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RECOMMENDATIONS FOR SHORT-TERM SIMULATION OF ATC CONCEPTS

HELICOPTER OPERATIONS DEVELOPMENT PROGRAM

February 1980

Task Report

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16. Abstract

A number of recommendations from a previous helicopter air traffic control (ATC) study (See Report FAA-RD-78-150) were examined. Those which appeared to have potential for early implementation were selected for further testing. The selected recommendations included: (1) dual-fix holding patterns to save airspace; (2) speed control procedures and short approach paths to save fuel; (3) various methods of reducing separation in order to increase airport or heliport capacity. Under item 3 above, a rationale for utilizing existing parallel approaches of helicopters and CTOL aircraft was presented for consideration.

Extensive use of flight simulation and ATC simulation was recommended in order to reduce the time and cost of evaluating the potential improvements. The steps of the recommended simulation program were arranged in the order of ascending cost, to learn as much as possible about the subject as quickly as possible and to weed out or revise impractical solutions before they reach a more expensive stage of evaluation or development. A detailed simulation program was prepared using a modified factorial design in order to isolate the effects of changes in various parameters.

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METRIC CONVERSION FACTORS

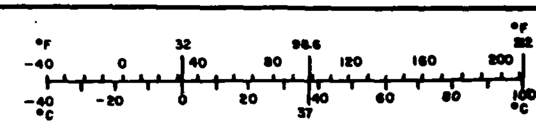
Approximate Conversions to Metric Measures

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	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions 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



RECOMMENDATIONS FOR SHORT-TERM SIMULATION OF ATC CONCEPTS

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I wish to express my sincerest gratitude to all the above stated organizations and look forward to continued association with them during my continued involvement in the helicopter program.

Raymond J. Hilton
ATC Helicopter Program Mgr.

RECOMMENDATIONS FOR SHORT-TERM SIMULATION OF ATC CONCEPTS

INTRODUCTION

Because of the high cost of helicopter flight time, it is desirable to utilize simulation to the maximum practical extent in the development of new procedures for helicopters. The sophistication of modern flight simulators and dynamic ATC simulators makes this a viable concept.

Figure 1 shows the sequence of stages proposed for the ATC portion of the Helicopter Operations Development Program. These steps are arranged in the order of ascending cost, in order to learn as much as possible about system behavior, and to weed out or revise impractical solutions, before they get into a more expensive stage of evaluation.

Thus, flight simulation will be done before in-flight testing of a new flight procedure , and limited ATC dynamic simulation will be done before going into a large-scale dynamic simulation of the application of new procedures for a specific airport or other location. If any new flight techniques are involved, flight simulation outputs will be applied in the ATC dynamic simulation phases.

One of the most useful products of any simulation program can be the generation of new ideas as the result of the insights provided by the tests themselves. These potentially useful by-products can be fed back into the program, as diagrammed by the feedback loops on either side of Figure 1.

SIMULATION FACILITIES

It is anticipated that most of the helicopter flight simulation could be conducted at NASA-Ames; their simulation facilities have the advantage of being directly connectable to the dynamic ATC simulator at NAFEC. This will be very useful in the conduct of the ATC simulator tests. However, military helicopter flight simulators may also be utilized for some of the feasibility tests of

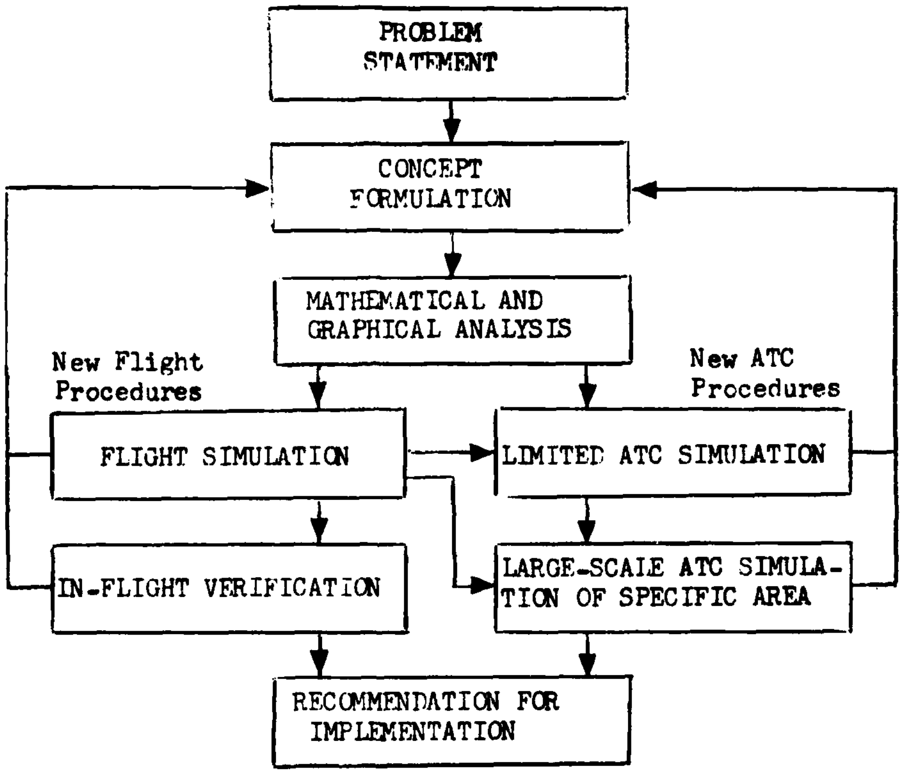


FIGURE 1 PROPOSED SIMULATION SEQUENCE

proposed flight techniques. For example, some training facilities used by Army Reserve pilots are used periodically by several hundred pilots representing an extremely wide range of civil as well as military experience. This would be very useful in any cases where it is deemed necessary to obtain a very large sample of U.S. helicopter pilots (assuming, of course, that appropriate arrangements can be made).

It is anticipated that the ATC simulation would be conducted primarily at NAFEC, using the real-time dynamic ATC simulator with inputs from the Ames flight simulator where appropriate. For the initial tests to optimize the integration of helicopter and CTOL traffic on the same runway, only a small number of targets would be necessary to maintain a continuous stream of aircraft in the base leg/final approach area. Later, more elaborate and more complex runs will be necessary, particularly when developing detailed procedures for a specific airport or area.

Any subsequent large-scale simulation which might be necessary, for example, in adapting helicopter routes and procedures to major terminal areas such as O'Hare or Atlanta, should utilize the large ATC simulator at NAFEC, with inputs from the NASA-Ames flight simulator where appropriate.

If the metering and spacing program at NAFEC can accommodate speed control, over the range of speeds possible in IFR helicopter flight, the smiulation of computer-generated speed control procedures (in lieu of holding) can be included in the ATC development program at NAFEC.

OBJECTIVES

The short-term ATC recommendations which have come out of the ATC portion of the HODP so far have one or more of the following objectives:

- Reducing airspace requirements
- Reducing fuel consumption
- Reducing Separation

Each of the recommended development items to be included in the short-term simulation program is discussed below.

The final section of this report contains a recommended test plan for each of the short-term development items. (Long-term items will be covered in a future set of detailed recommendations). The type of simulation, the recommended variables, and the number of runs in each set are designed to verify the suitability of each concept, for subsequent validation in operational tests.

