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NORTHEAST CORRIDOR HELICOPTER AREA NAVIGATION ACCURACY EVALUATI--ETC(U)
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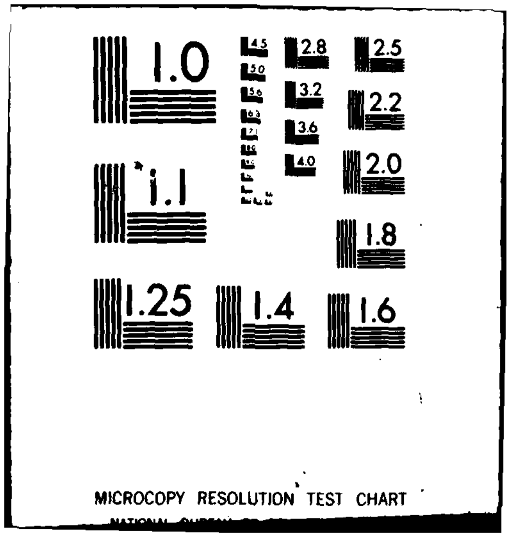
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AD A117445

Northeast Corridor Helicopter Area Navigation Accuracy Evaluation

Jack D. Edmonds

June 1982

Data Report

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US Department of Transportation
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Technical Center
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16. Abstract

This report presents area reduced navigation accuracy test flight data collected along an experimental area naviation route structure — the so-called Northeast Corridor. This corridor is an experimental helicopter airway structure extending between Washington, D.C., and Boston, Mass. It consists of 2 one-way, reduced width (4 nautical miles (nmi)) airways including one route spur from Allentown, Pa. These flight tests were a joint effort of the Federal Aviation Administration and the Helicopter Association International (HAI). The objective was to determine if the NEC could be navigated within the 4-nmi airway boundary at the 95 percent confidence level required by Advisory Circular (AC) 90-45A, "Approval of Area Navigation Systems for Use in the U.S. National Airspace System."

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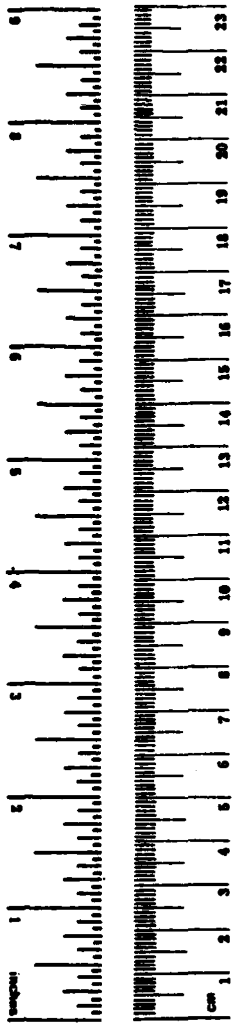
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

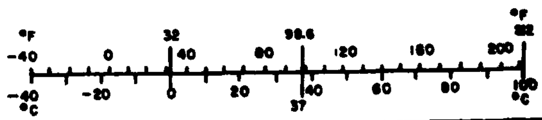
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature		Celsius temperature	°C

*1 in ≡ 2.54 (exactly). For other exact con[illegible] and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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INTRODUCTION

PURPOSE.

Helicopter test flights were made along the Experimental Northeast Corridor (NEC) area navigation (RNAV) route to determine the feasibility of discrete helicopter airways. These discrete airways would be low altitude, reduced width, RNAV airways separated from fixed wing airway routes whenever possible. The results of these test flights will be added to a data base for the development of discrete helicopter routes within the National Airspace System (NAS).

BACKGROUND.

Helicopter activities in the United States (U.S.) and the world have been growing at a rapid pace. They are being used in a wide variety of applications and weather conditions. This activity has prompted the Federal Aviation Administration (FAA) to review current helicopter operational criteria and procedures for possible improvement.

One area of possible improvement for helicopter Instrument Flight Rules (IFR) operations is the development of criteria and procedures on discrete helicopter RNAV routes. The FAA, in conjunction with the Helicopter Association International (HAI), started establishing an RNAV route structure (figures 1 through 4) in 1974 along the NEC for use as a pilot project. The route structure was designed to demonstrate the feasibility of helicopter IFR operations that would have minimum impact on fixed wing IFR operations and on the air traffic control (ATC) system.

After considering various concepts, an RNAV route structure was established that extended from Washington, D.C., to Boston, Mass. via Philadephia, Pa., and New York, N.Y., including route spurs and point-in-space approaches upon leaving the NEC.

The entire route was completed, flight checked, and approved for rho-theta RNAV by the FAA in January 1978. Because of this discrete route design, users were required to obtain specific approval prior to using the NEC. FAA authorization could be obtained by complying with criteria established in FAA Advisory Circular AC-73-2, "IFR Helicopter Operations in the Northeast Corridor," dated June 1979.

In implementing the NEC concept, a ±2-mile route width was found necessary in order to fit the structure into the airspace without affecting established airways. In so doing, an important factor, known as Flight Technical Error (FTE) in coventional airway structuring, had to be minimized. FTE is a measure of the accuracy with which the pilot/autopilot can adhere to the indicated track. Advisory Circular AC-90-45A, "Approval of Area Navigation Systems for Use in the U.S. National Airspace System," presents specific FTE values — nautical mile (nmi) — that must be considered in developing error budgets. These values are different for different airspace areas and are specified as follows:

Area	FTE Value (nmi)
En Route	±2.0
Terminal	±1.0
Approach	±0.5

AC-73-2 specified that terminal area FTE values should be applied even though the Northeast Corridor was an en route operation. The reduction of the FTE value from ±2 to ±1 nmi allowed the corridor to be placed within existing available airspace.

A pilot operating IFR on this structure with improper equipment or inadequate pilotage technique could disrupt air traffic operations along the conventional airway system and, possibly, necessitate cancellation of the helicopter route. In addition to the route width reduction, the RNAV holding pattern airspace on this route was designed smaller than holding pattern airspace required for conventional aircraft.

An operational evaluation of the NEC was considered beneficial for both the FAA and its users. In April 1979, the FAA entered into a 14-month contract with HAI to test the NEC concept. Commercial and corporate operators were solicited to participate in these tests.

TEST OBJECTIVE.

The objective of these flight tests was to determine if the NEC helicopter route could be navigated within a 4-nmi airway boundary at 95 percent confidence level as required by AC-90-45A. The results of these tests would be used to determine the feasibility of making the NEC a public use helicopter airway.

Two other reports have been published on this subject:

"Northeast Corridor User Evaluation," report No. FAA-RD-80-17, May 1980 (reference 1).

"Helicopter Northeast Operational Test Support," report No. FAA-RD-80-90, June 1980 (reference 2).

These reports contain all the details as to test participants, data collection methods, etc. These details will not be repeated in this report. This report provides quantitative data to supplement the previously published reports.

DISCUSSION

DATA COLLECTION.

The two prime sources of data for the NEC evaluation were pilot data logs and Automated Radar Terminal Systems (ARTS) tracking data. The ARTS tracking data were used for the quantitative analysis.

ARTS TRACKING DATA. The data required from the ARTS data extraction tapes include: facility of origin, date of recording, time of each aircraft position update, and aircraft identification. In addition, ARTS III recorded aircraft beacon rho-theta position information for each radar scan, which was about every 4 seconds. The ARTS III recorded the discrete beacon code every scan. The discrete beacon code was then correlated to the aircraft identification number.

The ARTS I recorded an aircraft x-y position from the radar antenna site approximately every 4 seconds. The aircraft identification number was recorded with the desired data so there was no need to correlate it with the assigned beacon code.

ARTS ACCURACY. ARTS errors can be divided into two components: angular errors and range errors. These errors have been reported (reference 3) to be ±0.87° in azimuth and ±0.10 nmi in range (99.9 percent of the errors can be expected to fall within these limits with a confidence of 90 percent). Maximum ARTS error values, using the azimuth and range errors, were calculated for each segment of the route. These sets of orthogonal errors were then rotated to the desired track to obtain crosstrack and along track errors. The crosstrack errors are presented in table 1. It should be emphasized that these errors are maximum calculated errors based on reported ARTS accuracy measurements.

DATA COMPILATION FOR ANALYSIS.

The FAA Technical Center received 218 completed flight data logs from 13 pilots and 7 helicopter operator participants. A breakdown of company participation based on 218 flight logs received is shown in table 2. The disparity in contributions to the data base is easily discerned from the table.

During the course of this evaluation, meetings were held to encourage participation. One factor was identified as a cause of relatively low participation — anticipated deliveries of IFR equipped helicopters ordered by some of the companies desiring to participate did not materialize.

There were 102 ARTS data extraction tapes received on these flights from six ARTS equipped ATC terminal facilities which participated in these tests. Of these 102 data tapes, 41 contained recoverable data for flights of adequate duration (at least one complete segment).

A breakdown by segments of the flights for which ARTS data were recovered is shown in figures 5 through 9.

A breakdown of the 41 flights for which ARTS data was obtained is contained in table 3. This table considers the altitudes flown, flights by aircraft type, and flight weather conditions. Another breakdown of the 41 flights by pilot and company is contained in table 4. As seen in table 4, the quantitative data is from three companies and eight pilots, with one company contributing 64 percent of the data. (Note: Percentages do not necessarily total 100 because of rounding errors.)

The 41 ARTS tracked flights were flown in accordance with established FAA criteria. This includes compliance with AC-73-2. The FAA criteria compliance included:

1. The helicopters were certificated for IFR based on minimum equipment requirements. Flight director, autopilot, etc., were not a requirement for IFR certification. In reference to flight directors, previous RNAV flight test results in fixed wing aircraft (reference 4) found no statistically significant differences in FTE, as a function of guidance, when pilot subjects used either a flight director or radio deviation indicator.

2. The helicopters were equipped with RNAV equipment that was IFR approved in accordance with AC-90-45A. No criteria has been established for minimum waypoint storage capability.

3. The pilots were IFR helicopter rated and pilot techniques were adequate to fly RNAV under IFR.

4. The pilots were certified to fly the NEC in accordance with the AC-73-2 additional requirement of flying a portion of the route in simulated IFR conditions with an FAA or FAA designated flight check pilot.

USE OF APPROACH MODE SENSITIVITY FOR EN ROUTE FLIGHTS.

All pilots navigated the NEC using the approach mode of their RNAV systems. This mode may have affected the navigation accuracy statistical results. It typically increased sensitivity of an aircraft's crosstrack deviation indicator (CDI) by a factor 4. For example, a CDI that has a full-scale sensitivity of ±4 nmi when using the en route mode would have a ±1 nmi full-scale sensitivity while the approach mode was being used. Based on other RNAV test results (references 4, 5, and 6), this increase in CDI sensitivity should enable the pilots to reduce FTE standard deviation by a factor of 3. In addition, increased CDI sensitivity can increase pilot workload.

METEOROLOGICAL FLIGHT ENVIRONMENT.

ARTS track data were collected on 23 flights made in visual meteorological conditions (VMC) and 18 flights were made in instrument meteorological conditins (IMC) (see table 3). Four of the 41 flights were flown during the hours of darkness.

Quite often there is a question of data validity when IFR navigation tests are flown in VMC, unless the flight was made with the participating pilot under a hood. There was no requirement established for the participating pilots to use a hood at any time during each flight. After discussing this situation with cognizant personnel in the Office of Flight Operations, a decision was made to conduct a statistical analysis on only the IMC data.

TEST RESULTS

DATA ANALYSIS.

Each NEC route segment flown under IMC which had ARTS tracking data was examined for the number of times it was flown; route segments which were flown three or more times in the same direction were selected for analysis. There were nine route segments (six on V-314R and three on V-309R) that met this requirement. ARTS tracking data for 10 flights, spread among the nine segments (table 5) were used for analysis. The individual track plots of the 10 flights are shown in the appendix. Total system crosstrack deviations, grouped by segments for analysis, are graphically shown in figures 10 through 18.

