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Research Product 86-31

# A Self-Correcting Compass Course for Training Dead Reckoning

ARI Field Unit at Fort Benning, Georgia  
Training Research Laboratory

October 1986

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U. S. Army Research Institute for the Behavioral and Social Sciences

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)  Dead reckoning involves navigating by distance (pace count) and direc- tion (compass azimuth). The purpose of this paper is to describe a self- correcting compass course designed to train this skill. Additionally, a computer program has been written that can be used to generate the azimuth and distance for each leg of the course, facilitating course set up. The compass course can be easily modified to work in any training area to assist (continued)		

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20. (Continued)

and reinforce training on dead reckoning. Similar courses have been used by the Rangers and Special Forces to increase soldiers' confidence in their navigational abilities. Advantages of the new course include its self-correcting aspect and the fact that the soldier is forced into using an accurate pace count.

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## **A Self-Correcting Compass Course for Training Dead Reckoning**

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Training Land Navigation

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## FOREWORD

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As part of the U.S. Army land navigation training, every soldier learns to use a compass and measure distance using a pace count. This form of navigation is called dead reckoning. Although dead reckoning is an important navigational technique, effective means for developing azimuth and distance determination skills are lacking.

In response to this problem, the Army Research Institute, in cooperation with the U.S. Army Infantry Center at Fort Benning, Georgia, developed a self-correcting compass course, which can be used in a parking lot or in a field and which is designed to test a soldier's ability to use a compass and pace count. An accompanying computer program that enables the instructor to specify training area dimensions and that provides randomly generated azimuths and distances for the course set-up was written.



EDGAR M. JOHNSON  
Technical Director

# A SELF-CORRECTING COMPASS COURSE FOR TRAINING DEAD RECKONING

## EXECUTIVE SUMMARY

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### Requirement:

All soldiers need to know how to use a compass and to determine distance using a pace count. However, there is currently a lack of effective means to train these dead-reckoning skills. In response to this need, a compass course that can be set up quickly, provide detailed error information, allow varying number of soldiers to train simultaneously, and be used in a variety of training areas was developed.

### Procedure:

A compass course was set up so that the outline of stakes formed two concentric rectangles. The use of concentric rectangles forced the navigator to use both azimuth and distance, the two components of dead reckoning. A computer program was written so instructors could specify course dimensions; the azimuth and distance for each leg of the course can be generated to facilitate course set-up.

### Findings:

The self-correcting compass course offers opportunities for dead reckoning and land navigation training enhancement. The training advantages to this course are that it can be used in areas of limited size, that soldiers are in an easily controlled area, and that errors are self-correcting.

### Utilization of Findings:

The self-correcting compass course is designed for use in both unit and institutional settings and can be used to improve dead reckoning skills. The computer program allows the trainer to specify course dimensions to accommodate virtually any training area. In addition to facilitating course set-up, the computer-generated azimuth and distance information allows for the detection and correction of soldiers' errors during dead reckoning training.

A SELF-CORRECTING COMPASS COURSE FOR TRAINING DEAD RECKONING

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## A SELF-CORRECTING COMPASS COURSE FOR TRAINING DEAD RECKONING

### INTRODUCTION

Move, shoot and communicate is every soldier's mission. However, teaching the soldier to navigate accurately and effectively can be a trainer's nightmare. This is especially true when personnel at city-based Reserve Officers' Training Corps (ROTC) and Reserve components are required to teach and practice navigational techniques where training areas and/or the terrain may be limited.

Dead reckoning is the ability to navigate by following an azimuth and using a pace count. It is an easily taught land navigation skill that is useful in dense terrain, such as jungles, as well as in low-visibility conditions. Ranger and Special Forces cadre use a compass course to increase soldiers' skills and confidence in dead reckoning. For example, if a soldier training to be a Ranger receives a NO GO on land navigation, he is required to receive additional dead reckoning training.

One course is embedded in an overgrown wooded area. The course consists of engineer stakes marked with numbers, placed in the ground in a rectangular pattern. The stakes are approximately 7.62 meters apart with the overall dimension of the course approximately 38.10 meters by 68.58 meters. Each soldier is given a series of azimuths and corresponding distances and is required to move from one point to another, recording the stake number as he goes. Upon finding the required number of stakes (3 to 10), he returns to the instructor for feedback on his performance.

This type of compass course provides an effective means for evaluating a soldier's ability to follow an azimuth. However, the use of only a single rectangular array of stakes does not provide for the evaluation of both dead reckoning skills, that is, following both an azimuth and pace count. Additionally, scoring is a problem. The soldier is given all azimuths and corresponding distances prior to navigating the course. Thus if the soldier makes an error on an initial leg, then subsequent legs also will be in error.

There are at least two ways in which this course can be improved. First, to evaluate pace count, a concentric rectangle of stakes is required. This second rectangle of stakes forces the navigator to discriminate distance between two stakes along the same azimuth. The second way to improve the course is to rectify the scoring problem. This can be done by making the course self correcting. In other words, instead of giving the soldier all azimuths and corresponding distances prior to navigating the course, he is given a starting stake, from there, a new azimuth and distance is provided at each successive stake.

