Using the Astro-compass to Study Solar Access

Figure 1: *Astro-compass*

The Astro-compass can be used to trace the paths of astronomical bodies across the sky vault. The sky vault is an imaginary dome around any position on the Earth, with the horizon as the base of the dome and the zenith overhead.

The Astro-compass replicates the physical relationship of the Earth's surface to the sun, and is adjustable for location on Earth (latitude), time of year (Earth's declination), and time of day (hour angle). Looking over the sight plates of the Astro-compass and turning the hour wheel allows you to trace the path of the sun across the sky for a given location and season.

The Astro-compass can also be used as a transit to measure the angular height of all horizon obstructions in order to generate a ***horizon shading mask*** for a site. A shading mask can be overlaid on an ***equidistant sun-path diagram*** to provide a year-round chart of solar access for a specific location.

Setting Up the Astro-compass

This section will teach you how to make all the necessary adjustments to the Astro-compass.

Leveling

1. **Mount the Astro-compass on a tripod and roughly level the device.** Position the Astro-compass as high as possible while still being able to read its bubble levels. Roughly level the tripod by changing the length of its legs. Make sure all adjustments on the tripod are locked; final leveling adjustments will be made on the Astro-compass itself.
2. **Level the Astro-compass using its leveling wheels.** One wheel is provided for each axis in the plane parallel to the ground. Adjust each wheel so that the bubble in the corresponding bubble level is centered between the two lines.

Adjustments for Location

1. **Orient the Astro-compass to true North.**
    - Orient the Astro-compass to true North by turning the cardinal direction (lowest) wheel until "N" points to true North. After making this adjustment, be careful not to shift the body when changing other settings on the Astro-compass.
    - A conventional compass or a street grid can be used to reference the site, using the orientation of North on a map of the area. See the Compass application notes for

information on magnetic deviation and other skewing of compass readings; find the magnetic deviation for a specific location with the magnetic deviation calculator.

- The Astro-compass itself has sufficient iron to pull a compass needle off magnetic North, so place compass away from the Astro-compass for a more accurate reading. If a compass is used to find true North, a plastic clipboard, ruler or other non-magnetic object to aid in aligning the Astro-compass to the compass. The Energy Center has an aluminum tripod extension that can be used to hold the compass at a distance from the Astro-compass.

2. **Adjust the Astro-compass for the latitude of project site.** The sun's rays strike the surface of the Earth at an angle that depends on latitudinal location on the Earth. Latitude for any given location can be found from an atlas, from the Etak Guide website, or by contacting the Energy Center staff. To set the latitude, turn the latitude knob until the right dial shows the tens digit of the latitude and the left dial shows the ones digit. For instance, Monterey's latitude is about 36° N, set as shown in ***Figure 2***. For northern latitudes read the white numbers, for southern latitudes read the red numbers.

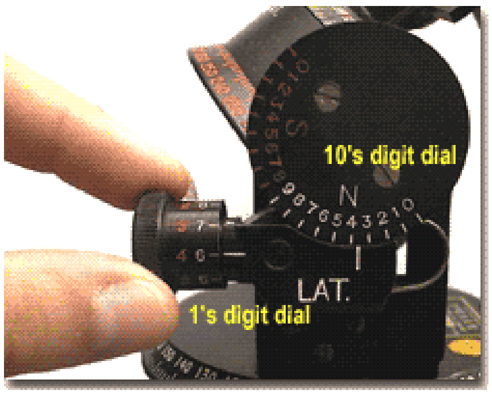

Figure 2: *Latitude setting for 36° N*

Adjustments for Time

1. **Adjust the declination angle for the day or season in question.** The declination is the tilt of the Earth away from or towards the sun; this is the variable that cause seasons. The solstices are the extremes: the declination on June 21st is 23.5° and on December 21st is -23.5°. At the equinoxes (March and September 21st), the declination is 0°.

