L.O.S.A.N.G.E.

Line Operations Safety Analysis
using Naturalistically Gathered Expertise

Report n°1

direction générale
de l'Aviation civile

direction des affaires
stratégiques et
techniques

sous-direction
de la sécurité et de
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**bureau des aéronefs
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Report 1

STATE OF THE ART
LOSA

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DOCUMENT REVIEW

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DOCUMENT BACKGROUND

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TABLE OF CONTENTS

GLOSSARY

ALPA	AirLine Pilots Association
CRM	Crew Resource Management
FC	Flight Crew
FOQA	Flight Operations Quality Assurance
HF	Human Factors
IATA	International Air Transport Association
IFALPA	International Federation of Airline Pilots Associations
LOSA	Line Operations Safety Audit
LOSANGE	Line Oriented Safety Analysis using Naturalistically Gathered Expertise
ICAO	International Civil Aviation Organisation
SOP	Standard Operating Procedure
TEM	Threat and Error Management
UAS	Undesired Aircraft State
UT	University of Texas

1 INTRODUCTION

1.1 Context of the study

In view of the success of LOSA (Line Operations Safety Audit), and because of the interest raised by this methodology within international organisations such as ICAO, the French DGAC started the LOSANGE study aimed at describing and evaluating the features of the methodology, in order:

- To provide airlines with a realistic view of the LOSA contributions and implementation conditions,
- To suggest LOSA adaptations for the airlines associated to the study taking into account their actual needs,
- To identify or suggest some alternative methods for in-flight systematic observations of normal operations.

This study should therefore provide airlines with arguments for explaining their LOSA adaptation choices internally (with management, professionals and pilot unions) and externally (with international organisations).

1.2 Objectives of the state of art

This document is the first LOSANGE report, dealing with a state of the art concerning the LOSA methodology and a critical analysis of the theoretical basis.

This report provides:

- An analysis of the theoretical and methodological background of the LOSA methodology
- An identification of the issues encountered when implementing the LOSA methodology
- An objective review of the methodology strengths and weaknesses

1.3 Working Method

A number of documents concerning LOSA have been studied. The complete list of reviewed documents is presented in Appendix 1. Most of the available documents came from the University of Texas, in other words the LOSA methodology developers. Others, such as articles or proceedings of symposium, are testimonies from airlines that have implemented LOSA or contributions from institutions (ICAO, IATA). Only few critical documents have been found to help in analysing the LOSA methodology. Therefore, this work is also based on interviews with various experts in order to substantiate the report.

1.4 How to read this document?

This document is organised as follow:

- Detailed description of the theoretical model (Threat and Error Management - TEM) supporting the LOSA methodology,
- Critical analysis of the TEM model,
- Detailed description of the LOSA approach : implementation conditions, aims, steps,
- Critical analysis of the proposed methodology (strengths and weaknesses).

2 PRESENTATION OF THE "TEM" MODEL

2.1 General properties of the TEM Model

2.1.1 Bases and principles

- Psychologists of the University of Texas designed the TEM model based on aeronautical incidents and accidents analysis.
- The model (see Figure 1) assumes a sequential handling of threats and errors by the pilot.
- According to the model, part of pilot's activity consists in managing threats and errors. Threats cause errors, errors that can lead to an undesired aircraft state. Errors and undesired aircraft states should be detected and recovered to guarantee flight safety.
- The errors and threats management is performed through « CRM behaviours », which are behaviours implying non-technical skills gained from CRM courses.

2.1.2 Objectives of such a model in the LOSA methodology

Such a model aims at identifying through observations:

- weaknesses in training and knowledge,
- insufficient or ineffective strategies of potential error detection,
- effective strategies of error recovery or management,
- strategies of threat detection and management,
- systemic threats,
- errors types according to the taxonomy presented in the model:

- **Intentional non-compliance errors (violations):** intentional and conscious violations of SOPs or regulations, including shortcuts or omission of required briefings or checklists.
- **Procedural errors:** errors including slips, lapses or mistakes in the execution of regulations or procedures. The intention is correct but the execution is flawed.
- **Communication errors:** occurs when information is incorrectly transmitted or interpreted within the cockpit crew or between the cockpit crew and external sources such as air traffic control.
- **Proficiency errors (*skills errors*):** indicate a lack of knowledge or stick and rudder skill.
- **Operational decision errors:** discretionary decisions not covered by regulation and procedure that unnecessarily increases risk. Examples include extreme manoeuvres on approach, choosing to fly into adverse weather, or over-reliance on automation.

2.2 The TEM model components and the model adaptation to the flight crew's work

2.2.1 TEM model components

The following diagram shows the different components of the TEM model and their links.

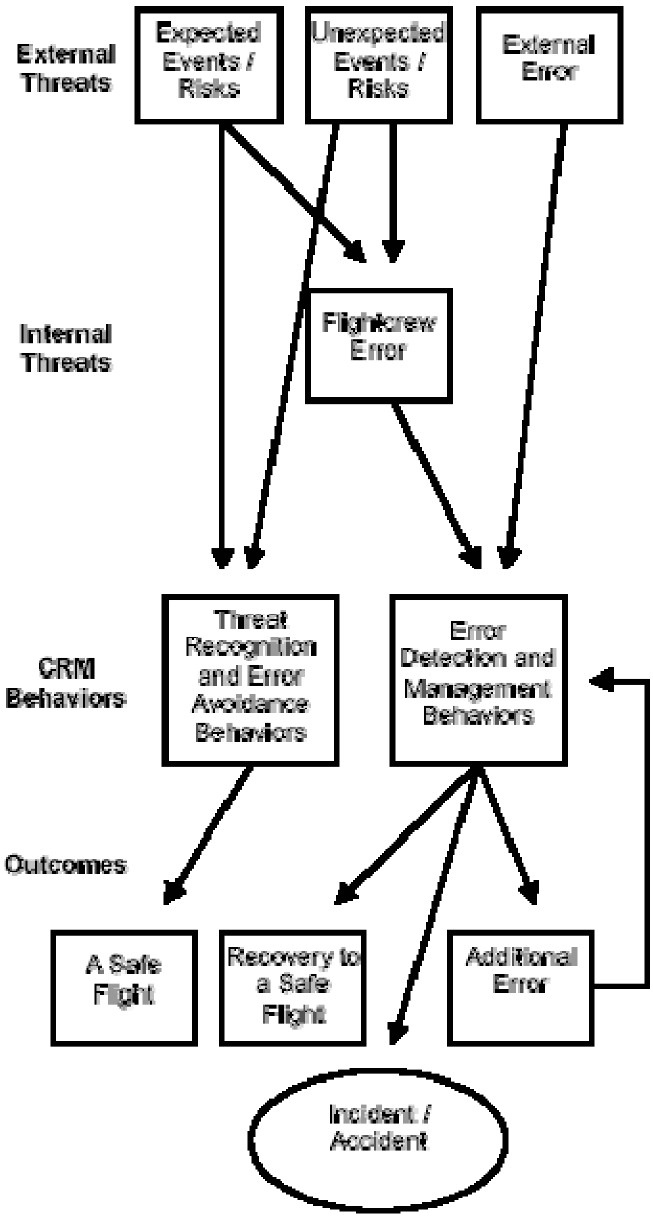

Figure 1 : TEM Model (University of Texas)

Some explanations are given by the authors of the model on the « **External threat** » and the « **Flight crew error** » notions.

An External threat is defined as an event (in relation to the environment or the aircraft) or an error (from another aircraft, air traffic control or maintenance) occurring outside the influence of the flight crew (not caused by the flight crew). It increases the operational complexity of a flight and requires crew attention and management if safety margins are to be maintained.

A **Flight crew error** is defined as an action or inaction that leads to a deviation from crew or organizational intentions or expectations. Error in the operational context is considered as a factor reducing the margin of safety and increasing the probability of adverse events.

