TVET CERTIFICATE III in LAND SURVEYING

OPERATION OF TOTAL STATION AND GPS

LSVSG301

Operate Total station and GPS

Competence

Learning hours: 60

Credits: 6

Sector: Construction and Building Services

Sub-sector: Land Surveying

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Purpose statement

This is a core module which describes the performance outcomes, skills knowledge and attitude required to operate Total station and GPS.

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Learning Unit 1 – Determine Classifications and specifications of Total station and GPS

LO 1.1 – Identify the Total station and GPS

- Topic 1: Brief introduction on Total station and GPS

A **Total Station (TS)** is an electronic/optical instrument used in modern surveying. The total station is an electronic theodolite (transit) integrated with an electronic distance meter (EDM) to read both vertical and horizontal angles and slope distances from the instrument to a particular point.

A total station often requires two people to record measurements, with one person operating the total station and another positioned at the other point that the total station is using in its calculations. Some total stations are robotic though, enabling the operator to stand at the opposite point and still control the total station.

Uses of total station (TS):

1. Average of multiple angles measured.
2. Average of multiple distance measured.
3. Horizontal distance.
4. Distance between any two points.
5. Elevation of objects and
6. All the three coordinates of the observed points.

The **Global Positioning System** (**GPS**), is a space-based satellite navigation system that provides location and time information in all weather conditions, anywhere on or near the Earth where there is an unobstructed line of sight to four or more GPS satellites.

A global navigation satellite system consisting of positioning satellites and their associated ground stations. The system provides critical capabilities to military, civil and commercial users around the world. It is maintained by the US government and is freely accessible to anyone with a **GPS receiver.** A user needs only GPS receiver. The receiver measures the travel time of the signals from satellites and calculate position (latitude and longitude) and the elevation altitude of the station with reference to a selected datum.

Uses of GPS:

A Global Positioning System, also known as GPS, is a system of thirty- one satellites designed to help navigate on the Earth, in the air, and on water.

A GPS receiver shows where it is. It may also show how fast it is moving, which direction it is going, how high it is, and maybe how fast it is going up or down.

Many GPS receivers have information about places. GPSs for automobiles have travel data like road maps, hotels, restaurants, and service stations.

GPSs for boats contain nautical charts of harbors, marinas, shallow water, rocks, and waterways. Other GPS receivers are made for air navigation, hiking and backpacking, bicycling, or many other activities. Most GPS receivers can record where they have been, and help plan a journey. While traveling a planned journey, it predicts the time to the next destination.

- Topic 2: Manufacturing of Total station and GPS

Some of the **manufacturers of Total Station** are:

1. *Kern & Co. AG* (until 1992, today Leica Geosystems)
2. *Wild Heerbrugg AG* (historical). The company was incorporated into *Leica Geosystems* in 1990
3. *Miller, Innsbruck* (until ca. 1990)
4. *Carl Zeiss* (historical), today part of Trimble Navigations Ltd.
5. *Geodimeter* (historical), today part of Trimble Navigations Ltd.
6. *Spectra Precision*, today part of Trimble, although still manufactured under its own brand.
7. *Fennel* (today: *Geo-Fennel*)
8. Other manufacturers are: *Hilti, Leica Geosystems, Geomax, Pentax, Stonex, Nikon, Sokkia, Topcon, Trimble Navigation Ltd,* and *F. W. Breithaupt* & *Sohn*

GPS Manufacturers: The GPS project was started by the U.S. Department of Defense in 1973, with the first prototype spacecraft launched in 1978 and the full constellation of 24 satellites operational in 1993. GPS was developed by United States defense department and was called as Navigational System with Time and Ranging Global Positioning System (NAVSTAR) or which is now simply known as GPS. Its most manufacturer is *GARMIN*

- Topic3: Identification of Total station

Angle measurements

Most modern total station instruments measure angles by means of electro-optical scanning of extremely precise digital bar-codes etched on rotating glass cylinders or discs within the instrument. The best quality total stations are capable of measuring angles to 0.5 arc-second. Inexpensive "construction grade" total stations can generally measure angles to 5 or 10 arc-seconds.

The electronic theodolite part of total station is used for measuring vertical and horizontal angle. For measurement of horizontal angles any convenient direction may be taken as reference direction. For vertical angle measurement vertical upward (zenith) direction is taken as reference direction.

Distance measurements

Measurement of distance is accomplished with a modulated microwave or infrared carrier signal, generated by a small solid-state emitter within the instrument's optical path, and reflected by a prism reflector or the object under survey. Electronic distance measuring (EDM) instrument is a major part of total station. Its range varies from 2.8 km to 4.2 km. The accuracy of measurement varies from 5 mm to 10 mm per km measurement. They are used with automatic target recognizers. The distance measured is Horizontal, vertical and sloping distance from instrument to the object.

Physical specifications

Except where stated, the following specifications apply to all models:

Telescope	Length	171mm
	Magnification	30X
	Image:	Erect
	Field of view	1°30'
	Reticle illumination:	5 brightness levels
Angle measurement	Angle units:	Degree/Gon/Mil (selectable)
	Minimum display:	ES-102L/105L: 1" ES-107: 5"
	Accuracy:	ES-102L: 2" ES-105L: 5" ES-107: 7"
	Horizontal angle:	Right/Left (selectable)
	Vertical angle:	Zenith/Horizontal/Horizontal (selectable)
Distance Measurement	Measuring method:	Coaxial phase shift measuring system
	Signal source:	Red laser diode 690nm
	Minimum display: *Fine/Rapid measurement*:	0.001m
	Minimum display: *Tracking measurement:*	0.01m
	Maximum slope distance display with *Prism:*	7680m
	Maximum slope distance display (Reflector-less)	768m
	Distance unit:	m/ft/inch (selectable)
Guide Light	Light source:	LED (red 626 nm/green 524 nm)
	Distance:	1.3 to 150m
	Brightness:	3 levels (bright/normal/dim)
Memory	Internal memory Capacity	1MB (10,000 points)

	External memory: *USB flash memory*	up to 8 GB
Power Supply	Power source:	Rechargeable Li-ion battery BDC70
	Working duration at 20 °C:	BDC70: about 36 hours BT-73Q: about 89 hours
	Battery state indicator:	4 levels
	Auto power-off:	5 levels (5/10/15/30 min/Not set) (selectable)
	External power source:	6.7 to12V
	Charging time at 25 °C:	about 5.5 hours
General	Operation panel (keyboard):	25 keys (soft function, operations, power on, light) with illuminator
	Laser sighting function:	Provided On/Off (selectable)
	Operating temperature	Standard models: -20 to 50 °C Low temperature models: -30 to 50 °C High temperature models: -20 to 60 °C
	Storage temperature	-30 to 70 °C
	Instrument height:	192.5 mm from tribrach mounting surface 236mm from tribrach bottom
	Size (with handle):	191 (W) X 181 (D) X 348 (H) mm
	Weight (with battery):	5.6kg

Total station accuracy

The less expensive unit with a single prism reflector can measure distances up to 2,000 m. Those in the higher price range are capable of measuring distances up to 4,000 m, when single prisms are used. A typical total station can measure distances with an accuracy of about 1.5 millimeters + 2 parts per million over a distance of up to 1,500 meters. The accuracy of angle measurement varies from 2 to 6 seconds.

To measure horizontal and vertical angles, the electronic theodolite of device is used with an accuracy of *2-6 seconds*. To measure the distance, Electronic Distance Measuring (EDM) instrument of total station is used with an accuracy of *5-10 mm per km*.

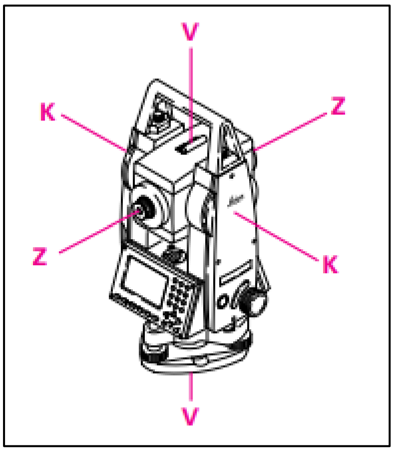
Operating system and data processing

Total Station is provided with an inbuilt microprocessor. The microprocessor averages multiple observations. With the help of slope distance and vertical and horizontal angles measured, when height of axis of instrument and targets are supplied, the microprocessor computes the horizontal distance and X, Y, Z coordinates. The processor is capable of applying temperature and pressure corrections to the measurements, if atmospheric temperature and pressures are supplied.

Some models include internal electronic data storage to record distance, horizontal angle, and vertical angle measured, while other models are equipped to write these measurements to an external data collector, such as a hand-held computer. When data is downloaded from a total station onto a computer, application software can be used to compute results and generate a map of the surveyed area.

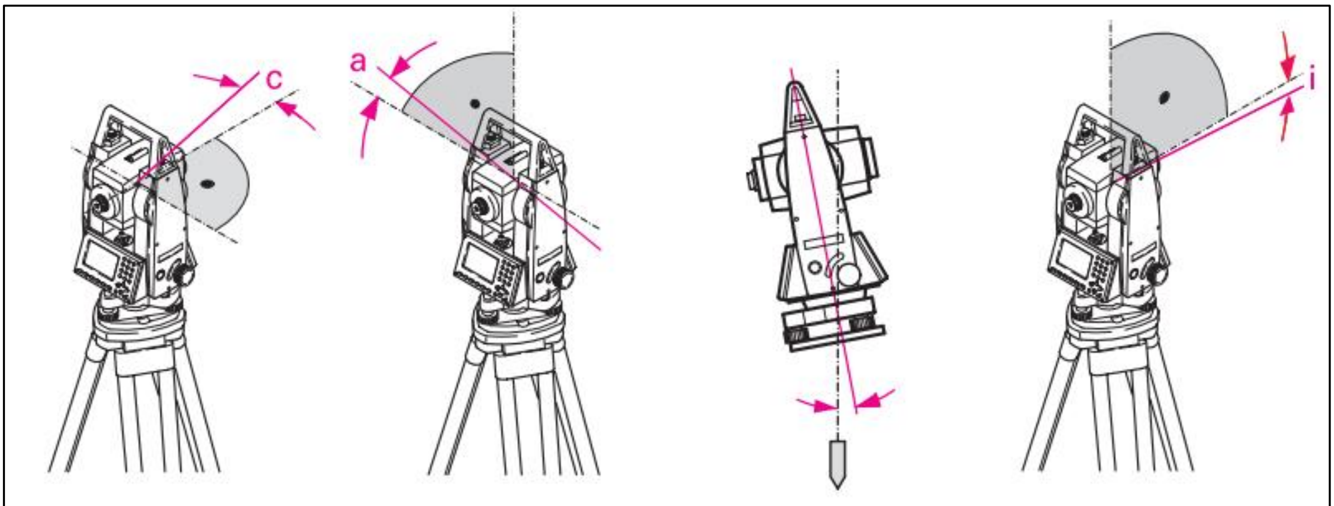
- **Topic 4: Identification of Sources of errors on the total station**

Ideally, the total station should meet the following requirements:



i) Line of sight ZZ perpendicular to tilting axis KK
ii) Tilting axis KK perpendicular to vertical axis VV
iii) Vertical axis VV strictly vertical
iv) Vertical-circle reading precisely zero at the zenith

If these conditions are not met, the following terms are used to describe the particular errors:



Line-of-sight error (c) (Hz collimation) | Tilting-axis error (a) | Vertical-axis tilt | Height-index error (i) (V index)

1. **Line-of-sight error**, or **collimation error** " ***c*** " (deviation from the right angle between the line of sight and the tilting axis)
2. **Tilting-axis error** " ***a*** " (deviation from the right angle between the tilting axis and the vertical axis)
3. **Vertical-axis tilt** (angle between plumb line and vertical axis).

The effects of these three errors on the measurement of horizontal angles increase with the height difference between the target points.

Taking measurements in both telescope faces eliminates line-of-sight errors and tilting-axis errors. The line-of sight error (and, for highly precise total stations, also the tilting-axis error, which is generally very small) can also be determined and stored. These errors are then taken into consideration automatically whenever an angle is measured, and then it is possible to take measurements practically free of error even using just one telescope face. The determination of these errors, and their storage, are described in detail in the appropriate user manual. Vertical-axis tilt does not rate as being an instrument error; it arises because the instrument has not been adequately levelled up, and measuring in both telescope faces cannot eliminate it. Its influence on the measurement of the horizontal and vertical angles is automatically corrected by means of a two-axis compensator.

4. **Height-index error** " **i** "(*the angle between the zenith direction and the zero reading of the vertical circle, i.e. the vertical circle reading when using a horizontal line of sight*), is not 100 gon (90°), but 100 gon + i.

By measuring in both faces and then averaging, the index error is eliminated; it can also be determined and stored.

Note: The instrument errors change with temperature, as a result of vibration, and after long periods of transport. If you want to measure in just one face, then immediately before the measurements you must determine the instrument errors and store them.

Avoiding Errors in total station surveying

With EDM instrument and support equipment properly adjusted and calibrated, errors and blunders to watch for are:

a. Incorrect temperature barometric pressure (ppm) are entered into the instrument.
b. Misalignment of the retro-prism to the EDM. Misalignment in either the horizontal or vertical

While Setting Up:

1. **Tripods checks:** The weight of EDM equipment puts an added strain on tripods and instrument stands. Thus, the tripods used to support EDM instruments must be sturdy and in good condition.
2. **Tribrach Checks**: Tribrach must be checked for adjustment (bubble and optical plummet) frequently. This includes not only the tribrach used for the EDM instrument, but also those used with the reflectors. If a tribrach is accidentally bumped, dropped, or knocked over, it must be checked before any additional measurements are made.

3. **Instrument Stability**: The setup for an EDM instrument should be very stable. Not only are EDM instruments heavy but they also offer larger areas of wind resistance. In addition, the electrical cords place added forces on the setup.

- ***Reflections from Extraneous Objects***

  1) **Natural and Man-Made Obstructions:** Under most circumstances, an EDM measurement will be within the accuracy specified for that instrument. This is true even if the line of sight passes through trees, fences, or other such obstructions. However, such objects can sometimes reflect or interrupt the light rays and cause erroneous measurements. Usually this occurs only if the object is relatively close to the instrument.

     Be especially careful of plastic reflectors, such as those used on guide marker posts. If one of these is in the path of or behind the prism, it can and often does cause erroneous measurements. When the line of sight can not be cleared, the recorder should note the conditions of the measurement. Then, if poor closures result, these distances can be isolated and checked.

  2) **Extra Prisms Set Out:** When making EDM measurements, only one set of reflectors should be facing the instrument along the line of sight. If an extra set of reflectors faces the instrument, it might reflect light rays to the instrument and cause error. This can occur when various distances are being measured along a straight line of fairly uniform grade when more than one reflector is being used. When doing such work, reflector tenders should always keep their reflectors turned away from the instrument except during the actual measurement to their point.

- Topic 6: Identification types of Total station and GPS

Types of Total Stations:

In the early days, three classes of total stations were available, **based on their functioning**: *manual, semiautomatic* and *automatic.*

1. **Manual Total Stations** It was necessary to read the horizontal and vertical angles manually in this type of instrument. The only value that could be read electronically was the slope distances.
2. **Semiautomatic Total Stations** The user had to manually read the horizontal circle for these instruments, but the vertical circle readings were shown digitally. Slope distances were

measured electronically and the instruments could, in most cases, be used to reduce the values to horizontal and vertical components.

3. **Automatic Total Stations** This type is the most common total station used nowadays. They sense both the horizontal and vertical angles electronically and measure the slope distances, compute the horizontal and vertical components of those distances, and determine the coordinates of observed points. To compute the coordinates of observed points, it is necessary to properly orient the instrument to some known directions such as true north, magnetic north or to some known bearing. The coordinate information obtained can either be stored in the total station's memory or by using an external data collector.

