THIRTEENTH EUROPEAN ROTORCRAFT FORUM

PAPER NO. ~~89~~ 96

AN ANALYTICAL TOOL TO DEFINE CRITERIA FOR HELICOPTER AIRBORNE RADAR APPROACH PROCEDURES TO OFFSHORE INSTALLATIONS

by

Ben W.G. Schute
National Aerospace Laboratory NLR
Amsterdam, The Netherlands

and

Herry J. Klumper
Netherlands Department of Civil Aviation RLD
Schiphol East, The Netherlands

September 8 - 11, 1987

ARLES, FRANCE

ASSOCIATION AERONAUTIQUE ET ASTRONAUTIQUE DE FRANCE

AN ANALYTICAL TOOL TO DEFINE CRITERIA FOR HELICOPTER AIRBORNE RADAR APPROACH PROCEDURES TO OFFSHORE INSTALLATIONS

by

Ben W.G. Schute
National Aerospace Laboratory NLR
Amsterdam, The Netherlands

and

Herry J. Klumper
Netherlands Department of Civil Aviation RLD
Schiphol East, The Netherlands

ABSTRACT

Nowadays, helicopter operators fly the Airborne Radar Approach (ARA) procedure, using weather-mapping radar guidance, to obtain the lowest possible weather limits for the approach to offshore installations. In order to define criteria for the ARA procedure, a mathematical model has been developed, under contract with the Netherlands Department of Civil Aviation RLD, according to the ICAO instrument flight procedures as contained in the "Procedures for Air Navigation Services - Aircraft Operations" (PANS-OPS DOC 8168).
With this model, the position of the missed approach point (MAPt) can be determined such that a safe missed approach can be carried out.
Discussions should take place resulting in an internationally accepted ARA procedure which could be proposed for inclusion in TERPS and/or PANS-OPS as an non-precision approach procedure. The mathematical model developed might form the basis for such discussions.

1 INTRODUCTION

Offshore activities require helicopter availability on a 24 hour basis. This implies that flights need to be performed under all weather conditions. Till the end of the 1960's the existing helicopter offshore intrument approach minima were so restricting that many flights were delayed or cancelled. In order to obtain lower minima, KLM HELIKOPTERS developed the Airborne Radar Approach (ARA) procedure which was based on the use of weather-mapping radar guidance (Ref. 1). The Netherlands Department of Civil Aviation RLD set and approved limits (visibility 800 m, Minimum Descent Height 150 ft) according to the then existing minima for Special VFR helicopter operations.

In 1981, the FAA published the Advisory Circular AC 90-80 (Ref. 2) which presents guidelines for offshore helicopter airborne radar approaches. It is based on a NASA/FAA flight test investigation program which has been carried out in the Gulf of Mexico 1978 (Ref. 3) to investigate the use of an airborne weather and mapping radar as an instument approach system for offshore installations. The flight tests showed that the rig approach is a high workload procedure and that instrument errors and flight technical errors play an important role in the definition of the ARA procedure. The weather minima presented in the AC are a cloud base of 200 ft and 0.5 NM visibility (during day with use of weather radar and NDB). However, from 15 pilots, who performed the flight tests, 4 pilots recommended higher weather minima (cloudbase higher than 300 feet and/or visibility more than 0.5 NM).

Although many discussions on the minima to be used have taken place between operators and authorities, no international criteria have been established yet. This in contrast to other instrument approach procedures for which criteria are laid down in Terminal Instrument Procedures (TERPS; Ref. 4) and Procedures for Air Navigation Services - Aircraft Operations (PANS-OPS; Ref. 5).

In 1985, a Netherlands helicopter collided with one of the legs of a drilling rig with the sponson during the execution of a missed approach during poor weather conditions. Because of this, the Netherlands Department of Civil Aviation RLD contracted the National Aerospace Laboratory NLR to carry out an investigation on the various parameters influencing the helicopter airborne radar approach procedure to a rig and to develop a method to calculate safe approach minima for this type of approach (Ref. 6).
Because of the fact that the RLD wishes to stimulate the acceptance of an internationally agreed method for establishing and approving ARA procedures, the calculation method should be in accordance with the instrument procedures as described in PANS-OPS.

In this paper, first a review is given of the approach procedure to offshore installations as performed by most operators nowadays. On the basis of the approach procedure, the outer boundary for the final and missed approach is then constructed by making use of a computer model developed at NLR. In this model navigation and flight technical errors, as far as described in the PANS-OPS for non-precision approaches, are taken into account. Finally, some results are given.

2. FLIGHT PROCEDURE TO OFFSHORE INSTALLATIONS

2.1 Flight profile

The ARA procedure has been approved for dual pilot operations only. A general overview of a radar approach flight profile is depicted in figure 1 and consists of five parts:

- enroute position/approach preparations
- initial approach (straight in or via overhead)
- intermediate approach
- final approach
- visual landing or missed approach

In the following, only the final and missed approach segment will be considered during which the weather-mapping radar (primary mode) and radar altimeter are used as the main approach guidance instruments. Primary identification of the platform to be landed on is carried out by making use of weather-mapping radar in combination with NDB, LORAN-C, DECCA or VLF/OMEGA.

