

PRELIMINARY STATISTICAL RESULTS  
OF SIMULATIONS OF GOVERNMENT-PROVIDED  
SCENARIOS FOR CONFLICT ALERT  
REQUIREMENTS FOR AAS

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JANUARY 31, 1986

## I. Introduction

In November, 1984, the Federal Aviation Administration, in accordance with contracts DTFA01-84-C-00039 and DTFA01-84-00040, and as part of the design phase of the Advanced Automation System (AAS) contract, furnished sets of aircraft scenarios to be used by the contractors to evaluate the performance of their design for the conflict alert function (FAA-GFP-130-001B, subparagraphs 6.0 and 6.2). The MITRE document, Government-Provided Scenarios for Conflict Alert Requirements for the Advanced Automation System Design Competition Phase, contained sets of scenarios intended for use by the contractors in demonstrating by simulation that the performance of their tracking and conflict alert functions satisfy the performance requirements in the AAS System Level Specification.

This report analyzes these conflict alert scenarios and provides summary data on the number of violation scenarios, minimum aircraft separation of each scenario, and time to violation after most recent maneuver. This analysis provides valuable information for a future study, when these same scenarios will be used for tracking and conflict alert evaluation.

## II. Scenarios

A total of 2100 scenarios were provided and are evaluated in this study.

The scenarios are divided into four different types:

1. En Route single-pair scenario	(1530)
2. En Route multiple-pair scenario	(270)
3. Terminal single-pair scenario	(255)
4. Terminal multiple-pair scenario	(45)

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Total number of scenarios (2100)

Multiple-pair scenarios consist of three aircraft, creating three single-pair scenarios.

Input scenario parameters for each aircraft were: scenario number, initial lateral location (nmi), initial altitude (ft), true lateral air speed (kts), initial heading (degrees from north), time at which speed maneuver begins, longitudinal acceleration (kts/sec), speed maintained after maneuver (kts), time at which vertical maneuver begins, new altitude (ft), altitude transition rate (ft/min), time at which horizontal maneuver begins, turn direction, heading after turn (degrees from north), turn rate (degrees/sec), and time at which the scenario ends. Speed maneuvers and turn maneuvers are lateral maneuvers while altitude maneuvers are vertical maneuvers. Speed maneuvers and turn maneuvers never occur simultaneously for an individual aircraft. A speed maneuver never begins before a turn maneuver ends, and vice versa.

### III. Analysis

For each scenario, actual aircraft trajectories were modelled to simulate constant lateral acceleration, vertical velocity, and lateral turns. Aircraft positions were computed at 4 second intervals to simulate radar scan rates. The three parameters examined were:

- 1) Whether a violation occurred in a scenario.
- 2) Time to violation after a maneuver began or ended.
- 3) Minimum separation distance between aircraft as a function of lateral and vertical standards.

Minimum separation standards for aircraft in terminal airspace are 3 nmi laterally and 1000 ft. vertically. In en route airspace, minimum separation standards are 5 nmi laterally and 1000 ft. vertically. If, in en route airspace, either aircraft is above 29,000 ft. altitude, the vertical separation standard changes from 1000 to 2000 ft. If at any time  $t$  during each scenario, aircraft positions indicated that these lateral and vertical separation

standards were violated, then a violation was constituted for that scenario. If only the lateral or vertical separation was violated, then a violation was not constituted. Multiple-pair scenarios, in which three aircraft were involved, were treated as three single-pair scenarios.

The time to violation after a maneuver (lateral turn, lateral acceleration, altitude change) began or ended is a very useful parameter when studying tracking and conflict alert functions. Important topics when studying the tracker are how maneuvers affect the stability of the tracker and the ability of the tracker to recover from a maneuver. When the time to violation after a maneuver began or ended is relatively short, with respect to the number of radar scans and required AAS warning time to conflict (30 seconds in terminal airspace and 80 seconds in en route airspace), then the conflict alert functions, which use tracker outputs, may predict a nuisance alert in instances when no violation exists, and may miss an actual conflict alert, in instances when violations do occur. This study examines only instances when a violation occurs. For a scenario in which a violation occurs at some time  $t$ , the time counting back to the most recent maneuver is the time to conflict. A time to conflict of 999 seconds indicates that no maneuver occurred prior to violation.

In an attempt to transform a two-dimensional lateral miss distance into a three-dimensional miss distance, with respect to lateral and vertical separation standards, a dimensionless parameter,  $D$ , a measure of the degree of violation or minimum separation, was computed:

$$D = \left[ \left( \left( \frac{\Delta \text{ lat}}{\text{latsp}} \right)^2 + \left( \frac{\Delta \text{ vert}}{\text{vertsp}} \right)^2 \right) / 2 \right]^{\frac{1}{2}}$$

where  $\Delta \text{ lat}$  = aircraft lateral separation,

$\Delta \text{ vert}$  = aircraft vertical separation,

$\text{latsp}$  = lateral separation standard,

$\text{vertsp}$  = vertical separation standard.

If two aircraft, at some time  $t$ , are in violation, then the time of minimum separation is the time corresponding to the smallest value of  $D$  for the times when the aircraft pair are in violation. However, if the aircraft are never in violation during the scenario, then the time corresponding to the smallest  $D$  will give the time at which the two aircraft are at a minimum distance.

#### IV. Results

Table 1 shows the total number of violations for each of the four types of scenarios. Table 2 shows the distribution of violations/ no violations of the minimum separation standard over the range of  $D$ , the degree of violation. The number 1.00 indicates the two aircraft separated by exactly the minimum lateral and vertical separation standards. A number less than 1.00 for no violation cases indicates that the lateral or vertical separation was less than the standard, but not both. Table 3 shows the distribution of the times to violation following the maneuver, and the specific type of maneuver. The bar graphs present these results visually. Finally, computer printouts which contain the results for each individual scenario have been generated and are available for inspection, upon request.

