# BULLETIN

## HAVARIKOMMISJONEN FOR SIVIL LUFTFART (HSL)

Postboks 8, 2007 KJELLER
Telefon: 64 84 57 60
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BUL 12/99
Avgitt: 23. juni 1999

| | |
|---|---|
| Luftfartøy | |
| -type og reg.: | Eurocopter AS 332L2 Super Puma, LN-OHC |
| -fabr. år: | 1994 |
| -motorer: | 2 stk. Turbomeca Makila 1A2 |
| Radiokallesignal: | HKS 10H |
| Dato og tidspunkt: | 31. oktober 1997, kl. 0915 |
| Hendelsessted: | Rullebane 11/29 Stavanger lufthavn Sola |
| Type hendelse: | Luftfartsulykke, tap av kontroll under innflyging |
| Type flyging: | IFR/VFR |
| Værforhold: | METAR ENZV 310750Z 19009KT 2500 -DZ BR SCT 002 BKN 003 10/09 Q 1028 TEMPO 1500= TAF ENZV 310615Z 19010KT 9000 SCT 006 BKN 010 TEMPO 0615 3000 DZ BKN 005 |
| Lysforhold: | Dagslys |
| Flygeforhold: | IMC/VMC |
| Reiseplan: | IFR |
| Antall ombord: | 2 |
| Personskader: | Ingen |
| Skader på luftfartøy: | Skader på felger for hoved- og nesehjul. Kabinstruktur høyre side bak kabindør bulket. Bulket hud på begge sider av halebom |
| Andre skader: | Ingen |
| Fartøysjefen | Mann |
| -alder: | 48 år |
| -sertifikat: | ATPL-H |
| -flygererfaring: | 12 936 timer |
| Informasjonskilder: | Fartøysjefens rapport, styrmannens rapport, rapport fra selskapets interne undersøkelsesgruppe og egne undersøkelser. |

Alle tidsangivelser i denne bulletin er lokal tid (UTC + 1 time), hvis ikke annet er angitt.

## FAKTISKE OPPLYSNINGER

Den etterfølgende tekst er i det alt vesentlige hentet fra selskapets interne undersøkelsesgruppe. Flight Data Recorder (FDR) ble avspilt og analysert på Sola 02.11.1997. HUMS data ble registrert og skrevet ut.

Som en del av øvelsene som gjennomføres i en halvårlig periodisk flygetrening (PFT) forberedte besetningen seg til og ble klarert for en instrumentinnflyging til Stavanger lufthavn Sola. Besetningen besto av en fartøysjef (instruktøren) og en annenflyger som i fortsettelsen omtales som eleven. Det skulle øves på avbrutt innflyging på en motor til bane 11 med Auto Flight Control System (AFCS) (= autopilot) utkoblet. Det var marginale værforhold. Etter å ha forlatt ventemønsteret ved SONNY (se vedlegg 1) ble en "Copter ILS+DME" innflyging startet.

Før helikopteret var stabilisert på lokalisatoren simulerte instruktøren motorkutt på motor nr. 1 ved å sette motoren i "training idle mode". Prosedyrer for flyging med en motor ute av drift ble deretter gjennomgått. Innflygingen ble til å begynne med utført ved at eleven fløy med automatikken innkoblet (4-akser). Da instruktøren fikk visuell kontakt i ca. 300 ft koblet han ut AFCS, og eleven fortsatte innflygingen manuelt. Helikopteret var da etablert på lokalisator og glidebane ned til minima. 200 ft er "DH" for denne innflygingen, og i denne høyden initierte eleven som planlagt en avbrutt innflyging i henhold til prosedyren. Hastigheten og gjennomsynkningen var normal for en slik en-motors innflyging.

På finalen satte instruktøren som avtalt "bleed offset" bryteren til "av" for å ha mer motorkraft tilgjengelig ved utflygingen etter minima. "One Engine Inoperative" (OEI) - "Hi - Low" bryteren var satt i "Low", og besetningen valgte ikke å forandre på dette på finalen eller under utflygingen. I følge Standard Operating Procedures (SOP) skal denne bryteren settes til "Hi" på finalen før landing. Siden meningen ikke var å lande, men å fly ut etter minima, valgte besetningen å la bryteren stå i "Low". Overgangen til den avbrutte innflygingen ble altså startet med AFCS avslått. Allerede ved begynnelsen av denne utflygingen fikk eleven problemer med å opprettholde hastighet og stabilitet i "pitch"-planet. Under utflygingen så instruktøren at helikopteret driftet over til venstre. Han ba eleven svinge til høyre for å korrigere. Samtidig ba han om reduksjon i kollektiv setting, da denne var noe høy. Eleven sier i ettertid at han på dette tidspunkt jobbet med å holde oppe hastighet og stabilitet i "pitch"-planet.

Registrering fra FDR viser ikke noe unormalt lavt rotorturtall, og besetningen hørte ingen "NR low - Warning". NR var stabilt rundt 95-96%. Torque setting på motor nr. 2 var lav, med verdier på ca. 32-46% under utflygingen. Hastigheten avtok raskt fra 72 kt IAS da helikopteret var på minimumshøyden til rundt 40-60 kt IAS under utflygingen for hurtig å falle til 0 IAS like før helikopteret satte seg hardt på banen etter å ha snudd 180° i forhold til banens retning. Den vertikale hastigheten varierte sterkt under utflygingen, med verdier varierende fra 800 ft/min stigning like etter starten, til en gjennomsynkning på 2 600 ft/min like før settingen.

Problemene med pitch kontroll, som ga store variasjoner i vertikal hastighet og avtagende IAS sammen med lite motoruttak, medførte at helikopteret under denne utflygingen endte opp på baksiden av "power-kurven". Besetningen hadde mistet den visuelle kontakten under utflygingen, og dette medførte at situasjonen fikk lov til å utvikle seg lenger enn den ville ha gjort dersom det hadde vært VMC forhold. Besetningen hadde mistet sin situasjonsbestemte oppmerksomhet. Begge flygerne merket at helikopteret begynte å miste høyde og hastighet. Instruktøren valgte å resette "training idle" bryteren til motor nr. 1, slik at full motor-effekt ble tilgjengelig. På dette tidspunkt hadde gjennomsynkningen mot bakken økt kraftig. 2-3 sekunder før landingen kom kollektiv inn til fullt pådrag, samtidig som motor nr. 1 hadde akselerert til å kunne gi nesten full motorkraft. Dette reduserte gjennomsynkningen noe før kontakten med banen, men det var ikke tidsnok innsatt til å forhindre en meget hard landing. Eleven antar i ettertid at han fikk visuell kontakt med rullebanen i ca. 200 ft høyde. Dette var ca. 4 sek før landingen, og helikopteret hadde på dette tidspunkt ingen hastighet framover.

Da motor nr. 1 var i ferd med å akselerere opp, hadde helikopteret fortsatt en rotasjon mot høyre. På dette tidspunkt var begge flygerne på kontrollene og kollektiv ble økt til maksimalt pådrag, mot mekanisk stopp. Helikopterets "attitude" ble løftet opp til ca. 5° over horisonten like før landingen. Dette medførte at gjennomsynkningen ble noe redusert. Helikopteret landet med en trepunktslanding, med en retning på ca. 290° på rullebane 11/29, det vil si ca. 180° i forhold til innflygingsretningen. Instruktøren mener i ettertid at gjennomsynkningen var godt over 1 000 ft/min ved settingen. Besetningen merket at landingen ble meget hard, og de sier i ettertid at de hadde kontroll/respons på helikopteret i "roll og pitch" planet, men at de ikke klarte å stoppe gjennomsynkningen. Besetningen hadde ikke kontroll på hvor helikopteret ville treffe bakken, men de forsøkte å treffe med hjulene først og samtidig unngå å drifte sideveis.

Noen få sekunder før den harde landingen kan følgende avleses fra FDR: "Attitude" på helikopteret var ca. 15° under horisonten, gjennomsynkningen mot bakken var på mer enn 1 300 ft/min (som økte raskt til ca. 2 600 ft/min), helikopteret roterte hurtig mot høyre, AFCS var fortsatt avslått, og total motorkraft for begge motorene var ca. 40% torque. Se vedlegg nr. 3: Den interne undersøkelsesgruppens STEP ( Sequential - Time - Events - Plotting).

Beregninger viser at det ville være nødvendig med en total motorkraft for begge motorene på 68,7% torque for å kunne holde helikopteret i stabil hover (ut av bakkeeffekt) i 200-300 ft høyde. Denne motorkraften måtte økes betydelig for å kunne stoppe den høye gjennomsynkningen. FDR viser at pådrag av motorkraft på begge motorene opp mot og over 69% først ble utført i ca. 100 ft høyde, 3 sek før landingen. I ettertid kan det sies at tallverdiene og den informasjon som FDR viste ved denne hendelse innen enkelte områder er noe uklare og således ikke helt til å stole på. Dette gjør at den interne undersøkelsesgruppen i selskapet ikke med sikkerhet kan si hvor stor den maksimale påkjenningen som helikopteret ble utsatt for ved landingen var. Den høyeste verdi som kommer frem på FDR viser en G-verdi på 5,528G. Denne verdien er målt ved landingsøyeblikket og det lar seg ikke gjøre å bekrefte nøyaktig om dette er høyeste påkjenning. G-verdien blir målt 8 ganger i sekundet. Skadene på felger og merker på dekkene viser at helikopteret hadde en liten sideveis drift mot høyre ved selve landingen. Utskrift fra HUMS viser en torque (overtorque) på 128% i mer enn 2 sek ved landingen.

På grunn av fullt pådrag av kollektiv ved landingen "spratt" helikopteret fort opp i luften igjen. Instruktøren gjenvant kontrollen over helikopteret og stabiliserte det i 10-20 ft. hover. Deretter ble det utført en forsiktig landing på bane 29.

Under treningen var vinden fra syd til sydvest med styrke ca. 10 kt, og det ga besetningen en sidevindskomponent fra høyre på ca. 10 kt. Skybasen og sikten denne dagen var ned mot minima for denne innflygingen. Dette betyr i seg selv en økt arbeidsbelastning for besetningen. Når så i tillegg innflygingen utføres med en motor ute av drift og med AFCS utkoblet, blir arbeidsbelastningen meget høy. Det er opp til instruktøren å vurdere den totale belastning i hvert enkelt tilfelle. De regler som gjaldt ved treningen som førte til ulykken var de samme som var gjeldende for vanlig flyging.

