Operational Procedures using *THALES Avionics* HUD/EVS "ENHANCED VISION SYSTEM"

A report on an experiment with the BOEING 737- 300 simulator

Pascal Beaudouin
THALES Avionics

pascal.beaudouin@thales-avionics.com

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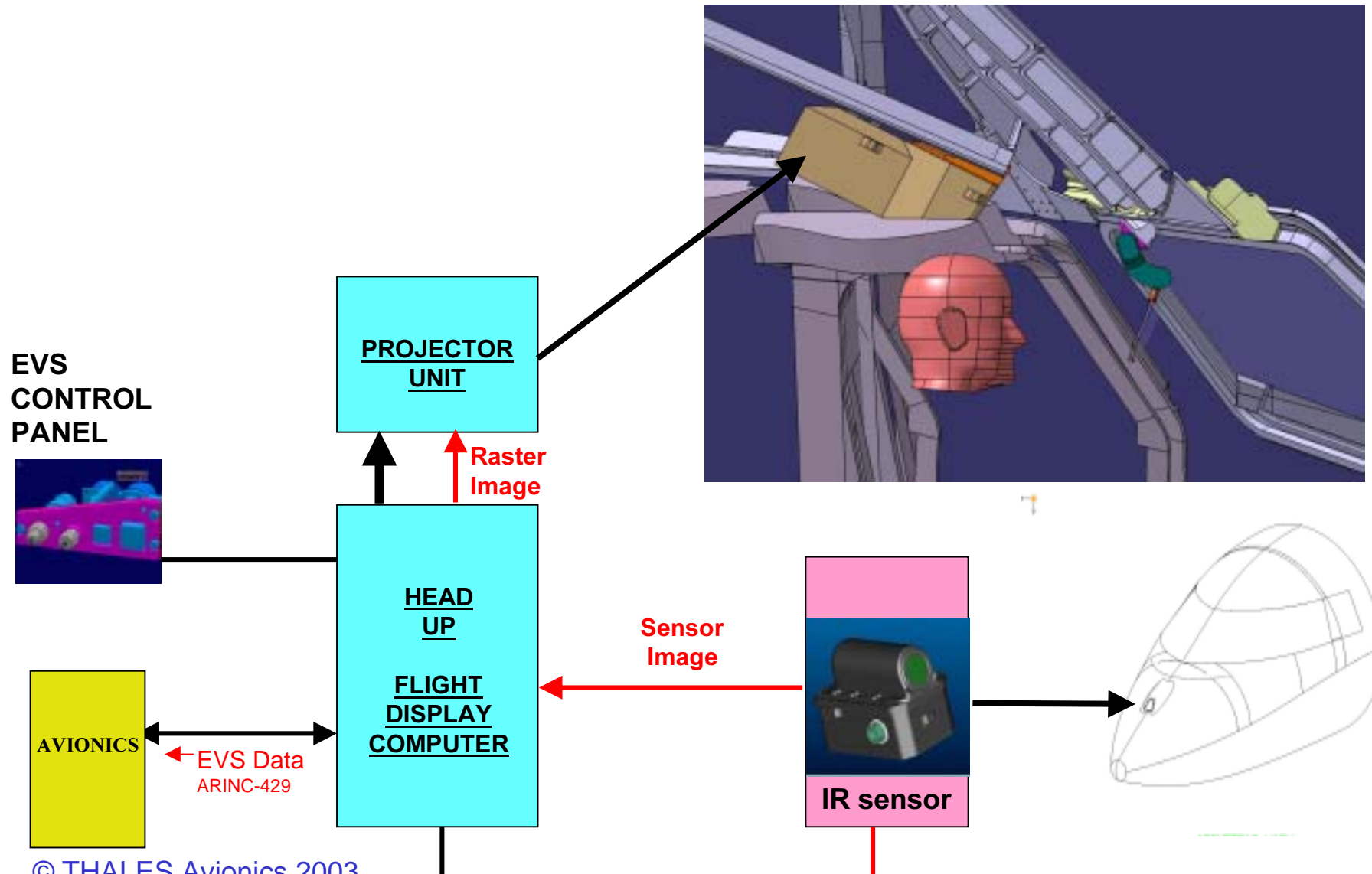## *SUMMARY*

- **STATUS**
  - Since 1992 with NORTHWEST Airlines

- **CONTENT OF « SIGNAL 2 » STUDIES**

- **RESULTS OF THE EXPERIMENT :**
  - CAT I EVS
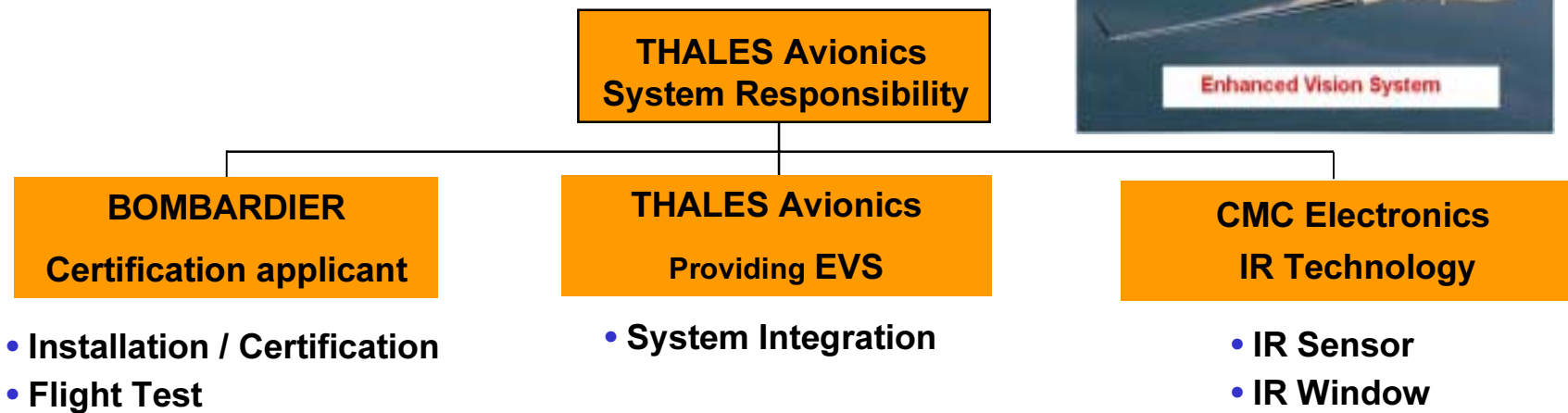 - NPA EVS

- **CONCLUSION - NEXT STEP FORWARD**

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EVS CONTROL PANEL

PROJECTOR UNIT

Raster Image

HEAD UP FLIGHT DISPLAY COMPUTER

AVIONICS

EVS Data
ARINC-429

Sensor Image

IR sensor

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HFDS + FLIR EVS

GLOBAL EXPRESS

- Basic on *GEX* and Option for *GLOBAL 5000*

- Certification (TC) : 1st Q 2005

Enhanced Vision System

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                    ┌─────────────────────┐
                    │  THALES Avionics     │
                    │ System Responsibility│
                    └─────────────────────┘
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BOMBARDIER	**THALES Avionics**	**CMC Electronics**
Certification applicant	**Providing EVS**	**IR Technology**

- **Installation / Certification**
- **Flight Test**

- **System Integration**

- **IR Sensor**
- **IR Window**

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■ **Gulfstream G-V EVS Special Condition (FAA/STC) - *06/2001***

  ■ **FAA Statements**

    ● Enhancement of pilot's situational awareness

    ● EVS image compensates the field of view obstruction due to raster display (safely and in compliance with §25.773).

