SURVIVAL POSITION LOCATION USING STAR SIGHTING*

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P-1764

August 20, 1959

*To be published in the Journal of the Institute of Navigation.

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ACKNOWLEDGMENT

The author wishes to acknowledge the invaluable assistance of Colonel E. F. Perrin, USAF, in the development and testing of the method described herein. Colonel Perrin at the time was USAF liaison officer to the Institute of Navigation.

INTRODUCTION

At a regional meeting of the Institute of Navigation, a representative of the Air Force Survival School, Stead AFB, described their need for a simple method of locating one's geographical position. As a result of this request, a method using star sighting which can be used by persons having no knowledge of celestial navigation has been developed and tested. Neither a sextant nor an almanac is required. The necessary equipment fits into a shirt pocket and provides an accuracy of 10 to 20 miles under realistic field conditions.

Basically, longitude is determined by measuring the time of upper transit of any one of 42 standard navigation stars. Latitude is obtained by measuring the altitude of Polaris.

The equipment in the shirt-pocket-size packet consists of (1) a 6-ft-high, preformed sighting triangle made of nylon fishing line; (2) a plastic altitude-measuring tape; and (3) a sheet of paper containing a star chart, directions for setting up the triangle and performing the measurements, and a computation form.

In brief the method is as follows: the user sets up the sighting triangle (Fig. 1) by suspending it from any convenient support, such as the limb of a tree, and adjusting the several tie-downs until the triangle is in a vertical plane and oriented in a north-south direction. By sighting through the bottom line and hypotenuse of the triangle, he then determines the precise GMT time of transit of a selected star through the plane of the triangle (Fig. 2). This time value he records on the computation sheet. Next he sights from the bottom south corner of the triangle at Polaris and sets a small marker on the vertical side of the triangle (the plumb line) at such a position that the south corner, the tip of the marker, and Polaris