Reducing Airspace Requirements

Holding Patterns. The slow-speed capability of the helicopter, with its consequently short turning radius at such speeds, offers the possibility of reducing significantly the amount of airspace presently required for such operations. A preliminary flight simulation program was started with the cooperation of the Army's Synthetic Flight Training Facility at Annville, Pa. to look at the feasibility and the pilot workload associated with the various holding patterns shown in Figure 2. Results indicate that Pattern B is quite practical; it may be able to reduce the length of the holding pattern airspace by 1 to 1½ NM. However, Pattern C has been found too short to be useful when there is a strong tailwind on the inbound leg. Patterns D and E are dual fix patterns, which offer the greatest possibility of reducing the holding airspace. Tests indicate that they are very easy to fly when the aircraft is equipped with a double-needle RMI. Pattern F has been suggested by several helicopter pilots as a means of minimizing lateral flight deviations in a known crosswind; in this concept, all turns are started into the wind. Pattern G is a dual-fix application of the figure eight concept.

The elimination of unsuitable patterns, and the verification of helicopter holding airspace requirements, is basic to further ATC terminal area simulation. Therefore, this subject is considered to be a short-term development item. It is recommended that most of the work be conducted at the NASA Ames Flight Simulation Facility, verified by an adequate number of actual flights.

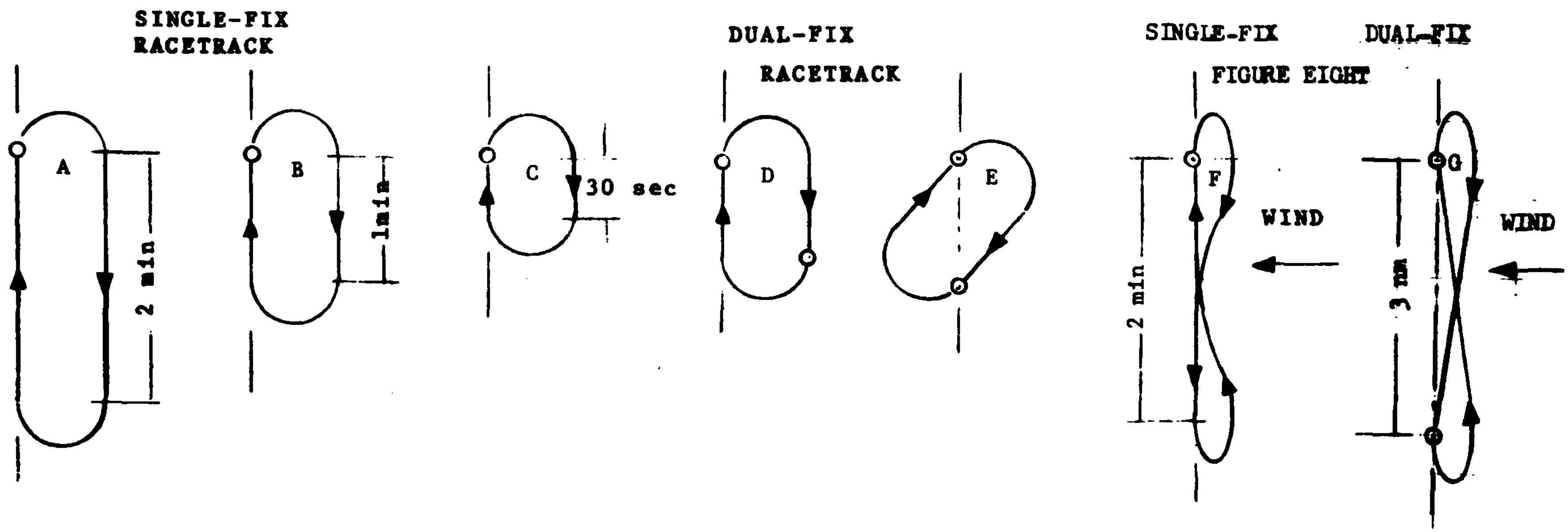


FIG. 2 HELICOPTER HOLDING PATTERNS

Reducing Fuel Consumption

Speed Control. Airspace and fuel could be saved if helicopters never had to get into a holding pattern. Because of its unique speed range, the helicopter is particularly well adapted to a delay-absorption technique through a controlled reduction in crusing speed, in order to absorb a predetermined amount of delay enroute to the destination. This point is brought out in Figure 3, using a 60-knot deceleration as an example. A CTOL slowing from 240 knots to 180 knots picks up only 5 seconds of delay per nautical mile at the slower speed; whereas a helicopter slowing from 120 knots to 60 knots picks up 30 seconds of delay per nautical mile, at the slower speed.

Figure 4 shows another aspect of this relationship. A 240-knot CTOL slowed to 180 knots requires 12 nautical miles to pick up one minute of delay, whereas a 120-knot helicopter slowed to 60 knots can pick up one minute of delay every 2 nautical miles. This means that, without going into a holding pattern, the helicopter can absorb a considerable amount of delay close to its destination, by slowing down earlier than usual.

As compared to absorbing the delay in a conventional holding pattern, this delay technique can reduce fuel consumption because the helicopter flies less total distance, and flies more of this distance at a speed closer to its minimum-drag speed. Pilot workload is less, because the aircraft remains on its assigned course without maneuvering; for the latter reason, the aircraft also uses less airspace. This could be a significant advantage in crowded terminal areas.

Some delay adjustment in the form of eyeball-adjusted (manual) speed control instructions issued by the controller, can be included in the short-term simulation runs. This would tend to show the feasibility of using this technique in lieu of conventional holding for helicopters in the traffic situation.

The actual ATC simulation runs could be made on either the NASA Ames or the NAFEC dynamic ATC simulator. Inputs from the Ames flight simulator would provide realistic deceleration/acceleration rates for the helicopters, as well as

