3. COMPASS AND NAVIGATIONAL GPS

Two different methods of navigation will be used while you conduct monitoring. You will use a **navigational GPS** to locate a transect start point, keep track of meters walked, record coordinate data if the Bluetooth GPS does not work properly, check the Bluetooth grab for validity and, find your way back to your vehicle from the transect. A **compass** will be used to keep you on the correct bearing, assist you in walking a straight line, and to report azimuth and bearing. Your Bluetooth GPS unit is not interactive and is not for navigation; it is used solely to transfer location data to the RDA.

The **goal** of Compass and Navigational GPS training is to enable you to confidently and correctly apply your existing knowledge of GPS and compass navigation to monitoring. It is expected that you already have a basic understanding of how to navigate with a compass and a standard recreational grade GPS unit. These skills are crucial not only to collecting data, but also to your own personal safety and the safety of those around you.

Objective 1: Basic understanding of GPS.

Navigational GPSs are provided by each monitoring team, not by the USFWS, so unit operation and set up to the standards specified in this training are the responsibility of each monitoring team. This portion of USFWS training should be considered supplemental to required basic understanding of GPS by field crews. Emphasis in training is on application to line distance sampling for desert tortoises.

Standard: Understand GPS basics, including what GPS is and how it works
Standard: Understand coordinate systems and how they are applied to GPS
Standard: Understand the importance of GPS signal strength
Standard: Understand how GPS is applied to monitoring, distinguishing when to use the navigational GPS and when to use the compass

Objective 2: Basic understanding of compass use.

Compasses are provided by each monitoring team, not by the USFWS, so compass operation and set up to the standards specified in this training are the responsibility of each monitoring team. This portion of USFWS training should be considered supplemental to required basic understanding of compasses by field crews. Emphasis in training is on application to line distance sampling for desert tortoises.

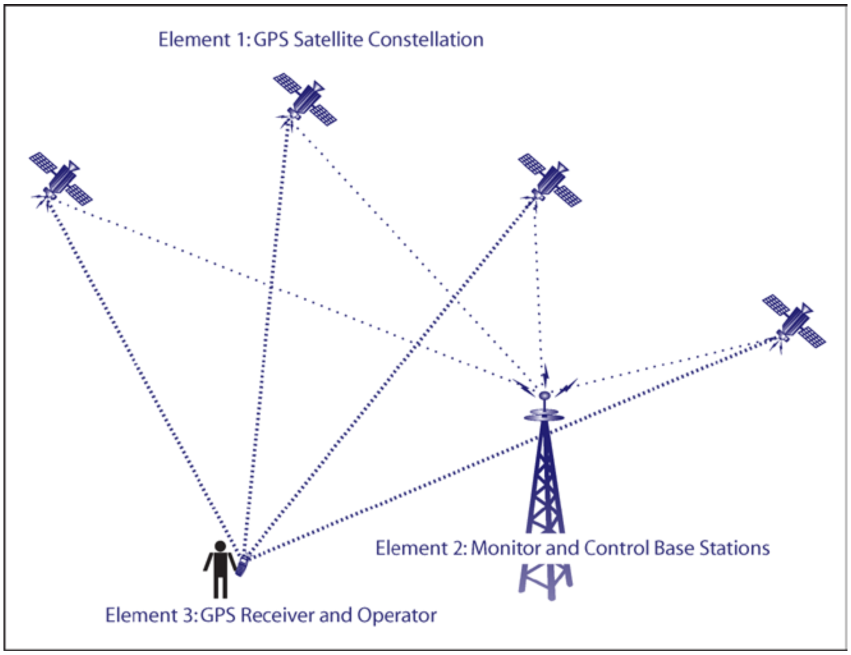
Standard: Know basic compass terminology and anatomy
Standard: Understand the difference between true and magnetic north.
Standard: Understand the use of compass navigation specifically for monitoring, distinguishing when to use the compass and when to use the navigational GPS

Metrics: Trainees will be evaluated on their understanding of compass and navigational GPS through practical exercises, including performance on training lines and navigation on practice transects. The USFWS requires demonstrated proficiency for anyone conducting distance sampling.

Objective 1: Basic Understanding of GPS

1. GPS Basics

- What is GPS - The Global Position System (GPS) was originally developed for military purposes by the U.S. Department of Defense, but in the 1980s, the system, which provides positioning, navigation, and timing (PNT) services, became available for civilian use. In addition, in 2000 selective availability[1] was turned off. According to www.gps.gov, there are three basic elements to the system:



i. The space element is made up of a constellation of 24 operating satellites that transmit one-way signals of the GPS satellite's current position and time.