The segments were divided into along track distance (range) bins which were 0.2 nmi in length. Sums and sums of the squares of total crosstrack error were accumulated over all flights which passed the particular route segment in question. This was done for each range bin by taking he datum from each flight which was within the range bin and was the m[illegible] a[illegible] track distance point with respect to the center of the range bin in questi[illegible].

Sample means (X) and 1 standard deviations (S) were computed for each range bin. Range bins which did not contain a datum from each flight which passed the segment in question were eliminated from further consideration. Bins which were within 2 nmi of either end of a segment were also eliminated from further consideration in order to exclude turn data from the statistical analysis.

All remaining bins for a particular segment were tested against each other by ratio of variances (F-test) at a 5 percent significance level (reference 7). Range bins varying significantly from this remaining group of bins are identified in table 6. These were eliminated from further consideration.

A group of range bins which were spaced by at least 2 nmi of along track distance (center to center) were pooled to generate summary statistics for each segment.

The range bins which entered this analysis are listed in table 7. The segment summary statistics based on range bin data are presented in table 8.

Two bins, which normally would be eliminated by the outlined procedure, are included in the analysis. In the first instance, segment 3 is 3.3 nmi in length, making it impossible to select a range bin at least 2 nmi from each waypoint. Therefore, the range bin corresponding to 1.5 nmi along track distance was selected (the approximate midpoint of segment 3). The second instance occurred on segment 5 for which a range bin corresponding to 1.9 nmi along track distance was entered into the analysis. This range bin violates the 2 nmi from waypoint constraint by 0.1 nmi; however, it was found to be valid in all other respects and was included.

Once the segments were summarized, an F-test (5 percent significance) was performed, pairwise, for all segments within each route. As a result, the segments were pooled to yield route summary statistics (table 9).

Finally, an F-test (5 percent significance) of route versus route indicated that pooling of the route data was acceptable. The pooled results are shown in table 9.

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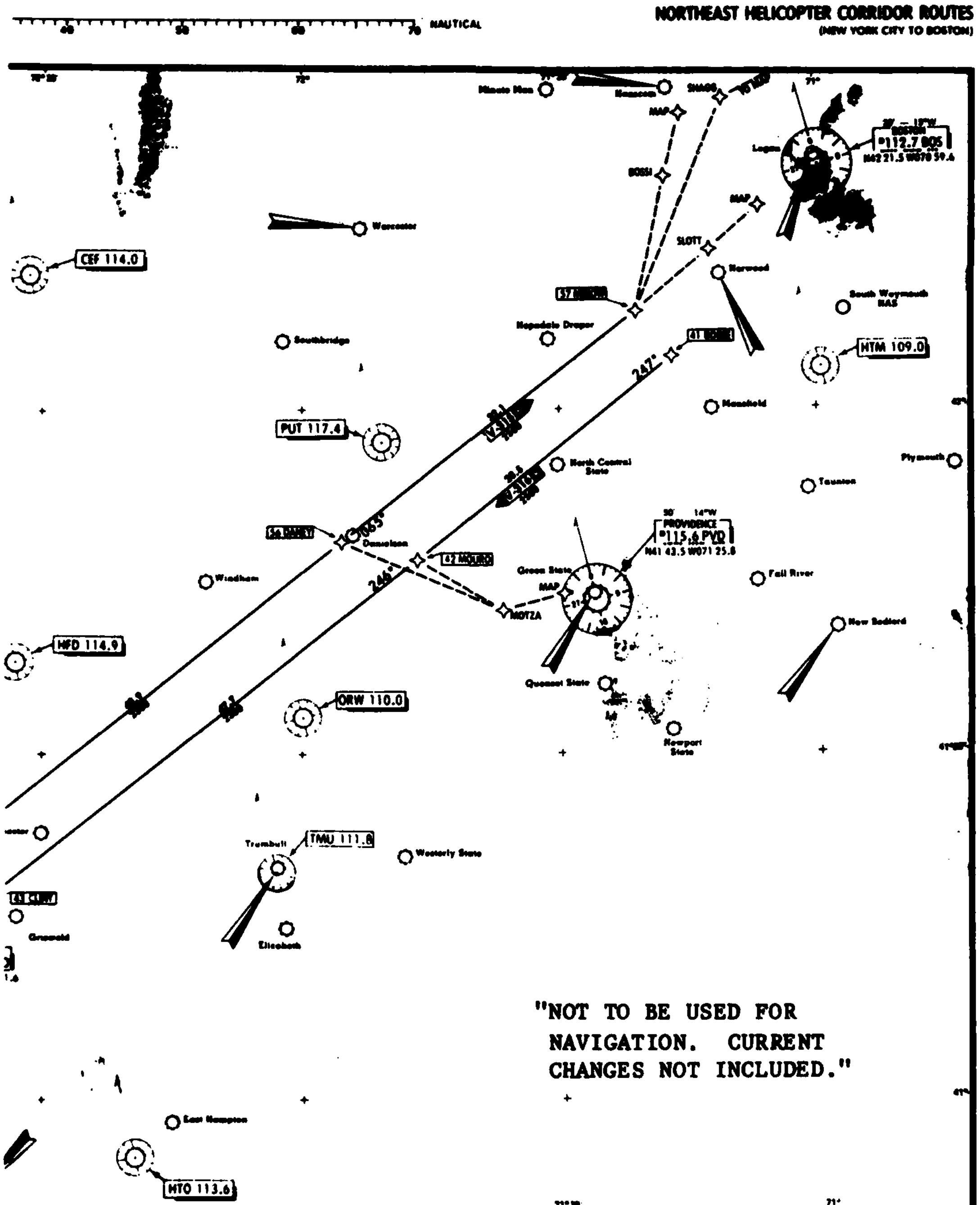


Victor airway 313R Washington D C to Bridgeport
(This airway continued from Northeast Helicopter Corridor Routes (Washington D C to New York) chart)

NO	NAME	IDENT	FREQ	ELEV	BEARING/DME DIST	VAR	LAT LONG
32	ROLER	JFK	115 9	00	061 0° 20 0	11W	N405104 8/W732831 1
33	MAUDE	RVH	117 2	01	284 0° 19 8	13W	N405401 4/W732052 1
34	FLOPP	RVH	117 2	01	331 8° 13 0	13W	N410330 3/W730804 8
35	IGORR	RVH	117 2	01	359 8° 20 2	13W	N411324 1/W730052 5

Victor airway 315R, New York to Boston

NO	NAME	IDENT	FREQ	ELEV	BEARING/DME DIST	VAR	LAT/LONG
51	AMUSE	DPK	111 2	01	315 0°/19 5	12W	N405805 7/W733850 1
52	HIPAN	DPK	111 2	01	335 0°/16 8	12W	N410054 9/W733136 2
53	ORALE	DPK	111 2	01	007 5° 18 3	12W	N410545 4 W732008 7
54	IGORR	RVH	117 2	01	359 8°/20 2	13W	N411324 1/W730052 5
55	DROUN	MAD	110 4	02	024 9° 2 9	13W	N412139 9/W724045 9
56	DANEY	PVD	115 6	01	297 0°/21 9	14W	N414819 5/W715420 4
57	MEEOW	BOS	112 7	00	245 4°/20 4	15W	N420828 3/W712045 9

82-57-1

FIGURE 1. NORTHEAST CORRIDOR, NORTHEAST PORTION

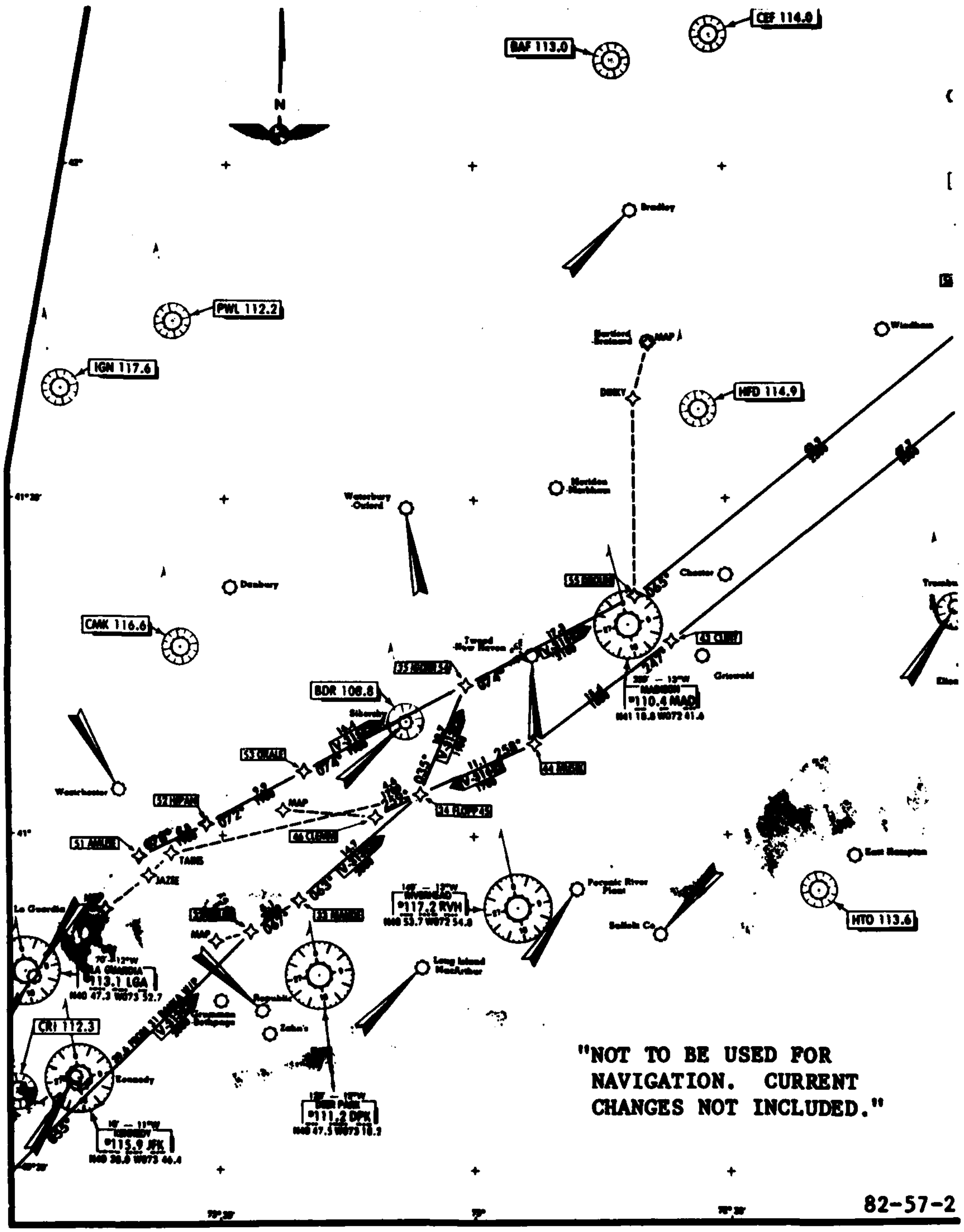
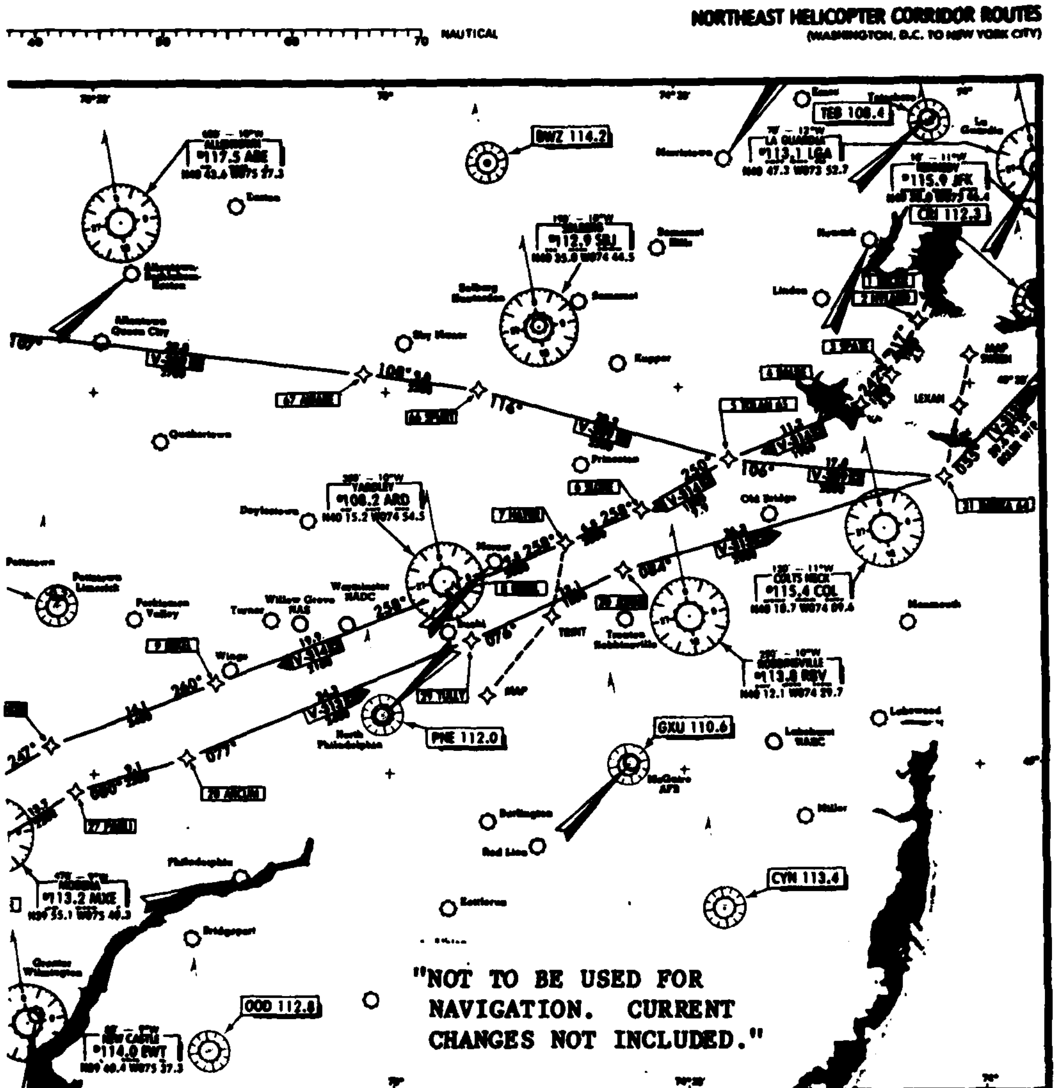