Begge flygerne i denne hendelsen er meget erfarne helikopterflygere, og blant de som innen selskapet har lengst flygetid på typen. Treningen frem til hendelsen forløp uten problemer, begge flygerne hadde stor tillit til den andres ferdigheter og vurderinger. Treningen var en PFT hvor instruktøren fungerte både som fartøysjef og kontrollant. I et slikt kontrollant/elev-forhold var det vanskelig å få til en naturlig CRM-prosedyre/kommunikasjon mellom flygerne. Det var spesielt den korrekte kommunikasjon som uteble. Eleven ble pålagt problemer som skulle løses, og kontrollanten (instruktøren) skulle holde seg tilbake - være passiv. Flygerne bekreftet i etterhånd at dette var tilfelle på denne flygingen. Ved en vanlig flyging ville sannsynligvis begge ha vært mer aktive for å korrigere en slik situasjon på et tidligere stadium.

## HAVARIKOMMISJONENS KOMMENTARER

Ved denne hendelsen har to erfarne flygere blitt satt opp sammen i en treningssituasjon. Dette kan lett føre til "complacency", og derved mangelfull gjennomgang av oppdrag som skal utføres. Under en PFT der instruktøren fungerer både som fartøysjef og kontrollant er det spesielt viktig at briefingen av oppdraget og CRM- prosedyrer blir nøye gjennomført, på samme måte som f. eks. når cockpitbesetningen består av to kapteiner. Dersom man på forhånd ikke har en nøye gjennomgang av hvem som skal utføre hvilke oppgaver underveis, og satser på at begge parter vet dette på grunn av lang erfaring, oppstår lett uklarheter når problemer dukker opp og nødprosedyrer må igangsettes.

I tillegg kan "complacency" føre til at reaksjonstiden blir lenger enn nødvendig før man setter i gang korrekte prosedyrer fordi kommunikasjonen er mangelfull eller ikke eksisterende. Det er også uheldig at man opererer med ulike prosedyrer under forskjellige betingelser. For at CRM-prosedyrer skal være til hjelp må de integreres i alle operasjoner. Ellers vil de oppfattes som et vedheng til operative rutiner, og derved miste noe av sin effekt. Det er derfor viktig at selskapet gjennomgår sine rutiner for å sette begrensninger for hvordan denne type trening kan utføres med luftfartøy.

Særlig vanskelige - avanserte - øvelser bør etter HSLs mening kun finne sted i simulator. HSL anser at denne treningen som førte til hendelsen ikke skulle ha funnet sted under de aktuelle værforhold. Instruktøren lot flygingen få utvikle seg for langt før han innså at situasjonen kom ut av kontroll, og når han selv forsøkte å kontrollere den, var det for sent.

I et helikopter, hvor besetningen har visuell kontakt med landingsområdet, kan det uproblematisk og rutinemessig manøvreres for landing. Når en helikopterbesetning gjør innflyging i marginale værforhold, eksempelvis i tåke ned til CAT I og CAT II forhold, oppstår en annen situasjon. Da stilles det krav til sikt og skyhøyde for at besetningen skal kunne justere seg i den krevende overgangsfasen fra IMC til visuelle forhold.

Selskapets interne undersøkelsesgruppe har i etterhånd anbefalt begrensninger på værminima for instrumenttreningsflyging hvor det skal utføres nødtrening. Videre anbefales selskapet av gruppen å innføre begrensninger for "multiple failures" i gjennomføringen av PFT. Under det interne arbeid ble det oppdaget behov for oppdatering/kontroll av Company Flight Manual.

HSL har vurdert de tilrådinger gruppen har gitt og finner det ikke nødvendig å fremme egne tilrådinger.

HSLs tilknyttede ekspert på tung helikopterflyging uttaler i en konklusjon:

> "Det som skjedde med LN-OHC var et resultat av flyging med en motor ute av drift (dårlig stigeytelse) og AFCS eller ASE ute av funksjon. Kombinasjonen dårlig ytelse og dårlig stabilitet er vanskelig nok å håndtere med visuelle referanser. Denne kombinasjonen og med referanser kun til instrumentene, er en utfordring for selv den mest rutinerte helikopterflyger."

HSL har fått tilsendt fra Civil Aviation Autority, Safety Regulation Group i England "Helicopter Fog Flying Trials". Denne undersøkelsen ble utført for en tid tilbake. Utredningen har ikke noen direkte relevans til denne flygingen, som ble fløyet som en standard CAT 1 ILS ned til en DH av 200 ft. HSL tar likevel utredningen med som et vedlegg, etter tillatelse, da den av brukere i miljøet blir oppfattet å være av generell interesse og gi nyttig informasjon om emnet innflyging i tåke eller forhold med dårlige visuelle referanser.

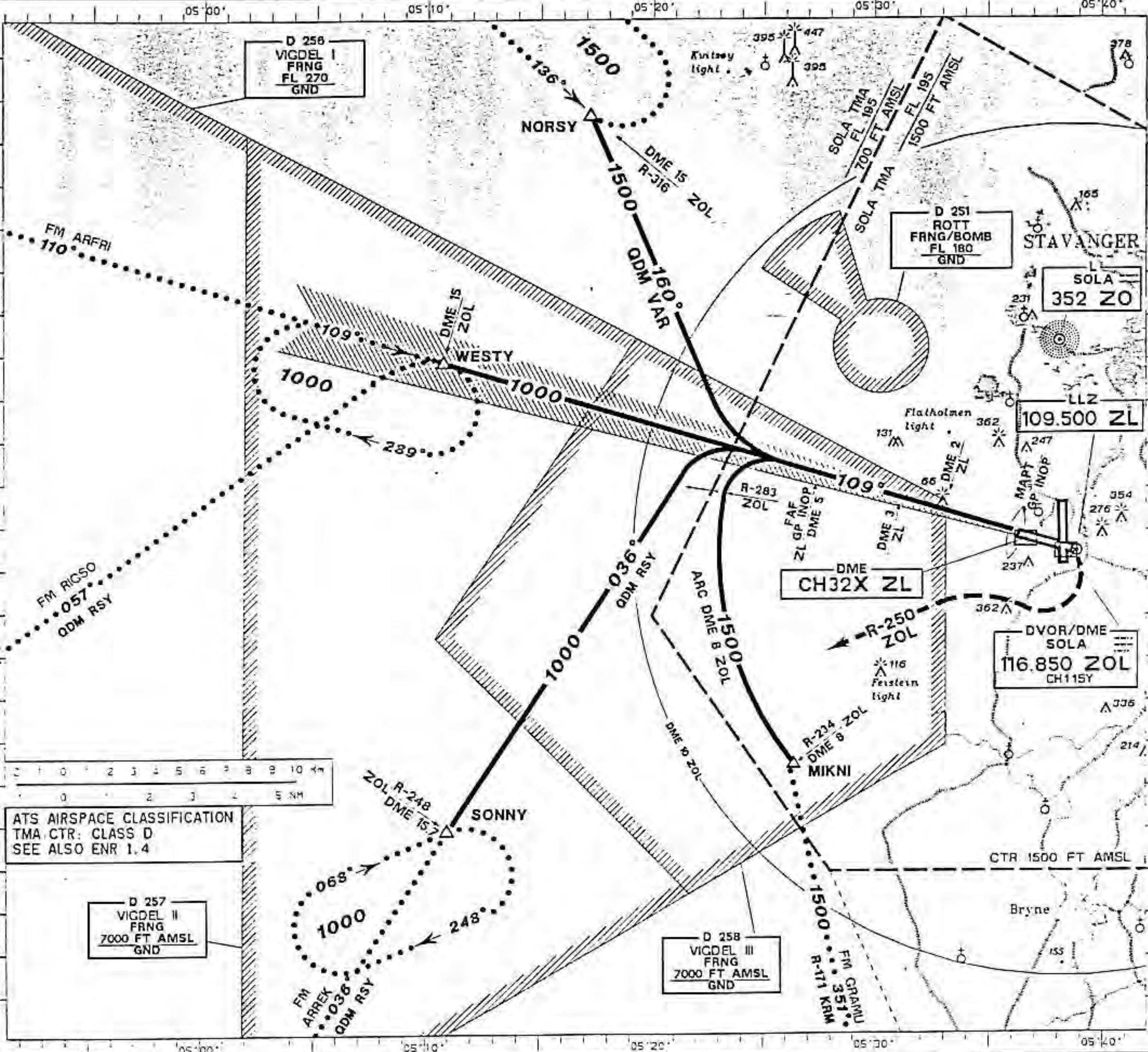
## VEDLEGG:

1. Stavanger Sola Copter ILS+DME-11

2. N. Talbot and M. L. Webber: Helicopter Fog Flying Trials

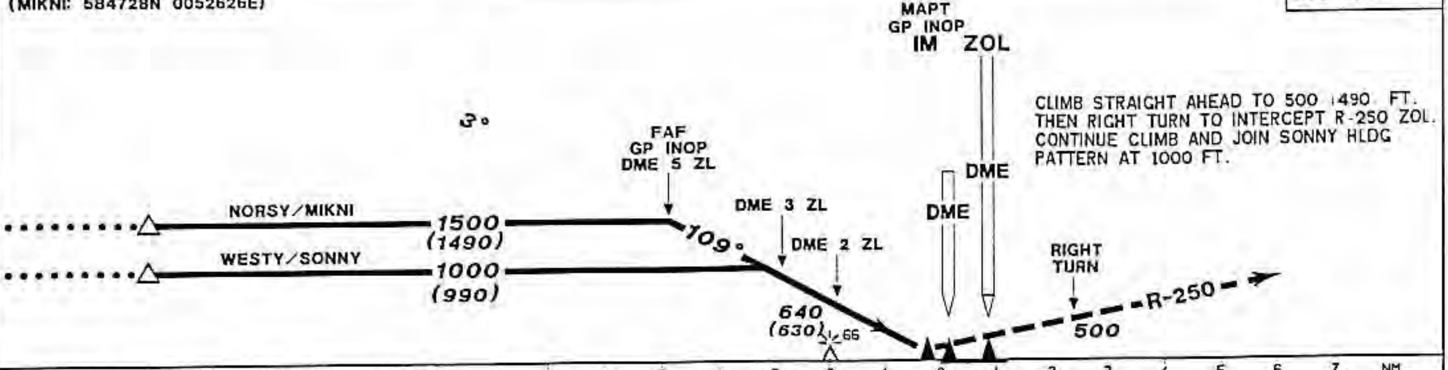
3. Undersøkelsgruppens STEP. (Oppstillingen er satt opp med flere linjer under hverandre for å passe kronologisk sammen med den øvre del av STEP analysen. For å følge tidsaksen må hele diagrammet, inkludert FDR data, leses fra venstre mot høyre uavhengig av linje).