■ **FAA Notice for Proposal RuleMaking (NPRM) in progress for Enhanced Flight Vision System (EFVS)- *Initialized in 02/2003***

  ■ Objective : Takeoff and landing under IFR (§91.175) Amdt

    ● EFVS enables the pilot to determine « enhanced flight visibility » at MDA(H) or DA(H) in lieu of flight visibility [cf. §91.175(c)(2)] ;

    ● EFVS permits descent and operation below MDA(H) or DA(H) based on EFVS images

Note : NPRM doesn't cover CAT II and CAT III operations

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Authorities involved :

- **CAA / DPAC (*CONTRACT MANAGER*)**
- **CAA / DGAC / OCV**
- **CAA / DGAC / SFACT / E (*OPERATIONS*)**
- **DGA / CEV (*FLIGHT TEST CENTER*)**

Airlines (pilot panel) :

- **AIR France (through SNPL COMETEC)**
- **BRIT AIR**

...and Aircraft Manufacturers :

- **BOMBARDIER**
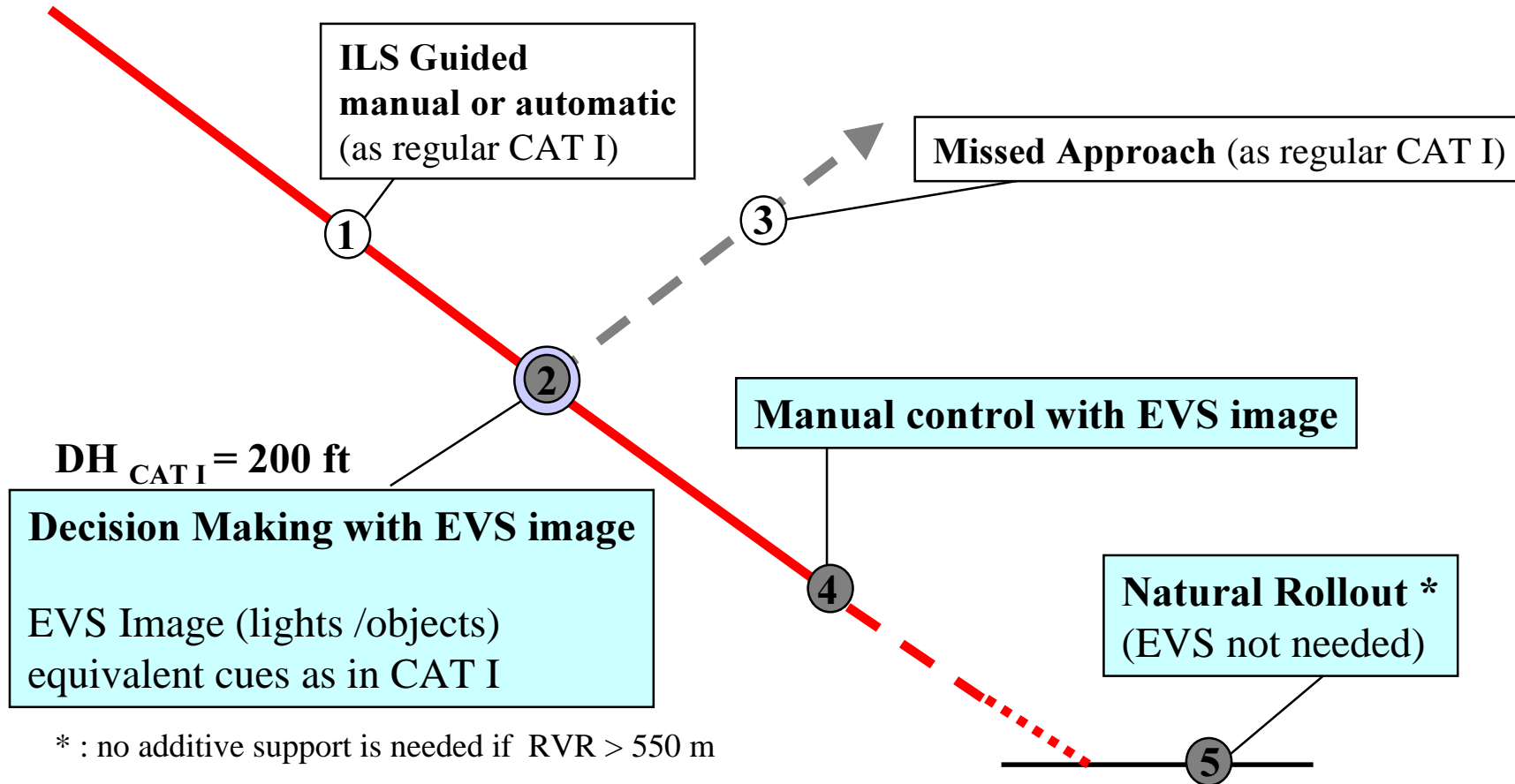- **DASSAULT AVIATION (FALCON F7X)**
- **AIRBUS**

THALES

RVR reduced to 550m *1800ft*

JAR OPS 1.430 and AC 120-29A appendix 7 (C074)

Cat I minima (with lateral and vertical guidance)				
Decision height	Facilities/RVR			
	Full	Interm	Basic	Nil
(JAR) 200 ft	550 m	700 m	800 m	1000 m
(FAR) 200 ft	550 m	750 m	1000 m	1200 m

ILS Guided manual or automatic (as regular CAT I)

①

Missed Approach (as regular CAT I)

③

②

DH $_{CAT\ I}$ **= 200 ft**

Manual control with EVS image

Decision Making with EVS image

EVS Image (lights /objects) equivalent cues as in CAT I

④

Natural Rollout * (EVS not needed)

⑤

* : no additive support is needed if RVR > 550 m

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Airport Database Simulator THAV Constraint

ICAO CODE LFBD

DH	FULL	INTER	BASIC	NIL
	RVR for Category C Aircraft (B 737-300)			
200 ft	550 m	700 m	800 m	**1000 m**
201-250 ft	600 m	700 m	800 m	1000 m
251-300 ft	650 m	800 m	900 m	1200 m
301 ft +	800 m	900 m	1000 m	1200 m

Non conformity(1) :
for   - contrast and brightness of lights
**   - geometry of ALS**

Non conformity(1) of Airport ALS Simulator THAV Constraint

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THALES

RVR reduced to 800m 2400ft

JAR OPS 1.430 and AC 120-29A appendix 7 (C053 and C054)

MDA(H)	Straight-In minima (NPA)			
	Facilities/RVR			
	Full	Interm	Basic	Nil
250 ft to	800 m	1000 m	1200 m	1500 m
>650 ft	1800 m	2000 m	2000 m	2000 m

(1) — **Manual or automatic IFR approach** (as regular NPA)

MAPt

(2) — **MDA(H) > 250 ft** **Decision Making with EVS image**

(3)

(4)

RVR = 800 m on NIL facilities airfield

Manual control with EVS image *(Visual cues at 100 ft)*

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MDH	FULL	INTER	BASIC	NIL
	RVR for Category C Aircraft (B 737-300)			
250-299 ft	800 m	1200 m	1400 m	1600 m
300-449 ft	1000 m	1400 m	1600 m	**1800 m**
450-649 ft	1200 m	1600 m	1800 m	2000 m
650 ft +	1400 m	1800 m	2000 m	2000 m

Airport Database Simulator THAV Constraint

ICAO CODE LFPO

Non conformity(1) of Airport ALS Simulator THAV Constraint

Non conformity(1) :
for   - contrast and brightness of lights
**   - geometry of ALS**

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THALES

- **STANDARD CONFIGURATION**
  - **NO HUD**
  - **USED FOR INITIAL TRAINING**
  - **USED TO GENERATE THE « BASELINE »**
    - **MEASUREMENT OF THE PILOT 'S STANDARD PERFORMANCE (reference)**

