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SIGLE : **E/TSM**
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VISA :
DATE : 13/6/2001

SIGLE :
NOM :
VISA :
DATE :

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NOM : **F. TOULMAY**
VISA :
DATE : 13/6/01

VISAS D'ORIGINE DIRECTION EMETTRICE

VISAS D'ORIGINE AUTRES DIRECTIONS

TITRE

HELICOPTER FAILURES CORRECTION TIMES

SUMMARY DOCUMENT

SERVICE

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NOM : **P. CARIOU**
VISA :
DATE : 13/6/01

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VISA :
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SIGLE :
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SFACT – Issy Les Moulineaux			

PROGRAMME	MARCHE N°	LOT N°	CAT. DIFFUSION	REF. BIBLIO.
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MODIFICATIONS

IND.	PAGE(S) MODIF.	DATE	DESCRIPTION DE LA MODIFICATION	REDACT.	VISAS RESP. SERVICE	AUTRES DIRECTIONS MARQUE
A	**X**	8/06/2001	New document	S. HEDBAUT S. BAILLY	Y. BRUN P. CARIOU	F. TOULMAY

LIST OF ACRONYMS

AC	Advisory Circular
ACJ	Advisory Circular, Joint
AFCS	Automatic Flight Control System
ALT	Altitude
APU	Auxiliary Power Unit
BAT	Battery
CAT	Catastrophic
CDS	Control Display System
CDP	Critical Decision Point
CWP	Central Warning Panel
EC	EuroCopter
ECS	Electrical Control System
EGS	Electrical Generation System
EMS	Emergency Medical Service
ENG	Engine
FADEC	Full Authority Digital Engine Control
FAR	Federal Aviation Regulations
FCS	Flight Control System
FHA	Functional Hazard Assessment
FLIR	Forward Looking Infra-Red
FND	Flight & Navigation Display
HAZ	Hazardous
H/C	Helicopter
IEBD	Integrated Engine Backup Display
IHM	Interface Homme Machine
IMC	Instrument Meteorological Condition
IPS	Ice Protection System
IRS	Inertial Reference System
JAR	Joint Aviation Requirements
LDP	Landing Decision Point
L/G	Landing Gear
LS	Landing System
MAJ	Major
MIN	Minor
MGB	Main Gear Box
MFD	Multi Function Display
NA	Not Applicable
NAV	NAVigation system
NVG	Night Vision Goggle
OEI	One Engine Inoperative
OHCP	OverHead Control Panel
PA	Pilote Automatique
PHL	Preliminary Hazard List
PMS	Plant Management System
PT	ProtoType
RA	Radio Altimeter
RAGB	Remote Access Gear Box
SAR	Search And Rescue
SAS	Stabilization Augmentation System
SHA	System Hazard Analysis
SOV	Shut Off Valve
TGB	Tail Gear Box
VMC	Vision Meteorological Condition
VMD	Vehicle Management Display
V_{NE}	Speed Not to Exceed
WAT	Weight, Altitude, Temperature

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WWWS Windshield Washer Wiper

TABLE OF CONTENTS

1. INTRODUCTION

The increasing automation of systems as well the evolution in the technologies applied to helicopters has modified crew workloads. The pilot is now a supervisor and decision maker and leaves the basic tasks to systems.
This new role as well as new interfacing capabilities helped review the man/machine interfaces for best synthesis of the helicopter's condition and to let the pilot act as a true supervisor and decision maker.
However, system automation distances the pilot from basic helicopter data; it must be ascertained that his/her mental picture of this helicopter is not false and the time required to appreciate and correct a worsening fault is appropriate.
Should a degraded mode occurred, the current regulations specify time-related detection and recovery modalities. These regulations need to be updated to take the new pilot role into account.
The purpose of this study is to provide technical bases from which the regulations could evolve as regards correction times for (major or hazardous) failures with catastrophic consequences in the absence of a quick pilot reaction.
The following steps have been completed to establish a basic reference which is the purpose of Phase 1 of this study.

- 1: FAR/JAR 29 regulations analysis
- 2: Definition of failures that need to be studied
- 3: Scope of failures to be selected
- 4: Experiments with a reference pilot

Tests could be performed with a representative pilot panel in a second phase.

2. REFERENCE DOCUMENTS

The regulatory reference documents are:

- JAR 29 (11/05/1993)
- FAR Part 29 (08/15/1985)
- AC29-2C (09/30/1999)
- AC29-2A (09/16/1987)
- ACJ29 - subpart of JAR 29 (11/05/1993)

The internal documents related to this study and acting as intermediate reports are:

- Minutes of "Study launch" meeting held on 03/30/2000– E/TSM/1086/2000 (06/19/2000)
- Minutes of "Phase 1 – 1st Quarter" meeting held on 06/19/2000– E/TSM/1087/2000 (06/19/2000)
- Minutes of "Phase 1 – 2nd Quarter" meeting held on 09/25/2000– E/TSM/1144/2000 (10/19/2000)
- Minutes of "Phase 1 – 3rd Quarter" meeting held on 01/19 /2001– E/TSM/1044/2001 (03/07/2001)

The internal reference document related to the study, acting as an intermediate document and presenting the regulations analysis and failures selection is entitled:

- "Analyzing helicopter failures correction times "– Ref. TN X 000 AR 414 E01 issue B (08/06/2001)

3. SCOPE OF STUDY

3.1 APPROACH

The study is divided into several phases as follows:

➢ **Stage 1: Regulations analysis**
  ☞ *Performed by certification specialists*

➢ **Stage 2: Theoretical analysis of failures and their consequences for new generation helicopters**
- Analysis of failures and their consequences for new systems
- Identification of risks according to mission phases and most constrictive flight types
- Analysis of minimum acceptable response times
- Analysis of suitability of the current regulations for these failures and identification of those points that require updating

  ☞ *Performed by safety and helicopter systems specialists*

➢ **Stage 3: Scope**
- Selection of reference failures
- Configurations and theoretical situations
- Scenario patterns
- Descriptions of detailed scenarios

  ☞ *Performed by safety, helicopter systems, human factors and flight testing specialists*

➢ **Stage 4: Experiments**
- Definition of methodology
- Development in a simulator
- Tests in SPHERE simulator with 1 EUROCOPTER pilot
- Data processing
- Validation of measuring equipments, scenarios and failures

  ☞ *Performed by simulation, human factors and flight testing specialists.*

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3.2 DEFINITION OF TIMES RELATED TO FAILURE SOLUTIONS

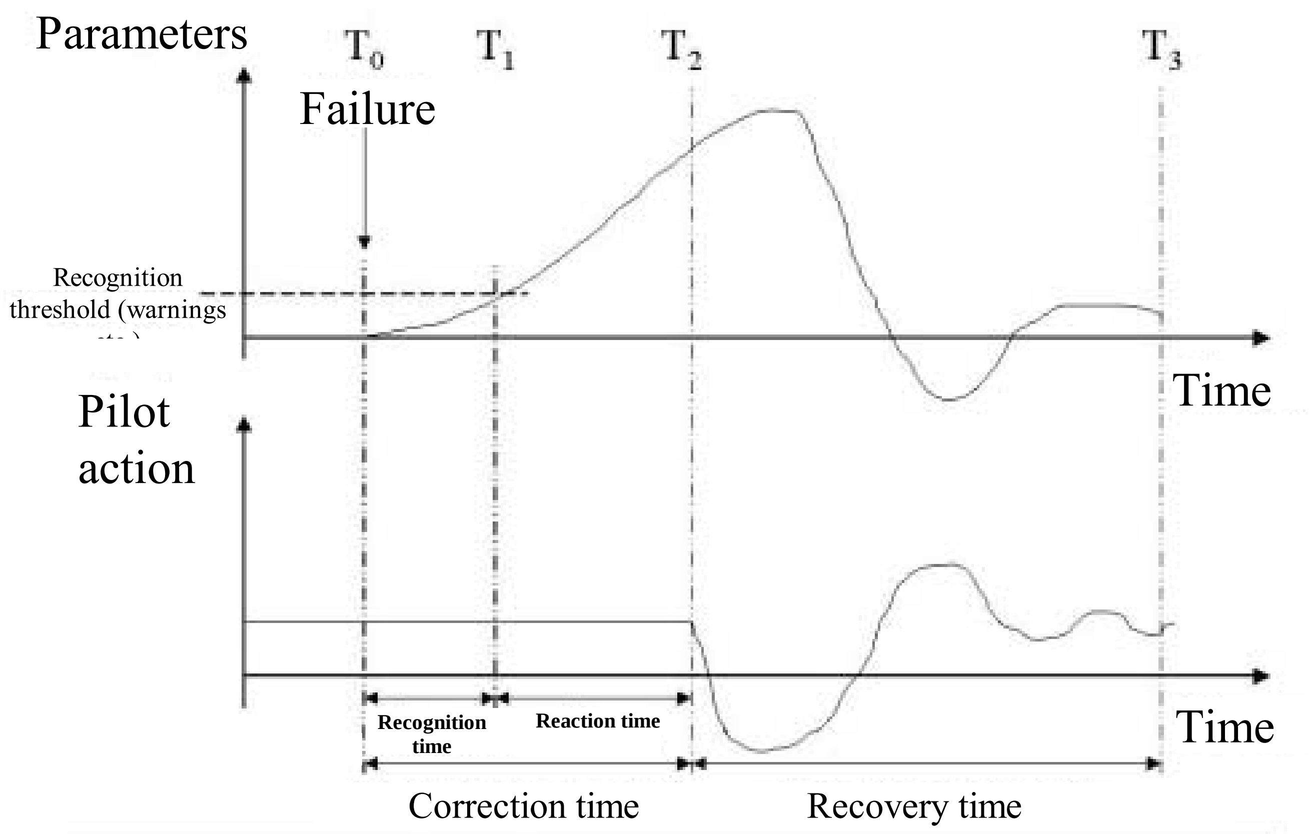
The terminology used for time is different between the System Hazard Analysis (SHA) and the Man/Machine Interface (MMI) fields. The following definitions (drawn from SHA terminology) have been applied so that the terms used are understood more accurately:

Recognition time: Time elapsed between failure occurrence (T_0) and initial pilot reaction (T_1) i.e. the pilot needs to understand a failure has occurred.

Reaction time: Time elapsed between the pilot's mental acknowledgement of a failure (T_1) and the initial, proper corrective action (T_2) i.e. the time the pilot needs to initialize the appropriate corrective actions once he/she has realized a failure has occurred.

Recovery time: Time elapsed between the initial, proper corrective action (T_2) and the system's return to nominal operation (T_3) i.e. the time needed for corrective action.

The times of interest in our study are the pilot's recognition and reaction times i.e. T_0 to T_2.



Correction time = Recognition time + reaction time

Figure 1: Definition of times under study

3.3 TYPICAL CONFIGURATION OF A NEW GENERATION HELICOPTER

A single generic machine is considered in this study and it is representative of the new generation, medium/heavy, twin engine helicopters (i.e. 6 to 10 tons and compliant with JAR and FAR 29 regulations). This generic machine is equipped with a "full glass" cockpit including a basic helicopter management system.

The scope of this study covers the civil missions performed by this helicopter with a single or 2 pilots. The tests shall be performed with a single pilot so as to obtain the most suitable results.

3.4 APPLICABLE CIVIL MISSION TYPES

The scenarios are built from the following flight and mission types scheduled for 2005:

- Outside environment:
  - Day and night VMC
  - Ice, rain
  - IMC
- Piloting aids:
  - Automatic pilot (AFCS, hands off)
  - 4-axis AFCS with upper modes
  - NAV
- Terrain types:
  - Flat (ground, sea, lakes)
  - Rough (mountains, hills, trees, obstacles etc.)
- Mission types
  - Offshore
  - Passenger and / or load transport
  - Slinging with single pilot
  - Slinging
  - Search And Rescue (SAR),
  - Emergency Medical Services (EMS).

3.5 STUDY LIMITATIONS

3.5.1 Failures

5 failures shall be selected in the experimental phase of this study with one occurrence in the most favorable setting and with a single pilot in control.
Those failures classified as catastrophic i.e. from which no recovery can be envisaged as well as minor i.e. with very limited effect on safety shall not be considered.

3.5.2 Simulator

The experiment shall proceed in EUROCOPTER development simulator known as SPHERE (See Appendix 1) with projection of the outside world over a fixed, non vibrating field 180° x 80° horizontally and vertically respectively. The cabin installed in the simulator for the purpose of this study is anew generation one representative of an 8 to 10 tons helicopter. The simulation process itself includes a number of limitations that will be taken into account as the failures and their occurrences are selected.

SPHERE limitations will not allow simulating those failures detected either by the crew's proprioceptive sensors (vibrations, accelerations, oscillations etc.) or by some exteroceptive sensors such as smelling or hearing sounds other than those transmitted by the sound and audio message generator. Those failures selected shall thus be those detectable by sight, feel and/or audio warnings.

The simulator effect may have an impact on time measurement. The failure scenarios shall be as realistic as possible to limit this effect.

In addition, Phase 2 pilots shall be selected according to their ability not to under-react (Safety feeling induced by the simulator) over-react or be destabilized by internal ear data (nausea).

3.5.3 Time

The tests shall be performed in a generic helicopter representative of the new generation ones. Yet recovery times are helicopter specific and they shall therefore not be taken into account.

4. REGULATIONS ANALYSIS

The reference regulatory documents analysed in the medium/heavy helicopter range under study are:

- JAR 29 (11/05/1993)
- FAR Part 29 (08/15/1985)
- AC29-2C (09/30/1999)
- AC29-2A (09/16/1987)
- ACJ29 - subpart of JAR 29 (11/05/1993)

Regulation analysis is detailed in a document entitled "Analyzing helicopter failure recovery times"– Ref. TN X 000 AR 414 E01 issue B (02/07/2001) attached document. It includes and synthetizes qualitative and quantitative data regarding pilot recovery times further to the occurrence of one or several failures.

Summary of regulatory requirements:

JAR and FAR 29 regulations mainly provide qualitative safety objectives to be applied whenever a pilot action is required. The only exception is engine failures for which quantified recovery times are provided according to flight phases.

The Advisory Circulars (AC) are more specific and recommend maximum recovery times according to the occurrence of one or several SAS failures. These maximum times are function of the different flight phases and conditions (IMC, VMC etc.). The safety objectives are demonstrated in IMC. The maximum recovery times also apply to hardovers.
This data (mainly drawn from AC29-2A) is summarized in the table below (See figure 2) but does not apply to he flight control systems.

As regards those failures detected by the helicopter and reported with a visual (red) or audio warning, the maximum failure recognition time by the pilot is usually 0.5 sec.

As regards those failures not detected by the helicopter on the other hand, the failure recognition time by the pilot includes his / her failure detection time.

The recovery times applicable further to non engine and flight control system failures have not yet been defined. Those times defined for SAS or engine failures can thus be applied but they are not covered in JAR / FAR regulations or ACs.

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	CERTIFICATION IFR			CERTIFICATION VFR	
	General (Single pilot)	*2 pilots WITH upper mode(s)*	**2 pilots WITHOUT upper mode(s)**		
Pilot's degree of attention		→		→	
Hover	**Rec. T + 0 sec (Reaction time)**	*Rec.T + 1 sec (Reaction time) Auto hover mode*	**Rec. T + 0 sec (Reaction time)**	*Rec T. + 1 sec (Reaction time) Auto hover mode*	**Rec. T + 0 sec (Reaction time)**
Take-off Landing	**Rec. T + 0 sec (Reaction time)**		**Rec. T + 0 sec (Reaction time)**	**Rec. T + 0 sec (Reaction time)**	
Approaches	**Rec. T + 1 sec (Reaction time)**		**Rec. T + 1 sec (Reaction time)**	**Rec. T + 0 sec (Reaction time)**	
Descent Climb	**Rec. T + 3 sec (Reaction time)**		**Rec. T + 1 sec (Reaction time)**	**Rec. T + 1 sec (Reaction time)**	
Cruise	**Rec. T + 3 sec (Reaction time)**		**Rec. T + 1 sec (Reaction time)**	**Rec. T + 3 s* (Reaction time)**	**Rec. T + 1 s* (Reaction time)**

[grey box] **IMC demonstration required**

⇨ **The failure recognition time (Rec. T) is normally considered as being 0.5 sec for those failures reported with warnings**

⇨ **The data in italics are not defined in AC29-A but suggested by the French authorities for the certification of automatic SAR modes (Night SAR mode)**

* **The pilot(s) reaction times in cruise as well as VFR certification are dependent upon helicopter speed. Should that speed be comprised between V_H and V_{NE} , a 1 sec reaction time is appropriate but should that speed be lower than or equal to V_H, the normal reaction time is 3 sec (See page 13, AC 29-2B, Chapter 3, § 775b-(6)(iii)(A))**

Figure 2: Theoretical failure recognition times drawn from AC 29-2A

It stems from the table above that the pilots failure recognition times depend upon speed V_H in cruise phase and VMC conditions.

VH is the maximum speed the helicopter can reach at a given altitude and maximum power.

Figure 3 below defines V_H with respect to the various specific speeds of the helicopter and as a function of power at constant altitude.
Two additional speeds are also defined at constant altitude:
- Max long range cruise speed at which the helicopter covers the longest leg
- Speed V_Y at which the helicopter flies longest (maximum endurance). It also is the speed at which power is minimum in level flight and the helicopter thus has a large power reserve to climb.

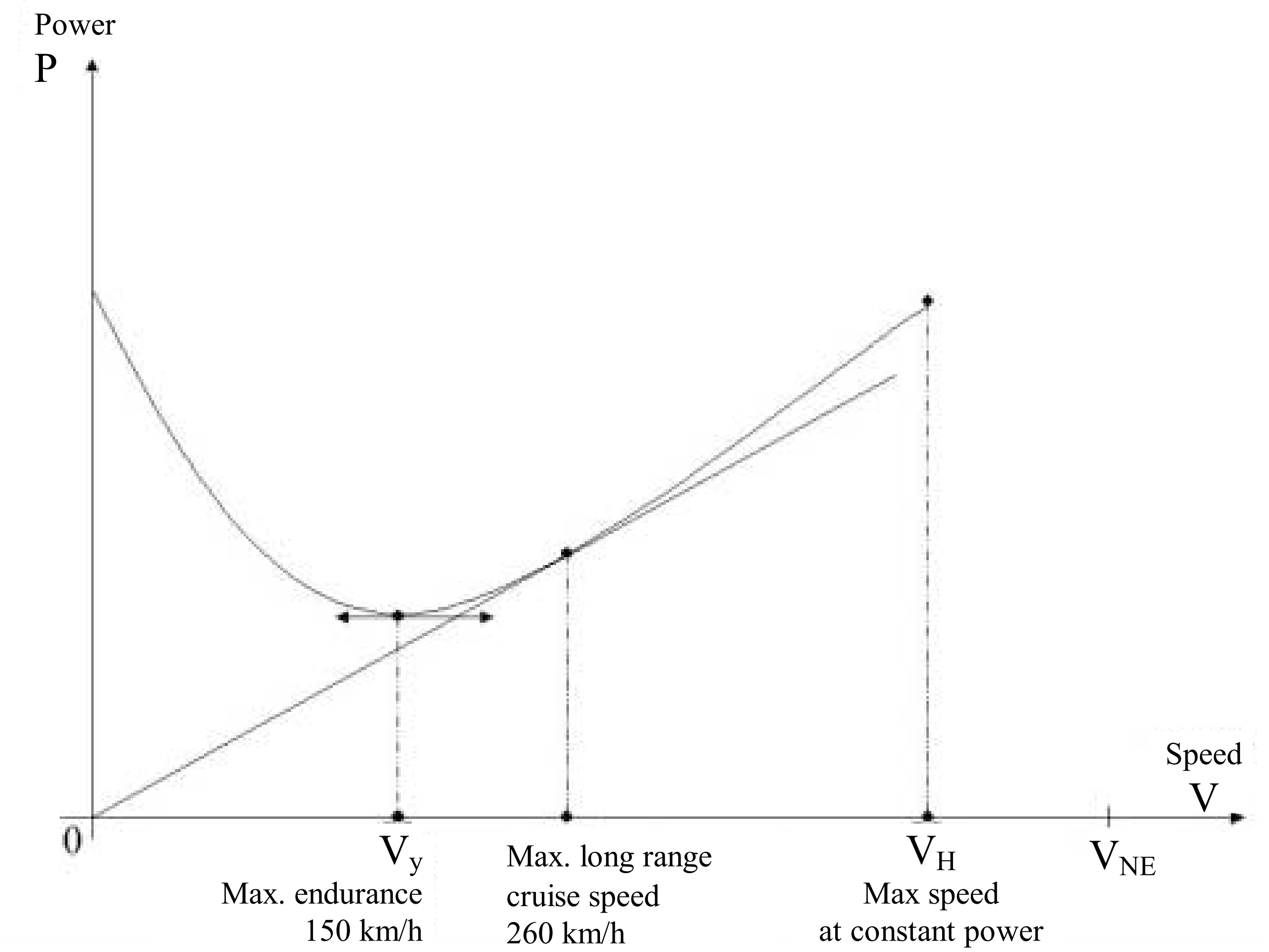

Figure 3 Definition of maximum speed Vh at a given altitude

5. THEORETICAL ANALYSIS OF FAILURES AND THEIR CONSEQUENCES

5.1 ANALYSIS OF SHA APPLICABLE TO THE GENERIC HELICOPTER

System Hazard Analyses (SHA) provide extensive lists of those failures that require pilot actions to ensure flight safety. They equally provide a criticality breakdown that takes not only cross-failures with other systems or functions into account but also unfavourable environmental conditions and flight phases during which failures are occurring.

Furthermore, SHA identify expected pilot action(s), detection or non detection of failures by the system and warning displays.

An exhaustive list of failures requiring pilot action is presented in the appendix to a document entitled "Analysis of helicopter failures recovery times " – Ref. TN X 000 AR 414 E01 issue B (08/06/2001), attached document.

5.2 FACTORS INFLUENCING PILOT REACTIVITY

The conditions of failure occurrences have a direct influence on pilot reaction times. The nature of the failure (fast or slow) excepted, the pilot's degree of attention depends upon:

- The flight phases
- His / her workload
- The terrain
- The meteorological conditions
- The flight stability

The most critical failures disturb the helicopter's trajectory in hover or at low speed close to obstacles or the ground.

5.3 FAILURES SELECTION CRITERIA

The failures selected are derived from major or hazardous failures with catastrophic consequences in the absence of a quick pilot reaction; those include:

- A type warnings
- B type warnings, if required
- Slow drifts of the slowover type that cannot be detected immediately

The catastrophic failures i.e. those from which no recovery is possible or minor failures i.e. those with very limited effects on safety are not included in this study.

5 failures were selected according to their criticality, their suitability for a new generation helicopter and their applicability within the scope of the study specified in § 3.2. above. The indications given in the SHA as well as the regulatory requirements help establish scenario patterns suitable for each failure occurrence (Condition and equipment or system degradation mode associated to different degree of pilot's attention). In addition, the warning concept and the list of warnings allow identifying the resources available to the pilot for failure detection.

These 5 failures are derived from the following 4 types:

- Reported failures (detection with red or amber warnings and, possibly, audio warnings)
- Non reported failures (Detection system failure or no detection)
- Fast failures (Failures with almost immediate effects e.g. hardovers)
- Slow failures ("Perverse" failures without immediate effects e.g. slowovers, slow drifts etc.)

They occur in one of following flight conditions:

- Flight without flight instruments i.e. VFR,
- Flight with instruments and satisfactory visibility i.e. IFR(VMC); Should the instruments fail, the pilot can use external visibility to solve the problem.
- Flight with instruments only i.e. IFR(IMC); the pilot has no external aid and relies on his/her instruments only.

They occur with a workload described as follows:

- Low workload (Typically, cruise in altitude with upper modes engaged; the pilot's workload is low in this case)
- Relatively high workload designated W (Mean altitude with or without upper modes, turn or approach)
- Very high workload designated W^{++} (e.g. take-off, landing or sling loading)

They can induce one of the following behaviour types as the failure is being resolved:

- Low procedural (No or little thought processing on the pilot's part; the failure is simple and requires few corrective actions),
- Procedural (No reflex action on the pilot's part; he/she must recognize the failure and act according to memorized rules),
- High procedural (Typically, dual failures requiring extensive thought processing to identify failures and perform several corrective actions)
- Procedural up to cognitive limits (The pilot no longer applies memorized rules but assumes and interprets personal observations)

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5.4 SELECTED FAILURES

The 5 selected failures and their associated occurrences are:

	Failure	Occurrence
1	Slow IRS2 drift at 2,4°/sec	Cruise in IMC
2	Engine loss detected by FADEC	HOVER while sling loading operation is in progress
3	Partial loss of engine power	VFR approach during night landing
4	Slow drift of AFCS altitude hold upon barometric altimeter failure	Cruise in IMC
5	Hardover on AFCS roll axis	Cruise at low altitude in VMC

The 3D failure characteristics show the space covered by the 5 failures selected:

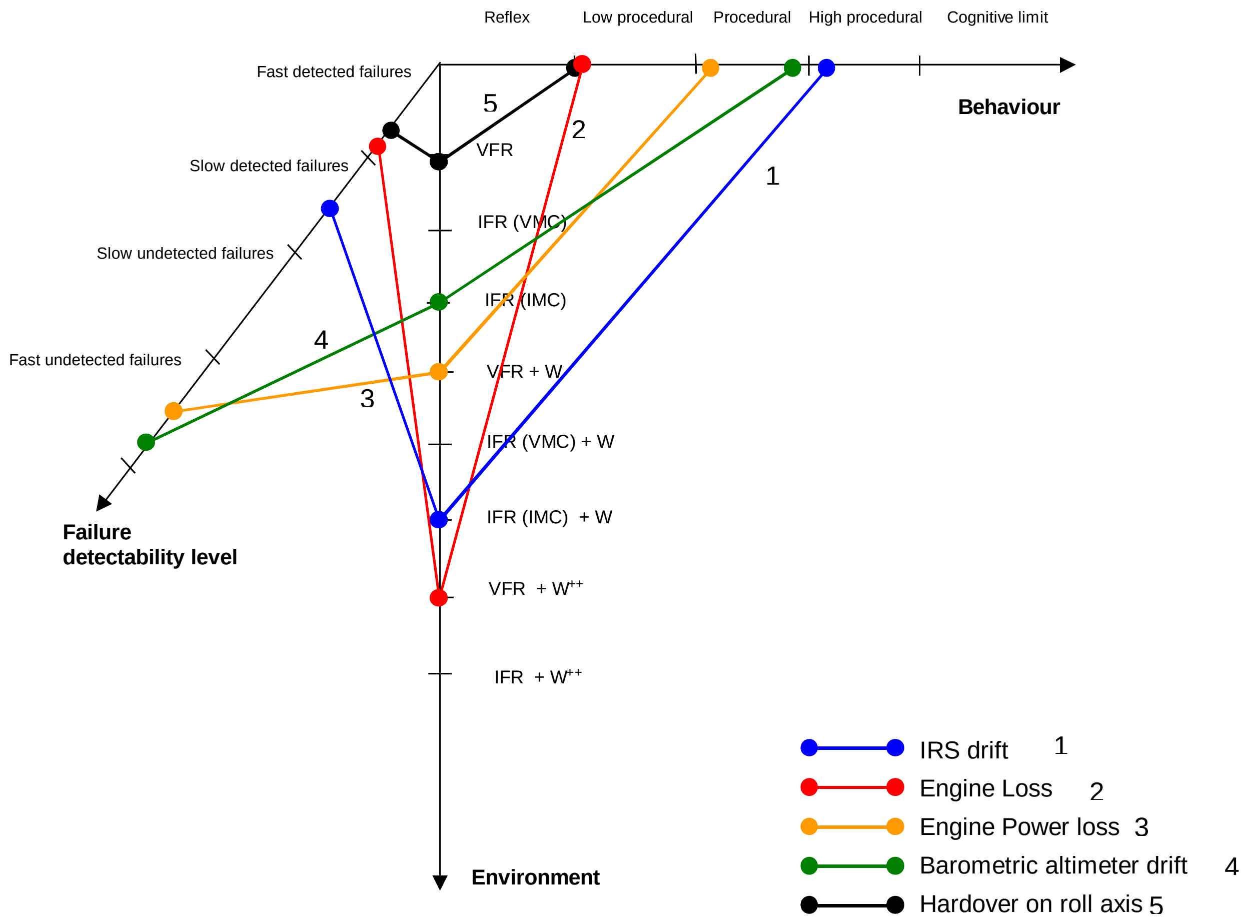

Figure 4: 3D characteristics of failures – human behavior

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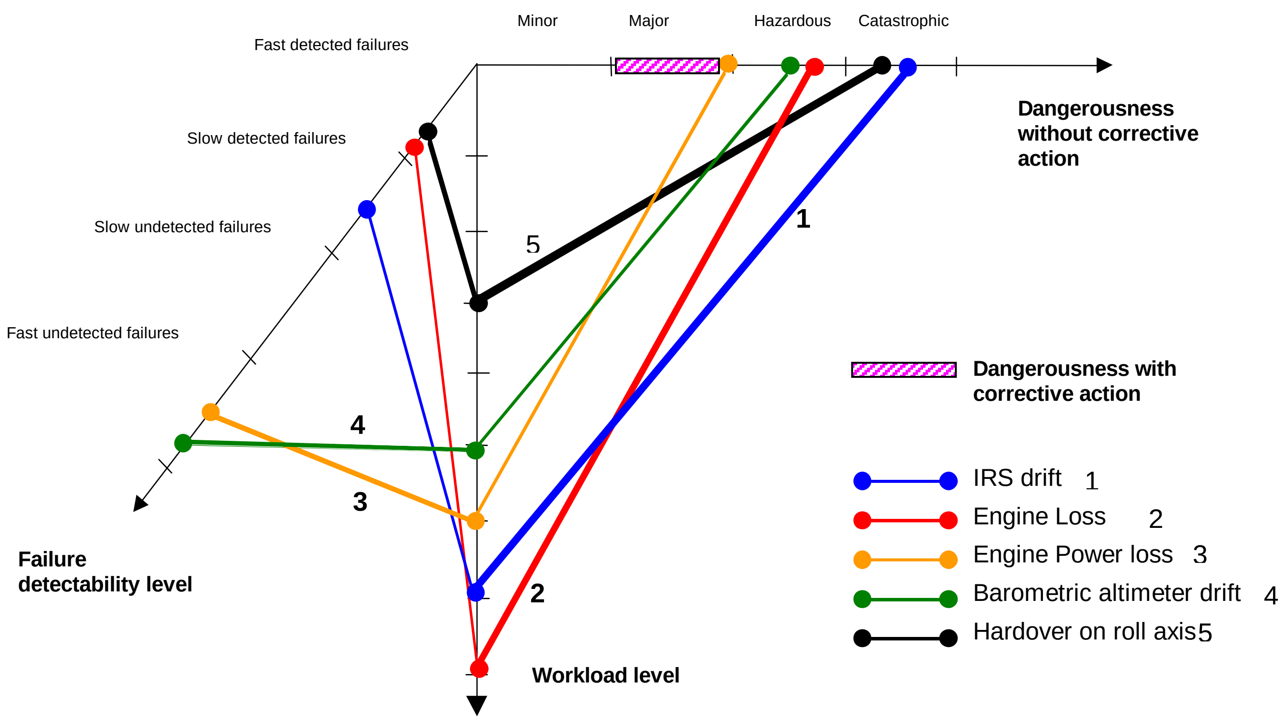

