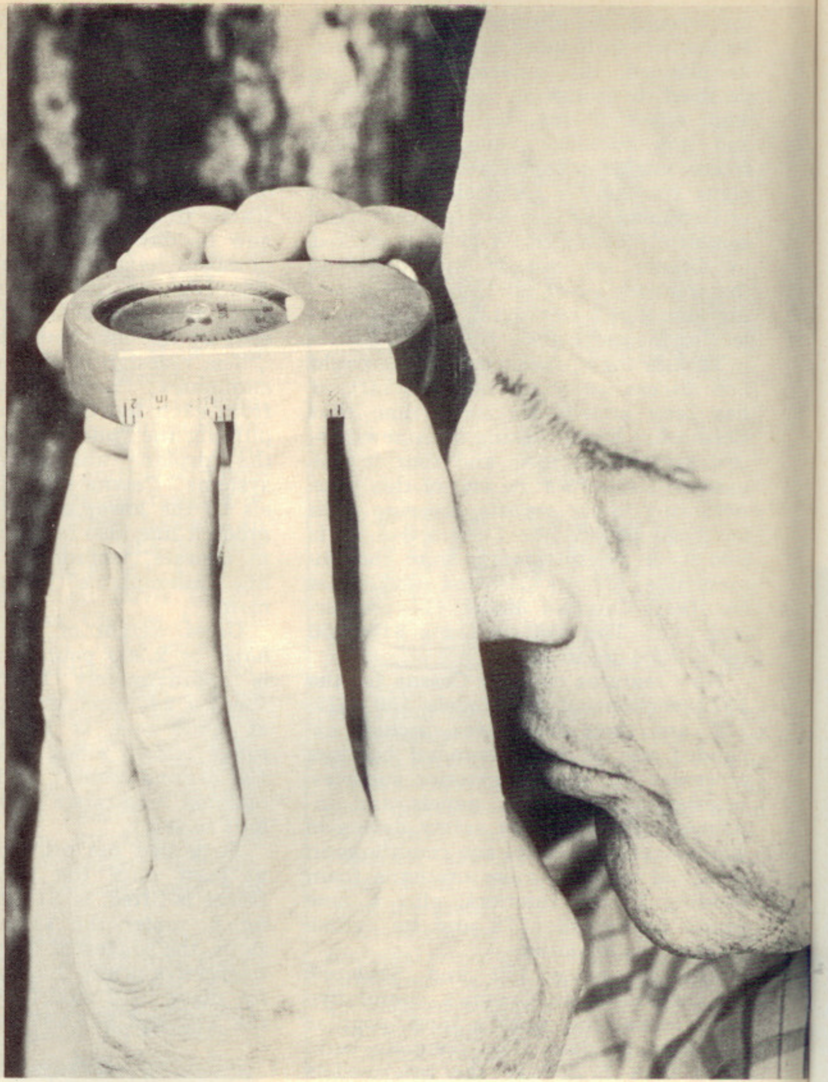
Keeping Your Compass Accurate

Compass deviation cards in many general aviation planes are inaccurate, need 'air swinging' to correct deficiency. Ex-military pilot-navigator and researcher relates new low-cost way to do it. He also details procedures for 'ground swinging' compasses

by D. B. RICHARDS / AOPA 402142



The Suunto compass is being used here by the author to sight the longitudinal axis of an airplane. The compass man simultaneously looks into the reading aperture and over the top of the compass. By an optical illusion, the hairline of the reading aperture appears to rise up into the air above the compass and can be placed accurately on the object being sighted. When shooting the sun, a dark clip-end of photographic film is held in front of (or scotch-taped to) the compass to protect the eye.

■■ The average plane owner will spend hundreds of dollars for a remote indicating compass and thousands of dollars for electronic gear, yet will completely neglect the most basic navigation instrument of them all, the simple airplane compass. Unfortunately, neglect breeds further neglect. *The typical general aviation compass is badly out of adjustment and has a completely unreliable deviation card.* No wonder the average pilot tends to put his money and his faith elsewhere. This is unfortunate, since with proper calibration the compass is an extremely reliable instrument.

Since dead reckoning is basic to other forms of navigation, such as pilotage, radio, and celestial, every plane should have a well-calibrated compass. The Federal Aviation Regulations (FARs) recognize this fact by stating that each compass shall have a calibration card. About all this regulation has accomplished to date is that someone obligingly puts some values on the card with little or no regard for the actual compass deviation. This practice unfortunately seems to be nearly universal. I have calibrated quite a few plane compasses and *I have yet to find one where the compass card even remotely agreed with the true deviation.* Let me cite an example which is not untypical.

I was recently planning a trip involving some overwater navigation. True, the radios would get me on in, but I've had radios fail, and when you're out of sight of land it's nice to be able to trust your dead reckoning, just in case!

The plane compass had the required correction card, of course. The maximum deviation indicated on the compass card was 1°. Because of a well-justified suspicion of such calibration cards I took the plane up and ran an air swing on the compass (calibration of the compass is called "swinging the compass"). The compass deviation varied from minus 6° at one extreme to a plus 12° at the other! Even though I didn't have time to adjust and reswing the compass, I did make a graph of the deviation to take on my trip. As luck would have it, one leg of my journey involved the heading with the 12° correction; the destination—a small island 170 miles away.

While either of the plane's omnis would bring me in, I left them tuned in for emergency use only and never centered the needles. Instead, I applied that 12° correction to the magnetic heading and flew the leg by dead reckoning just to see how it would work.

When the island came in sight, I still flew out my heading and ETA and came about four miles from my exact destination. Not brilliant—each of you can relate a better performance, I'm sure, and so can I—but it was at least satisfactory. For comparison, let's think what would have happened if I hadn't applied the 12° correction. I could have been somewhere in the neighborhood of 35 miles off and the haze was bad enough that I could only see an island about 15 miles out. Without an omni it would have been a bit rough to find that island.

Even the pilot who never gets more than 40 miles from an omni can simplify his flying by swinging his compass. It makes things easier to have only a few degrees of drift as you shoot a VOR or ILS approach. Those 10° and 15° crab angles you've been having in the past are probably compass error.

