Unit 1. Geospatial Information and Services

1–1. Evolution of Geospatial Information and Services

THE new phrase Geospatial Information and Services (GI&S) replaces Mapping, Charting, and Geodesy (MC&G). GI&S is much more than having a map or chart at your workstation in order to perform your duties as an operational intelligence technician.

401. Understanding the need for geospatial information

In today's world, all military operations peace and wartime require geospatial information. Geospatial information provides the necessary framework upon which all other relevant strategic and tactical information is layered. GI&S is neither a product nor a system, but rather a concept for the collection, production, archiving, dissemination, and exploitation of information about the Earth's surface. Geospatial information exists in both digital (softcopy) and paper (hardcopy). GI&S allows for the migration to the digital computerized environment that the world has shifted to over the past ten years. The legacy of MC&G products was paper charts that required manual plotting and were a less efficient employment of data. Today, we still operate in a mostly paper environment, but are moving towards the digital realm. In the near future, we will achieve a totally digital environment for GI&S, which results in the increased flexibility and utility of Geospatial information through the creation of a more efficient data transfer and update capability.

As an operations intelligence technician, you must have a firm understanding of GI&S products and their uses within our career-field. Command staff decisions are made from our inputs based on the intelligence we receive. If we are to plot a coordinate off by one number, the mistake can have great consequences. Your job is to understand the characteristics of maps and charts, and the different uses.

402. Identifying different scales and uses of map, chart, and geodesy

A map is a graphic representation of an area of the earth's surface illustrated on a flat surface (plane), at an established scale, including natural and man-made features on the whole or in parts. The graphic's features are positioned as accurately as possible, usually relative to a coordinate system. A chart is a specialized map with aeronautical information such as airfields, restricted airspace, or hazards to flight overprinted on the map sheet. As a general rule, the Air Force uses charts, while ground forces use maps. The terms map and chart are often used as inter-changeable terms, you need to know the difference. Geodesy is the branch of mathematics that deals with the determination of the size of the earth and the positions of points on its surface. Because our career field does not deal in depth with geodesy, we will concentrate primarily on maps and charts.

Scale

A scale is the overall size of features on a map or chart relative to the true size of the feature on the surface of the earth. Scale is usually depicted by a representative fraction or by ratio (1/250,000 and 1:250,000). In either case, the number in the above examples means that one-inch on the chart represents 250,000 inches on the ground. This number for charts used by the Air Force ranges from as high as 1:5,000,000 to as low as 1:5,000. Note the smaller numbers (in the denominator of the fraction) indicate larger amounts of detail on the chart. Scale is referred to in the general terms of large, medium, and small. These terms relate to the level of detail on the map or chart.

Large-scale charts

Large-scale charts are those 1:200,000 and below. Large-scale charts represent a large amount of detail on these charts as the features portrayed are closer to the actual size of features on the Earth and are most commonly used for targeting. An example of a large scale map can be seen in figure 1–1.

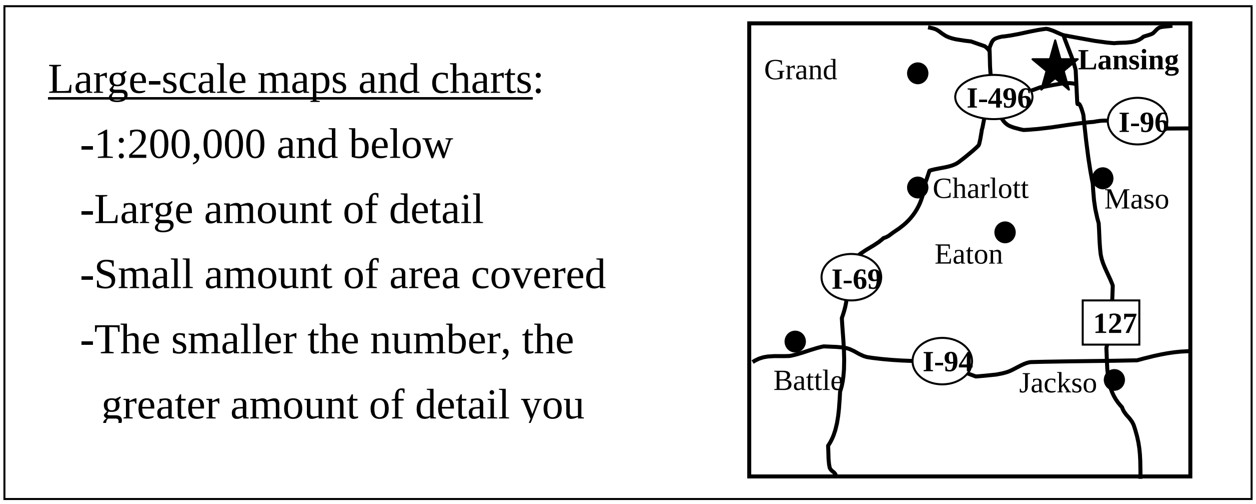


Figure 1–1. Large scale maps and charts.

Medium-scale charts

Medium-scale charts portray small areas of the Earth with a relatively large amount of detail. Medium-scale charts are about the size of a state map or a small country. Charts between 1:200,000 and 1:600,000 are considered medium scale. These types of charts are most commonly used for en-route navigation or for intelligence briefings. An example of a medium scale map can be seen in figure 1–2.

Medium scale maps and charts:

-1:200,000 to 600,000

-Relatively large amount of detail

-Small areas of the Earth covered

-About the same size and amount

Figure 1–2. Medium scale maps and charts.

Small-scale charts

Small-scale charts portray very small amounts of detail and are any chart 1:600,000 and above in scale. The smaller the scale of the map or chart the further the size of the feature portrayed will be from the actual size of the feature on the earth's surface. These charts are most commonly used for long-range navigation. These charts are occasionally used for intelligence briefings. An example of a small scale map can be seen in figure 1–3.

Small scale maps and charts:

-1:600,000 and above

-Small amount of detail

-Large amount of area covered

-Good for taking a look at

Figure 1–3. Small scale maps and charts.

Charts

Charts are broken into several different types. We will now name some of the most common charts with a brief explanation of each.

Global navigational chart (GNC)

GNCs have a scale of 1:5,000,000 (small scale) and are used for in-flight navigation by long range, high altitude, and extremely high-speed aircraft.

Jet navigational chart (JNC)

JNCs have a scale of 1:2,000,000 (small scale) and are designed to satisfy the requirements of long range, high altitude, high-speed aircraft. JNCs are interchangeable with GNCs. The units mission and availability of the charts dictate which chart to use.

Operational navigational chart (ONC)

ONCs have a scale of 1:1,000,000 (small scale). ONCs are used by high-speed; high altitude aircraft for preflight planning and en-route navigation and staff level situation briefings of the overall mission.

Tactical pilotage chart (TPC)

TPCs have a scale of 1:500,000 (medium scale). These charts place an emphasis on ground features and are used for detailed low level preflight planning and mission analysis.

TPCs use an interrelated series number with ONCs; four TPCs provide the same amount of coverage as one ONC only with a greater detail. This can be seen in figure 1–4.

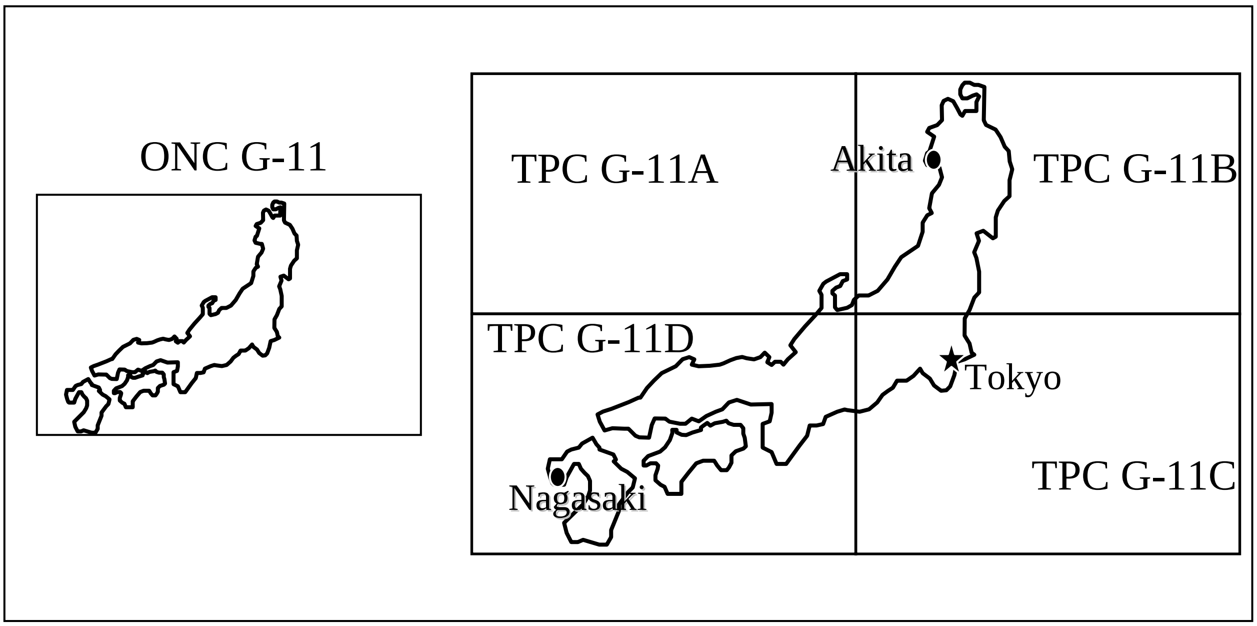


Figure 1–4. ONC/TPC series number relationship for southern Japan.

Joint operations graphics (JOG)

JOGs are also referred to as Series 1501s. They are medium scale charts with a scale of 1:250,000. The basic JOG was designed to provide all military services with a chart for use in the many phases of joint combat operations. The same chart is modified and over-printed in different manners to provide four distinct types of graphics.

JOG-A (Air)

These charts are used for close air support, interdiction and navigation by all aircraft at low and very low altitudes.

JOG-G (Ground)

JOG-Gs are used to meet the needs of the ground forces in joint operations (Army and Marines). The terrain elevation is expressed in meters for ground forces. Since there is no aeronautical information found on a JOG-G, it is a map and not considered a chart.

JOG-C (Combined)

The JOG-C is a mixture of a JOG-A and JOG-G and is used for combined air and ground operations. These charts are being withdrawn from use as stocks are depleted.

JOG-T (Target)

JOG-Ts are used for RADAR navigation and RADAR bombing. These charts depict information that is significant only to RADAR. JOG-T's are classified charts and were referred to in the past as JOG-R's.

403. Identifying and understanding geodetic datums

Geodetic datums

The introduction of long-range ballistic missiles and the increase in accuracy in both strategic and tactical weapon systems have highlighted the traditional cartographic methods of point positioning. Positioning support to strategic systems requires deriving coordinates within a local datum and then tying or relating these coordinates to another datum.

Location only makes sense when compared to some frame of reference. The subject of datums is one of the most misunderstood topics of GI&S. A large number of critical mistakes have been made in the field while using maps and charts due to the lack of understanding about the fundamental theory of datums. Datums are the foundation of how we relate position and data to a reference or coordinate system. A full understanding of datums is required in order to fully know how to manipulate and analyze foundation data. A datum is merely any numeric or geometric quantity that serves as a reference point to measure other quantities or putting it simply, datums are fixed locations or starting points on the Earth's surface that are placed on our charts and used to determine either the vertical or horizontal location of other points by one of two means – physical triangulation or satellite triangulation. There are two types of datums used in mapping: horizontal and vertical.

