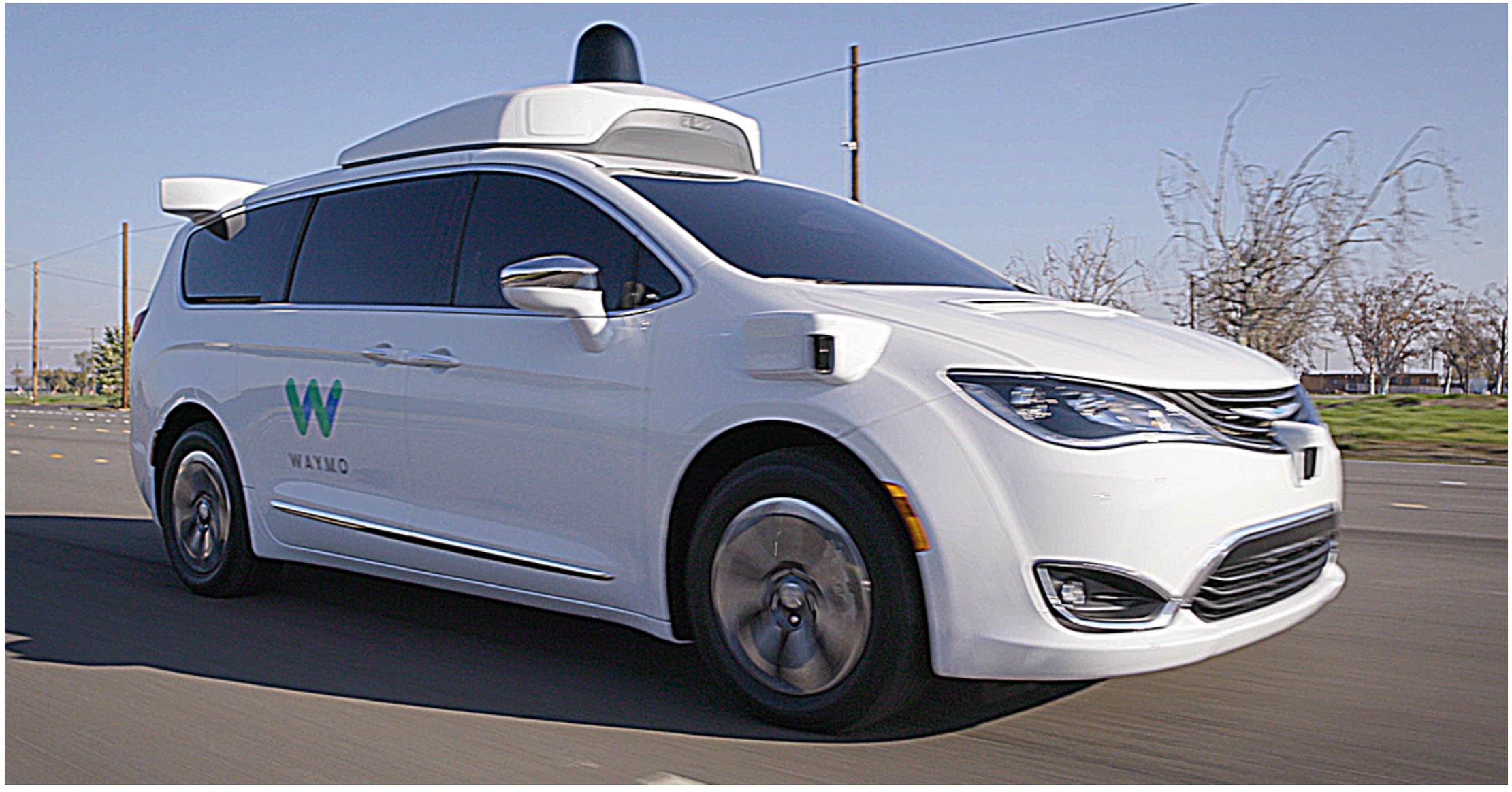
FREQUENCY	1	2	3
NO. OF QTR. WAVELENGTHS (N)	(2780)	(2794)	(2864)
QUARTER WAVELENGTH X N	20831.0104	20832.0629	20835.7942
NO. OF LIGHT COND. X 0.7995	7.9950	6.3960	3.1980
FINE DELAY READING	0.1175	0.6584	0.1338
SUM OF CONSTANTS	0.9961	0.9961	0.9961
SLOPE DISTANCE (METERS)	20840.1190	20840.1134	20840.1221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

MEAN SLOPE DISTANCE 20840.1162

FIGURE 22.—Computations of Geodimeter observations.


LiDAR

LIDAR for autonomous cars



Retro-reflector on the moon