Boy Scouts of America
High Adventure Training
Land Navigation Module

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Navigating With GPS and a MAP

Let's Talk about your GPS Hand Held Tool.
Is a GPS Hand Held the magic bullet? Can it solve all your navigation needs? How do I know if I am calibrated to my map? I am not very good with Latitude and Longitude so will I be able to navigate?

This course is not going to answer the question, what is GPS and how does it work other then to point out the information you need to navigate with and I highly recommend the book "GPS Land Navigation by Michael Ferguson" It is one of the best books regarding this topic.

ALWAYS treat the GPS UNIT as your BACK-UP to a compass and Map, never become dependent on a device that uses batteries or have have the screen crack, it is not a substitute but nearly and enhancement.

Why do I say this, this military controls the resolution or accuracy of the GPS system, and without warning, they can change the resolution which will throw your accuracy out the door no matter how high sensitive your unit is. This is called "Selective Availability" and this how the US keeps others from using our GPS network against us, so why is important, there is never 100% accurate, the military always has a certain amount of offset built in. There are several website that can give you the offset prior to planning your trip.

The Basic Process
Using a GPS receiver with a map in the field involves two skills:

1. Translating GPS position coordinates from the receiver to a physical location on the map.
2. Translating physical locations on the map - (Your destination, a point along the way, some other point of interest) into coordinates that can be used in the GPS receiver.

These questions and so many more run through our heads when we pick up a GPD unit for the first time or even as an experienced user you have thought, hmmm, could I be doing it wrong?

Understanding you GPS unit is first the primary concern, and Garmin is the world leader in hand held GPS devices, thus this course will be using the Garmin eTrex unit, it is pretty straight forward which makes it a good learning tool. All maps in a hand GPS are really just ok because the resolution of the screens make it difficult to be completely accurate. So you ask the question, what about this new 3D 1:24k unit with color and contour shading?, Well it is a very nice you that will enhance your usage and provides a "Big Picture" point of view, but if you fail to setup your GPS prior to your trip, the pretty maps and contours no longer are a help but a hindrance.

So let's look at those GPS units:
Garmin's eTrex

This unit has all the tools needed to properly navigate with a map,

Barometric Pressure
High Sensitivity Receiver

Pre-Loaded Maps
Tracks
Routes
Waypoints

And the most important feature, the ability to configure the setup for the location you are heading into.

Let's take a look at those settings and why they are so important?
It is important that you properly enter certain critical parameters, especially if you use your GPS receiver with an external information such as mapping software or paper maps, compasses, or even coordinate listings. Without proper settings, a GPS receiver cannot give you accurate navigational info.

The MOST important of these "Critical" parameters is the datum associated with the map or coordinate data you are using. Setting the wrong datum can lead to position error in excess of one mile.

Declination
Matching the declination mode setting, or consciously adjust for it between the GPS, your compass, and your map is very important. A failure at this point and I get called out on a Search and Rescue mission. A failure to to match compass and GPS receiver declination can result in heading errors over 20 degrees. Traveling 20 degrees off course will put you 1800 feet over 1/3 of a mile wide of you intended objective that is just 1 mile away, and even with an error of 5 degrees you'd get no closer than 460 feet of the objective, that is enough to put you behind enemy lines when all you wanted to do was talk with Major, but really, that is enough to put you well out to sea it you are aiming at say San Francisco. In the navigation world, that is like aim for the moon and ending up at Neptune. Now you know why people with GPS units report after the search and rescue teams locate them, how they got so far a field.

If you used the wrong declination direction say east instead of west, the error would be twice the amount of the actual declination. A 40 degree direction error means you would miss an objective that is one mile away by 3400 feet also 2/3 of a mile, again not even close.

The **TIME**
The time of day given by the GPS receiver, while very accurate, is stored inside the receiver as ***Universal Time Coordinated***, or UTC. To display the correct local time you must set the offset of the from the UTC. It is easy to do while at home, and it is always the best place because you know the time at your home. This may not seem important but has a large impact on accuracy.

Coordinate System
The Type of coordinate system to be used for example UTM (Universal Transverse Mercator) System or LAT and LONG. An we can't forget about the Datum. In order to use a map with a GPS unit, the Datum setting is critical.

