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USE OF ERRONEOUS PARAMETERS AT TAKEOFF

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FOREWORD

This document is the summary report of the "Use of erroneous parameters at takeoff" study ordered from the LAA by the BEA and the DGAC, in which Air France and Corsairfly participated.

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We wish to offer our sincere thanks to all those who contributed to this study:

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- All those who made a contribution to drafting the report and its translation into English.

CONTENTS

GLOSSARY

ACARS	Arinc Communications Addressing and Reporting System
BLT	Boeing Laptop Tool
Card	Paper document on which takeoff parameters are shown
C/L	Check List
CRZ	Cruise
EFB	Electronic Flight Bag
HF	Human Factors
Flex TO	Takeoff at reduced thrust
FMS/FMGS	Flight Management System/ Flight Management and Guidance System
FOB	Fuel On Board
FRAM	Functional Resonance Analysis Model
GRWT/GWT	Gross Weight
kt	Knots
Loadsheet	Loading report, weight and balance breakdown
MAC	Mean Aerodynamic Chord
MCDU	Multipurpose Control and Display Unit
MTOW	Maximum Take Off Weight
ND	Navigation Display
Co-pilot	Co-pilot
PF	Pilot Flying
PFD	Primary Flight Display
PLN	Flight plan
PNF	Pilot Not Flying
QFU	Magnetic bearing of runway
QRF	Quick Return Flight
TOW	Take Off Weight
V1	Decision speed
V2	Takeoff safety speed
Vr	Rotation start speed
VMO	Maximum Operating Speed (added by translator, see page 22)
ZFW	Zero Fuel Weight

INTRODUCTION

Two similar serious incidents occurred in France in July 2004 and December 2006. The first occurred at Paris Charles de Gaulle and involved an Airbus A 340-300 belonging to Air France, the second occurred at Paris Orly and involved a Boeing B 747-400 belonging to Corsairfly.
The common cause of these two events was the crew entering much lower than normal takeoff weight and values for associated parameters (thrust and speeds). The effect in each case was an early rotation with a tailstrike on the runway followed by a return after dumping fuel. Beyond the damage to the aircraft, these takeoffs were undertaken with inadequate thrust and speed, which could have led to a loss of control of the aircraft.
These incidents were the subject of BEA investigations and reports, the first published in the "Incidents in Air Transport" journal number 4, July 2006, and the second referenced df-ov061210 and dated January 2007. These reports can be consulted on the BEA web site: www.bea.aero.

Elsewhere in the world, several other accidents, serious incidents and incidents of the same type have occurred during recent years. These generally involved new generation aircraft, being caused by more or less significant errors in entering takeoff parameters that were not detected by crews. They occurred in various airlines and on various types of large aircraft manufactured by Airbus and Boeing. The most serious event involved the destruction of a B 747-200 Cargo on takeoff at Halifax and the death of all the crew members.

Finally other incidents arising from errors of the same type, but of lesser magnitude, were reported more recently, on latest-generation large and medium-sized aircraft, such as an Embraer 190 in 2006.

During 2007, following the investigation of the second serious incident that had occurred in France, a working group was established bringing together the BEA, the DGAC (French Civil Aviation Authority), representatives of two French operators (Air France and Corsairfly) and a laboratory specialising in human factors (Applied Anthropology Laboratory, LAA), in order to study processes for errors specific to the flight phase prior to takeoff and to analyse the reasons why skilled and correctly trained crews were unable to detect them.
Foreign investigation bodies, airlines and manufacturers were consulted during the study.

The work of the group related to the following points:

1) To list, at an international level, events of the same type that were the subject of an investigation or analysis.

2) To make a state-of-the-art review by analysis of HF publications that handle the subject directly or in more general terms but applicable to the question raised of the process of error and recovery therefrom.

3) To carry out an ergonomic inspection of the various systems used by crews.
   A documentary study of the various procedures in airlines was completed by handling FMS's assigned to crew training. The assessment focussed essentially on "ergonomic criteria" in order to list the functional characteristics of tools offered by Airbus and Boeing, and on applying the associated crew procedures by taking pains to determine the potential risk of errors.