Note: The weather-mapping radar has two modes of operation i.e. beacon and primary mode. In the beacon mode the radar displays only signals that are received from radio beacon transponders. In the primary mode, the radar displayes all reflected radar returns.

2.2. Final and Missed approach

At the Down Wind Final Approach Point (DWFAP), which is located at about 4 NM from the rig of intended landing (Fig. 1), the final approach commences. It is carried out into the wind. At about 3 NM from the rig a descent may be initiated to the Minimum Descent Height (MDH; e.g. 150-200 ft) only if an obstacle-free path is available. At the so called Offset Initiation Point (OIP; Fig. 2), which is positioned at 1.0-1.5 NM from the platform, a heading change of e.g. 10 deg (offset angle), either to the right or to the left, is initiated. At the Missed Approach Point (MAPt), which is located at Decision Range (DR), the decision is taken whether a visual landing or a missed approach will be carried out. The missed approach consists of a climbing turn at best rate of climb speed to e.g. a reciprocal heading. The climbing turn is performed into the same direction as the heading change performed at OIP.

3. OUTER BOUNDARY FLIGHT PATH CONSTRUCTION

3.1 Criteria and assumptions

To establish the criteria that will provide safe obstacle clearance for rig approaches it is necessary to define an obstacle-free area. The area is bounded by the "worst case" flight path (outer boundary flight path). Because the "succes" of the approach is reflected in either a safe (visual) landing or a safe missed approach it is important to define the position of the MAPt such that it complies with the following requirements:

1) for a safe visual landing:
   - rig in sight
   - remaining distance to rig (decision range; DR) is adequate to decelerate from the final approach speed to hover.

2) for a safe missed approach:
   - remaining distance to rig (DR) is adequate to execute a climbing turn whereby the minimum distance between helicopter and rig (Miss Distance; MD) should not be less than a predefined distance.

So, the DR should not be less than a predetermined "Required Safe Approach Distance" (RSAD) which gives the pilot enough time to prepare for a safe landing, thus avoiding the situation of "too close for comfort". In order to guarantee that the MAPt is indeed located at the position complying with above requirements an outer boundary flight path has to be determined. This means that (all) factors, influencing the accuracy of the desired (planned) flight path, have to be considered.

In the framework of the study, the following assumptions have been made:

a) the basis is the procedure type as depicted in figure 2.
b) single rig approach; surrounding obstacles are not considered, which means that the approach direction is of no interest in the context of the study.
c) deviation from final approach path between DWFAP to OIP is accounted for in a position error of the nominal OIP position.
d) missed approach is based on:
   - Required Safe Apporach Distance (RSAD)
   - lateral obstacle clearance (miss distance)

In the following, the factors and errors which influence the geometry of the nominal flight path will be discussed.

3.2 Navigation and flight technical errors

The exact position of OIP and MAPt will differ from the nominal position because of navigation and flight technical errors, together called the "Total System Error" (TSE). See figure 3. The navigation error, mainly caused by the weather-mapping radar, consists of:

- Radar Range Error (RRE)
- Scan Rate Delay Time (SRDT)
- Radar Bearing Error (RBE)
- Screen Resolution Error (SRE)
- Lateral Radar Reflection Offset (LRRO)

The RRE is the difference between the radar measured range (indicated on the scope) and the actual range.
Concerning the SRDT, the antenna scan rate introduces, in combination with the helicopter's groundspeed, an error in range due to the update delay.
The RBE is the angular difference between the radial of the helicopter position in relation to the rig indicated by the radar compared to the radial of the actual helicopter position to the rig.
The SRE is a part of the range error due to the resolution of the radar display.
The LRRO is the difference between the radial to the front centre of the rig and true track radial caused by a resolution error due to radar beam width and obstacle configuration ("glint").

During investigation of the weather radar accuracy, the figures as contained in the TSO C63B/C (Ref. 7) and RTCA (Ref. 8), appeared to be very restrictive. The manufacturers do not provide the radar accuracy at close range since these radars were not developed as a primary navigation instrument.

As flight technical errors are considered:

a) deviation in:
   - airspeed
   - selected heading change at OIP
   - turn rate during missed approach turn

b) allowances for:
   - pilot reaction time
   - bank establishment time

3.3 Outer boundary flight path construction with a computer model

A computer model has been developed with which it is possible to construct the helicopter outer boundary flight path (during final and missed approach) as function of navigation and flight technical errors. In accordance with PANS-OPS requirements undetected tailwind on final approach and omnidirectional wind during the missed approach turn are taken into account. The omnidirectional wind causes the radius of the missed approach flight path to increase during the turn. An example of the outer boundary flight path construction is given in figure 4.

As mentioned before, the real MAPt will differ from the nominal position. To be able to perform a safe landing the real MAPt, however, shall not be closer to the platform than the predefined Required Safe Approach Distance (RSAD). Based on the computed outer boundary, the Decision Range (DR) and Miss Distance (MD) are calculated.
The input data of the model are mentioned in table 1.

The parameters can be inserted and varied according to the judgement of the user. By varying the parameters, the DR based on required MD can be obtained (in an iterative way; Fig. 5).
In this way it also is possible to investigate the contribution of each parameter to the DR and MD separately.

