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HUMAN FACTORS MODELS AND CLASSIFICATION SCHEMES FOR IMPROVING OCCURRENCE DATA REPORTING SYSTEMS

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Abstract

One of the most important issues, which are facing the present of aviation accidents/incidents mandatory databases, is represented by the scarce content of information concerning Human Factors. These are usually presented, in database reports, in unstructured forms, such as "narrative" report, or based on a superficial classification scheme with shallow connection to a human behaviour model.
This problem demands the improvement of current classification schemes by considering more sophisticated taxonomies of human errors, and the validation of these.
In this paper we present our first attempt to study the validation issue, for which the following method has been applied. First of all, the new ICAO classification scheme, known as ADREP-2000, has been studied and compared with the previous version. Then, well-known accident cases have been selected, and database reports elaborated on the basis of the two ADREP classifications. Finally, accurate analysis of the accidents has been devised from the two different accident reports for each accident case. The differences between the current ADREP and the ADPREP-2000 reporting schemes, are then confronted and compared with the thorough outcome of the accident analysis based on the Inquiry Commission accident Report*. Gains obtained by the use of new taxonomy are then discussed together with possible future improvements of the new format.

Introduction

The analysis of complex systems for the prevention of air accidents demands the availability of a set of data, which can be used for the identification of an occurrence key causal factors, such as pilots decision making process in topical situations. Information obtained from the analysis of these data, represent the basis in the definition process of specific guidelines for improving of Flight Safety.
In this context, the creation of a worldwide "mandatory occurrence reporting system" format is one of the most important goals to aiding and promoting the data exchanging among different institutions.

Purpose of the work

The performed study aims at analysing the content of the new, but not completely defined, ICAO format, ADREP 2000, in comparison with the existing format to provide possible improvements. For this purpose, the "Events" section of the ADREP format has been used for the analysis of four well-known accident cases. This is deemed sufficient because of the significance of this section, which can be considered as the most important for the codified report. In this paper we show results for one only accident case but these have been compared with other similar works already performed.

Working methodology

The working methodology by which the study has been performed can be summarised as follows:

1. Analysis of the main characteristics of some selected occurrences through the study of the Inquiry Commission Report*.
2. Isolation of "Findings and Causes" which are to be translated into the ADREP format and identification of the most representative keywords.
3. Organisation of the identified keywords in a logical/chronological scheme.

* In this study, the Inquiry Commission report has been always indicated as "Report", to distinguish it from a database codified report, named "report".

4. Identification of the most suitable ADREP encoding, in the two formats, by which the occurrence can be best reported.
5. Using the ECCAIRS** "Data Entry Application", creation of the ADREP 87 reports.
6. Creation of the ADREP 2000 reports, by hand since no tool is available at the moment.
7. Comparison between the ADREP 2000 and the ADREP 87 version of the two reports through the discussion of the differences that exist between the two formats and improvements derived by the use of the new ADREP "Explanatory Factors" taxonomy
8. Analysis of possible improvements of the new ADREP 2000 format.
9. Creation of an enhanced ADREP 2000 report based on the proposed improvements.

Flow chart of the work is presented in figure 1.
It's important to remark that, for the cases chosen, no accidental analysis has been done to find out new causes, systemic or human, not identified in the Inquiry Commission Report.
The principal purpose of this work is to evaluate the outcome of the accident Report presented through the two ADREP formats, which are considered only as "filters" for the information contained in the original Report.
The "Conclusions" section of an occurrence Report represent the main basis for these studies, although the entire document is necessary for a wide description and logical/chronological reconstruction of events, which led to the accident. Items not directly referred to the "Conclusions" section of a Report are completely avoided, except for those few that are extremely necessary for the outline of the report and which clearly derive from other sections of the Report.