FIGURE 2. NORTHEAST CORRIDOR, NORTH-CENTRAL PORTION



Victor Airway 308R, Allentown to New York

NO	NAME	IDENT	FREQ	ELEV	BEARING/DME DIST	VAR	LAT/LONG
68	EAST TEXAS	ABE	117.5	.07	240.2°/13.6	10W	N403451.2/W7[illegible]4103.6
67	AWARE	SBJ	112.9	02	265.0°/14.0	10W	N403119.6/W7[illegible]0215.6
66	SPURT	SBJ	112.9	02	238.0°/7.3	10W	N403005.0/W74[illegible]038.4
65	TOLAN	SBJ	112.9	02	135.0°/18.0	10W	N403437.0/W742513.6
64	SANKA	COL	115.4	01	081.0°/6.5	11W	N402252.3/W740305.7

Victor Airway 313R, Washington, D.C. to Bridgeport

NO	NAME	IDENT	FREQ	ELEV	BEARING/DME DIST	VAR	LAT/LONG
21	BERNY	BAL	115.1	01	151.5°/12.2	08W	N3[illegible]0028.0/W7[illegible]3023.0
22	MORRH	BAL	115.1	01	130.0°/17.7	08W	[illegible]
23	RUBEY	BAL	115.1	01	083.0°/22.8	08W	N391608.3/W761120.2
24	ABZUG	ENO	111.4	00	308.0°/24.6	08W	[illegible]
25	[illegible]	EWT	114.0	01	283.0°/11.2	08W	N394107.6/W75[illegible]147.5

82-57-3

FIGURE 3. NORTHEAST CORRIDOR, SOUTH-CENTRAL PORTION

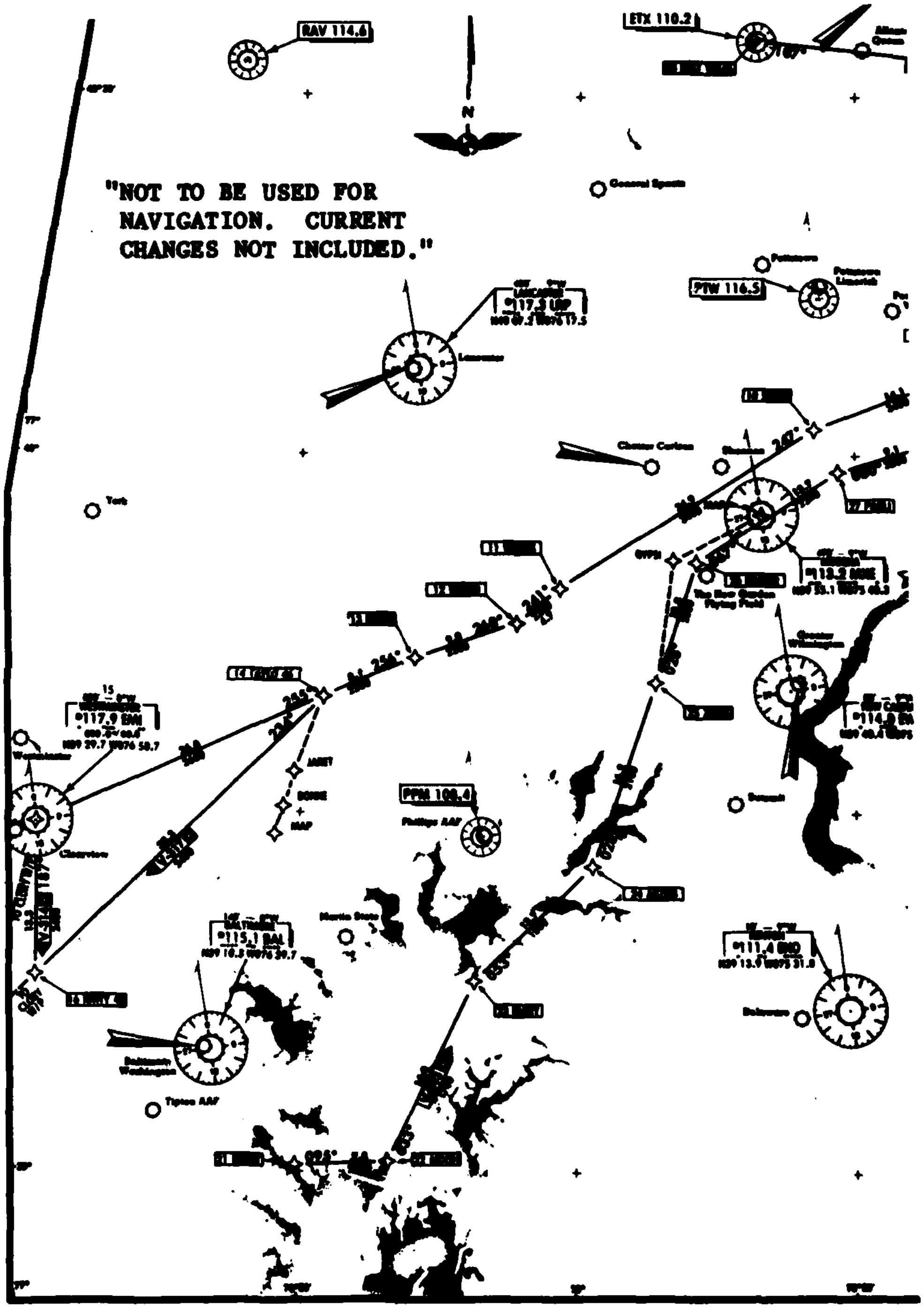


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FIGURE 4. NORTHEAST CORRIDOR, SOUTHWEST PORTION

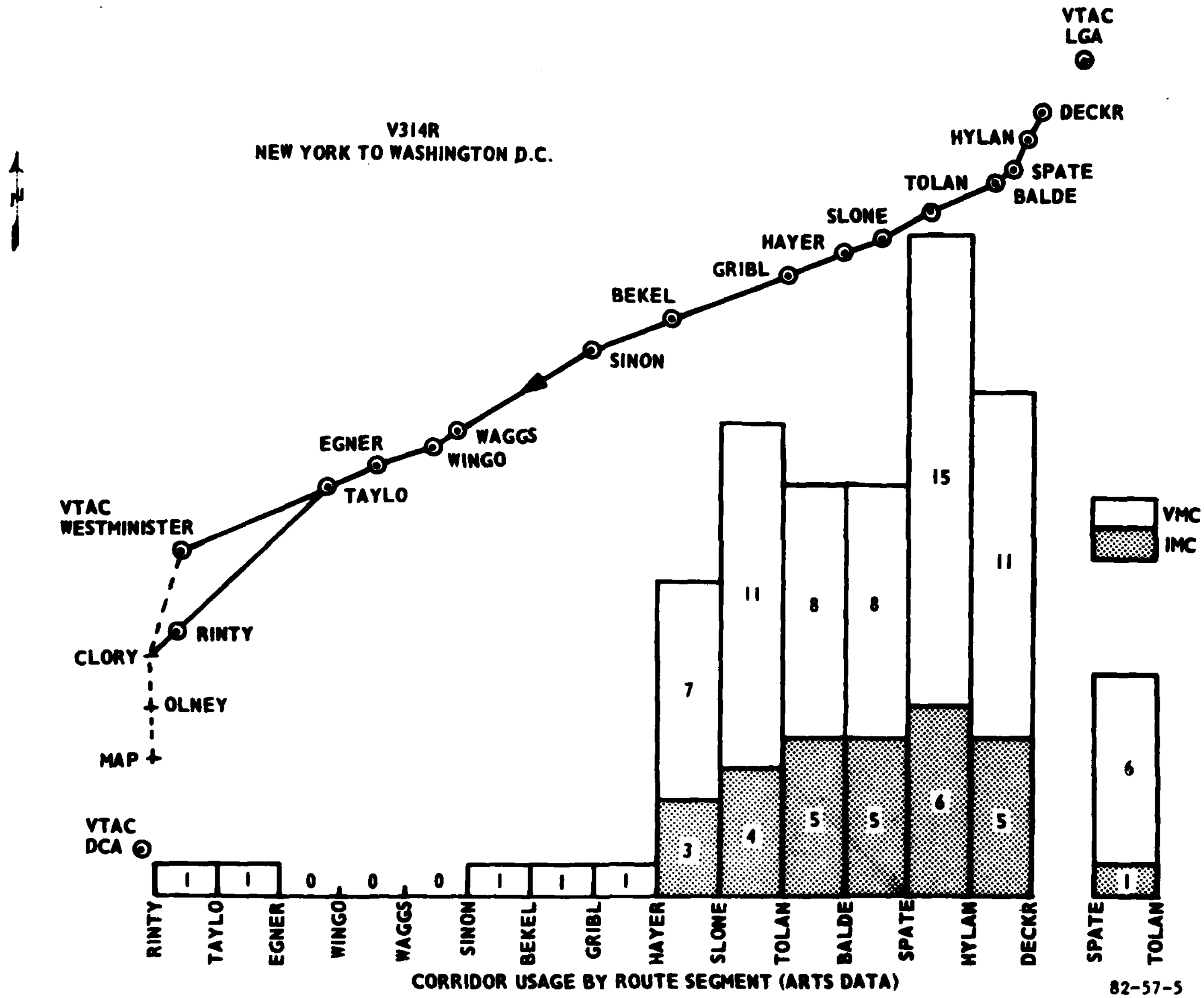

FIGURE 5. V314R CORRIDOR USAGE BY ROUTE SEGMENT (ARTS DATA)

