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 transect start points, keep track of meters walked, check the Juno grab for validity, and return to your vehicle from the transect. A **compass** will be used to set and hold the correct bearing as you walk, and to report azimuth and bearing. The integrated Juno GPS is not for navigation; it is used solely to transfer location data to the collection system.

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 distance sampling. 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 to collecting data, as well as to your personal safety and the safety of those around you.

Objective 1: Basic understanding of GPS.
Navigational GPSs are provided by each monitoring team, so unit set up, operation, and maintenance are the responsibility of each team. Emphasis in USFWS training is on application to 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: Correctly utilize GPS in the context of distance sampling surveys

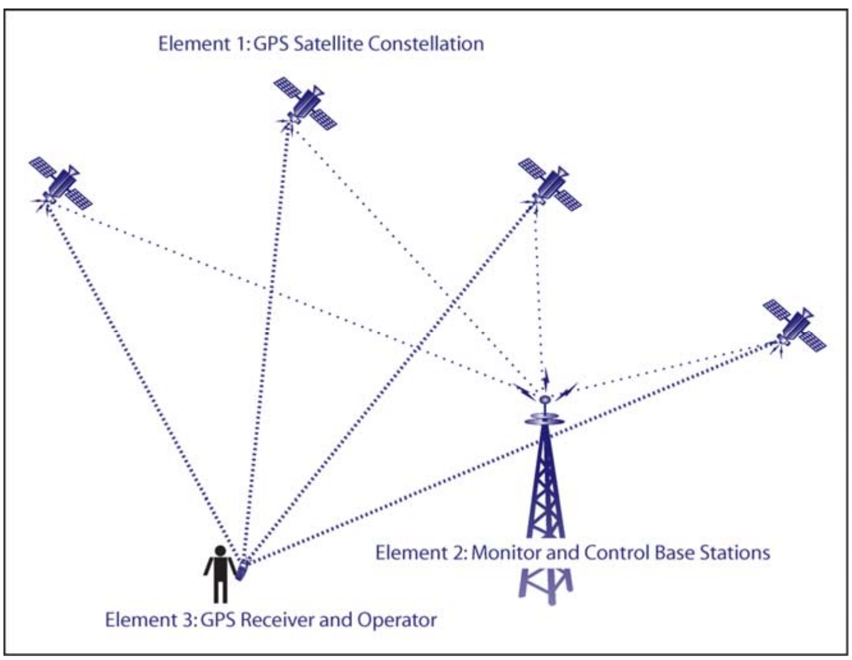
Objective 2: Basic understanding of compass use.
Compasses are provided by each monitoring team, so compass set up, operation, and maintenance are the responsibility of each team. Emphasis in USFWS training is on application to line distance sampling for desert tortoises.

Standard: Know basic compass terminology and anatomy
Standard: Understand the difference between true and magnetic north.
Standard: Correctly utilize compasses in the context of distance sampling surveys

Metrics: Trainees will be evaluated on use of compass and navigational GPS through practical exercises, including performance on training lines and navigation on practice transects. Proficiency must be demonstrated by everyone conducting distance sampling.

Objective 1: Basic Understanding of GPS

- **GPS Basics**
  - What is GPS - The Global Position System (GPS) was originally developed for military purposes by the U.S. Department of Defense. 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. There are three basic elements to the system (www.gps.gov):



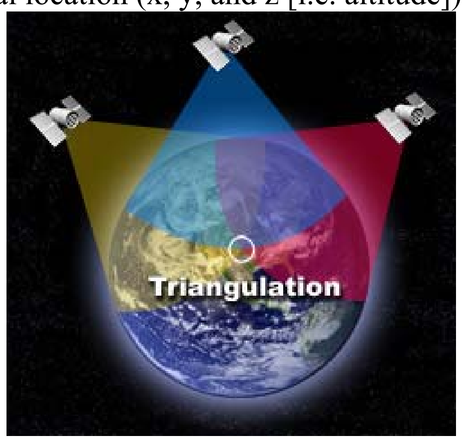
i. The space element is made up of a constellation of 24 operating satellites that transmit one-way signals of the GPS satellite's current position and time.
ii. The control element consists of monitor and control base stations around the world that ensure the satellites stay in their proper orbits and stay accurately

[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.