WIDE ANGLE VISUAL

MASTER CAUTION

MCP

RUDDER PEDALS & TOE BRAKES

CONTROL COLUMN & WHELL

LANDING GEAR

ANTISKID/ AUTOBRAKE

CONTROL STAND

STAB TRIM PANEL

TRIM CONTROL PANEL

"Space Magic" Landscape Generation

In/Out Cockpit Bench

NH5802

EDINT32

SCRAMNET

CPU BI-PPC 88110

SILICON GRAPHICS MANAGT

"HARIS" Computer

Ethernet
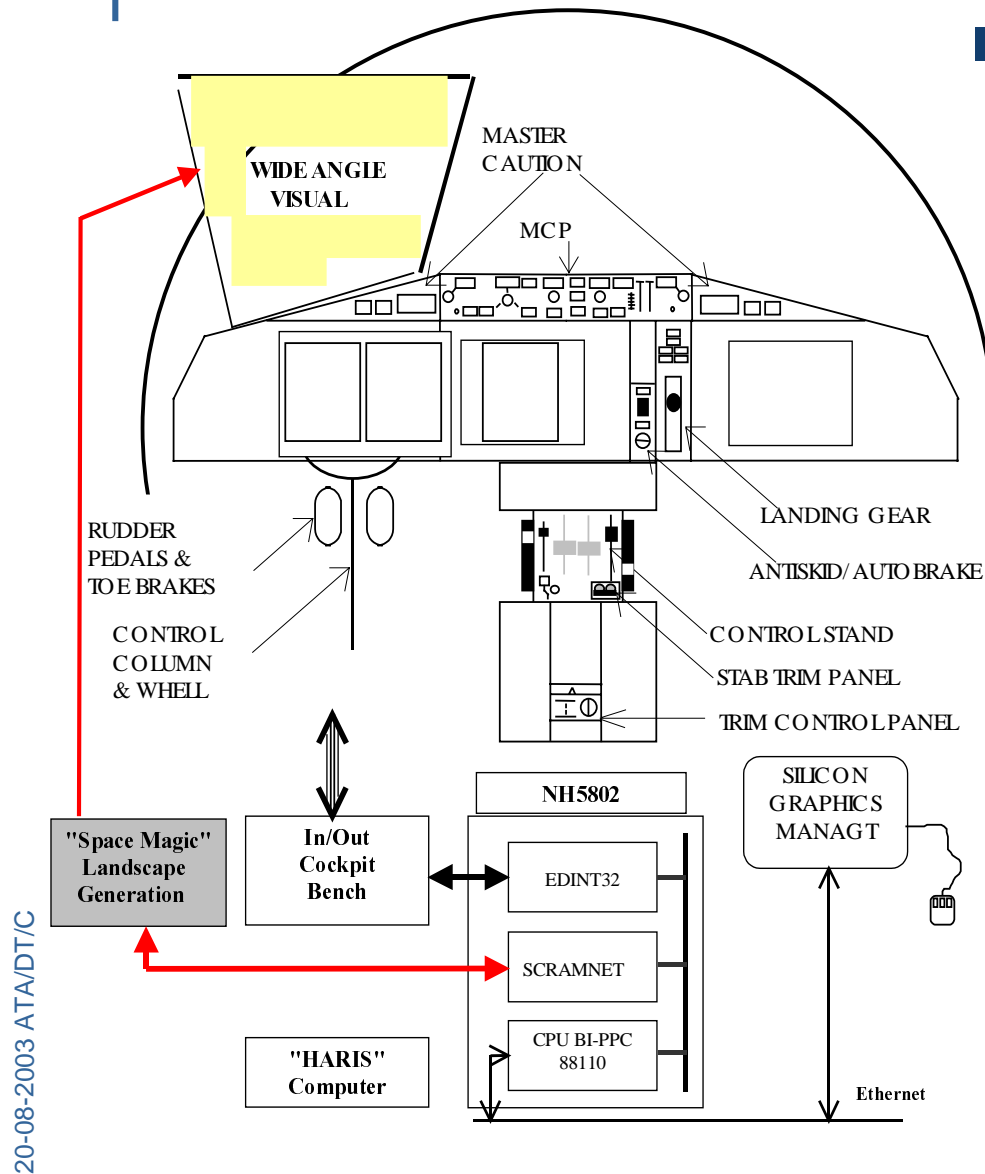
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Setting of VISUAL for initial training : CAVOK - Height = 200 ft

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Setting of VISUAL in « BASELINE ILS CAT I»
ALS OUT - RVR = 1000 m - Height = 200 ft

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HUD SYMBOLOGY
(USING AIRCRAFT DATA)

WIDE ANGLE
VISUAL

MASTER
CAUTION

MCP

RUDDER
PEDALS &
TOE BRAKES

CONTROL
COLUMN
& WHELL

LANDING GEAR

ANTISKID/ AUTOBRAKE

CONTROL STAND

STAB TRIM PANEL

TRIM CONTROL PANEL

HARMONIZATION
OF IR IMAGE
(SOFTWARE)

**FLIR MODEL
SILICON
GRAPHICS
STATION**

*"Space Magic"
Landscape
Generation*

**In/Out
Cockpit
Bench**

NH5802

EDINT32

SCRAMNET

CPU BI-PPC
88110

SILICON
GRAPHICS
MANAGT

**"HARIS"
Computer**

Ethernet

- ■ HUD WITH EVS IMAGE **(1)**
- ■ USED TO :
  - ● **MEASUREMENT** OF THE PILOT 'S PERFORMANCE
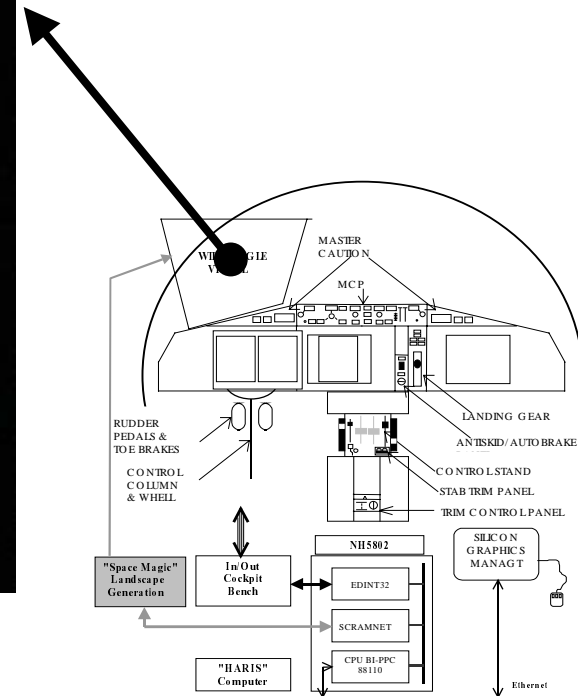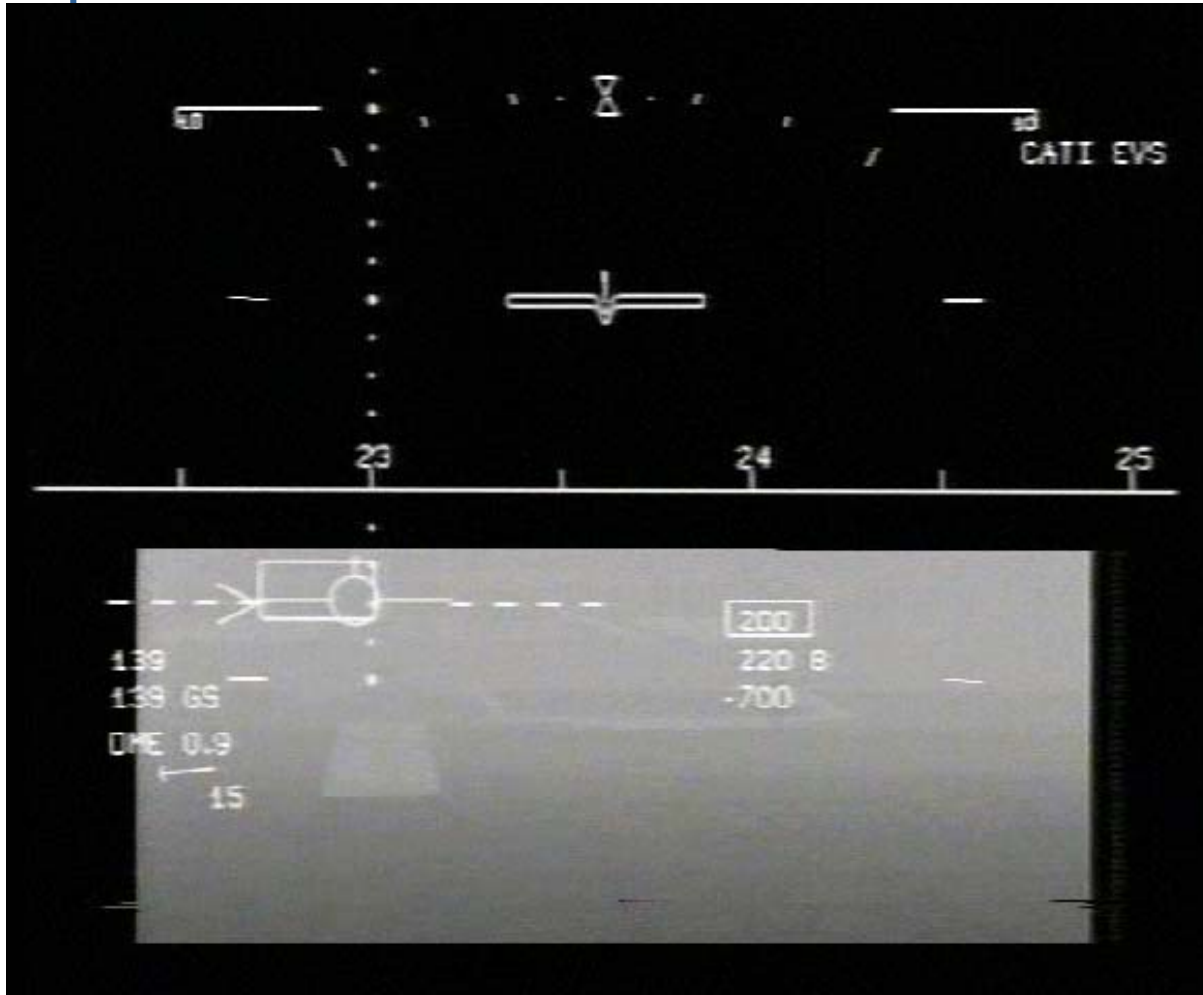
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■ The runway threshold in IR imagery appears
3 seconds before Decision Height.