Manual total stations and semiautomatic total stations are obsolete now. At present, it is the age of fully automatic total stations and robotic total stations.

*Based on a **primary use** the Total Station is designed for, there are four basic types of total stations and they include:*

a) **Robotic Total Station**: It permits the user to control the device remotely, meaning that you do not have to have an instrument operator standing by the total station. This is greatly beneficial that you need not hire an assistant to hold the rod for you.

b) **Imaging Total Station:** This kind of total station adds either a photographic or a laser scanning element or both. With this new tool, the surveyors could offer many more services that greatly benefit from these high-resolution images. Moreover, the laser scanner component can capture topographic data automatically. The imaging capability provides an accurate photo documentation of the site's existing condition, which in effect, is beneficial in generating productivity and minimizing expenses caused by re-visits to the site.

c) **Construction Total Stations**: These types of total stations are specifically designed to aid construction efforts.

d) **Optical Total Station:** This type of total station is the basis for both robotic and imaging total stations. While an optical total station can have many features, this type of total station will require an instrument operator at the device. It will also have the imaging capabilities mentioned above. This device is essentially designed for your everyday surveying applications

Types of Global Positioning System (GPS) receiver:

A general classification of various **types of GPS** receivers *based on various GPS applications* are listed below:

1. ***Navigations GPS Receivers:*** Used for land air and sea (marine) navigation and tracking including precise navigation, collision avoidance, cargo monitoring, vehicle tracking, search and rescue operation, etc. This kind of applications require modest accuracy and the user hardware is comparatively of low cost, and the integrity and speed with which the results are needed is generally high.
2. ***Surveying GPS Receivers:*** Used for surveying and mapping on land, at sea and from air, and the applications include geophysical and resource mapping, GIS data capture, surveying and positioning, and general engineering applications. The applications are of relatively high accuracy, for positioning in both the static and moving receiver mode, and generally require specialized receivers and software.
3. ***Military GPS Receivers:*** The military grade GPS systems are developed according to military specifications and they are capable of tracking encrypted codes such as precision code (P-code).
4. ***GPS Receivers for Recreational Activities:*** Used for recreational purposes on land, sea and in the air. The requirement is low-cost equipment that are easy to use.
5. ***GPS Receivers for Scientific Applications:*** Used for scientific applications such as time transfer, altitude determination, spacecraft applications, atmospheric studies, crustal deformation studies, geodetic studies, etc. Such applications require special type of costly receivers.

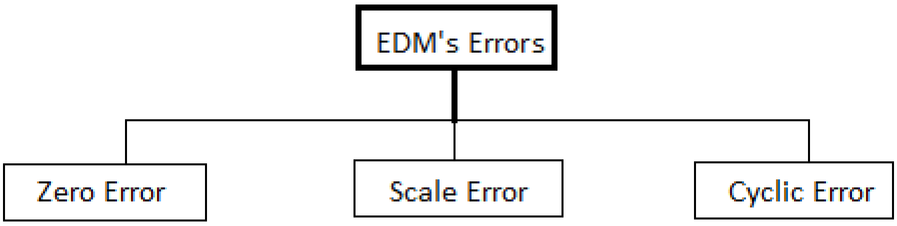
Three general **classes of GPS receivers** are:

a) ***Navigation/Recreational grade****:* These are gps units used in vehicles and for recreational purposes, which can range in accuracy from 5 to 15 meters. Typically, these range in cost from $200-$500.
b) ***Mapping grade****:* These include a range of positional accuracy; however, with WAAS enabled this can improve to under 3 meters. Accuracy improves with the use of differential correction and the use of higher quality antennas. These can range from $500 to thousands of dollars. Additional features may be present to identify different map features from the GPS unit, use a stylus for GPS unit navigation, and additional accessories to increase functionality. With the use of differential GPS, accuracy can increase to be less a meter.
c) ***Survey grade****:* These include GPS receivers which can receive accuracy levels in the 1 meter range or better in terms of less than a foot, centimeter, and millimeter. Based on the USGS

Global Positioning Application and Practice site, for a GPS receiver to be considered survey grade, the receiver must record the full range of signal strengths and frequencies (dual-frequencies), and simultaneously track eight satellites.

- Topic 7: Identification of EDM's errors

The distances measured by EDM reflector combination are subject to three types of error, as shown in Figure below:



1. **Zero Error** *(Additive Constant)*: is caused by three factors as listed by:
   - ✓ Electrical delays, geometric detours, and eccentricities in the EDM,
   - ✓ Differences between the electronic center and the mechanical center of the EDM,
   - ✓ Differences between the optical and mechanical centers of the reflector.

The additive constant or zero/index correction is added to the measured distances to correct for these differences. This error may vary with changes of reflector, so only one reflector should be used for EDM calibration.

2. **Scale errors**: are linearly proportional to the measured distance and can arise from both internal and external sources. Internal sources are ageing and temperature effects (e.g. insufficient warm-up time).
   - ✓ Internal frequency errors, including those caused by external temperature and instrument "warm-up" effects,
   - ✓ Un-modelled variations in atmospheric conditions which affect the velocity of propagation,
   - ✓ Non-homogeneous emission/reception patterns from the emitting and receiving diodes.
3. **Cyclic Error** *(Short Periodic Error)*: is a function of the actual phase difference measurement by the EDM. Phase measurement error is caused by unwanted feed through the transmitted signal onto the received signal.

Cyclic error is usually sinusoidal in nature with a wavelength equal to the unit length of the EDM. The unit length is the scale on which the EDM measures the distance, and is derived from the fine measuring frequency. The stability of the EDM internal electronics can also vary with age, therefore, the cyclic error can change significantly over time.

Cyclic error is inversely proportional to the strength of the returned signal, so its effects will increase with increasing distance (i.e., low signal return strength). Calibration procedures exist to determine the EDM cyclic error that consist of taking bench measurements through one full EDM modulation wavelength, and then comparing these values to known distances and modeling any cyclic trends found in the discrepancies.

LO 1.2 – Identify Total station and GPS components

- Topic 1: Identification of Parts of Total Station and GPS

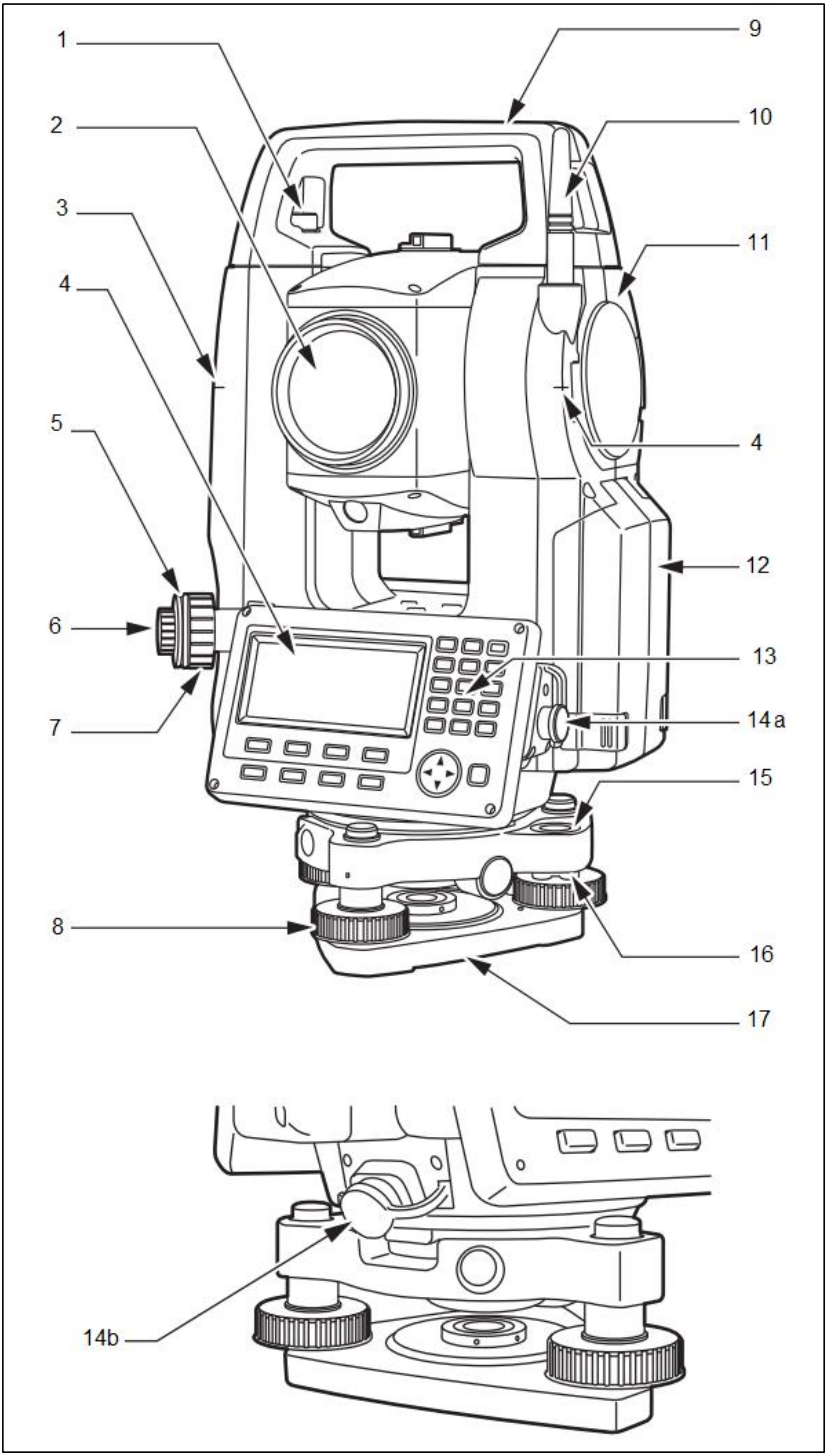
  Parts of Total station


Carrying handle
Stylus pen
Optical sight
(Finder)
Telescope
focusing ring
Telescope
eyepiece
Horizontal axis
indication mark
Diopter ring
USB ports
Reticle plate cover
Vertical tangent
screw
Battery box
Face-1 display /
keyboard
Battery box
release knob
Upper plate
tangent screw
Label for FCC
(For details,
refer to p.x.)
Label for CFR
(For details,
refer to p.x.)
Tribrach clamp knob

1 Handle locking screw
2 Objective lens
3 Display unit
4 Instrument height mark
5 Optical plummet reticle cover
(5 - 7 : Not included on instruments with laser plummet)
6 Optical plummet eyepiece
7 Optical plummet focussing ring
8 Levelling foot screw
9 Handle

10 *Bluetooth* antenna
11 External interface hatch (USB port)
12 Battery cover
13 Operation panel
14 a) Serial connector
b) Combined communications and power source connector
15 Circular level
16 Circular level adjusting screws
17 Base plate
18 Instrument center mark
19 Sighting collimator

20 Telescope focussing ring
21 Telescope eyepiece screw
22 Tribrach clamp
23 Tubular compass slot
24 Vertical clamp
25 Vertical fine motion screw
26 Speaker
27 Trigger key
28 Horizontal fine motion screw
29 Horizontal clamp
30 Plate level
31 Plage level adjusting screw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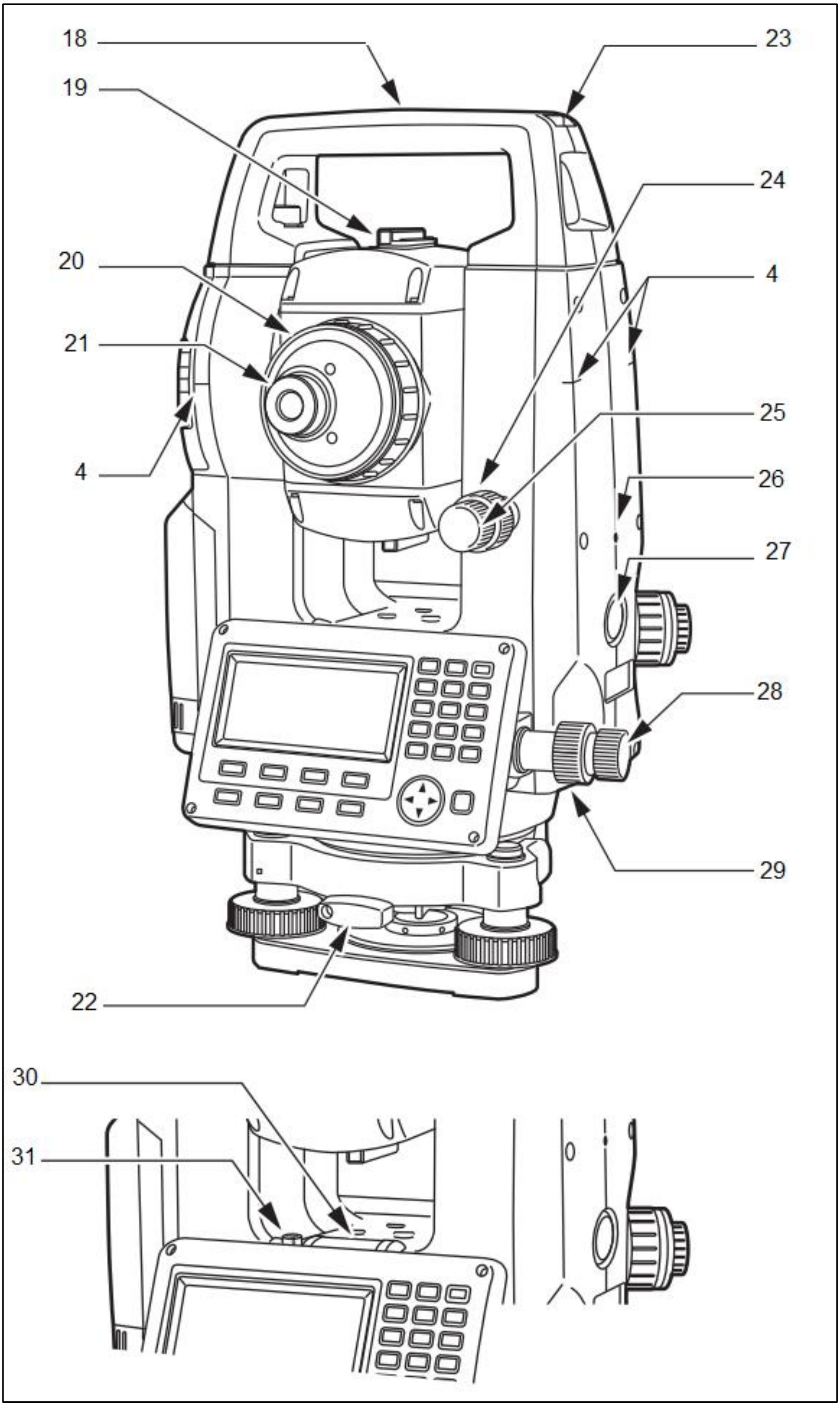
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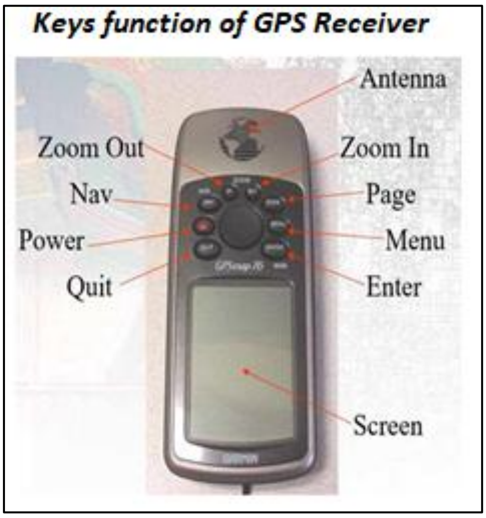
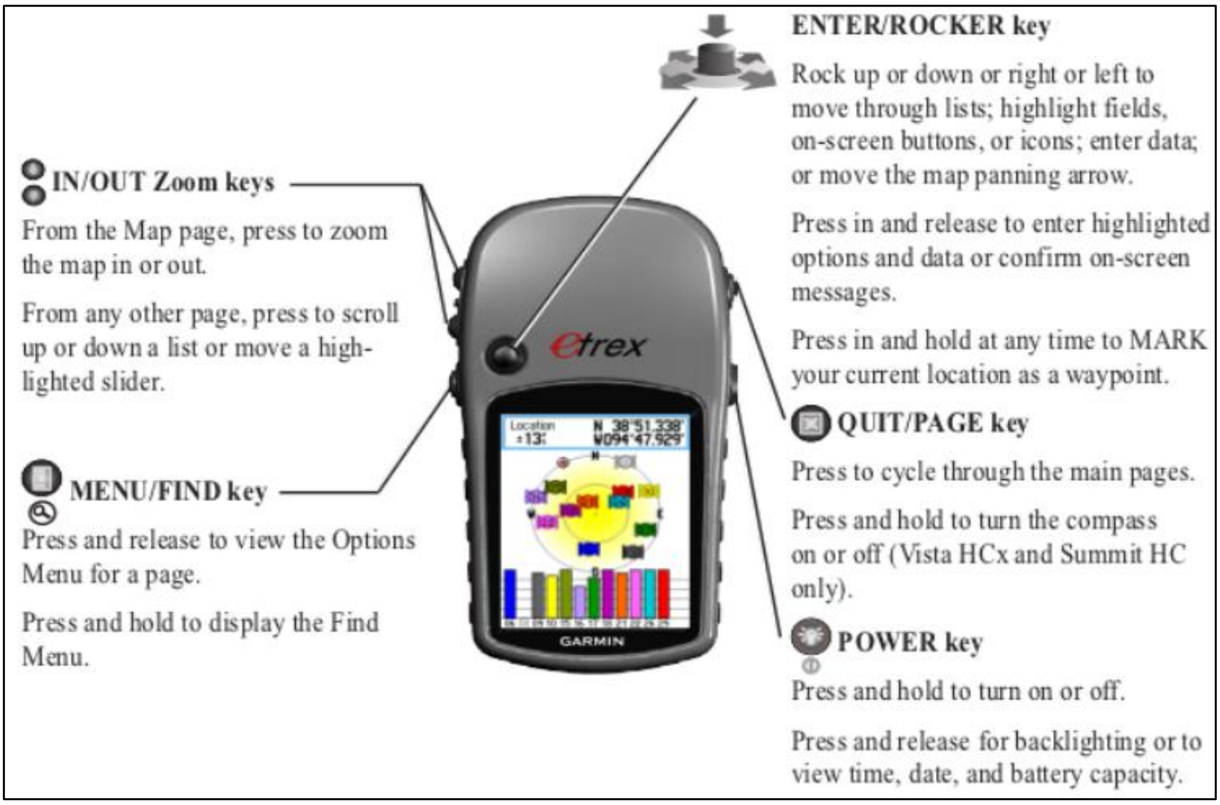
Parts of GPS Receiver