4) To study the selected incident and accident reports.
   The FRAM model (Functional Resonance Analysis Model) developed by Hollnagel in 2004 was used as a tool in this study. Using reading files created for each event, the model is based on a breakdown of the general process into basic functions in order to identify failures and their possible recovery, taking account of contextual factors. For each function, a certain number of barriers were proposed: physical, material, incorporeal, functional or symbolic.

5) To research changes that manufacturers propose in the design of their on-board systems in order to avoid or recover from the errors studied.

Airbus, Boeing and Honeywell were questioned by the working group.

6) To gather testimony from pilots who have been confronted with errors made in takeoff parameters, using completed questionnaires from the survey carried out in one of the airlines.

7) To observe the work by the crew and the use of systems, particularly in the "preparation" and "departure" phases of the flight.
   Sixteen trips were carried out with two observers per flight, on different aircraft types of the participating airlines (A 320, A 330, B 747, B 777).
   Using evaluation charts designed for the purpose, the observations enabled listing of all the tasks carried out by each crew member from the start of preparation until takeoff, in their operational context, subject to different temporal and environmental limitations. These flights also enabled the remarks and thoughts of aircrews on the subject to be noted.
   Modified charts were also updated in order to be used in the future by pilot instructors or managers, to assess the effectiveness of procedures implemented by the operators.

This report describes all these steps.

1 Analysis of Literature on Human Factors (HF)

1.1 Approach Adopted

An initial review was made of the state of the art relating to HF publications covering this aspect. The purpose was not to carry out an exhaustive review of the subject but to identify work likely to help in understanding input errors, this work being directly relatable to the subject or more generally to the ergonomics of interactions with the FMS. This review was carried out using databases of HF publications accessible to LAA (Ergonomics Abstracts…).

1.2 List of Articles Selected

The literature search enabled identification of two document types:

Manufacturers' Notes
Some manufacturers' documents (Boeing, Airbus) deal with the subject of "tailstrikes" and takeoff parameter calculation errors directly.

Two documents were selected as part of the literature analysis:
Airbus Briefing Notes - Understanding takeoff speeds
Boeing Document - Erroneous takeoff reference speeds

However, these documents are not necessarily focused on HF problems. Their aim is rather more to provide information to airlines and pilots, enabling them to gain a general understanding of the problem and in this respect were a good starting point for the analysis.

Scientific articles on Human Factors
The literature search did not enable identification of HF publications directly related to the subject. In total, eight articles were selected. They related to the following subjects:
- Errors linked to using FMS (the studies did not relate directly to errors linked to takeoff parameters).
- Memorisation of speeds in the cockpit (the study related to approach speeds).
- Go or No-go decision for takeoff.

These articles, while they don't relate directly to the subject, do nonetheless include some items that can be related to the topic of the study and so enable a better understanding of some of its aspects and serve as a possible basis for recommendations.

The following table lists the selected articles, the associated reading files being in the Appendix.

Title	**Author**	**Year**
Understanding Takeoff speeds	AIRBUS	
Erroneous takeoff reference speeds	BOEING	
The effect of an advisory system on pilots' go/no-go decision during take-off	T. Bove	2002
Response Time to reject a takeoff	Harris	2003
Difficult access: the impact of Recall steps on Flight Management System errors	K.Fenell	2006
Skill Decay on takeoffs as a result of varying degrees of expectancy	S.M. Stevens	2007
Pilot Interaction with cockpit automation II: an experimental study of Pilots' Model and Awareness of the FMS	N.B. Sarter	1994
When does the MCDU interface work well	L. Sherry	2002
How a cockpit remembers its speeds	E. Hutchins	1995

Table 1: List of articles selected

1.3 Definition of the Problem

Airbus Briefing Notes - Understanding takeoff speeds
Boeing Document - Erroneous takeoff reference speeds

Airbus states that takeoff speeds are a key element of safety for takeoff that allow pilots' decisions to be guided in this very dynamic situation:

Using erroneous values can lead to a tailstrike, a takeoff rejected at high speed or a climb with reduced performance. Regarding the human factors involved, Airbus states that last minute changes, time pressure or an increased work load can be the cause of errors in speed calculations.
The work load of the PF during pushback and taxiing phases being high, cross checks can be difficult.