**TABLE 1**

OVERALL NUMBER OF SCENARIO VIOLATIONS

1. En Route Single-Pair

Total number of scenarios : 1530

A/C 1 - A/C 2	Violations - 714 (46.7%)	No Violations - 816 (53.3%)
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2. En Route Multiple-Pair

Total number of scenarios : 270

Pair Analyzed

A/C 1 - A/C 2	Violations - 118	No Violations - 152
A/C 1 - A/C 3	Violations - 231	No Violations - 39
A/C 2 - A/C 3	<u>Violations - 159</u>	<u>No Violations - 111</u>
	Total 508 (62.7%)	Total 302 (37.3%)

Total number of scenarios with 0 violations :	14
Total number of scenarios with 1 violations :	101
Total number of scenarios with 2 violations :	58
<u>Total number of scenarios with 3 violations :</u>	<u>97</u>
Total number of scenarios	270

3. Terminal Single-Pair

Total number of scenarios : 255

A/C 1 - A/C 2	Violations - 147 (57.6%)	No Violations - 108 (42.4%)
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4. Terminal Multiple-Pair

Total number of scenarios : 45

Pair Analyzed

A/C 1 - A/C 2	Violations - 23	No Violations - 22
A/C 1 - A/C 3	Violations - 39	No Violations - 6
A/C 2 - A/C 3	<u>Violations - 25</u>	<u>No Violations - 20</u>
	Total (64.4%)	Total (35.6%)

Total number of scenarios with 0 violations :	2
Total number of scenarios with 1 violations :	13
Total number of scenarios with 2 violations :	16
<u>Total number of scenarios with 3 violations :</u>	<u>14</u>
Total number of scenarios	45

**TABLE 2**



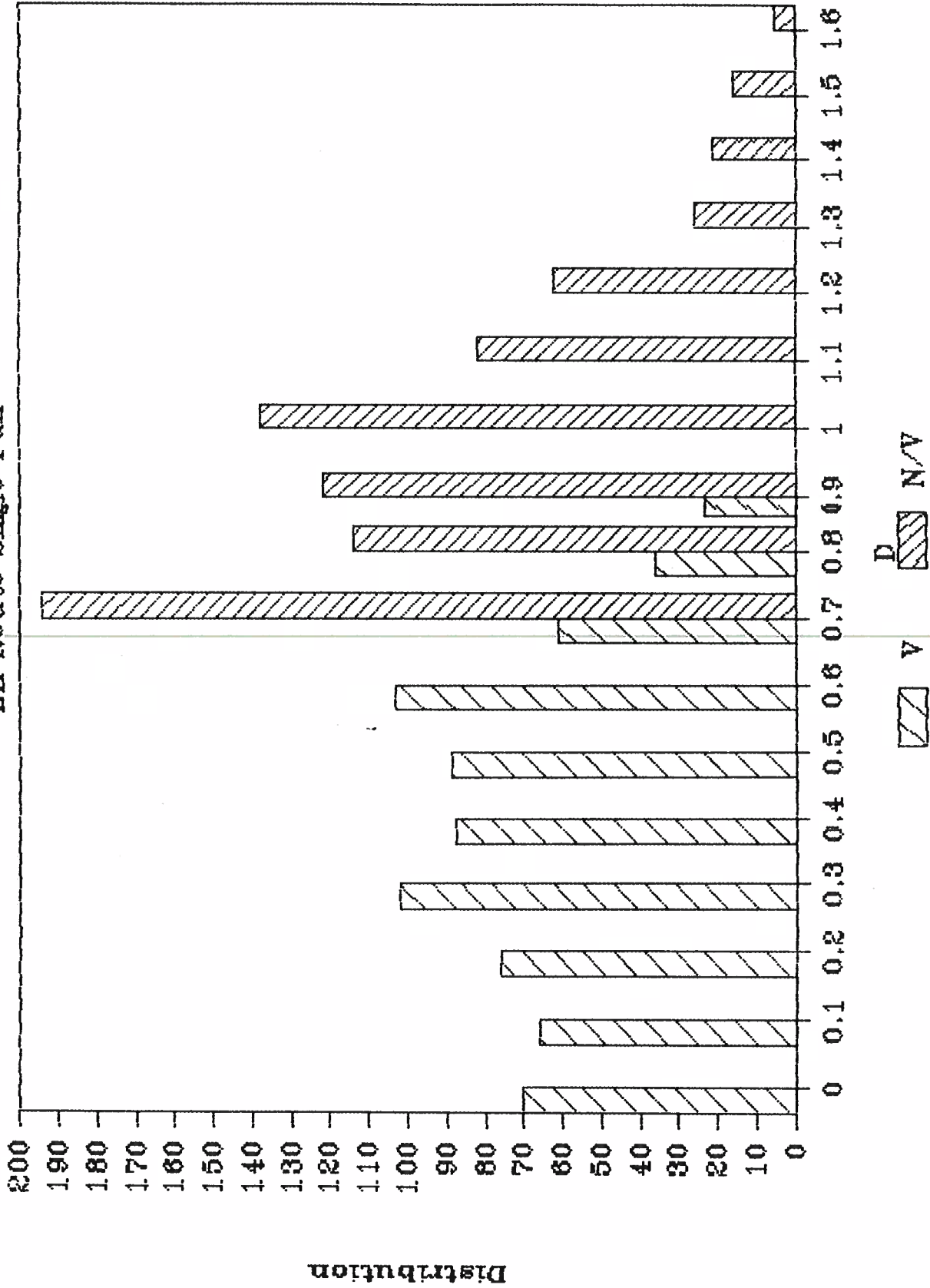
MINIMUM DEVIATION OF SEPARATION STANDARD DISTRIBUTION