The Unit of Measure
Metric or Standard, is the distance going to ready in meters or miles, and are they going to be statue miles, (the most common for land navigation)

Let's look through our GPS ***units now to determine where and how to change your settings.***

How to Navigate with a Map
You can use your GPS unit to locate your position, you need to know where you are, prior to heading out. There are many ways to plan a trip, and the we will look at some of those.

Planning a ahead, my personal favorite because then I can give my route to my family and if I fail to check in, then they have a means to alert the authorities to route and speeds the rescue by nearly 12 to 18 hours, that is very significant if you are caught in a snow storm with white out conditions, that is why we don't head off thinking we can find our way back, you only make it worst.

You Should:
Have a copy of the map you are planning to use with the GPS unit, and know the your locations and the UTM of those locations and or the LAT/LONG. More about that in a moment. IF using the Garmin Way Point manager or TOPOS Software then you will need to transfer the "Route", and or "Waypoints" to your GPS. The map should be marked and the profile of your trip should be listed in the GPS unit. You should plan to store waypoints for the trailhead for example, campsite, points of interest, or other key locations on the route.

Using Mapping Software, and brief side-bar:
THere are several GPS software packages out there, but the one you want to consider is one that can product a 7.5 minute map, or 1:24k resolution. This is one of the most accurate resolutions to the beginning navigator.   The 2.5 minute has marks on the edge or interior of the the 7.5 minute topo map are very handy and and you should locate them on the map as they provide a high degree of accuracy.

TOPO by National Geographic, this software just like you GPS unit needs to be configured prior to use otherwise you will have bad information being downloaded to your GPS Unit.

Let's Take a look.

Now that you have had a chance to see the software in action, a key consideration when planning your route is to understand or know how too take aback bearing. Just enter the coordinates for the reference point if they are not already stored and and then perform a "GoTo" from your current location. Note the distance and direction and then add or subtract 180 degrees from the direction. The result is the back bearing.

So hey I am out there with my map, now what, always carry a square protractor, know before you leave how to orientate the map. OK now for how to use UTM and you Map.

Why Use UTM Coordinates

The UTM coordinate system offers the following benefits:

A square grid

UTM Provides a constant distance relationship anywhere on the map. In angular coordinate systems like latitude and longitude, the distance covered by a degree of longitude differs as you move towards the poles and only equals the distance covered by a degree of latitude at the equator. Since land navigation is done in a very small part of the world at any one time using large scale maps. The UTM system allows the coordinate numbering system to be tied directly to a distance measuring system.

No negative numbers or East-West designators

Grid values increase from left to right and bottom to top

This is just like the X Y Cartesian coordinate system you learned high school math class. Simple Cartesian coordinate mathematics can be used. No spherical trigonometry is required!

Coordinates are decimal based

Ones, tens, hundreds and so on. No more minutes and seconds to convert.

Coordinates are measured in metric units

All UTM coordinates are measured in meters. Most of the world has already adopted the metric system. Now you won't need to remember how many feet are in a mile. And what's that in yards?

More details about the UTM coordinate system

The Universal Transverse Mercator projection and grid system was adopted by the U.S. Army in 1947 for designating rectangular coordinates on large scale military maps. UTM is currently used by the United States and NATO armed forces. With the advent of inexpensive GPS receivers, many other map users are adopting the UTM grid system for coordinates that are simpler to use than latitude and longitude.

