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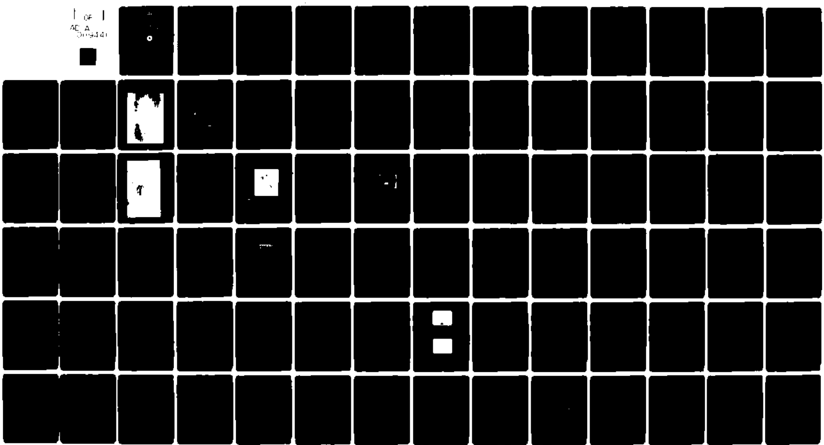

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Report No. FAA-RD-80-88-2

RECOMMENDED SHORT-TERM ATC IMPROVEMENTS FOR HELICOPTERS. VOLUME II. RECOMMENDED HELICOPTER ATC TRAINING MATERIAL.

AD A089441

November 1980

Task Report

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Prepared for

U.S. DEPARTMENT OF TRANSPORTATION

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This effort was sponsored by the Systems Research and Development Service, Navigation and Landing Division, Helicopter Systems Branch under the direction of Raymond J. Hilton, Program Manager.

16. Abstract

The recommended Short Term ATC Improvements for Helicopters are documented in three volumes, i.e.:

- Vol. I is a summary report of all improvements studied. Improvements are categorized as to those that can be recommended for immediate operational consideration or use and those that require limited short term simulation or test.

The recommendations for immediate use include: (1) Helicopter ATC training material, (2) Operational Description of LOFF, (3) Recommendations concerning military training routes and (4) Survey data for use in Gulf communications and route structure planning.

The recommendations for short term simulation include: (1) Dual waypoint holding patterns, (2) other holding patterns and (3) shortened entry procedures for intercepting final approach path.

- Vol. II is the complete training material for helicopter ATC. It contains major sections on Helicopter Capabilities and Limitations, on Helicopter Navigation and on Helicopter Control Procedures.
- Vol. III is the complete Operational Description of the Experimental Loran Flight Following (LOFF) in the Houston Area. It describes both airborne and ground components and states the objectives that are being sought in the experiment.

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METRIC CONVERSION FACTORS

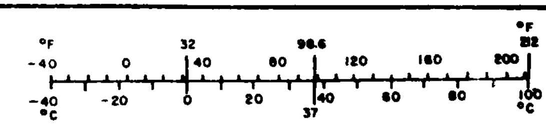
Approximate Conversions to Metric Measures

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



RECOMMENDED HELICOPTER ATC TRAINING MATERIAL
VOLUME II
(SHORT-TERM ATC IMPROVEMENTS FOR HELICOPTERS)

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ACKNOWLEDGEMENT

The information and effort reflected in this report could not have been achieved without the cooperation and assistance of other Divisions of SRDS, the FAA Technical Center and the Transportation System Center. The FAA Headquarters, Regional and facility operations support received was essential to this effort. The cooperation and assistance received from the many trade associations, helicopter manufactures, helicopter operators and their respective regional associations as well as the various industries and public organizations using helicopter services was invaluable. These organizations provided time, facilities and other available resources to support the program manager and his staff in conducting this effort.

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.

SECTION 1

BACKGROUND

The IFR helicopter is a comparative newcomer in the NAS. It has entered an enviroment in which the ATC procedures and criteria, as well as the navigation and communications facilities, have been developed and refined over many years for fixed-wing aircraft, but are not necessarily well adapted to the unique characteristics of rotary-wing aircraft.

In 1978 the FAA Helicopter Operations Program was established to determine what problems were being encountered in the operation of IFR helicopters in the ATC system, and to determine what changes could be made to relieve these problems.

It soon became aparent that special training in helicopter characteristics and limitations would be useful in enabling controllers to take advantage of these unique characteristics in expediting traffic, and in avoiding hazardous conditions.

It also appeared desirable to provide controllers with more specific information regarding the use of offshore helicopter navigation and approach procedures, which are quite different from those used by fixed-wing aircraft in the NAS.

The lack of uniform application of Helicopter Special VFR procedures indicated that additional training material would be desireable on this subject. The growing need for special helicopter arrival and departure procedures in certain areas indicated that a series of guidelines on this subject might be useful to ATC planners.

Accordingly, this manual has been prepared for direct use by ATC personnel, and for adaptation as appropriate by FAA training officers, in setting up national, regional, and local training programs, to increase the efficiency and safety of helicopter ATC operations.

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SECTION 2

HELICOPTER CAPABILITIES AND LIMITATIONS

Introduction

The average controller knows much more about the characteristics of fixed-wing aircraft, than those of rotary-wing aircraft. But the helicopter has certain capabilities which, if properly exploited, can make things easier for the controller -- and for the helicopter pilot and the other airspace users as well. The helicopter also has certain limitations with which the controller should be familiar, for reasons of safety. The following material has been prepared to provide controllers with an overview of the capabilities and limitations of current helicopters.

Size

Presently certificated helicopters range in size from 2 to 25-place. The largest passenger-carrying helicopter presently under development in the U.S.A. is a 44-place civil version of the Boeing-Vertol 234 Chinook (CH-47).

Controls

Helicopters are designed for one or two-pilot operation. Customarily, the helicopter pilot or aircraft commander sits on the right side. The significance of this point to ATC is that if there is a choice, the pilot would usually prefer to make right turns in low visibility. Many of the newer helicopters are equipped with stability augmentation systems, autopilots, and approach couplers, to ease the pilot's workload.

The cyclic stick, operated by the right hand, controls pitch and bank by tilting the direction of the main rotor thrust, in relation to the fuselage. The collective pitch, operated by the left hand, controls the amount of the main rotor thrust. The throttle, which is usually on the collective pitch stick, controls the power to the main rotor. (On some twin-turbine powered helicopters, the throttles are located overhead). Directional control pedals, operated by the feet, change the amount of the tail rotor thrust in order to compensate for the torque of the main rotor, and control the heading.

The ATC implication is that a single pilot, with both hands and both feet busy flying the aircraft, may not always be able to switch communications channels or beacon codes instantly, on request. For this reason, controllers should try to keep requests for such changes at a minimum.

Ground Operations and Hover-Taxiing

A helicopter can approach to, and take off directly from, its terminal parking position, although local obstacles may make it necessary for the pilot to use a takeoff point or approach aiming point, at some location away from the parking area. The latter situation requires some ground movement, although it could be much less than that required for fixed-wing aircraft. For helicopter operating efficiency, ground movement should be minimized.

Helicopters with wheel-type landing gear can taxi on prepared surfaces. Those with skid-type landing gear cannot taxi on the surface; instead, their ground movement must be done by hover-taxiing a few feet off the ground. Hover-taxiing helicopters need not necessarily be restricted to maneuvering over paved surfaces or taxiways. However, consideration should be given to dust, loose snow, or debris that may be thrown into the air by the helicopter's downwash.

Some helicopters are equipped with inflatable (pop-out) floats, for emergency water landings. Additionally, other helicopters are sometimes equipped with permanently inflated floats for both land and water operations. Helicopters not equipped with either inflatable or permanently inflated floats should not be vectored, or otherwise requested, to fly over extended water routes.

The helicopter differs from the airplane in that it can stand still (hover) in flight, and can even fly sidewards or backwards if desired.

Although the term hovering usually means remaining over a certain spot on the surface, aerodynamically it means flight at zero airspeed. Staying over one spot in a 20-knot wind is equivalent (as far as the rotor aerodynamics are concerned) to forward flight at a speed of 20 knots in a calm wind condition.

Hovering with nose into the wind is preferred, as a helicopter tends to "weathervane" into the wind. Hovering with tail into the wind produces an unstable condition which increases the difficulty of the pilot's task.

Hovering requires relatively high power and fuel consumption, as is indicated by the power/airspeed curve in Figure 2-1. However, if the helicopter is hovering at or below a height of about 1/2 the rotor diameter, the rotor downwash is partially trapped under the rotor, forming a cushion of air which decreases the downwash velocity, and the power required to remain at a hover. This is called hovering in ground effect (HIGE) as opposed to hovering at a higher altitude, referred to as hovering out of ground effect (HOGE), which requires significantly more engine power.

In general, the heavier the helicopter, the stronger the downwash. As shown in Figure 2-2, the downwash generated by a hovering helicopter becomes outwash strong enough to damage nearby light aircraft if they are not tied down with their controls locked. Controllers should be aware of this potential hazard when helicopters are hover-taxiing near aircraft parking areas. As a general rule, such helicopters should be operated at a distance of at least three rotor diameters away from light aircraft parked on the airport, and perferably even further away if the helicopter is passing upwind of the other aircraft. In some cases, it would be advantageous to have separate servicing areas for light airplanes and helicopters.

While helicopters may be a potential hazard to light unsecured aircraft, large aircraft may also be a hazard to a hovering helicopter. High velocity propeller wash or turbo-jet engine exhaust from aircraft beginning to taxi can cause serious control problems for helicopters hovering close behind.

Height/Velocity Diagram

Figure 2-3 is a typical Height/Velocity (H/V) diagram. The shaded areas show the combinations of heights and airspeeds which should be avoided in order to accomplish a successful autorotation landing in case of engine failure. The importance of the H/V diagram may be gathered from the fact that, before the days of twin-engine helicopters, the H/V Diagram was better known as the Dead Man's Curve. Each H/V Diagram contains a low-speed and a high-speed Avoid area.

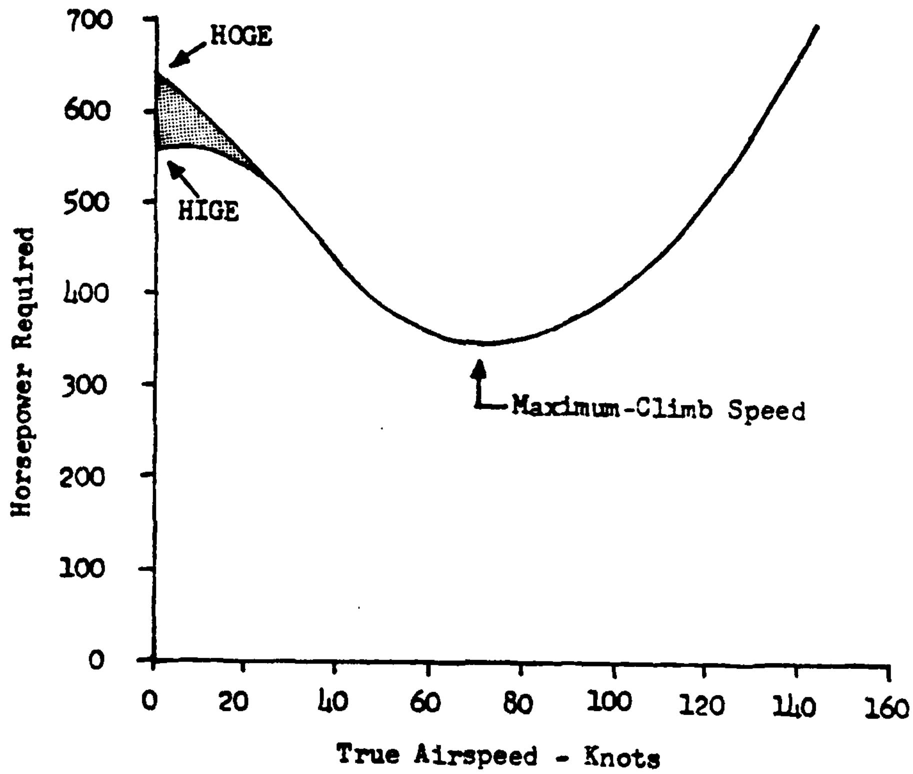


FIGURE 2-1 REQUIRED HORSEPOWER VERSUS TRUE AIRSPEED, FOR TYPICAL HELICOPTER

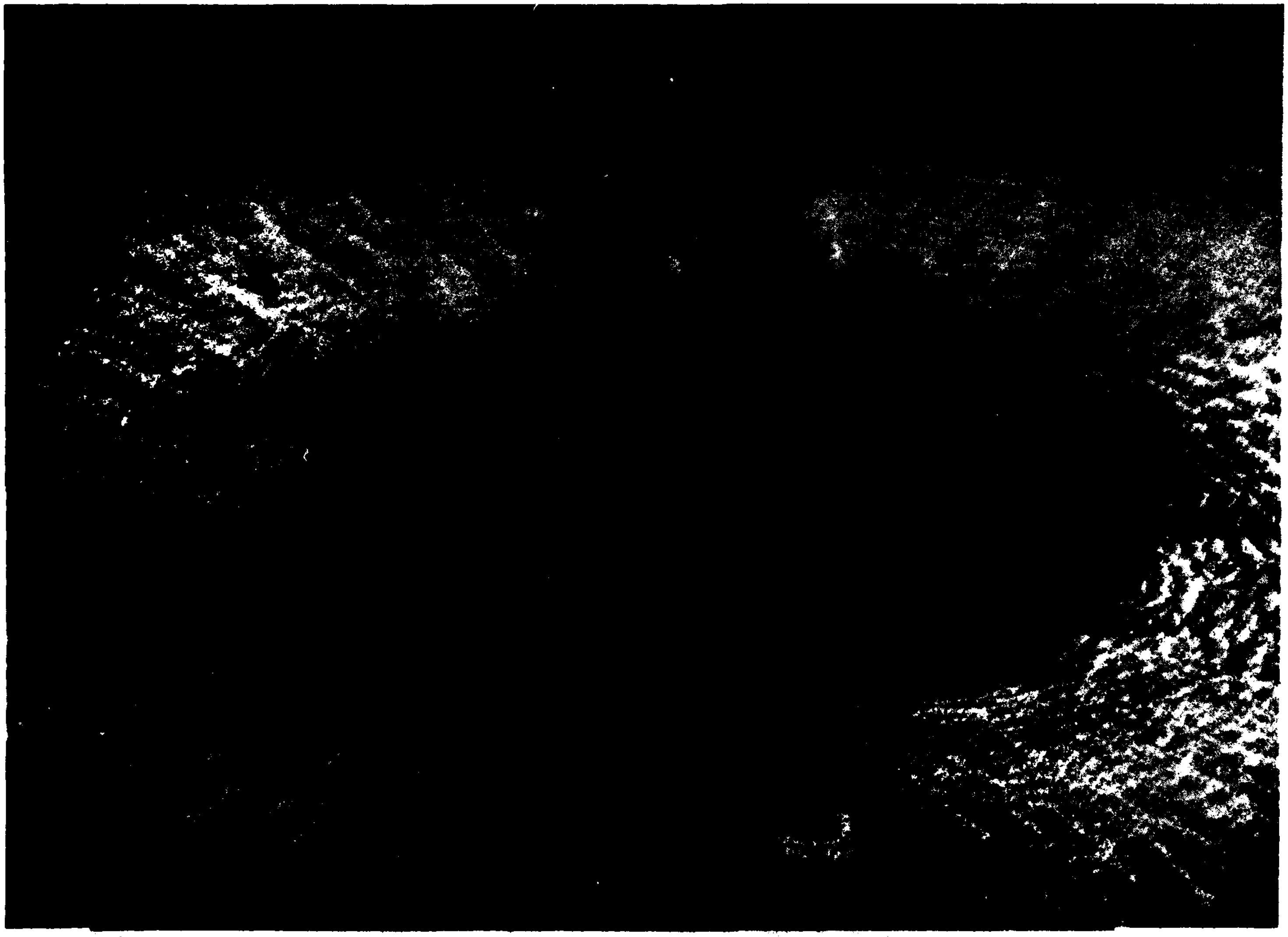


FIGURE 2-2 RADIAL WIND-STREAKS, CONCENTRIC WHITECAPS, AND A TEMPORARY DIMPLE ON THE FACE OF THE OCEAN, SHOW THE INTENSITY OF THE DOWNWASH AND OUTWASH, AS THIS HR-2S HELICOPTER HOVERS LONG ENOUGH TO SNATCH AN ASTRONAUT FROM A FLOATING MERCURY SPACE CAPSULE

--NASA Photo

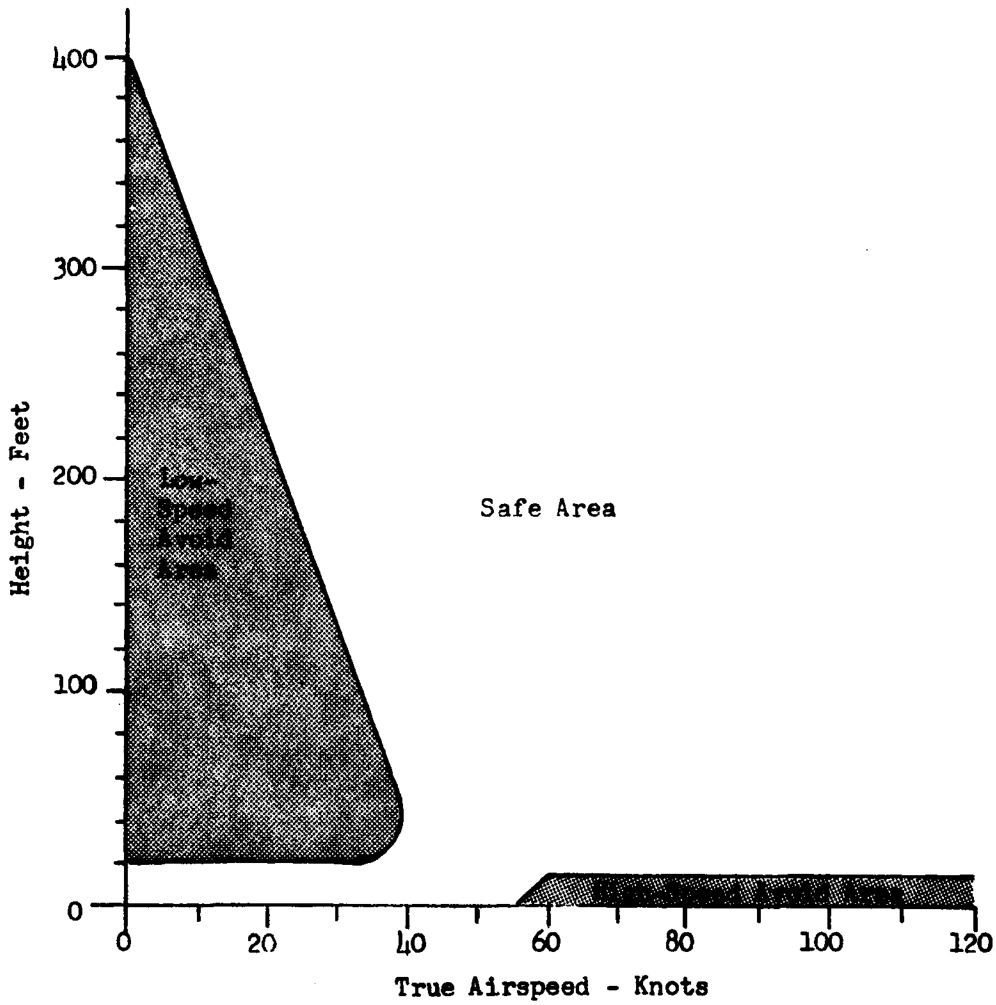


Figure 2-3. HEIGHT/VELOCITY DIAGRAM FOR TYPICAL HELICOPTER

The low-speed Avoid area usually extends from zero to 40 knots, and from heights of 12-20 feet up to about 400 feet. Under conditions of high load or high density altitude this area could extend as high as 800 feet. One application of this curve to ATC is that, in winds of less than 40 knots, holding in a slow orbit would be preferable to hovering over one spot, if the helicopter is within the critical height range. (The orbit pattern can be quite small). Also, a steep descent at an airspeed above 40 knots would be preferable to a vertical descent through the critical height range.