EN ROUTE SINGLE PAIR

D -	A/C 1 - 2 -----	
	VIOLATIONS -----	NO VIOLATIONS -----
0.0 - 0.1	70	-
0.1 - 0.2	66	-
0.2 - 0.3	76	-
0.3 - 0.4	102	-
0.4 - 0.5	88	-
0.5 - 0.6	89	-
0.6 - 0.7	103	-
0.7 - 0.8	61	194
0.8 - 0.9	36	114
0.9 - 1.0	23	122
1.0 - 1.1	-	138
1.1 - 1.2	-	82
1.2 - 1.3	-	62
1.3 - 1.4	-	26
1.4 - 1.5	-	21
1.5 - 1.6	-	16
1.6 - 1.7	-	5
1.7 - 1.8	-	6
1.8 - 1.9	-	5
1.9 - 2.0	-	2
2.0 - 2.1	-	6
2.1 - 2.2	-	1
2.2 - 2.3	-	0
2.3 - 2.4	-	2
2.4 - 2.5	-	5
2.5 - 2.6	-	1
2.6 - 2.7	-	0
2.7 - 2.8	-	2
2.8 - 2.9	-	1
2.9 - 3.0	-	2
3.0 - 3.1	-	0
3.1 - 3.2	-	0
3.2 - 3.3	-	0
3.3 - 3.4	-	0
3.4 - 3.5	-	0
3.5 - 3.6	-	0
3.6 - 3.7	-	0
3.7 - 3.8	-	0
3.8 - 3.9	-	1
3.9 - 4.0	-	0
4.0 - 4.1	-	0
4.1 - 4.2	-	0
4.2 - 4.3	-	2
4.3 - 4.4	-	0
	-----	-----
TOTALS :	714	816