   The declination can be changed by moving the sight plate until the white arrow lines up to the correct position. In ***Figure 3***, the declination is set to -12°, which corresponds approximately to February or October 21st. The declinations for specific times of year are listed in ***Figure 5***. On the Astro-compass, declination angles to the side marked "S" (in white) are negative angles; to the "N" (in white) are the positive declinations.

   The convention on the Astro-compass is white numbers and letters reference the Northern Hemisphere, while red numbers and letters reference the Southern Hemisphere. (This protocol outlines use in the Northern Hemisphere, but can easily be adjusted for the South.)

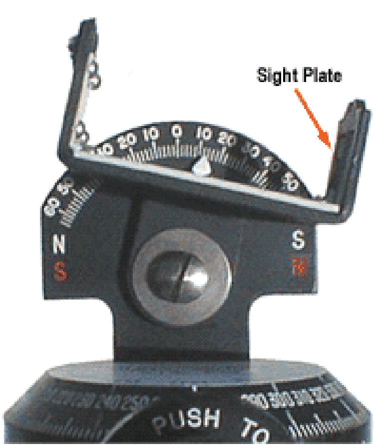

Figure 3: *Declination setting for February or October 21st*

2. **Adjust the hour angle to locate the sun at a specific time of day.** The Earth rotates 15° longitude every hour, so every degree is 4 minutes of time. The Astro-compass hour

wheel uses 2° divisions, equivalent to 8 minutes of time. Some of the hours are marked on the dial but, the Astro-compass can be adjusted for any time of day.

To adjust the hour angle, use the dial labeled "Push to turn". The angle that is aligned with the white line labeled "TRUE BEAR'G" corresponds to the time for which the Astro-compass is set. At 0° the hour is set for midnight, at 120° the hour is set for 8am (8 hours x 15°/hour = 120°). For example, as in ***Figure 4***, at 6:00 p.m. the white line labeled "True Bear'g" should line up with 270° (18 hours x 15° /hour = 270°). The following section will discuss the solar time from this wheel while moving the Astro-compass across the sun's path (see Tracing of Sun Paths below).

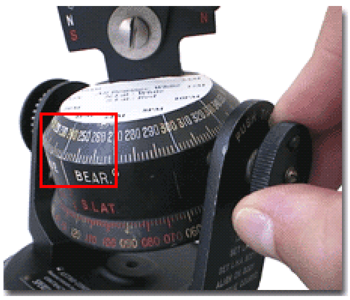

Figure 4: *Hour setting for 6pm.*

Since it is the sun's path that is being measured, solar time must be used. It varies from clock time by a few minutes through half the year, and approximately an hour earlier when daylight savings time is in effect. However, the amount of solar exposure for a given day at a location does not vary between solar and clock time. For more details, see 'Converting to Solar Time' below.

Calibrating the Astro-compass

If direct sun is available when setting up the Astro-compass, the time of day, time of year and latitude can be checked to ensure the instrument is properly calibrated. Declination of the earth towards or away from the sun for this time of year will be needed to perform this calibration (see ***Figure 5***). The solar time equivalent for the clock time will be needed when the reading is taken. For this, latitude and longitude of the site will be necessary.

Date	Declination Angle
December 21 (winter solstice)	-23.5°
January 21 / November 21	-20°
February 7 / November 1	-15°
February 21 / October 21	-12°
March 14 / October 1	-5°
March 21 / September 21 (equinox)	0°
April 1 / September 14	5°
April 21 / August 21	13°
May 1 / August 14	15°
May 21 / July 21	20°
June 21 (summer solstice)	23.5°

Figure 5: *Declination Angles*

1. **Set the adjustments on the Astro-compass.** To convert solar time to clock time, find today's value on the equation of time (***Figure 5***), find the standard meridian for project time zone (***Figure 6***), and use the following formula:

   Solar time (minutes) = local (clock) time + value from the equation of time + [4 x (standard time zone meridian - local longitude)] - 60 (if Daylight Savings is in effect)

   (Where Daylight Savings is in effect in the U.S., it adds an hour from 2am the first Sunday in April until 2am the last Sunday in October.)