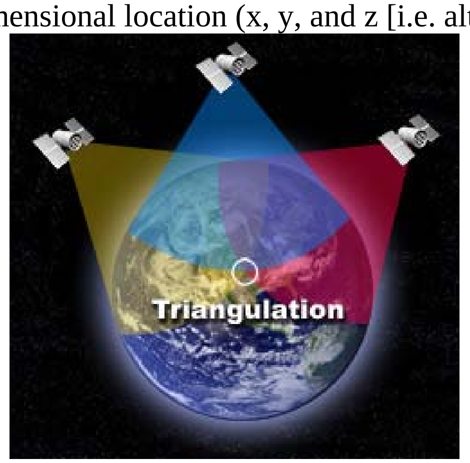
[1] Selective Availability (SA) is the intentional degradation of GPS signals that was put in place by the U.S. Department of Defense as an attempt to prevent military adversaries from acquiring highly accurate GPS data. SA was turned off in May of 2000, vastly improving the accuracy of civilian GPS receivers.

ii. The control element consists of monitor and control base stations around the world that ensure the satellites stay in their proper orbits and stay accurately timed. These stations also track the GPS satellites, update them with navigational data as it becomes available, and collectively maintain the health and status of the GPS constellation.

iii. An end user is the final element, which is made up of the GPS receiver equipment and you, the equipment operator. The equipment uses signals received from the GPS satellites to calculate the user's three dimensional position and time and then, if applicable, displays it to the user in an understandable way.

- How GPS works –
  i. Each operational GPS satellite circles the earth in a very precise asynchronous orbit twice a day and transmits signal data to any active and within view GPS receiver.

  ii. The receiver uses the signal data to calculate the user's location through triangulation.
     - Triangulation compares the time a signal is sent by a satellite with the time it was received to determine how far away the satellite is.
     - Triangulation requires at least three satellite signals to determine a 2 dimensional location (x and y).
     - With four or more satellite signals, a receiver can calculate its 3 dimensional location (x, y, and z [i.e. altitude]).

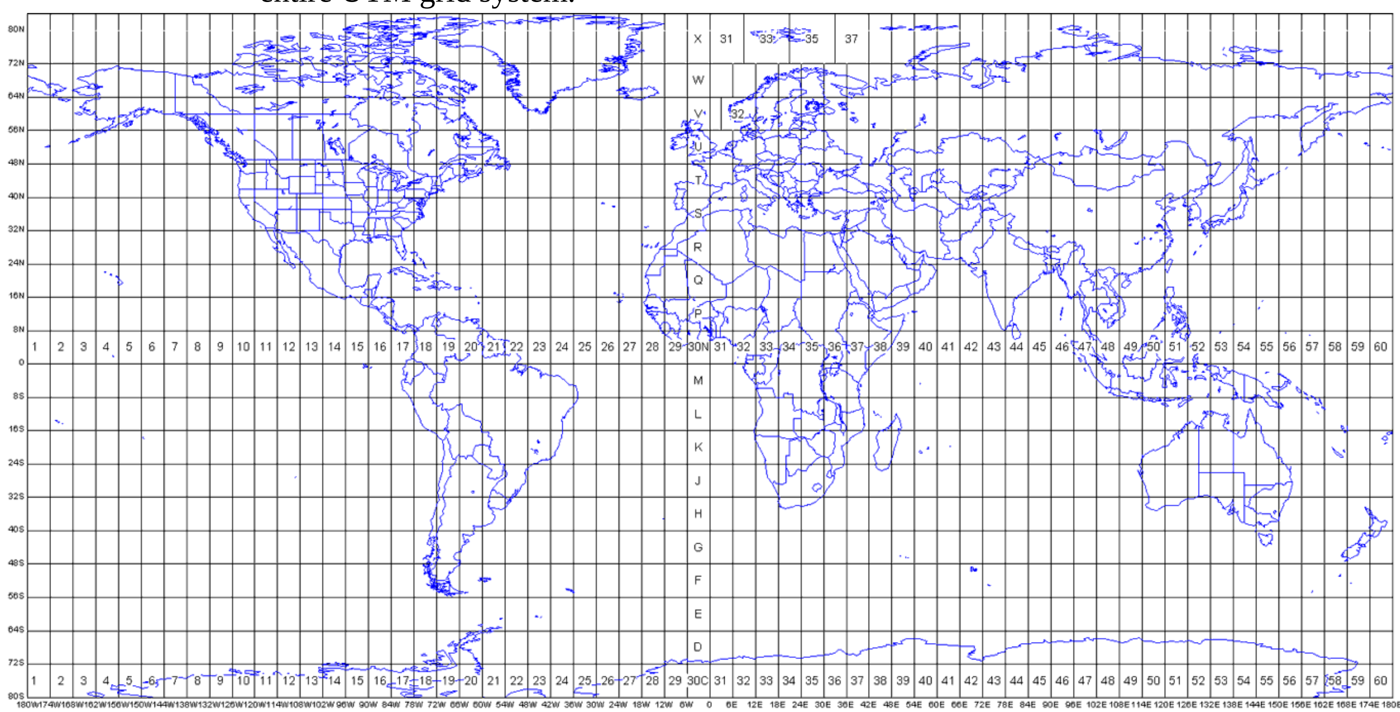


  iii. Once the location is determined, the receiver can track speed, distance, elevation gain, and other information.