Figure 5: 3D characteristics of failures – failure dangerousness

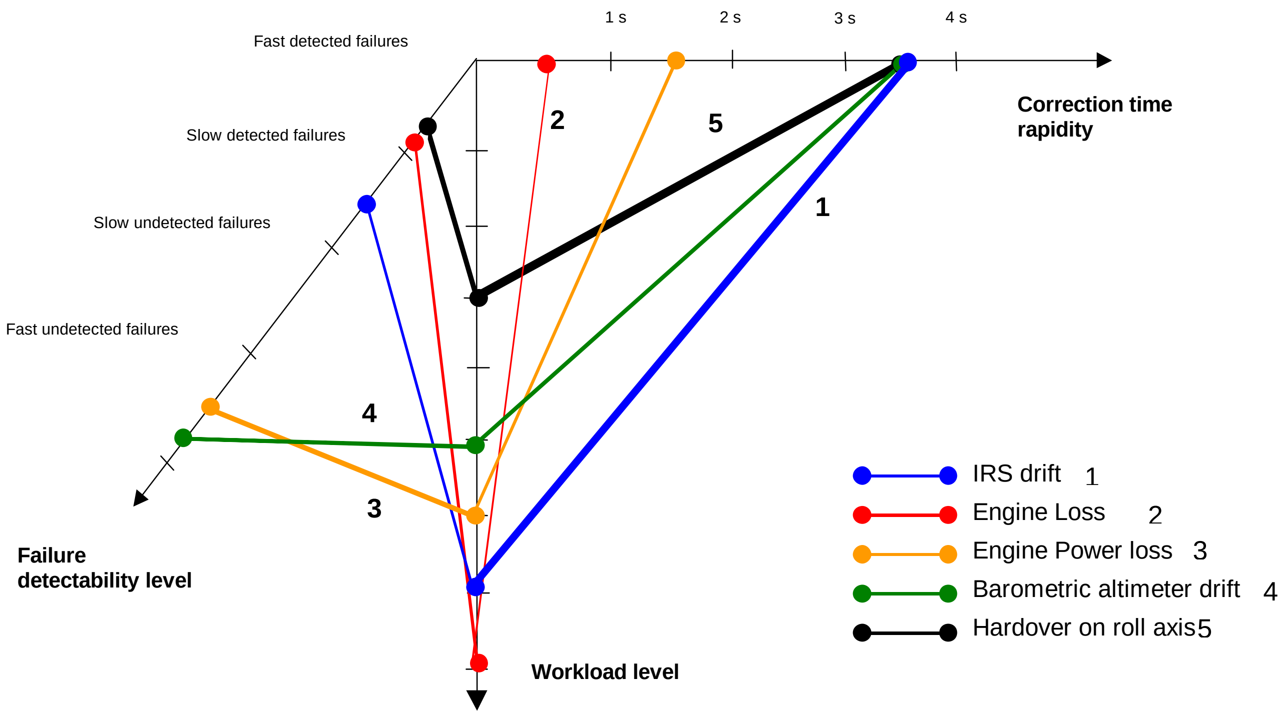

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Figure 6: 3D characteristics of failures – correction time rapidity

5.5 FAILURES DESCRIPTION

Each failure is presented with a description of its constituents as follows:

- Systems involved in failure
- Data display resources
- System failure detection thresholds
- Failure detection elements
- Failure corrections expected from pilot
- Effects induced in the absence of corrective actions
- Effects induced thanks to proper corrective actions applied by pilot
- Recognition and reaction times expected from pilot
- Temporal sequences of failure resolution tasks undertaken by pilot

Likewise, the failure occurrence conditions are also presented:

- Combinations:
  - Helicopter configuration / mission type
  - Flight phase / Flight parameters
  - Meteorological conditions
  - Scenario pattern on map

Those elements necessary for briefing and mission preparation are also presented:

- Briefing data sheet including:
  - Mission timing
  - External conditions
  - Helicopter configuration
  - Mission configuration with number of passengers + crew on board
  - Mission routes

- The En route data sheet
  - Altitude /height/heading/speed directives
  - Waypoint times
  - Failure occurrence time

- Complete mission scenario description
  - Pilot tasks
  - Timing
  - Flight parameters (height / altitude / speed /heading)
  - Navigation and radionavigation parameters

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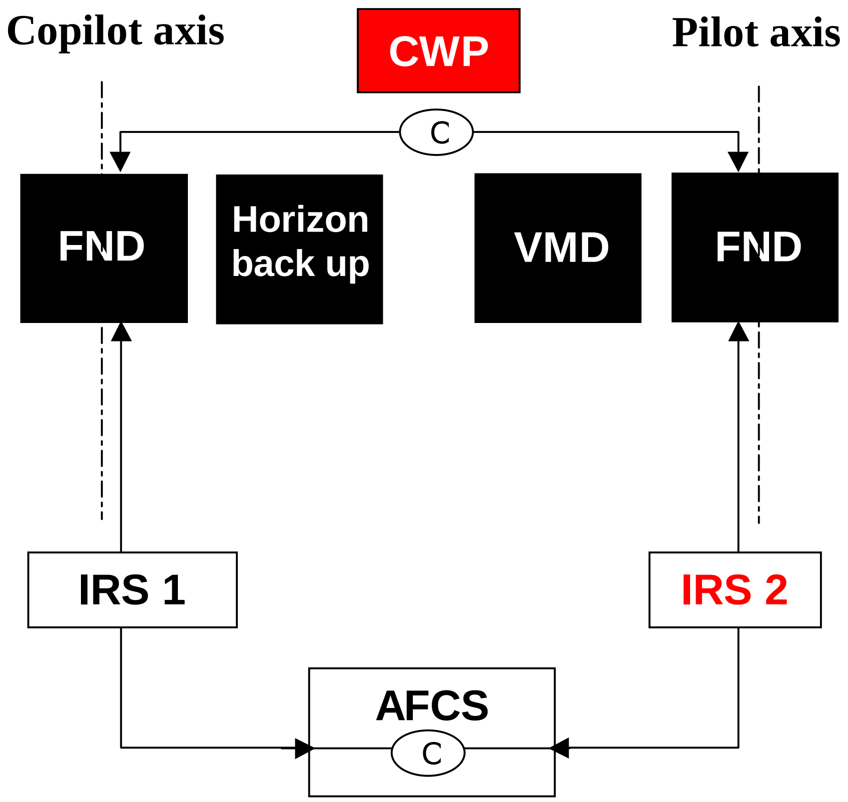
5.5.1 Failure No 1: Slow IRS2 drift

The slow IRS2 drift failure was selected for its "slowover" aspect detectable by the pilot. It is an illustration of the potential temporal drift of a failure if the pilot does not recoup pertinent data between equipment items after detection of a deviation between 2 IRS.
The data sheet describing the failure input data is presented in a document entitled "Analyzing helicopter failures correction times"– Ref. TN X 000 AR 414 E01 issue B (08/06/2001) attached document.

5.5.1.1 Description of failure No 1 constituent elements

❖ Systems involved in failure and data display resources



❖ System failure detection threshold:

- ➢ Attitude deviation higher than 3° between IRS1 and IRS2
- ➢ Angular speeds deviation higher than 2,5°/sec between IRS1 and IRS2

☞ Failure detected by system 1,25 sec after occurrence
☞ 1,25s + 3,5s => 11°4 roll and pitch deviation

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❖ Failure detection elements and corrections expected from pilot

FAILURE DETECTION ELEMENTS	FAILURE CORRECTION
- Nose down movement and RH roll	- Correction time ≤ 3.5 sec
- Loss of upper modes (ALT, speed, attitude hold)	- Crosscheck between both screens and standby instrument
- Deviation between FND symbologies	- Warning Acknowledge
- "HANDS ON" audio warning	- Identification of screen providing false information
- "HANDS ON" + " IRS1/IRS2 DEGRAD or "AVIONICS" CWP warning	- MFD2 reconfiguration on IRS1 * *Automatic AFCS switch off*

❖ Effects induced in the absence of corrective actions or thanks to proper pilot corrective actions

EFFECTS INDUCED	
NO CORRECTIVE ACTIONS: CATASTROPHIC	PROPER CORRECTIVE ACTIONS: MAJOR EFFECTS
- RH roll - Pitch nose down - Spatial disorientation in the absence of external references	- Helicopter stabilization - Identification of screen providing false information

❖ Recognition and reaction times expected from the pilot

The failure will occur in IMC cruise to provide no external information for the failure solve.

EXPECTED PILOT REACTION
- Recognition time: 0.5 sec
- Reaction time: 3 sec
- Recovery time: NA

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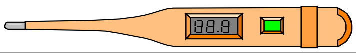
❖ Temporal sequence of failure resolution tasks by pilot

TRPH – SCENARIO NO 1					
			N°	LOW IRS2 DRIFT FAILURE RESOLUTION TASKS	TIME
			1	Failure occurrence	0.5 sec
X	X		2	« Hands On » audio warning + Master display	
	X		3	« HANDS ON » + «IRS/AVIONICS DEGRAD» display on CWP	3 sec
	X	X	4	Grasping collective and cyclic controls	
	X		5	Cross checking MFDs 1and 2	
	X		6	Cross checking with horizon back-up to identify screen displaying false data	
	X	X	7	Checking helicopter attitude	
	X	X	8	Switching from MFD 2 to IRS 1 via reconfiguration panel on console	
	X	X	9	Acknowledging master	


= Task No 4 to 7

Recognition time

Reaction time

Recovery time

5.5.1.2 Failure No 1 occurrence conditions

❖ Helicopter configuration / mission type, flight phase / flight parameters, meteorological conditions

OPERATIONAL CONFIGURATION
- Single pilot
- IMC
- Cruise
- 1500 ft (TBC)
- 150 kt
- Flight over the sea
- AFCS programming + communications with ground

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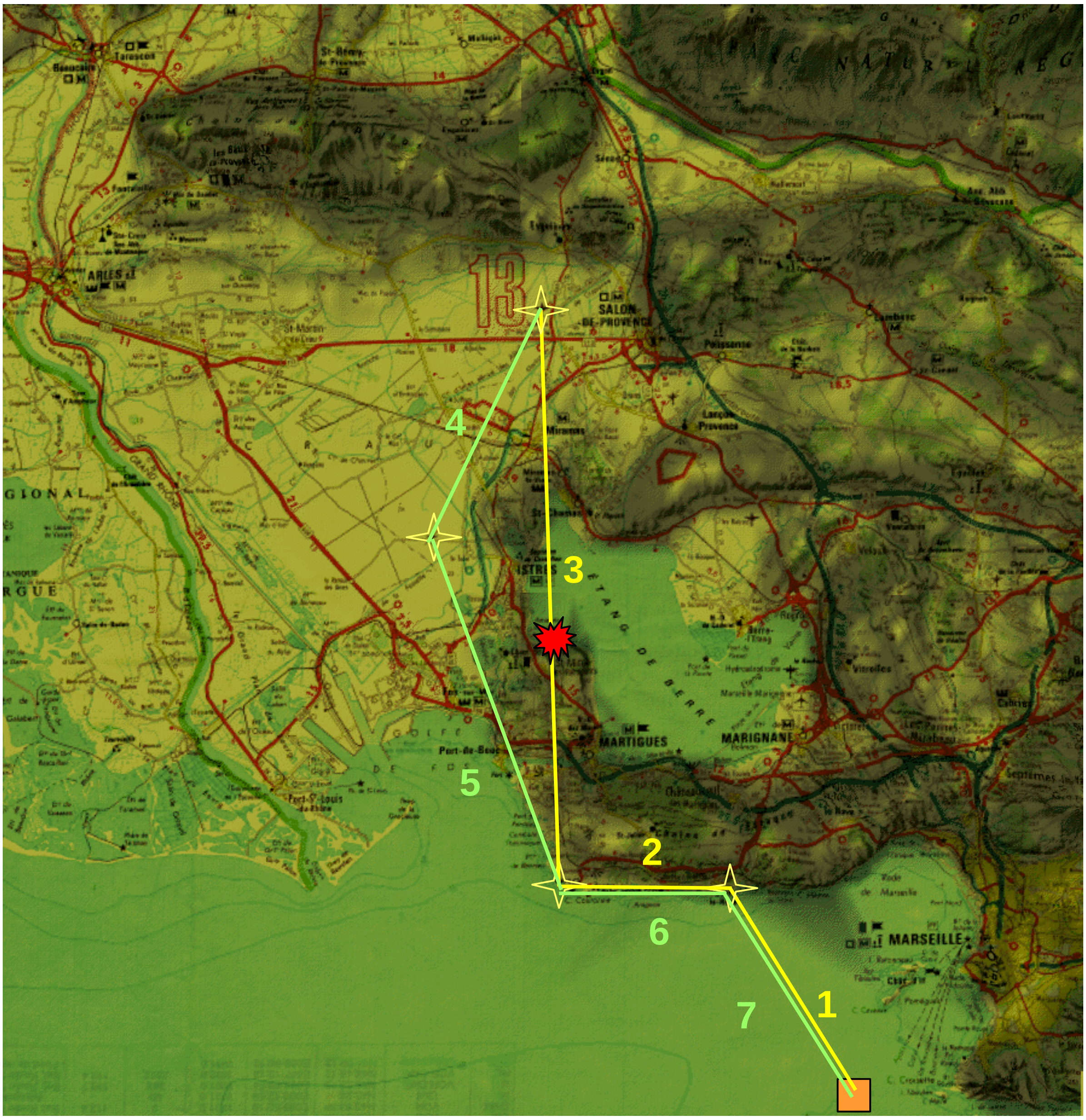
❖ Scenario pattern on map

Occurrence: Flying over Etang de Berre, crossing a TMA imposing extra caution, ATIS communication, AFCS programming completed.



: Offshore platform

: Failure occurrence

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5.5.1.3 Briefing and description of failure No 1 process

❖ Briefing data sheet

<table>
<tr><td colspan="4">TRPH – SCENARIO NO 1</td><td>TTO</td><td>9 :00</td><td>TOIP</td><td>-------</td></tr>
<tr><td>DATE</td><td>30/1/2001</td><td>HELO</td><td>F/TRPH</td><td>TOT</td><td>9 :18</td><td>END</td><td>9 :38</td></tr>
<tr><td colspan="4">EXTERNAL CONDITIONS</td><td colspan="4">HELO CONF. : 8.7 TONS</td></tr>
<tr><td colspan="2">WIND</td><td colspan="2">150/2kts</td><td colspan="2">FUEL</td><td colspan="2">max</td></tr>
<tr><td colspan="2">VISIBILITY ON 1RST WP</td><td colspan="2">5 KM</td><td colspan="2">ENDURANCE</td><td colspan="2">6 hours</td></tr>
<tr><td colspan="2">VISIBILITY ON T WP</td><td colspan="2">5 KM</td><td colspan="2">LOADS</td><td colspan="2">none</td></tr>
<tr><td colspan="2">CEILING</td><td colspan="2">1300 FT<>2000ft</td><td colspan="4">CREW AND PASSENGERS</td></tr>
<tr><td colspan="2">RELAT. HUM.</td><td colspan="2">80%</td><td colspan="2">PILOT</td><td colspan="2">1</td></tr>
<tr><td colspan="2">AIR T°</td><td colspan="2">12° C</td><td colspan="2">COPILOT</td><td colspan="2"></td></tr>
<tr><td colspan="2">QNH</td><td colspan="2">1013</td><td colspan="2">CABIN CREW</td><td colspan="2"></td></tr>
<tr><td colspan="2">FORECAST</td><td colspan="2">NOSIG during the next 4 hours</td><td colspan="2">PASSENGERS</td><td colspan="2">5</td></tr>
<tr><td colspan="8">MISSION: Passenger transport from Eyguière to offshore station</td></tr>
<tr><td>Leg 1</td><td colspan="7">Take off from offshore station to le Rouet – AFCS Pogramming</td></tr>
<tr><td>Leg 2</td><td colspan="7">AFCS engagement and ATIS communication prior to transit</td></tr>
<tr><td>Leg 3</td><td colspan="7">Modifying altitude in accordance with ATIS advice</td></tr>
<tr><td>Eyguière</td><td colspan="7">Embarking passengers for offshore station</td></tr>
<tr><td>Leg 4>6</td><td colspan="7">Transit to offshore station via Istres with AFCS ON</td></tr>
<tr><td>Leg 7</td><td colspan="7">Flight over water to offshore station and landing</td></tr>
<tr><td></td><td colspan="7"></td></tr>
</table>

a

❖ <u>En route data sheet</u>

Waypoint	X	Y	h(m)	Alt (ft)	Route	Dist	Speed	TTG	Time
station off shore	47 709	5 155							09:00
				Take off	180	0,0	0	0:02	
station off shore	47 709	5 155							09:02
				500	327	7,6	150	0:03	
le rouet	39 986	16 916							09:05
				500	270	5,1	150	0:02	
carro	30 530	16 978							09:07
				1500	357	20,5	150	0:08	09:11
eyguière	28 324	54 885							09:15
				landing	180	0,0	20	0:03	
eyguière	28 324	54 885							09:18
				0	180	0,0	0	0:03	
eyguière	28 324	54 885							09:21
				take off	180	0,0	150	0:02	
eyguière	28 324	54 885							09:23
				1500	206	8,9	150	0:03	
istres	21 074	40 006							09:26
				1500	158	13,4	150	0:05	
carro	30 530	16 978							09:32
				1500	90	5,1	150	0:02	
le rouet	39 986	16 916							09:34
				1500	147	7,6	150	0:03	
station off shore	47 709	5 155							09:37
				landing	180	0,0	0	0:03	
station off shore	47 709	5 155							**09:40**

a

❖ Complete mission scenario description:

TASKS/EVENTS	HEIGHT (Ft)	CRS	Time	VOR/DME/TACAN	COM / Iff Plan
1.TAKE OFF PREPARATION	Offshore station	NA	NA		
1.1. Communications with offshore station					
1.2. General information about take off and flight plan				MTG 117.3 / 120X	
1.3. **Clearance from offshore station**					
2.TAKE OFF	Climb	N	**T0**		
2.1. DTO to LE ROUET					
3. CRUISE IN ACCORDANCE WITH FLIGHT PLAN	Less than 500 ft	328			
3.1. Engage AFCS mode					
3.2. Fly over Carry le Rouet			T0 + 3 mn		
3.3. Prepare communications with MRS ATIS. Selection of frequencies		270			
3.4. Contact MRS ATIS		270			
3.5. Fly towards CARRO	Climbing to 1500ft				
3.7. Fly to SALON	1500ft				
3.6. Failure : IRS 2 SLOWOVER OF 2,4°/s			Crossing « Etang de Berre » shore		
3.6.1. The crew acknowledges caution on Master caution panel					
3.6.2. The crew investigates the failure on MFD/VMD formats					
3.6.3. The crew solves the failure and recovers a safe situation					
3.7. Continue flight to SALON	1500ft				
4. LANDING	Transdown				
4.1. Communication with Salon military area for clearance					
4.2. Landing at SALON					

TASKS/EVENTS	HEIGHT (Ft)	CRS	Time	VOR/DME/TACAN	COM / Iff Plan
5.TAKE OFF					
5.1. Communication with Salon military area for clearance					
5.2. Take off from SALON					
6.STARTING RETURN LEG	1500 FT				
6.1. Communication with ISTRES area for vertical flight clearance					
8. LANDING ON OFFSHORE STATION					
8.1. Communication with offshore station					
8.2. Landing					
END OF MISSION					

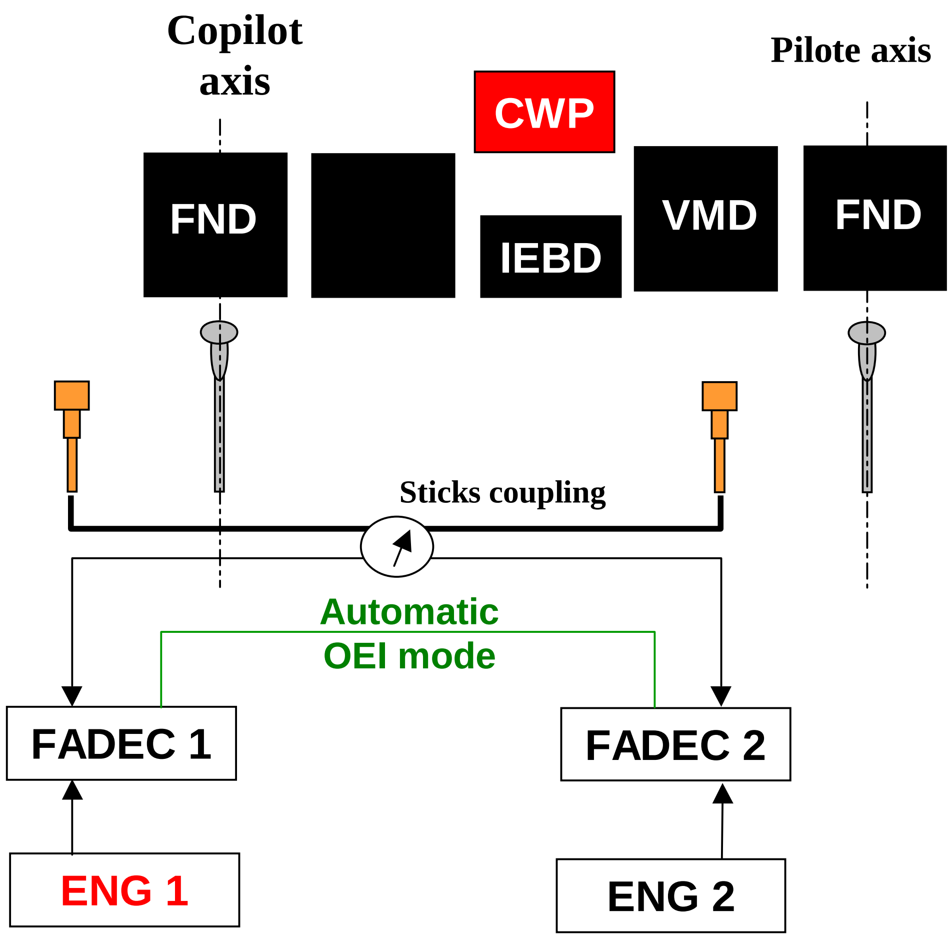
a

5.5.2 Failure No 2: Loss of engine No 1 detected by FADEC

Loss of engine No 1 was selected for its slow failure aspect detected by the pilot. This illustrates a failure degrading helicopter pilotability and occurring concomitantly in a flight phase where pilotability finesse is required.
The data sheet describing this failure is presented in a document entitled "Analyzing helicopter failures recovery times"– Ref. TN X 000 AR 414 F01 issue B (08/06/2001) attached document.

5.5.2.1 Description of failure No 2 constituents

❖ <u>Systems involved in failure and data display resources</u>



a

❖ System failure detection thresholds

- Torque deviation > 25 % between both engines detected by FADEC
- Maximum engine parameters prior to detection

☞ Failure detected by FADEC 3 sec after occurrence
☞3s + 1/2s => Limit before crash

❖ Failure detection elements and failure corrections expected from pilot

FAILURE DETECTION ELEMENTS	FAILURE CORRECTION
- Engine No 2 switch to OEI mode for 30 sec - Engine parameters modification displayed with red warnings on IEBD - OEI mode reported on FND - "ENG DF" warnings on CWP and audio warning	- Correction ≤ 0,5 s - Sling load release - Lowering collective pitch to retain rotor NR - Acknowledging warning - Switching engine No 1 off to prevent fuel inlet

❖ Effects induced in the absence of corrective actions or thanks to proper pilot corrective actions

EFFECTS INDUCED	
NO CORRECTIVE ACTIONS: HAZARDOUS	WITH PROPER CORRECTIVE ACTIONS: MAJOR
- Altitude loss and crash risk *(Hard landing to crash)*	- Helicopter stabilization - Faulty engine stop

❖ Recognition and reaction times expected from pilot

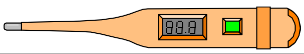
The failure will occur during a landing with a limited area, with an heavy external load to imply a very quick reactivity from the pilot.

EXPECTED PILOT REACTION
- Recognition time: 0.5 sec
- Reaction time: 0 sec
- Recovery time: NA

a

❖ Temporal sequence of failure resolution tasks undertaken by pilot

TRPH – SCENARIO NO 2					
			N°	ENGINE NO 1 LOSS RESOLUTION TASKS	TIME
			1	Failure occurrence	0.5 sec
X	X		2	Audio warning + « OEI » display on FND + master display	
	X	X	3	Sling load release	
	X		4	« ENG DF » warning display on CWP	
	X	X	5	Collective pitch lowering + Engine parameters display	
	X	X	6	Switching Engine 1 shut-off valve to OFF	
	X	X	7	Switching Engine 1 OFF	
	X	X	8	Acknowledging master caution	


= Task No 3

Recognition time

Reaction time

Recovery time

5.5.2.2 Failure No 2 occurrence conditions

❖ Helicopter configuration / MISSION type, flight phase / flight parameters, meteorological conditions

OPERATIONAL CONFIGURATION
- Single pilot - VMC - Hover - 50 ft - 0 kt - Offshore station - Sling with 3 tons load

a

❖ <u>Scenario pattern on map</u>

<u>Occurrence</u>: Slinging at all-up weight to deposit load on offshore platform, failure vertically above platform while helicopter is hovering. Correction must be short or a crash might follow.