■ Airfields selected : « ALS OUT » configuration.

HUD/EVS is a combined use of HUD symbology and IR image.

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Simulated Aircraft configuration

- **B737-300**

- **GROSS WEIGHT : 40 tons**

- **FLAPS SETTING**
  - RUN START : 0°
  - LANDING : 30°

- **SPEED**
  - RUN START : 240 kt
  - LOC INTERCEPT : 210 kt
  - FINAL APP : 140 kt

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- 2 experts (CAA/DGAC/OCV) for validation of EVS procedures
- 7 Air Transport pilots flying in airlines
  - HUD trained and non trained
  - B737 qualified and non qualified

PE1	PE2
Aged 58	Aged 53
15762 h	15400 h
Captain	Captain
B747	B747

PL1	PL2	PL3	PL4	PL5	PL6(*)	PL7
Aged 52	Aged 53	Aged 32	Aged 30	Aged 52	Aged 36	Aged 51
14500 h	13000 h	2400 h	3000 h	11000 h	5500 h	8000 h
Captain	Captain	F.Off	F.Off	Captain	Captain	Captain
CRJ100	CRJ100	B777	A320	B747	B737	B777

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List of discrete criteria used
for pilot performance measurement

- TOTAL NUMBER OF :
  - SUCCESSFUL LANDINGS
  - GO-AROUND
  - TOUCHDOWN THEN GO-AROUND
  - CRASHES

- TOTAL NUMBER OF CASES WHERE MAIN WHEELS:
  - ARE UNDER FLIGHT PATH ANGLE (3°)
  - ARE UNDER THE OBSTACLE CLEARANCE

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List of continuous criteria used
for pilot performance measurement

- *« Flight Crew Licensing » regulations*
  - HEIGHT at DH or MDH (+50 ft tolerance)
  - HEIGHT at TCH (Threshold Crossing Height - Z =50 ft)
  - HEADING VALUES (+ or - 5°)
  - HORIZONTAL SPEED (+ or - 5 kt)

- *« All Weather Operations » regulations*
  - LONGITUDINAL TOUCHDOWN DISTANCE (threshold)
  - LATERAL TOUCHDOWN DISTANCE

- *« Aircraft limitations»*
  - VERTICAL SPEED (Landing gear limitations)
  - ROLL VALUES (+ or - 8° due to B737 nacelle position)

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THALES
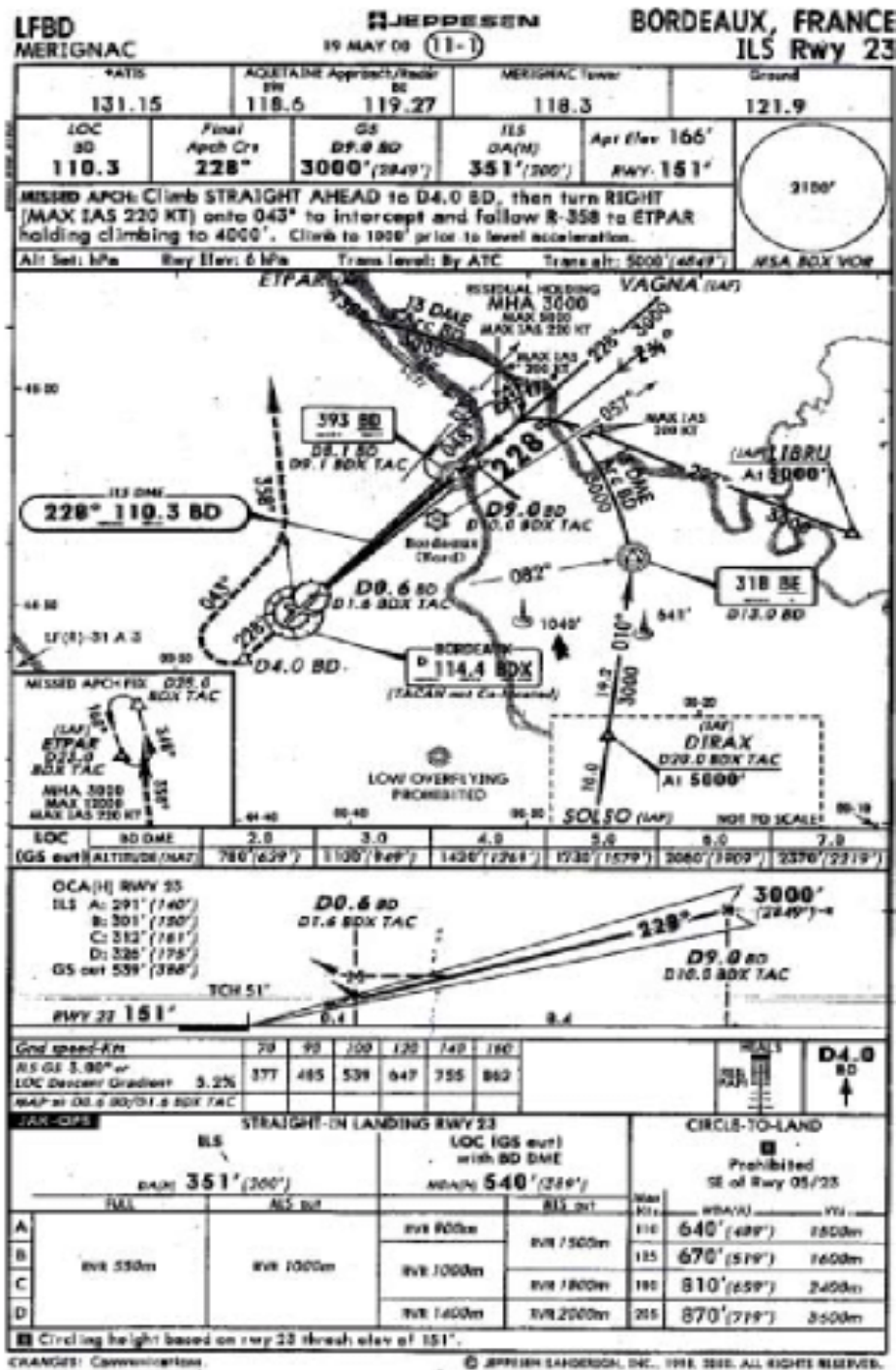
Experiment 1 Scenario