If you really have confidence that your compass is correct, then any large apparent drift angles under light wind conditions should also warn you that your omni is not very accurate and it's time to have it checked over.

One of the reasons so few compasses are properly calibrated is that most pilots question a ground swing and few pilots or mechanics know how to conduct an accurate air swing. (An "air swing" means checking the compass deviation at various headings aloft in actual cruising flight). Neither of these objections is completely valid since a good ground swing is certainly far better than no swing at all, and a really good air swing can now be performed by any competent pilot. If you're a really conscientious pilot who wants to do precision dead reckoning, you will want to air swing your compass. Here's how. As far as I know this method is new, yet it rivals in accuracy the classical astrocompass swing which used to be the only really satisfactory way to air swing a compass.

It is usually advisable to compensate (i.e., adjust) your compass first to take out most of the deviation due to hard iron magnetism and electrical current. This is not difficult but the FAA calls it a minor repair and requires that a licensed A&P sign this compensation off in the plane's logbook. Just to make everything absolutely legal, you can easily do the work yourself and have the A&P sign it off as being done under his supervision.

With or without the blessing of an A&P, *do not compensate the compass unless you immediately swing the compass to get a new set of values for the deviation card.*

First of all, get a Suunto KB-14 hand compass. I've tested a couple of dozen compasses and it is the only hand-held compass with sufficient accuracy for the job. Most of the time it will read within 0.2 to 0.3 of a degree of the correct magnetic bearing and it is well worth the $17 it costs. The smart fixed-base operator will buy one of these compasses and soon pay for it by renting it out at a dollar or so per usage for compass compensation and compass swinging. It's faster and much easier to use than the tripod compasses often used for this groundwork.

If you've never used a Suunto KB-14, you'll want to take several practice shots to get used to it. To take a magnetic bearing you simultaneously look into the sighting window and over the top of the compass. By an optical illusion, the hairline in the sighting window appears extended into the air above the compass and can be used to sight a distant object at the same time the bearing is read under the hairline in the sighting window.

While compass compensation can be done alone, it saves a lot of engine starting and stopping to have one person in the cockpit and one outside to read the Suunto compass. The cockpit man taxies out onto a flat area free of magnetic disturbances, turns the radios on and, after rolling the nosewheel straight, runs the engine up on an East heading and reads the compass. Meanwhile the compass man kneels about 60 feet behind the plane and moves his position around until he can simultaneously sight the tailskid and the nosewheel strut and takes a reading with the Suunto. He then runs up and gives his reading (the magnetic heading) to the cockpit man.

The cockpit man adjusts the East-West compensator so that on subsequent runup the compass reads the magnetic heading of the plane. He then taxies the plane to a South heading, rolls the nosewheel straight, and repeats the whole procedure, this time adjusting out the deviation with the North-South compensator so that on subsequent runup the compass reading is the same as the Suunto magnetic heading. He then turns to a West heading and repeats the procedure, except that this time he only adjusts out one-half of the deviation.

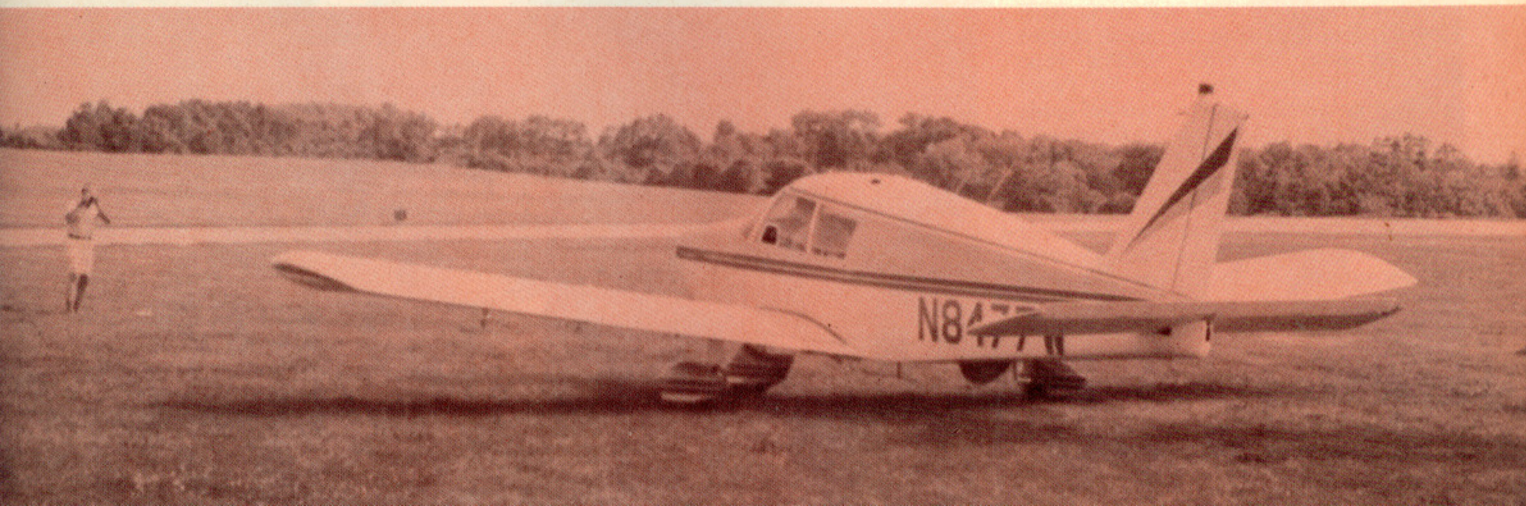
Thus, if the plane compass reads 270° and the compass man reported his Suunto at 266°, then the cockpit man would only adjust the E-W compensator enough so that on subsequent runup the plane compass would read 268°. He then taxies to a North heading and again compensates out only half of whatever deviation is found there. The compass is now compensated and is ready to be swung. While I've described an E, S, W, N compensation, you can start with any one of the four cardinal headings and progress around as long as you compensate the first two headings completely, then only take out half the deviation on the last two cardinal headings. There is, however, some advantage to starting on E or W since they usually have larger deviations than do N or S. Once it is compensated, the compass is ready for swinging. In case some obstruction (such as a radio loop housing) prevents your sighting the tailskid and nose strut simultaneously from the rear, the compass man will have to sight the longitudinal axis of the plane from the front and take the reciprocal of each reading.