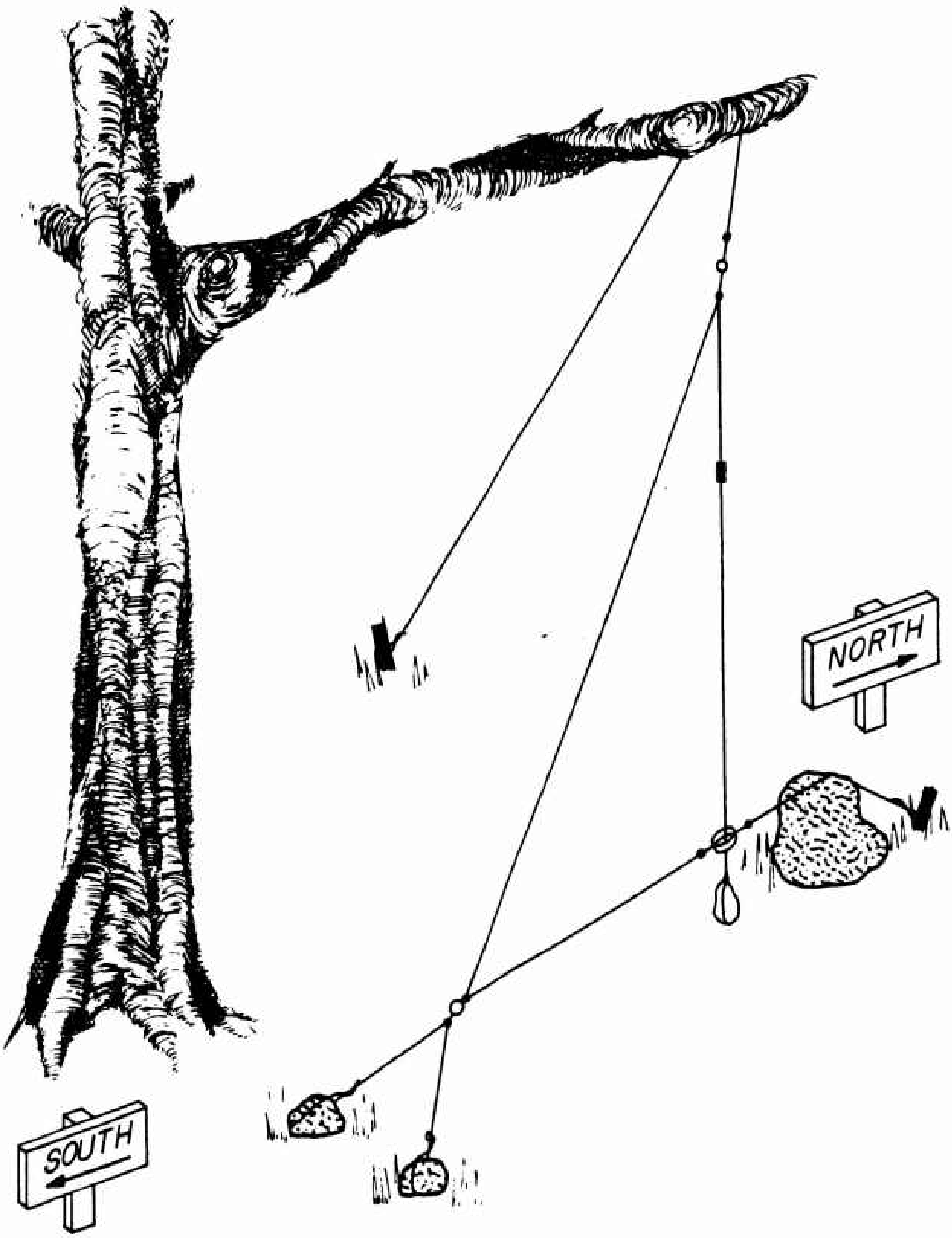

Fig. 1 — General layout of position-finding apparatus

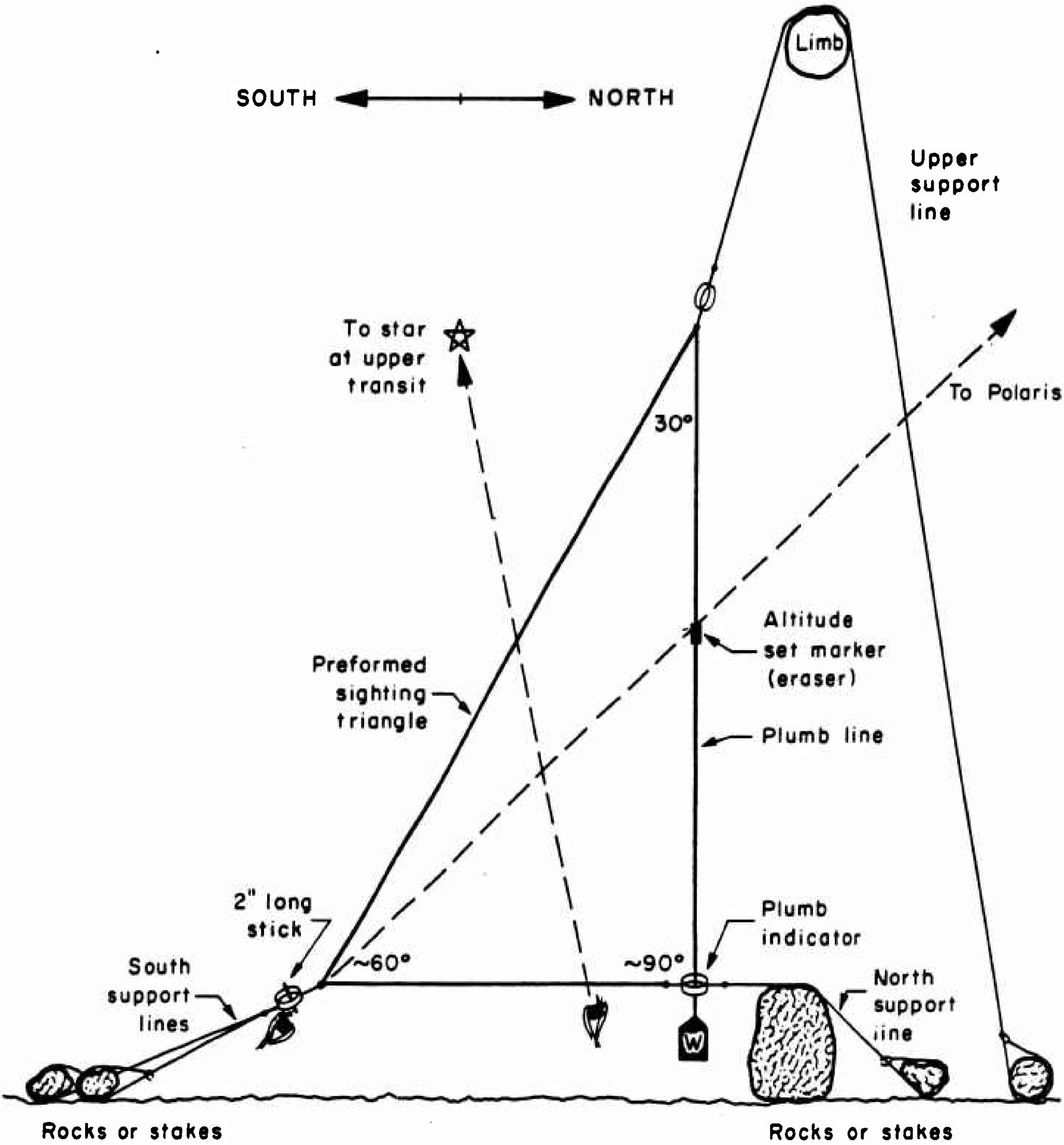

Fig. 2 — Details of sighting triangle

are in a straight line. By placing the tape measure along the plumb line of the triangle, he then measures the altitude of Polaris opposite the tip of the marker and records this value on the computation sheet. Finally, he enters the day, month, year, and transit-star number in the appropriate spaces on the computation form and performs the operations indicated to compute his latitude and longitude.

The combination of preformed triangle and measuring tape actually represents a sort of giant-sized sextant which gives a fairly precise value for the altitude of Polaris. Use of the same triangle to establish a north-south vertical sighting plane allows precise upper-transit timing. Obviously, such a method necessitates waiting until one of the numbered stars passes through upper transit. However, under survival conditions the user is not usually pressed for time.

The computation method has been modified considerably from the usual method one might use in order to minimize the chances for making mistakes. This is an essential requirement for a device to be used mainly by unskilled persons. As a result, the method of solution is not particularly self-evident.