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. The final element is the end user, consisting of the GPS receiver equipment and you, the equipment operator. The equipment uses GPS satellite signals to calculate the user's three dimensional position and time. If applicable, it displays this information to the user in an understandable way.

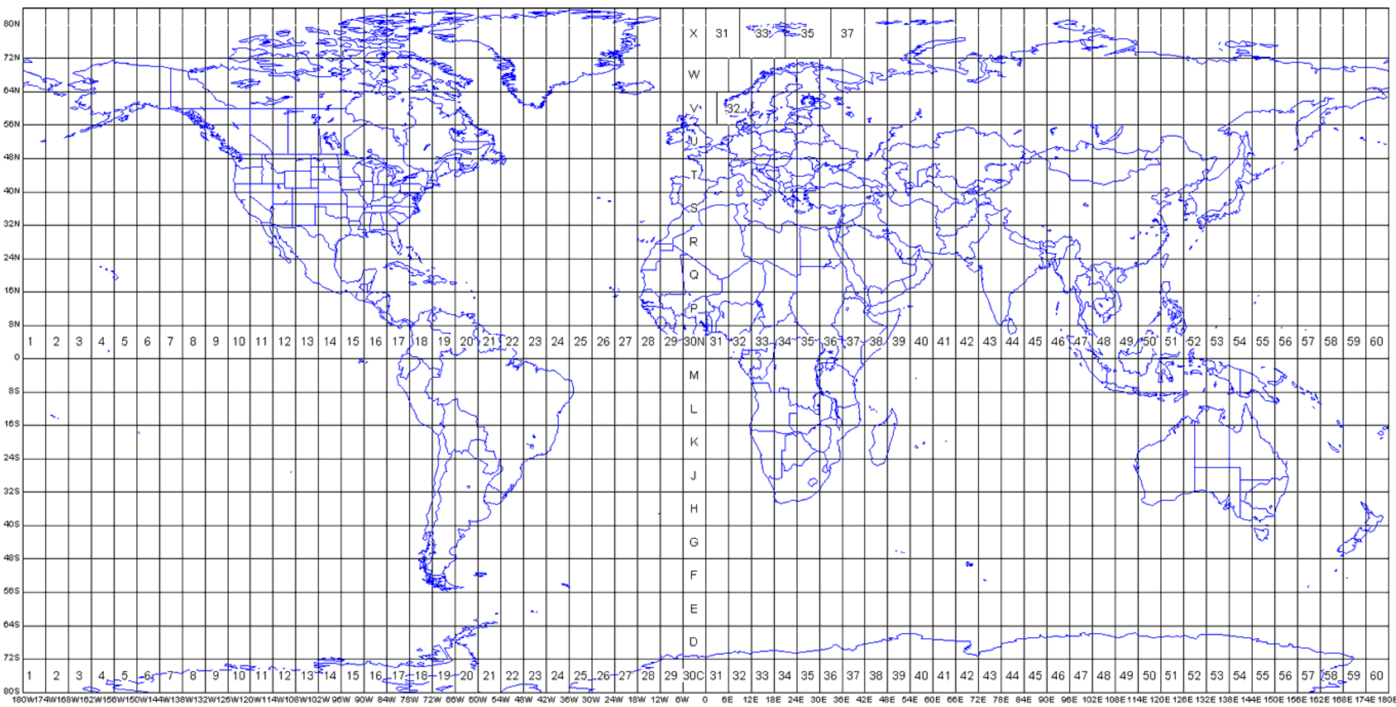
- How GPS works –
  - **i.** Each operational GPS satellite circles the earth in a very precise asynchronous orbit twice a day, transmitting signal data to active, within-view GPS receivers.
  - **ii.** The receiver uses the signal data to calculate the user's location through triangulation.
    - Triangulation 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.