The high-speed Avoid area extends from the surface to a height of 10-15 feet above the surface, at speeds above 50 knots.

Takeoff

Helicopter takeoffs are generally made directly into the wind, but can be safely made up to 45° of either side of the wind direction as well as crosswind and downwind depending on wind speed. Taking off into the wind is optional if the wind is calm to light; preferable if the wind is light to moderate; and mandatory if the wind speed is moderate to strong.

As Figure 2-1 shows, less power is required for forward flight than for hover. Therefore, pilots of helicopters with wheel-type landing gear may prefer to make a STOL-type (rolling) take off from a prepared surface (such as a runway, taxiway, or apron),particularly when operating with a heavy load, or at a high density altitude. Only enough pavement is needed to allow the helicopter to accelerate to lift-off speed, which in most cases will be an airspeed less than 40 knots.

However, for helicopters which do not request the use of a runway for takeoff, there is no reason to delay them until a runway is available, if they can use a takeoff path which diverges from, and is completely independent of, the paths used by other aircraft. This point is mentioned because there have been cases where controllers have delayed departing helicopters needlessly, waiting for a runway, to the point where pilots have had to return to the apron to obtain additional fuel.

Transition and Climbout

Forward flight is obtained by tilting the rotor forward. There is a slight loss of lift as the aircraft leaves its ground cushion behind, at an airspeed of about 7 knots. Beyond this speed, the power required for level flight decreases, up to the minimum-drag speed, as shown in Figure 2-1, leaving progressively more power available for acceleration and climb.

In general, certificated helicopters have a very good climb capability -- up to 3000 feet per minute, depending upon load and density altitude. Turbine powered helicopters have the highest rate of climb.

The speed for the best rate of climb ranges between 40 and 70 knots (see Figure 2-1). Turbine-powered helicopters can climb at an angle up to about 30° in calm wind conditions.

Cruising Speed

Cruising speeds for turbine-powered helicopters are normally between 100 and 150 knots. Some small piston-engine powered helicopters may cruise at speeds as low as 60 knots.

One factor which limits the top speed of conventional helicopters is aerodynamic stalling of the outer portion of the retreating blades, as shown in Figure 2-4. The higher the forward speed of the helicopter, the larger the stalled portion of the rotor disc (the circular area swept by the rotor blades). Flight tests have shown that control becomes marginal when the outer 1/4 of the retreating blades are operating in a stalled condition.

Theoretically, retreating blade stall could be reduced by increasing the rotor rpm. However, this leads into another condition in which the blade tips on the advancing side are approaching transonic speeds and thereby getting into compressibility problems, with high noise (blade slap), excessive vibration, and a large increase in drag. Thus, the combination of retreating blade stall and advancing blade Mach number limits the maximum speed of conventional helicopters to about 170 knots.

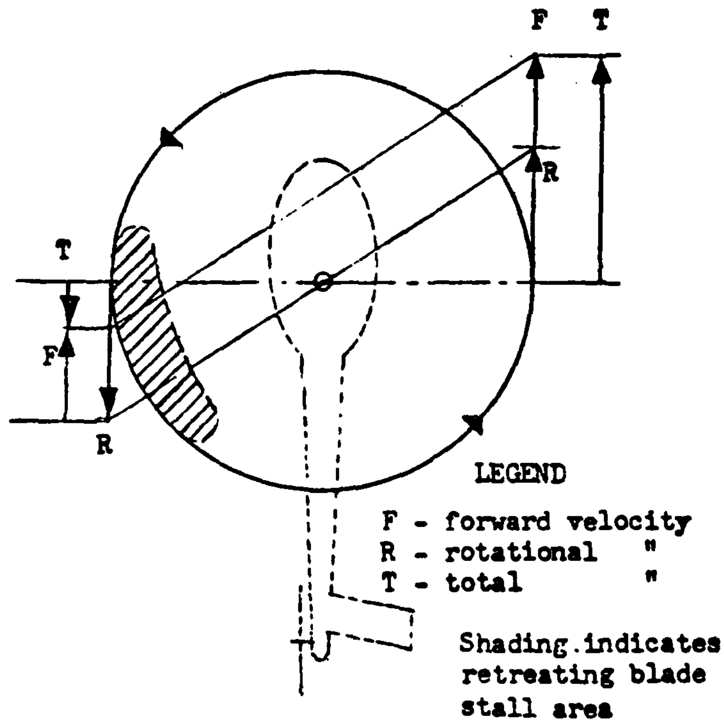


FIGURE 2-4 RETREATING BLADE STALL

Cruising Altitude

Helicopter cruising altiutdes seldom exceed 10,000 MSL: most flights are below 5000 MSL. There are several reasons for this:

- No helicopters are pressurized; few if any carry oxygen systems.
- Most helicopter flights are relatively short.
- The decrease of air density with altitude accentuates the phenomenon of retreating blade stall; this reduces the allowable maximum speed of conventional helicopters 2 to 3 knots per thousand feet of altitude.
- However. because of their relatively high loading per square foot of blade area, as well as the flexibility designed into their main rotor, helicopters tend to ride much smoother than fixed-wing aircraft. Thus, a flight through low-altitude turbulence that would be quite uncomfortable in a light fixed-wing aircraft could be quite comfortable in a helicopter.
- Because of the lack of de-icing capability in current U. S. helicopters, the normal decrease of temperature with altitude forces these aircraft to remain at altitudes below the freezing level when flying through clouds or precipitation.

FAR 91.79 (d) exempts helicopters from compliance with the minimum altitude (general) requirements prescribed for other aircraft, provided that they do not impose a hazard to persons or property on the surface. This principle can sometimes be used in establishing helicopter arrival or departure routes beneath a normal light plane traffic pattern, with due regard, of course, to noise problems and obstructions. Because of the difference in speeds, the segregation of helicopters and airplanes in different patterns and flight routes is an important means of reducing ATC workload.

Range

Compared to fixed-wing aircraft, the typical helicopter is a relatively short-range vehicle. As a result of early military helicopter design criteria, for years nearly all of the helicopters manufactured in the USA had a fuel capacity of only 2 1/2 hours. At the relatively low cruising speeds of the early helicopters, this limited their range in still air, to less than 250 NM. This was seldom enough to fly to an IFR destination, then to another airport with weather good enough to meet the published requirements for an alternate airport, and to get there with the required minimum of reserve fuel. Special Federal Air Regulation (SFAR) 29.2 alleviated this problem slightly by reducing the alternate fuel reserve from 45 minutes to 30 minutes.

There has been considerable discussion of the need to relax the alternate airport weather minimums for helicopters, because:

1. Flights are relatively short; weather at destination and alternate airports has less time to deteriorate below the forecasted conditions.
2. Except in an emergency, the helicopter is never committed to land; the pilot can start a go-around at any time, without changing the aircraft configuration (flap settings, gear retraction, turbine spool-up, etc.)
3. The slow approach speed of the helicopter gives the pilot much more time to get oriented once he achieves visual contact; also the field of vision from the cockpit of a helicopter is generally much greater than that from the cockpit of an airplane.
4. As it can decelerate to hover speed in the air, the helicopter does not need to be perfectly aligned with a runway, to make a safe and successful approach.

The range of the new generation of helicopters is typically 300 to 500 nm. The civil version of the Chinook is being designed for a range of 650 nm.

Wind

Because the helicopter operates in a lower speed regime than most fixed-wing aircraft, a given wind will have a correspondingly greater effect on elapsed time, range and drift angle. With a combination of low speed and short range, a strong headwind may force cancellation of certain cross-country flights.

Icing

Icing of helicopters includes all the critical effects encountered in the icing of airplanes, most notably a decrease in thrust and lift, with an increase in drag and weight. Helicopters have four other potential icing problems:

- The pilot is unable to see the buildup of ice on the rotor blades.
- Icing of the middle third (spanwise) of each blade can preclude a successful autorotation in the event of a power failure.
- Shedding of ice from main or tail rotor blades can damage the fuselage, and cause FOD (foreign object damage) to engines. This hazard appears to be more threatening to large multi-engine aircraft (over 12,500 pounds), and especially tandem rotor systems.
- Uneven shedding of ice from opposite blades can develop critical vibrations.

Research indicates that asymmetrical shedding can be minimized by avoiding static temperatures lower than -5° C. In warmer temperatures, shedding generally occurs symmetrically.

As of this writing, only one US-built civil helicopter, the Sikorsky S-61, has been certificated for operation in known or forecasted icing conditions. Rotor-blade leading edges of some European-built helicopters are electrically heated to inhibit the accretion of ice. De-icing and anti-icing systems for helicopters are under development in the U. S.; it appears probable that some of these systems will be utilized on future U. S. helicopter designs.

Holding

The most economical speed for helicopter holding is at or slightly above the minimum drag (or maximum climb) speed (See Figure 1). Consequently, helicopters hold at speeds of 40 to 70 knots.

From the ATC standpoint, the low holding speed is advantageous in that a helicopter can hold in a very small area. For example, an orbiting pattern at 15° bank and 60 knots airspeed has a turn radius of about 555 feet. For a constant bank angle, the turn radius varies as the square of the speed. Holding requires no change in the aircraft configuration.

Speed Control

The ability of the helicopter to fly at speeds considerably lower than the speed range of fixed-wing aircraft, makes it particularly adaptable to the use of speed reduction techniques, in lieu of conventional holding techniques, for absorbing in-flight delay. This principle is illustrated in Figure 2-5, using a 60-knot slowdown for comparison. A fixed-wing aircraft which is slowed from 240 knots to 180 knots picks up only 5 seconds of delay for each nautical mile flown at the slower speed; on the other hand, a helicopter which is slowed from 120 knots to 60 knots picks up 30 seconds of delay for each nautical mile flown at the slower speed.

Figure 2-6 shows another aspect of this relationship. A 240-knot airplane slowed to 180 knots requires 12 nautical miles to pick up one minute of delay at the slower speed; whereas a 120-knot helicopter slowed to 60 knots can pick up one minute of delay for every 2 nautical miles at the slower speed. This means that the helicopter can absorb a considerable amount of delay close to its destination, without going into a holding pattern.

As compared to absorbing the delay in a conventional holding pattern, this technique (which is known in Europe as linear holding) can reduce fuel consumption because the aircraft 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. However, helicopters should not be required to slow to speeds less than 60 knots while flying on instruments, as manual control becomes marginal when depending on present instrumentation, at low speeds.

Obviously the use of speed reduction to absorb arrival delay requires that the ATC system be able to predict the acceptance time for each aircraft. However, for the reasons described above, the prediction time can be shorter for a helicopter than for an airplane.

Descent

Helicopters can descend at any forward speed up to their never-exceed speed (V_{ne}), which ranges from 130 to 170 knots for turbine-powered helicopters, down to 90 knots -- and even less -- for piston-engine helicopters.

Normal descent angles are up to 30° (3500 feet per nautical mile, in calm air). Instrument approaches can be made at approach angles up to 8°;

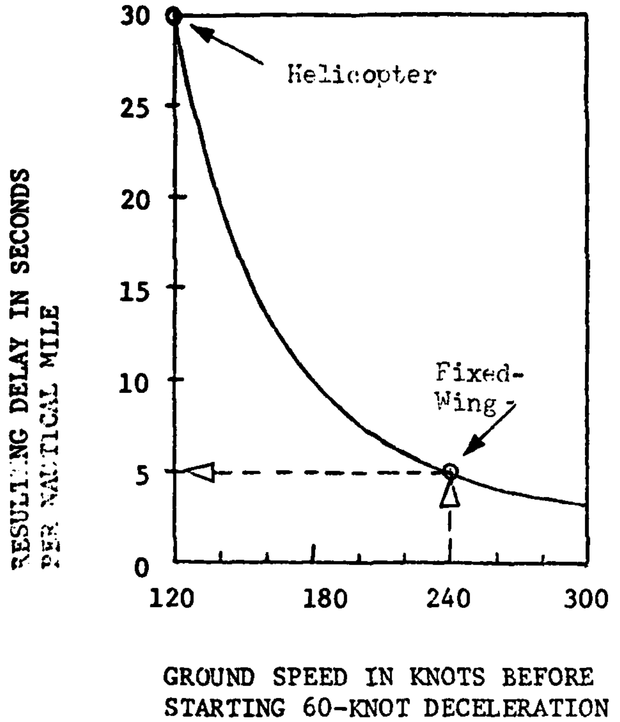


FIGURE 2-5 Effect of Advancing the Point Where Aircraft Starts 60 KT Slowdown

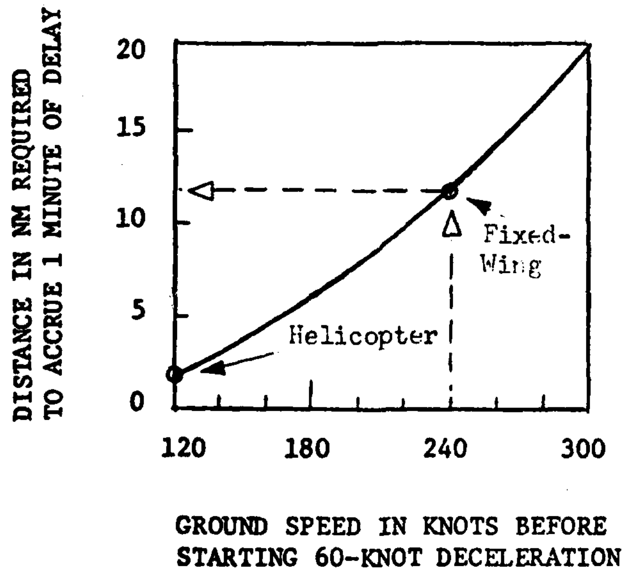


FIGURE 2-6 Distance Required to Absorb 1 Minute of Enroute Delay after 60 KT Slowdown

thus, the final approach path can be quite short. Instrument approaches are normally made at between 60 to 90 knots; this keeps the aircraft out of the Avoid areas of the H/V diagram, and also provides good directional control as well as adequate reserve power in case a go-around is necessary (See Figures 1 and 3). Approaches in visual conditions are normally made at speeds between 40 and 70 knots.

Helicopters can make instrument or visual approaches in any direction, as long as they will have ample opportunity to turn into the wind for final deceleration and landing. Controllers can take advantage of this capability in segregating fixed-wing and rotary-wing traffic on different runways or on different parts of the airport.

The efficiency of helicopter operations can be improved by establishing a termination (or aiming) point for helicopter visual approaches closer to the helicopter servicing area. Helicopter pilots normally are not interested in terminating their approach on a runway, anyway.

Settling with Power

Controllers should be aware of a condition known as "settling with power", which is unique to VTOL aircraft, such as helicopters. This condition occurs when the aircraft is settling in its own downwash, at a very low forward airspeed. It is most likely to occur in marginal power situations involving high density altitude or high gross weight. Aerodynamically, the inner portion of the rotor disc is stalled; attempts by the pilot to reduce the descent rate by pulling up on the collective pitch control can aggrevate the condition by stalling more of the rotor and causing an even higher rate of decent.

Helicopter pilots are trained to recognize this potentially hazardous situation, and to recover by noising down to pick up forward airspeed and thus fly out of and away from the downwash. Controllers should avoid any situation which would require the helicopter to operate in the low-speed Avoid area of the H/V diagram (see Figure 2-3).