THE SIGHTING TRIANGLE

Construction of the triangle is shown in Fig. 2. The bottom leg is 100 cm long, the hypotenuse 200 cm long, and the vertical side about 173 cm long. Light-weight fishing swivels are used at the corners of the triangle to eliminate twist in the lines. It should be noted that the plumb line passes through the barrel of the bottom swivel, providing a quite sensitive plumb indicator. Tie-down lines are fastened at each corner of the triangle. The same cloth bag which holds the rolled-up triangle in storage is used--when filled with dirt or stones--as the plumb-line weight when the triangle is in use. The triangle, its tie-down lines, and the cloth bag are all permanently fastened together; there are no loose parts to get lost. The sides of the 30-60-90° triangle are made of nylon-covered stainless-steel leader material, since it is essential that the bottom and hypotenuse legs of the triangle do not stretch. Small radio battery clips are attached to the ends of the tie-down lines to facilitate vernier adjustments. The marker on the plumb line can be either another battery clip or, preferably, an ordinary pencil-end eraser threaded on the plumb line during construction of the triangle.

SETTING UP THE TRIANGLE

The triangle is unrolled and laid out on the ground. The upper support line is thrown over a limb and the entire assembly hauled up until the plumb bob hangs about 6 inches off the ground. The upper supporting line is then secured. The auxiliary tie-down lines should be fastened to rocks or stakes and roughly positioned so that the plumb-line side of the triangle is to the north and the double tie-down side to the south. Normally this preliminary work will be done in daylight using the sun or a magnetic compass to determine a rough north.

After nightfall, more precise alignment of the triangle is completed using Polaris. The user sights through the hypotenuse and plumb line and readjusts the positions of the three lower tie-downs until Polaris is in the plane of the triangle, at the same time making sure that the plumb-bob line hangs free within the ring. (When the plane of the triangle is precisely vertical, the plumb-bob line will "float" within the small ring of the swivel at the 90° corner of the triangle.) Next he inserts a 2-inch twig or match stick symmetrically through the ring of the swivel at the south corner of the triangle (Fig. 2), and aligns it so that it is parallel to the line in the sky connecting Polaris and the star at the end of the handle of the Big Dipper (Alkaid). As a final step he readjusts the tie-downs (making sure the plumb line floats freely within the ring), so that Polaris lies directly behind the plumb line when he sights from the Alkaid end of the small stick through the plumb line. The plane of the triangle is now lined up north-south to an accuracy of about 15 minutes of arc, and is aligned vertically to an accuracy of about 3 minutes of arc.

DETERMINING TIME OF UPPER TRANSIT

Sighting through the bottom line and hypotenuse (Fig. 3), the user now compares the sky with his star chart (Fig. 3a) and picks out the numbered star which will next pass through the plane of the triangle from left to right, i.e., east to west. Lying on his back with his eye under the bottom line, he waits until the selected star passes through the plane of his two sighting lines at which moment he reads to the nearest minute his GMT watch time and records this on the computation sheet.

If there is not sufficient local or moonlight illumination of the lines, a small fire built close by will provide such reticle illumination.

DETERMINING ALTITUDE OF POLARIS

Soon after the time determination, the user sights from the south corner of the triangle through the plumb-bob line at Polaris. Because Polaris will not usually be exactly in the plane of the triangle, he sets the twig or match stick horizontal and uses it rather than the corner to sight on Polaris. He then successively adjusts the position of the marker on the plumb-bob line until he can sight from the corner over the tip of the marker and just see Polaris. He next takes the measuring tape and, setting the top index

OPERATING INSTRUCTIONS

Step A: Setting Up Sighting Triangle

1. Use limb or support to hold triangle. Fill bag with dirt or small stones.
2. Adjust line W so C is about one foot off the ground.
3. Fasten lines Y and Z around rocks and place to the south.
4. Set support D to the north. Tie line X around rock.
5. Adjust lines X, Y, and Z so that line BC floats in ring C.
6. Locate North star (Polaris). Adjust X, Y, and Z so that lines BA, BC, and North star are in the same plane.
7. Repeat step 5.
8. Center two-inch stick in hole of swivel at A. Turn stick to make it parallel to line through North star and end star in Dipper handle.
9. Adjust tie-downs so that North star, line BC, and end of stick on Dipper-star side are in a line.
10. Repeat steps 5 and 9 until North star alignment and vertical alignment are both satisfactory.

Step B: Determining Longitude.

1. Lie on your back with your eye under line CA. Sight through lines CA and BA. Using star chart (Fig. 3a), pick a numbered star to the east that will soon pass through the plane of the sighting lines. (Use stars nearly overhead or toward the south, if feasible.)
2. Note GMT of passage of star through the plane of the triangle. Record this time on computation sheet. (It is preferable to have your watch set to GMT; if not, make the necessary correction for the time zone in which your watch was set.)

Step C: Determining Latitude.

1. Lie with your head between tie-down lines Y and Z and sight through point A at North star.
2. Set marker on line BC about in line with A and North star. Repeat steps 1 and 2 until point A, the tip of the marker, and North star are in a line. Set stick horizontal at A and use for sighting if star is off to side of line BC.
3. Using tape, set $35 mark at corner B and read value on tape opposite tip of marker.
4. Record measured value on computation sheet.

(Do Step C within 15 minutes after Step B.)