The Boeing study defines the different types of errors likely to occur assuming that the input values are correct:
- Error in data conversion
- Error in selection of weight on loadsheet
- Key errors during input (weight or speed)
- Error in field selection during input (Perf Init or TakeOff ref)
- Error in table selection in the case of a manual calculation
- Error in using the table
- Error in selection of the high-lift flaps

In terms of margins for error, Boeing states that, taking account the models in the FMS, an error is detected if the ZFW entered is too low. On the other hand, the margins are such that a ZFW can be entered instead of a GW.

1.4 Input into the FMS

Among the articles selected, two concerned FMS input errors: Fenell (2006) and SHERRY (2000).

Fenell (2006) conducted an experiment with 22 C130 pilots on the tasks to be performed using the FMS. Errors were classified into four categories:
- Format,
- Input,
- Verification,
- Access.

The results revealed that the majority of difficulties concerned accessing the appropriate function (access error). Errors occurred more frequently when there was no real match between the task to be performed and FMS functionalities. In this case the pilot must reformulate what he has to do and call on his memory to access the appropriate initial page. If the guidance is also inadequate, access errors increase.

Possible implications

The errors studied in Fenell's (2006) experiment don't relate to tasks involving input of takeoff parameters. However, they do show errors linked to flight plan input tasks. During the preparation phase, problems of access to pages can lead to an increase in the work load and leave little room for the memorisation of other items such as aircraft weights.

The previous study showed that the MCDU interface is very well adapted when:

- The pilot's task is directly supported by a function,
- Access to pages and data formats is guided by labels or other visual indications.

Sherry (2000) stated that the interaction can be described in 5 steps:

1. Reformulation
2. Access to the appropriate interface
3. Formatting of data to be entered
4. Data input
5. Verification of input data

Each step is carried out either by recalling the action to be performed from long-term memory or by recognising certain environmental indications. Thus the recall and recognition tasks can be distinguished: a task is said to be a recall task if it has no visual signals such as a prominent label or a message. In the opposite case, we talk about a recognition task.
Recognition is more robust and faster. In particular, <u>recognition is more resistant to interruption of tasks and to work overload.</u>

Consequently the design of future systems must be guided by two broad principles:

- Establish tasks and sub-tasks for the job that are supported by the automated equipment,
- Add sufficient labels, prompts and feedback to enable pilots to carry out the 5 steps described above.

In addition, resorting to a graphic interface could be helpful:

- For the reformulation and verification steps. A graphic representation can simplify the presentation of the situation.
- The other steps can be simplified by using dialogue boxes or drop-down menus.

Possible implications

This study shows the importance of guidance by the interface and the suitability of the interface for the task. This is especially true for interactions linked to the flight preparation phase where interruptions to the task can be numerous.
If some design recommendations are drafted following this study, these items should be considered. For example we can refer to late changes that are not supported by the interface and that require significant reformulation on the part of the crew.

On the other hand the article suggests interest in using a graphic interface for presenting input data relating to reformulation and verification aspects. This could be applied to weight and/or speed data, a graphic representation of weight data could make verification easier and avoid errors in confusing ZFW and TOW, for example (see chapter on symbolic barriers).

1.5 Memorising Parameters

Among the articles selected, that of **Hutchins (1995)** was concerned with memorising landing speeds. The author describes the way in which these landing speeds are memorised in the cockpit. The memorisation of speeds is described according to three approaches:

- A procedural approach
- A cognitive description of the representations and processes external to the pilots
- A cognitive description of the representations and processes internal to the pilots

The author describes the different representations of speed values by distinguishing them according to their permanence, from the most lasting (e.g.: Speed/Weight matching cards) to the most transient such as those spoken.
These descriptions show that if these speeds are memorised in the cockpit (in other words, that they are "known" by the system made up of the aircraft, equipment, documents and crew), they're not necessarily memorised by the pilots, even in working memory.

