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Honeywell Flight Management System (FMS) Lateral Navigation (LNAV) Investigation

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12. Abstract

Honeywell B747, A320 and MD11 FMS validation facilities were used to gather data on the Honeywell Transport Category FMS's ability to fly a series of fly-by and fly-over waypoints. The intent of the investigation was to arrive at some limiting segment lengths for various speeds and course configurations. Plots of the flight tracks are provided. FMS discontinuities are described.

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HONEYWELL FLIGHT MANAGEMENT SYSTEM (FMS) LATERAL NAVIGATION (LNAV) INVESTIGATION

1.0 INTRODUCTION. Approximately 20% of major air carriers' aircraft are equipped with Flight Management Systems (FMS), a figure that is expected to reach 50% by 1995. FMSs are microprocessor based and provide, among other capabilities, area navigation with both lateral (LNAV) and vertical (VNAV) modes. Various sensors such as DME/DME, VOR, INS and potentially GPS are used as navigational inputs to the FMS. These inputs along with internal flight path computation algorithms and an extensive database containing pre-loaded departures, arrivals, approaches and fixes allow the FMS to navigate the aircraft over the desired route. In order to allow operators to take full advantage of it's capabilities, FMS-specific instrument procedures criteria must be developed. FMS-specific criteria can only be developed after a thorough understanding of the various FMS modes. This report presents the results of an investigation into the lateral navigation capability of the Honeywell Transport Category FMS.

1.1 OBJECTIVE. The objective of this investigation was to gather data on the Honeywell FMS LNAV mode in support of FMS-specific Terminal Instrument Procedures (TERPS) criteria development.

2.0 TEST LOCATION. The test was conducted in Phoenix, AZ on Jun 25-26, 1992 at the Honeywell Commerical Flight Systems Group building.

3.0 TEST DESCRIPTION.

3.1 TEST EQUIPMENT. The test was conducted using Honeywell B747-400, MD11 and A320 engineering validation facilities (simulators). The simulators are termed engineering because they were not equipped with normal pilot training features such as a visual system or motion base. The simulators are used by Honeywell technical personnel for system development/integration and software testing. However, each simulator did contain a FMS hardware and software suite representative of that in the actual aircraft. The fidelity of the MD11 simulator was the highest in that it also contained the actual aircraft autopilot.

3.2 METHOD. Each FMS/simulator was programmed to fly the spirals found in Appendix 1. The spirals have constant angular course changes (30°, 60°, 90° and 120°, respectively) between segments. The initial segment length is 10 nm for the 30°, 60° and 90° spirals and 12 nm for the 120° spiral. Each subsequent segment is 1/2 nm shorter. AVN-540 provided a listing of the spiral waypoints in latitude and longitude and Honeywell loaded these waypoints into the respective FMS databases. The simulators flew the spirals until the FMS produced a discontinuity. The segment length at which a discontinuity occured serves as an indicator of the minimum leg length for that ground speed and angular course change.

As the FMS-computed flight paths are ground speed dependent, the spirals were flown at a "worst case" condition of 10,000' MSL with standard temperature and pressure. The simulators were flown at the following airspeeds; 213 KIAS, 253 KIAS, 272 KIAS and 303 KIAS. These speeds correspond to indicated airspeeds of 160, 200, 220 and 250 knots at 10,000' MSL with a constant 60 knot tailwind applied. Each airspeed profile was flown twice, once with fly-by waypoints and once with fly-over waypoints. Table 1 contains the scenario matrix. Autopilot and autothrottles were used to maintain altitude, airspeed and flight track.

Table 1 - Scenario Matrix

Spiral #	160 KIAS	200 KIAS	220 KIAS	250 KIAS
1 (fly-by)	1	2	3	4
1 (fly-over)	5	6	7	8
2 (fly-by)	9	10	11	12
2 (fly-over)	13	14	15	16
3 (fly-by)	17	18	19	20
3 (fly-over)	21	22	23	24
4 (fly-by)	25	26	27	28
4 (fly-over)	29	30	31	32

3.3 TEST PERSONNEL. AVN-540 provided a pilot to observe the test and complete the logsheet (Appendix 2) for each run. Honeywell provided engineering personnel to operate the simulators and conduct the test.

3.4 DATA COLLECTION. Each simulator was equipped with a data collection system which recorded a slightly different set of parameters. Data parameters were recorded at a 2 Hz rate and are shown in Table 2.

Table 2 - Data Parameters

PARAMETER	B747	MD11	A320
local time	X	X	X
roll	X	X	X
position (lat/long)	X	X	X
airspeed	X	X	X
altitude	X	X	X
cross track error	X	X	X
desired track	X	X	X
fish discontinuity		X	X
ATD to next waypt	X	X	X
next waypt position	X	X	
roll command	X		
leg segment			X
track angle error		X	X
active waypt ID			X

3.5 TEST CRITERIA. As stated earlier, the simulators were to fly each spiral until the FMS produced a discontinuity. The spiral segment at which the discontinuity occured was recorded for use in determining the minimum leg length. The next two sections describe what constitutes a discontinuity in both the fly-by and fly-over waypoint modes.

3.5.1 FLY-BY WAYPOINT DISCONTINUITY. The following criteria were used to determine a fly-by waypoint discontinuity;

a. the simulator was unable to maintain the commanded flight path within a cross track error of 0.1 nm. That is, the radius of turn as computed by the FMS exceeded the turn capability of the flight control system as evidenced by a cross track error greater than 0.1 nm.

b. a "fish" discontinuity occured.

The length of the first spiral segment where either discontinuity condition a. or b. occured was considered the minimum leg length for that scenario. While condition a. is self-explanatory, Figures 1, 2 and 3 serve to illustrate FMS operations leading to a fish discontinuity.

CASE 1 - NORMAL FMS OPERATION. Figure 1 shows a FMS map display with four fly-by waypoints (A, B, C and D) and three RNAV leg segments (AB, BC and CD). Since all waypoints are fly-by, the FMS will use turn anticipation to transition to the next leg. T1 and T2 represent the FMS computed transitions for legs AB-BC and BC-CD, respectively, and vary according to aircraft ground speed and angular course change. Also shown are roll anticipation distances (RAD) RAD1 and RAD3. RAD is a FMS computed value and is the distance the aircraft takes to "roll up" to the bank angle required for the turn. T1 does not start until RAD1 is complete and the aircraft is at the computed bank angle. RAD2 and RAD4 are actually roll out distances and are shown only to illustrative the finite distance required for a transport category aircraft to roll out of a turn. In Figure 1, the length of segment BC is sufficient to allow T1 including RAD2 to complete before RAD3 and T2 begin.

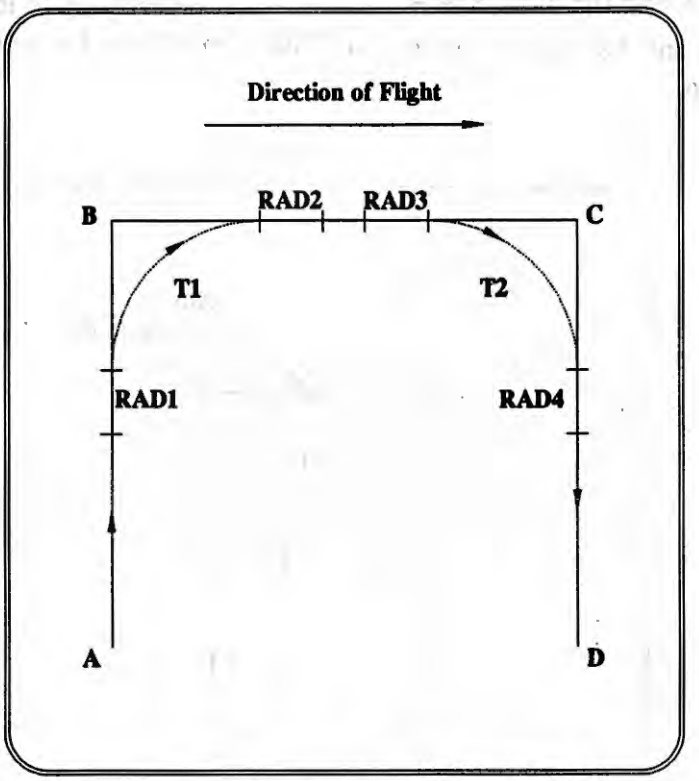


Figure 1. FMS Operation - Case 1

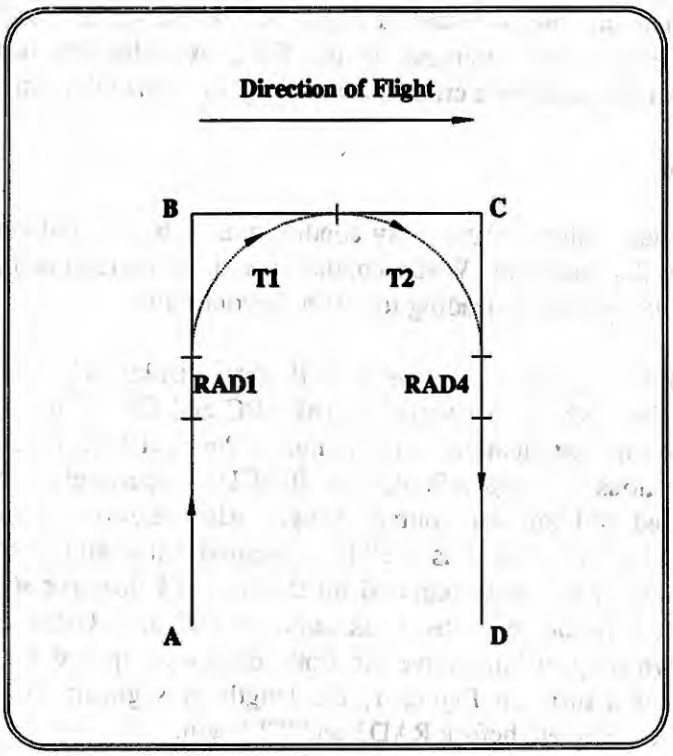


Figure 2. FMS Operation - Case 2

CASE 2 - CONTINUOUS TURN. In Figure 2, the length of segment BC has been decreased until the end of T1 and the beginning of T2 are the same point. In this case, RADs are not needed between T1 and T2 because the aircraft is already in a bank from T1 and T2 requires a turn in the same direction. This situation will result in a continuous turn from leg AB to CD.

CASE 3 - FISH DISCONTINUITY. In Figure 3, the length of segment BC has been further decreased until T1 cannot be completed before T2 starts. In the exaggerated case shown here, T1 and T2 overlap in such a way as to give the appearance of a fish tail, hence the name fish discontinuity. In less extreme cases, the transition overlap will not be as pronounced as in Figure 3, but a fish discontinuity can still be readily seen on the FMS map display by a double line where the transitions overlap.

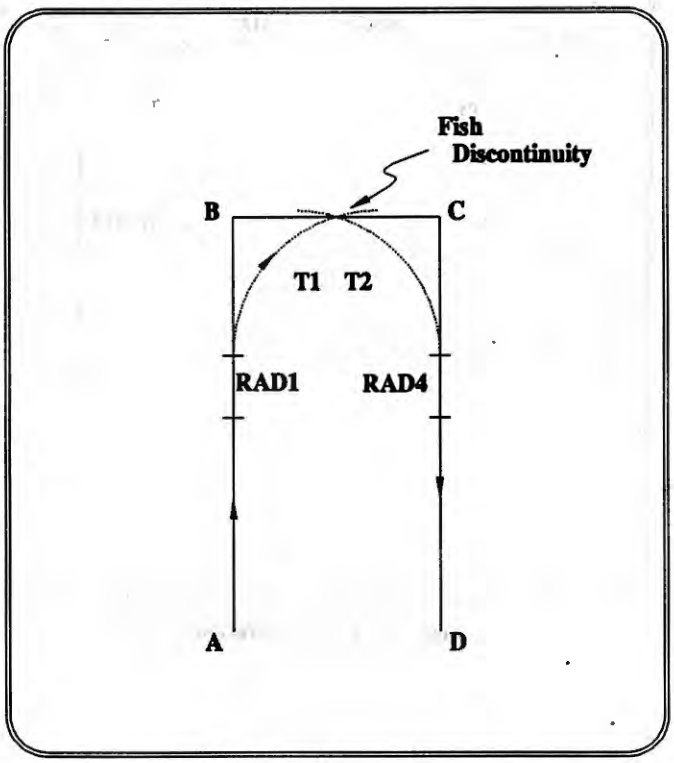


Figure 3. FMS Operation - Case 3

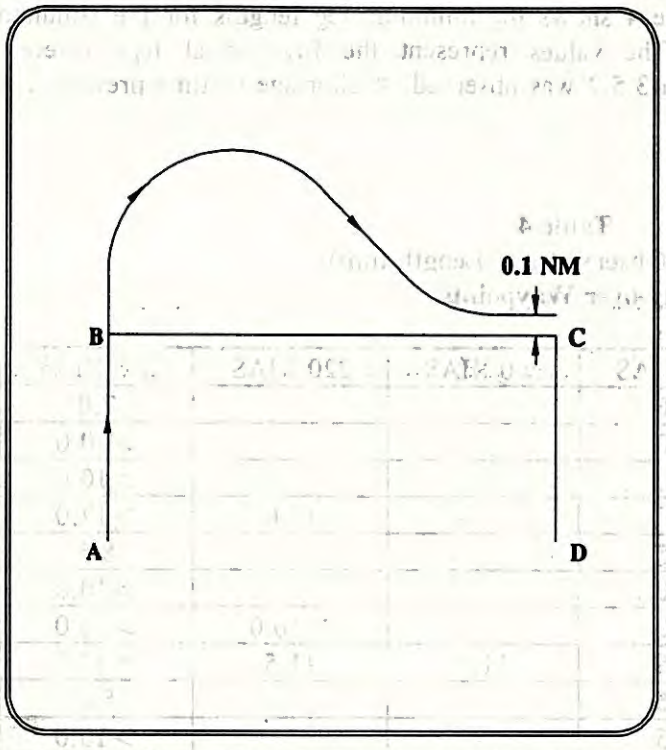


Figure 4. FMS Operation - Fly-over waypoint

3.5.2 FLY-OVER WAYPOINT DISCONTINUITY. During the pre-test meeting, it was agreed by FAA and Honeywell personnel that a fly-over waypoint discontinuity would occur anytime the simulator could not return to within 0.1 nm. cross-track error of the present leg before starting the next leg. Figure 4 illustrates a fly-over waypoint discontinuity.

4.0 ANALYSIS OF RESULTS.

4.1 FLY-BY WAYPOINTS. Table 3 shows the minimum leg lengths for the simulator scenarios with fly-by waypoints. The values represent the first spiral leg where a discontinuity as described in paragraph 3.5.1 was observed. Trouble encountered with the B747 data collection system prevented all scenarios from being completed. Plots of the fly-by waypoint runs are found in Appendix 3. (Only the higher order 16 bits of the B747 FMS position was recorded, resulting in "stair step" plots .)

Table 3
Minimum Observed Leg Length (nm)
Fly-by Waypoints

FMS TYPE	COURSE CHANGE	160 KIAS	200 KIAS	220 KIAS	250 KIAS
B747	30°	1.5			3.0
B747	60°	2.0			4.5
B747	90°	4.0			8.0
B747	120°	6.5			11.5
A320	30°	1.5		1.5	2.0
A320	60°	2.0	3.0	3.0	4.5
A320	90°	3.5	5.0	6.0	7.5
A320	120°	6.0	9.0	10.5	11.5
MD11	30°	1.5	1.5	2.0	2.5
MD11	60°	2.0	3.0	3.5	4.5
MD11	90°	4.0	5.5	6.0	7.5
MD11	120°	6.5	9.0	10.5	11.5

4.2 FLY-OVER WAYPOINTS. Table 4 shows the minimum leg lengths for the simulator scenarios with fly-over waypoints. The values represent the first spiral legs where a discontinuity as described in paragraph 3.5.2 was observed. A shortage of time prevented all scenarios from being completed.

Table 4
Minimum Observed Leg Length (nm)
Fly-over Waypoints

FMS TYPE	COURSE CHANGE	160 KIAS	200 KIAS	220 KIAS	250 KIAS
B747	30°	4.0			7.0
B747	60°	6.0			>10.0
B747	90°	6.0	8.5		>10.0
B747	120°	7.0		11.0	>12.0
A320	30°	5.5			8.5
A320	60°	7.0			>10.0
A320	90°	7.0		>10.0	>10.0
A320	120°	7.5	11.5	11.5	>12.0
MD11	30°	4.5			8.0
MD11	60°	6.5			>10.0
MD11	90°	7.0	9.5		>10.0
MD11	120°	7.0		11.5	>12.0

The values shown in Table 4 are larger than had been expected and, in many cases, are greater than the longest leg of the respective spiral. This is because of the way Honeywell chose to implement course capture after a fly-over waypoint. Figure 5 demonstrates this method. As shown in Figure 5, the FMS commands an initial turn until approximately a 45° intercept to the desired course is reached. At some point, shown as A, the FMS begins to lessen the intercept and a very shallow intercept results. This method makes for smaller bank angles, providing greater passenger comfort. However, from a airspace management viewpoint, it also lengthens the distance for course capture. Plots of the fly-over waypoint runs are in Appendix 4. (Only the higher order 16 bits of the B747 FMS position was recorded, resulting in "stair step" plots.)

Additional information concerning fly-over waypoints is found in Appendix 5. Found here are tabulated values for air distance to next waypoint, cross track error, track angle error and bank angle for entire segments of various B747 fly-over waypoint scenarios.

5.0 OBSERVATIONS AND CONCLUSIONS.

a. The FMS-computed flight tracks observed during this test are ground speed dependent. A particular RNAV segment which can be readily flown at a certain ground speed may not be flyable at a higher ground speed. For example, at 160 KIAS the A320 simulator flew the 90° fly-over spiral to a leg length of 7 nm; however, at 220 KIAS no leg of the spiral could be flown successfully.

b. FMSs can be programmed with routes beyond the aircraft's ability to fly. These routes can cause FMS discontinuities as described in this report.

c. Prior to this test, AVN-540 performed a mathematical analysis to theoretically predict minimum leg lengths for fly-by and fly-over waypoints. In comparing actual versus theoretical results, LNAV performance in flying a series of fly-by waypoints was as predicted. However, LNAV performance in flying a series of fly-over waypoints was not as predicated. Minimum leg lengths observed during the test were approximately 2 nm. longer than anticipated. This was due to the method Honeywell uses for course capture after a fly-over waypoint.

d. On many occasions during this test, the FMS/flight control system was presented with a flight path beyond its capability to fly. In each case, the system still attempted to fly the path using a bank limit of approximately 25° and with an increasing cross track error.

e. Until a "true track over the ground" capability is available in FMSs, any FMS instrument procedure criteria must account for the speed variability of the flight tracks, either through speed specific criteria (eg, a computer program which accepts a target indicated airspeed and a maximum altitude and returns leg lengths and turn radii) or using a worst case ground speed as was done in this test.

f. The results reported herein have been incorporated into FAA Order 8260.YY, Flight Management System (FMS) Procedures.

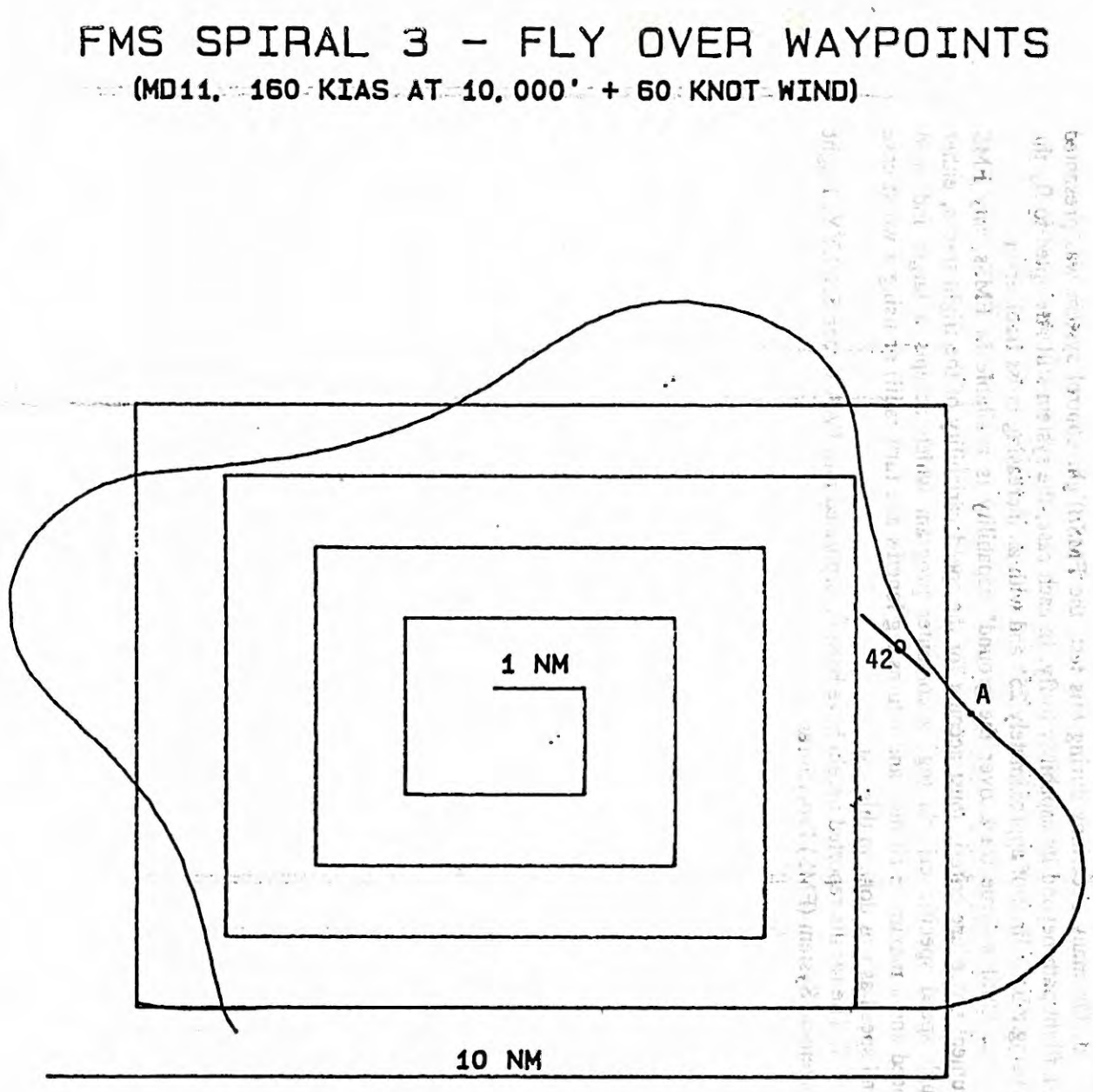
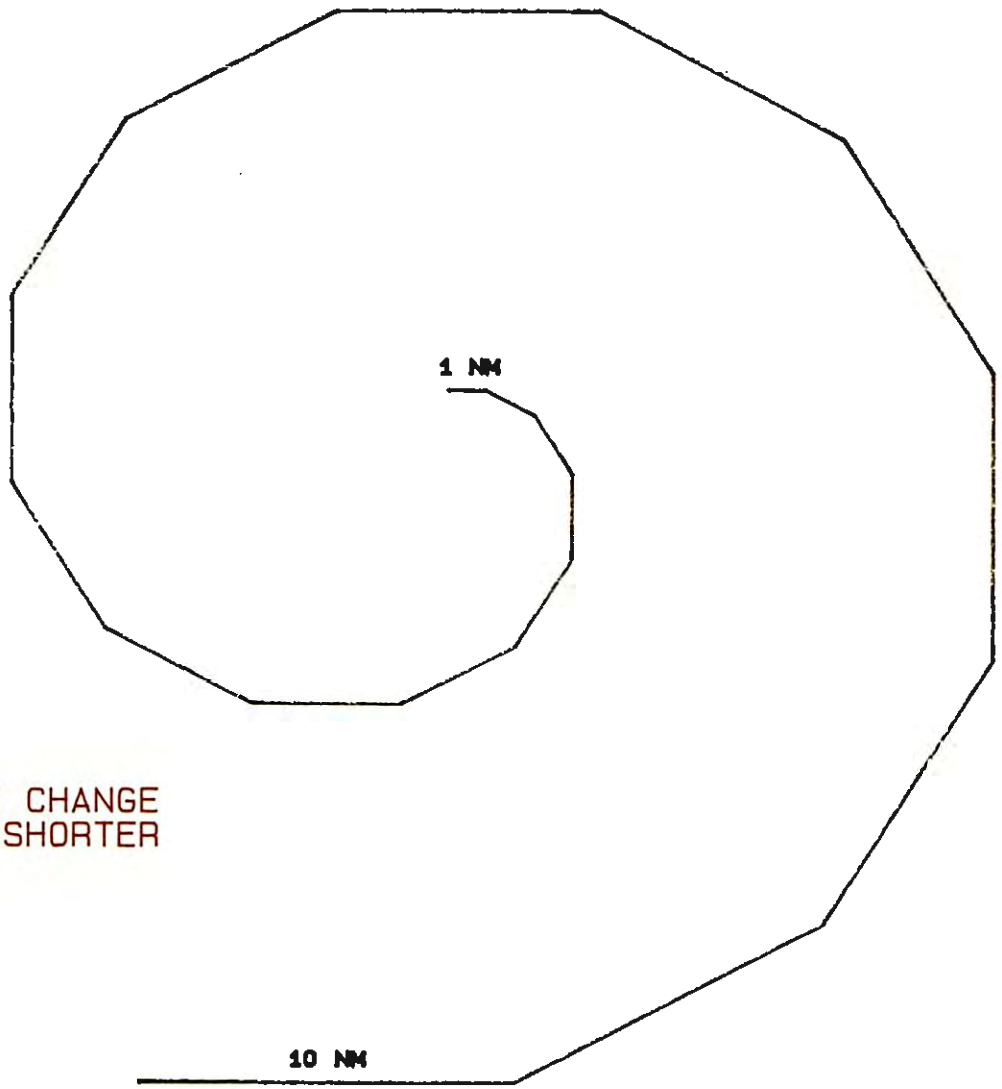


Figure 5. FMS Operation - Fly-over Waypoint

APPENDIX 1

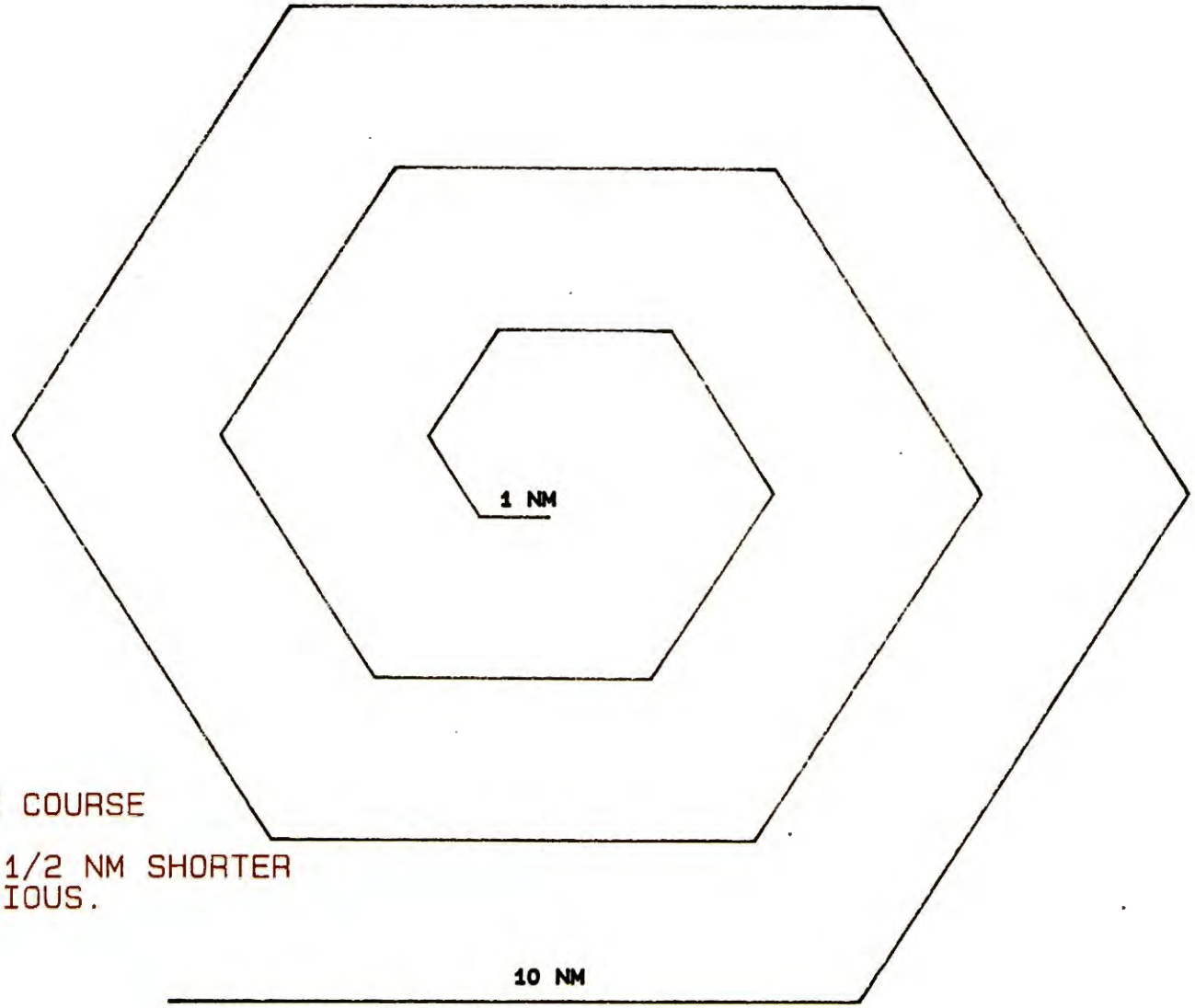
FMS SPIRALS

FMS SPIRAL- 1



CONDITIONS
1. 30 DEGREE COURSE CHANGE
2. EACH LEG 1/2 NM SHORTER THAN PREVIOUS.

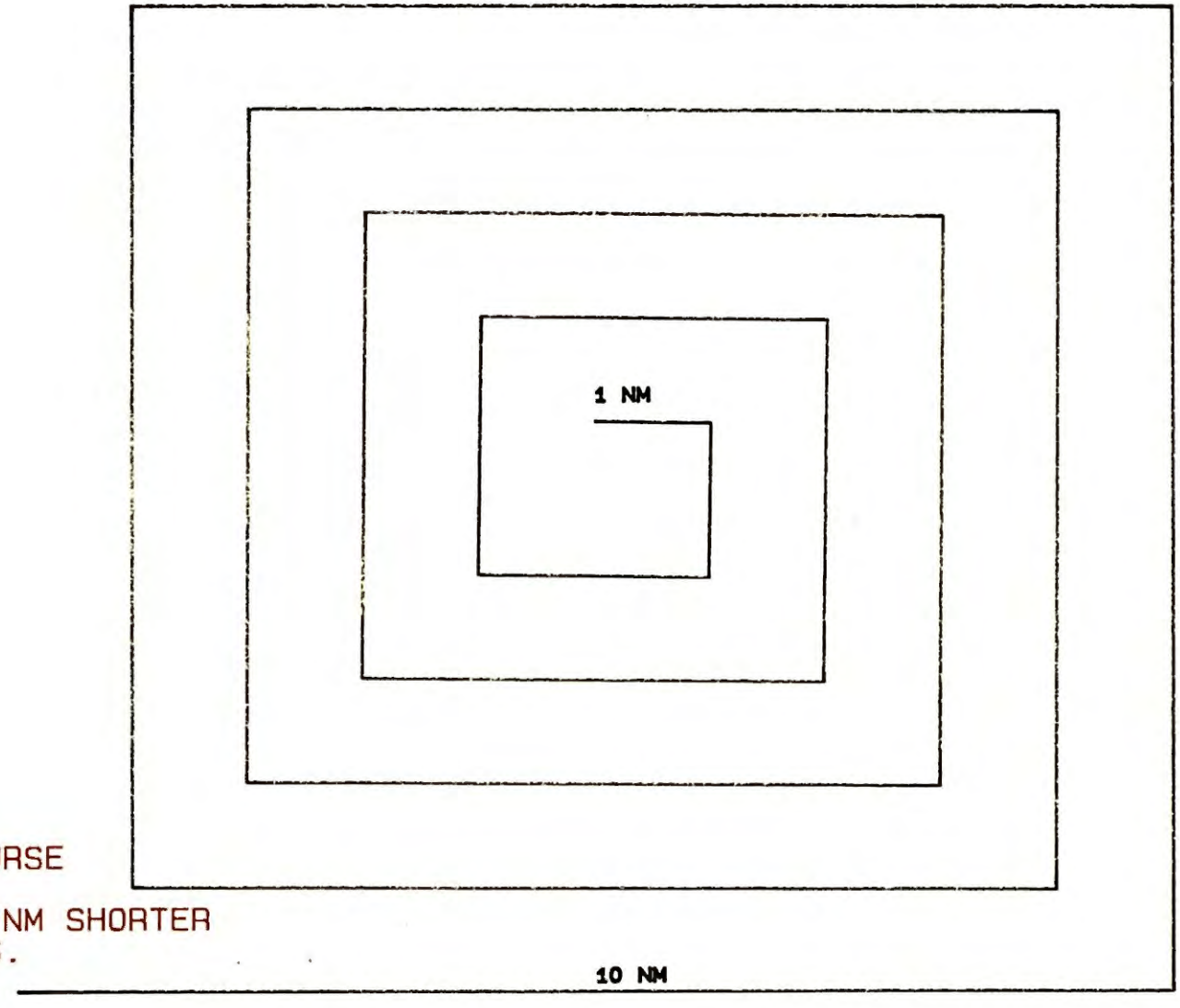
FMS SPIRAL- 2



CONDITIONS

1. 60 DEGREE COURSE CHANGE.
2. EACH LEG 1/2 NM SHORTER THAN PREVIOUS.

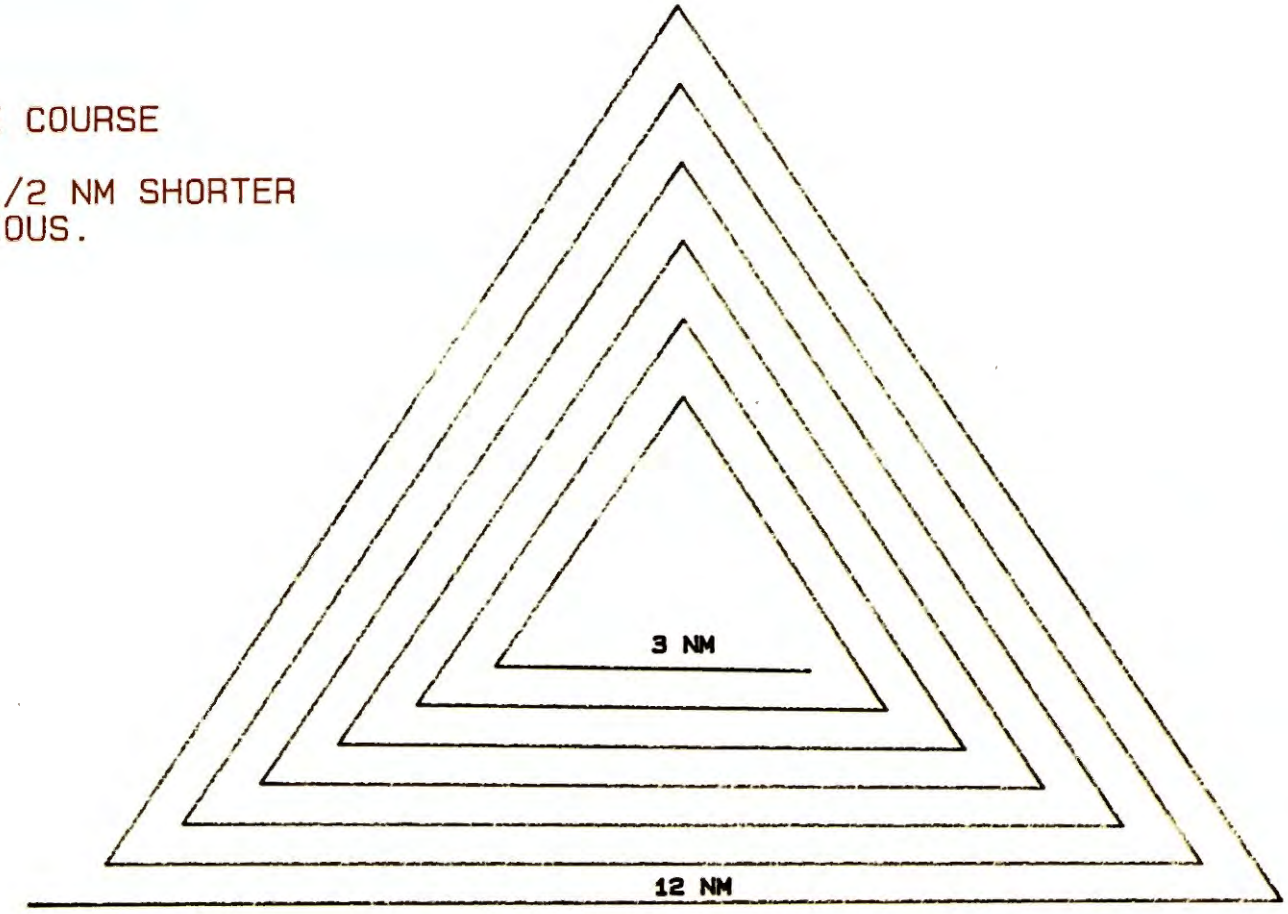
FMS SPIRAL- 3



CONDITIONS
1. 90 DEGREE COURSE CHANGE.
2. EACH LEG 1/2 NM SHORTER THAN PREVIOUS.

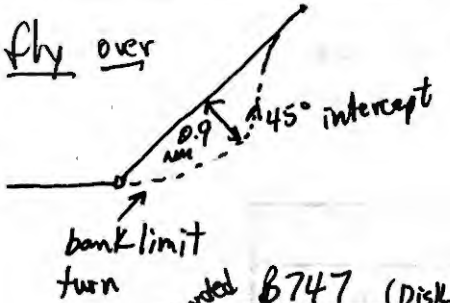
FMS SPIRAL- 4

CONDITIONS
1. 120 DEGREE COURSE CHANGE.
2. EACH LEG 1/2 NM SHORTER THAN PREVIOUS.