### SELF-CORRECTING COMPASS COURSE

On an open parade ground, 200 meters by 260 meters, stakes (numbered tent pegs) were laid flush to the ground so that the soldier could not sight on the stakes. The distance between stakes was 20 meters. An inner rectangle of

stakes was added. The inner rectangle required the soldier to use both azimuth and pace count to determine the correct stake number. For example, if the target stake was a stake in the inner rectangle, but the soldier's pace count was long, he would end up between the inner and outer rectangle. Therefore, he must attend more closely to his pace, or adjust his 100 meter pace count for that terrain. Thus, a soldier's error was detected if he strayed to the left or right, or was long or short of the intended goal. Figure 1 represents the course layout.

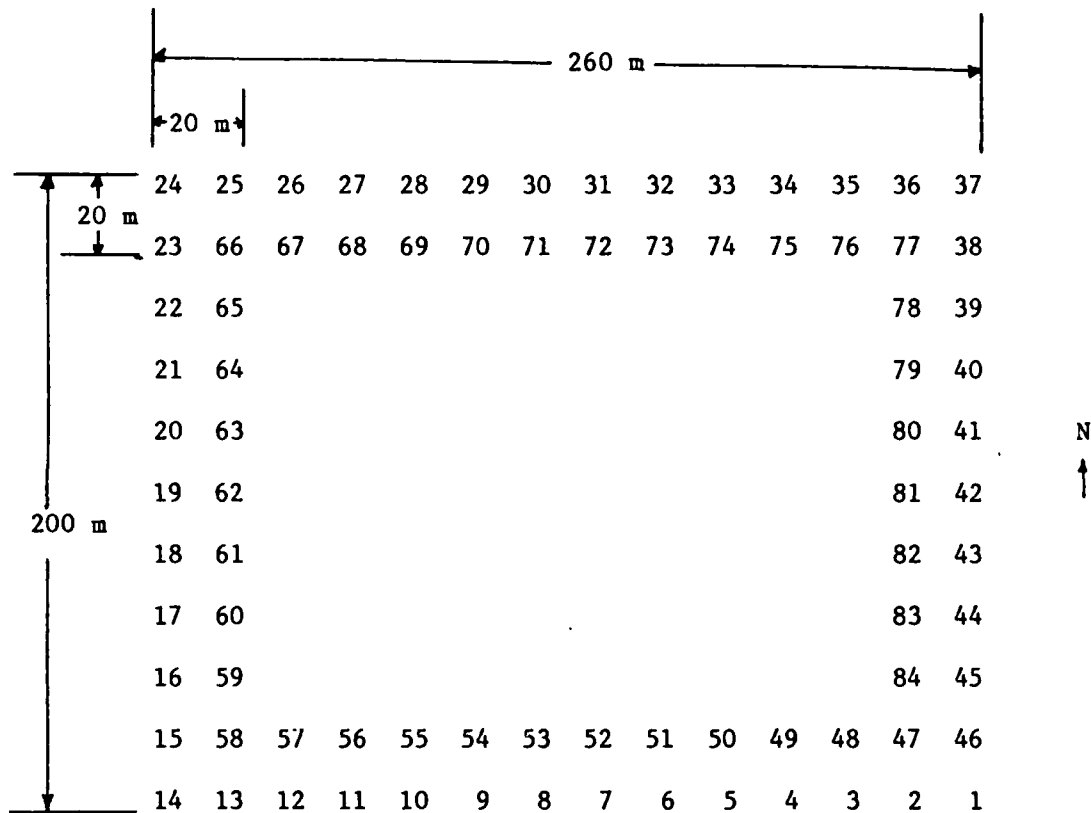


Figure 1. Self-Correcting Compass Course

To begin the field exercise, the soldier received a starting stake (1, 2, 3, . . . 84) and lane identifier (A, B, C, . . . J). From this point, he checked his lane identifier (e.g., 1A) to determine his required azimuth and distance. After traversing the distance, he marked the stake number on his score sheet.

He recorded his next azimuth and distance, which were posted on the stake, based on his original starting lane letter. The following would be located at Stake #1.

Lane	A	B	C	D	. . . . .	J
Stake 1	AZ 333	305	329	312		321
	DIST 224	316	233	297		256

The course was designed to be self-correcting. For example, if the soldier went to an incorrect stake, he was given an azimuth and distance based on that stake. Upon returning to the scoring/instructor area, his errors (short/long pace or left/right drift) were identified. In the example below, a soldier was assigned to 1A and was required to find four stakes.