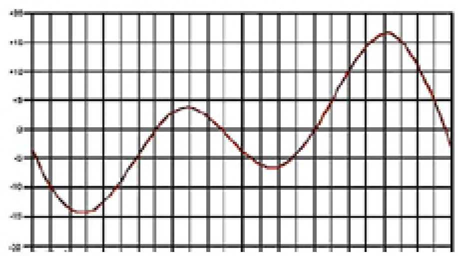

Figure 5: *Equation of Time graph*

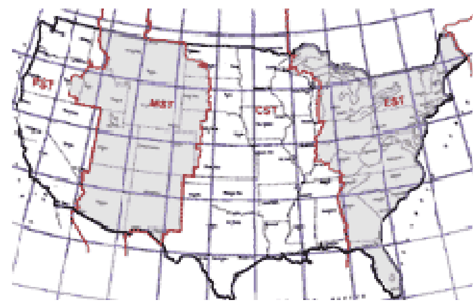

Figure 6: *Standard Time Zone Meridians for continental U.S.*

2. **Use the shadow on the sight plates to confirm Astro-compass set-up.** Rather than sight as one normally would, towards the sky, let the shadow that the sun casts off of the forward plate onto the rear plate to ensure the Astro-compass is accurately calibrated. **Do not look directly at the sun!**

Figure 7: *Shadow alignment on the rear plate when the Astro-compass is correctly calibrated*

The shadow should align with the white casting surface on the inside of the rear plate as shown in ***Figure 7***. It's not too problematic if the shadow does not exactly line up. Some approximated factors may cause the inaccuracy: latitude, declination for the time of year, true North. Adjust these settings until the shadow does line up exactly to the sun. But first check the solar time calculation and ensure the instrument is still level.

Tracing Sun Paths / Site Solar Access

The Astro-compass can track the path of the sun over a specific point on a given site in the field to create a site solar access. This enables one to visualize the sun at different times of year for the point of evaluation. Since the sun's position is dependent on a specific location on the Earth, the solar access evaluated in this exercise is specific to a particular latitude. In addition, the surrounding context affects the amount of sun a particular spot gets. Several readings are recommended if the solar access conditions (topography, trees and adjacent buildings) vary considerably across the site.

The best way to get a sense of the solar access throughout the year is to do a series of sweeps tracing the sun's path for winter, equinox and summer. To do this, set the Astro-compass to a particular day of the year and then look over the sight as the hour dial is moved through the course of a day.

The first section of this document explained the details of making adjustments to the Astro-compass. Click on the "details" links below to review the adjustment procedures.

1. **Level the Astro-compass and orient it to true north.**
2. **Adjust the Astro-compass to the latitude of the site.**
3. **Adjust the declination for the season in question.** For winter solstice, adjust the declination to -23.5°, for the equinox to 0°, for the summer solstice to +23.5°. See ***Figure 5*** for specific declination angles.
4. **Adjust the hour wheel to the approximate time of sunrise.** For instance, if sunrise is at five a.m. (solar time), set the hour wheel to 75°. Sunrise occurs when the sight points to the eastern horizon.

- Find object using the view finder.
- With one eye, sight through the glass of the rear plate and over the projected intersection of the cross hairs inscribed on the forward plate (see ***Figure 8***). Leave the other eye open to see distant objects.

The lens of the rear plate focuses one's eye on the cross hairs so this split view does not cause eye strain. In this example, one is sighting on the location that the sun would be on that day of the year. Be careful not to look directly at the sun when its actual location corresponds to the projected location.

Fig. 8: *Astrocompass sighting mechanism*

5. **Move the hour wheel through the day, using the dial labeled "Push to turn".** This process tracks the sun's path across the sky. As one sweeps through the day, notice the angle of the sun; this will provide a sense of how deeply the sun's rays would penetrate into a

window or under an overhang. Make note of when the sun is obscured by nearby buildings or trees. Note how many hours of unobstructed sun the site receives at that time of year. The hour wheel reading will provide the exact solar time when the sun goes behind obstructions.