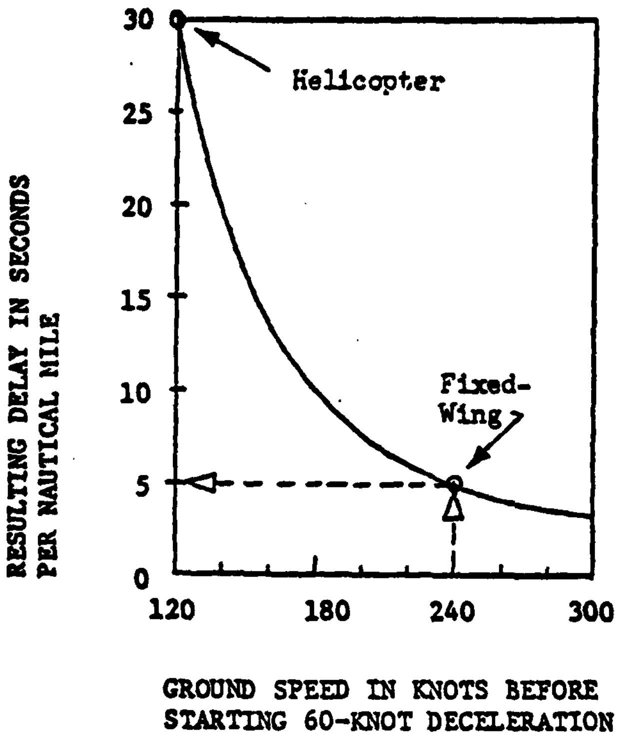


FIGURE 3 Effect of Advancing the Point Where Aircraft Starts 60 KT Slowdown

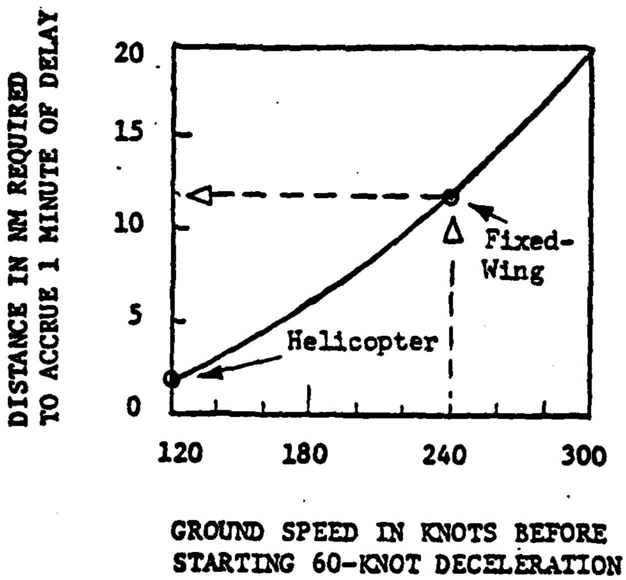


FIGURE 4 Distance Required to Absorb 1 Minute of Enroute Delay after 60 KT Slowdown

measurements of the comparative controller workload and pilot workload in speed control versus conventional holding, for the helicopters in the problem.

Any subsequent large-scale simulation which might be necessary, for example, in adapting helicopter routes and procedures to major terminal areas such as O'Hare or Atlanta, should utilize the large ATC simulator at NAFEC, with inputs from the NASA-Ames flight simulator where appropriate.

Short Approach Paths. The helicopter is a short-range vehicle with a relatively high operating cost per mile. There is a need to minimize the flight distance and fuel consumption required in completing approaches. Consequently, helicopter pilots prefer to avoid making unnecessary procedure turns, and to keep their approach paths as short as practicable, with due regard for pilot workload and safety.

The helicopter is particularly well adapted to making short approaches. Its capability to fly at a slow speed and make short-radius turns enables it to intercept the desired final approach course with a minimum amount of overshoot. Its ability to fly slowly enables it to descend on a considerably steeper glide slope than a CTOL aircraft, without picking up a high sink rate.

Until now, controllers have been required to use fixed-wing approach criteria when turning helicopters on final approach, although there is considerable evidence that helicopters could safely negotiate much shorter final approach paths.

The longer the common path, the longer the approach interval whenever a helicopter follows a faster aircraft down the final approach path. The longer the average interval, the lower the airport capacity.

Figures 5 and 6 show a number of flight techniques for intercepting a final approach course at the outer locator, without making a procedure turn. Preliminary simulation runs on the Huey flight simulator at the Army Synthetic Flight Training Center at Annville, Pa. indicated that no particular problem was incurred in completing an ILS approach, even when intercepting the approach

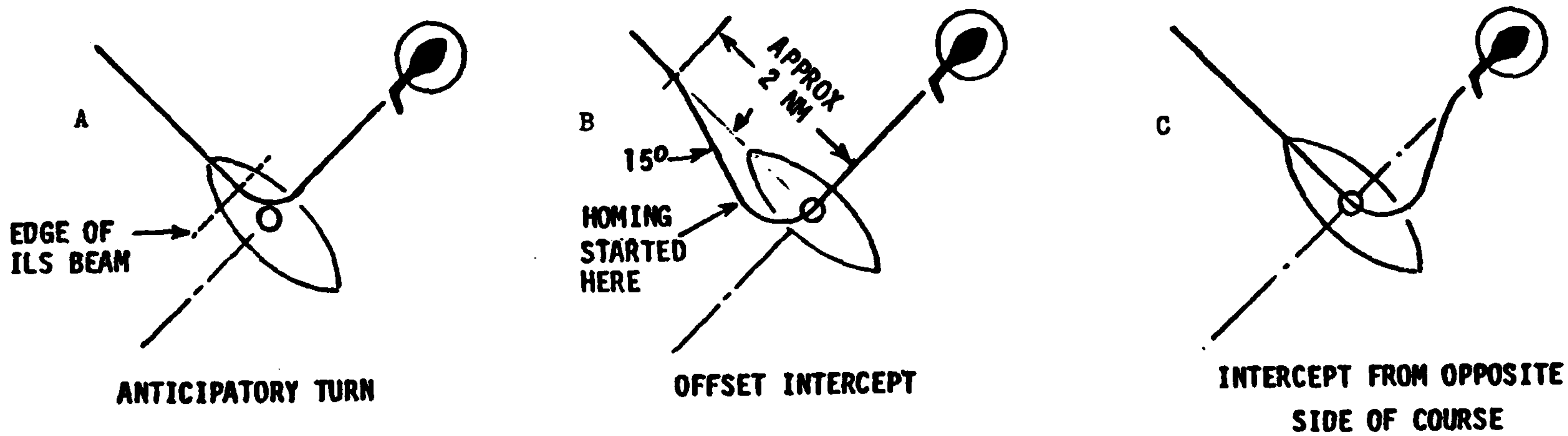


FIG. 5 90° HELICOPTER INTERCEPTS AT OUTER LOCATOR

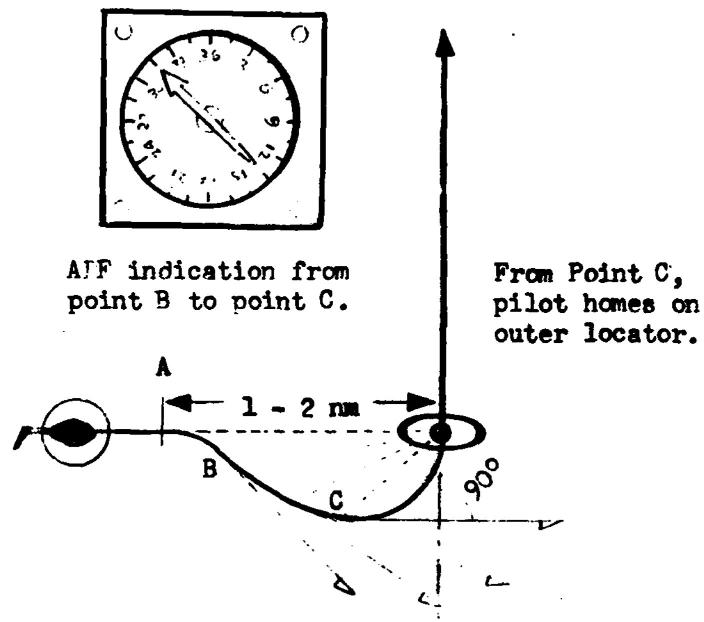


FIGURE 6 . SPIRAL INTERCEPT

course from the opposite side (See Figure 5).

Figure 7 shows a number of course interception techniques, including course reversals, made without employing a conventional procedure turn. These techniques exploit the helicopter's short turning radius to complete the maneuver in a very short distance. All are designed to save flight distance and fuel, from that required with a conventional procedure turn. The symmetrical procedure turn (Figure 7D) is designed to minimize lateral displacement of the aircraft from the centerline of the course.

Because the desired information is of basic importance to subsequent terminal area simulation studies, the subject of short turn-ons is classified as a short-term development item. All of the maneuvers can be accomplished on the Army's helicopter flight simulators. It is recommended that the NASA-Ames helicopter flight simulators be used also, in the collection of data on pilot workload and course deviations.