2.2.2 TEM model adaptation to error management by the flight crew

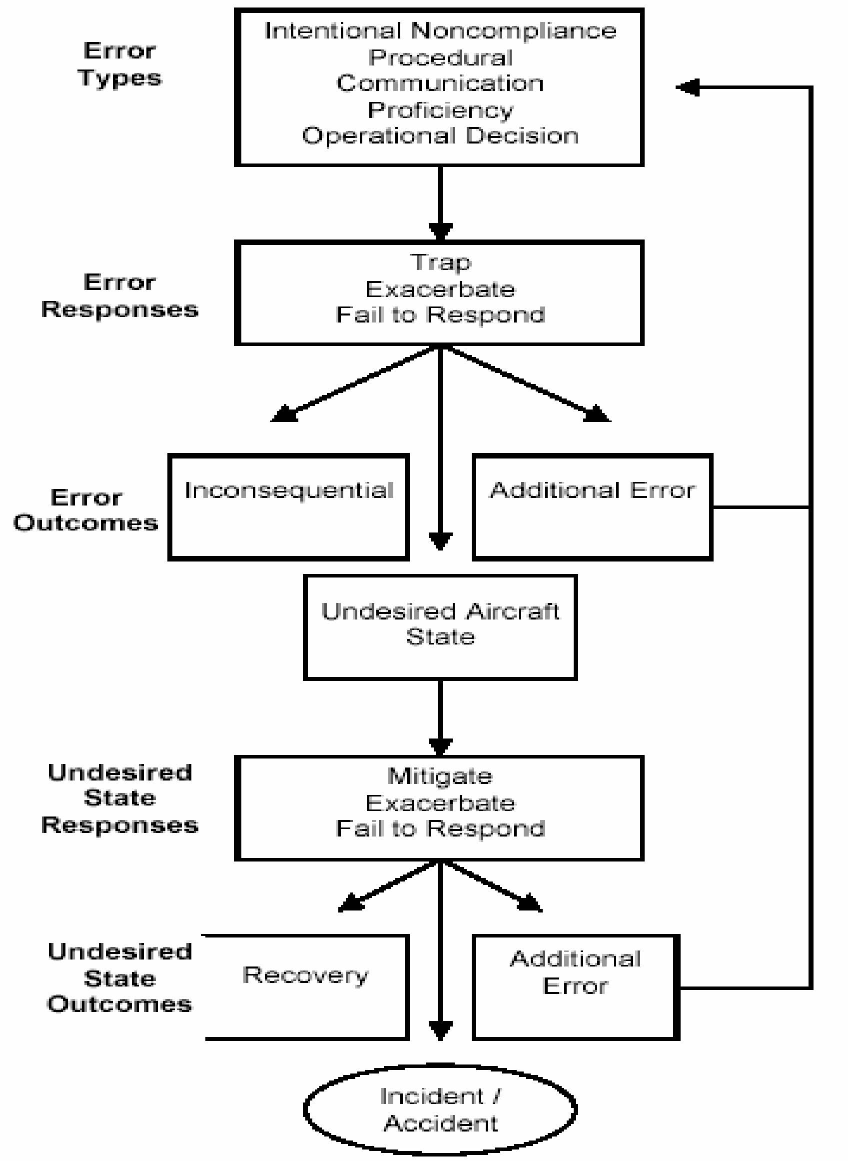

Figure 2 : Model of flight crew error management (University of Texas)

From the **five errors types** proposed in the model, **three possible error answers** are presented:

- **Trap:** the error is detected and managed before it becomes consequential,
- **Exacerbate:** the error is detected but the crew's action or inaction leads to a negative outcome,
- **Fail to respond:** the crew fails to react to the error either because it is undetected or ignored.

An **Undesirable aircraft state** is defined as a position, condition or attitude of an aircraft that clearly reduces safety margins and is a result of actions by the flight crew.

This undesirable aircraft state leads to **three possible types of results**:

- **Inconsequential:** the error has no effect on the safe completion of the flight, or was made irrelevant by successful cockpit crew error management. This is the modal outcome, a fact that is illustrative of the robust nature of the aviation system
- **Undesired aircraft state:** the error results in the aircraft being unnecessarily placed in a condition that increases risk. This includes incorrect vertical or lateral navigation, unstable approaches, low fuel state, and hard or otherwise improper landings. A landing on the wrong runway, at the wrong airport, or in the wrong country would be classified as an undesired aircraft state. The undesirable aircraft states can be:

- **Mitigated**
- **Exacerbated**
- **Fail to respond**: there can be a flight crew failure to respond to the situation

There are **three possible resolutions** of the undesired aircraft state:

- **Recovery** : is an outcome that indicates the risk has been eliminated
- **Additional error** : the actions initiate a new cycle of error and management
- **Crew-based incident or accident**

3 CRITICAL ANALYSIS OF THE TEM MODEL

A model is an attempt to describe reality through the generalisation or the simplification of the specificity and complexity of reality. The difficulty while designing a model is to find the balance between a model too simple (which quickly becomes wrong), and one too complex (which becomes unusable).

In this report, we tried to identify the generalisation and the simplification of the TEM model, which could lead to misunderstandings of the pilots' actions when they are managing errors and threats.

In addition, we tried to evaluate the consequences of the strengths and weaknesses of the model, and the impact on pilots and airline HF culture.

The integration of the TEM model in the LOSA methodological approach is presented at the end of the chapter.

3.1 The relationship between the model and reality

3.1.1 The simplification of reality

The TEM model was built from incident/accident analysis. Thus, it is based on a reconstruction of the facts, made afterwards. The sequence "error-consequence-recovery" is relatively easy to rebuild after the events, but the problem is that observers are going to make live observation. In this situation, the identification of such a sequence is extremely difficult and may be questioned.

Therefore, the sequential aspect of the model allows only a partial reconstruction of the pilot activity. For example, the causal relationship between two actions is extremely difficult to identify by observation, and is necessarily derived from an interpretation between the different observed elements.

In addition, a recovery action is not inevitably unique and isolated but can be an element of a more general strategy: the recovery can be a set of actions. A strategy can also be designed to deal with several errors or threats that have led to an erroneous understanding of the situation (poor situation awareness).

The TEM model proposes to begin the description of the events by the error. That is to say that the starting point is one surfacing outcome of pilot activity, and not the underlying mechanism. This explains why the error classification proposed by the TEM authors is a classification by error "domain" and not by error "mechanism" (the TEM model asks "what happened?" and not "How did this happen?").

The fact that this model is sequential might be a deliberate choice of the developers to keep it as simple as possible to allow its understanding by non-experts persons. The down side of this choice is that the underlying mechanism of errors is not taken into account: drawing conclusions on threats or errors management actions is hazardous at best, if not impossible.

The model considers the absence of recovery action as a crew failure. But according to other validated theoretical models ([17], [22]), the absence of error recovery could be interpreted as a cognitive strategy in order to save mental resources, when the crew judges that the error does not present any risk for flight safety.

To conclude, it appears that the TEM model does not adequately capture the complexity of the way pilots manage the safety of their flight.

3.1.2 The questioning links

We would like here to insist on some links or absence of links in the structure of the model:

- There is no link between « external error » and « pilot error »: however, in some context, this link does exist as a major contributor to an event (e.g. an error of the Air Traffic Controller could lead to a pilot error).
- There is no link between "additional error" and "incident/accident": according to the model, each error should be detected and managed. The absence of an action following

an error is considered as a failure. However, in some operational contexts, the pilot makes priority in order to save mental resources.

- The model implicitly states that errors are always induced by external threats: the case of errors caused by problem of co-operation, fatigue, or stress is not taken into account by the model.

3.2 Strengths and weaknesses of the model

The analysis grid used in this chapter and the content are partially derived from Bove T. (2002) ([6]).

3.2.1 The strengths and their consequences

Diagnosis capacity

- The description of the main stages of threat management, errors and error management captures a large variety of human behaviours.
- The model proposes a coherent description of several possible scenarios of sequence of events.

Comprehensiveness

- The model captures human errors and their management in both normal and abnormal conditions. This means that the framework is able to deal with both successful and unsuccessful behaviours.
- The model is unique insofar as it is the only model that incorporates threats as an integrated part of the model. This issue has not previously been emphasised in any other model of error and error management.

Usability

- The model provides an intuitively logical structure to understand the error management process. Furthermore, the concepts do not require any theoretical background and should therefore be easy to understand.

3.2.2 Weaknesses of the model and their consequences

Reliability of the taxonomy

- It is interesting to note that the model distinguished between the error, the management of the error when it occurs and the management of the outcome of this error. However, this introduces a problem: determining “what” is observed might compromise the classification related to the response and outcome of the error.
- The proposed “domain” error typology cannot provide a reliable classification if based only on observation. The classification of the error in this type of typology often demands the pilot’s comments on his/her own actions. Thus, you might reconstruct the internal process which has led to an undesired state of the situation:
    - How to classify a phraseology error: communication error, procedural error, or proficiency error? Based only on observation and without knowing the underlying mechanism, you can classify an error of phraseology into one of those three categories.
    - Proficiency error and decision error: a lack of proficiency can contribute to a decision error. The same error can be rightly classified into several domains therefore the proposed classification is not exclusive. The analysis of the results becomes difficult.
- The taxonomy used for error is too simplistic and could lead to misinterpretation, especially for violation which is considered by the model as a specific error (refer to § 3.3.2 for further discussion)

Exhaustivity (level of detail)

- The model has been developed based on accident analysis (and then refined with empirical elements). It does not stem from the analysis of pilots' activity. Its capacity to proactively analyse the activity is therefore diminished, especially because the internal context of the pilots is not taken into account.
- The possible under or over estimation of the risk by the pilots is not taken into account
- The variability of risk according to context characteristics is not taken into account.