2. **Coordinate Systems and GPS –** Geographic coordinate systems allow any point on Earth to be defined and represented by a numbering scheme, the most common of which is latitude and longitude, but monitoring data will be collected in the Universal Transverse Mercator (UTM) coordinate system.
   - Most GPS receivers come out of the box set to latitude and longitude, so you may need to refer to the receiver's user manual to change the settings to display in UTM. Your group leader should be able to help with this. **Your display units must be in UTM.**
   - UTM is typically a better choice for a coordinate system when navigating across and collecting data on smaller areas, like the monitoring strata. When navigating

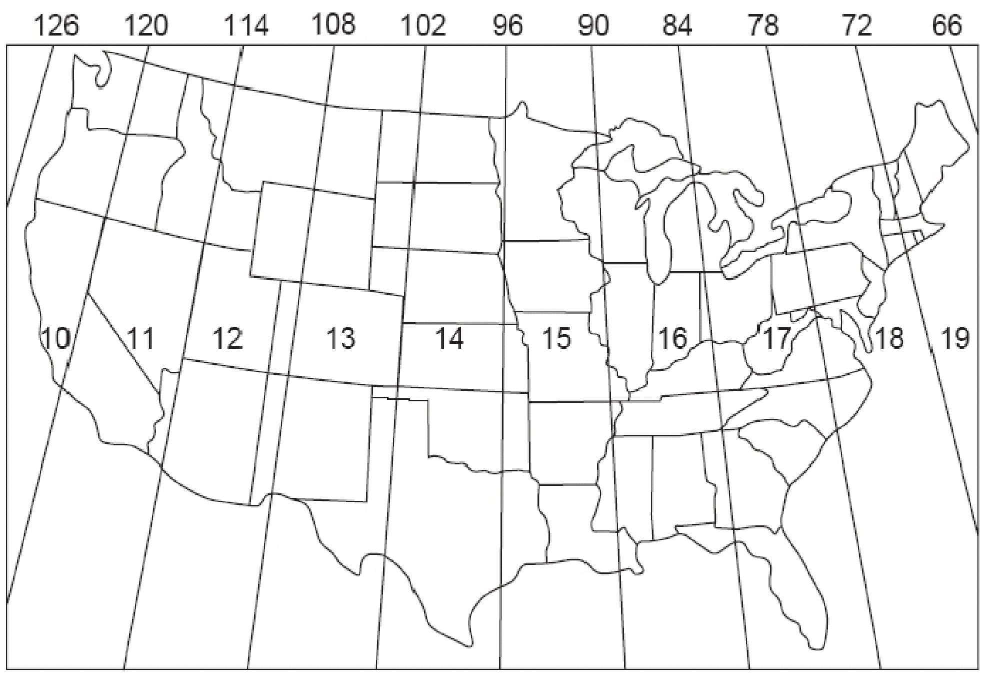
across great distances, like the travels of pilots and sailors, the latitude longitude system is easier to use.

- The UTM grid system originated in 1947 out of the U.S. Army's need for a way to designate rectangular coordinates on large scale (i.e. small area) military maps, but with the more recent boom of the GPS industry for civilian use, the UTM system is becoming more prevalent because the coordinates are easier for the typical civilian navigator to use than latitude and longitude.
- With the UTM system, the earth is divided into 60 zones, numbered 1 (starting at the International Date Line) and proceeding east to 60. Each zone is 6 degrees of longitude wide.
- Each numbered zone is then divided into horizontal lettered bands that span 8 degrees of latitude, starting with C in the south and proceeding to X in the north. I and O are skipped due to their similarity to 1 and 0. The map below shows the entire UTM grid system.



- UTM coordinates are expressed in Easting and Northing
    i. Easting – easting is measured from the vertical center line, or central meridian, of the zone. The center line is given an arbitrary value of 500,000 meters, so anything to the west of the central meridian is less than 500,000, and anything to the east is greater. Because the zones are 6 degrees wide and never more than 674,000 meters wide, an easting of zero is not possible.
    ii. Northing – northing is measured relative to the equator.
        - In the northern hemisphere, the equator is assigned a value of 0 meters north and increases as you travel north.