Reducing Separation

HSVFR. One procedure for expediting helicopter traffic in IMC (Instrument Meteorological Conditions) is the use of HSVFR (Helicopter Special VFR) procedures, which are covered in Chapter 5 Section 14, Paragraphs 1140-1141 of Air Traffic Control Handbook 7110.65B.

It is possible that the sheer complexity of the HSVFR rules, with their many qualifying restrictions, have discouraged many controllers from memorizing them. Without familiarity, controllers hesitate to apply these rules.

It appears possible that a more simplified presentation, to supplement the existing material in 7110.65B, would make the applicable rule easier to remember. To this end, a matrix has been prepared which lists the actual separation standard for each aircraft combination. Thus the HSVFR criteria can be summarized on a card small enough to be posted at the local control position in the control tower (see Table 1).

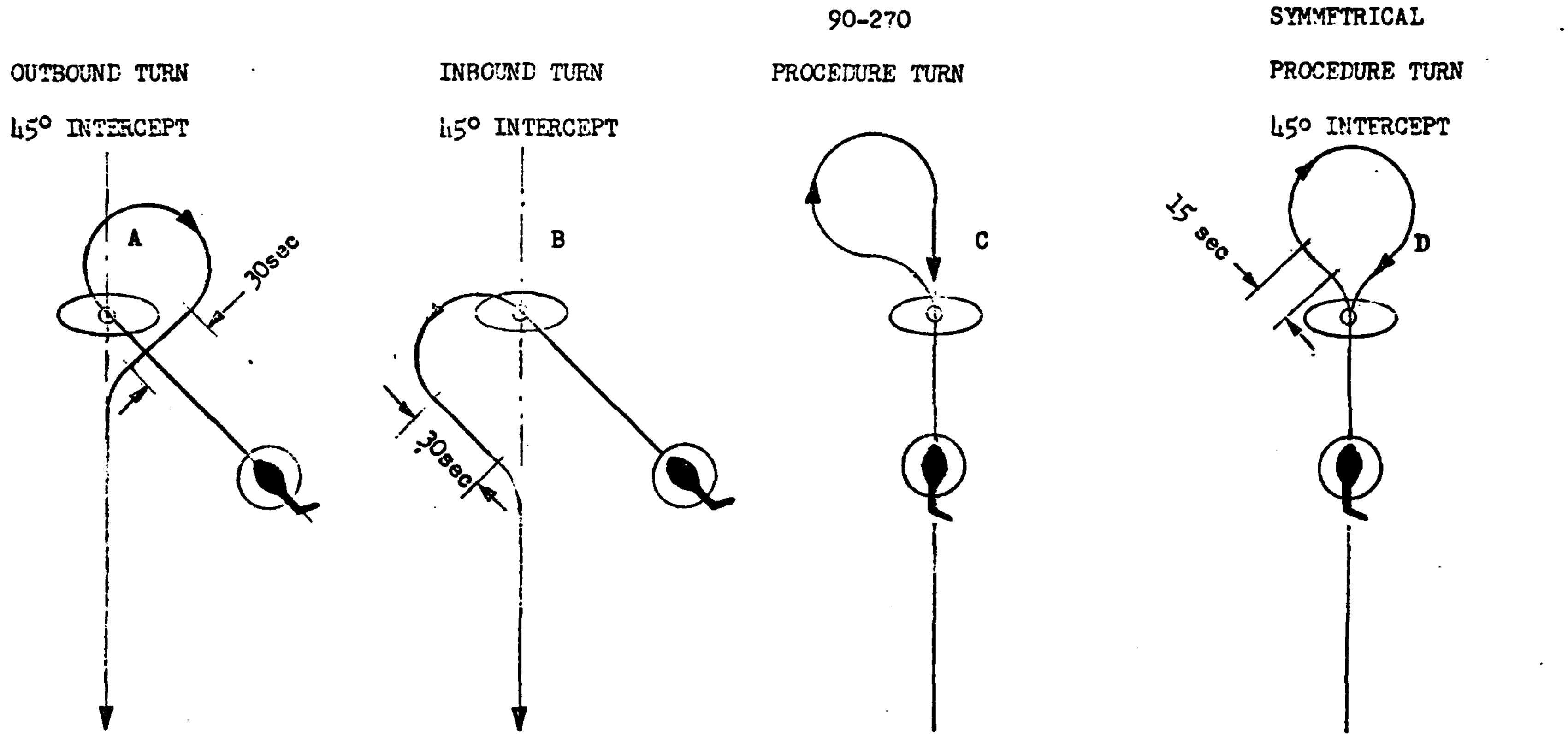


FIGURE 7 INTERCEPT PROCEDURES FOR COURSE CHANGES OF MORE THAN 90°

TABLE 1

SUMMARY OF SEPARATION MINIMA
IN NAUTICAL MILES
FOR VARIOUS AIRCRAFT COMBINATIONS
INVOLVING HSVFR HELICOPTERS

AIRCRAFT → COMBINATIONS ↓			HSVFR HELICOPTER DEPARTURE	HSVFR HELICOPTER ARRIVAL
HSVFR HELICOPTER	DEPARTURE		1 *200 ft.	1
HSVFR HELICOPTER	ARRIVAL		1	1
IFR FIXED-WING	DEPARTURE	<1/2 NM BEYOND RUNWAY	* 1/2	1/2
IFR FIXED-WING	DEPARTURE	≥1/2 NM BEYOND RUNWAY	* 1/2	2
IFR FIXED-WING	STRAIGHT-IN APPROACH	<1 NM FROM RUNWAY	NOT AUTHORIZED	1/2
IFR FIXED-WING	STRAIGHT-IN APPROACH	≥1 NM FROM RUNWAY	*1	1-1/2
IFR FIXED-WING	CIRCLING OR MISSED APPROACH		NOT AUTHORIZED	2

* DIVERGING COURSES ONLY

The chief difference between helicopter operational characteristics in IFR and HSVFR is that, in low visibility conditions, the HSVFR pilot will be able to fly at much lower airspeeds (if necessary), than he would normally care to fly if he were actually on instruments. However, in order to stay out of the low-speed Avoid area, he normally will not want to fly slower than 40 knots through the critical altitudes of the Height/Velocity Diagram (see Volume 2, Section 2, Figure 2-3 of this report).

The safety of simultaneous HSVFR arrivals with fixed-wind IFR arrivals, on laterally converging courses, ultimately depends on positive controller/pilot communications, plus the assurance that ATC can control the path or progress of the helicopter as necessary to maintain the necessary seperation from the other aircraft.

This assurance is enhanced if the controller can observe the progress of the helicopter on a radar display. If this is not possible, assurance could be enhanced if the helicopter pilot were navigating visually on a standard VFR helicopter route which is known to both pilot and controller, is clear of fixed-wing traffic paths, and includes one or more distinctive visual landmarks which can be used as standard reporting points and visual holding points.

Techniques for delaying the helicopter to provide separation from other traffic include speed reduction, holding patterns, 360° turns, and pathstretching (radar vectoring). At low helicopter airspeeds, holding patterns and 360° turns require only a small amount of airspace. The pilot should not be asked to hover for delay purposes. Hovering requires high power with relatively high fuel consumption.