- ILS CAT I Rwy 23

- JAR OPS

- BORDEAUX,France

- BRIEFING STRIP 11-1 **JEPPESEN**

- Axis : 228°

- ILS Glide slope 3° or 5,2%

- DH = 200 FT at 0,4 Nm of runway threshold

- For « Category C » A/C
  - **ALS OUT : RVR =1000m** 3000ft
  - **ALS FULL : RVR =550m** 1800ft

- IAF «LIBRU» 5000' (~9 min)

- Wind : 320° 15 kts

THALES
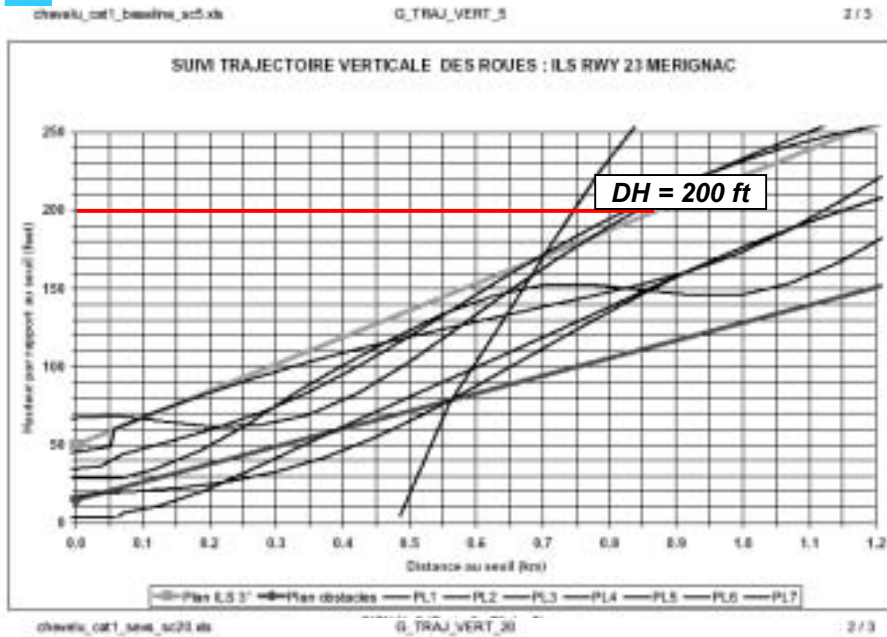
WITHOUT HUD/EVS

- **N=7 Standard ILS CAT I App**
- **RVR = 1000 m - FOG**
- **ALS out**
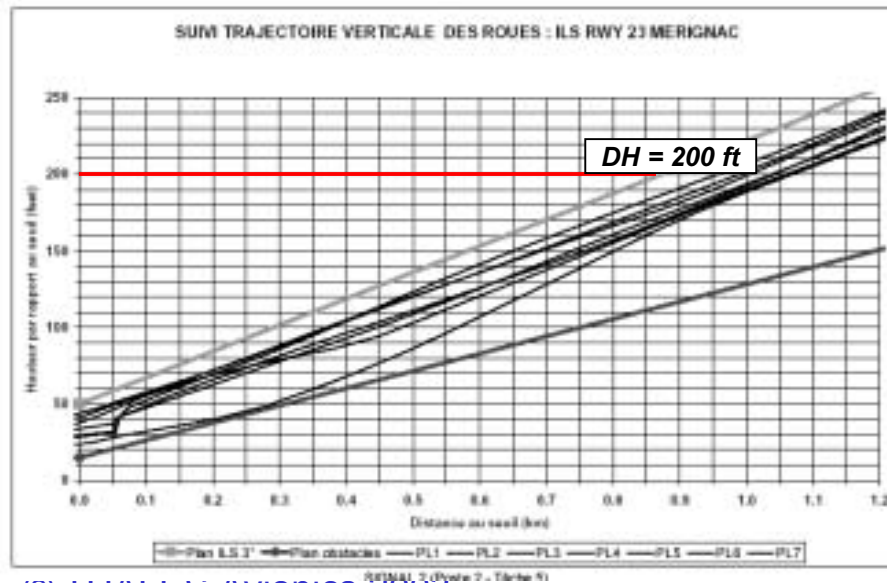
WITH HUD/EVS 🙂

- **N=7 ILS CATI EVS App**
- **RVR reduced to 550 m - FOG**
- **ALS out and DH = 200 ft**
- **Results :**
  - **Stability of flight**
  - **FCL tolerances improved**

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THALES
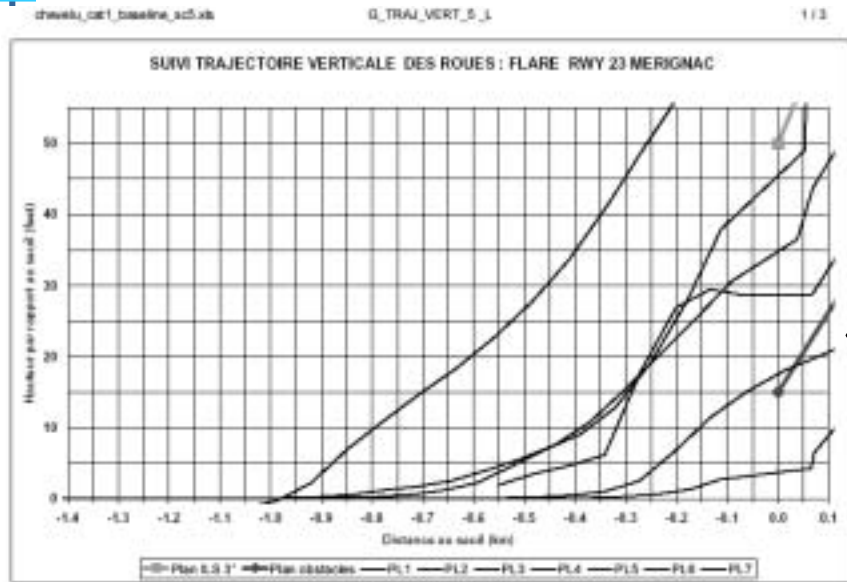
WITHOUT HUD/EVS