The calculation results are displayed on a graphic screen and written to an output data file.
The program is written in Turbo Pascal and runs on an IBM-PC-AT under MS-DOS 3.2. The compiled version contains 52K bytes with a run time between 6 and 8 seconds. Computer experience to run the program is not required.

4. RESULTS

The following program results are based on an example of a prescribed ARA procedure for which the nominal final and missed approach path are defined by the following parameters:

- final approach speed (IAS); 70 knots
- Offset Initiation Point (OIP) position; 1 NM from oil rig
- offset angle (δ) at OIP; 10 deg
- Required Safe Approach Distance (RSAD); 800 m
- missed approach turn rate (rate one); 3 deg/s

Based on these figures, and ignoring pilot and equipment errors, the decision range and miss distance are (see figure 6a):

DR = 0.43 NM (800m)
MD = 547m

On the basis of this nominal flight path, the outer boundary flight path can be computed taking into account navigation and flight technical errors. By introducing each factor that contributes to the definition of the outer boundary flight path, separately, the increase in DR and decrease in MD can be clarified as presented in table 2. In accordance with PANS-OPS guidelines the "error in airspeed" and "error in rate of turn" are set to zero. They are accounted for in the "undetected tailwind" and "omnidirectional wind".

The used input data in this example do not necessarily reflect official standpoints neither do they constitute a standard or regulation. The results only account for the assumptions as stated in 3.1.
The flight technical errors correspond to data as used in the PANS-OPS and the navigation errors are based on the results of the FAA flight tests in the Gulf of Mexico (Ref. 2).

From table 2 it can be seen that the DR is mainly influenced by:

- RSAD
- radar range error
- pilot reaction time.

The MD is mainly influenced by:

- omnidirectional wind
- radar bearing error
- error in OIP heading offset
- bank establishment time at MAPt.

Based on the figures of table 2, the resulting DR and MD are (no wind taken into account):

- DR = 0.63 NM
- MD = 148m

The corresponding flight path is depicted in figure 6b. On the basis of this outer boundary flight path a sensitivity analysis has been executed from which the main results are listed below.

Approach speed

The approach speed influences both the DR and MD because of the effects of time delay factors such as pilot reaction time, bank establishment time and radar scan time. A reduced airspeed has a positive influence on both the DR and MD. An airspeed reduction of e.g. 10 knots decreases the DR and increases the MD as follows (Fig. 7):

- 0.01 NM/10 KIAS for DR and
- 35m/10 KIAS for MD

Note: The reduction in airspeed, however, is limited by the minimum IFR instrument speed (FAR 29; Ref. 9) which, for most helicopters, is around 50-60 knots. The margin in approach speed to obtain a lower DR is very small unless minimum IFR speeds below 60 knots are approved.

OIP position and offset angle

For 3 different OIP-positions and heading offset angles the DR and MD are given in table 3. It can be seen that neither the OIP-position nor the heading offset angle influences the DR. Only at an offset angle of 15 deg, the OIP position change has an influence on the Miss Distance.

Increasing the offset angle influences the Miss Distance with about:

- 120m/10 deg offset angle

Note: The maximum offset angle is limited by the fact that "blind flight path" segments may occur. This happens when the "blip"-return of the rig disappears from the radar screen.

Required safe approach distance (RSAD)

The relationship between RSAD, radar range error and Decision Range (DR) is given in figure 8a.
A RSAD reduction of 100m reduces the DR with about the same value (0.05 NM/100m). The same applies for the radar range error. However, a reduction in RSAD of only 100m will decrease the MD from 148m to 93m (Fig. 8b).
The minimum RSAD is limited by the minimum tracking range of the radar. At a distance closer to the rig then the minimum tracking range (given in the radar manual) the range indication is unreliable.

Wind

Headwind component; an approach into the wind results in a reduced groundspeed. In general, the radar approach to a rig will be into the wind. So the most critical DR and MD occur in zero wind situation. An approach at 70 KIAS with a headwind of 30 knots will result in the same DR and MD as an approach with 40 KIAS in no-wind situation.

Note: If an RSAD of 800m is taken in combination with an airspeed of 70 knots (no wind), then the pilot has 25-30 sec. available for the deceleration to hover if visual contact is established at MAPt. If this time period is taken as a "required safe approach time" the RSAD can be reduced according the reduction in groundspeed.

Crosswind component: the influence of crosswind components on the MD during a missed approach turn is illustrated in figure 9. If the missed approach turn is to leeward side, the Miss Distance decreases. Above that, the required airspace, to complete a 180° turn, is much greater compared to a MAP-turn in the opposite direction. Further, it can be seen from figure 10, that crosswind components might result in a situation that the "blip"-return of the rig disappears from the radar screen. This is because of the large wind correction angle required to keep track. So, crosswind components must be kept as small as possible.

5 CONCLUDING REMARKS

The ARA procedure is a method to conduct helicopter operations to offshore installations under IMC. The procedure can be considered as a non-precision instrument approach procedure for which, in contrast to other instrument approach procedures, no internationally accepted criteria are laid down.
The ARA procedure is analysed according to the methods for procedure design as used in ICAO PANS-OPS.