: Offshore platform

: Failure occurrence

5.5.2.3 Briefing and description of failure No 2 process

❖ Briefing data sheet

TRPH – SCENARIO NO 2				TTO	9 :00	TOIP	--------
DATE	30/1/2001	HELO	F/TRPH	TOT	9 :16	END	9 :33
EXTERNAL CONDITIONS				**HELO CONF.** : 10 TONS			
WIND		150/2kts		FUEL	max		
VISIBILITY ON 1RST WP		CAVOK		ENDURANCE	6 hours		
VISIBILITY ON T WP		CAVOK		LOADS	Sling > 3 T		
CEILING		5000 ft		**CREW AND PASSENGERS**			
RELAT. HUM.		80%		PILOT	1		
AIR T°		12° C		COPILOT			
QNH		1013		CABIN CREW			
FORECAST		NOSIG during the next 4 hours		PASSENGERS			
MISSION: Sling loading to offshore station							
Istres	Take off from Istres offshore platform via Carro and Le Rouet						
Leg 1 > 3	AFCS engagement and ATIS communication prior to transit						
Offshore station	Sling load deposit						
Leg 4 > 5	Return empty to Istres via Carro						

a

❖ En route data sheet

Waypoint	X	Y	h(m)	Alt (ft)	Route	Dist	Speed	TTG	Time
istres	21 074	40 006							09:00
				take off	154	0,0	20	0:03	
istres	21 074	40 006							09:03
				1500	158	13,4	150	0:05	
carro	30 530	16 978							09:08
				1500	90	5,1	150	0:02	
le rouet	39 986	16 916							09:10
				1500	327	7,6	150	0:03	
Offshore station	47 709	5 155							09:13
				approche	180	0,0	20	0:03	
Ofshore station	47 709	5 155							09:16
Failure				stationnaire	180	0,0	0	0:03	09:16
Ofshore station	47 709	5 155							09:19
				fin élingue	180	0,0	20	0:01	
Offshore station	47 709	5 155							09:20
				1500	125	11,3	150	0:04	
carro	30 530	16 978							09:24
				1500	158	13,4	150	0:05	
istres	21 074	40 006							09:30
				landing	154	0,0	20	0:03	
istres	21 074	40 006							09:33

a

❖ Full description of operating scenario

TASKS/EVENTS	HEIGHT (Ft)	CRS	Time	VOR/DME/TACAN	COM / Iff Plan
1.TAKE OFF PREPARATION	Istres	NA	NA		
1.1. Communications with offshore station					
1.2. General information about take off and flight plan				ITR 115.7 / 104X	
1.3. Clearance from Istres					
2.TAKE OFF	Climb	158	**T0**		
2.1. DTO to Carro					
3. CRUISE IN ACCORDANCE WITH FLIGHT PLAN	1500 ft	158			
3.1. Engage AFCS mode					
3.2. Prepare communications with MRS ATIS. Selection of frequencies					
3.3. Contact MRS ATIS					
3.4. Fly over Carro			T0 + 8 mn		
3.5. Fly to Le rouet	1500ft	90			
3.6. Fly over Le rouet			T0 + 10 mn		
3.7. Fly to offshore station	1500ft	327			
3.8. Communication with offshore station for clearance					
4. SLING OPERATION					
4.1. Prepare load deposit	hover	180	T0 + 16 mn		
4.2. Failure : Engine failure			T0 + 16 mn		
4.2.1. The crew activates the emergency jettison for sling release					
4.2.2. The crew switches off the failed engine					
4.2.3. The crew acknowledges the master warning					
4.3. Depositing load					
5. STARTING RETURN LEG					
5.1.Communication with ATIS for clearance					
5.2. Take off from offshore station	hover	180	T0 + 20 mn		

a

TASKS/EVENTS	HEIGHT (Ft)	CRS	Time	VOR/DME/TACAN	COM / Iff Plan
6. RETURN FLIGHT					
6.1. Fly to Carro	1500 FT	125			
6.1. Fly over Carro to Istres	1500 FT	158	T0 + 24 mn		
6.1. Communication with ISTRES area for approach and landing clearance					
8. FINAL LANDING					
8.1. Communication with ISTRES area for landing clearance					
8.2. Landing		154	T0 + 33 mn		
END OF MISSION					

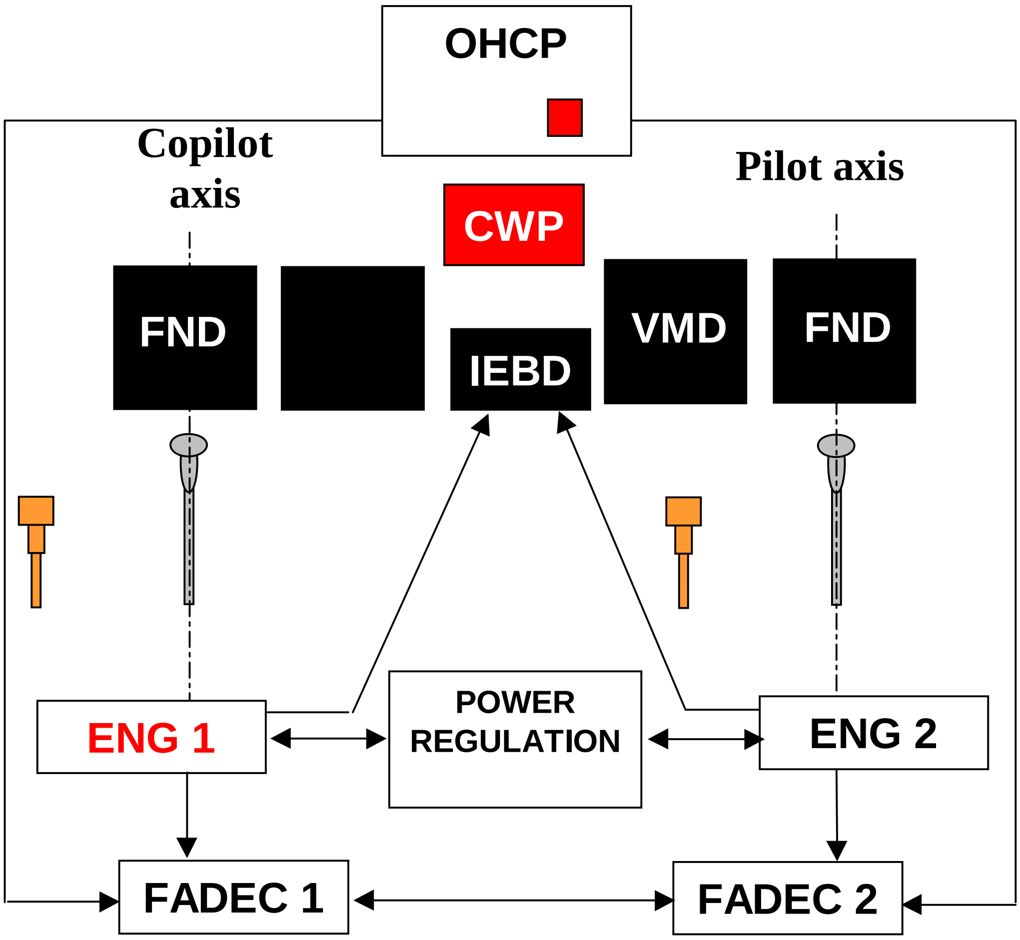
a

5.5.3 Failure No 3: Partial reduction of engine 1 power below OEI threshold

The partial reduction of engine No 1 power below the OEI threshold has been selected for its drift (« slowover ») aspect that is not quickly detectable by the pilot. This illustrates the potential temporal drift of a failure and the pilotability degradation it generates if the pilot does not perform engine information checks and is warned only when the system has detected a deviation between both FADECs. This failure also illustrates a loss of helicopter performance in a high workload phase that involves a pilot choice.
The data sheet describing the failure is presented in a document entitled "Analysing helicopter failures recovery times"– Ref. TN X 000 AR 414 F01 issue B (08/06/2001) attached document.

5.5.3.1 Description of Failure No 3 constituents

❖ Systems involved in failure and data display resources



❖ System failure detection thresholds:

➢ Torque deviation > 25% between both engines detected by FADEC *(Engine regulation induces an Engine No 1 offset by Engine No 2)*

☞ Power deviation displays on IEBD

❖ Failure detection elements and corrections expected from pilot

FAILURE DETECTION ELEMENTS	FAILURE CORRECTION
-Power indication for both engines on IEBD and crosscheck with the associated VMD page *If no detection to begin with:* - Switch to OEI mode reported on FND - "ENG DF" warnings on CWP and audio warning	- Correction ≤ 1 s - Failed engine 1 stop and switch to controlled OEI mode

❖ Effects induced in the absence of corrective actions or thanks to proper pilot corrective actions

EFFECTS INDUCED	
NO CORRECTIVE ACTION: MAJOR to HAZARDOUS	SUITABLE CORRECTIVE ACTIONS: MAJOR
- No max. power available to "break" speed during landing speed - Automatic switch to OEI mode during landing phase	- Helicopter regulation and faulty engine stop

❖ Recognition and reaction times expected pilot

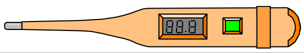
The failure will occur during landing phase, without any possibility for a rolled landing, to oblige the pilot to solve the failure, before the landing.

EXPECTED PILOT REACTION
- Recognition time: TBD - Reaction time: 1 sec - Recovery time: NA

a

❖ Temporal sequence of failure resolution tasks undertaken by pilot

TRPH – SCENARIO NO 3					
			N°	PARTIAL ENGINE 2 POWER REDUCTION FAILURE RESOLUTION TASKS	TIME
			1	No failure report	
			2	Failure occurrence	**0.5 sec**
X	X		3	Audio warning + « OEI » display: on FND + master caution display	
	X		4	« ENG DF » display on CWP	**1 sec**
	X		5	Engine parameters display	
	X	X	6	Checking helicopter attitude	
	X	X	7	Switching engine 1 shut-off valve to OFF	
	X	X	8	Switching engine 1 OFF	
	X	X	9	Potential switch to OEI Low	
	X	X	10	Acknowledging master caution	



= Task No 6

Recognition time

Reaction time

Recovery time

5.5.3.2 Failure No 3 occurrence conditions

❖ Helicopter configuration / mission type, flight phase / flight parameters, meteorological conditions

OPERATIONAL CONFIGURATION
- Single pilot monopilote - Night VMC - Approach - 1000 ft - 70 kt - Clearing on land OR offshore platform - Passengers transport (at all-up weight) + communications with cabin and/or copilot

a

❖ Scenario pattern on map;

Occurrence: In transdown immediately before landing phase, in a narrow spot to avoid a rolled landing. The recovery times are necessarily short otherwise a hard landing might occur

:Offshore platform

: Failure occurrence

5.5.3.3 Briefing and description of failure No 3 process

❖ <u>Briefing data sheet</u>

<table>
<tr><td colspan="4">TRPH – SCENARIO NO 3</td><td>TTO</td><td>9 :00</td><td>TOIP</td><td>--------</td></tr>
<tr><td>DATE</td><td>30/1/2001</td><td>HELO</td><td>F/TRPH</td><td>TOT</td><td>9 :21</td><td>END</td><td>9 :40</td></tr>
<tr><td colspan="4">EXTERNAL CONDITIONS</td><td colspan="4">HELO CONF. : 10 TONS</td></tr>
<tr><td colspan="2">WIND</td><td colspan="2">150/2kts</td><td colspan="2">FUEL</td><td colspan="2">max</td></tr>
<tr><td colspan="2">VISIBILITY ON 1RST WP</td><td colspan="2">Night level 1, 21h</td><td colspan="2">ENDURANCE</td><td colspan="2">6 hours</td></tr>
<tr><td colspan="2">VISIBILITY ON T WP</td><td colspan="2">Night level 1, 21h</td><td colspan="2">LOADS</td><td colspan="2">none</td></tr>
<tr><td colspan="2">CEILING</td><td colspan="2">5000 FT</td><td colspan="4">CREW AND PASSENGERS</td></tr>
<tr><td colspan="2">RELAT. HUM.</td><td colspan="2">80%</td><td colspan="2">PILOT</td><td colspan="2">1</td></tr>
<tr><td colspan="2">AIR T°</td><td colspan="2">12° C</td><td colspan="2">COPILOT</td><td colspan="2"></td></tr>
<tr><td colspan="2">QNH</td><td colspan="2">1013</td><td colspan="2">CABIN CREW</td><td colspan="2"></td></tr>
<tr><td colspan="2">FORECAST</td><td colspan="2">NOSIG during the next 4 hours</td><td colspan="2">PASSENGERS</td><td colspan="2">14</td></tr>
<tr><td colspan="8">OPERATION: Passenger transport from MRS to Les Baux by night</td></tr>
<tr><td></td><td colspan="7">Take-off from MRS – AFCS programming</td></tr>
<tr><td>Leg 1>2</td><td colspan="7">AFCS engagement and communication with TWR + ATIS to leave TMA</td></tr>
<tr><td>Leg 3</td><td colspan="7">Night cruise flight at 1000 ft to Les Baux</td></tr>
<tr><td>Les Baux</td><td colspan="7">Disembarking passengers</td></tr>
<tr><td>Leg 4</td><td colspan="7">Transit to ILS – MTG entry point</td></tr>
<tr><td>Leg 5 > 7</td><td colspan="7">Approach and flight through ILS</td></tr>
<tr><td></td><td colspan="7"></td></tr>
</table>

a

❖ <u>En route data sheet</u>

marignane	43 296	31 085							09:00
				Take off	135	0,0	0	0:02	
marignane	43 296	31 085							09:02
				1500	193	7,9	150	0:03	
le rouet	39 986	16 916							09:05
				1500	270	5,1	150	0:02	
carro	30 530	16 978							09:07
				1500	337	27,5	150	0:11	
les baux	10 942	64 053							09:18
Failure				landing	180	0,0	70	0:03	09:20
les baux	10 942	64 053							09:21
				0	180	0,0	0	0:03	
les baux	10 942	64 053							09:24
				take off	180	0,0	20	0:03	
les baux	10 942	64 053							09:27
				2000	150	24,8	150	0:09	
martigues	34 042	24 448							09:37
				1650	346	7,5	150	0:03	
MAR APP	30 665	37 938							09:40
				1650	91	3,0	150	0:01	
MAR MKR	36 249	37 876							09:41
				landing	134	5,3	150	0:02	
marignane	43 296	31 085							09:43
				0	135	0,0	0	0:03	
marignane	43 296	31 085							09:46

a

❖ Full description of operating scenario:

TASKS/EVENTS	HEIGHT (Ft)	CRS	Time	VOR/DME/TACAN	COM / Iff Plan
1.TAKE- OFF PREPARATION	Offshore station	NA	NA		
1.1. Communications with MRS TWR					
1.2. General information about take off and flight plan				MTG 117.3 / 120X	
1.3. **Clearance from MRS TWR**					
2.TAKE OFF	Climb	135	**T0**		
2.1. DTO to LE ROUET					
3. CRUISE IN ACCORDANCE WITH FLIGHT PLAN	1500 ft	193			
3.1. Engage AFCS NAV mode					
3.2. Fly over to Carry le Rouet		270	T0 + 5 mn		
3.3. Prepare communications with MRS ATIS. Selection of frequencies					
3.4. Contact MRS ATIS					
3.5. Fly towards CARRO		337	T0 + 5 mn		
3.6. Fly to Les Baux	1500ft				
4.LANDING					
4.1. Prepare for landing					
4.2. Failure : Engine SLOWOVER			While approaching		
4.2.1. The crew acknowledges the caution on Master caution					
4.2. 2. The crew investigates the failure on MFD/VMD formats					
4.2.3. The crew solves the failure and recovers a safe situation					
4.3. Land at Les Baux			T0 + 24 mn		
5.TAKE OFF					
5.1.Take off from Les Baux			T0 + 27 mn		

a

TASKS/EVENTS	HEIGHT (Ft)	CRS	Time	VOR/DME/TACAN	COM / Iff Plan
7. LEAVING FOR MARSEILLE AIRPORT	2000 FT	150			
7.1. Communications with Civilian ATCs					MRS APP : 131.225
7.2. Clearance by Civilian ATCs					
7.3. Communications with MRS TWR					MRS TWR : 119.5
7.4. NH contact Marseille Airport for landing					
7.5. Clearance for landing at Marseille Airport					
8. LANDING AT MARSEILLE AIRPORT		QFU 14L	T0 + 43 mn		
8.1. Landing					
8.2. Communications with Mission CONTROL & MRS TWR					
END OF MISSION					

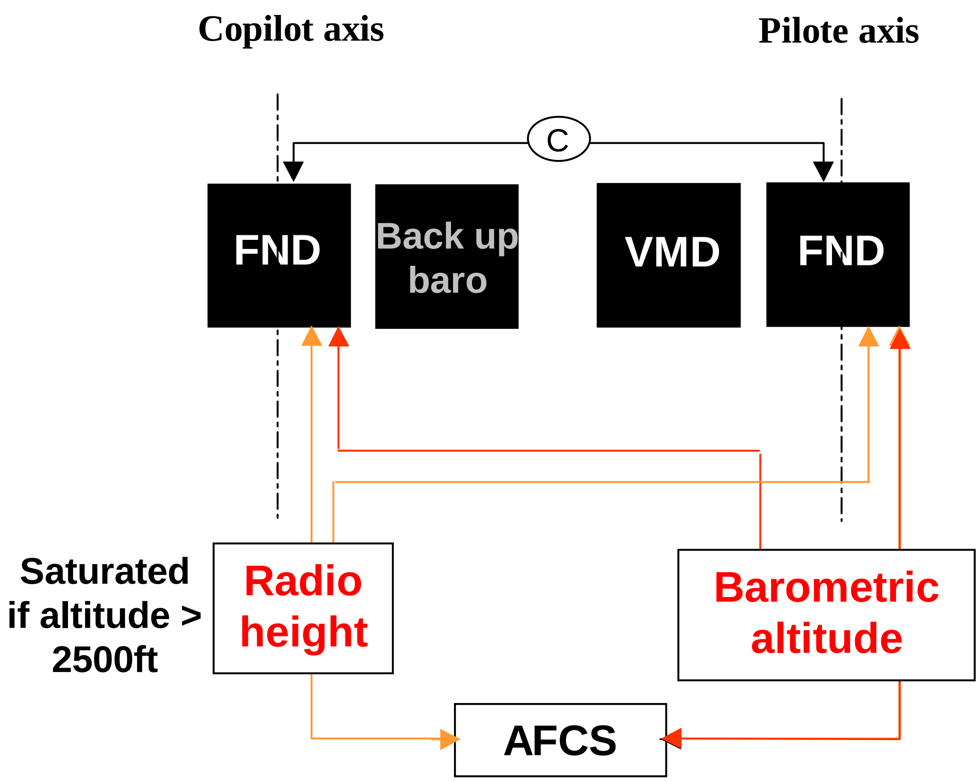
a

5.5.4 Failure No 4: Slow drift of AFCS altitude hold resulting from a barometric altimeter failure.

The slow drift of AFCS altitude hold as a result of barometric altimeter failure was selected for its very slow drift (« slowover ») aspect that is not rapidly detectable by the pilot. This illustrates the potential temporal drift of a very slow failure if external events, the flight phase (Radio height in this case) and his/her workload concomitantly prevent the pilot from fully monitoring flight parameters, recouping equipment data and being warned of this failure once the deviation between both IRS has been detected only.
The data sheet describing this failure is presented in a document entitled "Analyzing helicopter failures recovery times" – Ref. TN X 000 AR 414 E01 issue B (08/06/2001) attached document.

5.5.4.1 Description of failure no 4 constituents

❖ Systems involved in failure and data display resources



❖ System failure detection thresholds

- Altitude hold deviation > 300ft/min
- Pressured deviation on barometric altimeter back-up
  - ☞ Low rate of climb displayed on vertical climb indicator

❖ Failure detection elements and corrections expected from pilot

FAILURE DETECTION ELEMENTS	FAILURE CORRECTION
- Vertical climb indicator reporting a 100 ft/min drift	- Correction ≤ 3,5 s - ALT mode disengagement

❖ Effects induced in the absence of corrective actions or thanks to proper pilot corrective actions

EFFECTS INDUCED	
NO CORRECTIVE ACTIONS: HAZARDOUS	WITH PROPER CORRECTIVE ACTIONS: MAJOR
- Helicopter altitude increase - Risks of collision with other aircraft	- Proper altitude hold with hands on - Disengagement of altitude hold upper mode - High air traffic workload

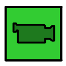
❖ Recognition and reaction times expected from pilot

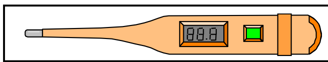
The failure will occur in IMC cruise to provide no external information for the failure solve.

EXPECTED PILOT REACTION
- Recognition time: TBD - Reaction time: 3 sec - Recovery time: NA

a

❖ Temporal sequence of failure resolution tasks undertaken by pilot

TRPH – SCENARIO NO 4					
			N°	RESOLUTION TASKS FOR SLOW AFCS ALTITUDE HOLD DRIFT RESULTING FROM BAROMETRIC ALTIMETER FAILURE	TIME
			1	Initial drift	?
X			**2**	problem identification	
	X		**3**	Crosschecking barometric altimeter with altimeter back-up + vertical climb indicator display, if required	3 sec
	X		**4**	Switching to hands on piloting	
	X	X	**5**	Grasping cyclic stick and collective lever	
	X	X	**6**	Disengaging ALT mode	



= Task No 4

Recognition time

Reaction time

Recovery time

5.5.4.2 Failure No 4 occurrence conditions

❖ Helicopter configuration / mission type, flight phase/flight parameters, meteorological conditions

OPERATIONAL CONFIGURATION
- Single pilot - IMC - Cruise flight in turbulence - 2500 ft (ALT mode + attitude hold) - 150 kt - Flat terrain - Passengers transport + communications with cabin and/or copilot

a

❖ <u>Scenario pattern on map</u>

<u>Occurrence:</u> This failure occurs in cruise flight, on return from mission, without any tell-tale signs that might alert the pilot, approximately into the third quarter of a fairly long leg.

: Offshore platform

: Failure occurrence

a

5.5.4.3 Briefing and description of failure No 4 process

❖ Briefing data sheet

TRPH – SCENARIO NO 4				TTO	9 :00	TOIP	--------
DATE	30/1/2001	HELO	F/TRPH	TOT	9 :20	END	9 :46

EXTERNAL CONDITIONS		**HELO CONF.** : 10 TONS	
WIND	150/2kts, turbulences	FUEL	max
VISIBILITY ON 1RST WP	5 KM	ENDURANCE	6 hours
VISIBILITY ON T WP	5 KM	LOADS	none
CEILING	1300 FT	**CREW AND PASSENGERS**	
RELAT. HUM.	80%	PILOT	1
AIR T°	12° C	COPILOT	
QNH	1013	CABIN CREW	
FORECAST	NOSIG during the next 4 hours	PASSENGERS	14

MISSION: Transporting passengers from MRS to moulin de Daudet	
	Take off to MRS
Leg 1	Transit to ILS – MTG entry point
Leg 2 > 4	Approach and led-down through ILS
MRS	Embarking passengers
Leg 5 > 6	AFCS engagement and communication with TWR + ATIS to leave TMA
Leg 7	Cruise flight at 2500ft in IMC to moulin

a

❖ <u>En route data sheet</u>

Waypoint	X	Y	h(m)	Alt (ft)	Route	Dist	Speed	TTG	Time
moulin de Daudet	4 390	61 244							09:00
				Take off	180	0,0	20	0:02	
moulin de Daudet	4 390	61 244							09:02
				2500	141	25,5	150	0:10	
martigues	34 042	24 448							09:12
				1650	346	7,5	150	0:03	
MAR APP	30 665	37 938							09:15
				1650	91	3,0	150	0:01	
MAR MKR	36 249	37 876							09:16
				500	134	5,3	100	0:03	
marignane	43 296	31 085							09:19
				landing	135	0,0	0	0:01	
marignane	43 296	31 085							09:20
				0	135	0,0	140	0:03	
marignane	43 296	31 085							09:23
				take off	135	0,0	140	0:03	
marignane	43 296	31 085							09:26
				1500	193	7,9	140	0:03	
le rouet	39 986	16 916							09:29
				1500	270	5,1	150	0:02	
carro	30 530	16 978							09:32
Failure				2500	329	27,8	150	0:11	09:32
moulin de Daudet	4 390	61 244							09:43
				landing	180	0,0	20	0:03	
moulin de Daudet	4 390	61 244							09:46

a

❖ Full description of mission scenario

TASKS/EVENTS	HEIGHT (Ft)	CRS	Time	VOR/DME/TACAN	COM / Iff Plan
1.TAKE OFF PREPARATION					
1.1. General information about take off and flight plan				MTG 117.3 / 120X ITR 115.7 / 104X	
1.2. take off from le moulin de Daudet			T0		
2.FLYING TO MARSEILLE AIRPORT	2500 FT	141			
2.1. Communications with Civilian ATCs					MRS APP : 131.225
2.2. Clearance by Civilian ATCs					
2.3. Communications with MRS TWR					MRS TWR : 119.5
2.4. NH contact Marseille Airport for landing					
2.5. Clearance for landing at Marseille Airport					
3. LANDING AT MARSEILLE AIRPORT		QFU 14L			
3.1. Landing			**T0 + 20 mn**		
3.2. Communications with Mission CONTROL & MRS TWR					
4.TAKE OFF PREPARATION					
4.1. Communications with MRS TWR					
4.2. General information about take off and flight plan				MTG 117.3 / 120X	
4.3. **Clearance from MRS TWR**			T0 + 23 mn		
5.TAKE OFF	Climb	135			
5.1. DTO to LE ROUET					

a

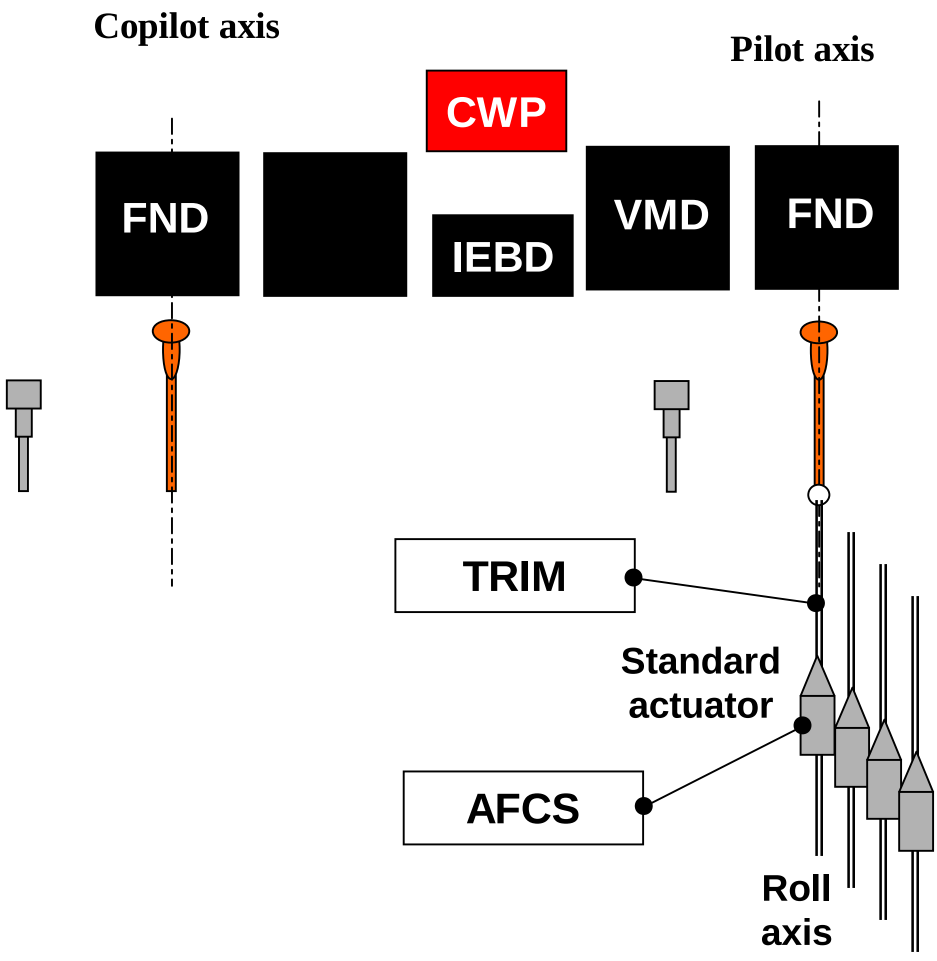
TASKS/EVENTS	HEIGHT (Ft)	CRS	Time	VOR/DME/TACAN	COM / Iff Plan
6. CRUISE IN ACCORDANCE WITH FLIGHT PLAN	1500 ft	193			
6.1. AFCS NAV mode ENGAGEMENT					
6.2. Flight over Carry le Rouet		270	T0 + 29 mn		
6.3. Communications with MRS ATIS. Selection of frequencies					
6.4. Contact WITH MRS ATIS					
6.5. Flight towards CARRO		329	T0 + 32 mn		
6.6. Flight to le moulin de Daudet	2500ft				
6.7. Failure : Barometric altimeter SLOWOVER			T0 + 32mn		
6.7. 1. The crew acknowledges the caution on Master caution					
6.7. 2. The crew investigates the failure on MFD/VMD formats					
6.7..3. The crew solves the failure and recovers a safe situation					
7.LANDING					
7.1. Preparation for landing					
7.2. Landing at Les Baux			T0 + 46 mn		
END OF MISSION					

5.5.5 Failure No 5: Hardover on AFCS roll axis

The hardover on AFCS roll axis failure has been selected for its sudden occurrence very quickly detectable by the pilot. This illustrates a failure that occurs suddenly and is concomitantly detected The data sheet describing this failure is presented in a document entitled "Analyzing helicopter failures recovery times"– Ref. TN X 000 AR 414 E01 issue B (08/06/2001) attached document.

5.5.5.1 Description of failure No 5 constituents

❖ Systems involved in failure and data display resources



a

❖ System failure detection thresholds

➢ Actuator authority = 7% , setting against stop in 300 ms , > 7% deviation to the right on roll axis
➢ "HANDS ON" warning activation in 100 ms
  ☞ Sudden and perceptible detection

❖ Failure detection elements and corrections expected from pilot

FAILURE DETECTION ELEMENTS	FAILURE CORRECTION
- Red "HANDS ON" warning and audio warning	- Correction ≤ 3.5 sec - Correction with cyclic stick

❖ Effects induced in the absence of corrective actions or thanks to proper pilot corrective actions

EFFECTS INDUCED	
NO CORRECTIVE ACTIONS: CATASTROPHIC	PROPER CORRECTIVE ACTIONS: MAJOR
- Stability and attitude hold on roll axis - Slow exponential drift during which the helicopter may turn on its back	- Trajectory hold

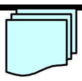
❖ Recognition and reaction times expected from pilot

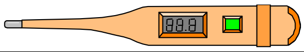
The failure will occur in low altitude cruise to increase the stress of the pilot , who will react more quickly.