APPENDIX 2

FMS LOGSHEETS



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FMS TEST LOG

B747 (Disk #)

SCENARIO #	DATE	TIME	LAST SEGMENT	REMARKS
B004 (1)	6/25/92	01	P1	303 IAS, 348 TAS, bank angle = 1/2 course change ≈ 15°, xtrk error = 0.1 to .2 NM, P1 first transition cross over fix.
B008 (2)	6/25/92	~~[illegible]~~	H1 - I1	TAS 348, winds 272/3, reached 0.1 NM at 2.0 nm from next fix.
B012 (2)	6/25/92	1312-1316 ~~[illegible]~~	M2 - N2 unable to maintain track w/in .1 NM L2 - M2 - first transition overlap	recorded from J2-O2
* B016 (1)	6/25/92	1040-1055	B2 - C2	recorded to F2
* B020 (1)	6/25/92	1102-1111	E3 - F3 first transition overlap F3 - G3 could not maintain track w/in .1 nm	recorded to H3
B024 (1)	6/25/92	1135-1145	B3 - C3	recorded to D3 max xtrk error - 4.6 NM - Good Data
B028 (2)	6/25/92	1325-1330	B4 - C4 first xtion overlap B4 - C4 unable to maintain track w/in .1 NM	max xtrk error - 4.2 NM
B032 (2)	6/25/92	1337-1347	B4 - C4	max xtrk error - 6.4 NM
B001 (3)	6/25/92	1500-1502 ~~1455-1448~~	always stayed within .1 NM xtrk. R1 - S1 - xtion overlap	started Q1 ~~went D2 C1 to I1~~ TAS 246
B005 (2)	6/25/92	1443-1452	N1 - O1	started at H1
B009 (3)	6/25/92	1515-1520	R2 - SR could not track w/in .1 NM. Q2 - R2 first xtion overlap	started at M2
B013 (3)	6/25/92	1526-1545	J2 - K2	started at C2
B017 (3)	6/25/92	1554-1600	M3 - N3	started at F3
B021 (3)	6/25/92	1605-1622	J3 - K3	started at C3
B025 (4)	6/25/92	1633-1638	L4 - M4 ← could not track w/in .1 NM first transition overlap	D→ A4 to K4
B029 (4)	6/25/92	1643-1725	L4 - M4	

recorded again

Data recording problems originally

SAT -6°C

max bank 25°

had wind 045/28 in first run caused by difference in IRS radio position turned off radio

transition xover is shown by double magenta line on map display

waypts
A1
B1
C1
⋮

23
31

STUCKERT

AIRBUS 320

FMS TEST LOG

CAS	SCENARIO #	DATE	TIME	LAST SEGMENT	REMARKS			LEG LENGTH	
303	4	6/25/92	~0900	Q-R .02	MAX XTK. DATA START O	DATA STOP S		2.0	
	8		~0933	D-E .178	MIN XTK AT E DATA START C	DATA STOP F		8.5	
	12		~0950	L-M		J	N	4.5	
	16		~1012	B-C	.29 MIN XTK AT C	A	D	9.5	
	20		~1025	F-G.	.2 MAX XTK AT G (ACFT OUTSIDE OF TURN)	D	H	7.5	
	24		~1045	UNACCEPTABLE B-C	FLEW OUTSIDE C-TURNED RT TO INTCPT NEXT LEG	A	D	9.5	NEED LONGER SEGMENTS
	28		~1054	B-C		A	D	11.5	
	32		~1108	UNACCEPTABLE B-C	SAME AS 24	A	D	11.5	
					XTK	DATA START	DATA STOP		
213	1		~1307	S-T	MAX .062 AT S	Q	T	1.0	NEED 1am-1am or shorter
	GS 246 5		~1326	K-L	MIN .091 AT K .109 AT L	I	M	6.0	
	9		~1337	Q-R	MAX .027 AT Q	O	S	2.0	
	OVERWRITTEN 13	ACCIDENTALLY	~1353	H-I	MIN ~~.071 AT H .118 AT I~~	F	J	~~6.5~~	
	17		~1410	N-O	MAX .046 AT N	L	P	3.5	
	21		~1425	H-I	MIN .079 AT H .063 AT G .113 AT I	F	J	6.5	
	25		~1450	M-N	MAX .010 AT M	K	O	6.0	
	29		~1500	K-L	MIN .097 AT K .052 AT J .168 AT L	I	M	7.0	
	13		~1535	H-I	MIN .067H .118 AT I	F	J	6.5	

NOTE: SIM CLOCK TIME WAS LOGGED. THIS IS ~20 MIN BEHIND DATA LOGGER! DATA LOGGER USED IT'S OWN PC INTERNAL CLOCK.

AIRBUS 320

STUCKERT

FMS TEST LOG

CAS	SCENARIO #	DATE	TIME	LAST SEGMENT	XTK	REMARKS		LEG LENGTH
272	31	6/25/92	N/A	B - C	MIN 0.097	NO DATA RECORDED	START / STOP	
	23		N/A	UNACCEPTABLE B-C	NO DATA RECORDED			
253	30		~1616	B-C	MIN .110 AT C	A	D	9.5
272	31		~1625	B-C	MIN .103 AT C	A	D	11.5
272	3	6/26/92	~0840	S - T	SAT ON ALL	Q	T	NEED SHORTER LEG
	11		~0847	O-P	STARTE ~~D~~ L S TURN AT M	M	Q	3.0
	19		~0857	I-J	MAX .034 AT I	G	K	6.0
	27		~~0905~~ 0914	~~E-F~~ D-E		B	F	10.5
253	10		~0924	O-P	MAX .059 AT O	M	Q	3.0
	18		~0935	K-L	.039 AT K	I	M	5.0
	26		~0945	G-H		E	I	9.0

No overfly button on MD & Boeing but is on Airbus.

Scenarios 24 & 32 do not have long enough legs.

MD11 has real autopilot. - may explain why the MD-11 took so long to get back on track after a fly over waypt

FMS TEST LOG

KCAS

	SCENARIO #	DATE	TIME	LAST SEGMENT	REMARKS			
303	MD04	6/26/92	0815-0817	Q1-R1	Max bank 30° ~~D2~~ L1 TAS 349 GS 349			
	MD08	6/26/92	0850-0855	E1-F1				
	MD12	6/26/92	0902-0905	M2-N2	~~D~~ J2			
	MD16	6/26/92	0923-0926	B2-C2	max xtrk 2.3 nm			
253	MD20	6/26/92	0939-0940	F3-G3	started at D3			
	MD24	6/26/92	0947-0951	B3-C3	max xtrk 4.7 nm .6 nm xtrk at changeover			MD24 & MD32
	MD28	6/26/92	-1018	B4-C4				
272	MD31	6/26/92	-	B4-C4	.110 nm xtrk at C4 .138 nm xtrk at D4			
213	MD01	6/26/92	1056-1058	flew all segments without discontinuity	~~183~~			
	MD05	6/26/92	1128-	L1-M1	~~183 nm to M1~~ TAS 247			
	MD09	"	1245-	Q2-R2	XTK .1 MAX AT Q2	START O2	STOP S2	LEG LENGTH (nm) 2.0
	MD 13	"	1252-	H2-I2	.123 MIN AT J2	F2	J2	6.5
	MD 17	"	1313-	N3-O3	.245 MAX AT M3	L3	R3	3.5
	MD 21	"	1324-	G3-H3	MIN .146 AT H3	E3	I3	7.0
	MD 25	"	1342-	L4-M4	WATCH FOR XTK .1 (IT WAS HIGHER)	J4	N4	6.5
	MD 29	"	1401-	K4-L4		I4	M4	7.0
253 ~~272~~	MD23	"	1414-	B3-C3	.146 MIN	A3	D3	9.5
272	MD 03	"	1427	R1-S1		P1	T1	

recorded Fish Discon is not right on these runs.

MD11

STUCKERT

FMS TEST LOG

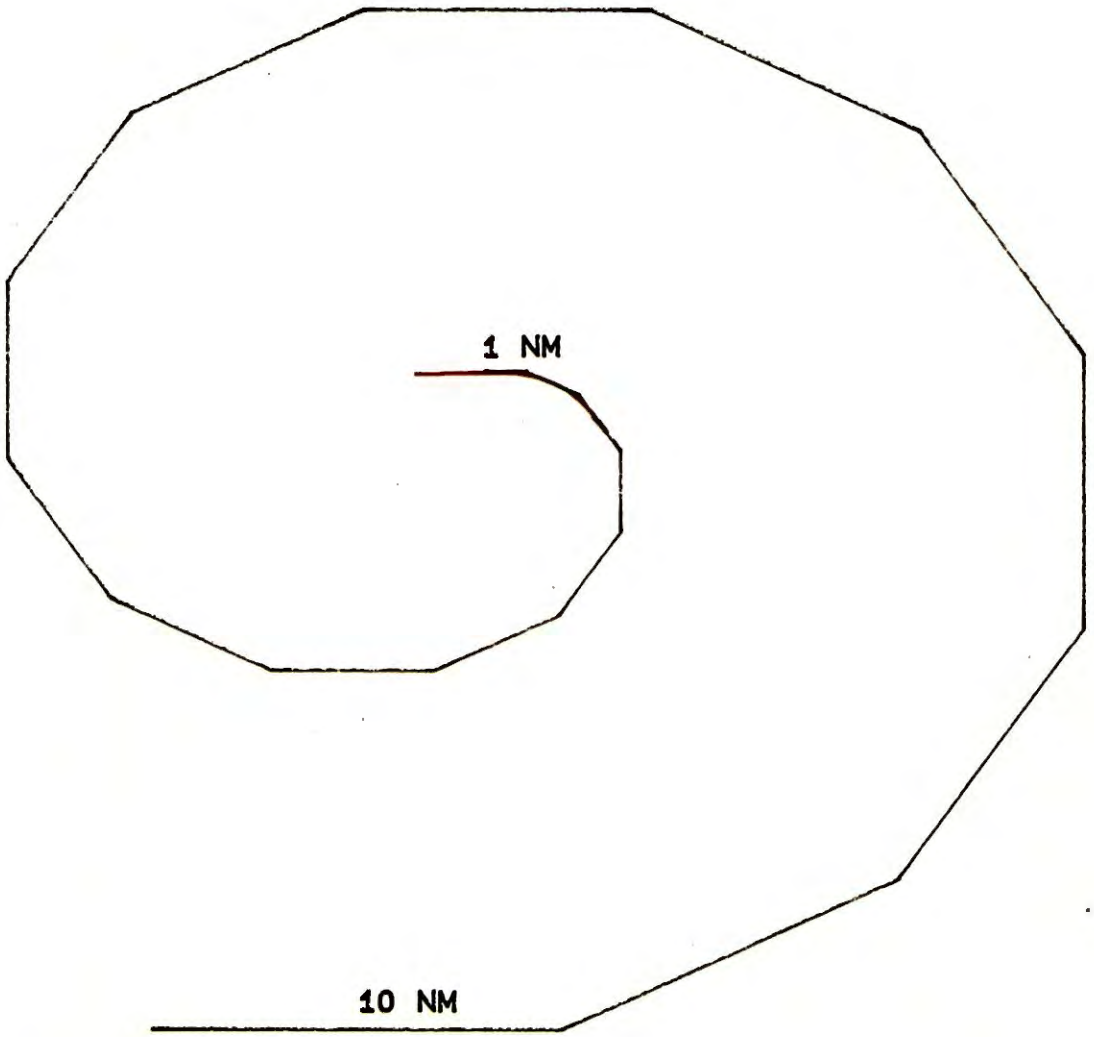
KCAS	SCENARIO #	DATE	TIME	LAST SEGMENT	XTK MAX	REMARKS	DATA START	DATA STOP	LEG LENGTH
272	MD11	6/26/92	1438-	N2-O2	XTK WAS 7.1 nm AT N2 (LOOK!)		L2	P2	3.5
	MD19		1448-	I3-J3	0.214 AT I3		G3	K3	6.0
	MD27		1500-	D4-E4	0.2 AT D4		B4	F4	10.5
253	MDØ2		1515-	NO FISH	XTK WAS 70.1 AT S1		Q1	T1	1.0
	MD 10		1525	O2-P2	0.12 AT O2		M2	Q2	3.0
	MD 18		1530-	K3-L3	0.3 AT K3		I3	M3	5.0
	MD 26		1543-	G4-H4	0.295 AT G4		E4	I4	9.0

APPENDIX 3

FMS FLY-BY WAYPOINT PLOTS

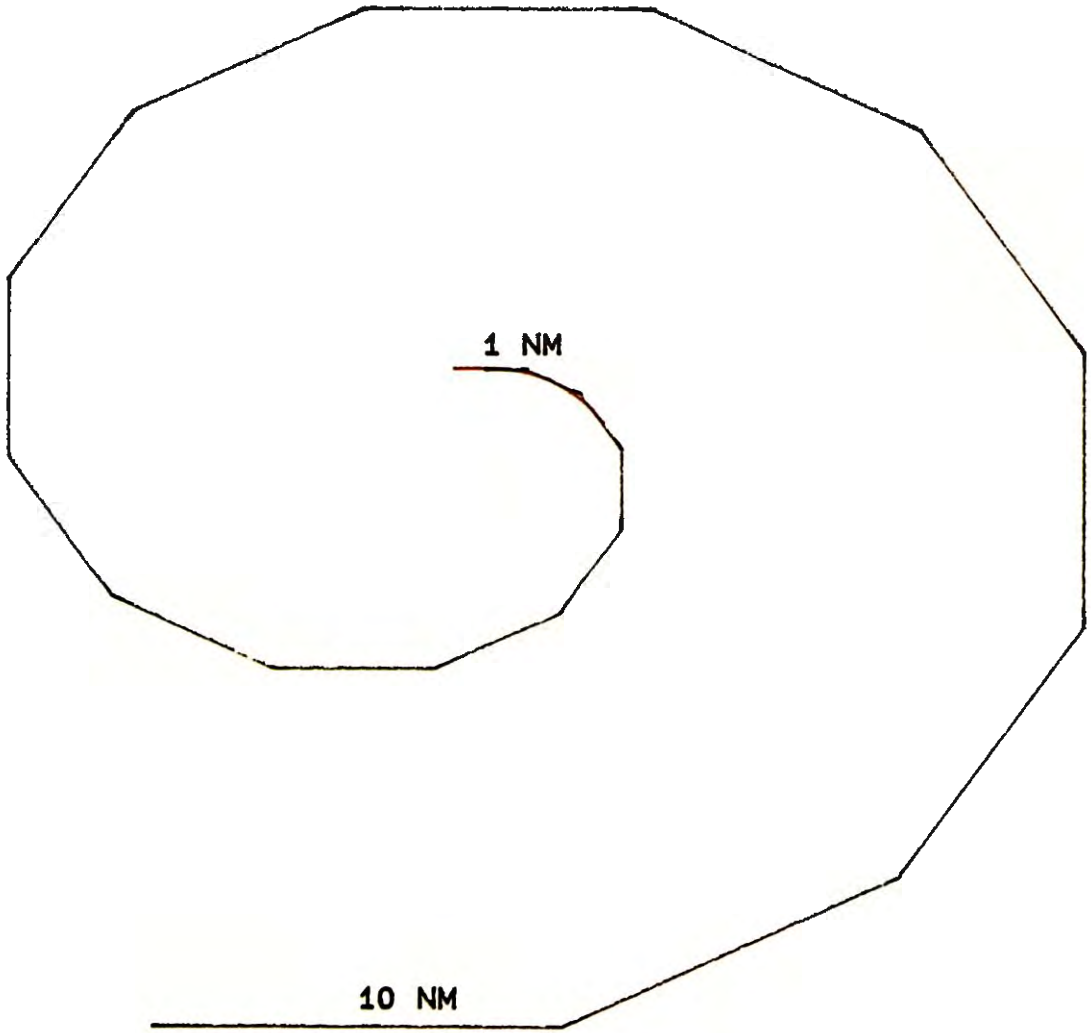
FMS SPIRAL 1-FLY BY WAYPOINTS

(A320, 160 KIAS AT 10,000' + 60 KNOT WIND)



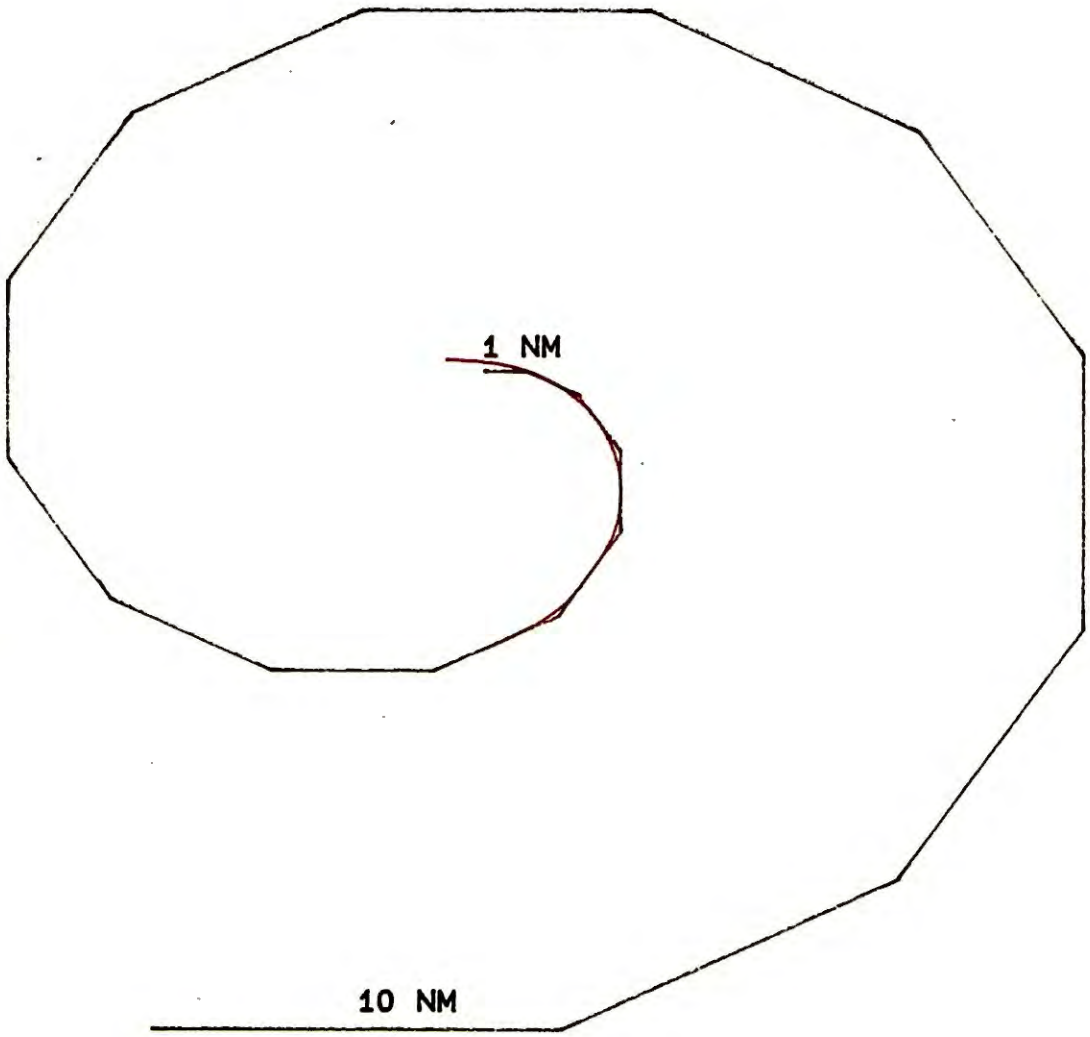
FMS SPIRAL 1-FLY BY WAYPOINTS

(A320, 220 KIAS AT 10,000' + 60 KNOT WIND)



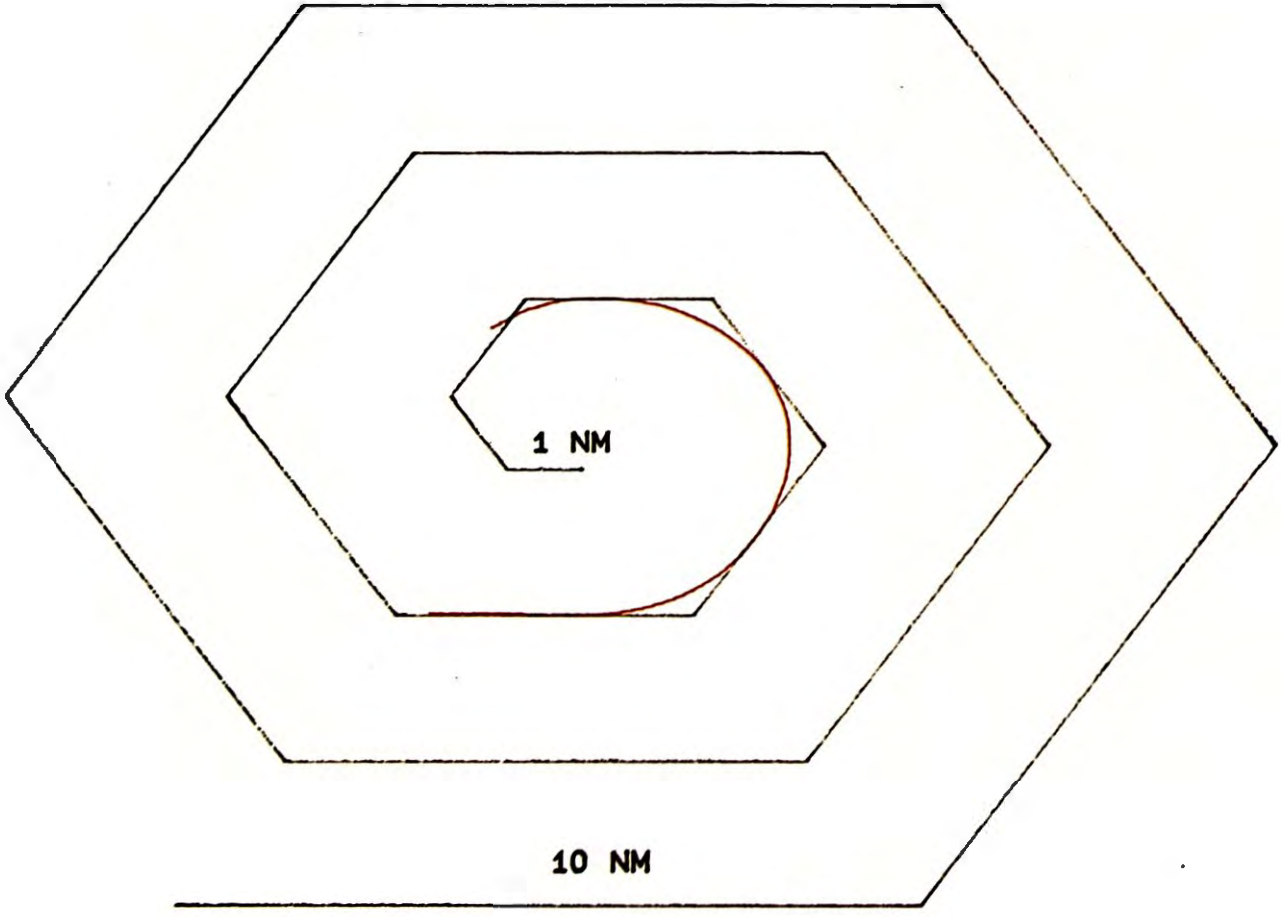
FMS SPIRAL 1-FLY BY WAYPOINTS

(A320, 250 KIAS AT 10,000' + 60 KNOT WIND)



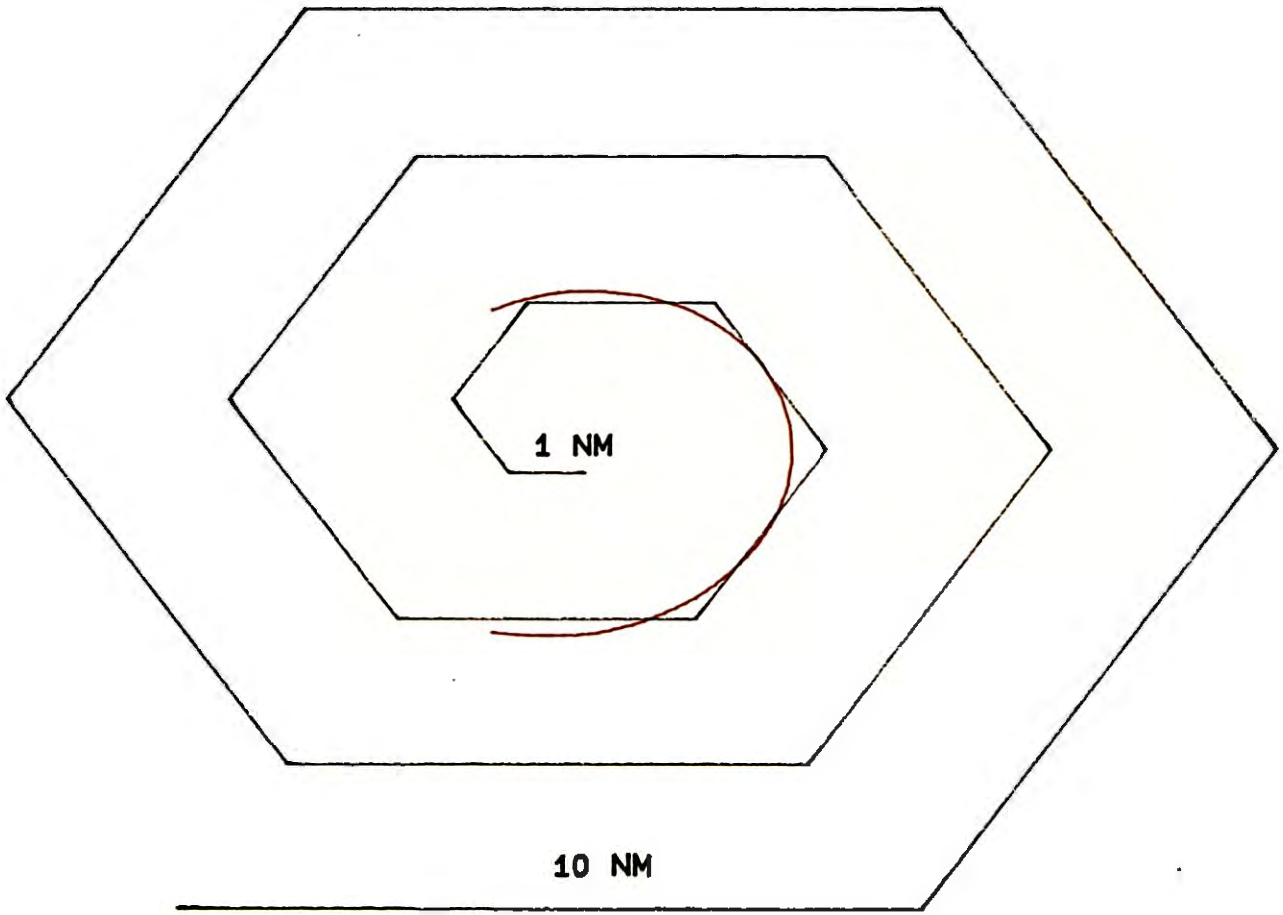
FMS SPIRAL 2-FLY BY WAYPOINTS

(A320, 200 KIAS AT 10,000' + 60 KNOT WIND)



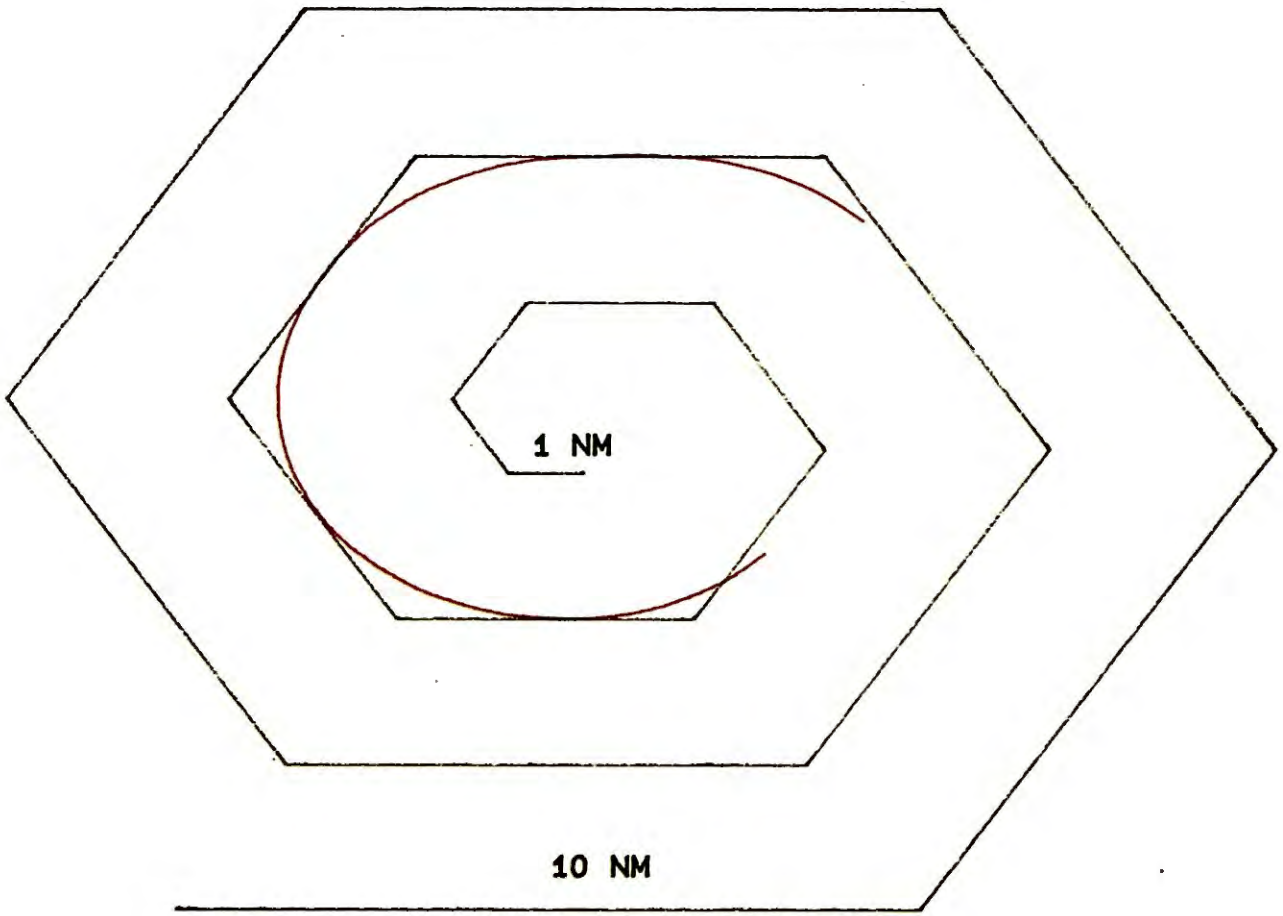
FMS SPIRAL 2-FLY BY WAYPOINTS

(A320, 220 KIAS AT 10,000' + 60 KNOT WIND)



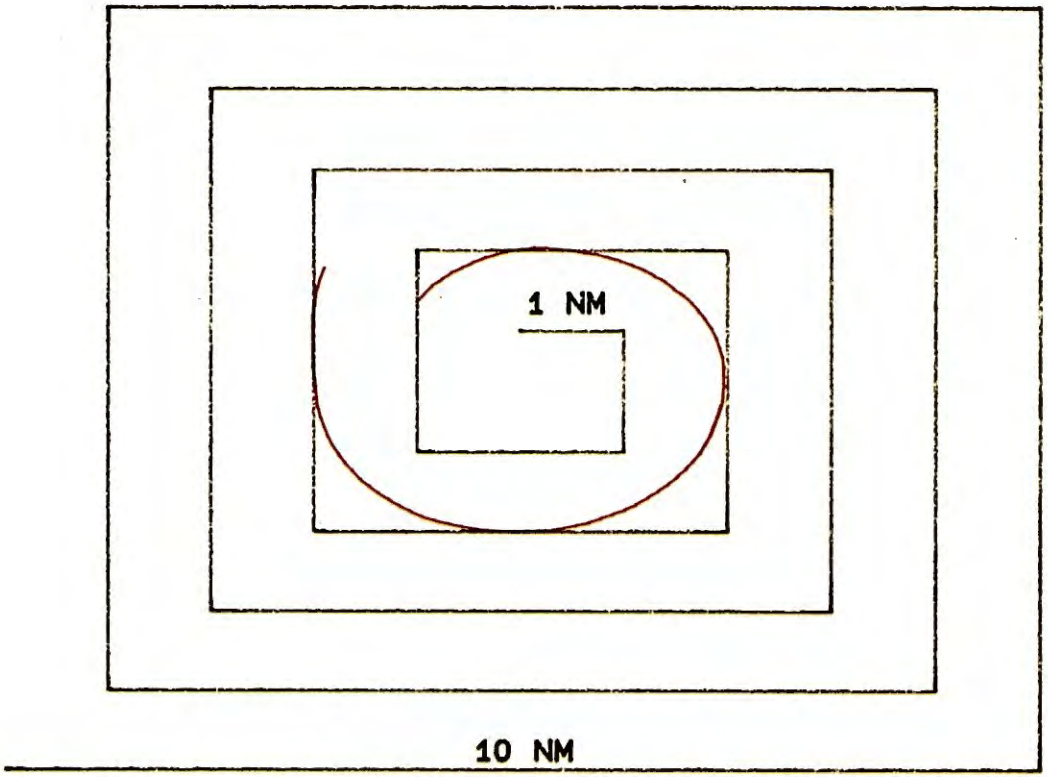
FMS SPIRAL 2-FLY BY WAYPOINTS

(A320, 250 KIAS AT 10,000' + 60 KNOT WIND)



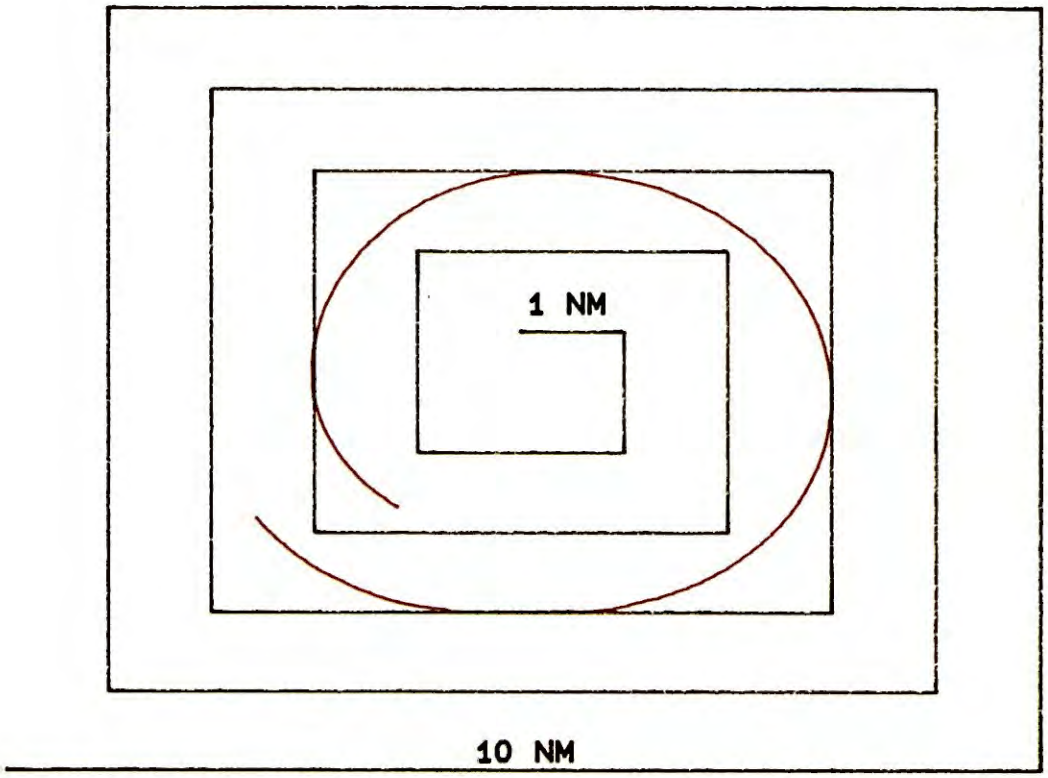
FMS SPIRAL 3 - FLY BY WAYPOINTS

(A320, 160 KIAS AT 10,000' + 60 KNOT WIND)



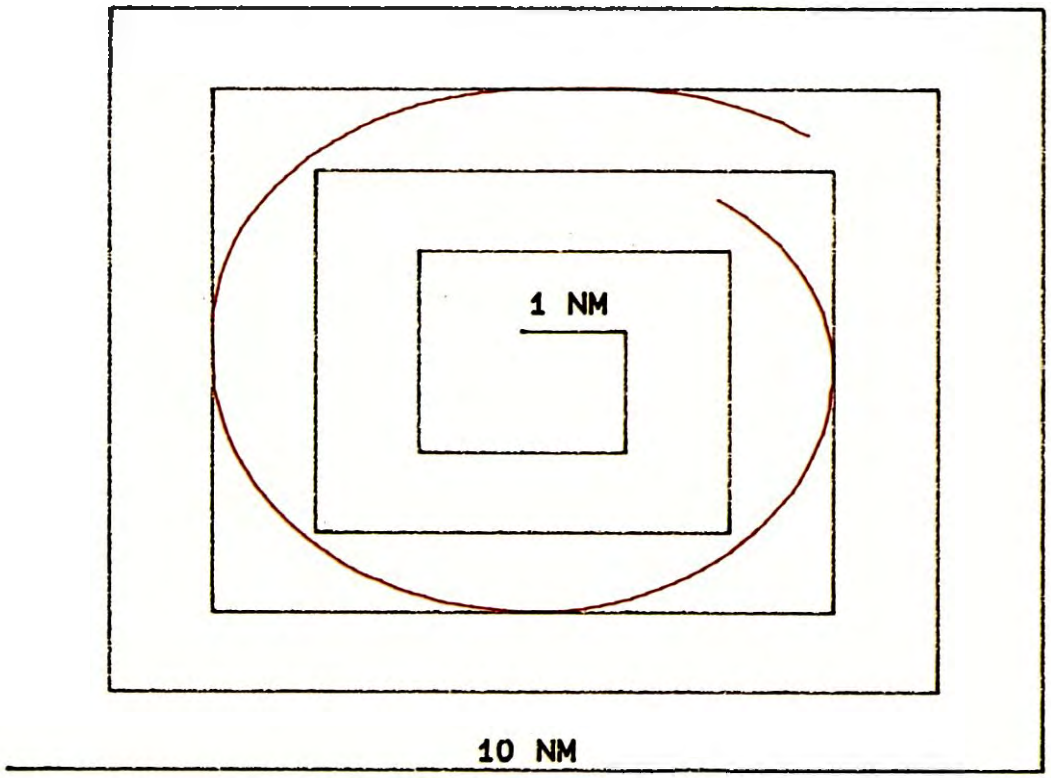
FMS SPIRAL 3 - FLY BY WAYPOINTS

(A320, 200 KIAS AT 10,000' + 60 KNOT WIND)