# Min. Deg. of Sep. Std.

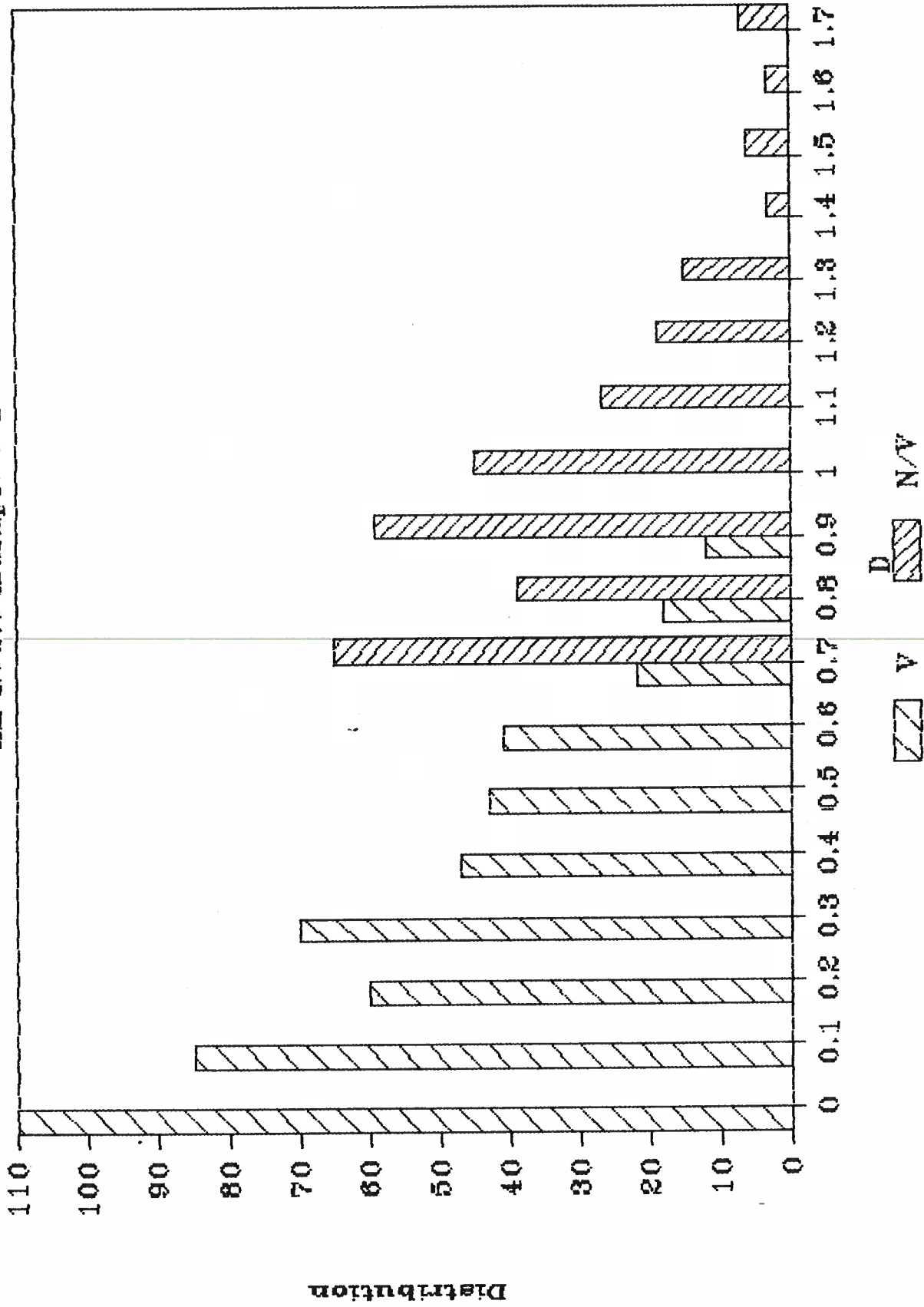
En Route Single Fair



MINIMUM DEGREE OF SEPARATION STANDARD DISTRIBUTION  
EN ROUTE MULTIPLE PAIR

D	A/C 1 - 2		A/C 1 - 3		A/C 2 - 3		TOTALS	
	V	N/V	V	N/V	V	N/V	V	N/V
0.0 - 0.1	14	-	66	-	30	-	110	-
0.1 - 0.2	11	-	54	-	21	-	85	-
0.2 - 0.3	11	-	37	-	12	-	60	-
0.3 - 0.4	19	-	23	-	28	-	70	-
0.4 - 0.5	14	-	13	-	20	-	47	-
0.5 - 0.6	11	-	9	-	23	-	43	-
0.6 - 0.7	16	-	13	-	12	-	41	-
0.7 - 0.8	10	24	3	19	9	28	22	65
0.8 - 0.9	9	25	6	1	3	13	18	39
0.9 - 1.0	3	35	7	5	2	19	12	59
1.0 - 1.1	-	29	-	4	-	12	-	45
1.1 - 1.2	-	18	-	2	-	7	-	27
1.2 - 1.3	-	7	-	4	-	8	-	19
1.3 - 1.4	-	6	-	3	-	6	-	15
1.4 - 1.5	-	0	-	3	-	0	-	3
1.5 - 1.6	-	2	-	1	-	3	-	6
1.6 - 1.7	-	1	-	0	-	2	-	3
1.7 - 1.8	-	1	-	2	-	4	-	7
1.8 - 1.9	-	1	-	0	-	0	-	1
1.9 - 2.0	-	0	-	0	-	0	-	0
2.0 - 2.1	-	0	-	0	-	2	-	2
2.1 - 2.2	-	0	-	1	-	1	-	2
2.2 - 2.3	-	1	-	0	-	2	-	3
2.3 - 2.4	-	1	-	0	-	1	-	2
2.4 - 2.5	-	1	-	0	-	1	-	2
2.5 - 2.6	-	0	-	0	-	0	-	0
2.6 - 2.7	-	0	-	0	-	0	-	0
2.7 - 2.8	-	0	-	0	-	1	-	1
2.8 - 2.9	-	0	-	0	-	0	-	0
2.9 - 3.0	-	0	-	0	-	0	-	0
3.0 - 3.1	-	0	-	0	-	0	-	0
3.1 - 3.2	-	0	-	0	-	1	-	1
3.2 - 3.3	-	0	-	0	-	0	-	0
TOTALS :	118	152	231	39	159	111	508	302