| INSTRUMENT APPROACH CHART-ICAO 1:275000 | MNM SECT ALT: ZOL 25 NM, 380°–180° 4800, 180°–380° 3000 | HGT RELATED TO THR 11 ELEV 7 FT. CIRCLING HGT RELATED TO AD ELEV 29 FT. ALTITUDE, ELEVATION AND HGT IN FT. BEARINGS ARE MAG. | TWR 118.350 122.100 GND 121.750 | APP/TAR 119.600 119.400 122.100 | VDF 119.600 | ATIS 126.000 | STAVANGER SOLA NORWAY |
|---|---|---|---|---|---|---|---|
| | | | TA 7000 | VAR 3° W (1995) | | | COPTER ILS+DME-11 |




(MIKNI: 584728N 0052626E)

ILS RDH 51




CLIMB STRAIGHT AHEAD TO 500 (490) FT. THEN RIGHT TURN TO INTERCEPT R-250 ZOL. CONTINUE CLIMB AND JOIN SONNY HLDG PATTERN AT 1000 FT.

| OCA (H) | | | | | |
|---|---|---|---|---|---|
| CAT OF ACFT | | H | B | C | D |
| STRAIGHT-IN | CAT I | 130 (123) | - | - | - |
| | GP INOP | 260 (250) | - | - | - |
| CIRCLING | | - | - | - | - |
| NOTE: | | | | | |

| FINAL APPROACH | DISTANCE FM FAF TO MAPT: 4.7 NM | | | | | |
|---|---|---|---|---|---|---|
| SPEED | KT | 60 | 90 | 120 | 150 | 180 |
| TIME | MIN:SEC | 4:42 | 3:08 | 2:21 | 1:52 | 1:34 |
| RATE OF DESCENT | FT/MIN | 320 | 475 | 635 | 790 | 950 |

| DIST DME ZL | 4 | 3 | 2 | 1 | |
|---|---|---|---|---|---|
| ALT (HGT) | 1280 (1270) | 960 (950) | 640 (630) | 330 (320) | |

CHANGES: ARRIVAL ROUTE FM GRAMU, PROC TITLE, OBST, CROSS, ALT PROFILE, PAGE RENUMBERED

# HELICOPTER FOG FLYING TRIALS

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## Abstract

The airworthiness and operational regulations for the All Weather Operation of Fixed Wing aircraft have been established for many years, based on fog flying trials that established the required amount of visibility and maximum lateral offset to enable safe landings from an Instrument Landing System approach. This work had not been completed for helicopters which have different flying characteristics. In order to investigate the All Weather Operation of helicopters, a helicopter fog flying trial was carried out. The trial used simulators, and an SA365N Dauphin helicopter. A large number of approaches were carried out in the simulators and in the helicopter in both clear weather and fog conditions. It was established that the helicopter can land from large offsets in clear visibility, but that it was not possible to use this manoeuvrability in conditions of restricted visual cues. Helicopters could operate in more restricted Runway Visual Ranges with helicopter specific lighting patterns and delivery accuracy. Several recommendations for further research are made and provisional recommendations for lateral offset limits and visual segment requirements are made.


## Background

British Airworthiness Requirements (BCAR) 29 Sub part 2 (Paper 29-14, All Weather Operations, currently at working draft level) contains the requirements for Rotorcraft decision heights below 200 feet and down to 100 feet.

A trials programme was designed to validate both these requirements and the Rotorcraft Operational Requirements equivalent to CAA Document CAP 359.

The Fog Flying Programme was carried out using the personnel and trials facilities of the CAA and RAE Bedford and an Aerospatiale SA365N helicopter leased from Bond Helicopters. This work has been complemented by the use of simulators. The Fog Trial also includes the use of the RAE Bedford Wessex and Sea King helicopters: this work, however, is not included in this paper.

The majority of the requirement work to date has been conducted in respect of aeroplanes and based on the low-visibility operations carried out by this class of aircraft over the last fifteen years or so. For Decision Heights below 200 feet, airworthiness considerations are of prime importance: for example, excess deviation parameters have been established to ensure:

- that the visual references available at decision height in low visibility are placed optimally for visual contact prior to making the decision to land;
- that large lateral flight path corrections are unnecessary for a safe landing to be made in the touchdown zone in low visibility;
- adequate clearance from obstacles on the approach path.

One option would be to grant no special concessions to helicopter operations below 200 ft, and to require aeroplane operational and airworthiness requirements to stand (ie. JAR-AWO 2 or BCAR Paper 742). It is recognised, however, that the helicopter is a machine with certain unique flying qualities. The extent to which these qualities may justify special treatment was the prime objective of the research programme.

It should be noted, however, that until approach systems are developed specifically for helicopters (eg, using MLS), such aircraft will continue to be constrained to use the systems that were developed for aeroplanes, namely:

- ILS with a straight-in, nominal 3° approach angle.
- Long paved runway.
- Calvert approach lighting and runway lights.

The CAA wishes to acknowledge the valuable assistance given by RAE Bedford, Bond Helicopters, Rediffusion Simulation and the BHAB in carrying out this trial.

## Trials Objectives

The objectives of the trial were:

1. To validate the Requirements of BCAR Working Draft Paper 29-14 sub-part 2, in particular with respect to:-

    a. Suitable Localiser Excess Deviation parameters for Decision Heights below 200 feet and down to 100 feet.
    b. A comparison between straight-in landings and landings from offset positions with respect to the runway.
    c. Controls/Indications/Alerts/ Warnings required.
    d. Presentation of information to the crew.
    e. Failure conditions, probabilities and effects.
    f. Go-Around and subsequent height loss.
    g. Flight path and speed control.
    h. Minimum equipment.
    i. Mode selection and switching.
    j. Flight Manual Data.

2. To establish the Minimum Visual Segment/RVR required to take-over control at Decision Height and continue to a successful landing.
3. To investigate the use of Category 1 lighting and determine the benefits of supplementary lighting up to category 2 standards for Rotorcraft decision heights below 200 feet and down to 100 feet.
4. To investigate the requirements for take-off in low visibility.

Data recording objectives were:-

1. To record Localiser, Glideslope, Radio Altimeter signals using a suitable flight data recorder. The ability to event key points in the approach has also been provided.
2. To track the helicopter path in space using the RAE Bedford Bell Radar Tracking equipment.
3. To record the approach and recovery manoeuvre using an on-board video camera.
4. To measure accurately the weather and visibility conditions on the ground during the trial.
5. To carry out a qualitative assessment of handling qualities during the recovery cases using the Cooper-Harper rating scale.

## Trials Procedures

Callouts were initiated on receipt of an advanced warning of fog for the next morning from the RAE Met Officer. At this time, a briefing sheet would be raised to cover the tasks to be completed during the sortie, and then faxed to RAE in order that all relevant trials personnel may be notified.

That afternoon/evening the aircrew would make their way to the aircraft operating base (either North Denes/Great Yarmouth or Strubby/Lincolnshire), and prepare for an early departure next morning to RAE Bedford. Meanwhile, the helicopter would be taken off the line and equipped with the Flight Data Recorder and video camera. Take off time was usually in the bracket 0700-0745 local. The trial has not yet progressed to night fogs.

Radar vectoring to an 8nm final was standard. A (two pilot) low visibility monitored ILS approach procedure, typical of that adopted by UK offshore operators, was used throughout. All approaches were flown to a go-around, except when sufficient visual references were available for a landing decision to be made. In such cases, the aircraft would be flown to a low hover over the runway.

Decision Heights of 150ft Rad Alt and 100ft Rad Alt were used to evaluate both the proposed Cat IH procedure and the full Cat II procedure respectively. The minimum allowable RVR was 200m. Only two airspeeds have been flow coupled - 100kt and 80kt.

Centreline approaches were flown in a variety of ways: manual, flight director and coupled. However, most offsets were flown coupled, to ensure that an additional error Greater than the maximum experimental value was not introduced inadvertently due to the poorer tracking performance likely with flight director or manual approaches. Coupler performance was frequently of a poor standard, however.

During the early work-up stages of the trial, approaches were flown in VMC in order to build confidence.

<u>Helicopter & Equipment</u>

The standard North Sea SA365N was equipped as follows:

- 3-axis (pitch, roll and yaw) autopilot:
- each axis controlled by two mutually monitored lanes in a fail passive configuration.
- 2-axis (pitch and roll) simplex autopilot coupler giving various flight director modes provided, including an ILS coupled mode with automatic switching from a capture phase to a track phase.

<u>EMI Flight Data Recorder</u>: This recorded localiser, glideslope and radio altimeter information, together with an event marker discrete.

<u>Video Recorder</u>: This recorded cockpit voice information and the usual scene.

<u>Flight Record Sheets</u>: These were used by the CAA observer to log in-flight data, including an assessment of handling qualities.

<u>Ground Equipment at RAE Bedford</u>

<u>Bell Tracking Radar</u>: produced X-Y and X-Z plots of helicopter position in space using glide path origin (GPO) as zero reference, and velocity plots in all axes.

<u>Precision Approach Radar (PAR)</u>: used as an independent means of monitoring the position of the helicopter with respect to localizer and glide path.

<u>Full Cat III Instrument Landing System (ILS)</u>: Runway 27 with a facility to offset the centreline of the localizer in predetermined steps in either direction:

18uA
25uA : corresponds to 1/3 dot on HSI
37.5uA: corresponds to 1/2 dot on HSI

<u>RVR Reporting</u>: An improved method of reporting Runway Visual Range (RVR) was provided by an Erwin Sick Model SM5 Transmissometer System at the touchdown point. This system differs in a number of ways from that which is operated by the CAA at Heathrow and Gatwick, particularly in the control and processing algorithms. The read-cross of RVR-based results to other airfields and other types of RVR measurement is currently being pursued by RAE Bedford.

Lighting: Two principal lighting patterns were used:

- Civil Cat I pattern of Approach, Threshold and 150ft width Runway Edge Lights.
- Full Civil Cat II Lights.

## Simulators

Current training simulators, although possessing a fair degree of realism both in the night/dusk visual scene and in their representation of the aircraft, do not truly model the real world in low-visibility conditions. In particular, the visual segment does not open out from decision height to landing in the way that this would happen in practice. Moreover, the effect of the polar diagrams and setting angles of approach lights become important in low visibility conditions where the location and brightness of the visual references can become a critical factor. These considerations are ignored in training simulators.

Nevertheless, it was intended that a simulator research programme should be undertaken in order to reduce the amount of the validation fog flying required in a real aircraft. However, it would be necessary to use a simulator which modelled the real world more realistically in low visibility conditions.