PILOT REACTION EXPECTED
-Recognition time: 0.5 sec -Reaction time: 3 sec -Recovery time: NA

a

❖ Temporal sequence of failure resolution tasks undertaken by pilot

TRPH – SCENARIO NO 5					
			N°	HARDOVER ON AFCS ROLL AXIS FAILURE RESOLUTION BY PILOT	TIME
			1	Failure occurrence	0.5 sec
X	X		**2**	« HANDS ON » audio warning + FND or external display + Master caution display	
	X		**3**	Switching to hands on	3 sec
	X	X	**4**	Grasping cyclic and collective controls, regulating cyclic	
	X	X	**5**	Acknowledging master caution	



=Task No 3

Recognition time

Reaction time

Recovery time

5.5.5.2 Failure No 5 occurrence conditions

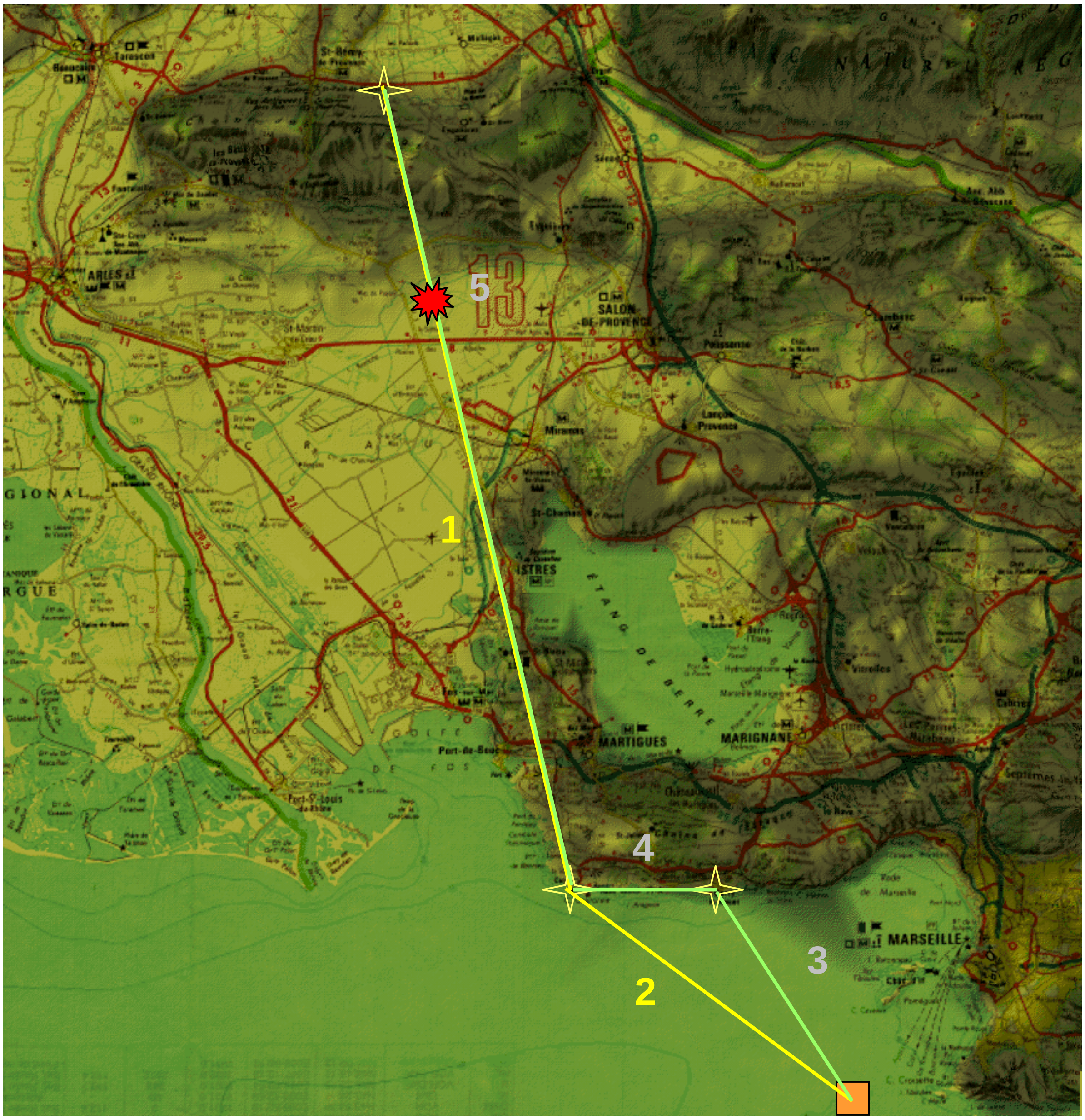
❖ Helicopter configuration / Mission type, flight phase / flight parameters, meteorological conditions

OPERATIONAL CONFIGURATION
- Single pilot - VMC - Cruise - 500 ft - PMC - Flat terrain - 4-axis AFCS with upper modes

a

❖ Scenario pattern on map

Occurrence: This hardover failure is sudden and clearly identifiable. It occurs at low altitude, it is, consequently, stressful for the pilot and reduces his/her level of performance.



: Offshore platform

: Failure occurrence

5.5.5.3 Briefing and description of failure No 5 process

❖ Briefing data sheet

TRPH – SCENARIO NO 5				TTO	9 :00	TOIP	--------
DATE	30/1/2001	HELO	F/TRPH	TOT	9 :19	END	9 :44
EXTERNAL CONDITIONS				**HELO CONF.** : 9.5 TONS			
WIND		150/2kts		FUEL		max	
VISIBILITY ON 1RST WP		CAVOK		ENDURANCE		6 hours	
VISIBILITY ON T WP		CAVOK		LOADS		none	
CEILING		5000 FT		**CREW AND PASSENGERS**			
RELAT. HUM.		80%		PILOT		1	
AIR T°		12° C		COPILOT			
QNH		1013		CABIN CREW			
FORECAST		NOSIG during the next 4 hours		PASSENGERS		5	
MISSION: Passenger transport from Le Mazet to offshore station							
	Take off from le Mazet to Carro – AFCS programming						
Leg 1	AFCS engagement and ATIS communication prior to transit						
Leg 2	Flight over sea at 500 ft from Carro offshore station						
Offshore station	Desembarking passengers on offshore station						
Leg 4>5	Return to Le Mazet via Le Rouet and Carro at 500 ft						

a

❖ En route data sheet:

Waypoint	X	Y	h(m)	Alt (ft)	Route	Dist	Speed	TTG	Time
le mazet	18 957	67 078							09:00
				Take off	180	0,0	0	0:02	
le mazet	18 957	67 078							09:02
				2500	167	27,8	160	0:10	
carro	30 530	16 978							09:12
				500	125	11,3	150	0:04	
Offshore station	47 709	5 155							09:16
				landing	180	0,0	20	0:03	
Offshore station	47 709	5 155							09:19
				0	180	0,0	0	0:03	
Offshore station	47 709	5 155							09:22
				take off	180	0,0	20	0:03	
Offshore station	47 709	5 155							09:25
				500	327	7,6	150	0:03	
le rouet	39 986	16 916							09:28
				500	270	5,1	150	0:02	
carro	30 530	16 978							09:31
Failure				2500	347	27,8	160	0:10	09:38
le mazet	18 957	67 078							09:41
				landing	180	0,0	20	0:03	
le mazet	18 957	67 078							09:44

a

❖ Full description of mission scenario:

TASKS/EVENTS	HEIGHT (Ft)	CRS	Time	VOR/DME/TACAN	COM / Iff Plan
1.TAKE OFF PREPARATION		NA	NA		
1.1. Communications with offshore station					
1.2. General information about take off and flight plan				MTG 117.3 / 120X ITR 115.7 / 104X	
1.3. Clearance from le Mazet and take off			T0		
3. CRUISE IN ACCORDANCE WITH FLIGHT PLAN	2500 ft	167			
3.1. Engage AFCS mode					
3.2. Prepare communications with MRS ATIS. Selection of frequencies					
3.3. Contact MRS ATIS					
2.1. DTO to Carro					
3.4. Fly over Carro			T0 + 12 mn		
3.7. Fly to offshore station	500ft	125			
3.8. Communication with offshore station for clearance					
4. LANDING OPERATION					
4.3. Land on offshore station			T0 + 19 mn		
5. RETURN FLIGHT					
5.1. Communication with ATIS for clearance					
5.2. Take off from offshore station		180	T0 + 22 mn		

a

TASKS/EVENTS	HEIGHT (Ft)	CRS	Time	VOR/DME/TACAN	COM / Iff Plan
6. RETURN FLIGHT					
6.1. Fly to le rouet	500 FT	327			
6.1. Fly over le rouet		270	T0 + 28 mn		
6.1. Fly to Carro					
6.1. Fly over Carro to le Mazet		347	T0 + 31 mn		
6.1. Communication with ISTRES area for clearance					
6.7. Failure : Hardover on roll axis			T0 + 38mn		
6.7. 1. The crew acknowledges the caution on Master caution					
6.7. 2. The crew investigates the failure					
6.7..3. The crew solves the failure and recovers a safe situation					
8. FINAL LANDING					
8.1. Communication with le mazet for landing clearance					
8.2. Landing		180	T0 + 44 mn		
END OF MISSION					

6. RECOGNITION AND REACTION TIME MEASURING METHOD

6.1 DESCRIPTION

6.1.1 Principles

Recognition and reaction times are mainly evaluated from simulation parameters records. To understand the pilot's cognitive process prior to failure, as failure occurs and once failure has been resolved, his/her activities shall be analyzed according to the following qualitative or pseudo-quantitative criteria:

- Qualitative analysis of pilot activities:
  - Voice and gestures (recorded with a camera and via the intercommunication system)

- Quantitative analysis of pilot activities:
  - Measuring failure occurrences and pilot reactions on controls with time and regulation mode definition (Human performances).
  - Physiological activities (electrocardiogram); cognitive detection of failure (measured via stress display)
  - Measuring workload and performance level prior to failure, as failure occurs and pre / post failure regulation (Post-operative measurements)

Workload is the only measurement performed post-operatively; every other measurement is performed in real time.

The records required for the analyses mentioned above impose the following resources:

- 1 simulator with virtual picture of the outside world (See Appendix 2)
- 1 camera
- 1 VCR (video + audio)
- 1 tachy-cardio-frequencymeter
- Simulation parameters records (See detail in § 6.2)

a

The output data expected from those resources are:

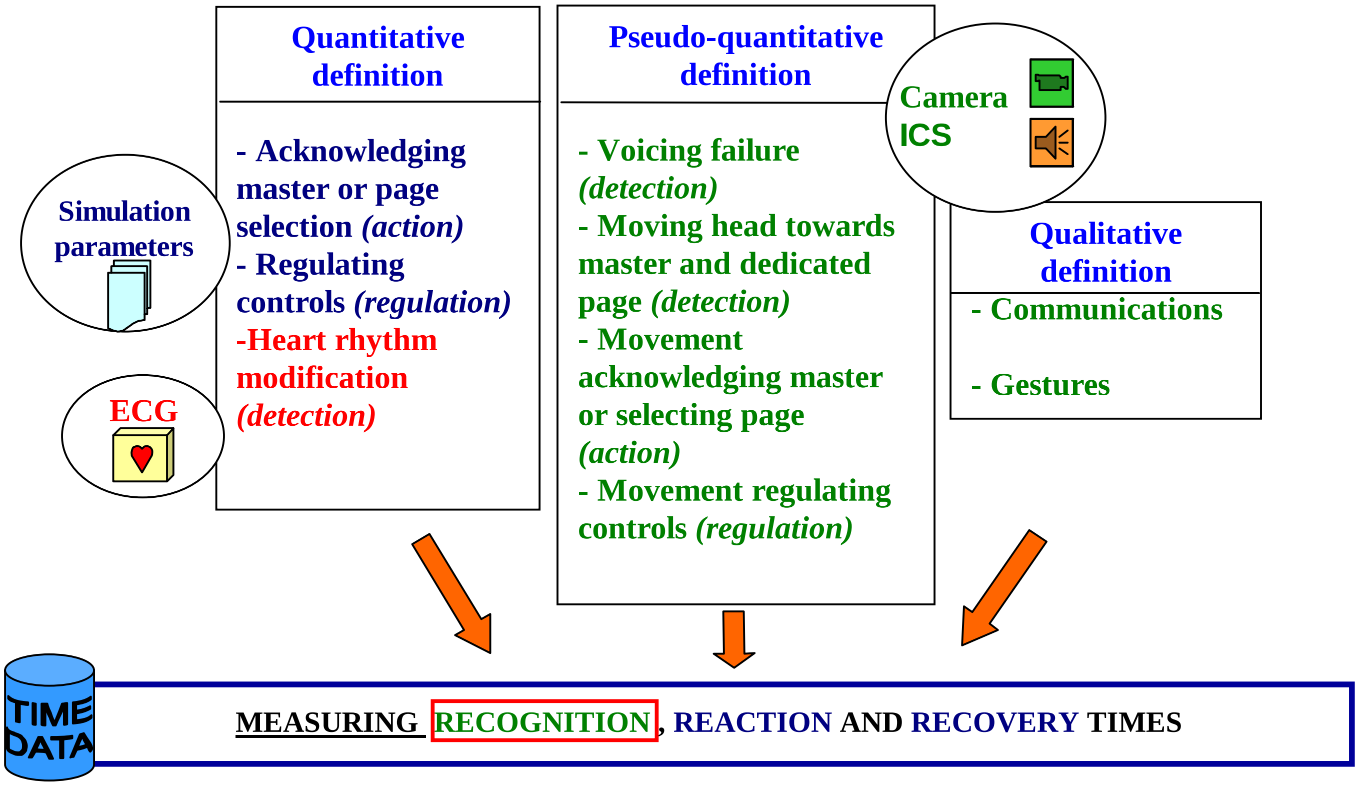


Figure 5: Description of output data

6.1.2 Temporal time measuring sequence

The temporal process applied to evaluate recognition and reaction times is detailed below:

- The mission scenarios used as media in the evaluation of recognition and reaction times are implemented and initialized.

- The evaluating pilot is fitted with a tachy-cardio-frequencymeter by medical personnel.

- The pilot is then briefed prior to each simulated session. He/she is provided with flight conditions, a briefing data sheet as well as en-route data sheet to prepare his/her mission. He/she receives no data regarding failure occurrence. The failure resolution procedures are assumed to be well known since only those pilots able to control and manage a generic helicopter are selected initially.

- Once the evaluating pilot has completed his/her preparation in the briefing room, he/she sits down in the simulator and performs the necessary helicopter preparation, navigation and mission management tasks.

- The evaluating pilot then informs the air traffic control (simulated in the test follow-up room) that he/she is ready for take-off and the "air traffic controller" gives the authorization to take off. The recording and take-off tops are registered simultaneously. Communications are realistic throughout the "flight" An observer analyses (in the test follow-up room) the gestures, communications and failure resolution strategy selected by the evaluating pilot.

- The failure is injected according to scenario and the pilot proceeds with failure resolution.

- Once the scenario has been effectively completed according to failure (e.g. in failure No 2 with engine loss occurring while slinging, the scenario is interrupted after landing on the offshore platform), the evaluating pilot debriefs the mission scenario and his/her failure management. The proper debriefing session starts with a "hot" debriefing.

- The evaluating pilot then evaluates his/her workload before, on occurrence, during and after the failure so as to correlate the recognition and reaction times with this workload, the evaluation sheets are presented in appendix 4. The tachy-cardio-frequencymeter records are processed to identify the heart frequency variations timing and the simulation parameters are processed as well. The sources of problems (errors etc.) or uncertainties regarding the failure response process can then be identified and analyzed with the evaluating pilot and the observer.

A graphic representation of the recognition and reaction time evaluation sequence is given below:

a

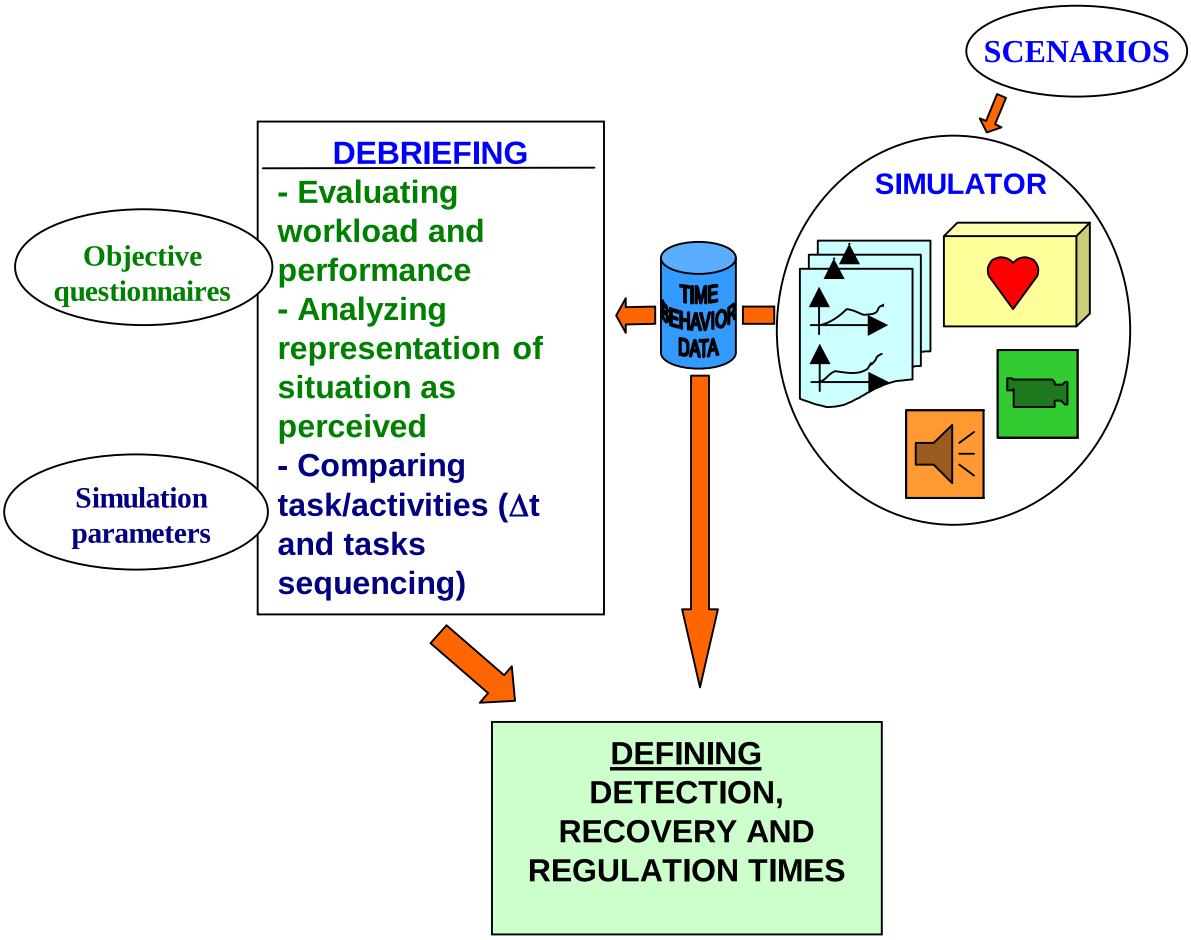


Figure 6: Times evaluation sequence

a

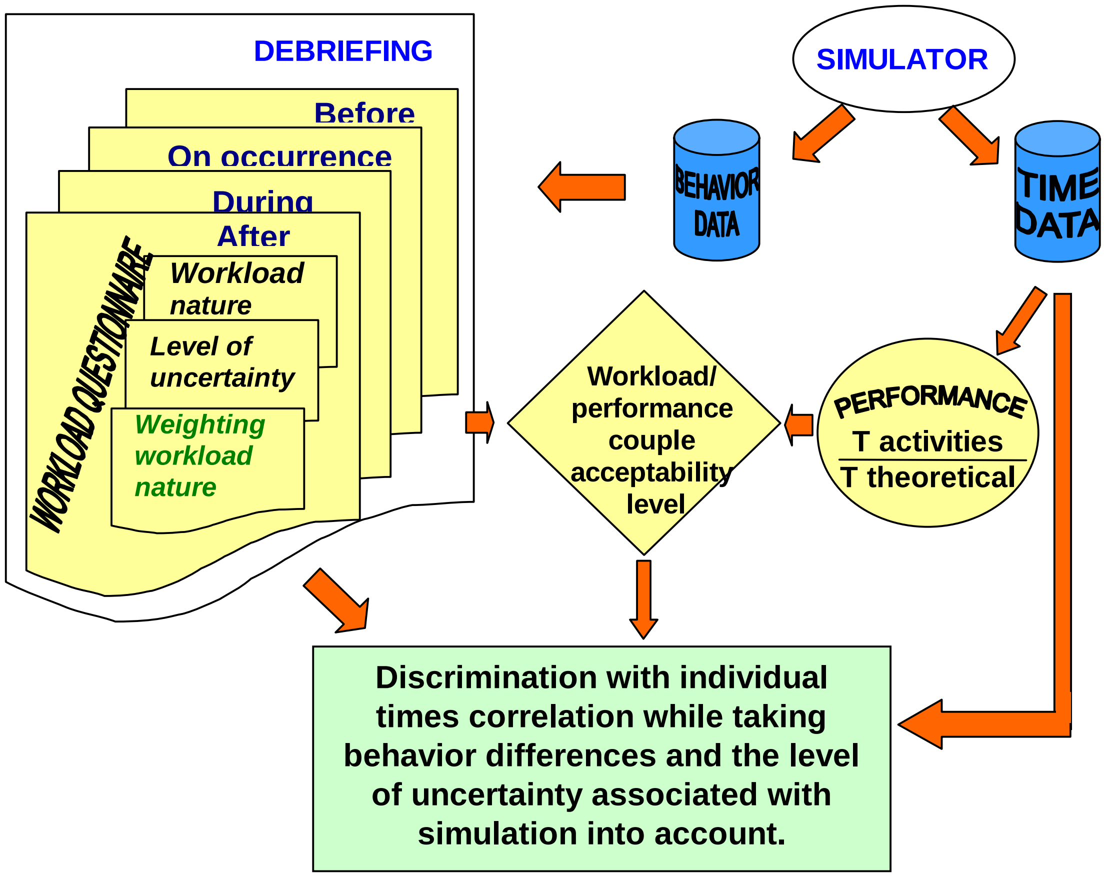


Figure 7: Workload evaluation

6.2 PARAMETERS RECORDED

The following parameters must be recorded synchronously to determine the recognition and reaction times as well as the recovery times for information:

- ***(Sampling over 500 ms):***
- Effective trajectory along x, y, and z axis superimposed to scheduled trajectory
- Gestures + communications (with camera+VCR)

- ***From 10 seconds before failure occurrence to resolution (Sampling over 40 ms):***
- ρ, θ, ψ, acceleration, angular speed
- Pressing switches (master acknowledge, page or mode selection, control panel switches etc.)
- Flight controls regulation mode on the 4 axes
- Parameters associated with failure occurrence and regulation (Failure-type dependent)

From T0 to the end of the mission:

- Cardiac frequency (TCG90 tachy-cardio-frequencymeter operating autonomously)

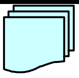
a

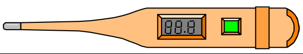
7. RESULTS FROM DATA TREATMENT

7.1 FAILURE N° 1

7.1.1 Simulation parameters analysis

The simulation parameters analysis needed for the failure n°1 data treatment give the following results (curves given in appendix 3) :

TRPH – SCENARIO 1				
	N°	LOW IRS2 DRIFT FAILURE RESOLUTION TASKS	TIME secondes mesured	TIME secondes theoretical
SWITCH 1	**1**	Failure occurrence	T0	T0
	D	System detection	1.25	1.25
	2	« Hands On » audio warning + Master display	-	
	3	« HANDS ON » + «IRS/AVIONICS DEGRAD» display on CWP		TD + 0,5
RQ +RP+ PHI+THETA+ POSABSROU+ POSABSTANG +POSABSLAC+ POSABSCOL	**4**	Grasping collective and cyclic controls	TD +0.66 (pitch) TD +0.78 (roll)	T2 + 3
	5	Cross checking MFDs 1and 2	-	
	6	Cross checking with horizon back-up to identify screen displaying false data	-	
NX+NY+NZ	**7**	Checking helicopter attitude	-	-
ETAT RCP	**8**	Switching from MFD 2 to IRS 1 via reconfiguration panel on console	T4(roll)+ 7.01	-
-	**9**	Acknowledging master	-	-



= task n°4 à 7

The pilot has undertaken the right corrective action since hands on: task n°4. The value is associated with the roll recovery. The knowledge of the slowover direction, as the scenarios were validated on the simulator, and taking into account the generic helicopter pilot expertise, can explain partly the direct answer of the evaluation pilot, and so the short correction time.

Correction time failure n° 1 = 0.78 secondes, Theoretical = 3,5 secondes

a

7.1.2 Heart rate variation analysis

The pilot heart rate variation analysis did not allow to establish the correlation with the failure n°1 occuracy recognition for the following 3 reasons:

- the pilot did not felt any stress for following reasons:
  - nominal behavior
  - simulator effect
  - scenarios knowledge and failures occurency.
- The heart rate records have a sampling of 1 seconde, which is not suffisant for a good discrimination of the recognition .

These remarks are also valid for the failures n° 2 to 5.

This implies that only the correction time can be really measured.

7.1.3 Evaluation pilot behavior analysis

The evaluation pilot has followed the predefined procedures, a has felt no particuliar stress. The failure recovery has been performed nominally and the failure was considered as easy to recover, while the pilot was not guided par the acceleration stimulated the proprioceptif sensors.

7.1.4 Workload analysis

The evaluation pilot, selected for the phase n°1, knowing perfectly the simulator, the generic helicopter, the associated functions and the failure recovery procedures, having evaluated previously the scenario realism, has indicated no uncertainty sources for his workload level evaluation. Thus, the values measured are fixed numeric values, without uncertainty borders. Moreover, the low proclivity to stress of the evaluation pilot did not imply important gap during the failure occurrence.

WORKLOAD LEVEL *			
BEFORE	DURING	WHILE RECOVERY	AFTER RECOVERY
1,92	2,53	2,2	1,92

* : 1 <low < 3 < average < 5 < high <6 < very high<8 < unacceptable < 10

The workload evaluation values show an increase of the workload during the occurrence phase, linked mainly with the increase of the mental load.

a

7.1.5 Correlated correction time determination

The results show that the pilot time and the workload level are below the theoretical values. These values have to be considered as minimum, taking into account the intrinsic characteristics of the evaluation pilot:

- Scenarios and failures occurrence knowledge
- Scenarios and failures validation before evaluation
- Perfect knowledge of the generic helicopter capacities
- Low proclivity to stress

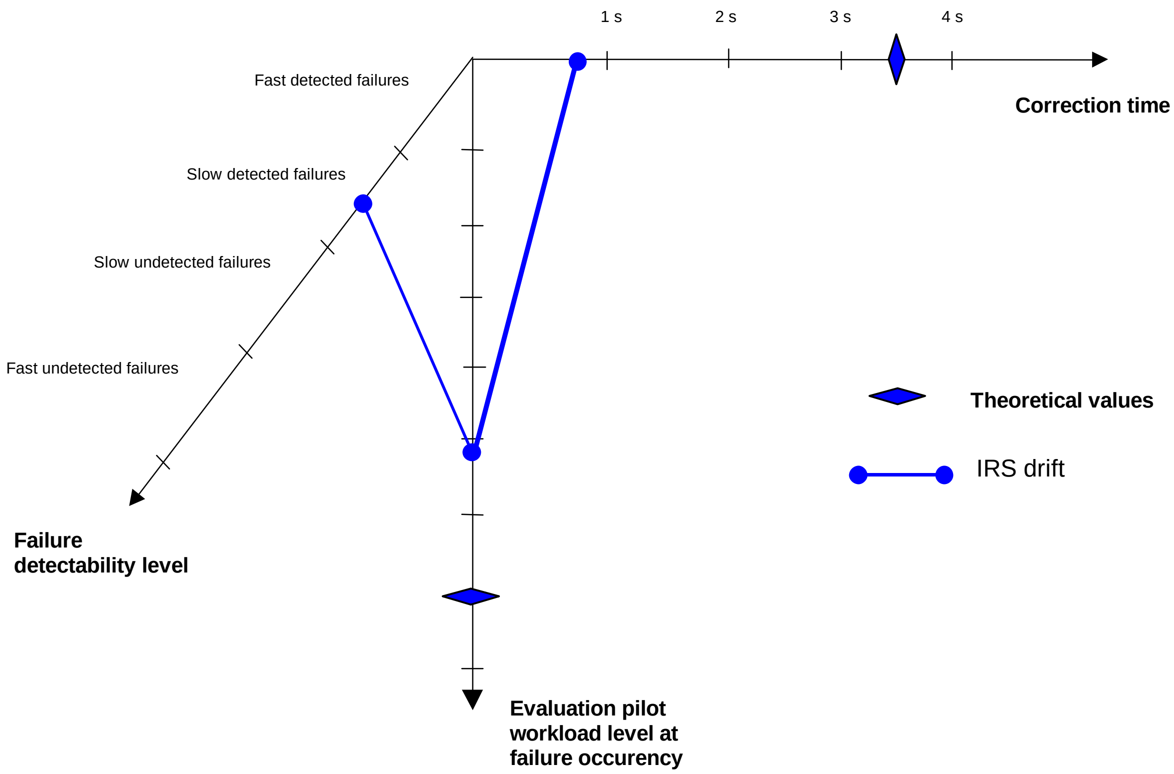


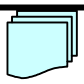
Figure 8: Evaluation pilot test results – failure n°1

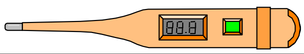
a

7.2 FAILURE N°2

7.2.1 Simulation parameters analysis

The simulation parameters analysis needed for the failure n°2 data treatment give the following results (curves given in appendix 3) :

TRPH – SCENARIO 2				
	N°	ENGINE NO 1 LOSS RESOLUTION TASKS	TIME seconds	
			Measured	Theoretical
SWITH 2	1	Failure occurrence	T0	T0
OEI STATUS	2	System detection : Audio warning + « OEI » display on FND + master display	T0 + 0.48	T0 + 0.48
MASSE HELI	3	Sling load release	T2 + 0.32	T2 + 0.5
	4	« ENG DF » warning display on CWP	-	-
POSABSC OL	5	Collective pitch lowering + Engine parameters display	T3 + 0.64	-
SOV STATUS	6	Switching Engine 1 shut-off valve to OFF	-	-
MOT STOP	7	Switching Engine 1 OFF	Not stopped	-
-	8	Acknowledging master caution	-	-


= task n°3

The correction time corresponds to the sling load release. In the present case, the theoretical correction time is 0.5 seconds, without any reaction time, taking into account the flight configuration before landing.

Correction time failure n° 2 = 0.32 secondes, Theoretical = 0,5 secondes

7.2.2 Heart rate variation analysis

See remarks § 7.1.2

7.2.3 Evaluation pilot behavior analysis

The evaluation pilot has followed the pre-required procedures. During the construction of the scenarios, he estimated that he will not release the sling load, taking into account the generic helicopter capacities. Nevertheless, the pilot has released 3 times the sling load for security reasons, demonstrating that, in extreme urgency situation, the acquired reflex, and not specific to the generic helicopter, occur. The recovery of the failure has been considered as easy to recover in spite of the induced workload.

7.2.4 Workload analysis

The evaluation pilot, selected for the phase n°1, knowing perfectly the simulator, the generic helicopter, the associated functions and the failure recovery procedures, having evaluated previously the scenario realism, has indicated no uncertainty sources for his workload level evaluation. Thus, the values measured are fixed numeric values, without uncertainty borders. Moreover, the low proclivity to stress of the evaluation pilot did not imply important gap during the failure occurrence.