- Topic 2: Identification of Components used with Total Station surveying

Total station surveying is defined as the use of electronic survey equipment used to perform horizontal and vertical measurements in reference to a grid system (e.g. UTM, mine grid).

The two main components of a total station are ***a theodolite*** and ***an electronic distance meter (EDM).***

The theodolite is one of the oldest surveying instruments, with its origins dating back a few centuries. Modern total stations are built around theodolites with EDMs integrated into the housing. The components function together as a telescope, with the operator bringing the opposite point into the telescope's crosshairs. The surveyor can then measure the angle and the distance between the two points. If the total station is also fitted with a data collector, the data collector reads out these measurements, enabling the surveyor to record them for drawing up the survey later.

There are numerous total station accessories. Being familiar with these accessories/components helps surveyors to use their total stations effectively.

a) Tripods

The tripod supports the total station, holding it steady so that the surveyor can make accurate calculations. A tripod must be able to support the weight of the total station that sits on it for an extended period of time.

b) Prisms and Poles

As mentioned above, the EDM sends out an infrared beam to measure the distance between the total station and another point. The beam bounces back and the EDM measures how long it takes for the beam to arrive back at the total station in order to calculate the distance between the total station and the other point. In order for the beam to bounce back, it has to hit a highly reflective target at the point. A ***prism*** makes the ideal target for this, reflecting the beam back powerfully and accurately.

Surveyors generally mount a prism on a ***pole*** that is staked into the ground at the opposite point from the total station. This holds the prism target in place for the EDM to reflect its infrared beam.

c) Electronic Notebook (Data collector)

Many total stations have a data collector built into them, but those that do not require that the surveyor purchase one as an accessory. It is a critical device because it automatically records the surveyor's measurements. ***Data collectors* as** accessories often require surveyors to input the measurements manually.

An accessory data collector needs to be rugged and able to withstand the range of weather conditions in which it might be used. It should therefore be waterproof and tolerant of both extreme cold and extreme heat. Its buttons should also make it easy for surveyors to input data without removing their gloves. It should be able to house rechargeable batteries and have capability to connect to an additional external power source.

Electronic notebook is the "brains" of the total station. The notebook will record, calculate, and even manipulate field data automatically saving valuable time and manpower.

- The electronic notebook records the slope distance, horizontal and vertical angles from the total station and can perform numerous calculations using operating software which is loaded into the unit.
- The main menu of the notebook is made up of a number of directories:
  - Function menu
  - Survey menu
  - COGO menu
  - Road menu
  - Level menu

1. **Function menu**

The function menu consists of a series of sub-menus which contain specific input options which may be used during on particular job or may apply to all survey jobs.

The function sub-menus are:

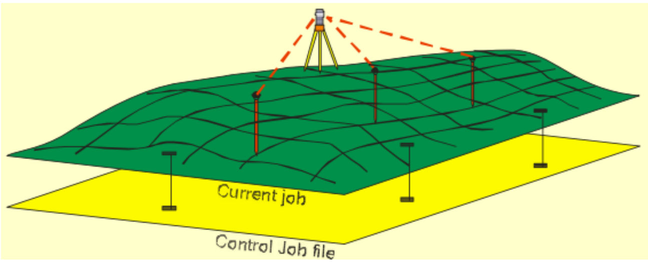
- *Job*: multiple jobs can be stored
- *Instrument type:* instrument type, prism constant, orientation (azimuth)

- *Job settings:* current job, atmospheric correction, curvature and refraction correction, and sea level correction
- *Configure reading:* allows control over how information can be numbered and stored (POS or OBS), single/double angle measurement setting, allows code lists to be activated, as well as compatibility with other instruments (WILD)
- *Tolerances*: Hor. And Ver. Angle = 30”, EDM = 5mm allows accuracy of duplicate readings to be checked.
- *Communications*: downloading or uploading data (SDR, MOSS, DXF)
- *Feature Code List*: list to identify survey details
- *Hardware*: system info, battery life
- *User Program*: allows programs to be uploaded
- *Language*: English but you can upload more languages
- Other sub-menus are: *Units, Date and Time, Job Deletion, Calculator,* and *Upgrade.*

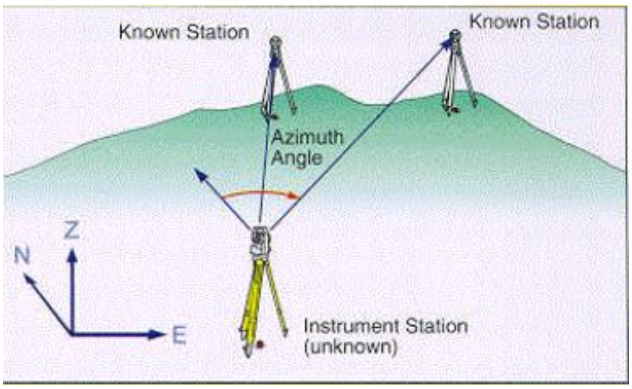
2. **Survey menu**

The survey menu consists of a series of sub-menus which contain specific software to use the raw data recorded from the total station and transform this information into usable survey results. The survey sub-menus are:

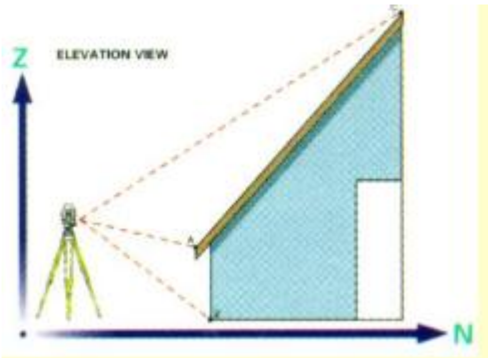
- *Topography*: allows topography of a region to be measured.



- *Traverse Adjustment*: allows series of stations used as traverse to be calculated for closure. The program can then calculate the adjustments required in the stations to ensure closure.
- *Resection:* calculates the coordinates of an unknown or free station by observing a number of unknown stations from the unknown point.



- *Set Collection* and *Set Review*: structured method for collecting multiple sets of information from a station.
- *Building Face Survey*: used to survey details of a building including details where the prism cannot be placed.

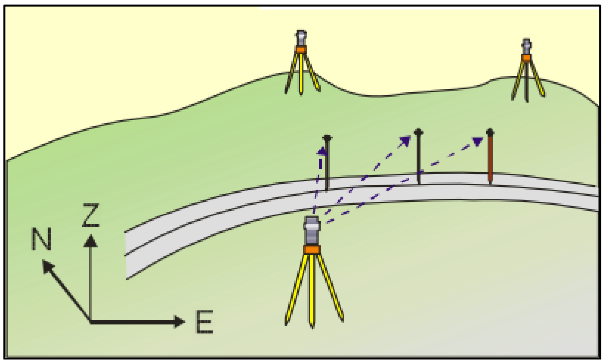


- *Collimation*: used to measure error in single angle measurements.
- *Remote Elevation*: used to measure elevations of points in which the target can't be placed. (e.g. Powerline heights, bridge heights). The prism is placed directly below the object and the slope distance to the prism is recorded along with the angle up to the remote elevation. Based on these measurements, the remote elevation point can be calculated.

3. **COGO menu**

COGO is a suite of programs aimed at coordinate geometry problems in civil engineering. The COGO menu consists of a series of sub-menus which contain specific software used for coordinate geometry calculations and setting out work in the field. The COGO sub-menus are:

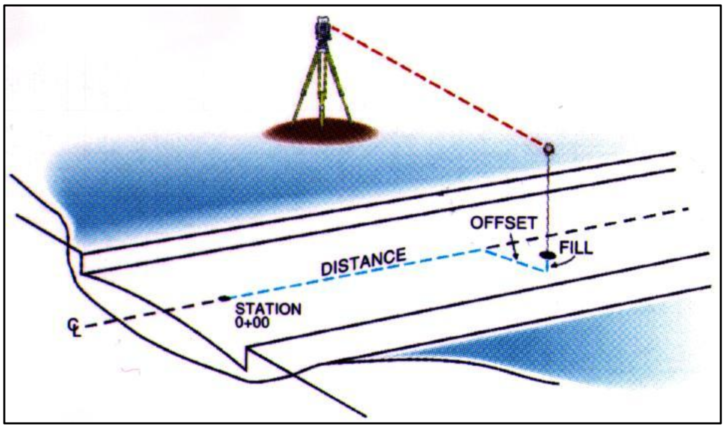
- *Setting out Coordinates*: allows coordinates to be placed in the field.



- *Inverse:* allows calculation of point to point info,
- Other sub-menus are: *Areas, Setting out Line, Set out Arc, Resection, Intersections, Point Projections,* and *Taping from Baseline.*

4. **Road menu**

The Road menu consists of a series of sub-menus which contain specific software used to perform a detailed road or highway survey. The details of the road can be entered into the data collector and the road can be laid out in the field including all appropriate cut and fill information at each point.



The cross-section survey sub-menu allows for measurements of earthwork areas which can be uploaded into CAD for earthwork volume calculations.

5. **Level menu**

The level menu consists of a series of sub-menus which contain specific software used to perform a levelling and level adjustment calculations.

d) Data Cables

Surveyors who have external data collectors may occasionally need to replace the data cables that connect the data collector to the total station. Some data collectors use a pin-based connection, while others feature a USB port. When purchasing a cable, it is therefore important that the type of connection on the cable match the connection on the data collector. When it comes to pin-based connections, the cable should have the same number of pins on the connector that the female end on the data collector is designed to accept.

e) Battery and radios

These include extra rechargeable lithium-ion batteries that surveyors can use to swap out dying batteries while in the field. There are also replacement battery cables to connect to chargers and replacement battery chargers for those that no longer work.

f) Adapters (Tribrach)

A single prism mounted on a tribrach and a 360 degree prism

There is a wide range of adapters that improve a surveyor's ability to move and position a total station on a tripod. One popular type of adapter is *a tribrach.* This is an attachment plate that enables a surveyor to place a total station in the exact same position on a tripod repeatedly.

g) Diagonal Eyepieces

A diagonal eyepiece is a beneficial accessory to have when an obstacle stands between the total station and the point that the surveyor wants to use to take measurements. It attaches to the eyepiece on the total station and projects diagonally outward from it, enabling the surveyor to see around the obstacle and take the necessary measurements.

- Topic 3: Identification of the Main Components of GPS

GPS is a satellite-based system that uses a constellation of 24 satellites to give a user an accurate position on earth. The full GPS consists of three distinct segments/ components: *Space Segment, Control Segment, and User segment or GPS receivers.*

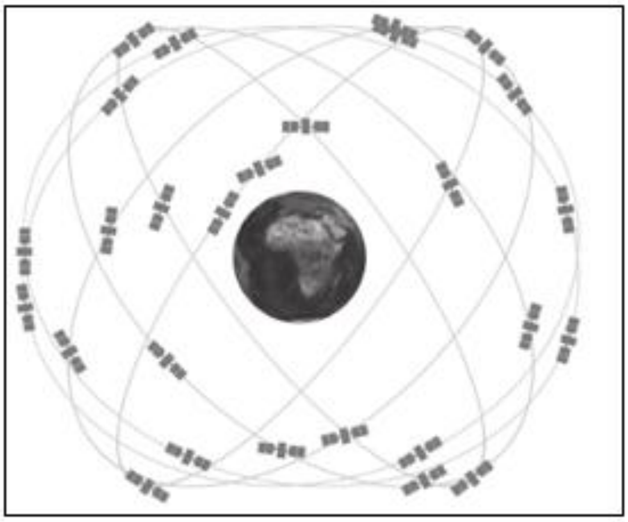
1. **The Space Segment:** The space segment consists of all the *GPS satellites* orbiting around the earth. GPS satellites (a minimum of 24 in constellation) send signals to earth with satellite position information, including time the signal is received.

The space segment is also known as satellite segment. The space segment is designed to have 24 fully operational satellites well placed at an altitude of 20,200 km above earth's surface. The orbits are nearly circular and equally spaced about the equator at 60 degrees separation with an inclination relative to the equator of 55 degrees. The orbital radius (distance from the center of mass of the earth
to the satellites) is approximately 26,600 km.

The satellite constellation provides a 24-hour global user navigation and time determination capacity. The space segment is designed in such a way that there will be a minimum of four satellites visible above a 15-degree elevation angle from any point on the earth's surface at any one time.

The GPS satellite orbits are nearly circular, with eccentricity less than 0.02, a semi-major axis of 26,560 km, that is, an altitude of 20,200 km. Orbits in this height are referred to as medium earth orbit. The satellites are revolving around the earth with a velocity of 3.9 km/sec and a nominal period of 12-hour sidereal time (11 hour 58 minutes 2 seconds solar time), repeating the geometry each sidereal day.