According to the methodology as used for non-precision approaches, a computer model has been developed to calculate the Decision Range and Miss Distance. The input parameters, which are used in this model, can be varried to the judgement of the procedure designer.

Calculations showed that Required Safe Approach Distance and radar range accuracy have a great influence on the required Decision Range while the Miss Distance is mainly influenced by the offset angle.

It is recommended to discuss helicopter airborne radar approach (ARA) procedures to offshore installations and to define the navigational and flight technical parameters influencing the procedure (e.g. pilot reaction time, radar errors, RSAD). The goal of the discussions should be an internationally accepted ARA procedure which could be proposed for inclusion in TERPS and/or PANS-OPS as a non-precision approach procedure.
The computer model developed might form the basis for such discussions.

6. LIST OF ABBREVIATIONS

AC	Advisory Circular
ARA	Airborne Radar Approach
DR	Decision Range
DWFAP	Down Wind Final Approach Point
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulations
IAS	Indicated Airspeed
ICAO	International Civil Aviation Organisation
IFR	Instrument Flight Rules
IMC	Instrument Meteorological Conditions
KIAS	Knots Indicated Airspeed
NDB	Non-Directional Beacon
NLR	National Aerospace Laboratory
NM	Nautical Mile(s)
OIP	Offset Initiation Point
PANS-OPS	Procedures for Air Navigations Services-Aircraft Operations
RBE	Radar Bearing Error
RLD	Netherlands Department of Civil Aviation
RRE	Radar Range Error
RSAD	Required Safe Approach Distance

KLM	Royal Dutch Airlines	RTCA	Radio Technical Commission for Aeronautics
LRRO	Laterial Radar Reflection Offset	SRDT	Scan Rate Delay Time
MAP	Missed Approach	SRE	Screen Resolution Error
MAPt	Missed Approach Point	TERPS	Terminal Instrument Procedures
MD	Miss Distance	TSE	Total System Error
MDH	Minimum Descent Height	TSO	Technical Standard Order
NASA	National Aeronautics and Space Administration	VFR	Visual Flight Rules

7. REFERENCES

1. R.J. van der Harten, "Some Aspects of Instrument Flight", VERTIFLITE, November-December 1982;
2. Anon, FAA Advisory Circular AC 90-80, Approval of Airborne Radar Approach (ARA) procedures for Helicopters to Offshore Platforms, FAA, AFO-210/s60/730, 18th May 1981;
3. D.P. Pate and J.H. Yates, Airborne Radar Approach FAA/NASA Gulf of Mexico Helicopter Flight Test Program, FAA report no. AFD-507-78-2, January 1980;
4. Anon, United States Standard for Terminal Instruments Procedures (TERPS), FAA, 7th July 1976;
5. Anon, Procedures for Air Navigation Services - Aircraft Operations (PANS-OPS), document 8168-OPS/611, Volume II, 3rd edition 1986;
6. B.W.G. Schute, A Study on Helicopter Airborne Radar Approach Procedures to Offshore Platforms, NLR Report VV-86-51 L, 10th July 1987;
7. Anon, Technical Standard Order (TSO-C63 B/C), Department of Transportation, Federal Aviation Administration, Office of Airworthiness, Washington D.C., 18th August 1983;
8. Anon, Minimum Operational Performance Standards for Airborne Weather and Ground mapping pulsed radars, Document no. RTCA/DO-173, November 1980;
9. Anon, FAR parts 1 to 59, Code of Federal Regulations, Aeronautics and Space U.S., Government Printing Office, Washington, 1st January 1986.

TABLE 1

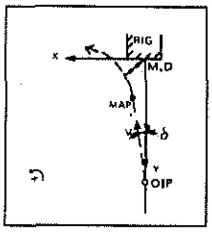
Program Input

INPUT
- RSAD
- RADAR RANGE ERROR
- RADAR BEARING ERROR
- SCAN TIME
- PILOT REACTION TIME
- INDICATED AIR SPEED (IAS)
- ERROR IN IAS
- OFFSET INITIATION POINT (OIP)
- OIP HEADING OFFSET
- ERROR IN HEADING OFFSET
- RATE OF TURN DURING MAP
- ERROR IN RATE OF TURN
- BANK ESTABLISHMENT TIME
- LATERAL RADAR REFLECTION OFFSET
- WIND SPEED
- WIND DIRECTION
- OMNIDIRECTIONAL WIND
- RIG DIMENSIONS

TABLE 2

Decision Range (DR) and Miss Distance (MD) as a function of nominal approach parameters and errors

Required Safe Approach Distance (RSAD) [m]	800	800	800	800	800	800	800	800	800
Offset Initiation Point [NM]	1	1	1	1	1	1	1	1	1
Rate of turn [deg/sec]	3	3	3	3	3	3	3	3	3
OIP heading offset [deg]	10	10	10	10	10	10	10	10	10
Air speed [knots]	70	70	70	70	70	70	70	70	70
Omnidirectional wind speed during MAP-turn [knots]	0	15	15	15	15	15	15	15	15
Radar range error [m]	0	0	200	200	200	200	200	200	200
Radar bearing error [deg]	0	0	0	-5	-5	-5	-5	-5	-5
Scan time [sec]	0	0	0	0	3.5	3.5	3.5	3.5	3.5
Reaction time [sec]	0	0	0	0	0	3	3	3	3
Error in OIP heading offset [deg]	0	0	0	0	0	0	-5	-5	-5
Bank establishment time at MAP [sec]	0	0	0	0	0	0	0	3	3
Distance for which radar beam is out of rig-centre [m]	0	0	0	0	0	0	0	0	-15