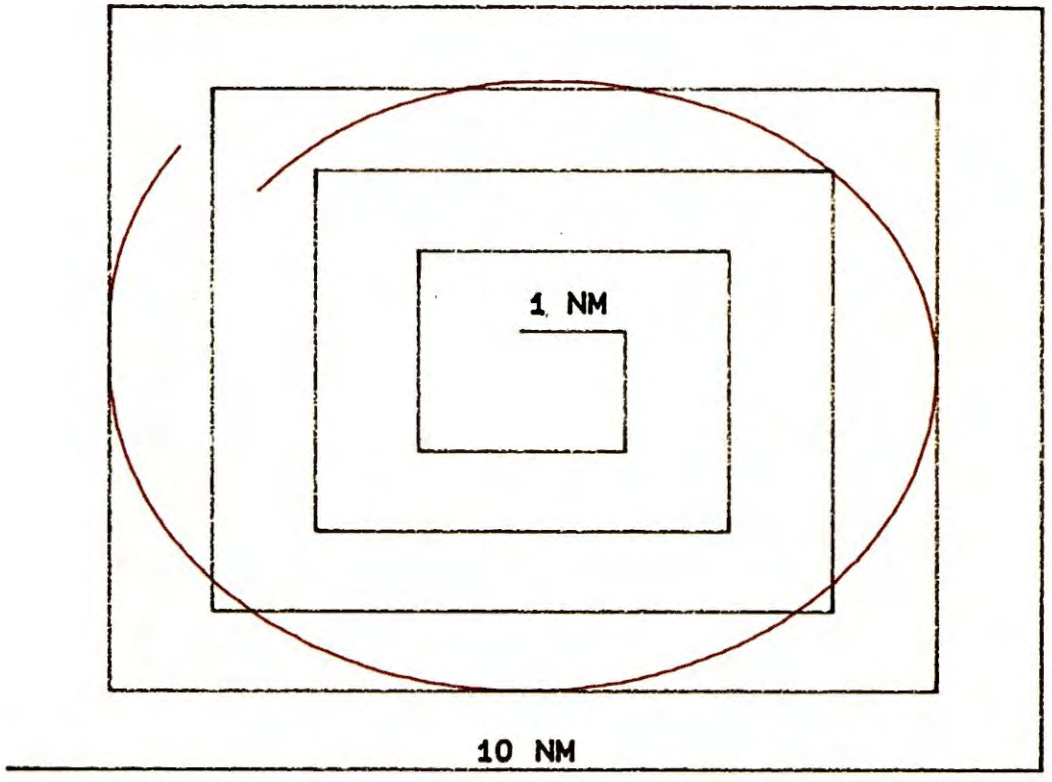
FMS SPIRAL 3 - FLY BY WAYPOINTS

(A320, 220 KIAS AT 10,000' + 60 KNOT WIND)



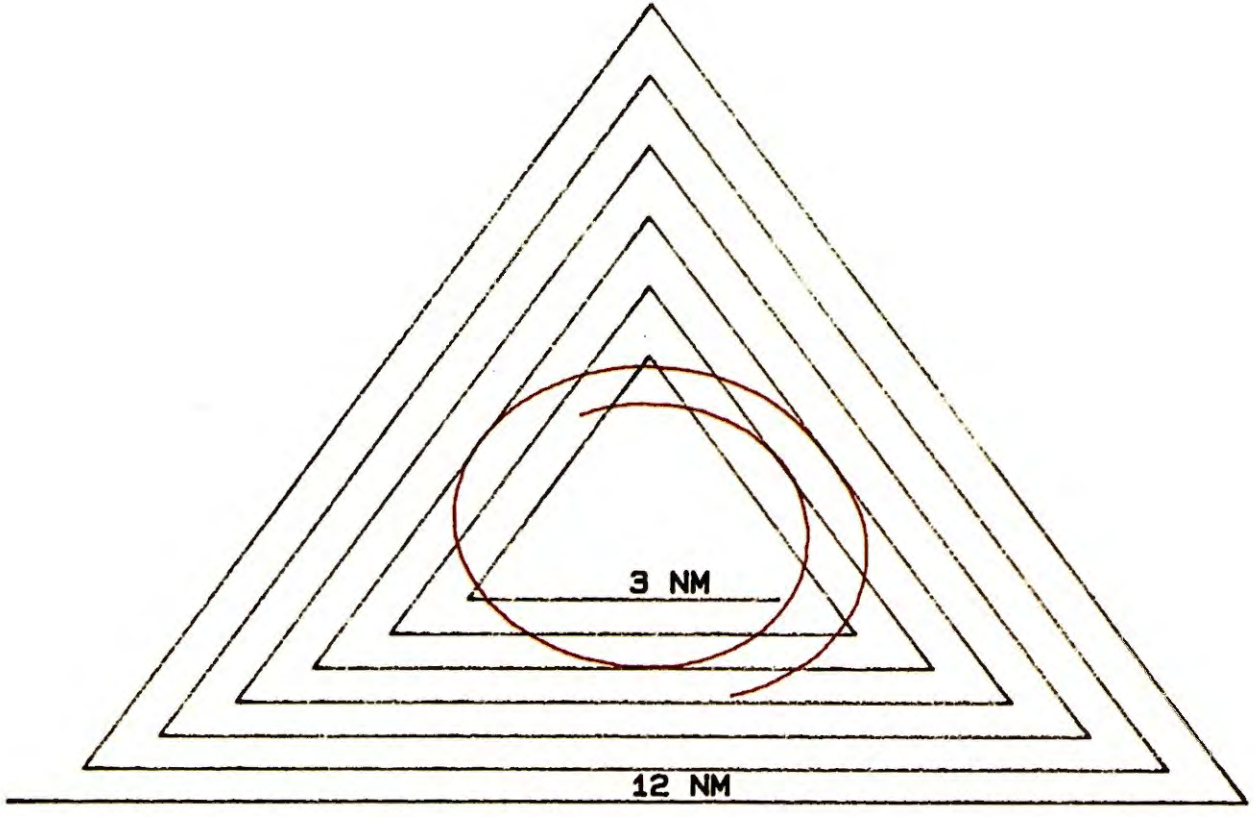
FMS SPIRAL 3 - FLY BY WAYPOINTS

(A320, 250 KIAS AT 10,000' + 60 KNOT WIND)



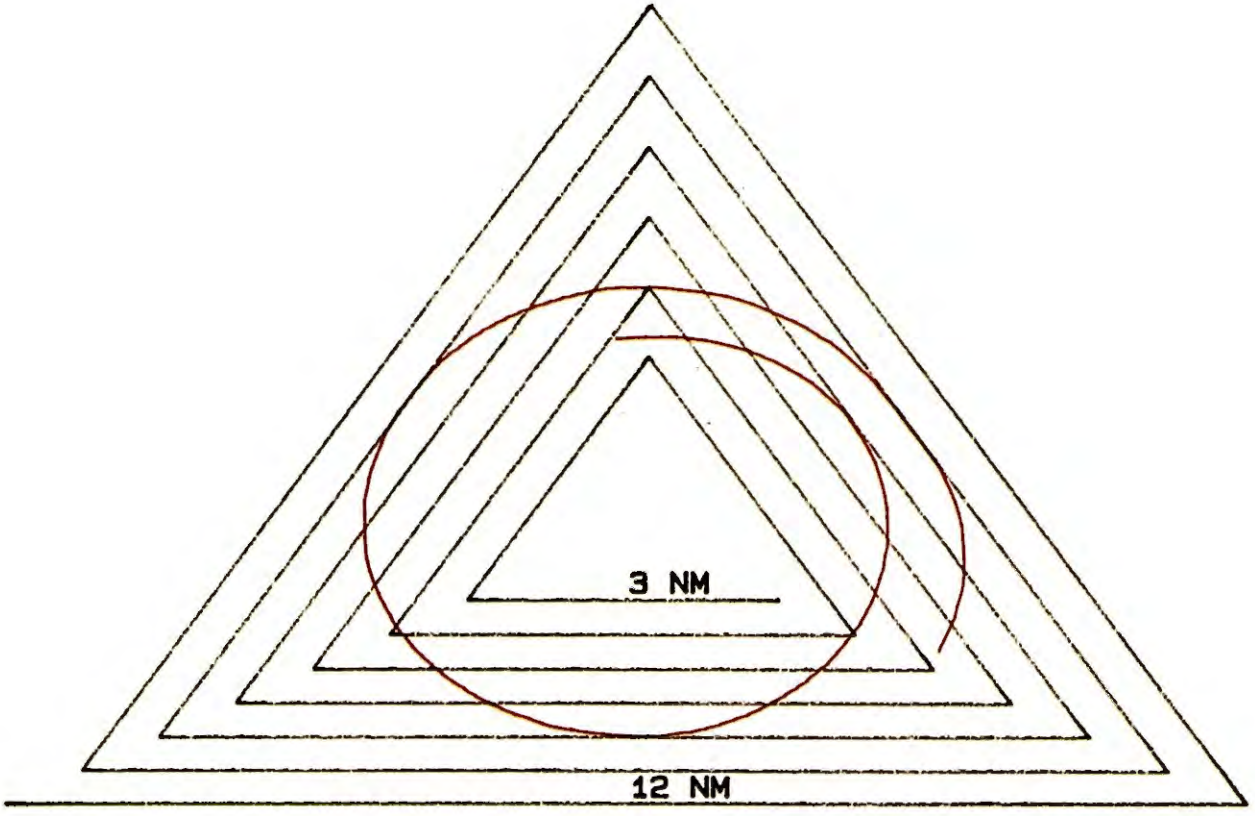
FMS SPIRAL 4 - FLY BY WAYPOINTS

(A320, 160 KIAS AT 10,000' + 60 KNOT WIND)



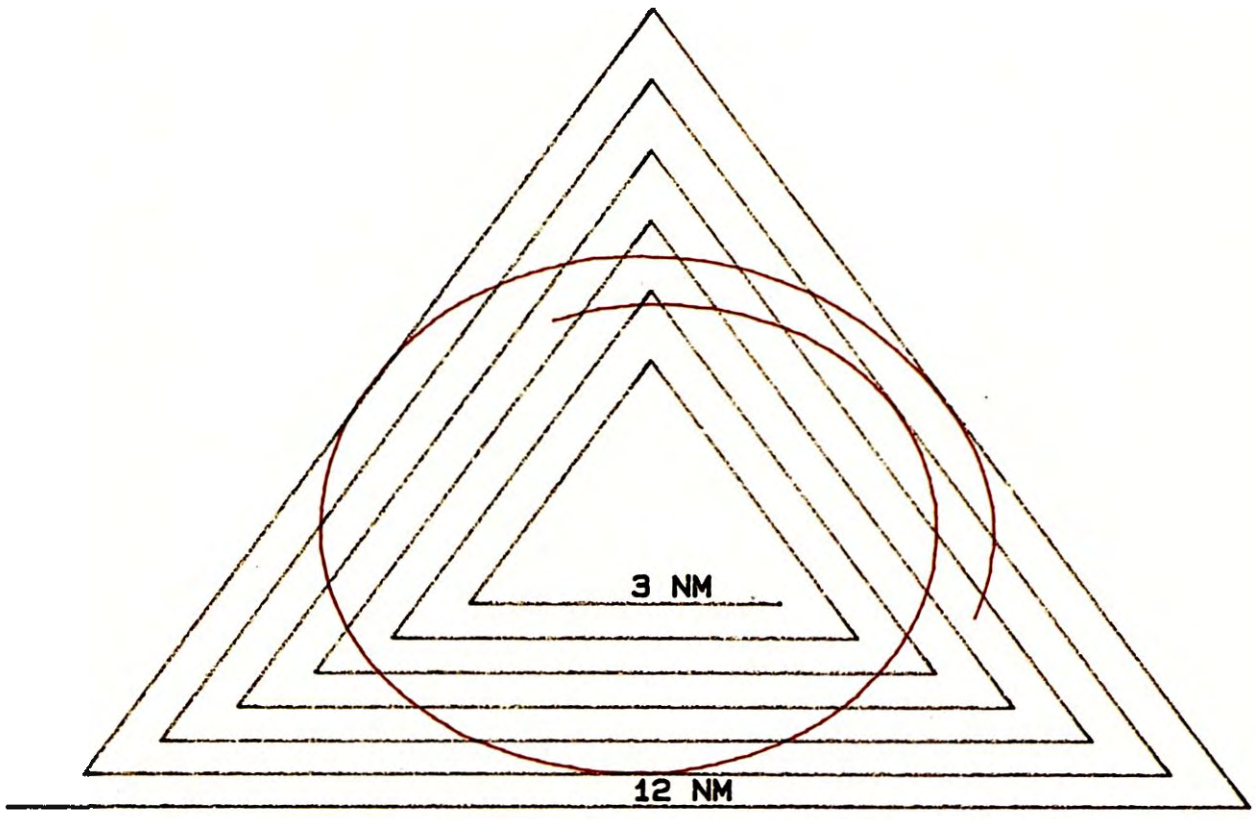
FMS SPIRAL 4 - FLY BY WAYPOINTS

(A320, 200 KIAS AT 10,000' + 60 KNOT WIND)



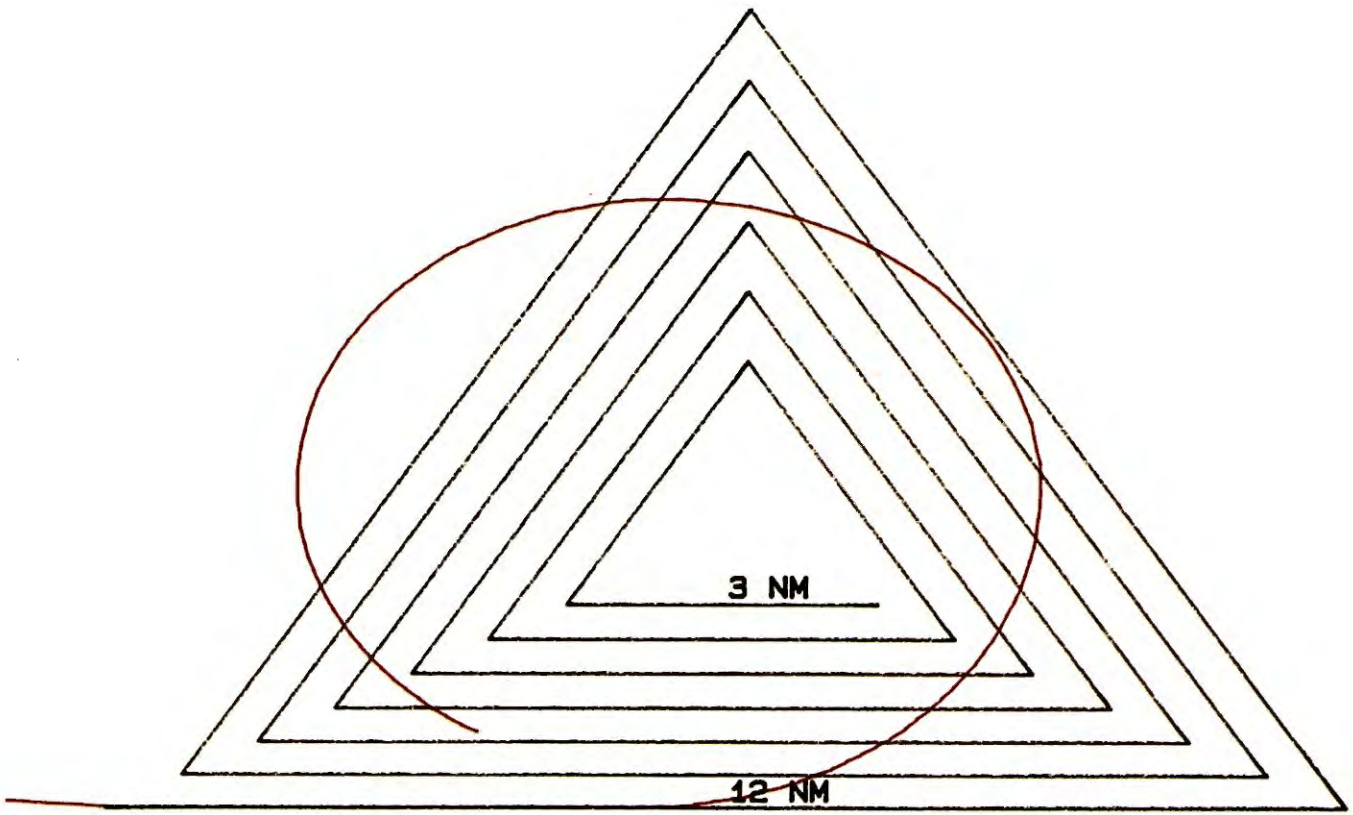
FMS SPIRAL 4 - FLY BY WAYPOINTS

(A320, 220 KIAS AT 10,000' + 60 KNOT WIND)



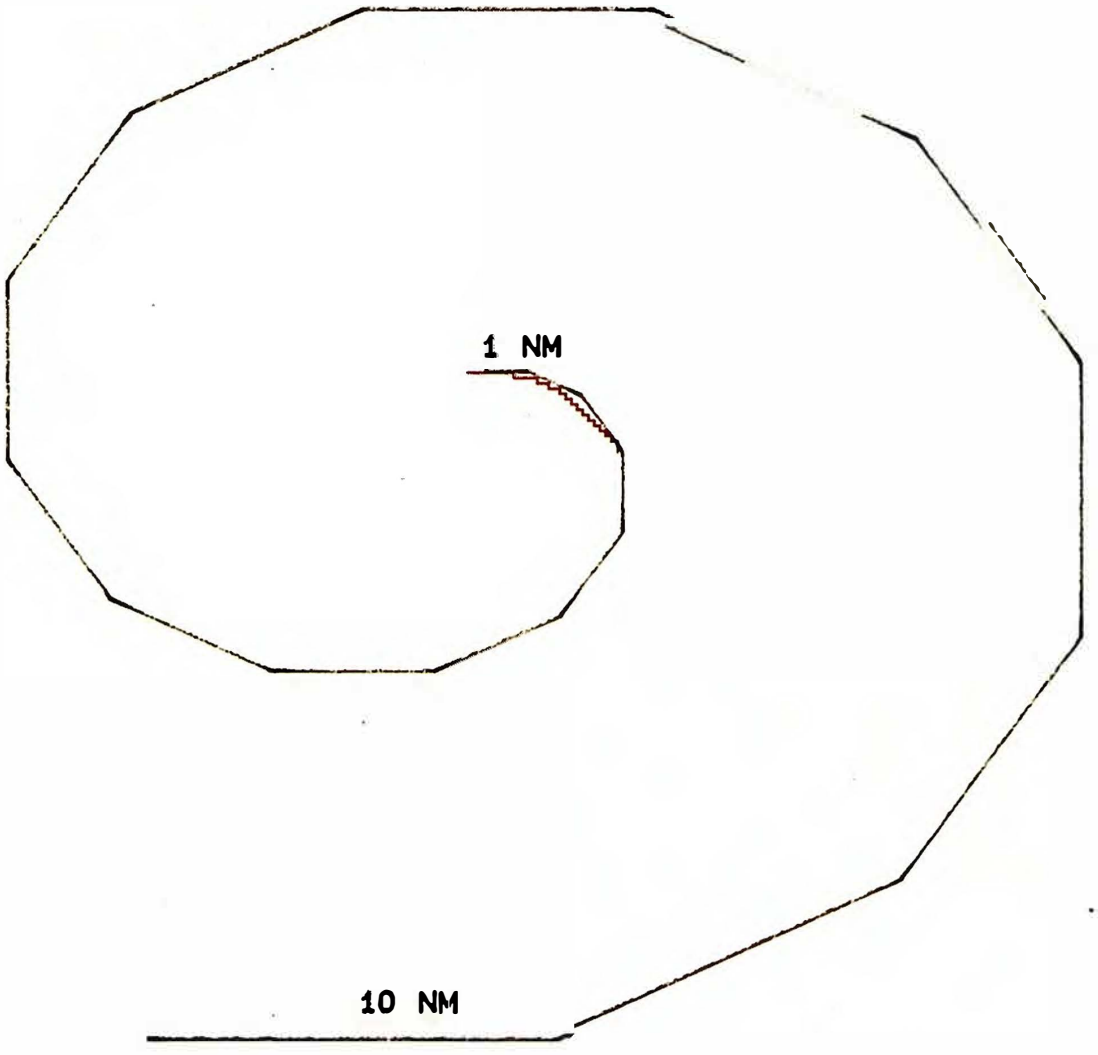
FMS SPIRAL 4 - FLY BY WAYPOINTS

(A320, 250 KIAS AT 10,000' + 60 KNOT WIND)



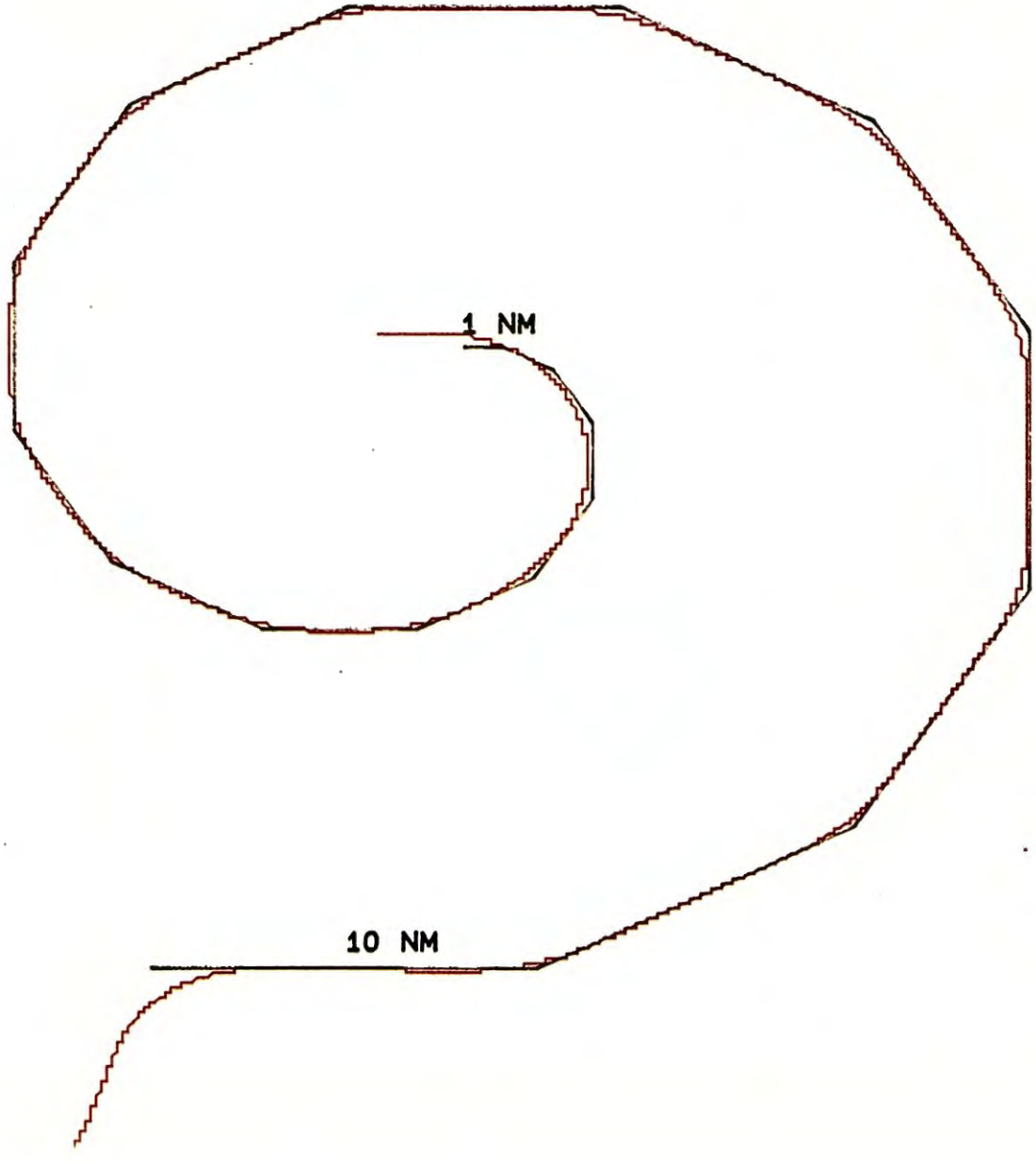
FMS SPIRAL 1 - FLY BY WAYPOINTS

(B747, 160 KIAS AT 10,000' + 60 KNOT WIND)



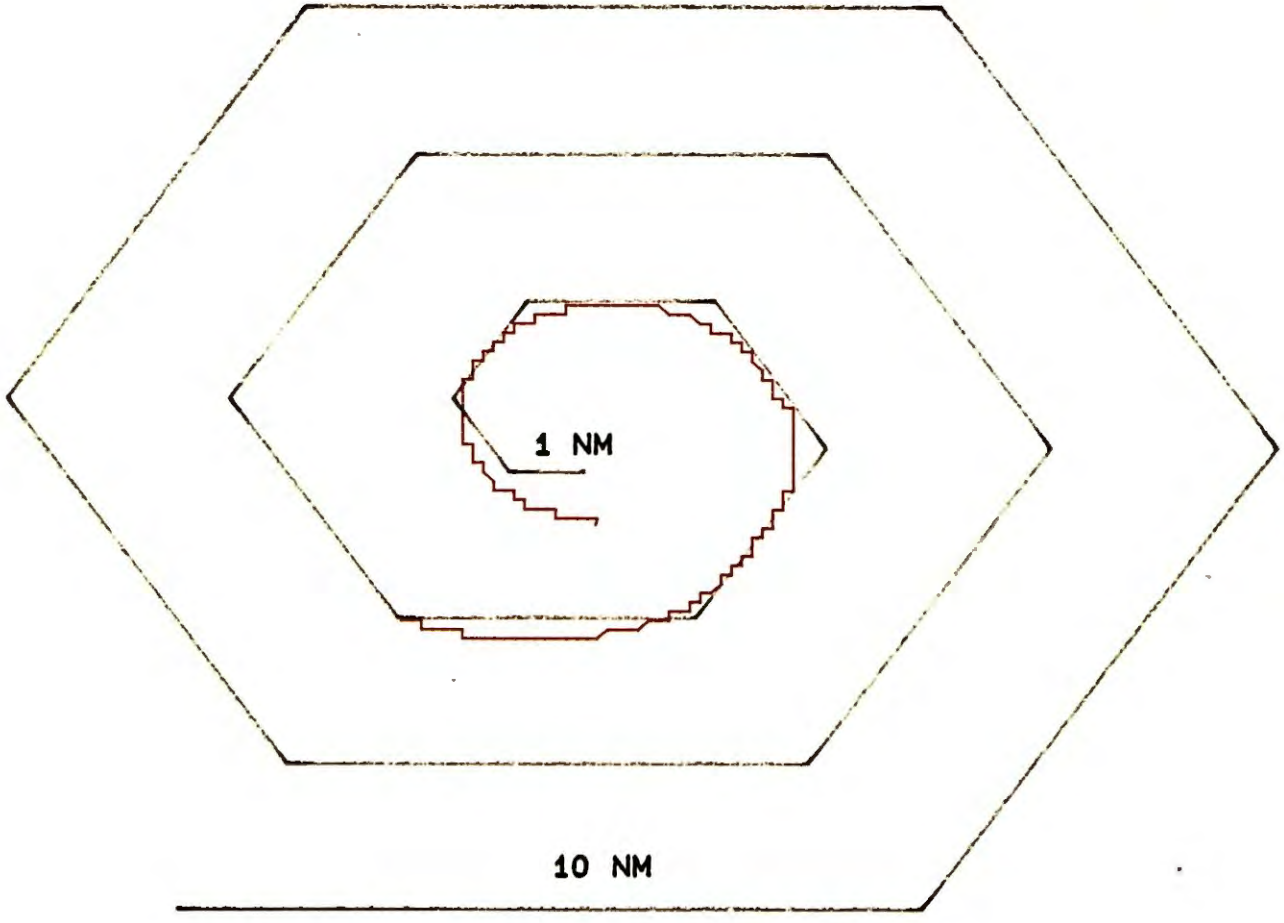
FMS SPIRAL 1 - FLY BY WAYPOINTS

(B747, 250 KIAS AT 10,000' + 60 KNOT WIND)



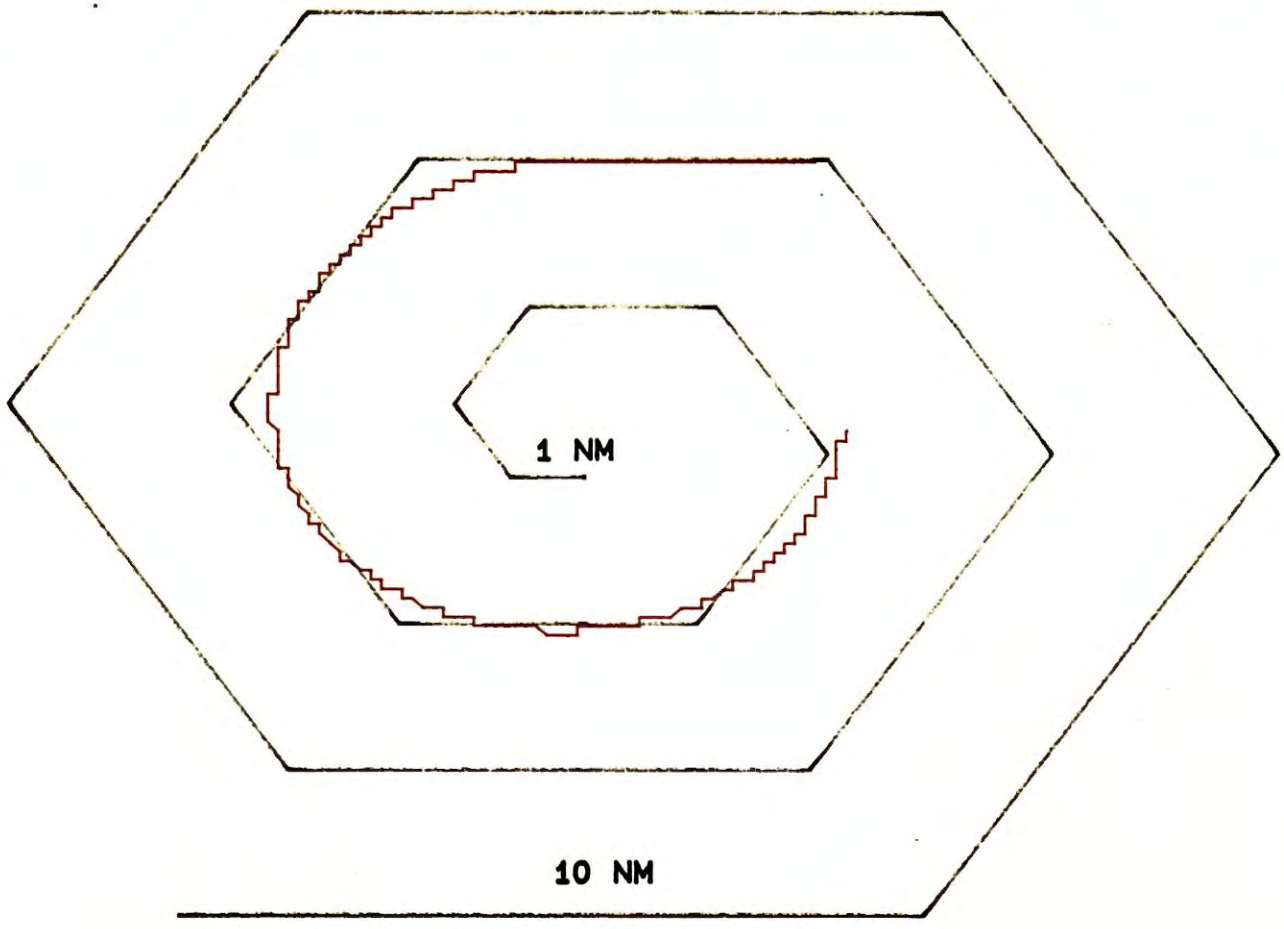
FMS SPIRAL 2 - FLY BY WAYPOINTS

(B747, 160 KIAS AT 10,000' + 60 KNOT WIND)



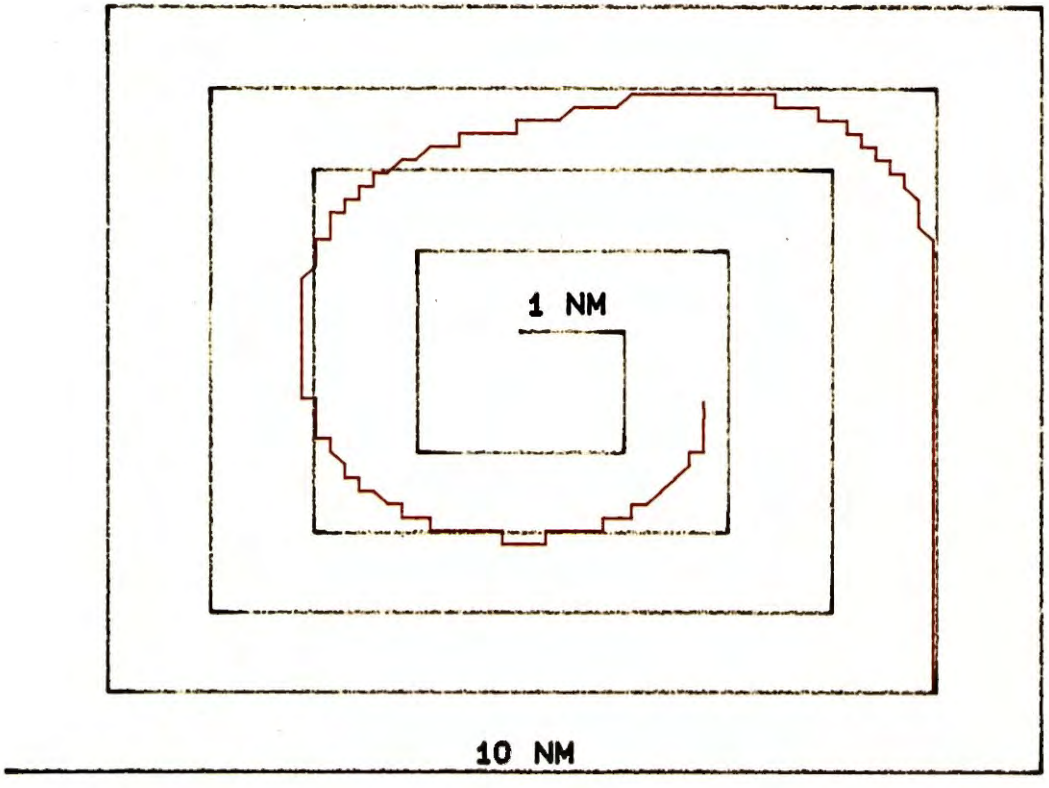
FMS SPIRAL 2 - FLY BY WAYPOINTS

(B747, 250 KIAS AT 10,000' + 60 KNOT WIND)



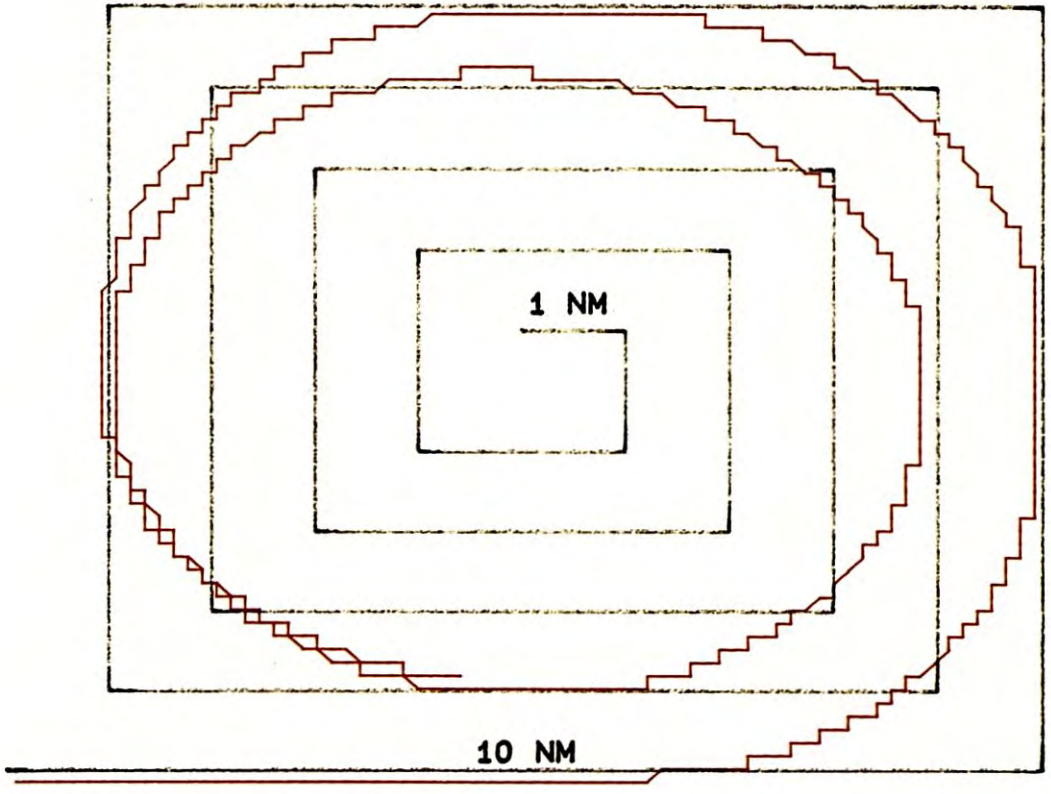
FMS SPIRAL 3 - FLY BY WAYPOINTS

(B747, 160 KIAS AT 10,000' + 60 KNOT WIND)