RAE Bedford has, over many years, produced a model (popularly known as the "Fog Model") of the variation of visual segment with height, based on the analysis of measurements during a significant number of real fogs. Indeed, CAA ORP 4 uses a number of elements of this model as a computer driven device to calculate operating minima, primarily for aeroplane decision heights below 100 feet (ie. Cat 3), but it can also be used to derive operating minima for decision heights of 200 feet and below.

Accordingly, it was decided that initially, this Fog Model would be programmed into the Rediffusion SP-X Development Simulator at Crawley, West Sussex. This simulator is equipped with a very high resolution visual system which provides an addressable pixel display capability, allowing accurate replication of fog both by day and by night. The programme accurately models, for a range of RVR values, the visual segment available as a function of height against the probability of encountering a given fog vertical density gradient

Both centreline and offset approaches were flown automatically to a landing.

Phase two of the simulator work involved transferral of the fog model to the Rediffusion AS332L Simulator in Stavanger, Norway, which is owned and operated by Helikopter Service A/S.

## Helicopter Handling Qualities

Helicopters have handling qualities that vary from fixed wing aircraft in some important ways. These differences could have an effect on the amount of visibility a pilot requires to carry out a successful landing in conditions of reduced visibility. In particular the helicopters ability to fly slowly without risk of stalling and to manoeuvre rapidly in a lateral sense regardless of airspeed were felt to confer benefits not available to fixed wing aircraft. These could possibly allow the helicopter to operate to a larger lateral offset at Decision Height than fixed wing aircraft. Equally, the helicopter is not constrained to land on or parallel to the runway centre line, allowing greater flexibility in choice of flight path. Against the perceived benefits, slow speed results in large drift angles and flight path variations due to cross wind. The value of visual cues could be reduced due to lack of streaming. Also most helicopters have to be flown in three dimensions until virtually stationary thereby requiring appropriate visual cues for the whole of the landing distance whereas the fixed wing aircraft landing task is only significant up to the point of touchdown, after which the task reduces to a two dimensional one.

As already mentioned, one of the objectives of the trial was to establish the extent to which the differences between helicopter and fixed wing handling qualities would effect the All Weather Operations requirements in relation to helicopters. In particular, wider lateral offset limitations at Decision Height could remove the need to equip the helicopter with automatic flight path control (ILS coupling) or a Flight Director to ensure accurate delivery, allowing use of manually flown approaches which are less accurate than automatic or Flight Directed approaches.

## Visual Segments

It is not perceived that helicopters will have an autoland capability in the near future, so the requirement remains for the pilot to take control at Decision Height (if adequate visual cues are available) and manually land the helicopter. To achieve this, an adequate amount of the approach lighting must be visible for the pilot to assess that a landing is possible, and subsequently a sufficient amount of approach and runway lighting (or surface texture and markings by day) must be visible to enable safe lateral manoeuvring, descent and deceleration of the helicopter to a stationary hover.

The amount of approach lighting visible to the pilot at any time is defined as the Visual Segment. The furthest point the pilot can see is known as the Far Point and is defined by a combination of the intensity of the lighting and the fog density. The nearest lighting in view is known as the Near Point and is defined by the geometry of the cockpit and the pilot's eye position. Fog density is not constant but reduces with height. The effect of this variation, combined with the lighting characteristics for RAE Bedford Runway 27 is shown in Figure 1 for Runway Visual Ranges (RVR) of 200 to 400 metres. The Far Point is given by the curved lines and the Near Point by the cockpit cut off angle line. The segment at any height is the difference between the Near and Far Points. In the example drawn for a pilot's eye height of 150ft with an RVR of 400m, the visual segment is 135m. The height for initial contact with lights is 180ft.

Fogs vary depending on a large number of factors, including the state of maturity of a given fog. This causes variations in the relationship between height and fog density which would be seen as a variation in Far Point versus height. Fogs are therefore categorised according to the probability of the Far Point being correct for a given RVR. For regulatory purposes a 90% fog is used ie. on 10% of occasions the Far Point will be closer than implied by the RVR given. It follows that a 90% fog will be more dense than a 50% fog, but that it will occur less frequently.

The size of the visual segment is strongly dependent on the cockpit cut off angle. With fixed wing aircraft, it is conventional to consider the cut off angle directly in front of the pilot as drift angles and offsets are small. When considering the helicopter and the possibility of large offsets and drift angles consideration has to be given to the cut off angle in a sector. This will take in the often shallow angle when looking across cockpit to the steep angle associated with "chin windows" and results in a large variation in visual segment in a given fog depending on the disposition of the visual cues in relation to the helicopter.

One of the primary objectives of the trial was to define the size of visual segment required. In the simulator trials it was possible to control the segment precisely by programming the appropriate relationship between height and Far Point. In real fog, the vertical structure was not known precisely so reliance was placed on pilot commentary and video recordings of the visual scene. The video recorder was of limited use as the field of view was restricted and no view below the cockpit coaming into the chin windows was possible. Useful data was obtained, however, from the video, particularly with an "over nose" visual segment.

## VMC Approaches

A large number of VMC (clear visibility) approaches were flown by day and night for trials purposes and for pilot currency training. Manually flown, Flight Director and coupled approaches were completed using Decision Heights of 150 and 100ft and lateral offsets from Nil to 325ft (equivalent to approximately 110uA offset - 75uA being half scale on the pilot's indicator) at speeds from 60 to 120kts. The current lateral deviation limit in the requirements is 25uA or equivalent to 63ft at 100ft Decision Height (DH) or 68ft at 150ft for a 10,000ft long runway.

Various techniques were examined for manoeuvring the helicopter from the position at Decision Height to a stationary hover over the runway. With unlimited visibility it was easy to make flight path judgements and point the helicopter at the estimated hover point thereby minimising lateral manoeuvring from offset positions and accepting a flight path that would cross the runway edge at an angle, some distance beyond the threshold. The helicopter could also be decelerated quickly by applying large nose up pitch attitudes (10°-15°) with ease, thereby minimising the distance required to land. It was considered, and confirmed by early simulator trials, that in conditions of limited visibility, from offset positions, the pilot would always turn towards the visual cues available. Because the hover point would not be in view, the turn towards the available cues would result in a flight path converging with the runway centreline such that if maintained a landing outside the runway would result. There would be, therefore, the requirement to carry out a classic "S" turn manoeuvre to reduce offset and align the helicopter flight path with although not necessarily on the runway centreline.

The landing task was defined to be:-

1. Pilot takes manual control at DH.
2. Lateral offset was to be removed by the time the helicopter crossed the threshold.
3. Final flight path was to be approximately parallel to the centreline, offset if required, although within the runway edges.
4. Descend and decelerate to a 10-15ft stationary hover.

Within these guidelines, the technique was optimised to give the easiest piloting task and the limiting offset was investigated. The easiest piloting task was found to be when pitch attitude and therefore speed was left largely constant after DH until all lateral manoeuvring was complete (usually by 50ft) at which stage the nose was raised to flare and reduce speed whilst maintaining a slow descent to 10-15ft with the final stages of the deceleration to the hover being level at this height. The task was assessed in two parts, the lateral manoeuvring part and the flare to hover part, with HQRs being assigned. A complete examination of the inter-relationship between all the significant factors ie. speed, distance from threshold, lateral offset, heading and vertical flight path was not completed but the results obtained are summarised below and are valid for speeds of 60 to 100 kts:-

A: HQR for lateral manoeuvring
B: HQR for flare
C: HQR for flare (NIGHT CASE with height calls)

| | DAY | | NIGHT | | |
|---|---|---|---|---|---|
| OFFSET | A | B | A | B | C |
| NIL | 2 | 3 | 2 | 5 | 4 |
| 65ft | 3 | 3 | 3 | 5 | 4 |
| 110ft | 3 | 3 | 3 | 5 | 4 |
| 230ft | - | - | 4 | 5 | 4 |
| 335ft | - | - | 4 | 5 | 4 |

The high HQR for the night flare was because of difficulty in judging height using only runway edge lights. The landing light was not used because in very low visibility, backscatter would negate any benefits. If the copilot gave radio altimeter height calls during the flare, the task becomes easier, reflected in the lower HQR. The two largest offsets were flown from a DH of 150ft, the others from 100ft. The helicopter flight path as measured by the Bell Tracking Radar is shown for the largest offset flown, in Figure 2. The X axis shows range in feet from the Glidepath Origin, which is 1000ft into the runway from the threshold, the threshold therefore being at a range of 1000ft. The angles of bank required increased with increasing offset, reaching a peak for the 335ft case of 35° applied quickly (30°/second) and reversed to 35° in the opposite direction to parallel the centreline

It was apparent whilst flying offset approaches that pilot opinion on the size of offset was strongly influenced by not only the actual offset, but also by flight path and heading. An 80ft offset with a flight path and heading towards the threshold was perceived as a smaller offset than a centreline approach with a divergent flight path.

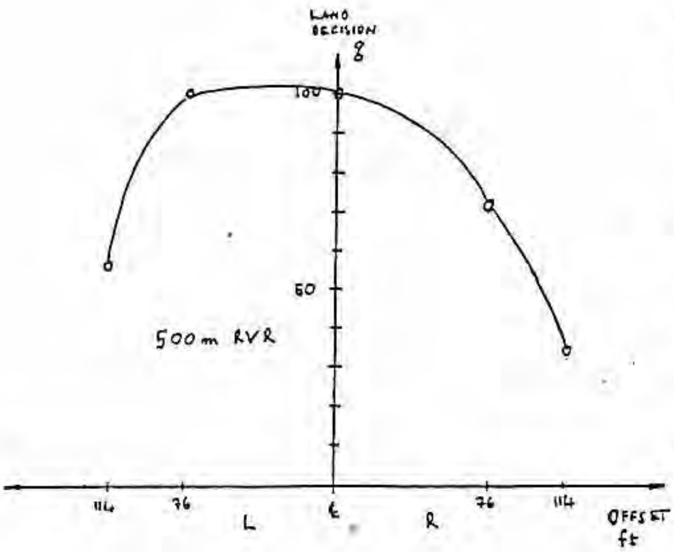
The results from the VMC approaches, although not representing an exhaustive examination of all aspects of the problem, gave a good indication of the appropriate techniques to use in fog conditions. They highlighted a potential problem in height judgement at night but also showed that the helicopter is capable, in unlimited visibility conditions, of landing from large offsets although rapid manoeuvring was required.