# Min. Deg. of Sep. Std. En Route Multiple Pair

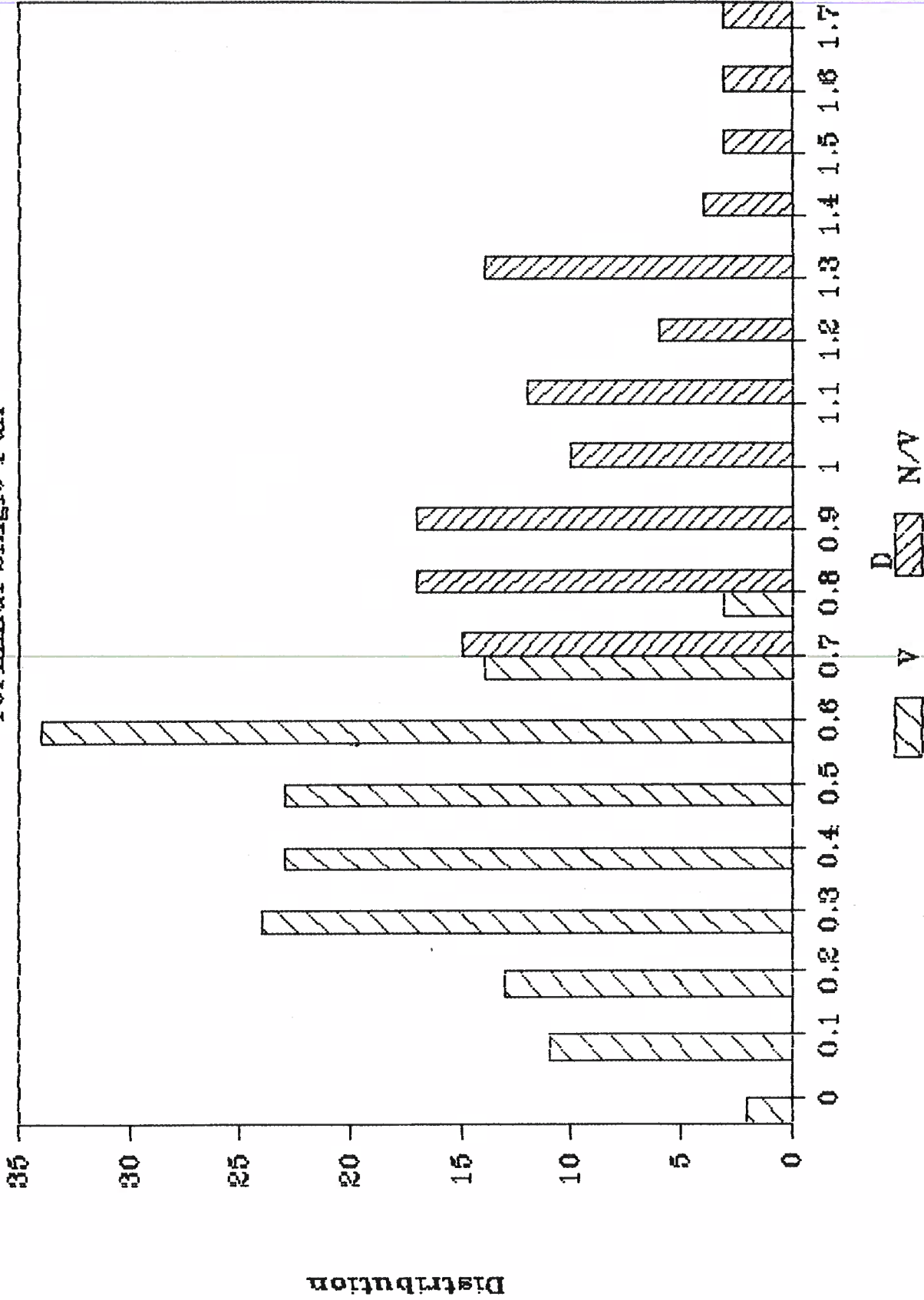


MINIMUM DEGREE OF SEPARATION STANDARD DISTRIBUTION

TERMINAL SINGLE PAIR

D -	A/C 1 - 2 -----	
	<u>V I O L A T I O N S</u>	<u>N O V I O L A T I O N S</u>
0.0 - 0.1	2	-
0.1 - 0.2	11	-
0.2 - 0.3	13	-
0.3 - 0.4	24	-
0.4 - 0.5	23	-
0.5 - 0.6	23	-
0.6 - 0.7	34	-
0.7 - 0.8	14	15
0.8 - 0.9	3	17
0.9 - 1.0	0	17
1.0 - 1.1	-	10
1.1 - 1.2	-	12
1.2 - 1.3	-	6
1.3 - 1.4	-	14
1.4 - 1.5	-	4
1.5 - 1.6	-	3
1.6 - 1.7	-	3
1.7 - 1.8	-	3
1.8 - 1.9	-	1
1.9 - 2.0	-	2
2.0 - 2.1	-	1
2.1 - 2.2	-	0
-----		
TOTALS :	147	108