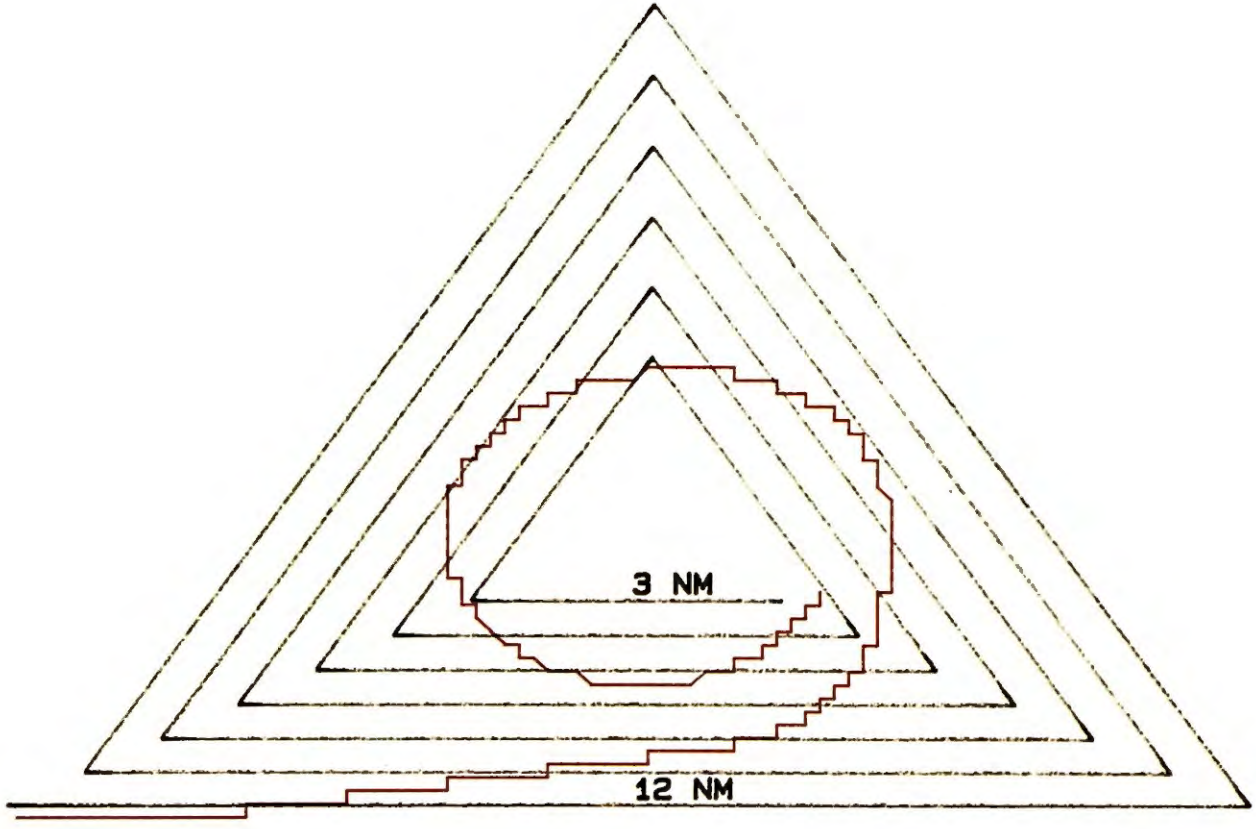
FMS SPIRAL 3 - FLY BY WAYPOINTS

(B747, 250 KIAS AT 10,000' + 60 KNOT WIND)



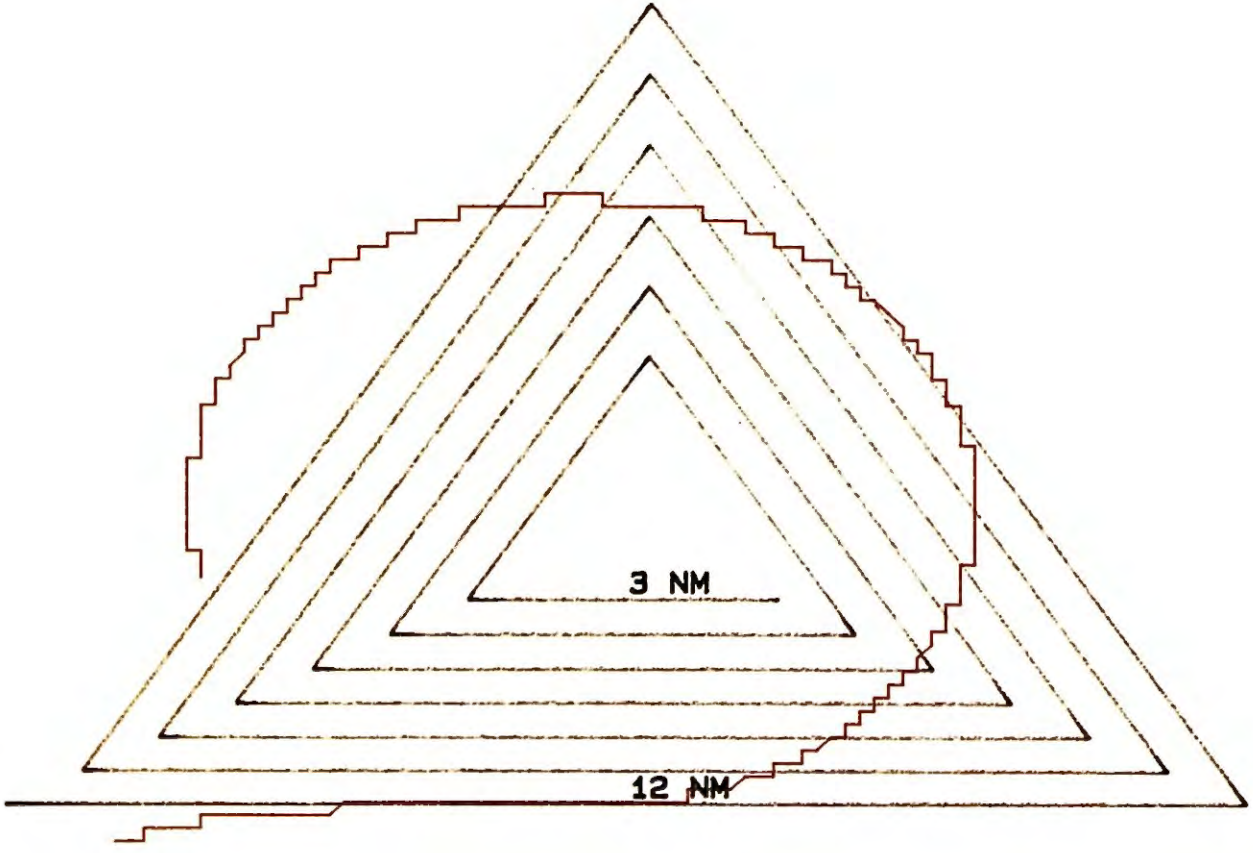
FMS SPIRAL 4 - FLY BY WAYPOINTS

(B747, 160 KIAS AT 10,000' + 60 KNOT WIND)



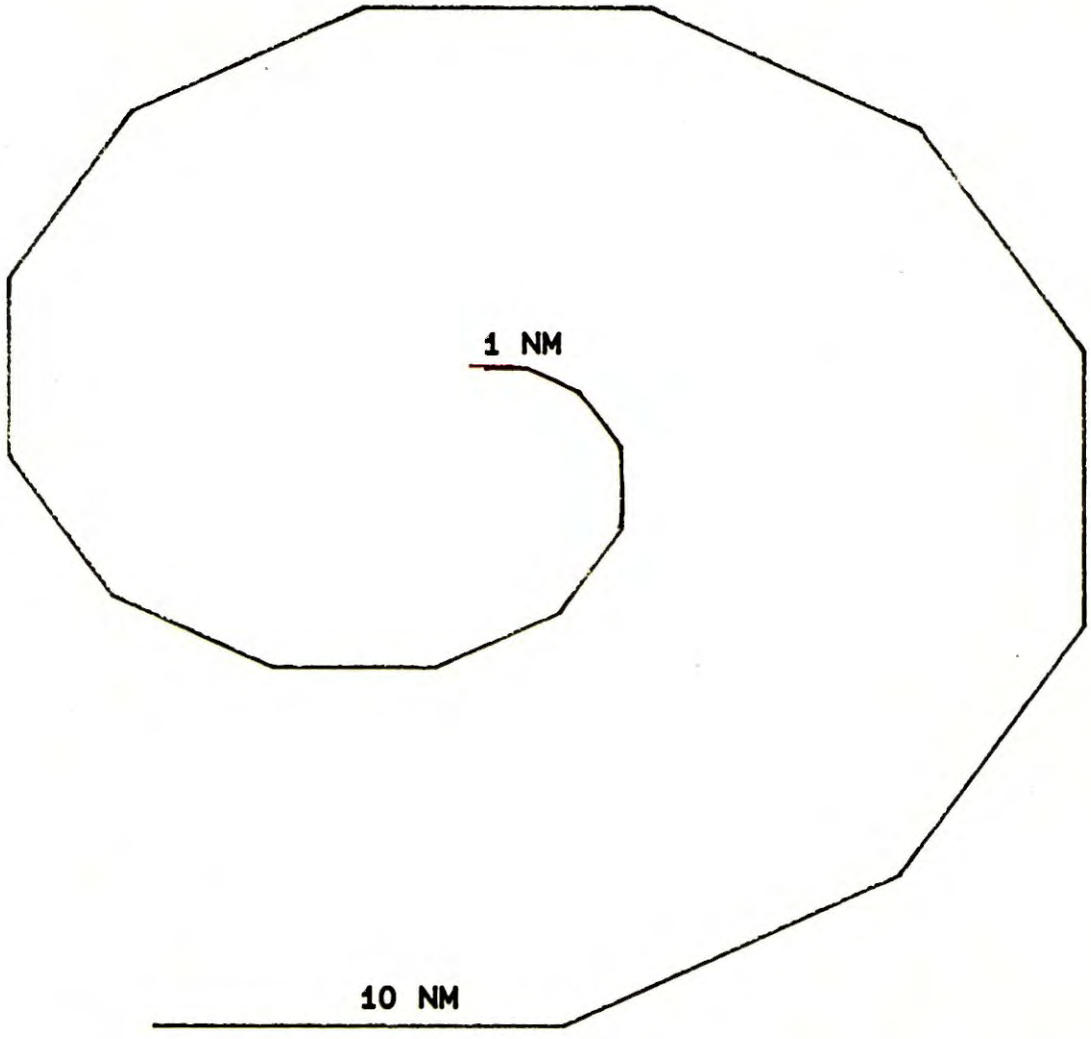
FMS SPIRAL 4 - FLY BY WAYPOINTS

(B747, 250 KIAS AT 10,000' + 60 KNOT WIND)



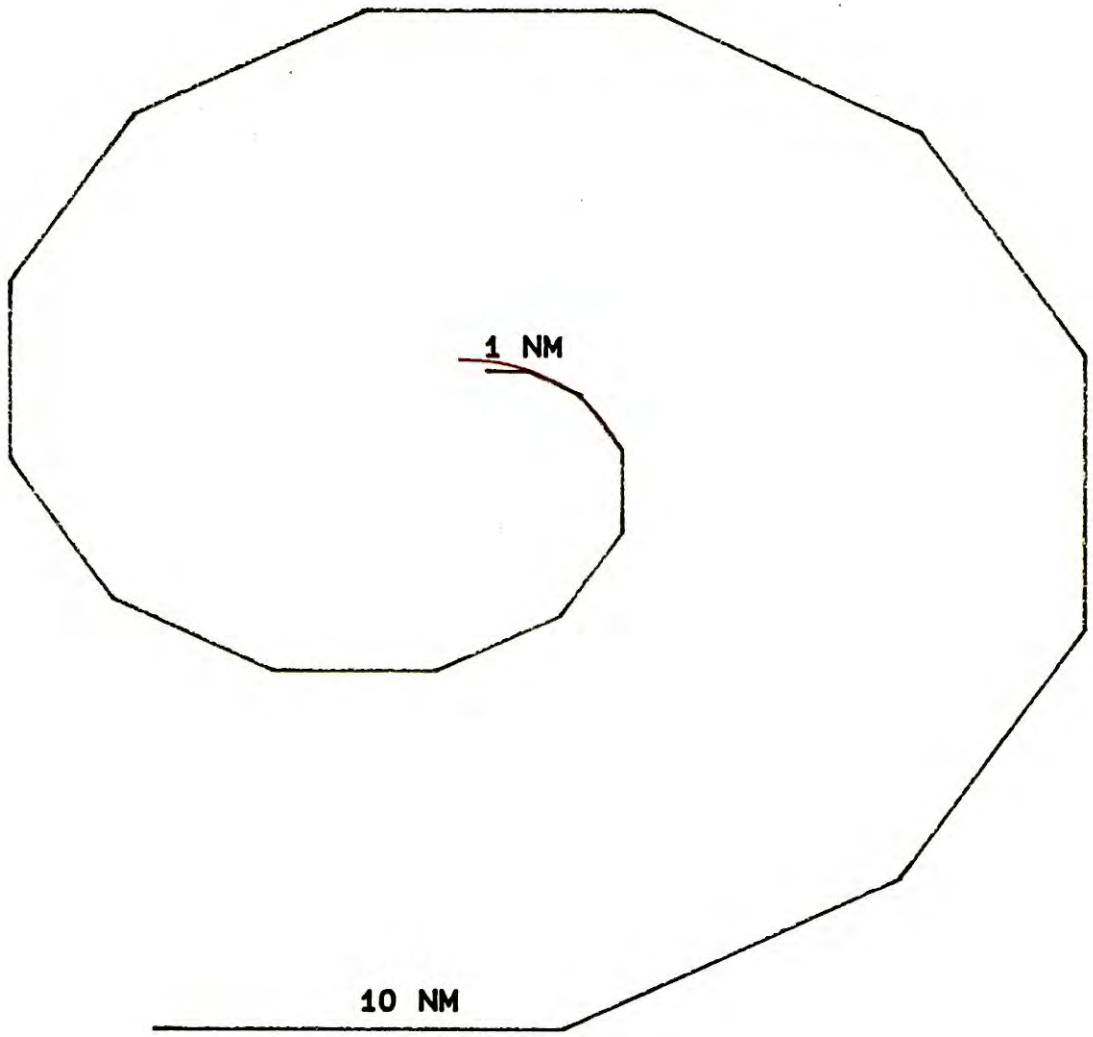
FMS SPIRAL 1 - FLY BY WAYPOINTS

(MD11, 160 KIAS AT 10,000' + 60 KNOT WIND)



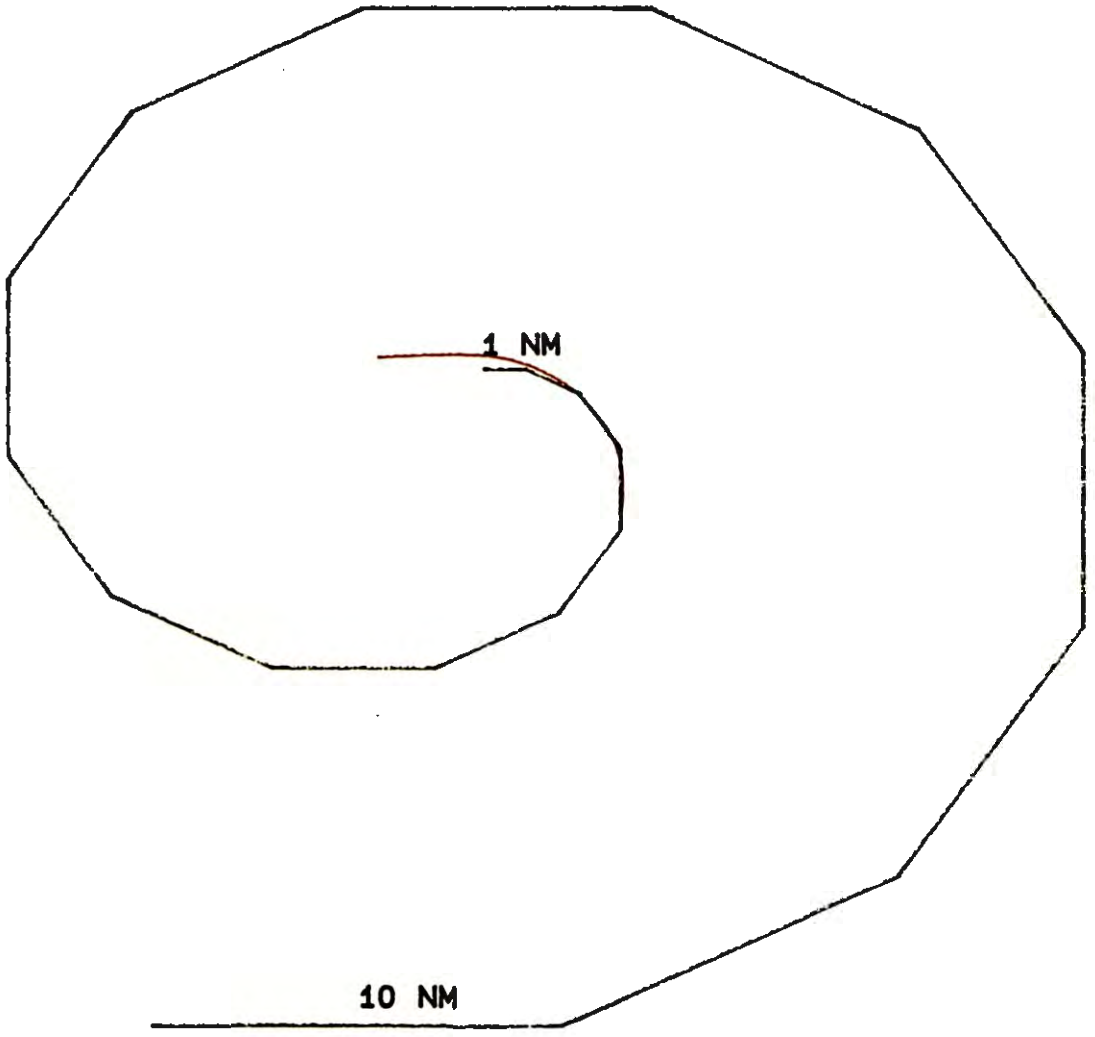
FMS SPIRAL 1 - FLY BY WAYPOINTS

(MD11, 200 KIAS AT 10,000' + 60 KNOT WIND)



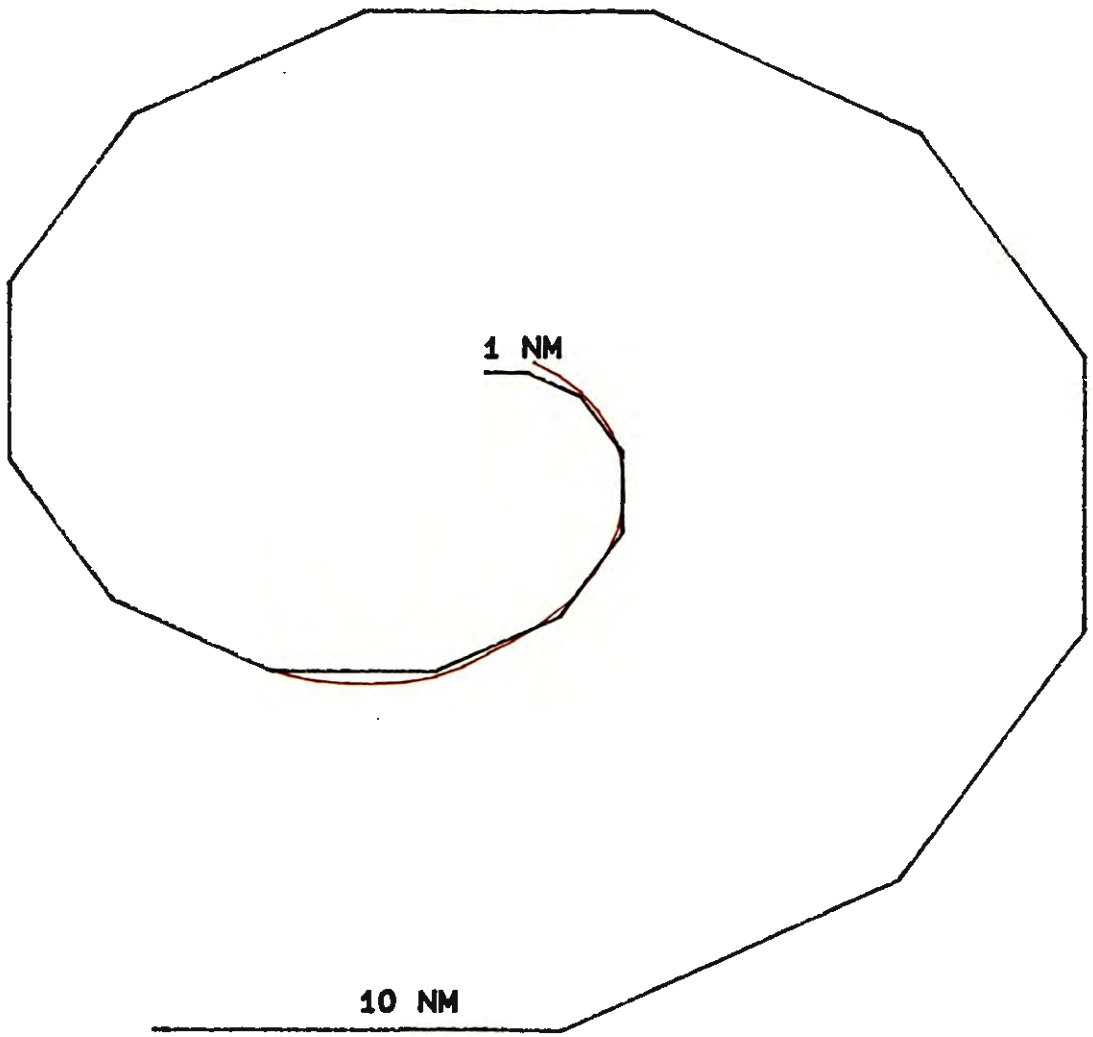
FMS SPIRAL 1 - FLY BY WAYPOINTS

(MD11, 220 KIAS AT 10,000' + 60 KNOT WIND)



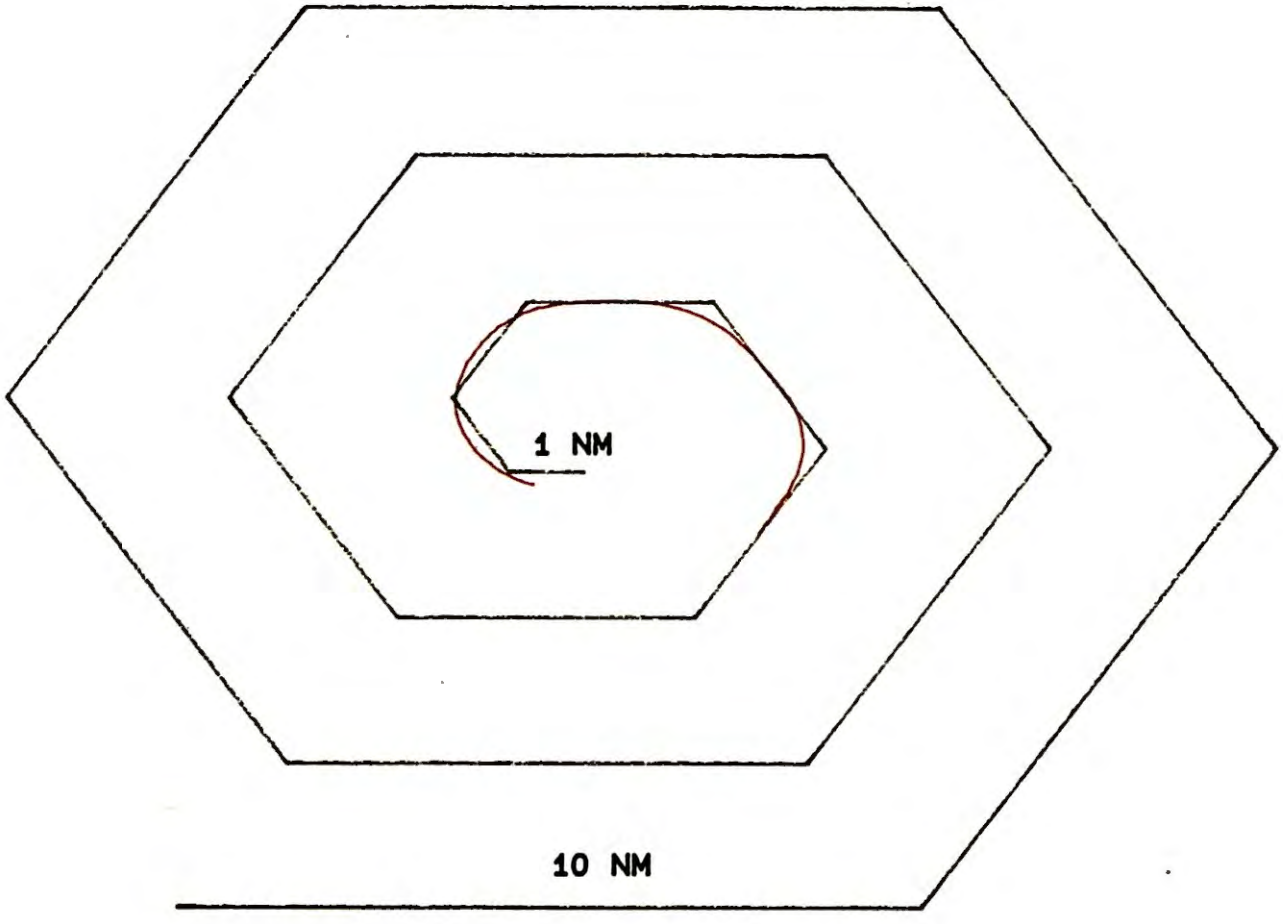
FMS SPIRAL 1 - FLY BY WAYPOINTS

(MD11, 250 KIAS AT 10,000' + 60 KNOT WIND)



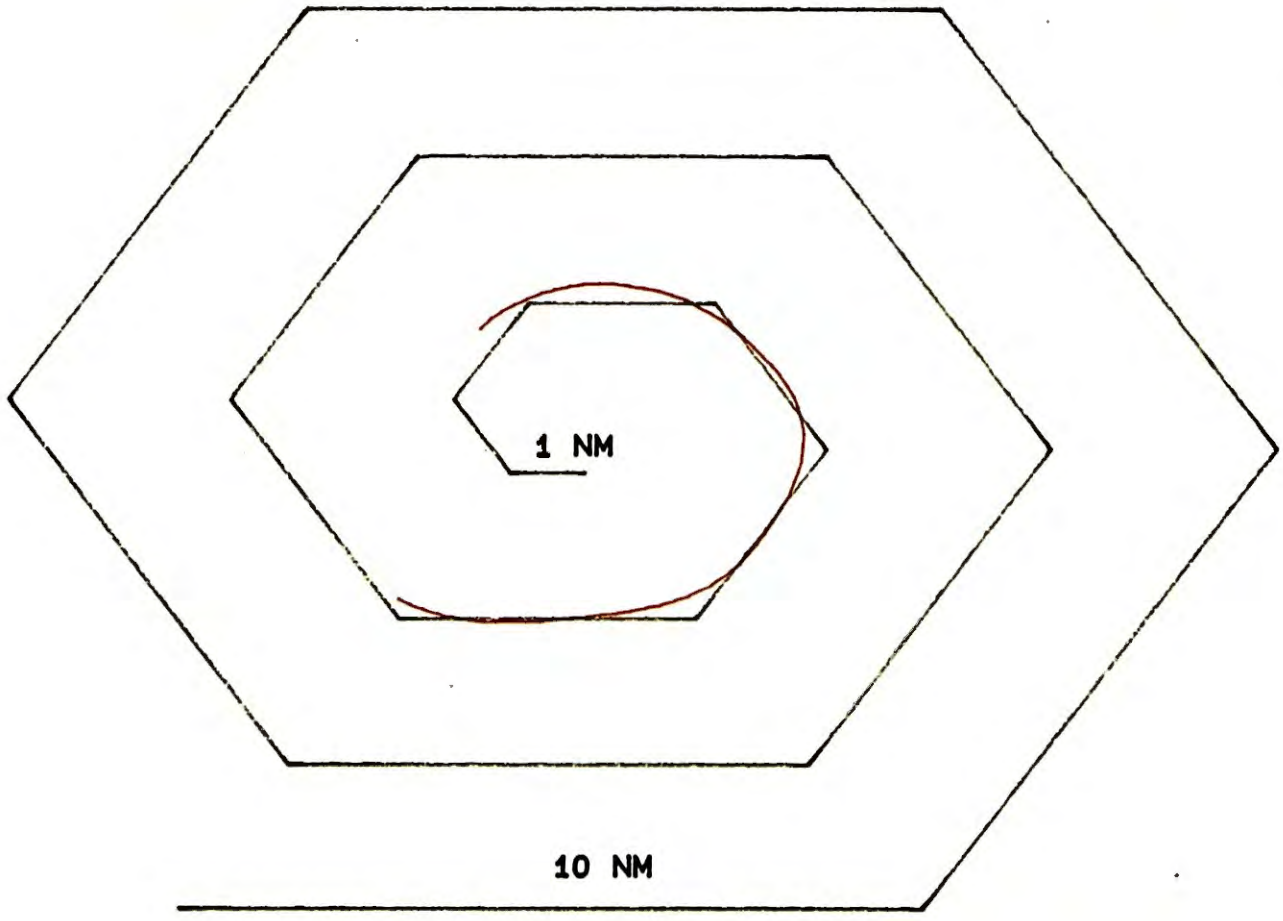
FMS SPIRAL 2-FLY BY WAYPOINTS

(MD11, 160 KIAS AT 10,000' + 60 KNOT WIND)



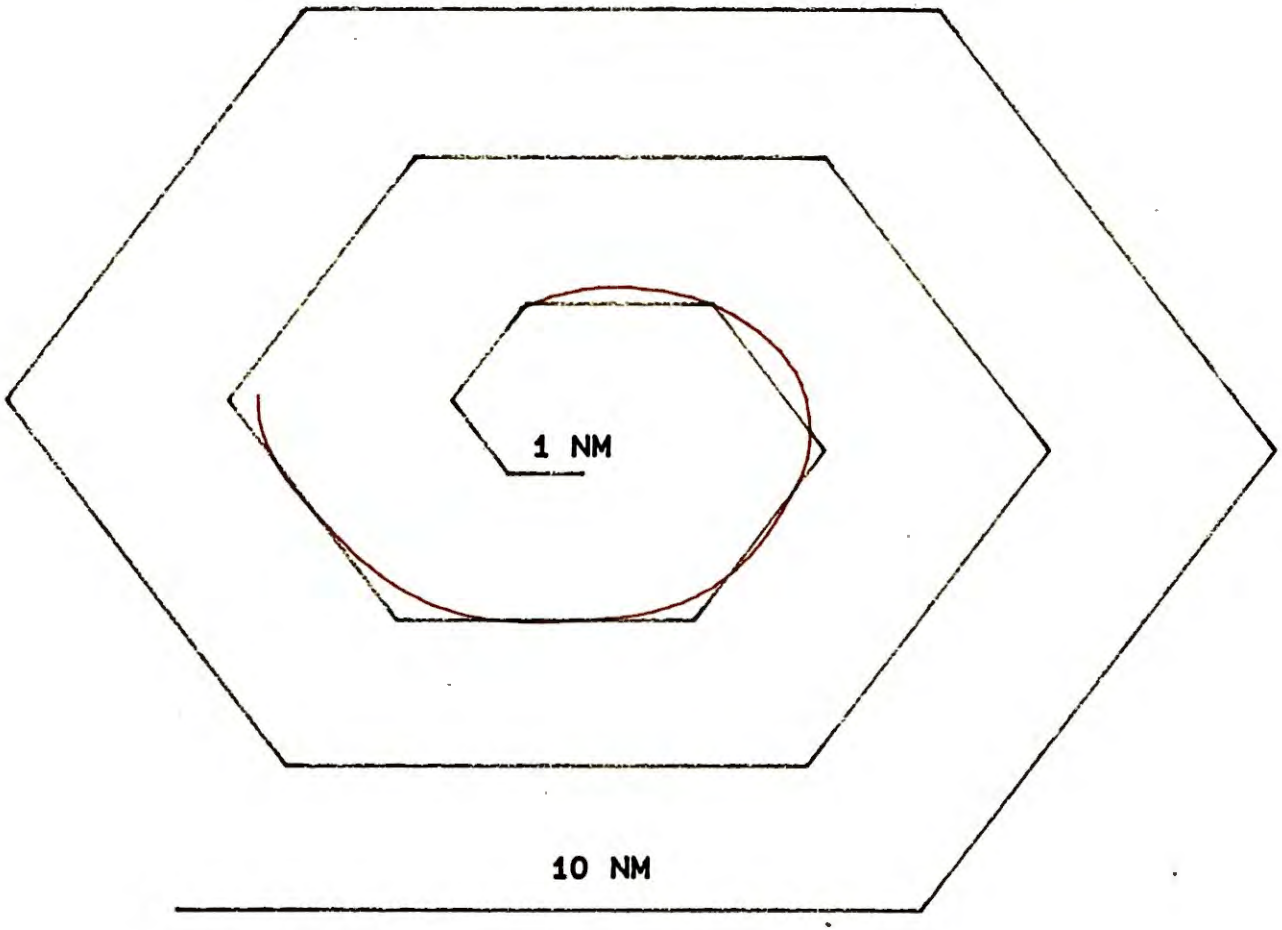
FMS SPIRAL 2 - FLY BY WAYPOINTS

(MD11, 200 KIAS AT 10,000' + 60 KNOT WIND)



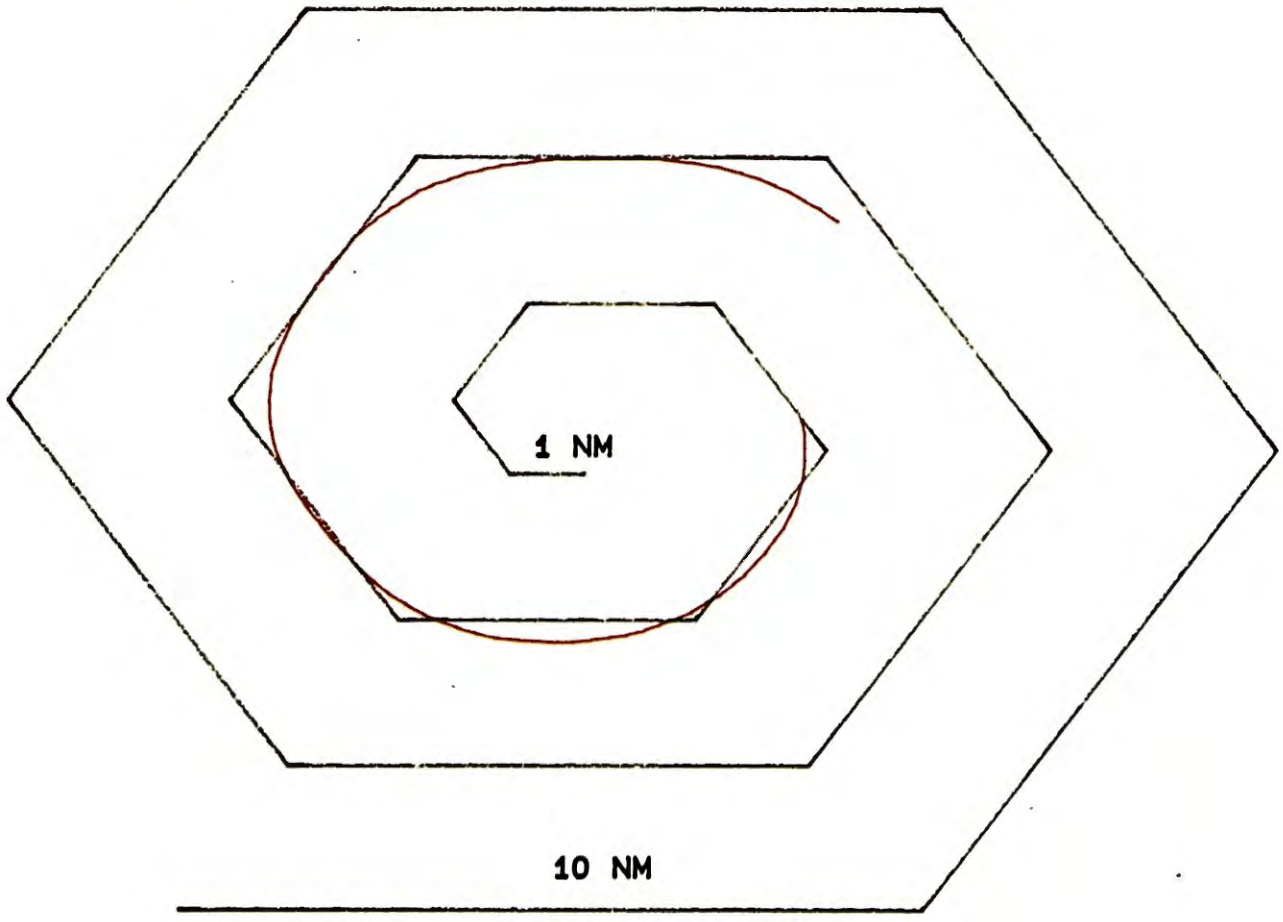
FMS SPIRAL 2 - FLY BY WAYPOINTS

(MD11, 220 KIAS AT 10,000' + 60 KNOT WIND)