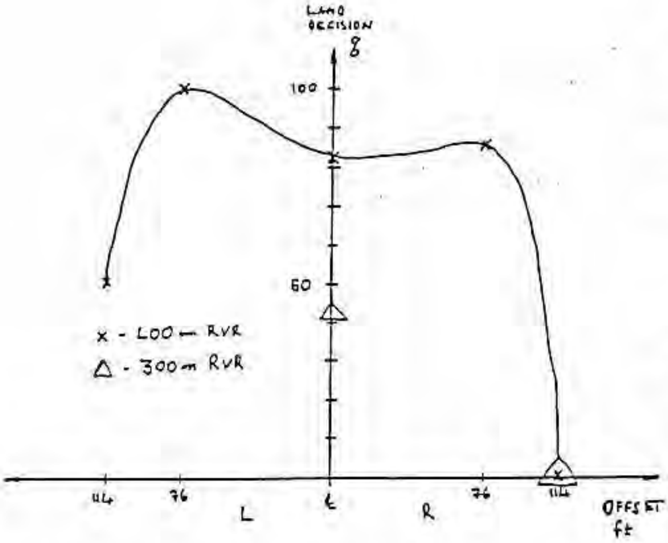
## Simulator Approaches

The simulator trials were carried out in two main phases. Firstly on the Rediffusion SPX demonstrator at Crawley, and subsequently on the Rediffusion AS332L (Super Puma) simulator in Stavanger, Norway.

### SPX Trials

The SPX demonstrator had a capable visual system that produced very realistic visual scenes in conditions of reduced visibility, by day and night. There was, however, no motion-system and it could not be flown using the cockpit controls. The simulator could be programmed to fly down predetermined flight paths. A series of experiments were constructed in which 8 pilots "flew" 103 approaches. The pilot's task was to observe the visual scene and decide at a 150ft Decision Height whether or not the visual cues were adequate to make a landing or whether a Go Around would be necessary. Approaches were flown with offsets of Nil, 25uA (76ft at DH) and 37.5uA (114ft at DH) to the left and right. Runway Visual Ranges (RVR) of 500, 400 and 300m were examined using fog probabilities of 90, 80 and 50%. Only the 90% results are referred to. The majority of approaches were flown at 80kts. The flight path of the simulator was always towards the centreline, the piloting task prior to DH was limited to monitoring height and the position at which the lights would appear in the visual system was very consistent for a given offset. These factors made the task considerably easier than would be the case in a real helicopter and to compensate for this, pilots were not told prior to each approach what offset or RVR to expect. The results obtained are summarised below, and show the percentage of "Land" decisions (ie. adequate cues) at each RVR and offset condition examined. The results show both day and night cases.




It is noticeable that the percentage of land decisions drops markedly as offset is increased beyond 76ft (25uA). Two main reasons for this were given:-

1. The offset position of the cues resulted in late aquisition. The cues were visible for only a maximum of 5-6 seconds prior to Decision Height so any delay in aquiring them reduced the limited time available to Decide on their adequacy.

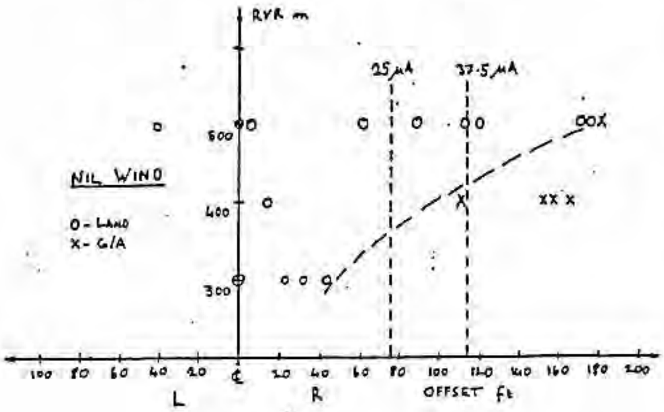
2. If the cues were seen quickly, the offset looked too large for a safe landing to be made.

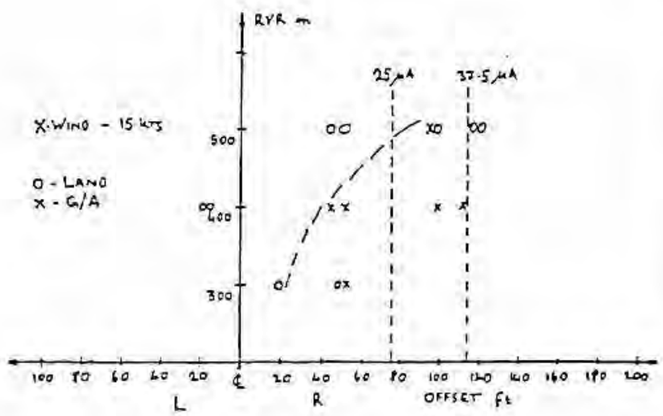
The land decision rate is better for left offsets than right offsets. This is due to all the decisions being made from the right hand seat from which the cues are better placed for early aquisition and also appear to be less offset.

## 332L Simulator

The 332L simulator was a full 6 axis motion training simulator with a "wide" visual system. The visual system was not as sophisticated as the SPX demonstrator and could only be used for night and dusk scenes. The visual system was programmed with the Fog Model data in the same way as for the SPX. Owing to an error in the airfield model being used (Aberdeen), the visual segments obtained at Decision Height were larger than expected and the variation of segment with height was not completely realistic. The most obvious difference was that although the initial contact heights were correct, the segment built up very quickly. It was considered that this effect resulted in a greater preparedness to make a "Land" decision than if the visual sequence had been correct. The results from this phase are included because they give a relative indication of the effect of the Variables used, although the absolute values are of questionable use.

All approaches were flown at 70kts to a Decision Height of 150ft. Nominal offsets of Nil, 76ft (25uA) and 114ft (37.5uA) to the right were used. All decisions were made from the right hand seat, giving cross cockpit cues, as this had been determined to be the more difficult case. The effect of crosswind was investigated by carrying out approaches in nil wind and with a 15kt crosswind from the right, again in the adverse sense. A range of task difficulty was therefore available, from a centreline nil wind, high RVR approach to one with maximum offset, crosswind and low RVR. The approaches were flown coupled in Glide Slope (G/S) and Airspeed Hold was used. The lateral guidance (localiser) was flown manually (for simulator reasons) so there was some variability in the accuracy of the lateral position at DH compared to the nominal offsets. The "Land" and "Go Around" decisions are shown below for the nil wind and cross wind cases.




These results suggest a boundary within which landings are made. The effect of crosswind is to reduce the lateral offset that is deemed acceptable. Although large offsets appear possible at 500m RVR with nil wind, the visual segment available was reported to be from 120 to 180m against a nominal segment of 108m for a centreline approach and 96m for a 114ft offset. With crosswind, which caused a 12° drift angle, even with the enlarged segment, offsets of 60ft or more either caused a Go Around or was considered to be a limiting case.

## Fog Flights

Four flights were carried out in real fog by day, at RAE Bedford. 28 approaches were completed in RVRs from 175 to 650m. The minimum Decision Height possible was 100ft which limited the number of landings which could be carried out in the low RVRs experienced. 9 approaches resulted in landings. 7 were analysed in detail using data from the video recorder, pilot commentary, aircraft recorder, Bell tracking radar and the RVR reporting. An Example of the analysis carried out is shown in Appendix 1 and shows the flight path measurement and plot of the pilot's view at Decision Height. A summary of the approaches that have been analysed is shown below.

| RVR M | DH FT | NOMINAL OFFSET | ACTUAL OFFSET | SEGMENT AT DH |
|---|---|---|---|---|
| 300 | 100' | NIL | 30'L | 134m |
| 200 | 100' | NIL | 96'L | 67m |
| 300 | 100' | 63'R | 30'R | 120m |
| 500 | 150' | 104'R | 45'R | 170m |
| 175 | 100' | 96'R | 46'L | 100m |
| 200 | 100' | 96'R | 87'L | 110M |
| 200 | 100' | NIL | 90'L | 160m |

The significant results are discussed below.

Techniques. The landing techniques evolved during the VMC approaches was found to be valid in fog conditions. The helicopter was always turned initially towards the visual cues unless the flight path was perceived to be correct. After the initial turn, the flight path was corrected to be parallel to the runway centreline. It was confirmed that the best strategy in pitch was to leave pitch attitude constant until a lower height was reached, otherwise an increased nose up pitch attitude reduced the size of the visual segment thereby making the task more difficult. The maximum angle of bank used in fog was 15°, with a visual segment of 160m and it is not considered feasible to use significantly greater angles with limited wind cues. With very restricted segments, such as the 67m case, only very small angles of bank can be used and a successful landing relies on the helicopter flight path being such that the pilot is required to do little lateral manoeuvring.

View and Visual Cues

Several landings were possible only because of the view though the chin window of approach lighting that could be seen only because the helicopter was offset in a favourable direction ie. left offset for right seat pilot's decision. Had the offset been in the opposite direction, or the decision been made by the other pilot, a Go Around would have been called. It is possible, therefore, that use could be made of chin windows, which have a steep cut off angle, to allow operations in reduced RVR conditions however it must be ensured that the visual references required will always be available. This would require a specially designed lighting pattern to cater for a range of lateral offsets, or very accurate delivery of the helicopter would be required to a less extensive lighting pattern.

For regulatory purposes, with current lighting patterns and likely offsets and drift angles, a visual segment visible over the nose of the helicopter must be required. This will have to take into account the most penalising cut off angle over which cues will have to be seen.

Lighting

Approaches were made using both Category I and Category II lighting. In the worst conditions (175-200m RVR) the Category II lighting allowed landings to be made, where Category I lighting did not provide sufficient references. The advantage of the Category II lighting was the "carpet" of lights prior to the threshold that provided a greater amount of information. As height was reduced to approximately 50ft and below, runway texture was more powerful as a cue than runway lighting by day. By night, texture would be absent and touchdown zone lighting would undoubtedly make the deceleration phase of the approach easier. A typical distance travelled between first contact with approach lights just before Decision Height and coming to a stationary hover was 3700ft, therefore the minimum combined length of approach and runway lighting should be in the region of 4000ft for helicopter All Weather Operations.

Current lighting patterns can be potentially confusing when observed from offset positions through very limited visual segments. On one approach, with a cross cockpit over nose segment, the initial turn was made in the wrong direction, and on another approach with a very limited chin window segment, it was felt that insufficient information would have been available to make flight path adjustments had any been required. It is felt that at high offsets with limited segments, difficulty could be experienced in deciding whether roll or pitch corrections are required if changes to the flight path are necessary. An example of lighting viewed from an offset of 96ft is shown below.