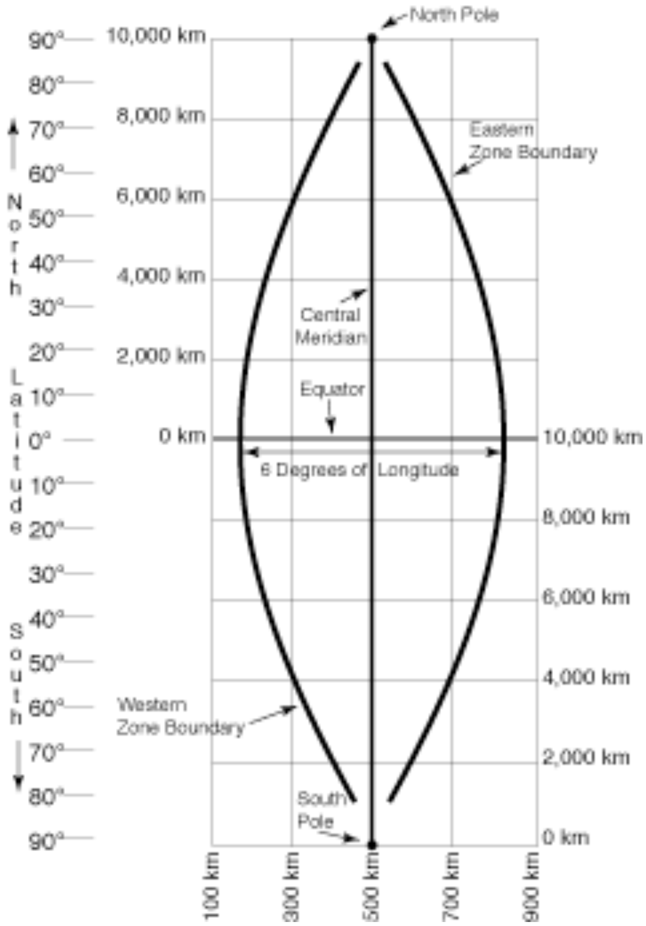
The UTM system divides the earth into 60 zones each 6 degrees of longitude wide. These zones define the reference point for UTM grid coordinates within the zone. UTM zones extend from a latitude of 80° S to 84° N. In the polar regions the Universal Polar Stereographic (UPS) grid system is used.

UTM zones are numbered 1 through 60, starting at the international date line, longitude 180°, and proceeding east. Zone 1 extends from 180° W to 174° W and is centered on 177° W.

Each zone is divided into horizontal bands spanning 8 degrees of latitude. These bands are lettered, south to north, beginning at 80° S with the letter C and ending with the letter X at 84° N. The letters I and O are skipped to avoid confusion with the numbers one and zero. The band lettered X spans 12° of latitude.

A square grid is superimposed on each zone. It's aligned so that vertical grid lines are parallel to the center of the zone, called the central meridian.

UTM grid coordinates are expressed as a distance in meters to the east, referred to as the "easting", and a distance in meters to the north, referred to as the "northing".



Eastings

UTM easting coordinates are referenced to the center line of the zone known as the central meridian. The central meridian is assigned an easting value of 500,000 meters East. Since this 500,000m value is arbitrarily assigned, eastings are sometimes referred to as "false eastings"

An easting of zero will never occur, since a 6° wide zone is never more than 674,000 meters wide.

Minimum and maximum easting values are:

160,000 mE and 834,000 mE at the equator

465,000 mE and 515,000 mE at 84° N

Northings

UTM northing coordinates are measured relative to the equator. For locations north of the equator the equator is assigned the northing value of 0 meters North. To avoid negative numbers, locations south of the equator are made with the equator assigned a value of 10,000,000 meters North.

Some UTM northing values are valid both north and south of the equator. In order to avoid confusion the full coordinate needs to specify if the location is north or south of the equator. Usually this is done by including the letter for the latitude band.

If this is your first exposure to the UTM coordinate system you may find the layout of zones to be confusing. In most land navigation situations the area of interest is much smaller than a zone. The notion of a zone falls away and we are left with a simple rectangular coordinate system to use with our large scale maps.

Frequently, in land navigation, the zone information and the digits representing 1,000,000m, and 100,000m are dropped. The 1m, 10m and 100m digits are used only to the extent of accuracy desired. Note that it's the smaller digits that are dropped in the notation used by the USGS on the edges of their maps. For example 4282000 mN. becomes 82.

Because pilots and sailors navigate over much greater distances they still favor the latitude longitude coordinate system.

UTM Coordinates on USGS Topographic Maps

All USGS topographic maps printed in the last 30 years or so include UTM grid tick marks, in blue, on the margin of the map. For a short time period after 1978 the USGS was printing a fine lined UTM grid on their topographic maps. They have since discontinued this practice.

Since most USGS 1:24,000 scale topographic maps do not have grid lines printed on them, you will need to draw them in by hand.

Start by finding a flat surface to work on. Use a straightedge that is long enough to draw a line across your map. Two to three feet long is a good length.