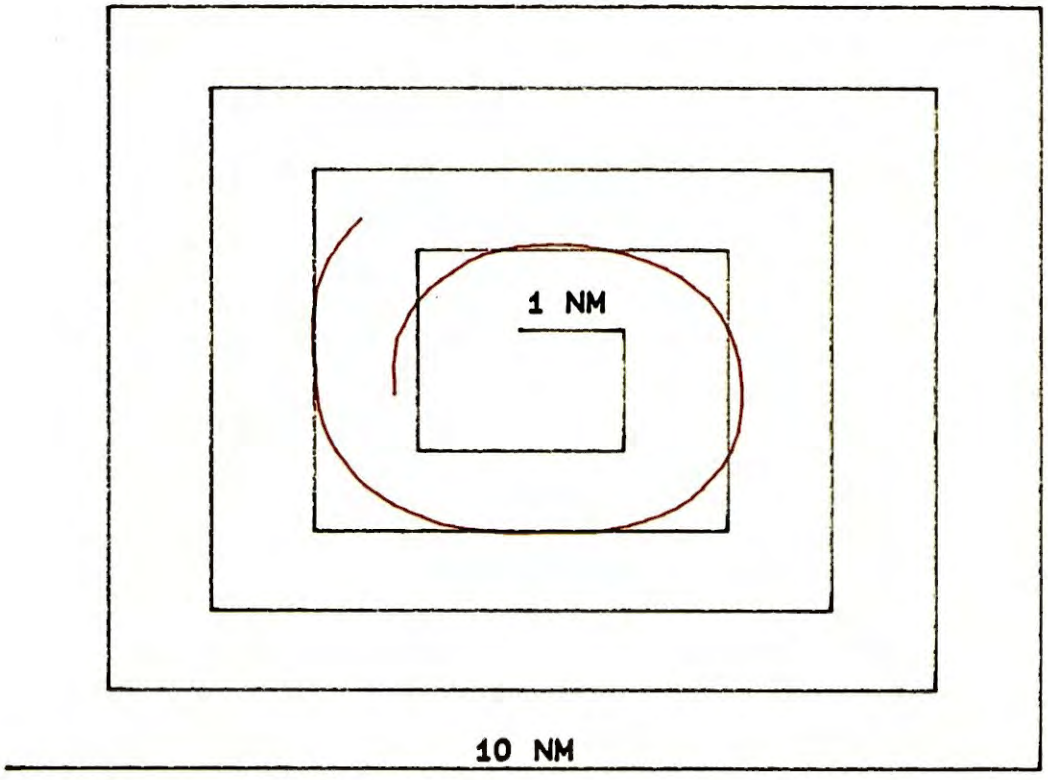
FMS SPIRAL 2 - FLY BY WAYPOINTS

(MD11, 250 KIAS AT 10,000' + 60 KNOT WIND)



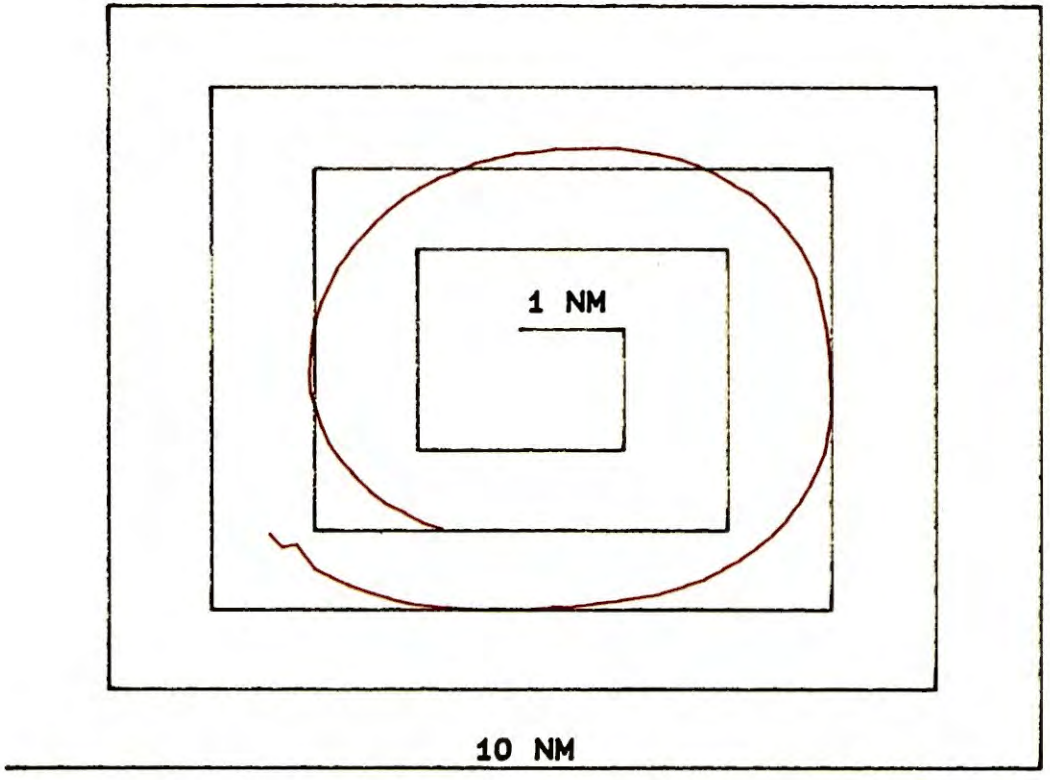
FMS SPIRAL 3 - FLY BY WAYPOINTS

(MD11, 160 KIAS AT 10,000' + 60 KNOT WIND)



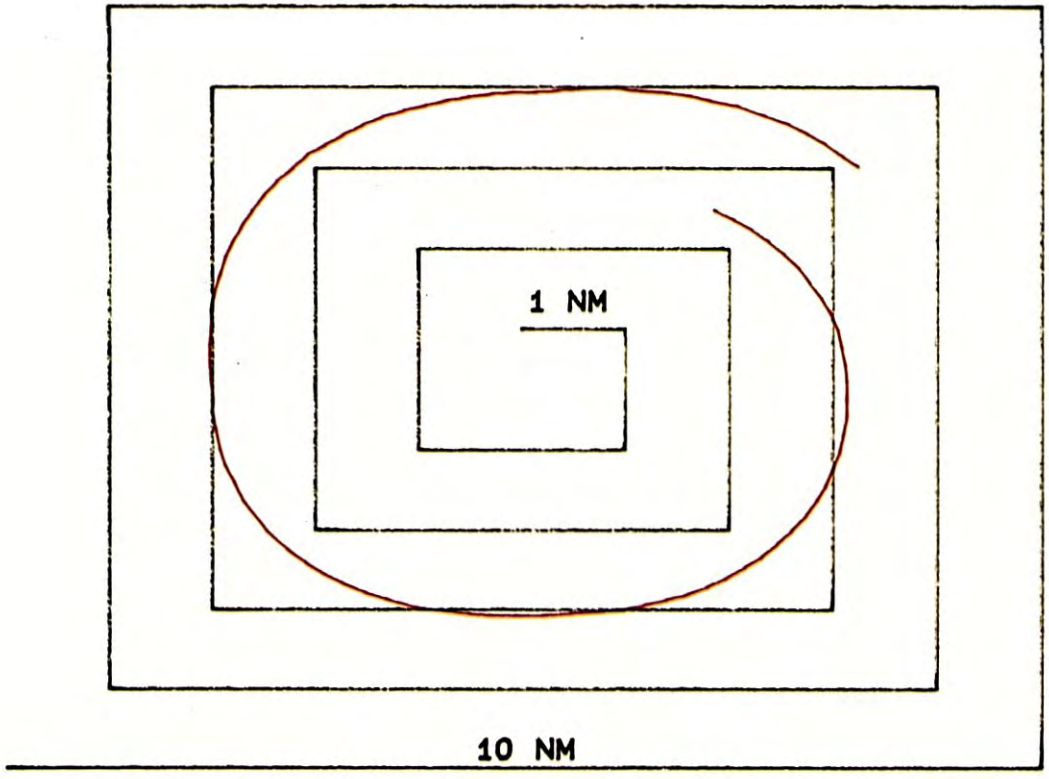
FMS SPIRAL 3 - FLY BY WAYPOINTS

(MD11, 200 KIAS AT 10,000' + 60 KNOT WIND)



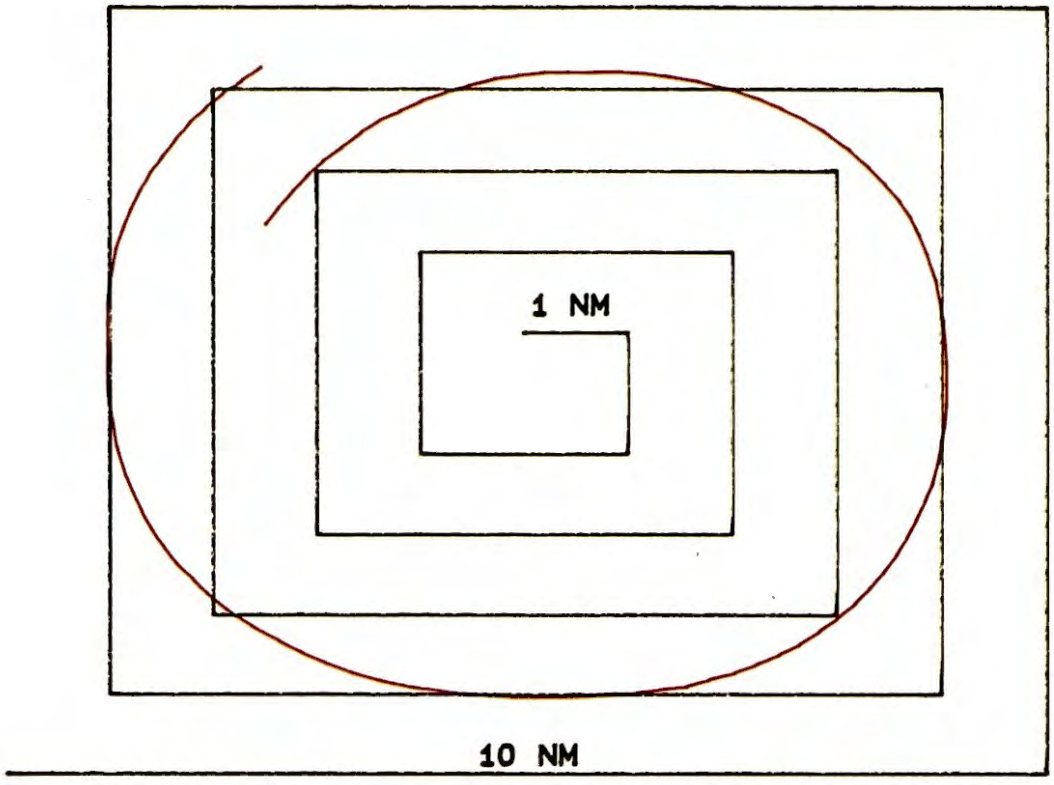
FMS SPIRAL 3 - FLY BY WAYPOINTS

(MD11, 220 KIAS AT 10,000' + 60 KNOT WIND)



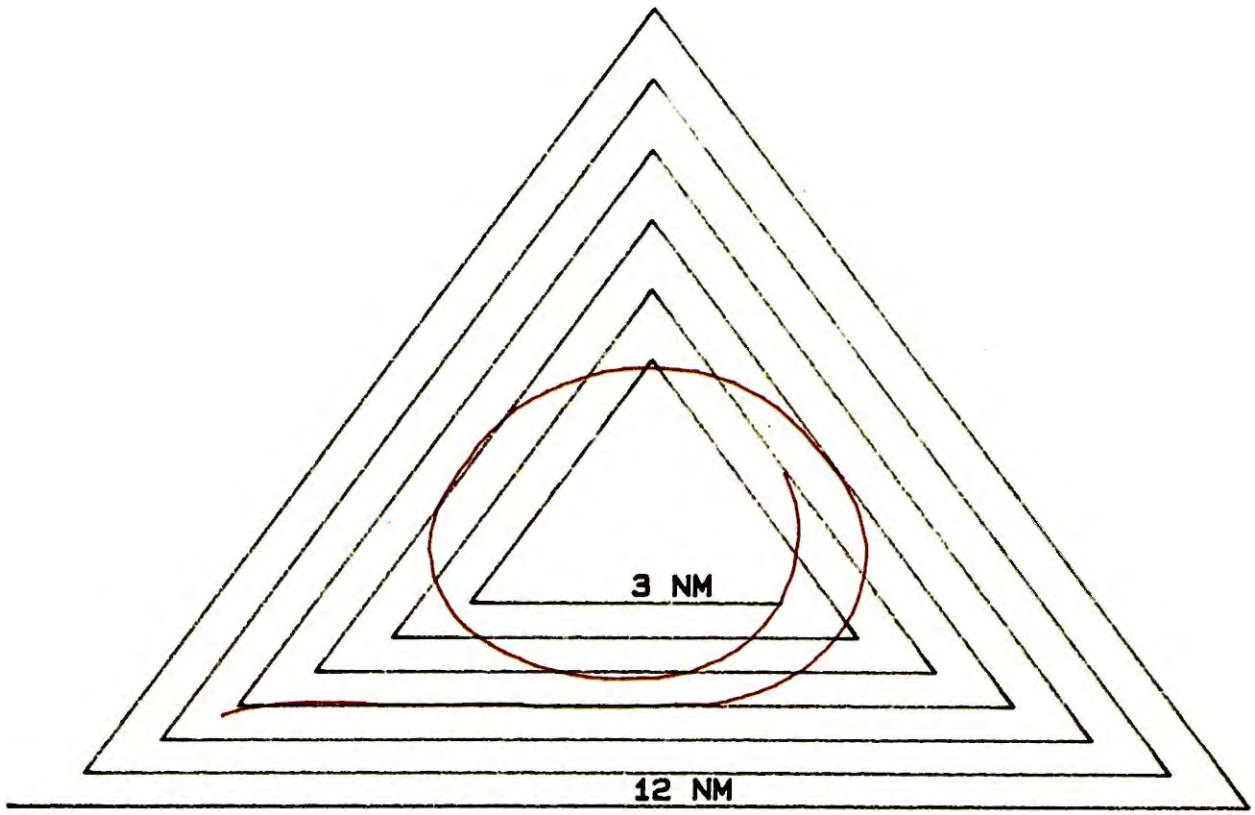
FMS SPIRAL 3 - FLY BY WAYPOINTS

(MD11, 250 KIAS AT 10,000' + 60 KNOT WIND)



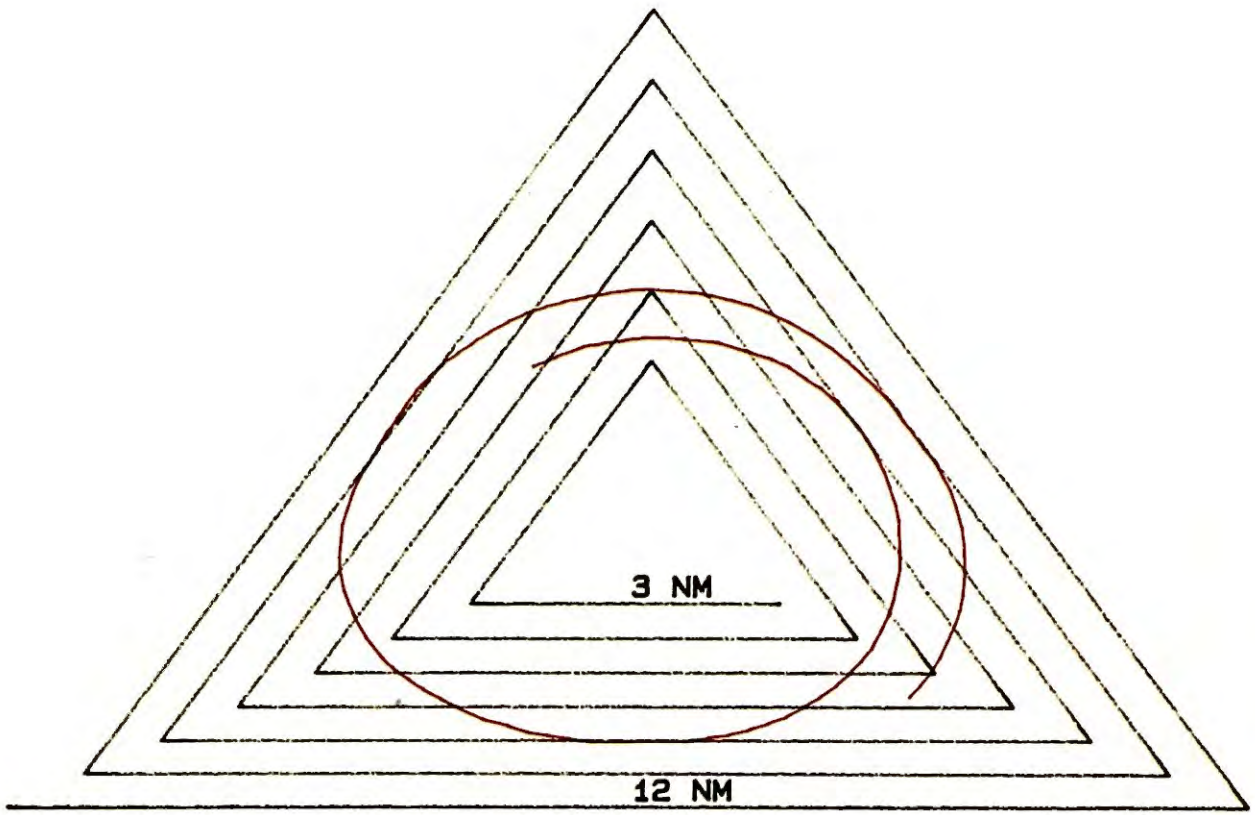
FMS SPIRAL 4 - FLY BY WAYPOINTS

(MD11, 160 KIAS AT 10,000' + 60 KNOT WIND)



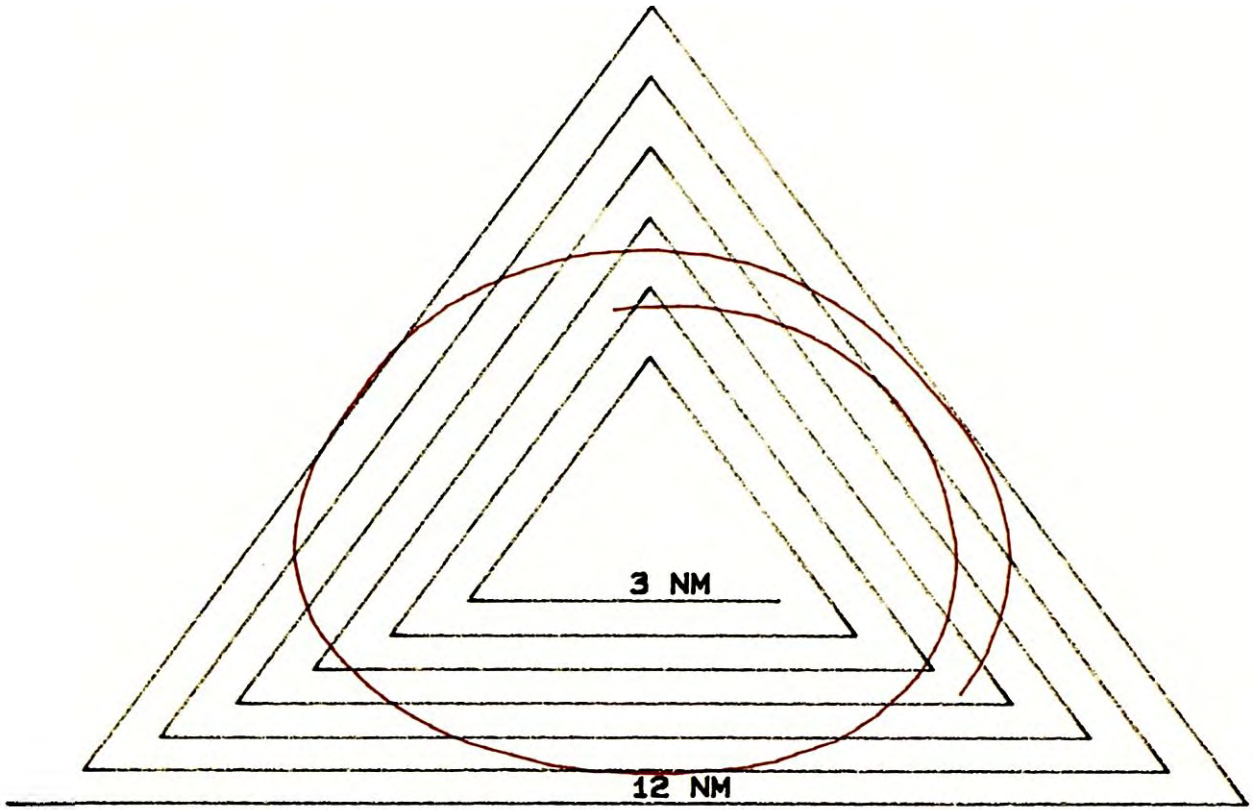
FMS SPIRAL 4 - FLY BY WAYPOINTS

(MD11, 200 KIAS AT 10,000' + 60 KNOT WIND)



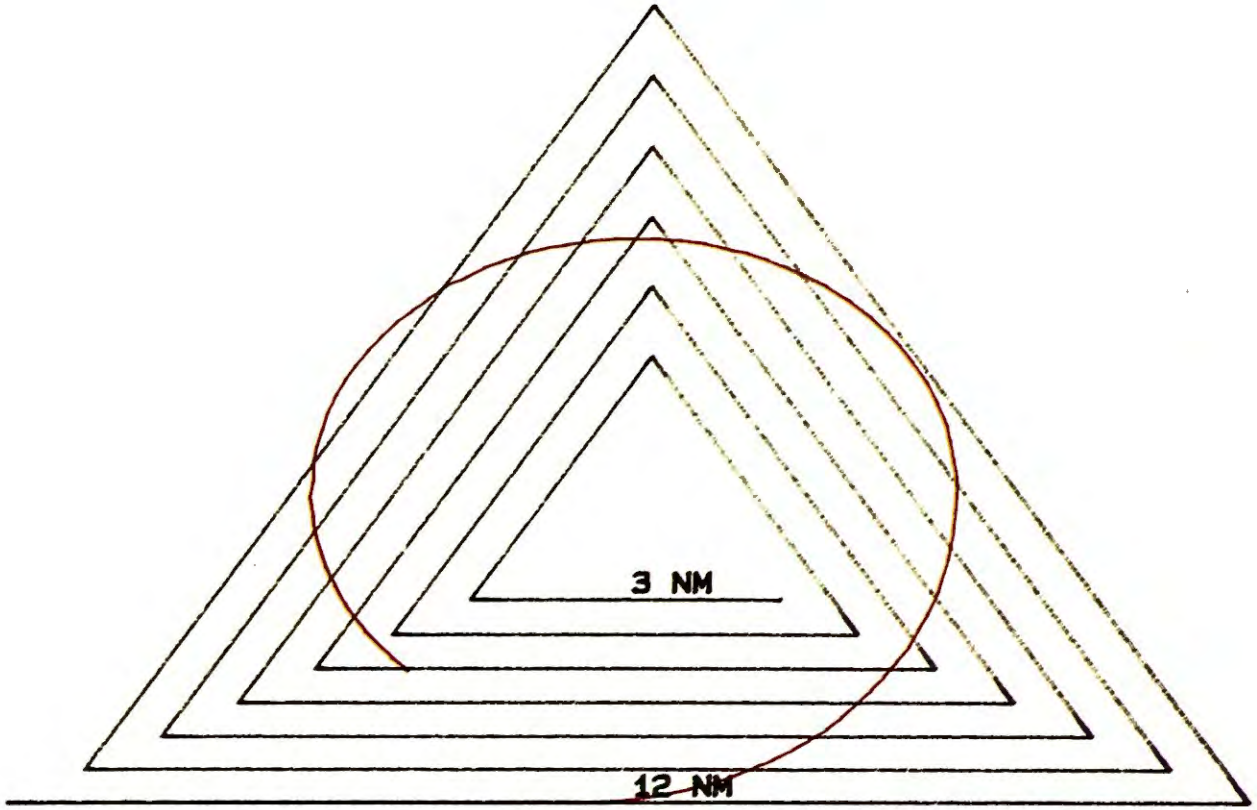
FMS SPIRAL 4 - FLY BY WAYPOINTS

(MD11, 220 KIAS AT 10,000' + 60 KNOT WIND)



FMS SPIRAL 4 - FLY BY WAYPOINTS

(MD11, 250 KIAS AT 10,000' + 60 KNOT WIND)

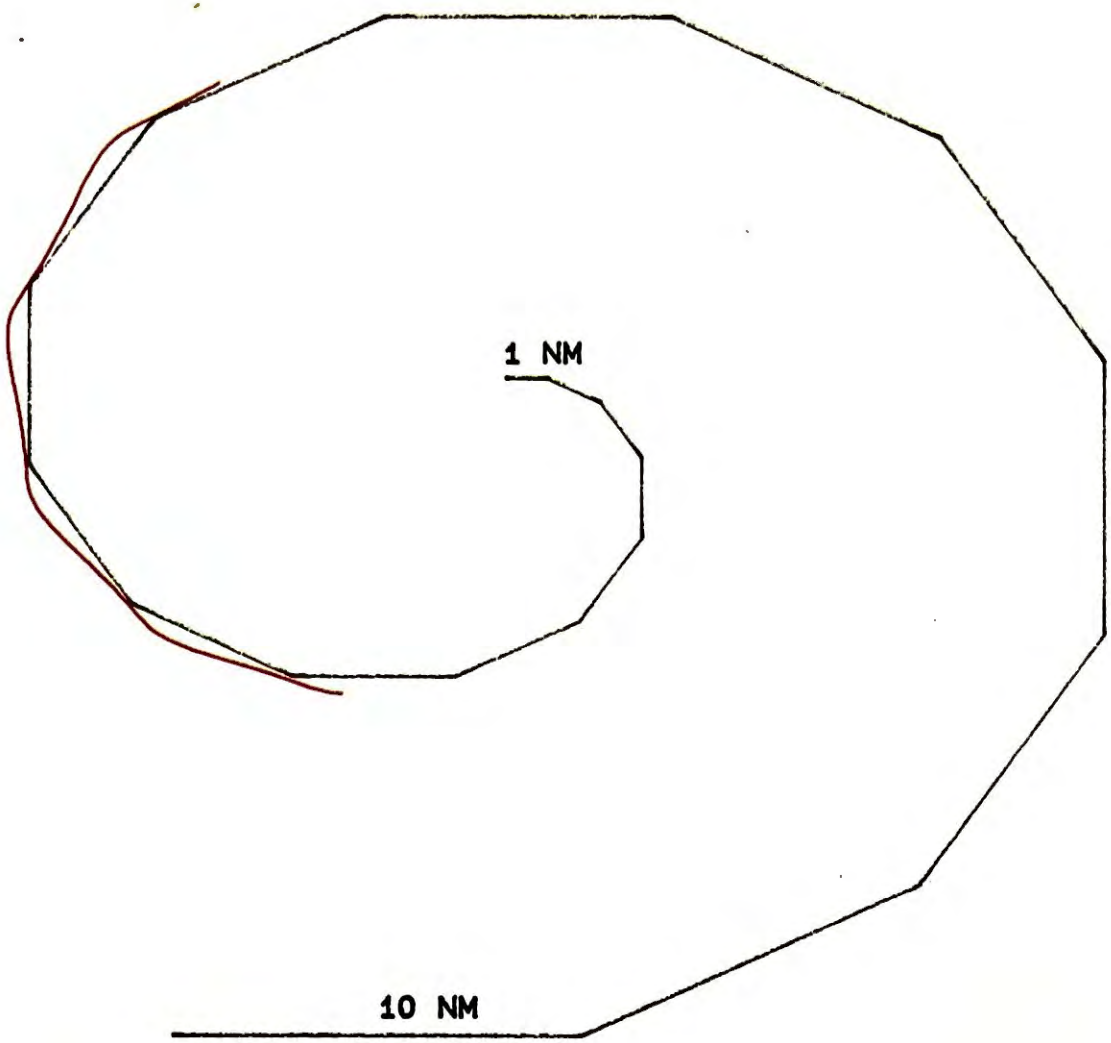


APPENDIX 4

FMS FLY-OVER WAYPOINT PLOTS

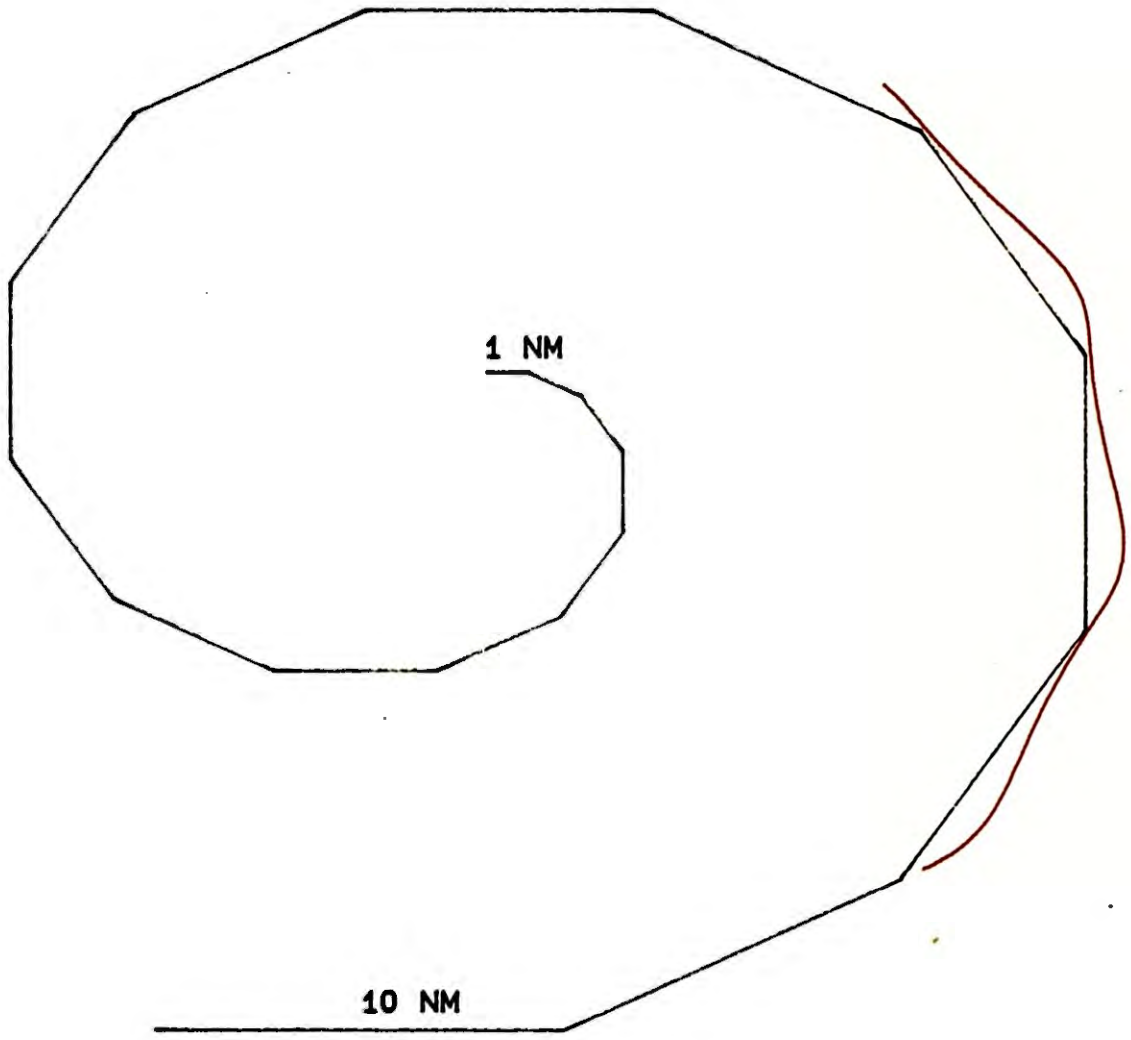
FMS SPIRAL 1-FLY OVER WAYPOINTS

(A320, 160 KIAS AT 10,000' + 60 KNOT WIND)



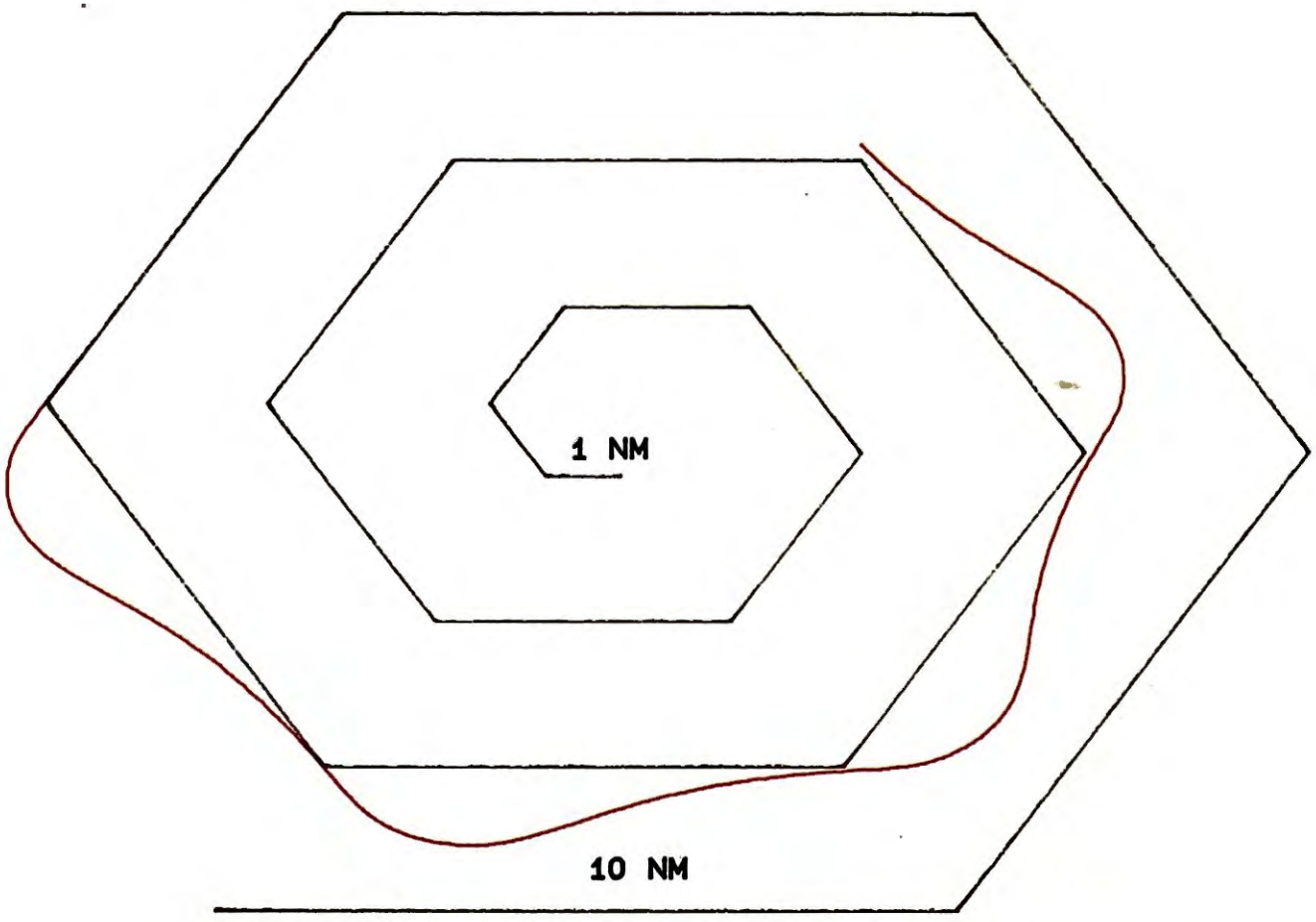
FMS SPIRAL 1-FLY OVER WAYPOINTS

(A320, 250 KIAS AT 10,000' + 60 KNOT WIND)



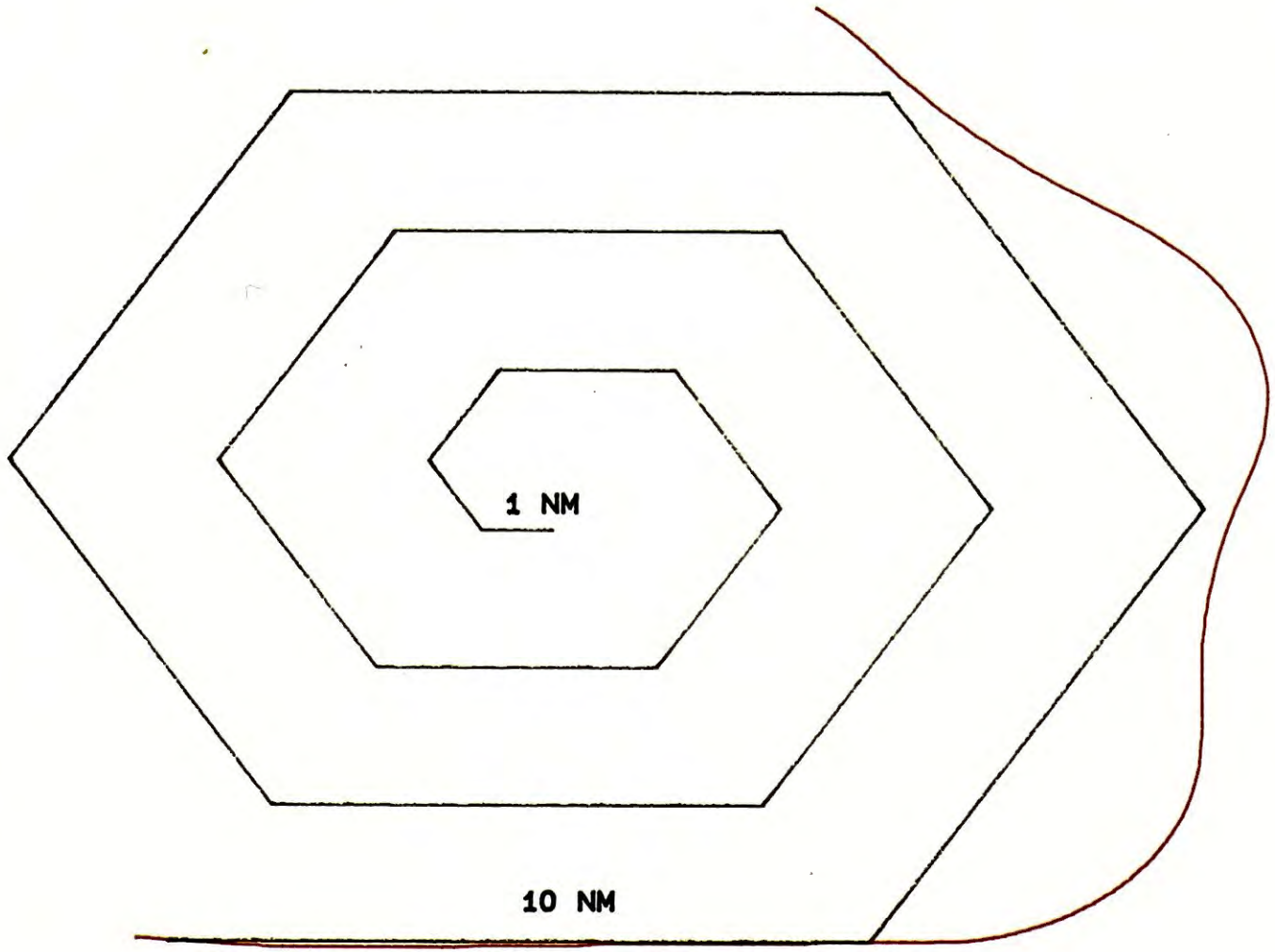
FMS SPIRAL 2-FLY OVER WAYPOINTS

(A320, 160 KIAS AT 10,000' + 60 KNOT WIND)