Landing

The landing normally consists of two operations. The pilot flares the approach by nosing up with the cyclic control, to reduce the descent rate and reduce the forward speed to some value below 30 knots. He then uses the collective control to reduce the remaining vertical and forward velocities. The actual touchdown preferably is made headed into the wind, at a vertical rate of about four feet per second.

Shutdown or Startup

If the wind is strong, the pilot will prefer to have the helicopter headed into the wind, when shutting down or starting up the main rotor. This is desirable as in going to or from zero rpm, the blades may pass through resonant conditions which can induce excessive blade flapping in a strong wind. Most helicopters are far more tolerant of this situation when they are headed into the wind (See Figure 2-7).

Emergencies

Autorotation. If the power fails, the pilot moves the collective pitch to the down position, to enable the main rotor to windmill in an autorotative descent. This is analogous to a power-off glide in a fixed wing aircraft; potential energy (altitude) is being traded for kinetic energy (thrust).

Whenever engine driving speed is less than rotor speed (as in autorotation) a freewheeling clutch disengages the engine to allow the main rotor and tail rotor to turn freely.

During autorotation the pilot can control the descent path by tilting the rotor in the desired direction. The tail rotor, which is geared to the main rotor, allows normal control of the heading. Minimum rate of descent normally takes place at air speeds of 40 to 70 knots; maximum glide angle (about 4 to 1) normally takes place at airspeeds of 70 to 100 knots.

An autorotation landing is an energy-management problem for the pilot; just before touchdown, the pilot converts some of the kinetic energy stored in the spinning rotor, into extra lift, in order to slow the sink rate. This

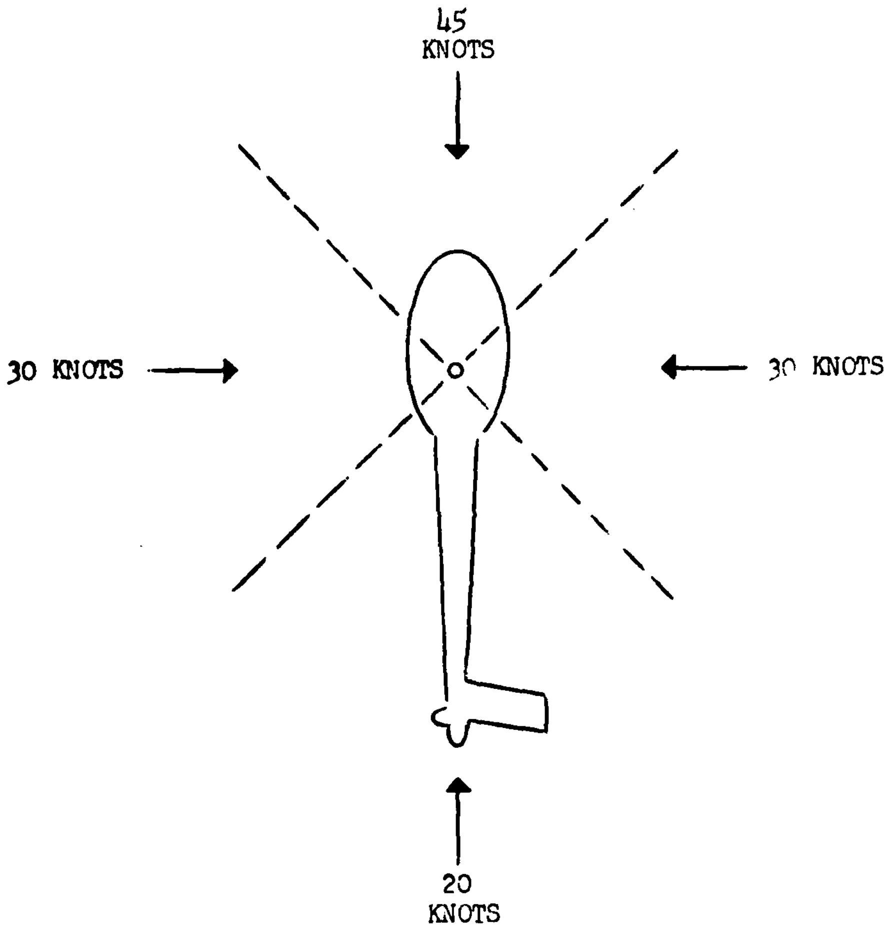


FIGURE 2-7 Shutdown/Startup Wind Tolerances (by Quadrant) for Typical Helicopter

is analogous to flaring a power-off landing in a fixed wing aircraft. The objective is to start the flare soon enough to avoid a hard landing, but not to bleed off too much kinetic energy (rotor rpm) too soon, which could result in a subsequent loss of control.

Tail-Rotor Failure. Failure of the tail rotor will require a sharp reduction of engine power in order to minimize the torque which would tend to rotate the fuselage in the opposite direction from the rotor blades. In the subsequent descent, the pilot can maintain directional control only by maintaining forward flight all the way to touchdown.

Choice of Landing Site. Controllers should remember that in most emergencies a helicopter does not need to be vectored to an airport runway, as it can set down on any suitably-sized level spot which is free of wires, trees, and other obstructions.

Turbulent Wakes

Some limited flight tests have indicated that helicopters are less affected by turbulent wakes than are fixed-wing aircraft of comparable size. Theoretically, it appears that helicopters could be spaced somewhat closer behind heavier aircraft, than today's vortex separation standards allow.

A program is underway to define specific spacing criteria for avoiding hazardous wake vortex and downwash effects between helicopters and other aircraft. In the meantime, existing standards must be used where applicable. A general understanding of wake vortex and downwash effects can help in situations not covered by existing standards.

Helicopters themselves generate a very turbulent wake. As with fixed-wing aircraft, the velocity of the downwash is directly proportional to aircraft gross weight, and inversely proportional to forward airspeed, air density, and the square of the wing span (or rotor diameter). In hovering flight the forward airspeed approaches zero, so the downwash velocity is high. For example, below a hovering medium-weight helicopter, the downwash velocity has been measured at 60 feet per second (about 35 knots).

Each rotor blade tip generates a separate vortex. The resulting vortex train is a highly complex, intertwined wake, as shown in Figure 2-8; however

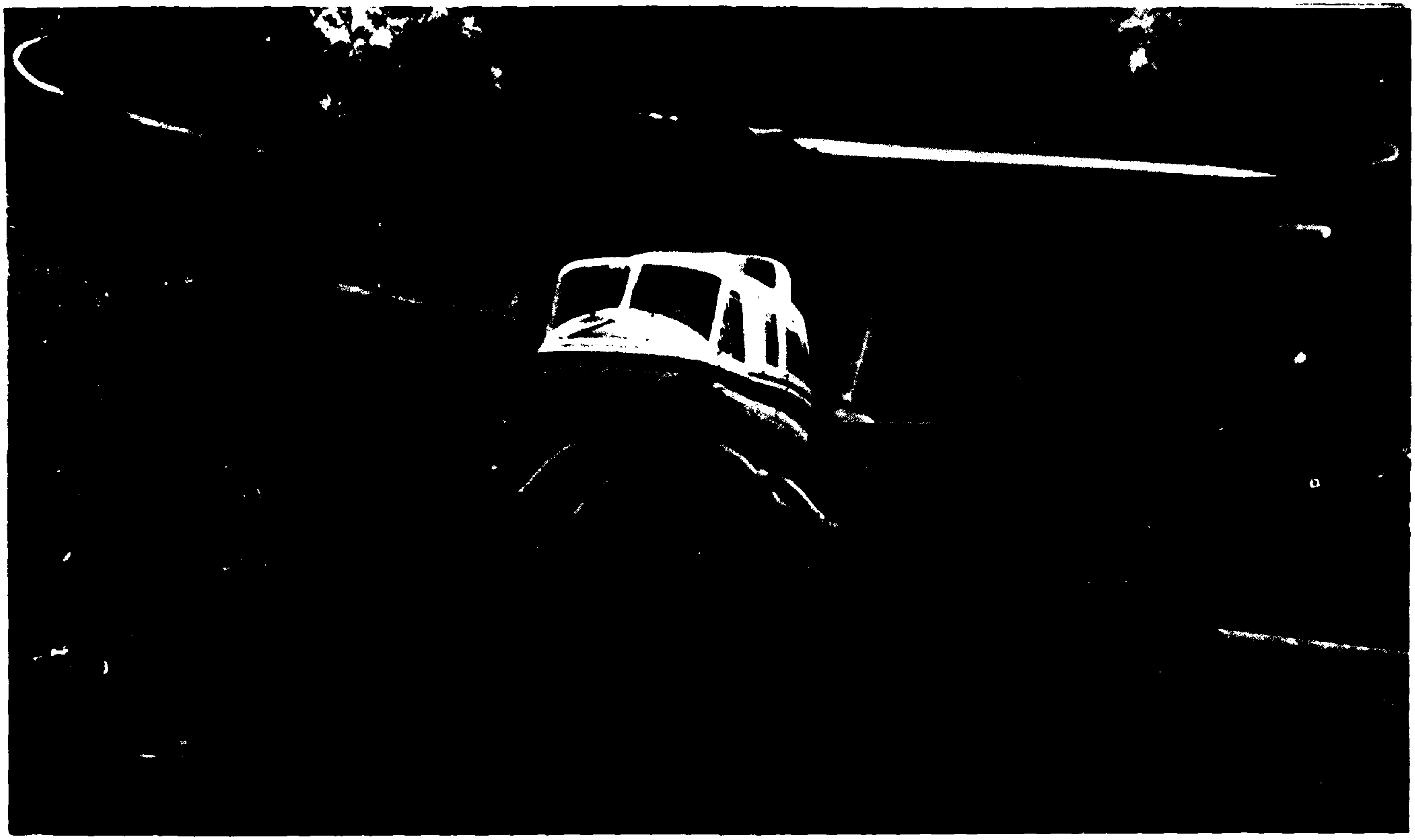


FIGURE 2-8 VAPOR TRAILS SHOW THE INTERTWINED VORTICES FROM THE BLADE TIPS OF A HOVERING HELICOPTER

--Bell Helicopter Textron Photo

in forward flight these individual vortices soon rearrange themselves to form the cores of twin vortices which trail the rotor path like wing-tip vortices trail an airplane wing (see Figures 2-9 and 2-10).

As with vortices generated by airplanes, helicopter vortices drift with the wind and settle downwards. If they reach the ground, they spread apart before they dissipate.

As shown in Figure 2-2, the downwash from a low-hovering helicopter spreads out in all directions when it reaches the surface. Thus, controllers should keep hovering helicopters at least 3 rotor diameters away from other aircraft on the ground -- and even further if the helicopter is passing on the upwind side of the other aircraft. It has also been recommended that helicopters not be hovered closer than 1000 feet upwind of an active runway.

Noise Abatement

The helicopter's unique noise signature is due partly to sound modulation by the relatively slow-turning main rotor. This tends to attract attention much as a flashing light is more noticeable than a steady one. The modulated sound is often referred to as "Blade Slap".

Blade slap accurs during three conditions:

(a) at forward speeds of over 100 knots, when a main rotor blade enters the compressible flow (transonic) region on the advancing-blade side;

(b) at lower speeds, when a blade intercepts its own tip vortex, or that generated by another blade;

(c) during steep turns, between 40 and 110 knots.

For medium helicopters, maximum slap occurs during partial power descents, at airspeeds between 60 and 80 knots, and descent rates between 200 and 400 feet per minute. Figure 2-11 shows the boundaries of slap conditions for typical medium-size turbine-powered helicopters. For light helicopters (under 5000 pounds) the maxumum slap areas occur between 70 and 85 knots, at descent rates between 200 and 500 feet per minute. Figure 2-12 shows the slap boundaries for a typical light helicopter, the Bell 206A.

[redacted] INSECTICIDE FROM SPRAY RIG OUTLINES WAKE OF HELICOPTER IN FORWARD FLIGHT. HORIZONTAL LINES IN WAKE ARE INDIVIDUAL BLADE-TIP VORTICES (SEE FIGURE 6) WHICH CURL UPWARDS (SEE ARROW) INTO MAIN VORTICES (SEE FIGURE 8)

—U.S. Forest Service Photo

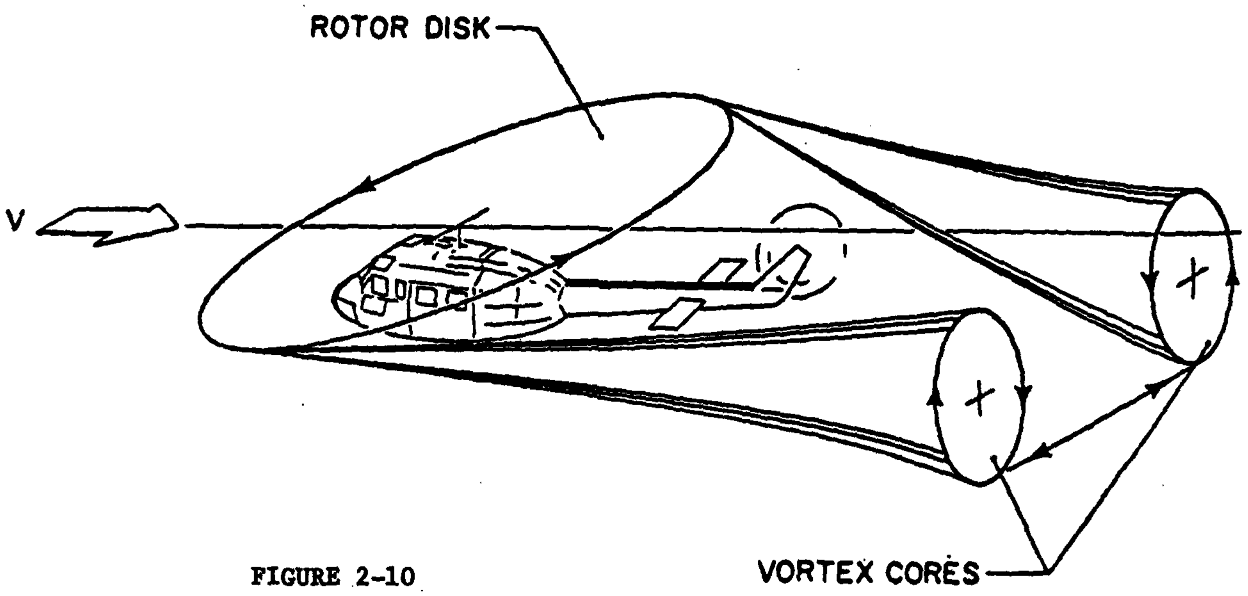


FIGURE 2-10

SIMPLIFIED VIEW OF HELICOPTER WAKE SHOWING
ROLLUP OF TWIN VORTEX CORES

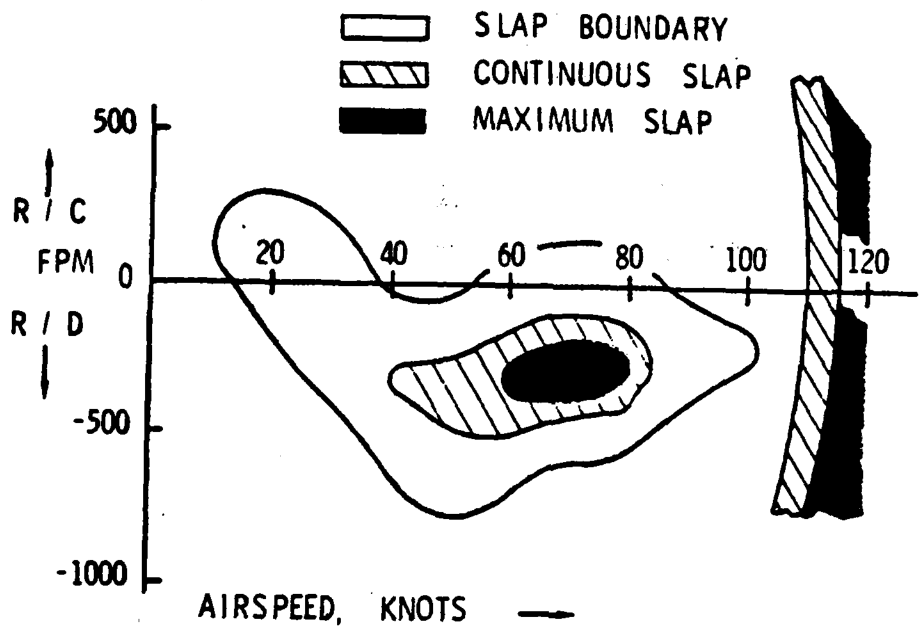


FIGURE 2-11 BLADE SLAP CONDITIONS FOR MEDIUM HELICOPTERS
--From "Flying Neighborly"

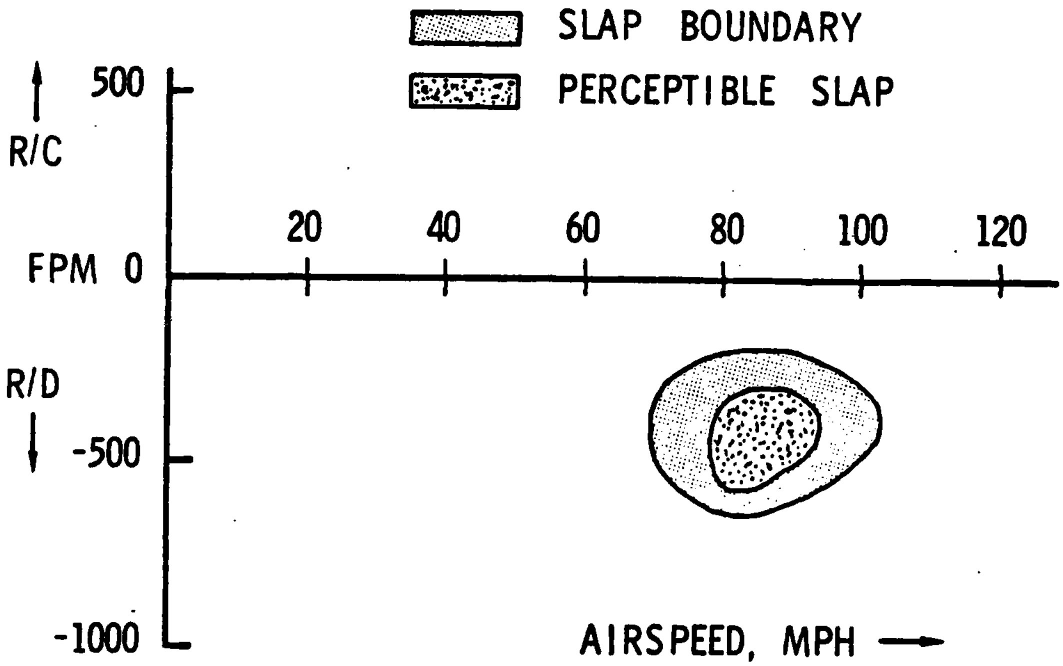


FIGURE 2-12 BLADE SLAP CONDITIONS FOR LIGHT HELICOPTERS UP TO 5000 POUNDS GROSS WEIGHT

--From "Flying Neighborly"

Planning the flight path to stay completely outside of the slap boundaries eliminates the most offensive type of helicopter noise. Remaining at the highest practical altitude before beginning descent, and selecting routes over least populated areas, are obvious methods of minimizing noise nuisance. Following inherently noisy ground routes, such as freeways or railway roadbeds, is one way to minimize increases in ambient noise levels. Having the helicopter begin descent before reducing airspeed, and then flying a somewhat steeper glide slope (6^o - 7^o) can reduce the noise footprint by as much as 80%.