Step D: Figuring Out Your Position

1. Record on computation sheet the star number, the year, month, and the date at *Greenwich*. Follow the instructions on the computation sheet to get longitude and latitude values in dollars and cents. (The same star number that was used for longitude is also used for the latitude calculation.)
2. After marking your chart in dollars and cents (Step E), plot the longitude and latitude on the chart using the dollars and cents units. From the chart read the latitude and longitude on the printed scales on the edge of the map.

Step E: Marking Your Chart.

1. At every degree line of north latitude, mark a dollars and cents value equal to 60 times the number of degrees, moving the decimal point two places. *Example:* 32°N; 32° × 60 = 1920; mark on 32°N line the value $19.20.
2. At every degree line of west longitude, use same procedure as above. At every degree line of *east* longitude, subtract the longitude degrees from 360°, and using the difference convert, as was done for latitude. *Example:* 121°E; 360° − 121° = 239°; 239° × 60 = 14340; mark on the 121°E longitude line the value $143.40.

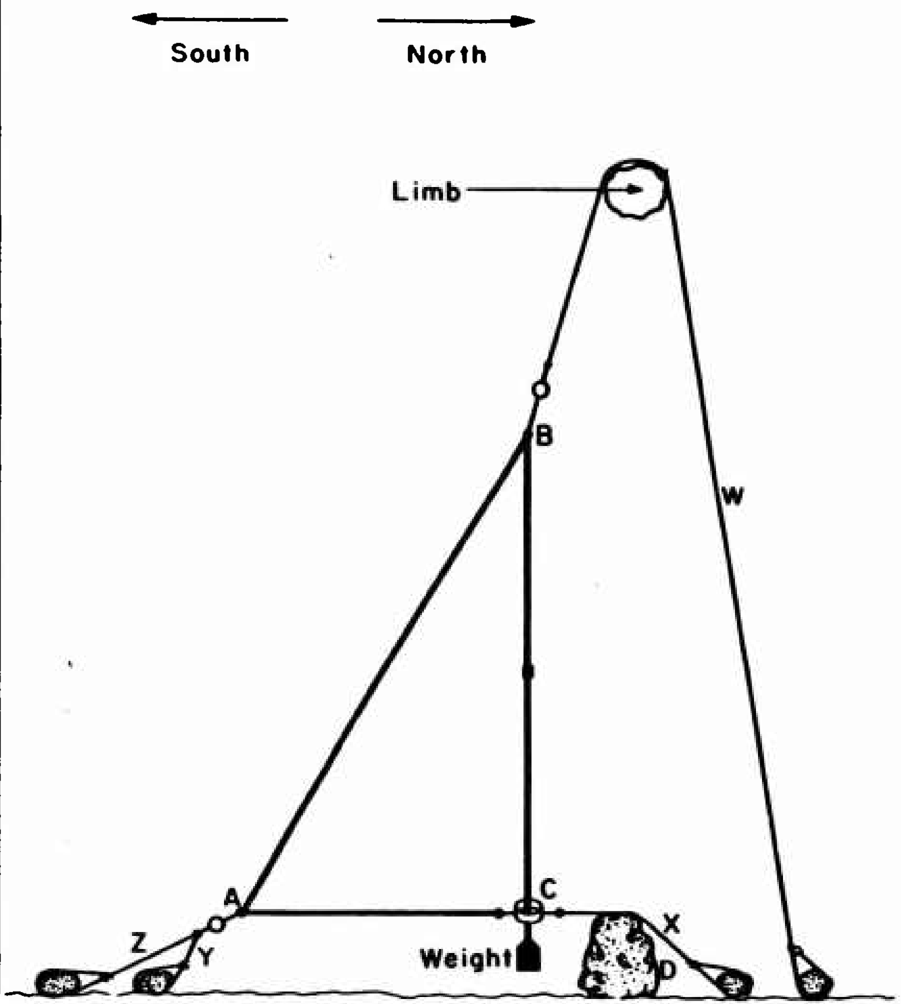

Fig. 3 — Star chart and operating instructions

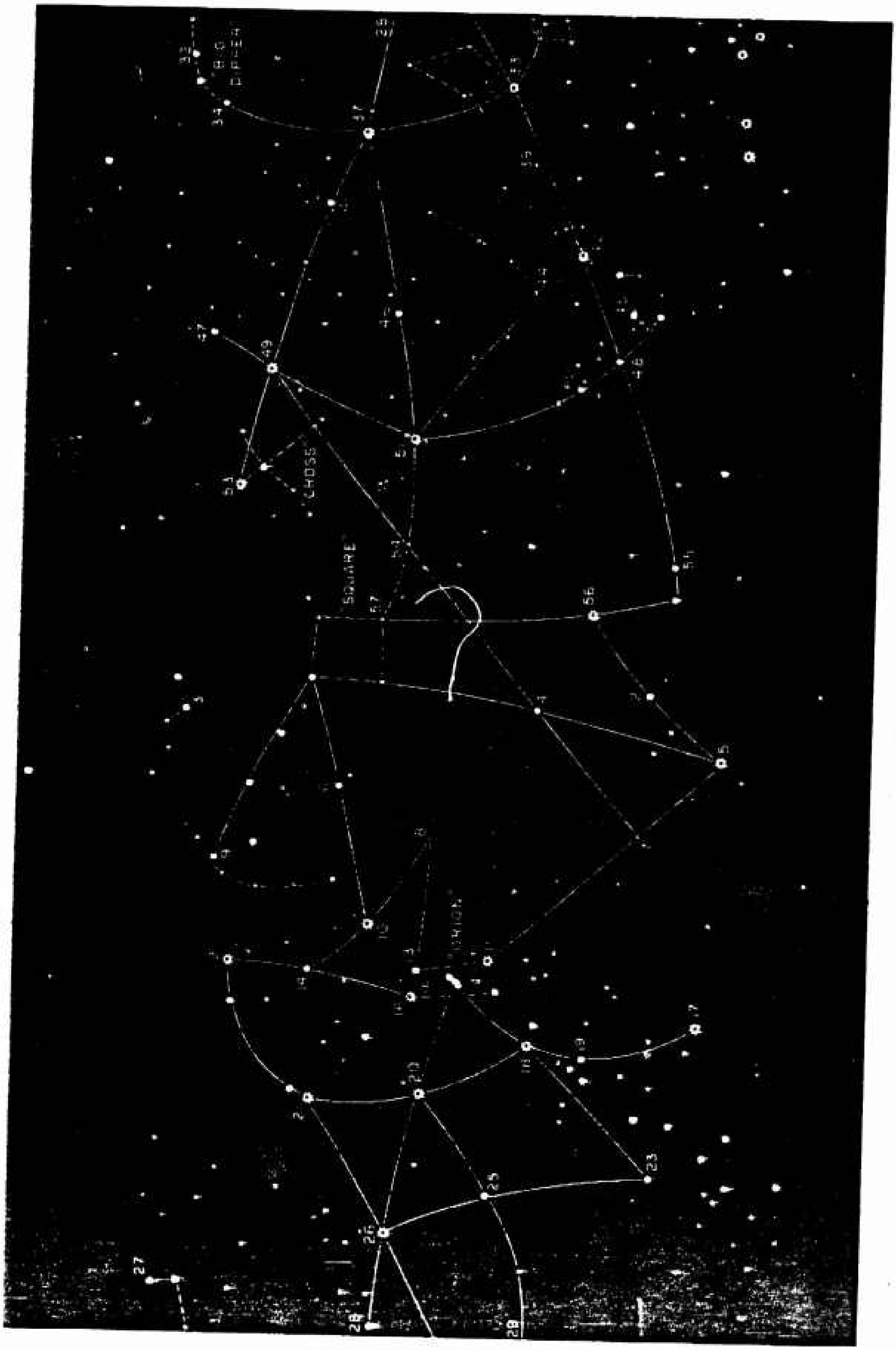

Fig. 3a

mark ($35) of the tape opposite the top corner of the triangle, reads the corresponding value for the altitude of Polaris opposite the tip of the marker. (For reasons to be explained later, this altitude value is in dollars and cents, not degrees and minutes of arc.)

DETERMINING LONGITUDE

The computation performed is:

LONG. OBSERVER = LONG. STAR = GHA ARIES + SHA STAR

The calculation the user makes is a very simple procedure. He has already entered on the computation form the year, month, day of the month, hour and nearest minute of upper-transit GMT time, and star number of the star used. As illustrated in Fig. 4, he now proceeds by selecting and adding the appropriate cash values from each table. After making one simple subtraction, he arrives at his longitude in dollars and cents.