The alert reader will note that this external sighting plus engine runup and compass reading procedure could be used to ground swing the compass on 30° increments of heading around the compass and thus furnish the data for a deviation card. With each man keeping his own data sheet, the average lightplane can be ground swung both "Radios On" and "Radios Off" in about 20 minutes this way and it will be as good a ground swing as you can get. If you can't air swing the compass immediately, by all means run this ground swing to tide you over until you can run a good air swing. While not as good as an air swing, it's lots better than nothing!

Some additional notes on compensation are in order, though, before we get into the air swing. Most official directions will tell you to either remove the compensating magnets or turn them to neutral before starting the compensation procedure, then add them back or adjust them to start compensation. Since the average person shouldn't remove the magnets and probably can't be sure when he's turned them to neutral, I'll suggest two alternate ways of handling this problem.

The first way is to swing the plane on the four cardinal headings without any compensation but recording the deviation on N, E, S, and W. Select the largest deviation of the four (it will usually be on E or W); start the compensation procedure on that heading, and progress around through the other

Shooting the longitudinal axis of a plane for compensation and ground swinging. Normally this is done from the rear but in this case the dome covering the ADF loop prevented simultaneous sighting of the tailskid and nosewheel strut, so the longitudinal axis had to be sighted from the front (compass man is at far left). This front-end sighting requires the compass man to take the reciprocal of each of his bearings to get magnetic heading of the plane.



three cardinal headings as directed above—compensating all the deviation out on the first two cardinal headings and half the deviation out on the second two cardinal headings.

The second and easiest way to handle the problem is to start checking the deviations on each cardinal heading, but do not compensate on any heading until you come to one with more than 2° of deviation. Once you find one with more than 2° of deviation, compensate it and also the next cardinal heading completely, then compensate the remaining two cardinal headings for only half of their deviation.

Another common compensation problem that is not always discussed adequately is a constant error or lubber line error. This may not become apparent until you've swung the compass and then it shows up by the fact that the deviations are not equally balanced above or below the zero value.

In the example I used earlier with a range of values from minus 6° to plus 12° with a fairly well-proportioned sine curve of deviation, it is obvious that the deviation curve would be more balanced above and below the zero line if the zero line could be moved up to what is now the plus three line. This lubber line error is due to the fact that the lubber line is not aligned correctly with the longitudinal axis of the airplane. It could be corrected in this case by having a mechanic remount the whole compass in a position rotated 3° counterclockwise from the old position. If the constant error is not too large, you can, of course, do nothing; your compass card or deviation graph will merely have larger deviation values of one sign (in the above example, larger plus values) than of the other, but the values will be valid if correctly applied. When the constant (i.e., lubber line) error is as much as 3° or 4° you will probably want to have a mechanic correct it to as near 0° as possible. If the correction is made by rotating the compass mount the required number of degrees without any other movement of the compass, you could use your calibration curve with the zero line displaced the required 3° or 4° of deviation. If the remounting involved any displacement of the compass (or if the rotation were more than a few degrees), then you would have to reswing the compass after the lubber line correction.

Now let's get on with the air swing.

In smooth air with a good directional gyro, all parts of an air swing are fairly straightforward, except one. That one is to find the accurate magnetic heading of the plane in flight on at least one heading both before and after the air swing. Since all of the rest of the air swing depends on it, this determination should be made as accurately as possible. If you have an astro-compass and know how to use it, by all means do so. I'll assume you're fresh out of astro-compasses or that your celestial navigation is a little rusty and suggest a couple of other ways to get those critical headings. Each method depends on your ability to line the plane up precisely with a known reference line while getting an accurate reading on the directional gyro. If you use the sun or the moon for that known reference, you can rival the accuracy of an astro-compass swing. You can now shoot the sun without all those mathematical calculations that used to be necessary for the azimuth of celestial bodies.

First of all, secure a 49-cent fiber point or nylon point pen that will make an easily visible mark on Plexiglas, a piece of string, some pressure-sensitive tape (such as 3M) of a color to contrast with the engine cowling, and a yardstick with a straight edge. Seated comfortably in the pilot's seat, measure the distance from your dominant eye (i.e. your gun-sighting eye—it's usually the right eye) to the centerline of the airplane.

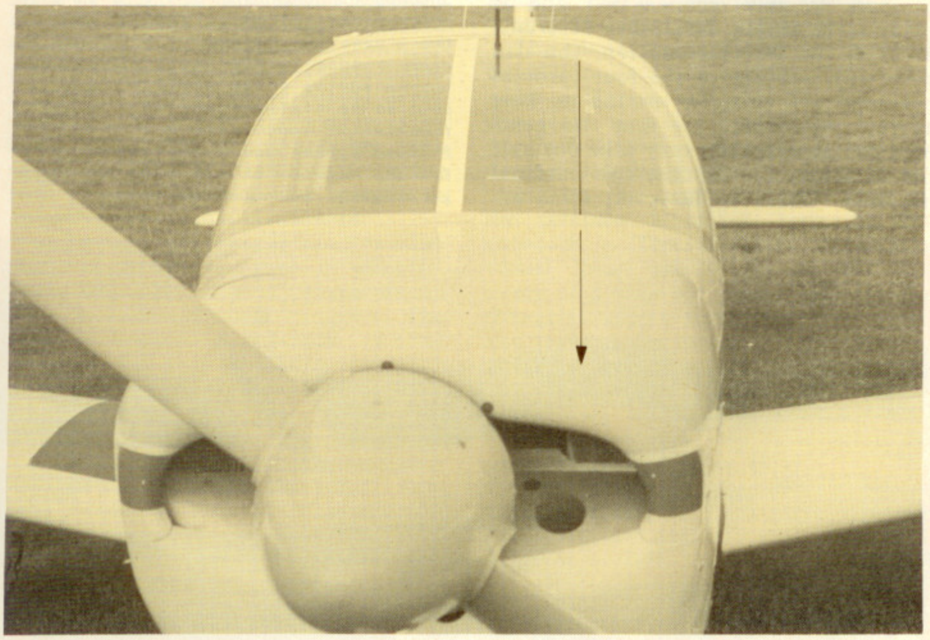
Now, with the nylon point pen, draw a line on the windshield exactly this distance from the centerline of the plane and another such line on the forward part of the engine cowling, each of them parallel to the centerline, of course. In measuring this distance, be sure to measure horizontally and not around the curve of the windshield or the cowling. Although not absolutely necessary, a level and a plumb bob may be helpful in making these measurements.