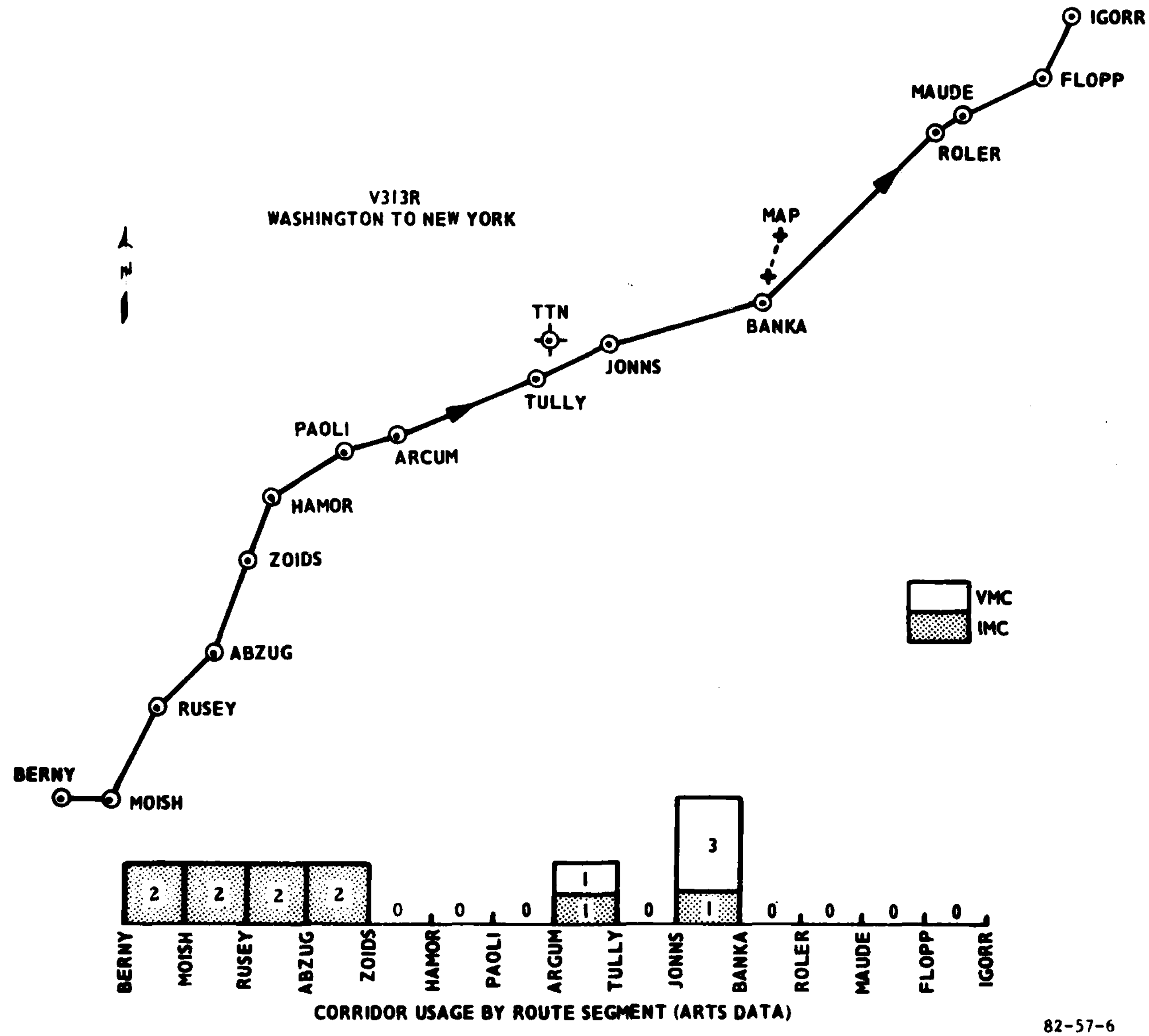

FIGURE 6. V313R CORRIDOR USAGE BY ROUTE SEGMENT (ARTS DATA)

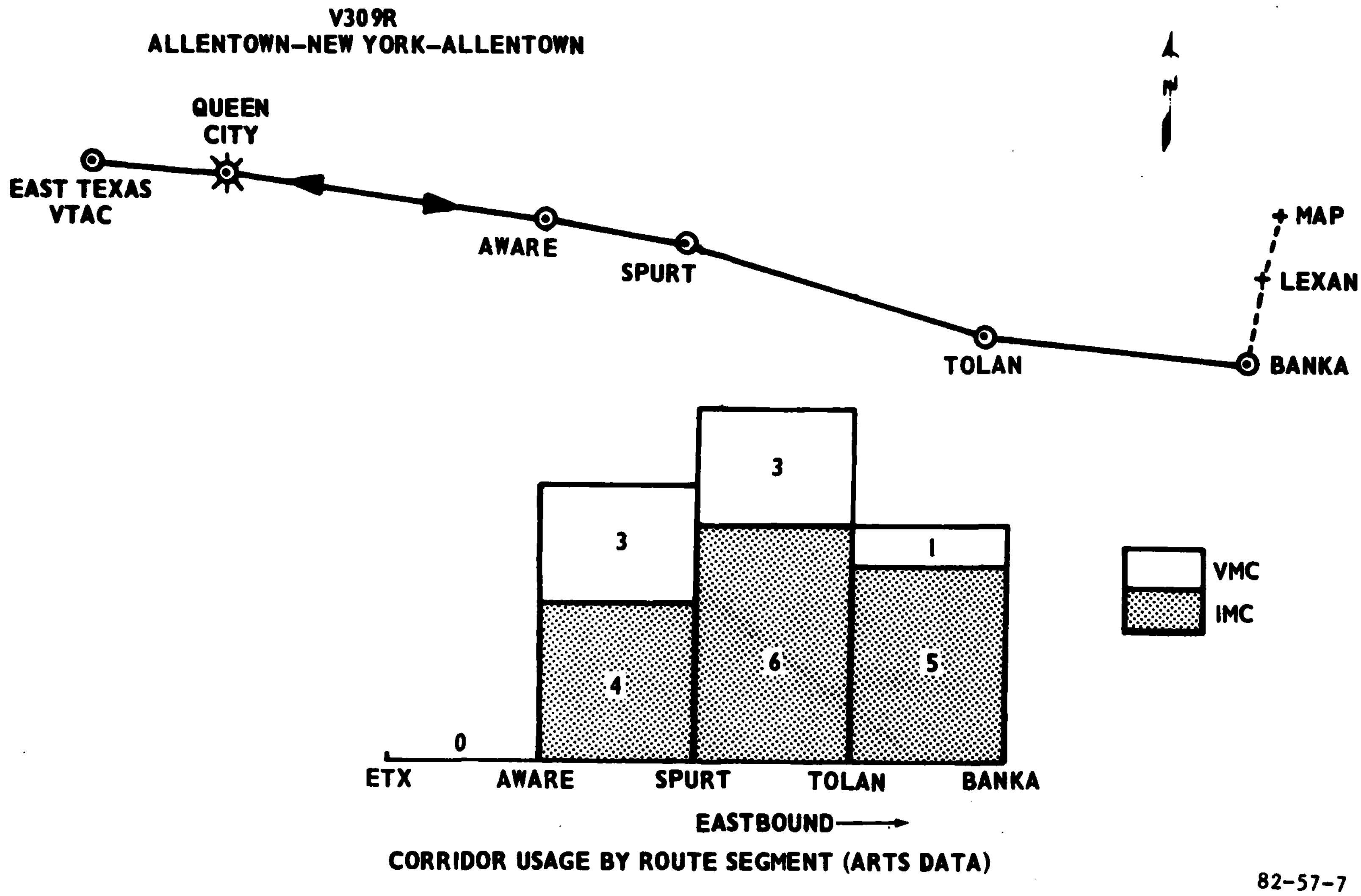

FIGURE 7. V309R CORRIDOR USAGE BY ROUTE SEGMENT (ARTS DATA)

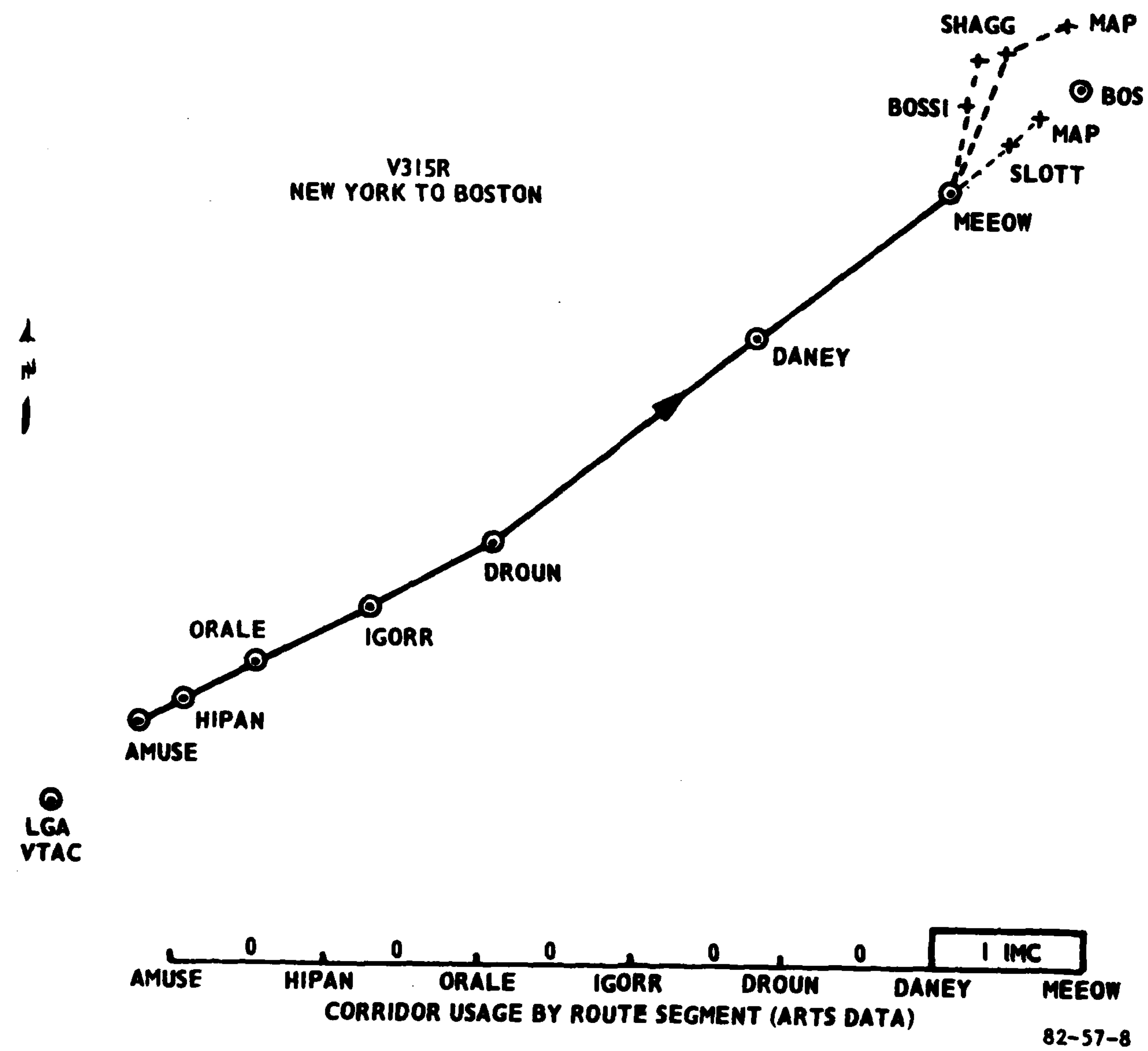

FIGURE 8. V315R CORRIDOR USAGE BY ROUTE SEGMENT (ARTS DATA)