Because the layout of HSVFR routes is a site-specific problem, any meaningful simulation tests of the adequacy of HSVFR routes, checkpoints, or procedures should be keyed to a specific location rather than to some generalized geographical area.

Comparative tests of HSVFR versus total IFR handling of helicopters would be useful, at various helicopter and CTOL traffic densities; data collection should include delays, communications, controller workload, and if possible pilot workload. Any possible display problems, such as scale factors, display resolution , or target identification, should be examined.

Because of the size of the traffic samples necessary, it is recommended that the simulation program be conducted at NAFEC. The ultimate objective of the simulation program would be the generation of guidelines for ATC planning personnel in the layout of HSVFR routes , together with the possible revision of HSVFR criteria and control procedures.

Simultaneous Approaches. A more realistic approach is needed in the establishment of radar separation standards for helicopters. A flight simulation program, supplemented by a dynamic ATC simulation program with flight simulation inputs, should be established to determine safe separation standards for converging simultaneous approaches for helicopters and CTOL aircraft. The concept should exploit the helicopter's slow speed and short turning radius as well as its ability to start a turning missed approach immediately with no height loss and no change in aircraft attitude or configuration

Data should first be taken to determine the distance required to start a missed approach and reverse course (distance A in Figure 8), with various combinations of helicopters, approach aids, approach speeds and wind conditions. This data should be applied to situations such as that shown in Figure 8, where it is assumed that precision approaches are being made to two runways simultaneously.

If it is determined that simultaneous approaches are not feasible at any specific airport because of the proximity of the helicopter missed approach point (MAP) to the CTOL runway, ATC simulation tests should be run, moving the MAP back to determine the actual separation that would be applicable at other airports. A possible concept would be the application of a no transgression zone, based on existing parallel approach criteria, as shown in Figure 9.

For simulating the concept shown in Figure 9, it is recommended that all the approaches started in the simulation runs for the 90° intercept procedures (see Figures 5 and 6) be flown all the way down to decision height,

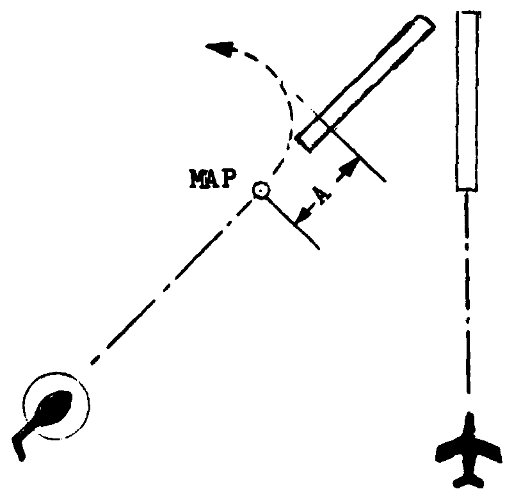


FIGURE 8 SIMULTANEOUS CONVERGING APPROACHES

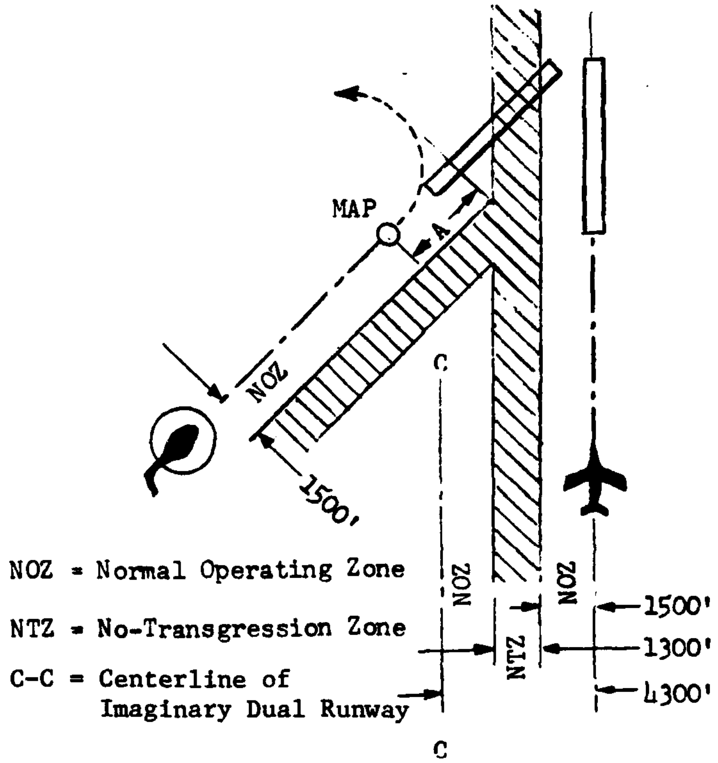


FIGURE 9. APPLICATION OF EXISTING PARALLEL-APPROACH CONCEPT TO CONVERGING APPROACHES

at which time a missed approach procedure will be started, involving an immediate climbing left turn of 120^{o}. Data should be recorded for analysis to determine the lateral deviations from the localizer course during the last 3 miles of the approach, as well as the longitudinal distance (see A on Figure 8) necessary to contain the initial turn of the missed approach path.

Reduced Longitudinal Separation. Where helicopters are concerned, the use of 3 nm radar separation results in excessive approach intervals, which lower the airport acceptance rate accordingly. The present 3 nm standard results in an approach interval of at least 180 seconds between two helicopters flying a ground speed of 60 knots, as compared to only 77 seconds between two jets at 140 knots ground speed.

With 2 nm separation, 60-knot helicopters would have an approach interval of at least 120 seconds. Even with ground speeds as high as 90 knots, the approach interval is at least 80 seconds, which is comparable to the present interval between the much less maneuverable jets.

A precedent for reduced IFR separation between helicopters was established several years ago when 2 nm separation was authorized for the helicopters of Los Angeles Airways. Thus, no further research may be necessary.

However, if any further verification is deemed necessary, it is recommended that the NAFEC dynamic ATC simulator be used, preferably with inputs from one or more helicopter flight simulators, to look at any possible problems with scale factors, display resolution, target identification, communications, or controller workload; and to define any new display or controller training requirements that should be met before a 2 nm separation standard between IFR helicopters can be authorized.

Integration of Helicopter and CTOL Traffic. Where practicable, it is desirable, because of speed differences, to segregate helicopter and CTOL traffic into different approach paths. However, where only one instrument approach procedure is available, it sometimes becomes necessary to integrate the two types of aircraft in a common path.

The longer the common path, or the greater the difference between approach speeds, the longer the approach interval, whenever a helicopter follows a faster aircraft down the final approach course; the longer the average interval, the lower the airport capacity. Three possible methods of minimizing the capacity loss are:

(1) To utilize the long interval between approaches by clearing off additional departures.

(2) To minimize the length of the common final approach path by using short turn-ons and/or higher glide slopes for helicopters.

(3) To have helicopters fly the approach path at speeds as close as possible to CTOL approach speeds.

It appears that many helicopters are able to fly instrument approaches at speeds up to their cruising speeds, in weather conditions down to Category I minima. However, high speed may be incompatible with a short turn-on, due to the possibility of overshooting and the distance required to get stabilized on the final approach course. Also, high approach speeds may not be compatible with high glide slope angles, as the sink rates may be excessive for safe operations.