On takeoff, using a high rate of climb and a smooth transition to forward flight minimizes the total ground area exposed to helicopter noise.

Conclusion

The U. S. helicopter fleet is composed of about 7000 aircraft and has been growing about 15% per year. The demand for helicopters in the petroleum industry is expected to double in the next five years. But the biggest growth in the civil helicopter market is expected to come from executive travel; one reason is that the average corporate executive spends 80% of his time within 200 miles of his home base. Within this range the helicopter is the fastest means of inter-plant travel, provided that the aircraft can be handled efficiently by the ATC system.

It is hoped that the information contained in this report will assist controllers in the safe and efficient handling of helicopter operations.

Acknowledgements

The preparation of this material was greatly assisted by the cooperation of Tom West and Al Futrell of the FAA Helicopter Staff, Alfred Gessow of NASA, Joe Kettles of Petroleum Helicopters, Inc., Joe Mashman, Hans Weichsel, and John Duhon of Bell Helicopter Textron. The noise abatement section was abstracted from "Flying Neighborly", by C. R. Cox of Bell Helicopter Textron.

SECTION 3
HELICOPTER NAVIGATION

LORAN C

Introduction. The present air traffic control system is based on the use of primary and secondary radar, as well as VHF/UHF navigation and communications. Unfortunately all these systems are subject to line-of-sight propagation; their signals are cut off by any intervening obstructions, including the curvature of the earth itself.

This characteristic becomes a limitation in the control of offshore helicopter traffic in the Gulf of Mexico area south of the Louisiana/Texas coastline. In this area helicopters seldom operate above 5000 feet and are usually much lower. Beyond 30 miles from the coastline, much of the helicopter traffic is beyond or below ATC radar, navigation, and communications coverage.

However, as shown in Figure 3-1, the area is blanketed by LORAN C coverage. LORAN C is a long-range hyperbolic navigation system which operates in the 100 KHz band and so is not subject to line-of-sight limitations. As a result, this system is being used by a growing number of helicopter users engaged in logistic support of the 6500 offshore platforms in this area. About 2400 of these platforms are equipped with helipads.

LORAN C has been selected as the US-provided radio navigation system for civil marine use in the Coastal and Confluence Zone (CCZ). Figure 3-2 shows the existing and proposed coverage of LORAN C around the continent of North America. The transmitting stations are operated under the jurisdiction of the U.S. Coast Guard (USCG).

The LORAN C system covers not only the CCZ and other waterways but also two-thirds of the land area of the contiguous 48 states. It is anticipated that LORAN C will be used increasingly to provide position information over land. To extend coverage to the entire 48 states will require three to five midcontinent stations.

SOUTH EAST USA CHAIN – GRI 7980

Diagram showing suggested secondaries to be used for obtaining the best fix and the best position line in different parts of the Ground Wave coverage area.

Figure 3-1. LORAN C Coverage in Gulf of Mexico Area

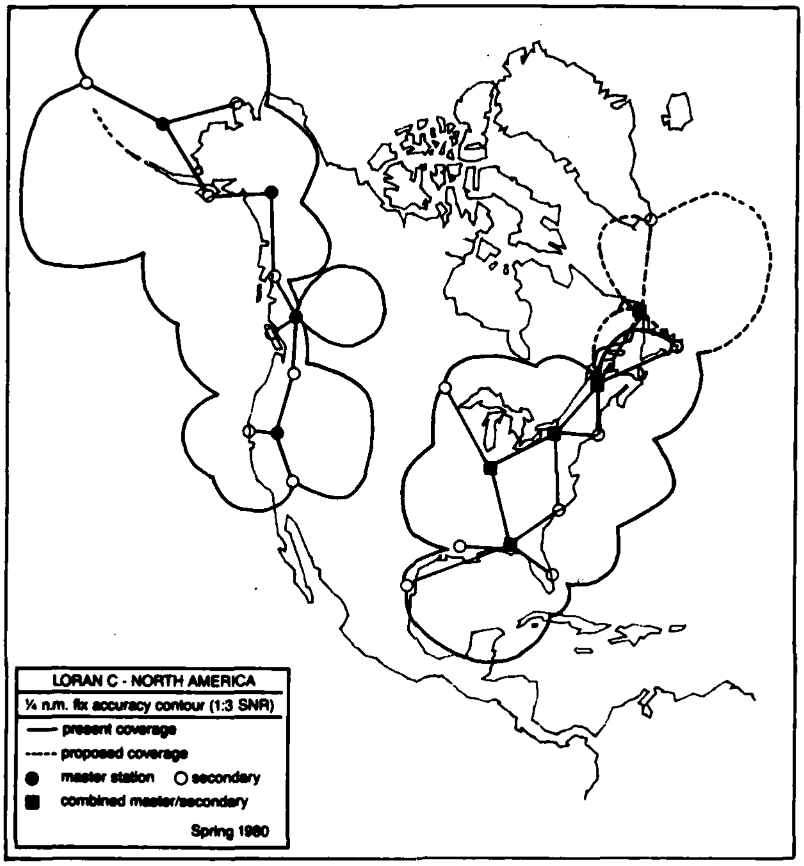


FIGURE 3-2 GROUNDWAVE COVERAGE OF NORTH AMERICAN LORAN C CHAINS

A joint program with the USCG has been established to evaluate the suitability of LORAN C for use by helicopters on the experimental Northeast Corridor RNAV routes. Continued and expanded joint programs with the USCG are being carried out to evaluate the suitability of LORAN C for use by helicopters in other areas.

Principles

LORAN C is a pulse type radio navigation system, in which the difference in arrival times of synchronized LORAN pulses transmitted from a master station and a secondary station is measured. The locus of all points having the same observed difference to a pair of stations is a hyperbola, called a line of position (LOP). Figure 3-3 shows a few of the LOP's generated by a pair of stations.

The intersection of two LOP's defines the position of the receiver. This capability is provided by pairing a master station with two secondary stations.

The master station broadcasts a series of 9 pulses, coded so that any LORAN C navigation receiver can identify it as the master signal. Secondary station A waits a precise interval and then broadcasts 8 coded pulses that identify it as a secondary station. The difference in the time of arrival of these two groups of pulses (or Time Difference A) at any LORAN receiver in the area determines which hyperbolic line of position the receiver lies along, as shown in Figure 3-4.

Secondary station B, after a longer delay than secondary A, broadcasts its own 8 coded pulses. The difference in arrival time between the master and secondary B signals (or Time Difference B) locates the receiver along a second line of position on a hyperbolic grid that is oriented in a different direction, as shown in Figure 3-5.

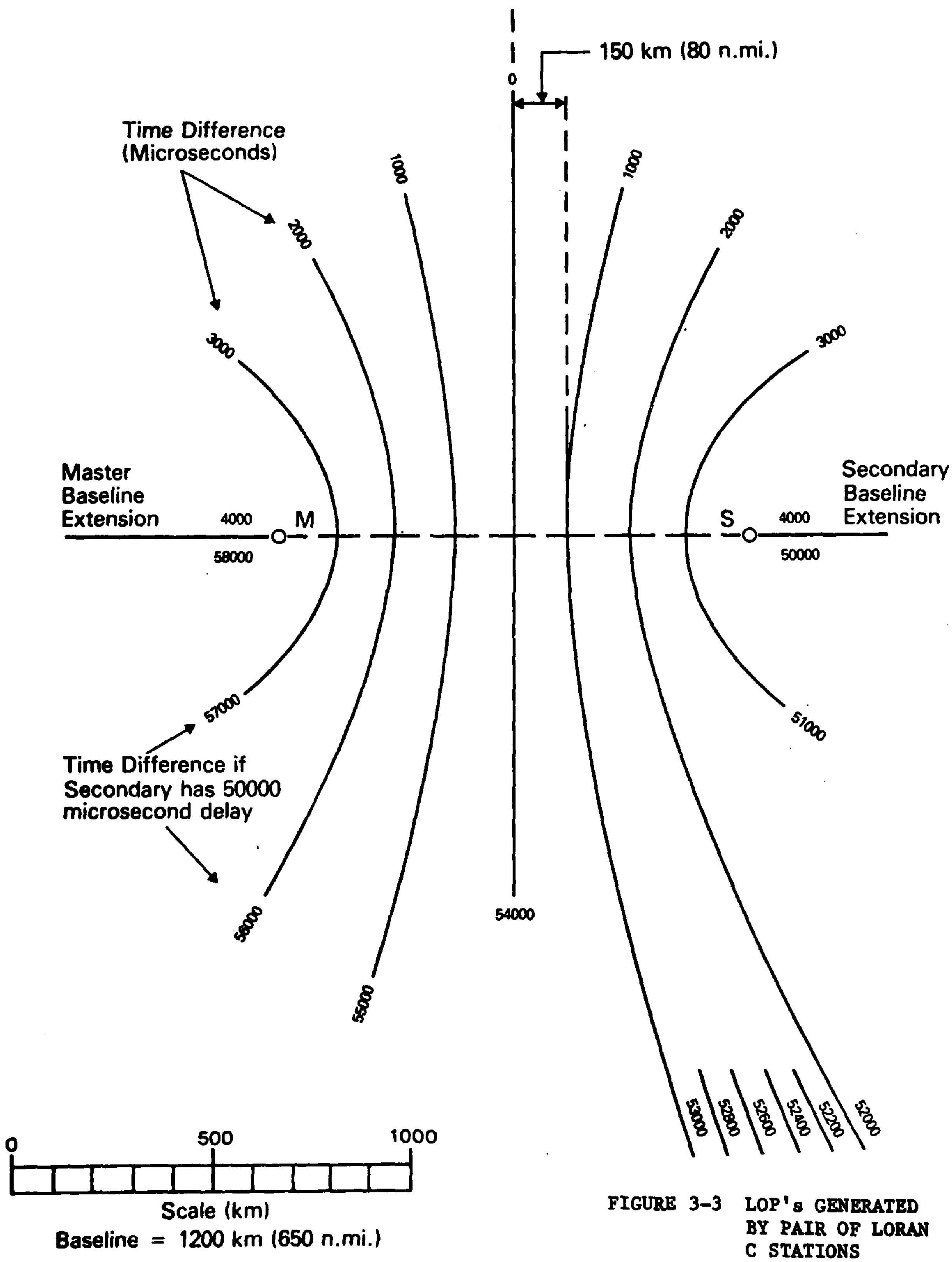


FIGURE 3-3 LOP's GENERATED BY PAIR OF LORAN C STATIONS

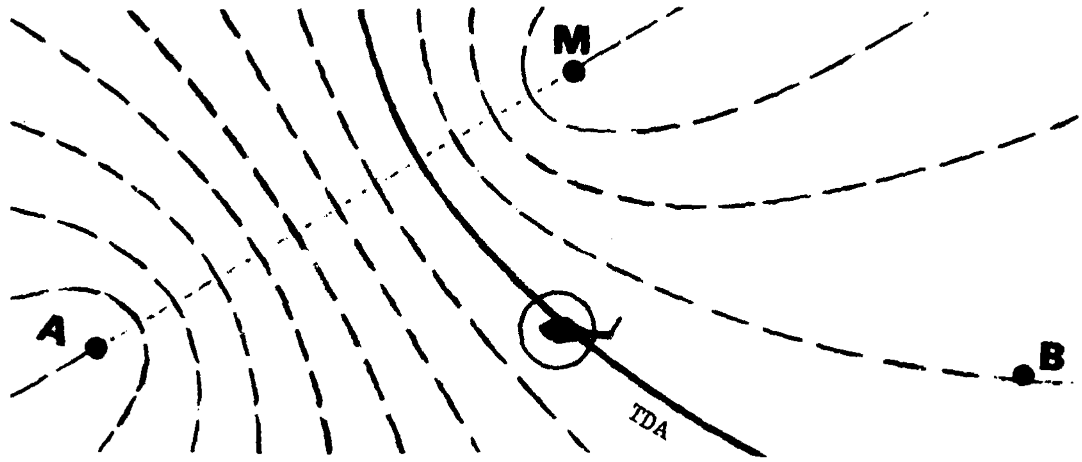


FIGURE 3-4 TIME DIFFERENCE A

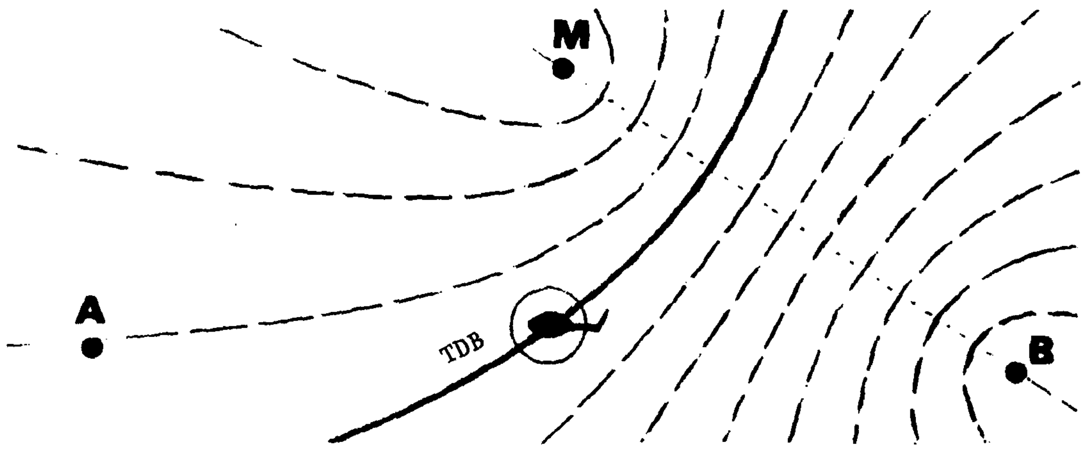


FIGURE 3-5 TIME DIFFERENCE B

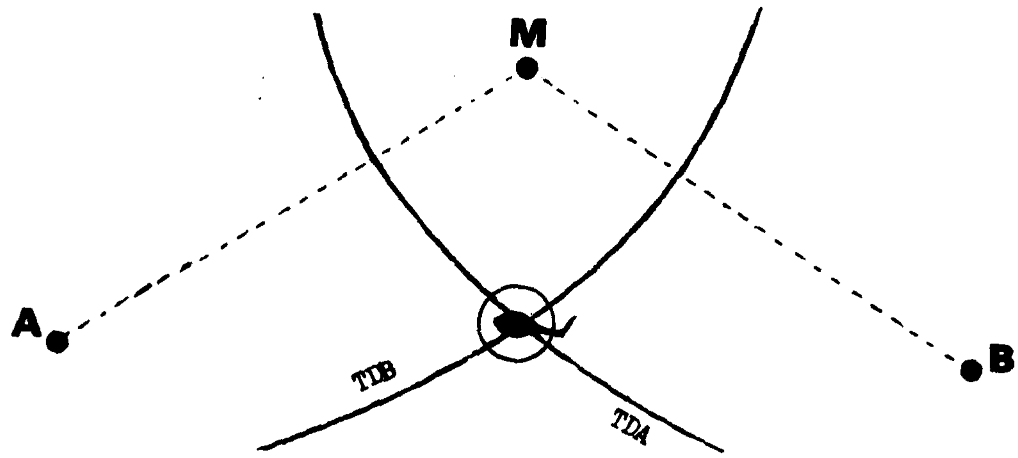


FIGURE 3-6 LORAN C FIX

When the two grids are superimposed on a common chart, the receiver position is known to be at the intersection of the two lines, as shown in Figure 3-6.

Geometrical Considerations. It may be noted from the above that various LOP's intersect each other at differing crossing angles, depending on the relative positions of the receiver and the 3 stations of the triad. As with the intersection of two VOR radials, the accuracy of a LORAN position fix is highest when the crossing angle is 90°, and the accuracy gradually degrades as the crossing angle decreases. In general, crossing angles of less than 20° should be avoided by switching to another triad, if possible.