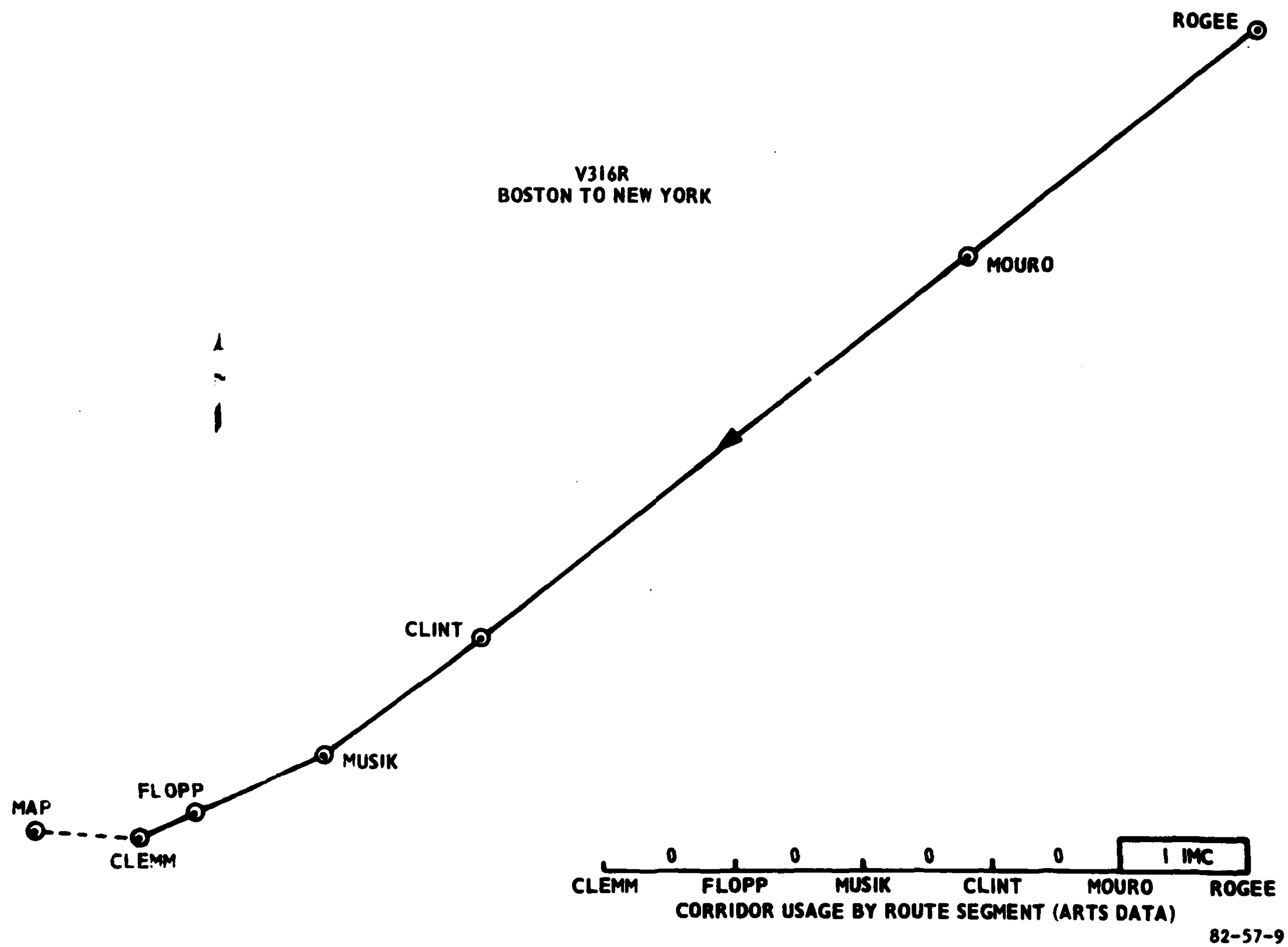

FIGURE 9. V316R CORRIDOR USAGE BY ROUTE SEGMENT (ARTS DATA)

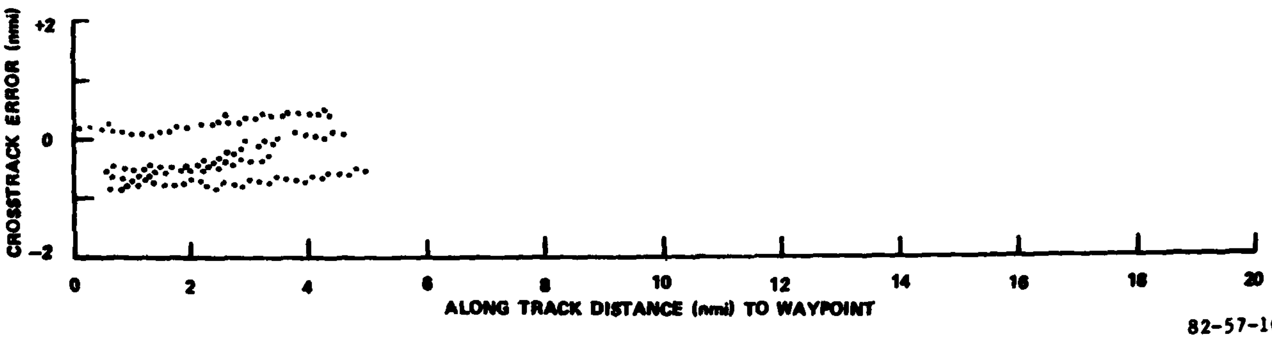

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FIGURE 10. ROUTE SEGMENT 1 FROM DECKR TO HYLAN (V-314R)

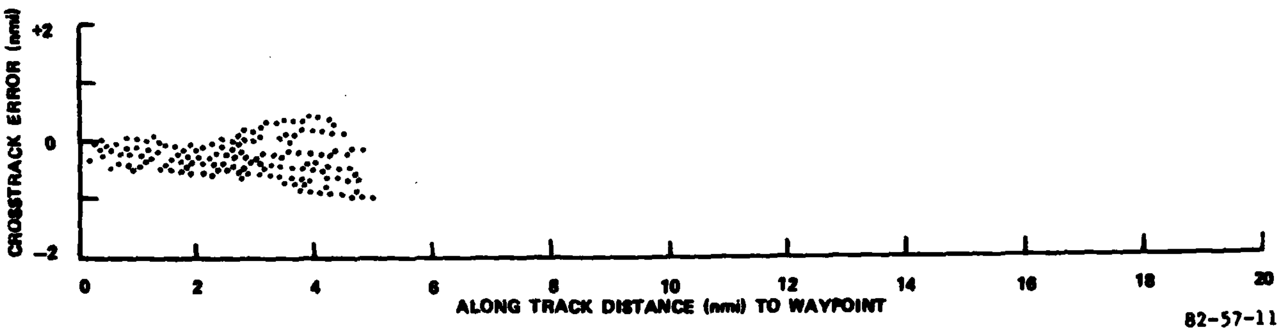

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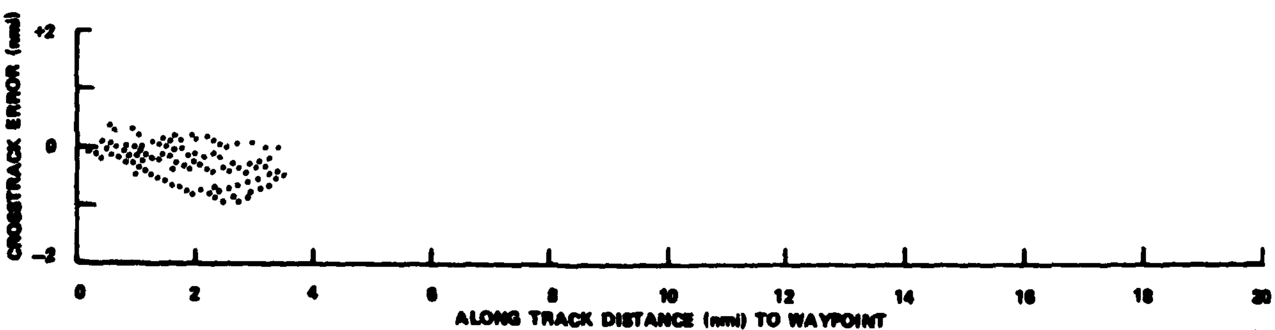
FIGURE 11. ROUTE SEGMENT 2 FROM HYLAN TO SPATE (V-314R)



82-57-12

FIGURE 12. ROUTE SEGMENT 3 FROM SPATE TO BALDE (V-314R)

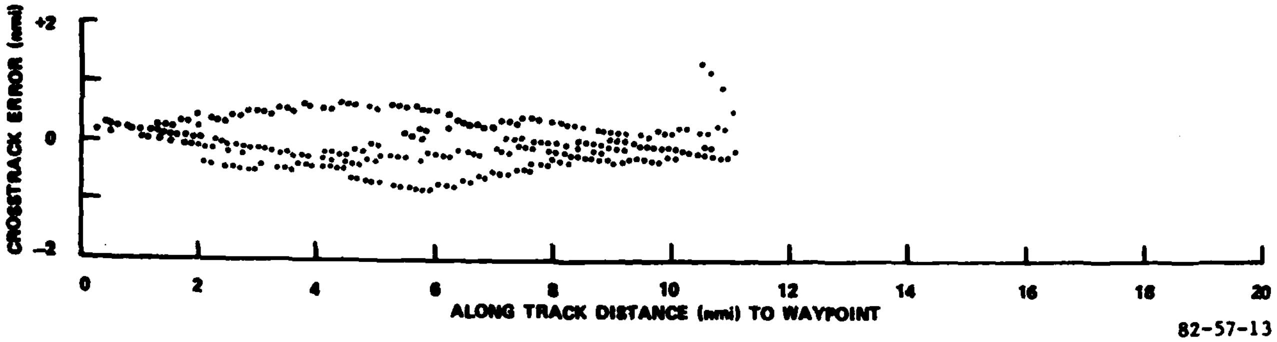


FIGURE 13. ROUTE SEGMENT 4 FROM BALDE TO TOLAN (V-314R)

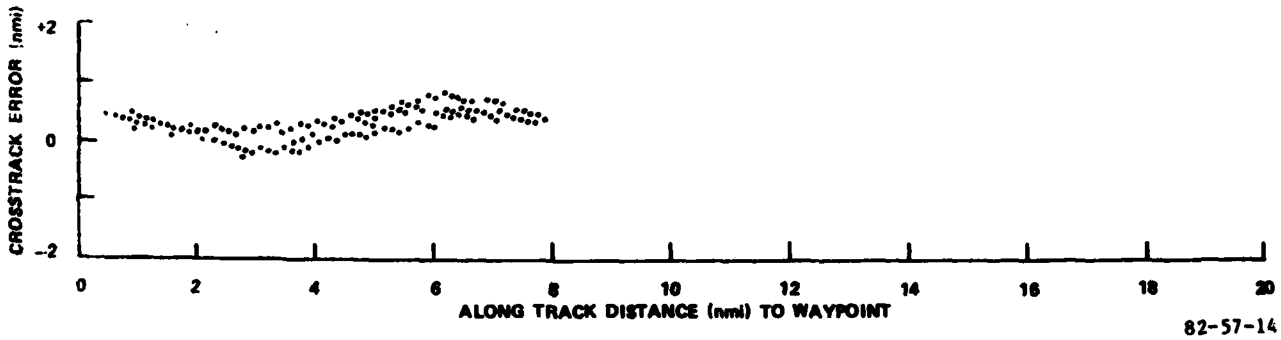


FIGURE 14. ROUTE SEGMENT 5 FROM TOLAN TO SLONE (V-314R)