Cut a 6-inch-long piece of the pressure-sensitive tape into a long triangle and stick it pointing forward like an arrowhead along the line on the cowling as far forward as practical but still in full view of the pilot. Now sit in the pilot's seat and look forward to the tip of the pressure-sensitive tape on the cowling. With your eye in its normal position, the line on the windshield should line up perfectly with the line on the cowling and also with the point of the tape arrowhead on the forward part of the cowling. Later on, in the air, this line will be used to sight the sun.

This method of sun-sighting (called "shooting" the sun) can only be done satisfactorily when the sun is not more than 20° (and preferably no more than 10°) above the horizon. In lower latitudes in the summer this means within 1½–two hours of sunrise or sunset. In higher latitudes there is more leeway. The bush pilot based at 50° N. latitude can probably shoot the sun at high noon on Christmas day as it will only be a little more than 16° above the horizon then. The Arctic pilot based at 65° N. latitude will only have about three hours of sunshine on Christmas day, but the sun will be low on the horizon all that time. On June 21, however, the Arctic pilot will have an acceptable shooting angle from suppertime until breakfast, except for a couple of hours around midnight when the sun dips below the horizon. If he were a bit further north inside the Arctic Circle, he could, of course, shoot the sun even at midnight on June 21.

Make up several data sheets with the following captions at the top of seven columns: Time; Mag. Hdg.; Gyro Error; Gyro Hdg.; Compass Dev.; Compass Hdg.; Remarks. Secure a dark clip-end of a developed roll of 35mm color film and some scotch tape. These little clip-ends are usually returned in the box to show that the processor developed all the film. Never stare at the sun for long periods through these films or eye damage may result, but they do give enough protection for a quick look needed in sighting the sun. You can also use a "Sunspot" eyeshield stuck to the windshield in place of the film.

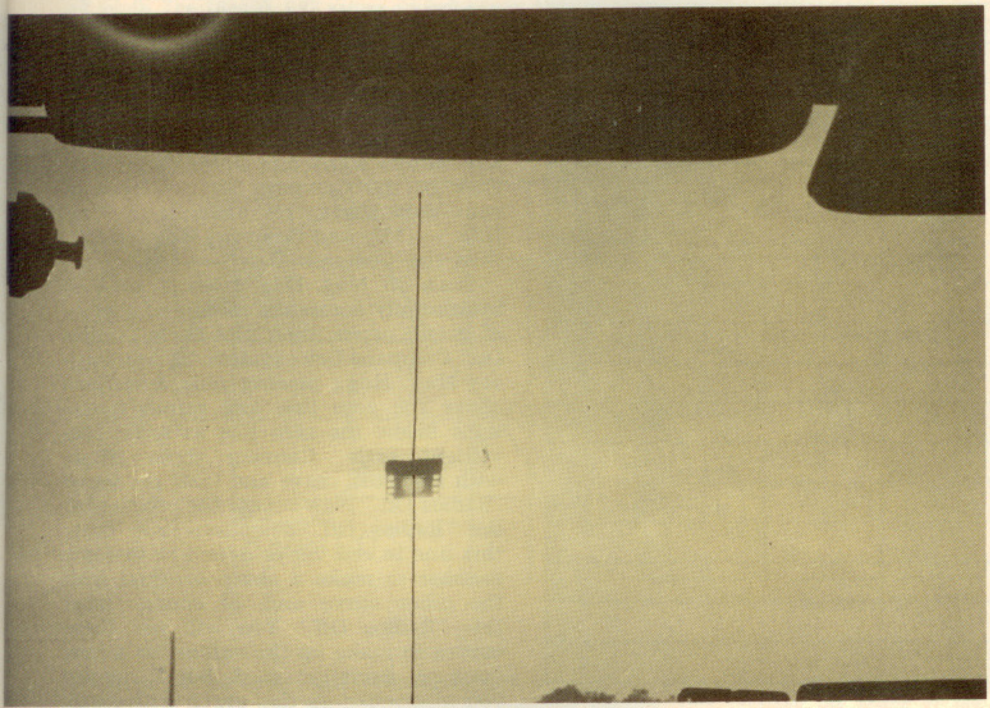
About 2½ hours before sunset, start shooting the sun with your Suunto KB-14 compass, holding the dark film in position for eye protection. Take two or three careful bearings at intervals of



Plane with windshield and cowling lines marked parallel to the longitudinal axis of the plane. In flight, the pilot "shoots" the sun by lining up these lines with the sun, which he views through a film-clip or "Sunspot" eyeshield.