The base line is the straight line between the master and a secondary station. A base line extension is a projection of this line in either direction, as shown in Figure 3-3. The use of baseline extension areas in any triad should be avoided where possible; in these areas small changes in time differences (TD's) represent large distances, and accuracy is degraded accordingly.

LORAN C system users and controllers should know what order of accuracy to expect from the system, and should be aware of any limitations or variations in system accuracy. The various types of errors are summarized below. More detailed data can be found in the relevant publications of the US Coast Guard and the US Defense Mapping Agency.

Variable errors. When the receiver is operating in the normal mode, errors that vary randomly with time will be at a minimum. In general, an allowance of plus/minus 0.25μs will cover these errors, except in high-noise or distant areas where the signal/noise ratio is low. This corresponds to a distance of about 37m (120ft) measured along the baseline. Away from the baseline the pattern expands and the distance corresponding to a given TD variation becomes greater. Variable errors affect the 'repeatability' of the system or the accuracy with which it enables the user to return to a position where a LORAN C fix was previously recorded. The USCG LORAN C User Handbook (Ref. CG-462) states "A LORAN C fix at a known location will normally vary less than 300 feet. In many areas the variation is less than 50 feet".

Fixed Errors. Radio waves travel at the rate of approximately 186,000 statute miles per second in free space; but the propagation speed of LORAN C ground waves is decreased slightly over land surfaces and particularly over cities and ice-covered areas. The result can be a slight displacement or distortion of the hyperbolic pattern, particularly in certain coastal areas where one of the signals travels mostly over sea-water while the other travels mostly over land. Such errors can be cancelled out by the pilot, using an area calibration procedure.

Weather effects. LORAN C performance can be affected by severe snow or by precipitation static. The special antistatic antenna used with the receiver is designed to minimize such effects.

Warning Signals. At the LORAN C transmitting stations precautions are taken to guard against interruption or malfunctioning of the emitted signals. If however a transmission should be significantly disturbed the chain concerned will transmit a 'blink' signal. The receiver recognizes this signal and displays a corresponding alarm.

Avionics. Modern airborne LORAN C navigation equipment displays TDA/TDB or lat/long information as desired, and also provides course guidance between any waypoints selected by the pilot. Up to 9 waypoints can be entered, either in terms of TD's or (preferably) in terms of lat/longs. Figure 3-7 shows the control display unit (CDU) of the TDL-711 LORAN Micro-Navigator. The display can be switched to the following positions:

POSITION	OUTPUT TO DISPLAY
WAY PT	Lat/long or TD's of selected waypoint
PRES POS	Lat/long or TD's of present position
DIST/BRG	Distance and bearing to selected waypoint
ETE/GS	Estimated time enroute and ground speed
OFST/VAR	Track offset distance and magnetic variation

As shown in Figure 3-8, a conventional Course Deviation Indicator (CDI) converts the outputs from the LORAN C receiver into steering needle commands. The CDI vertical needle provides an indication of cross-track distance; full-scale deflection represents a cross-track distance 1¼ nm left or right of course and is linear all the way across the scale. If the needle swings left the aircraft is off to the right of the selected course; the pilot "flies toward the needle" to get back on the selected course.

The steering needle NAV flag appears whenever steering information is not valid, i.e., when a new leg is being selected, when the receiver is not tracking a signal, or when a LORAN station is blinking. The TO/FR flag shows whether the aircraft is traveling to or from the selected waypoint.

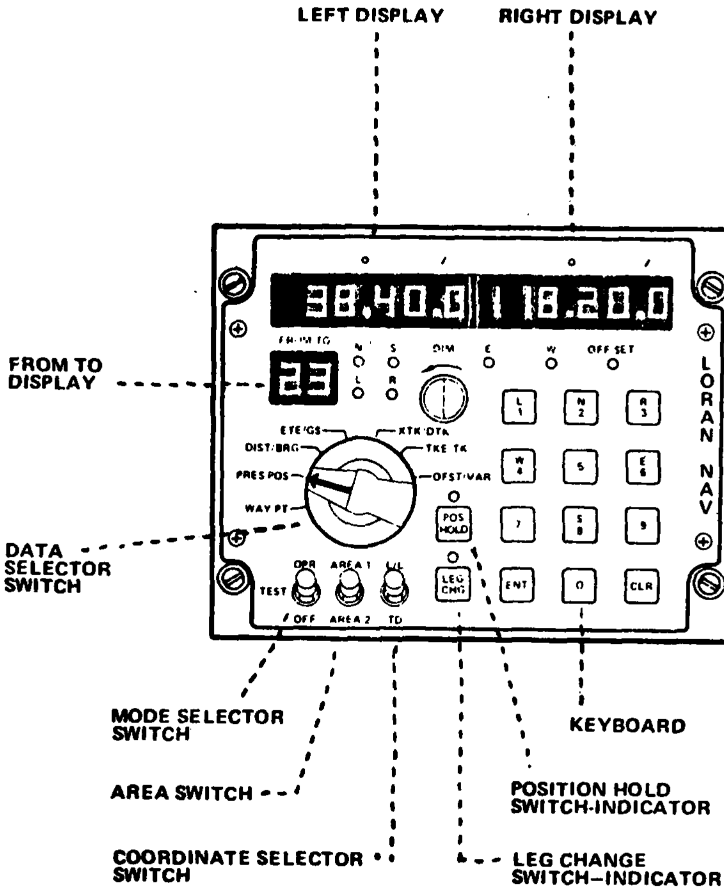
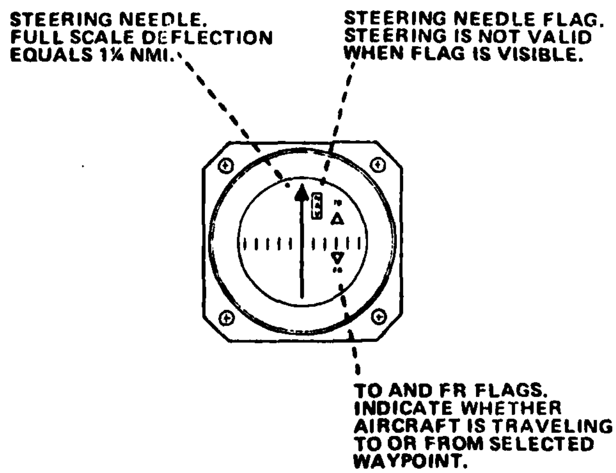


FIGURE 3-7 CONTROL DISPLAY UNIT (CDU)



FUGURE 3-8 COURSE DEVIATION INDICATOR (CDI)

Transmitter Failure: The use of Loran C in the Gulf region provides an extremely reliable and fail-soft system. Although the failure of a Loran transmitting station theoretically could affect a much larger geographical area than the failure of a single VOR station, statistics indicate that Loran C reliability is even higher than VOR. Coupled with this is the fact that most Loran C station outages are only momentary in nature; such gaps are bridged automatically by the TDL-711 receiver. Also, the availability of a third secondary station automatically provides a backup in case of prolonged failure of the master station or either of the two secondary stations in the selected trial.

In the event of signal loss from the master, or either of the two selected secondary stations, the TDL-711 goes into a dead-reckoning mode for 15 to 20 seconds.

Normally the interruption is over before that time; in which case the TDL-711 automatically recovers its new Loran C position and resumes normal operation.

If, however, the signal from the lost station is not received by the end of this 15-20 second period, the TDL-711 automatically switches the signal from the backup secondary station into the computer, and converts to the so-called master independent mode. During this conversion period, which lasts 20-30 seconds, the warning flag appears on the CDI and the decimal points light up steadily on the CDU.

When the conversion process is complete the warning flag disappears and the decimal points blink on and off to show that the system is again tracking, but not on the selected triad. In this case the accuracy may be degraded somewhat especially in terms of what is required for terminal and approach guidance.

Meanwhile the TDL-711 continues to search for the missing signal; as soon as it is re-acquired and tracked, the TDL-711 starts the conversion process back to the selected trial. During this conversion period, which last 20-30 seconds, the warning flag appears on the CDI and the decimal points light up steadily on the CDV.

When this conversion is complete the flag disappears and the decimal points are turned off to show that the equipment is back in the normal operating mode, on the selected triad.

Receiver Failure. Precipitation static, which can be a problem to Loran C reception in the Arctic, is not a problem in the Gulf of Mexico region.

If the aircraft is flying on instruments and the Loran C receiver fails, the following backups can be used:

- If the aircraft is still within VOR coverage, the pilot can use VOR navigation back to shore. Although not flight checked beyond 40 nm from the station over oceanic areas, the VOR signals are still available out to about 60 nm at helicopter cruising altitudes, and sometimes as far as 80nm.
- If the pilot is making an ARA approach to a platform, and already has the destination platform positively identified on the airborne radar, he will continue the approach.
- In all other cases the pilot will notify ATC, obtain a hard (exclusive) altitude, and use dead-reckoning navigation until he is back within VOR coverage.

LOFF (LORAN Flight Following)

Operating Concept. One of the most interesting applications of the LORAN C navigation system in ATC is its proposed use for automatic aircraft position reporting. The FAA is developing an experimental system which will generate a pictorial display of traffic operating in offshore airspace beyond radar cover. The system is called LOFF, which stands for LORAN Flight Following.

In this concept, each participating aircraft will transmit the position data received by its LORAN C navigation receiver, to the ATC facility (in this case the Houston Center). Each transmission will also include the identification code of the aircraft. The digital messages will be processed by a special computer at the ATC facility, to generate an alphanumeric PPI display which will resemble in many respects the automated displays produced by the NAS computer.

Figure 3-9 is a simplified diagram of the experimental LOFF system, which is being planned as a stand-alone system, independent of the NAS computer and the NAS displays. The display will not be used for the separation of traffic, but only as an enhancement to non-radar control operations.

Objectives. Separation standards based on procedural (non-radar) control will continue to be used. LOFF should enable controllers to make optimum use of such standards, by being able to exploit situations which might not be immediately obvious from scanning the flight progress strips alone.

LOFF will provide the controller with a graphic (CRT) display of aircraft identity, altitude, and position, along with the route structure being used. This will enable the controller to analyze the traffic situation faster, and with less mental effort, than from scanning only the tabular information on the flight progress strips.

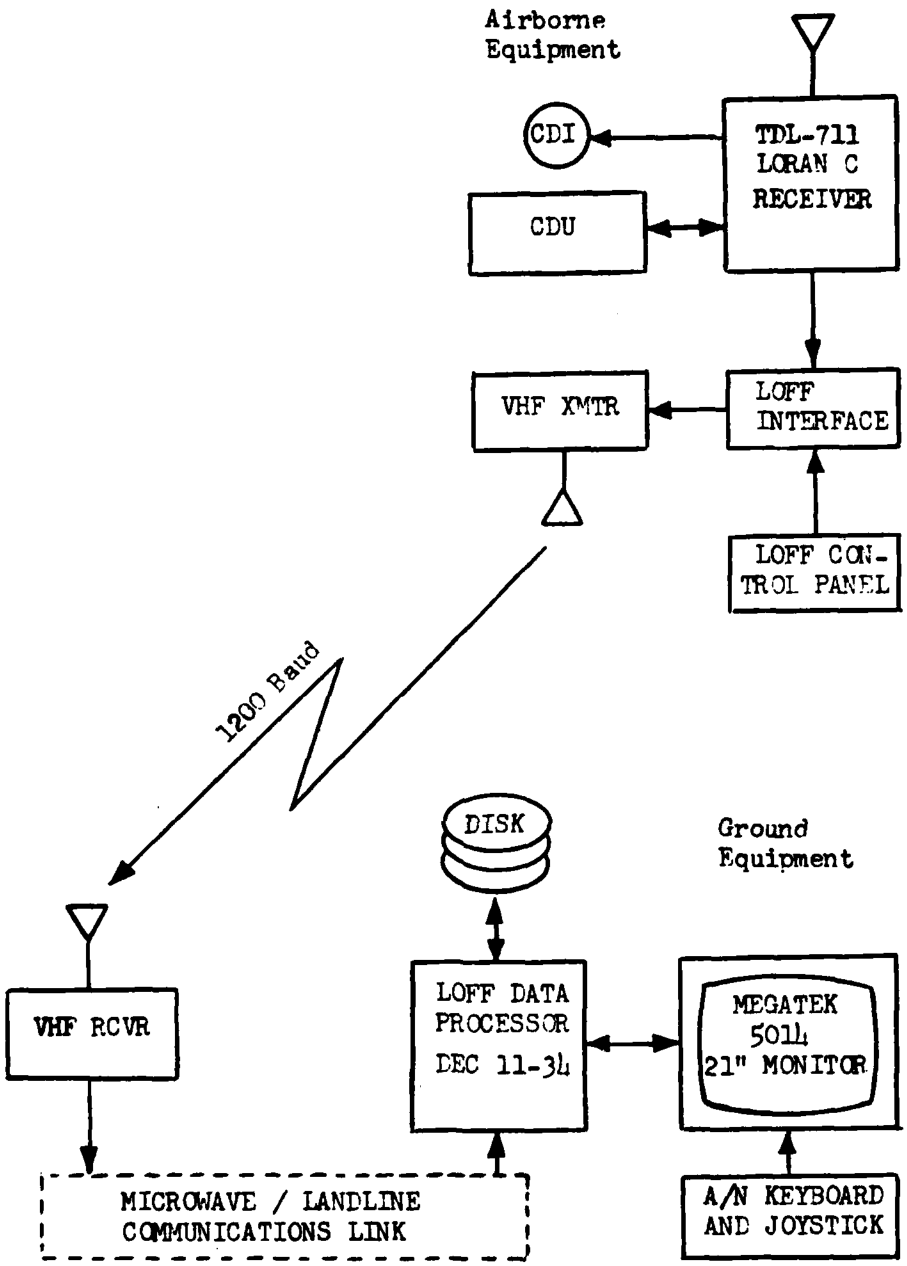


FIGURE 3-9. LOFF Concept

LOFF will provide the controller with a new degree of flexibility by being able to call up and display additional routes for off-airway traffic. These routes can be displayed on an as-needed basis, and erased instantly when not needed.

By being able to display the intended routes as well as the targets, LOFF will enable controllers to detect any navigational errors before they become critical. Other safety advantages are the ability to expedite medevac missions on direct routes, and to enhance search and rescue missions by being able to recall the last reported position of an aircraft in distress and to guide other aircraft to the same position.

Another objective of the LOFF test program will be to monitor the integrity of the LORAN C navigation system. Stationary LORAN C receivers will be installed at various locations to feed TD (time-difference) data to the LOFF computer. Here the data will be stored for later analysis of the performance of the navigation system.

Airborne Components. The experimental LOFF system will use LORAN C data from the TDL-711 LORAN C receiver in the aircraft. Outputs will be in the form of time differences (TD's), which will be fed to an interface box which stores the aircraft identification code and the latest LORAN C time difference data, for automatic transmission over one of the aircraft VHF transmitters. A digital message will be sent whenever a trigger pulse is received from a clock circuit in the interface box. The basic message repetition rate will be controllable, and will be randomized to reduce garble. Each message will require about ¼ second to transmit.

The pilot control panel will include the controls shown in Figure 3-10 although the actual arrangement may vary from the layout shown. The panel will include a 4-position switch which switches the output to either, neither,

CODE SETTING FOR MESSAGE REPETITION RATE	BASIC INTERVAL, SECONDS	RANDOM RANGE OF INTERVALS, SECONDS
0	*	*
1	15	13.5 - 16.5
2	30	27 - 33
3	45	40.5 - 49.5
4	60	54 - 66
5	90	81 - 99
6	120	108 - 132
7	180	165 - 195
8	240	225 - 255
9	300	270 - 330

* = Manual reporting mode only

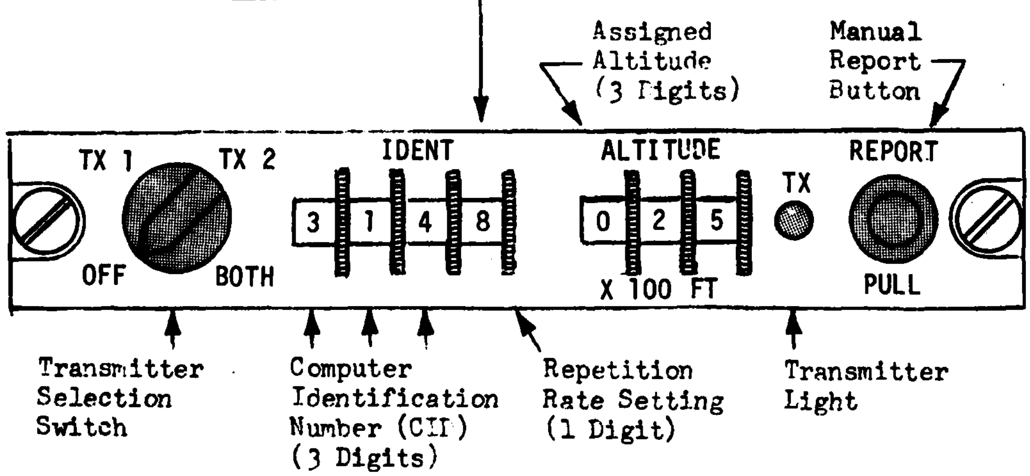


Figure 3-10 Functional Layout of Avionics Control Panel, with List of Message Repetition Rates Above

or both of the VHF transmitters in the aircraft.

The control panel will include four 10-digit (0-9) code switches for setting in the LOFF code assigned by ATC. This code is comprised of a 3-digit identification which will coincide with the computer identification (CID) of the flight plan. The fourth digit will control the message repetition rate, as listed at the top of Figure 3-10.