The satellites are well arranged on six orbital planes so that each orbit is having at least four slots. There is spare satellite slot in each orbital plane.



The constellation of GPS satellites in Space segment

The following points have been considered for the design of satellite Segment:

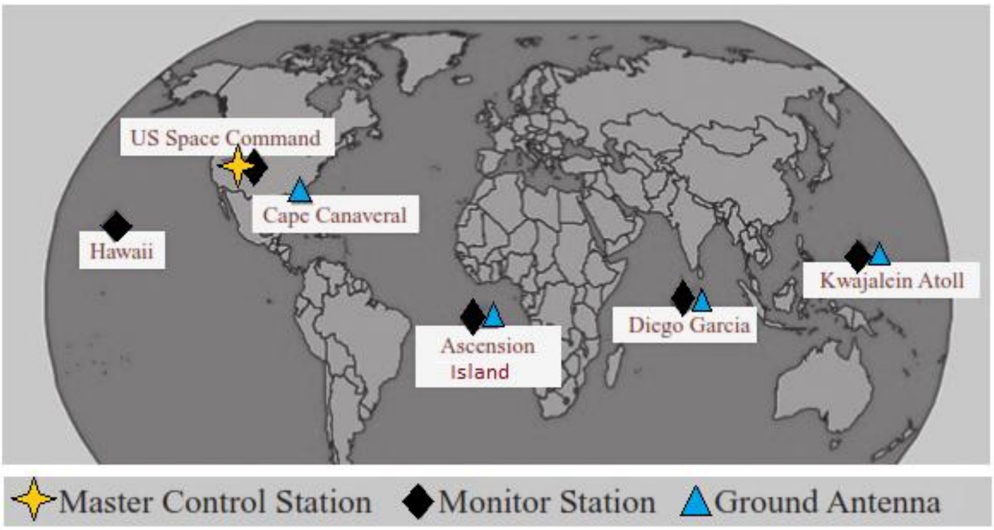
- **a)** Higher the satellites, the longer it is visible above horizon.
- **b)** The higher a satellite, the better the coverage area due to longer fly-over passes and extended visibility of the satellite across large areas of the earth.
- **c)** The higher a satellite, the less the rate of change of distance and lower the Doppler frequency of a transmitted signal.
- **d)** The greater the angle of inclination, the more northerly the track of the sub-satellite point across the surface of earth.
- **e)** No satellite can be seen simultaneously from all locations on the earth.
- **f)** Depending on the positioning principles being employed, there may be requirement for observations to be made to more than one satellite simultaneously from more than one ground station.

2. **The Control Segment:** The control segment comprises three physical components, the master control station, monitoring stations and the ground antennas. It consists of the ground facilities

carrying out the task of satellite tracking, orbit computations, data telemetry and supervision necessary for the daily control of space segment. The control segment consists of one master control station, five monitoring stations and 4 ground antennas distributed amongst five locations near the earth's equator.

- The control segment has the responsibility for maintaining the satellites and their proper functioning.
- The control segment tracks the GPS satellites, updates their orbiting position and calibrates and synchronizes the satellite clocks.
- A further important function is to determine the orbit of each satellite and predict its path for the following 24 hours. There may be a possibility of satellites travelling slightly out of orbits. Hence the ground monitor stations keep track of the satellite orbits, altitude, location and speed.
- The ground stations send the orbit data to the master control stations, which in turn send corrected data of the satellite. The corrected data is called ***Ephemeris data***, valid for 6 hours, and transmitted in coded form to the GPS receivers. This information is uploaded to each satellite and subsequently broadcast from it. This enables the GPS receiver to know where each satellite can be expected to be found.

There are five ground facility stations: *Hawaii, Colorado Spring, Ascension Island, Diego Garcia and Kwajalein.*



The satellite signals are read at Ascension, Diego Garcia and Kwajalein. All are owned and operated by US Department of Defense. All five stations are monitoring stations and are equipped with tracking systems to track satellites. The tracking data is then sent to the Master Control Station in Colorado Springs where they are processed to determine any errors in each satellite. The information is then sent back to the four monitor stations equipped with ground antennas and uploaded to the satellites.

3. **The User Segment (GPS Receivers):** Anyone, who uses the GPS signal for various applications, comes under this segment. *For example:* User holding a GPS unit using the data from the satellite to locate position on Earth.

LO 1.3 – Clarify Total station and GPS advantages

- Topic 1: Clarification of the advantages and disadvantages of Total Station

The **advantages** of total station include:

6. Quick setting of the instrument on the tripod using laser plummet
7. On-board area computation program to compute the area of the field
8. Greater accuracy in area computation because of the possibility of taking arcs in area computation
9. Graphical view of plots and land for quick visualization
10. Coding to do automated mapping. As soon as the field jobs are finished, the map of the area with dimensions will be ready after data transfer
11. Enormous plotting and area computation at any user required scale
12. Accuracy of measurement is high
13. Manual errors involved in reading and recording are eliminated
14. Calculation of coordinates is fast and accurate
15. More work can be accomplished within short time
16. Relatively quick collection of information (data)
17. Multiple surveys can be performed at one set-up
18. Digital design data can be uploaded to total station for setting out of structures to be constructed

Disadvantages of Total Station include:

1. Their use does not provide hard copies of field notes. Hence, it may be difficult for the surveyor to look over and check the work while surveying.
2. For an overall check of the survey, it will be necessary to return to the office and prepare the drawings using appropriate software.
3. Total station should not be used for observations of the sun, without special filters, if not, the EDM part of the instrument will get damaged.

4. The instrument is costly, and for conducting surveys using total station, skilled personnel are required.

- Topic 2: Clarification of the advantages and disadvantages of GPS

Global Positioning System (GPS) technology is having numerous advantages over the traditional surveying methods.

Generally, a good surveyor gives more importance to the accuracies and speed of work. With the aid of GPS, very high geodetic accuracy can be achieved within short time by applying suitable methodology. Efficient utilization of a GPS receiver in surveying field depends on the efficiency and dedication of the surveyor. Proper planning and preparation are essential ingredients for a successful survey using GPS. A surveyor must be well experienced with the capabilities, limitations of the GPS receiver and the methodology to be followed for getting good results, while using it.

The **advantages** of GPS over traditional methods of surveying are

1. Inter-visibility between points is not required.
2. Can be used at any time, day or night, and in all weather conditions.
3. Geodetic accuracy can easily be achieved.
4. Large area can be surveyed in small duration.
5. GPS surveys are less labor intensive and hence cost effective.
6. More work can be completed by utilizing less time and manpower.
7. Limited or less calculation and tabulation works are required.
8. Network-independent site selection can be used.
9. Three-dimensional (3D) coordinates of points are obtained.
10. Very few skilled persons are required to execute the work.
11. GPS can compute a position (latitude, longitude and height) directly, without the need to measure angles and distances between intermediate points.
12. Survey control can be established anywhere with a clear view of the sky to get uninterrupted signals from the GPS satellites.

The **disadvantages** of GPS-based surveying methods are:

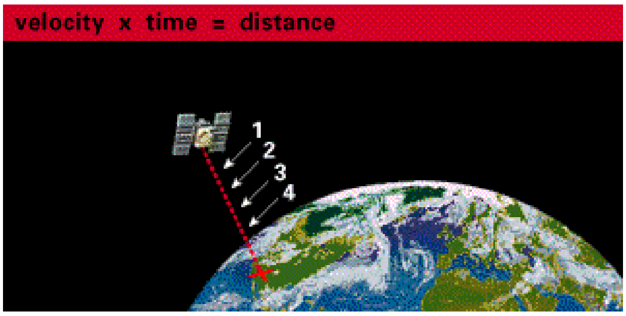
1. High initial cost (high cost of survey grade GPS receiver and related software).
2. GPS antenna must have a clear view to the sky for getting uninterrupted satellite signals.
3. Satellite signals can get blocks by high-rise buildings, trees, over bridges, etc.

4. GPS antenna must get signals from at least four satellites to compute a positional value.
5. Difficult to use in dense forests and town centers.
6. Coordinates derived from GPS must be transformed for conventional survey applications.
7. Highly skilled persons with a good knowledge about GPS-based surveying are necessary.
8. Good computer skills and good experience in operating electronic equipment are required
9. Software skills such as CAD are required for the surveyors for mapping.

Learning Unit 2 –Apply Measuring Principles (Pulse & Phase difference)

LO 2.1 – Identify measurements principles

- Topic 1: Calculating a satellite Position and Measuring Distance to Satellites



In order to determine user position, one must calculate satellite position. The GPS-receiver measures in fact pseudo distances (pseudo-ranges) to the satellites.

Pseudo-range = (velocity of light) x (travel time) + (receiver clock error) + (other errors)

To determine a position in 3 dimensional space it takes in theory 3 distance measurements from 3 satellite.

A position is calculated from distance measurements to at least three satellite. Timing is complex and we need precise clock to measure travel time. The travel time for a satellite right overhead is about 0.06 seconds.

The difference in sync of the receiver time minus the satellite time is equal to the travel time.

Remember this mathematical idea: *"If a car goes 60 miles per hour for two hours, how far does it travel?"*

Velocity (60 mph) x Time (2 hours) = Distance (120 miles)

In the case of GPS we're measuring a radio signal so the velocity is going **to be the speed of light or roughly 186,000 miles per second.**

The problem is measuring the travel time. First, the times are going to be terribly short. If a satellite were right overhead the travel time would be something like 0.06 seconds. So we're going to need some really precise clocks. But assuming we have precise clocks, how do we measure travel time?

To explain it let's use **a goofy analogy**:

Suppose there was a way to get both the satellite and the receiver to start playing "The Star-Spangled Banner" at precisely 12 noon. If sound could reach us from space (which, of course, is ridiculous) then standing at the receiver we'd hear two versions of the Star-Spangled Banner, one from our receiver and one from the satellite. These two versions would be out of sync. The version coming from the satellite would be a little delayed because it had to travel more than 11,000 miles. If we wanted to see just how delayed the satellite's version was, we could start delaying the receiver's version until they fell into perfect sync.

The amount we have to shift back the receiver's version is equal to the travel time of the satellite's version. So we just **multiply that time times the speed of light**. Congratulations! we've got our distance to the satellite.

In summary:

- *Distance to a satellite is determined by measuring how long a radio signal takes to reach us from that satellite.*
- *To make the measurement we assume that both the satellite and our receiver are generating the same pseudo-random codes at exactly the same time.*
- *By comparing how late the satellite's pseudo-random code appears compared to our receiver's code, we determine how long it took to reach us.*
- *Multiply that travel time by the speed of light and you've got distance.*

Basically, satellite positioning is a trilateration problem. From the known position of three satellites and the measured distances between them and the receiver, coordinates of receiver position can be calculated. The distances are determined by multiplying the travelling time of the radio signals by the speed of light. But how accurate is GPS tracking and how is a continual check to be kept on the positions of satellites? Their orbits are not completely deterministic but fluctuate due to celestial gravity forces.

Since radio signals travel at a speed of 300,000km per second, an inaccuracy in time measurement of 1 nanosecond (one billion part of a second or 10-9 second) induces a distance error of 30cm, whilst with geodetic receivers we can achieve accuracy at the centimeter level.

Position and time

The ground segment monitors and controls the position of GPS satellites. With a master station at Falcon Air Force Base, Colorado Springs, USA, and remote stations in Hawaii, Ascension Island, Diego Garcia and Kwajalein, the satellites are tracked and monitored for 92% of the time.

For two daily windows lasting one-and-a-half hours, each satellite is out of contact with the ground stations. The main station acts as data processing center for all information, including that collected at the remote stations. Orbit coordinates are continuously determined by triangulation.

Comparing the time of the satellites' four atomic clocks with similar devices on the ground provides information on time errors. When a satellite drifts slightly out of orbit, repositioning is undertaken. The clocks may also be readjusted, but more usually information on time errors is attached to GPS signals as correction factors. The computed corrections, time readjustments and repositioning information are transmitted to the satellites via three uplink stations co-located with the downlink monitoring stations.

In this way, all the GPS satellites are able to continuously attach corrections to the parameters they send out, which include ephemeris data, almanac data, satellite health information and clock correction data.

- Topic 2: Applying measuring Principles of the EDM (Pulse & Phase difference)

There are several principles of electronic distance measurement but only some of them are related to terrestrial geodetic measurement. ***The pulse method*** *and* ***the phase difference method*** *are the ones.*

1. The pulse method

The pulse method is not easy to realize with sufficient accuracy but it is very simple method to understand the principle. A short, intensive signal is transmitted by an instrument. It travels to a target point and back and thus covers twice the distance. By measuring the so-called time-of-flight between transmission and reception of the same pulse, the distance may be calculated as:

$$\boldsymbol{d} = \frac{c}{2n} * \Delta t' = \frac{\mathbf{v}}{\mathbf{2}} * \Delta \boldsymbol{t}'$$

Where: **d** is distance (in meter)

C is velocity of light in vacuum (m/s)

n is reflective index of ambient air

Δt' is time of flight (s)

V is velocity of light in ambient air (m/s)

The flight time is measured by the oscillator. Considering the velocity of light, an extreme accuracy of measuring the flight time is required. To obtain the precision of 3 mm in a measured distance, the precision of 20 picoseconds in time-of-flight is required.

The pulse method is frequently used in passive reflecting systems when the pulse is reflected directly from the surface and no reflecting prism is necessary. Some disturbing reflections can be identified and filtered out while analyzing the received pulses.

2. The phase difference method

Most important principle which enabled EDM instruments to measure with high accuracy is the phase difference method. Still a lot of today's instruments use it, regardless of whether they use light waves, infrared waves or microwaves as carrier waves. The measuring signal, which is modulated on the carrier wave in the emitter, travels to the reflector and back to the EDM instrument, where it is picked up by the receiver. The following equation can be used to determine the phase difference:

$$\boldsymbol{d} = mU + L$$

Where: **d** is distance (in meter)

m is number of full wavelengths over the path (uncertainty)

U is unit length of a distance meter [m]

L is fraction of the unit length U (determined by phase measurement) [m]

The uncertainty/ambiguity is solved by the introduction of more than one-unit length in an EDM instrument. The precision of an instrument depends on the choice of the main unit length, because of the limited resolution of the phase measurement.

LO 2.2 – Identify measurements methods

- Topic 1: Identification of instrument errors

a) Inspecting the line of sight (two-peg test)

In new levels, the compensator has been adjusted at room temperature, so that the line of sight is horizontal even if the instrument is tilted a little. This situation changes if the temperature fluctuates by more than ten or fifteen degrees, after a long journey, or if the instrument is subjected to strong vibration. It is then advisable to inspect the line of sight, particularly if more than one target distance is being used.

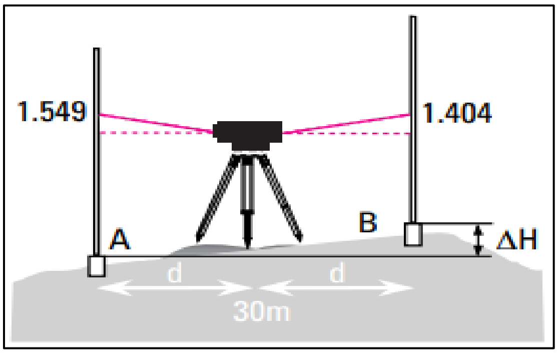
Procedure:

1. In flat terrain, set up two staffs not more than 30 meters apart.
2. Set up the instrument so that it is equidistant from the two staffs (it is enough to pace out the distance)
3. Read off from both staffs and calculate the height difference (illustration above).