Vertical datum

Mean sea level (MSL) is the datum, or starting point, used to determine elevations of any land feature on the Earth. There are many discrepancies among vertical datums. In Europe, there are fewer vertical datum problems than in Asia and Africa. Extensive leveling work has been done in Europe and practically all of it has been referred to the same mean sea level surface. However, in Asia and Africa the situation has been different. In some places there is precise leveling information available based on mean sea level, while in other areas, the zero elevation is an assumed elevation, which sometimes has no connection to any sea level surface. China has been an extreme example of this situation where nearly all of the provinces have had an independent zero reference. There is very little reliable, recent, vertical data available for much of the area of Africa and Asia. The mean sea level surface in the United States was determined by averaging high and low tide calculations collected over a 19-year period from 21 tidal stations in this country and five in Canada.

Horizontal datum

By 1940, every technically advanced nation had developed its own geodetic system. To an extent these systems were governed by each country's economic and military requirements. Some systems were developed by the expansion and unification of existing local surveys and others by new nationwide surveys replacing outdated local ones. Normally, neighboring countries did not use the same geodetic datum. There was no economic requirement for common geodetic information and the use of common datums was contrary to the military interests of each country. The only surveys of an international nature based on one datum were the few measurements of long arcs accomplished for determining the size and shape of the Earth. The net result was that there were many different surveys of varying size, which differed from each other remarkably. The national maps based on the surveys also differed widely. As military distance requirements increased, positioning information of local or even national scope became unsatisfactory. The capabilities of the various weapon systems increased until datums of at least continental limits were required. The best solution to be able to meet the increased military distance requirements was the establishment of a “single” datum for a large area and adjusting all local systems to it. The North American, European, and Tokyo Datums were initially selected for this purpose. The four major geodetic datums recognized by the Department of Defense (DoD) will be discussed next.

The North American datum, 1927

This datum is used in the Continental United States (CONUS) and originates at the Meades Ranch, Kansas. The datum is computed on the Clarke 1866 Ellipsoid and incorporates Canada, Mexico, and the West Indies, with a Central and South American connection.

The European datum

The initial point of this system is located at Potsdam, Germany. Numerous national systems have been joined into a large datum based on the international ellipsoid (1924). All of Europe, South Africa, and North Africa are molded into one great system. Through common survey stations, it was also possible to convert data from the Russian-Pulkovo 1932 System to the European Datum. As a result, the European Datum includes geodetic control data as far east as the 84th Meridian. Additional ties across the Middle East have permitted connection of the Indian and European Datums.

The Tokyo datum

The third preferred datum has its origin in Tokyo. It is defined in terms of the Bessel Ellipsoid (1841). Japan, the western Pacific islands, Korea, and most of China are included in this datum.

The Indian datum

The Indian Datum is used for India and several adjacent countries in Southeast Asia. It is computed on the Everest Ellipsoid (1830), with its origin at Kalianpur in Central India. The Indian Datum is probably the least satisfactory as compared to the previously discussed datums, however, of the over 150 total datums around the world, it still rates as one of the four preferred datums. The four preferred datums are illustrated in figure 1–5.

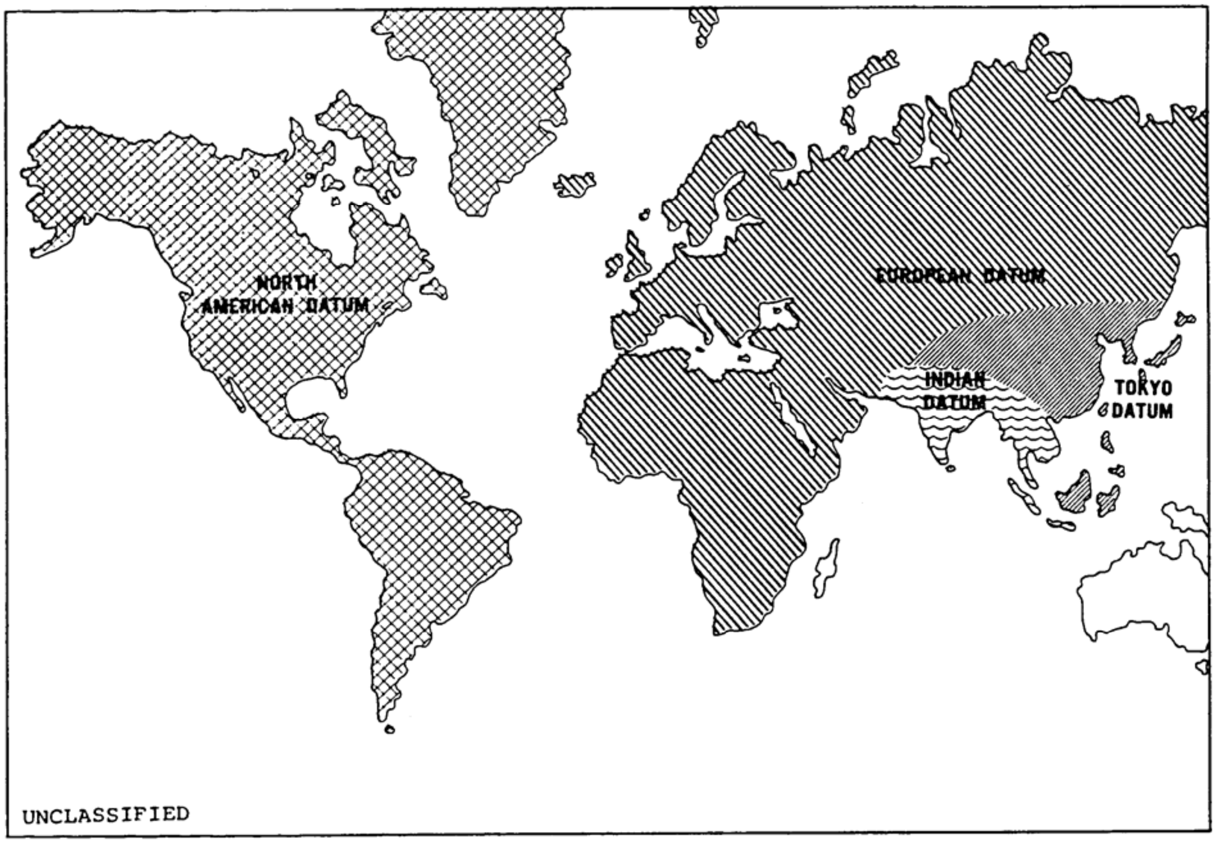


Figure 1–5. Local horizontal datums.

World geodetic system 1984 (WGS–84)

Nearly all of the maps, charts, and coordinate data produced in the DoD today are related to the WGS–84. The WGS–84 utilizes satellite triangulation vs. physical triangulation to create a mathematical model of the size and shape of the Earth. WGS–84 is based on the best-observed data available on a worldwide network of geodetic control points whose positions have been precisely established with respect to the Earth's center of mass. It allows for such variables as irregularities in the shape of the Earth and fluctuation in gravitational pull. The WGS–84 is the fourth iteration of the WGS and is often referred to as the True World Datum. DoD produced maps, charts, and coordinate data not related to WGS 84 are related to one of the four major geodetic datums preferred in the DoD.

Datum transformation

Mapping Datum Transformation software (MADTRAN) is designed to convert map and chart coordinates from local geodetic systems to WGS–84. MADTRAN is part of the mapping, charting, and geodesy utility software package that was developed by the National Geospatial-Intelligence Agency (NGA), formerly known as the National Imagery & Mapping Agency (NIMA).

Accuracy and reliability

Physical triangulation requires surveyors to go out and survey an area in order to build a map or chart. Because of this, there are multiple ways inaccuracies can work their way into our maps and charts. Most of these errors can be attributed to human error.

Classes of errors

The production and presentation of geospatial information involves many steps. Numerous observations, measurements, and display operations are involved. Because of instrumental imperfections and human limitations, errors can occur at almost any point in the production process. These errors fall into three general classes: blunders, systematic errors, and random errors.

Blunder

A gross mistake that is easy to spot and eliminate.

Systematic

A repetitive error caused by equipment, procedures or weather.

Random

Errors of an unknown cause. The size and direction of which cannot be predicted.

Other errors that work their way into our maps and charts are:

Survey

Raw data used on many charts may not be accurate. NGA often must use information provided by a non- U.S. source whose accuracy levels may not match ours. Also, the equipment for surveys may be miscalibrated or the team may be misusing the equipment.

Cartographic

Some errors are made on purpose during drafting. For instance, if a road, railroad, and river run parallel to each other, the drafter may elect to draw them separately so that the user can see them better. Put simply, a 4-lane road is generally considered to be 32 feet wide. On a chart, 32 feet would be thinner than a human hair, so the drafter will be forced to draw the road large enough for the user to see. Similar things are done with cities or other overlapping features.

Other information sources

Not all map production is based 100% on surveys. Often imagery or even other maps are used for information, and affect reliability.

404. Understanding accuracy and reliability levels

Accuracy levels

Although NGA does an excellent job of portraying the earth's surface on a map, it is almost impossible to be completely accurate. No map produced will give exact horizontal and vertical positions. NGA establishes production accuracy requirements for geospatial information products based on several criteria. The primary users of these products inform NGA on the intended use of these products and the level of accuracy required. NGA then produces the products to comply as closely as possible to these requirements. Since we primarily use NGA's aeronautical products, we should be knowledgeable of how they evaluate and publish these accuracy standards. Discussed below are several of the accuracy factors used by NGA.

Vertical accuracy

Vertical accuracy is equal to one-half of the contour interval on the chart, unless otherwise stated. For example, if a charts contour interval is 100 feet and there is an elevation of 1950 feet on the chart, that elevation is accurate within +/- 50 feet. This means that the elevation falls somewhere between 1900 feet and 2000 feet.

Horizontal accuracy

Horizontal Accuracy is also a factor of numerous measurements, and therefore an average value. There are two types of horizontal accuracy: absolute horizontal accuracy and relative horizontal accuracy.

Absolute horizontal accuracy

When the horizontal distance is measured from a datum or a known point, the horizontal accuracy will be absolute. For example, if a chart of Upstate New York was being developed and the starting point for chart production was Watertown, New York, then the locations on the chart for Carthage, New York and Lowville, New York, in relation to the starting point, would be absolute as indicated in figure 1–6.

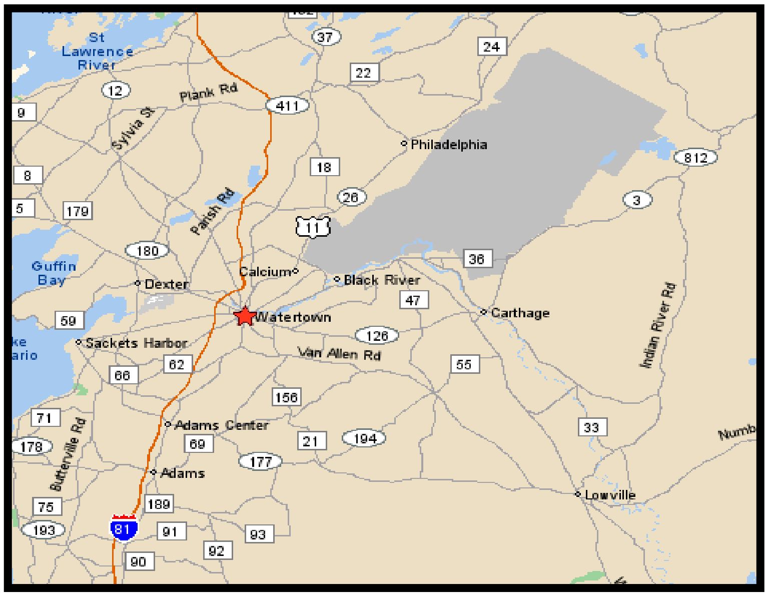


Figure 1–6. Absolute horizontal accuracy.