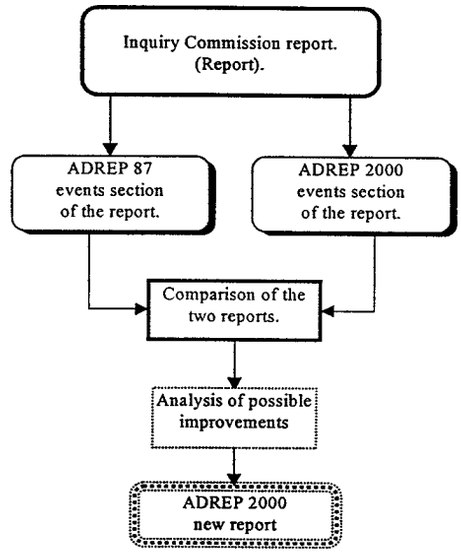

FIGURE 1. Flow chart of the work.

The reason for this study is the research of the best possible format in which data contained in a Report can be translated into a codified version, ready for computational tools. This codification reflects original information in best as possible way, with as less as possible information loss or adding.
In the final section of each accident analysis, a different version of the ADREP 2000 report, based on a new approach to the problem of presenting data, is presented, demonstrating possible improvements on the current ADREP 2000 scheme.
This approach has been considered to highlight possible "latent failures" when Human Factors play a central role in an accident genesis and evolution. Latent failures, for their nature, cannot be directly referred to human errors, but they are often related. For this reason, the "Root Cause Line" of the accident has been create. This, if well represented in a codified report, plays a central role in the process of retrieving all the possible reasons that led to the occurrence as well as gives a clear picture of occurrence's scenario. Besides, the root cause line favourites performing adequate computational safety analyses, which represent the main scope of a database report creation.
However, the process to highlight the accident root cause line is not always easily retrievable by an Inquiry Commission Report. In this work, we give an interpretation of how this process can be carried out.

**The ECCAIRS project (European Co-ordination Centre for Aircraft Incident Reporting System) is a Joint Research Centre activity started on request of Directorate General VII (Transport) of the European Commission. Objective of the project is to develop a permanent co-ordination activity at European level in the area of mandatory aircraft occurrence reporting systems. The ECCAIRS system is the heart of a network which objective it is to integrate the knowledge derived from aviation occurrence reporting systems running in various civil aviation authorities of the EU member states. The final product will be come available during 1998. In the ECCAIRS mandatory database about 30000 occurrences occurred, between 1984 and 1994, originating from Great Britain, Germany and some North European countries are currently stored. The standard used adheres to the ICAO-ADREP,87 format.

Casella

Analysis of the Strasbourg accident

The Strasbourg accident can be considered a typical "Controlled Flight Into Terrain" (CFIT) case in which pilots did not recognise the danger until they struck on ground. For this reason, this occurrence is a valid case especially to test the new Human Factor taxonomy of the ADREP 2000 format either for a comparison with the previous or to discuss possible future improvements.

Description of the occurrence

The aircraft, an Airbus A320 operated by Air Inter, departed on 20 January 1992 from Lyon-Satolas for a scheduled flight with planned destination Strasbourg-Entzheim.
While the aircraft was crossing FL 150 and 22 NM from the Strasbourg VOR was cleared to continue its descent to an altitude of 5000 ft QNH and then, after announcing the passing of the ANDLO point, cleared for a VOR-DME approach to runway 05.
The altitude and speed of the aircraft at this point were such that the direct approach procedure could no longer be carried out. The crew informed the ATC of their intention to perform an ILS runway 23 approach followed by a visual manoeuvre for runway 05 that was in use. The controller was instead waiting for a VORTAC runway 05 approach and warned them that this choice would mean a delay due to aircraft in the process of taking off from runway 05. The crew then modified their strategy and advised ATC that they would carry out a complete VOR-DME procedure for runway 05.
ATC then proposed radar guidance to bring them back to ANDLO, and shorten the approach procedure. The crew accepted and carried out the manoeuvres prescribed by the controller. While the aircraft was abeam the ANDLO point was cleared for the final approach procedure.
During this phase, carried out at night and IMC conditions, an abnormal high rate of descent was selected by the pilots. This caused the aircraft impacting into the mountain known as "La Bloss" during its descent towards the runway, at an altitude of approximately 800 metres and a distance of approximately 10.5 nautical miles from the runway threshold. The aircraft was completely destroyed; 82 passengers and 5 crewmembers were fatally injured.
No problem was reported by the crew during the flight.