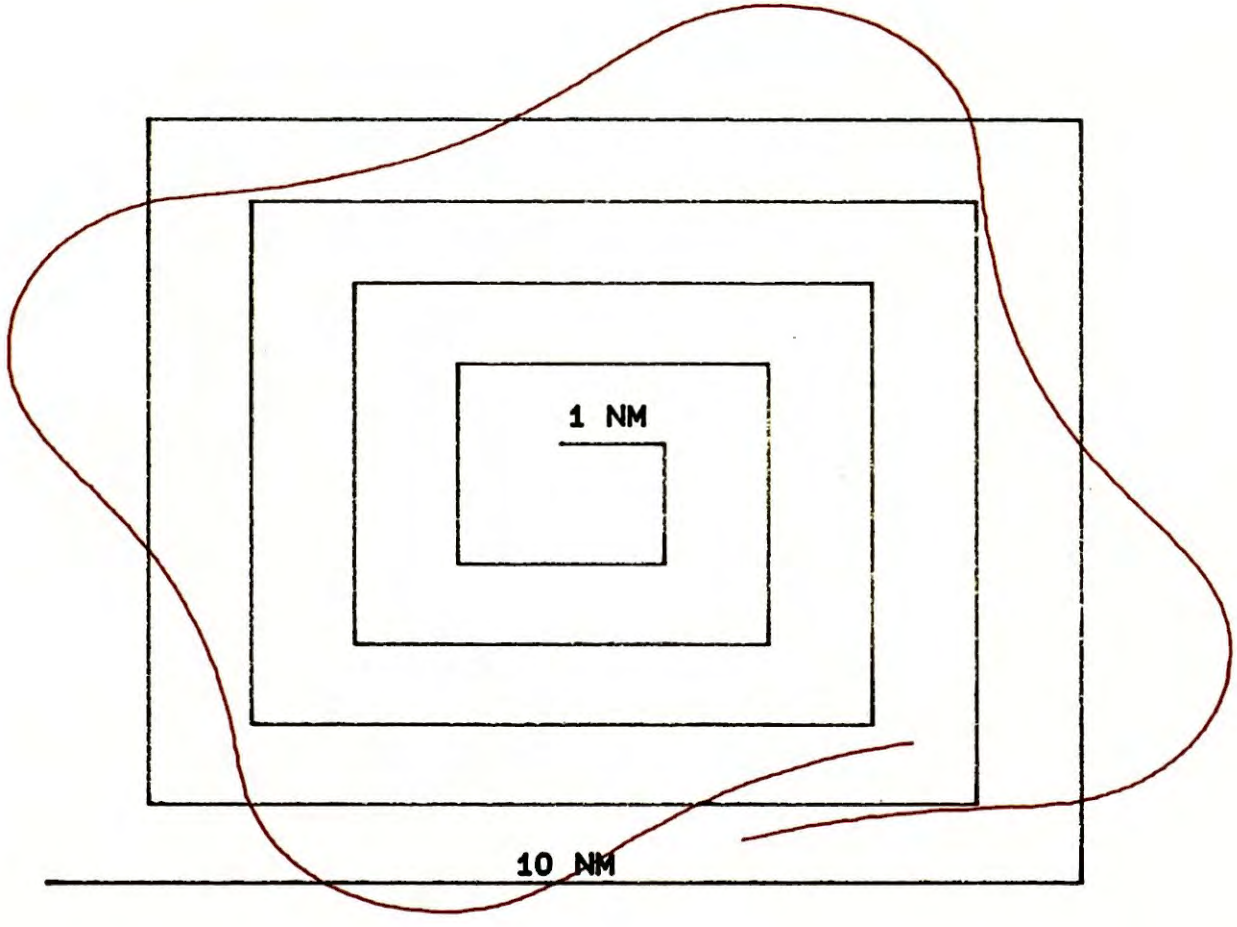
FMS SPIRAL 2-FLY OVER WAYPOINTS

(A320, 250 KIAS AT 10,000' + 60 KNOT WIND)



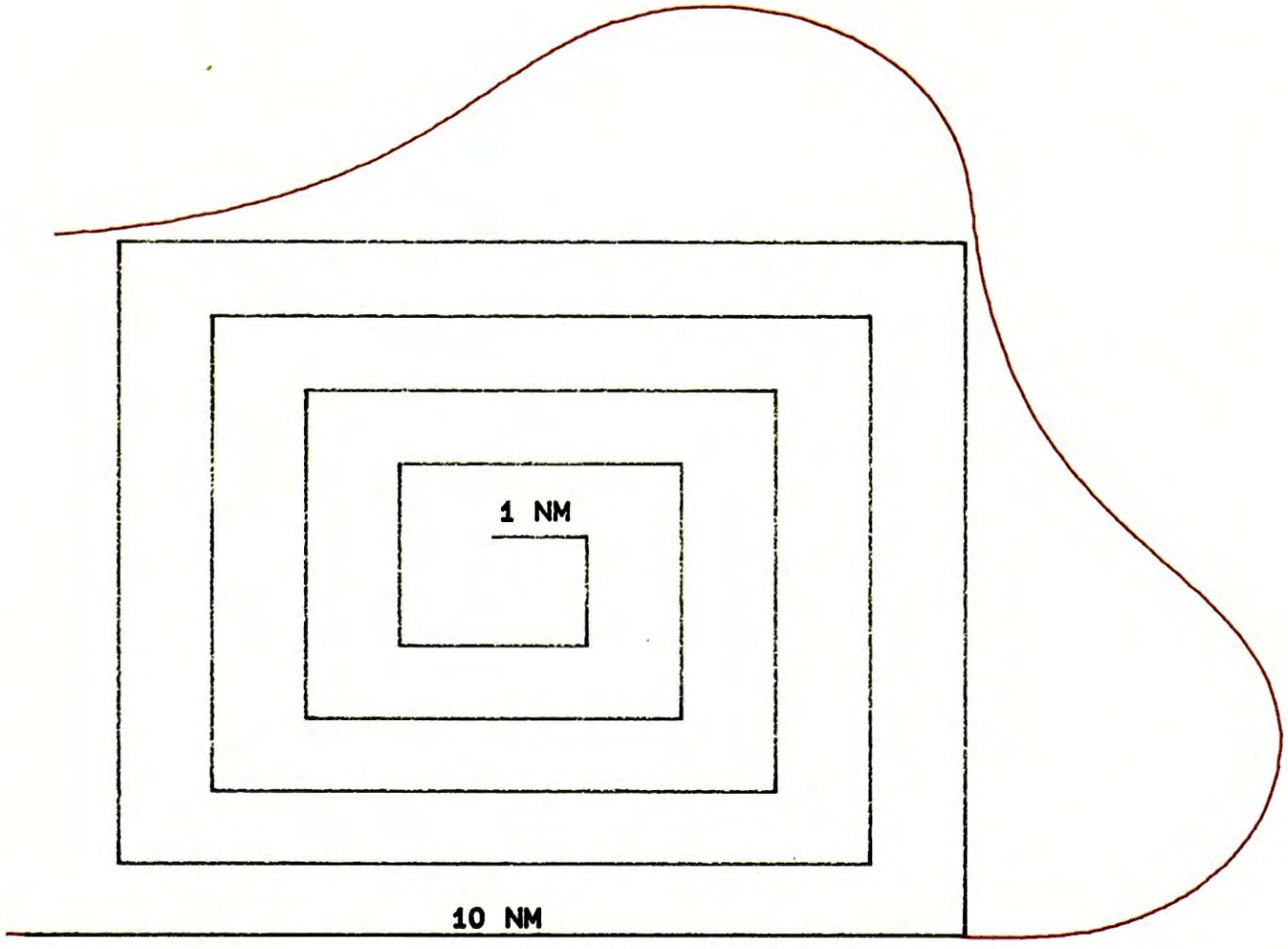
FMS SPIRAL 3 - FLY OVER WAYPOINTS

(A320, 160 KIAS AT 10,000' + 60 KNOT WIND)



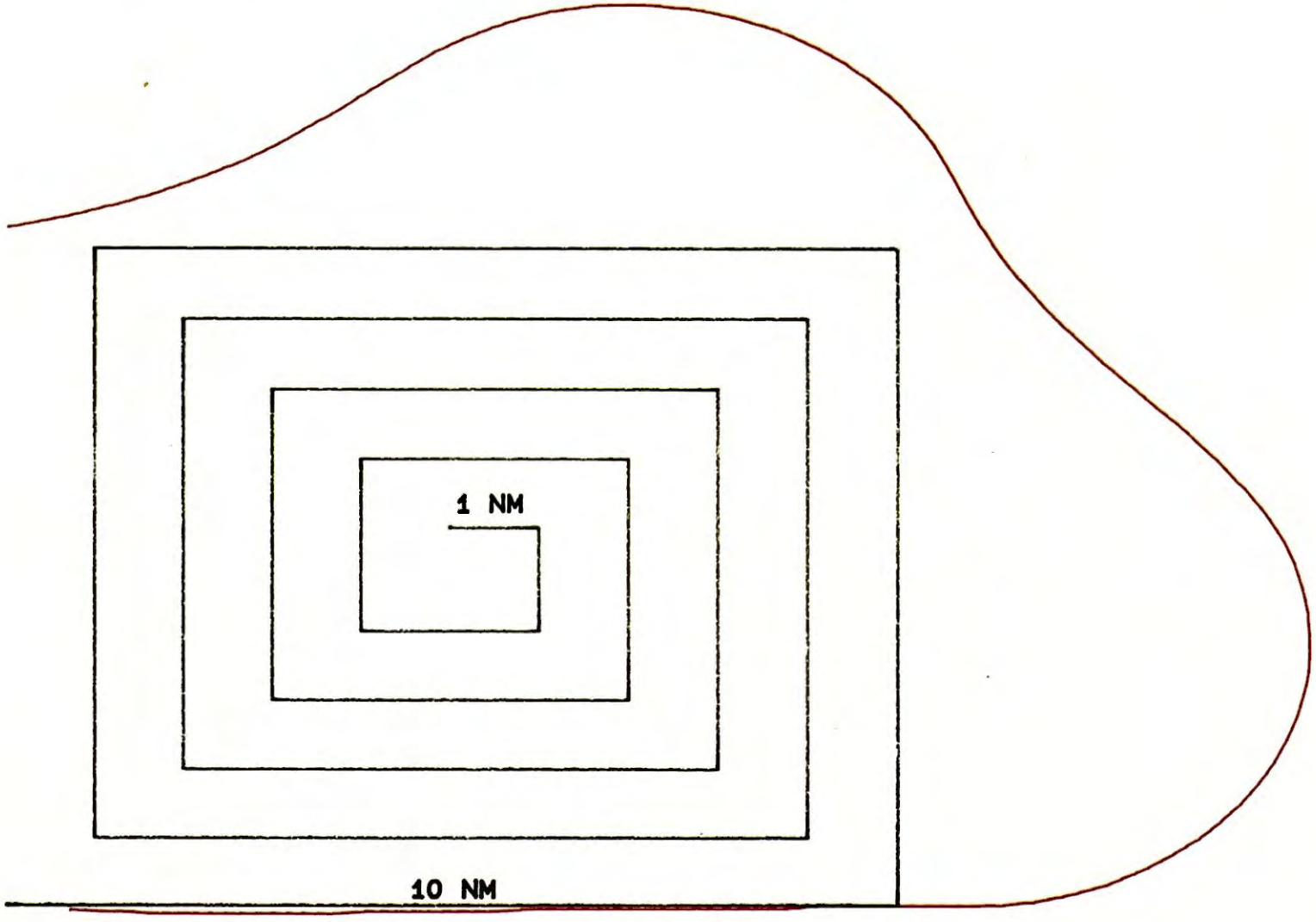
FMS SPIRAL 3 - FLY OVER WAYPOINTS

(A320, 200 KIAS AT 10,000' + 60 KNOT WIND)



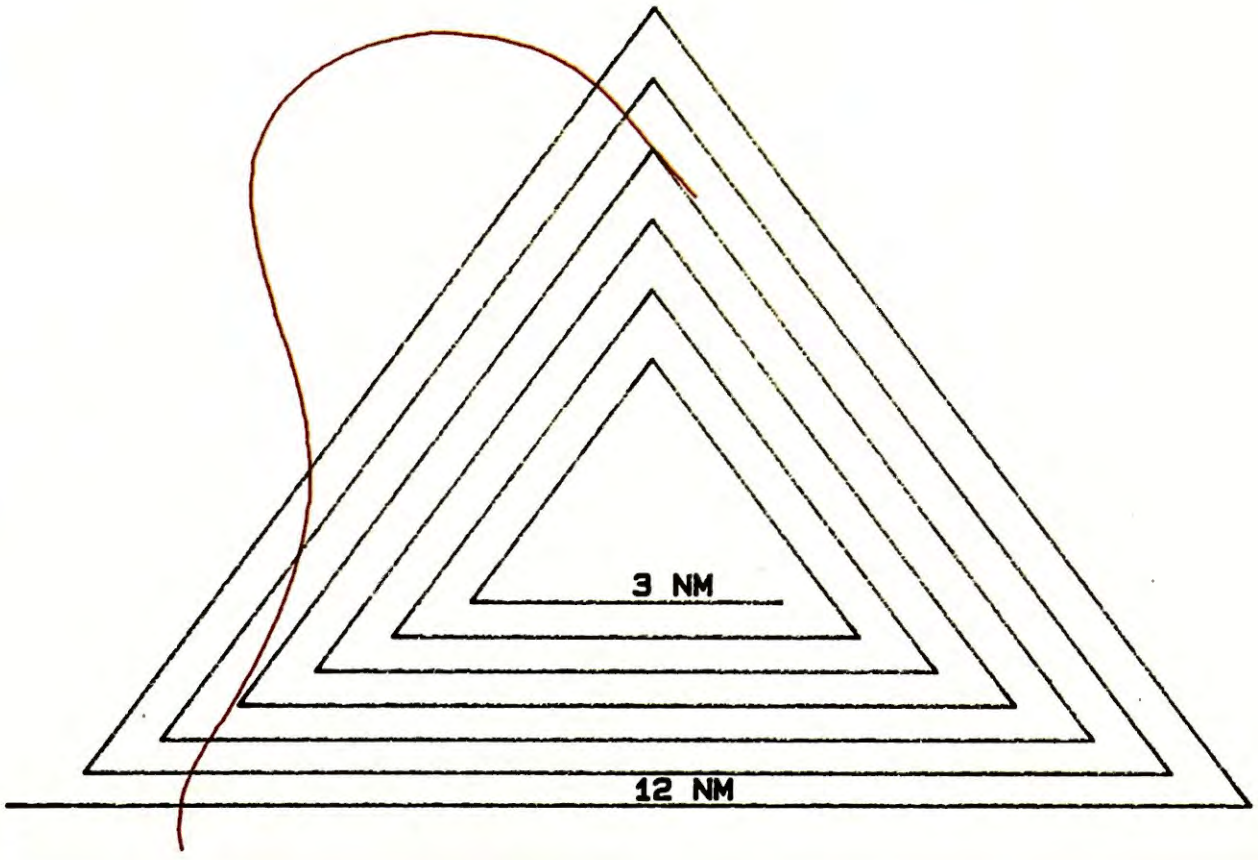
FMS SPIRAL 3 - FLY OVER WAYPOINTS

(A320, 250 KIAS AT 10,000' + 60 KNOT WIND)



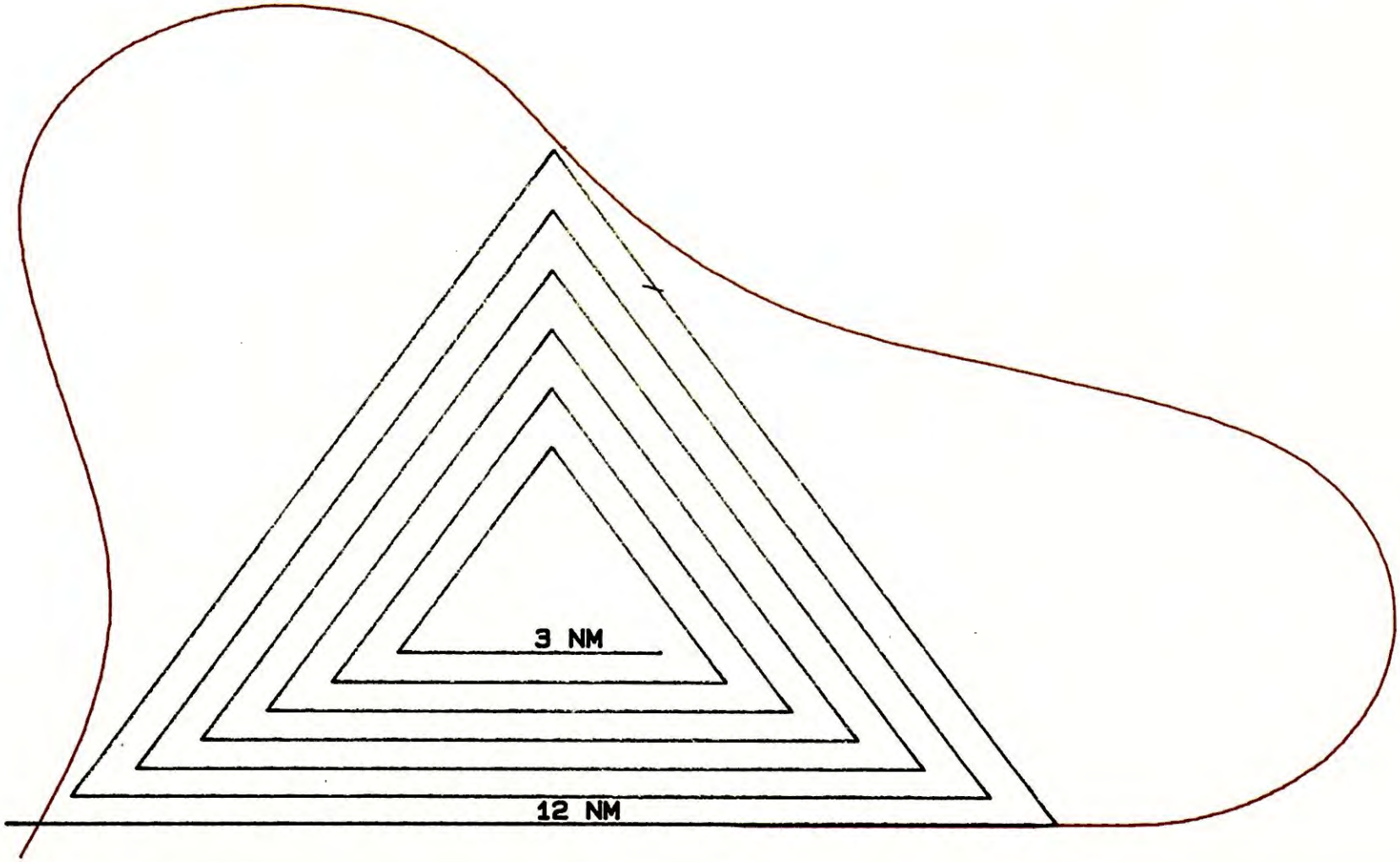
FMS SPIRAL 4 - FLY OVER WAYPOINTS

(A320, 160 KIAS AT 10,000' + 60 KNOT WIND)



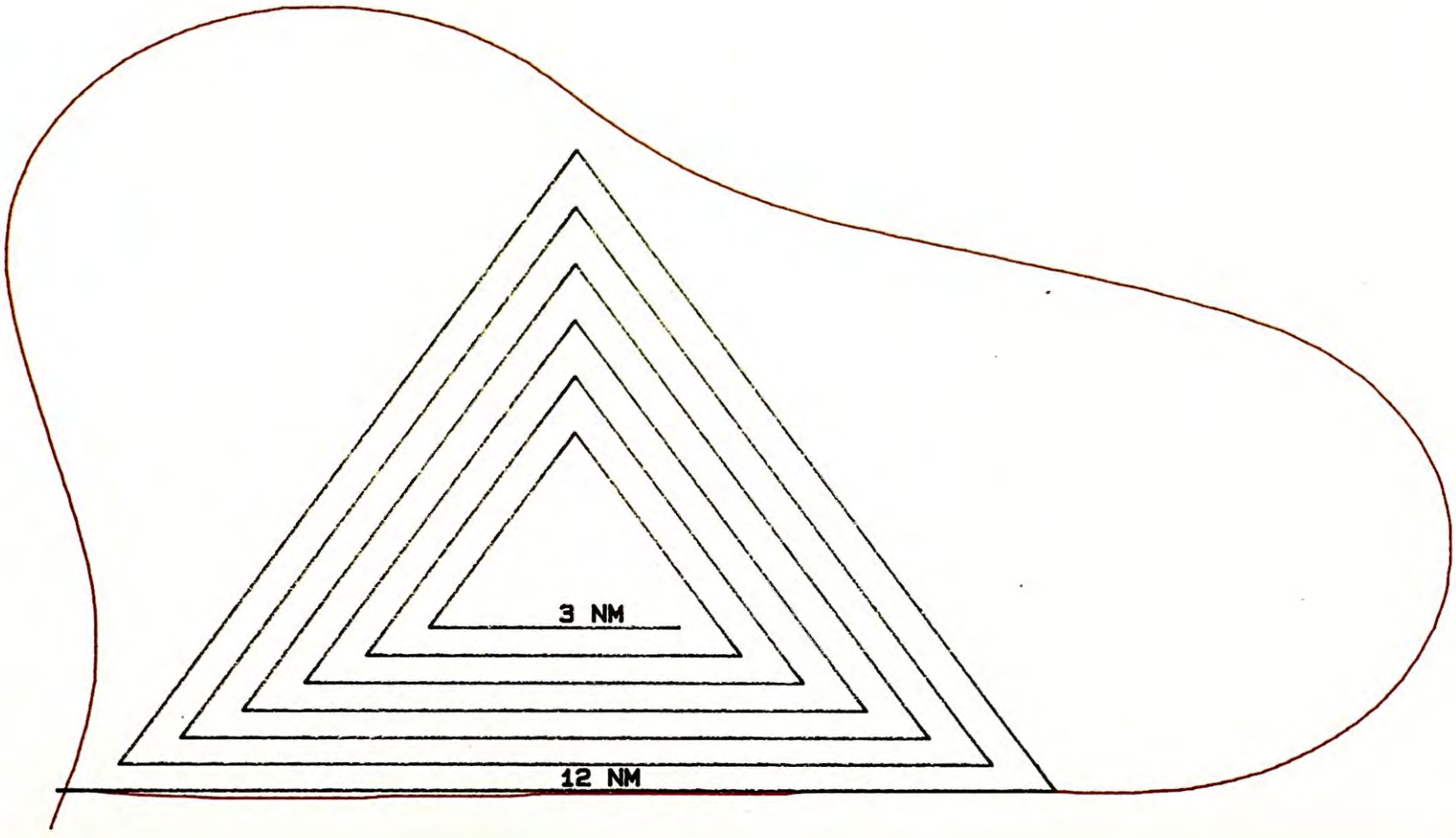
FMS SPIRAL 4 - FLY OVER WAYPOINTS

(A320, 220 KIAS AT 10,000' + 60 KNOT WIND)



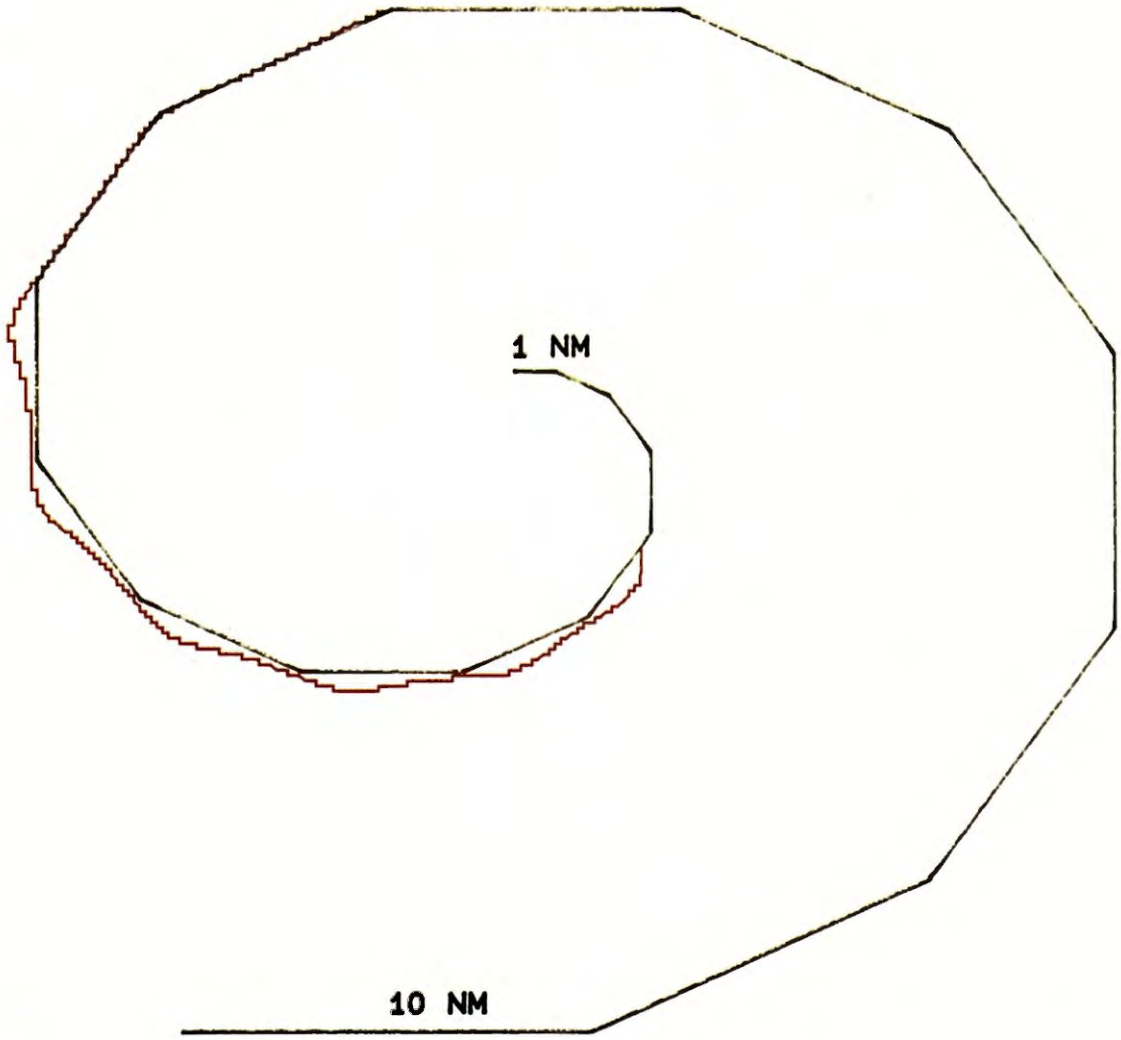
FMS SPIRAL 4 - FLY OVER WAYPOINTS

(A320, 250 KIAS AT 10,000' + 60 KNOT WIND)



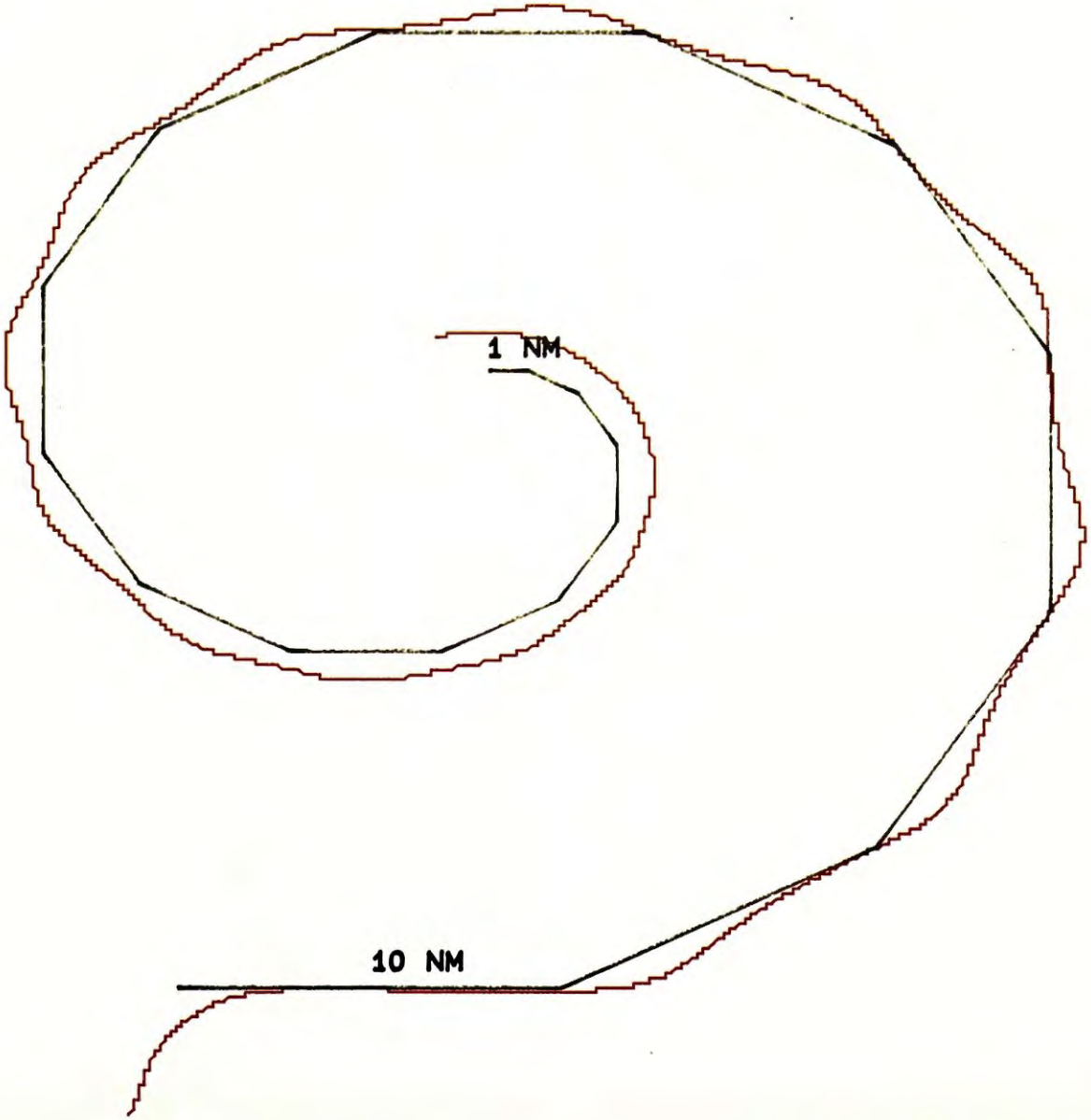
FMS SPIRAL 1 - FLY OVER WAYPOINTS

(B747, 160 KIAS AT 10,000' + 60 KNOT WIND)



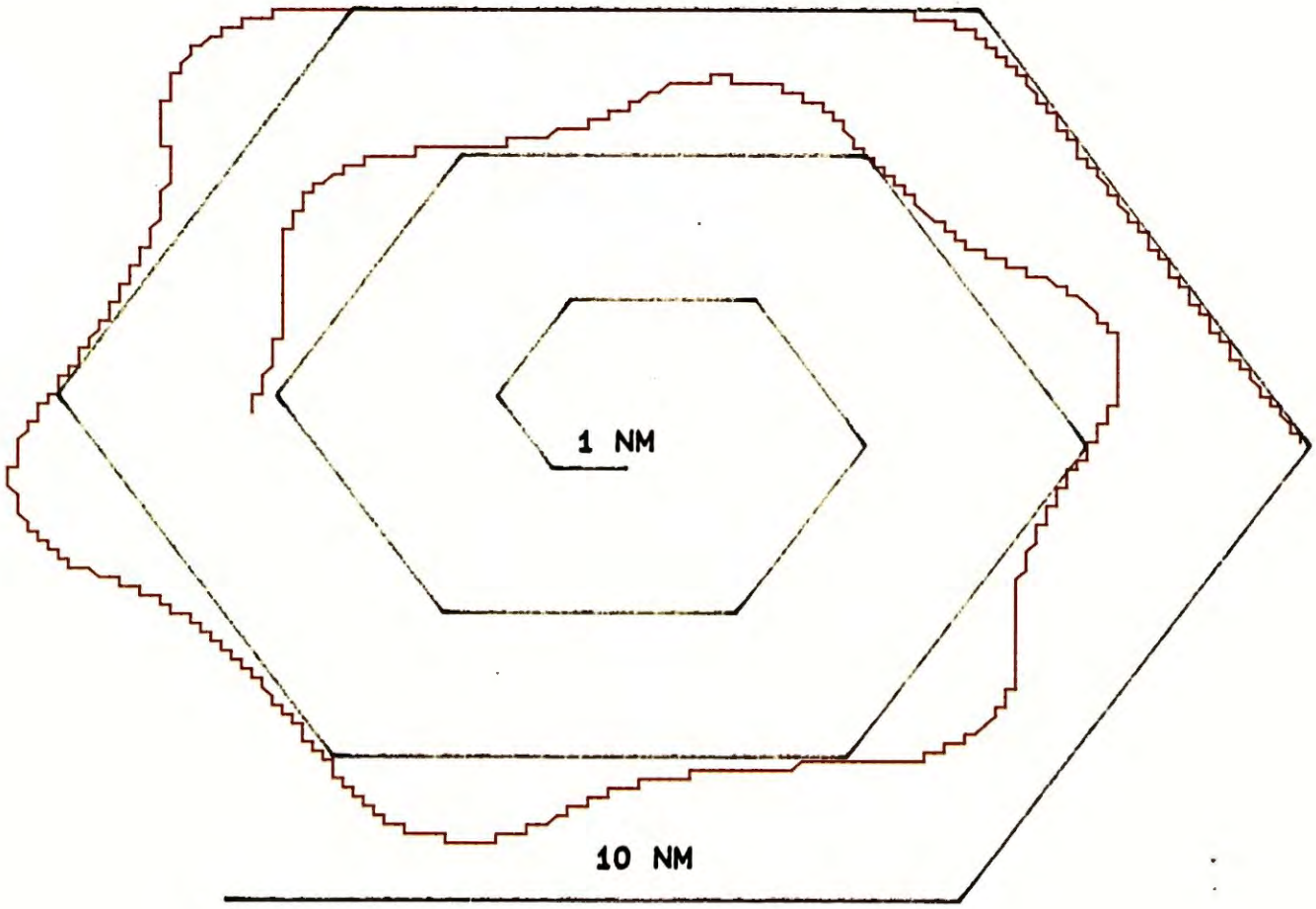
FMS SPIRAL 1 - FLY OVER WAYPOINTS

(B747, 250 KIAS AT 10,000' + 60 KNOT WIND)



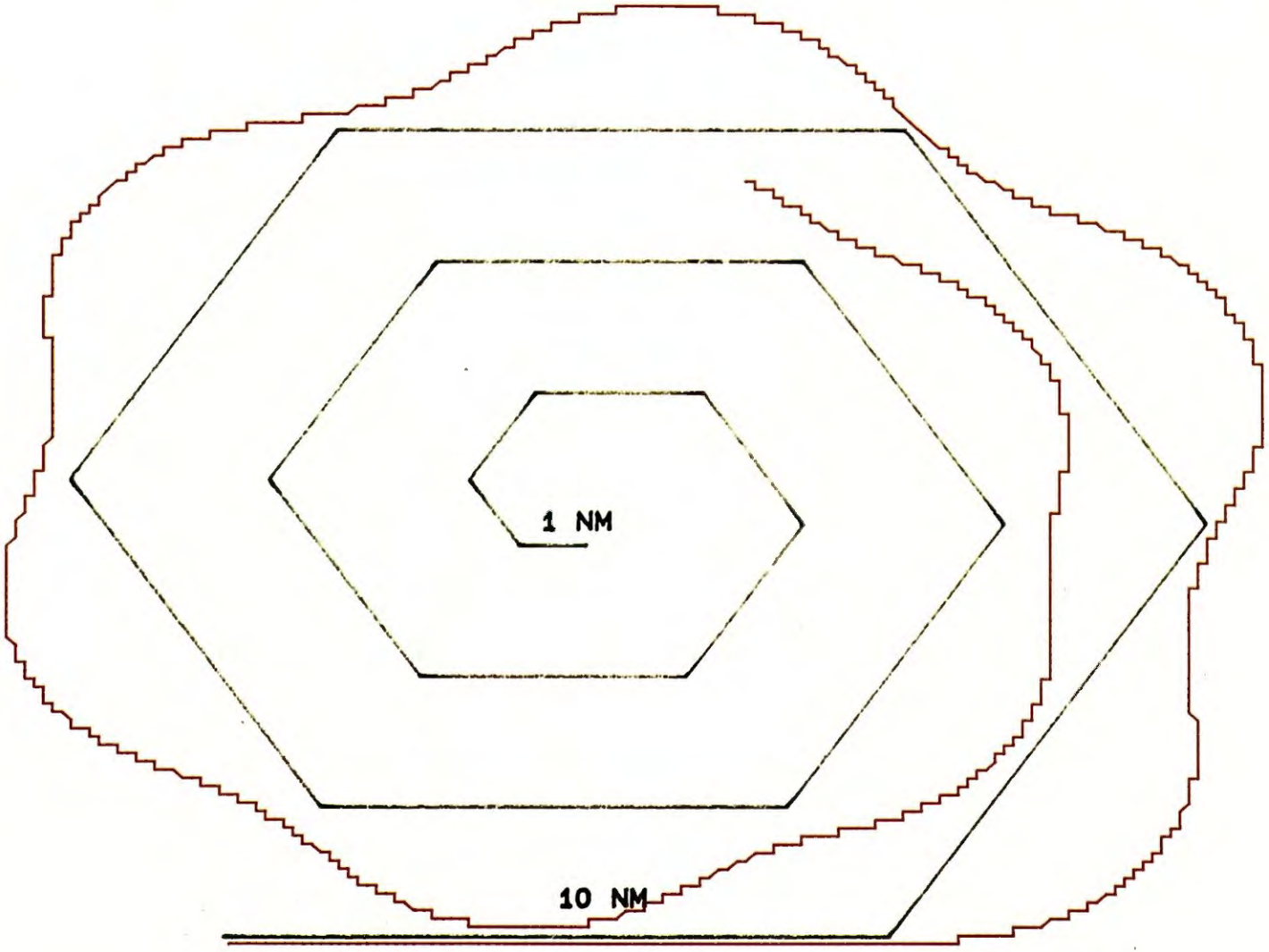
FMS SPIRAL 2 - FLY OVER WAYPOINTS

(B747, 160 KIAS AT 10,000' + 60 KNOT WIND)