Relative horizontal accuracy

When features on a chart are compared to each other, but not tied to a datum or a starting point they are relatively accurate. That is to say, the actual location has not been surveyed, but it is in the general location. For example, if Croghan, New York (located northeast of Lowville and southeast of Carthage) were added to the chart using relative horizontal accuracy, it would be added using a general location concept. In other words, it is an educated guess as indicated in figure 1–7.

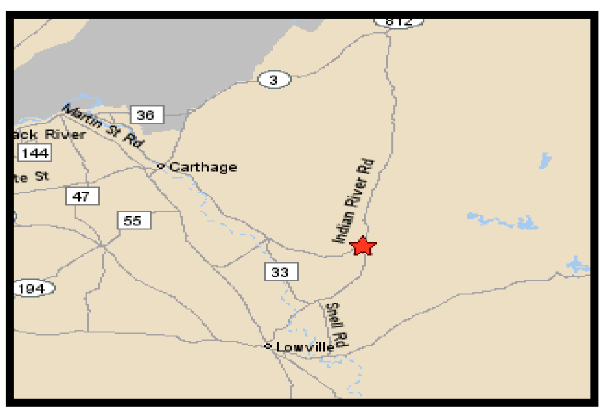


Figure 1–7. Relative horizontal accuracy.

Marginal data and symbology

Now that we have some basic chart information, let's get into reading the charts. NGA has created and made available, standardized symbols and methodology so users can interpret charts with little difficulty. These symbols are in the margins of your charts, commonly referred to as marginal data. In order to effectively use a map or chart you must be able to understand the information that is presented on the body of the map or chart. This is where marginal data comes into play. Marginal data explains most of the symbols used on the map or chart, but not all symbols are in marginal data due to them being common knowledge information. Examples would be campsites, ruins, ghost towns and mines. Marginal Data, on a map, is divided into two basic areas, hydrographic and hypsographic information. On a chart, there are three basic areas, hydrographic, hypsographic and aeronautical information.

Hydrographic information is the study of water and drainage. It is generally represented as either perennial (permanent) or intermittent (present only in rainy season). Hydrographic information can be represented with depth curves, which outline water depth with varying shades of blue. This is normally done only for large bodies of water. Miscellaneous information such as swamps, marshes, rice paddies, etc., are also represented. Overall, a hydrographic feature provides the user with excellent navigational checkpoints and also helps ensure conformability of charts.

Hypsographic information is the study of dry land, specifically dealing with the study of the Earth's natural terrain and the rise and fall of that terrain. Hypsographic information is primarily portrayed on maps and charts by use of elevation tinting, shading and contour lines.

Elevation tinting

Elevation Tinting is a method of showing relief on a map or chart by coloring in different shades those parts of a map or chart, which lie between different elevations. Not exactly accurate, but adds to expressing relief.

Shading

Shading is when a chart is artificially illuminated from the northwest causing shadows on the southeast side of mountains, creating a 3 dimensional effect of the terrain; hill and valley shading are examples.

Contour lines

Contour lines are imaginary lines on the ground, all points of which are at the same elevation above or below a specified surface, usually mean sea level (MSL). Through the use of contour lines, relief (rise and fall of terrain) is represented, aiding the user in determining the overall shape or contour of the land on the chart. Contour lines may be used to interpret the terrain. There are four main types of contour lines (Index, Intermediate, Supplementary, and Depression) but you need to understand contour interval first.

Contour interval is the prescribed difference in elevation between each contour line. For instance, if the contour interval for a chart is listed as 200 feet, then the elevation difference between successive contour lines is 200 feet. Remember these important facts about contour lines. The closer together two adjacent contours are, the steeper the terrain will be. The farther apart two adjacent contours are, the flatter the terrain. Evenly spaced contour lines indicate a uniform slope and unevenly spaced contours indicate a rougher non-uniform slope.

Index contour lines

Index contour lines are the darkest contour line shown every fourth or fifth contour with their assigned elevation values. They are used as indexes or reference point when determining elevation.

Intermediate contour lines

Intermediate contour lines are drawn between index contours. They do not have a value printed on them. Intervals are written in marginal data and normally vary from series to series.

Supplementary contour lines

Supplementary contour lines are drawn to present additional elevation information between intermediate contours to increase the topographic expression of an area, usually used in areas of low relief. Value is half of the contour interval for the chart.

Depressions

Depressions are a closed contour showing an area of lower elevation than the surrounding terrain. Directional ticks extend from the contour in a downhill direction. Normally craters, dry lakebeds, or other low areas would be depressions.

Spot elevations are used when contour lines aren't good enough. A spot elevation is a known location with a known elevation. It consists of a black dot or an "x" with an elevation value next to it. There are three types of spot elevations. They are indicated on maps and charts as shown in figure 1–8.

Critical spot elevations

Critical spot elevations, which represent an area of interest for aerial navigation, use a thick dark number. These are a sharp rise from surrounding elevations and are commonly used to indicate the highest elevation within that portion of the chart.

Normal spot elevations

Normal spot elevations, a significant point with a known location. Shown as a standard size number with a black dot for its location.

Approximate spot elevations

Approximate spot elevations are marked with an "x" with a "+" or "-" sign. It is used when elevations in the depicted area can't be accurately measured such as sand dunes. (Locations of sand dunes change as the wind blows and moves the sand from one place to another.)

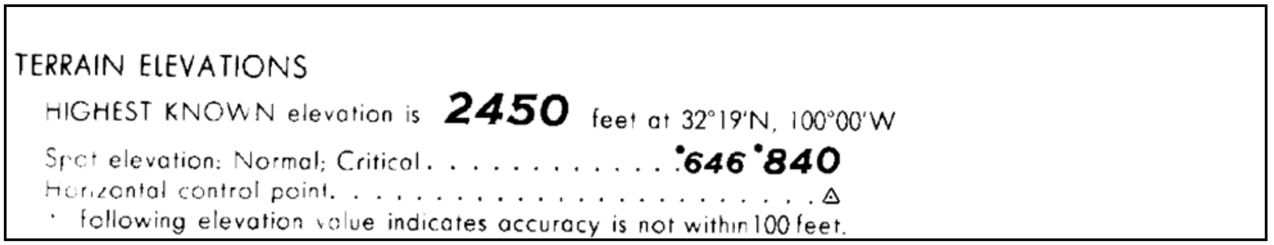


Figure 1–8. Terrain elevations.

Maximum elevation figures

Maximum elevation figures (MEF) are numbers representing the elevation of the highest feature known within a quadrangle. Elevation includes man-made and natural features, and a vertical error for the chart. The values are read as thousands and hundreds of feet (add two zeros). This is theoretically the minimum safe flying height through a given quadrangle. These elevations are indicated on a chart as shown in figure 1–9.

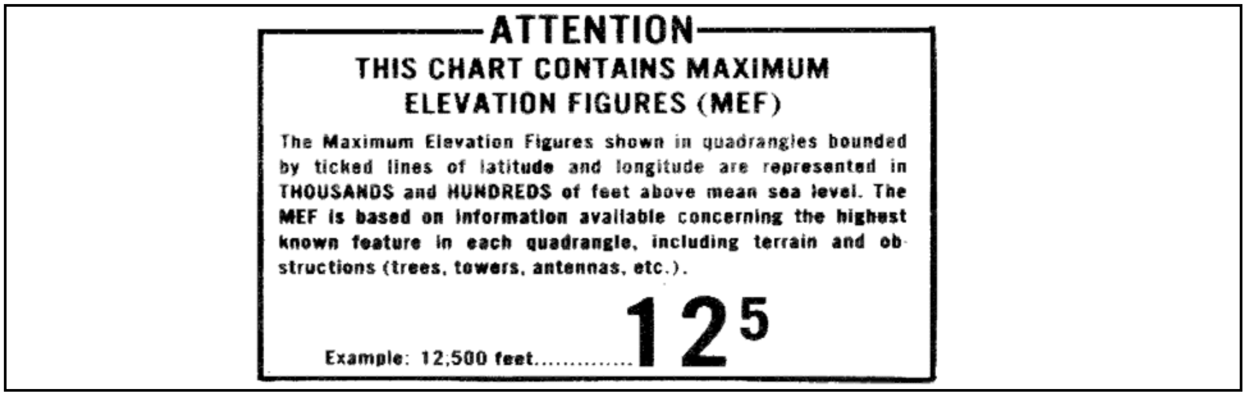


Figure 1–9. Maximum elevation figure.

Other marginal data information

Other types of hypsographic data include man-made features called cultural information (roads, railroads, cities, populated places, landmarks and political boundaries) and other natural features such as vegetation.

Aeronautical information is additional information which is printed on a chart for the specific purpose of showing select terrain, cultural and hydrographic features, and supplemental information required for air navigation, pilotage or for planning air operations. This would include airfields, vertical obstructions, restricted flight zones, and minimum safe altitude warnings.

Airfield Descriptions provide you with the following information on all the airfields found on a given chart. By the way, an Aerodrome is the same thing as an Airfield. Airfields are depicted on charts as shown in figure 1–10.

- Name.
- Length of longest runway to nearest 100 ft.
- Runway surface.
- Number under description is elevation of airfield above mean sea level.

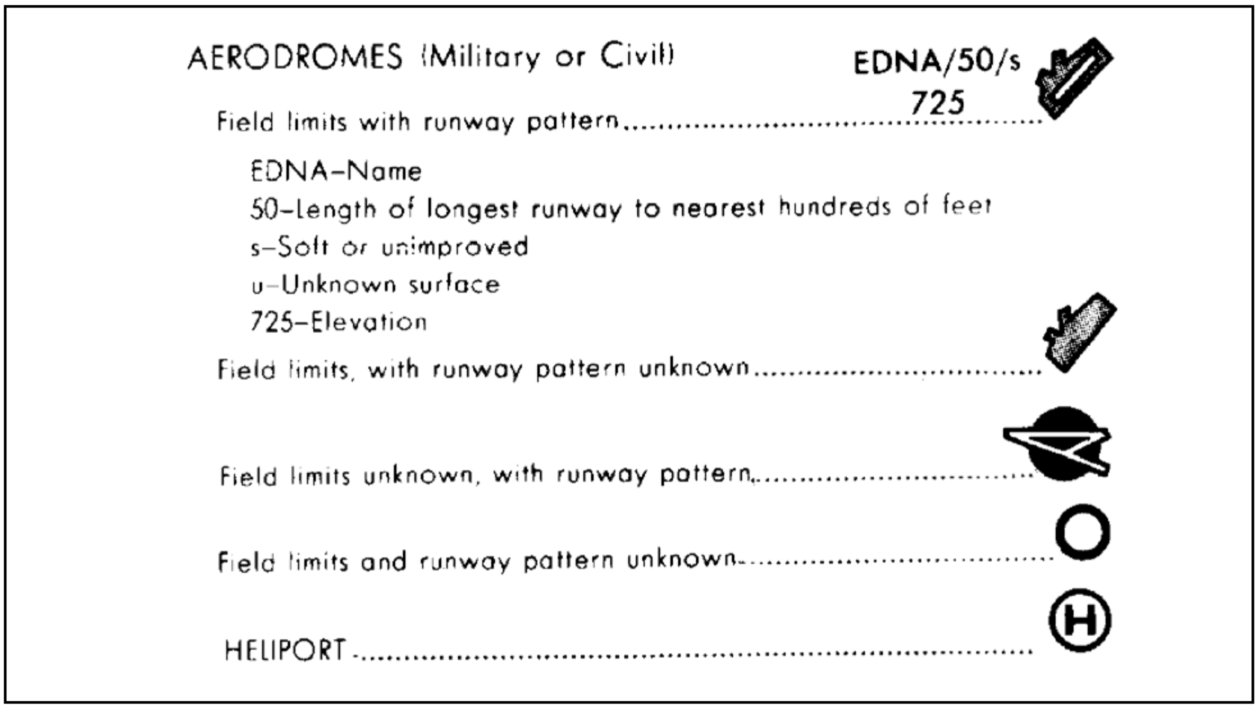


Figure 1–10. Aerodrome/airfield format.