    - In the southern hemisphere, the equator is assigned a value of 10,000,000 meters north and decreases as you travel south, which avoids the possibility for negative numbers.
    - It is possible to have the same Northing value in the north and in the south, but this can be avoided by including the letter of the latitude band or by including North or South.
    - Because Northing is determined based on the equator instead of the latitude bands, the bands become unnecessary and are often not used.
    - Many GPS receivers denote whether the northing is north or south of the equator by simply adding N or S to the number (which adds confusion because technically southern Nevada and California are in UTM Zone 11 latitude band S, but on your navigational GPS, it will likely show up as UTM Zone 11N because it is north of the equator).
  - Arizona and Utah transects are in UTM Zone 12 and your navigational GPS unit should automatically switch to the new zone when you cross over. Once you have your navigational unit set to UTM, you will not need to worry about switching zones. The map below shows the UTM zones of the U.S. with Longitude along the top.



  - Datum – A datum is the model used to match the location of a feature on the ground to the coordinates of the feature on a map. GPS uses the World Geodetic System (WGS) 1984, which is an Earth-centered datum that was adopted from the North American Datum of 1983. **Make sure your navigational GPS is set to UTM, WGS 1984.**

3. **How GPS is Applied to Monitoring -** while completing a transect, you will use both a navigational, interactive GPS unit and a Bluetooth, non-interactive unit. Because the

navigational GPS unit is not provided by the USFWS, units may differ between field teams, so training on menu navigation and GPS care is up to you and your team leaders.

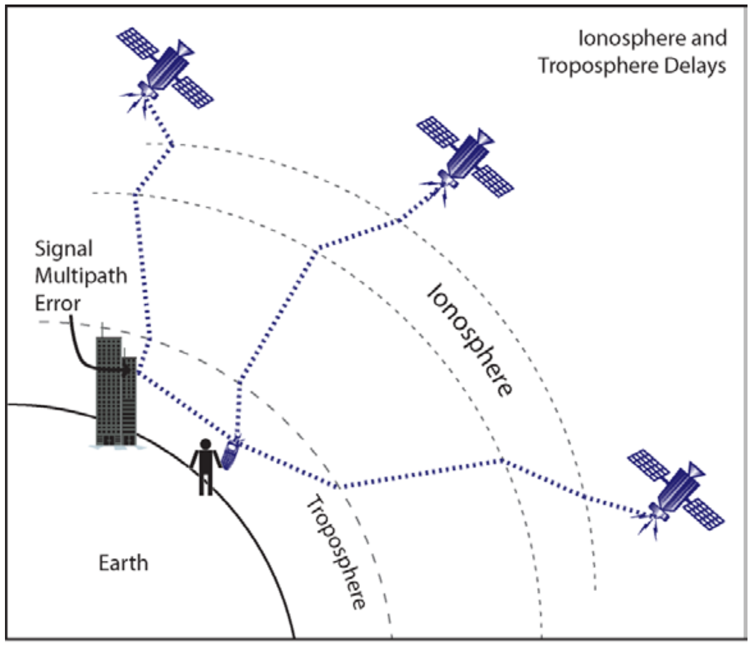
- The navigational GPS unit will be used in five different ways:
    - **i.** Navigating to a transect start point – for each transect assigned to you, you will be given the start point (southwest corner) coordinates and it is up to you, your team mate, and your group to determine how you will get there, or to an alternate point on the transect. It is not required that you use the SW corner as your start point, it is not even recommended. You should navigate to the closest possible location on the theoretical transect.
    - **ii.** Keeping track of meters walked – a handy feature of most navigational GPS units is their ability to display distance traveled. Instead of pacing 500 meters in your head as you walk, you will use the GPS interface to keep track of distance traveled from waypoint to waypoint.
    - **iii.** Recording coordinate data if the Bluetooth GPS grab does not work – Odds are that at some point during your monitoring duties, your Bluetooth GPS unit will not take a grab for one reason or another. On these (hopefully rare) occasions, you will have to manually enter the easting and northing, and zone if applicable, into the RDA according to the reading on your navigational GPS.
    - **iv.** Checking the validity of the Bluetooth grab when necessary – Occasionally, you will need to compare the GPS reading from your Bluetooth unit to the GPS reading on your navigational unit. The circumstances in which you will compare the two are outlined in the Pendragon Forms and Database module Objective 4, Standard 5.
    - **v.** Finding your way back to your vehicle – If necessary, you can use the navigational GPS unit for its most traditional purpose – finding your way from point A (end point) back to point B (drop off point).
- The Bluetooth GPS unit is used for one purpose only – to electronically transfer coordinate data onto the RDA.