Conclusions of the inquiry commission

In analysing the mechanisms of the accident, the Inquiry Commission reached some conclusions that can be summarised as follows.

Conclusions relative to the mechanisms of the accident

The **pivotal** event in the accident sequence has been identified in crew's setting of an abnormal and never corrected **high rate of descent** (3,300 ft/min instead of about 800 ft/min).
The reason for this setting was not established with any degree of certainty but the Commission identified some hypotheses retained the most likely. These were:

- ❖ misunderstanding in vertical mode, which is the result of one of these events:
  - an omission to change the trajectory reference;
  - poor execution of the command to change the trajectory reference;

and the

- ❖ error in selecting the consigned value probably originating by an unconscious selection of numeric value given out during the briefing.

In all of these hypotheses, the Inquiry Commission considered the accident was made possible by a **crew's lack of perception** resulting in:

- discrepancy in the vertical course, as showed by a rate of vertical speed which was four times higher than the reference value;
- an abnormal pitch-down attitude;
- an increase in speed over the flight path.

This lack of perception was attributed to the following factors, which are arranged in no particular order of importance:

- below average **crew** functioning, characterised by a distinct **lack of mutual checks** and monitoring of the results of actions delegated to automatic equipment. This lack manifested itself especially in terms of disregard for a large proportion of the in-flight announcement specified by the Operation Manual and the absence of height/distance checks laid down for the execution of a VOR DME approach;
- an atmosphere among the **crew** characterised by **minimum levels of communication**;
- the **ergonomy** of presenting control parameters for the vertical flight path, appropriate for normal situations, but not possessing a sufficient warning capability for a crew in a situation where there is a space perception error;
- belated modification of the approach strategy, induced by **ambiguities in communication** between the **crew** and **ATC**;

- **slackening of the crew's attention** during the radar guidance phase, followed by a sudden intensive workload which led them to privilege horizontal navigation and the setting of the aircraft's configuration, and to hand over vertical navigation completely to the aircraft automatic system;
- during the alignment phase on to the approach track, the two crew members **focussed** their **attention on horizontal navigation** and failed to monitor the vertical flight path being managed in automatic mode;
- the **absence of a GPWS** together with an appropriate usage procedure, which deprived the crew of one final warning opportunity concerning the serious irregularity of the situation.
- In other respects, and notwithstanding hypothesis of FCU malfunction, the Commission considers that the **ergonomic design of Autopilot** controls in vertical fin could have had a part to play in the origin of the situation that led to the accident. In fact, this design appeared to the Commission, particularly in cases involving sudden and **significant workload**, to be inclined to increase the probability of certain utilisation errors.

Conclusions relative to the operational background

These conclusions can be considered as the bottom level of the root cause line, i.e. what are called "latent failures". These are:

- the **deficiencies** in the national and international **experience feedback system**, essentially in operational utilisation of aircraft. An essential safety element, this system relies on the active collaboration of pilots, airlines, aircraft manufacturers and the authorities. Here certainly, the gathering and distribution of information are manifestly inadequate;
- the absence of a **national regulation** making it **mandatory** for aircraft to **use** a Ground Proximity Warning System (**GPWS**);
- the **limited** amount of **experience** acquired by **both pilots** on **this type of aircraft** and the absence of regulations or national/international recommendations on this subject;
- the **inadequacy of technical control exercised over Air Inter by the authorities**, which can hardly detect possible drifts in operation (for example, with regard to checklist in-flight announcements);
- the **low number of conventional approaches** in Type Rating and line familiarisation programmes, together with the **limited practice** of these types of approach **in normal operation;**
- the maladjustment of current interpretations of the certification regulations and of the accepted means of accordance proof associated with them, to ergonomic problems affecting the aircraft crew interface raised by the latest generation of flight decks.