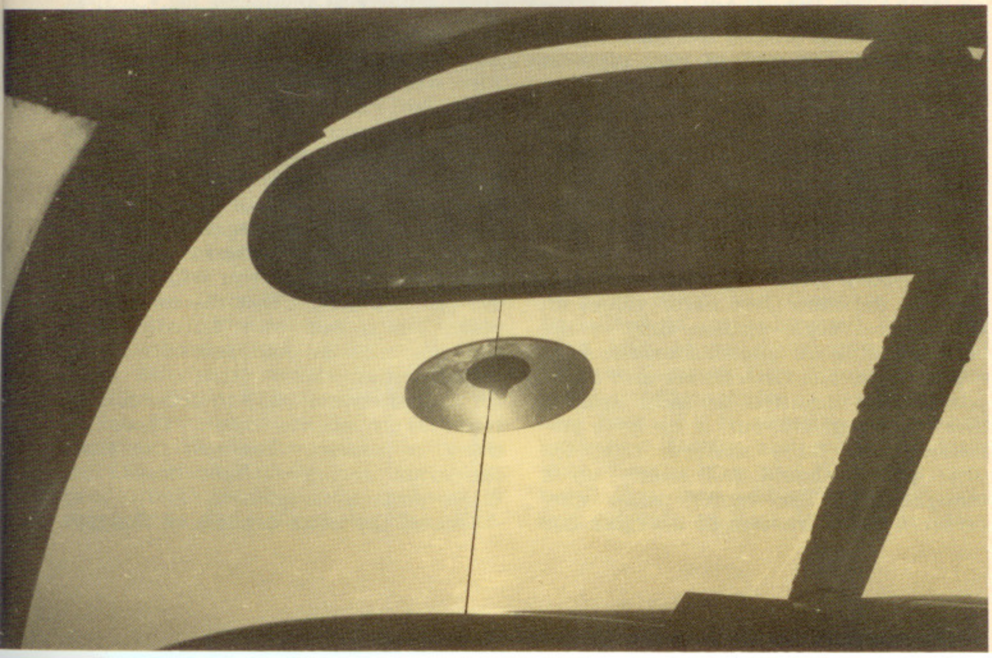
a minute or more and record both the magnetic bearing of the sun and the exact time of the bearing. Get the plane all ready to go, then take one or two last shots of the sun (recording the exact time) before taking off. In mid-latitudes, plan your takeoff for about two hours before sunset (as you get more experienced, you can reduce that to 1½ or even one hour before sunset). Crank up, taxi out for takeoff, set your directional gyro as best you can, then never touch the gyro again throughout the flight. If it's off a few degrees to start with, that's all right—in fact, it will probably improve the accuracy of your swinging if you know the gyro is off a bit because you'll then read the compass honestly rather than try to make it agree with the gyro! Don't worry about those few degrees of gyro error because later you'll correct them plus the gyro precession with your reference shots.

After clearing traffic, head for an uncongested area while climbing to a smooth air altitude. The swinging area should have the same magnetic variation as the home airport or else appropriate corrections should be applied. While en route, turn directly into the sun, level your wings and scotch-tape the dark film to the windshield line at the correct position to shield your sighting eye from the sun. Line up the windshield line with your cowling line (arrowhead) at the same time you line it up with the sun (wings level) and read the gyro. It is very important for your wings to be level—otherwise your reference line is tilted. Record the gyro reading and the exact time, and write "sun-shot" in the Remarks column of your data sheet.



↑ *The sun being "shot" with the windshield lines and a film-clip eyeshield.*

↓ *The sun being "shot with the windshield and a "Sunspot" eyeshield.*



On arrival at a smooth air altitude, level out, trim up for cruising flight, and shoot the sun twice more with your windshield line, recording the exact time and the gyro reading for each shot. You'll now be heading crudely west, so turn to 240°, 270°, or 300° on your gyro (whichever is closest) and start in swinging the compass with all the normal radio equipment on.

If 300° is your nearest heading, turn to it, level your wings, hold 300° on your gyro until the compass settles down (it may take 30 seconds or more), then read the compass as accurately as possible (averaging swings if necessary) and record the exact time, the gyro reading, and the compass reading. Turn the plane to 330° and repeat the process. Proceed around the compass in this manner by 30° increments of gyro reading until you've completed all 12 readings (you may want to take a 13th reading as a repeat of your first reading to check reproducibility of your values).

To do a good job requires precision flying with concentration on the instruments, so in congested areas have a copilot along as a safety pilot (he can also read the compass for you, if you wish, and be your recorder). Don't forget to record the time of each reading (or at least every other reading) as the time will be used to correct for gyro precession.

Upon completion of the 12 readings of the first swing, turn all your radios off and let them cool down while you shoot the sun several times with your windshield line, recording each gyro reading and time with "sun-shot" in the Remarks column. Now put a caption of "Radios Off" across your compass column and start right in again and swing by 30° increments of your gyro around the compass for the 12 headings. Don't get lazy and omit the "Radios Off" swing. When your radios are off is exactly the time when you most need an accurate compass!

Upon completion of the "Radios Off" swing, immediately shoot the sun a couple of times with your windshield line, recording the gyro reading and time. Now head for home. Shoot the sun once more on your way home. As soon as you've parked the plane, get out and shoot the sun several times with your Suunto KB-14, recording the time and magnetic bearing each time. These final shots are very important so don't forget them. In fact, if your air work runs a little slow you may have to break off and come home to get those shots before sundown. One way to avoid this homeward rush is to start your swing at sunrise rather than near sunset. The best procedure, of course, would be to have a trusty friend on the ground to take the Suunto sun shots at the beginning and near the end of your flight, if there's any doubt about your getting down before sunset. Be sure he records the time of each shot.

Since we are going to plot a straight line through the sun-shots, some of you may be worried about whether this

Air Swing of Airplane Compass						
Time	Mag. Hdg.	Gyro Error	Gyro Hdg.	Compass Dev.	Compass Hdg.	Remarks
8:07 p.m.	286.4	−2.4	284			Sun shot
8:07½	286.5	−3.0	283½			Sun shot
8:08	286.6	−2.6	284			Sun shot
					Radios Off	
8:09	273.8	−3.8	270	+11.2	285	
:10	304.2	−4.2	300	+5.8	310	
:11	334.5	−4.5	330	+1.5	336	
:12	4.8	−4.8	0	−2.8	2	
:12½	34.9	−4.9	30	−4.9	30	
:14	65.4	−5.4	60	−5.4	60	
:15	95.7	−5.7	90	−2.7	93	
:16	126.0	−6.0	120	−3.0	123	
:17½	156.4	−6.4	150	−1.4	155	
:20	187.2	−7.2	180	+2.8	190	
:21	217.5	−7.5	210	+5.5	223	
:22	247.8	−7.8	240	+12.2	260	
8:24½	289	−8.0	281			Sun shot
8:25½	289.2	−8.7	280½			Sun shot
8:26	289.3	−9.8	279½			Sun shot
						Aug. 7, 1970
						N8477W

Author's data sheet from an actual air swing after the calculations were completed.

is accurate. Even near sunset there is indeed a slight curve in the plot of sun azimuth versus time. For the 1½- to two-hour period of our concern, this departure from a straight line plot amounts to a small fraction of a degree whenever the sun is within 20° of the horizon. If you do everything else correctly, this curve will contribute less than one-half of a degree error and even that amount will be largely averaged out by your plot of gyro precession.