The panel will include three other 10-position switches which may be used for manually setting in the assigned altitude (in hundreds of feet). There is a future option to utilize automatically input altitude data (from aircraft equipped with altimeter transducers).

The control panel will include a manual button which, when operated by the pilot, will trigger the transmitter to send three complete messages in quick succession.

Communications Links. Offshore IFR helicopters carry two VHF transceivers for voice communication on company and ATC channels. For economy, the LOFF system will use one of these units to transmit digital messages over a VHF voice channel. The channels used for company air/ground VHF communications utilize remote VHF outlets which are linked to shore stations via a microwave network. The digital LOFF messages will go from the helicopter via VHF to one of these remote outlets, thence via microwave links to a shore station, thence via land lines to the LOFF computer in the Houston Center.

The Southwest Region of the FAA has plans to install several remote VHF outlets on strategically located offshore platforms, plus some improved and additional RCAG facilities on shore. The offshore FAA facilities will be connected to shore facilities via microwave links owned by the petroleum industry; the shore facilities will be linked to the Houston Center via land lines. Completion of this network will not only provide the necessary channels for LOFF transmissions, but will initiate the much-needed capability for direct ATC air/ground communication between the Houston Center and off-shore helicopters operating beyond the horizon.

Ground Equipment. The LOFF will be designed as a stand-alone system, not connected to the NAS Computer. It will utilize a DEC 11-34 Microprocessor, with disk storage, to decode the digital information received from the various aircraft, and present this on a CRT Display. The Microprocessor will also generate, from digitally-stored data, a background map showing relevant routes, airports, heliports, and landing platforms.

The interactive display control will include a standard alphanumeric keyboard, plus a joystick which will move an electronic cursor across the screen, to designate geographic targets on the traffic display or to call up data or commands.

When a LOFF flight plan is received by the NAS computer a proposed departure strip will be printed at the LOFF Sector, with a computer identification number (CID). Using the LOFF keyboard, the controller will type in the CID with the aircraft identification to associate these two data elements in the LOFF data processor memory. Then, whenever the processor receives a LOFF message with this CID, it will automatically print out the appropriate aircraft identification alongside the target position.

The LOFF display will be presented on a Megatek 5014 21" CRT Monitor. The symbology will duplicate, wherever possible, that used in the NAS system, in order to minimize training time, and to avoid confusion when transitioning to and from other sectors. Figure 3-11 shows some typical targets. Figure 3-12 shows a typical display.

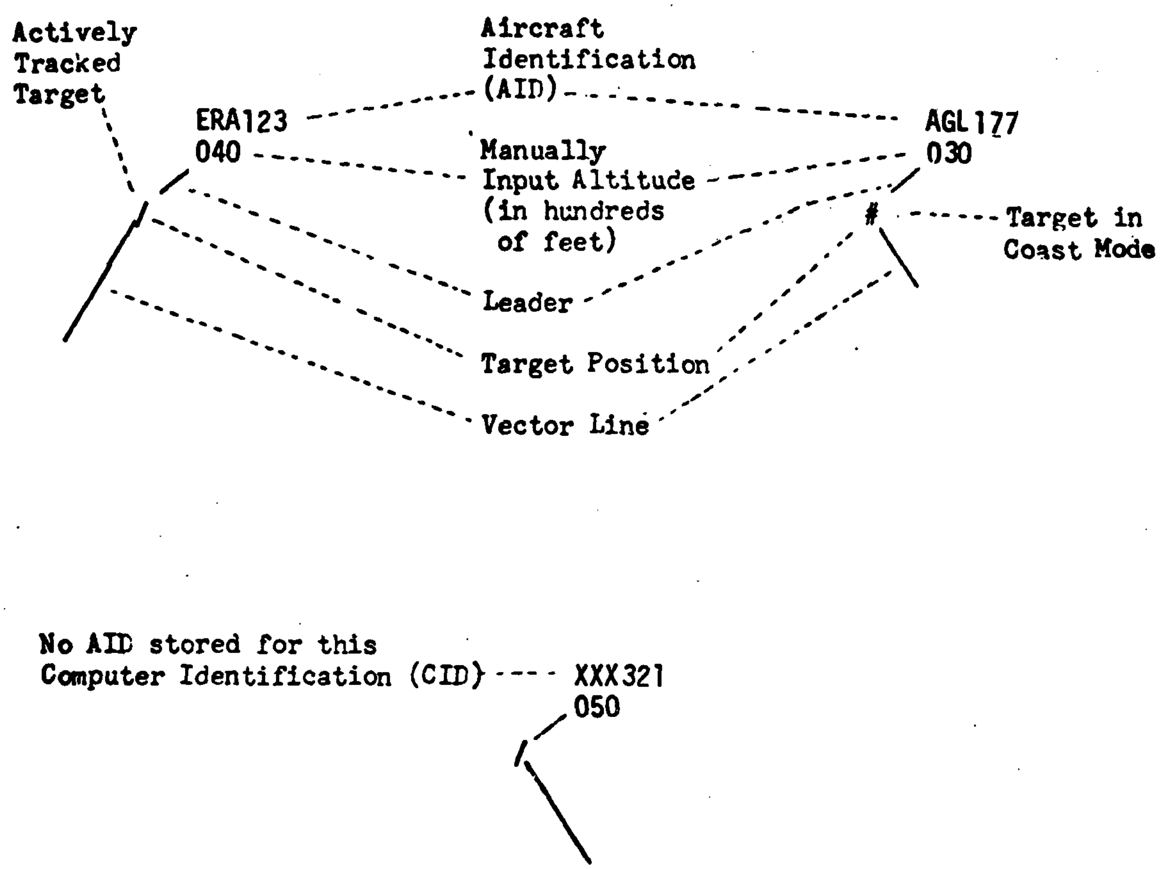


Figure 3-11 Typical Target Formats

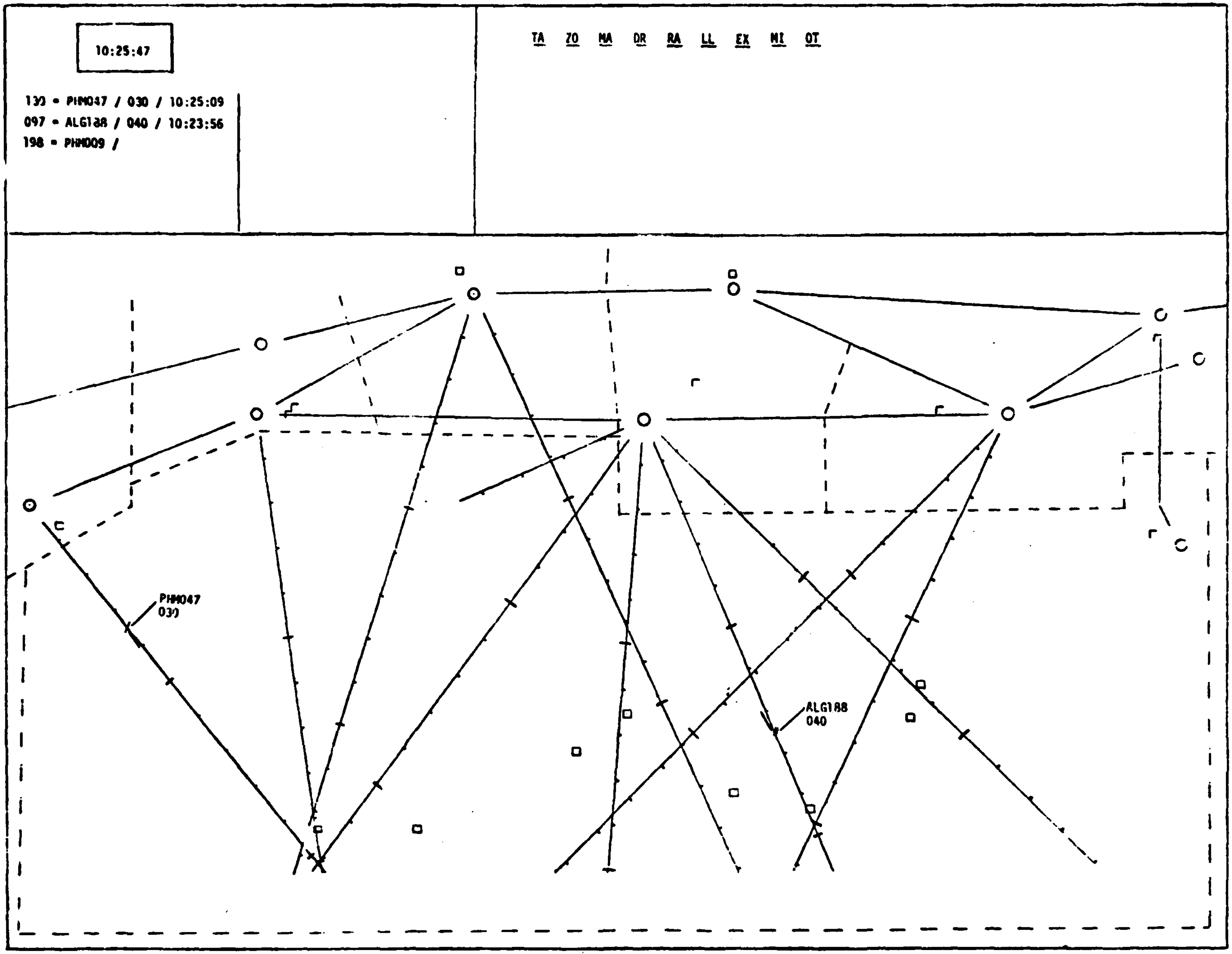


FIGURE 3-12 TYPICAL LOFF DISPLAY

Conclusion. LOFF is being designed to do a job that cannot be accomplished with today's system. If the Houston Area tests are successful, an improved system could provide similar advantages in the control of air traffic over a much larger volume of the world's airspace that cannot be covered by conventional ATC surveillance systems.

Omega/VLF

Omega is a very long range, very low frequency (VLF) hyperbolic navigation system used by aircraft, surface vessels, and submarines. The system was installed by the U.S. Navy, with the participation of the various other counties involved.

Omega operates on the 10-14 KH2 band, using continuous wave (CW) transmissions from eight stations which are designated and located as shown in Table 3-1 and Figure 3-13.

All stations are synchronized. Each station transmits sequentally on 3 frequiencies.

When all stations are operating at full power, the system will provide complete global coverage to all equipped users. However, Omega does not meet FAA requirements for navigation in the domestic airspace; the system is subject to accuracy and reliability limitations caused by sudden ionospheric disturbances, polar ice cap anomalies, precipitation static and atmospheric effects, as will as power level variation and power outages at some of the transmitting sites.

The basic data outputs of Omega receivers are Lines of Position (LOPs) within a lane. Because Omega receiver operation is based on phase measurement of a CW signal, the signal is ambiguous, in that one lane is 8 NM wide at the 10.2 KH_2 frequency. (In other words, from the standpoint of the receiver, the signal repeats itself every 8 NM). Use of 2-frequency and 3 frequency Omega receivers reduces this ambiguity somewhat by increasing the effective lane widths to 24 and 72 NM respectivally. However, the initial position must be known to within one lane width.

When the equipment is turned on the pilot must enter the position coordinates (correct to within one lane width). As long as the equipment is operating normally, it continually tracks and updates the aircraft position. But if normal operation is interrupted over a significant

TABLE 3-1 Omega Station Locations and Codes

CODE	NAME	LOCATION	
		LATITUDE	LONGITUDE
1	Norway	N66°25′	E13°09′
2	Liberia	N06°18′	W10°39′
3	Hawaii	N21°24′	W157°49′
4	North Dakota	N46°21′	W98°20′
5	La Reunion	S20°58′	E55°17′
6	Argentina	S43°03′	W65°11′
7	Trinidad (Temporary)	N10°42′	W61°38′
7	Australia	S38°29′	E146°56′
8	Japan	N34°36′	E129°27′

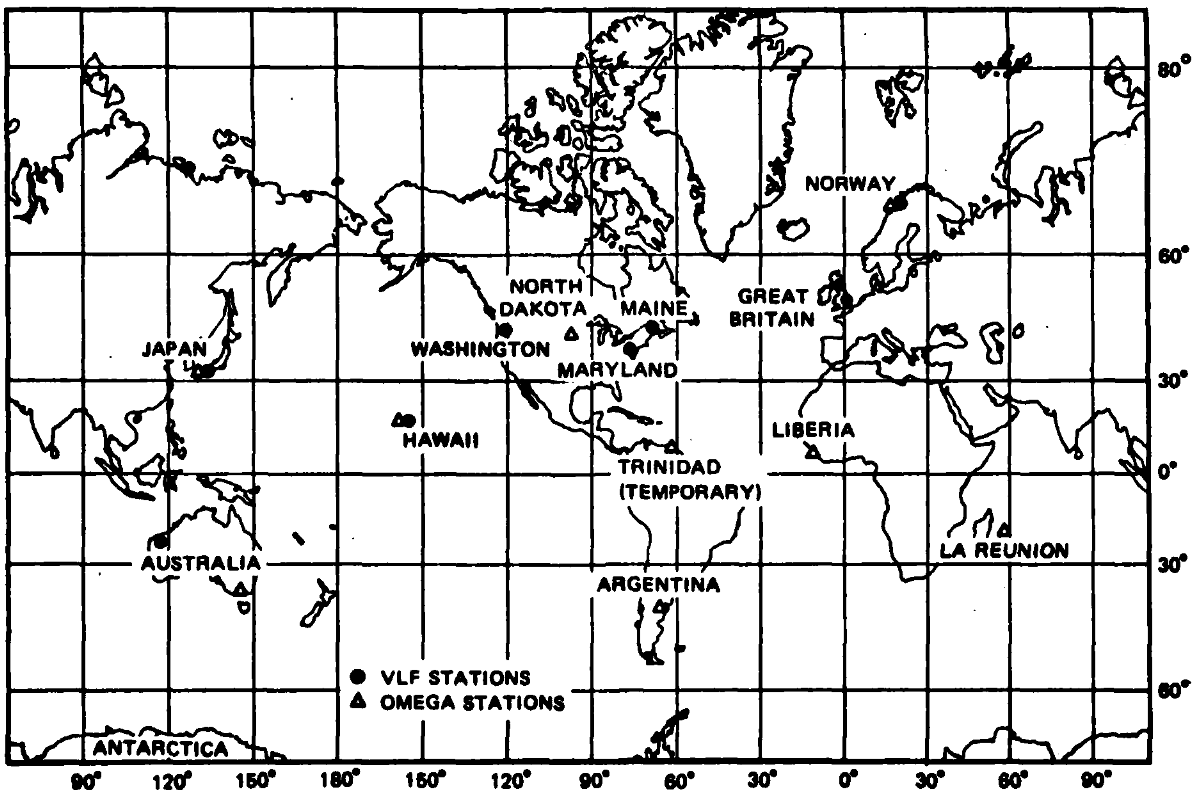


FIGURE 3-13 VLF AND OMEGA STATION LOCATIONS

period, the equipment will not necessarily recover its correct position automatically.

Some Omega receivers are equipped with a dead-reckoning mode, and switch automatically to that mode if a useable set of Omega signals is not being received, using the last known wind data.

Some Omega receivers can be equipped with a VLF option which allows the reception and processing of up to 9 stations from the worldwide communication network operated by the U.S. Navy. The location of these stations is listed in Table 3-2 and is shown in Figure 3-13. The use of the VLF stations to supplement the Omega network provides the Omega receiver with additional referencies, to reduce the probability of its having to revert to the Dead Reckoning mode.

A number of Omega sets are being used in offshore helicopter operation. However, because of accuracy problems, plus the higher accuracy and lower cost of the Loran C avionics now on the market, there is now a general trend toward the adoption of Loran C for offshore helicopter IFR operations.

Table 3-2 VLF Station Assignments

STATION DESIGNATION	LOCATION	LATITUDE	LONGITUDE
1	Great Britain (Rugby, England) 16.0 kHz	52°22'10"N	01°11'55"W
2	Norway (Helgeland) 16.4 kHz	67°04'00"N	14°04'00"E
3	Japan (Yosami) 17.4 kHz	34°58'15"N	137°01'19"E
4	Maine, U.S. (Cutler) 17.8 kHz	44°30'54"N	67°16'54"W
5	Washington, U.S. (Jim Creek) 18.6 kHz	48°12'12"N	121°55'00"W
6	Maryland, U.S. (Annapolis) 21.4 kHz	38°59'06"N	76°27'12"W
7	Australia (Northwest Cape) 22.3 kHz	21°49'00"S	114°09'48"E
8	Hawaii (Lulualei) 23.4 kHz	21°25'30"N	158°09'18"W
9	Great Britain (Anthorne, England) 19.0 kHz	54°54'54"N	63°16'24"W

AIRBORNE RADAR (ARA)

Weather Avoidance. Airborne weather radar scans the airspace ahead of the aircraft, to receive echoes from liquid or frozen water droplets in the area swept by the radar beam. The areas of precipitation are presented pictorially on the pilot's radar indicator, in terms of range and relative bearing. The relative density of the precipitation is shown by the relative intensity of the returns painted on the radar indicator; this characteristic is most important to the pilot, as heavy precipitation is usually associated with heavy turbulence.

Navigation. Most airborne radars have what is called a map or search mode, in which the antenna is tilted downward a few degrees, to scan the earth's surface instead of the clouds ahead. This capability is called ground mapping. It enables the radar to be used for navigation.

Ground mapping is especially well adapted to offshore navigation, due to the normally high contrast between the reflectivity of water and of solid objects. This capability enables the pilot to track shipping, spot oil rigs, and make landfalls. Figure 3-14 is a typical display of offshore targets. Radars used for offshore navigation must be able to suppress sea clutter, in order to avoid masking the desired targets.