    - **i.** You will use the Bluetooth unit whenever you record a waypoint or a tortoise, whether live or carcass, transect or opportunistic.
    - **ii.** Automatically transferring coordinate data eliminates the opportunity for human caused error.
    - **iii.** Beyond the RDA screen used to record a point, it is not possible to interact with the Bluetooth unit.

4. **GPS Signal Strength** – the reliability of a GPS satellite reading or grab is almost entirely dependent on the strength and geometry of the signals coming from the satellites. In this case, this effects both your navigational and Bluetooth GPS
    - There are occasions when a GPS signal weakens, becomes undetectable, or degrades before it reaches a GPS receiver. The following outlines when and why this degradation occurs.
        - **i.** Ionosphere and troposphere delays – as the satellite's signal passes through the atmosphere, it slows down, throwing the receivers triangulation calculation off (see graphic below). This is partially

compensated for through a built-in calculation based on the average delay time.

ii. Signal multipath happens when the GPS signal bounces off of a surface, like a tall building or a large rock formation, before reaching the receiver, which increases the travel time and thereby causes an error (see graphic below).

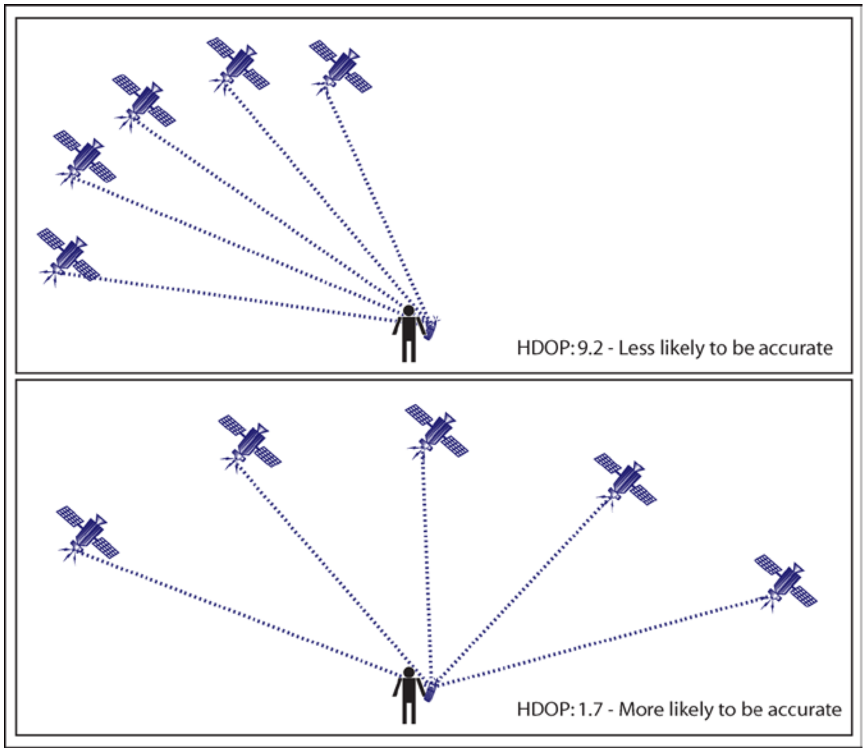


iii. Receiver clock errors occur when the built-in clock on a receiver is not as accurate as the atomic clock on a GPS satellite, causing slight timing errors.

iv. Orbital errors occur when the reported location of a satellite is inaccurate.

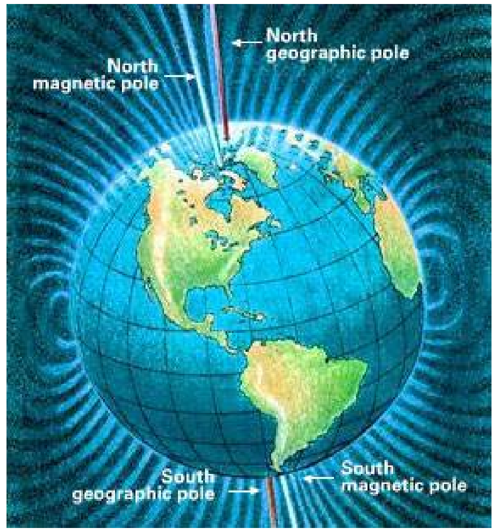
v. Number of satellites visible – The more satellites a GPS receiver has clear access to, the stronger its positional accuracy will be. Satellite signals are blocked or degraded by buildings, mountains, dense foliage, and other electronic signals, and typically do not work indoors, underground, or underwater. You will be using the number of satellites to assess the accuracy of waypoint and observation GPS grabs.