- **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 user manual to change the settings. **Your display units must be in UTM.**
  - UTM is typically a better coordinate system for navigating across and collecting data on smaller areas, like transects and monitoring strata. When navigating larger distances, the latitude longitude system is easier for pilots and sailors 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 is becoming more prevalent because the coordinates are easier for the typical civilian navigator to use than latitude and longitude.

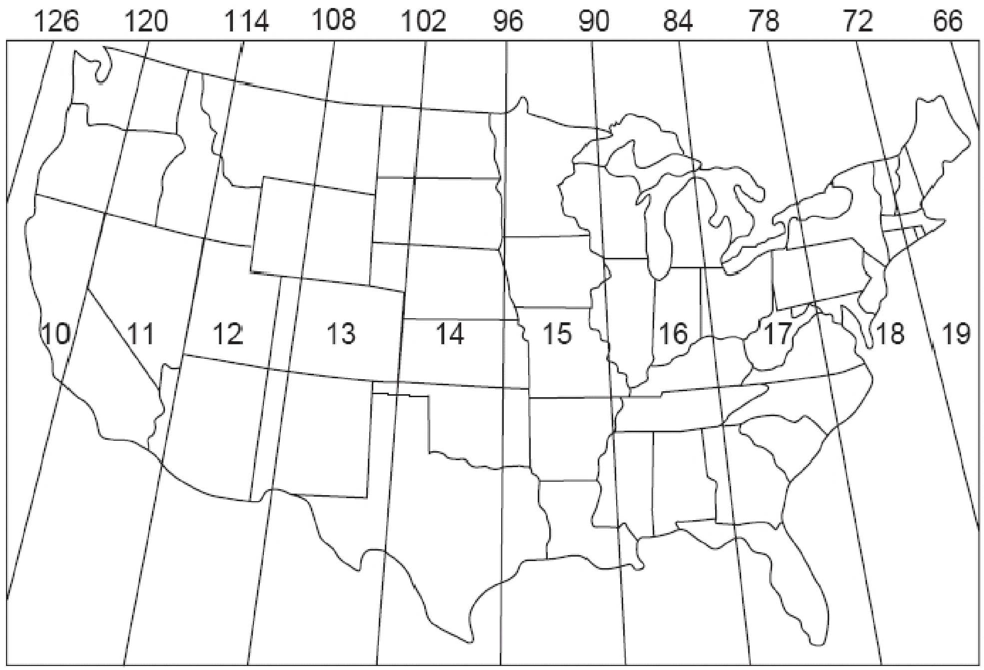
- With the UTM system, the earth is divided into 60 zones, numbered 1 (at the International Date Line) and proceeding east to 60. Each zone is 6 degrees of longitude wide.
- Each numbered zone is then divided into horizontal lettered bands that span 8 degrees of latitude, starting with C in the south 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 confusion is 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. This can create confusion

because 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 as appropriate. 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, 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 the non-interactive GPS that is integrated into the Juno. The navigational GPS unit is not provided by the USFWS, 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, it is up to you, and your group to determine how you will get to the [closest] access point on the transect.
     - **ii.** Keeping track of meters walked – most navigational GPS units display distance traveled. Instead of pacing 500 meters in your head as you walk, use the GPS interface to track distance traveled since previous waypoint.
     - **iii.** Recording GPS coordinates on paper – At each waypoint, record navigational GPS coordinates on the paper sheets. These coordinates may not match those grabbed into the electronic form, so they provide important information.
     - **iv.** Checking the validity of the Juno grab – Compare electronic and navigational GPS coordinates to confirm validity of the electronic version. This comparison is important when

- Your Juno has been off for more than an hour
- Your HDOP is six or more
- There are fewer than five available satellites
- The grab took an unusually long amount of time

v. Recording coordinate data if the integrated Juno GPS grab does not work – At some point during your monitoring duties, your Juno GPS unit may not take a grab for one reason or another. In this case, manually enter the easting, northing, and zone from your navigational GPS into the electronic database.

vi. Finding your way back to your vehicle – If necessary, use the navigational GPS unit for its most traditional purpose – finding your way from point A (transect end point) to point B (pick up location).