Staff reading A = 1.549

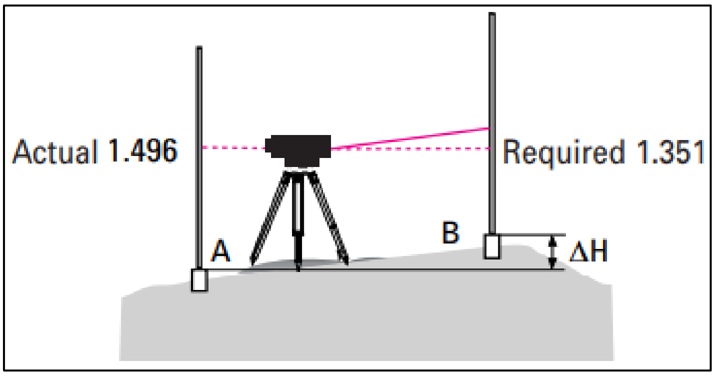
Staff reading B = 1.404

ΔH = A – B = 0.145



4. Set up the instrument about one meter in front of staff A and take the staff reading (as illustrated on figure below): Staff reading A = 1.496
5. Calculate the required reading B: Staff reading A = 1.496 - ΔH = 0.145

Required reading B = 1.351



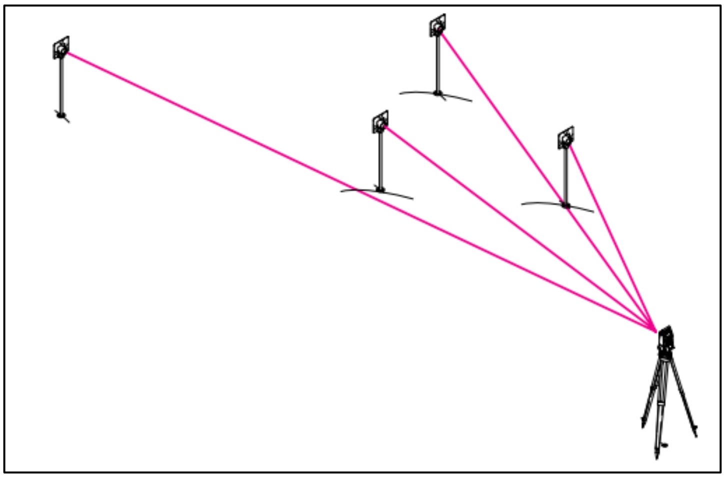
6. Take the staff reading B. If it differs from the required reading by more than 3mm, adjust the line of sight (referring to the instruction manual of the instrument).

b) Inspecting the EDM of the total station

Procedure:

- Permanently mark four runs within the range typical for the user (e.g. between 20 m and 200 m).
- Using a new distancer, or one that has been calibrated on a standard baseline, measure these distances three times. The mean values, corrected for atmospheric influences (refer to the user manual) can be regarded as being the required values.

- Using these four runs, measure with each distancer at least four times per year. Provided that there are no systematic errors in excess of the expected measuring uncertainty, ***the distancer is in order.***



- Topic 2: Perform Total Station configuration

1. Procedures of Total Station configuration

Set up a notebook page, or use the *Instrument Station Setup Checklist*. You will fill out this page before you enter all the numbers into the Total Station. This is done to make sure that nothing is missed.

Measure *Instrument Height*. Record instrument height. This should be measured from the ground to the tilting axis of the instrument. If setting up over a benchmark, measure height to top of BM *and* the height above the ground. The titling axis of the instrument is marked on the side opposite from the on/off switch. It is a small hole inside a raised circle.

Measure *Temperature*, and record,

Measure *Pressure*, and record.

***Enter PPM* Correction into Total Station.** The speed of light in air changes with the density of the air, so we must make a correction to the measured distance. This is done by measuring the temperature and pressure. The correction factor is in terms of parts per million (ppm), or mm/km. From the temperature and pressure, you can look up the correction factor in a chart included with the total station, or you can enter the temperature and pressure in the instrument and it will calculate the correction.
We apply the correction to the instrument. This way the corrected distance is passed to the SDR33

notebook. You must make sure that the SDR does not repeat the correction! To enter the temperature and pressure, press the key (bottom right) then the EDM key (top left). From the menu select item [3. ppm], then item [2. Temp & Press]. Enter the temperature and press ENT, then enter the pressure and press ENT. At this time the top item in three-line display above the main display will show the ppm correction.

Record instrument coordinates. *Eo*, *No*, *Ho* are the *E* and *N* coordinates or the station. *Ho* is, for our "plane-table" mapping purposes, the ground elevation. For the first instrument station you may want Eo = 0.0, No = 0.0, and Ho = 100.0. For subsequent instrument stations use the coordinates of the point that you are setting up on. These will be entered into the SDR33 notebook if you are using one.

Record reflector heights and prism constants for each reflector. The instruments are set for a default prism constant of -40mm. Some of the prisms we have are -30mm prisms. Measure the reflector height, DO NOT rely on the calibration on the rod's being correct.

Enter a backsight, or desired angle. Details given below. How you enter this depends on if your are using a SDR33 and on how much information the SDR33 contains.

2. Entering a Backsight

You should have the SDR33 notebook setup correctly before you enter a backsight to orient the Total Station. The backsight is a key step in setting up the instrument correctly. It is essential to get the instrument oriented correctly, and it is impossible to orient the instrument with any accuracy using a compass. Surveying measures the angle between two lines of sight, the actual bearing of the lines is generally not of importance.

The important thing is to get a survey internally correct. You can establish the absolute orientation of your network of points by surveying in two known locations. For example, you may use existing benchmarks, or GPS to control two of your points.

A) Entering a Backsight using the SDR33 Electronic Notebook

The SDR33 will not let you begin to collect data without either specifying a backsight or telling it that no backsight is needed.

Case I. Starting a new job

If you are starting a new job this is the time to set up your coordinate system. If you are making a control-point map then you will want to orient "North" along the long axis of your mapping project. Point the total station along the long axis and use the instrument control panel to set the direction to zero (see instructions below). Then, when the SDR33 prompts you for the instrument station number, enter any number (usually 1). When prompted for a backsight reading, just press OK, and then confirm that you want to skip the backsight. The SDR will not reset the instrument under these conditions.

If you are making a precise survey of a quadrilateral, then it is the angle between lines that is important, so you do not need to set a backsight. In fact, you do not need to set the orientation of the instrument, you can just start taking readings. When the SDR33 asks you for a backsight, just press OK and confirm that you do not want a backsight reading.

Case II. Continuing an existing job

If you are continuing a job where it is important to orient the instrument, you should set up the instrument over a known point, and set up a reflector over a second known point. When starting to use the SDR33 specify the station number where the instrument is located. If the point number exists in the current job, then the SDR will display the stations coordinates and ask you for a instrument height. If the point number is not found in the current job then you will need to enter the coordinates of the current instrument station and the instrument height.

After specifying the location of the instrument, you have to indicate the backsight point number. Again, if this point exists in the current job, you will be asked to point the instrument at a target over this point and take a reading. If the point does not exist, you are given the choice of either entering the coordinates of the backsight point, or the direction to that point. Once you have entered the information about this point, then you will be asked to take a reading to this point

The SDR will set the horizontal circle to value you entered, or from it's record of point. It will then take a reading to the point and verify that the range and elevation difference match what is has **in the job database (if it is a pre-existing point).**

B) Entering a Backsight by using the Total Station Keyboard

- Press the [3] key. This will put the display in theodolite mode. The vertical (ZA) and horizontal (HAR) angles will now be displayed.
- Point the Total Station at your target, or some clearly defined feature that you can accurately line up on again, and either press: the [0 SET] key to set a the instrument to zero (North) or the [1] key.
- Now type in the horizontal angle in the form of *ddd.mmss*, where *d* is degrees, *m* is minutes, and *s* is seconds using the numeric keypad.
- Press OK when done.

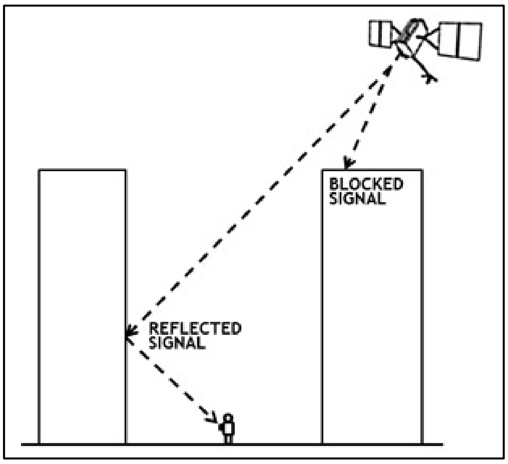
LO 2.3 – Compare measurement methods

- Topic 1: Identification of the accuracy in Electronic distance measurement (EDM)

How accurate is GPS?

It depends. GPS satellites broadcast their signals in space with a certain accuracy, but what you receive depends on additional factors, including satellite geometry, signal blockage, atmospheric conditions, and receiver design features/quality. Many things can degrade GPS positioning accuracy. Common causes include:

- Satellite signal blockage due to buildings, bridges, trees, etc.
- Indoor or underground use
- Signals reflected off buildings or walls ("multipath")



Far less, common causes may include:

- Radio interference or jamming

- Major solar storms
- Satellite maintenance/maneuvers creating temporary gaps in coverage
- Improperly designed devices that do not comply with GPS Interface Specifications

In many cases, a device's GPS hardware is working fine, but its mapping software is faulty. For example, users are often misled by:

- Incorrectly drawn maps
- Mislabeled businesses and other points of interest
- Missing roads, buildings, communities, etc.
- Incorrectly estimated street addresses

How accurate is GPS for speed measurement?

As with positioning, the speed accuracy of GPS depends on many factors. The government provides the GPS signal in space with a global average user range rate error (URRE) of ≤0.006 m/sec over any 3-second interval, with 95% probability. This measure must be combined with other factors outside the government's control, including satellite geometry, signal blockage, atmospheric conditions, and receiver design features/quality, to calculate a particular receiver's speed accuracy.

How accurate is GPS for timing?

GPS time transfer is a common method for synchronizing clocks and networks to Coordinated Universal Time (UTC). The government distributes UTC as maintained by the U.S. Naval Observatory (USNO) via the GPS signal in space with a time transfer accuracy relative to UTC(USNO) of ≤40 nanoseconds (billionths of a second), 95% of the time. This performance standard assumes the use of a specialized time transfer receiver at a fixed location

- Topic 2. Apply Total Station Setup with its EDM operation

1. Setup the total station (TS) over the benchmark. Extend the legs of the tripod and bring it up to about chin height.
2. Fan the legs out and get the tripod relatively level (tighten the leg bolts).
3. Place the TS on top of the tripod (keep one hand on top of the TS at all times) and thread the tripod bolt into the tribrach.
4. Center the TS on the tripod to allow for future adjustments.

5. Be sure to close the TS box after the TS has been secured onto the tripod.
6. Use the optical scope on the TS to target the benchmark. If you are not directly above the benchmark carefully move the tripod so that the reticle is centered on the benchmark (placing a foot over the benchmark may help orientation).
7. Secure the tripod by stomping leg points into the ground.
8. Look through the optical scope to make sure the TS is still centered over the benchmark. If the TS is not centered, loosen the tripod bolt and slowly move the TS until it is centered (retighten the bolt).
9. Adjust the tripod legs and use the level bubble to get the TS level.
10. Turn on the TS.
11. Press Enter when the TS begins to count down to enter the precision leveling screen.
12. Turn the TS so that the front is parallel to two screws (one screw behind)
13. Center the e-bubble using the total station screws and press down.
14. Repeat until 1:10 is centered and then press Exit.
15. Turn on the TSC3 handheld data collector (TSC3) and connect it to the TS.
16. Once connected to TSC3, the TS screen will go blank and the TS is now ready to begin surveying

Learning Unit 3 – Perform basic applications of Total station and GPS

LO 3.1 – Select Total station and GPS

- Topic 1: Explanation of factors to Use When Choosing a GPS and Total station Units

These are **considerations while choosing a GPS Unit:**

1. **Application:** When shopping for a receiver, the first thing to consider is what you will use the receiver for.
2. **Accuracy:** When you listen to people who own GPS receivers comparing their qualities, they often describe them in terms of their accuracy (within how many feet or meters). Most people want their GPS to be as accurate as possible.
3. **Data storage capacity (Waypoints):** How many waypoints can the unit store? How does the number of waypoints stored relate to your recreational and fieldwork needs?
4. **GPS Software:** There are a number of different sets of software that can be used with GPS. All GPS receivers have some software on the unit. Stopping into stores that carry a range of GPS receivers, and trying out their software (by pushing buttons) can help you identify which receivers' software is more intuitive for your use.

5. **Electronic Compass**: Reminder the GPS receiver does not determine the direction or location of a user is headed, if the user is not moving. Electronic compass aid in the real-time navigation by letting the user know cardinal directions (North, South, East or West).
6. **Display:** Are you seeking specific display features, such as widescreen or touch screen, and/or other viewing characteristics?
7. **Memory:** Will you be loading additional content, base maps, or auxiliary data to your GPS? Some GPS Units have the ability to add additional memory through an SD card.
8. **Receiver Characteristics:** How well does the receiver receive satellite signals? Does the receiver support WAAS capability?
9. **Accessories:** Are additional accessories available to improve accuracy, such as an antenna? Is additional battery power available for the unit? Are the required cables available for transfer of GPS data from the unit to computer and/or other devices? Is there a carrying case available for the unit?
10. **Price:** How much are you looking spend on a GPS unit? Are there tradeoffs if going with a more/less expensive model?

Important things to consider when choosing a Total Station:

When choosing a Total Station, the first thing to consider is *the application*. Your decision will be based on the type of work you will be using it for and the distance over which you will be measuring. How you will use the equipment will help you determine the angular and distance accuracies you need, as well as range, *portability*, and *ease of setup.* Therefore, *the accuracy* is the most important consideration while selecting a Total Station unit.

LO 3.2 – Use Total station and GPS

- Topic 1: Perform Total Station Centering

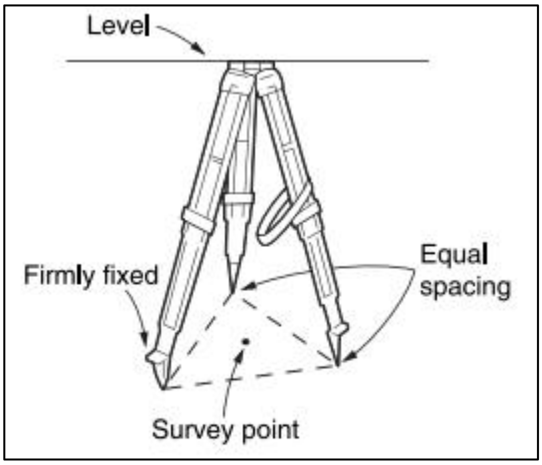
Because the Total Station contains delicate electronic components they are not as rough as ordinary Theodolite. They must be packed and transported carefully, handled gently and carefully removed from their cases.

The setting of Total Station over the station mark is similar to an ordinary Theodolite.