The value for the star used is its SHA, in dollars and cents, at a going rate of one cent per minute of arc. The year, month, day, hour, and minute uniquely define GHA ARIES. The individual values for each of these quantities and their sum are in dollars and cents, again at a rate of a penny per minute of arc.

The reason for using dollars and cents rather than degrees and minutes of arc on the computation form and altitude tape was to eliminate mistakes in angular conversion. While it is difficult to explain minutes-to-degrees conversion to an unskilled person in a few well-chosen words, and equally difficult to explain how to handle angles larger than 360°, almost anyone is well skilled in the equivalent of adding up a grocery bill. Map marking is used to translate both longitude and latitude into degrees and minutes, as will be discussed below.

COMPUTATION SHEET

A. LONGITUDE DETERMINATION

1. Record measured Greenwich star transit time (24 hour clock), Greenwich date, month, year, and number of star used in appropriate blanks at the head of each table

MINUTES ___	
1min—$0 15	31min—$4 66
2min—$0 30	32min—$4 81
3min—$0 45	33min—$4 96
4min—$0.60	34min—$5 11
5min—$0 75	35min—$5.26
6min—$0 90	36min—$5 41
7min—$1 05	37min—$5 57
8min—$1 20	38min—$5 72
9min—$1 35	39min—$5 87
10min—$1 50	40min—$6 02
11min—$1 65	41min—$6 17
12min—$1 80	42min—$6 32
13min—$1 96	43min—$6 47
14min—$2 11	44min—$6 62
15min—$2 26	45min—$6 77
16min—$2 41	46min—$6 92
17min—$2.56	47min—$7 07
18min—$2 71	48min—$7 22
19min—$2.86	49min—$7 37
20min—$3 01	50min—$7 52
21min—$3 16	51min—$7.67
22min—$3 31	52min—$7 82
23min—$3 46	53min—$7 97
24min—$3 61	54min—$8 12
25min—$3 76	55min—$8 27
26min—$3 91	56min—$8 12
27min—$4 06	57min $8 57
28min $4 21	58min $8 72
29min—$4 36	59min—$8 87
30min—$4 51	