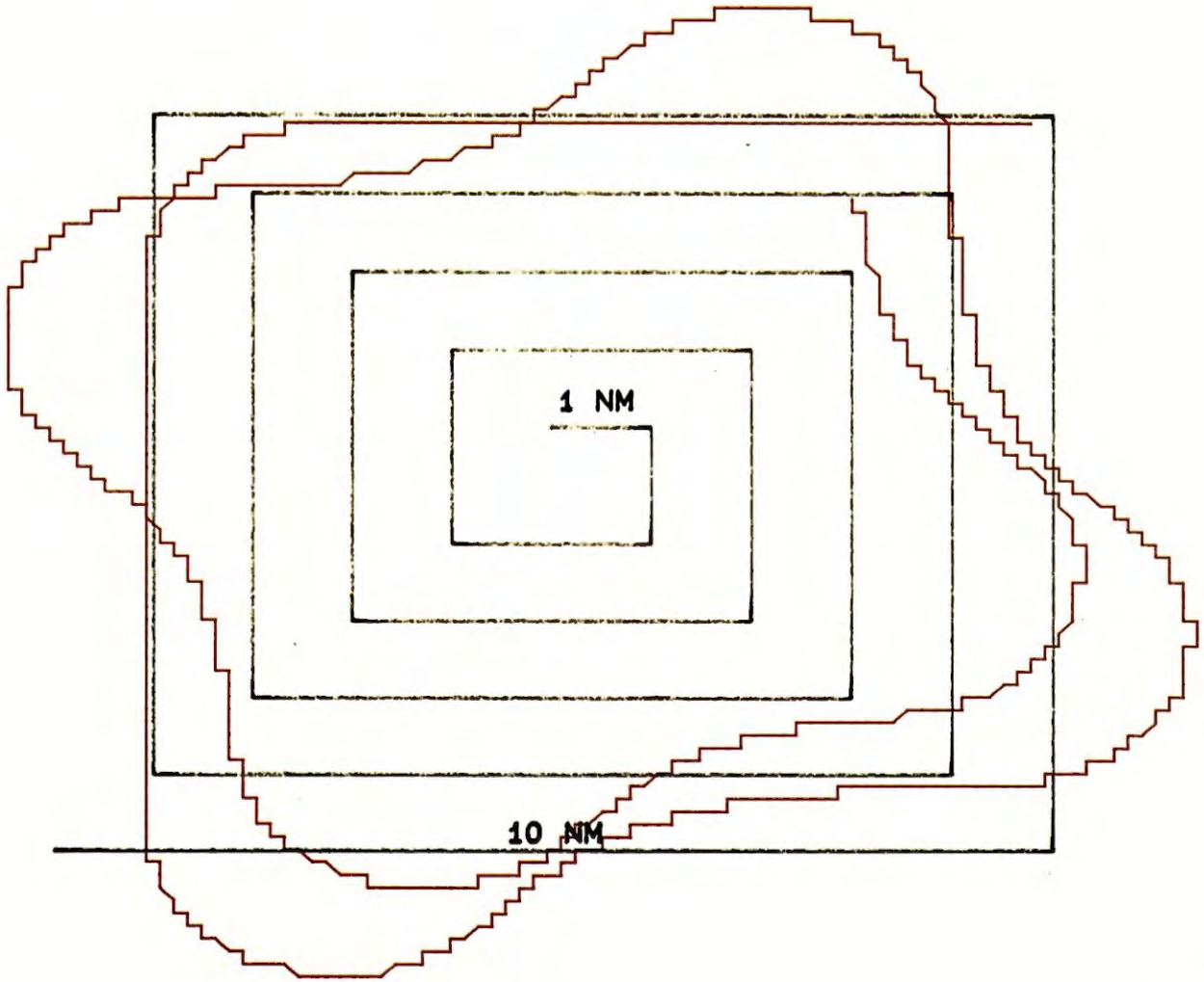
FMS SPIRAL 2 - FLY OVER WAYPOINTS

(B747, 250 KIAS AT 10,000' + 60 KNOT WIND)



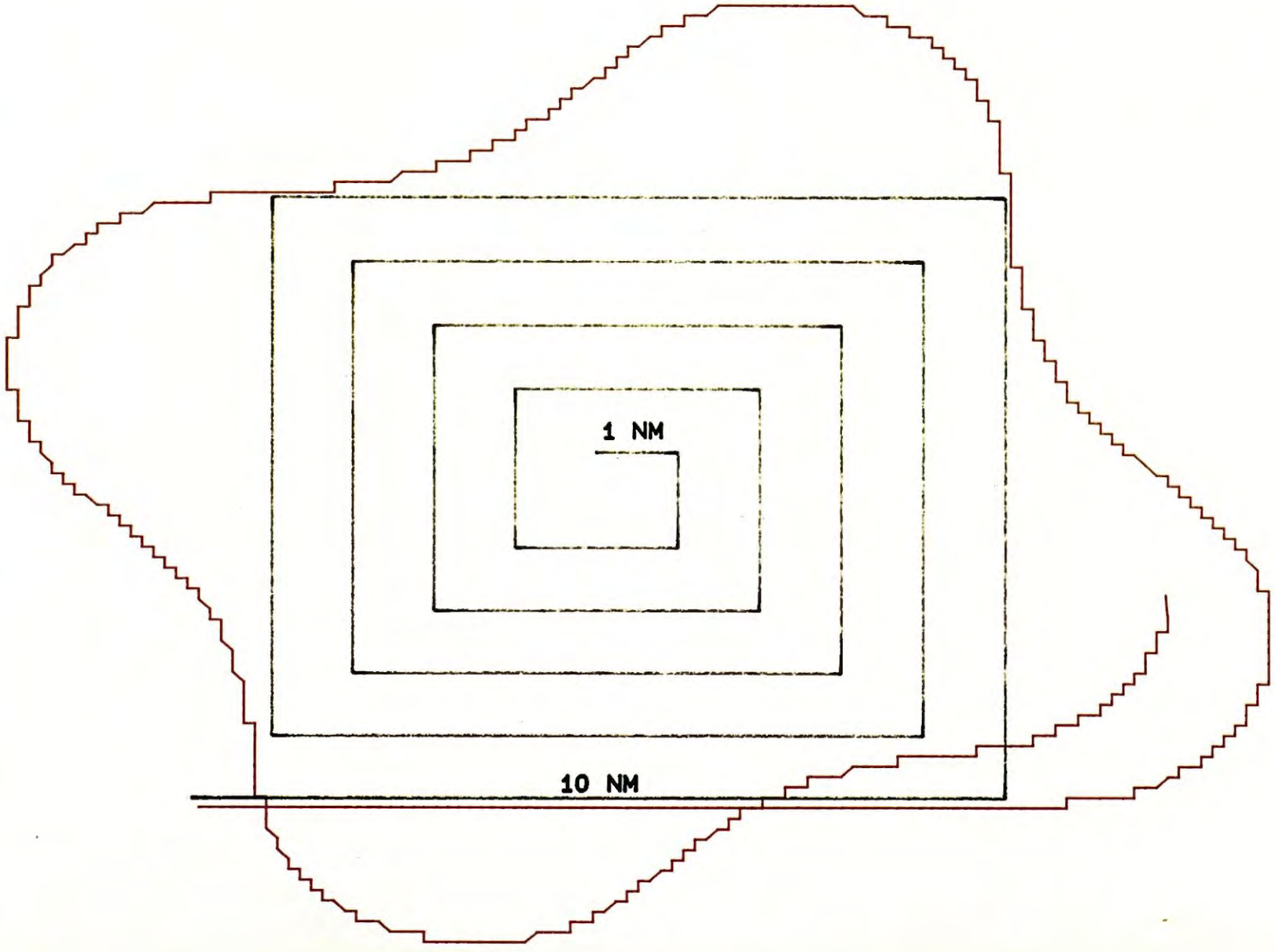
FMS SPIRAL 3 - FLY OVER WAYPOINTS

(B747, 160 KIAS AT 10,000' + 60 KNOT WIND)



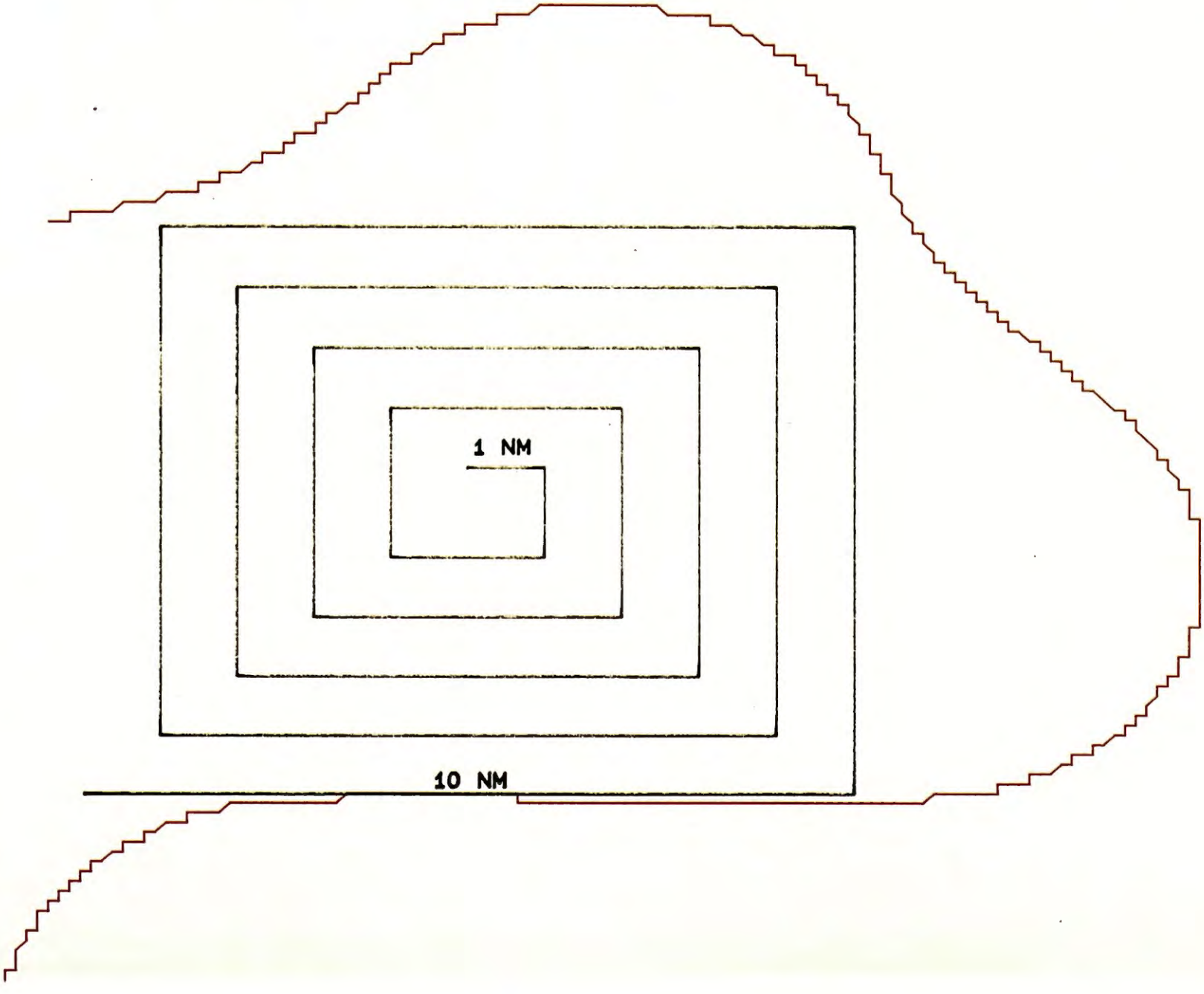
FMS SPIRAL 3 - FLY OVER WAYPOINTS

(B747, 200 KIAS AT 10,000' + 60 KNOT WIND)



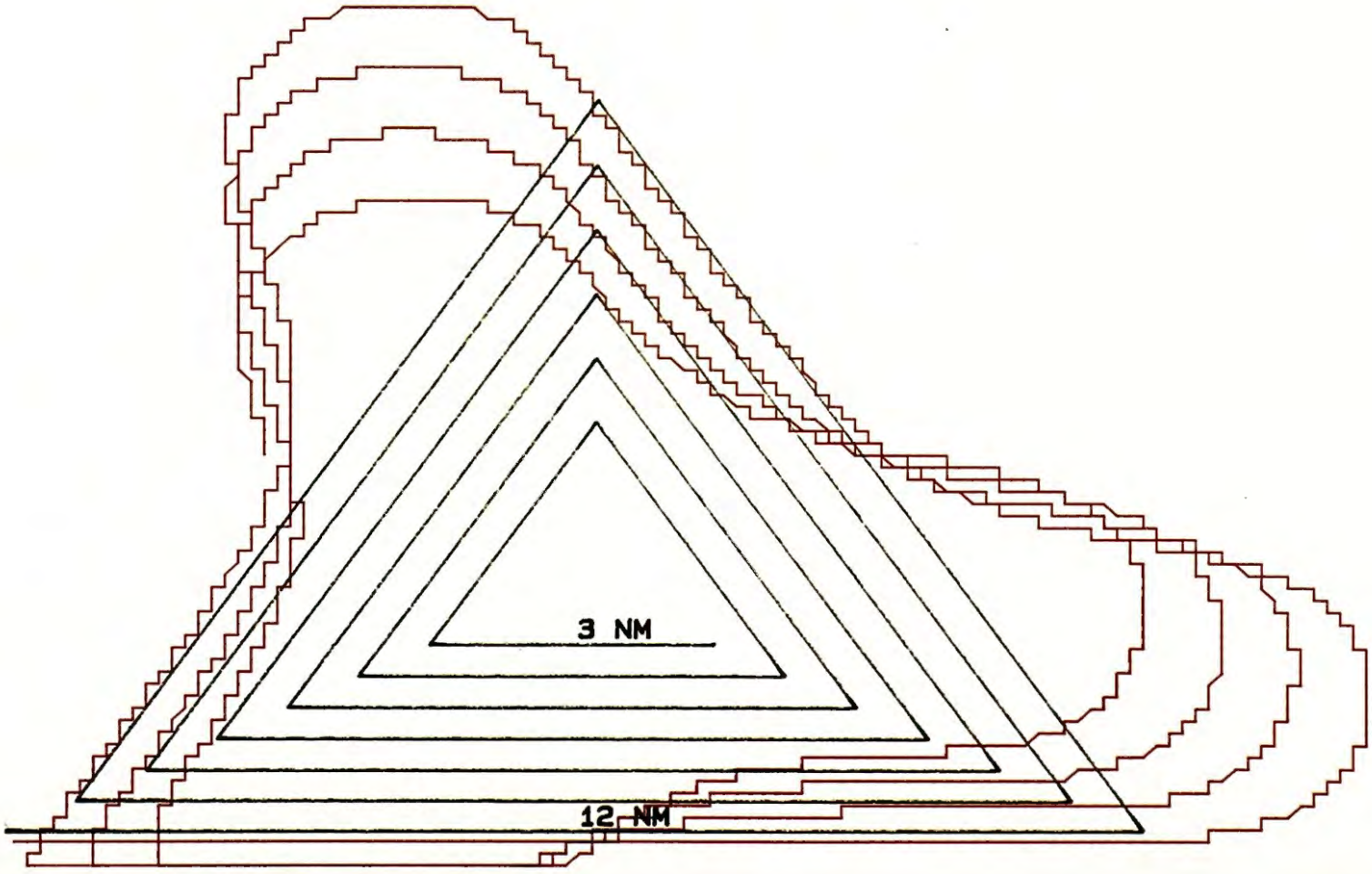
FMS SPIRAL 3 - FLY OVER WAYPOINTS

(B747, 250 KIAS AT 10,000' + 60 KNOT WIND)



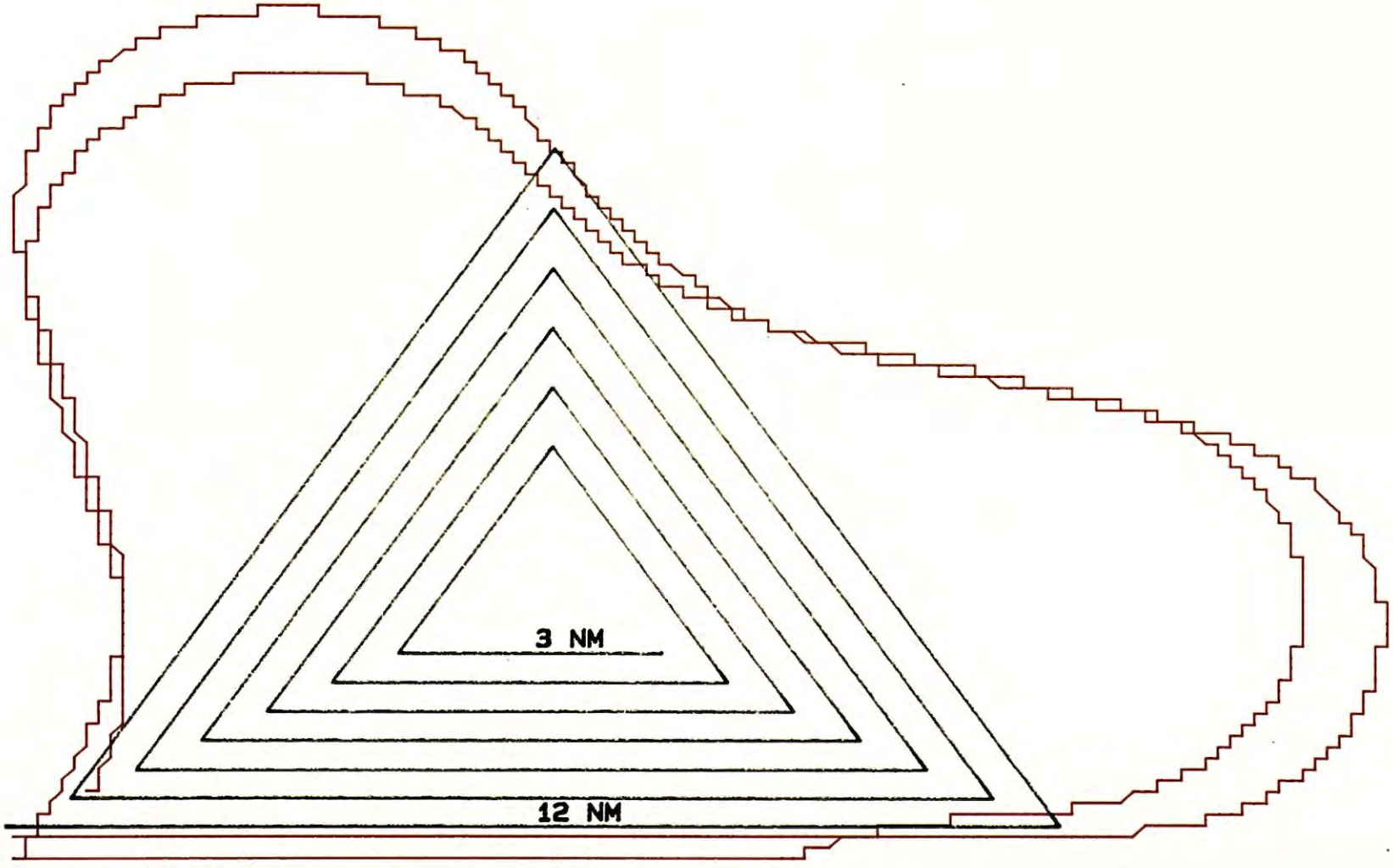
FMS SPIRAL 4 - FLY OVER WAYPOINTS

(B747, 160 KIAS AT 10,000' + 60 KNOT WIND)



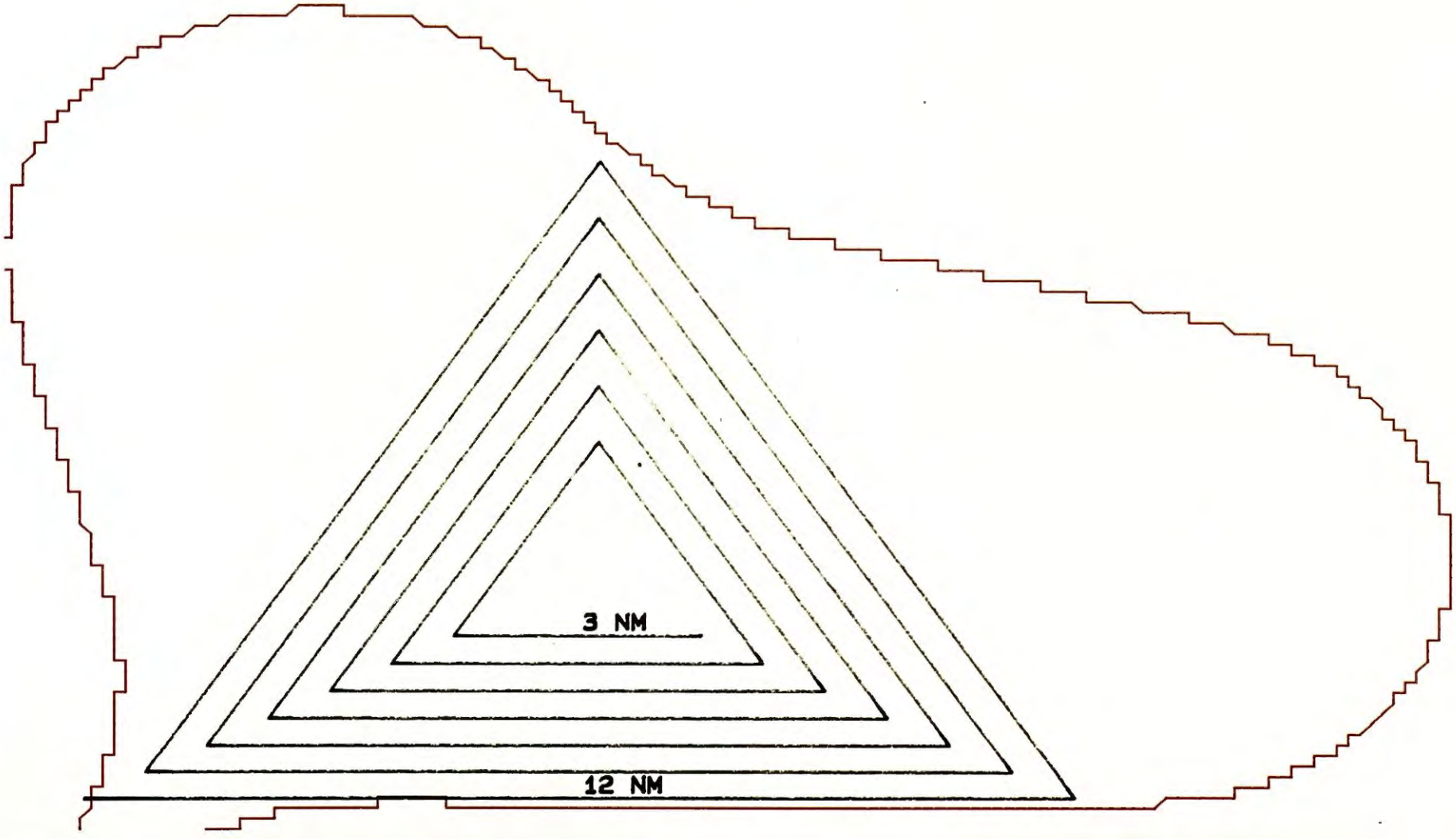
FMS SPIRAL 4 - FLY OVER WAYPOINTS

(B747, 220 KIAS AT 10,000' + 60 KNOT WIND)



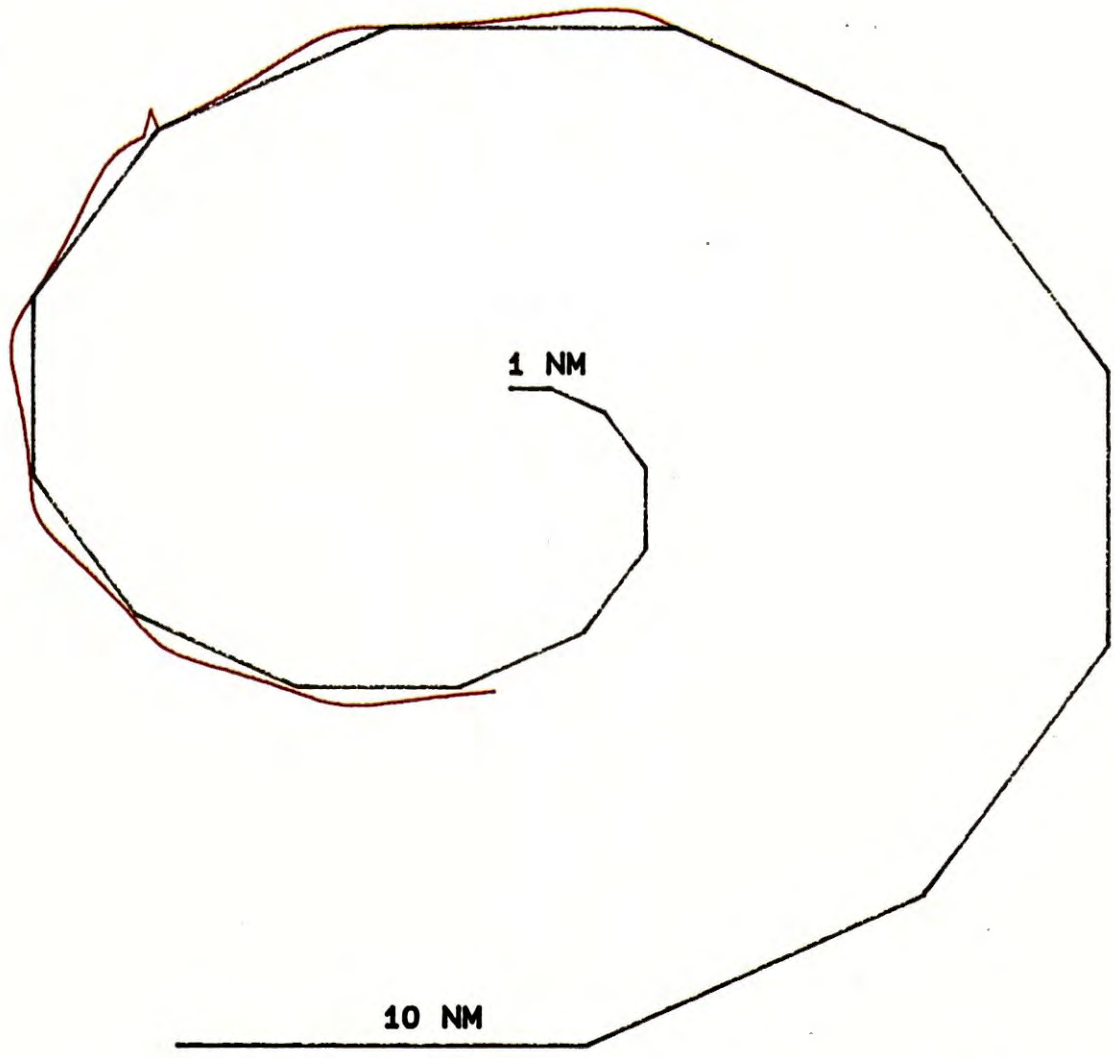
FMS SPIRAL 4 - FLY OVER WAYPOINTS

(B747, 250 KIAS AT 10,000' + 60 KNOT WIND)



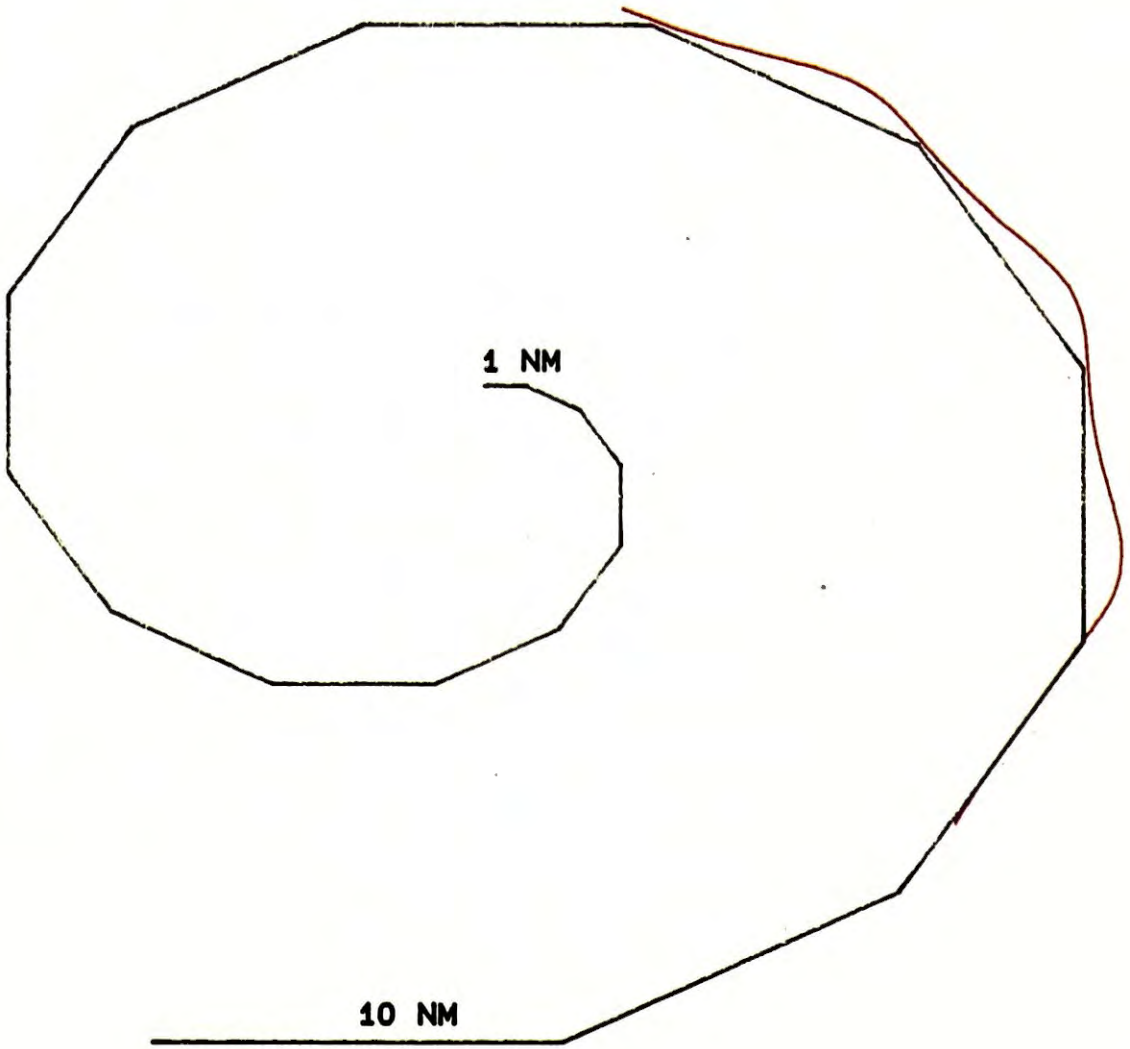
FMS SPIRAL 1 - FLY OVER WAYPOINTS

(MD11, 160 KIAS AT 10,000' + 60 KNOT WIND)



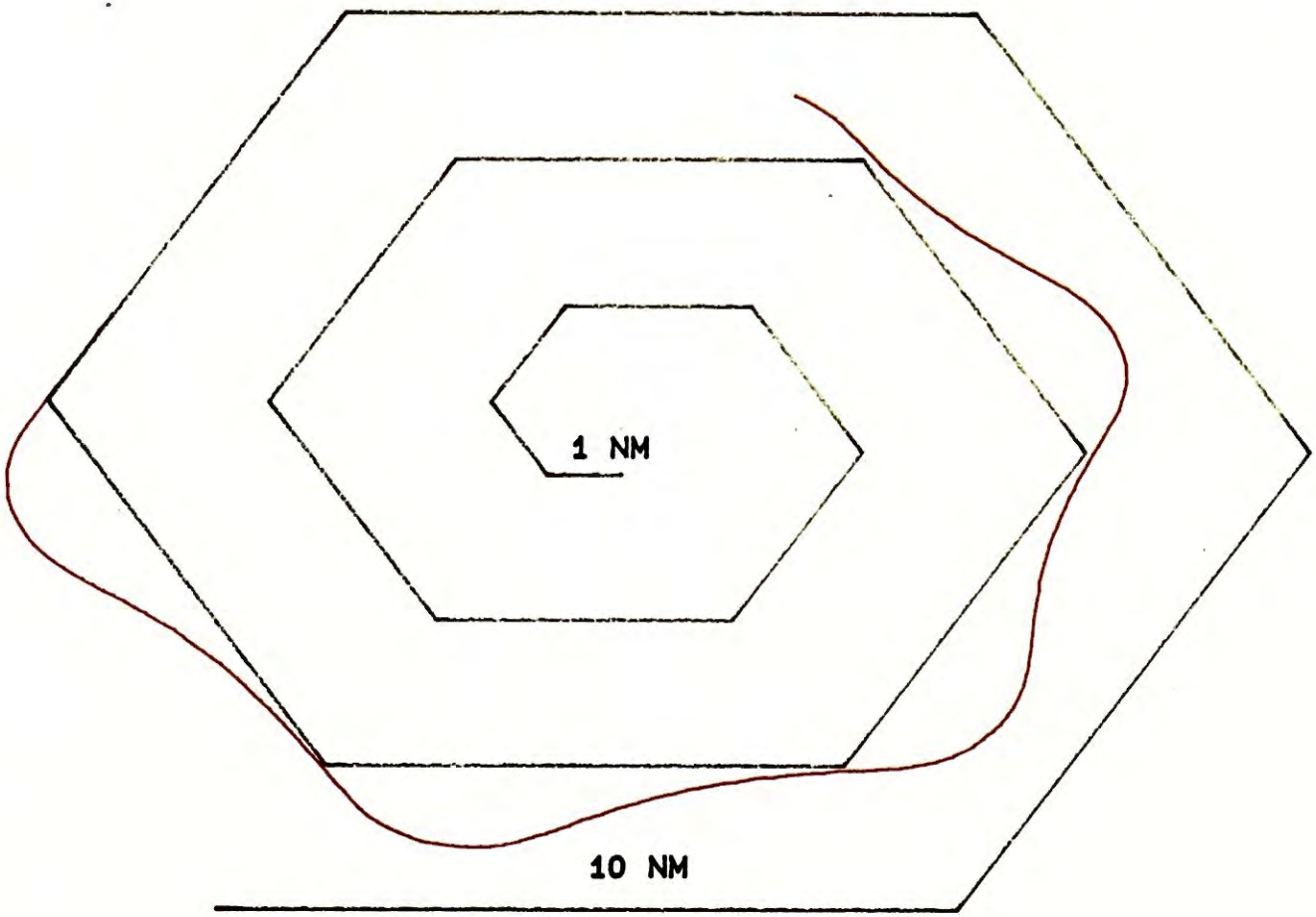
FMS SPIRAL 1 - FLY OVER WAYPOINTS

(MD11, 250 KIAS AT 10,000' + 60 KNOT WIND)



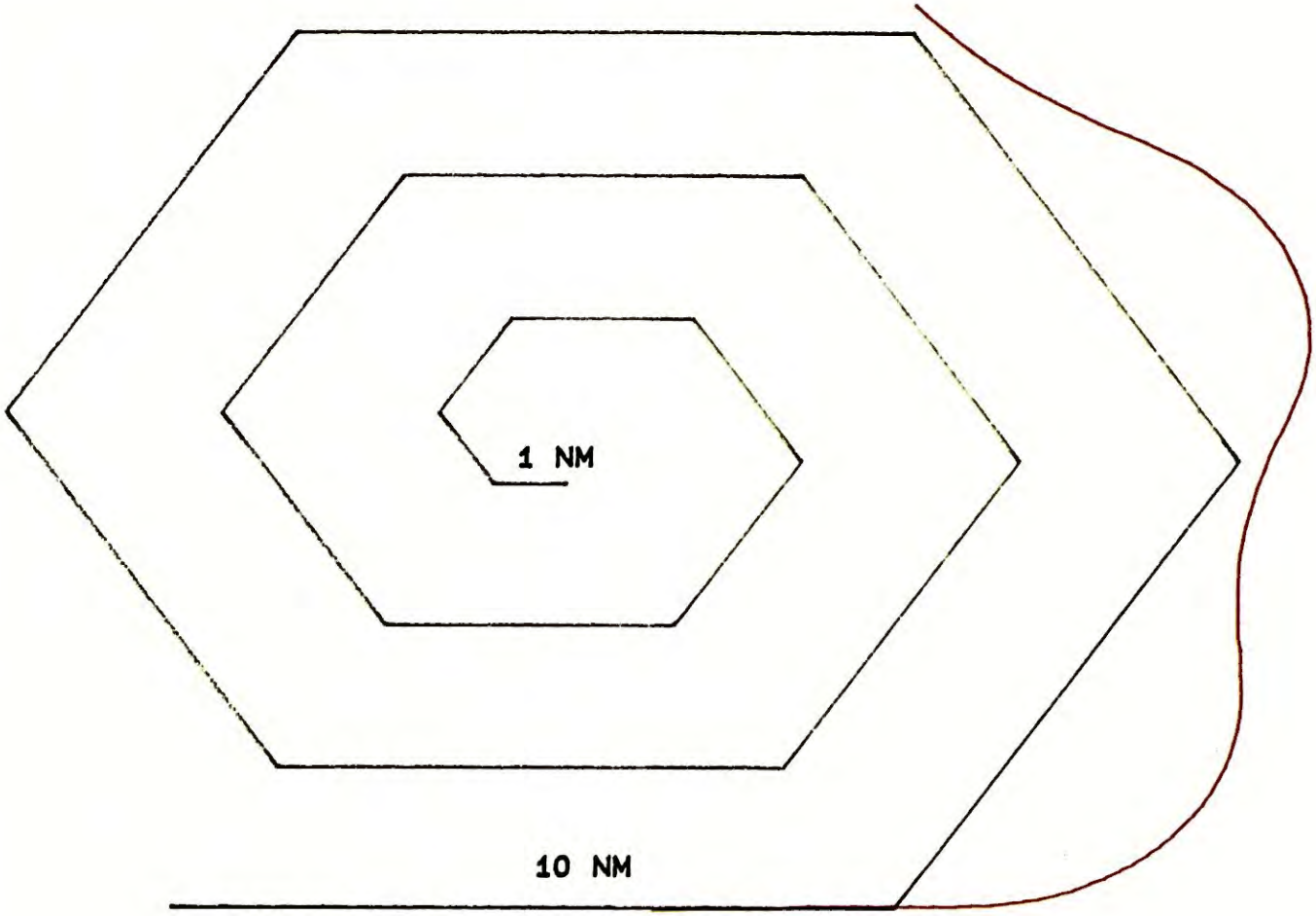
FMS SPIRAL 2 - FLY OVER WAYPOINTS

(MD11, 160 KIAS AT 10,000' + 60 KNOT WIND)