WORKLOAD LEVEL *			
BEFORE	DURING	WHILE RECOVERY	AFTER RECOVERY
2,72	3,38	3,05	2,21

* : 1 <low < 3 < average < 5 < high <6 < very high<8 < unacceptable < 10

The workload evaluation values show a increase of the workload during the failure occurrence, mainly linked with an increase of the time constraint .

a

7.2.5 Correlated correction time determination

For the same reasons as defined in § 7.1.5, the measured results show that the time and the workload level of the evaluation pilot are below theoretical values.

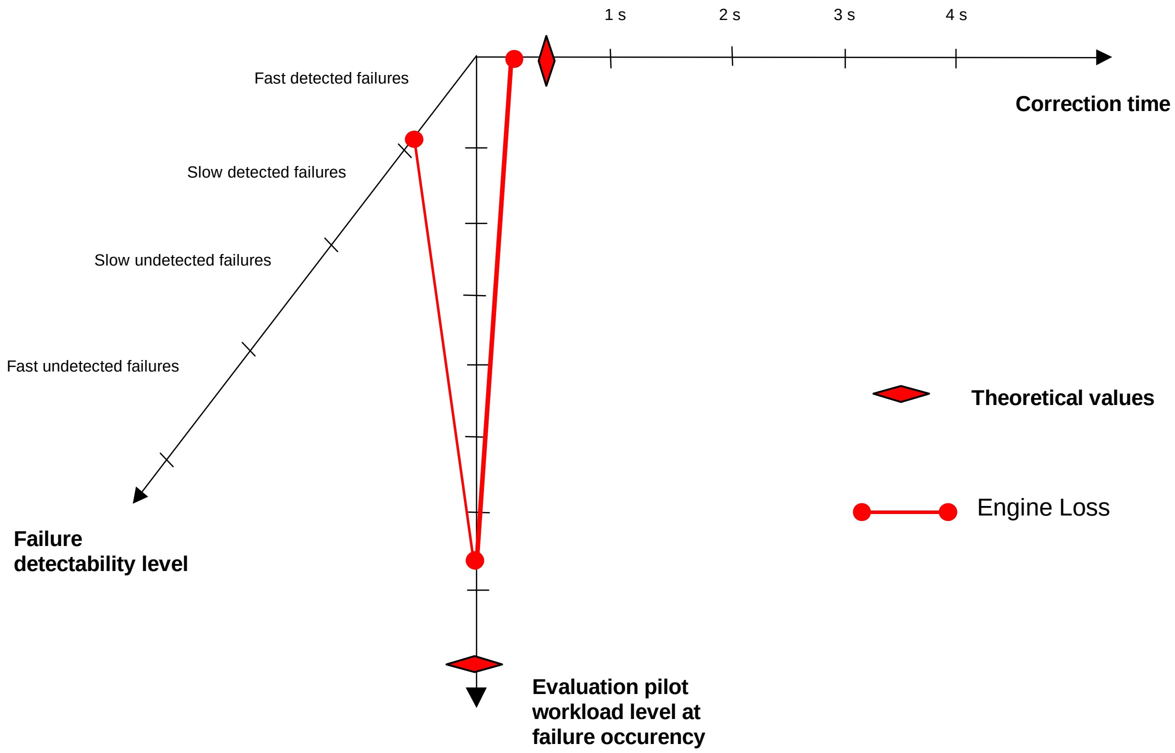


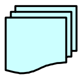
Figure 9: Evaluation pilot test results – failure n° 2

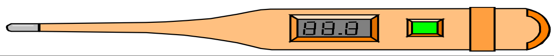
a

7.3 FAILURE N°3

7.3.1 Simulation parameters analysis

The simulation parameters analysis needed for the failure n°3 data treatment give the following results (curves given in appendix 3) :

TRPH – SCENARIO 3				
	N°	PARTIAL ENGINE 2 POWER REDUCTION FAILURE RESOLUTION TASKS	TIME seconds	
			Measured	Theoretical
SWITCH 3	1	No failure report	T0	T0
MOT 1 NV	2	Failure occurrence : FADEC 25%	T0 + 15	T0 + 15
OEI STATUS	3	Audio warning + « OEI » display: on FND + master caution display	T2 + 1 -	-
	4	« ENG DF » display on CWP	-	T3 + 0.5
	5	Engine parameters display	-	
POSABSCOL	6	Checking helicopter attitude	Not determined	T5 + 1
SOV STATUS	7	Switching engine 1 shut-off valve to OFF	-	-
POSABSCOL	8.1	Collective hand off to switch off engine	T3 + 3.41	-
MOT STOP	8.2	Switching engine 1 OFF	T6 + 3.46	-
OEI HILO	9	Potential switch to OEI Low	-	-
-	10	Acknowledging master caution	-	-



= task n°6, not determined

The correction time corresponds to the collective hands on, task 8.1. It is not possible to quantify properly the correction time value, since the parameters are not sufficiently discriminant. In the present case, the pilot has, among other, considered the generic helicopter capacities, which allow a big recovery flexibility.

Correction time failure n° 3 = not determined < 3.41 secondes, Theoretical = 1,5 secondes

7.3.2 Heart rate variation analysis

See remarks § 7.1.2

7.3.3 Evaluation pilot behavior analysis

The above mentioned values are extracted from a test which has followed the more the procedures. In a first step, the evaluation pilot did not follow the foreseen procedures: he has kept the helicopter control with maximum height without switching off the failed engine. His task was to maintain the helicopter and to land, thanks to the offered possibility of the generic helicopter to land without applying all the failure recovery procedure. The failure was considered as easy to manage, in spite of the induced workload. The trajectory has been maintained inducing no danger for the pilot. The delay consequences for correction are acceptable.

7.3.4 Workload analysis

The evaluation pilot, selected for the phase n°1, knowing perfectly the simulator, the generic helicopter, the associated functions and the failure recovery procedures, having evaluated previously the scenario realism, has indicated no uncertainty sources for his workload level evaluation. Thus, the values measured are fixed numeric values, without uncertainty borders. Moreover, the low proclivity to stress of the evaluation pilot did not imply important gap during the failure occurrence.

WORKLOAD LEVEL *			
BEFORE	DURING	WHILE RECOVERY	AFTER RECOVERY
1,6	2,44	2,17	1,6

* : 1 <low < 3 < average < 5 < high <6 < very high<8 < unacceptable < 10

The workload evaluation values show an increase of the workload during the failure occurrence, mainly linked with the landing phase under a degraded mode.

7.3.5 Correlated correction time determination

The given results show that the workload level of the evaluation pilot was under the theoretical value. The correction time is not determined exactly, since the flexibility of the generic helicopter allow a reaction slower than the requirement of the regulation.

a

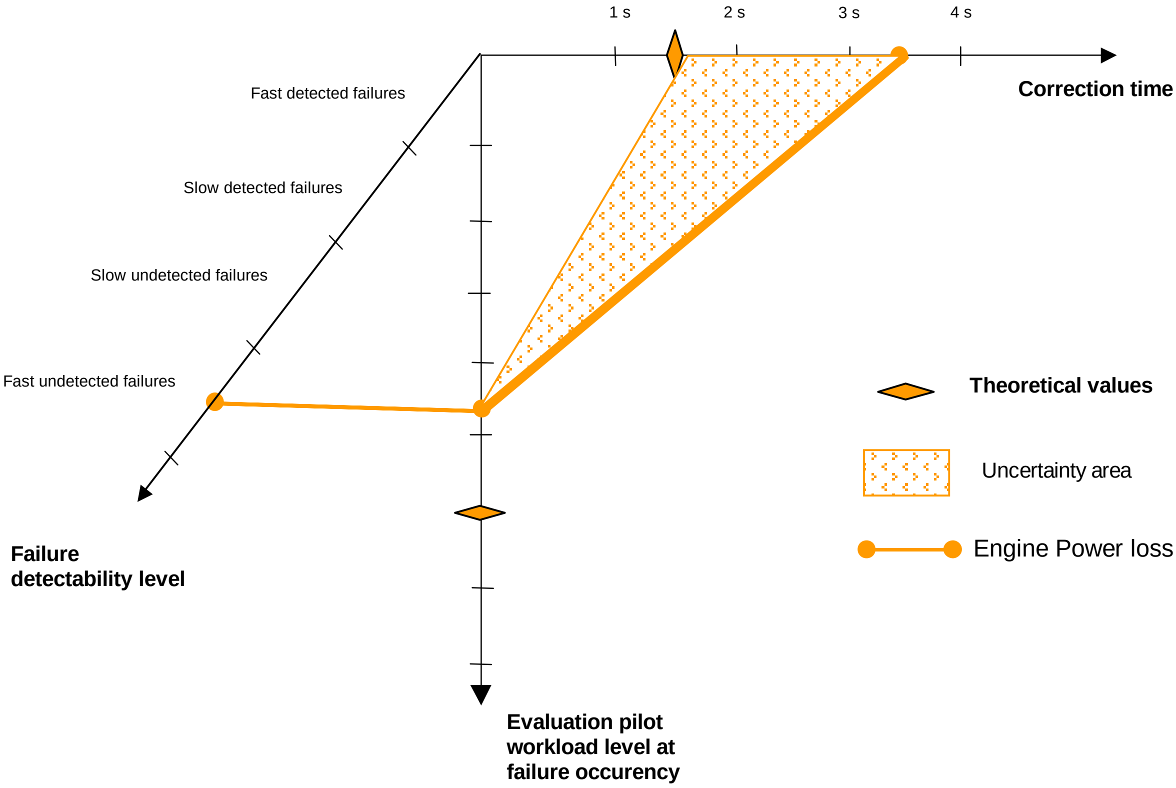


Figure10: Evaluation pilot test results – failure n°3

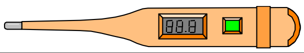
a

7.4 FAILURE N°4

7.4.1 Simulation parameters analysis

The simulation parameters analysis needed for the failure n°4 data treatment give the following results (curves given in appendix 3) :

TRPH – SCENARIO 4				
	N°	RESOLUTION TASKS FOR SLOW AFCS ALTITUDE HOLD DRIFT RESULTING FROM BAROMETRIC ALTIMETER FAILURE	TIME seconds	
			Measured	Theoretical
SWITCH 4	**1**	Initial drift	T0	T0
	2	problem identification	-	T2 (recognition included)
	3	Crosschecking barometric altimeter with altimeter back-up + vertical climb indicator display, if required	-	-
POSABSTANG, POSABSROU, POSABSLAC, POSABSCOL	**4**	Switching to hands on piloting	T0 + 53,99	T2 + 3
	5	Grasping cyclic stick and collective lever		-
PIT ALT	**6**	Disengaging ALT mode		-

 = task n°4

The theoretical value is considered as applicable in an alert case, so 3.5 seconds.

Correction time failure n° 4 = 53,99 secondes, Theoretical = Not Applicable

7.4.2 Heart rate variation analysis

See remarks § 7.1.2

7.4.3 Evaluation pilot behavior analysis

The evaluation pilot has followed the foreseen procedure since the failure detection. The failure has been considered as easy to manage in spite of the workload after induced recovery. The pilot has never felt and been in danger since the variation after 53.99 seconds induces only a gap of 90ft. This explains the correction time of this not alerted failure, which implies a important recognition time.

a

7.4.4 Workload analysis

The evaluation pilot, selected for the phase n°1, knowing perfectly the simulator, the generic helicopter, the associated functions and the failure recovery procedures, having evaluated previously the scenario realism, has indicated no uncertainty sources for his workload level evaluation. Thus, the values measured are fixed numeric values, without uncertainty borders. Moreover, the low proclivity to stress of the evaluation pilot did not imply important gap during the failure occurrence.

WORKLOAD LEVEL *			
BEFORE	DURING	WHILE RECOVERY	AFTER RECOVERY
1,6	1,93	1,6	1,6

* : 1 <low < 3 < average < 5 < high <6 < very high<8 < unacceptable < 10

The workload evaluation values show an increase of the workload during failure occurrence, mainly linked with the increase of the failure understanding workload.

7.4.5 Correlated correction time determination

For the same reasons as for the § 7.1.5, the results show that the evaluation pilot workload level was under the theoretical values. The available tools did not allow to determined the recognition time which is the most part of the correction time. The heart rate variability could have been discriminant, but the record did not show any variation, since the pilot knew the scenario and did not feel any stress.

This slowover inducing no alert signal, the time constraints theoretically required are not applicable and show that this failure is not linked strictly to the time constraint.

a

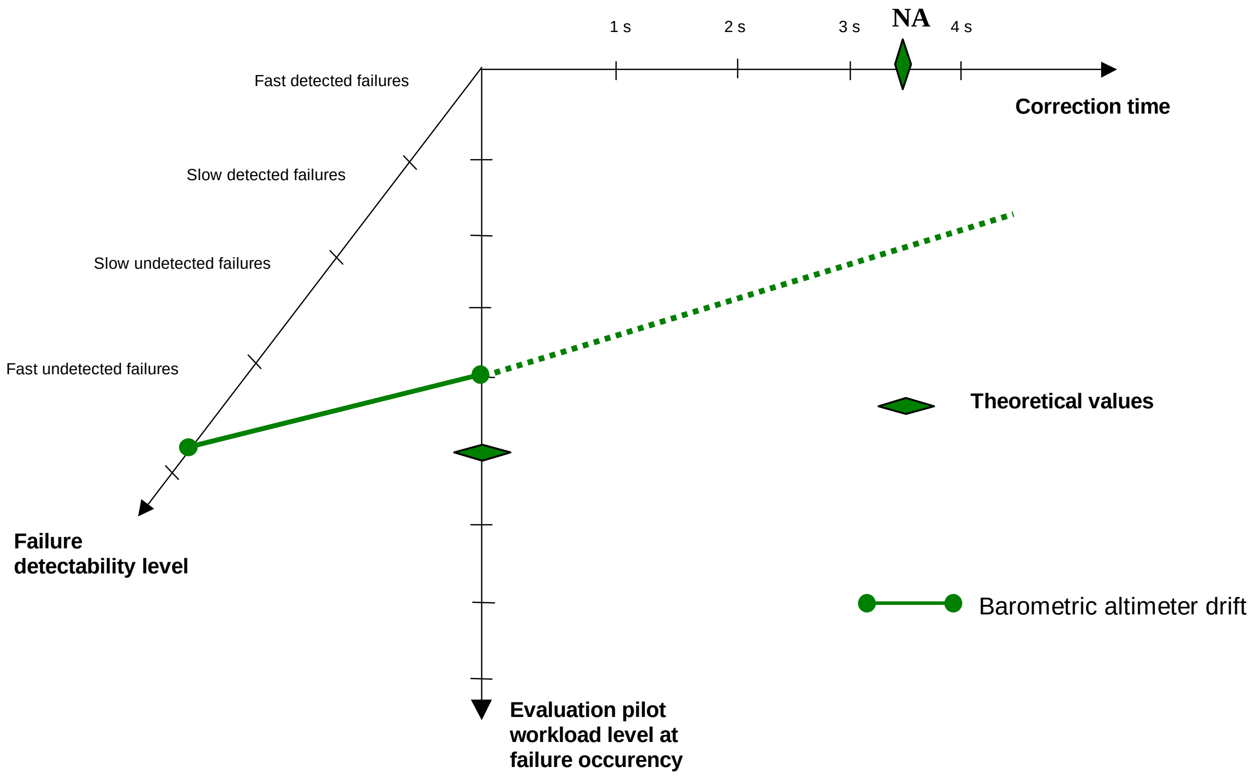


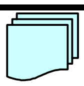
Figure11: Evaluation pilot test results – failure n° 4

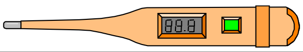
a

7.5 FAILURE N°5

7.5.1 Simulation parameters analysis

The simulation parameters analysis needed for the failure n°5 data treatment give the following results (curves given in appendix 3) :

TRPH – SCENARIO 5				
	N°	HARDOVER ON AFCS ROLL AXIS FAILURE RESOLUTION BY PILOT	TIME seconds	
			Measured	Theoretical
SWITCH 5	**1**	Failure occurrence	T0	T0
	2	« HANDS ON » audio warning + FND or external display + Master caution display	-	T0 + 0.5
RP, POSABSROU	**3**	Switching to hands on	T0 + 0.8	T2 + 3
	4	Grasping cyclic and collective controls, regulating cyclic		-
-	**5**	Acknowledging master caution	-	-


= task n°3

The correction time corresponds to the hands on cyclic and the modification of the stick position by the pilot action..

Correction time failure n° 5 = 0.8 secondes, Theoretical = 3,5 secondes

7.5.2 Heart rate variation analysis

See remarks § 7.1.2

7.5.3 Evaluation pilot behavior analysis

The evaluation pilot has followed the foreseen procedures since the failure detection. The failure has been considered as easy to manage since clearly identifiable, and purely linked with a reflex answer, helped by the VMC conditions. The low altitude did not induce stress to the evaluation pilot.

a

7.5.4 Workload analysis

The evaluation pilot, selected for the phase n°1, knowing perfectly the simulator, the generic helicopter, the associated functions and the failure recovery procedures, having evaluated previously the scenario realism, has indicated no uncertainty sources for his workload level evaluation. Thus, the values measured are fixed numeric values, without uncertainty borders. Moreover, the low proclivity to stress of the evaluation pilot did not imply important gap during the failure occurrence.

WORKLOAD LEVEL *			
BEFORE	DURING	WHILE RECOVERY	AFTER RECOVERY
1	1,56	1,56	1,56

* : 1 <low < 3 < average < 5 < high <6 < very high<8 < unacceptable < 10

The workload evaluation values show an increase of the workload during failure occurrence mainly linked with the trajectory management (physiological effort and recovery time constraint).

7.5.5 Correlated correction time determination

For the same reasons than defined in § 7.1.5, the results show that the time and the level of the evaluation pilot workload are below the theoretical values.

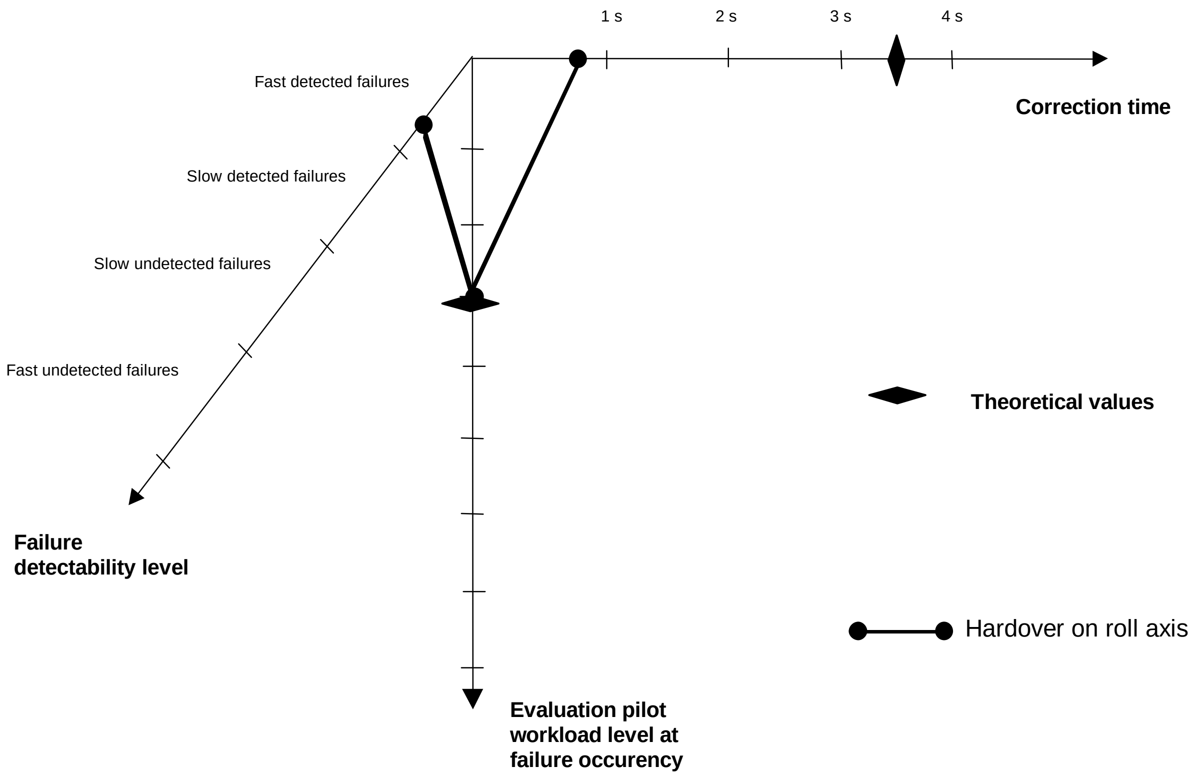


Figure12:Evaluation pilot test results – failure n°5

8. CONCLUSION

The basis reference establishment for the study of the failures (major or hazardous) correction time inducing catastrophic consequences without any quick answer from pilot side, has been realised with a reference pilot who :

- knows perfectly the generic helicopter
- has the habit of simulation flight
- has no stress proclivity.

The mission scenarios, the failures and their occuracy are considered as realistic and discriminant.

The measures realised consist of the sum of the recognition time and the reaction time, so the correction time.

The results have shown the following limitations of the measurements tools :

- Lack of precision of the heart rate measurement tool, propably linked with the knowledge of the failures occuracy by the evaluation pilot, and his low proclivity to stress.
- The video records, due to the simulator low light level, should be replaced by an observer in the simulator but not intrusive, and send of additional markers to records parameters.

The simulation parameters allow a good correction time measurement, which means recognition time plus reaction time.

a

The measured results show that, since the discrimination is sufficient, the evaluation pilot has had a correction time corresponding to the waits. Taking into account the intrinsic characteristic of the evaluation pilot, the reference overall measures need to be corroborate by a wider representive pilots panel.

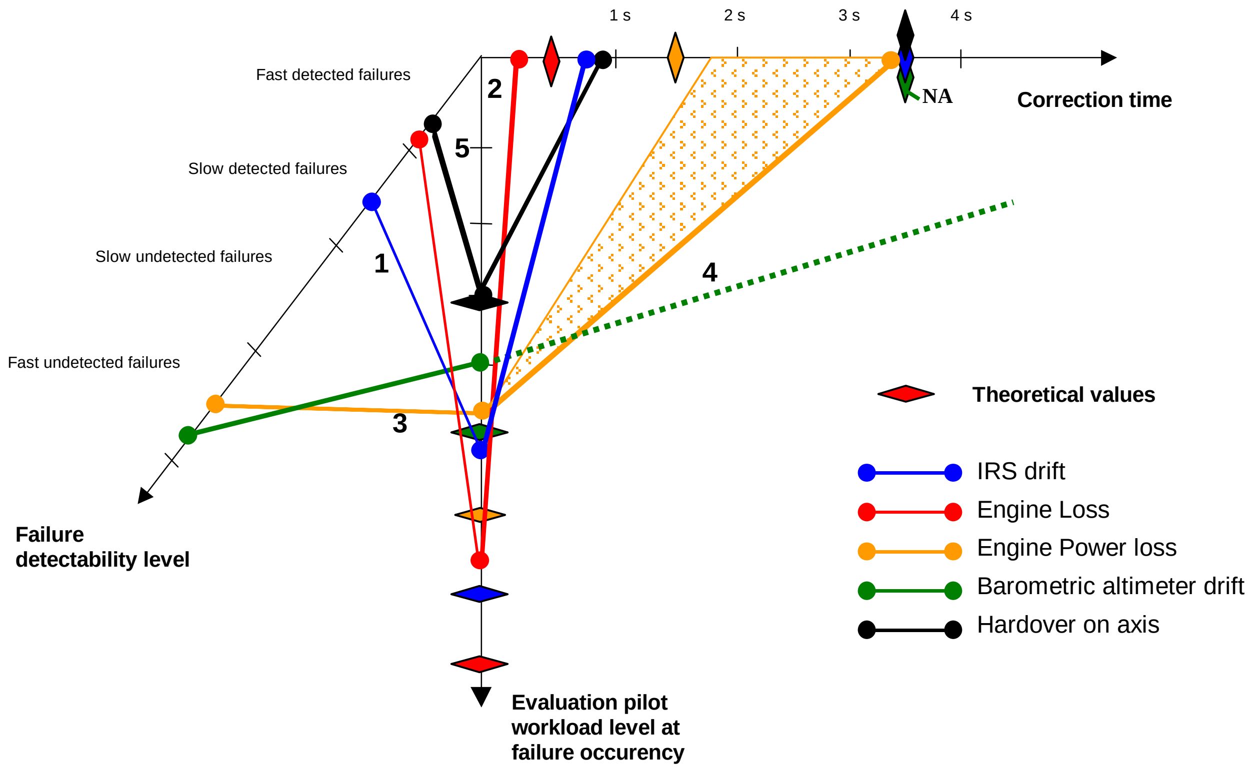


Figure 13: Evaluation pilot test results

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APPENDICES

a

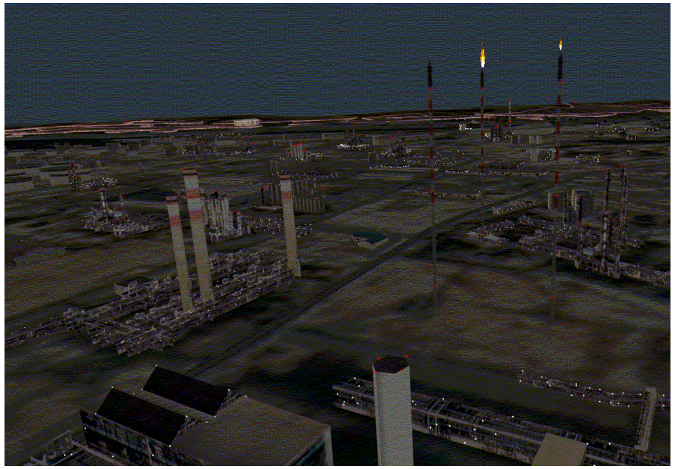
APPENDIX 1

SPHERE SIMULATOR

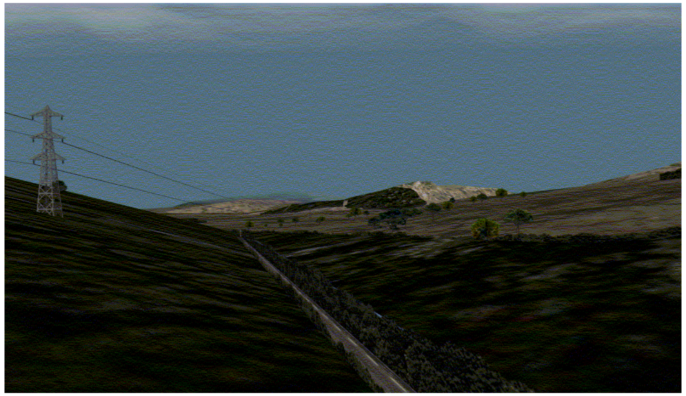
a

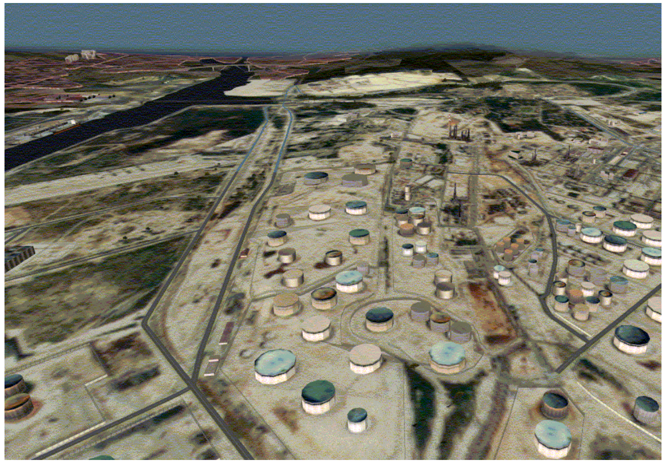
SIMULATION FACILITIES

State-Of-The-Art Image generation system



- local area terrain data base (correlation with real flights)
- Specific detailed zones
  - Urban, industrial, NOE,…)
  - Helipads (frigates, off-shore platforms, hospital roofs,…)
- special effects & complex meteorological conditions
  - realism of tactical situations
  - flights in adverse conditions (day, night, bad weather)





a

SIMULATION FACILITIES

Dedicated environment

- 8 m diameter immersive Dome
- H/C specific Field Of View 180°H x 80°V(-50)
- Hardware flexibility
- Software flexibility

a

APPENDIX 2

SIMULATION PARAMETERS

a

RECORDED PARAMETERS	
TEMPS	**Record time**
Z baro	**Baroaltitude**
RHT	**Radioaltitude**
IAS	**Indicated speed**
NX	**Acceleration on x axis**
NY	**Acceleration on y axis**
NZ	**Acceleration on z axis**
RP	**Angular roll spees (+ to the right)**
RQ	**Angular pitch speed (+ nose up)**
RR	**Angular yaw speed (+ nose to the right)**
PHI	**Roll Angle**
THETA	**Pitch Angle**
PSI	**Yaw Angle**
RVI	**Air speed**
RX0XG	**Ground displacement on x axis**
RX0YG	**Ground displacement on y axis**
RZ0ZG	**Ground displacement on z axis**
RVXSOL	**Ground projection on x axis**
RVYSOL	**Ground projection on x axis**
RVZGDT	**Projection on x axis Projection en z**
CDT01	**Collective range – main rotor**
CDT02	**Yaw range – tail rotor**
CDTC1	**Rollrange – main rotor**
CDTS1	**Pitch range – main rotor**
POSABSROU	**Absolute Roll Position - cyclic stick**
POSABSTANG	**Absolute Pitch Position - cyclic stick**
POSABSLAC	**Absolute Yaw Position - rudder pedals**
POSABSCOL	**Absolute Collective stick Position**
POSANCRAGEROUL	**Cramping roll Position**
POSANCRAGETANG	**Crampingpitch Position Position**
POSANCRAGE LAC	**Cramping yaw Position Position**
POSANCRAGECOL	**Cramping collective Position**