# Min. Deg. of Sep. Std. Terminal Single Pair

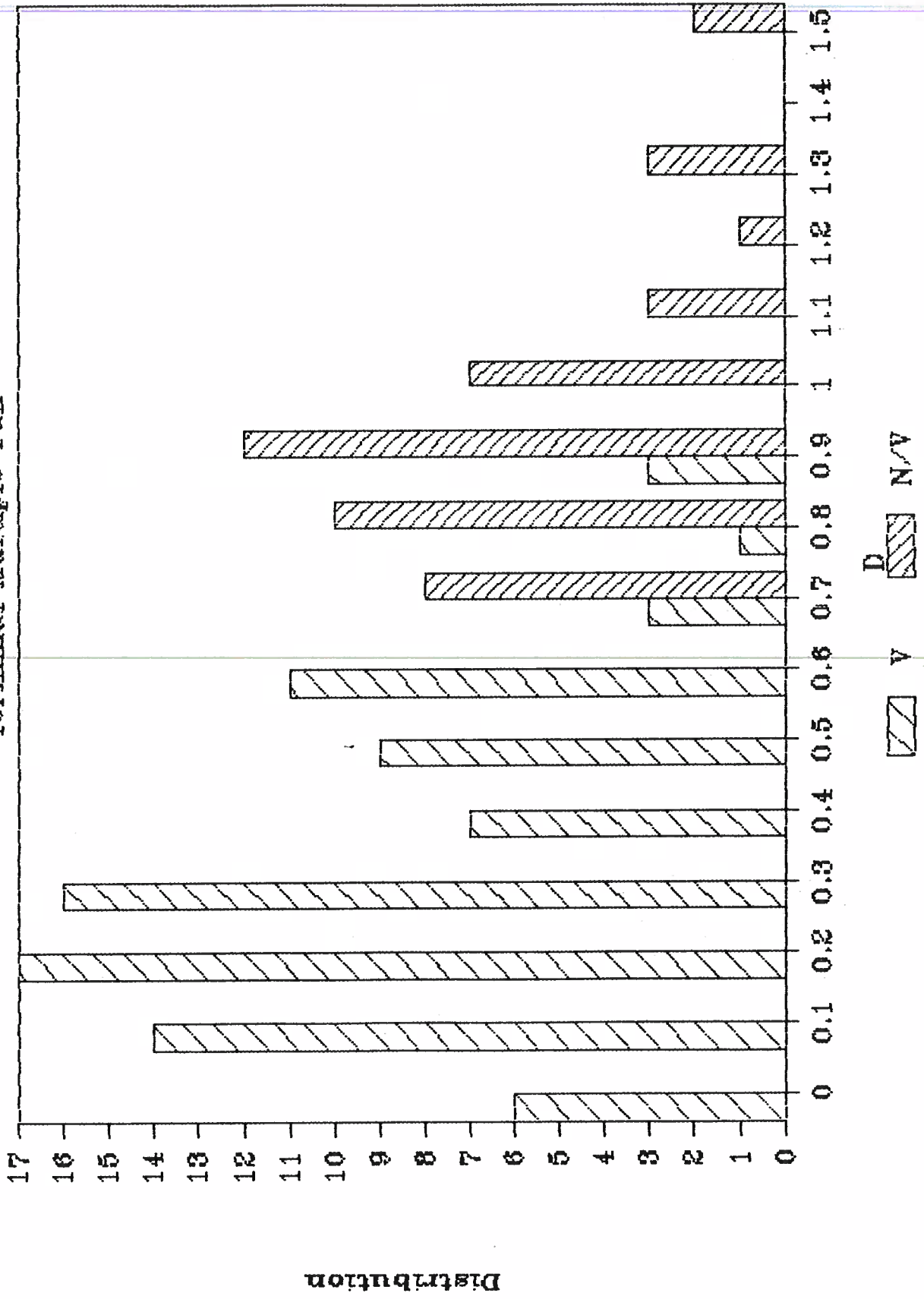


MINIMUM PERCENT OF SEPARATION STANDARD DISTRIBUTION  
 TERMINAL MULTIPLE PAIR

D	A/C 1 - 2		A/C 1 - 3		A/C 2 - 3		TOTALS	
	V	N/V	V	N/V	V	N/V	V	N/V
0.0 - 0.1	0	-	5	-	1	-	6	-
0.1 - 0.2	1	-	10	-	3	-	14	-
0.2 - 0.3	3	-	10	-	4	-	17	-
0.3 - 0.4	3	-	10	-	3	-	16	-
0.4 - 0.5	3	-	1	-	3	-	7	-
0.5 - 0.6	4	-	0	-	5	-	9	-
0.6 - 0.7	5	-	1	-	5	-	11	-
0.7 - 0.8	2	2	0	3	1	3	3	8
0.8 - 0.9	1	8	0	0	0	2	1	10
0.9 - 1.0	1	5	2	0	0	7	3	12
1.0 - 1.1	-	2	-	1	-	4	-	7
1.1 - 1.2	-	2	-	1	-	0	-	3
1.2 - 1.3	-	1	-	0	-	0	-	1
1.3 - 1.4	-	0	-	0	-	3	-	3
1.4 - 1.5	-	0	-	0	-	0	-	0
1.5 - 1.6	-	1	-	1	-	0	-	2
1.6 - 1.7	-	1	-	0	-	0	-	1
1.7 - 1.8	-	0	-	0	-	1	-	1
1.8 - 1.9	-	0	-	0	-	0	-	0
1.9 - 2.0	-	0	-	0	-	0	-	0
TOTALS :	23	22	39	6	25	20	87	48

# Min. Deg. of Sep. Std.

Terminal Multiple Pair





**TABLE 3**

TIME TO VIOLATION AFTER LAST MANEUVER DISTRIBUTION

EN ROUTE SINGLE PAIR

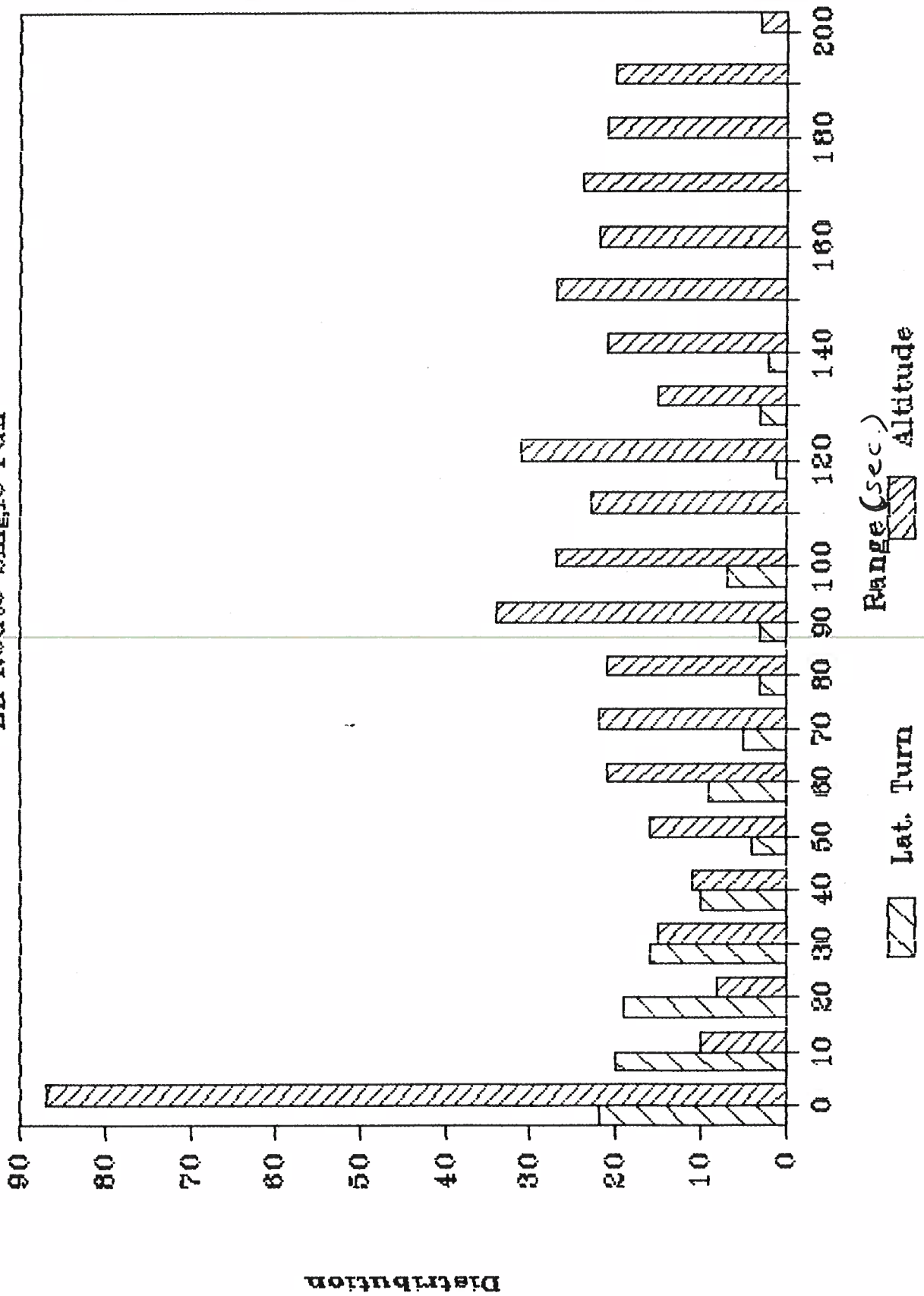
RANGE	A/C 1 - 2	
	LAT. TURN	ALTITUDE
0 - 10 SEC.	22	87
10 - 20	20	10
20 - 30	19	8
30 - 40	16	15
40 - 50	10	11
50 - 60	4	16
60 - 70	9	21
70 - 80	5	22
80 - 90	3	21
90 - 100	3	34
100 - 110	7	27
110 - 120	0	23
120 - 130	1	31
130 - 140	3	15
140 - 150	2	21
150 - 160	0	27
160 - 170	0	22
170 - 180	0	24
180 - 190	0	21
190 - 200	0	20
200 - 210	0	3
210 - 220	0	1
220 - 230	0	3
230 - 240	0	0
240 - 250	0	0
250 - 260	0	1
260 - 270	0	0
-----		
TOTALS :	124 (17.4%)	484 (67.8%)

NUMBER OF VIOLATIONS WITH NO PRECEDING MANEUVER : 106  
(14.8%)

THERE WERE NO LATERAL ACCLERATION MANEUVERS.