Route		Starting Stake #1
	AZ 333	Lane A
	DIST 224	Correct Stake #32
	AZ 158	Correct Stake #2
	DIST 215	
	AZ 309	Correct Stake #24
	DIST 312	
	AZ 94	Correct Stake #38
	DIST 261	

However, if on the first leg and each successive leg, the soldier drifted to his right, then his route resulted in the following course:

Route		Starting Stake #1
	AZ 333	Correct Stake #32
	DIST 224	Went to #33
	AZ 174	Correct Stake #4
	DIST 201	Went to #5
	AZ 294	Correct Stake #18
	DIST 197	Went to #19
	AZ 114	Correct Stake #3
	DIST 224	Went to #4

After outlining the intended course versus the actual course (see Figure 2), the instructor's feedback on this soldier's performance was that he continually drifted to the right and must compensate for this drift. The instructor also emphasized that this error would become much worse over extended distances.

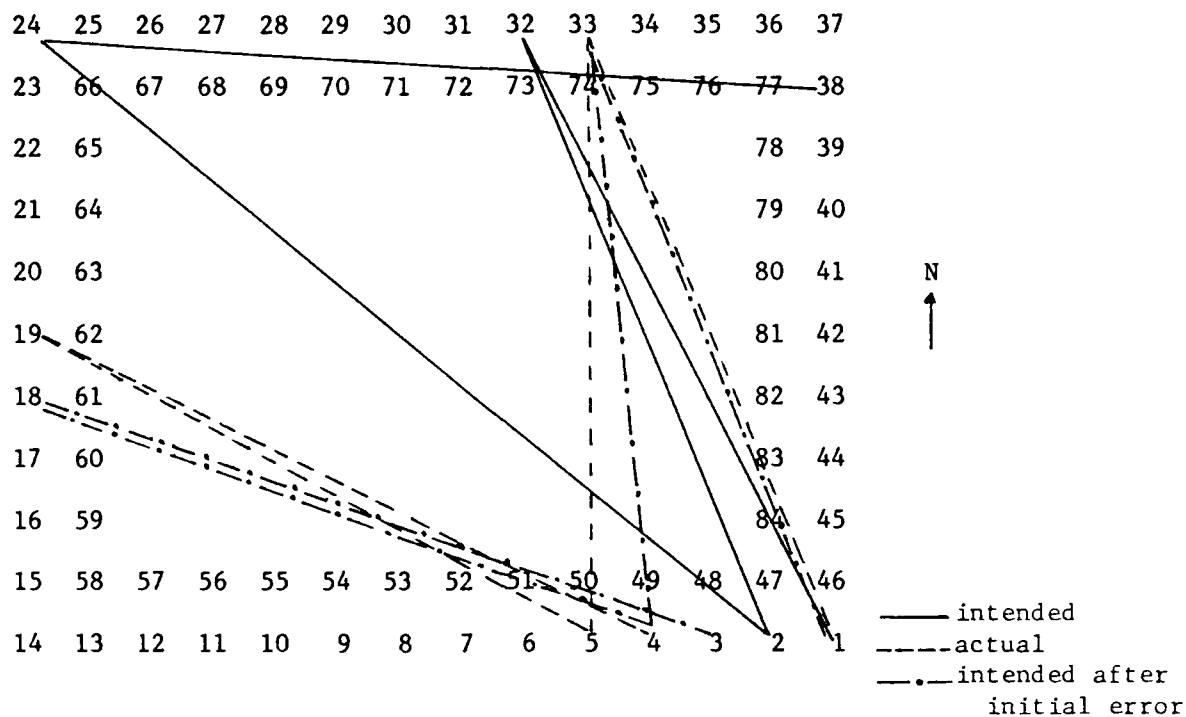


Figure 2. Intended and Actual Routes

#### COMPUTER PROGRAM

This course could be initiated easily and used in any training area. The following is a "flowchart" for the computer program:

1. Dimension Navigational Course matrix, Path Number matrix, Distance array, Azimuth array and "Its's Chosen" array.
2. Initialize variables
3. Ask to output to Console or Printer. Open device accordingly.
4. Get navigational course information.
5. Set up navigational course matrix and print it.
6. Get starting stake number and find coordinates (x1,y1).
7. Set error value to 0. Get proposed path stake number and find coordinates (x2,y2).
8. Find distance and azimuth.
9. Check stake number, distance and azimuth for errors. Set error value.
10. If error value is 1 then go to 7.

11. Set stake number in "its's chosen" array.
12. If more paths then go to 7.
13. Print distance and azimuth for paths per starting stake number.
14. Clear "it's chosen" array.
15. If more starting stake numbers then go to 6.
16. Print chosen stake number for paths per starting stake number.
17. END.

A computer program, written in Basic (see Appendix A), was used to generate the azimuth and distances for the compass course (see Appendixes B and C for azimuths/distances and correct stakes, respectively). Refer to Appendix D for course layout, equipment, instructions, and scoring procedures.