Establishing a diagnosis

The model includes only classification of behaviours (i.e. the phenotypical level), and outcomes. There is no classification of the underlying cognitive processes (i.e. the genotypical level). That is, the model classification provides a description of *what* happened but not *how* it happened. Therefore, the framework should be supplemented with other taxonomies to describe those underlying processes.

Usability

The simplicity of the model affects the range of the diagnosis. In this condition, the observation is not easy: for example, how to distinguish a communication error from a violation of the phraseology? The only possible way to discriminate the different types of error proposed by the model is to take into account the mental representation and the objectives of the pilots. Without this kind of information, the interpretation done based on observation alone remains a hypothesis that calls for validation.

3.3 The TEM model and HF culture in French Airlines

3.3.1 Human error matter

The TEM model, described in the previous chapter, does not represent a noticeable evolution of the Human Factors notions developed in the actual French CRM training. The error management topic has been addressed for at least ten years in CRM and in ab-initio training (HF certificate) through an entire chapter dealing with error detection and recovery aspects. Compared to French CRM syllabus, TEM model does not represent any added value to French Airlines pilot HF culture.

3.3.2 Discussion around Violation

There exists an ambiguous statement from LOSA concerning the issue of procedure violation. The developers claim that violations are equally collected as the errors and threats, but at the same time, the "blame free" policy is not guaranteed for observed violations.

The French CRM has the same ambivalent view, dealing with error and violation in the same training module. Those notions are respectively defined as unintentional (error) and intentional (violation). Does it mean that a violation is an intentional error?

The way LOSA and French CRM consider violating a procedure is quite paradoxical: the violation is part of the error taxonomy, but it is not an error.

Academic researches[1] about the concept of violation consider violation as an important tool for operational experts. So, why do we have to define an element of the operator expertise

[1] Alain Gras, les Macro Systèmes Techniques. Que sais-je ?

James Reason "Managing the Risks of Organisational Accidents". Ashgate. 1997

Charles Perrow. "Normal Accidents. Living with High Risks technologies". Princeton University Press. 1999.

Hofstede. "Culture's consequences".

Ashleigh Merritt, The University of Texas. Various articles on the University of Texas website on cultural differences.

Philippe d'Iribarne. La logique de l'honneur. Points SEUIL. 1989 as an error? This bias may come from the fact that even experts in the situation have difficulties to anticipate the negative consequences of a procedure violation. In addition, despite the fact that the action is done against official rules (regulation pressure), operators still feel the need to do it. Despite normative pressure, there is a variety of motives behind procedural deviation and they can be determined even for experts. The procedure is judged as incomplete, not adapted, too complex, inconsistent with higher level objectives, not related to operational culture, the reason has been forgotten (routine), or the procedure is too restricting.

Taking into account the procedure violation should lead us to consider it for what it is, that is a more or less conscious operational decision (routine violation). Learning about pilots' prioritization process when faced with operational pressures represents a clear added value.

Depending on the context, a violation could be tolerated (it is the case for most of the violations). The decision for a pilot, as a domain expert, to purposely violate a procedure, reflects his/her objective to reach a positive outcome when managing the situation. If the outcomes are not the expected ones, then the pilot was not in a position where he/she could anticipate the consequences of his/her actions. It is a decision error. The specific nature of this decision error lies in the fact that an official rule has been broken, and that the negative outcomes are particularly difficult to manage (the front line actor "enters" in unchartered territory).

This is not to say that not complying with procedures should become the norm. Strict adherence to procedure is necessary to ensure safe flight. However, the system needs to learn about actual line operations practices either to adapt itself to safe pilot practices or to eradicate unsafe deviations (the minority of deviations).

Another kind of model that would consider violation with unexpected outcomes as a decision error, or a proficiency error, should be more reliable and should provide a better diagnosis of the pilot's strategies for managing risk. A better knowledge about the decision-making mechanisms and its contributing factors would improve the analysis of the relationship between pilot and procedures (especially when coping with different operational constraints).

3.4 Methodological perspectives

- What are the observable elements used to identify the different types of errors?
- How to be sure that the observed action is a recovery action done to manage the outcome of one single anterior error?
- How do we identify the sequential process proposed by the model when we solely refer to observation?

The questions above are the ones raised by the critical analysis of the TEM model. The following chapter will be an attempt to evaluate the way LOSA methodology gathers data (errors, management actions), achieves the stated objectives and responds to the identified limits of the TEM model.

For example, in order to guaranty the validity of the collected data, the LOSA methodology should take into account the biases linked to the observation process and result classification (observation error, classification error).

In fact, the way an observer is going to select an element in a situation, and the way he/she is going to interpret it, is influenced by the following observation biases:

- Performing a selective observation based on stereotypes (the pilot is young, old, is a woman…)

Vaughan, D. (1996) "the challenger lauch decision: risky technology, culture and deviance at NASA". Chicago, IL: University of Chicago Press
Mathilde Bourrier. « Le nucléaire à l'épreuve de l'organisation ». PUF 1999.
CETCOPRA, Groupe Anthropologie Technique de la Sorbonne. Alain Gras, Sophie Poirot Delpech, Caroline Morricot. « Le contrôleur, le pilote, l'automate".

- Performing a selective observation according to the way one knows the observed person
- Having specific expectations based on the way one manages the situation (use our own reference as the only one). This bias is particularly true when the observer is himself / herself an expert of the task.
- Making confusion between the interpretation of the fact and the fact itself.
- Modifying the pilot's behaviour by creating a too formal atmosphere in the cockpit.

The best observation practice should take into account this kind of biases, and thus be restricted to writing down only facts. However, this discipline is impossible, incompatible with the human way to observe (need to refer to our own references, need to interpret what we observe in order to understand it). The observation biases are inherent to human being. Nevertheless, it should be possible to go beyond these observation limitations by the use of a structured method and tools, e.g. carried out during a debriefing session with the pilots.

The observation sessions alone are not sufficient to assess the pilot risk management. The debriefing session is the only way to gather very relevant elements to understand how specific skills are applied and the conditions to be efficient.

4 LOSA METHODOLOGY DESCRIPTION

4.1 LOSA Objectives

The LOSA developers announce several objectives of different levels.

The general objectives are the following:

- **To improve flight safety**,
- To identify and validate **flight safety precursors** (prevention),
- To better manage the change processes**.**

These general objectives can be divided into operational objectives:

- To detect the strengths and weaknesses of the actual crew pratices in term of safety**,**
- To gather the various information collected in a **data base**,
- To get **pilots' support for flight safety actions** ,
- To bring **airlines and pilots' associations closer** on the issue of flight safety**,**
- To collect in vivo data by performing **observations** of **pilots'** activity in **normal operations**.

4.2 Expected results

According to the methodology developers, the LOSA implementation should lead to the following results for the airline:

- To collect raw data according to a structured format,
- To provide data for procedures design and definition,
- To point out good examples of crew performance,
- To build a database in order to identify and study the recurrences.

4.3 Resources needed

According to airlines that have implemented the LOSA approach, the estimated cost of a campaign is roughly 350 000 Euros per campaign (source: UTC Fee, J. Klinect 2003 Dublin), keeping in mind that two campaigns are necessary to evaluate the progress achieved.

It is difficult to quantify the profitability of such an approach, but the financial impact of incidents on maintenance and insurance shows a strong sensitivity to any flight safety improvement on operational costs.

It is also important to take into account the impact of such an approach on the airline image (on passengers, on partners airlines and competitors, and on regulating authority) in a context where a great number of airlines have already carried out a LOSA and where the programme is supported by IATA, IFALPA and ICAO.

The number of observers for an audit depends on the audit size and on the observers' availability. Indeed the observers' work is not only performed during the observation phase. An additional work is required for filling in the observation form and the narrative elaboration for each phase of flight. Therefore, the LOSA designers recommend that a given observer be in charge of a maximum of 10 to 15 flights (according to rotations and planning). For example, on the one hand, if in a LOSA audit 150 domestic flights are expected to be observed, then a minimum of 10 observers are required. On the other hand, the observation of 300 flights including international flights requires 20 to 25 observers.