Many offshore rigs are arranged in clusters. In order to obtain positive identification of an individual landing platform, some airborne radars have a beacon mode which is used in conjunction with a special coded transponder installed on the offshore rig. As shown in Figure 3-15, radar pulses from the aircraft trigger off single or dual-pulse replies from the transponder. For identification, the spacing between the dual

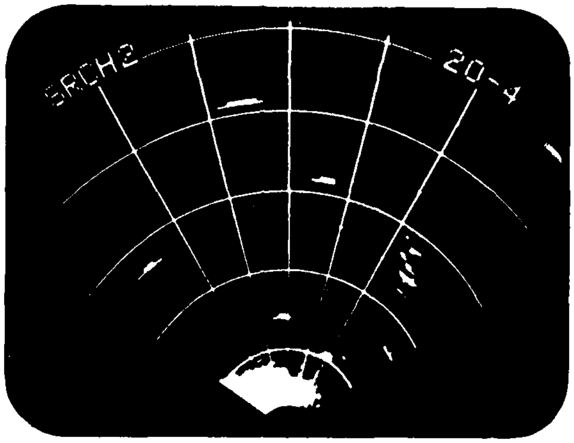


FIGURE 3-14 TYPICAL ARA DISPLAY OF OFFSHORE TARGETS

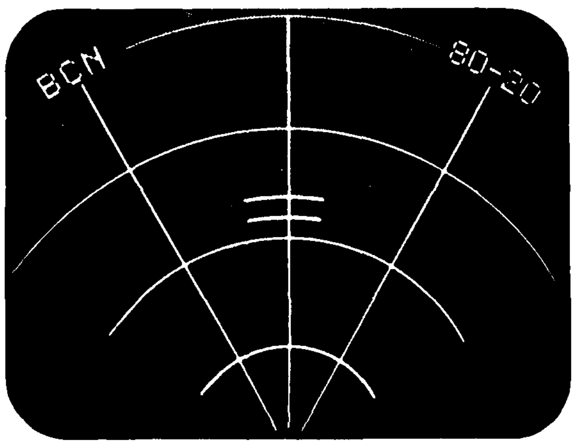


FIGURE 3-15 TRANSPONDER TARGET WITH 4 NM BLIP SPACING AT 44 NM RANGE

transponder reply pulses can be set to show spacings of 4, 6, 8, 10, or 12 miles between the twin blips on the radar display.

Early airborne radars were of the C-band type, which provided excellent weather detection capabilities at long range. In offshore helicopter operations, however, X-band radars are used because of their better performance at short range, and because of size and weight considerations.

A typical X-band radar transmits on 9375 kHz and receives the radar echoes on the same frequency. The oil-rig transponder receives the radar pulses on 9375 kHz and transmits its reply pulses on 9310 kHz. Switching the radar to the beacon mode allows the radar receiver to pick up the transponder replies on 9310 kHz, but then it may no longer be able to receive the radar echoes on 9375 kHz.

There is a remote possibility that a hazard could arise during a low approach if the radar was switched to the beacon mode and, unknown to the pilot a large vessel started to cross the final approach path in front of the helicopter. Therefore a need exists to display the radar returns simultaneously with the transponder replies. Some ARA's can do this, using a time-sharing principle.

ARA Approach Concepts

The FAA now authorizes the establishment of non-precision instrument approaches to defined points in space. In the Gulf of Mexico offshore area, LORAN C is used for enroute navigation, supplemented by ARA for approach guidance to the landing platform.

An ARA approach uses headings determined in the cockpit, from air-derived information -- instead of in an ATC facility, from ground-derived information. One pilot operates the radar controls and issues heading instructions (vectors) as well as range information to the other pilot, who flies the aircraft through the procedure.

A radio altimeter provides exact height information over the essentially uniform surface of the water, and is expected to become standard equipment for helicopters making ARA approaches to offshore platforms.

Usually the destination platform is visible on the ARA display from at least 25 miles out. Like ATC radars, airborne radars have various range settings. To obtain the most precise bearing and range information on the target, the pilot normally will reset the display range from time to time, to the shortest range setting which will include the destination target in the picture. He will also readjust the gain control as necessary to optimize target definition.

An FAA Advisory Circular now in process includes interim criteria for airborne approaches to offshore platforms. Figures 3-16 and 3-17 (from this document) show the dimensions required for the intermediate segment and the final approach segment for approaches to a single (isolated) platform and to a platform cluster, respectively. A cluster approach is defined as an approach to a platform which is less than 4 NM from any other stationary platform, rig, or drill ship.

Single Platform Approach

After determining wind direction and velocity at the platform, the pilot plans his approach to the downwind final approach position (DWFAP), which is located 4 NM from the destination platform. One operator uses the following criteria:

(1) If the wind velocity is 5 knots or less, the DWFAP is assumed to lie on the direct approach to the platform, and a straight-in approach is made, as shown in Figure 3-18A.

(2) If the wind is over 5 knots, the final approach will be made upwind in order to minimize wind drift corrections and rate of closure, thus giving the pilot more time to obtain visual contact with the

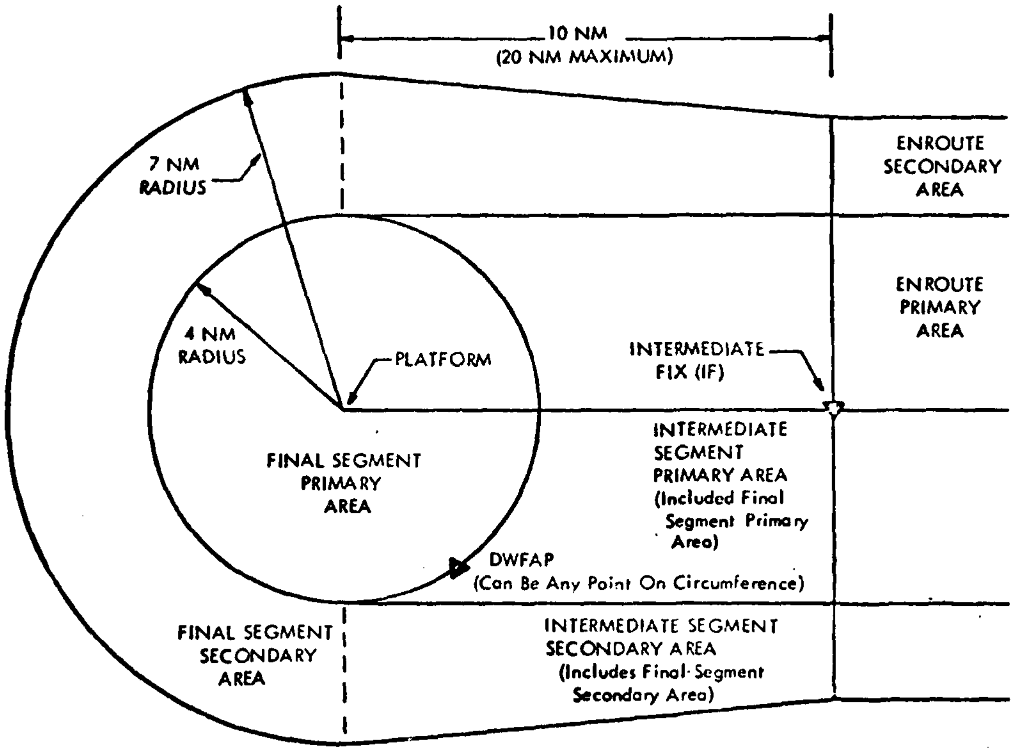


FIGURE 3-16 INTERMEDIATE AND FINAL SEGMENTS FOR SINGLE-PLATFORM APPROACH

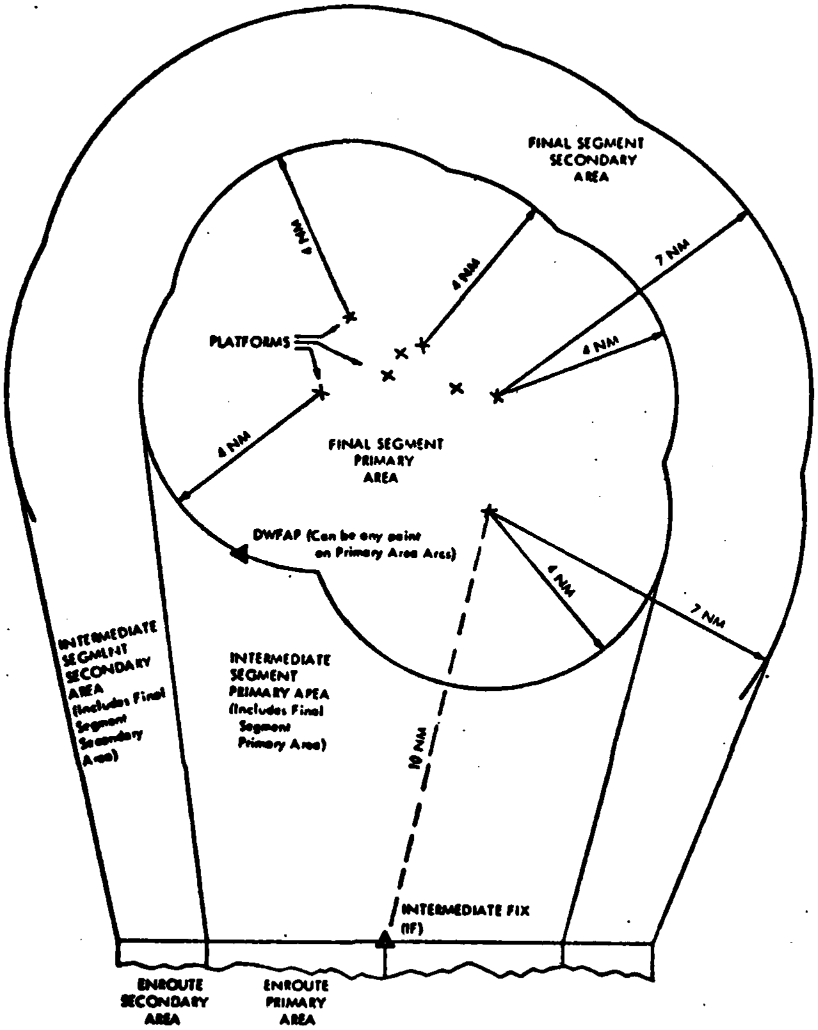


Figure 3-17 INTERMEDIATE AND FINAL SEGMENTS FOR PLATFORM CLUSTER APPROACH

platform. If the angle between the final approach course and the direct course to the platform, is 45° or less, the pilot has the option of proceeding direct to the DWFAP to start a straight-in final approach, as shown in Figure 3-18B.

(3) In all other cases, the pilot makes an overhead approach, then begins a teardrop pattern to bring the aircraft across the DWFAP inbound on the final approach, as shown in Figure 3-18C.

In all cases, descent from the intermediate altitude to the minimum descent altitude is made on the final approach course inside the primary area.

If the platform is not in sight at 1 NM radar range, a 10° turn is made for a fly-by approach. If the platform is still not in sight by the time the aircraft reaches the Missed Approach Point (MAP) the pilot executes the missed approach procedure. Unless otherwise specified, the missed approach path includes a climbing turn back to the intermediate fix. (See Figure 3-19)

Platform Cluster Approach

After determining the wind direction and velocity at the intended landing platform, the pilot selects a target platform on the perimeter of, and on the downwind side of, the cluster. A perimeter platform is selected so that the aircraft will have an unobstructed climbout path if a missed approach becomes necessary. The pilot then sets up a DWFAP for approach to the target platform. The DWFAP will be located on the curved perimeter of the final approach primary segment area, as shown in Figure 3-17.

If the target platform is not the intended landing platform, the pilot will carefully pre-plan his route from the target platform to the intended landing platform, to stay clear of intervening obstructions.

The pilot starts his final approach inbound from the DWFAP to the target platform. If the platform is not in sight at 1 NM radar range, a

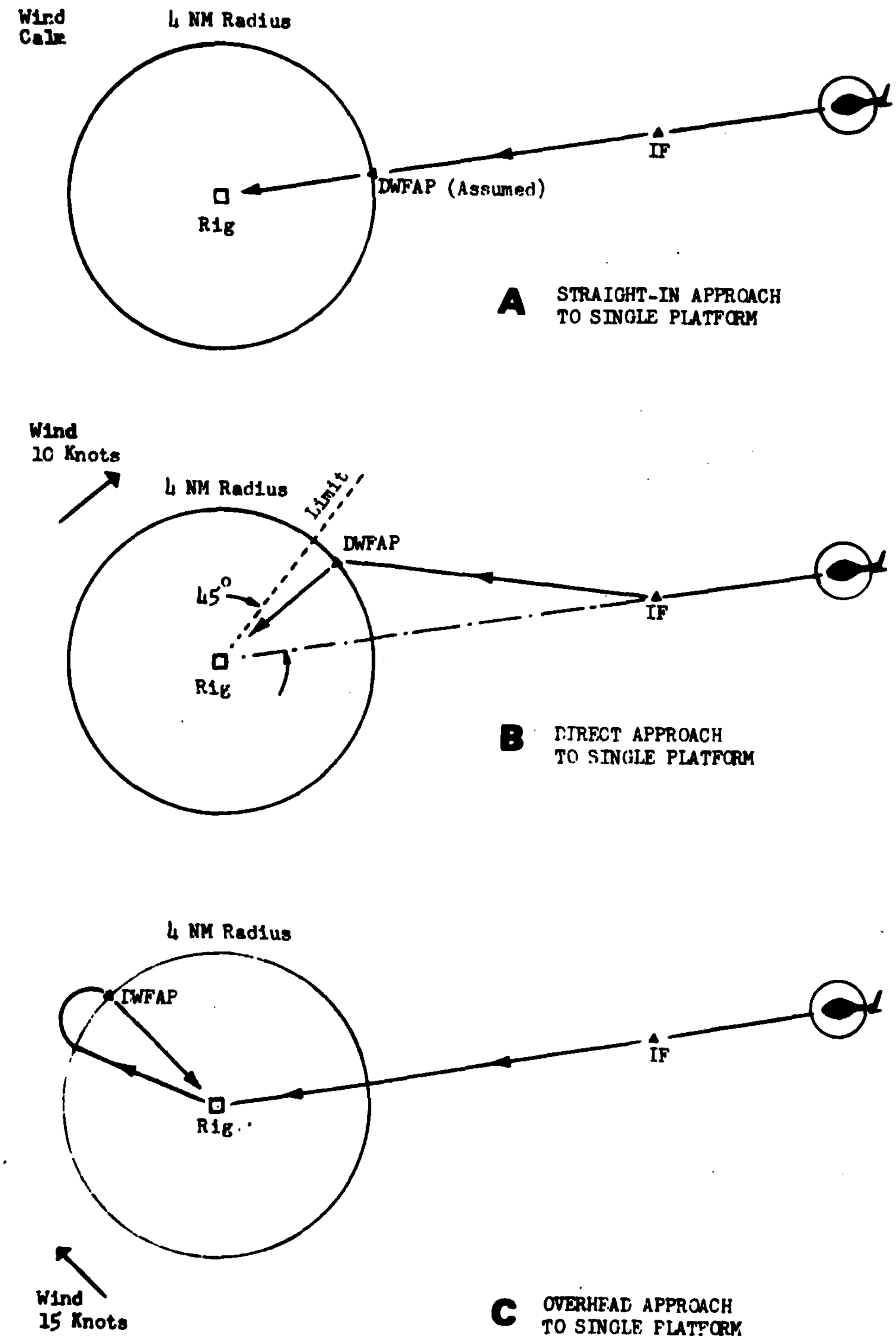


FIGURE 3-18 ARA APPROACHES TO SINGLE PLATFORM

10° turn is made for a fly-by approach. If it is still not in sight at the Missed Approach Point (MAP), the pilot executes a missed approach procedure. However, if the platform is in sight before reaching the MAP, the pilot proceeds visually to the platform of intended landing, using the radar as a supplementary aid for guidance and for avoiding obstructions.

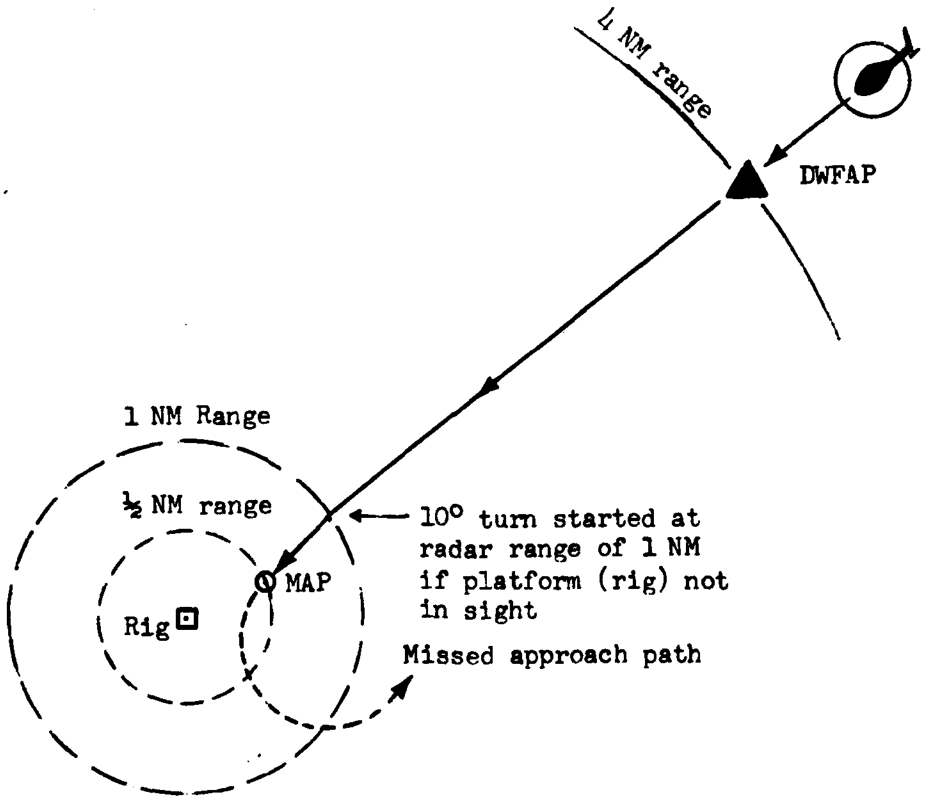


FIGURE 3-19 MISSED APPROACH PATH

TACAN

TACAN (Tactical Air Navigation) is used for offshore helicopter navigation in the Gulf of Alaska. In this case, the TACAN is located on the offshore platform where it transmits azimuth and range information for navigation and non-precision approaches to the rig. As the platform is less than thirty miles from shore, the line-of-sight limitation of this navaid presents no operational problem to helicopters in this case.