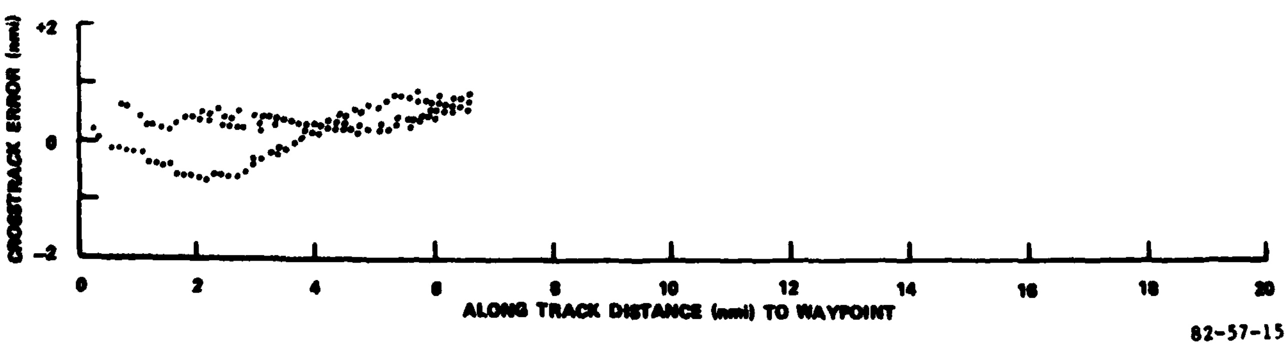


FIGURE 15. ROUTE SEGMENT 6 FROM SLONE TO HAYER (V-314R)

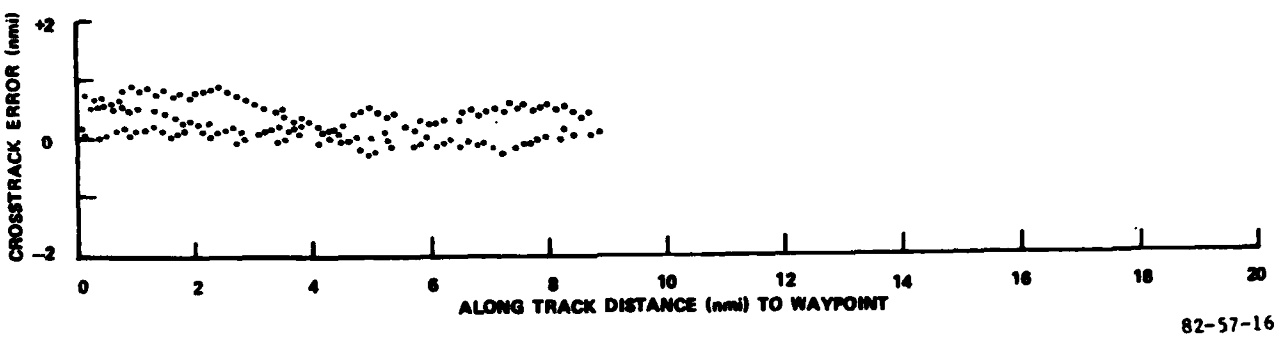


FIGURE 16. ROUTE SEGMENT 7 FROM HAYER TO SPURT (V-309R)

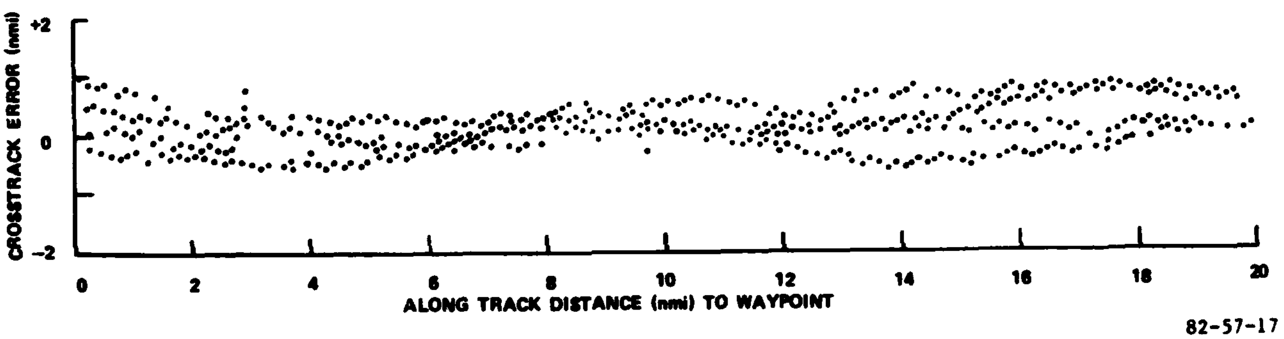


FIGURE 17. ROUTE SEGMENT 8 FROM SPURT TO TOLAN (V-309R)

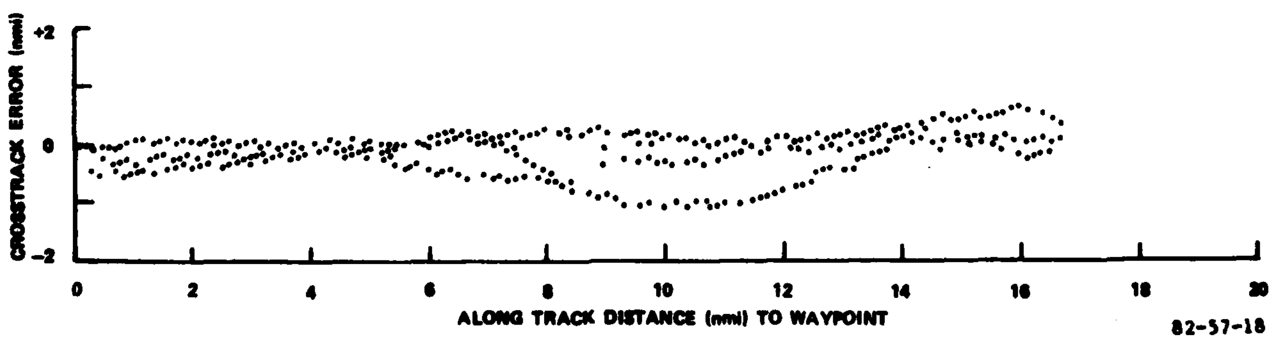


FIGURE 18. ROUTE SEGMENT 9 FROM TOLAN TO BANKA (V-309R)

TABLE 1. COMPUTED MAXIMUM ARTS SYSTEM TRACKING ERRORS

Waypoint 1	To Waypoint 2	Crosstrack Position Uncertainity (nmi)	ARTS Facility
DECKR (1)	HYLAN (2)	0.15	JFK
HYLAN (2)	SPATE (3)	0.14	EWR
SPATE (3)	BALDE (4)	0.14	EWR
BALDE (4)	TOLAN (5,65)	0.26	EWR
TOLAN (5,65)	SLONE (6)	0.40	EWR
SLONE (6)	HAYER (7)	0.48	EWR
HAYER (7)	GRIBL (8)	0.62	EWR
GRIBL (8)	BEKEL (9)	0.37	PHL
BEKEL (9)	SINON (10)	0.15	PHL
WAGGS (11)	WINGO (12)	0.51	PHL
WINGO (12)	EGNER (13)	0.55	BAL
EGNER (13)	TAYLO (14,46)	0.44	BAL
TAYLO (14,46)	RINTY (16)	0.42	BAL
BERNY (21)	MOISH (22)	0.24	BAL
MOISH (22)	RUSEY (23)	0.22	BAL
RUSEY (23)	ABZUG (24)	0.52	BAL
ABZUG (24)	ZOIDS (25)	0.54	PHL
PAOLI (27)	ARCUM (28)	0.14	PHL
ARCUM (28)	TULLY (29)	0.37	PHL
TULLY (29)	JONNS (30)	0.60	PHL/EWR
JONNS (30)	BANKA (31,64)	0.40	EWR
BANKA (31,64)	ROLER (32)	0.31	JFK
ROLER (32)	MAUDE (33)	0.38	JFK
MAUDE (33)	FLOPP (34)	0.78	EWR
ROGEE (41)	MOURO (42)	0.38	NCO/BOS
MOURO (42)	CLINT (43)	0.36	NCO/BDL
IGORR (55)	DROUN (55)	0.88	JFK/BDL
DROUN (55)	DANEY (57)	0.32	BDL/NCO
DANEY (56)	MEEOW (57)	0.44	BOS/NCO
BANKA (64,31)	TOLAN (5,65)	0.15	EWR

TABLE 2. DATA PERCENTAGE BY COMPANY PARTICIPATION FOR FLIGHT LOGS RECEIVED

Company	Percent of Flight Logs
A	74
B	5
C	14
D	4
E	2
F	0.5

TABLE 3. NEC HELICOPTER DATA SUMMARY FOR ARTS TRACKED FLIGHTS

ARTS Tracking Data Totals

Data Flights	41
Route Segments	138
Distance (nmi) Flown	1,440
Avg No. Route Segments Flown	3.4

Flights by Aircraft Type

Bell 212 (2)	34 (83%)
Augusta 109	6 (15%)
Gazelle	1 (2%)

Altitudes Flown

2,000 ft	22	(56%)
3,000 ft	14	(34%)
4,000 ft	3	(7%)
5,000 ft	2	(5%)

Flight Weather Conditions

VMC	23	(56%)
IMC	18	(44%)

TABLE 4. FLIGHTS FLOWN BY PILOT AND COMPANY FOR WHICH ARTS DATA WERE AVAILABLE

Company	Flights	Percentage	Pilot	Percentage
A	26	64	1	27
			2	22
			3	15
B	6	14	4	7
			5	7
C	9	22	6	2
			7	17
			8	2

TABLE 5. NEC ROUTE SEGMENTS ANALYZED

Segment No.	Times Flown	From Waypoint	To Waypoint	Route
1	4	DECKR	HYLAN	V-314R
2	6	HYLAN	SPATE	V-314R
3	6	SPATE	BALDE	V-314R
4	4	BALDE	TOLAN	V-314R
5	3	TOLAN	SLONE	V-314R
6	3	SLONE	HAYER	V-314R
7	3	HAYER	SPURT	V-309R
8	4	SPURT	TOLAN	V-309R
9	3	TOLAN	BANKA	V-309R

TABLE 6. BINS SHOWING MARKED DEVIATION

Segment No.	Range Bin (nmi)	Mean (X) (nmi)	1 Standard Deviation (nmi)	Number of Samples
6	3.9	-0.235	0.084	3
8	17.1	-0.327	0.572	4
8	7.9	-0.201	0.142	4
9	4.3	-0.090	0.090	3
9	4.1	-0.063	0.098	3
9	3.9	-0.075	0.081	3
9	3.7	-0.126	0.082	3
9	3.3	-0.150	0.083	3

TABLE 7. RANGE BINS ENTERED INTO ANALYSIS

Segment	Range Bin	No. of Samples	Mean (nmi)	1 Standard Deviation (S) (nmi)
1	2.5	4	0.271	0.445
2	2.5	6	0.268	0.211
3	1.5	6	0.273	0.332
4	8.9	4	0.063	0.224
4	6.9	4	0.058	0.365
4	4.9	4	0.151	0.534
4	2.9	4	0.075	0.421
5	5.9	3	-0.503	0.204
5	3.9	3	-0.155	0.203
5	1.9	3	-0.123	0.068
6	4.3	3	-0.331	0.134
6	2.1	3	-0.057	0.619
7	4.9	3	-0.064	0.401
7	2.9	3	-0.218	0.321
8	18.1	4	-0.379	0.391
8	15.9	4	-0.233	0.496
8	13.9	4	-0.109	0.512
8	11.9	4	-0.074	0.235
8	9.9	4	-0.277	0.194
8	7.7	4	-0.113	0.199
8	5.7	4	0.080	0.214
8	2.3	4	0.051	0.323
9	14.9	3	-0.204	0.203
9	12.9	3	0.140	0.318
9	10.9	3	0.392	0.554
9	8.9	3	0.262	0.554
9	6.9	3	0.158	0.378
9	4.9	3	0.080	0.138
9	2.9	3	0.160	0.204