## APPENDIX A

## BASIC SELF-CORRECTING COMPASS COURSE

```

001 Rem Land Navigation Program
002 Rem Self Correcting Compass Course
003 Rem Written by William H. Greene
004 Rem
005 Dim nc$(20,20), pn%(20,400), ds%(20), az%(20), ic%(400)
006 for y = 1 to 20: for x = 1 to 20: nc$(x,y)="" : next x: next y:
    c$ = chr$(147): ch$ = chr$(19)
007 print c$;"Do you want output to": print "(p)rinter": print:
    print "(c)onsole": d = 4
008 input a$: if a$ = "c" then d = 3
009 Rem
010 Rem Main Program Logic
011 open 4, d, 7: print #4, c$;: gosub 100: gosub 200: poke 53280, 0:
    poke 53281, 0
012 print #4, ch$; c$;: for s = 1 to ns: z = s: gosub 300: xl = x: yl = y
013 for p = 1 to np: er = 0
014 pn%(p,s) = int(rnd(1) * (ns) + 1): if pn%(p,s) = s then 14
015 z = pn%(p,s): gosub 300: x2 = x: y2 = y: gosub 400: gosub 500:
    if er <> 0 then er = 0: goto 14
016 ic%(pn%(p,s)) = 1: next p: sl = 1: gosub 600: for a = 1 to ns:
    ic%(a) = 0: next a: next s
017 print #4, ch$; c$;: sl = 4: gosub 700: print #4, ch$;: close 4: end
018 Rem
099 Rem Navigational Course Setup
100 input "enter number of stakes east-west"; e: if e > 20 then gosub 120:
    goto 100
101 input "enter number of stakes north-south"; n: if n > 20 then gosub 120:
    goto 101
102 input "enter number of paths"; np: if np > 20 then gosub 120: goto 102
103 input "double rows-columns(1-n / 2-y)"; rc: if rc < 1 or rc > 2 then 103
104 input "enter distance between stakes"; ud
105 input "enter minimum path distance"; mp: if mp < 1 then goto 105
106 ns = (e * n) - ((e - rc * 2) * (n - rc * 2))
107 ne = (e - 1) * ud: nn = (n - 1) * ud
108 print #4, " your course is"; e; "stakes east-west and"
109 print #4, n; "stakes north-south. You will have"
110 print #4, ns; "stakes with"; ud; "meters between each."
111 print #4, " The size of your course is"; ne; "meters"
112 print #4, " east-west by"; nn; "meters north-south.": print #4, np;
113 print #4, "Paths will be plotted from each"
114 print #4, " stake. The minimum path distance is": print #4, mp; "meters."
116 t$ = "": for i = 1 to e: t$ = t$ + " ": next i
117 print #4: print #4, t$; " N": print #4, t$; "W + E": print #4, t$; " S":
    print# 4
119 return
120 print "must be less than 20": for i = 1 to 2000: next: return
198 Rem
199 Rem Setup stake# to nc$-location

```

```

200 print #4: sn = 1: for y = 1 to rc: for x = 1 to e: nc$(x,y) = str$(sn):
    sn = sn + 1: next x: next y
202 for y = (rc + 1) to (n - rc): for x = 1 to rc: nc$(x,y) = str$(sn):
    sn = sn + 1: next x
203 for x = (e + 1 - rc) to e: nc$(x,y) = str$(sn): sn = sn + 1: next x:
    next y
204 for y = (n - rc + 1) to n: for x = 1 to e: nc$(x,y) = str$(sn):
    sn = sn + 1: next x: next y
205 ln = len (nc$(e,n)): for y = 1 to n: for x = 1 to 3
206 lc = len (nc$(x,y)): if lc < ln then nc$(x,y) = " " + nc$(x,y):
    goto 206
207 print #4, nc$(x,y);: next x: print #4: next y: return
298 Rem
299 Rem Find x,y coordinates of stake#
300 for y = 1 to n: for x = 1 to e: if z = val (nc$(x,y)) then return
301 next x: next y: er = 1: return
398 Rem
399 Rem Find Distance and Azimuth
400 cx = x1 - x2: cy = y1 - y2: ds%(p) = int(sqr(cx**2 + cy**2) * ud + .5):
    if cx = 0 then er = 1: goto 410
401 az%(p) = int((atn (cy / cx) * 180 / 3.14) + .5)
402 if cx < 0 then az%(p) = 90 + az%(p): goto 410
403 az%(p) = 270 + az%(p)
410 return
498 Rem
499 Rem Error Trapping Routine
500 if er <> 0 then return
501 if x1 = x2 or y1 = y2 then er = 1: return
502 if ds%(p) < mp then er = 1: return
503 if ic%(pn%(p,s)) <> 0 then er = 1: return
504 return
598 Rem
599 Rem Print Routine for Distance and Azimuth
600 if s = 1 or fl = 1 then gosub 800: fl = 0
601 ls$ = "": if s < 100 then ls$ = " ": if s < 10 then ls$ = " "
602 ll = len (str$(s)): s$ = ls$ + mid$(str$(s), 1, ll) + " ds":
    print #4, s$;
603 d$ = "": for p = 1 to np: ls$ = " ": if ds%(p) < 100 then ls$ = " ":
    if ds%(p) < 10 then ls$ = " "
604 d$ = d$ + ls$ + str$(ds%(p)): next p: print #4, d$: d$ = "      az"
605 for p = 1 to np: ls$ = " ": if az%(p) < 100 then ls$ = " ":
    if az%(p) < 10 then ls$ = " "
606 d$ = d$ + ls$ + str$(az%(p)) :next p: print# 4, d$
607 print# 4, hl$: ifs / 19 = int (s / 19) then fl = 1
608 return
698 Rem
699 Rem Print Routine for Chosen Stakes
700 for s = 1 to ns: if s = 1 or fl = 1 then gosub 800: fl = 0
711 ls$ = "": if s < 100 then ls$ = " ": if s < 10 then ls$ = " "
712 ll = len (str$(s)): s$ = ls$ + mid$(str$(s), 1, ll) + " pt":
    print# 4, s$;: d$ = ""