Automatic Stabilisation Equipment. The helicopter used had attitude demand Auto Stabilisation Equipment (ASE). This meant that helicopter attitude was related to stick position. It was considered that stick position provided a significant cue to the pilot about attitude in pitch and roll, in conditions of limited visual cues. This feature was of particular importance when manoeuvring using predominantly chin window references, when no horizontal references were available. If helicopters were to operate routinely using "chin window" visual segments, it is likely that attitude demand ASE would be required. Further work could usefully be carried out into the relationship between ASE characteristics, visual cues and the use of steep cut off angles.

Height Judgement

It was found that height judgement was difficult with limited visual segments, either through chin windows or over the nose. This was particularly noticeable in the 80-60ft range when the approach lighting was going out of view and the runway visual reference had to be used. This difficulty could be compensated for by using the other pilot to give radio altimeter height calls.

## Conclusions

The following provisional conclusions have been reached, although some further analysis remains to be completed and areas of further work have been identified:-

The helicopter is capable of landing satisfactorily from large lateral offsets, when in conditions of clear visibility.

The best technique for landing a helicopter in fog conditions was determined.

Height judgement is difficult when manoeuvring using only runway edge lights.

The percentage of "land" decisions drops as offset and crosswind are increased for a given RVR.

More "land" decisions are made if the visual cues are displaced slightly to the side the pilot is sitting.

Landings in very low RVRs are possible using chin window references if the helicopter is correctly placed and the flight path is in an advantageous direction.

An attitude demand ASE can compensate for poor visual cues.

The maximum offset allowable is constrained by the visual cue environment, not the helicopter's characteristics.

Further work should be carried out to investigate the benefits of specifically designed helicopter lighting patters, the required delivery accuracy and the ASE requirements.

Over nose visual segments are required when using existing lighting patterns and likely offsets and this segment at Decision Height should be at least 120m.

The maximum lateral offset for helicopter Decision Heights between 200 and 100ft should be 25uA.

## Acknowledgements

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Mr A Puffett - RAE Bedford

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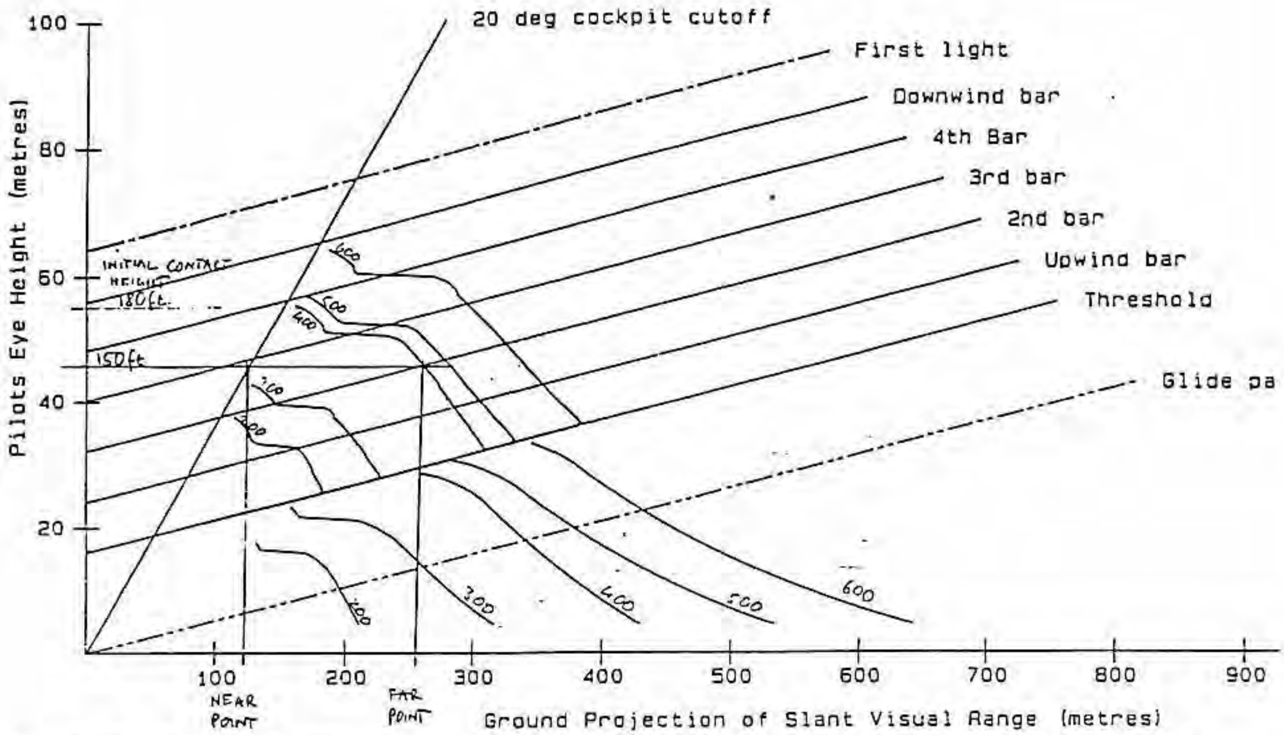
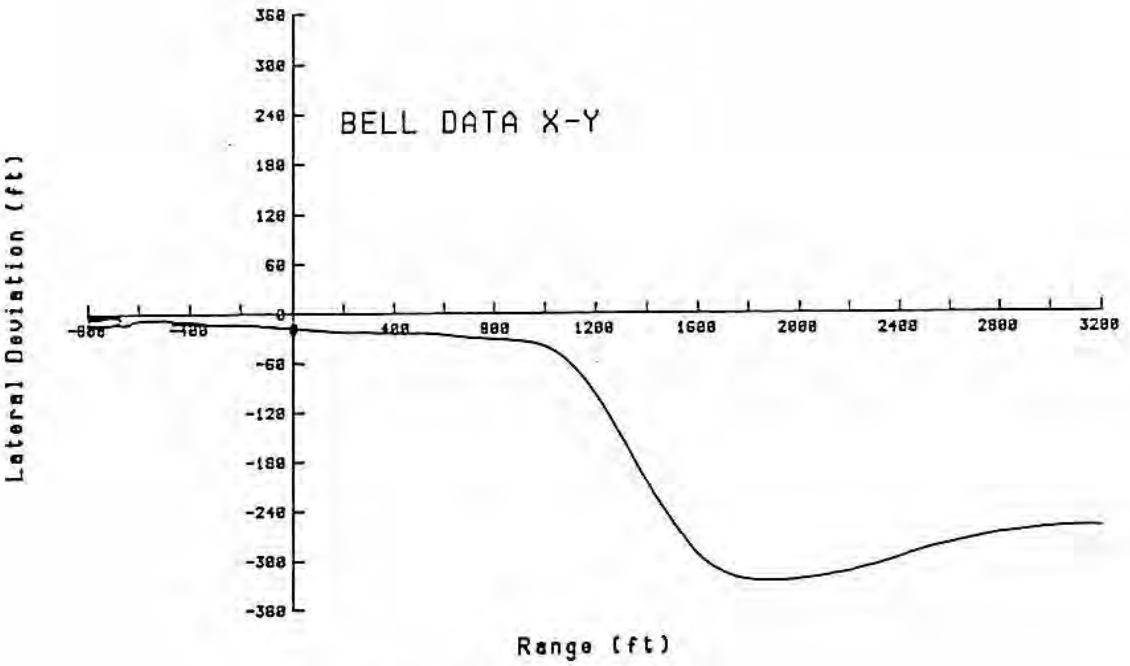



Bedford 3 deg. WP13 App. 150ft edge. Dull day LgEt=-4. 200 - 600m RVR (7Kcd). P=0.1

Run ident "80Z02 4:18 PM MON., 16 JAN., 1989

FIGURE 1




FLIGHT 13 RUN05

FIGURE 2

Flight: 9 Run: 07 Date: 14/10/88 Land/GA: Land

1. BASIC PARAMETERS
   a. Handling Pilot: B Seat: L
   b. Non Handling Pilot A Seat: R
   c. Decision Height: 100ft
   d. ILS Offset: NIL
   e. Lighting: CAT II enhanced
   f. Target Airspeed: 80kts
   g. Approach Method: Coupled
   h. Wind: 060/10kts
   i. RVR: 200m
   j. Cross Cockpit Cues? NO

2. 1ST CONTACT WITH LIGHTS
   a. Height: 170ft
   b. Range from Threshold: 1750ft
   c. Lateral Position: 100ft L

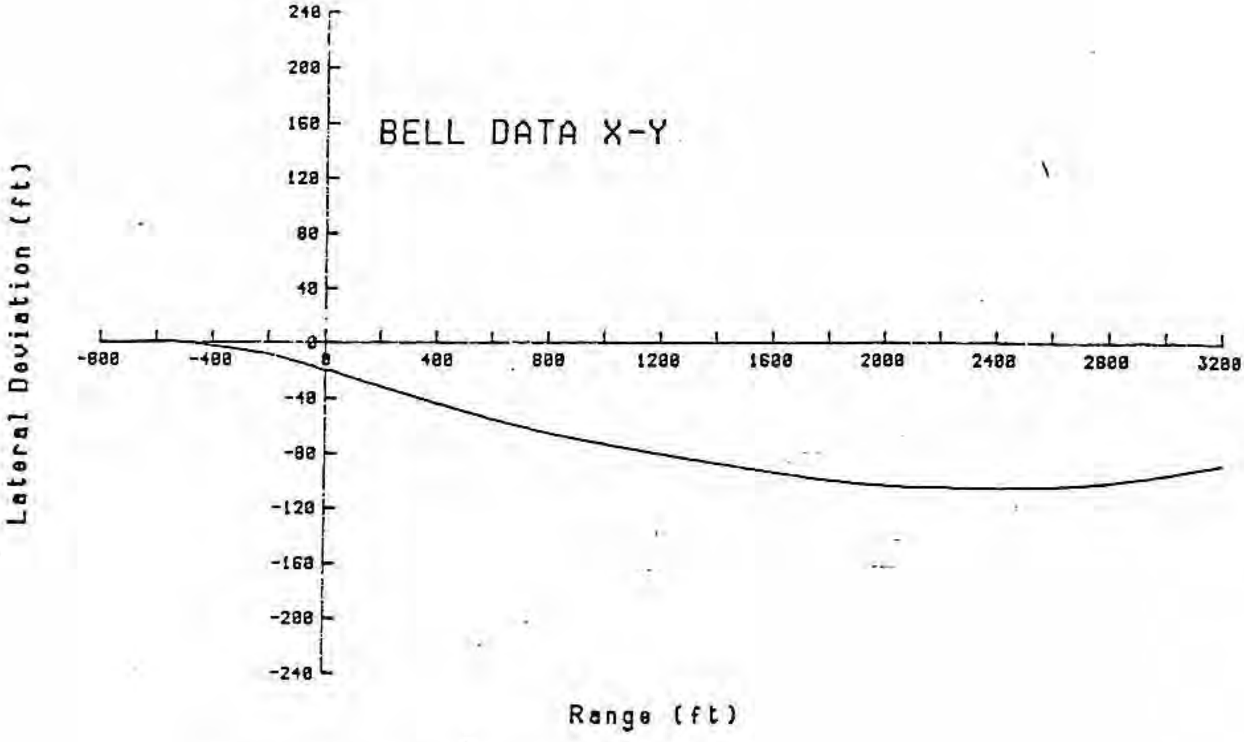
3. AT DECISION HEIGHT (DH)
   a. Time from 1st Contact to DH:6 seconds
   b. Range from Threshold: 700ft
   c. Lateral Offset: 96ft L
   d. Flight Path Vector/Heading: 1.5° towards L/273°
   e. Speed: IAS 80kts G/S 86kts
   f. Decision/Ease of Decision: Land/Difficult due to minimal cues.
   g. Visual Scene at DH: All below coaming, through lower part of windscreen and chinwindow. Segment 67m at DH.
   h. General Comments: Land decision due to well plae cues vsible in chin windows due to offset. Previous approaches to similar position allowed "practice". First time similar cues seen, G/A called. Very limiting.