- The GPS unit integrated into the Juno is used for one purpose only – to capture coordinate data in the electronic database.

  i. You will use the Juno unit whenever you record a waypoint, tortoise, or carcass.

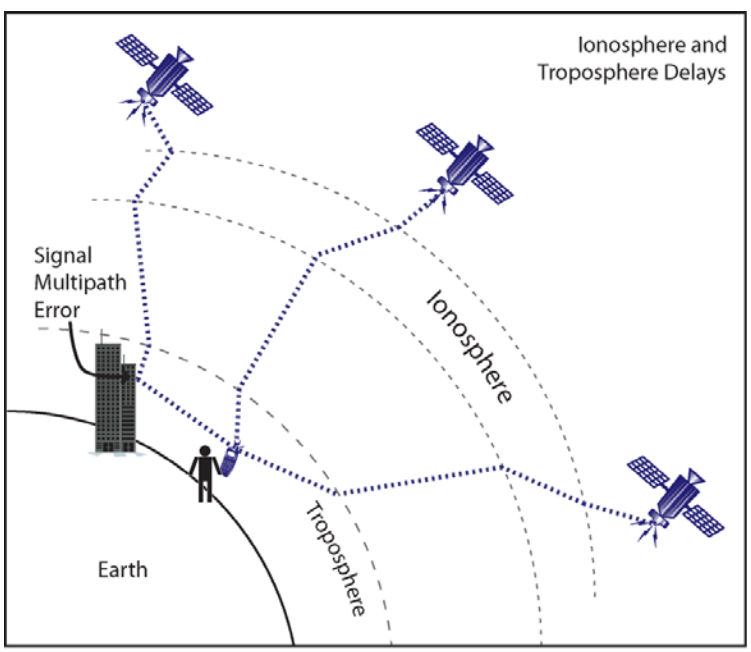
  ii. Automatically transferring coordinate data eliminates the opportunity for human-caused error.

4. **GPS Signal Strength** – Reliability of a GPS satellite reading or grab is almost entirely dependent on the strength and geometry of the signals coming from the satellites.

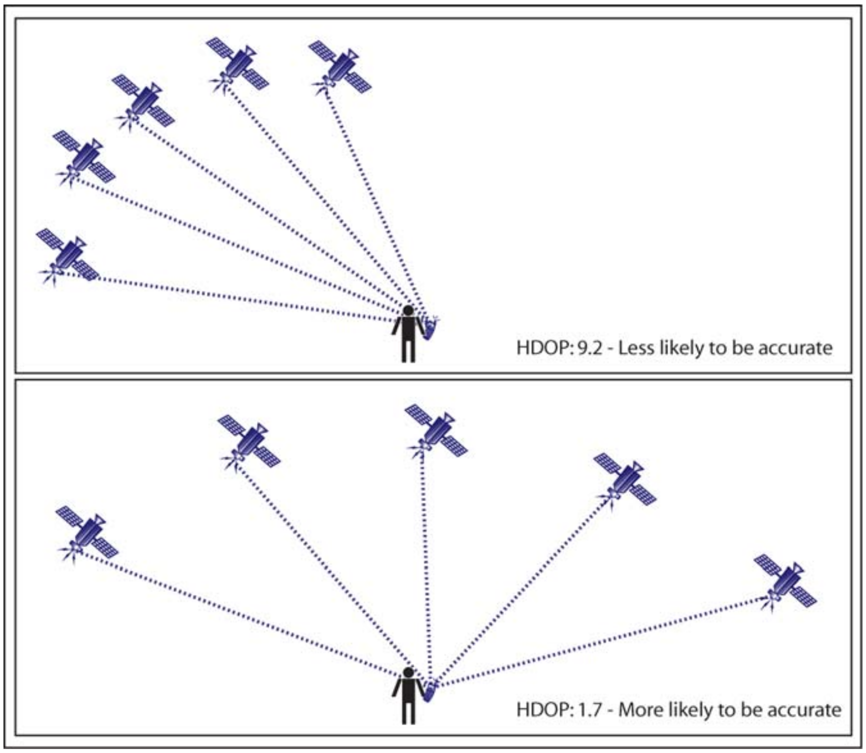
- There are occasions when a GPS signal weakens, becomes undetectable, or degrades before it reaches a GPS receiver. When and why this degradation occurs:

  i. Ionosphere and troposphere delays – As the satellite's signal passes through the atmosphere, it slows down, disrupting the receiver's triangulation calculation (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. This increases the travel time and causes a calculation error (see graphic below).

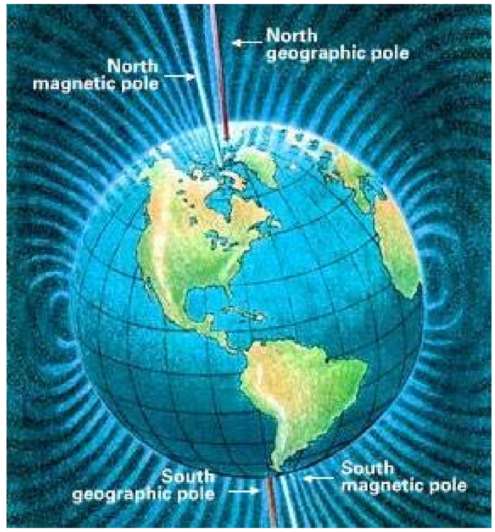


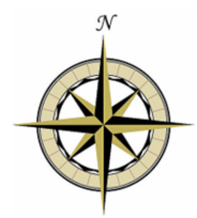
iii. Receiver clock errors occur when the built-in clock is not as accurate as the atomic clock on a GPS satellite, causing slight timing errors.
iv. Orbital errors occur when the reported location of a satellite is inaccurate.
v. Number of satellites visible – The more satellites a GPS receiver has clear access to, the better 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.
vi. Satellite geometry – The spread, or geometry, of satellites available to a receiver can affect the accuracy of a reading. When satellites are closer together in the sky, the reading is likely to be less accurate than one from satellites that are spread out. The goodness of satellite geometry is expressed most commonly as HDOP or PDOP (Horizontal or Positional Dilution of Precision):



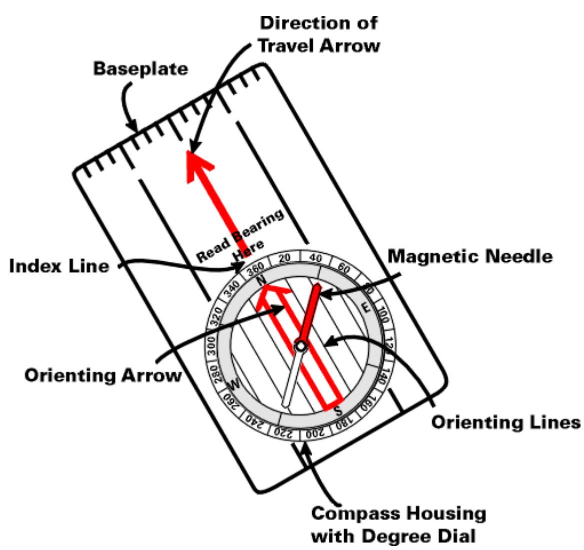
- Knowing what makes a signal go bad or get interrupted can help you get the best signal possible. Here are some other tips:
  i. The receiver needs as clear a view of the sky as possible – since your body can block a signal, hold it out in front of you with your arm extended.
  ii. Many navigational GPS units have a Skyplot option, which lets you see the position and the strength of available satellites. This can help determine if you need to compare the Juno grab coordinates to the navigational GPS coordinates.
  iii. The signal is more likely to introduce error to the grab when you are in an area with large rock formations or rocky substrate. In situations like this, the GPS reading is likely to bounce around as it refreshes. If readings vary more than 20m, 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