DECISION RANGE [NM]	.43	.43	.54	.54	.56	.63	.63	.63	.63
MISS DISTANCE-MD [m]	547	448	425	334	332	325	238	160	148

TABLE 3

Influence of OIP-position and heading offset angle (δ) on DR and MD

HEADING OFFSET ANGLE [deg]	δ=5°	δ=10°	δ=15°		
OIP-POSITION [NM]	VARIABLE FROM 1.0-1.5	VARIABLE FROM 1.0-1.5	1.0	1.25	1.5
DR [NM]	.63	.63	.63	.63	.63
MD [m]	91	148	212	275	305

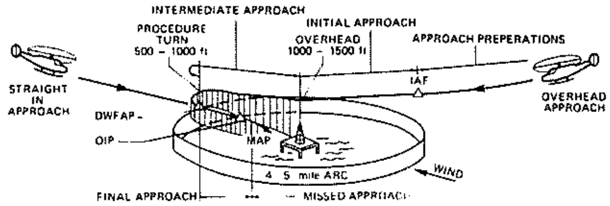


Figure 1: A general helicopter radar approach to offshore platform

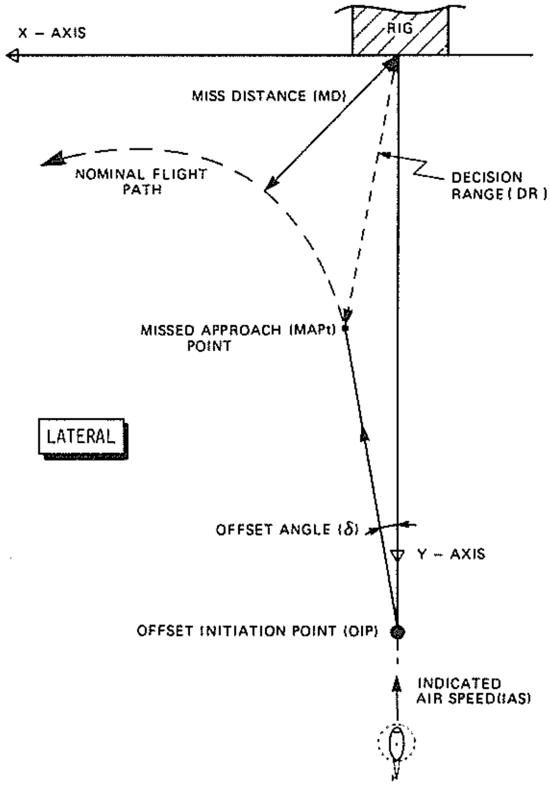


Figure 2: Nominal final and missed approach flight path