Scale off the total timespan for all the sun-shots (for example 6-8 p.m.) horizontally along the bottom of a piece of graph paper to some convenient scale and scale the total range of sun-bearings (for example 275° to 295°) vertically. Now plot each Suunto ground sun-shot against its time and draw a straight line that best represents these points. If your shooting has been accurate, all these points should be within a fraction of a degree of this straight line. For each of the nine times you shot the sun in the air, take a magnetic sun-bearing value off your straight line plot of Suunto sun-bearing versus time and enter it in the Mag. Hdg. column of your data sheet beside the time of the air sun-shot. For each of your nine air sun-shots subtract this Mag. Hdg. from the Gyro Hdg. and enter this difference in the Gyro Error column. Be sure and enter the plus and minus signs. If the Mag. Hdg. is larger than the Gyro Hdg., the Gyro Error is minus (for example, Mag. Hdg. = 281° and Gyro Hdg. = 274° gives a Gyro Error of −7°).

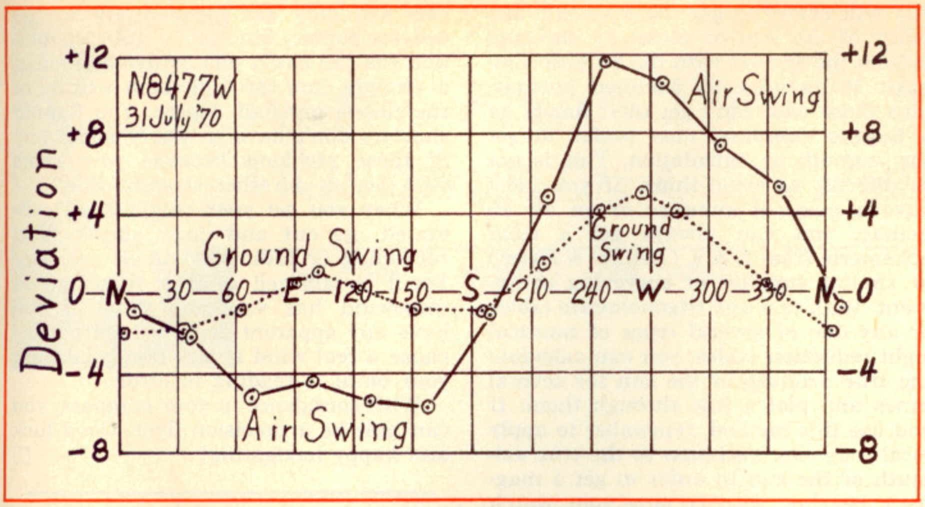
Now, on a piece of graph paper, plot each of the nine Gyro Error values on the vertical scale against time of the corresponding air sun-shot on the horizontal scale. The Gyro Errors may all be positive, all negative, or some positive and some negative, but, if the gyro precessed at a fairly uniform rate, the nine points should fall nearly on a straight line. The center points may be off a small fraction of a degree due to the slight curvature in the sun azimuth line, but this slight departure will not effect your accuracy appreciably. Draw the best straight line you can fit to the nine Gyro Error points.

Using the straight line through the sun-shot values of Gyro Error, pick off a Gyro Error value corresponding to the time of each magnetic compass reading and record this value on the appropriate line in the Gyro Error column. If you failed to record the time of any compass reading, interpolate its time between the times of the adjacent readings. Now apply this Gyro Error backwards to the gyro reading to get the correct Mag. Hdg. for each compass reading. Since you're going backwards from Gyro Hdg. to Mag. Hdg., add a minus value and subtract a plus value of Gyro Error (for example if the Gyro Hdg. = 300° and the Gyro Error = −5°, add 5° to the gyro reading to get 305° for Mag. Hdg.). With a correct Mag. Hdg. for each Compass Hdg., it is now a simple matter to calculate the compass deviation by subtracting the Mag. Hdg. from the Compass Hdg. Again be sure to keep track of the plus and minus signs and enter this difference in the Compass Dev. column of your data sheet (for example if Mag. Hdg. = 33°, and Compass Hdg. = 29°, then the Compass Dev. = −4°).

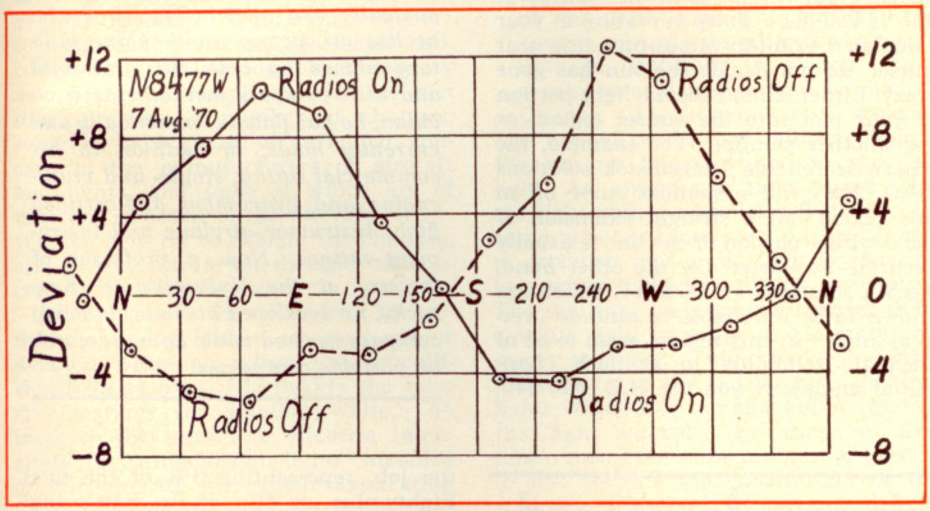
Scale off Mag. Hdg. from 0° to 360° horizontally across the middle of a piece of graph paper, then plot each "Radios On" Compass Dev. against its appropriate Mag. Hdg., placing plus deviations above the zero line and minus deviations below the zero line to some convenient scale. Connect these points with a smooth curve and label the curve "Radios On." Now repeat the process for the "Radios Off" deviations and draw this line in red ink or dotted or in some manner to make a sharp contrast with the other curve and, of course, label this "Radios Off." You will use these curves to make up the values for a new compass deviation card, but I suggest you also make up this graph with large, easily seen printing and fasten it to the back of your sun visor, on top of the instrument panel or in some easily visible location in the plane. Since fatigue and stress can make our minds play tricks, I also suggest you print in bold letters on the graph, "Add deviation to Mag. Hdg. to get Compass Hdg." Also, date the graph so that anyone at a later date can tell if the compass has or has not been swung since any major engine, electrical, or radio change.