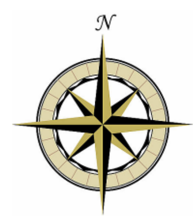
vi. Satellite geometry – The spread, or geometry, of satellites available to a receiver can affect the accuracy of a reading. When satellites are bunched together in the sky, the reading is likely to be less accurate than a reading from satellites that are evenly spread out. The goodness of satellite geometry is expressed on your GPS receiver most commonly as HDOP (Horizontal Dilution of Precision) or PDOP (Position Dilution of Precision). See the diagram below. In addition to number of satellites, you will also be using HDOP to assess the accuracy of waypoint and observation GPS grabs.



- Knowing what makes a signal go bad or get interrupted can help you get the best signal possible. Here are some other tips:
    i. The receiver needs as clear a view of the sky as possible – even you can block a signal; hold it out in front of you with your arm extended.
    ii. Many navigational GPS units have a Skyplot option, which lets you see the position and the strength of available satellites. This can help you determine if you need to compare the Bluetooth grab coordinates to the navigational GPS coordinates.
    iii. If you are in an area with large rock formations or the ground is mostly rock, the signal is more likely to bounce and introduce error to the grab. Keep an eye on your navigational GPS in situations like this because it is constantly refreshing. If its reading is bouncing around and varying more than 20 meters, the grab is more likely to be poor. Compare the grab to the most consistent navigational GPS reading.
- For more detailed information on GPS, visit www.gps.gov.

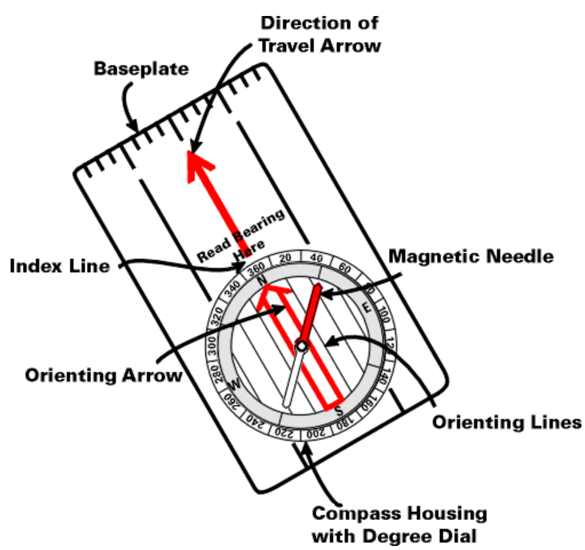
Objective 2: Understanding Compass Basics





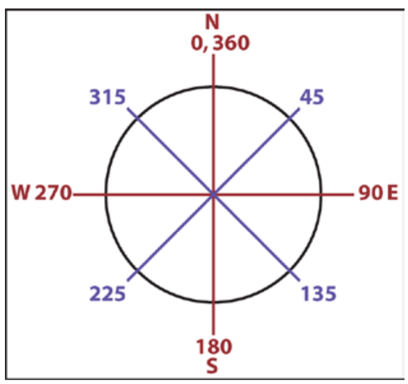
1. Basic Compass Terminology and Anatomy

- **Bearing and Azimuth:** Both bearing and azimuth are determined using your compass. They refer to direction in degrees and are very similar. For our purposes, bearing is the direction in degrees you walk along a transect and ranges from 0 to 360 degrees. Azimuth is the angle from the line you are walking to a tortoise or carcass and also ranges from 0 to 360.
- **Compass Anatomy:** The four most important pieces of your compass, and the ones that you will use every day are the direction of travel arrow, orienting arrow, magnetic needle and compass housing. Compasses are provided by each monitoring team, not by the USFWS. Therefore, our description of compass anatomy may vary from what your actual compass looks like or comes with.



i. **Compass Housing:** the sealed center compartment of the compass that contains the magnetic needle and a liquid that allows the needle to move freely, but not rapidly or shakily
ii. **Baseplate:** the bottom part of the compass that you hold flat in your hand; includes the direction of travel arrow and any millimeter and inch scales
iii. **Direction of Travel Arrow:** points in the direction you should travel after setting your bearing
iv. **Magnetic Needle:** located within the compass housing and is typically a red and white needle; the red end is magnetized and points to magnetic north when the compass is held steady and flat
v. **Degree (Bearing) Dial:** the numbers located along the compass housing that indicate the angular difference in degrees between any point and magnetic north (can be adjusted for declination); bearings range from 0 to 360 degrees
vi. **Orienting Lines:** parallel lines in or on the compass housing and base
vii. **Orienting Arrow:** stationary arrow within the compass housing
viii. **Declination Adjuster:** typically a small notch on the back of the compass that requires a key to turn; allows you to adjust for declination (not shown on figure). You must have a compass with an adjustable declination.