One concept for increasing traffic capacity would be to have the helicopter fly a higher glide slope and thus stay clear of the vortices shed by the preceding CTOL aircraft. This concept theoretically would allow the separation to be reduced to 3 nm. It is recommended that various combinations of helicopter approach speeds, turn-on distances, and glide slope angles be explored in order to determine safe and practical limits in optimizing the control of mixed helicopter and CTOL traffic when using common ILS or MLS approach aids.

It is recommended that the NASA 30-target ATC simulator, with inputs from one or preferably two helicopter flight simulators, be used for the initial test program. The recorded data plus debriefings after each run should provide useful information regarding pilot and controller workload, safe operating limits, and airport acceptance rates with mixed traffic.

SIMULATION PROGRAM DETAILS

A. Flight Simulation. Tables 2 through 13 list the combinations of variables which are recommended for testing in the flight simulation program. A modified factorial design is used in setting up the various experiments. This should enable the effects of various wind conditions, turbulence conditions, and pilot skill level to be determined from the analysis of a minimum number of simulation runs.

The tentative program calls for a total of nearly 500 runs, most of which will not exceed 15 minutes in duration. Depending on setup time, about 125 hours of simulation time is called for, in testing the various holding patterns, ILS intercepts, and turning missed approaches. The latter are combined with the intercept tests, to provide greater realism as well as to reduce the number of runs necessary.

It is possible that the total number of runs can be further reduced if the initial runs indicate that certain proposed flight procedures are not operationally acceptable and should be dropped from the program.

In the holding pattern tests, it is recommended that pattern entries always be made from the upwind direction; this tends to represent the worst-case conditions as far as overshooting is concerned.

B. ATC Simulation. Tables 14 through 16 show the recommended combination of variables to be explored in simulation tests of the integration of helicopter and CTOL approaches using the same ILS or MLS. The NASA 30-target ATC simulator, supplemented by one or two helicopter flight simulators, should have adequate capacity to handle this portion of the program. It is assumed that an MLS will be available for runs using the 6° and 8° glide slopes. It is also assumed that controllers will assist helicopter pilots in intercepting the final approach course; this is particularly important for the short (3 nm) turn-ons.

The MLS tests will include runs in which the helicopter approach path is offset radially about 20° from the centerline path used by the CTOL aircraft. This introduces the problem of bringing some of the helicopters across the CTOL path to get on the helicopter final approach path.

Saturated traffic samples of at least 20 aircraft, comprised of approximately 25% fast and 25% slow helicopters with 25% heavy and 25% light CTOL's, are recommended in order to obtain an adequate number of H-C, C-H, and H-H sequences (where H= helicopters, C=CTOL) and learn as much as possible in the time available, about the dynamics of mixing helicopter and CTOL traffic.

Tables 14 through 16 call for 50 runs, for a total of about 75 simulator hours. However, this program may be shortened by dropping certain combinations if early tests show that the concept is unfeasible. Conversely, other runs may be added if the tests indicate that additional effort on some other phase of the program would be productive.

Table 2
Flight Simulation

HOLDING PATTERN B
SINGLE-FIX ONE-MINUTE RACETRACK

(See Figure 2)

Helicopter IAS, Knots	ENVIRONMENTAL CONDITIONS								Number of Runs
	Cross-Wind 45°	Turbulence	Cross-Wind 135°	Turbulence	Cross-Wind 225°	Turbulence	Cross-Wind 315°	Turbulence	
60	0 kts.	-	0 kts.	-	0 kts.	-	0 kts.	-	20
	10 "	Light	10 "	-	10 "	-	10 "	-	
	20 "	-	20 "	Severe	20 "	-	20 "	-	
	30 "	-	30 "	-	30 "	Light	30 "	-	
	40 "	-	40 "	-	40 "	-	40 "	Severe	
90	0 "	-	0 "	-	0 "	-	0 "	-	20
	10 "	-	10 "	-	10 "	-	10 "	Light	
	20 "	-	20 "	-	20 "	Severe	20 "	-	
	30 "	-	30 "	Light	30 "	-	30 "	-	
	40 "	Severe	40 "	-	40 "	-	40 "	-	

40 Total

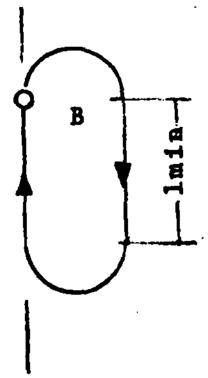


Table 3
Flight Simulation

HOLDING PATTERN E
DUAL FIX RACETRACK

(See Fig. 2)

Heli-copter IAS	ENVIRONMENTAL CONDITIONS				No. of Simulation Runs
	Cross Wind 45°	Turbulence	Cross Wind 315°	Turbulence	
60 kts.	0 kts.	-	0 kts.	-	10
	10 "	Light	10 "	-	
	20 "	-	20 "	-	
	30 "	-	30 "	-	
	40 "	-	40 "	Severe	
90 kts.	0 kts.	-	0 kts.	-	10
	10 "	-	10 "	Light	
	20 "	-	20 "	-	
	30 "	-	30 "	-	
	40 "	Severe	40 "	-	
				Total	20

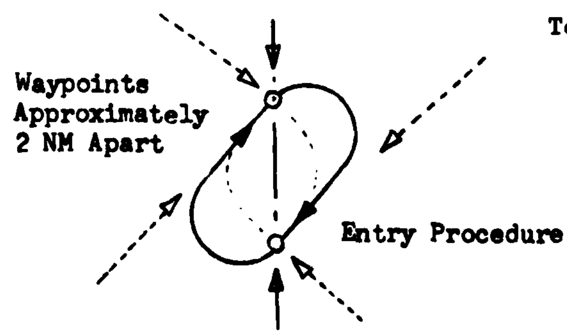


Table 4
Flight Simulation

HOLDING PATTERN F
SINGLE FIX

(See Fig. 2)

Heli-copter IAS	ENVIRONMENTAL CONDITIONS				No. of Simulation Runs
	Cross Wind 45°	Turbulence	Cross Wind 135°	Turbulence	
60 kts.	0 kts.	-	0 kts.	-	10
	10 "	Light	10 "	-	
	20 "	-	20 "	Severe	
	30 "	-	30 "	-	
	40 "	-	40 "	-	
90 kts.	0 kts.	-	0 kts.	-	10
	10 "	-	10 "	-	
	20 "	-	20 "	-	
	30 "	-	30 "	Light	
	40 "	Severe	40 "	-	

Total 20

Table 5
Flight Simulation

HOLDING PATTERN G
DUAL FIX

See Fig. 2)

Heli-copter IAS	ENVIRONMENTAL CONDITIONS		No. of Simulation Runs
	Cross Wind 45°	Turbulence	
60 kts.	0 kts.	-	5
	10 "	Light	
	20 "	-	
	30 "	-	
	40 "	-	
90 kts.	0 kts.	-	5
	10 "	-	
	20 "	-	
	30 "	-	
	40 "	Severe	
			10