HOURS ___
1hr—$ 9 02
2hr—$ 18 05
3hr—$ 27 07
4hr—$ 36 10
5hr—$ 45 12
6hr—$ 54 15
7hr—$ 63 17
8hr—$ 72 20
9hr—$ 81 22
10hr $ 90 25
11hr—$ 99 27
12hr—$108 30
13hr—$117 32
14hr—$126 35
15hr—$135 37
16hr—$144 39
17hr—$153 42
18hr—$162 44
19hr $171 47
20hr—$180 49
21hr—$189 52
22hr—$198 54
23hr—$207 57

DATE			
1st	$0 59	17th	$10 05
2nd	$1 18	18th	$10 65
3rd	$1 77	19th	$11 24
4th	$2 37	20th	$11 83
5th	$2 96	21st	$12 42
6th	$3 55	22nd	$13 01
7th	$4 14	23rd	$13 60
8th	$4 73	24th	$14 19
9th	$5 32	25th	$14 79
10th	$5 91	26th	$15 38
11th	$6 51	27th	$15 97
12th	$7 10	28th	$16 56
13th	$7 69	29th	$17 15
14th	$8 28	30th	$17 74
15th	$8 87	31st	$18 33
16th	$9 46		

MONTH ___
Jan—$ 59 18
Feb—$ 77 51
Mar—$ 94 07
Apr—$112 41
May—$130 15
June $148 48
July—$166 22
Aug—$184 55
Sept—$202 89
Oct—$ 4.63
Nov—$ 22 96
Dec—$ 40 70

YEAR ___	
1957	$0 47
1958	$0 32
1959	$0.17
1960 (Jan Feb)	$0 02
1960 (Mar Dec)	$0.61
1961	$0 45
1962	$0 30
1963	$0 15
1964 (Jan-Feb)	$0 00
1964 (Mar-Dec)	$0 59
1965	$0 43
1966	$0.28

	Dollars	Cents
Minutes	$	
Hours	$	
Date	$	
Month	$	
Year	$	
Star	$	
	$	(W)
	$	(X)

STAR USED #		
# 1—$215 06	#19—$153 44	#41—$76 06
# 3—$210 27	#20—$147 42	#42—$67 06
# 4—$209 77	#21—$146 57	#44—$61 79
# 6—$197 27	#25—$131 16	#45—$58 37
# 7—$189 19	#26—$125 07	#46—$58 01
# 8—$188	#27—$116.81	#47—$54 65
# 9—$185 79	#28—$109.05	#48—$50 78
#10—$171 96	#29—$105 94	#49—$48 67
#12—$168 95	#32—$100 16	#50—$46 09
#13—$167 56	#33—$ 95 54	#51—$37 68
#14—$167 44	#34—$ 92 11	#53—$30 00
#15—$165 88	#36—$ 89 36	#54—$20 67
#16—$163 05	#37—$ 87 93	#56—$ 9 69
#18—$155 50	#39—$ 82 71	#57—$ 8 59

2. Select corresponding cash values from each table, enter in columns, and ADD the six values
3. At (X) enter $000, $216, $432, or $648, whichever is next smaller than (W)
4. SUBTRACT (X) from (W) THIS IS YOUR LONGITUDE (east-west position)

$ ______.______

B. LATITUDE DETERMINATION

1. At (Y) record tape-measure cash value which is the altitude of the North Star
2. From North Star Correction table at right select cash value for the same numbered star that was used to determine longitude, enter at (Z)
3. ADD (Y) and (Z) THIS IS YOUR LATITUDE (north south position)

Dollars	Cents	
$		(Y)
$		(Z)

$ ______.______

NORTH STAR CORRECTION		
—$0	#19—$0 86	#41—$1 51
# 3—$0 48	#20—$0 96	#42—$1 44
# 4—$0,47	#21—$0 97	#44—$1 37
# 6—$0 45	#25—$1 22	#45—$1.33
# 7—$0 46	#26—$1 31	#46—$1 33
# 8—$0 47	#27—$1 40	#47—$1 28
# 9—$0 48	#28—$1 47	#48—$1 23
#10—$0 57	#29—$1 50	#49—$1 20
#12—$0 64	#32—$1 53	#50—$1 16
#13—$0 66	#33—$1.55	#51—$1.02
#14—$0 66	#34—$1 55	#53—$0 90
#15—$0 68	#36—$1 55	#54—$0 75
#16—$0.72	#37—$1.55	#56—$0 61
#18 $0 83	#39—$1.54	#57—$0 60

Fig. 4 — Computation sheet

The computation tables should be good for about ten years, after which time another set of tables will be necessary since the non-time-proportional variation in the SHA of the various stars will have accumulated to something like 5 to 10 minutes of arc. Year values on the computation sheet include a correction of 1' per year average shift in the SHA values.

DETERMINING LATITUDE

The value for the altitude of Polaris has already been entered in the computation form. Taking the star number used for longitude determination (which is equivalent to defining LHA ARIES), the user extracts the corresponding correction from the table given and adds it to the measured altitude of Polaris to determine latitude in dollars and cents.

In order to avoid possible mistakes in the sign of the correction (Q-value), the measuring tape is calibrated 100 cents (100 minutes of arc) too low. The table of corrections is 100 cents (100 minutes of arc) higher than the standard Q-values. This subterfuge allows the simplicity of always adding the altitude correction.