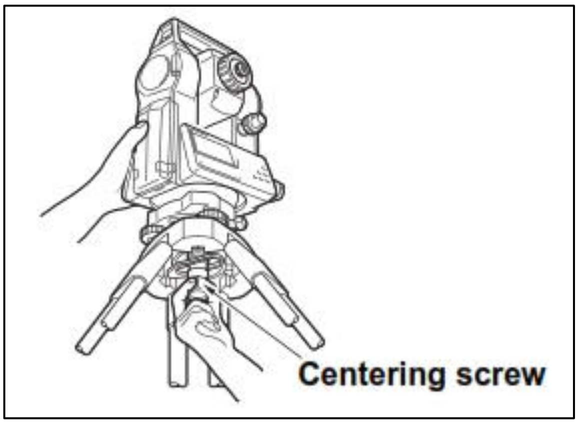
Mount the battery in the instrument before performing this operation because the instrument will tilt slightly if the battery is mounted after levelling.

a) Centering with the optical plummet eyepiece

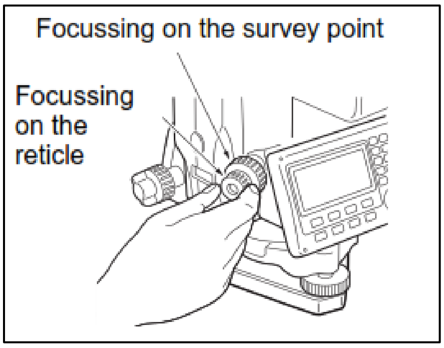
1. Make sure the legs are spaced at equal intervals and the head is approximately level. Set the tripod so that the head is positioned over the survey point. Make sure the tripod shoes are firmly fixed in the ground.



2. Place the instrument on the tripod head. Supporting it with one hand, tighten the centering screw on the bottom of the unit to make sure it is secured to the tripod.



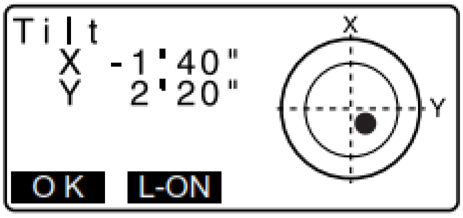
3. Looking through the optical plummet eyepiece, turn the optical plummet eyepiece to focus on the reticle. Turn the optical plummet focusing ring to focus on the survey point.



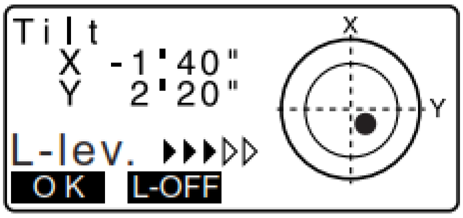
b) Centering with the laser plummet (⊋)

1. Set up the tripod and affix the instrument on the tripod head.

2. Press **{ON}** to power on. The circular level is displayed on the screen.



3. Press **[L-ON]**. The laser plummet beam will be emitted from the bottom of the instrument.



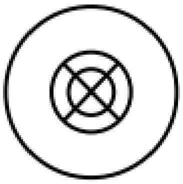
4. Use {▶}/{◀} to adjust the brightness of the laser.
5. Adjust the position of the instrument on the tripod until the laser beam is aligned with the center of the survey point.
6. Press **[L-OFF]** to turn the laser plummet off. Alternatively, press **{ESC}** to return to the previous screen. The laser plummet will switch off automatically. Visibility of the laser spot may be affected when operating in direct sunlight. In this event, provide shade for the survey point.

- Topic 2: Perform Total Station Levelling

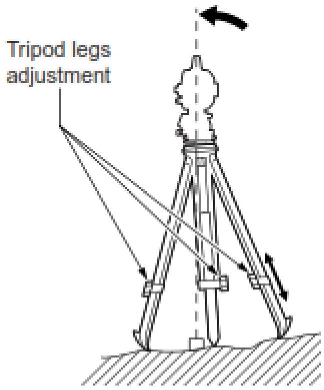
Total station can be levelled using screen or plate level.

a. Levelling using screen

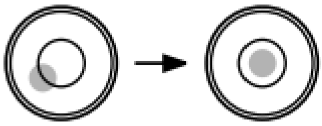
1. Adjust the levelling foot screws to center the survey point in the optical plummet reticle.



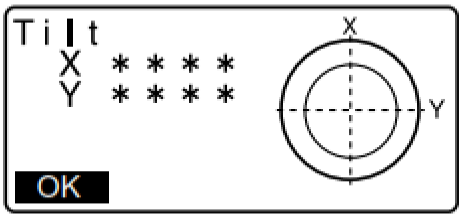
2. Center the bubble in the circular level by either shortening the tripod leg closest to the off-center direction of the bubble or by lengthening the tripod leg farthest from the off-center direction of the bubble. Adjust one more tripod leg to center the bubble.



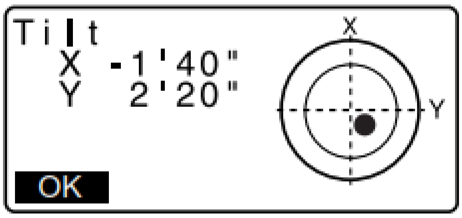
3. Turn the levelling foot screws while checking the circular level until the bubble is centered in the center circle.



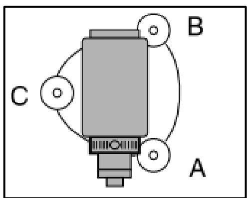
4. Press **{ON}** to power on. The circular level is displayed on the screen. "●" indicates bubble in circular level. The range of the inside circle is ±4' and the range of the outside circle is ±6'. Tilt angle values X and Y are also displayed on the screen. "●" is not displayed when the tilt of the instrument exceeds the detection range of the tilt sensor. Level the instrument while checking the air bubbles in the circular level until "●" is displayed on the screen.



When executing the measurement program, if measurement starts with the instrument tilted, the circular level is displayed on the screen.



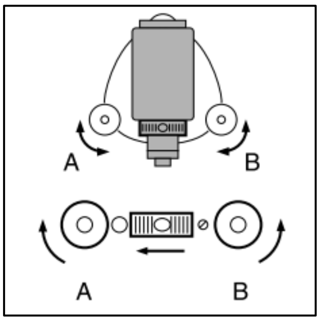
5. Center "●" in the circular level as illustrated above or if the bubble is centered, press **[OK]**.
6. Turn the instrument until the telescope is parallel to a line between levelling foot screws A and B, then tighten the horizontal clamp.



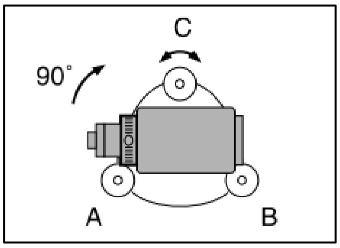
7. Set the tilt angle to 0° using foot screws A and B for the X direction and levelling screw C for the Y direction.
8. Loosen the centering screw slightly. Looking through the optical plummet eyepiece, slide the instrument over the tripod head until the survey point is exactly centered in the reticle. Retighten the centering screw securely. When the instrument was centered using the laser plummet, emit the plummet beam again to check position over the survey point.
9. Confirm that the bubble is positioned at the center of the circular level on the screen. If not, repeat the procedure.
10. When levelling is completed, press **[OK]** changes to the OBS mode.

b. Levelling using plate level

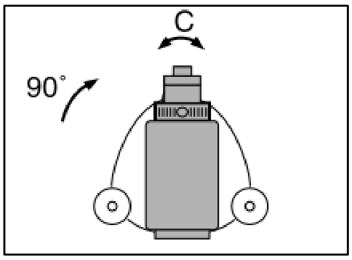
1) Center the bubble in the circular level. Loosen the horizontal clamp to turn the upper part of the instrument until the plate level is parallel to a line between levelling foot screws A and B. Center the air bubble using levelling foot screws A and B simultaneously. The bubble moves towards a clockwise rotated levelling foot screw.



2) Turn the upper part of the instrument though 90°. The plate level is now perpendicular to a line between levelling foot screws A and B. Center the air bubble using levelling foot screw C.



3) Turn the upper part of the instrument a further 90° and check to see if the bubble is still in the center of the plate level.



If the bubble is off-center, perform the following:

- Turn levelling foot screws A and B equally in opposite directions to remove half of the bubble displacement.
- Turn the upper part a further 90°, and use levelling foot screw C to remove half of the displacement in this direction. Or adjust the plate level.

4) Turn the instrument and check to see if the air bubble is in the center position in all directions. If it is not, repeat the levelling procedure.
5) Loosen the centering screw slightly. Looking through the optical plummet eyepiece, slide the instrument over the tripod head until the survey point is exactly centered in the reticle. Retighten the centering screw securely.

   When the instrument was centered using the laser plummet, emit the plummet beam again to check position over the survey point.
6) Check again to make sure the bubble in the plate level is centered. If not, repeat the procedure starting from the second step.

- Topic 3: Total Station Focusing and target sighting

Eliminating parallax

Parallax is the relative displacement of the target image with respect to the reticle when the observer's head is moved slightly before the eyepiece.

When sighting the target, strong light shining directly into the objective lens may cause the instrument to malfunction. Protect the objective lens from direct light by attaching the lens hood. Observe to the same point of the reticle when the telescope face is changed.

Parallax will introduce reading errors and must be removed before observations are taken. Parallax can be removed by refocusing the reticle.

Procedure:

1. Look through the telescope eyepiece at a bright and featureless background. Turn the eyepiece screw clockwise, then counterclockwise little by little until just before the reticle

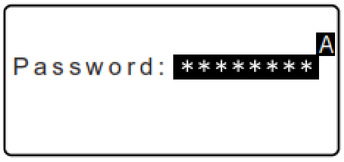
image becomes focused. Using these procedures, frequent reticle refocusing is not necessary since your eye is focused at infinity.

2. Loosen the vertical and horizontal clamps, then use the sighting collimator to bring the target into the field of view. Tighten both clamps.
3. Turn the telescope focusing ring to focus on the target. Turn the vertical and horizontal fine motion screws to align the target with the reticle. The last adjustment of each fine motion screw should be in the clockwise direction.
4. Readjust the focus with the focusing ring until there is no parallax between the target image and the reticle.

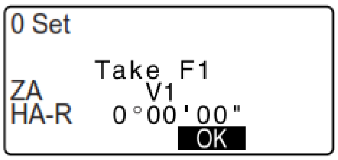
Power On/Off a Total Station

To power on a total station, follow these steps:

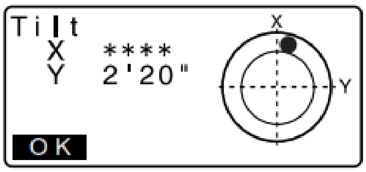
1) Press **{ON}**. When the power is switched on, a self-check is run to make sure the instrument is operating normally. When password is set, the display appears as at right. Input password and press **{ENT}**.



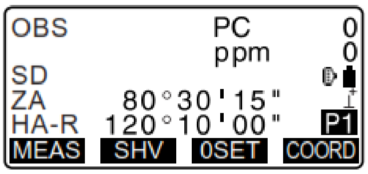
When “V manual” is set to “**Yes**”, the display appears as at right. Manually indexing the vertical circle by face left, face right measurements.



2) After that, the tilt screen is displayed. Press **{ESC}** to skip levelling. Then, the electric circular level is displayed in the screen.



3) After leveling the instrument, press **[OK]**to enter into the OBS mode.



4) If “Out of range” or the Tilt screen is displayed, level the instrument again.

Note this:

- When "Resume" in "Instr. config" is set to "On", the screen previous to power off is displayed (except when missing line measurement was being performed).
- "Tilt crn" in "Obs. condition" should be set to "No" if the display is unsteady due to vibration or strong wind.

To power off a total station, do the following:

1. Long push **{ON}** button.
2. When there is almost no battery power remaining, the symbol will be displayed every 3 seconds. In this event, stop measurement, switch off the power and charge the battery or replace with a fully charged battery.
3. To save power, power to the TS is automatically cut off if it is not operated for a fixed period of time. This time period can be set in "Power off" in "Instr. config."

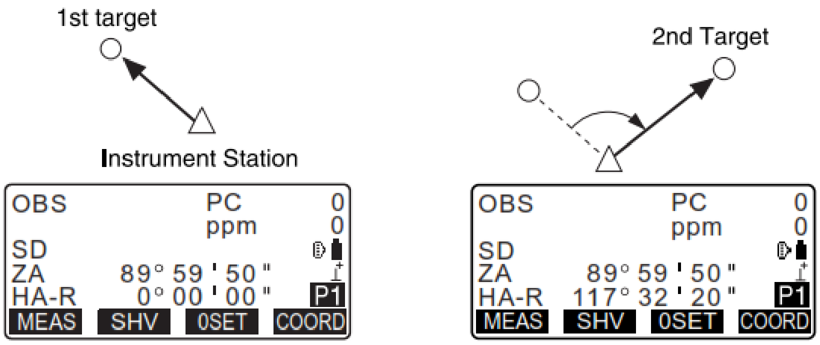
- Topic 4: Use Total Station for measuring angles

Measuring the Horizontal Angle between Two Points (Horizontal Angle 0°)

Use the "0SET" function to measure the included angle between two points. The horizontal angle can be set to 0 at any direction.

Procedure:

1. Sight the first target as at right.
2. In the first page of the OBS mode screen, press **[0SET]**. **[0SET]** will flash, so press **[0SET]** again. The horizontal angle at the first target becomes 0°.



3. Sight the second target. The displayed horizontal angle (HA-R) is the included angle between two points.

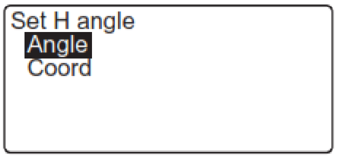
Setting the Horizontal Angle to a Required Value (Horizontal Angle Hold)

You can reset the horizontal angle to a required value and use this value to find the horizontal angle of a new target.

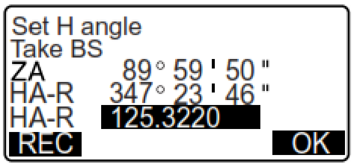
Procedure

a) *Entering the horizontal angle:*

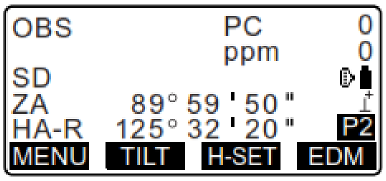
1. Sight the first target.
2. Press **[H-SET]** on the second page of the OBS mode and select "Angle."



3. Enter the angle you wish to set, then press **[OK]**. The value that is input as the horizontal angle is displayed.



4. Press **[REC]** to set and record the horizontal angle.



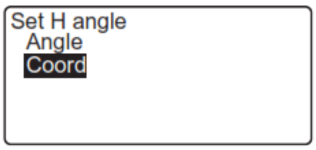
5. Sight the second target. The horizontal angle from the second target to the value set as the horizontal angle is displayed.

   Notes:

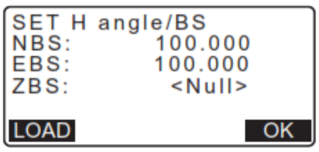
   - Pressing **[HOLD]** performs the same function as above.
   - Press **[HOLD]** to set the displayed horizontal angle. Then, set the angle that is in hold status to the direction you require.

b) *Entering the coordinate*

1. Press **[H-SET]** on the second page of the OBS mode and select "Coord."

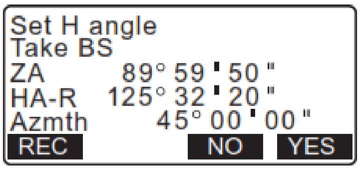


2. Set the known point coordinate. Enter the coordinate for the first point, and press **[OK]**.



3. Press **[YES]** to set the horizontal angle.

4. Press **[REC]** to set and record the horizontal angle.



5. Sight the second target. The horizontal angle from the set coordinate is displayed.

Angle Measurement and Outputting the Data

The following explains angle measurement and the features used to output measurement data to a computer or peripheral equipment.

Procedure:

1. Connect TS and computer.
2. Allocate the **[HVOUT-T]** or **[HVOUT-S]** softkey to the OBS mode screen. Pressing the softkey outputs data in the following format:

   [HVOUT-T]: GTS format

   [HVOUT-S]: SET format
3. Sight the target point.
4. Press **[HVOUT-T]** or **[HVOUT-S]**.
5. Output measurement data to peripheral equipment.