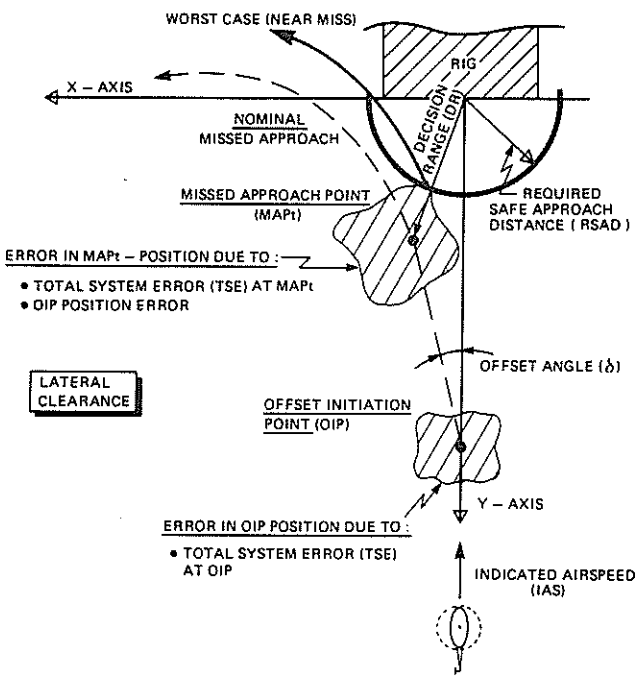


Figure 3: Influence of total system error (TSE) on OIP- and MAPt-position

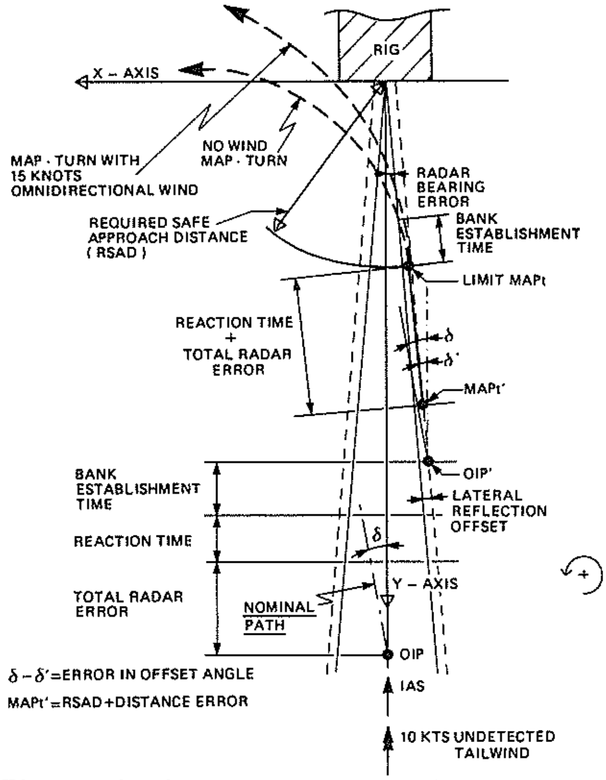


Figure 4: Outer boundary flight path for airborne radar approach (PANS-OPS methodology has been applied)

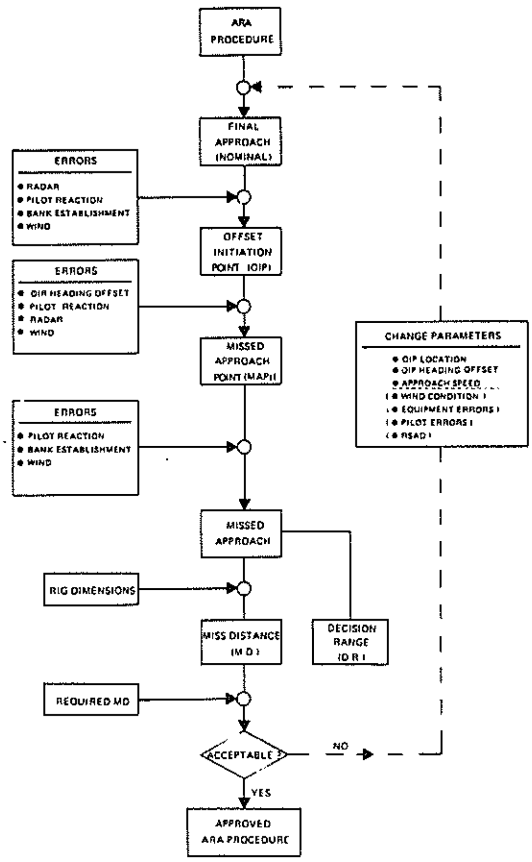


Figure 5: Flow chart for the definition of ARA procedure

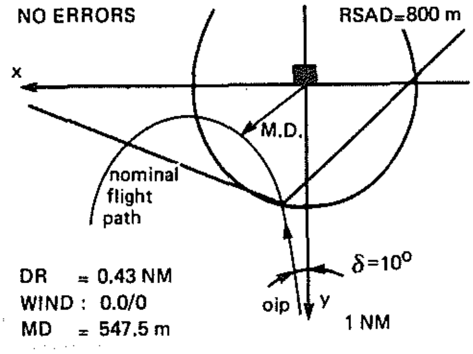


Figure 6a: Nominal final and missed approach flight path

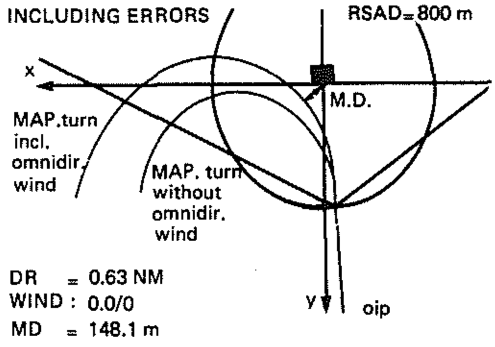


Figure 6b: Final and missed approach outer boundary flight path (errors as mentioned in table 2)