```

```

713 for p = 1 to np: ls$ = " ": if pn%(p,s) < 100 then ls$ = " ":
    if pn%(p,s) < 10 then ls$ = " "
714 d$ = d$ + ls$ + str$(pn%(p,s)): next p: print #4, d$
715 print #4, hl$: if s / 27 = int(s / 27) then fl = 1
716 next s: return
798 Rem
799 Rem Page Header Routine
800 h$ = " ": for l = 1 to np: h$ = h$ + " " + chr$(64 + l): next l
801 ll = len(h$) + 1: hl$ = "": for l = 1 to ll : hl$ = hl$ + "*": next l
802 for lf = 1 to sl : print #4: next lf: print #4, h$: print #4, hl$: return
ready.

```

APPENDIX B

Azimuth & distances for  
200 m by 260 m area

	A	B	C	D	E	F	G	H	I	J
1AZ	333	305	329	312	349	308	354	310	276	321
1DS	224	315	333	297	204	328	201	312	181	256
2AZ	310	329	312	333	315	332	318	343	321	349
2DS	312	235	297	224	283	215	269	209	236	204
3AZ	290	309	329	318	333	321	338	325	343	13
3DS	234	384	233	269	224	256	215	244	209	184
4AZ	281	301	318	333	321	338	325	343	329	349
4DS	204	233	269	224	236	215	244	209	233	204
5AZ	294	303	321	333	325	338	329	343	349	6
5DS	197	223	256	224	244	215	233	209	204	201
6AZ	311	313	329	343	321	349	325	354	17	29
6DS	213	241	233	209	255	204	244	201	209	206
7AZ	319	322	329	322	349	325	354	343	17	6
7DS	213	223	233	224	204	244	201	209	209	201
8AZ	319	322	333	349	326	343	338	6	17	354
8DS	134	333	224	304	215	209	215	201	209	201
9AZ	331	323	338	333	343	354	349	17	11	6
9DS	206	189	215	224	209	201	204	209	204	201
10AZ	333	343	17	336	354	349	31	11	6	429
10DS	215	209	209	197	201	204	233	204	201	269
11AZ	349	342	343	354	6	17	11	22	31	27
11DS	204	190	209	201	201	209	204	215	233	224
12AZ	347	354	17	31	349	6	11	27	42	51
12DS	134	201	209	233	204	201	204	224	269	284
13AZ	354	354	6	17	11	22	31	27	35	42
13DS	131	201	201	209	204	215	233	224	244	269
14AZ	9	11	27	17	31	22	35	39	48	42
14DS	201	204	224	209	233	215	244	256	297	269

	A	B	C	D	E	F	G	H	I	J
15AZ	191	197	134	13	12	36	33	43	42	51
DS	197	197	134	203	190	216	228	269	241	284
16AZ	39	37	32	41	48	45	51	56	54	58
DS	245	200	139	213	241	226	256	283	272	305
17AZ	108	45	41	49	55	52	58	62	60	65
DS	190	193	184	213	244	223	261	295	278	293
18AZ	49	59	107	55	108	77	110	103	107	56
DS	134	233	272	296	353	267	334	267	209	216
19AZ	114	53	122	61	63	69	111	81	113	94
DS	242	183	139	205	224	279	279	263	260	261
20AZ	70	124	66	115	77	121	72	127	103	81
DS	234	215	197	236	267	233	253	200	267	263
21AZ	75	131	72	120	81	128	76	118	94	125
DS	226	215	190	275	263	223	247	293	261	244
22AZ	50	139	77	126	86	135	148	132	143	139
DS	224	213	134	272	261	226	189	241	200	250
23AZ	34	133	55	151	167	155	162	132	156	129
DS	131	241	231	206	134	255	190	269	197	284
24AZ	94	163	153	163	149	158	145	99	141	107
DS	261	204	224	209	233	215	244	263	256	272
25AZ	156	145	186	141	104	153	149	153	174	130
DS	161	244	201	256	247	215	233	224	201	312
26AZ	95	162	153	193	135	191	132	136	149	100
DS	211	207	239	194	233	204	297	201	233	224
27AZ	197	143	191	145	186	141	96	153	169	133
DS	209	223	204	244	201	256	201	224	204	269
28AZ	96	162	174	163	136	145	197	108	158	149
DS	161	264	201	262	201	244	209	190	215	233