As shown in Figure 3-20, final approaches can be made from any direction, depending on the wind. The same procedures shown in Figure 3-18 would be employed unless the aircraft has an RNAV capability, in which case the 45° limit shown in Figure 3-18B would not necessarily apply.

The final approach starts from a downwind final approach point (DWFAP) which is selected in the same manner as that previously described for ARA approaches. The DWFAP is located on the 4.0 DME arc. It will be noted from Figure 3-20 that the ceiling minimum is reduced 140 feet when an airborne radar is in use.

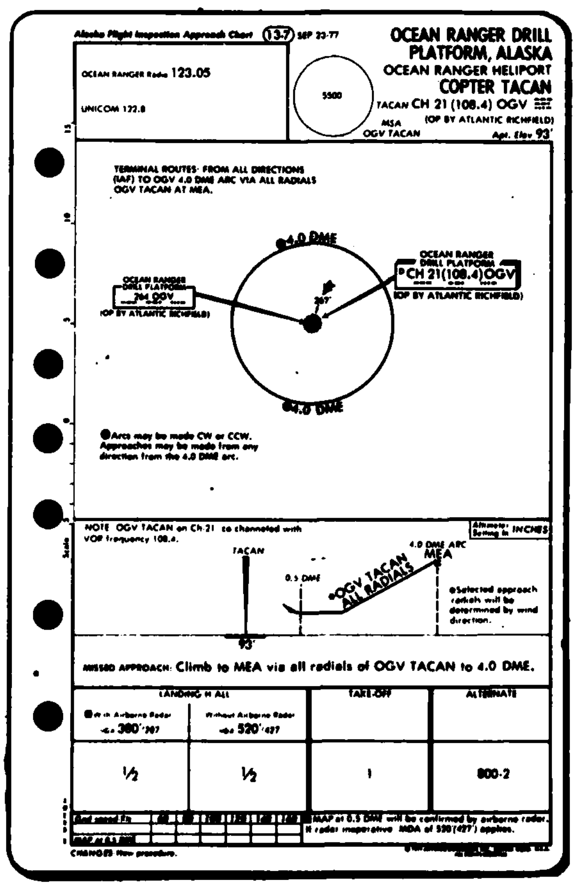


FIGURE 3-20

TACAN APPROACH TO OFFSHORE PLATFORM

SECTION 4

HELICOPTER CONTROL PROCEDURES

Terminal Procedures

The design of helicopter IFR arrival and departure procedures is governed by the obstruction criteria in TERPS (Terminal Instrument Procedures). Some changes in these criteria are expected during the next year, in order to take advantage of the unique flight characteristics of the helicopter.

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 Section 14, Paragraphs 1140-1141 of Air Traffic Control Handbook 7110.65B.

Some towers have refused to permit HSVFR procedures. It is possible that the wording of Paragraph 1141 has led some facility chiefs to believe that a Letter of Agreement is required before any HSVFR operations can be approved. Such was not the intent of the wording.

It is also possible that the sheer complexity of the HSVFR rules, with their many qualifying restrictions, has 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 at least make the applicable rule easier to find and remember. To this end, a matrix has been prepared which shows the applicable reference for each of the various arrival/departure combinations involving HSVFR operation. This matrix is shown in Table 4-1. Example A in this table shows that the required separation for the combination of an HSVFR helicopter arrival and an IFR fixed-wing arrival which is making a straight-in approach and is more than 1 NM from the runway, is covered by Paragraph 1141 b (1).

TABLE 4-1

APPLICABLE PARAGRAPH REFERENCES IN ATC HANDBOOK 7110.65B COVERING SEPARATION MINIMA FOR HSVFR HELICOPTER OPERATIONS

AIRCRAFT → COMBINATIONS ↓			HSVFR HELICOPTER DEPARTURE	HSVFR HELICOPTER ARRIVAL
HSVFR HELICOPTER	DEPARTURE		1141a	1141a
HSVFR HELICOPTER	ARRIVAL		1141a	1141a
IFR FIXED-WING	DEPARTURE	<1/2 NM BEYOND RUNWAY	1141e	1141d (1)
IFR FIXED-WING	DEPARTURE	≥1/2 NM BEYOND RUNWAY	1141e	1141d (2)
IFR FIXED-WING	STRAIGHT-IN APPROACH	<1 NM FROM RUNWAY	1141f	1141b (1) ← Example A
IFR FIXED-WING	STRAIGHT-IN APPROACH	≥1 NM FROM RUNWAY	1141f	1141b (2)
IFR FIXED-WING	CIRCLING OR MISSED APPROACH		NOT AUTHORIZED	1141c

From Table 4-1, a second table (4-2) has been prepared, which lists the actual separation standard for each aircraft combination. Thus the HSVFR criteria can be summarized in a chart small enough to be posted at the local control position in the control tower.

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 Figure 2-3 of Section 2).

The safety of simultaneous HSVFR arrivals with fixed-wing 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 path-stretching (radar vectoring). At low helicopter airspeeds, holding patterns and 360° turns require only a small amount of airspace. The helicopter should not be asked to hover for delay purposes. Hovering requires high power with relatively high fuel comsumption.

TABLE 4-2

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

IFR Arrivals

Sequential Approaches on Common Path to Airport. The integration of helicopter and fixed-wing arrivals in the same approach path presents problems because of the difference in the approach speeds of the two types of aircraft. This normally results in a very long gap in the approach sequence whenever a helicopter follows a fixed-wing aircraft down the final approach path. Although this gap can sometimes be used to advantage in clearing extra departures, it generally results in lost runway capacity, and delays to succeeding aircraft.

The gap can be shortened either by having the helicopter fly the final approach at a speed considerably higher than its normal approach speed, or by making a short turn-on to keep the common path as short as possible. A research program has been planned to determine the practical parameters for short helicopter approach paths, using various types of approach aids.

Sequential Approaches on Different Paths to Airport. When an airport has approved approach procedures from different directions, it sometimes is practical to use one approach for fixed-wing aircraft and another for helicopters, as shown in Figure 4-1. Normally the convergence angle between the two approach courses should not exceed 90°. In this case a close-in holding fix is established for helicopters, which are cleared off this fix on short notice, to use time-slots between fixed-wing arrivals on the other approach path.

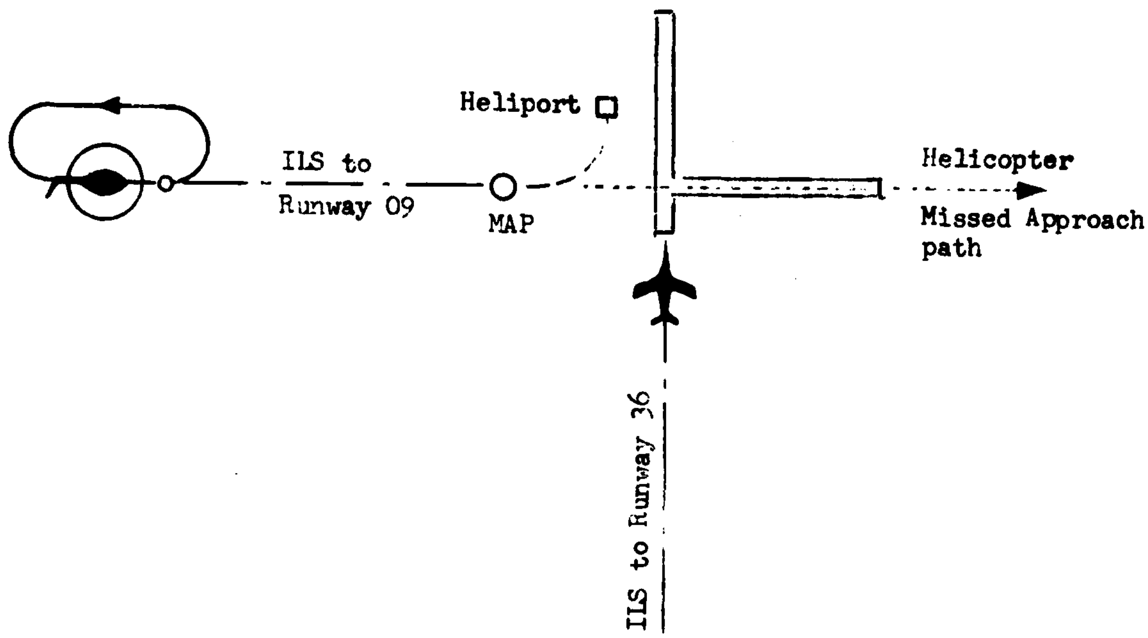


FIGURE 4-1. SEQUENTIAL APPROACHES ON DIFFERENT PATHS TO AIRPORT

Simultaneous Approaches on Different Paths to Airport. If it is possible to lay out the helicopter approach and missed approach areas so that they are completely clear of fixed-wing approach and missed approach areas, it should be possible to run simultaneous helicopter and fixed-wing approaches. Ideally, as shown in Figure 4-2, the convergence angle between the approach courses should not exceed 45°. This will enable the helicopter to make a 90° turn and diverge immediately from the fixed-wing traffic, if a missed approach becomes necessary. The MAP (missed approach point) is placed far enough back from the airport that the helicopter will always be able to complete this maneuver without encroaching on the fixed-wing airspace.

Approaches to Heliport. Normally, helicopter operators would prefer to stay out of congested airports and use separate heliport facilities. With the exception that helicopter approaches probably could be shorter and steeper than those presently required for fixed-wing aircraft, with shorter-radius turns and greater allowance for wind drift, there need be little difference from present procedures, in the way IFR helicopter arrivals will be vectored and sequenced into an IFR heliport.

Missed Approaches. A number of existing helicopter approach procedures have missed approach paths which simply make a 180° climbing turn and return to the initial holding fix. This is adequate if there is very little helicopter IFR traffic, but would tend to reduce capacity and increase delays in busy periods,as each aircraft blocks the entire approach path and the lowest useable altitude at the holding fix, until the aircraft reaches a point where it is assured of landing, or the pilot can cancel his IFR clearance.

Nearly all IFR helicopters are equipped with some form of area navigation (RNAV). There is a need to change the TERPS criteria, to give credit for the added flexibility and accuracy of RNAV equipment. Such credit is particularly needed in reducing the length and width of the missed approach area. With RNAV the pilot knows his position continuously, and can anticipate the exact time when he will be over the MAP. Therefore he can start his missed approach procedure the moment he reaches this point.

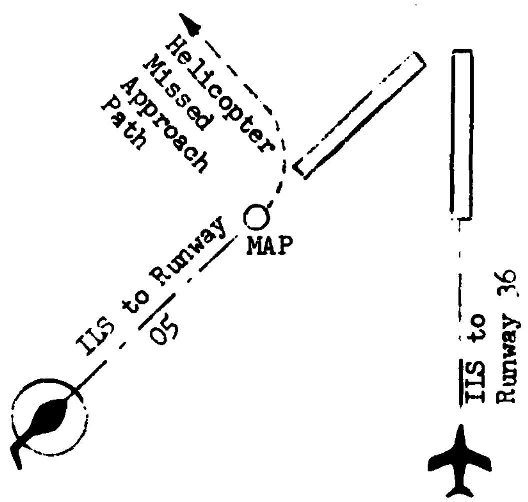


FIGURE 4-2 SIMULTANEOUS APPROACHES

The pilot has three other advantages by being in a helicopter instead of a fixed-wing aircraft: (1) he can arrest his descent without height loss, instantly at decision height; (2) he can start his missed approach climbout without changing the aircraft configuration and without needing to wait for engine spoolup; (3) he can start a turn immediately. All these points should be given consideration in changing TERPS criteria for the length of the missed approach path for an RNAV-equipped helicopter.

In addition, criteria regarding the width of the missed approach area for such aircraft should be reconsidered in light of the fact that with RNAV, there is no reason why navigational guidance along the missed approach path should be any less accurate than guidance down the final approach path.

Until the TERPS criteria are changed, however, the missed approach area will remain excessively large for this type of aircraft.

IFR Departures

The layout of standard IFR helicopter departure routes usually involves a compromise between a number of requirements, some of which may be mutually conflicting. The following discussion is intended as a kind of checklist for ATC planners, to ensure that all important factors are given due consideration in arriving at an optimum configuration.

Few helicopters need to start their takeoff from a runway. If the wind velocity is over 5 knots, the liftoff and initial climbout are made into the wind. However the helicopter can turn in any direction as soon as it has reached an airspeed of about 40 knots.

From the standpoint of fuel economy the ideal departure procedure for any flight would be straight out on course. However, from the standpoint of air traffic control it would be advantageous to keep the helicopter departure path as clear of fixed-wing paths as possible. Where this is impractical, any possible points of interference should be within ATC visual or radar surveillance coverage.

Environmental considerations may make it desirable to keep the departure path away from noise-sensitive areas, particularly when alternate routes are available. From the safety standpoint, flight paths obviously must have adequate clearance from obstructions.

Departure routes should be navigable by the pilot. With RNAV, a high degree of flexibility is available, so departure routes need not be confined to ILS localizer courses and VOR radials, provided that the aircraft will always be within VOR/DME coverage.

Because departures must be separated from arrivals, it may be possible for helicopter departure routes to coincide with helicopter missed approach paths, in order to conserve airspace in highly congested terminal areas.

Enroute Control

Over the years, the ATC system has developed into an exclusively ground-based system, with all control decisions being made by controllers in terminal or enroute ATC facilities. The provision of separation between fixed-wing aircraft operating under IFR has been designed and built around the use of surveillance radars. Navigation and approach aids, as well as the air/ground communication system, are based on the use of the VHF and UHF bands, which have the advantage of being relatively free of atmospheric noise, but which are subject to line-of-sight cut-off characteristics.

The helicopter is a relatively low-altitude vehicle. Its specialized uses will take it below and beyond radar and communications coverage, not only in offshore airspace but in domestic airspace as well. For this reason the use of procedural control will need to be applied, in geographical areas that have long been subject only to the use of radar control procedures; local training programs should re-emphasize familiarity with the use of time separation.

The characteristically slow speed of helicopters increases the relative effect of the wind on ground speed and wind drift, as any given wind velocity represents a greater percentage of the airspeed of a helicopter, than the airspeed of a jet transport.

The short range and the high flexibility in the choice of landing sites has increased the need for helicopters to be able to fly direct routes between selected random waypoints, in order to operate efficiently. A significant percentage of these routes would be off the established airways.

Today's ATC system is not well adapted for handling random route traffic between off-airway waypoints. One problem has been the difficulty for controllers to visualize where some of these points are if they are not shown on the video map. However, it would not be desirable to show all of these points on the video map, as this would generate a very confusing problem on the radar scope. What is needed is a method of calling up certain random waypoints for display on the PVD and ARTS displays, on an as-needed basis. The LOFF display described in Section 3 will have this capability.

These routes could be called up either automatically by flight-plan input, or manually by reference to lat-long or VOR/DME coordinates. Implementation of this capability would enhance the capability of the ATC system to control off-airway traffic; and in doing so would enhance significantly the use of area navigation systems.

The capability to control random-route traffic on a routine basis will determine whether the full potential of IFR helicopter operations can ever be realized. This capability is also applicable to normal domestic IFR aircraft in all categories. The more specific limitation is the human factor limit to control only a small number of aircraft on conflicting courses at a given time.

SECTION 5

TRAINING RECOMMENDATIONS

This manual represents an initial effort in the assembly of basic information relevant to the control of helicopter operations in the ATC system. It is intended that this material be adapted and incorporated as deemed appropriate by the FAA Academy, in the development of programs for the initial training of ATC personnel.

Some of this material will be more applicable to terminal facilities, and other material more adaptable to enroute facilities; also, the relevance of certain material may vary in different parts of the country. Therefore it is to be expected that Regional and Facility Training Officers will adapt this material to the needs of their own programs for recurrent training.

As no two facilities are exactly alike, local helicopter patterns and procedures must be tailored to local geographical, enviromental, and operational requirements. It is hoped that the material contained in this manual can provide useful guidance in the establishment of such procedures.

Controller interest and training effectiveness can be increased in local helicopter ATC training programs if cockpit visits or (preferably) familiarization flights can be arranged with local helicopter operators. At least one ATC facility is already doing this, with excellent results in giving controllers a better understanding of helicopter operations. Similarly, the visits of helicopter pilots to ATC facilities, with pilot/controller discussions of helicopter and ATC problems and local procedures, is to be encouraged.

The FAA is now investigating the availability of training films and other audio/visual aids which may have a useful application in ATC helicopter training programs. Further information on this subject should be forthcoming in the near future.

Meanwhile, feedback is solicited from users or potential users of this manual, as to the suitability or usefulness of its contents, as well as the need for additional data, or additional subjects which should be covered.