- **Standard ILS CAT I**
- **RVR = 1000 m - FOG**
- **No Runway Center Line**
- **Success rate : 5/7 LANDINGS**
  (71%)
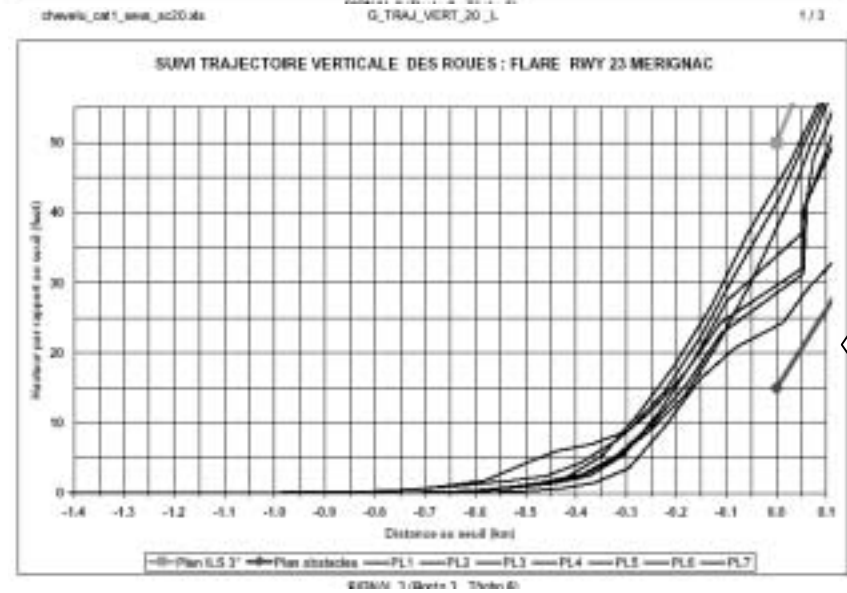
WITH HUD/EVS ☺

- **ILS CAT I EVS**
- **RVR = 550 m - FOG**
- **No Runway Center Line**
- **Success rate : 7/7 LANDINGS**
  (100%)

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THALES

Chevelu "Scénario 5"
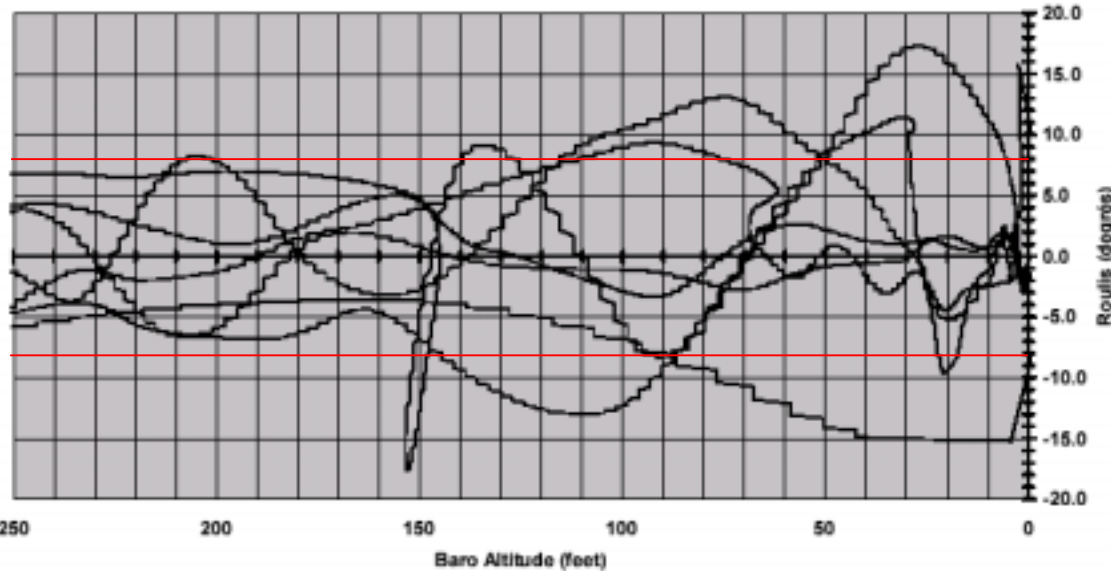
ROLL 250 ft - 0 ft

WITHOUT HUD/EVS

- **Standard ILS CAT I**
- **RVR = 1000 m - FOG**
- **ALS out**

(Max variation+ 17°- 18°)
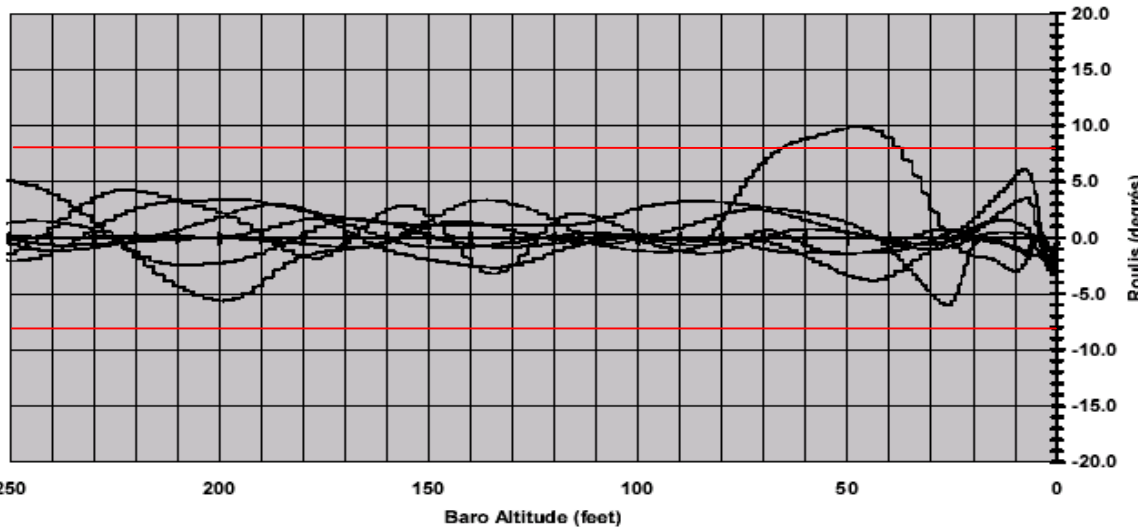
WITH HUD/EVS ☺
ROLL CONTROL IMPROVED

- **ILS CATI EVS**
- **RVR = 550 m - FOG**
- **ALS out**

(Max variation + 10 - 6°)

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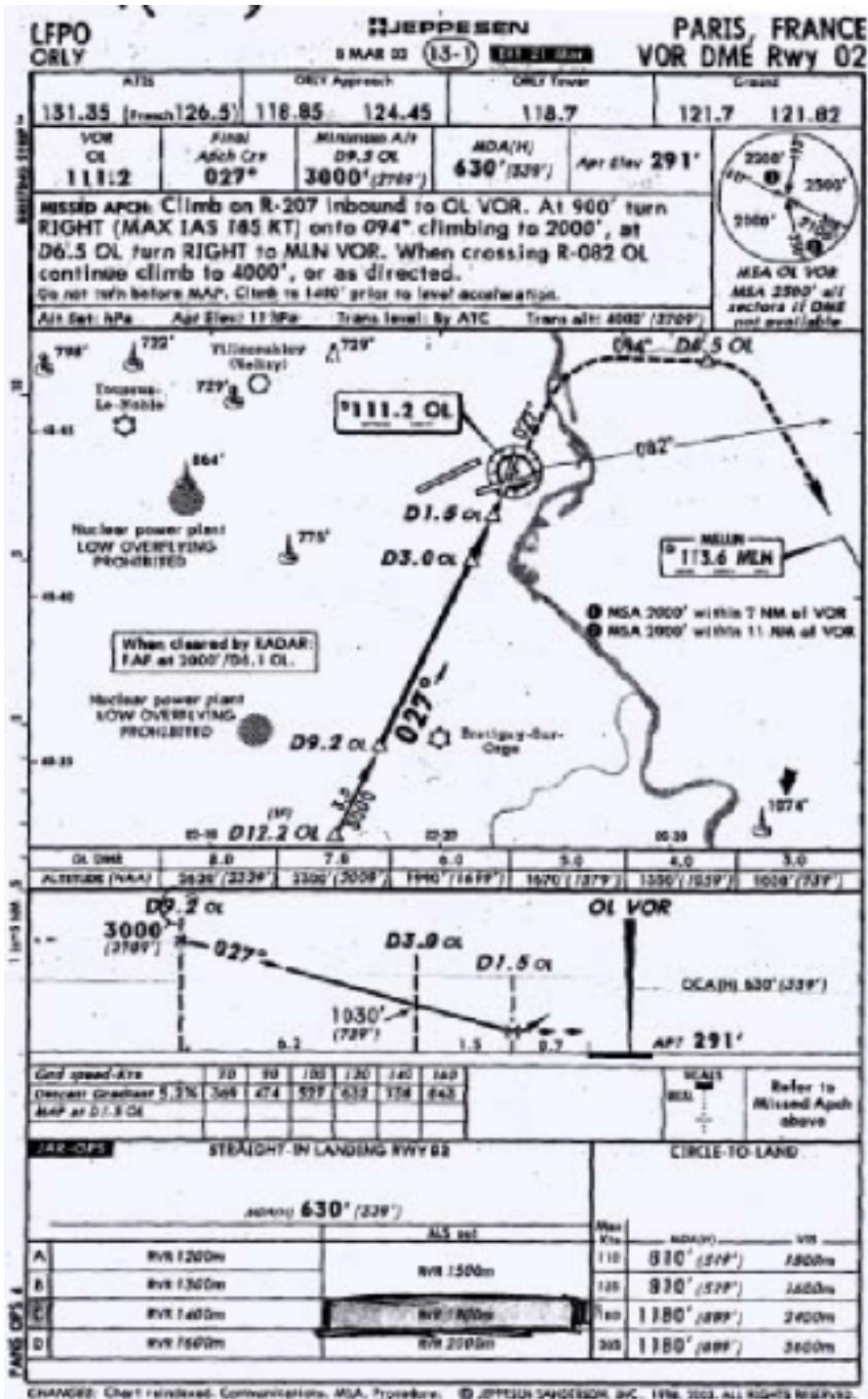
Experiment 2 Scenario