	A	P	C	D	E	F	G	H	I	J
**29AZ	**207	**193	**202	**143	**177	**141	**191	**163	**153	**159
**29DS	**224	**233	**215	**244	**239	**255	**204	**209	**224	**215
**30AZ	**202	**159	**137	**153	**171	**149	**136	**145	**211	**214
**30DS	**215	**213	**209	**224	**204	**233	**201	**244	**233	**216
**31AZ	**149	**212	**174	**197	**153	**191	**167	**169	**159	**211
**31DS	**233	**244	**201	**209	**224	**204	**209	**204	**215	**233
**32AZ	**152	**211	**153	**207	**177	**162	**174	**163	**186	**202
**32DS	**215	**233	**224	**224	**209	**204	**201	**209	**201	**215
**33AZ	**174	**203	**194	**197	**167	**191	**158	**186	**215	**219
**33DS	**201	**213	**206	**209	**209	**204	**215	**201	**244	**256
**34AZ	**191	**207	**169	**203	**163	**197	**219	**229	**231	**239
**34DS	**204	**224	**204	**213	**209	**209	**256	**269	**256	**233
**35AZ	**222	**203	**197	**211	**215	**231	**241	**246	**255	**198
**35DS	**239	**213	**209	**233	**244	**234	**231	**242	**228	**190
**36AZ	**191	**204	**136	**197	**211	**222	**225	**230	**240	**256
**36DS	**204	**215	**201	**209	**233	**269	**233	**312	**279	**247
**37AZ	**242	**232	**238	**225	**257	**257	**266	**185	**211	**235
**37DS	**293	**232	**297	**283	**272	**267	**281	**181	**233	**216
**38AZ	**231	**225	**221	**233	**242	**249	**261	**275	**276	**275
**38DS	**234	**235	**241	**205	**295	**279	**263	**241	**181	**221
**39AZ	**201	**257	**279	**279	**280	**283	**281	**225	**242	**221
**39DS	**263	**267	**243	**263	**224	**184	**204	**198	**295	**184
**40AZ	**221	**233	**235	**240	**249	**266	**284	**229	**261	**289
**40DS	**134	**227	**244	**273	**279	**261	**247	**134	**263	**209
**41AZ	**274	**279	**237	**293	**293	**294	**290	**243	**233	**252
**41DS	**231	**233	**272	**213	**253	**197	**234	**224	**257	**253
**42AZ	**257	**266	**279	**293	**299	**297	**302	**297	**250	**287
**42DS	**267	**261	**263	**260	**299	**242	**136	**224	**234	**272

A	B	C	D	E	F	G	H	I	J
43AZ	227	307	285	311	304	252	279	255	301
43DS	268	200	286	184	216	190	263	228	333
44AZ	228	300	311	302	315	305	319	257	295
44DS	225	278	213	251	193	244	134	184	280
45AZ	309	312	319	315	320	255	303	275	328
45DS	250	241	213	226	200	221	303	241	189
46AZ	235	315	326	309	331	228	336	342	384
46DS	236	255	216	324	203	232	197	190	247
47AZ	297	318	315	322	331	26	339	347	342
47DS	208	241	255	322	306	316	197	184	190
48AZ	235	318	321	312	339	315	342	367	181
48DS	228	241	206	269	197	255	190	184	181
49AZ	254	301	313	326	323	331	342	336	347
49DS	201	233	241	216	228	206	190	197	184
50AZ	230	308	222	326	342	318	347	339	354
50DS	134	228	223	316	190	241	184	197	181
51AZ	311	322	326	342	319	347	336	354	180
51DS	213	228	216	190	241	184	197	181	190
52AZ	311	326	342	319	336	331	18	354	347
52DS	184	216	190	213	197	206	190	131	184
53AZ	323	331	326	336	347	362	354	6	18
53DS	200	206	216	197	184	190	161	131	190
54AZ	331	354	333	347	342	13	6	13	29
54DS	206	181	139	184	190	184	181	130	206
55AZ	240	181	333	354	13	34	24	28	13
55DS	190	181	197	181	190	216	197	228	184
56AZ	347	354	13	342	13	247	38	29	42
56DS	124	181	13	190	190	197	228	206	24