To use the results of this article in the context of the study, it is quite straightforward to draw a parallel between landing speeds and takeoff speeds:
<u>How are weights and speeds memorised in the cockpit?</u>

First objective: to take off at the correct speeds.
Rotation speed Vr is called out to the PF by the PNF. To do this, does the PNF need to remember this speed? No, the presence of speed bugs or indicators on the PFD turns this memorisation task into a spatial connection task for Vr or an auditive recognition task for V1. The different representations of these speeds in the cockpit are linked to the precise context of a takeoff and so remain for a short time ("card", FMS, PFD). These representations become still more transient when the values are called out (during input, during C/L).
If we consider the cockpit as a whole (FMS, "card", laptop, crew, PFD), we can say that these speeds are memorised.
Each of these representations enables it, but does not ask the pilot to call on his memory. In fact, when the pilot inputs the speeds into the FMS, depending on allocation of tasks foreseen by the procedure, the pilot calls on a very short term memory or a short term working memory. He doesn't necessarily compare this value to values that could be stored in long term memory (long term working memory). This may explain why it may happen that gross errors may not be picked up.
With experience pilots might develop internal structures to reconcile with a provisional structure in the environment (this is what we will qualify as recognition of orders of magnitude). However, the presence of the different media does not require the pilot to keep these speeds in working memory.
The longest lasting representations of values are less vulnerable to <u>task interruptions</u>.

Intermediate objective: To take the correct weight into account for speed calculation.
Takeoff speeds ((V1, Vr, V2) are calculated for each flight taking account of:
- permanent aspects of the aircraft such as the empty weight,
- specific aspects of the flight such as the load and number of passengers,
- contextual aspects such as the length of the takeoff runway and the weather forecast.

Decisions by the pilots may or may not have an impact on the specific aspects of the flight (fuel vs load). In the same way as for speeds, if we consider the entire cockpit system (loadsheet, "card", FMS, laptop, pilots), we can say that the weights are memorised. The total weight at takeoff is a determining parameter for speed calculations. Depending on operating mode, this weight is read, calculated, written and/or inputted. It is represented in the aircraft on different media, each having a more or less significant duration of validity: preliminary loadsheet, final loadsheet, "card", flight file and FMS.
Unlike the speeds, these data have levels of accuracy that differ depending on the media. They come either from outside, or from calculation, or an input, or a calculation by the system. Differences in accuracy, validity and units make an immediate comparison without interpretation <u>practically impossible</u>. So the verification of these values must involve a manipulation, which leads pilots to store these values (for a longer or shorter time) in their working memory. However, the number of different values for the same weight and the number of different weights handled can overload this working memory and render it difficult or even impossible to make any internal reconstruction of the situation based on these different values.

Possible implications

The transposition of ideas highlighted by the Hutchins article shows that the representations of weights and speeds enable memorisation at the level of the cockpit ("card", loadsheet, FMS, PFD, laptop) but not necessarily by the pilot:
The presence of different media means that crews don't necessarily need to store takeoff speeds in working memory. So it's difficult for them to develop knowledge of orders of magnitude.
As for weight data, these are manipulated by the crews (rounded, units transposed, comparison of close weights). However, the number of values manipulated is such that working memory can be saturated, making any comparison with orders of magnitude difficult.

1.6 Takeoff – Detection of an Anomaly

Among the articles selected, three were more particularly concerned with rejected takeoffs in the event of an anomaly being detected: Sarter (1994), Bove (2002), Stevens (2007).

Sarter (1994) conducted a study with 20 experienced pilots in a part-task simulator (B737) with the aim of studying the pilots' understanding of FMS operation.
One of the tasks related to rejected takeoffs. During this task, when the aircraft reached 40 knots, pilots were asked what they would do to reject the takeoff. The aim was to study their understanding of the functioning of the auto-throttles.
The results showed that 80% gave the wrong answer. This revealed existing gaps in the pilots' mental models of the functional structure of the automation in abnormal situations subject to time pressure.
These results as well as those obtained on other tasks show that:

- There are gaps in pilots' understanding of the automation,
- the interface does not facilitate understanding of system status by pilots,
- pilots are not necessarily aware of these gaps.

The author underlines that the problems are not inherent to the system but more to limitations in the way the automation has been integrated and in particular in the allocation of tasks (and knowledge) carried out by the system and by the pilots.

Possible implications

The most interesting item in the Sarter article is that it's not concerned with input of takeoff parameters. The study deliberately did not include initialisation of performance because "observations during training have shown that these tasks did not put pilots to the test. The study preferred to concentrate on in flight tasks, ground tasks being less subject to time pressure and to competing tasks". This shows the difficulty of observing the context of takeoff preparation in a simulator and of reproducing all the interactions in order to have a truly ecological approach (one that reproduces the real working environment) in the study of this phase. This supports the choice of real in-flight observations.