Data organisation

Information contained in the previous section must be presented in the most synthetic format, which can be directly used for the ADREP translation. For this reason we have first reorganised data in a ADREP-ready format by reassuming the identified causes, expressed in the previous sections, through some keywords, which highlight the relevant factors for the accident causes. Second we have referred these ones to well-defined ADREP codes for the creation of the report. These keywords are reported in bold character in the previous section.

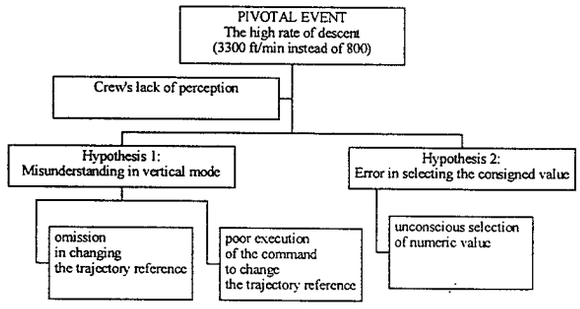

FIGURE 2. The "Crew's lack of perception" hypotheses for the Strasbourg accident.

In Figure 2 the outline of the most likely hypotheses for the accident occurring have been reassumed. These turn around the pivotal identified cause "Crew's lack of perception", while the identified causes are presented by a scheme, such as that presented in the figure 3, which, apart from making a simple list, highlights any dependence among these ones. This scheme has been also used to modify the outline of the ADREP 2000 version of the report to create the Root Cause Line of the accident.

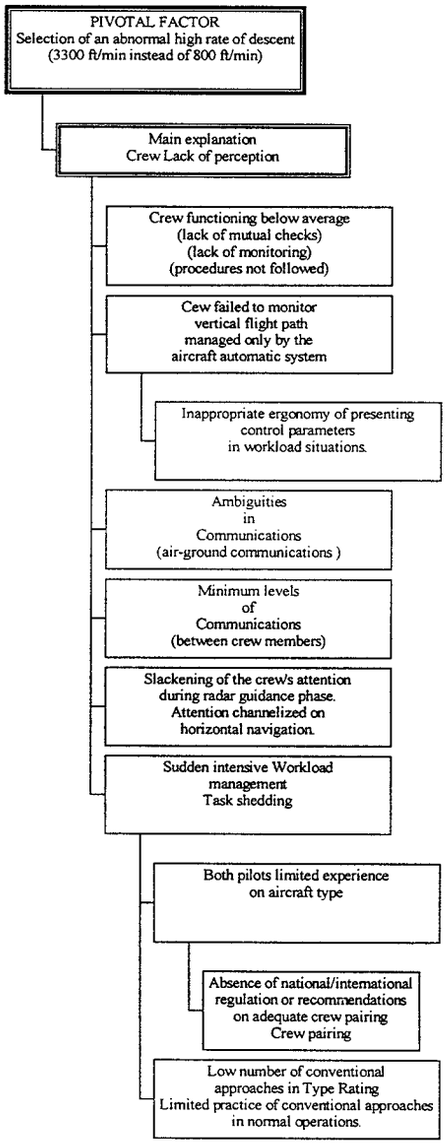

FIGURE 3. Representation of keywords chosen and their mutual dependence.

ADREP 87 events section of the report

The most important differences between the ADREP 87 and the ADREP 2000 format can be found in the "Event types" and "Explanatory factors" codes, since there are at this moment no relevant changes in other sections of the ADREP 2000 taxonomy for the purpose of the study.
For this reason we report the "Events" section either the old (ADREP 87) or the new (ADREP 2000) version in a table.
In this section no Root Cause Line has been created because of the low importance of such a process for this old format.
"Events" section of the ADREP 87 report is presented, at the end of the document, in appendix 1.