4.4 Preliminary conditions to LOSA implementation

4.4.1 Transversal communication on the project

A LOSA approach presents a systemic dimension: this project involves several airlines' actors towards a common objective, with an active participation of the line pilots to global safety objectives. This is a transversal project requiring a specific organisational learning.

Moreover, it is necessary to strongly involve pilots' associations in the LOSA approach. Therefore, it is of primary importance to build a formal agreement with the management and pilots' unions. It is also important to enable pilots' unions to participate in the LOSA Steering Committee in order to assure pilots' acceptance and confidence in the approach (by guaranteeing them that the analysed data are confidential, anonymous and stored in a safe place, and that line pilots participating in the audit will be protected by the de-identification of data).

4.4.2 Key functions to be defined in the airline

A specific team to manage the organisation of the LOSA approach (a LOSA Steering Committee) should be established in the airline willing to implement a methodology like LOSA.

The LOSA project manager (or LOSA Co-ordinator) within the airline should be a professional respected and recognised by the line pilots and the pilots' associations. This Co-ordinator has many responsibilities including the management of the observers recruited jointly by the airline management and the pilots' unions. He/she should know perfectly the company structures in order to maintain a transversal communication network.

It is recommended to involve in the LOSA Steering Committee representatives from all departments that may potentially be involved, including flight operations, training, flight standards, the safety department and the pilot representatives.

4.4.3 Key elements to obtain the LOSA label

IATA and ICAO accepted the following elements. The comments on these elements formulated by the University of Texas (UT) have been added here to clarify some points.

1. **Jump-seat observations during normal flight operations**
   LOSA observations should be limited to regular operations. Line checks, initial operating experience or other type of training flights should be off limits because of the stress context where the pilots are during such kind of flights. Performing observations during operational flights implies some level of trust between the pilots and the observer being in the cockpit. This confidence requires good preliminary information (pilots need to be made aware of the upcoming audit) and an adapted observer's behaviour.

2. **Joint management/pilots' unions sponsorship**
   The project should be supported by the airline actors: both management and pilots' union should officially endorse the LOSA approach. Therefore, every airline pilot should receive a letter of agreement signed by both parties.

3. **Voluntary flight crew participation**
   All LOSA data are collected with voluntary crew participation: no uncertainty should remain concerning the LOSA aims and before any observation, the observer should first ask the flight crew for permission to be observed. If the crew declines, the observer takes another flight with no question asked.
   UT comments:
   If an airline conducting a LOSA has an unreasonably high number of declines, this should serve as an indicator that there are critical "trust" issues concerning the observer or the LOSA approach.

4. **Anonymous, confidential and safety-minded data collection**
   Data collected should be anonymous, confidential and safety-minded: LOSA is not the place for a pilots' check, but it is an opportunity for organisations to learn about safety practices.
   UT comments:

Observers do not record elements that could allow identifying the observed flight crew (e.g. names, dates, flight number…). Moreover, observers should assure pilots that observed errors would not be used against them for disciplinary reasons.

5. **Observation instruments with appropriate targets**
Observation supports should be adapted to LOSA objectives: the targets to be collected are the behaviours related to risk management under normal operations. Present LOSA audit supports are based on the TEM model.
UT comments:
According to LOSA designers, it is preferable to use also the TEM in CRM training. From their perspective, if another theoretical framework is used during the LOSA audit, it must generate meaningful data on what the crews did well, what they did poorly and how they managed each phase of flight. A narrative written by the observer should have sufficient detail to allow other audit actors (like data analyst for example) to understand what happened during the flight.

6. **Trained and calibrated observers**
Observers are trained to carry out observation and keep the required discretion about it: observers have more chance to be competent if they are pilots themselves. Observers should be trained to use the TEM concept and the LOSA methodology.
UT comments:
A "calibration" phase during the training would allow minimising the observation differences between observers.

7. **Trusted data repository**
Collected data should be stored in a trusted data repository: data are stored confidentially in a database. This database can be managed by an internal airline entity (as far as this entity is able to manage confidential data, as it is the case presently for the data coming from FOQA). A third party neutral and trustworthy can act as a repository for airlines subject to strong social, political and economical difficulties.

8. **Data scrutinised before data analysis**
Raw data are carefully examined and checked before analysis: special meetings are organised to scrutinize the raw data obtained during observations. The participants to those meetings consist of representatives from pilots' unions, operational experts on the observed fleet and LOSA Steering group members.
UT comments:
The aim of specail meeting discussions is to check the consistency between elements considered as errors by observers and the ones mentioned in the flying standard (Pilot manual). The observations considered as irrelevant by the group are removed from the database.

9. **Data are used to identify targets for enhancement**
Data are analysed and patterns can emerge (recurrence of an issue or an error), and allow to assess procedures or training contents. After a minimum of three years, the airline can conduct another audit to see if there have been performance improvements.
UT comments:
The airline could develop an action plan in order to change the identified issues.

10. **The results are given to the pilots**
Results and management plan for improvements are given to pilots as soon as possible in order to avoid the pilot to mistrust the overall approach.

4.5 LOSA step by step

The Figure 3 presents the different phases of LOSA. The approach can be described following four main steps:

1. The preparation step

2. The observation step
3. The data processing step
4. The result production and dissemination step

The preparation of the audit consists in the management of a set of tasks by the LOSA Co-ordinator and/or a LOSA Progress Comity before to start the observation:

- To gather information from other airlines which have already conducted a LOSA
- To set out an agreement within the airline between the management and the pilots representatives (pilot association or unions).
- To inform pilots that a LOSA is going to be carried out in the airline via internal communication means
- To distribute to each pilot a letter explaining the LOSA objectives, with the signature of management and pilots representatives.
- To eventually decide of the specific domain which are going to be addressed by LOSA, with the agreement of all stakeholders
- To define the scope of the audit (number of observation sessions, type of flight to be observed, …)
- To select the observers, and to organise the training and observation planning. This specific aspect is detailed further in this section.
- To create and adapt the methodological tools (observation grid, …)
- To organised and secure the database and the data processing (software, location...)

The three following step (observation, data processing and dissemination of the results) will be detailed in the last part of this section.