Vertical obstructions annotations are used to warn of possible hazards to flight. They are normally represented by a blue "tower" symbol with an identifier (mast, tower, smokestack, building, etc.) and two numbers representing height. The upper number (not in parentheses) is the elevation of the top of the obstruction above MSL. The lower number (in parentheses) is the elevation of the top of the obstruction above ground level (AGL). To get the elevation of ground level you would subtract the lower number from the upper number.

Obstructions must be 200 ft. tall before they are depicted on a chart. Miscellaneous annotations such as power transmission lines, beacons, navigation aids and lights are also annotated. These features are depicted on charts as shown in figure 1–11.

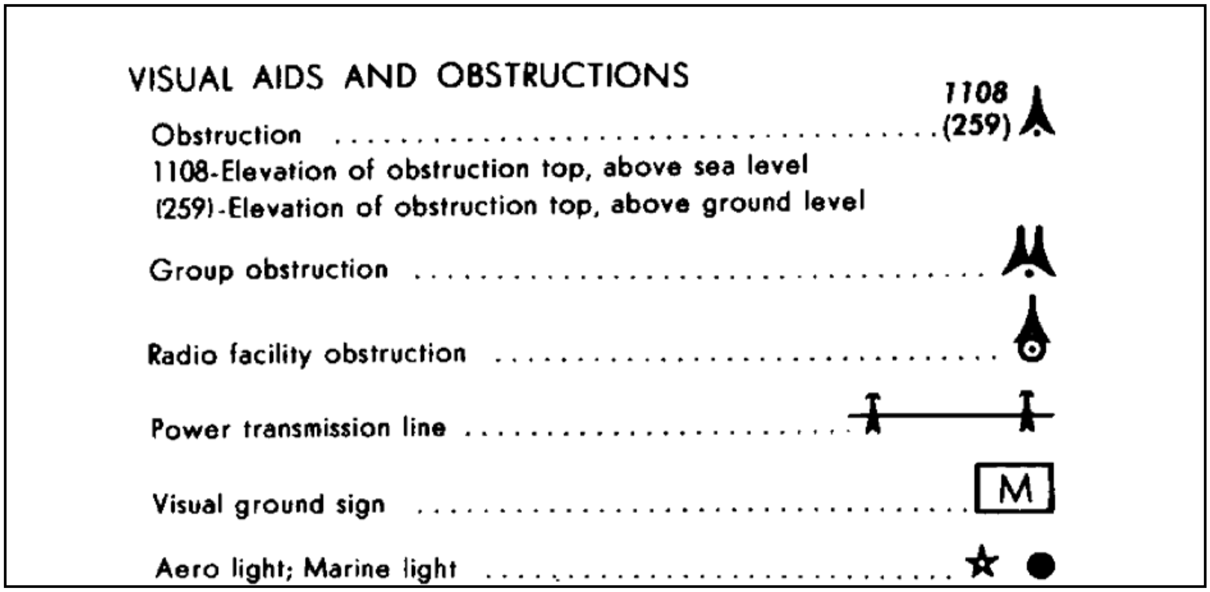


Figure 1–11. Vertical obstructions.

Magnetic lines of variation are one more piece of aeronautical information that we have yet to cover. These are blue, dashed lines that run across the chart. They show the declination of magnetic north from true north within the area covered by the chart. Magnetic lines of variation have the specific declination printed on them, EX: 7° 45’ W.

Target materials

There are three items that we need to discuss under the category of target materials, the JOG-T (Target) and the Series 200 Air Target Chart (ATC) and topographic line maps.

The JOG-T (Target)

The JOG-T (Target) is also a series 1501 JOG chart. This is a medium scale chart used for radar navigation and radar bombing. Depicts only information that is significant to radar. It is a classified chart.

Series 200 Air target chart (ATC)

Series 200 Air Target Chart (ATC), scale is 1:200,000; medium scale chart used for radar navigation and bombing. Depicts information that is significant only to radar just like the JOG-T but provides more detail over a smaller area. This is also a classified chart.

Topographic maps

Topographic maps are the last piece of target material that we need to discuss. Scales for these maps vary, 1:50,000 is the most common scale. These maps are used for in-depth target study; no aeronautical information is overprinted on them. Topographic maps provide a great amount of detail over a concentrated area which makes them ideal for giving aircrew a close up look at a given target area.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

401. Understanding the need for Geospatial Information

1. What provides the necessary framework upon which all other relevant strategic and tactical information is layered?

2. What concept does GI&S provide?

3. What does GI&S allow?

402. Identifying different scales and use of map, charge and geodesy

1. What are two ways to write scale for a chart?

2. Medium scale charts have what scale?

3. What are the four types of JOG's?

4. What is the difference between a chart and a map?

403. Identifying and understanding geodetic datums

1. What is a Datum?

2. What are the two types of datums used in mapping?

3. What are the four major geodetic datums recognized by the DoD?

4. Which datum utilizes satellite triangulation?

5. The software developed by NGA for datum transformation is known as what?

404. Understanding accuracy and reliability levels

1. What are four types of accuracies?

2. What is the purpose of marginal data?

3. Marginal data on a chart is divided into what three areas?

4. What is the purpose of maximum elevation figures?

5. What three products are categorized as target materials?

1–2. Coordinate Systems

There are four main coordinate systems used for geographic coordinates. For the purpose of these CDCs, we will focus on the three types of coordinates that operations intelligence technicians are most likely to deal with; geographic, Military Grid Reference System (MGRS) and the Universal Tranverse Mercator (UTMs). This section will briefly discuss a few of the other systems in order to provide a little more background information.

405. Identifying different coordinate systems

From our previous unit, a datum was defined as an initial point and reference surface. A coordinate system determines how locations are referenced from that datum. Four coordinate systems can be referenced to the same single point on the earth's surface.

Cartesian System

The Cartesian System is the Earth-centric system used by Global Positioning Systems (GPS) satellites and is extremely difficult to conceptualize. It is used in the WGS–84 model and has its origin located at the center of the Earth's mass. The Cartesian coordinate system consists of three number lines perpendicular to each other at their 0's. The horizontal axis is called the x-axis; the vertical axis is called the y-axis, while the axis that passes through the center of the Earth is called the z-axis. This allows us to assign a coordinate to each point in a plane. Each coordinate consists of three sets of numbers, the first of which is the x-coordinate; the second is the y-coordinate, and the third being the z-coordinate written (x, y, z).

Example: X= 1,109,928m Y= –4,860,097m Z= 3,965,162m

The remaining three systems are more widely used in the field.

Geographic Coordinate System or GEOCOORDS

The point of origin for the Geographic Coordinate System is the intersection of the equator and the Prime Meridian as shown in figure 1–12. The equator has a value of 00 degrees latitude and divides the world into northern and southern hemispheres. Meridians of latitude run east and west around the earth, but they measure how far north or south a given point is from the equator. There are a maximum of 90 degrees in each hemisphere. Likewise, the Prime Meridian has a value of 000 degrees and divides the world into eastern and western hemispheres. Meridians of longitude run from the North Pole to the South Pole, but they measure how far east or west a given point is from the Prime Meridian. Meridians of longitude have a maximum value of 180 degrees. This meridian is also known as the International Dateline.

Each degree of latitude and each degree of longitude is composed of 60 equal parts known as minutes and each minute is also divided into 60 equal parts, known as seconds.

For the Air Force and the Navy, geographic coordinates are commonly used. A geographic coordinate for a single point on the earth can be described in three different ways:

- Decimal Degrees (DD): 38° .684N, 077° .150W
- Degrees and Minutes (DM): 38° 41.145N, 077° 08.135W
- Degrees, Minutes, and Seconds (DMS): 38° 41 08.73N, 077° 08 08.37W

Note: The DMS is the most common way that you as an intelligence analyst will use the geographic coordinate system. The tenths and hundredths positions are commonly rounded up or down. The above DMS example would be written as: "384109N0770808W."

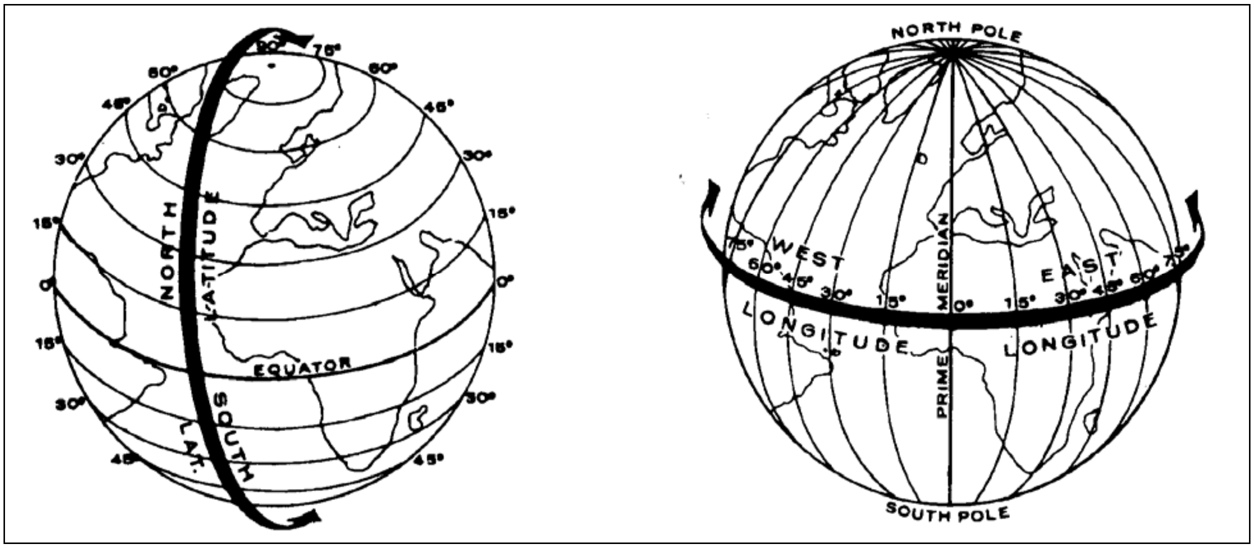


Figure 1–12. Equator and prime meridian.