MAP MARKING

At this point it is pertinent to discuss the use of the position data we have obtained. For some purposes, it might be adequate simply to know one's position in dollars and cents; for example, if a special map were available already marked with longitude and latitude in monetary values. However, without such a special map it is necessary for the user to mark his conventional map with the appropriate monetary values.

This can easily be done by marking every integral degree line of north latitude and west longitude with a dollars and cents value equal to 60 times the number of degrees divided by 100. For example 32°N becomes:

$32^{\circ} \times 60 = 1920 \div 100 = \$19.20$.

To determine the dollars and cents values for integral degree lines of east longitude, subtract the number of degrees from 360°, multiply the difference by 60, and divide by 100. For example 121°E converts as follows: $360^\circ - 121^\circ = 239^\circ \times 60 = 14340 \div 100 =$ \$143.40, the cash value to be marked on the chart at 121°E longitude.

SPECIAL FEATURES AND ACCURACY

From the discussion so far it is evident that the design of this position-locating system meets certain desirable field requirements. The equipment required is light in weight, of small size, low cost, sturdy, and will not deteriorate in storage.

Cost of the material needed for the kit is quite low. Enough raw material to make several kits can be purchased from local retail stores (i.e., nylon leader line, swivels, 8-mm photographic leader material, small radio battery clips, and Bull Durham sacks) for about \$2.

The simplest method of constructing a kit is to make an altitude-measuring tape first, using the data in Table 1, and then lay out the triangle from tape dimensions. The bottom leg of the triangle -- from the center of the bottom swivel to the 60° corner -- is made equal to the distance between the -\$1 mark and the \$26 mark. (These are the equivalent 0 and 45° marks. The distance is 100 cm.) The hypotenuse leg is made to equal twice this distance. The plumb-line length is not critical and should be about the same as the hypotenuse.

The dimensional stability of the sighting triangle and measuring tape is excellent. In an earlier preliminary design where ordinary monofilament nylon line was used, a slow unsymmetrical stretch of the triangle resulted in a gradual drift of the latitude values obtained. Changing to nylon-covered stainless-steel leader material eliminated this problem.

Table 1

CALIBRATION DATA FOR ALTITUDE-MEASURING TAPE

Distance	Marking	Distance	Marking	Distance	Marking	Distance	Marking
0.00cm	-$1	27.42cm	$8.20	58.51cm	$17.20	101.17cm	$26.20
.58cm	-$0.80	28.05cm	$8.40	59.30cm	$17.40	102.35cm	$26.40
1.16cm	-$0.60	28.67cm	$8.60	60.09cm	$17.60	103.55cm	$26.60
1.75cm	-$0.40	29.30cm	$8.80	60.88cm	$17.80	104.77cm	$26.80
2.33cm	-$0.20	29.94cm	$9	61.68cm	$18	105.99cm	$27
2.91cm	$0	30.57cm	$9.20	62.49cm	$18.20	107.24cm	$27.20
3.49cm	$0.20	31.21cm	$9.40	63.30cm	$18.40	108.50cm	$27.40
4.07cm	$0.40	31.85cm	$9.60	64.12cm	$18.60	109.77cm	$27.60
4.66cm	$0.60	32.49cm	$9.80	64.94cm	$18.80	111.06cm	$27.80
5.24cm	$0.80	33.14cm	$10	65.77cm	$19	112.37cm	$28
5.82cm	$1	33.78cm	$10.20	66.61cm	$19.20	113.69cm	$28.20
6.41cm	$1.20	34.43cm	$10.40	67.45cm	$19.40	115.04cm	$28.40
6.99cm	$1.40	35.08cm	$10.60	68.30cm	$19.60	116.40cm	$28.60
7.58cm	$1.60	35.74cm	$10.80	69.16cm	$19.80	117.78cm	$28.80
8.16cm	$1.80	36.40cm	$11	70.02cm	$20	119.18cm	$29
8.75cm	$2	37.06cm	$11.20	70.89cm	$20.20	120.59cm	$29.20
9.33cm	$2.20	37.72cm	$11.40	71.77cm	$20.40	122.03cm	$29.40
9.92cm	$2.40	38.39cm	$11.60	72.65cm	$20.60	123.49cm	$29.60
10.51cm	$2.60	39.06cm	$11.80	73.55cm	$20.80	124.97cm	$29.80
11.10cm	$2.80	39.73cm	$12	74.45cm	$21	126.47cm	$30
11.69cm	$3	40.40cm	$12.20	75.35cm	$21.20	127.99cm	$30.20
12.28cm	$3.20	41.08cm	$12.40	76.27cm	$21.40	129.54cm	$30.40
12.87cm	$3.40	41.76cm	$12.60	77.19cm	$21.60	131.11cm	$30.60
13.46cm	$3.60	42.45cm	$12.80	78.13cm	$21.80	132.70cm	$30.80
14.05cm	$3.80	43.14cm	$13	79.07cm	$22	134.32cm	$31
14.65cm	$4	43.83cm	$13.20	80.02cm	$22.20	135.97cm	$31.20
15.24cm	$4.20	44.52cm	$13.40	80.98cm	$22.40	137.64cm	$31.40
15.84cm	$4.40	45.22cm	$13.60	81.95cm	$22.60	139.34cm	$31.60
16.43cm	$4.60	45.92cm	$13.80	82.92cm	$22.80	141.06cm	$31.80
17.03cm	$4.80	46.63cm	$14	83.91cm	$23	142.81cm	$32
17.63cm	$5	47.34cm	$14.20	84.91cm	$23.20	144.60cm	$32.20
18.23cm	$5.20	48.06cm	$14.40	85.91cm	$23.40	146.41cm	$32.40
18.83cm	$5.40	48.77cm	$14.60	86.93cm	$23.60	148.26cm	$32.60
19.44cm	$5.60	49.50cm	$14.80	87.96cm	$23.80	150.13cm	$32.80
20.04cm	$5.80	50.22cm	$15	88.99cm	$24	152.04cm	$33
20.65cm	$6	50.95cm	$15.20	90.04cm	$24.20	153.99cm	$33.20
21.26cm	$6.20	51.69cm	$15.40	91.10cm	$24.40	155.97cm	$33.40
21.86cm	$6.40	52.43cm	$15.60	92.17cm	$24.60	157.98cm	$33.60
22.47cm	$6.60	53.17cm	$15.80	93.25cm	$24.80	160.03cm	$33.80
23.09cm	$6.80	53.92cm	$16	94.34cm	$25	162.12cm	$34
23.70cm	$7	54.67cm	$16.20	95.45cm	$25.20	164.26cm	$34.20
24.32cm	$7.20	55.43cm	$16.40	96.57cm	$25.40	166.43cm	$34.40
24.93cm	$7.40	56.19cm	$16.60	97.70cm	$25.60	168.64cm	$34.60
25.55cm	$7.60	56.96cm	$16.80	98.84cm	$25.80	170.90cm	$34.80
26.17cm	$7.80	57.73cm	$17	100.00cm	$26	173.21cm	$35
26.80cm	$8						