6. **Repeat steps 3-5 for other seasons.**

Recording a Shading Mask -- Astro-compass as a Transit

The last application described here is using the Astro-compass as a transit to develop a horizon survey of a chosen location. The Astro-compass can be set up to measure angular height of buildings or trees around the site. These can be plotted on an equidistant sun-path diagram to provide a comprehensive record of solar access for the site year-round. Contact the Energy Center staff for a copy of the sun-path diagram if it is not included in the loan.

1. **Level the Astro-compass and align the body to true North.**
2. **For use as a transit, set the latitude to 90°.** At a 0° declination angle, the sight line will now be parallel to the ground. The declination adjustment will be used to measure angular height, or altitude, from the horizon to the edge of sky obstructions. Altitude angles range from 0° to 90°.
3. **Rotate the hour wheel so that the sight points North (0° should line up with "True Bear'g").** The hour wheel will be used to measure degrees in the circle around the point at which one is standing. These degrees are in the plane parallel to the ground and are called azimuth angles. These angles range from 0° to 360°; the sight points East at 90°, South at 180°, and West at 270°. Obstructions can be plotted on a sun-path diagram with a combination of the azimuth angle and altitude angle. You will measure the edges of obstructions every 10° of horizon rotation (azimuth).
4. **At azimuth 0°, sight with the Astro-compass to the top of any horizon obstruction.** Tilt the altitude setting until the sight is at the edge between the sky and the object that would create shade on the site, as shown in ***Figure 10***. Note the coordinates: 0° azimuth, x° altitude. (If there is no obstruction to the horizon, the coordinates will be 0° azimuth, 0° altitude.) Plot the coordinates on a sun-path diagram for your latitude.

Figure 10: *Sighting altitude, or angular height, with the Astro-compass*

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5. **Move the hour wheel 10° to the West.** Take an altitude measurement here. Record and plot the coordinates: 10° azimuth, y° altitude. Repeat for every 10° increment of azimuth. In addition to plotting coordinates for obstructions every 10° azimuth, it is also useful to plot their corners or other significant points along their edges. Continue to advance all the way around back to true North.

   Note that if objects are sighted with altitude angles greater than 64°, it will be off the scale provided on the Astro-compass. Either use a clinometer to measure these altitudes or estimate (see Clinometer application notes). For objects of known height and a measurable distance away, you can also calculate the angle trigonometrically: altitude angle = arctan (height/distance). (In this way, the transit can also provide you with the heights of trees and other objects of a known distance away.)

6. **Connect the points you have plotted on your sun-path diagram to create an outline of the areas of the sky shaded by obstructions, as shown in *Figure 11*.**

   Since the sun-path diagram is a flattened projection of the dome of the sky, the outlines of objects will be greatly distorted. Distinguish objects that filter the sun, such as trees, from objects that completely block it. A horizon shading mask has been made: an overlay for the sun-path diagram that masks portions of the sky with locally produced shade. Sun/shade conditions can be read for this site from this diagram for any time of the year.

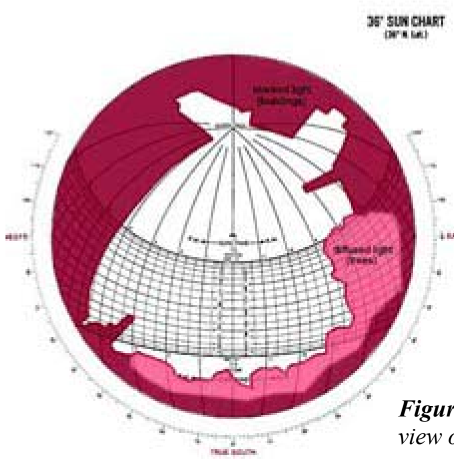

Figure 11: *Shading mask: hemispheric plan view of horizon shading on the site overlaid onto a sun path diagram*