TABLE 8. IMC SEGMENT SUMMARY STATISTICS

Segment	No. of Samples	Mean (X) (nmi)	1 Standard Deviation (S) (nmi)
1	4	0.271	0.445
2	6	0.268	0.211
3	6	0.273	0.332
4	16	0.087	0.362
5	9	-0.260	0.235
6	6	-0.194	0.428
7	6	-0.141	0.336
8	32	-0.138	0.341
9	21	0.141	0.355

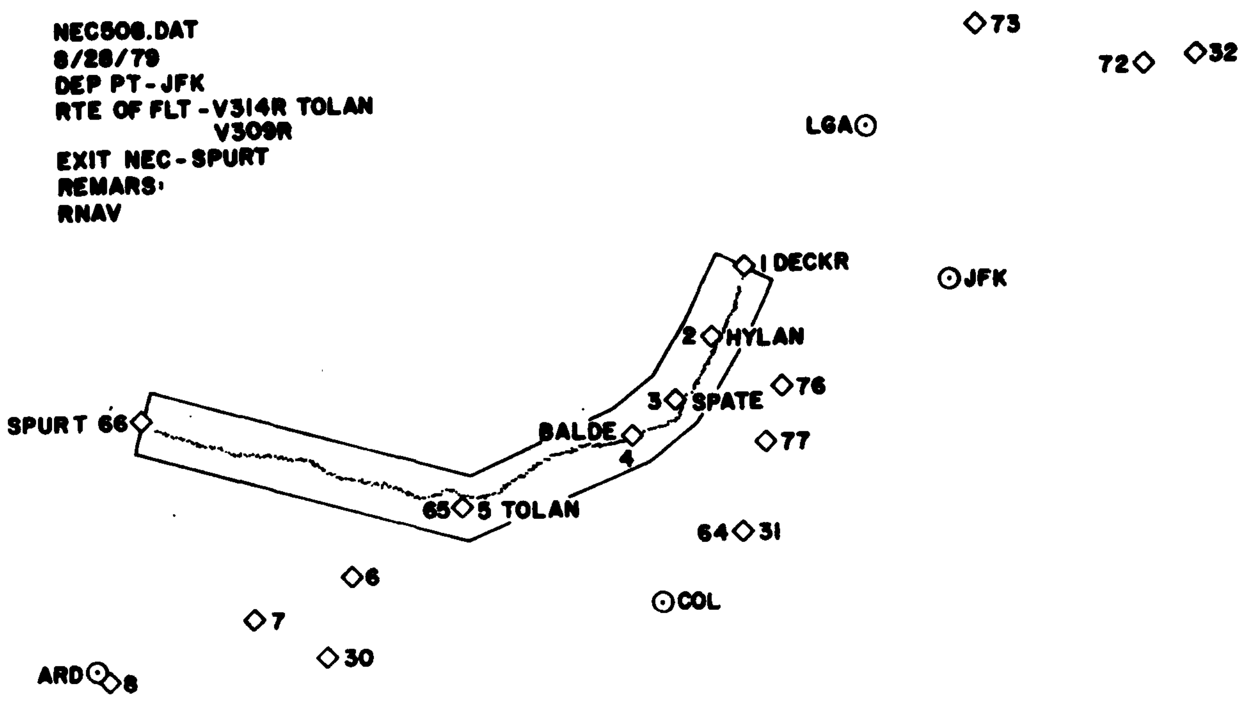
TABLE 9. SUMMARY STATISTICS FOR IMC FLIGHTS

Route	No. of Samples	Mean (X) (nmi)	1 Standard Deviation (S) (nmi)
V-314R	47	0.047	0.382
V-309R	59	-0.039	0.367
Pooled	106	-0.001	0.374

APPENDIX

ARTS TRACKING PLOTS

Automated Radar Tracking System (ARTS) tracking data were received from six air traffic control Terminal Radar Approach Control Facilities (TRACON) located along the Northeast Corridor. These data were made into plotted tracks for each of the helicopter flights. Each dot that forms a plot track indicates a recorded position update at approximately 4-second intervals. The 10 flights used in the data analysis are shown in figures A-1 through A-10.



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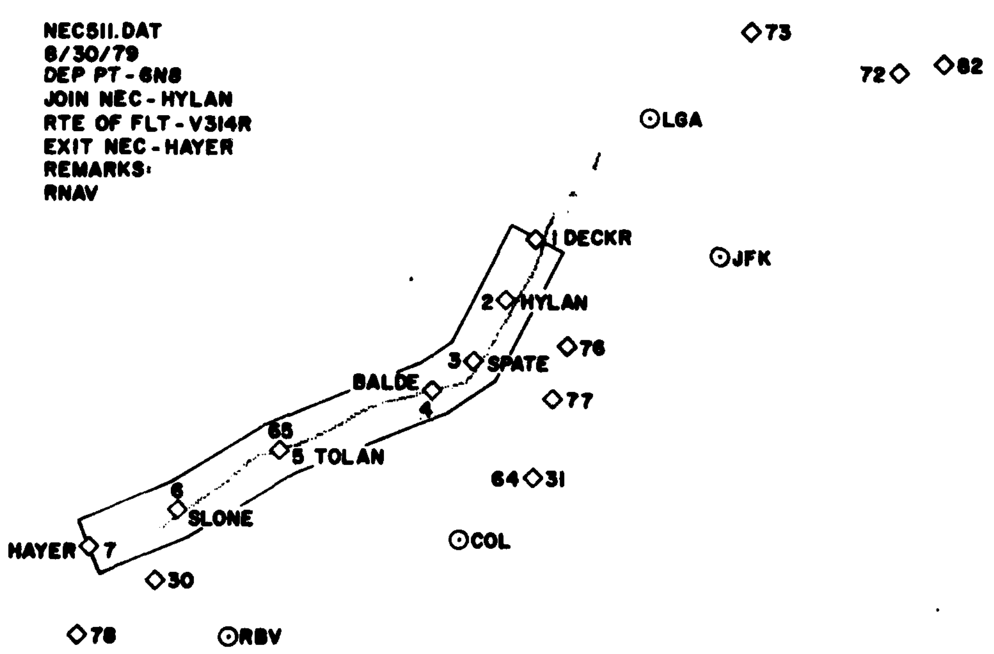

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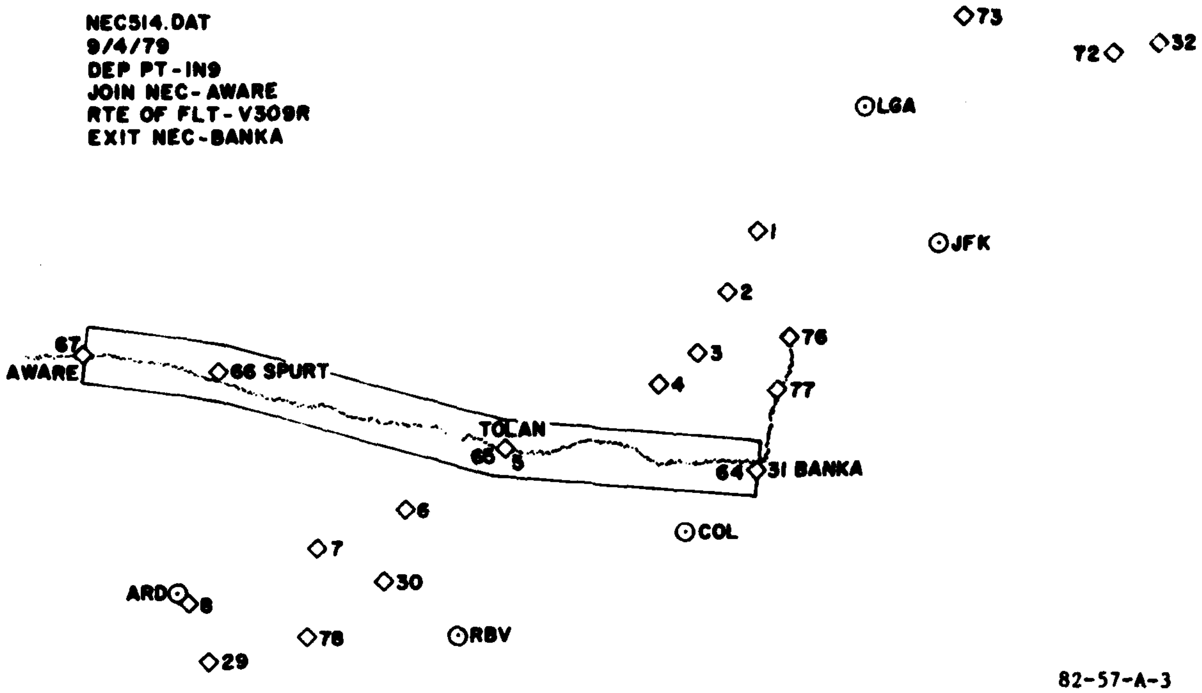

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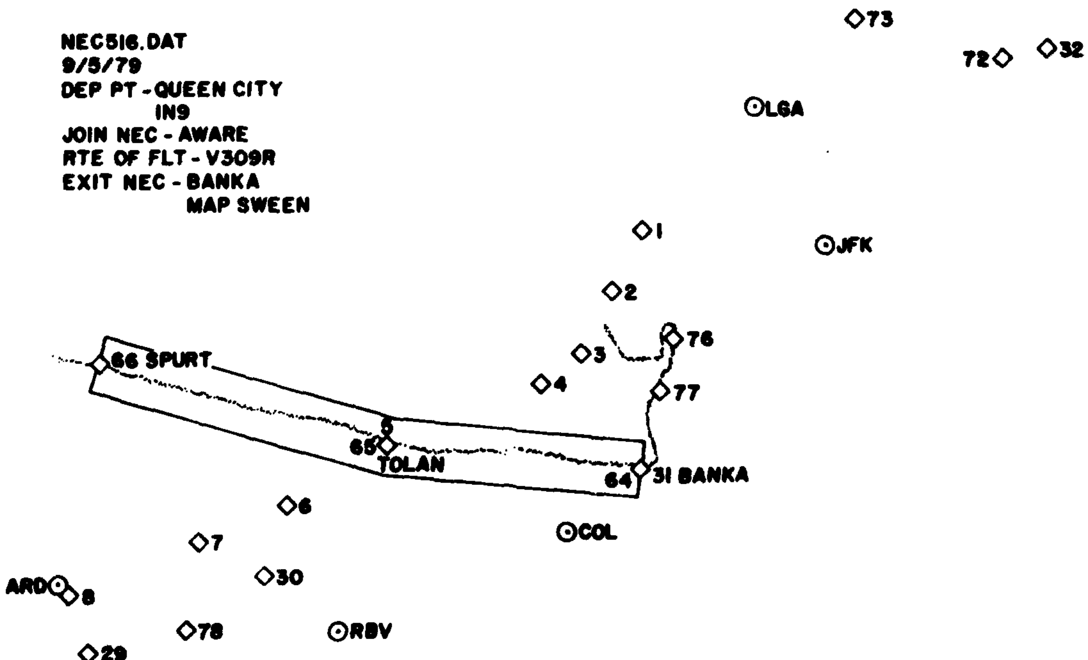