- VOR DME Rwy 02
- JAR OPS
- PARIS,France
- BRIEFING STRIP 13-1 **JEPPESEN**
- AXIS 027° *(offset 7°)*
- Descent Gradient 5.2%
- MDH = 339 ft at 0.7 Nm of runway threshold
- For « Category C » A/C
  ALS OUT : RVR =1800m 6000ft
  ALS FULL : RVR =1400m 4500ft
- IAF « ODRAN » 39 Nm in SW of OL VOR (~12 **min**)
- Wind : 320° 15 kts

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SUIVI TRAJECTOIRE VERTICALE DES ROUES : FLARE RWY 02 ORLY
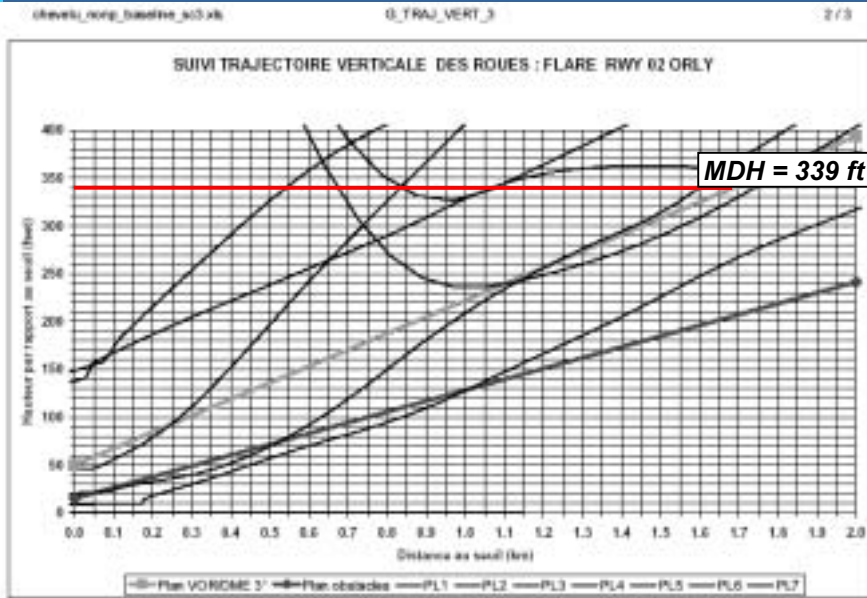
MDH = 339 ft

WITHOUT HUD/EVS

- **Standard VORDME**
- **RVR = 1800 m - FOG**
- **ALS out**
- **2 GO-AROUND**

SUIVI TRAJECTOIRE VERTICALE DES ROUES : FLARE RWY 02 ORLY

MDA = 339 ft
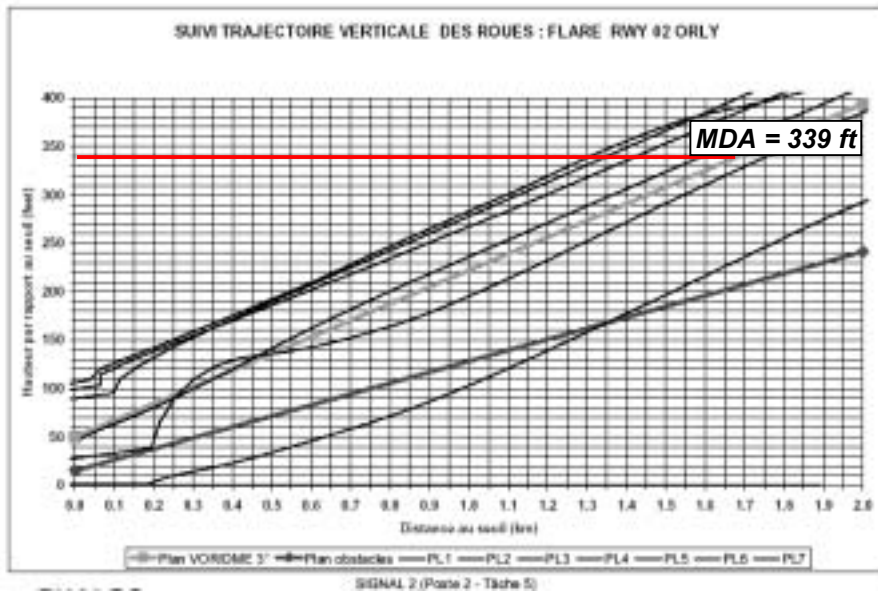
WITH HUD/EVS ☺

- **VOR DME EVS**
- **RVR = 800 m - FOG**
- **ALS out and MDH 339 ft**
- **Results :**
  - **Stability of flight**
  - **FCL tolerances improved**

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WITHOUT HUD/EVS

- **Standard VORDME**
- **RVR = 1800 m - FOG**
- **No Runway centerline**
- **Success rate: 5/7 LANDINGS**

    (71%)
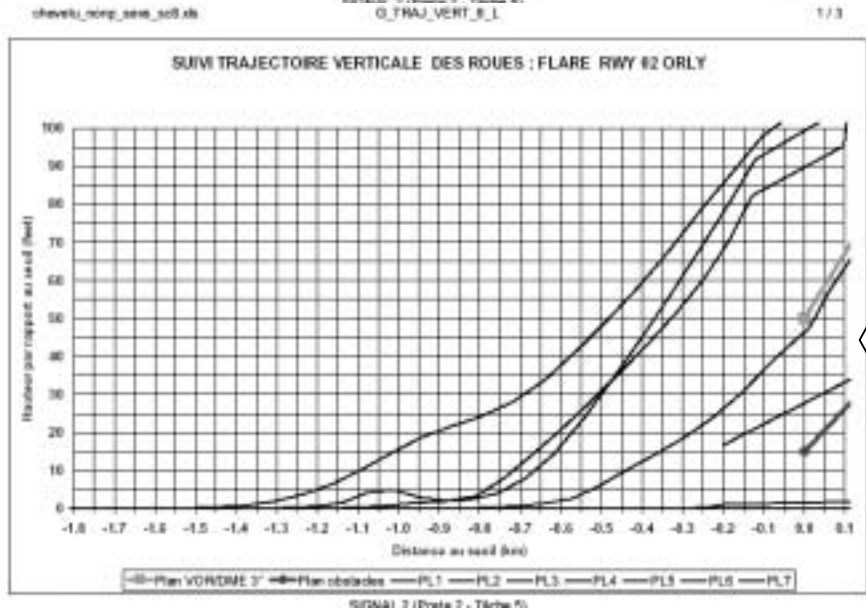
WITH HUD/EVS ☺

- **VOR DME EVS**
- **RVR = 800 m - FOG**
- **No Runway Center Line**
- **Success rate : 5/6 LANDINGS**