Bove (2002) conducted a study in a fixed base simulator on the contribution of a decision support system (ATOMS: Advisory Take Off Monitoring System) related to continuing or halting takeoff. The principle of this system relies on a comparison of theoretical performance of the aircraft in the conditions on the day with the real performance of the aircraft. During takeoff, graphic information is presented on the speed indicator of the PFD and the ND.
On the PFD (Figure 1), in the event of nominal performance a green sector appears indicating the minimum speed to take off and the maximum speed to stop. If the acceleration is less than that theoretically planned, the sector is amber and shows the minimum speed to be reached to take off.
On the ND (figure 2) a picture represents the runway. In the acceleration phase, a green sector indicates the minimum position to be reached to take off and the maximum position to be able to stop the aircraft. In the event of acceleration less than that calculated theoretically, the sector is amber and indicates the minimum position to be reached. In the event of rejection of takeoff, a green sector indicates that the deceleration is sufficient to stop the aircraft; if this is not the case, the sector is amber.

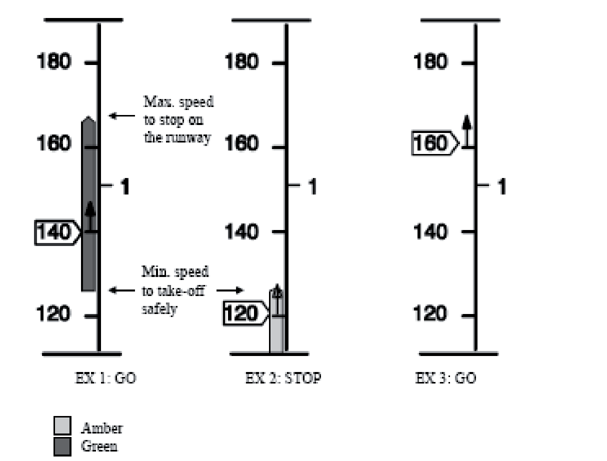


Figure 1: ATOMS symbols on the PFD

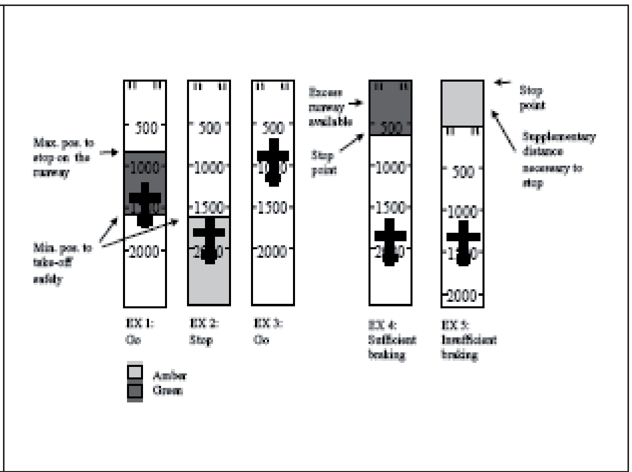


Figure 2: ATOMS symbols on the ND

In total 20 pilots of Airbus A320/330/340 took part in this study. Each was faced with 6 different scenarios with and without ATOMS (or the reverse):

- A. Nominal situation
- B. Braking problem
- C. Engine fire
- D. Engine problem + Fire
- E. <u>Erroneous weight and low acceleration remaining within predefined safety margins.</u>
- F. ATC alert

The results show that the presence of the ATOMS system had no significant influence in scenarios A, B, E and F. For scenario B, the ATOMS system enabled crews to detect the braking problem and reject takeoff. In scenario D, the ATOMS contribution was significant in terms of the speed at which the decision to reject takeoff was taken. Scenario E that related directly to our study is the one in which an erroneous weight was entered. However the scenario started when the weight and speed data had already been entered into the FMS. During the scenario, the safety margins fell (the sector remained green but reduced). So it was a matter of determining if the presence of the system in one case where the safety margins fall could have a side effect and influence the crew to reject the takeoff, which was not the case for the 10 crews taking part.