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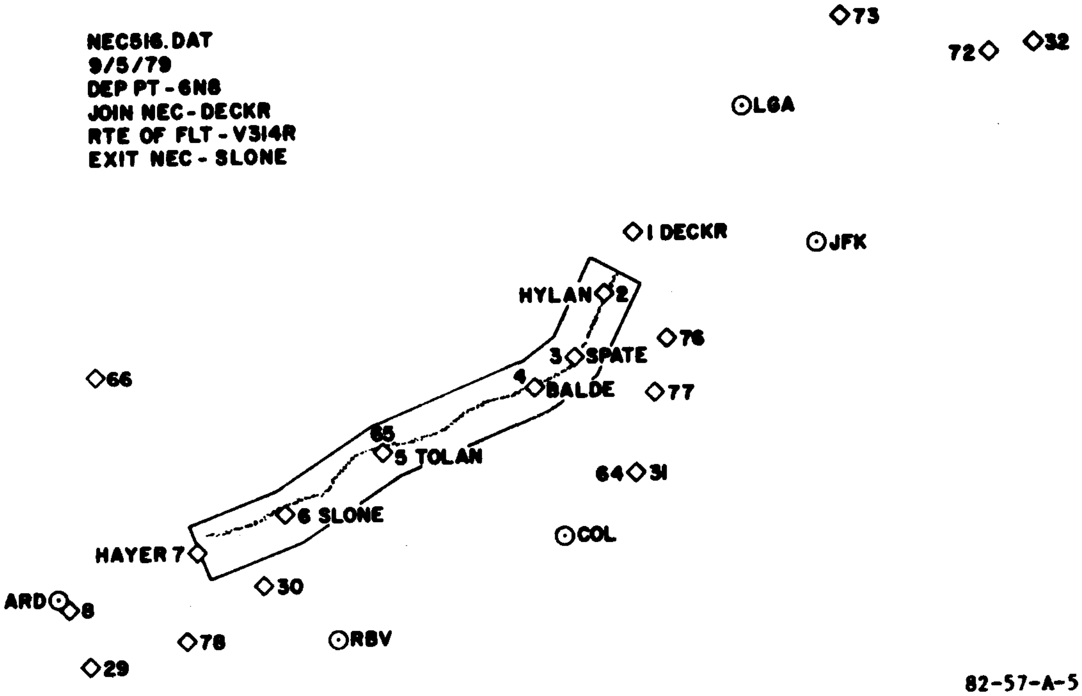

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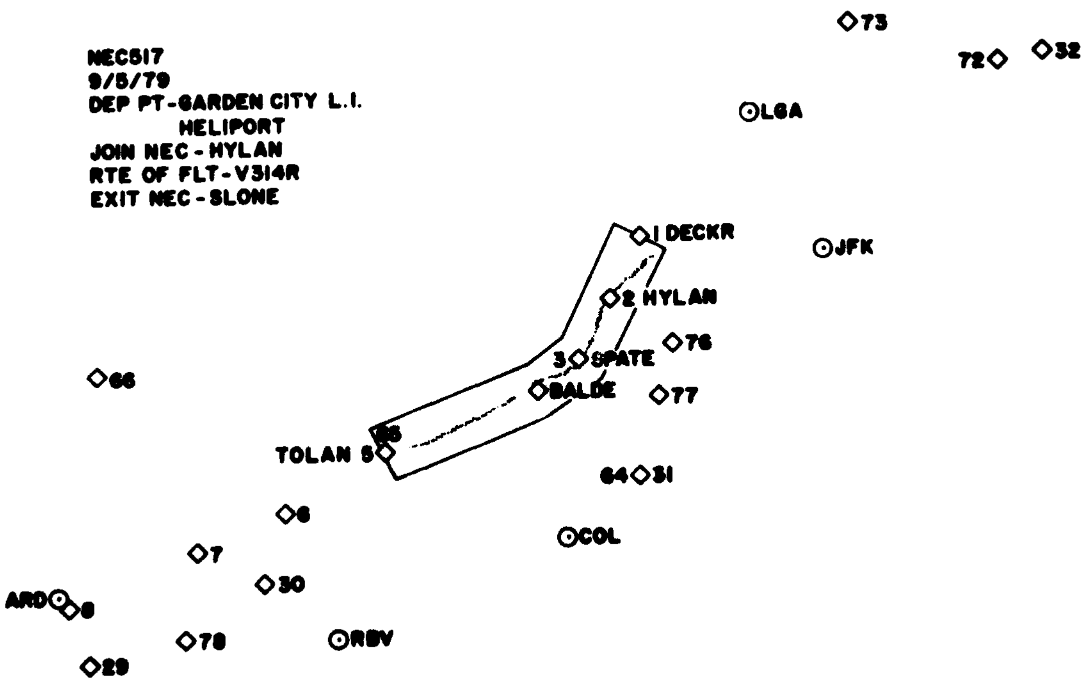

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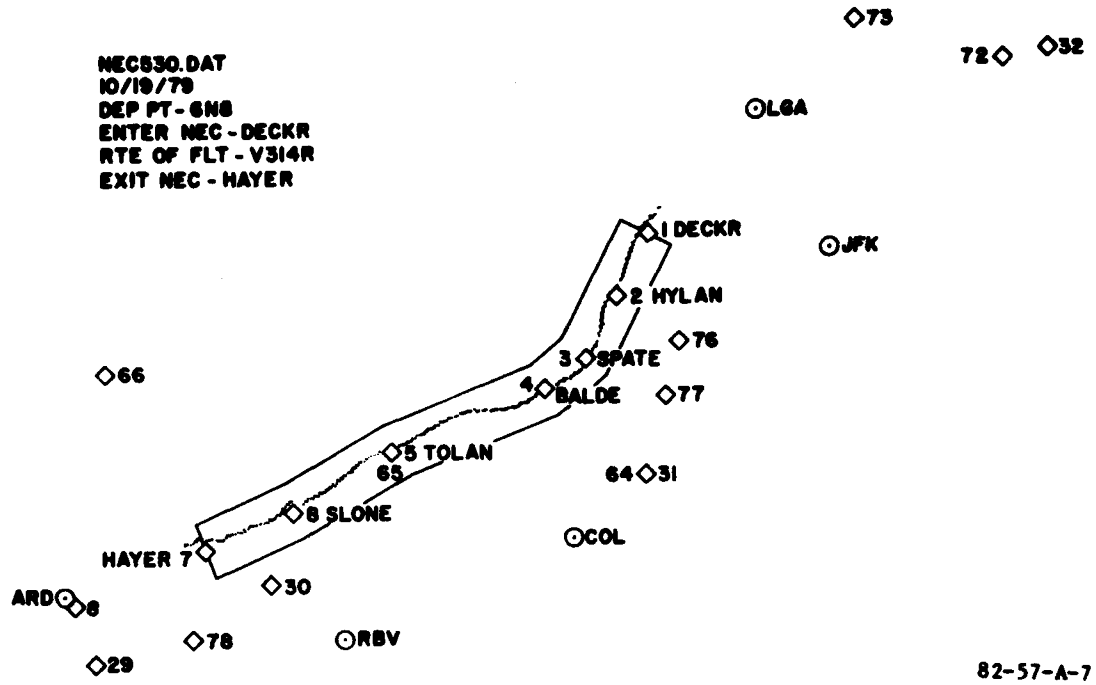

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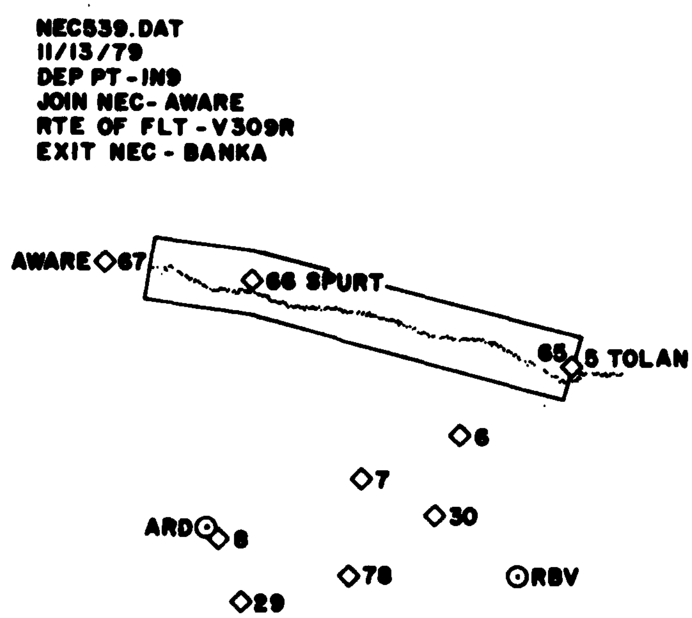

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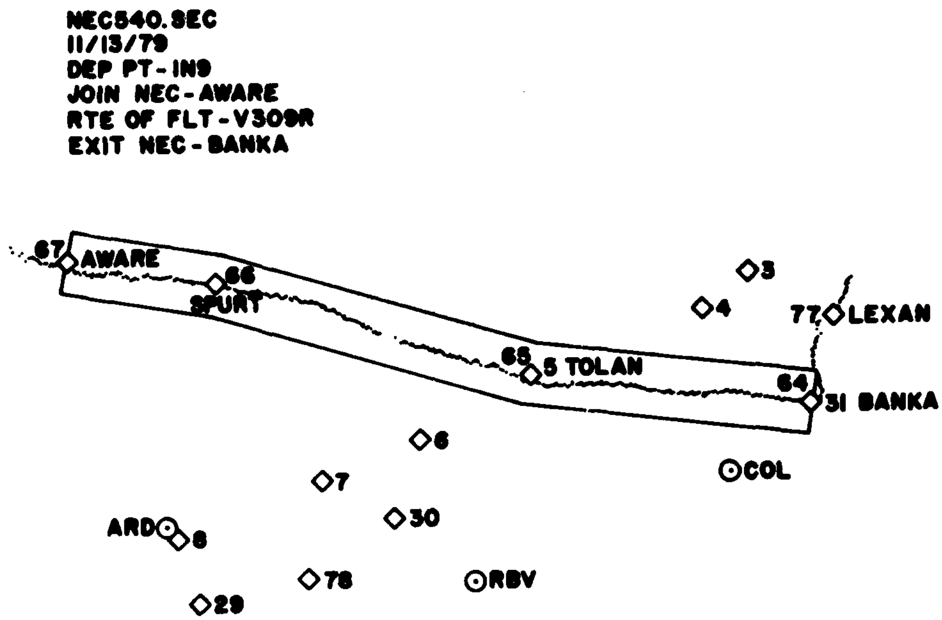

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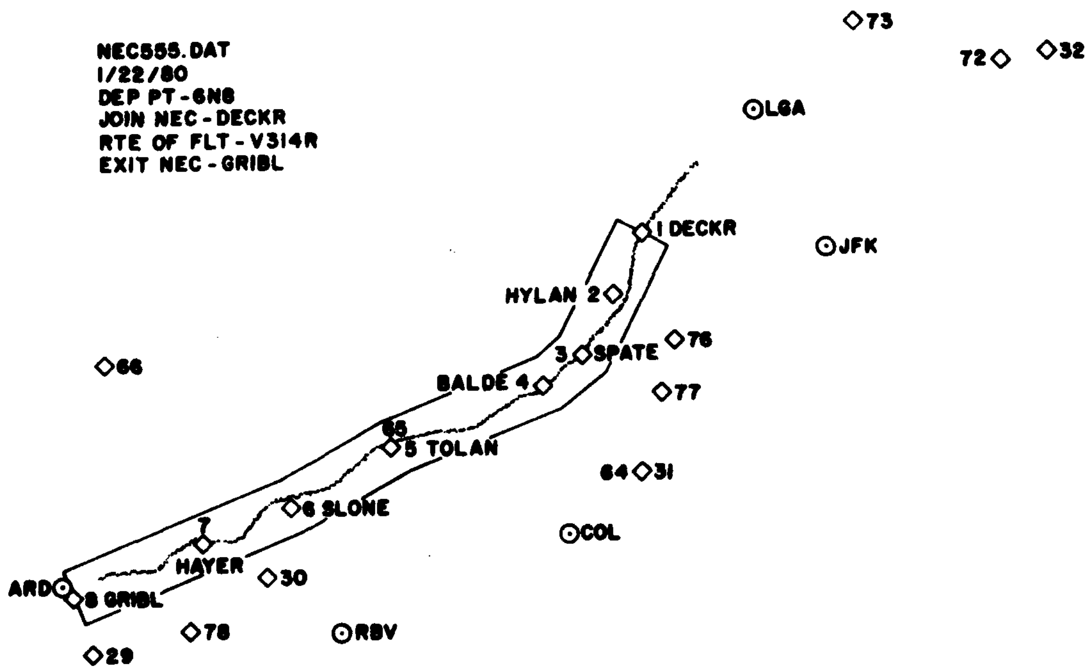

82-57-A-10