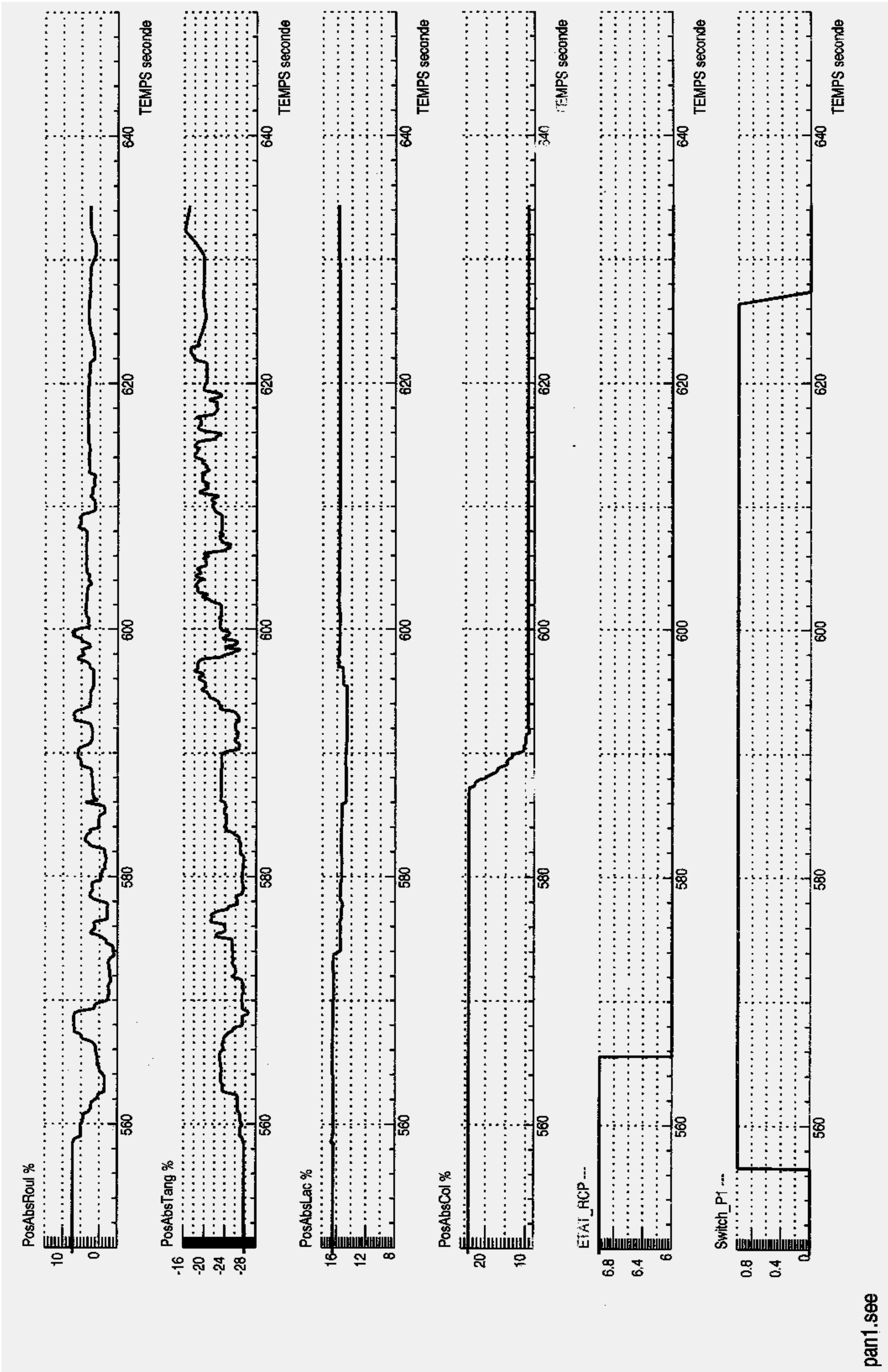
a

PHI RD	**Roll angle - radians**
THETA RD	**Pitch angle - radians**
PSI RD	**Yaw angle - radians**
Zp	**Pressure**
Wn	**Needed power**
Wd	**Available power**
TORQUE 1	**Engine 1 torque**
TORQUE 2	**Engine 2 torque**
DELTA TRQ	**Torques gap**
NG 1	**Engine 1 freeTurbine**
NG 2	**Engine 2 freeTurbine**
T4 1	**Engine 1 T4 Temperature**
T4 2	**Engine 2 T4 Temperature**
Ω	**Rotor/minutes**
MOTEUR 1 NV	**Engine no flight**
SWITCH P1	**Activation failure 1**
SWITCH P2	**Activation failure 2**
SWITCH P3	**Activation failure 3**
SWITCH P4	**Activation failure 4**
SWITCH P5	**Activation failure 5**
OEI STATUS	**Status « One Engine Inoperative »**
OEI HILO	**OEI HIGH or LOW**
MASSE HELI	**Helicopter weight**
ETAT RCP	**MFDReconfiguration panel state**
SOV STATUS	**Shut Off Valves status**
MOT STOP	**Engine switch off**
COL ALT	**Collective attitude control**
PIT ALT	**Cyclique attitude control**

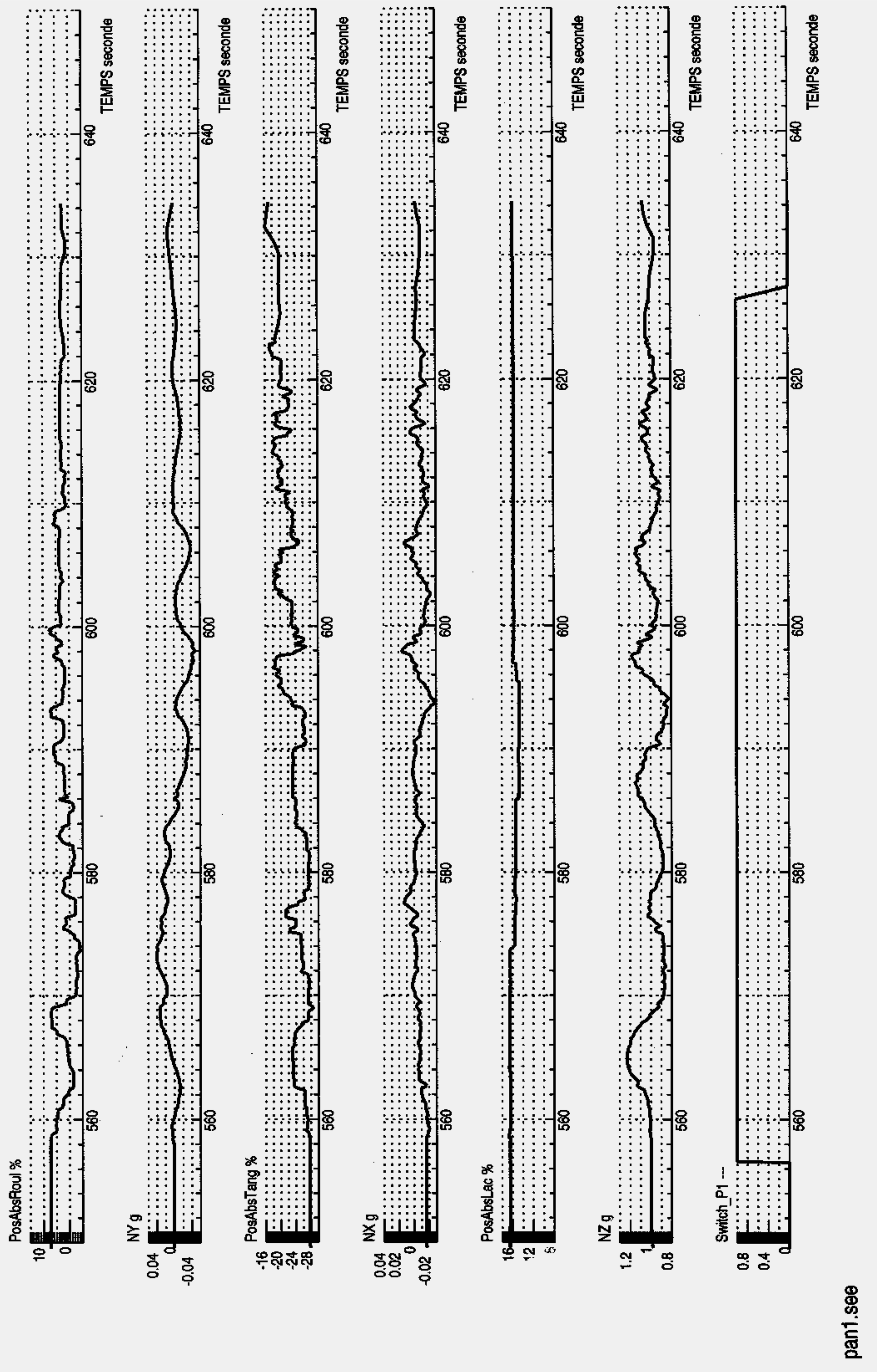
APPENDIX 3

RECORDED PARAMETERS

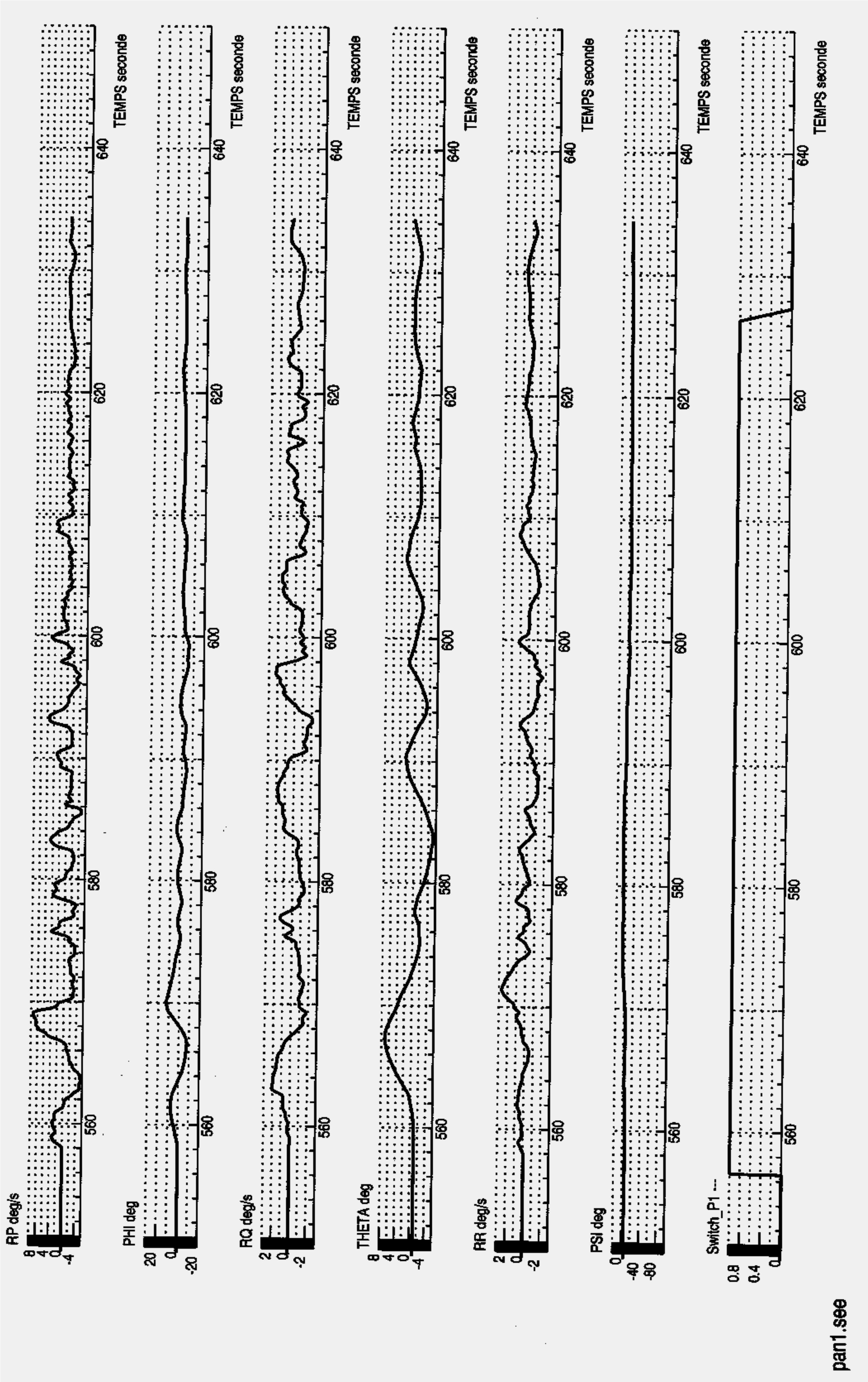
a


PosAbsRoul %
PosAbsTang %
PosAbsLac %
PosAbsCol %
ETAT_RCP ...
Switch_P1 ...
TEMPS seconde
560
580
600
620
640
pan1.see

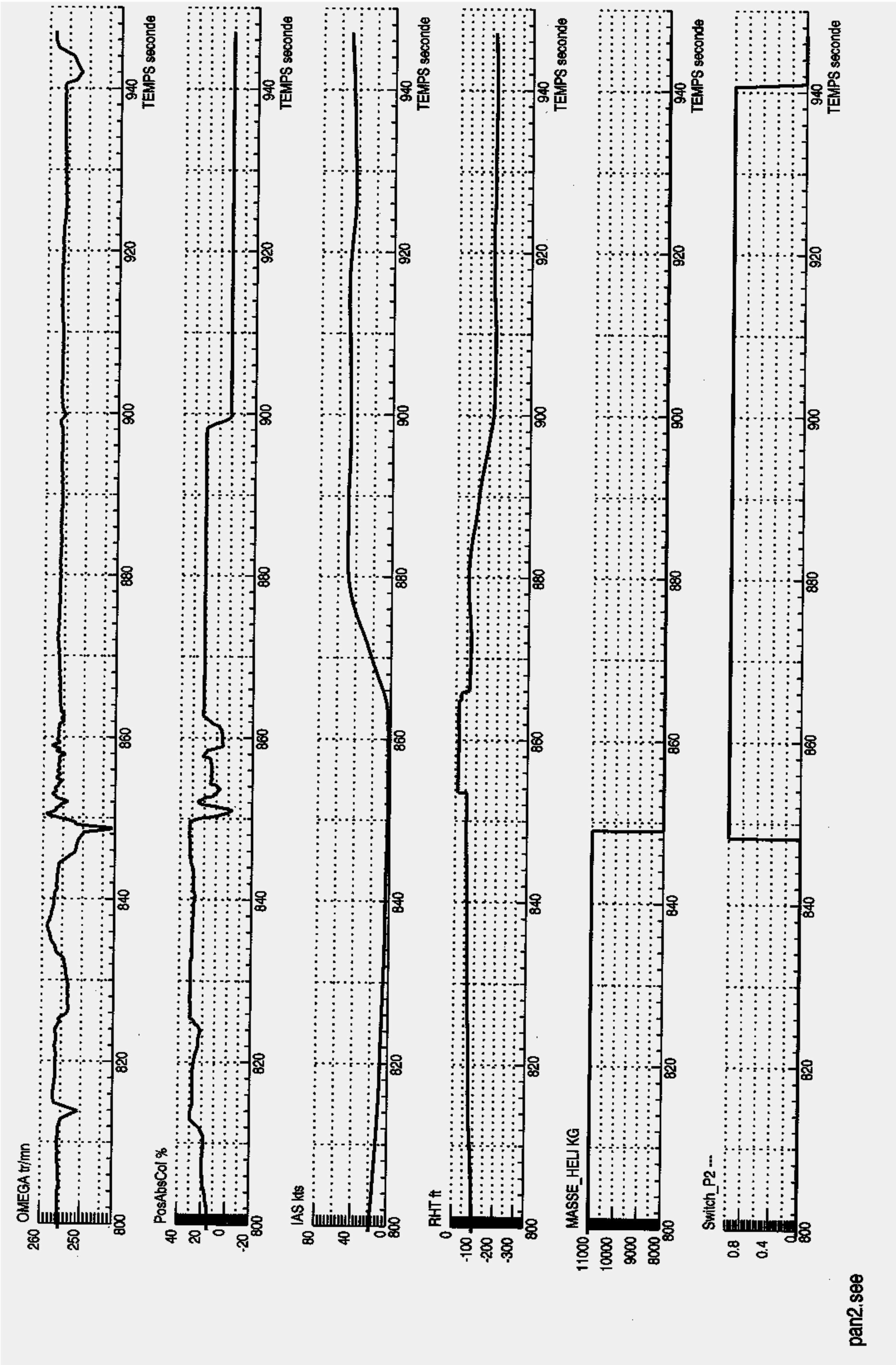
a


PosAbsRoul %
NY g
PosAbsTang %
NX g
PosAbsLac %
NZ g
Switch_P1 --
TEMPS seconde
560
580
600
620
640
pan1.see

a

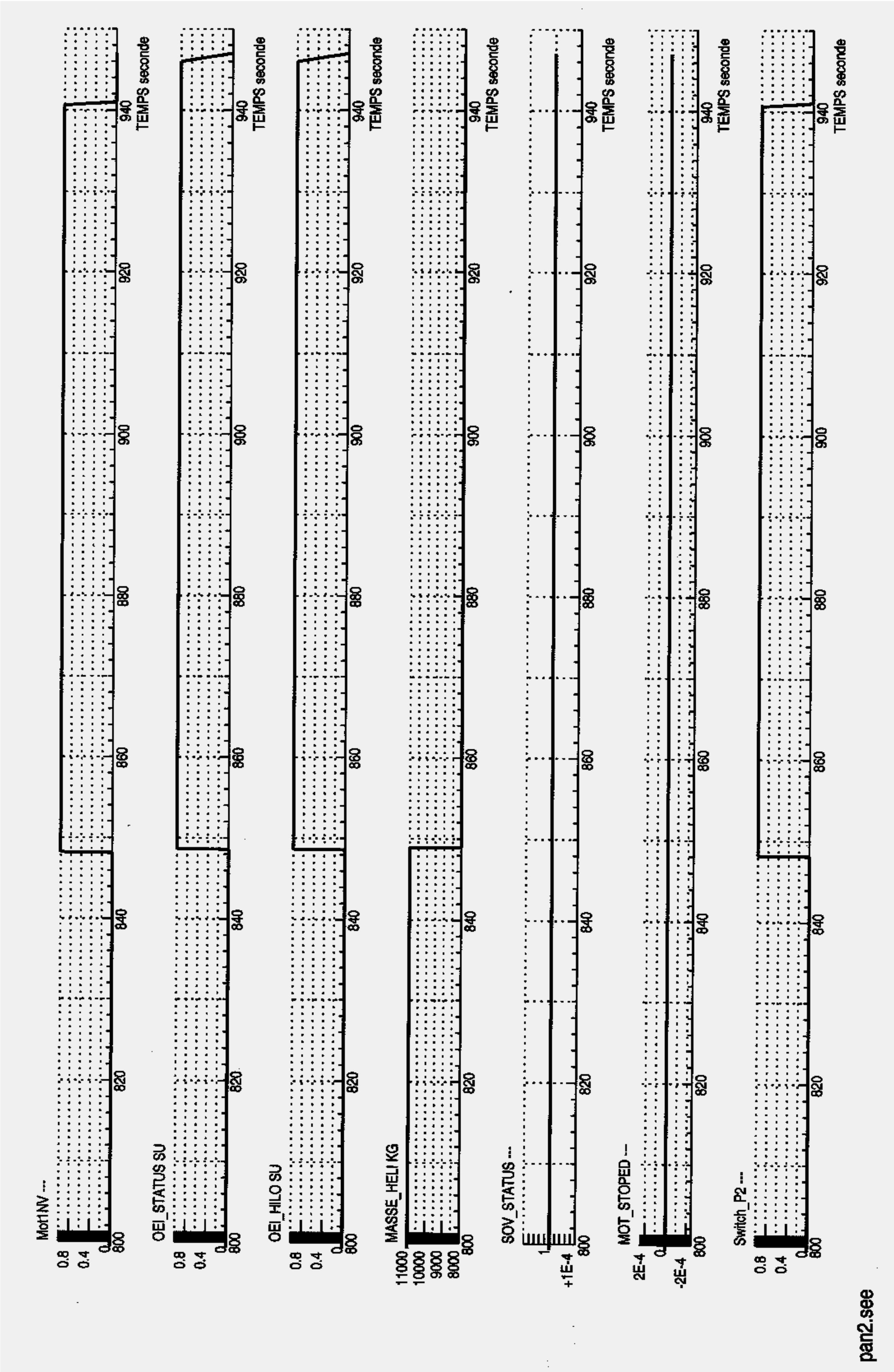

RP deg/s
PHI deg
RQ deg/s
THETA deg
RR deg/s
PSI deg
Switch_P1 ---
TEMPS seconde
560
580
600
620
640
pan1.see

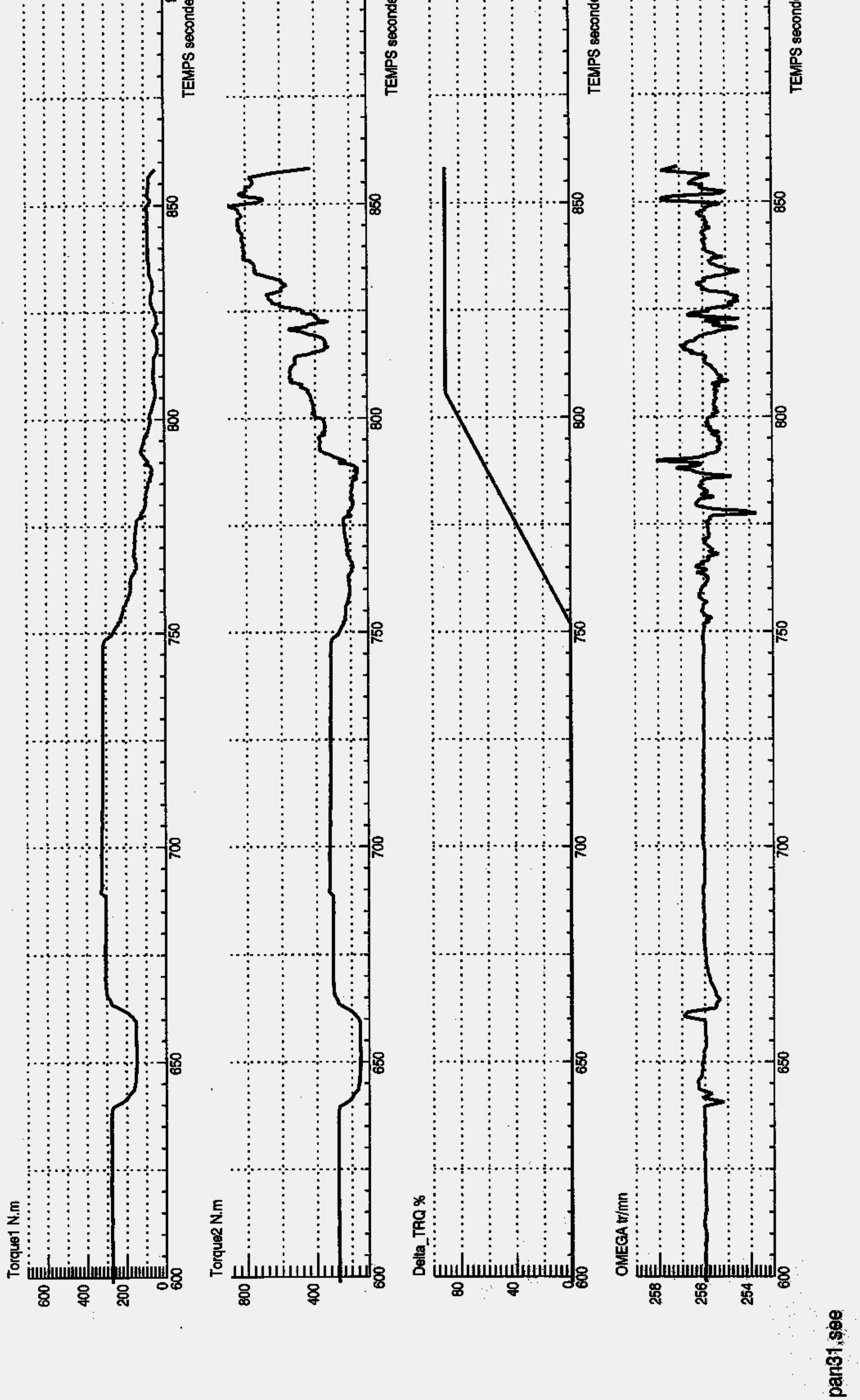
a



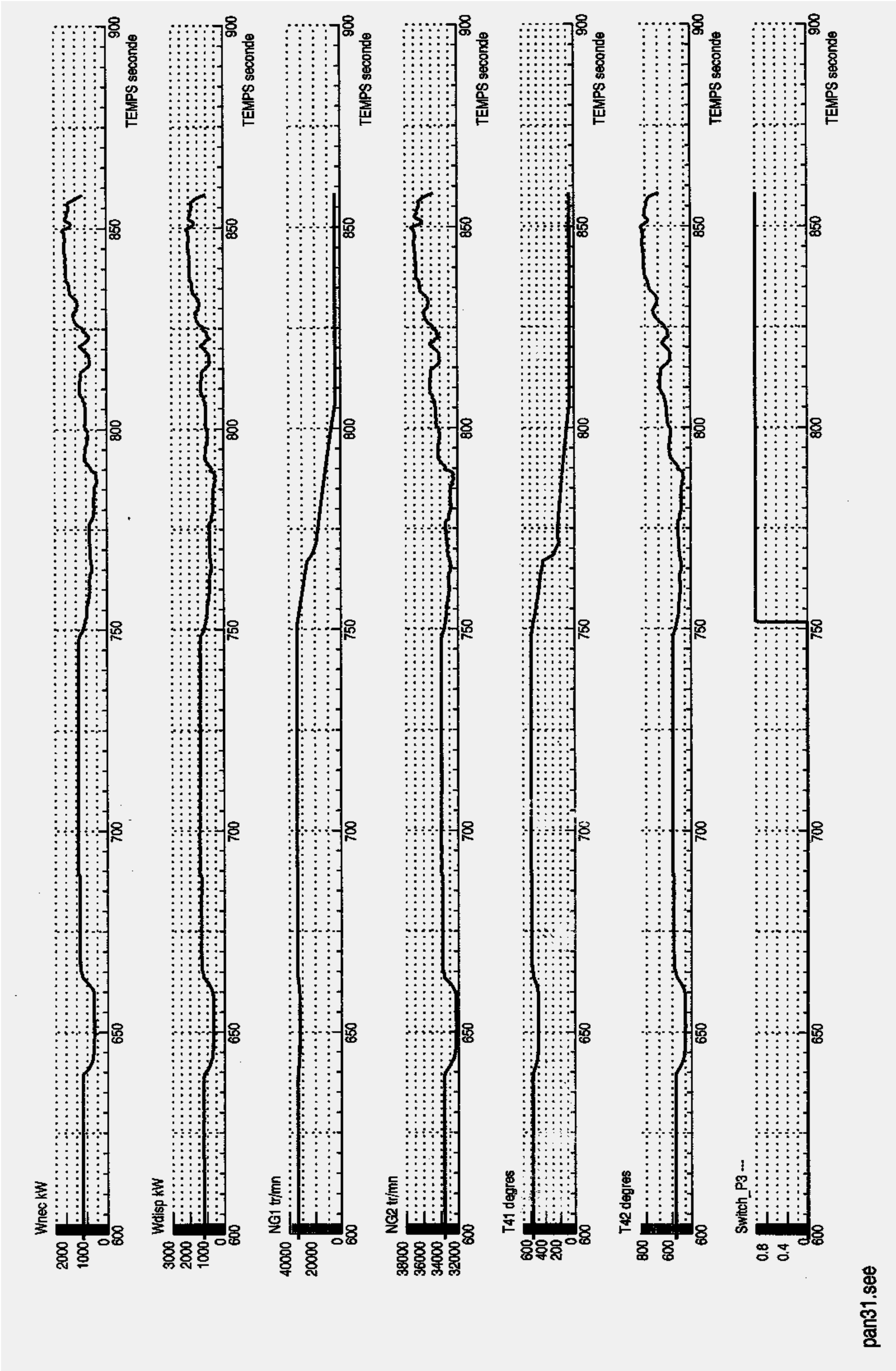
OMEGA tr/mn
PosAbsCol %
IAS kts
RHT ft
MASSE_HELI KG
Switch_P2 ---
TEMPS seconde
pan2.see

a


Mot1NV ---
OEI_STATUS SU
OEI_HILO SU
MASSE_HELI KG
SOV_STATUS ---
MOT_STOPED ---
Switch_P2 ---
TEMPS seconde
800
820
840
860
880
900
920
940
0.8
0.4
0
11000
10000
9000
8000
+1E-4
2E-4
-2E-4
pan2.see