4. MANOEUVRE
   a. 1st Angle of Bank: Nil (Flight path vector correct at DH)
   b. 2nd Angle of Bank 5° L
   c. Height at Threshold/GPO: 82ft/52ft
   d. Lateral Offset at Threshold/GPO: 75ft L/20ft L
   e. Adequacy of Visual Cues: Barely adequate. Very difficult to judge height. Cues improved below 50ft.
   f. HQR: 5
   g. General Comments: Deviated above G/S after DH.

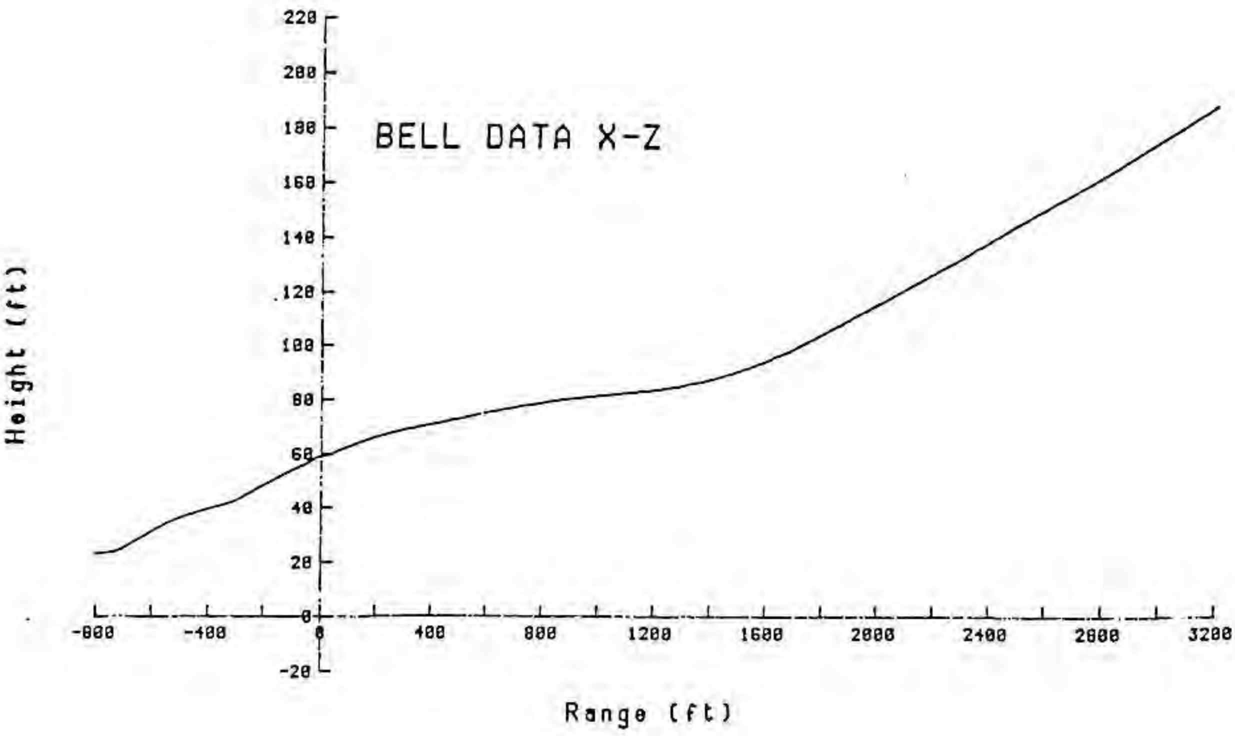
5. FLARE LANDING
   a. Flare Height: Initial nose up at DH, further flare at 3--25ft.
   b. Flare Attitude: 3° initially (-3° to 0°), then further 3°(0to +3°)
   c. Speed at Threshold/GPO: 76kts/59kts.
   d. Distance to Stop: 2100ft beyond threshold.
   e. Final position in relation to L: On L.
   f. HQR: 5
   g. Adequacy of Visual Cues: Initially poor, better below 50ft.
   h. General Comments: Very difficult to judge height above 50ft. Nedded height calls. Very gentle handing in pitch due to poor cues. Deviation above G/S.

6. GENERAL COMMENTS

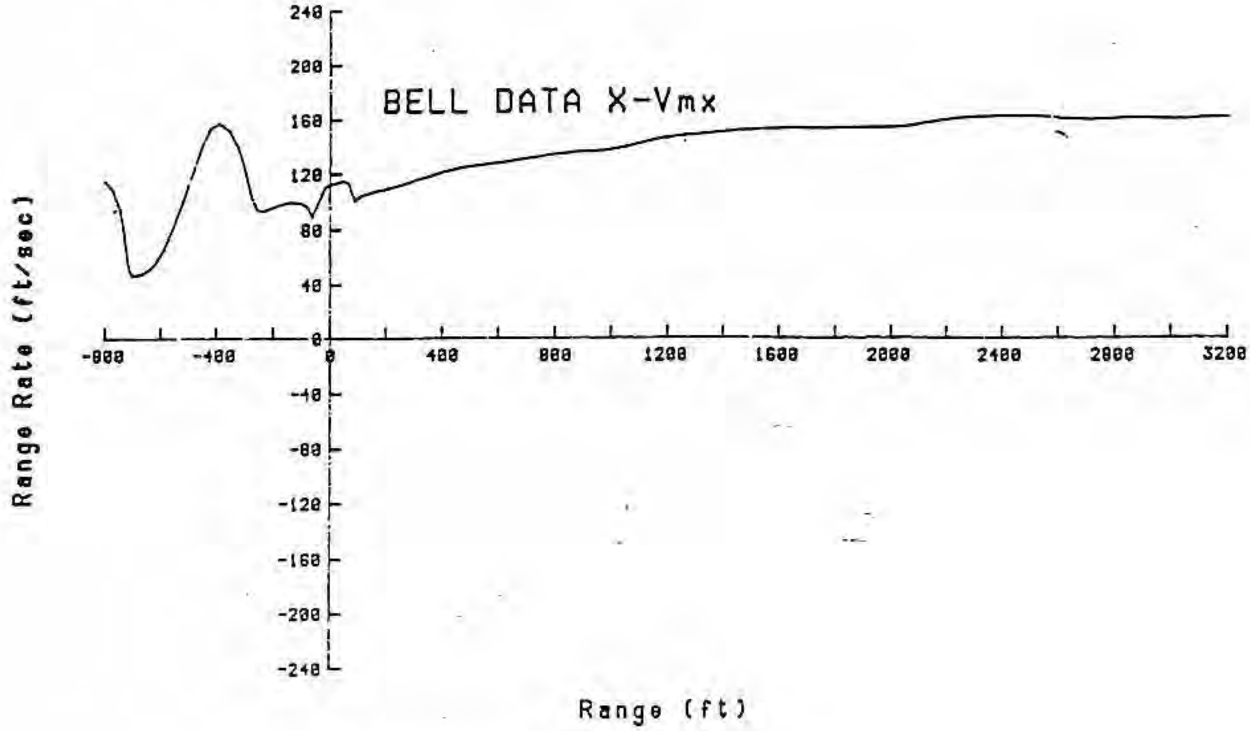
An extremely limiting case in which offset allowed adequate view. Flight path vector correct at DH so little manoeuvring required. Height judgement difficult. Previous approaches with similar cues resulted in G/A, therefore landing due to "practice".