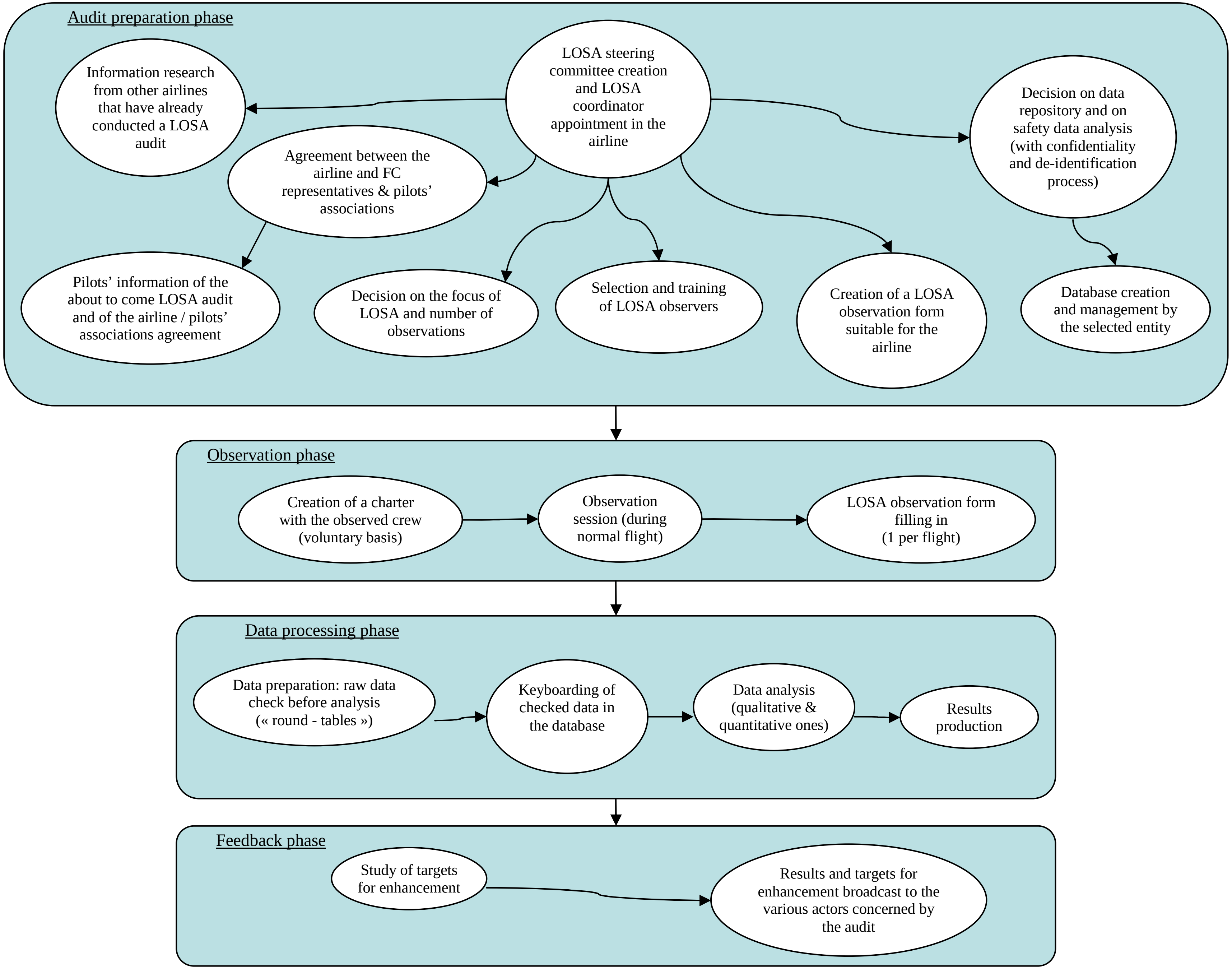

Figure 3 : LOSA step by step

4.5.1 The LOSA training

4.5.1.1 For whom?

The objectives of the LOSA training are:

- To allow the observers to understand the notions linked to Threat and Error Management
- To be able to explain if necessary to flight crew the aim of a LOSA audit
- To be able to code their observations (by using the LOSA Observation Form presented in Appendix 2)

The LOSA methodology designers recommend selecting observers among pilots (like line pilots, instructors, safety pilots). They need to be trusted and respected pilots in order to support the LOSA acceptance by the airline pilots.

The observers' team can include non-pilot observers as long as they can anticipate and understand flight crew tasks and their operational context. However, the LOSA designers specify that this kind of profile should be in minority in the observers' team.

4.5.1.2 How?

The University of Texas members conduct in general the LOSA observers' training in audited airline. This training comprises three parts:

- **The first part** (two or three days depending on airline's request) contains a presentation of the LOSA methodology; the TEM model and the LOSA Observation Form (see Appendix 2 for the Observation Form). More precisely, the following subjects are studied :
  - Threats and threat management observation and the corresponding coding using the LOSA Observation Form,
  - Errors and errors management observation and the coding using the LOSA Observation Form,
  - Observation and use of the LOSA Observation Form for the coding of the undesirable aircraft states and their management,
  - Writing of detailed narratives for each observed flight,
  - Sending the encoded files to « The LOSA Collaborative » (the LOSA working group of the University of Texas).

  The training also provides observers with some elements on how to present themselves to the crews and how to behave in the cockpit.
- The **Second part** is the implementation of the LOSA theoretical aspects. Observers should carry out one or two observations in the airline actual operational conditions in order to get used to the LOSA methodology.
- The **Third part** is a « calibration » phase for observers. Observers can speak about the observations performed in operational context and the difficulties potentially faced during observations and data coding.

To assist in the design of LOSA training in the airline, the LOSA methodology designers recommend to the LOSA Steering Committee members to attend a LOSA observer training at another airline first or to attend a LOSA Conference organised by the University of Texas.

4.5.2 LOSA observations and Behavioural Markers

This section deals with the second phase of the LOSA methodology: the observation phase.

4.5.2.1 Observations

According to the flight type (domestic/international, fleet type), pilot management and training can be different (according to the culture differences among flight sectors), which can have an impact on the way observed flight crew will behave. Therefore, it is of primary importance to consider the airline “sub-cultures” in the LOSA audit and then to consider the airline as composed of a set of sub-groups to be observed, to allow comparisons concerning the management and training of such sub-groups.

The LOSA designers give as general guideline to decide the number of flights to be observed during a LOSA audit, to match the number of observations per fleet to the relative number of departures per day. Therefore, if X percent of departures occurs on Fleet A, then approximately X percent of the LOSA observations should occur on Fleet A.

Moreover, according to the fleet size, the number of flight crews (sampled as far as possible with different characteristics) to be observed will vary:

- In large fleets, 50 or more crews (and not flight legs) selected randomly will provide statistically valid data,
- In smaller fleets, 30 or more crews will work, although the risk of bad conclusions starts to increase as the number of observed crews drops,
- Finally, if the fleet is small (below 20 crews), it is impossible to conduct statistical analyses. Therefore, the observed groups should be viewed as “case studies” rather than representing the overall fleet.

Before any observer can board an aircraft to perform an observation, the crew must grant permission. As LOSA is based on voluntary consent, the LOSA designers emphasise the fact that if this permission is not given, the observer should choose another flight,without asking any question. If an airline experiences a big number of crew refusals, this may be a sign that there are critical issues involving pilots trust in LOSA.

During observation flights, observers should keep in mind that their role is not to test or judge the crews, but to collect safety data on threats and errors appearance and their management during normal flight operations. Moreover, observers should act “as flies on the wall”, i.e. be non-threatening and unobtrusive in order to minimise the discomfort or pressure possibly felt by the crew when observed.

In the LOSA methodology, no debrief is planned after the flight. The explanation given by the LOSA designers is that with a debrief crews would be likely to think there are evaluated individually (like during line checks) and that pilots’ remarks could pollute the “data objectivity”.

Data collected during the flight should enable observers to fill out after each flight the LOSA Observation Form containing detailed narratives (see Appendix 2 for an example of Observation Form). This Observation Form is a six pages document composed of:

- A part presenting general information on the observed flight and the crew
- An open descriptive part (with detailed narrative) for each phase of flight (a total of four) and for the overall flight.
- A Threat Management Worksheet presenting the threat descriptions (according to a coded threat list) and their management
- An Error Management Worksheet presenting the error descriptions (according to a coded error list) and their management
- An Undesirable Aircraft State (UAS) Management Worksheet presenting the UAS descriptions (according to a coded UAS list) and their management

The LOSA designers recommend giving observers a contact name in the LOSA Steering Committee (for example the LOSA Coordinator) who they can consult if they experience difficulties concerning observations.

4.5.2.2 LOSA Behavioural Markers

The University of Texas uses behavioural markers in the LOSA methodology. These markers are presented in Table 2. Each marker has been validated as relating to either threat and error avoidance or management. If a behavioural marker is observed, it is rated in relation to the phase of flight concerned and according to a scale from 1 to 4 presented in Table 1:

1	2	3	4
Poor Observed performance had safety implications	**Marginal** Observed performance was barely adequate	**Good** Observed performance was effective	**Outstanding** Observed performance was truly noteworthy

Table 1: Behavioural evaluation scale

In Table 2, the phases of flight are presented as follows: **P**: Pre-departure/Taxi; **T**: Takeoff /Climb; **D**: Descent/Approach/Land; **G**: Global. Moreover, underlined items are commented in § 5.4.2.

Marker name	Explanation	Example	Phase
SOP Briefing	The required briefing was interactive and operationally thorough	- Concise, not rushed, and met SOP requirements - Bottom lines were established	P-D
Plans Stated	Operational plans and decisions were communicated and acknowledged	- Shared understanding about plans - "Everybody on the same page"	P-D
Workload Assignment	Roles and responsibilities were defined for normal and non-normal situations	- Workload assignments were communicated and acknowledged	P-D
Contingency Management	Crew members developed effective strategies to manage threats to safety	- <u>Threats and their consequences were anticipated</u> - <u>Used all available resources to manage threats</u>	P-D
Monitor / Crosscheck	Crew members actively monitored and cross-checked systems and other crew members	- Aircraft position, settings, and crew actions were verified	P-T-D
Workload Management	Operational tasks were prioritized and properly managed to handle primary flight duties	- <u>Avoided task fixation</u> - Did not allow work overload	P-T-D
Vigilance	Crew members remained alert of the environment and position of the aircraft	- <u>Crew members maintained situational awareness</u>	P-T-D
Automation Management	Automation was properly managed to balance situational and/or workload requirements	- Automation setup was briefed to other members - <u>Effective recovery techniques from automation anomalies</u>	P-T-D

Evaluation Of Plans	Existing plans were reviewed and modified when necessary	- Crew decisions and actions were openly analyzed to make sure the existing plan was the best plan	P-T
Inquiry	Crew members asked questions to investigate and/or clarify current plans of action	- Crew members not afraid to express a lack of knowledge - “Nothing taken for granted” attitude	P-T
Assertiveness	Crew members stated critical information and/or solutions with appropriate persistence	- Crew members spoke up without hesitation	P-T
Communication Environment	Environment for open communication was established and maintained	- Good cross talk – flow of information was fluid, clear, and direct	G
Leadership	Captain showed leadership and coordinated flight deck activities	- In command, decisive, and encouraged crew participation	G

Table 2: University of Texas behavioural markers rating scale

4.5.3 Data processing and results dissemination process

4.5.3.1 Data processing phase

The following phase in the LOSA methodology is the data processing.