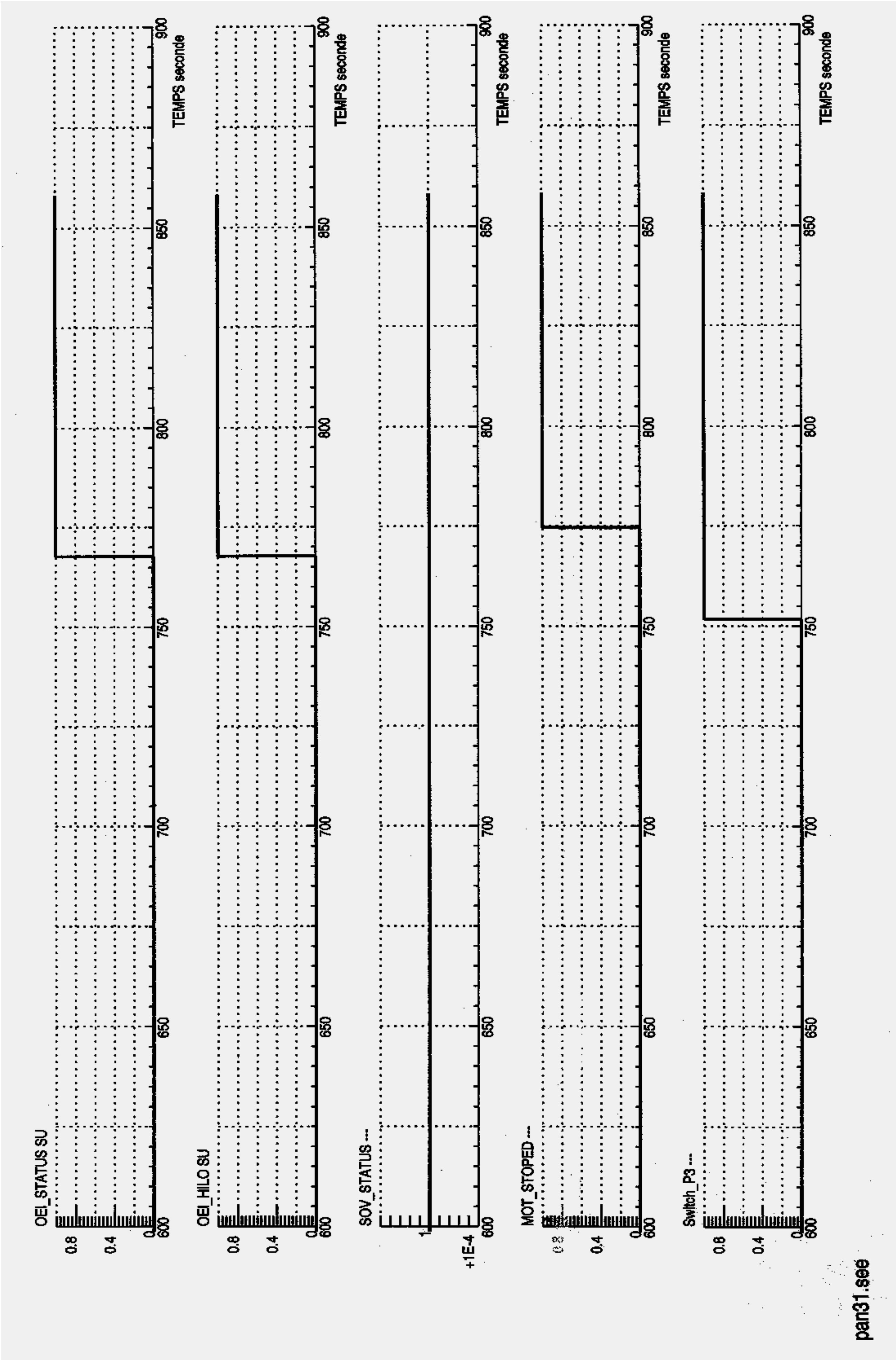

Torque1 N.m
Torque2 N.m
Delta_TRQ %
OMEGA tr/mn
TEMPS secondes
pan31.see

a

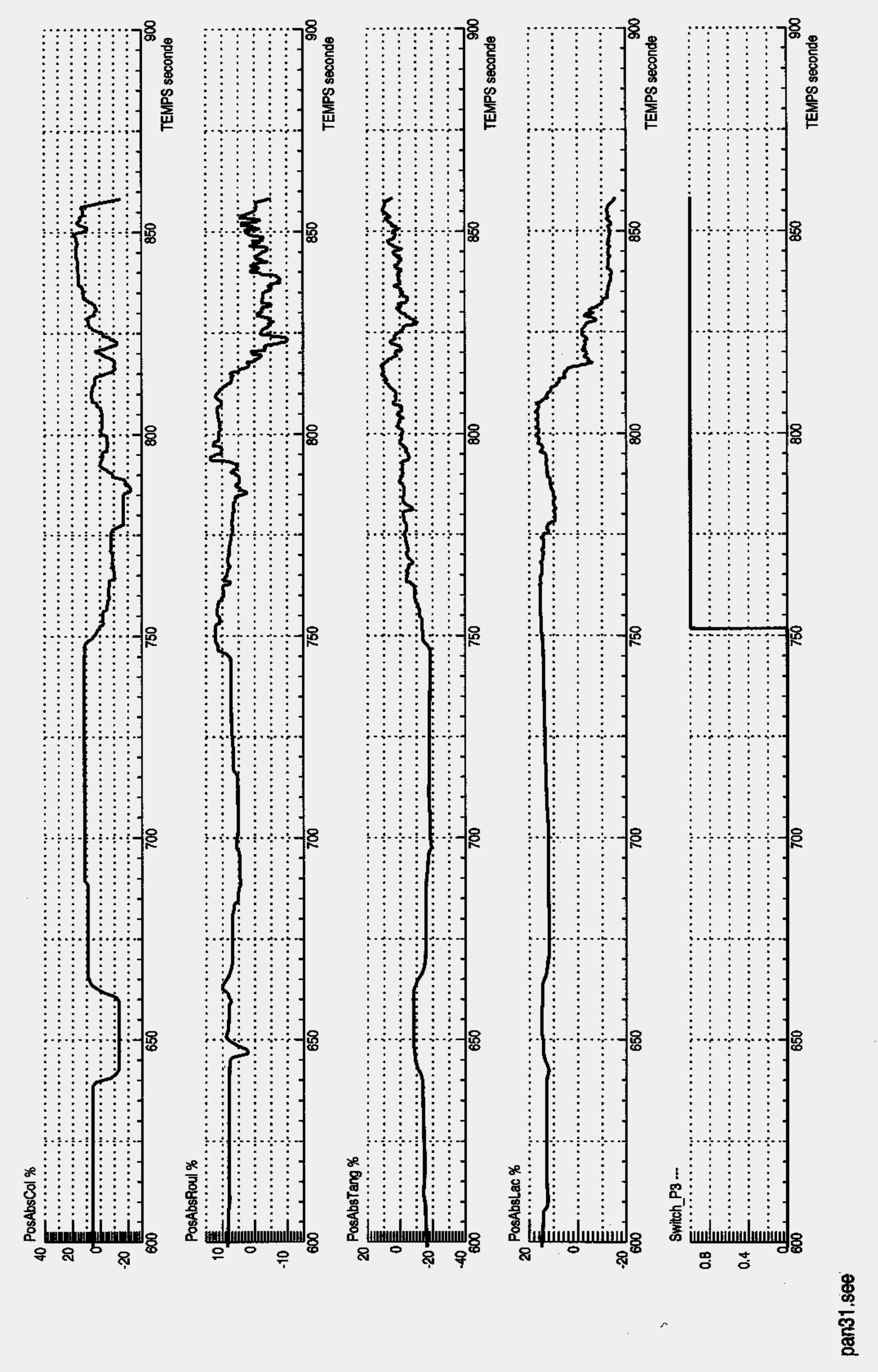


Wnec kW
Wdisp kW
NG1 tr/mn
NG2 tr/mn
T41 degres
T42 degres
Switch_P3 ---
TEMPS seconde
600
650
700
750
800
850
900
pan31.see

a


OEI_STATUS SU
OEI_HILO SU
SOV_STATUS ---
MOT_STOPED ---
Switch_P3 ---
TEMPS seconde
600
650
700
750
800
850
900
0.8
0.4
0
1
+1E-4
pan31.see

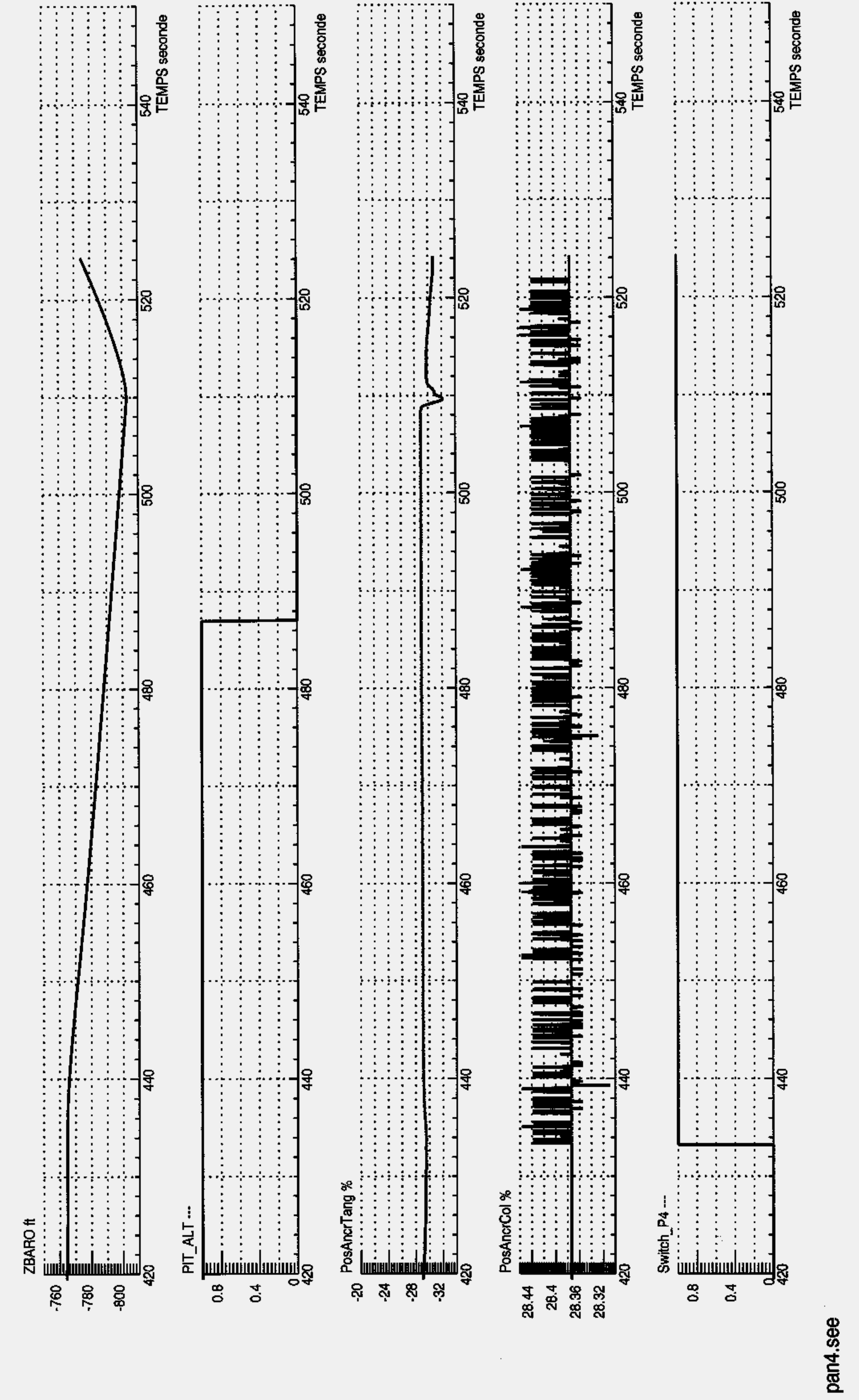
a



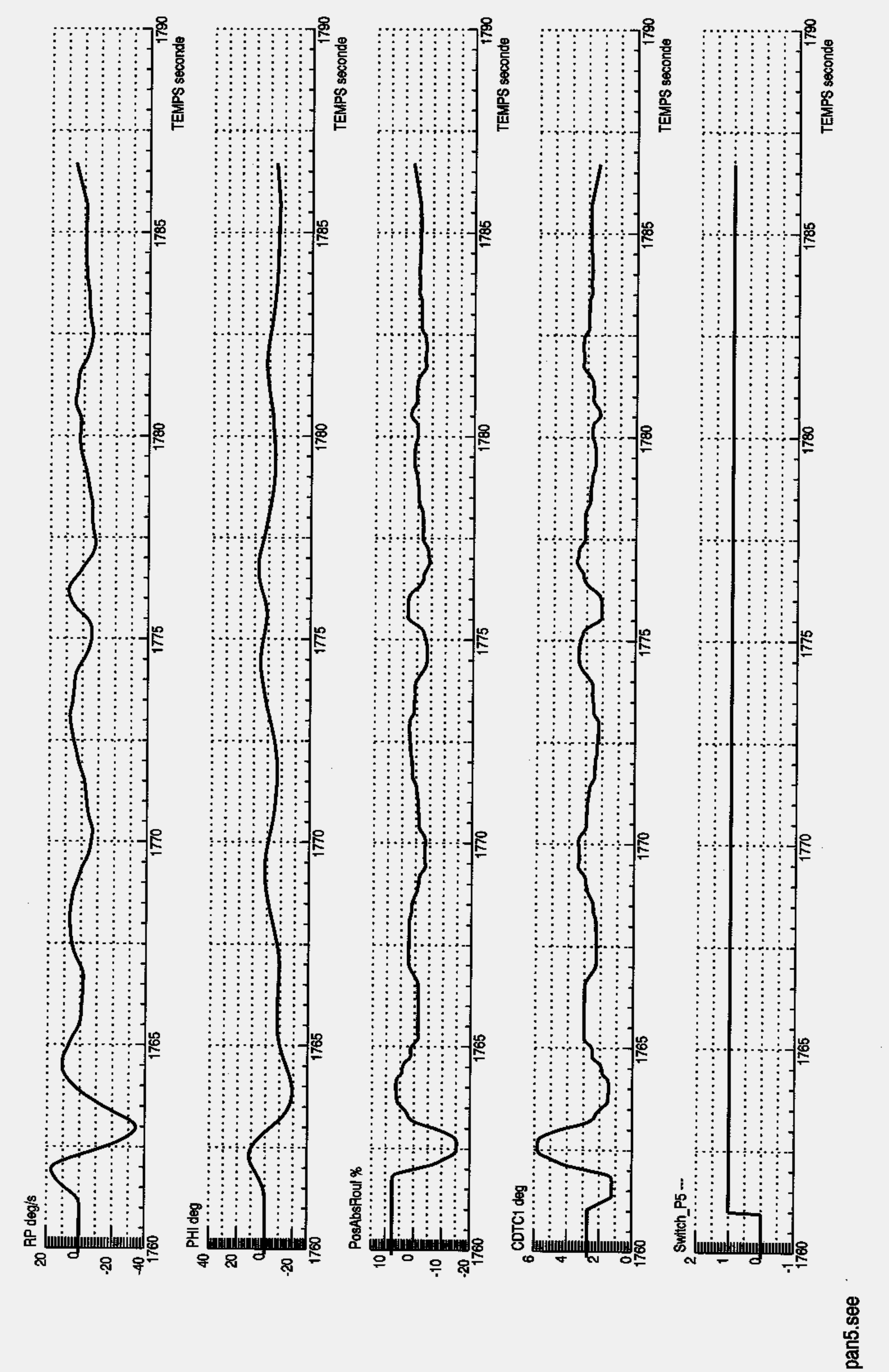
PosAbsCol %
PosAbsRoul %
PosAbsTang %
PosAbsLac %
Switch_P3 ---
TEMPS seconde
pan31.see

a


PosAbsCol %
IAS kts
OMEGA tr/mn
Switch_P3 ---
TEMPS seconde
pan31.see


ZBARO ft
PIT_ALT ---
PosAncrTang %
PosAncrCol %
Switch_P4 ---
TEMPS seconde
pan4.see

a


RP deg/s
PHI deg
PosAbsRoul %
CDTC1 deg
Switch_P5 ---
TEMPS seconde
1760
1765
1770
1775
1780
1785
1790
pan5.see

APPENDIX 4

WORKLOAD EVALUATION SHEETS

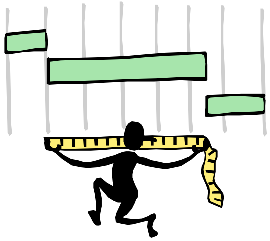
a

CREWMEMBER SPECIFICITIES

<table>
<tr><td colspan="3">NAME:</td><td colspan="2">BIRTH DATE:</td></tr>
<tr><td>ORGANIZATION</td><td colspan="2">PRESENT:</td><td colspan="2">PREVIOUS:</td></tr>
<tr><td>HELICO FLIGHT HOURS
TOTAL AMOUNT:</td><td>LIGHT H/C:</td><td>4/6 T:</td><td>8/10 T:</td><td>> 10 T:</td></tr>
<tr><td rowspan="2">OPERATIONAL
EXPERIENCE
(FLIGHT HOURS)</td><td>NOE:</td><td colspan="2">CONTOUR FLIGHT:</td><td>SHIP LANDING:</td></tr>
<tr><td>DAY:</td><td>NIGHT:
NVG:</td><td>IMC:
IFR:</td><td>FLIR:</td></tr>
<tr><td rowspan="2">SIMULATOR HABIT
(FLIGHT HOURS)</td><td colspan="2">MOVING BASE:</td><td colspan="2">FIXED BASE:</td></tr>
<tr><td>WITH VISUAL:
LIGHT H/C:
4/6 T:
8/10 T:
> 10 T:</td><td>WITHOUT VISUAL:
LIGHT H/C:
4/6 T:
8/10 T:
> 10 T:</td><td>WITH VISUAL:
LIGHT H/C:
4/6 T:
8/10 T:
> 10 T:</td><td>WITHOUT VISUAL:
LIGHT H/C:
4/6 T:
8/10 T:
> 10 T:</td></tr>
</table>

a

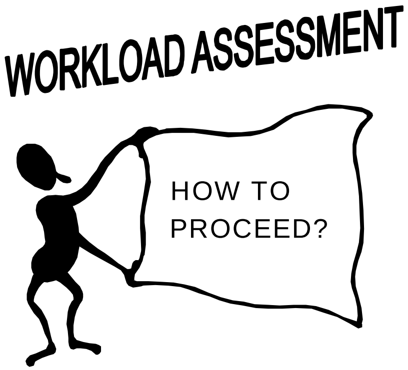
<u>*BREAKDOWN OF SCENARIO INTO HUMAN BEHAVIOR EVOLUTION SUBSEGMENTS:*</u>



SUB-SEGMENT	DESCRIPTION OF THE SUBSEGMENT	ALLOCATED TIME	PERFORMED TIME
1	....	....	....
2	....	....	....
3	....	....	....
4	....	....	....
5	....	....	....
6	....	....	....
7	....	....	....
8	....	....	....

a

WORKLOAD ASSESSMENT QUESTIONNAIRES (WLAQ)



The workload assessment questionnaires are shared in 4 parts which express the main workload components involved in a helicopter crewmember workload. These 4 workload components are:

- *MENTAL EFFORT,*
- *TIME CONSTRAINT,*
- *STRESS,*
- *PHYSIO EFFORT.*

Two kinds of questionnaires have to be filled per components (with an additive one for the mental workload, explained in detail inside). These two kinds of questionnaires are the following:

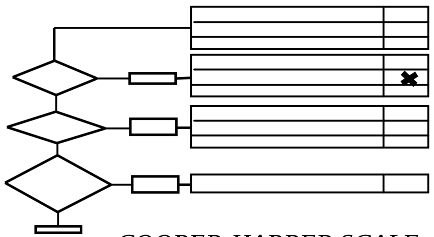
a

<u>WORKLOAD ASSESSMENT QUESTIONNAIRES (WLAQ)</u>

FIRST QUESTIONNAIRE

The goal of this questionnaire is to evaluate the workload component level felt during a sub-segment, with the configuration proposed (tactical scenario, simulator, knowledge and training, system functions).
You have to follow the flow chart to determine your felt level.

for each component



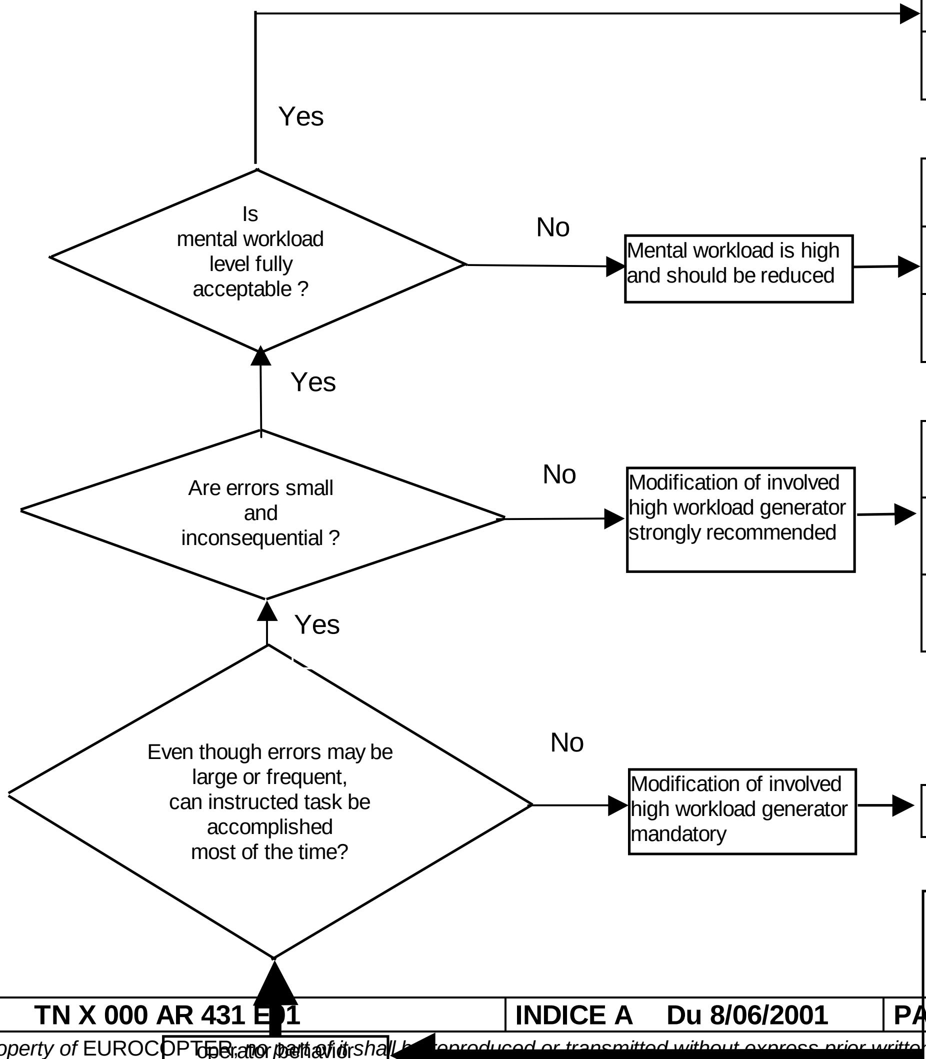
COOPER-HARPER SCALE

a

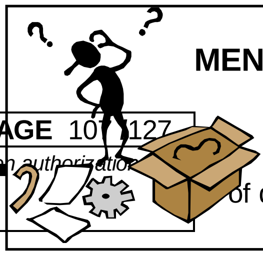
WORKLOAD ASSESSMENT QUESTIONNAIRE (WLAQ)

A - workload components level assessment -

Would you please fill the following questionnaire indicating your choice by a cross



Difficulty level	Operator demand level	Crewmember feeling
Very easy, highly desirable	Operator mental effort is negligeable	
Easy, desirable	Operator mental effort is low	
Fair, mild difficulty	Moderate operator mental effort is required to perform the tasks	
Minor but annoying difficulty	Moderately high operator mental effort is required to perform the tasks	
Moderately objectionable difficulty	High operator mental effort is required to perform the tasks	
Very objectionable but tolerable difficulty	Maximum operator mental effort is required to perform the tasks	
Major difficulty	Maximum operator mental effort is required to bring errors to moderate level	
Major difficulty	Maximum operator mental effort is required to avoid large or numerous errors	
Major difficulty	Intense operator mental effort is required to accomplish task, but frequent or numerous errors persist	
Impossible	Instructed task cannot be accomplished reliably	



MENTAL EFFORT ASSESSMENT SCALE:

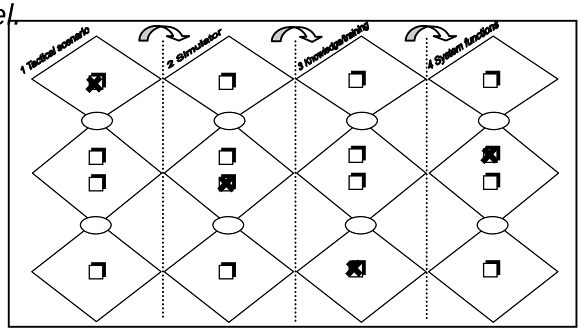
mental effort is intended to express the intensity of mental activity by means of quantifying the difficulties in finding information processing it and making decisions.

a

SECOND QUESTIONNAIRE

The goal of this questionnaire is to evaluate the influence of uncertainty sources on your assessment of the workload component for the sub-segment. The uncertainty sources are: tactical scenario, simulator, knowledge/training, system functions. These influence could have lead to estimate your workload component in a different way of this which could be assessed in a real situation.
You have to cross for each sources of uncertainty the influence level.

FOR EACH COMPONENT



a

B- uncertainty source effect on workload component level assessment -

Would you please fill the following questionnaire on uncertainty sources effect for the workload component MENTAL EFFORT

indicating your choice by a cross

1 Tactical scenario

The proposed scenario was representative enough of a real tactical situation and allowed a

CORRECT ☐

evaluation of the mental effort

OR

The proposed scenario could have been not representative of a real tactical situation, and so the mental effort level evaluation was

HIGHER ☐

LOWER ☐

than with a more realistic one

OR

The proposed scenario was not representative of a real tactical situation, and

I DON'T KNOW ☐

its influence on the mental effort evaluation, either in a worse or either in a better way

2 Simulator

The simulator configuration was representative enough of the reality (ext. environment, cockpit, aircraft model) and allowed a

CORRECT ☐

evaluation of the mental effort

OR

The simulator configuration could have not been representative of the reality (ext. environment, cockpit, aircraft model) and so the mental effort level evaluation was

HIGHER ☐

LOWER ☐

than with a more realistic one

OR

The simulator configuration not representative of the reality (ext. environment, cockpit, aircraft model), and

I DON'T KNOW ☐

its influence on the mental effort evaluation, either in a worse or either in a better way

3 Knowledge/training

The knowledge and training was sufficient (system operation information/training level) and allowed a

CORRECT ☐

evaluation of the mental effort

OR

The knowledge and training could have been not sufficient (system operation information/training level and so the mental effort level evaluation was

HIGHER ☐

LOWER ☐

than with a more realistic one

OR

The knowledge and training was not sufficient (system operation information/training level) and

I DON'T KNOW ☐

its influence on the mental effort evaluation, either in a worse or either in a better way

4 System functions

The simulated system functions was representative enough of a real configuration and allowed a

CORRECT ☐

evaluation of the mental effort

OR

The simulated system functions could have been not representative of a real configuration, being too much complicated, and so the mental effort level evaluation was

HIGHER ☐

LOWER ☐

than with a more realistic one

OR

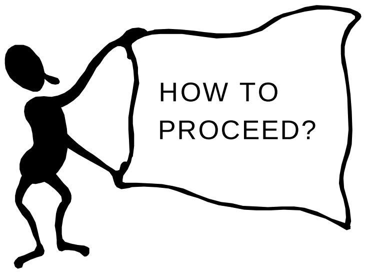
The simulated system functions scenario was not representative of a real configuration and

I DON'T KNOW ☐

its influence on the mental effort evaluation, either in a worse or either in a better way

a

BEHAVIOR LEVEL



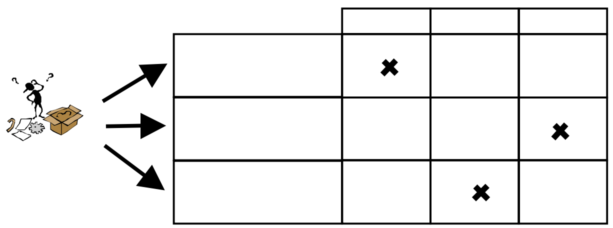
.

The mental effort is composed of 3 mental behaviors, not always used at the same level. These 3 mental behaviors are the following:

- *reflex behavior:* *application of predefined and fixed sequences of actions, automatisms,*
- *procedural behavior:* *selection and application of prepared procedures for wellknown situations, regulations,*
- *cognitive behavior:* *elaboration of new procedures from the available information, decisions.*

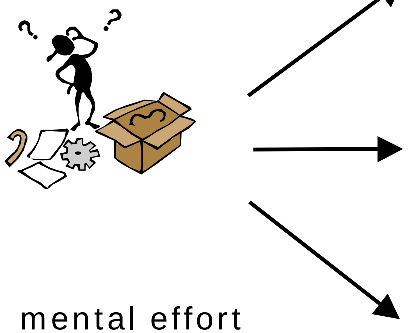
The goal of this questionnaire is to determine the nature of the mental effort during the sub-segment .