	A	B	C	D	E	F	G	H	I	J
**57AZ	**354	**347	**18	**13	**6	**74	**29	**24	**45	**42
**DS	**151	**184	**190	**134	**181	**216	**206	**197	**255	**241
**58AZ	**18	**5	**24	**54	**13	**34	**45	**38	**48	**29
**DS	**190	**181	**197	**181	**134	**215	**255	**228	**259	**206
**59AZ	**37	**42	**41	**51	**32	**45	**56	**67	**60	**72
**DS	**200	**241	**213	**256	**136	**226	**283	**260	**278	**253
**60AZ	**45	**55	**49	**58	**41	**52	**63	**76	**67	**81
**DS	**198	**244	**213	**251	**134	**223	**268	**247	**260	**243
**61AZ	**56	**103	**63	**110	**76	**112	**104	**108	**53	**49
**DS	**216	**253	**258	**234	**247	**215	**247	**190	**250	**184
**62AZ	**113	**59	**66	**114	**57	**61	**76	**119	**122	**117
**DS	**250	**187	**242	**242	**224	**206	**247	**206	**189	**224
**63AZ	**70	**127	**58	**119	**81	**124	**76	**117	**95	**121
**DS	**234	**200	**215	**251	**243	**215	**247	**268	**241	**233
**64AZ	**72	**128	**76	**131	**104	**75	**120	**73	**81	**135
**DS	**190	**223	**247	**213	**247	**228	**278	**209	**243	**198
**65AZ	**79	**139	**80	**135	**35	**148	**104	**143	**99	**132
**DS	**204	**213	**224	**226	**241	**189	**247	**200	**243	**241
**66AZ	**34	**145	**174	**142	**157	**133	**162	**135	**156	**132
**DS	**201	**215	**181	**223	**184	**241	**190	**255	**197	**229
**67AZ	**84	**140	**34	**142	**174	**133	**157	**135	**162	**132
**DS	**131	**216	**201	**228	**131	**241	**134	**255	**190	**269
**68AZ	**107	**196	**138	**193	**135	**159	**132	**121	**156	**151
**DS	**209	**190	**241	**184	**255	**181	**269	**233	**197	**206
**69AZ	**192	**151	**186	**146	**198	**156	**174	**138	**167	**135
**DS	**134	**206	**131	**216	**190	**197	**181	**241	**184	**255
**70AZ	**122	**193	**151	**189	**146	**193	**167	**162	**212	**209
**DS	**189	**184	**200	**181	**216	**193	**184	**190	**189	**197

	A	B	C	D	E	F	G	H	I	J
71AZ	151	204	149	193	142	193	167	186	174	217
DS	206	197	216	199	228	154	184	181	131	200
72AZ	174	189	167	198	146	193	209	214	221	139
DS	151	181	164	196	216	184	206	216	213	184
73AZ	209	158	204	151	198	214	218	225	238	148
DS	206	197	197	205	190	216	228	225	139	189
74AZ	214	159	209	189	167	193	193	222	255	233
DS	216	197	206	181	184	190	184	241	255	223
75AZ	214	182	209	193	167	185	198	204	255	255
DS	216	199	206	194	134	181	190	197	255	244
76AZ	222	204	174	193	167	193	214	231	241	260
DS	241	197	181	190	184	184	216	234	251	224
77AZ	243	233	228	225	256	261	279	275	276	217
DS	268	300	259	255	247	243	201	221	231	200
78AZ	221	213	231	240	243	252	265	280	229	270
DS	213	189	256	273	258	253	241	224	213	260
79AZ	243	240	252	259	265	279	238	287	233	284
DS	268	272	253	247	241	243	190	209	200	247
80AZ	234	292	241	243	256	275	250	288	238	255
DS	247	215	206	263	247	241	234	253	189	241
81AZ	294	288	294	297	246	261	255	302	234	283
DS	247	253	242	224	197	243	228	189	250	223
82AZ	289	297	304	299	307	301	311	209	255	261
DS	253	263	216	251	200	233	184	209	228	221
83AZ	275	283	302	311	306	315	303	319	260	275
DS	241	255	261	313	244	193	228	184	224	221
84AZ	233	304	312	306	323	309	328	312	264	264
DS	253	272	213	272	200	256	189	241	181	201

APPENDIX C

Answer stakes for  
200 m by 260 m area

	A	B	C	D	E	F	G	H	I	J
1	32	25	31	26	35	24	30	25	55	29
2	24	30	25	31	26	32	27	73	28	34
3	13	23	29	25	30	27	31	28	32	38
4	16	20	25	29	26	30	27	31	28	32
5	19	21	25	28	26	29	27	30	31	34
6	21	23	26	29	24	30	25	31	35	36
7	22	23	25	26	29	24	30	28	34	32
8	21	24	25	23	27	27	26	51	33	29
9	25	22	25	24	26	23	27	32	31	30
10	24	25	31	23	27	26	34	30	29	37
11	25	23	24	25	28	30	29	31	33	32
12	23	25	29	32	24	27	28	31	35	33
13	23	24	26	23	27	29	31	30	32	34
14	25	25	29	27	30	23	31	32	35	33
15	25	28	26	29	27	30	31	34	32	35
16	2	30	29	31	33	32	34	36	35	37
17	5	31	30	32	34	33	35	37	36	38
18	31	34	1	37	2	40	3	46	49	33
19	3	32	6	33	34	37	1	40	2	43
20	35	5	33	1	39	4	36	6	44	39
21	35	6	33	2	39	5	36	1	41	4