Universal transverse mercator (UTM)

The Army and the Marine Corps typically use UTM and MGRS. The UTM system breaks the entire world into blocks and is measured in meters. The UTM is the basis for the MGRS system. The UTM grid is a product of great practical importance for the military. UTM applies to worldwide coverage between 80° South and 84° North and is a rectangular grid with parallel lines forming a series of squares on a map or chart. It defines its scale through a grid system measured in meters with its orientation being north. There are 60 zones of 6° longitudinal, which equals 360° coverage of the world in the longitude direction. Each zone is divided in half vertically by a line known as a central meridian, and each zone is divided horizontally in half by the equator. Coordinates in each of the zones are identical, so knowing the zone number is essential for describing specific locations. UTM coordinates are given in three increments as follows:

- The zone number, 1–60.
- The Easting.
- The Northing.

Example: 18 314,251mE 4,284,069mN

Military Grid Reference System (MGRS)

The MGRS system is used on a global basis for tactical-level ground operations. It is based on the UTM system and uses degrees and meters as its unit of measure. The MGRS uses the same 6° east-to-west zones numbered from 1–60 that the UTM grid uses. It then subdivides the UTM grid with 8° north-to-south belts. The MGRS grid runs from 80° S to 84° N and is lettered from C to X going from south to north. The letters I and O are omitted to avoid confusion with the numbers "1" and "0."

Example: 18S

Grid zone designator

Knowing the grid zone and belt in which you are operating gives you an accuracy of a 6° x 8° box somewhere in the world. Each 6-degree by 8 degree block is divided into a 100,000-meter square, which is indicated by a two-letter designation. This two-letter designator is called the square identifier. Figure 1–13 provides an example of the UTM grid system. Adding in the square identifier gets you down to 100,000 meters somewhere on the Earth's surface. You can then further refine your position by adding in coordinate pairs. A 10-digit coordinate offers an accuracy on the Earth's surface of ± 1 meter. A 6-digit coordinate offers an accuracy of ± 100 meters. You can see that more digits mean better precision.

A further breakdown of the above MGRS is as follows:

- 18S = 6 X 8 degree square.
- 18SUH = a 100,000 meter square.
- 18SUH18 = a 10,000 meter square.
- 18SUH1484 = a 1,000 meter square.
- 18SUH142840 = a 100 meter square.
- 18SUH14258406 = a 10 meter square.
- 18SUH1425584065 = a 1 meter square.

For the purposes of these CDCs, you will only be asked to provide MGRS coordinates down to the 1,000-meter square.

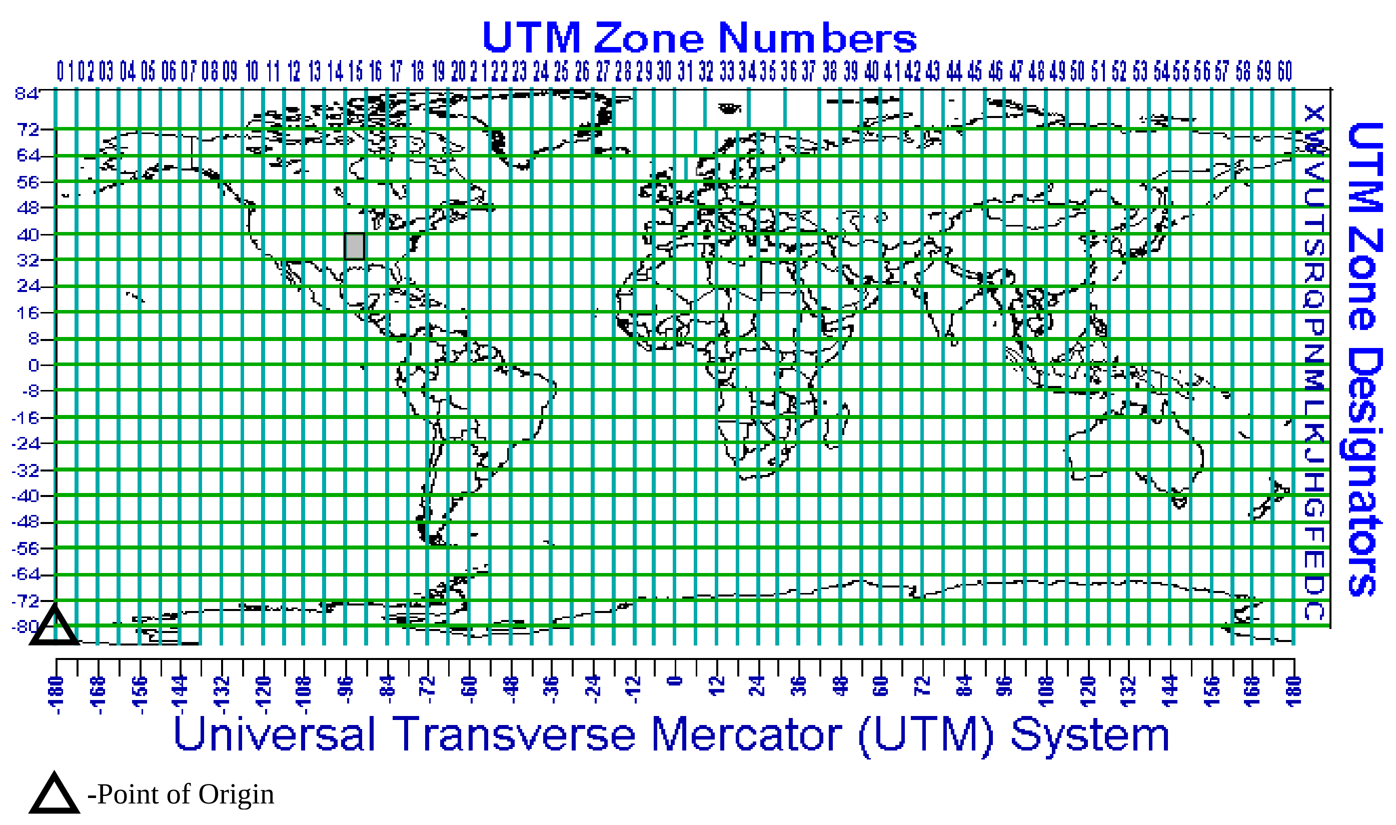


Figure 1–13. UTM grid system.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

405. Identifying different coordinate systems

1. What does a coordinate system determine?

2. Which coordinate system is Earth-centric and used by the Global Positioning System (GPS)?

3. Which coordinate system is widely used by the Air Force and Navy?

4. Which coordinate systems does the Army and Marines typically use?

5. What is the Military Grid Reference System (MGRS) used for?

6. How many meters square would a Military Grid Reference System (MGRS) be broken down to if it were presented as 52SCG25412541?

1–3. Plotting and Extracting Coordinates

As an intelligence operations technician, you will plot many points on a chart. Your plotting duties can include plotting orders of battle, mission planning, and finding locations on charts for situation briefs. You will be challenged with the plotting on the different coordinate systems used by the separate military services. This could include finding distance between coordinate points as well as converting these coordinates from one coordinate system to another. Decisions will be made based on the intelligence you provide to decision makers. Your plotting skills will play a crucial role in this process.

406. Plotting and extracting coordinates

Extracting geographic coordinates

To illustrate the proper way to write geographic coordinates, let's assume that you need to write the coordinates of a target. The target is located 30° 20' north of the equator and 135° 06' east of the prime meridian. Thus, the target is located at 30° 20' north latitude and 135° 06' East longitude. By combining latitude and longitude, you can express the target's geographic location as 30° 20'N 135° 06'E. To write these coordinates in the correct military form, however, you must eliminate the degree (°) and minute (') symbols. Thus, the coordinate should be written as 302000N1350600E (the additional zeros located at the end of the latitude and longitude coordinates represent seconds).

Writing geographic coordinates in the military form is necessary for wire and radio transmission of geographic coordinates. Why? The transmission equipment does not include the degree (°), minute ('), and second (") characters in their keyboards. Also, coordinates are stored in automated data processing computers, which are programmed to handle coordinates in the military characters or spaces. If the sequence of numbers and letters fed into a computer is less than 15 spaces or in error, the resulting printout will be meaningless.

When a position is located less than 10° latitude from the equator, a zero is added to the left of the degree number. For example, 7° of latitude is written as 07. Likewise, two digits are always used to designate minutes, and two digits for seconds. In expressing longitude, three digits are required to indicate degrees, two digits for minutes, and two digits for seconds; thus:

To write geographic coordinates more precisely than minutes, merely carry your coordinates out to include seconds. In this example, the top coordinate is "precise," or capable of accuracy, to plus or minus one-half degree. The middle coordinate is precise to plus or minus one-half minute. The bottom coordinate is precise to one-half second. Figure 1–14 provides an example.

	Latitude	Longitude
Degrees	7º N written 07N.	8º E written 008E.
Minutes	7º 6' N written 0706N.	8º 5' E written 00805E.
Seconds	7º 6' 5" written 070605N.	8º 5' 4" E written 0080504E.

Figure 1–14. Latitude and longitude structure.

Coordinates expressed in decimal minutes (degrees, minutes, and thousandths of minutes) are becoming quite common. To convert seconds to decimal minutes, divide the seconds by 60. To convert back to seconds, multiply the decimal minutes by 60. Other variations are expressions in degrees, minutes, and hundredths of minutes; or degrees, minutes, and tenths of minutes. Figure 1–15 provides an example.

Decimal Min.	Latitude	Longitude
Tenths of minutes	7º 6' 5" N written 0706.1N.	8º 5' 4" E written 00805.1E.
Hundredths of minutes	7º 6' 5" N written 0706.08N.	8º 5' 4" E written 00805.07E.
Thousands of minutes	7º 6' 5" N written 0706.083N	8º 5' 4" E written 00805.057E.

Figure 1–15. Expanded latitude and longitude structure.