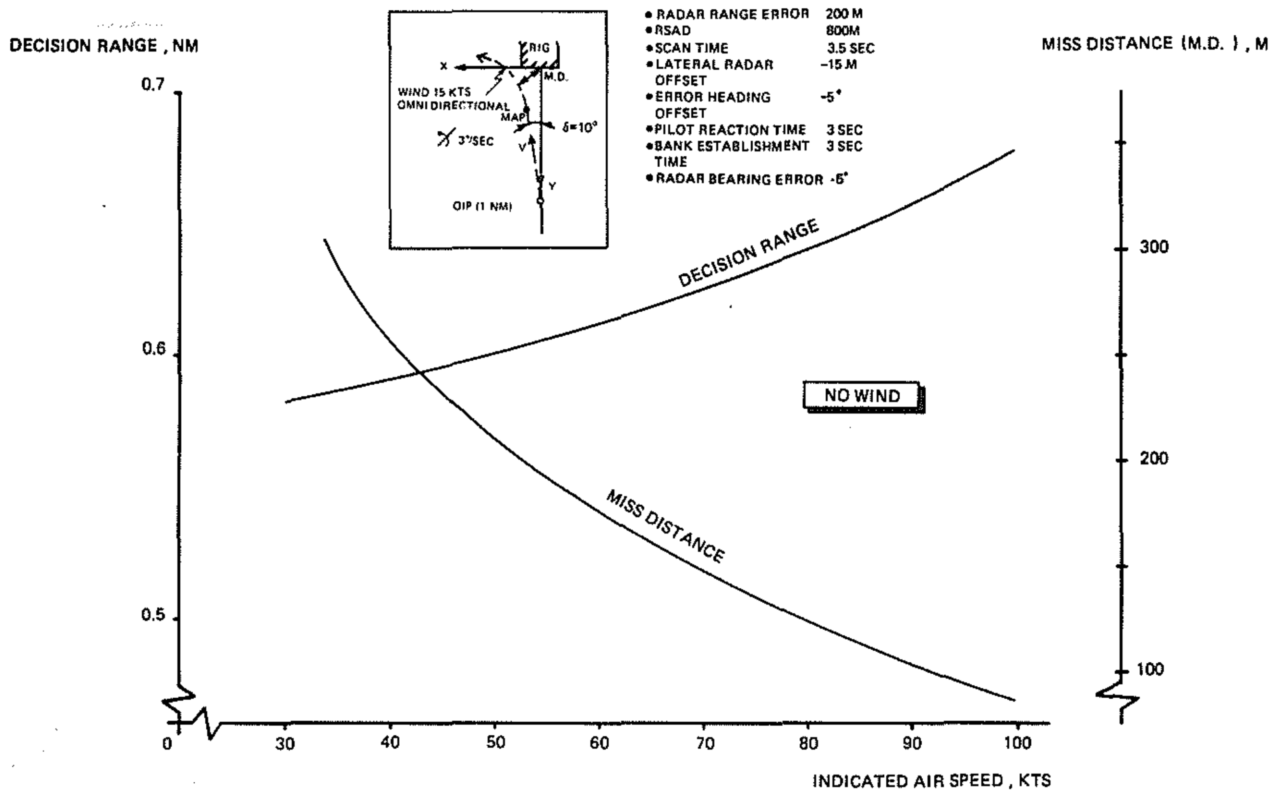


Figure 7: Influence of approach speed on Decision Range and Miss Distance

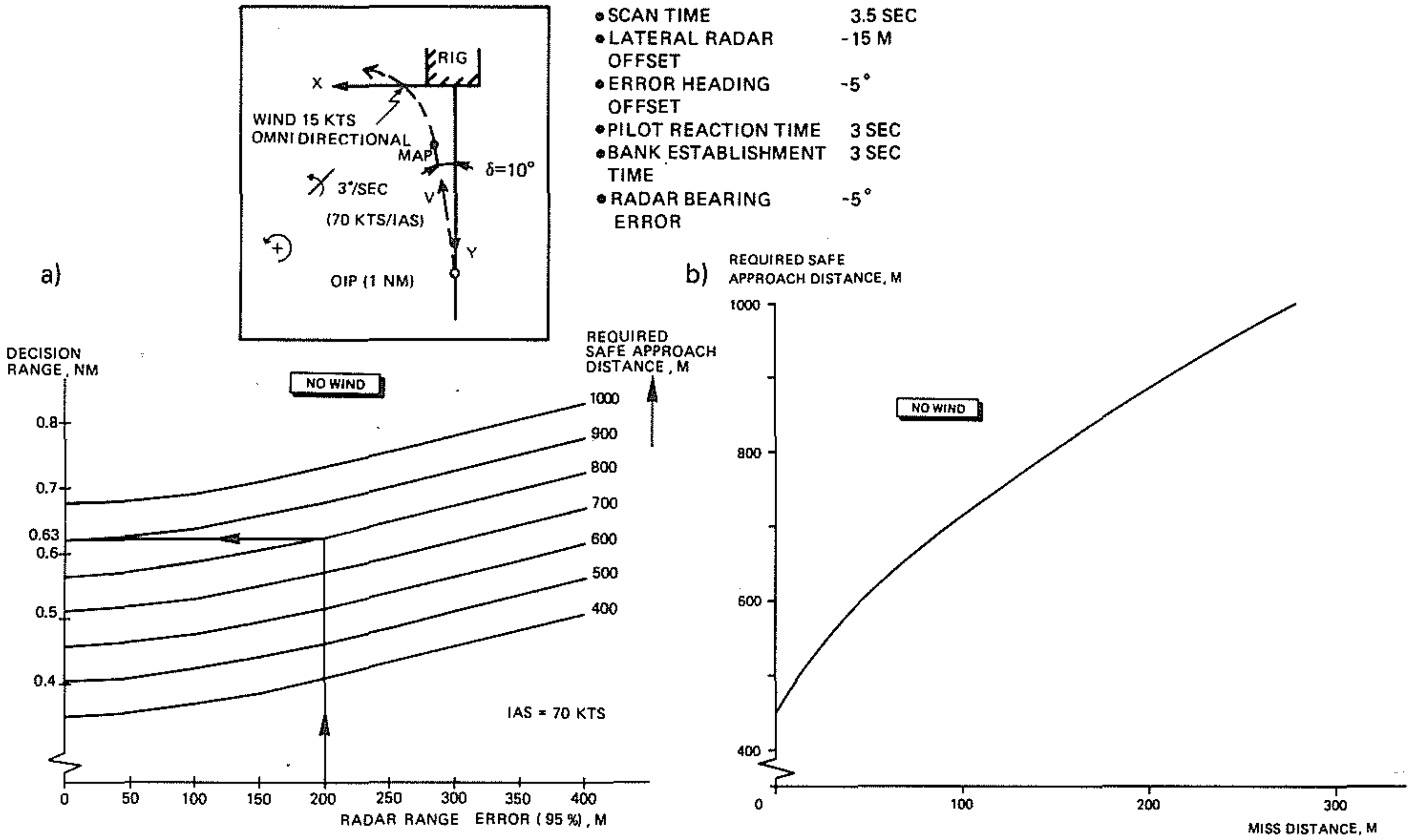
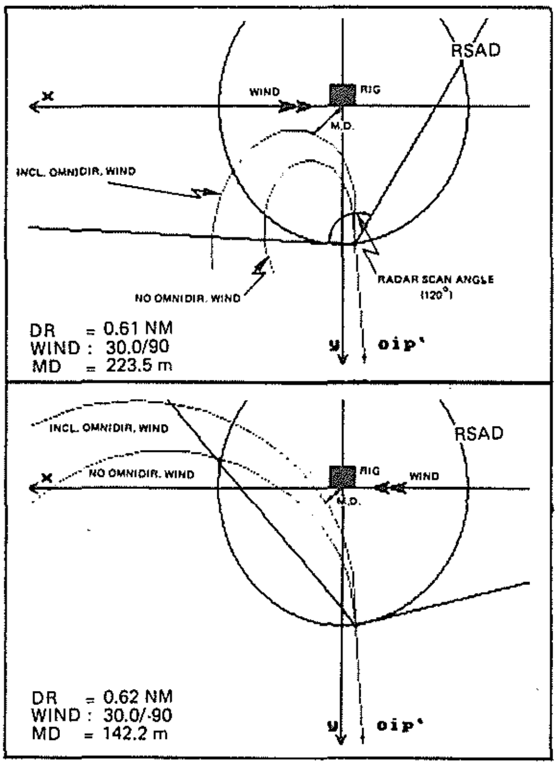
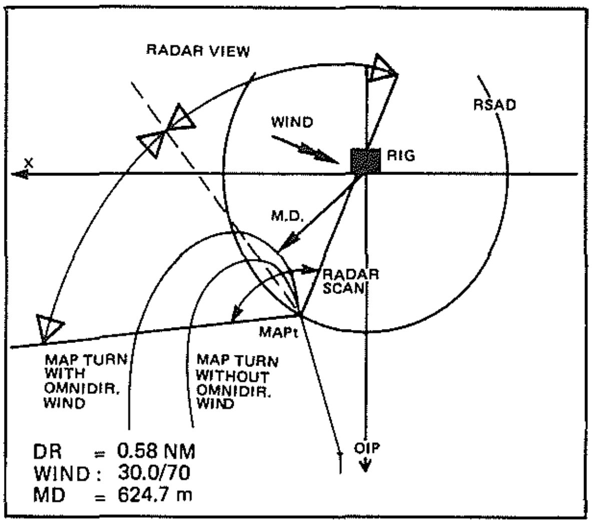


Figure 8: Influence of RSAD on Decision Range and Miss Distance



Radar range error	=	200.0 m
Radar bearing error	=	-5.0 deg
Scan time	=	3.5 sec
Reaction time	=	3.0 sec
Air speed	=	70.0 knots
Error in air speed	=	0.0 knots
Required Safe Approach Distance (RSAD)	=	800.0 m
Offset Initiation Point	=	1.0 nm
Rate of turn	=	3.0 deg/sec
Error in rate of turn	=	0.0 %
OIP heading offset	=	10.0 deg
Error in OIP heading offset	=	-5.0 deg
Bank establisment time at MAP	=	3.0 sec
Wind speed	=	30.0 knots
Wind angle	=	±90.0 deg
Distance for which radar beam is out of rig-centre	=	-15.0 m
Omnidirectional wind speed during MAP-turn	=	15.0 knots

Figure 9: Influence of crosswind component



Rig at MAP' positioned at max of +/- 60 deg

Radar range error	=	200.0 m
Radar bearing error	=	5.0 deg
Scan time	=	3.5 sec
Reaction time	=	3.0 sec
Air speed	=	70.0 knots
Error in air speed	=	0.0 knots
Required Safe Approach Distance (RSAD)	=	800.0 m
Offset Initiation Point	=	1.0 nm
Rate of turn	=	3.0 deg/sec
Error in rate of turn	=	0.0 %
OIP heading offset	=	10.0 deg
Error in OIP heading offset	=	5.0 deg
Bank establisment time at MAP	=	3.0 sec
Wind speed	=	30.0 knots
Wind angle	=	70.0 deg
Distance for which radar beam is out of rig-centre	=	15.0 m
Omnidirectional wind speed during MAP-turn	=	15.0 knots

Figure 10: Radar approach for which "blip-return" disappears from radar screen