ADREP 2000 events section of the report

In the new ICAO format, "Event types" codes are now organised through a hierarchical scheme that contains three levels of classification and a fourth one showing the detail (four levels). On the first level there are only five event classes. (ICAO 1997).
The new approach for reporting "Human factors" in the Explanatory Factors codes is based on a general accepted model, the SHELL model (Edwards 1972) and the widely known Reason's taxonomy.
"Event phases" and "Modifiers" used are taken from the old ADREP 87 format, since a new list is not available yet.
The report follows in appendix 2.

Analysis of the differences

The increased number of Human Factors items of the new ADREP format which, for this reason, results in more details, represents the first basic difference between the two formats.
In the new format Strasbourg accident report, the items:

1. *control & displays design [design/ergonomics] {cockpit equipment/cockpit design}*
2. *air-ground communications {Oral/Aural communications}*
3. *Workload management - task shedding*
4. *skill maintenance with automation [skill] {skill/technique/ability}*
5. *crew pairing {management/personnel policies}*

replace the old ADREP 87 items:

1. *instruments/controls design {design}*
2. *communication {communication}*
3. *task saturation {psychological condition}*
4. *skill {experience training}*
5. *personnel policies {management}*

The differences between the ADREP 87 as opposed ADREP 2000 format are:

1. No reference to the ergonomics of control displays.
2. No possibility to highlight the misleading communications between the ATC and crewmembers.
3. New item "*workload-task shedding*" is more appropriate than "*task saturation*".
4. ADREP 2000 item "*skill maintenance with automation*" expresses exactly the concept related to a possible reduction in skill level due to a lack of practice, as result of automation.
5. ADREP 87 item "*personnel policies*" is too generic. By the new item "*crew pairing*" we

can exactly express problems related to both pilots low experience on that type of aircraft.

Proposed modifications to ADREP 2000 report

For the purpose of showing the Root Cause Line of an accident, the ADREP 2000 Events section of the report has been modified briefly changing the structure of this section. This modification, allows to stress a possible mutual dependencies among Explanatory Factors, and not only by a Descriptive Factors.

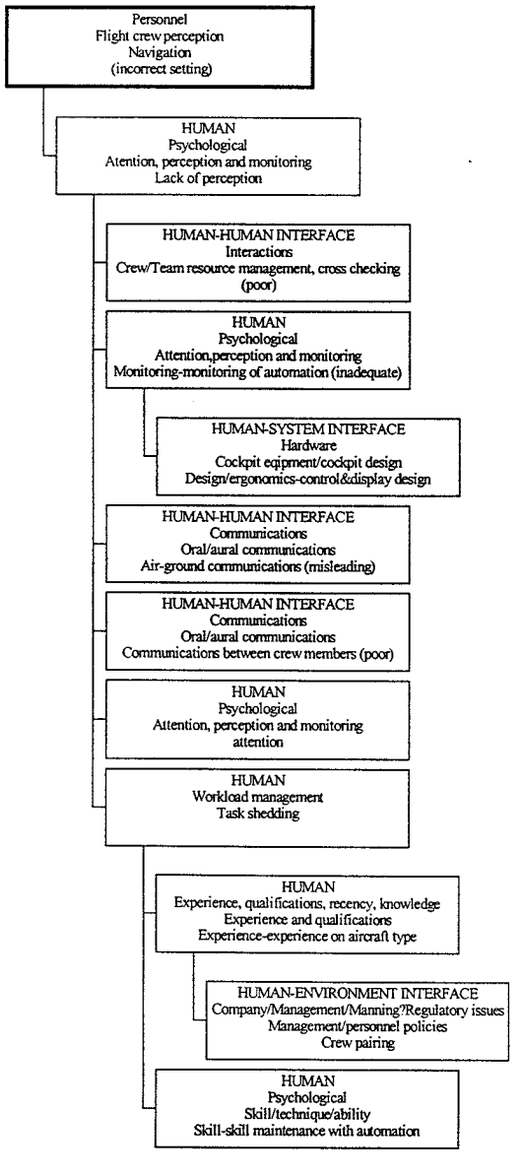

FIGURE 4. Proposed representation of "Explanatory factors", the "Root Causes Line"

These changes reflect the representation of figure 3 by ADREP codes. Such schème is not only a list of codified causes but, by relating these ones to each other, it provides a clear picture of the accident scenario.