Possible implications of results

The results of this experiment showed the importance of the ATOMS system for the detection of certain anomalies. If takeoff is started with an erroneous V1, Vr or inadequate thrust, the system can enable detection of non-nominal behaviour of the aircraft.
However, it should be noted that the results should be considered carefully, the use of a fixed simulator for the takeoff phase really limits the factors able to influence decision-making by pilots. It would be interesting to question manufacturers to find out if other experiments were conducted (without being published) and/or if other similar systems are being studied. An appropriate system could constitute the ultimate barrier in the event of errors in the takeoff parameters not being previously detected.

On the other hand, the article is particularly interesting in the approach that the author adopts to describe the factors that can influence the decision to continue or to reject a takeoff.
In fact the first parts are devoted to a description of the main aspects of the takeoff phase, then to the problems of handling information and evaluation of risks on the decisions to continue or to reject takeoff.
The author highlights the fact that the decision must be taken under <u>time pressure</u> although it involves <u>significant risks</u>. It must be based on incomplete, complex and dynamically changing information.
The author distinguishes three phases leading to rejection or otherwise of the takeoff.

1) diagnosis

This is done on the basis of:

- discrete events

- continuous signals:
  - visual movement passing outside the cockpit
  - The small jolts while rolling (or rather the differences between the jolts)
  - The sense of balance
  - The speed indicator: the difference between the current speed and the speed in 10 seconds is a measure of instantaneous acceleration
  - The rate of increase of engine thrust

Pilots can have difficulties in interpreting these signals because other factors affect the time required for takeoff (weight, temperature, altitude...).

2) the prognosis

This is a matter of being able to make reliable inferences, for example to project that the current acceleration is adequate. It can prove difficult to see or to judge the end of the runway (pilots don't necessarily apply the correct braking force) and an overestimation or underestimation effect can be noted depending on the visibility of the sides of the runway.

3) Decision-making.

The diagnosis and the prognosis lead to making a decision: to reject or to continue the takeoff.
The factors that can influence the decision in favour of continuing the takeoff are:

- V1 so take off is possible with one engine out,
- Possibility of increasing thrust.
- Possible uncertainty in the calculation of V1.

Possible implications

The article highlights the difficulties associated with the detection of an anomaly and with decision making during takeoff. In particular, the author underlines that V1 is considered as a reference in making the decision, when if one of the items used in the calculation of speeds is inaccurate (for example, if the engines don't provide the appropriate thrust), the calculated V1 will not correspond to a rejected takeoff made in a safe manner.
These items could be used in order to make pilots fully aware of these problems during their training.

Harris (2003) conducted a study on an Aerosoft 200 flight trainer (747-200). A total of 8 scenarios were tested by 16 pilots with calls to reject takeoff at the following speeds: 60, 80, 90, 100, 120, 130, 135 or 141 kts (V1 in all cases being equal to 141 kts). Those taking part did not know the speed at which the call to reject takeoff occurs.

The calculation of acceleration and stopping distances for the certification aspects of FAR/JAR 25 is central to the determination of safety margins at takeoff.
In the calculation of V1, the crew reaction time, the time to apply the brakes, the activation time for the thrust reversers and the time to deploy the spoilers must all be taken into account. To see the action through successfully, several steps are required:

1) Identification of the problem
2) Analysis and decision
3) Call to reject takeoff
4) Perception of the call
5) Cross check with V1
6) Decision
7) Action

In 114 tests, there were 9 cases where takeoff was continued. The results show that the response time reduced with ground speed but increased again as V1 approached Average responses corresponded to what is described for certification but when approaching V1 the typical difference increased.

Possible implications

The results of the study show that on approaching V1, reaction times are longer and on average they correspond to that described in certification. However, when approaching V1 the standard deviation increases, which indicates that extreme values (in other words, increased reaction times) may be observed.

Stevens (2007) conducted a study using a PC simulator, aimed at showing the influence of the degree of predictability in performance in order to stop takeoff. Trainees (147) and pilots (12) took part in the study. Performance was analysed on the basis of reaction time and deviation relative to a central line.
In the two cases performance fell off when the participants did not expect the event to arise:
- in terms of response times for the 2 types of participants
- in terms of deviation for the students

Possible implications

These results highlight the difficulties in training crews for the flight preparation phase and especially for making a decision to reject or continue takeoff.
The results of this study underline how little data exists relating to the validity of transfer of skills acquired on a simulator during expected situations and their application to unexpected emergency situations.