The LOSA Steering Committee is in charge of organising the data processing. The analyst should be familiar with the airline operational procedures and should have database management and analysis skills.

Before the analysis itself, the raw data are reviewed and prepared. The time required for this should not be underestimated as it can take up to 70 percent of the overall data processing effort.

The process of data preparation before analysis follows the following steps of the “quality data management” (defined by the University of Texas):

- Consistency check in observation forms (i.e. review of narratives to check if each threats and errors are present in the other observation form worksheets in term of threat, error and undesirable aircraft state management)
- Check if the data are coded one by one completely and correctly
- Data review by a committee composed of the analyst and pilots qualified in the observed fleets (possibly fleet managers or LOSA Steering Committee members, but none of the observers). The group task is to review and verify the observations against current airline manuals, policies and procedures. They have to identify the significant data that will be maintained in the database in term of threats, errors and undesirable aircraft states. This step ensures a data integrity check and builds confidence in the results (during the dissemination phase) as the data are in line with the airline standards.
- Final check before analysis.

The prepared observation data are then analysed qualitatively and quantitatively. The most frequent threats, errors, undesirable aircraft states, their management and the « CRM countermeasures » are identified.

4.5.3.2 Results dissemination process

After results production, the LOSA Steering Committee organises the preparation of a written report in collaboration with the data analyst. According to the found results, the LOSA Steering Committee studies targets for enhancement. These targets need to be data-driven and action-focused.

Results and targets for enhancement are presented in the final report, which will be used to support the audit conclusions dissemination to airline management (in operations, training, safety…) and to airline pilots.

To monitor in a long-term perspective the evolution of enhancements after a LOSA audit, it is recommended to conduct a second LOSA audit about three years later.

4.6 LOSA description summary (LOSA designers point of view)

<u>The same theoretical model for observers and pilots</u>

The TEM model is included in the observers' training as a conceptual guide for observation. At the same time, the integration of this model in the pilots' CRM is recommended to provide them with an explanatory framework of their actions.

<u>Normal operations</u>

The LOSA methodology allows systematic collection and analysis of data coming from normal operations. These data give a precious outline of what airlines do well and the domains where enhancements are needed. LOSA data make it possible to clarify strengths and weaknesses in everyday operations (to fomally recognize what is already known informally).

<u>Real time data collection – A pro-active method</u>

According to LOSA designers, this methodology would avoid an important bias by collecting raw data in real time conditions and not in a postponed way (with a risk of "rebuilding" of the real situation afterwards if the testimonies are collected a long time after the flight). The authors use studies of testimonies reliability to illustrate their argument ("The disinformation effect" of E.F. Loftus and H.G. Hoffman).

According to LOSA designers, this methodology is pro-active whereas all the others analysis tools are reactive. This pro-activeness would enable a better understanding of the reasons for an error.

The methodology would allow showing the airline strengths thanks to positive examples of crew actions *(however, this is probably true in theory; no example is given in the articles studied in this project)*

<u>Possible combination with existing tools</u>

Another strength of LOSA would be the possible combination of this methodology with other safety tools / investigation methodologies. This methodology would be complementary and could allow the validation of conclusions obtained from the other investigation means. Therefore, the practical implementation of LOSA within a given airline can be adapted to its specific needs, and thus mitigate some limitations mentioned in this document.

It should be noted that LOSA data could be used for LOFT (Line Oriented Flight Training)

<u>Promote a safety culture establishment or improvement in the airline</u>

LOSA would promote safety culture establishment in airlines or help in the safety change process.

Moreover, the results of precedent studies have shown a certain variability between airlines and flight types, which can be explained by existing cultures or sub-cultures (by flight types) within the airline. Therefore, LOSA could help point out the practice differences linked to company cultures.

Other aspects

Finally, LOSA:

- Is an internal communication tool (between management and operational staff),
- Participates in the training improvement process,
- Allows data comparisons with other airlines.

LOSA is also a tool providing manufacturers with operational data on aircraft and airlines which can enable them to launch or update specific studies (like non-stabilized approaches). Therefore, LOSA could produce data helpful to design procedures.

5 CRITICAL ANALYSIS OF LOSA METHODOLOGY

5.1 Preliminary conditions to LOSA implementation

It is important to highlight that LOSA implementation implies actual investment for the airline in term of time, human resources, and then funding.

Moreover, there are three other constraints:

- Obligation to conduct two audits to compare the results to evaluate the impact of measures implemented after the first audit,
- The compliance to the ten key elements necessary to obtain the LOSA label requires preparation work, with the definition of roles and responsibilities within the airline,
- The airlines are supposed to evaluate for themselves the meaning of the results and figures, to be able to determine the corrective measures to be implemented. This work can require specific skills, particularly in Human Factors, and take a lot time.

5.2 The presented results

The results presented in the University of Texas articles or in the testimonies of airlines that have already conducted a LOSA, or in presentations given in the LOSA Conferences, give no information on risky or good practices performed by pilots in “Threats and error management”.

In these documents, statistical data by phase of flight, “counting” of observed errors or error classification according to the TEM typology give only little information on pilots’ risk management.

Moreover, when presented, the results are never in questions and there is no explanations on figures according to the way data are collected. Data should be kept as they are, as if they could by themselves reflect the reality of flights and the observed airline. The validity of results is never questioned, for example:

- In [21], a very low errors percentage for the Taxi/Park phase (2 percent) is not moderated by a possible observation bias. This phase of flight is presented here as the phase producing the least number of errors.
  However, at the end of flight, observer attention can decrease. Indeed, it is well known that incidents (runway incursions, taxiway error) occur during this phase of flight, in which pilots’ attention drops (because of fatigue, arrival stress).
- In [20], according to the authors company cultures differences explain the different distributions between “intentional non-compliance errors” and “procedural errors” which exist among several airlines (which remains a valid explanation).
  However, there is no explanation concerning the way the observer differentiated between these elements. Such a differentiation seems impossible if based only on observation without any debriefing with the observed pilot.
- In [19], the authors interpret an important rate of errors in automation handling and checklists monitoring as the two most frequent errors occurring for pilots’ activity.
  However, it is more valid to say that they are the most *observed* errors and not the most *frequent* errors in general. These kinds of errors are anyway the most easily notable errors (as they are procedural errors). Moreover, nothing is said concerning the risks created by this kind of error (Source: ATA Operations and Safety Forum 2000)

The interpretation of the results would require a little more moderation to determine more appropriately the targets for enhancement.

The percentages of errors do not allow a detailed understanding of the risky and good practices. No example of behavioural element is given in the results we studied.

5.3 LOSA training

In the documentation we studied, there is only little information on the training program and they are only general in nature. There is no detail on the way observers are "calibrated", or the explanations given to observers on observation process, the observation rules, the limitations and biases.

The TEM model and the LOSA Observation Form seem to constitute the core of the training.

However, it is important to make observers well aware of the different aspects linked to practicing observations, like:

- The Human Factors aspects related to the individual and collective error management: the different error mechanisms, the role of the context in error management, the conditions for collective error management, the risks linked to recovery of some errors or the lack of recovery…
- The precaution required when observing (awareness of observation bias, no intrusion in the on going activity, no judgement, the neutral role of the observer …)

5.4 The observation phase

5.4.1 Observation limitations

How is it possible to remove ambiguity on observed elements or to have a realistic image of the pilots' internal context (fatigue level, situation awareness…) without a debriefing with pilots?

The LOSA designers chose to consider the pilot as a « black box », stimulated by threats and able in return to create visible reactions more or less adapted. This simplistic vision of the psychological processes at stake and the expertise required to perform the piloting tasks is not likely to provide spectacular information on pilots' risk management practices.

A debriefing session presented adequately (taking the required precautions) in order not to put pilots uncomfortable nor giving them the impression to be tested (nor for them to have to justify the actions performed during the flight) would enrich the observers' collected elements and the vision he/she may have about the flight, as well as prevent some bias that could appear during observation.