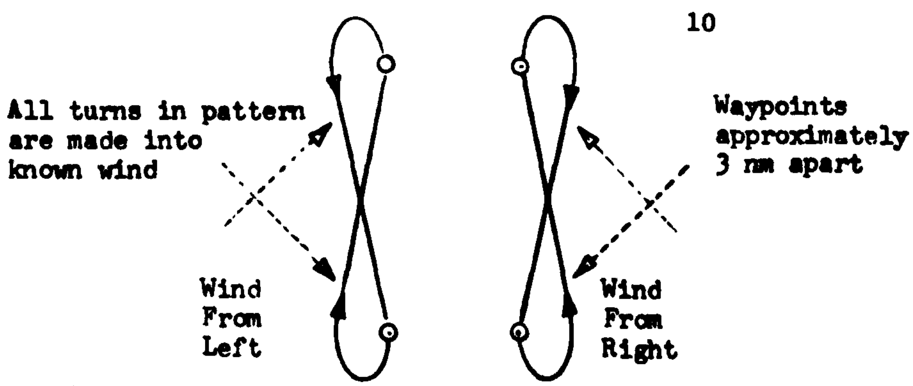


Table 6
Flight Simulation

ANTICIPATORY TURN

(See Figure 7A)

Heli-copter IAS, Knots	ENVIRONMENTAL CONDITIONS								Number of Runs
	Cross-Wind 45°	Turbu-lence	Cross-Wind 135°	Turbu-lence	Cross-Wind 225°	Turbu-lence	Cross-Wind 315°	Turbu-lence	
60	0 kts.	-	0 kts.	-	0 kts.	-	0 kts.	-	20
	10 "	Light	10 "	-	10 "	-	10 "	-	
	20 "	-	20 "	Severe	20 "	-	20 "	-	
	30 "	-	30 "	-	30 "	Light	30 "	-	
	40 "	-	40 "	-	40 "	-	40 "	Severe	
90	0 "	-	0 "	-	0 "	-	0 "	-	20
	10 "	-	10 "	-	10 "	-	10 "	Light	
	20 "	-	20 "	-	20 "	Severe	20 "	-	
	30 "	-	30 "	Light	30 "	-	30 "	-	
	40 "	Severe	40 "	-	40 "	-	40 "	-	
									40 Total

Fly approaches from start of base leg, to DH, start 120° climbing left turn at MAP.

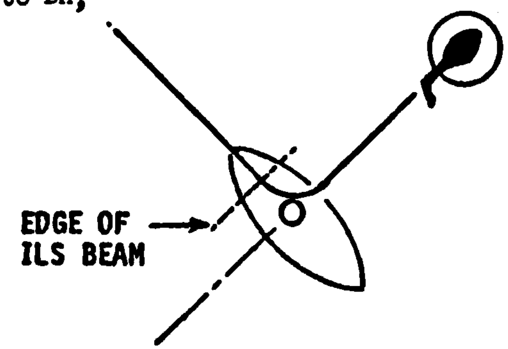


Table 7
Flight Simulation

OFFSET INTERCEPT

(See Figure 5B)

Heli-copter IAS, Knots	ENVIRONMENTAL CONDITIONS								Number of Runs
	Cross-Wind 45°	Turbu-lence	Cross-Wind 135°	Turbu-lence	Cross-Wind 225°	Turbu-lence	Cross-Wind 315°	Turbu-lence	
60	0 kts.	-	0 kts.	-	0 kts.	-	0 kts.	-	20
	10 "	Light	10 "	-	10 "	-	10 "	-	
	20 "	-	20 "	Severe	20 "	-	20 "	-	
	30 "	-	30 "	-	30 "	Light	30 "	-	
	40 "	-	40 "	-	40 "	-	40 "	Severe	
90	0 "	-	0 "	-	0 "	-	0 "	-	20
	10 "	-	10 "	-	10 "	-	10 "	Light	
	20 "	-	20 "	-	20 "	Severe	20 "	-	
	30 "	-	30 "	Light	30 "	-	30 "	-	
	40 "	Severe	40 "	-	40 "	-	40 "	-	
									40 Total

Fly approaches from start of base leg, to DH, start 120° climbing left turn at MAP.

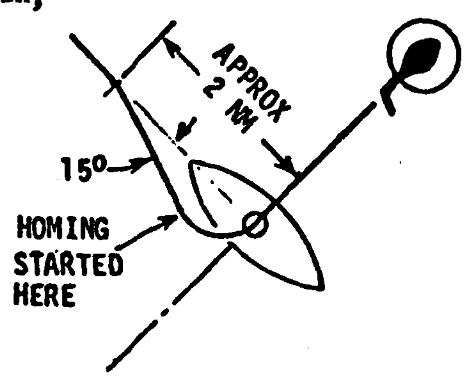


Table 8
Flight Simulation

INTERCEPT FROM OPPOSITE SIDE OF COURSE

(See Figure 5C)

Heli-copter IAS, Knots	ENVIRONMENTAL CONDITIONS								Number of Runs
	Cross-Wind 45°	Turbu-lence	Cross-Wind 135°	Turbu-lence	Cross-Wind 225°	Turbu-lence	Cross-Wind 315°	Turbu-lence	
60	0 kts.	-	0 kts.	-	0 kts.	-	0 kts.	-	20
	10 "	Light	10 "	-	10 "	-	10 "	-	
	20 "	-	20 "	Severe	20 "	-	20 "	-	
	30 "	-	30 "	-	30 "	Light	30 "	-	
	40 "	-	40 "	-	40 "	-	40 "	Severe	
90	0 "	-	0 "	-	0 "	-	0 "	-	20
	10 "	-	10 "	-	10 "	-	10 "	Light	
	20 "	-	20 "	-	20 "	Severe	20 "	-	
	30 "	-	30 "	Light	30 "	-	30 "	-	
	40 "	Severe	40 "	-	40 "	-	40 "	-	

Fly approaches from start of base leg, to DH, start 120° climbing left turn at MAP.

40 Total

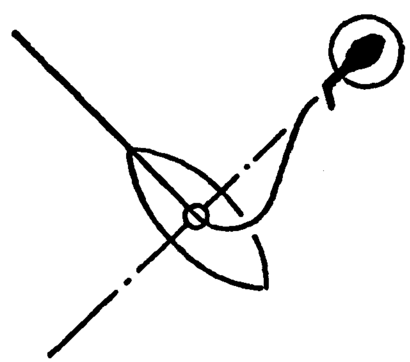


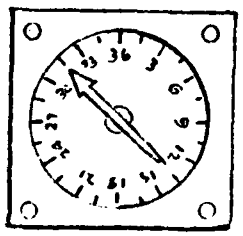
Table 9
Flight Simulation

45° OFFSET SPIRAL INTERCEPT

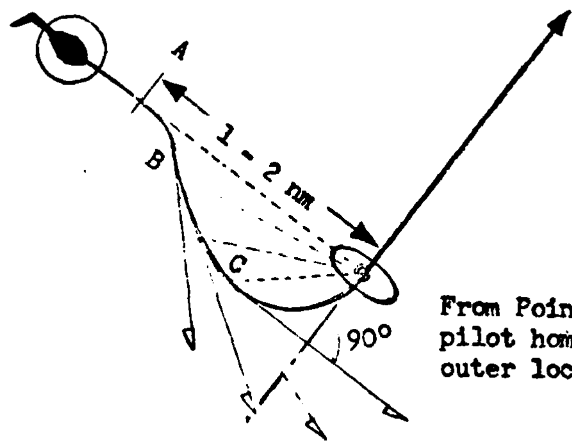
(See Figure 6).

