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 aqueduct
Semi-modern methods
Basic

- Triangles
- 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
CALCUTTA BASE LINE

from a sketch by James Prinsep, Jan'y. 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
possible to achieve the same result by switching a low frequency to a Kerr cell so that the phase of the outgoing light pulses was changed $180^\circ$ during each half cycle of the low frequency. Zero readings on the galvanometer thus occur halfway between alternating maxima, and where the slope is highest which means that the sensitivity will be maximum. Geodimeter is thus a phase intensity comparator and the intensity comparison is made at the point of maximum rate of change (Fizeau measured where the intensity was small). Such is the basis of the Geodimeter instruments.

When used in anger, if the distant mirror were moved backwards or forwards a position would be found where the currents balanced out and gave a null reading. Obviously it would be very inconvenient to have to move the mirror for each line. One alternative was to vary the frequency of light modulation until a null reading was obtained since the distance between the zeros is a function of the frequency. In conjunction with such a system the instrument had to be calibrated to allow for time lag within its electrical circuits. The Bergstrand-built prototype of the Geodimeter was built according to this arrangement using a frequency of 8.332 230MHz. For the first AGA production model instead of varying the frequency the phase of the voltage was varied by use of a variable time delay in the circuit joining the plates of the Kerr cell to the anode of the phototube.

The advantage with fixed frequencies was that even short distances could be measured, which at that time would have been very difficult using variable frequencies. This would have necessitated a large frequency range combined with high accuracy, impossible to achieve for portable equipment before the advent of transistor technology.

The basis of the distance computation when the galvanometer read zero was that

$$D = K + (2N-1)\frac{\lambda}{8}$$

where

- $D =$ distance to be measured
- $K =$ constant dependent on electrical delay factors
- $N =$ positive whole number
- $\lambda =$ wavelength of the light pulses leaving the Nicol prism

The oscillations from the crystal controlled high frequency oscillator in models 1, 2 and 2A had a frequency of about $10^7$ cycles per sec. and amplitude of about 2000 volts and they were superimposed on oscillations of 50 cycles per sec. and 5000 volts which formed a carrier wave. These were rectangular waves which means that positive and negative voltages occurred over successive half oscillations and these deflected the galvanometer in opposite directions. Thus when voltages were equal there was a null deflection. Since the velocity of light was about $3 \times 10^8$ m/sec. with a frequency of $10^7$ cycles/sec. this gave a wavelength of about 30 m.

Among the wavelengths used in various models of Geodimeter are:

- Mercury vapour lamp 5500 Å
- Standard lamp 5650
- Red laser light 6328
- Infra-red 9200
- Infra-red 9300
Geodimeter model 2 (1955)

.... being transported through the forest.

Geodimeter Model 2 ....
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 Observations**

**State:** New Mexico  **Locality:** Cuba  **Date:** 9/1/58

**Station:** Lybrook  **To:** Union

**Observer:** G.B. Lesley  **Height Geodimeter:** 110  **Meters**
**Mirror:** J.P. Rigley  **Height Mirror:** 175  **Meters**

**Time Heater on:** 1920  **Chief of Party:** C.W. Thorson
**Time Plate on:** 1922  **Recorder:** C.W. Thorson
**Lamp Voltage:** 3.6  **Focus, Transmitting:** 10.8
**Heater Voltage:** 6.3  **Focus, Receiving:** 8.4

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**Time:** 1917  **Geodimeter:** 1927  **Geodimeter:** 1940

**Temp.:** 23.2°C  **21.4**  **23.0**  **21.0**  **22.8**  **21.0**

**Pres.:** 7520A  **4228**  **7520**  **8205**  **7510**  **4180**

**Slope:** 71° 5' 5"E  **28°**

**Geodimeter Calibration Constant:** 1.1288

**Geodimeter Eccentricity:** 0.0810

**Mirror No.: 1 Constant:** 0.0085

**Mirror Eccentricity:** 0.0064

**Focus Correction:** 0.0011

**Sum of Constants:** 40.9951

**Computation of Length**

**FREQUENCY**

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**Computation of Constants**

**FREQUENCY**

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**Mean Slope Distance:** 20840.1162

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Figure 17.—Geodimeter observations, Form 23.
LIDAR for autonomous cars
Retro-reflector on the moon