Line the straightedge up between two corresponding UTM tick marks along the neat line (the edge) of the map. Remember that UTM grid lines are not exactly North-South or East-West anywhere but in the center of a zone. This means that the grid lines will not be parallel to the neat lines.

Using a mechanical pencil or a fine pointed pen draw a line between the two tic marks. If you are using a pen, select one that has waterproof ink. In addition, you will want to use a straightedge that has the edges lifted off of the paper. This will help keep from leaving an ink smudge when you move the straightedge. High quality straightedges will often have a thin piece of cork stuck to the bottom. This helps keep the rule from slipping, and keeps the edge off of the paper. A piece of masking tape centered on the bottom of your straightedge will work also. Occasionally wipe of the edge of the straightedge to avoid any ink build up.

Grinding maps is tedious work. We all wish the USGS would go back to printing the grid on the map. But even then, we would still need to grid our existing maps. As you can see this is not the kind of thing you want to do on the hood of a truck or using a flat rock. Grid your maps before you need them in the field! In a pinch you can fold the map over on itself and use the edge of the paper as a straightedge.

Photocopies of Maps

Frequently, you may use a photocopy of a small portion of a map rather than the entire map. This cuts down the wear and tear on the original map and allows several copies to be distributed among a group.

Make sure you transfer at least the large-print portion of the UTM grid markings onto the photocopy. It's also helpful to provide scale and contour information. Preprinted scale bars on Post-It note paper are available or just make a copy of the scale bars and "cut and paste"

Avoid the temptation to change the scale of the map with the zoom on the copier. If you use maps often you will have a good sense of distance. Alter the scale and it will be harder to judge distances. Plus your overlay tools will no longer be useful.

If you do change the scale using the copier, be sure and copy the scale bars at the same time, so they will correctly reflect the new scale.

If you are marking roads, trails or boundaries on the photocopied map, avoid obscuring the underlying feature with the mark. Pencil lines will usually allow the feature to show through as will highlighter pens.

There is nothing more frustrating than needing to know what is under a big black mark on your copy of the map.