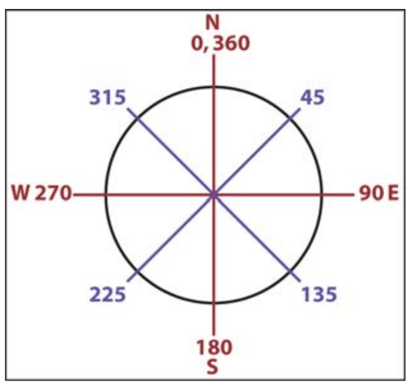


1. **Basic Compass Terminology and Anatomy**
   - **Bearing and Azimuth:** Bearing and azimuth refer to direction in degrees and are determined using your compass. For our purposes, bearing is the direction in degrees you walk along a transect, whereas azimuth is the angle from the line you are walking to a tortoise or carcass. Both range from 0 to 360 degrees.
   - **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.

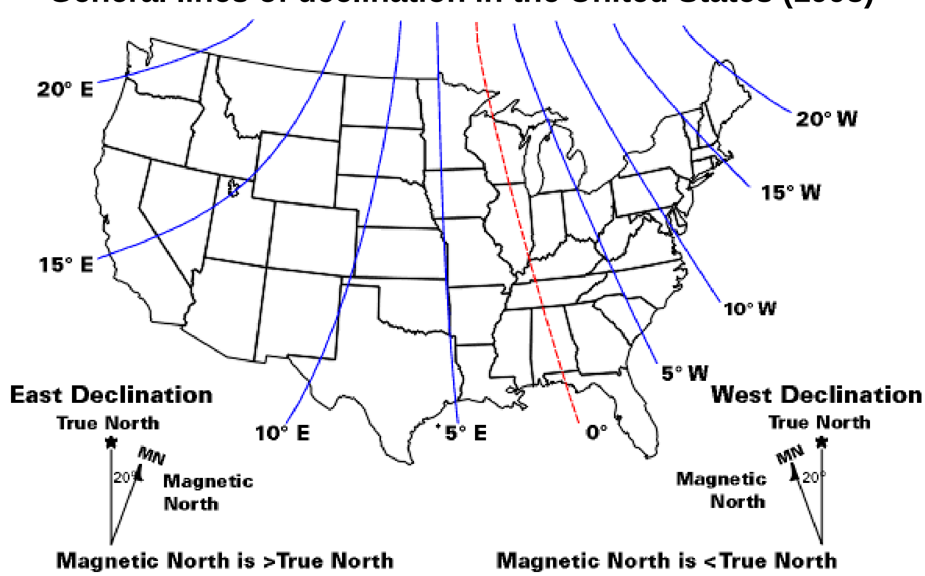
- **Read a Bearing from a Map:** Occasionally you may reflect a transect and travel in a non-cardinal direction. To read the correct bearing from the map, you will orient using the north arrow and base lines on the map.
  i. Settle the baseplate of the compass on the map so that the compass housing straddles 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:

i. Immediately stop walking when you spot a live tortoise or carcass. 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 in the mirror. Meantime, 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 Norths 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 is 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 shifts gradually. 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. Declination depends on where you are:

General lines of declination in the United States (1998)



- **Declination for Tortoise Monitoring:** 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 southwestern US), the declination is positive. In an added twist, the lines of declination shift westward about 0.5 to 1 degrees every year. So 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/geomag-web/. For instance, the declination in Barstow, CA on 10 April 2015 will be 12 degrees and 8 minutes east and in Las Vegas, NV it will be 11 degrees and 55 minutes east. After you adjust your compass to compensate for declination, recheck the setting at least once a week.

- **Example to further clarify declination:** You are starting a transect near Las Vegas and want to travel along a true north bearing (0˚). 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 should adjust your compass for declination. 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 segment will be ~750m off (~250m/km), with the error compounding as the transect gets longer.**