5.4.2 Validity of proposed behavioural markers

The behavioural markers underlined in Table 2 (§4.5.2.2) are examples of elements said to be "observable" but in fact are difficult to really observe, their detection is more often based on interpretations, impressions or generalities. The behavioural markers can appear for different situations or psychological contexts making obsolete the thematic classification proposed. Indeed, a given behavioural marker can correspond to several explanations according to the context and the pilot's mental representation. It is therefore useful to question the behavioural marker:
Why and how was this action decided? What level of risk awareness is displayed through this action? What is the operational context?

5.4.3 Context integration

The context integrated in the methodology (in the Observation Form), is above all the external context (the environment: departure and arrival airport, flight type, the flying pilot, the separation of observations by phase of flight…). This context is clarified in the detailed narratives for each given flight by the observer. Moreover, some contextual factors (including environmental and operational conditions, crew experience, crew composition, etc…) allow the building of the profile for the observed flight.

However, the internal context of pilots (mental representations, priorities, state of mind, fatigue level, stress level…) are not integrated.

Here also, a debriefing with the observed pilots would enable a better understanding of this internal context. Thus, the driving objectives, the situation awareness level, the pilot's state of mind could be taken into account to understand the observed actions.

5.5 Summary of the methodology review

A summary of end-user questions to the methodology is recorded hereafter (Adapted from an airline internal summary of the « Third LOSA week », DUBAI in October 2002):

- Learning nothing,
- Not being able to exploit the final results,
- Rejection of the approach by flight crews,
- Insufficient quality of observers,
- Lack of data confidentiality,
- Too much reliance on a third party,
- LOSA being only a fashion thing,
- Difficulties to obtain the support from all operational units,
- English translation of observation comments (if a third party is performing the data processing),
- Acceptance of the LOSA approach by the airline management,
- Costs and process control,
- Needing to perform 2 audits to measure the improvements,
- Problem to obtain a jump seat agreement for the observer.

Although some aspects are being addressed by LOSA, the detailed review in the previous paragraph shows that:

- The methodology implementation requires an important investment in resources for the airline.
- The observation biases are not taken into account during the data collection and processing, and during results analysis. Therefore, the data validity is not questioned enough.
- No debrief is planned with observed pilots after the flight, therefore there is no possibility to question the observer's interpretations on collected data.
- The internal pilots' context is not considered in the LOSA Observation Form, so there is no access to this context (mental representation, precise objective when performing the action, fatigue level…)
- The observation scope is reduced by the partial consideration of violation notion.

6 PERSPECTIVES FOR EXPANDING ON THE STATE OF THE ART

In the context of the LOSANGE project, a study of alternative techniques to LOSA will follow this State of the art:

- In other industrial or academic domains: the theme of “front line operators” practices relying on non-technical skills is a subject shared with other industries (especially in air traffic control and nuclear), and is a research subject for industrial psychology.
- In French (and European) airlines: many approaches and initiatives dealing with flight safety are implemented by airlines (flight data monitoring, pilots’ voluntary reports, and incident analysis). The next steps of the LOSANGE project should enable to highlight the redundancies between these airlines approaches and LOSA.

APPENDIX 1: LIST OF CONSULTED REFERENCES

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APPENDIX 2: LOSA OBSERVATION FORM

This appendix presents an example of LOSA Observation Form extracted from the document « LOSA Advisory Circular – Draft submitted to FAA (AFS-230), 14/09/2004 » [[2]], written by the Human Factors Research Project (University of Texas).

LOSA Observation Form

Observer Information

Observer ID (Employee number)	*3059*	**Observation Number**	*#1*

Crew Observation Number (e.g., "1 of 2" indicates segment one for a crew that you observed across two segments)	*1*	of	*1*

Flight Demographics

City Pairs (e.g., PIT-CLT)	*PIT - LAX*			
A/C Type (e.g., 737-300)	*B-757*			
Pilot flying (Check one)	CA		FO	*X*

Time from Pushback to Gate Arrival (Hours:Minutes)	*4:55*	**Local Arrival Time** (Use 24 hour time)	*09:55*
Late Departure? (Yes or No)	*Yes*		

Predeparture / Taxi

Narrative	Your narrative should provide a context. What did the crew do well? What did the crew do poorly? How did the crew manage threats, crew errors, and significant events? Also, be sure to justify your behavioral ratings.

The CA established a great team climate – positive with open communication. However, he seemed to be in a rush and not very detail oriented. The FO, who was relatively new to the A/C, tried to keep up but fell behind at times. The CA did not help the cause by interrupting the FO with casual conversation (marginal workload management).

All checklists were rushed and poorly executed. The CA was also lax verifying paperwork. This sub-par behavior contributed to an undetected error - the FO failed to set his airspeed bugs for T/O (poor monitor/cross-check). The Before Takeoff Checklist should have caught the error, but the crew unintentionally skipped over that item. The FO noticed the error upon commencing the takeoff roll and said, "Missed that one."

The Captain's brief was interactive but not very thorough (marginal SOP briefing). He failed to note the closure of the final 2000' of their departing runway (28R) due to construction. Taxiways B7 and B8 at the end of the runway were also out. The crew was marked "poor" in contingency management because there were no plans in place on how to deal with this threat in the case of a rejected takeoff. Lucky it was a long runway.

24

Takeoff / Climb

Narrative	Your narrative should provide a context. What did the crew do well? What did the crew do poorly? How did the crew manage threats, crew errors, and significant events? Also, be sure to justify your behavioral ratings.

Takeoff was normal. ATC granted a right turn VFR climb which was commenced at 600 ft. Climb to flight level 20000 with step climbs to 35000 ft. Eventually leveled at 31000 ft about 90 miles North. When established at FL200, ATC cleared the crew to FL270. They accepted and the First Officer dialed 230 instead of 270 in the MCP. The Captain caught the error on cross-verification.

Cruise

Narrative	Your narrative should provide a context. What did the crew do well? What did the crew do poorly? How did the crew perform during the handover?

Crew stayed attentive to aircraft position throughout cruise.

25

Descent / Approach / Land / Taxi

Narrative	Your narrative should provide a context. What did the crew do well? What did the crew do poorly? How did the crew perform during the handover?

Briefing to TOD – The approach brief much better than their takeoff brief. They expected runway 25L from the Civet Arrival for a straight-in visual approach. Jepp charts were out, contingencies talked about, and everything was by the book (outstanding SOP brief and plans stated).

10000' to slowing and configuring – ATC cleared the crew to 25L, but at 8000', ATC changed us to the Mitts Arrival for runway 24R due to a slow moving A/C on 25L. The CA changed the arrival and approach in the FMC, tuned the radio, and quickly briefed 24R. As soon as everything was clean, ATC called back and told the crew they could either land on 25L or 24R at their discretion. Since time was a factor, the crew discussed and decided to stick with the approach into 24R. The crew was flexible and the CA did a nice job assigning workload. FO flew the plane while the CA checked everything over one more time (outstanding evaluation of plans). The crew was also better monitors and cross checkers. However, their execution of checklists was still a little sloppy – late and rushed (marginal monitor and cross check)

Bottom lines to Flare / Touchdown – The approach was stable, but the FO let the airplane slip left, which resulted in landing left of centerline. Since the FO was new to this aircraft (1 month flying time), the observer chalked it up to a lack of stick and rudder proficiency.

Taxi-in – The crew did a great job navigating taxiways and crossing the active 24L runway. Charts were out and both heads looking for traffic. (outstanding taxiway / runway management). However, there were no wing walkers meeting the aircraft in a congested ramp area.. A common problem in LAX.

Overall Flight

Narrative	This narrative should include your overall impressions of the crew.

Overall, the crew did a marginal job with planning and review/modify plans during predeparture. However, during the descent/approach/land phase, it was excellent. Their execution behaviors were marginal to good for the entire flight.

While the takeoff brief was marginal, the CA made an outstanding approach brief. Open communication was not a problem. Good flow of information when the flight's complexity increased with the late runway change. They really stepped it up.

During predeparture, the CA introduced an unnecessary element of being rushed, which compromised workload management. However, his decisiveness and coordination in the descent/approach/land phase kept his leadership from being marked "marginal."

The big knock against this crew involved checklists, cross verifications, and all monitoring in general. They were a little too complacent during low workload periods (e.g., No altitude verifications during climb). The CA set a poor example in this regard. When the workload increased, the crew did a good job.