The level is determined through the answer to the following questionnaire indicating your choice by a cross expressing, within the mental effort, the level of each mental behavior felt during the considered sub-segment:

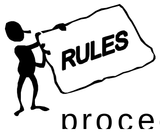


a

Would you, please, fill the following questionnaire indicating your choice by a cross expressing, within the mental effort, the level of each mental behavior felt during the considered sub-segment:



mental effort

	+	+ +	+ + +
 reflex behavior			
 procedural behavior			
 cognitive behavior			

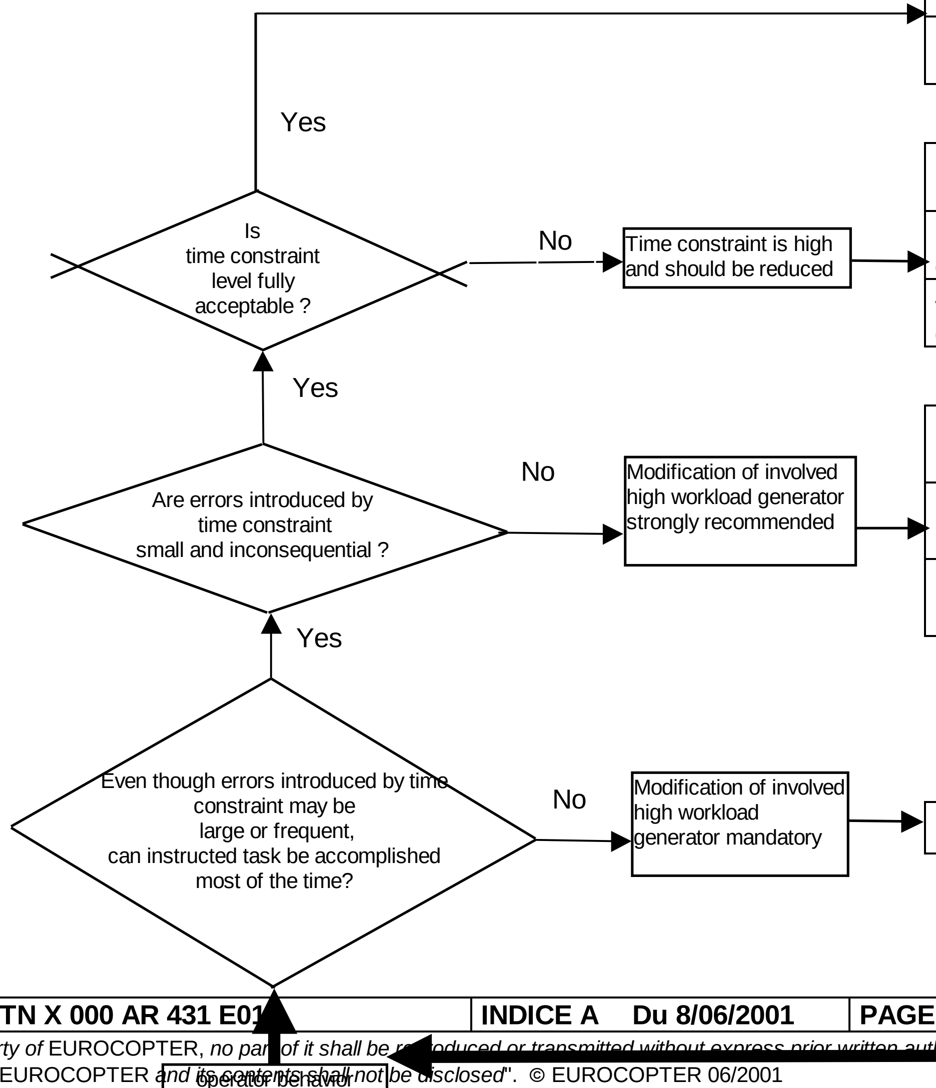
a

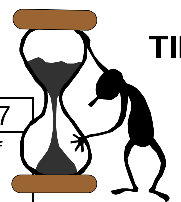
WORKLOAD ASSESSMENT QUESTIONNAIRE (WLAQ)

A - workload components level assessment -

Would you please fill the following questionnaire indicating your choice by a cross

Difficulty level	Operator demand level	Crewmember feeling
Very easy, highly desirable	Time constraint applied to operator is negligeable	
Easy, desirable	Time constraint applied to operator is low	
Fair, mild difficulty	Moderate time constraint is applied to operator to perform the tasks	
Minor but annoying difficulty	Moderately high time constraint is applied to operator to perform the tasks	
Moderately objectionable difficulty	High time constraint is applied to operator to perform the tasks	
Very objectionable but tolerable difficulty	Maximum time constraint is applied to operator to perform the tasks	
Major difficulty	Maximum time constraint is applied to operator to accomplish task, but bringing errors to moderate level	
Major difficulty	Maximum time constraint is applied to operator to accomplish task, avoiding large or numerous errors	
Major difficulty	Intense time constraint is applied to operator to accomplish task, but frequent or numerous errors persist	
Impossible	Instructed task cannot be accomplished reliably	



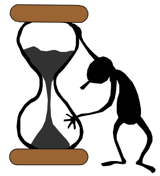


TIME CONSTRAINT ASSESSMENT SCALE:
time constraint is intended to evaluate the time-induced pressure generated by time allotted to complete task and the speed with which the tasks follow each other; this also identifies any slack periods.

a

- WORKLOAD ASSESSMENT QUESTIONNAIRE (WLAQ)

B- uncertainty source effect on workload component level assessment -



Would you please fill the following questionnaire on uncertainty sources effect for the workload component TIME CONSTRAINT indicating your choice by a cross

1 Tactical scenario

The proposed scenario was representative enough of a real tactical situation and allowed a

CORRECT ☐

evaluation of the time contraint

OR

The proposed scenario could have been not representative of a real tactical situation, and so the time contraint level evaluation was

HIGHER ☐

LOWER ☐

than with a more realistic one

OR

The proposed scenario was not representative of a real tactical situation, and

I DON'T KNOW ☐

its influence on the time contraint evaluation, either in a worse or either in a better way

2 Simulator

The simulator configuration was representative enough of the reality (ext. environment, cockpit, aircraft model) and allowed a

CORRECT ☐

evaluation of the time contraint

OR

The simulator configuration could have not been representative of the reality (ext. environment, cockpit, aircraft model) and so the time contraint level evaluation was

HIGHER ☐

LOWER ☐

than with a more realistic one

OR

The simulator configuration not representative of the reality (ext. environment, cockpit, aircraft model), and

I DON'T KNOW ☐

its influence on the time contraint evaluation, either in a worse or either in a better way

3 Knowledge/training

The knowledge and training was sufficient (system operation information/training level) and allowed a

CORRECT ☐

evaluation of the time contraint

OR

The knowledge and training could have been not sufficient (system operation information/training level and so the time contraint level evaluation was

HIGHER ☐

LOWER ☐

than with a more realistic one

OR

The knowledge and training was not sufficient (system operation information/training level) and

I DON'T KNOW ☐

its influence on the time contraint evaluation, either in a worse or either in a better way

4 System functions

The simulated system functions was representative enough of a real configuration and allowed a

CORRECT ☐

evaluation of the time contraint

OR

The simulated system functions could have been not representative of a real configuration, being too much complicated, and so the time contraint level evaluation was

HIGHER ☐

LOWER ☐

than with a more realistic one

OR

The simulated system functions scenario was not representative of a real configuration and

I DON'T KNOW ☐

its influence on the time contraint evaluation, either in a worse or either in a better way

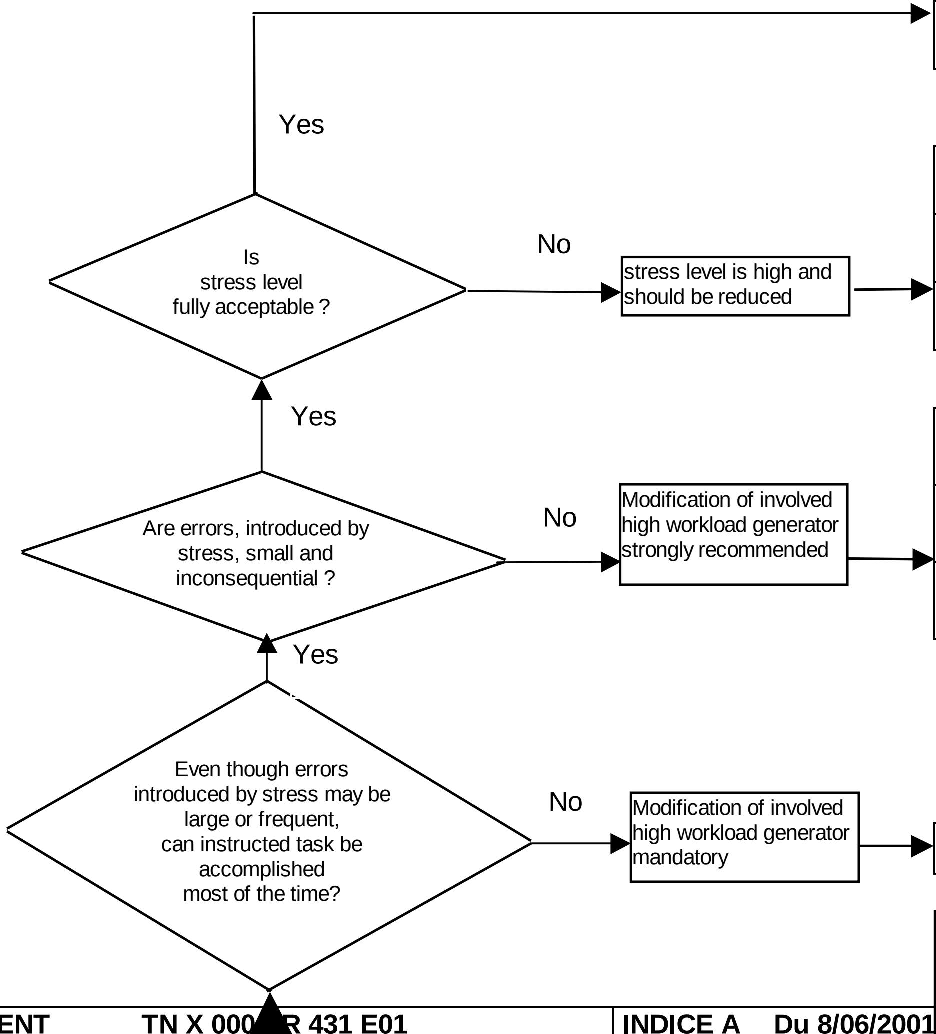
a

- WORKLOAD ASSESSMENT QUESTIONNAIRE (WLAQ)

A - workload components level assessment -

Would you please fill the following questionnaire indicating your choice by a cross

Difficulty level	Operator demand level	Crewmember feeling
Very easy, highly desirable	Stress applied to operator is negligeable	
Easy, desirable	Stress applied to operator is low	
Fair, mild difficulty	Moderate stress is applied to operator to perform the tasks	
Minor but annoying difficulty	Moderately high stress is applied to operator to perform the tasks	
Moderately objectionable difficulty	High stress is applied to operator to perform the tasks	
Very objectionable but tolerable difficulty	Maximum stress is applied to operator to perform the tasks	
Major difficulty	Maximum stress is applied to operator to accomplish task, but bringing errors to moderate level	
Major difficulty	Maximum stress is applied to operator to accomplish task, avoiding large or numerous errors	
Major difficulty	Intense stress is applied to operator to accomplish task, but frequent or numerous errors persist	
Impossible	Instructed task cannot be accomplished reliably	



STRESS ASSESSMENT SCALE:

stress is intended to express
a lack of confidence,
a feeling of subjective constraint
and nervous tension

a

- WORKLOAD ASSESSMENT QUESTIONNAIRE (WLAQ)

B- uncertainty source effect on workload component level assessment -

Would you please fill the following questionnaire on uncertainty sources effect for the workload component STRESS indicating your choice by a cross

1 Tactical scenario

The proposed scenario was representative enough of a real tactical situation and allowed a CORRECT ❒ evaluation of the stress

OR

The proposed scenario could have been not representative of a real tactical situation, and so the stress level evaluation was HIGHER ❒ **OR** LOWER ❒ than with a more realistic one

OR

The proposed scenario was not representative of a real tactical situation, and I DON'T KNOW ❒ its influence on the stress evaluation, either in a worse or either in a better way

2 Simulator

The simulator configuration was representative enough of the reality (ext. environment, cockpit, aircraft model) and allowed a CORRECT ❒ evaluation of the stress

OR

The simulator configuration could have not been representative of the reality (ext. environment, cockpit, aircraft model) and so the stress level evaluation was HIGHER ❒ **OR** LOWER ❒ than with a more realistic one

OR

The simulator configuration not representative of the reality (ext. environment, cockpit, aircraft model), and I DON'T KNOW ❒ its influence on the stress evaluation, either in a worse or either in a better way

3 Knowledge/training

The knowledge and training was sufficient (system operation information/training level) and allowed a CORRECT ❒ evaluation of the stress

OR

The knowledge and training could have been not sufficient (system operation information/training level and so the stress level evaluation was HIGHER ❒ **OR** LOWER ❒ than with a more realistic one

OR

The knowledge and training was not sufficient (system operation information/training level) and I DON'T KNOW ❒ its influence on the stress evaluation, either in a worse or either in a better way

4 System functions

The simulated system functions was representative enough of a real configuration and allowed a CORRECT ❒ evaluation of the stress

OR

The simulated system functions could have been not representative of a real configuration, being too much complicated, and so the stress level evaluation was HIGHER ❒ **OR** LOWER ❒ than with a more realistic one

OR

The simulated system functions scenario was not representative of a real configuration and I DON'T KNOW ❒ its influence on the stress evaluation, either in a worse or either in a better way

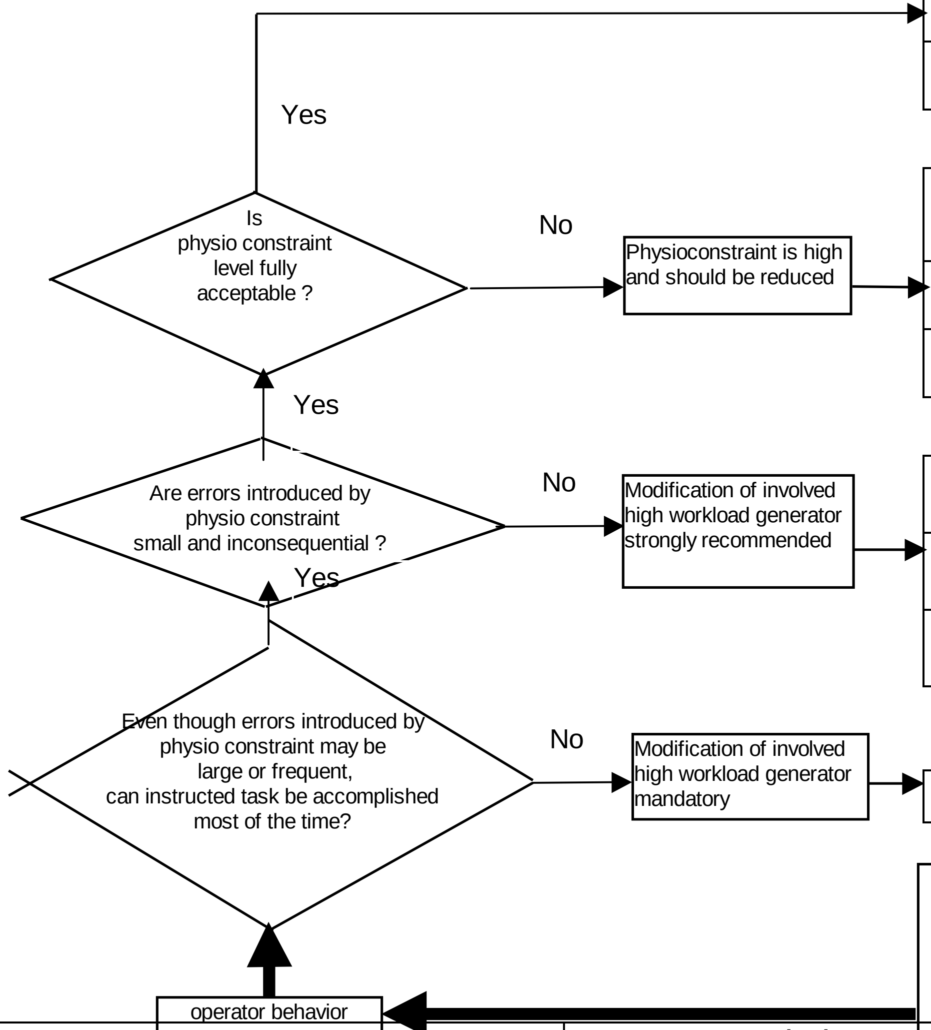
a

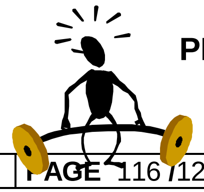
- WORKLOAD ASSESSMENT QUESTIONNAIRE (WLAQ)

A - workload components level assessment -

Would you please fill the following questionnaire indicating your choice by a cross

Difficulty level	Operator demand level	Crewmember feeling
Very easy, highly desirable	Physio constraint applied to operator is negligeable	
Easy, desirable	Physio constraint applied to operator is low	
Fair, mild difficulty	Moderate physio constraint is applied to operator to perform the tasks	
Minor but annoying difficulty	Moderately high physio constraint is applied to operator to perform the tasks	
Moderately objectionable difficulty	High physio constraint is applied to operator to perform the tasks	
Very objectionable but tolerable difficulty	Maximum physio constraint is applied to operator to perform the tasks	
Major difficulty	Maximum physio constraint is applied to operator to accomplish task, but bringing errors to moderate level	
Major difficulty	Maximum physio constraint is applied to operator to accomplish task, avoiding large or numerous errors	
Major difficulty	Intense physio constraint is applied to operator to accomplish task, but frequent or numerous errors persist	
Impossible	Instructed task cannot be accomplished reliably	





PHYSIO EFFORT ASSESSMENT SCALE:

physio effort constraint is intended to evaluate the induced physical and psychological tiredeness sensation generated by cockpit equipments to complete task.

a

B- uncertainty source effect on workload component level assessment -

Would you please fill the following questionnaire on uncertainty sources effect for the workload component PHYSIO EFFORT indicating your choice by a cross

1 Tactical scenario

The proposed scenario was representative enough of a real tactical situation and allowed a

CORRECT ❐

evaluation of the physio effort

OR

The proposed scenario could have been not representative of a real tactical situation, and so the physio effort level evaluation was

HIGHER ❐

LOWER ❐

than with a more realistic one

OR

The proposed scenario was not representative of a real tactical situation, and

I DON'T KNOW ❐

its influence on the physio effort evaluation, either in a worse or either in a better way

2 Simulator

The simulator configuration was representative enough of the reality (ext. environment, cockpit, aircraft model) and allowed a

CORRECT ❐

evaluation of the physio effort

OR

The simulator configuration could have not been representative of the reality (ext. environment, cockpit, aircraft model) and so the physio effort level evaluation was

HIGHER ❐

LOWER ❐

than with a more realistic one

OR

The simulator configuration not representative of the reality (ext. environment, cockpit, aircraft model), and

I DON'T KNOW ❐

its influence on the physio effort evaluation, either in a worse or either in a better way

3 Knowledge/training

The knowledge and training was sufficient (system operation information/training level) and allowed a

CORRECT ❐

evaluation of the physio effort

OR

The knowledge and training could have been not sufficient (system operation information/training level and so the physio effort level evaluation was

HIGHER ❐

LOWER ❐

than with a more realistic one

OR

The knowledge and training was not sufficient (system operation information/training level) and

I DON'T KNOW ❐

its influence on the physio effort evaluation, either in a worse or either in a better way

4 System functions

The simulated system functions was representative enough of a real configuration and allowed a

CORRECT ❐

evaluation of the physio effort

OR

The simulated system functions could have been not representative of a real configuration, being too much complicated, and so the physio effort level evaluation was

HIGHER ❐

LOWER ❐

than with a more realistic one

OR

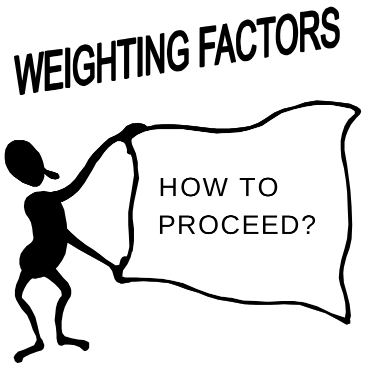
The simulated system functions scenario was not representative of a real configuration and

I DON'T KNOW ❐

its influence on the physio effort evaluation, either in a worse or either in a better way

a

- WEIGHTING FACTORS QUESTIONNAIRE (WFQ)

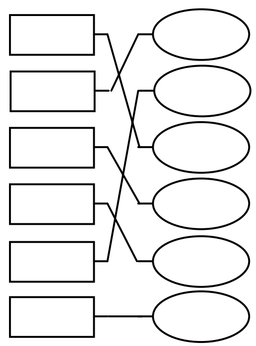


The weighting factors questionnaire allow the weighting of each worload component, which are:

- *MENTAL EFFORT,*
- *TIME CONSTRAINT,*
- *STRESS,*
- *PHYSIO EFFORT.*

To smooth your answer, they are combined through couples of components.

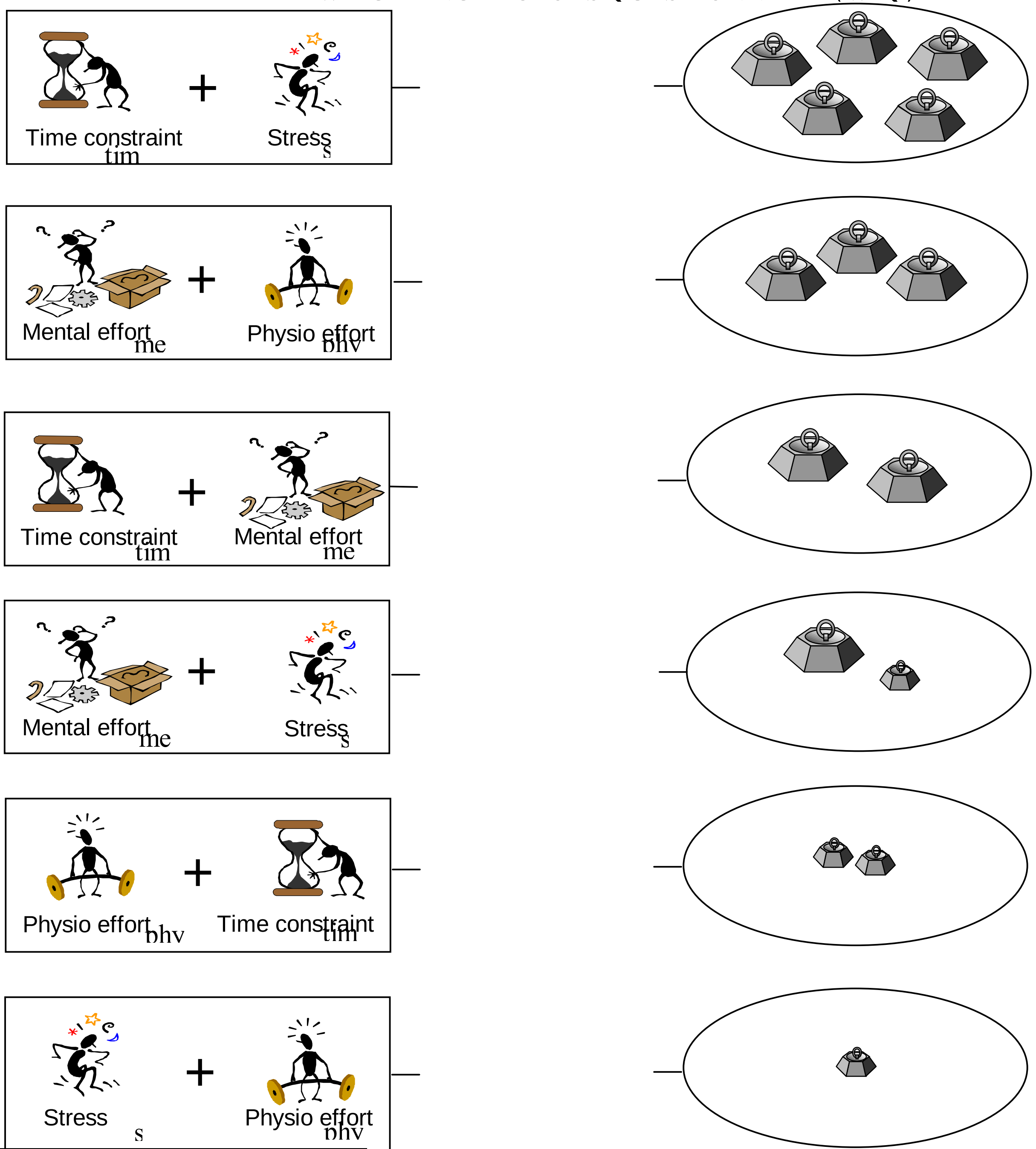
The goal is to classify each couple of workload components w.r.t. the weight felt during the sub-segment.
Each rectangle (couple of components) has to be linked to a single oval (weight):



a

- WEIGHTING FACTORS QUESTIONNAIRE (WFQ)

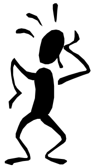
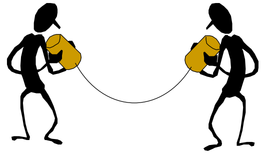
The goal is to classify each couple of workload components w.r.t. the weight felt during the sub-segment.
So, please link each rectangle (couple of components) to a single oval (weight):

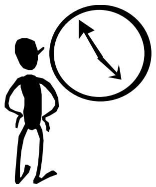
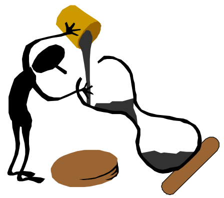


a

- SEGREGATION QUESTIONNAIRE (SQ)

Would you, please, answer to the following questions :

Were your mental activities mainly a management of unknown situations or a management of well-known situations?	*Did you perform activities which were not planned in your task allocation?*
 ❑ **or**  ❑ **unknown situation** **wellknown situation**	 ❑ YES ❑ NO **extra task**

Was the time allocated well sized to reach the target of the phase?	*If you have spent more time than expected, please explain the need of additive time?*
 ❑ YES ❑ NO **on time**	 **additive time needed**

a

Did you feel overloaded during this sub-segment?

NO ❑

Please, jump to the next sub-segment, if any.

YES ❑

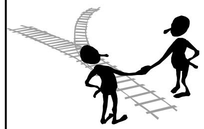
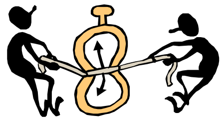
Please, fill the extra overload questionnaire.

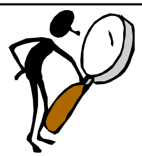
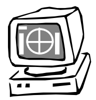
a

OVERLOAD QUESTIONNAIRE

a

- SEGREGATION QUESTIONNAIRE → OVERLOAD QUESTIONNAIRE (SOQ)

Do you think that the tasks can be shared out differently between the crew members?	*Do you think that the tasks assigned to the crew can be time-sequenced differently?*
 YES ❑ NO ❑ *if yes, please substantiate*	 YES ❑ NO ❑ *if yes, please substantiate*

What were the critical mission and/or flight control phases?	*What were the related equipment?*
	

a

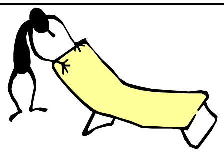
Is there a need to modify an equipment or a information presentation?

YES ❑ *if yes, please substantiate*
NO ❑

Are essential functions lacking at equipments level?

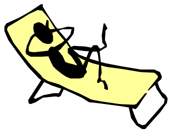
YES ❑ *if yes, please substantiate*
NO ❑

Does the system sufficiently support crew members mental basic actions?



YES ❑ *if yes, please substantiate*
NO ❑

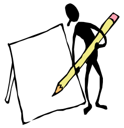
Does the system sufficiently support crew members reflex actions?



YES ❑ *if yes, please substantiate*
NO ❑

a

Do you have any other comments or suggestions?



a

THE END

a

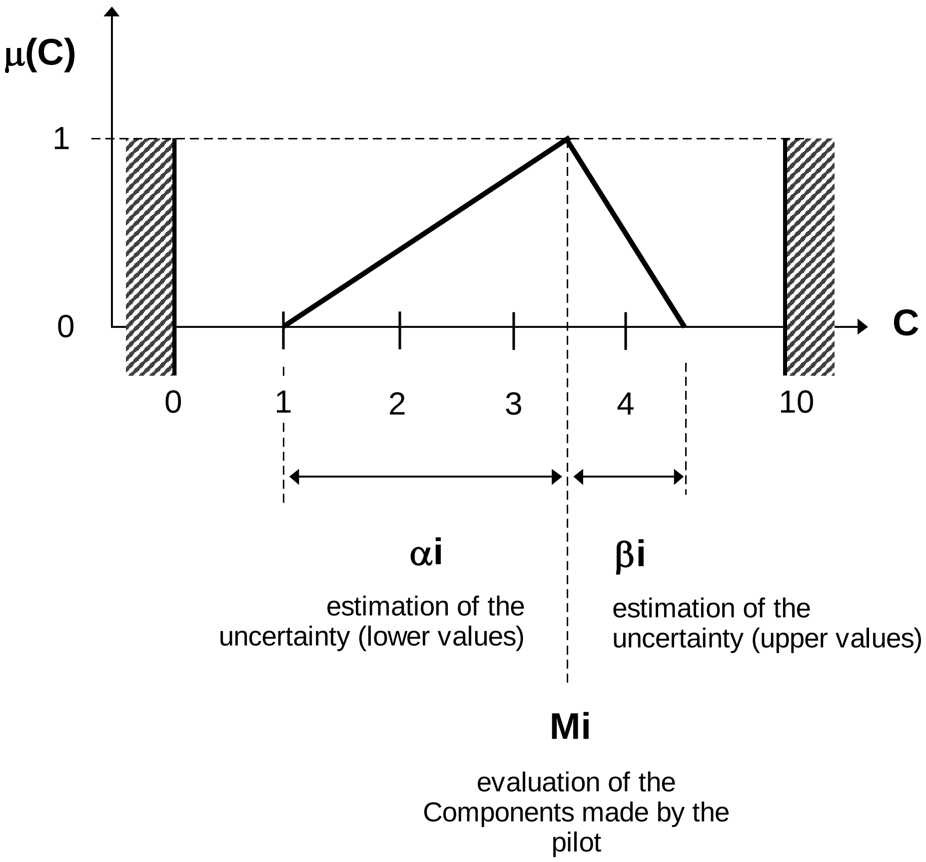
- UNCERTAINTY QUESTIONNAIRE (UQ)

- FUZZY LOGIC ESTIMATION -

The level of uncertainty, associated to the evaluation of the components, is determined by :

αi = 0.5+Sum of the answers [=3 or 4],
limited such that : $(Mi-\alpha i) \geq 0$
βi = 0.5+Sum of the answers [=2 or 4],
limited such that : $(Mi+\beta i) \leq 10$

with:
CORRECT= 1
HIGHER= 2
LOWER= 3
I DON'T KNOW = 4



Then, the fuzzy quantity, describing the evaluation of the component Ci on the workload, is :

$$WLCi = (Mi, \alpha i, \beta i)$$