2 Analysis of procedures and ergonomic inspection

2.1 Comparative analysis of procedures

2.1.1 Description of different procedures

AIR FRANCE B777

Items relating to the input and verification of performance data for takeoff are found in the following documents:

- Normal flight phase procedures:
  Initial preparation of flight compartment.
  FMS initialisation,
  Before starting.
  Before takeoff.
- Normal system procedures:
  These procedures describe inputs into the FMS more specifically:
  FMS – flight compartment preparation,
  FMS - Before starting.

Items relating to the verification of parameters are also found in the pre-takeoff briefing.

By relying on these procedures, the input of weight and speed data into the FMS is done in two stages:

1. During the "FMS initialisation" phase, the PF inputs the data and the PNF verifies the inputs. In particular the PF inputs the forecast ZFW. He also selects the takeoff thrust required, either my means of a theoretical temperature or by choosing full thrust. Reference speeds calculated by the FMS are displayed. And as soon as refuelling status allows it, the crew is asked to check the GRWT as well as the reference speeds.

2. During the "Start" phase, the input of final weight breakdown must be done by the Co-pilot by cross checking with the Captain.
   At the time of receipt of the final loadsheet, this is verified jointly by the Captain and the Co-pilot. The Co-pilot transfers the takeoff weight to the "card" and compares it with that on the "card".
   The Co-pilot inputs the zero fuel weight (ZFW) into the FMS and compares the GRWT with the loadsheet.
   The Captain calls out the takeoff parameters and the Co-pilot confirms or modifies the reference speeds.

This phase ends with the "Before start C/L" during which the FMS data relating to takeoff (V1, Vr, V2 and N1) are announced.

During the pre-takeoff briefing, the PF must give a reminder of the takeoff parameters. It is stated that this briefing is the time to confirm the conditions (level of thrust, temperature, runway condition) taken into account during preparation of the takeoff card.

On the other hand, it is recommended that during the "takeoff" phase of the flight, the PF's MCDU display should be *TAKEOFF REF ½* and that of the PNF should be *LEGS*.

AIR FRANCE A340

Items relating to the input and verification of performance data for takeoff are found in the following documents:

- Normal flight phase procedures:
  Initial preparation of flight compartment.
  Departure,
  Before starting,
  Before takeoff.
- Normal system procedures:
  These procedures describe inputs into the FMGS more specifically:
  FMGS – flight compartment preparation,
  FMGS - departure
  FMGS – before starting.

Items relating to the verification of parameters are also found in the pre-takeoff briefing.

By applying these procedures, input of speed and weight data is done during the "departure" phase.

The PF inputs the ZFW. It is stated that as long as the final weight breakdown is not available, the crew can input the ZFW to obtain estimates of fuel unballasting, from the flight time and optimum flight altitude.
Speeds V1, Vr and V2 are also input during this phase.
The inputs must be verified by the PNF.

During the departure briefing, the takeoff weight and speeds are recalled by the PF with the aid of MCDU pages.

During the "Start" phase, the loadsheet is verified and signed by the Captain.

The takeoff card is completed and verified by the Captain (writes the weight from the loadsheet on the "card" and compares it with the weight forecast on the "card")
The weight data are brought up to date by the Captain.
The ZFW is inserted, speeds V1, Vr and V2 are verified.
Performance is completed by the Co-pilot.

This phase ends with the "BEFORE START C/L" during which performance inputs are checked.

During the pre-takeoff briefing, the PF recalls the takeoff parameters. It is stated that this briefing is the time to confirm the conditions (level of thrust, temperature, runway condition) taken into account during preparation of the takeoff card.

It is stated that if a change of QFU takes place during taxiing, the V1, Vr and V2 data must be brought up to date after cross checking.

On the other hand, during the "takeoff" flight phase, the PF's MCDU display should be *PERF TO* and that of the PNF should be *F-PLN*.

AIR FRANCE B747

Items relating to the input and verification of performance data for takeoff are found in the following documents:

- Normal flight phase procedures:
  Initial preparation of flight compartment.
  FMS initialisation,
  Before startup,
  Before takeoff.
- Normal system procedures:
  These procedures describe inputs into the FMS more specifically:

FMS - flight compartment preparation,
FMS - Before startup.