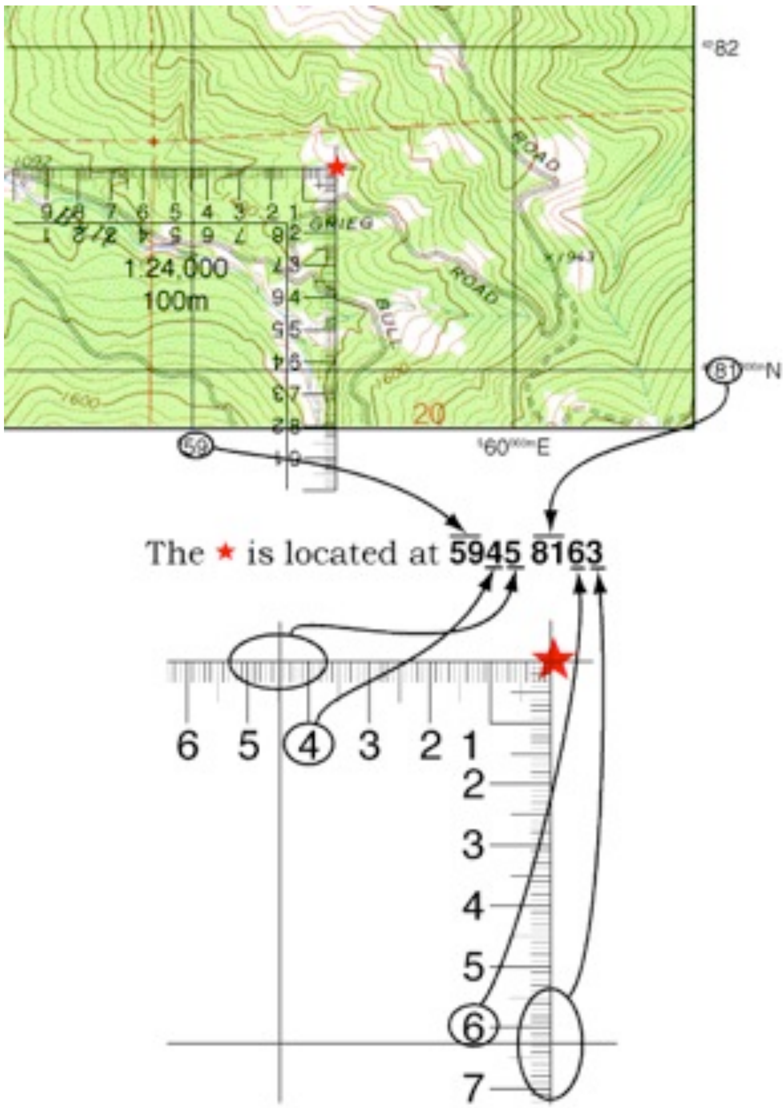
Using a UTM Corner Ruler

A UTM Corner Ruler consists of two scales at right angles to each other. UTM Corner Rulers will typically provide an additional digit of precision beyond a UTM Grid Overlay. On a 1:24,000 scale map you will be able to determine a position to within a 10m square. The trade off is that the Corner Ruler is somewhat harder to use.

Start by placing the top right corner of the Corner Ruler on the SW corner of the UTM grid that contains the feature. The ruler edges should extend to the West and South. To find the UTM coordinates of a feature marked on your map slide the rulers North and East until the corner is on top of the feature to be measured. Read the UTM coordinate values from the starting grid lines. To locate a UTM coordinate on the map slide the ruler North and East until the desired distances are indicated at the grid lines.

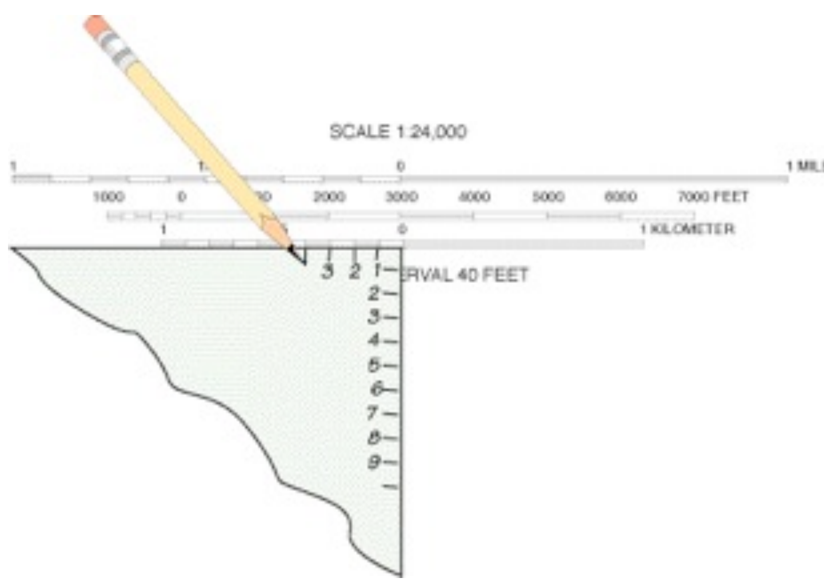
If the grid square you are using is on the edge of your map, you may need to start from a corner other than the southwestern one. You can still use the corner ruler, remember that UTM coordinate values increase from West to East and from South to North.

You should return to the exercise and try it using a 1:24,000 scale UTM Corner Ruler.



If you are using an odd scaled map or if you left your UTM tools behind, you can quickly make a simple corner ruler using the scale bars on the map.

Start with the corner of a scrap of paper. Mark off a one kilometer distance and the 100m subdivisions using the metric scale bar. Repeat this process along the other edge. Number both rules starting from the corner which would be zero.



Map Datums

A datum describes the model that was used to match the location of features on the ground to coordinates and locations on the map. Maps all start with some form of survey. Early maps and surveys were carried out by teams of surveyors on the ground using transits and distance measuring "chains". Surveyors start with a handful of locations in "known" positions and use them to locate other features. These methods did not span continents well. Frequently they also did not cross political borders either. The "known points" and their positions are the information that the map datum is based. As space based surveying came into use, a standardized datum based on the center of the earth was developed.

Every map that shows a geographic coordinate system such as UTM or Latitude and Longitude with any precision will also list the datum used on the map.