2. **Basic Compass Navigation:** Correctly navigating with and reading a compass is an essential part of monitoring. The steps below explain what you need to know, and should be a review.



- **Follow a Bearing (i.e. use a compass to walk in a certain direction):** On transects you need to follow a bearing; a compass will help you keep on that bearing. You will mainly be heading north (0), east (90), south (180), and west (270), focusing the majority of your attention on finding tortoises, and only occasionally checking that you are following the correct bearing. Here's how:
  i. With the compass open, the bottom held as flat and steady as possible, and the direction of travel arrow pointing away from you, rotate the compass housing until the desired degree lines up with your direction of travel arrow (i.e. 0, 90, 180, 270).
  ii. With the compass held directly in front of you at chest level, turn your body until the magnetic needle lines up with the orienting arrow. In nearly every compass Red in the Shed is the rule.

iii. Now lift the compass to eye level and fold the mirror until you can see the arrow’s reflection. Make sure they stay aligned during the next step.
iv. Look down the direction of travel arrow, beyond the compass, and find an object that stands out (i.e. a Joshua tree off in the distance, prominent mountain features) and lines up with the direction of travel arrow.
v. Walk towards the chosen object, glancing up occasionally to ensure you are still on the right path.
vi. If a distant navigational target is not available, pause every hundred meters or so to check your bearing and identify new, closer targets as necessary.

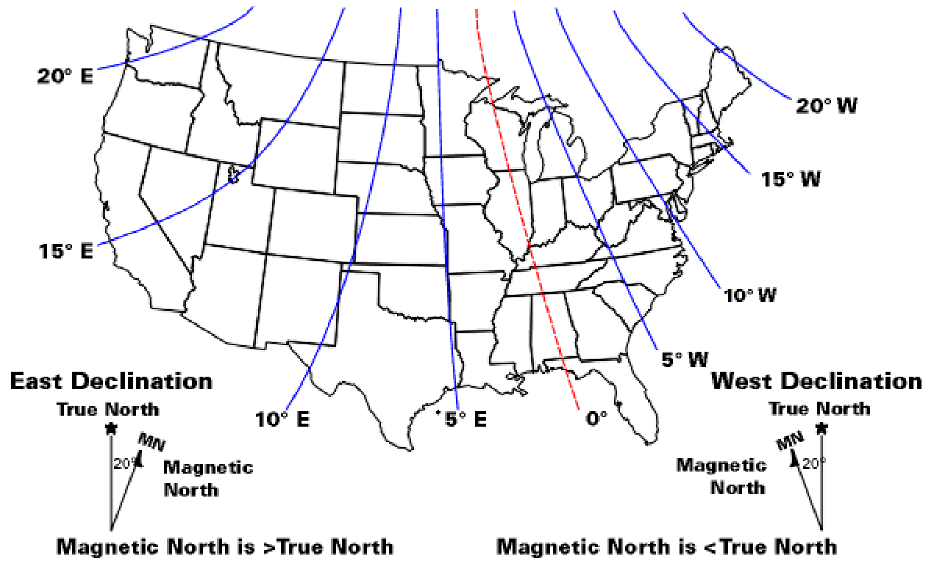
- **Read a Bearing from a Map:** Occasionally you will reflect a transect and travel in a non-cardinal direction. To read the correct bearing from the map, you will orient using the north arrow and base lines on the map.
  i. Settle the baseplate of the compass on the map so that the compass housing straddles the path for which you will determine a bearing.
  ii. Rotate the compass housing so that the compass orienting lines are parallel to north-south base lines on the map; the 360 position on the degree dial now indicates north as depicted by the map.
  iii. Read the bearing of interest where the mapped path crosses the degree dial.
- **Take a Bearing (i.e. use a compass to find your direction of travel):** You will record a local bearing and a transect bearing each time you find a tortoise or carcass. The transect bearing is the bearing that you planned to walk (i.e. 0 for North, 90 for East, etc.); this is a planned, not a measured quantity. You will use your compass to take the local bearing, which is the bearing you are actually walking. *We want you to focus on looking for tortoises rather than looking at instruments to stay on an exact bearing the whole time, so we also expect that your actual bearing will vary from the transect bearing*, but hopefully not too much. The directions below assume you have a compass with a folding mirror.
  i. With the compass open, the bottom held as flat and steady as possible, and the direction of travel arrow pointing away from you, hold the compass up to your sighting eye.
  ii. Standing at your position (leader or follower), line up the direction of travel arrow with the 25m tape. **NOTE:** The bearing measured back from the leader position (“back-bearing”) will be 180° different from the bearing from the follower position. Either bearing will give the correct calculation.
  iii. Fold the mirror portion so you can see the magnetic needle and orienting arrow in its reflection. Keeping the compass steady, rotate the compass housing with the bearing degrees until the orienting arrow (hollow and within housing) lines up with the north end of the magnetic compass needle, so the red end of the magnetic needle fits nicely within the hollow of the orienting arrow. Red in the Shed!
  iv. By using the mirror, you avoid lowering the compass and shifting its orientation as you line up the orienting arrow with the magnetic needle. Look in the reflection to align the two, then lower the compass and record the bearing at the index line. That is the local bearing.