- Topic 5: Distance measuring with Total Station

Perform the following settings as preparation for distance measurement:

- ✓ Distance measurement mode
- ✓ Target type
- ✓ Prism constant correction value
- ✓ Atmospheric correction factor
- ✓ EDM ALC

When using the Laser-pointer function, be sure to turn OFF the output laser after distance measurement is completed. Even if distance measurement is canceled, the Laser-pointer function is still operating and the laser beam continues to be emitted. (After turning ON the Laser-pointer, the laser beam is emitted for 5 minutes, and then automatically switches OFF. But in the Status screen and when target symbol (ex.) is not displayed in the OBS mode, the laser beam is not automatically turned off.)

Make sure that the target setting on the instrument matches the type of target used. ES automatically adjusts the intensity of the laser beam and switches the distance measurement display range to match the type of target used. If the target does not correspond to the target settings, accurate measurement results cannot be obtained.

Accurate measurement results cannot be obtained if the objective lens is dirty. Dust it off with the lens brush first, to remove minute particles. Then, after providing a little condensation by breathing on the lens, wipe it off with the wiping cloth.

During reflector-less measurement, if an object with a high reflective factor (metal or white surface) is positioned between the ES and the target, accurate measurement results may not be received.

Flashing may affect the accuracy of distance measurement results. Should this occur, repeat measurement several times and use the averaged value of the obtained results.

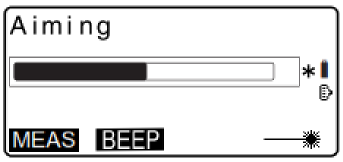
Returned Signal Checking

• Check to make sure that sufficient reflected light is returned by the reflective prism sighted by the telescope. Checking the returned signal is particularly useful when performing long distance measurements.

• When the light intensity is sufficient even though the center of the reflective prism and the reticle are slightly misaligned (short distance etc.), "*" will be displayed in some cases, but in fact, accurate measurement is impossible. Therefore, make sure that the target center is sighted correctly.

Procedure:

1. Allocate the **[S-LEV]** softkey to the OBS mode screen.
2. Accurately sight the target.
3. Press **[S-LEV]**. <Aiming> is displayed. The intensity of the light of the returned signal is displayed by a gauge.



• The more displayed, the greater the quantity of reflected light.

• If "*" is displayed, only enough light for the measurement is returned.

• When "*" is not displayed, accurately re-sight the target.

4. Press **[BEEP]** to make a buzzer sound when measurement is possible. Press **[OFF]** to shut off the buzzer.
5. Press **[MEAS]** to start distance measurement.
6. Press **{ESC}** to finish signal checking and return to Obs Mode.

<u>*Note:*</u>

• When [redacted] is displayed persistently, contact your local dealer.

• If no key operations are performed for two minutes, the display automatically returns to the OBS mode screen.

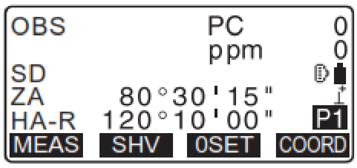
Distance and Angle Measurement

An angle can be measured at the same time as the distance.

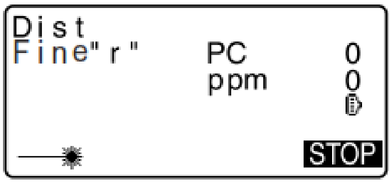
Procedure:

1) Sight the target.

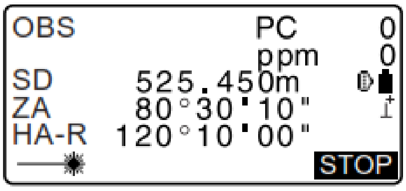
2) In the first page of Obs Mode, press **[MEAS]** to start distance measurement.



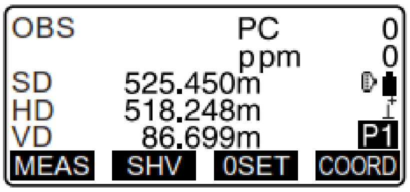
3) When measurement starts, EDM information (distance mode, prism constant correction value, atmospheric correction factor) is represented by a flashing light.



4) A short beep sounds, and the measured distance data (SD), vertical angle (ZA), and horizontal angle (HA-R) are displayed.



5) Press **[STOP]** to quit distance measurement. Each time **[SHV]** is pressed, SD (Slope distance), HD (Horizontal distance) and VD (Height difference) are displayed alternately.



Note:

• If the single measurement mode is selected, measurement automatically stops after a single measurement.

• During fine average measurement, the distance data is displayed as S-1, S-2, ... to S-9. When the designated number of measurements has been completed, the average value of the distance is displayed in the [S-A] line.

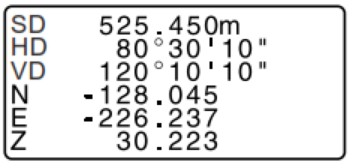
• If the tracking measurement is conducted with the target type "reflector-less", the measured data for a distance exceeding 250m is not displayed.

Recalling the Measured Data

The distance and angle that are most recently measured remain stored in the memory until the power is off and can be displayed at any time. The distance measurement value, vertical angle, horizontal angle, and the coordinates can be displayed. Distance measurement values converted into the horizontal distance, elevation difference, and the slope distance can also be displayed.

Procedure:

1. Allocate the **[CALL]** softkey to the OBS mode screen.
2. Press **[CALL]**. The stored data that is most recently measured is displayed.



   If you have pressed **[SHV]** beforehand, the distance values are converted into the horizontal distance, elevation difference, and the slope distance and recalled.

3. Press **{ESC}** to return to OBS mode.

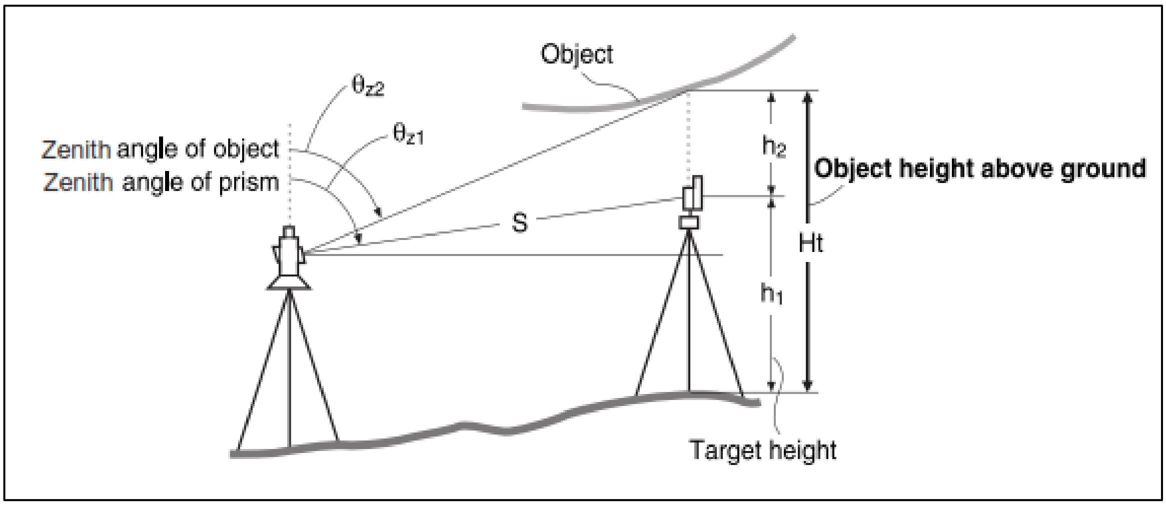
- Topic 6: Use a Total Station for REM Measurement

An REM measurement is a function used to measure the height to a point where a target cannot be directly installed such as power lines, overhead cables and bridges, etc.

The height of the target is calculated using the following formula:

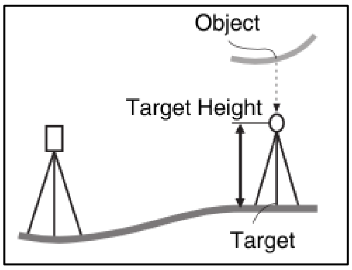
$$Ht = h1 + h2$$

$$h2 = S \sin \theta z1 \times \cot \theta z2 - S \cos \theta z1$$

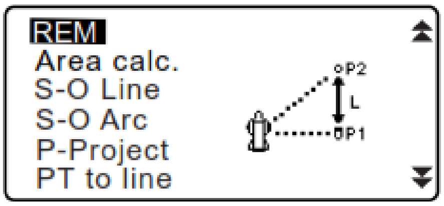


Procedure:

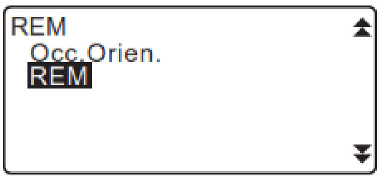
1. Set the target directly under or directly over the object and measure the target height with a tape measure etc.



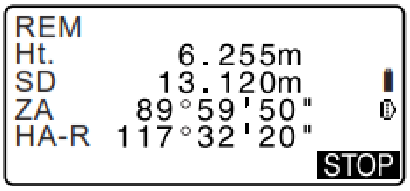
2. After inputting the target height, accurately sight the target. Press **[MEAS]** in page 1 of OBS Mode to carry out measurement. The measured distance data (SD), vertical angle (ZA), and horizontal angle (HA-R) are displayed. Press **[STOP]** to stop the measurement.
3. In the second page of OBS mode screen, press **[MENU]**, then select "REM".

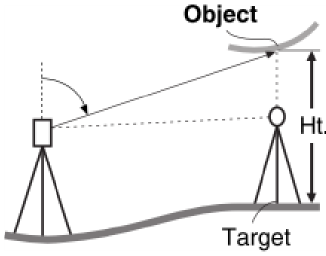


4. Enter into the REM menu. Select "REM."



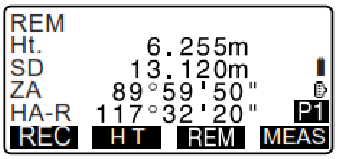
5. Sight the target. Pressing **[REM]** starts REM measurement. The height from the ground to the object is displayed in "Ht.".



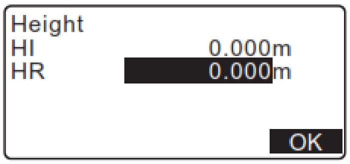


6. Press **[STOP]** to terminate the measurement operation.

   • To re-observe the target, sight the target, then press **[MEAS]**.



   •Press **[HT]** to enter an instrument height (HI) and a target height (HR).



   • When **[REC]** is pressed, REM data is saved.

   •Press **[HT/Z]** on the second page of the REM measurement to display the Z coordinate for the height from the ground to the target. Pressing **[HT/Z]** again returns to the height display.

7. Press **{ESC}** to finish measurement and return to the OBS mode screen.

Note:

- ✓ It is also possible to perform REM measurement by pressing **[REM]** when allocated to the OBS mode screen.
- ✓ Inputting instrument and target height: Press **[HT]** to set instrument and target height. It can be set also in "Occ. Orientation" of coordinate measurement.

- Topic 7: Setting up a GPS Unit (Garmin eTrex)

a) Installing batteries and a microSD card

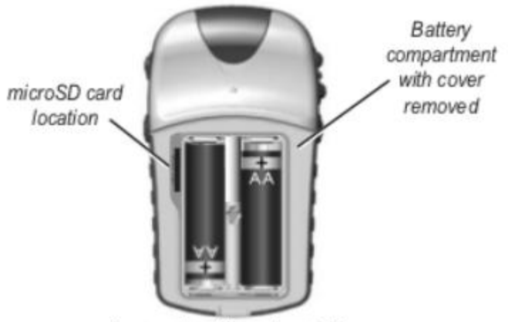
The eTrex operates on two AA batteries which are not included. To install the batteries:

➢ Remove the battery compartment cover from the back of the unit

➢ Insert the batteries, observing the proper polarity

The SD card should be included in the Garmin eTrex folder bundle. It should be installed in the slot on the left side of the batteries. To install a microSD card:

- Remove the battery compartment cover from the back of the unit
- Locate the card slot at the upper-left edge of the battery tray, and slide the card into the slot.



Accessing the microSD card slot

Installing and removing the microSD card

Accessing the USB port

b) Transferring data to and from the GPS unit

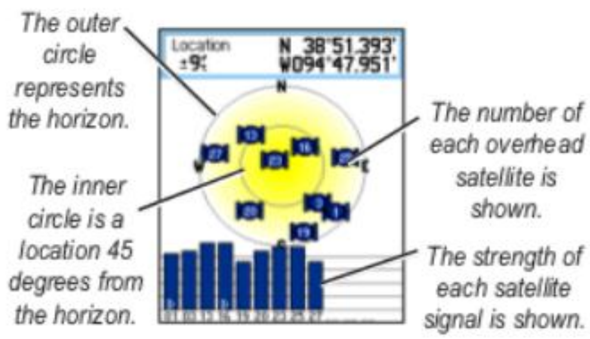
To transfer data to and from the device:

- Lift the weather cover from the USB unit on the back of the unit
- Connect the USB cable to the USB port on your computer and the USB port on the back of the unit
- Transfer the data

c) Initializing the GPS Receiver

When the satellite is turned on for the first time, the receiver must collect satellite data and establish its location. To receive the satellite signals you must:

- Be ***outdoors*** and have a clear view of the sky
- GPS is now searching for the satellite signals
- The *Locating Satellites* is replaced by *Acquiring Satellites* message
- Once the connection is established the *Location* and *Coordinates* appear in the *Acquiring Satellites Window*



d) Loading a Map

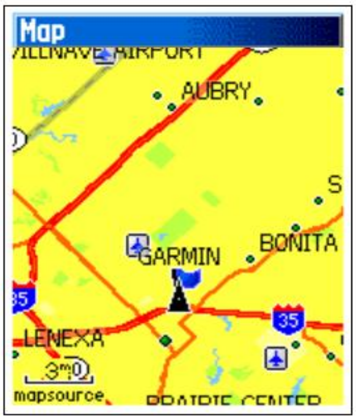
The Garmin maps are in .img format.

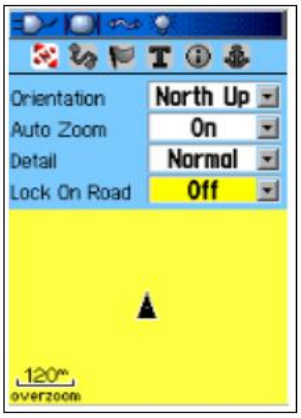
Load the map onto the Garmin device by putting the device into USB Mass Storage mode, and copying

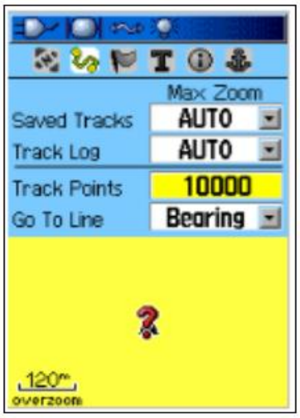
over the file, by following these steps:

- Press *Menu* twice or *Page* key until arriving to *Main Menu*
- Select the *Setup* icon, press *Enter*, then select the *Interface* icon, and press *Enter*
- Connect the GPS to the Computer via USB cable, highlight the *USB Mass Storage* button and press *Enter*, the device shows up on a system as a drive
- If it doesn't exist create a folder called *Garmin* on the device
- Copy the downloaded *gmapsupp.img* file to the *Garmin folder*; if the file already exists you might want to archive the existing file
- Disconnect the GPS or press the *Power* button to restart the unit - the map should be available

e) Map Setup







Set up a map on the Map Page:

- Press Quit/Page key until arriving at the Map Page
- Press Menu/Find key, select Setup Map and press Enter/Rocker key

Use the Rocker key and move it left and right between different Map setups.