A good vertical is necessary for a system of this kind. Fortunately, getting the sighting plane quite precisely vertical is easy to do. The geometry of the triangle and the plumb ring is such that the maximum vertical error (if the plumb line is just grazing the edge of the ring) is about 6 minutes of arc. It is not possible to get the north-south alignment to this accuracy, but an extremely accurate north-south alignment is not necessary if the stars used are at a reasonable altitude, as will usually be the case. In general, error sources giving errors less than 5' have been ignored.

The system works well in windy environments. The triangle lines are so light and small that wind drag has a negligible effect if one precaution is taken. When the wind is blowing the cloth bag used as a plumb-bob weight must be protected. This can be done by setting a helmet liner or equivalent around the bag, or by digging a hole in which the bag is sheltered from the wind.

In the models used to date, the maximum north latitude at which latitude measurement has been possible is 60°. Should it be desirable to have the system operate at higher latitudes than this, another eraser can be added on the bottom line for sighting through the top corner of the triangle, and a 60 to 90° scale constructed on the back of the present tape to allow latitude measurement in the range from 60 to 90°N. While north-south alignment errors increase at these higher latitudes, the closer mileage spacing of longitude lines tends to offset this and accuracy should still be quite adequate.

The star chart used is a modification of the chart in the Air Almanac. All coordinates, constellation lines and names, star names, and the ecliptic have been eliminated. Only the star numbers of those stars used are retained.

A "pointer" system to aid the unskilled user in reliably finding the desired stars has been added. Emphasis is placed on the Big Dipper, Orion, Square of Pegasus, and Northern Cross as starting points for finding other stars by the built-in pointer system.

It has been found that the main factor limiting the accuracy of this system is the precision of the user's watch. In practice, the accuracy of longitude data generally has averaged within 10 to 15 miles of actual position, while latitude accuracy has been about 5 miles. These accuracy figures refer to single measurements; some improvement is obtained by averaging successive star timing and altitude measurements.

The fact that the user is able to place his eye close to the lower line of the triangle is of distinct advantage when sighting to determine time of upper transit. By doing so, the lower line blurs out of focus and it is possible to place the distinct hypotenuse line directly in the middle of the blurred image of the closer bottom line, thus achieving a relatively high degree of pointing accuracy.

It was found necessary in using the measuring tape to index at the top of the triangle -- the equivalent 60° mark. This is because the right-angle corner of the triangle is usually not exactly a right angle, since there is no way available under the primitive conditions of use to set the bottom side of the triangle accurately horizontal. Indexing from the top side-steps any problem here; small variations of the bottom leg from the horizontal have a trivial effect on the accuracy of the altitude angle read off.

Use of the method is restricted to the Northern Hemisphere since there appears to be no easy way of measuring latitude in the Southern Hemisphere.

IN CONCLUSION

This method of position finding was field-tested by Colonel Perrin and the author and subsequently given a fairly thorough testing at the USAF Survival School, Stead AFB. A training movie was made at Stead which discusses the method and shows the procedure for setting up the sighting triangle.

Of possible interest to navigators in general is the following rule of thumb tried during development of this equipment but which turned out not to be practical for unskilled persons. If one knows GHA ARIES for 0000 GMT, 0 January of any year (31 December of the previous year), then the GHA ARIES for 0000 GMT on any day of that year may be found simply by adding 1° per day of the year to this value, subtracting 1' for each day, and adding 1' per week. Adding 2.5' per hour plus 15° per hour plus 15' per minute will then give the desired GHA ARIES for any shot time without the necessity of recourse to an almanac. The resulting answer has been within 1' of the almanac value for all cases tried. This information, along with a list of star coordinates, printed on a wallet-size card could be of real utility on those rare occasions when an almanac turns up missing.