# Time to Violation

En Route Single Pair



TIME TO VIOLATION AFTER LAST MANEUVER DISTRIBUTION

EN ROUTE MULTIPLE PAIR

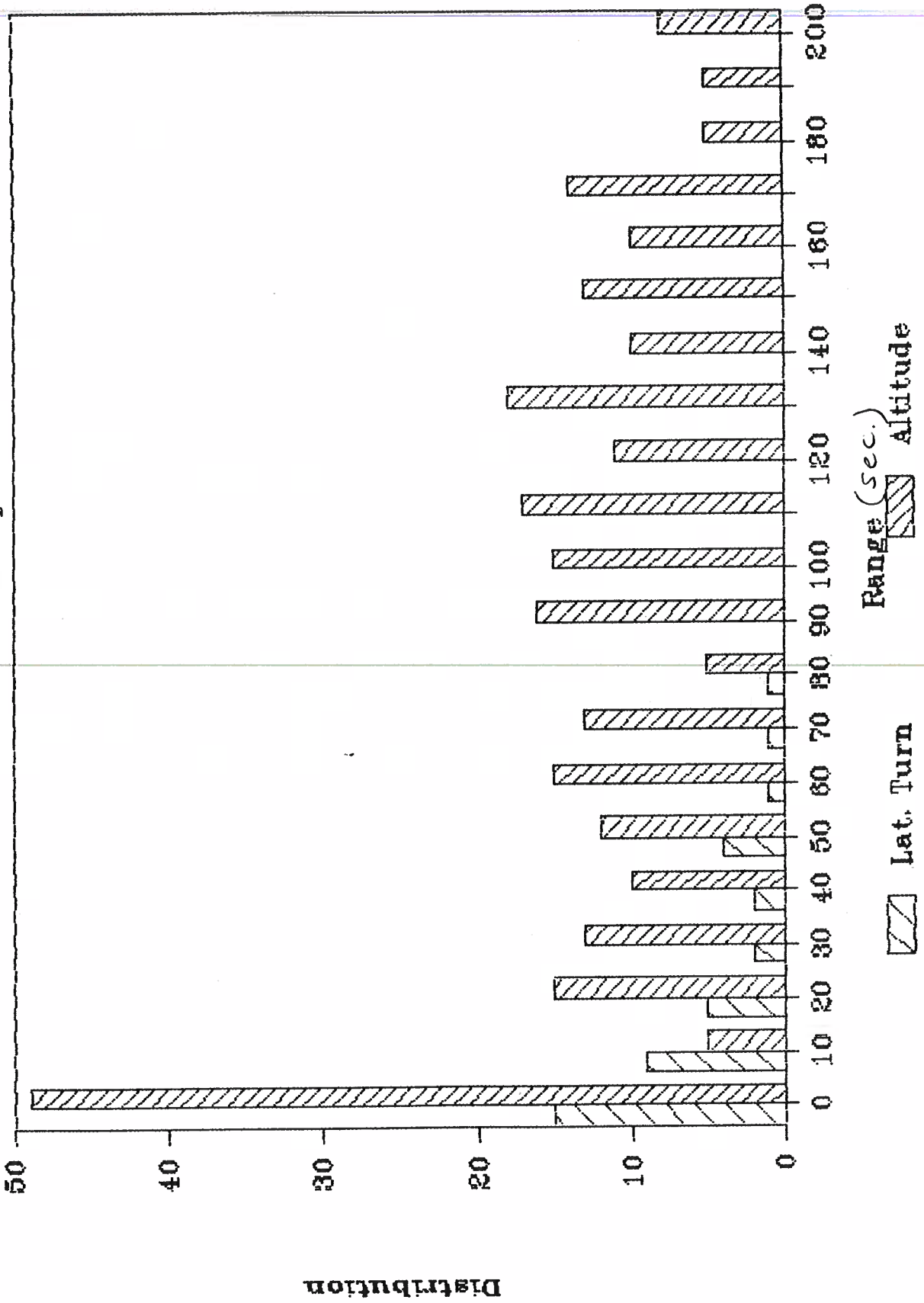
RANGE -----	TOTALS	
	LAT. TURN -----	ALTITUDE -----
0 - 10 SEC.	15	49
10 - 20	9	5
20 - 30	5	15
30 - 40	2	13
40 - 50	2	10
50 - 60	4	12
60 - 70	1	15
70 - 80	1	13
80 - 90	1	5
90 - 100	0	16
100 - 110	0	15
110 - 120	0	17
120 - 130	0	11
130 - 140	0	18
140 - 150	0	10
150 - 160	0	13
160 - 170	0	10
170 - 180	0	14
180 - 190	0	5
190 - 200	0	5
200 - 210	0	8
210 - 220	0	4
220 - 230	0	2
230 - 240	0	2
240 - 250	0	0
-----		
TOTALS :	40 (7.9%)	287 (56.5%)

NUMBER OF VIOLATIONS WITH NO PRECEDING MANEUVER : 181  
(35.6%)

THERE WERE NO LATERAL ACCLERATION MANEUVERS.