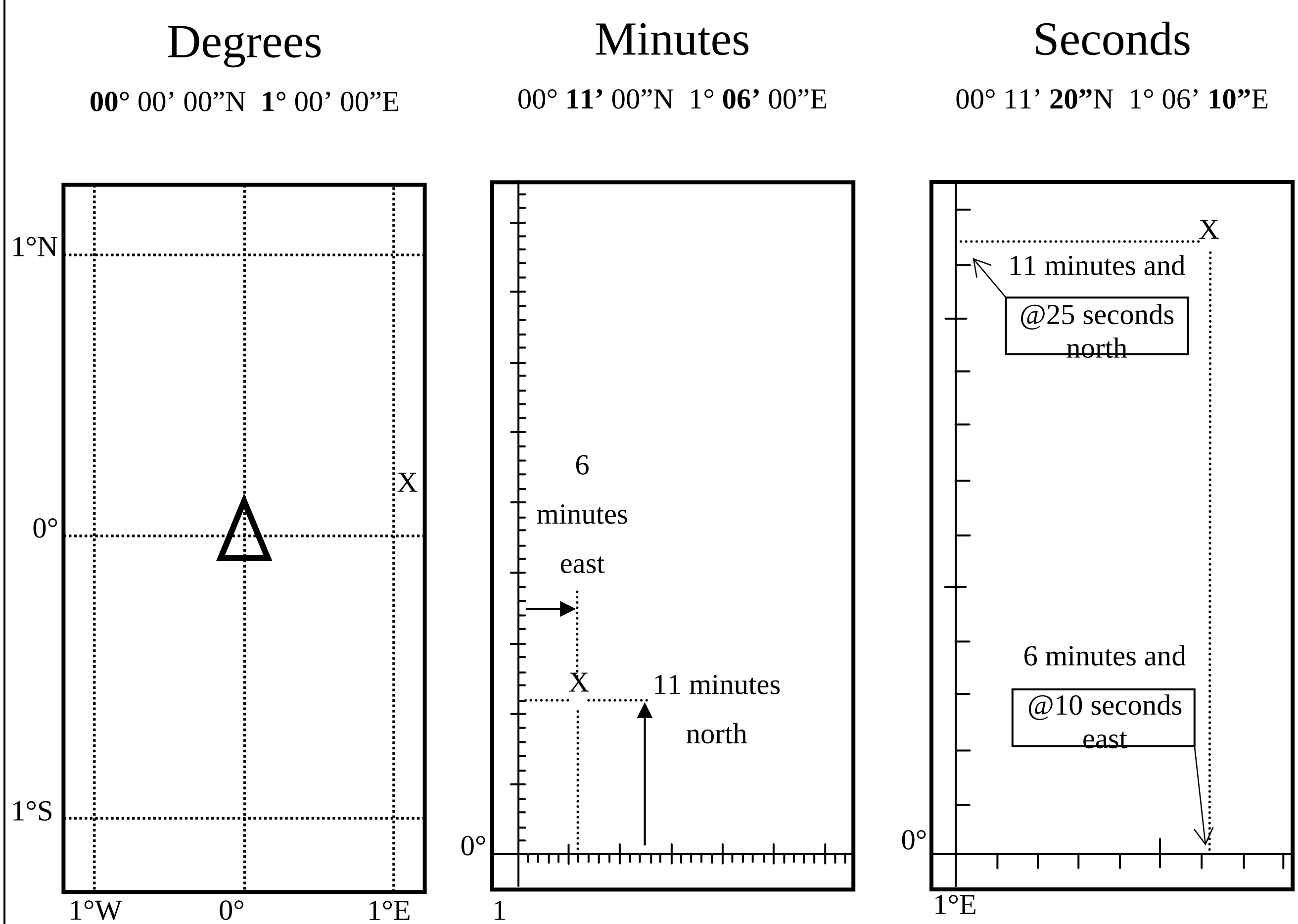
In general, there are five rules to follow in correctly writing geographic coordinates:

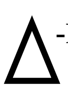
1. Write latitude first, followed by longitude.
2. Use an even number of digits for latitude and an odd number of digits for longitude.
3. Do not use a dash or leave a space between latitude and longitude.
4. Use single uppercase letters to indicate direction from the equator and prime meridian (N, S, E, or W).
5. Omit the symbols for degrees, minutes, and seconds.

Plotting GEOCOORDS.

Follow the general procedures listed below in order to plot a point on the chart. (See figure 2–5.)

- Step l: Locate the parallel of latitude for degrees (38° N).
- Step 2: Find the meridian of longitude for degrees (104° W).
- Step 3: Move to the meridian (usually a tick mark) for minutes (08° W).
- Step 4: Move to the parallel (usually a tick mark) for minutes (28° N).
- Step 5: Plot the point on the map (point A in figure 1–16 plots at 382800N1040800W).





NOTE: When you are measuring seconds, you have to make an educated guess. If 1 minute equals 60 seconds, then 1/2 a minute equals 30 seconds and 1/4 a minute equals 15 seconds. Bottom line, take your best shot, just as long as it is within +/- 20 seconds of the correct answer.

Figure 1–16. Plotting GEOCOORDS.

Plotting Military Grid Reference System (MGRS).

An MGRS coordinate consists of letters and numbers, ex. 15SWN5532. At first, plotting these coordinates may seem difficult, but it really is not. To plot MGRS coordinates, the first step to take is to ensure you are within the proper 6^{o} by 8^{o} rectangle. The first three characters denote this box, ex. 15S. Obviously this is a very large box (360 NM by 480 NM), so we have to break this 6^{o} by 8^{o} box into smaller squares. This box is broken into smaller 100,000-meter squares, the columns are lettered

A – Z and rows are lettered A – V. The next 2 letters in the coordinate denote this box, ex. 15S**WN**. Each 100,000-meter square is further broken into 10,000 meter squares. Rows and Columns in the grid are numbered 0 – 9 both ways. When identifying the specific 10,000 meter square, you must first start in the lower left hand corner of your 100,000 meter square and count to the **RIGHT**, then **UP**. The 10,000-meter square is the smallest breakdown that is printed on a JOG. After the 10,000-meter square, we must use a template to plot the coordinates further. This process is illustrated in figure 1–17.

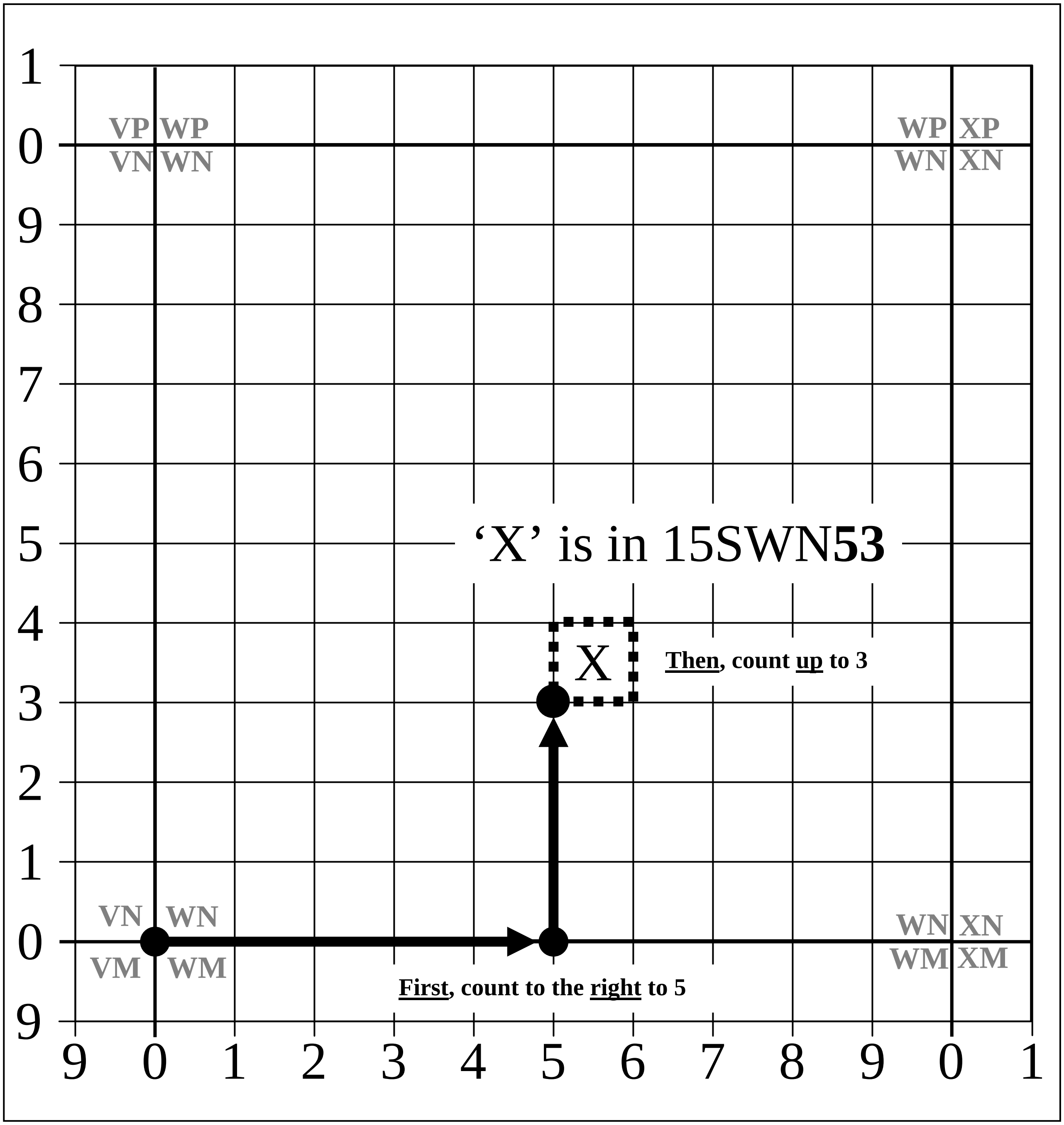


Figure 1–17. UTM 10,000-meter grid squares.

The system continues to be broken down into smaller meter blocks using squares numbered 0–9. This is where your GTA–5–2–12, “Department of the Army Graphic Training Aid, Coordinate Scale and Protractor” comes in. This device is also known as a “UTM plotter” for short. We use this plotter to read in-between the lines on the chart so that we can read the last part of our MGRS coordinate. Figure 1–18 shows a GTA–5–2–12.

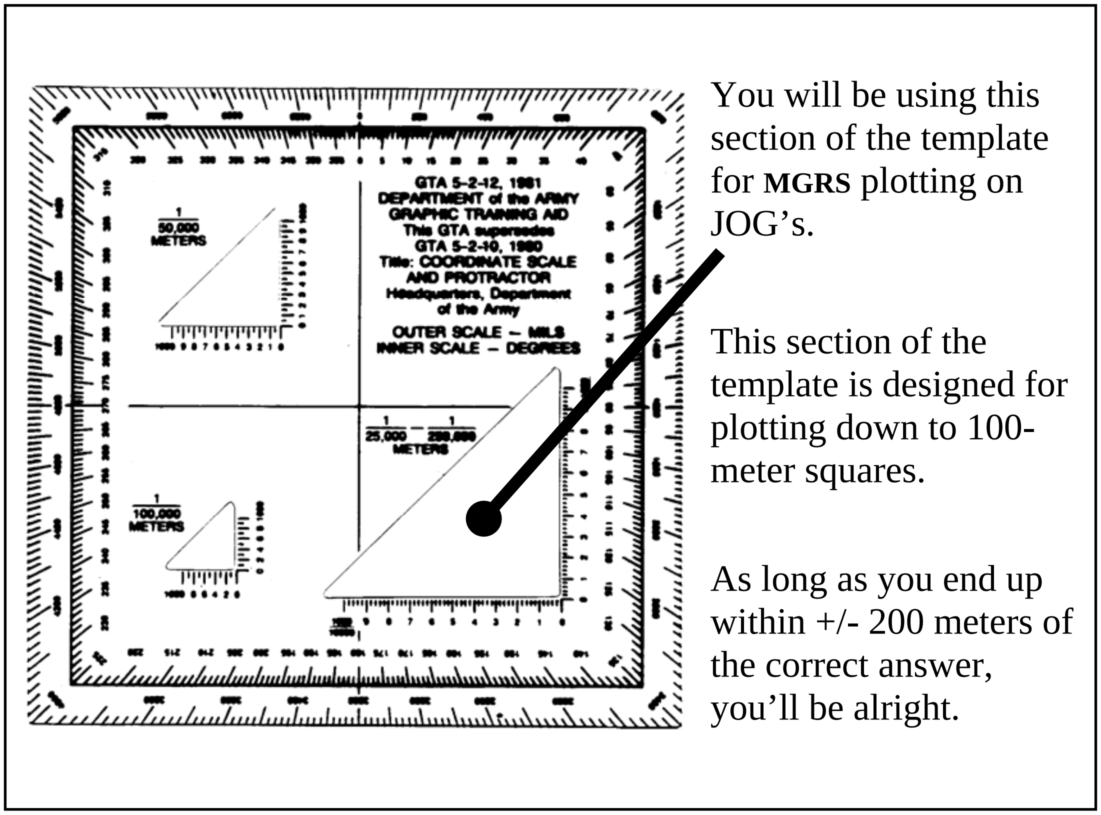


Figure 1–18. UTM plotter.