Conclusions

Even though this paper is based on only one but very significant case, some first conclusions can be stressed.
Main improvements resulting from applying the ADREP 2000 format are:
1. A better structured "Event type section". The identification of an event becomes simpler, although there is no conceptual improvement, because of the ATA classification
2. A better-structured Explanatory Factors section, based on a completely changed taxonomy results in a more detailed codification. The chosen SHELL model assists the analyst better in finding relevant keywords through the five main levels. This makes it easier to identify the "root cause" of what happened.
In the case of the accident examined, the four top levels (of five) that have been selected:
1. Human;
2. Human-Human interface;
3. Human-System interface;
4. Human-Environment support interface
are already enough to indicate problems related to:
1. an individual and his performance;
2. company/management issues;
3. lay out and design of instruments;
4. problems covering the relations between pilots (operators) and environment and its influences on their performance.
These top levels give a general but important indication of what may have affected the reliability of the socio-technical system. The other more detailed levels make clear which were the true causes that led to the accident, helping to explain "why" something happened as opposed to "what" happened.
Despite these improvements, ADREP 2000 does not solve all problems.
Descriptive Factors have not changed; they can still express both "what" happened and "why" it happened resulting in a mixture between "causes" and "effects" in the same section. A re-organisation of these in order to eliminate Human Factors related codes from this section should be considered by ICAO, leaving only to Explanatory Factors the task to express HFs.
The new distinct approach in information presenting, the "Root Causes Line", reflects the attempt to remark possible correlation among the identified causes. It results in a more detailed and ready for future safety analysis report.
Furthermore, this format reduces the risk of misinterpretation of the report by non-HFs experts.

Appendix 1

Detailed report

France OPCSTRAS	accident France	4/21/98 MONT SAINT ODILE
Aircraft:	AIRBUS INDUSTRIES	A320

Aircraft

Manufacturer: **AIRBUS INDUSTRIES**	*Itinerary*
Model: **A320**	Last departure point: **LYON**
State of registry: **France**	Planned destination: **STRASBOURG**
Registration: **F-GGED**	Duration of flight: **59** minutes
Operator: **air inter, societe**	Occurrence on ground: **no**
Aircraft Type: **fixed wing**	*Operation* *Air line*
Power type: **turbofan**	Air line operation type: **passenger**
Landing gear type: **tricycle type retractable**	Operation scheduled: **scheduled**
Year manufactured: **1988**	Domestic/international: **domestic**
Serial number: **015**	*Engines*
Maintenance documents: **current**	1 GENERAL ELECTRIC Unknown
Certficate of airworthiness: **valid**	
Approval icing conditions:	
Approval precision approach:	
Weight group: **5700-27000 Kg**	

Event: 1 Type: **too close to ground {altitude related event}**
Phase: **final approach {approach}**

Factors subject:	*Modifiers:*
rate of descent {crew a/c handling | flight crew a/c handling}	excessive

Explanation: lack of perception {psychological condition} flight crew
Explanation: channelized attention {psychological condition} flight crew
Explanation: lack of attention {psychological condition} flight crew
Explanation: inadequate monitoring {management} flight crew
Explanation: poor communication flight crew
Explanation: poor crew co-ordination {supervisory factor} flight crew
Explanation: excessive task saturation {psychological condition} flight crew
Explanation: too low skill {experience/training} flight crew
Explanation: lack of experience on a/c type {experience/training} flight crew
Explanation: misleading communication flight related persons
Explanation: not comfortable instruments/controls design {design} manufacturer - design staff {manufacturer}
Explanation: inadequate personnel policies {management} operator - management {operator}

Event: 2 Type: **collision with hill/mountain {collision with terrain}**
Phase: **final approach {approach}**

Factors subject:	*Modifiers:*
gpws {flight and navigation systems}	not available
Explanation: poor regulations {management} caa - management {government - caa}	
standard operating procedure {personnel | flight crew procedures}	not followed
Explanation: not checked procedures {management} caa - management {government - caa}	