Heli-copter IAS, Knots	ENVIRONMENTAL CONDITIONS								Number of Runs
	Cross-Wind 45°	Turbu-lence	Cross-Wind 135°	Turbu-lence	Cross-Wind 225°	Turbu-lence	Cross-Wind 315°	Turbu-lence	
60	0 kts.	-	0 kts.	-	0 kts.	-	0 kts.	-	20
	10 "	Light	10 "	-	10 "	-	10 "	-	
	20 "	-	20 "	Severe	20 "	-	20 "	-	
	30 "	-	30 "	-	30 "	Light	30 "	-	
	40 "	-	40 "	-	40 "	-	40 "	Severe	
90	0 "	-	0 "	-	0 "	-	0 "	-	20
	10 "	-	10 "	-	10 "	-	10 "	Light	
	20 "	-	20 "	-	20 "	Severe	20 "	-	
	30 "	-	30 "	Light	30 "	-	30 "	-	
	40 "	Severe	40 "	-	40 "	-	40 "	-	
									40 Total

Fly approaches from start of base leg, to DH, start 120° climbing left turn at MAP.



ADF indication from point B to point C.



From Point C, pilot homes on outer locator.

Table 10
Flight Simulation

INTERCEPT PROCEDURES OVER 90°

OUTBOUND TURN (See Fig. 7A)

PILOTS A-B-C-D-E				No. of Simulation Runs
IAS, Kts.	Wind Direction	Wind Velocity	Turbulence	
60	45°	10 kts.	Light	15
		20 "	Mod.	
		30 "	Severe	
60	135°	10 kts.	Mod.	15
		20 "	Light	
		30 "	Severe	
90	225°	10 kts.	Mod.	15
		20 "	Severe	
		30 "	Light	
90	315°	10 kts.	Severe	15
		20 "	Light	
		30 "	Mod.	

60 Runs

Table 11
Flight Simulation

INTERCEPT PROCEDURES OVER 90°

INBOUND TURN (See Fig. 7B)

PILOTS A-B-C-D-E				No. of Simulation Runs
IAS, Kts.	Wind Direction	Wind Velocity	Turbulence	
60	45°	10 kts.	Light	15
		20 "	Mod.	
		30 "	Severe	
60	135°	10 kts.	Mod.	15
		20 "	Light	
		30 "	Severe	
90	225°	10 kts.	Mod.	15
		20 "	Severe	
		30 "	Light	
90	315°	10 kts.	Severe	15
		20 "	Light	
		30 "	Mod.	

60 Runs

Table 12
Flight Simulation

INTERCEPT PROCEDURES OVER 90°

90/270 PROCEDURE TURN (See Fig.7C)

PILOTS A-B-C-D-E				No. of Simulation Runs
IAS, Kts.	Wind Direction	Wind Velocity	Turbulence	
60	45°	10 kts.	Light	15
		20 "	Mod.	
		30 "	Severe	
60	135°	10 kts.	Mod.	15
		20 "	Light	
		30 "	Severe	
90	225°	10 kts.	Mod.	15
		20 "	Severe	
		30 "	Light	
90	315°	10 kts.	Severe	15
		20 "	Light	
		30 "	Mod.	

60 Runs

Table 13
Flight Simulation

INTERCEPT PROCEDURES OVER 90°

SYMMETRICAL PROCEDURE TURN (See Fig. 7D)

PILOTS A-B-C-D-E				No. of Simulation Runs
IAS, Kts.	Wind Direction	Wind Velocity	Turbulence	
60	45°	10 kts.	Light	15
		20 "	Mod.	
		30 "	Severe	
60	135°	10 kts.	Mod.	15
		20 "	Light	
		30 "	Severe	
90	225°	10 kts.	Mod.	15
		20 "	Severe	
		30 "	Light	
90	315°	10 kts.	Severe	15
		20 "	Light	
		30 "	Mod.	

60 Runs

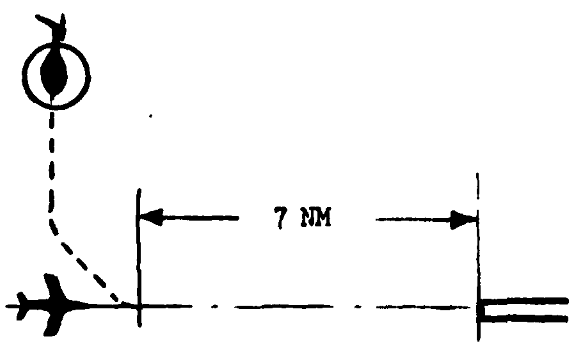
TABLE 14

ATC SIMULATION

INTEGRATION OF HELICOPTERS AND CTOL's

7-mile Turn-On to ILS
5-mile Turn-On to MLS

Helicopter Approach Speed, IAS	7-mile Turn-on to same ILS/MLS Course		5-mile Turn-on to offset MLS Course		Number of Runs
	Head-wind, Knots	Glide Slope, Degrees	Head-Wind, Knots	Glide Slope, Degrees	
50% at 60 kt 50% at 90 kt	0	3	-	-	
	20	3	-	-	
	0	6	0	6	6
	20	6	20	6	
50% at 90 kt 50% at 120kt	0	3	-	-	
	20	3	-	-	
	0	6	0	6	6
	20	6	20	6	
					12



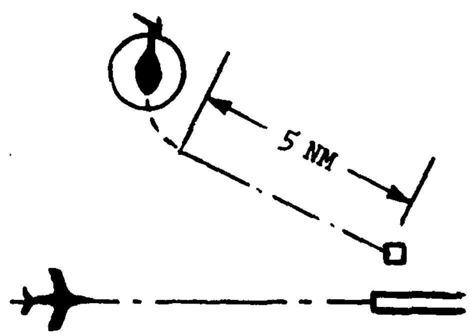


TABLE 15

ATC SIMULATION

INTEGRATION OF HELICOPTERS AND CTOL's

5-mile Turn-On To
Same ILS/MLS Course

Helicopter Approach Speed, IAS	5-mile Common Path on ILS/MLS			Number of Runs
	Head-wind, Knots	Glide Slope, Degrees	Turbu-lence	
50% at 60 kts 50% at 90 kts	10 20 10 20 10 20	3 3 6 6 8 8	Light - - Mod - Severe	6
50% at 90 kts 50% at 120 kts	10 20 10 20 10 20	3 3 6 6 8 8	- Mod - Severe Light -	6
			Total=	12

TABLE 16
ATC SIMULATION

INTEGRATION OF HELICOPTERS AND CTOL's

3-mile Turn-On to Same
ILS/MLS Course

Helicopter Approach Speed, IAS	PILOT A			PILOT B			PILOT C			Number of Runs
	Head-Wind Knots	Glide Slope Degrees	Turbu-lence	Head-Wind, Knots	Glide Slope, Degrees	Turbu-lence	Head-Wind, Knots	Glide Slope, Degrees	Turbu-lence	
	0	6	-	0	6	-	0	6	Light	
	10	6	-	10	6	Mod	10	6	-	
	20	6	Severe	20	6	-	20	6	-	
50% at 60 kts.	0	8	Light	0	8	-	0	8	-	18
50% at 90 kts.	10	8	-	10	8	Mod	10	8	-	
	20	8	-	20	8	-	20	8	Severe	
	10	3	Light	10	3	-	10	3	Mod	
	20	3	-	20	3	Severe	20	3	-	
50% at 90 kts.	10	6	-	10	6	Mod	10	6	-	18
50% at 120 kts.	20	6	Severe	20	6	-	20	6	Light	
	10	8	-	10	8	Light	10	8	Severe	
	20	8	Mod	20	8	-	20	8	-	
									Total=	36