The same general technique can be used to shoot the full moon with a couple of obvious changes. Your windshield and cowling marks must be made visible in moonlight; you will not need eye protection for either the compass or plane shots, but your Suunto KB-14 compass must be equipped with an internal tritium lamp (that's $8 extra for a total cost of $25) in order to take night shots of the moon. There are times, of course, when you can shoot the moon during daylight hours, and this is perfectly acceptable.

One of the extra benefits of the gyro



Deviation plotted against magnetic heading to show the difference between a ground swing and an air swing. The "Radios Off" values are not shown because they went completely off the graph with a —18 and a +24 deviation, the author said. While the ground swing showed essentially the same pattern as the air swing, the extreme values differed by as much as 5° to 7°. The fact that this sometimes occurs is ample justification for running the air swing, according to the author. Much of the time, however, the ground swing will be within a few degrees of the air swing, he said.



Deviations for the same plane compass as that in the other deviation chart after a single compensation of —14° was made on the 270° magnetic heading. This reversed the shape of the "Radios On" plot, so that it really is very little better than it was, but subtracting 14° from the "Radios Off" brought it from 26° down to 12° so it could at least be plotted on a reasonable scale. This plane, the author said, shows poor radio installation design as all the radio wires pass directly by the compass. While either "Radios On" or "Radios Off" deviation could be compensated to near zero it is impossible to do them both at once, he stated, and the compensation indicated in this figure is a fair compromise between the conflicting requirements. This graph also shows about 3° of lubber line error as discussed in the text. The deviation could be reduced by rotating the whole compass 3° counterclockwise and eliminating the lubber line error. This would have the effect of balancing the deviations above and below a zero line located where the +3 line would be.

swing is that you end up with an accurate value for the rate of gyro precession. This can be very helpful in precision dead reckoning.

On one plane that I air swung on two different occasions the gyro precession was minus 1° in eight minutes each time. This means you could purposely set the gyro 2° higher than your Mag. Hdg. and not touch it for 32 minutes while it precessed slowly 4°. If you flew the desired Mag. Hdg. on the gyro, the plane would start out flying 2° to the left of the true Mag. Hdg., pass through the Mag. Hdg., and end up flying 2° to the right of the Mag. Hdg. This averages out your Mag. Hdg. much better than continually resetting your gyro while it continually drifts off to the same side of the Mag. Hdg.

In all the discussion so far I've used + and — values to designate the values of Gyro Error and Compass Dev. to be added to, or subtracted from, the Mag. Hdg. to get the appropriate Gyro Hdg. or Compass Hdg. Some flyers and many mariners prefer to use West (W) and East (E) to describe these same correction factors and recite the little ditty "East is least and West is best" to recall that they add a West deviation and subtract an East deviation to Mag. Hdg. to get Compass Hdg. in the same manner that they add West and subtract East variation to true heading to get Mag. Hdg. Either of these systems works if you keep everything straight and remember that the ditty (as well as the + and — signs I used) only work in going across the data sheet (or logsheet) from left to right (i.e. from true heading to Mag. Hdg. to Compass Hdg.). Old pilots with ribald taste used to use the mnemonic "True Virgins Make Dull Company" to help them remember the appropriate order of True heading, Variation, Magnetic heading, Deviation, and Compass heading. Regardless of the system you use, however, you have to remember that in coming back across the data sheet (or logsheet) from right to left (i.e. from CH to MH to TH) you have to use the opposite sign for all corrections.

Quite naturally there are ways other than sun- and moon-shots for getting that critical reference heading before and after the gyro swing of the compass. Unfortunately, none of them gives as consistently accurate results as do the celestial shots and hence I can't really recommend them. The two that seem most promising are to get permission to fly low over the runway on a no-drift day, or else use the windshield-cowling line to line up with a straight stretch of road, railroad, or powerline at low altitude. This latter system sounds good but has many pitfalls, one of which is that the map does not always depict the road accurately enough for you to get a good map measurement of its heading. Try them if you wish; they are certainly better than no calibration at all, but they do not approach the sun-shot for accuracy.

If you decide to use a ground reference swing I recommend the following technique, which will average out the larger errors. Select a long straight stretch of railroad track, powerline, highway, or, best of all, a four-lane freeway in the area you will use for swinging. Measure its heading accurately on a map and apply variation to get an accurate magnetic bearing for the straight stretch. Since I've found a number of these map bearings wrong I suggest you also drive out to the road, get away from your car and any fences, and check the Mag. Hdg. of the road with your Suunto compass.

When you get back to the airport, take off with your gyro set on the runway mag heading. By use of your windshield sighting line, point the plane down the runway (not crabbing, but letting it drift) and read the gyro and note the time when the plane is perfectly aligned with the runway.

As you climb on out, record the gyro reading along with the time. Proceed to the planned swinging area and at 500 feet agl, with the wings level, point the plane (using the windshield sight) directly down the road and read the gyro. Do not crab! If there is a crosswind, start on the upwind side of the road so you can take your gyro reading as you're exactly centered over the road and sighting along it. If it's a four-lane road, let the plane drift on across and get a second reading when pointed along the second roadbed. Record the time and gyro reading. Do a 180° turn and repeat the sighting in the opposite direction, recording the time and gyro reading.