A	B	C	D	E	F	G	H	I	J
22	*	*	*	*	*	*	*	*	*
35	7	33	3	38	6	9	5	8	4
*	*	*	*	*	*	*	*	*	*
33	6	35	9	12	5	11	4	10	3
*	*	*	*	*	*	*	*	*	*
38	12	9	11	8	10	7	39	6	41
*	*	*	*	*	*	*	*	*	*
15	9	14	5	40	9	7	3	12	1
*	*	*	*	*	*	*	*	*	*
38	10	9	15	2	14	1	13	6	39
*	*	*	*	*	*	*	*	*	*
14	5	13	4	12	3	38	6	9	2
*	*	*	*	*	*	*	*	*	*
28	8	9	7	11	3	13	40	6	4
*	*	*	*	*	*	*	*	*	*
14	3	13	2	12	1	11	6	4	5
*	*	*	*	*	*	*	*	*	*
12	4	11	3	10	2	9	1	14	15
*	*	*	*	*	*	*	*	*	*
1	14	6	10	2	9	4	5	3	13
*	*	*	*	*	*	*	*	*	*
2	12	1	11	9	4	5	3	7	10
*	*	*	*	*	*	*	*	*	*
4	9	3	3	2	7	1	6	12	13
*	*	*	*	*	*	*	*	*	*
6	9	2	4	1	7	12	15	16	18
*	*	*	*	*	*	*	*	*	*
12	7	5	9	10	13	18	19	21	51
*	*	*	*	*	*	*	*	*	*
4	9	3	5	8	11	12	14	17	21
*	*	*	*	*	*	*	*	*	*
17	14	12	11	20	21	23	47	7	15
*	*	*	*	*	*	*	*	*	*
13	10	9	15	16	12	21	25	28	26
*	*	*	*	*	*	*	*	*	*
20	19	25	24	26	23	27	53	15	52
*	*	*	*	*	*	*	*	*	*
7	10	11	13	16	20	25	53	19	27
*	*	*	*	*	*	*	*	*	*
21	22	24	27	25	23	26	56	23	59
*	*	*	*	*	*	*	*	*	*
19	18	21	25	28	26	29	27	57	23
*	*	*	*	*	*	*	*	*	*

	A	B	C	D	E	F	G	H	I	J
43	25	29	24	30	23	55	20	57	27	
44	24	25	27	26	30	27	31	55	23	
45	27	29	30	29	31	57	24	60	32	
46	21	22	31	26	32	30	33	34	61	
47	21	23	27	29	31	30	32	34	33	
48	18	22	27	30	31	26	32	33	36	
49	14	17	21	29	27	29	31	30	32	
50	17	19	22	26	27	25	31	29	32	
51	22	25	25	26	24	30	28	31	35	
52	21	24	25	23	27	26	34	30	29	
53	23	25	25	24	23	27	29	31	33	
54	24	25	28	25	27	26	30	32	34	
55	25	26	27	24	27	31	32	35	30	
56	25	26	27	27	24	30	34	32	35	
57	25	29	29	23	27	32	30	35	34	
58	25	29	29	24	27	31	32	35	30	
59	31	34	32	35	30	33	40	38	41	
60	32	33	33	30	31	34	41	39	42	
61	34	37	37	3	40	3	49	33	52	
62	1	33	20	2	35	34	4	5	3	
63	30	35	35	2	39	4	1	42	3	

A	B	C	D	E	F	G	H	I	J
64	4	37	3	47	36	1	35	39	9
65	5	36	5	39	3	42	7	41	4
66	7	13	9	11	5	10	4	9	3
67	5	36	5	11	4	10	3	9	2
68	41	3	13	2	12	1	44	7	6
69	12	11	4	13	6	9	2	8	1
70	11	4	10	3	12	7	5	15	13
71	3	2	11	1	10	6	9	7	15
72	6	5	10	1	9	12	13	15	45
73	11	10	1	9	12	13	15	18	45
74	11	10	3	3	3	7	13	14	19
75	10	9	5	2	5	7	6	13	16
76	11	7	6	1	5	9	14	17	21
77	17	12	11	20	21	24	25	27	53
78	9	12	15	16	13	21	25	55	17
79	15	17	1	20	23	27	26	59	24
80	23	56	14	17	21	50	24	55	19
81	22	25	26	56	17	59	23	58	65
82	22	27	35	28	25	29	57	58	60
83	13	25	23	26	29	27	30	58	61
84	20	29	25	30	25	31	27	56	57

## APPENDIX D

### COMPASS COURSE REQUIREMENTS

#### Materials needed:

1. Stakes (e.g., tent pegs, surveyor's stake, coffee can tops)
2. Meter measuring tape
3. Compass
4. Azimuth/distance marking at each stake
5. Score sheet for each student
6. Compass for each student
7. Pencil for each student
8. Mapped answer sheet for each student
9. Master answer sheet

#### Information at each stake:

1. Stake number
2. Azimuth and distance for each lane identifier

#### Instructions to soldiers:

1. Self-correcting compass course
2. Use azimuth and pace count
3. Given starting stake and lane identifier (e.g., 1A, 10J)
4. At each stake, given azimuth and distance for next leg
5. Write stake number on score sheet
6. After finding X number of stakes, return to scoring area

#### Scoring:

1. Provide course lay out for each student
2. Indicate "correct" route (this can be marked prior to training)
3. Indicate "route taken"
4. Identify errors (i.e., stray to left, right, pace too long, too short)
5. Recommend ways of correcting errors (e.g., recount 100 meter pace)