26

Threat Management Worksheet

Threat ID	Threat Description			Threat Management	
	Describe the threat	**Threat Type**	**Phase of Flight** 1 Predepart / Taxi 2 Takeoff/Climb 3 Cruise 4 Des/App/Land 5 Taxi-in	**Linked to flight crew error?** (Yes / No)	**How did the crew manage or mismanage the threat?**
T1	*Runway and taxiway construction on their departing runway (final 2000')*	*103*	*1*	*No*	*Threat mismanaged – CA failed to include the construction and closures in his brief. No plans were made in the event of a rejected takeoff, which is required by airline SOP.*
T2	*Late ATC runway change - changed runway to 24R from 25L due to a slow moving aircraft on 25L*	*101*	*4*	*Yes*	*Threat managed – CA reprogrammed the FMC, handled the radios, and placed emphasis on the FO to fly the aircraft.*
T3	*After a late runway change, ATC called back and told the crew that it was at their discretion to land on 24R or 25L*	*101*	*4*	*Yes*	*Threat managed – CA asked for the FO's preference. They mutually decided to continue the approach into 24R because it was already in the FMC.*
T4	*On taxi-in, there were no wing walkers meeting the aircraft in a congested ramp area in LAX*	*204*	*5*	*Yes*	*Threat managed – The crew called ground ops and wing walkers were dispatched to the airplane*
T5					
T6					

Threat Codes

Environmental Threats		Airline Threats	
100 Adverse Weather	103 Airport Conditions	200 Airline Operational Pressure	204 Ground / Ramp
101 ATC	104 Heavy traffic (air or ground)	201Cabin	205 Dispatch / Paperwork
102 Terrain	199 Other Environmental Threats	202 Aircraft Malfunctions / MEL Items	206 Manuals / Charts
		203 Ground Maintenance	299 Other Airline Threats

Error Management Worksheet

Error ID	Error Description: Describe the crew error	Phase of flight (1 Predepart / Taxi, 2 Takeoff/Climb, 3 Cruise, 4 Des/App/Land, 5 Taxi-in)	Linked to threat? (If Yes, enter the Threat ID)	Error Type	Error Response / Outcome: Crew Error Response (1 Detected, 2 No response)	Error Outcome (1 Inconsequential, 2 Undesired state, 3 Additional error)	Error Management: How did the crew manage or mismanage the error?
E1	*CA failed to brief a rejected takeoff for shortened departing runway due to construction.*	*1*	*T1*	*403*	*2*	*1*	*No error management.*
E2	*FO failed to set his airspeed bugs.*	*1*		*304*	*2*	*3*	*Linked to error #3*
E3	*In running the Before Takeoff Checklist, the FO skipped the takeoff data item.*	*1*		*401*	*2*	*2*	*Linked to UAS #1*
E4	*At FL200, the crew was cleared to FL270. They accepted and the FO dialed 230 instead of 270 in the Mode Control Panel.*	*2*		*302*	*1*	*1*	*Error managed - Captain caught the error on cross-verification.*
E5	*FO, hand flying, let the airplane slip a little to the left during the final approach.*	*4*		*300*	*2*	*2*	*Linked to UAS #2*

Error Type Codes

Aircraft Handling	Procedural	Communication
300 Manual Flying	400 SOP Cross-verification	500 Crew to External Communication
301 Flight Control	401 Checklist	501 Crew to Crew Communication
302 Automation	402 Callout	599 Other Communication
303 Ground Handling	403 Briefing	
304 Systems / Instruments / Radios	404 Documentation	
399 Other Aircraft Handling	499 Other Procedural	

28

Undesired Aircraft State (UAS) Management Worksheet

UAS ID	UAS Description		UAS Response / Outcome			UAS Management
	Linking Error? (Enter the Error ID)	**Undesired aircraft state description**	**UAS Code**	**Crew UAS Response** 1 Detected 2 No response	**UAS Outcome** 1 Inconsequential 2 Additional error	**How did the crew manage or mismanage the undesired aircraft state?**
UAS 1	*E2*	*Wrong airspeed bugs on takeoff roll*	*1*	*1*	*1*	*Errors mismanaged – The bug error should have been caught with the Before Takeoff Checklist, but the FO missed the item. The FO detected and corrected the error on the roll.*
UAS 2		*FO landed left of the centerline.*	*86*	*1*	*1*	*Error mismanaged - FO tried to correct but still landed left of the centerline. Approach was stable and made the first high-speed taxiway.*
UAS 3						

Undesired Aircraft State Type Codes

Configuration States
1 Incorrect A/C configuration - flight controls, brakes, thrust reversers, landing gear-
2 Incorrect A/C configuration – systems (fuel, electrical, hydraulics, pneumatics, air-conditioning, pressurization, instrumentation)
3 Incorrect A/C configuration – automation
4 Incorrect A/C configuration - engines

Ground States
20 Proceeding towards wrong runway
21 Runway incursion
22 Proceeding towards wrong taxiway / ramp
23 Taxiway / ramp incursion
24 Wrong gate
25 Wrong hold spot
26 Abrupt aircraft control - taxi

Aircraft Handling States – All Phases
40 Vertical deviation
41 Lateral deviation

42 Unnecessary WX penetration
43 Unauthorized airspace penetration

44 Speed too high
45 Speed too low

46 Abrupt aircraft control (attitude)
47 Excessive banking
48 Operation outside aircraft limitations

Approach / Landing States
80 Crew induced deviation above G/S or FMS path
81 Crew induced deviation below G/S or FMS path

82 Unstable approach
83 Continued landing - unstable approach
84 Firm landing
85 Floated landing
86 Landing off C/L
87 Long landing outside TDZ
88 Landing short of TDZ

99 Other Undesired States

APPENDIX 3: ABOUT THE AUTHORS AND THE REPORT

The authors of this document at Sofréavia are presented below:

The project manager, **Mr. Ludovic Moulin** is a Human Factors expert (ergonomist – psychologist, with a Master's degree in Ergonomics) with 8 years of experience in different domains like aeronautics and nuclear, in various activities such as air traffic control, avionics maintenance, piloting, cabin safety, nuclear maintenance, nuclear maintenance conduct. The interventions carried out consisting in production of study reports, training report and support (CRM, TRM, and other trainings on Human Factors and safety aspects) and development of methodologies of non-technical skills observation. The techniques used to perform these works, in addition to classical methods such as work analysis and individual interviews, experiments, have often consisted in interdisciplinary work group animation.

Mrs. Stéphanie Joseph is a Human Factors specialist (ergonomist with a Master's degree in Ergonomics) with a 3 years experience in aeronautics. She was involved in two large-scale studies on emergency evacuations from commercial aircraft cabins, including experimental protocol definition, the carrying out of the study and the experimental follow up. Thanks to professional and personal activities, she acquired a good knowledge in the piloting domain. Her participation in several training projects enabled her to develop skills dealing notably with training programs, needs analysis and interviews.

Mr. Laurent Claquin is a Human Factors specialist (ergonomist – psychologist with a Master's degree in Ergonomics) with a 6 years experience in different domains like industry, services, aeronautics and nuclear, with always the aim of safety and/or health improvement. Thanks to his different missions of consulting and studies, he developed skills in methodology design, Human Factors assessment tools, and training. His participation to cockpit simulation and projects dealing with NOTAMs enabled him to acquire experience about on-board activities.

The reviewers from the F-DGAC/DAST who approved this document are presented hereafter:

Mr. Stéphane Deharvengt is the Head of the Human Factors Programme for the F-DGAC/DAST (French – Direction Générale de l'Aviation Civile – Directorate for Strategic and Technical Affairs). He is an Aviation Engineer with a Master's degree in Ergonomics. He is presently studying for a Ph.D. in Ergonomics. On the international side, he represents F-DGAC on the JAA-HFStG (in this context, he has recently been nominated Chairman of this JAA - Human Factors Steering Group) and at ICAO (in the ICAO Flight Safety and Human Factors Study Group). He was also a European Commission evaluator and technical advisor for several aviation research studies. Moreover he has skills in Cockpit design and certification (he is Human Factors assistant specialist in the A380 certification and helped developed the new EASA proposed regulation for cockpit Human Factors certification), in CRM, in Experience Feedback - Flight Data Monitoring, and in Cabin Safety. He has an experience in training as he taught Aviation Human Factors regulation, experience Feedback and Cabin Safety courses to Aviation Engineers and Ergonomists. He has an 11 years private pilot license.

Mr. Claude Valot is a Senior Research Psychologist, employed in the Cognitive Science department of the Aerospace Medical Research Institute (IMASSA) where he has been since 1980. He received his PhD in ergonomics from Toulouse University. He has been involved in numerous Human Factors fields of military and civilian aeronautics: maintenance, Human Factor courses, human errors, violation, designing. He is a consultant for CRM programs in the French Air Force, in Navy and Army aviation. He is also involved in Human Factors certification team and he is a consultant for French Civil Aviation Authority. His current research interests include: cockpit automation, reasoning, decision making and temporal constraints, metacognition.

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