    (83%)

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ROLL 400 ft- 0 ft

WITHOUT HUD/EVS

- **Standard VORDME**
- **RVR = 1800 m - FOG**
- **ALS out**
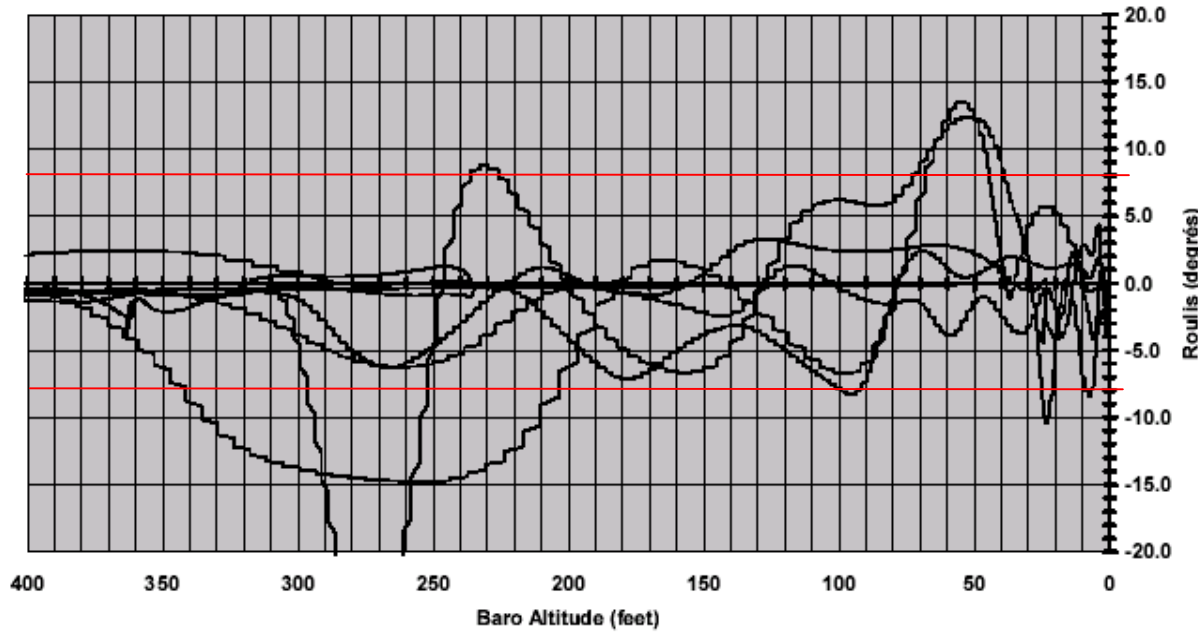
WITH HUD/EVS ☺
ROLL CONTROL
IMPROVED

- **VOR DME EVS**
- **RVR = 800 m - FOG**
- **ALS out**

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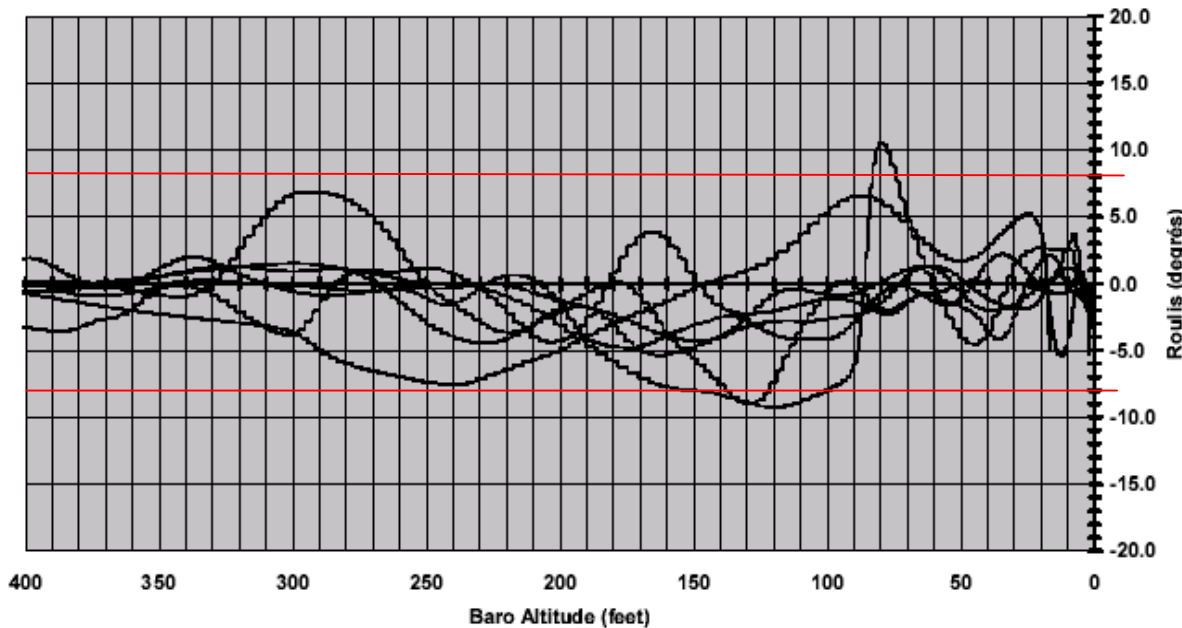
Workload analysis

- **Experimental method**

  - After training and familiarization,the pilots perform the baseline scenarios then HUD/EVS scenarios

- **Workload :**

  - analysed using "NASA-Task Load Index" method

- **Results :**

  - The confidence intervals test is significant (threshold 0,01) and shows a workload decrease when HUD/EVS is used.

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EVS vs Baseline workload decrease (NASA-TLX)

Workload

Scenario number

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AVIONICS

■ Has developed a concept to get an "*Additional credit use*" HUD/EVS

■ Has demonstrated :

- ■ Enhanced Approach procedures (ILS CAT I EVS / VORDME EVS)

- ■ Better performances in flight safety compared to baseline performed at minima values (RVR reduced)

EVS function in a HUD improves airfield approaches

for CAT I and NONP for large aircraft

under reduced visual conditions with fog

■ Is ready to work in partnership with customers to **save money** and **improve safety of flight** using HUDs fitted with EVS function.
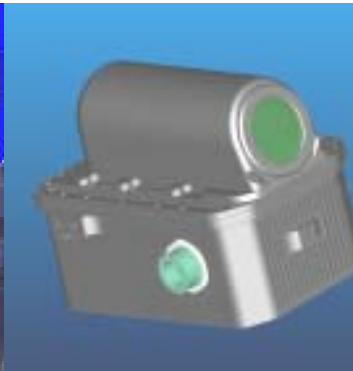
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Projector and Combiner
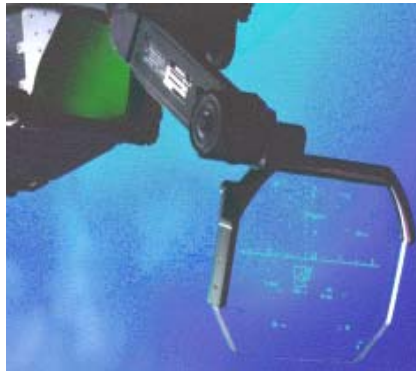
Head-up Flight Display Computer

InfraRed Sensor Unit (ISU)

InfraRed Window (IRW)

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CMC

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