- **Take an Azimuth (i.e. use a compass to find the direction of an object):** Accurately recording the distance a carcass or live tortoise is from the transect line you are walking is an essential part of monitoring. The calculation of this distance requires the exact azimuth and distance of the tortoise from where you spotted it on the transect line. To take an azimuth, follow the steps below:
    i. Immediately stop walking when you spot a live tortoise or carcass and let your team member know. It is important to record the azimuth from where you first spotted it, not two steps down the line.
    ii. With the compass open, the bottom held as flat and steady as possible, and the direction of travel arrow pointing away from you, hold the compass up to your sighting eye.
    iii. Without stepping from your spot, rotate your body until you can point the direction of travel arrow directly at the tortoise or carcass
    iv. Fold the mirror down until you can see the magnetic needle and orienting arrow reflecting in the mirror.
    v. Rotate the bearing dial until the magnetic needle and orienting arrow align, using the mirror so you can keep the direction of travel arrow pointed directly at your find.
    vi. Once the arrows are aligned, lower your compass and record the bearing number that aligns with the direction of travel arrow. That is the azimuth of the tortoise.

3. **True and Magnetic North:** When navigating by compass, there are two different North's to consider: the north that can be found on a map (true), and the north that a compass points to (magnetic).
    - **True North** (also geographic north or map north): True north is the geographic North Pole where all longitude lines on a map meet. Nearly all maps have a north arrow indicating true north, but a compass's arrow points towards magnetic north.
    - **Magnetic North:** The earth can be considered a giant magnet with a magnetic field that is inclined at about 11 degrees from the planet's axis, so magnetic north and true north do not usually line up. Because Earth's core is molten, the magnetic field is always slightly shifting. This magnetic field pulls the magnetic arrow within a compass away from true north and towards magnetic north.
    - **Declination:** Declination is the angular difference between true north and magnetic north. The figure on the next page illustrates how declination depends on where you are. In Mississippi, we wouldn't have to worry about declination; true north and magnetic north would more or less line up. Declination values are expressed as Easterly (positive) or as Westerly (negative) values. When magnetic north is east of true north (as in the Mojave), the declination is positive. In an added twist, the lines of declination shift westward about 0.5 to 1 degrees every year. For this reason, although declination is indicated at the bottom of many local maps including all USGS topographic maps, older maps will not reflect current conditions. A declination calculator for a particular area on a particular day can be found at http://www.ngdc.noaa.gov/geomagmodels/Declination.jsp. For instance, the declination in Barstow, CA on 15 April 2011 will be 12 degrees and 33 minutes east and in Las Vegas, NV it will be 12 degrees and 19 minutes east.

After you adjust your compass to compensate for declination, you might stop thinking about it for now, but it's a basic component of reading a compass and an important concept to understand.

General lines of declination in the United States (1998)



- **Example to further clarify declination:**
  You are in Las Vegas and want to travel along a true north bearing (0˚), a feat you will attempt each day on one leg of an actual monitoring transect. Because the area around Las Vegas currently has a declination value of about 12 degrees east (+12), when your compass indicates 0° from magnetic north, you are actually traveling a bearing of 12° from true north (0 + (+12) = 12°)). To travel a true 0° path, subtract 12° from your planned bearing. Following a bearing of (360-12)=348° will compensate for declination and result in a true 0° path. Instead of doing this on the fly you can adjust your compass for declination. Work with the declination adjuster until the orienting arrow points to 12 (details below). When the declined compass indicates a bearing of 0 degrees, you are following true north.
- **Adjusting for Declination:** The compass you use on transects must adjust for declination. Here's how to adjust for declination in the Las Vegas area:
  i. As you will be walking transects that have easterly declinations, you will need to follow a bearing of twelve degrees less than magnetic north.
  ii. On the back of your compass, there should be a small screw that you can turn with the key provided on the lanyard. Turn the screw until the magnetic north arrow points at 12. After adjustment, your bearings and azimuths will report true bearings and collect true azimuths.
  iii. **If you fail to adjust for declination, your first 3km leg will be ~750m off (~250m/km), with the error compounding on each additional leg of the transect.**