After identifying your 10,000 meter square use your UTM plotter to read the 1,000 meter and 100 meter squares. Start with the right edge of the grid against the right edge of the 10,000-meter square in which your point is located. Ensure the bottom edge is lined up with the bottom of the map grid. Slowly slide the template to the left until the right edge of the template is over your point. Ensure the bottom edge is still lined up with the bottom of the map grid. Read the bottom of the grid where it crosses the 10,000-meter square left edge (blue line); this is the thousands and hundreds number in your **RIGHT** coordinate. Read the right edge of the grid where the point meets the template. This is the thousands and hundreds number in your **UP** coordinate. A 1,000-meter square would be represented as 15SWN5736. A 100-meter square would be represented as 15SWN571362. A break down to one meter is possible with the right map or chart and template. This procedure is shown in figure 1–19.

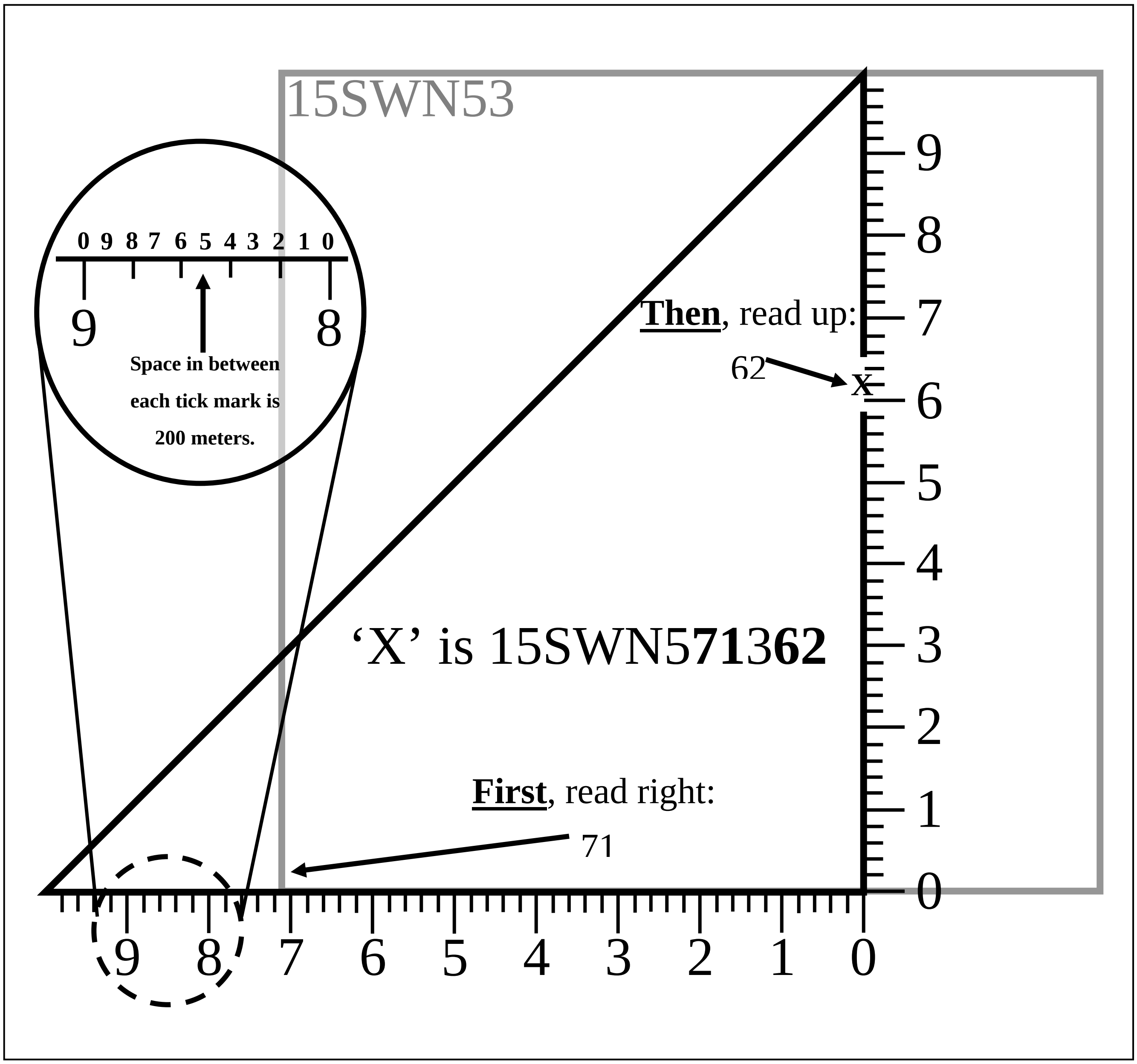


Figure 1–19. UTM 1,000 and 100 meter grid squares.

407. Computing distance and direction

Scale

Scale is expressed as a representative fraction or a ratio. One inch on a chart with a scale of 1:500,000 represents 500,000 inches on the ground.

Some of the standard scales used for aeronautical charts are: 1:250,000; 1:500,000; 1:1,000,000; 1:2,000,000; and 1:5,000,000. You can find the scale of a chart printed in the marginal data. It is indicated by a statement such as, "scale 1:250,000." You can use any convenient unit of measure with a scale expressed as a representative fraction. If, for example, you measure 8 inches on a map that has a scale of 1:500,000, then the mathematical solution for ground distance is:

- Ground distance (GD)= map distance (MD) X map scale reciprocal (MSR).
- (The map scale reciprocal is 500,000:1.
- GD = MD X MSR.
- GD = 8" X 500,000.
- GD = 4,000,000 inches.

There is another commonly used variation of this formula. Assume that you receive information that an enemy headquarters is located 5.4 nautical miles (nm) due south of town "A." You must plot the location of the headquarters on a map with a scale of 1:250,000. How far south of town "A" should the headquarters plot (in feet)?

If: GD = MD X MSR.

Then: MD = GD (solving for MD)

MSR

Substituting: MD = $\frac{5.4 \text{ nm}}{250{,}000}$

(MD answer would be in miles)

So: MD = $\frac{5.4 \text{ X } 6076'}{250{,}000}$ (expressing nautical miles in feet)

Then: MD = 0.131 foot

NOTE: Thus, the headquarters plots 0.131 feet below town "A" on the map (about 1.57 inches). Also note that nautical miles is only expressed as the acronym "nm" when associated with a specific amount of miles.

Distance

Distance on a chart may be found in two ways, using the bar scale on the chart or measuring longitude lines with a 6-inch divider. Bar scales are available at the bottom of the chart and provide conversions for nautical and statute miles as well as kilometers. An example bar scale can be seen in figure 1–20. On smaller scale charts the bar scales are sometimes not accurate enough for our purposes.

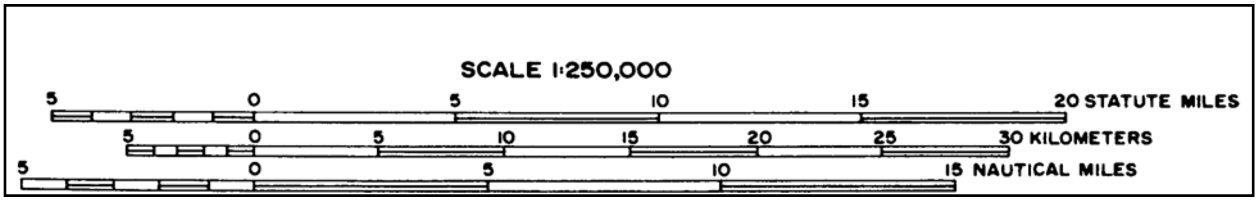


Figure 1–20. Bar scale.

In order to achieve accurate measurements, we use great circles to measure distance. All longitude lines are great circles. This means that they are all equal in length and can be used to measure distances on charts. One degree measured on any great circle is equal to 60 nautical miles. Each degree has 60 minutes, so one minute equals one nautical mile. The steps to measuring distance using the great circle are:

1. Use 6-inch dividers to measure distance between two given points.
2. Place the 6-inch dividers on any line of longitude and count the number of minutes. If the distance is in minutes and seconds, the seconds should be converted to tenths of a nautical mile. EX: 4 and 1/2 minute = 4.5 nautical miles
3. To measure short distances, put one tip of the divider at the start point, and the other tip at the end point. Now measure the distance from a longitude line.
4. To measure longer distances, draw a line between your start point and your end point. Using a longitude line, open the dividers to a convenient distance (10, 15, 30 nm) and “walk” the dividers along the course line. Closing down the dividers and measuring against a longitude line can measure any remaining distance.

Direction

Cardinal point system

The cardinal point system has been used for centuries in marine navigation. It is still used with a high degree of accuracy when direction of travel is not required. This system uses the North and South Poles as direction of reference, together with intermediate, equally spaced directions or “points” as they are called. East is on the side of the rising sun and west is on the side of the setting sun.

Azimuthal system

The azimuthal system is the most commonly used system in air navigation where fairly precise measurements of direction are required. The Azimuthal System is based on a 360-degree circle. In this system “0” and “360” are North,”90” degrees is East, “180” degrees is South, and “270” degrees is West as indicated in figure 1–21. Direction is always expressed in 3 digits to prevent confusion. Hence, 5 degrees is written as 005 and 98 degrees as 098.

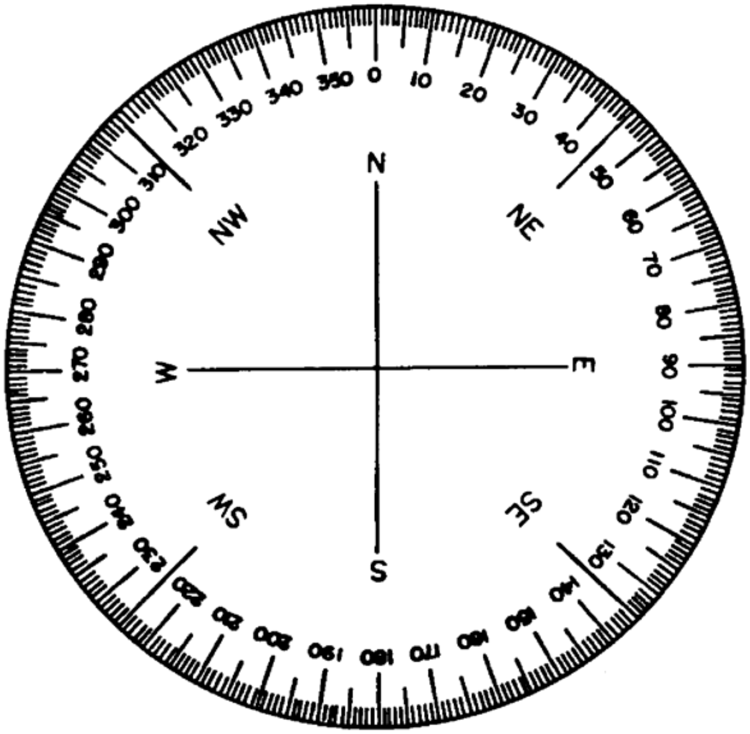


Figure 1–21. Azimuthal system.