The Global Positioning System uses an earth centered datum called the World Geodetic System 1984 or WGS 84. WGS 84 was adopted as a world standard from a datum called the North American Datum of 1983 or NAD 83. For all practical purposes there is no difference between WGS 84 and NAD 83.

Most USGS topographic maps are based on an earlier datum called the North American Datum of 1927 or NAD 27. (Some GPS units subdivide this datum into several datums spread over the continent. In the Continental United States use NAD27 CONUS.)

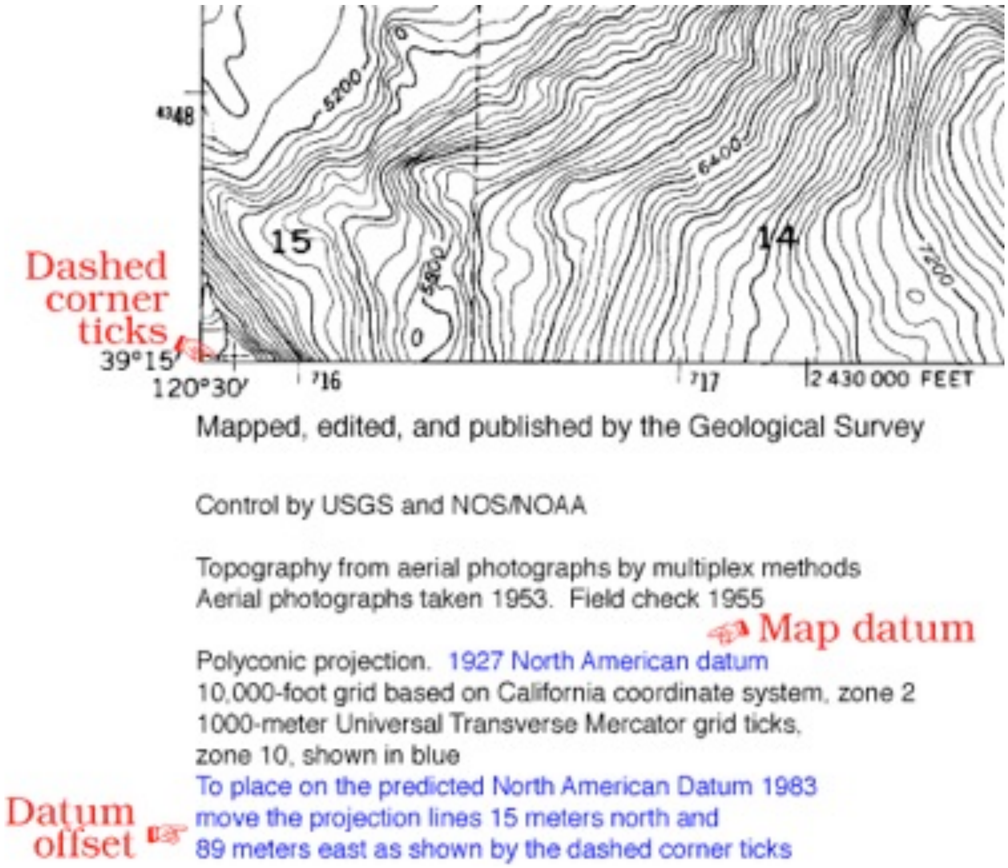
In the Continental United States the difference between WGS 84 and NAD 27 can be as much as 200 meters.

You should always set your GPS unit's datum to match the datum of the map you are using.

On a USGS topographic map the datum information is in the fine print at the bottom left of the map. The datum will always be NAD 27. There may be information on how many meters to shift a position to convert it to NAD 83. Think of this as the error that will be introduced if you leave your GPS unit set to WGS 84. A dashed cross in the SW and NE corners of the map gives a visual indication of the difference between the two datums.

If you have somehow set your GPS to use the Borneo Datum of 1818, it's hard to say how far off you position may be. Let's just sat that this "datum thing" is something you need to pay attention to.

If you are coordinating with aircraft, they will likely have their datum set to WGS 84, as most aviation charts now use WGS 84. Should you worry about the difference in datums? Typically a pilot will not have any difficulty locating you on the ground if you can get them within several hundred meters of your location. If you are engaged in a mission that requires more precision, then your datums



References:
Garmin Using a Garmin GPS
National Geographic Basic Map and GPS Skills.