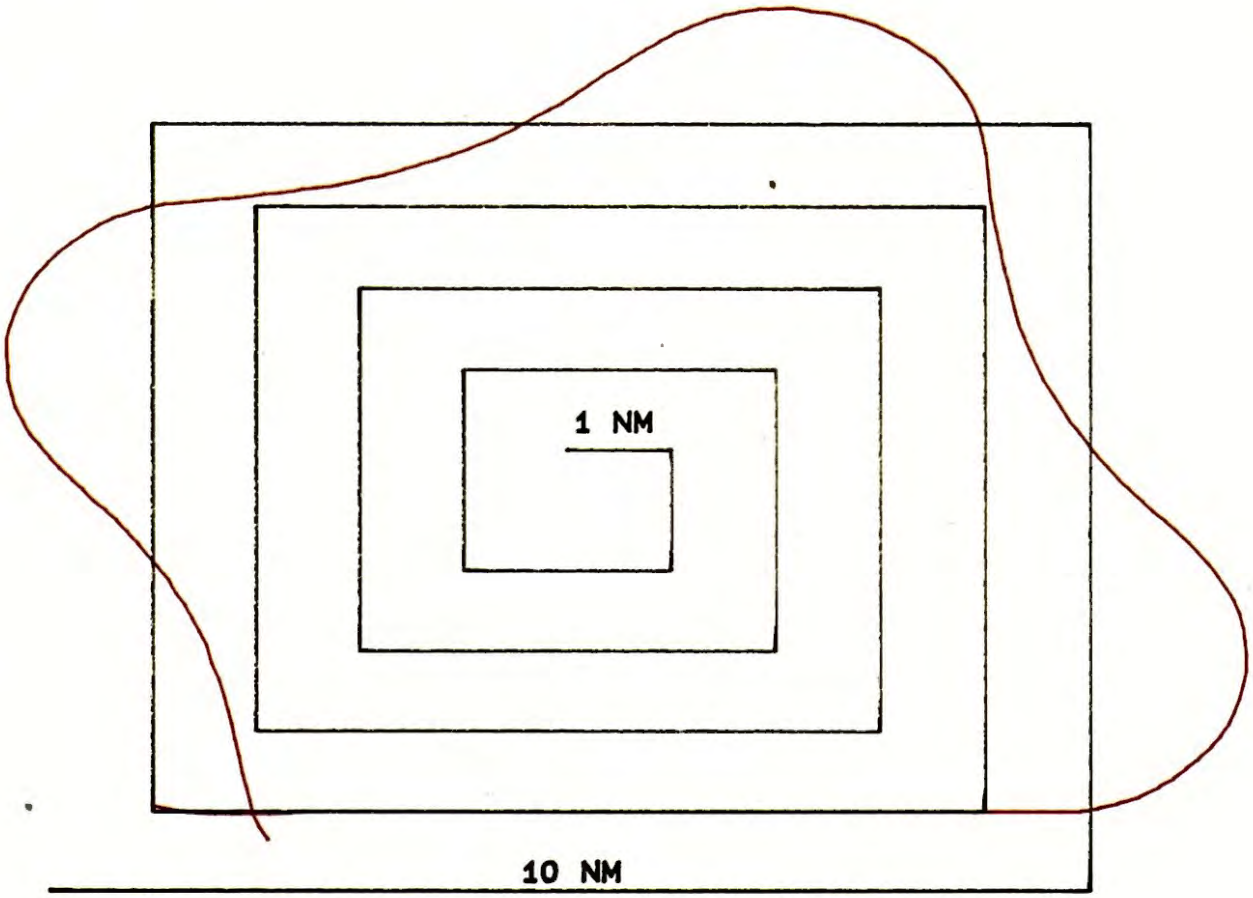
FMS SPIRAL 2 - FLY OVER WAYPOINTS

(MD11, 250 KIAS AT 10,000' + 60 KNOT WIND)



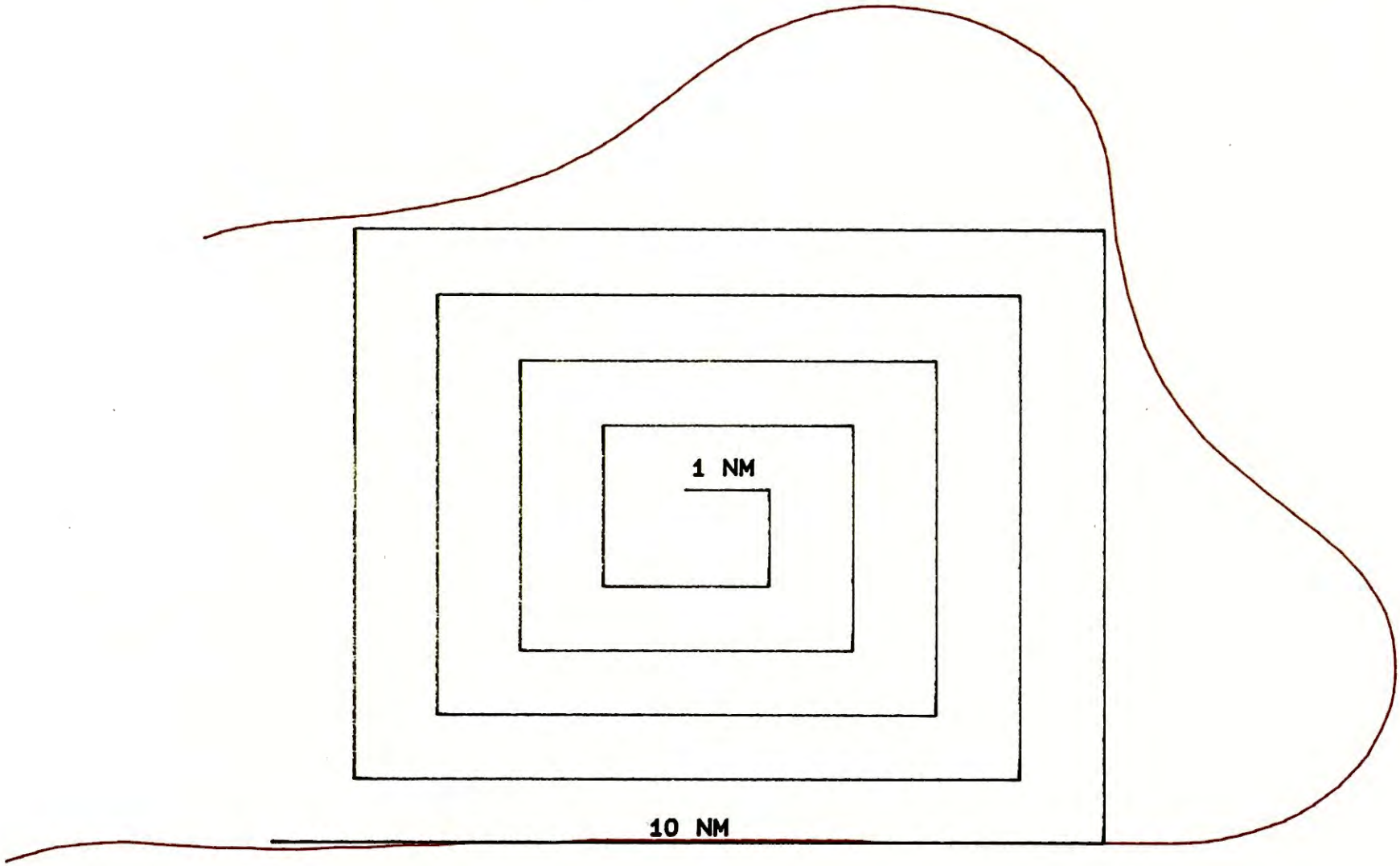
FMS SPIRAL 3 - FLY OVER WAYPOINTS

(MD11, 160 KIAS AT 10,000' + 60 KNOT WIND)



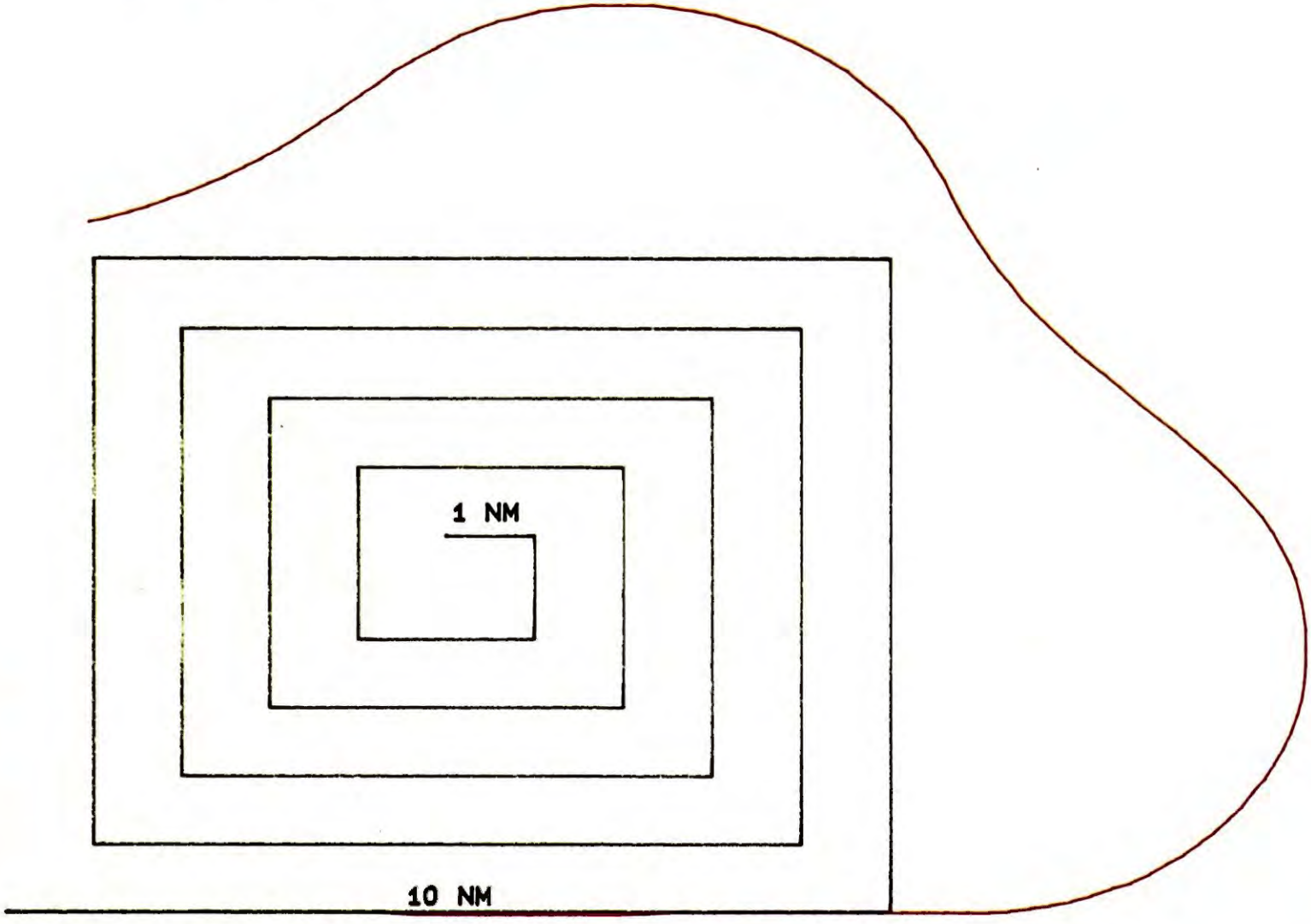
FMS SPIRAL 3 - FLY OVER WAYPOINTS

(MD11, 200 KIAS AT 10,000' + 60 KNOT WIND)



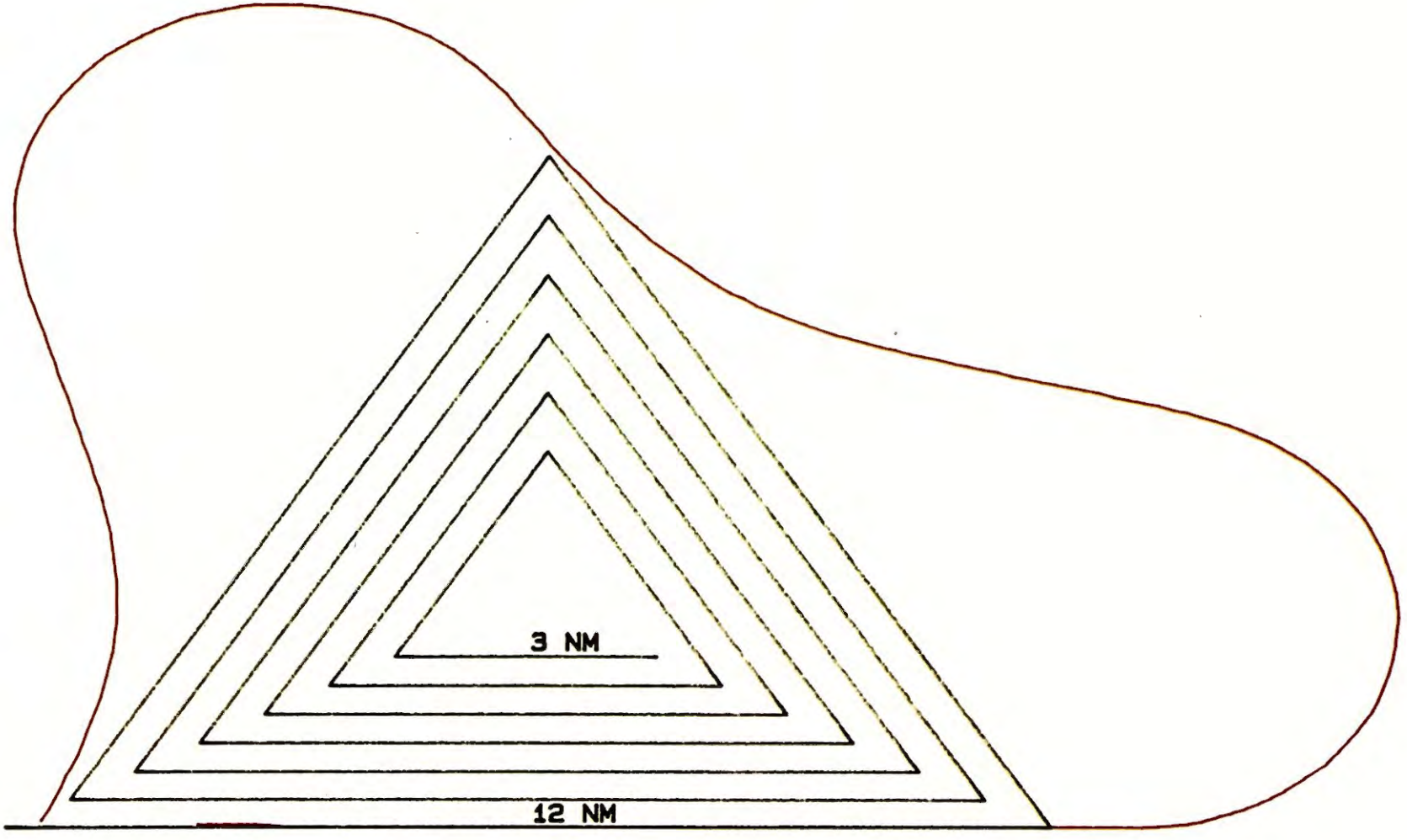
FMS SPIRAL 3 - FLY OVER WAYPOINTS

(MD11, 250 KIAS AT 10,000' + 60 KNOT WIND)



FMS SPIRAL 4 - FLY OVER WAYPOINTS

(MD11, 220 KIAS AT 10,000' + 60 KNOT WIND)



APPENDIX 5

FLY-OVER WAYPOINT TABULATED DATA

TABLE 1
TABULAR DATA
SCENARIO 5, B747, SEGMENT 10

AIR DISTANCE TO NEXT WAYPT (NM)	CROSS TRACK ERROR (NM)	TRACK ANGLE ERROR (DEGS)	BANK ANGLE (DEGS)
5.19	-0.05	-29.50	0.00
5.00	-0.14	-29.65	-0.63
4.81	-0.22	-29.31	-5.27
4.63	-0.30	-27.44	-12.10
4.45	-0.38	-24.45	-19.20
4.24	-0.45	-19.69	-24.10
4.06	-0.50	-14.38	-24.90
4.09	-0.54	-9.06	-25.04
3.91	-0.56	-3.64	-25.04
3.76	-0.56	1.37	-24.93
3.58	-0.55	6.43	-22.61
3.42	-0.52	10.47	-16.22
3.27	-0.48	13.07	-9.26
3.11	-0.44	14.24	-2.99
2.98	-0.41	14.43	0.47
2.83	-0.36	14.07	3.47
2.65	-0.32	13.02	5.41
2.49	-0.28	12.01	6.11
2.33	-0.25	10.68	6.22
2.18	-0.22	9.57	5.91
2.01	-0.19	8.48	5.47
1.85	-0.17	7.34	4.97
1.70	-0.15	6.49	4.35
1.52	-0.14	5.59	3.82
1.38	-0.11	4.97	3.25
1.20	-0.10	4.26	2.93
1.05	-0.09	3.80	2.45
0.89	-0.08	3.30	2.19
0.73	-0.07	2.99	1.97
0.58	-0.07	2.57	1.74
0.41	-0.05	2.25	1.32
0.27	-0.04	1.99	1.33
0.10	-0.04	1.76	1.29

TABLE 2
TABULAR DATA
SCENARIO 13, B747, SEGMENT 5

AIR DISTANCE TO NEXT WAYPT (NM)	CROSS TRACK ERROR (NM)	TRACK ANGLE ERROR (DEGS)	BANK ANGLE (DEGS)
8.05	-0.18	-60.08	-0.21
7.86	-0.33	-59.92	-3.30
7.67	-0.47	-58.86	-9.80
7.48	-0.59	-56.34	-17.10
7.29	-0.71	-52.79	-22.80
7.10	-0.84	-48.03	-24.70
6.91	-0.95	-43.23	-25.00
6.73	-1.06	-38.23	-25.00
6.59	-1.15	-33.57	-25.00
6.42	-1.24	-28.26	-25.00
6.27	-1.30	-23.56	-25.00
6.09	-1.36	-18.25	-25.00
6.03	-1.40	-14.23	-25.00
5.84	-1.43	-8.95	-25.03
5.65	-1.45	-4.15	-25.03
5.47	-1.46	0.81	-25.03
5.30	-1.45	5.44	-25.03
5.16	-1.42	10.42	-25.03
5.00	-1.39	14.94	-25.03
4.84	-1.34	20.07	-25.03
4.67	-1.28	25.02	-24.39
4.55	-1.21	29.10	-20.08
4.39	-1.12	32.40	-13.19
4.27	-1.04	34.15	-5.76
4.12	-0.95	34.58	1.92
3.94	-0.85	33.72	8.58
3.81	-0.77	31.59	13.03
3.66	-0.69	29.19	14.97
3.52	-0.62	26.29	15.16
3.37	-0.55	23.49	14.39
3.20	-0.49	20.84	13.29
3.03	-0.44	18.56	11.87
2.87	-0.39	16.51	10.57
3.36	-0.35	14.82	9.37
3.21	-0.31	13.11	8.27
3.05	-0.28	11.85	7.37
2.91	-0.25	10.52	6.55
2.76	-0.22	9.49	5.91
2.62	-0.20	8.53	5.30
2.48	-0.18	7.60	4.75
2.32	-0.16	6.87	4.16

2.17	-0.15	6.10	3.75
2.01	-0.13	5.63	3.32
1.85	-0.12	4.82	3.00
1.70	-0.10	4.57	2.70
1.55	-0.09	3.85	2.41
1.40	-0.08	3.82	2.13
1.23	-0.08	3.09	1.91
1.08	-0.07	2.71	1.71
0.91	-0.06	2.52	1.42
0.77	-0.06	2.18	1.33
0.61	-0.05	2.04	1.14
0.46	-0.05	1.76	1.12
0.30	-0.04	1.60	0.90
0.13	-0.04	1.37	0.85

TABLE 3
TABULAR DATA
SCENARIO 16, B747, SEGMENT 2

AIR DISTANCE TO NEXT WAYPT (NM)	CROSS TRACK ERROR (NM)	TRACK ANGLE ERROR (DEGS)	BANK ANGLE (DEGS)
10.32	-0.17	-60.21	0.33
10.12	-0.37	-60.10	-1.42
9.93	-0.59	-59.51	-7.40
9.73	-0.79	-57.99	-14.53
9.54	-1.00	-55.24	-21.59
9.34	-1.20	-52.00	-24.58
9.14	-1.39	-48.31	-25.02
8.95	-1.56	-44.57	-25.04
8.75	-1.74	-40.73	-25.04
8.55	-1.88	-37.23	-25.03
8.35	-2.03	-33.27	-25.03
8.16	-2.15	-29.77	-25.03
7.96	-2.27	-25.91	-25.03
7.75	-2.37	-22.27	-25.03
7.54	-2.46	-18.43	-25.03
7.31	-2.52	-14.90	-25.03
7.07	-2.59	-11.06	-25.03
6.82	-2.62	-7.40	-25.03
6.56	-2.64	-3.55	-25.03
6.30	-2.65	-0.05	-25.03
6.09	-2.64	3.91	-25.03
5.85	-2.62	7.43	-25.03
5.60	-2.58	11.27	-25.03
5.34	-2.53	14.89	-25.03
5.08	-2.45	18.72	-25.03
4.83	-2.37	22.22	-25.03
4.62	-2.26	25.93	-25.03
4.38	-2.16	29.55	-24.74
4.11	-2.03	33.12	-21.36
3.85	-1.89	35.68	-14.41
3.59	-1.74	37.32	-7.19
3.36	-1.59	37.78	0.35
3.15	-1.44	37.20	7.84
2.90	-1.30	35.72	13.97
2.65	-1.16	33.33	17.25
2.40	-1.04	30.88	18.65
2.15	-0.91	28.06	18.81
2.03	-0.81	25.46	18.26
1.79	-0.70	22.79	17.42
1.54	-0.62	20.51	16.46
1.30	-0.53	18.10	15.31

1.05	-0.47	16.09	14.12
0.79	-0.39	14.14	12.85
0.59	-0.34	12.43	11.69
0.29	-0.29	10.86	10.50
0.15	-0.25	9.45	9.47

TABLE 4
TABULAR DATA
SCENARIO 21, B747, SEGMENT 5

AIR DISTANCE TO NEXT WAYPT (NM)	CROSS TRACK ERROR (NM)	TRACK ANGLE ERROR (DEGS)	BANK ANGLE (DEGS)
9.66	-0.08	-90.09	-0.31
9.45	-0.26	-89.85	-0.18
9.25	-0.43	-89.48	-4.42
9.05	-0.60	-87.91	-11.20
8.98	-0.77	-85.01	-18.40
8.88	-0.95	-80.40	-23.60
8.79	-1.12	-75.41	-24.90
8.66	-1.28	-69.97	-25.00
8.48	-1.44	-64.98	-25.00
8.29	-1.59	-59.51	-25.00
8.09	-1.75	-54.07	-25.00
7.93	-1.88	-48.91	-25.00
7.74	-2.00	-43.47	-25.00
7.55	-2.12	-38.48	-25.00
7.36	-2.22	-32.85	-25.00
7.19	-2.31	-27.88	-25.00
6.99	-2.38	-22.43	-25.00
6.81	-2.44	-17.45	-25.00
6.62	-2.48	-12.00	-25.00
6.46	-2.51	-6.88	-25.03
6.26	-2.52	-1.44	-25.03
6.07	-2.51	3.98	-25.03
5.89	-2.50	9.11	-25.03
5.73	-2.46	14.57	-25.03
5.55	-2.41	19.71	-25.03
5.38	-2.34	25.21	-25.03
5.18	-2.26	30.21	-25.00
5.01	-2.17	35.54	-23.16
4.84	-2.07	39.72	-17.33
4.66	-1.95	42.70	-10.92
4.48	-1.83	44.22	-5.86
4.34	-1.70	45.08	-2.23
4.15	-1.57	45.32	-0.23
3.98	-1.44	45.16	2.25
3.82	-1.32	44.38	6.33
3.67	-1.20	42.68	10.46
3.52	-1.10	40.36	13.22
3.34	-0.98	37.77	14.90
3.16	-0.88	34.46	15.58
3.01	-0.79	31.48	15.46
2.83	-0.70	28.21	14.84

2.66	-0.63	25.45	13.85
2.50	-0.56	23.06	12.92
2.30	-0.50	20.64	11.83
2.13	-0.44	18.29	10.74
1.98	-0.40	16.48	9.85
1.83	-0.35	14.88	8.96
2.30	-0.32	13.41	8.20
2.14	-0.28	11.90	7.46
2.00	-0.25	10.87	6.86
1.86	-0.23	9.84	6.30
1.73	-0.21	8.92	5.79
1.60	-0.19	8.17	5.32
1.47	-0.17	7.47	4.87
1.38	-0.16	6.84	4.50
1.27	-0.15	6.41	4.21
1.20	-0.15	6.16	3.99
1.06	-0.13	5.61	3.61
0.98	-0.12	5.08	3.36
0.88	-0.11	4.79	3.20
0.80	-0.11	4.60	3.03
0.69	-0.10	4.30	2.82
0.59	-0.08	3.77	2.57
0.50	-0.08	3.66	2.36
0.41	-0.07	3.53	2.25
0.31	-0.07	3.32	2.20
0.23	-0.07	2.82	2.15
0.12	-0.07	2.79	2.00
0.02	-0.07	2.65	1.70

TABLE 5
TABULAR DATA
SCENARIO 22, B747, SEGMENT 2

AIR DISTANCE TO NEXT WAYPT (NM)	CROSS TRACK ERROR (NM)	TRACK ANGLE ERROR (DEGS)	BANK ANGLE (DEGS)
12.05	-0.14	-90.37	0.03
11.85	-0.33	-90.22	-1.04
11.65	-0.52	-89.71	-5.94
11.45	-0.70	-88.25	-13.00
11.26	-0.89	-85.84	-20.10
11.17	-1.08	-82.16	-24.10
11.08	-1.26	-78.29	-24.90
10.90	-1.45	-74.11	-25.00
10.69	-1.62	-70.31	-25.00
10.48	-1.80	-66.10	-25.00
10.28	-1.96	-62.02	-25.00
10.08	-2.13	-57.79	-25.00
9.88	-2.28	-53.83	-25.03
9.67	-2.43	-49.69	-25.03
9.47	-2.57	-45.81	-25.03
9.26	-2.69	-41.59	-25.03
9.05	-2.81	-37.65	-25.03
8.86	-2.92	-33.45	-25.03
8.66	-3.01	-29.65	-25.03
8.46	-3.11	-25.31	-25.03
8.26	-3.18	-21.17	-25.03
8.06	-3.24	-17.17	-25.03
7.87	-3.28	-13.37	-25.03
7.66	-3.33	-9.19	-25.03
7.47	-3.35	-5.26	-25.03
7.27	-3.36	-1.10	-25.03
7.07	-3.36	2.83	-25.03
6.89	-3.33	7.00	-25.03
6.69	-3.30	10.79	-25.03
6.48	-3.26	14.97	-25.03
6.30	-3.20	18.90	-25.03
6.09	-3.13	23.09	-25.03
5.90	-3.06	27.03	-25.03
5.70	-2.96	31.22	-24.98
5.51	-2.87	35.05	-23.09
5.30	-2.74	38.51	-18.38
5.12	-2.62	40.91	-13.21
4.92	-2.50	42.68	-8.67
4.73	-2.38	43.69	-5.34
4.56	-2.24	44.36	-3.07
4.38	-2.11	44.73	-1.65

4.17	-1.97	44.89	-0.81
4.00	-1.84	44.96	-0.27
3.83	-1.71	44.89	1.72
3.65	-1.58	44.40	5.56
3.48	-1.44	43.21	9.64
3.29	-1.32	41.59	12.90
3.09	-1.20	39.27	15.40
2.92	-1.09	36.89	16.90
2.73	-0.97	34.09	17.60
2.54	-0.88	31.28	17.80
2.34	-0.78	28.71	17.40
2.13	-0.71	26.64	16.90
1.95	-0.64	24.43	16.20
1.78	-0.58	22.53	15.40
1.64	-0.53	20.59	14.60
1.49	-0.48	18.52	13.50
1.34	-0.42	16.41	12.40
1.13	-0.37	14.58	11.20
1.69	-0.32	13.02	10.00
1.51	-0.28	11.63	9.05
1.31	-0.25	10.22	8.21
1.12	-0.22	9.15	7.37
0.92	-0.19	7.96	6.65
0.73	-0.17	7.08	5.90
0.52	-0.14	6.21	5.24
0.34	-0.12	5.45	4.72
0.14	-0.11	4.80	4.14

TABLE 6
TABULAR DATA
SCENARIO 29, B747, SEGMENT 2

AIR DISTANCE TO NEXT WAYPT (NM)	CROSS TRACK ERROR (NM)	TRACK ANGLE ERROR (DEGS)	BANK ANGLE (DEGS)
14.75	-0.16	-120.38	-0.10
14.54	-0.31	-120.14	-2.64
14.34	-0.44	-119.09	-9.09
14.32	-0.59	-116.61	-16.40
14.32	-0.70	-113.70	-21.85
14.21	-0.85	-109.51	-24.52
14.12	-1.01	-104.49	-24.99
13.95	-1.16	-99.96	-25.03
13.78	-1.32	-94.98	-25.03
13.60	-1.48	-90.31	-25.03
13.43	-1.64	-85.31	-25.03
13.27	-1.79	-80.64	-25.03
13.14	-1.95	-75.65	-25.03
12.97	-2.10	-70.97	-25.03
12.80	-2.25	-65.99	-25.03
12.63	-2.36	-62.07	-25.03
12.47	-2.50	-56.92	-25.03
12.31	-2.64	-51.93	-25.03
12.14	-2.76	-47.10	-25.03
11.97	-2.87	-42.42	-25.03
11.77	-2.97	-37.45	-25.03
11.59	-3.06	-32.77	-25.03
11.45	-3.14	-27.82	-25.03
11.30	-3.21	-23.32	-25.03
11.14	-3.26	-18.18	-25.03
10.98	-3.30	-13.69	-25.03
10.80	-3.33	-9.49	-25.03
10.66	-3.35	-4.97	-25.03
10.49	-3.36	-0.01	-25.03
10.33	-3.35	4.67	-25.03
10.18	-3.33	9.64	-25.03
10.00	-3.29	14.18	-25.03
9.83	-3.24	19.49	-25.03
9.67	-3.18	24.35	-25.03
9.50	-3.11	29.36	-25.03
9.34	-3.02	34.00	-24.07
9.18	-2.92	38.35	-19.60
8.99	-2.82	41.51	-13.19
8.82	-2.71	43.35	-8.03
8.70	-2.61	44.48	-4.12
8.57	-2.49	44.98	-1.80

8.43	-2.37	45.20	-0.49
8.30	-2.26	45.23	0.18
8.14	-2.14	45.16	0.43
7.98	-2.03	45.09	0.45
7.85	-1.92	45.02	0.33
7.72	-1.81	44.97	0.19
7.59	-1.69	44.94	0.11
7.44	-1.55	44.91	0.33
7.30	-1.43	44.68	2.26
7.11	-1.32	43.98	6.00
6.96	-1.20	42.54	9.58
6.84	-1.10	40.56	12.61
6.71	-1.00	37.97	14.52
6.58	-0.91	35.35	15.42
6.40	-0.81	32.31	15.58
6.21	-0.73	29.62	15.22
6.06	-0.66	26.80	14.49
5.91	-0.59	24.04	13.51
5.76	-0.52	21.52	12.38
5.60	-0.47	19.31	11.29
5.41	-0.42	17.40	10.34
5.23	-0.37	15.56	9.42
5.74	-0.33	13.95	8.58
5.58	-0.29	12.33	7.80
5.41	-0.26	11.00	6.98
5.23	-0.23	9.64	6.24
5.07	-0.20	8.70	5.56
4.90	-0.18	7.59	4.94
4.73	-0.16	6.83	4.36
4.57	-0.14	6.12	3.90
4.40	-0.12	5.35	3.54
4.24	-0.11	4.86	3.14
4.07	-0.10	4.28	2.82
3.91	-0.09	3.89	2.50
3.74	-0.08	3.38	2.27
3.58	-0.07	3.07	2.05
3.40	-0.06	2.65	1.82
3.23	-0.05	2.12	1.65
3.06	-0.04	2.10	1.42
2.89	-0.04	1.76	1.32
2.72	-0.03	1.80	1.11
2.55	-0.03	1.42	1.01
2.38	-0.03	1.15	0.93
2.23	-0.03	1.15	0.76
2.05	-0.02	0.90	0.71
1.88	-0.02	1.28	0.54
1.72	-0.02	0.76	0.49
1.56	-0.01	0.59	0.54
1.39	-0.01	0.71	0.37

1.23	-0.01	0.47	0.47
1.05	-0.01	0.87	0.31
0.89	-0.01	0.35	0.38
0.73	-0.01	0.21	0.31
0.56	-0.01	0.50	0.07
0.41	-0.01	0.20	0.25
0.23	-0.01	0.93	0.14
0.07	-0.01	0.21	0.02

2.20	-0.58	21.14	15.55
1.99	-0.51	19.02	14.43
1.78	-0.45	16.96	13.26
1.57	-0.40	15.16	12.15
2.14	-0.34	13.47	11.10
1.93	-0.30	12.04	10.13
1.71	-0.26	10.60	9.26
1.51	-0.23	9.40	8.38
1.28	-0.19	8.17	7.58
1.08	-0.17	7.26	6.82
0.84	-0.15	6.29	6.11
0.64	-0.12	5.54	5.42
0.41	-0.11	4.76	4.82
0.20	-0.09	4.10	4.30

TABLE 7
TABULAR DATA
SCENARIO 31, B747, SEGMENT 2

AIR DISTANCE TO NEXT WAYPT (NM)	CROSS TRACK ERROR (NM)	TRACK ANGLE ERROR (DEGS)	BANK ANGLE (DEGS)
17.66	-0.07	-120.50	0.09
17.44	-0.23	-120.29	-0.32
17.23	-0.41	-119.97	-4.34
17.02	-0.58	-118.89	-11.16
17.02	-0.76	-116.67	-18.52
16.98	-0.94	-113.73	-23.52
16.88	-1.13	-109.92	-24.85
16.69	-1.32	-106.24	-25.03
16.48	-1.51	-102.68	-25.04
16.27	-1.71	-98.75	-25.03
16.05	-1.90	-94.97	-25.03
15.85	-2.12	-91.02	-25.03
15.64	-2.31	-87.44	-25.03
15.43	-2.52	-83.43	-25.03
15.22	-2.70	-79.87	-25.03
15.01	-2.91	-75.95	-25.03
14.80	-3.10	-72.26	-25.03
14.59	-3.29	-68.35	-25.03
14.38	-3.47	-64.81	-25.03
14.17	-3.64	-61.13	-25.03
13.96	-3.81	-57.20	-25.03
13.75	-3.97	-53.51	-25.03
13.55	-4.14	-49.59	-25.03
13.34	-4.28	-45.88	-25.03
13.14	-4.41	-42.32	-25.03
12.93	-4.53	-38.61	-25.03
12.73	-4.64	-35.03	-25.03
12.52	-4.76	-31.07	-25.03
12.30	-4.86	-27.39	-25.03
12.09	-4.94	-23.46	-25.03
11.93	-5.00	-20.40	-25.03
11.72	-5.06	-16.69	-25.03
11.51	-5.11	-12.69	-25.03
11.30	-5.14	-8.97	-25.03
11.11	-5.16	-5.87	-25.03
10.92	-5.18	-2.33	-25.03
10.72	-5.18	1.43	-25.03
10.55	-5.17	3.99	-25.03
10.38	-5.15	7.40	-25.03
10.21	-5.12	10.45	-25.03
10.04	-5.09	13.58	-25.03

9.92	-5.07	15.60	-25.03
9.77	-5.02	18.27	-25.03
9.62	-4.97	20.86	-25.03
9.49	-4.92	23.42	-25.03
9.34	-4.86	25.99	-25.03
9.20	-4.80	28.57	-25.03
9.09	-4.74	30.65	-25.03
8.95	-4.67	33.09	-24.69
8.85	-4.62	34.86	-23.61
8.73	-4.55	36.72	-21.18
8.59	-4.47	38.51	-18.07
8.46	-4.39	40.07	-15.02
8.35	-4.32	41.03	-12.34
8.24	-4.26	41.93	-10.10
8.11	-4.16	42.77	-7.81
8.02	-4.11	43.15	-6.56
7.91	-4.05	43.59	-4.95
7.80	-3.96	43.92	-3.90
7.69	-3.88	44.20	-2.92
7.61	-3.82	44.35	-2.41
7.46	-3.72	44.53	-1.68
7.34	-3.64	44.65	-1.20
7.23	-3.57	44.72	-0.90
7.10	-3.49	44.80	-0.70
6.99	-3.42	44.83	-0.54
6.85	-3.35	44.86	-0.33
6.72	-3.27	44.88	-0.22
6.59	-3.20	44.89	-0.14
6.43	-3.12	44.89	-0.13
6.26	-3.02	44.90	-0.09
6.12	-2.93	44.91	-0.01
5.93	-2.81	44.92	0.00
5.73	-2.67	44.92	0.01
5.54	-2.53	44.91	0.02
5.34	-2.39	44.91	0.04
5.13	-2.26	44.90	0.08
4.92	-2.12	44.88	0.11
4.71	-1.97	44.86	0.24
4.50	-1.83	44.73	2.35
4.29	-1.69	44.09	6.28
4.09	-1.55	43.01	10.40
3.88	-1.41	41.23	13.80
3.67	-1.29	39.13	16.27
3.46	-1.16	36.59	17.76
3.25	-1.04	34.01	18.48
3.04	-0.93	31.28	18.58
2.83	-0.84	28.69	18.22
2.62	-0.74	25.99	17.50
2.41	-0.66	23.58	16.61