There are also some definitions you should learn before going to the map and plotting direction, they are listed as follows:

- True course (TC) - This is the raw course line that is drawn on the chart. It does not take into account the magnetic field of the Earth.
- Magnetic course (MC) - This is the course you would actually fly to reach your destination. It takes into account the magnetic field of the Earth and its effect on compasses.
- Magnetic variation (MV) - This is the number you will apply to the true course to derive the magnetic course. This number will differ with every chart and may add or subtract several degrees to the true course. The number is always a whole degree. Less than 30 minutes is rounded down, and 30 minutes and above will be rounded up to a whole degree.
- Isogonic lines - Lines of magnetic variations that have a positive value. They will affect your compass.
- Agonic lines - Lines of magnetic variations that have a value of zero (no value). They will not affect your compass, sometimes causing confusion to the user.
- Reciprocal heading - The heading you need to fly to get back in the opposite direction. Reciprocal heading is 180 degrees opposite of the measured bearing. Add or subtract 180 to the original heading. Note that the result must be between 0–360 degrees.

Determining true heading

We determine true heading with either the Weems plotter or the GTA 5–2–12 template. Either is effective.

Using the Weems plotter

To measure direction on our aeronautical charts, we use the Weems plotter and the latitude/longitude lines printed on the charts. First, estimate the approximate bearing. You only need to estimate within 90 degrees; it will help in determining if you are reading the plotter the right way. Align your plotter along the drawn course line, and slide it until the hole in the center intersects either longitude line. Follow the route to the outer edge of the plotter and read the bearing from a longitude line using the large outer arc. If your course line goes almost North to South, read the values using the small inner circle. The outer scale of the plotter, reading values from 0 to 180 degrees, is for measuring direction east of a point. The inner scale of the plotter, reading values from 180 to 360 degrees, is for measuring direction west of a point. Finally, use the estimated bearing to check your measurement. If you originally estimated your bearing to be between 90 and 180 degrees and you read 245 degrees from your plotter, you probably will want to try again.

Using the GTA 5–2–12 template (UTM plotter)

Place the center crosshairs of the template so that the vertical line of the template lies along a longitude line. Then, slide the template up/down until the crosshairs, longitude line, and course line all coincide. Lastly, read the azimuth from the inner scale of the grid where the course line crosses the numbers. If the course line is too vertical to use a longitude line, a latitude line will also work, using similar procedures.

Determining magnetic variation

The earth's magnetic field affects compasses used for navigation. The magnetic north pole is located in NE Canada, not at the geometric or grid north on a globe or map. We use lines of magnetic variation to show the angular difference between the compass needle and the true North Pole. These lines of magnetic variation are placed on charts using a dashed purple line. Each line will have an assigned value and a direction of change. For instance, a line labeled 7° W tells us to change our course line 7 degrees to the west.

Lines of magnetic variation are found as both east and west lines. To convert true course to magnetic course, we add or subtract the magnetic variation using a simple formula. True Course +/- Magnetic Variation = Magnetic Course, or TC +/- MV = MC. This is shown in figure 1–22.

In this equation, east variations are subtracted and west variations are added. An easy way to remember this rule is this jingle: east is least and west is best.

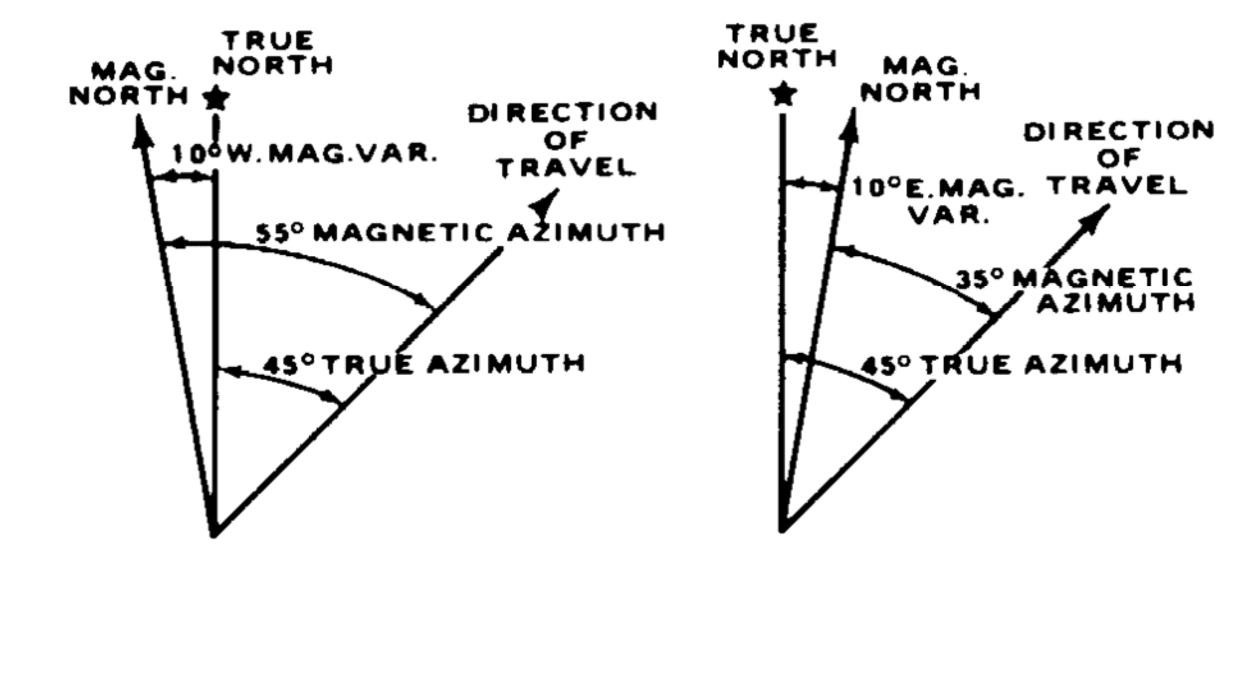


Figure 1–22. Magnetic variation.

So, if our mission was planned to fly between Osan AB, Korea, and Suwon AB, Korea, our true course is 354 degrees. Our magnetic variation is 007 degrees West. So we would add 007 to 354 and get 001 degrees for our Magnetic Course (remember, you can't go over 360 degrees).

There are some rules of thumb that you should apply when computing distance and direction. They are as follows:

- Use the magnetic variation line that is nearest to your destination. If you land between two lines, use the one you were flying toward.
- If you cross two or more lines, you should average them and use the resulting number.
- The magnetic poles are not static, so we have to account for changes over time. The annual rate of change is given in the marginal data of your chart. This is figured into the total magnetic variation before it is applied to the true course.

408. Converting Coordinates

Converting coordinates

There are two methods for converting coordinates, graphic and automated. Graphic conversion is used mainly for converting one or two coordinates at a time. Automated conversion, on the other hand is used for converting large numbers of coordinates in a short period of time. Coordinate conversion comes into play during joint operations. The Army uses UTMs most of the time, whereas we in the Air Force use GEOCCORDS. We need to be able to combine our operations with those of other services, which means we need to understand some of their ways of doing business.

Graphic conversion or "eyeball method"

With this method, you are simply plotting your GEOCOORDS on a map or chart. Then going back and extracting UTM coordinates. There are several drawbacks with this method. First, this can only be done with maps/charts with both geographic and UTM coordinate systems overprinted on them.

These charts only include JOGs and some large scale maps using the Transverse Mercator Projection. Finally, this method is only as accurate as the person doing the plotting.

Automated systems

There are also several automated systems in the field that are able to convert coordinates. The GEOTRANS2 system discussed below is one we often use.

Converting from datum to datum

Maps and charts are made for spatial orientation, which means locating objects in relation to other objects. And precise coordinates are just that, coordinates. If, for example, we had precise coordinates for a group of buildings depicted on a 1:50,000 scale map using the Tokyo datum, we would not be able to plot those coordinates on a chart using the WGS 84 datum and get them to match the position of the buildings. You must first convert the coordinates from the Tokyo datum to the WGS84 datum, and then it should plot out correctly.

Automated systems include a variety of computer programs now available for military use. GEOTRANS2 is a datum transformation and coordinate conversion software utility that was jointly designed and developed by NGA and the US Army's Topographic Engineer Center (TEC). The program is government freeware that operates on PC and UNIX platforms. It can easily transform datums, convert coordinates, and change map projections using a wide variety of known factors published in NGA documents.

Transformations that involve mathematically intensive equations to conduct calculations are made easy with this simple windows based program. The software also contains the Earth Gravitational Model 1996 (EGM 96). This feature allows users to calculate either ellipsoidal heights (geodetic) or Mean Sea Level (orthometric) heights. GEOTRANS2 can ingest coordinates from a text file, convert them, and output the results into a text file for use in any number of ways.

Programmable Calculators can also be used, although they are slower than computers but just as accurate.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

406. Plotting and extracting coordinates

1. What are the five rules to follow in correctly writing geographic coordinates?

2. How are the 100,000-meter squares labeled?

3. What is the smallest MGRS grid printed on a JOG?

407. Computing distance and direction

1. One minute on a longitude line equals how many nautical miles?

2. Degrees are always expressed in how many digits?

3. What is the reciprocal heading for 058?

4. What is the saying for applying magnetic variation?

5. How do you compute your Magnetic Course?

408. Converting coordinates

1. What are the two methods for converting coordinates?

2. Which converting method is simply plotting your GEOCOORDS on a map or chart, then going back and extracting UTM coordinates?

3. Why is it necessary to convert coordinates?

4. What automated coordinate system is a datum transformation and coordinate conversion software utility that was jointly designed and developed by NGA and the US Army's Topographic Engineer Center (TEC)?

Answers to Self-Test Questions

401

1. Geospatial information.
2. The collection, production, archiving, dissemination, and exploitation of information about the Earth's surface.
3. GI&S allows for the migration to the digital computerized environment.

402

1. Representative fraction or ratio.
2. to 600,000.
3. JOG-Air, JOG-Ground, JOG-Combined, JOG-Target.
4. Charts include aeronautical information.

403

1. The foundation of how we relate position and data to a reference or coordinate system.
2. Horizontal and vertical.
3. North American Datum (1927), European Datum, Tokyo Datum, and the Indian Datum.

4. WGS–84.
5. MADTRAN.

404

1. Vertical, horizontal, absolute horizontal, and relative horizontal.
2. Chart symbols are standardized so that users can interpret charts with little difficulty.
3. Hydrographic, Hypsographic, and Aeronautical Information.
4. They represent the elevation of the highest feature within a quadrangle. It is theoretically the minimum safe flying height through a given quadrangle.
5. The JOG-T, series 200 air target chart and topographic maps.

405

1. How locations are referenced from a datum.
2. Cartesian System.
3. Geographic coordinates.
4. UTM and MGRS coordinates.
5. Tactical-level ground operations.
6. 10 meter square.

406

1. (1)Write latitude first, followed by longitude.

   (2) Use an even number of digits for latitude and an odd number of digits for longitude.

   (3) Do not use a dash or leave a space between latitude and longitude.

   (4) Use single uppercase letters to indicate direction from the equator and prime meridian (N, S, E, or W).

   (5) Omit the symbols for degrees, minutes, and seconds.
2. Columns are lettered A – Z and rows are lettered A – V.
3. 10,000-meter square is the smallest breakdown on a JOG.

407

1. One.
2. Three digits.
3. 238 degrees.
4. East is least and west is best.
5. True Course +/- Magnetic Variation = Magnetic Course, or TC +/- MV = MC

408

1. Graphic and automated.
2. Graphic conversion or eyeball method.
3. Army uses UTMs while the Air Force uses GEOCCORDS.
4. GEOTRANS2.