General Setup

- Use the *Rocker* key (left and right) to move from icon to icon on the top menu and select the *General Setup*
- Move the *Rocker* key down to highlight *Orientation*, press *Enter*, select *North Up* and press *Enter* again

➢ Then highlight *Lock On Road*, press *Enter*, select *Off* and press *Enter* again.

Turning *Lock On Road ON* would automatically align the tracklog with the nearest road present on the map loaded into the GPS unit. By turning the *Lock On Road OFF* will record new data even in the presence of existing roads.

Tracks Setup

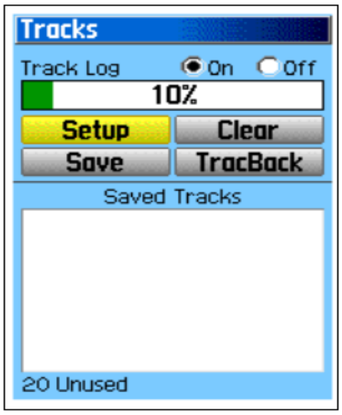
- ✓ Use the *Rocker* to move back to the *Icon Menu* on top
- ✓ Select *Track Setup*
- ✓ Move the *Rocker* down to highlight *Track Points* and press *Enter*
- ✓ Use the *Numeric Keypad* to enter 10000 and press *Enter*

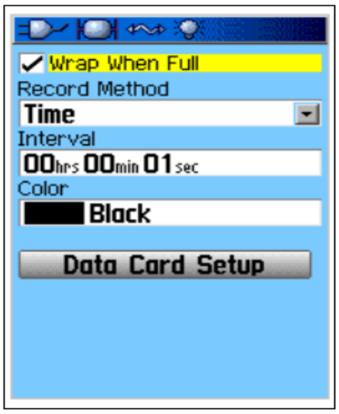
10000 is the maximum number of track points that can be recorded in the GPS units internal memory. The limit of the track points recorded to the microSD card is only limited by the size of the card.

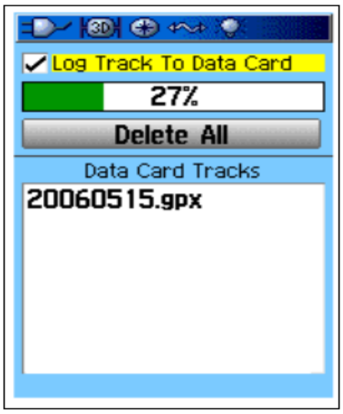
f) Track Log Setup

These steps make sure that the Garmin eTrex is recording track logs with a sample rate once per second

and recording the track logs to the data card. Setting the frequency of the track log recording to the highest possible (one second) will ensure the most complete track recording.







Make sure the Track Log is being recorded:

➢ Press *Menu* twice or *Page* key until arriving to *Main Menu*

➢ Select *Tracks* icon and press *Enter*

➢ If *Track Log* is set to *Off*, move the *Rocker* to highlight *On*, and press *Enter*

Configure the Track Log recording:

➢ Highlight the *Setup* button, and press *Enter* to open the *Tracklog Setup Page*

➢ Highlight *Wrap When Full*, and press *Enter* so that it is *Checked*

➢ Highlight *Record Method*, press *Enter*, select *Time*, and press *Enter*

➢ Highlight *Interval*, use the *Numeric Keypad* to set interval to *00 hrs 00 min 01 sec*, and select *OK*

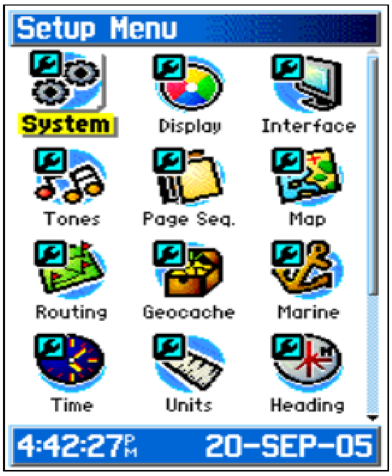
➢ Highlight *Color*, press *Enter*, select your choice, and press *Enter*

Configure the Data Card:

➢ Highlight the *Data Card Setup* button, and press *Enter* to enter the *Data Card Setup Page*

➢ Highlight *Log Track To Data Card*, and press *Enter* so that it is *Checked*

g) GPS receiver System setup



➢ Press *Menu* twice or *Page* key until you arrive to the *Main Menu*

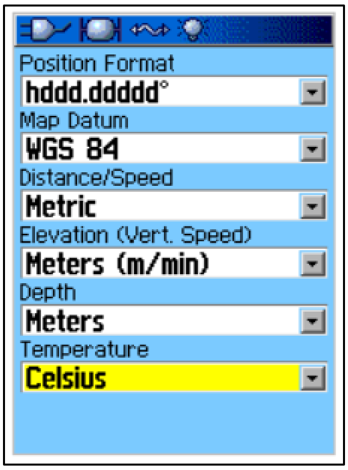
➢ Select the *Setup* icon, and press *Enter*, then select the *System* icon, and press *Enter*

➢ Highlight *GPS*, press *Enter*, select *Normal*, and press *Enter* again

➢ Highlight *WASS/EGNOS*, press *Enter*, select *Enabled*, and press *Enter* again

➢ Highlight *Battery Type*, press *Enter*, select depending on your battery type (most rechargeable batteries are usually *NiMH*, while the normal ones are *Alkaline*)

i) Units Setup



To set up Measuring Units:

➢ Press *Menu* twice or *Page* key until you arrive to the *Main Menu*

➢ Select *Setup* icon, press *Enter*, then select the *Units* icon, and press *Enter*

➢ Highlight *Position Format*, press *Enter*, select *hddd.ddddd°*, and press *Enter*

➢ Select *Map Datum*, press *Enter*, select *WGS 84*, and press *Enter*

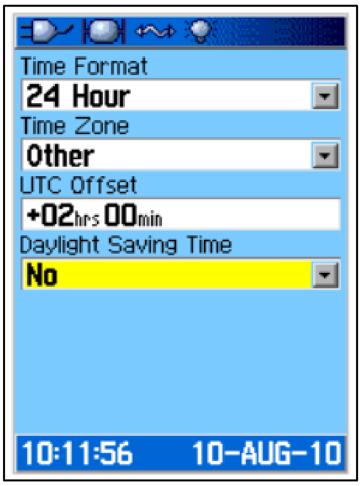
➢ Select *Distance/Speed*, press *Enter*, select *Metric*, and press *Enter*

➢ Select *Elevation*, press *Enter*, select *Meters (m/min)*, and press *Enter*

➢ Select *Depth*, press *Enter*, select *Meters*, and press *Enter*

➢ Select *Temperature*, press *Enter*, select *Celsius*, and press *Enter*

j) Time Setup



➢ Press *Menu* twice or *Page* key until you arrive to the *Main Menu*

➢ Select *Setup* icon, press *Enter*, then select the *Time* icon, and press *Enter*

➢ Highlight *Time Format*, press *Enter*, and select *24 Hour*

➢ Highlight Time Zone, press Enter, and select a city in your time zone. If no obvious choice is listed, select *Other*, and press *Enter*

➢ Highlight *UTC Offset*, press enter, and use the *Numeric Keypad* to manually set your time-zones offset. When finished, select *OK*.

k) Welcome screen setup

- ➢ Press *Menu* twice or *Page* key until you arrive to the *Main Menu*
- ➢ Select *Setup* icon, and press *Enter*, then select *Welcome* icon, and press *Enter*
- ➢ Use the *Alphanumeric Keypad* to enter a message

- Topic 8: Using GPS Unit (Garmin eTrex) to make measurements

1. Collect satellite data and establish location

The steps to initialize the GPS receiver are already described above (Initializing the GSP receiver). Before you set out to map, you need to initialize the GPS receiver, meaning, the receiver must collect satellite data and establish its location. To receive the satellite signals:

➢ Be ***outdoors*** and have a clear view of the sky!

➢ Turn the GPS device on by pressing the *Power* button

➢ GPS is now searching for the satellite signals

➢ The *Locating Satellites* is replaced by *Acquiring Satellites* message

➢ Once the connection is established the *Location* and *Coordinates* appear in the *Acquiring Satellites Window*

2. Collecting Points of Interest

Points of Interest (POI) are points/locations which are of special interest and usually the reason for conducting a mapping exercise. They are either physical points or events, placed somewhere in space and time. Some examples of Points of Interest are hospitals, schools, water points, toilets, shops, religious institutions, and even events, such as, demonstrations, clashes, rallies, etc. By mapping we determine the exact location of Points of Interest in space and time.

There are many different ways to collect Points of Interest. This step explains how to collect these points, also known as waypoints, using a hand-held GPS unit.

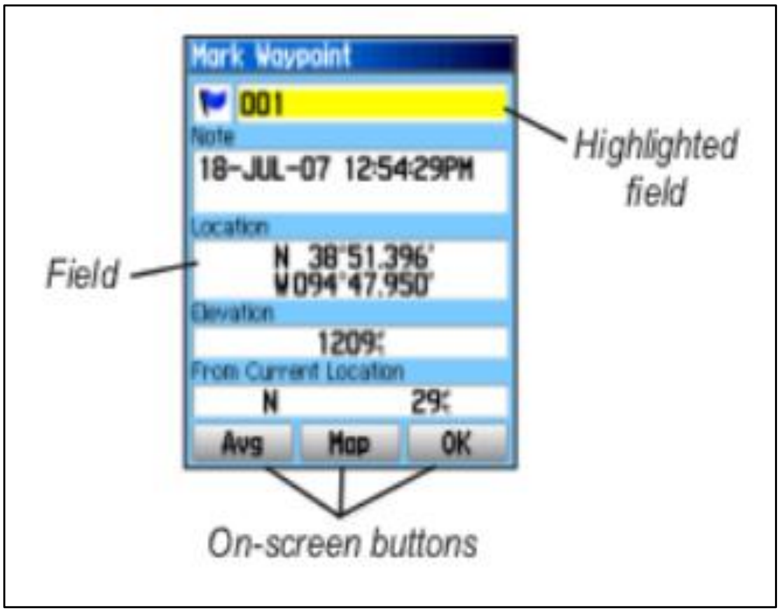
To collect a point:

➢ Stand in front of an object you wish to collect

➢ Press *Enter* key and hold it for one second until you arrive to *Mark Waypoint* screen

➢ Write down on a piece of paper (or into Waypoint Log Sheet) the number and the name of the point you are collecting (You can move up to the waypoint number field by using the Rocker key, and press Enter. Alphanumeric and Numeric Keypads appear. You can use these keypads to type in the name of the location you are mapping but for the sake of saving time it is better to use a sheet of paper and a pencil)

➢ *OK* should be highlighted, press *Enter* to save the location



3. Collecting Ways

Ways are lines connecting different locations. Ways can be highways, roads, paths, railway lines, bus lines, ship lines, bicycle routs, hiking trails etc.

Before you start collecting ways, you need to set the Track Log as described above in the Track Log Setup. Once the device is set to record track, all you need to do is walk along the way you wish to map, and the device does the rest. For maximum efficiency try walking in the middle of the way you are collecting, but do not put yourself in danger.

4. Collecting Areas

An area is an enclosed space usually of the same attribute/land use. Areas can be forests, lakes, seas, parks, fields, buildings, parking lots, squares, playgrounds, etc.

There is a couple of ways to collect an area with a GPS unit but the fastest and the easiest are:

Collect a point in the middle:

- Collect a point in the middle of an area you want to map, estimate the dimensions and draw an approximate sketch of an area on a piece of paper. This method is good for smaller areas like playgrounds but it's not very precise.

Collect points on the perimeter of the area:

- Walk around the perimeter of an area and collect points at the edges of an area.
- Write the waypoints of the edges of an area on a piece of paper.

LO 3.3 – Accurate recorded data during measurement

- Topic 1: Checking and Calibrating Total Station

Calibration is a comparison between measurements: one of known magnitude or correctness made or set with one device and another measurement made in as similar a way as possible with a second device. The device with the known or assigned correctness is called *the standard*. The second device is the *unit under test*, test instrument, or any of several other names for the device being calibrated.

All distances measured by a particular EDM/reflector combination are subject to a constant error. It is caused by three factors:

- Electrical delays, geometric detours, and eccentricities in the EDM;
- Differences between the electronic center and the mechanical center of the EDM; and
- Differences between the optical and mechanical centers of the reflector.

This error may vary with a change of reflectors, after receiving jolts, with different instrument mountings and after service. The additive constant (or prism constant) is a system constant that depends on the instrument and reflector being used. It cannot be attributed just to a reflector or an instrument alone. It is only valid for the combination of both. The additive constant or zero/index correction is an algebraic constant to be applied directly to every measured distance. However, the prism offset is a function of the physical and geometrical properties of the prism.

To maintain the high level of accuracy offered by modern total stations, there is now much more emphasis on monitoring instrumental error. With this in mind, some construction sites require all instruments to be checked on a regular basis using procedures outlined in the manuals. Some instrumental errors are eliminated by observing on two faces of the total station and averaging, but because one face measurements are the preferred method on site, it is important to determine the magnitude of instrumental errors and correct for them.

For total stations, instrumental errors such as collimation error, tilting axis error and compensator index error are measured and corrected using electronic calibration procedures that are carried out at any time and can be applied to the instrument on site. These are preferred to the mechanical adjustments that used to be done in labs by technicians.

Since calibration parameters can change because of mechanical shock, temperature changes and rough handling of what is a high-precision instrument, an electronic calibration should be carried out on a total station as follows:

- ✓ Before using the instrument for the first time.
- ✓ After long storage periods.
- ✓ After rough or long transportation.
- ✓ After long periods of work.
- ✓ Following big changes in temperature.

The instrument errors can be used to monitor the performance of the total station over time and if significant, should be applied to measurements taken subsequent to the calibration.

There are two methods for calibrating a total station, the field method and the laboratory method.

- ➢ For the field calibration, total station must be calibrated over a series of distances representative of the range of the instrument known as baseline. The baseline is a permanently marked distance, the length of which is known.

- For the laboratory calibration, a series of distances ranging from five to one hundred meters could be measured. In general, calibration measurements over short distances assist or help in the determination of the additive constant while longer distances help determine scale error

Calibration must be completed before coordinates can be obtained 3 possible calibrations:

- ***Backsight by angle:*** must know instrument coordinates and have a landmark/target at a known azimuth
- ***Backsight by coordinate:*** must know instrument coordinates and have mirror target set on a position of known coordinates
- ***Resection (triangulation):*** must have 3 or more mirror targets established at known 3D coordinates

- Topic 2: Describing Sources of GPS signal errors

GPS signal propagation is significantly affected by travel through the atmosphere. As GPS signals travel down to the Earth from space, the layers of the atmosphere refracts and slightly delays the signals, particularly within the ionosphere. *This delay interferes with the range solutions from the GPS receiver on the ground to the satellite, resulting in positional errors of several meters.*

Similarly, local space conditions—especially solar output—can affect the GPS signal. Major space weather events can and do affect WAAS as well, but the FAA (which operates it) has upgraded and hardened WAAS so it is more robust against solar interference.
However, WAAS does not correct for other common sources of GPS error, such as GPS points collected during a cold start of the receiver.

Receivers turned on after being off for several days (or even hours), or moved more than 500 miles use outdated satellite ephemeris data, which initially can cause *poor position solutions until the almanac is updated through the GPS signal.*

Likewise, multi-path error, which is interference caused by signal reflection off surfaces near the receiver, is a common problem as well. It is especially prevalent in urban environments and under thick tree coverings.

Since the signal reflecting off a surface can increase the distance from the satellite to the receiver, multi-path errors can affect the accuracy of positions by artificially increasing the pseudo-range. The major sources of GPS positional error are:

- Atmospheric Interference

- Calculation and rounding errors
- Ephemeris (orbital path) data errors
- Multi-path effects

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