Now climb to a smooth air altitude, swing the compass with "Radios On" at 30° increments against the directional gyro and descend for another gyro check in both directions along the roadway. Do *not* reset the gyro (you want it to continue precessing), but record the gyro readings and times.

Again climb to a smooth air altitude, turn the radios off and swing the compass against the gyro as before, but with radios off. Now descend to the roadway, check the gyro again in both directions and record the gyro readings and times. Fly back to base, get permission for a low pass, and again record the gyro reading and the time when you were perfectly aligned with the runway.

For each of the two runway passes and the six road checks, calculate the Gyro Error just as you did for sun-shots. Plot these Gyro Errors vertically against the corresponding time on the horizontal scale. Unless you're unusually lucky, these eight points will not form as neat a straight line as would similar sun-shots. Ignore any one or two obviously wild values and draw a straight line to represent the main trend of Gyro Error as the gyro precessed with time. Use this Gyro Error line just as you did for sun-shots in getting a Mag. Hdg. for each compass reading. While not as good as sun- or moon-shots, this method gives you a reasonable air swing.

In all this discussion I've assumed you will prefer to get the magnetic azimuth of the sun or moon by shooting it from the ground with the Suunto compass. Mathematically inclined persons, plus those who can't get their hands on a Suunto compass, may prefer to get the azimuth by calculation. This is not as difficult as some think. If you don't have a nautical almanac or an air almanac, you can always get a solar ephemeris from K & E (Keuffel & Esser) or similar supplier of surveying equipment. With this and trigonometric tables or any one of several types of nautical sight reduction tables, you can calculate the true azimuth of the sun for several times and plot a line through them. If you use this method, remember to apply local magnetic variation to the true azimuth of the sun in order to get a magnetic bearing! Also be sure your watch is correct at least to the minute and preferably to the half-minute or better.

One word of warning to celestial navigators. Some otherwise reliable sight reduction tables give slightly erroneous solutions near sunset or when the LHA (Local Hour Angle) is in the vicinity of 90°. If you get a sharp curvature in your calculated azimuth-versus-time line near sunset, do not decide the sun has gone crazy. Either extend the daylight portion of your plot into the sunset region, or use another solution. For example, the otherwise reliable Dreisonstok solutions (H.O. 208) will sometimes curve off in this region but a straight extension of the daylight portion of the line is usually accurate at sunset. On the other hand, Ageton solutions (H.O. 211), which are known to be unreliable in altitude (vertical angle) in this region, seem to be of adequate reliability in azimuth (horizontal angle). If you use H.O. No. 249, you will only get the azimuth to the nearest degree. Since this is a fast solution you can easily plot many values, and a straight line through them will be to the closest one-half degree. You Suunto shooters don't have to worry about any of these problems because your shots will plot as a rather straight line.

When you get your compass all calibrated, go out and do a simple dead reckoning or radio navigation problem. You'll be amazed at how that built-in crosswind has vanished. Now if you have any apparent drift, it is either because a real wind is blowing or because your omni is reading in error.

With confidence in your compass, you can now be a precision flyer. Good luck and happy navigating! □

THE AUTHOR

D. B. (Boyd) Richards (AOPA 402142) is a new contributing author for the PILOT. *He comes well qualified for this, his first article. Rated as both a navigator and pilot in the Air Force, he has air swung multi-engine military planes by both the drift-sight and astro-compass methods. As a civilian, he has flown commercially and currently holds, in addition to his commercial rating, single- and multi-engine land, instrument, and certified flight instructor–airplane and instrument–ratings. Now a professor of forestry at the University of Kentucky, he developed his new air swing compass method while doing research on portable compasses.*

Volpe: Minority Employees Increased

■■ Transportation Secretary John A. Volpe used a recent guest speaking appearance before the Negro Airmen International Association to review what he indicated were significant improvements in the employment of minorities by the Department of Transportation (DOT) and FAA.

Speaking before the group's annual meeting at the Barbados Hilton Hotel in Barbados, British West Indies, Volpe said that when he took over his job about 2½ years ago, he was "dismayed" over the fact that minority employees constituted only 7.3% of the department's total work force.

"This compared to a Government-wide average of 18%, meaning that in minority employment we ranked 33rd among 37 departments and agencies of the Executive Branch," Volpe told those attending the meeting. "I and my staff went to work. In approximately two years, we have been able to increase the number of minority employees holding super-grade positions (that's $27,000 a year and up) from zero to 19.

"Looking at the whole picture," Volpe continued, "we have, in the past two years, increased the number of total minority personnel by about 2,000. In the professional levels, Grades GS-11 through 15, the FAA now employs nearly 1,000 (924 as of June 1) non-whites. Two air traffic control facility chiefs (Grade 14) and two system maintenance chiefs (Grade 15) are blacks."

Out of FAA's 24,303 air traffic controller work force, 4%, or 1,010, are from minorities, the Transportation Secretary continued. "That compares to 458, or 2.5%, when we came in 2½ years ago. We have 630 electronic technicians from minority groups, representing 8% of that work force. In 1968, minorities held 349, or just 5%, of the jobs in that field."

In FAA's Flight Standards Service, there were "fewer than 1%" from minority groups when he assumed office, Volpe added. "Today we have 69 on the job, representing 3% of the total. Eighty-nine, or 4%, of the FAA's engineers are minority employees and we have a number of black Sky Marshals flying the airways and we are working to put more minority hires onto the very vital tasks of aviation security."

Singled out for special praise was a program at FAA's Aeronautical Center in Oklahoma City, whereby FAA attempts to attract new talent into its air traffic control and electronic technician occupations. "Prior education and experience requirements are waived somewhat, in favor of aptitude and on-the-job training. Students are admitted at the GS-4 level and on completion of the special training program they are promoted to Grade 5—in six months, instead of the full year normally required. From the school, they go to FAA facilities for further job training and experience, with opportunities for promotion up the ladder."

The Oklahoma City program has proven highly successful to date, Volpe stated. "The reports from tower and facilities' chiefs have been most flattering. And I am especially pleased that 233—81%—of the 287 trainees enrolled in the program thus far have been minorities." □