# Time to Violation

En Route Multiple Pair



TIME TO VIOLATION AFTER LAST MANEUVER DISTRIBUTION

TERMINAL SINGLE PAIR

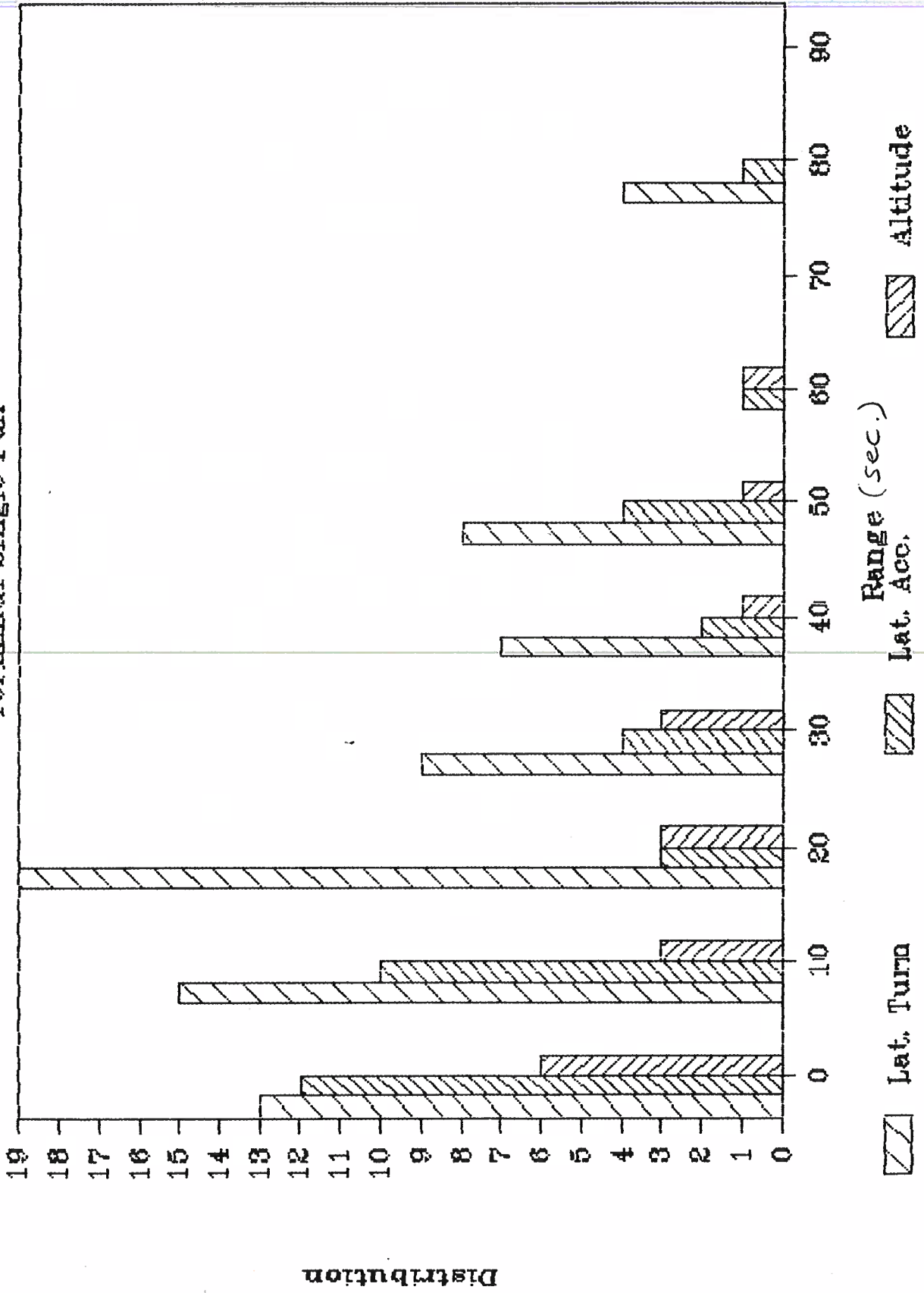
A/C 1 - 2

RANGE	LAT. TURN	LAT. ACC.	ALTITUDE
0 - 10 SEC.	13	12	6
10 - 20	15	10	3
20 - 30	19	9	3
30 - 40	9	4	3
40 - 50	7	2	1
50 - 60	8	4	1
60 - 70	0	1	1
70 - 80	0	0	0
80 - 90	4	1	0
90 - 100	0	0	0
100 - 110	1	0	0
110 - 120	0	1	0
120 - 130	0	0	0
TOTALS :	76 (51.7%)	38 (25.9%)	18 (12.2%)

NUMBER OF VIOLATIONS WITH NO PRECEDING MANEUVER : 15  
(10.2%)

# Time to Violation

Terminal Single Pair



TIME TO VIOLATION AFTER LAST MANEUVER DISTRIBUTION

TERMINAL MULTIPLE PAIR

RANGE -----	TOTALS -----		
	LAT. TURN -----	LAT. ACC. -----	ALTITUDE -----
0 - 10 SEC.	1	6	6
10 - 20	1	7	5
20 - 30	1	4	5
30 - 40	2	4	4
40 - 50	1	5	0
50 - 60	0	1	1
60 - 70	0	2	1
70 - 80	0	0	1
80 - 90	0	1	0
90 - 100	0	0	0
100 - 110	1	0	0
110 - 120	0	0	0
-----			
TOTALS :	7 (8.0%)	30 (34.5%)	23 (26.5%)

NUMBER OF VIOLATIONS WITH NO PRECEDING MANEUVER : 27  
(31.0%)



# Time to Violation

Terminal Multiple Pair