Event: 3 Type: **fire/explosion/fumes**
Phase: **post impact**

Factors subject:	*Modifiers:*

Appendix 2

ADREP 2000 Events section

France **Adrep 2000**	**accident** **France**	**20/01/92** **MONT SAINTE-ODILE**
Aicraft:	**AIRBUS INDUSTRIES**	**A 320**

Event: 1 Type: **Too close to ground [altitude rel ev] {operation of an aircraft rel ev}**
Phase: **Final approach {approach}**

Factors subject:	*Modifiers:*
Rate of descent {crew a/c handling | flight crew a/c handling}	excessive

Explanation: Flight crew - Human - Psychological
lack of perception {attention, perception and monitoring}
Explanation: Flight crew - Human- Human interface - Interactions
poor Crew/team resource management, cross checking
Explanation: Flight crew - Human - Psychological
inadequate monitoring of automation [monitoring] {attention, perception and monitoring}
Explanation: Manufacturer design staff {manufacturer} - Human-System interface - Hardware
control & displays design [design/ergonomics] {cockpit equipment/cockpit design}
Explanation: Flight related persons - Human-Human interface - Communications
misleading air-ground communications {Oral/Aural communications}
Explanation: Flight crew - Human-Human interface - Communications
poor communications between crew members {Oral/Aural communications}
Explanation: Flight crew - Human - Psychological
channelized attention {attention, perception and monitoring}
Explanation: Flight crew - Human - Psychological
lack of attention {attention perception and monitoring}
Explanation: Flight crew - Human - Workload management
task shedding
Explanation: Flight crew - Human - Experience, qualifications, recency, knowledge
lack of experience on aircraft type [experience] {experience and qualifications}
Explanation: Operator {manag} - Human-Environment interface - Comp./Manag./Man/Reg. issues
Inappropriate crew pairing {management/personnel policies}
Explanation: Flight crew - Human – Psychological
skill maintenance with automation [skill] {skill/technique/ability}

Event: 2 Type: **Coll high terrain/hill/mount (coll terr) [coll objects/obstacle/ground] {op aircraft rel ev}**
Phase: **Final approach {approach}**

Factors subject:	*Modifiers:*
gpws {flight and navigation systems}	not available

Explanation: Flight crew - Human-System interface - Automatic defence/ warnings systems
GPWS {cockpit warnings}
Explanation: CAA- management {government-CAA} - Human-Human interface - Regulatory activities
poor regulation

Standard operating procedure {personnel | flight crew procedures}	not followed

Explanation: CAA- management {government-CAA} - Human-Human interface - Regulatory activities
inadequate monitoring

Event:3 Type: **Fire/explosion {operation of an aircraft rel ev}**
Phase: **Post impact**

Factors subject:	*Modifiers:*

References

1. Casetta O. P., Surace G. (1996). Man-machine interaction analytical approach. Proceedings of the international conference on "Probabilistic Safety Assessment and Management" ESREL'96-PSAM III (Crete, 24-28 June 1996).
2. Edwards, E. (1972). Man and machine: Systems for safety. In Proceedings of British Airline Pilots Association Technical Symposium. British Airline.
3. ICAO. Accident/Incident reporting manual (ADREP MANUAL). Second edition, 1987.
4. Pilots Association, London. pp. 21-36R Maurino, D. E., J. Reason, N. Johnston, and R. B. Lee (1995). Beyond aviation Human Factors. Avebury Aviation, Aldershot, UK.
5. Ministry of Transport and Tourism 1994. Final Report on the accident AIRBUS A320 Air Inter on 20 January 1992 near Mont Sainte-Odile (1993).
6. ICAO 1994. International Civil Aviation Organisation. Aircraft Accident and Incident Investigation. Annex 13 to the convention on international civil aviation. Eighth edition, July 1994.
7. ICAO minutes of the meeting of the ADREP 2000 Study Group. Montreal, 4-6 May 1997.