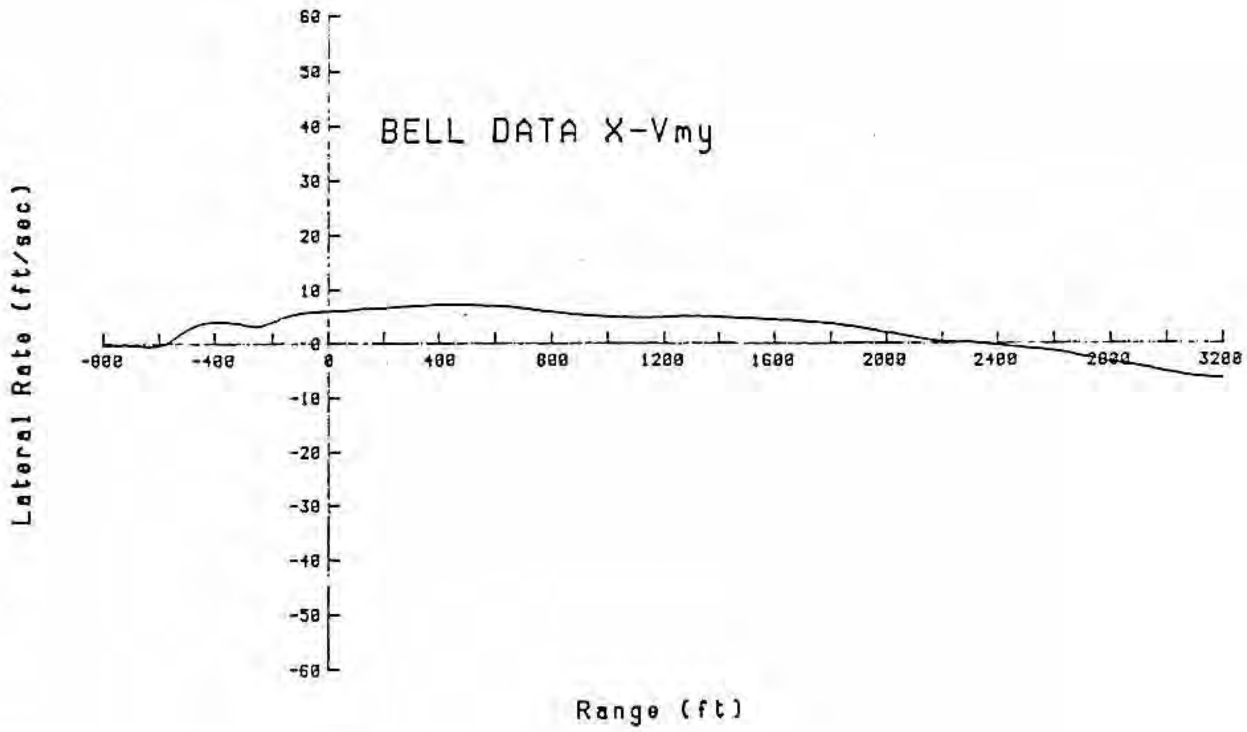

FLIGHT 09 RUN07



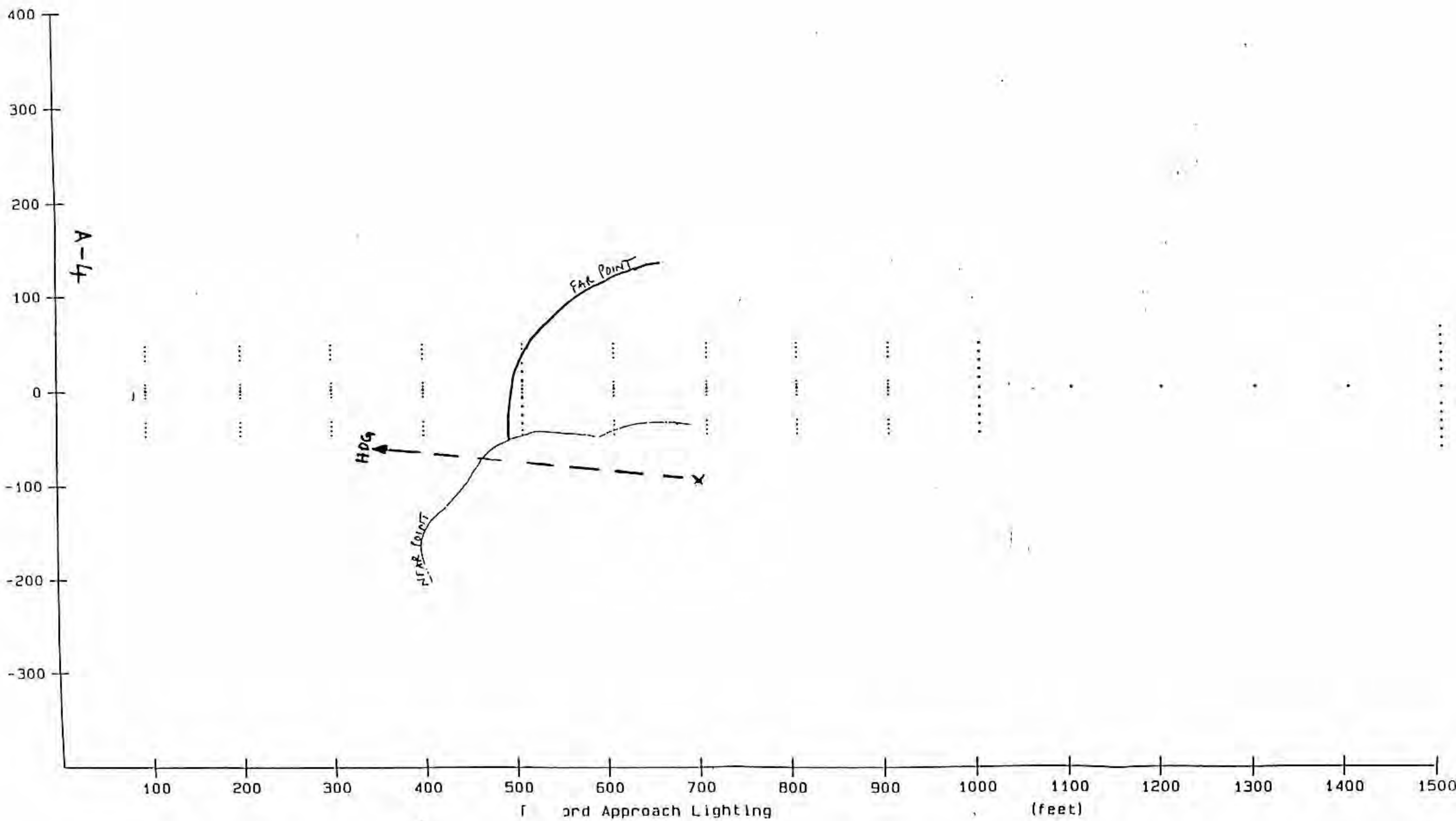

FLIGHT 09 RUN07




FLIGHT 09 RUN07




FLIGHT 09 RUN07


A-4
FAR POINT
NEAR POINT
HDG
400
300
200
100
0
-100
-200
-300
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300
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ord Approach Lighting
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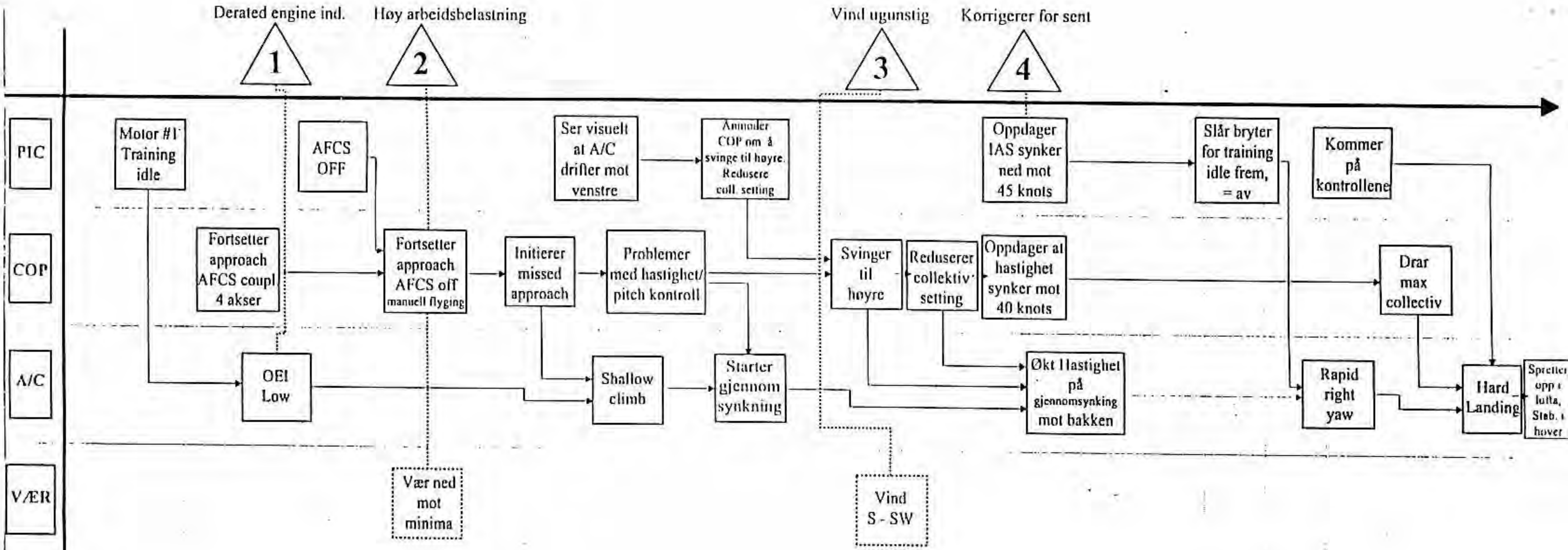


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Data fra FDR utskrift

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rad Alt ft | 331 | 349 | 330 | 325 | 310 | 291 | 289 | 318 | 316 | 287 | 321 | 331 | 301 | 256 | 253 | 224 | 180 | 105 | FDR |
| IAS kts | 52 | 48 | 53 | 53 | 56 | 59 | 60 | 54 | 58 | 61 | 47 | 30 | 36 | 0 | conv | conv | 0 | conv | SYNC. |
| V/S ft/s | +704 | +819 | -288 | -64 | -224 | -192 | +48 | +352 | -96 | -304 | +496 | +64 | -572 | +8 | -16 | -576 | -1308 | -2200 | FLAG |
| Hdg deg | 122 | 119 | 110 | 104 | 101 | 100 | 97 | 108 | 129 | 154 | 161 | 148 | 148 | 167 | 166 | 175 | 192 | 280 | WARNING |
| TQ 1/2 | /40.0 | /44.5 | /41.1 | /43.0 | /43.0 | /44.8 | /43.9 | /47.3 | /44.1 | /39.1 | /42.3 | /42.5 | /43.5 | .2/44.5 | .2/36.5 | 13.1/28.1 | 26.2/26.0 | 36.9/31.1 | |
| Time | 08:14:15 | :19 | :23 | :27 | :31 | :35 | :39 | :43 | :47 | :51 | :55 | :03 | :07 | :15 | :17 | :19 | :21 | :24 | 08:15:27 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
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| IAS kts | 54 | 60 | 37 | 39 | conv | conv | 0 | conv |
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| Hdg deg | | 148 | 160 | 162 | 165 | 170 | 209 | 291 |
| TQ 1/2 | | /39.8 | /45.5 | 0.2/40.8 | 0.2/44.5 | 6/30.5 | 25.6/26.6 | 54.1/46 |
| Time | 08:14:42 | :50 | :59 | :11 | :16 | :18 | :22 | :25 |

| | | | | |
|---|---|---|---|---|
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| IAS kts | 30 | conv | 0 | conv |
| V/S ft/s | +384 | -904 | -1320 | -1784 |
| Hdg deg | 160 | 181 | 238 | 2268 |
| TQ 1/2 | 44.3 | 18.0/23.6 | 27.7/26.4 | 58.0/52.2 |
| Time | 08:15:01 | :20 | :23 | :26 |