Items relating to the verification of parameters are also found in the pre-takeoff briefing.

According to these procedures, the input of weight and speed data into the FMS is done in two stages.

During the "FMS initialisation" phase, the Captain inputs the data and the Co-pilot verifies the inputs. Reference speeds calculated by the FMS are displayed. And as soon as the filling status allows it, the crew is asked to verify the GRWT as well as the reference speeds.

During the "Start" phase, the input of final weight breakdown must be done by the Co-pilot by cross checking with the Captain.

At the time of receipt of the final loadsheet, this is verified jointly by the Captain and the Co-pilot.
The Co-pilot transfers the takeoff weight to the "card" and compares it with that on the "card".
The Co-pilot inputs the zero fuel weight (ZFW) into the FMS and compares the GRWT with the loadsheet.
The Captain calls out the takeoff parameters and the Co-pilot confirms or modifies the reference speeds.
This phase ends with the "Before start" checklist during which the FMS data relating to takeoff (V1, Vr, V2 and N1) are called out.
During the pre-takeoff briefing, the PF recalls the takeoff parameters. It is stated that this briefing is the time to confirm the conditions (level of thrust, temperature, runway condition) taken into account during preparation of the takeoff card.

On the other hand, during the "takeoff" flight phase, the PF's MCDU display should be PERF TO and that of the PNF should be F-PLN.

CORSAIRFLY B747

Items relating to the input and verification of performance data for takeoff are found in the following documents:

- Expanded normal procedures:
  CDU - Preflight Procedure,
  Preflight Procedure,
  Before start Procedure,
  Taxi and Before TakeOff procedure.
- Additional normal procedures
  Calculation of performance VIA BLT and adjustment of CDU.

Each pilot completes his technical PLN using the loadsheet. The Captain calls out "ZFW_", "GRWT_","TOW_".

The Captain inputs the ZFW, the crew then verify consistency with the GRWT.
The performance data are then calculated using the BLT: The Co-pilot inputs the TOW in the Planned Weight, activates the CALCULATE button and passes the BLT to the Captain.
The Captain reads aloud the data entered into the BLT.

Inputting the speeds in the TAKEOFF REFERENCE page is carried out by the Captain in the following way:
"V1 calculated __(BLT), V1 suggested __(FMS) and inputs V1(BLT) after comparison, then the same procedure for Vr and V2.
The Co-pilot verifies and calls out CHECK.
During the takeoff briefing, the PF calls out "V1__", and "V2__", that he reads on the PFD.

2.1.2 Comparison of different procedures

	CORSAIRFLY 747				AIR FRANCE 747				AIR FRANCE 777				AIR FRANCE 340			
	PF	PNF	Captain	Co-pilot	PF	PNF	Captain	Co-pilot	PF	PNF	Captain	Co-pilot	PF	PNF	Captain	Co-pilot
Departure FMS initialisation							Input fore-cast ZFW		Input fore-cast ZFW				Input ZFW V1,Vr, V2	*Verif ZFW V1,Vr,V2*		
Departure briefing													*Recall TOW and speeds*			
Before startup			Input ZFW V1,Vr, V2	*Verif ZFW V1,Vr, V2*			*Verif ZFW V1,Vr, V2*	Input ZFW V1,Vr, V2			*Verif ZFW V1,Vr, V2*	Input ZFW V1,Vr, V2				Update ZFW V1, Vr, V2
Before start C/L					*V1, Vr, V2 called out by?*				*V1, Vr, V2 called out by?*				*Verify input (values?)*			
Pre-takeOff																
Takeoff briefing					*Recall*				*Recall*				*Recall*			

2.2 Ergonomic inspection

The assessment carried out on the man-machine interfaces consisted of an ergonomic inspection of its use. It consisted of a set of approaches requiring judgement by the assessors. Although all these methods have different objectives, they are aimed in general at detecting aspects of the interfaces that can lead to operating difficulties or burden the work of users. The inspection methods are distinguished from each other by the way in which the judgements by the assessors are achieved and by the assessment criteria forming the basis of their judgements.

Among the methods of inspection, those used most often are: the analysis of compliance with a set of recommendations, the analysis of compliance to standards, the use of heuristics and the use of criteria.

In the context of this study, inspection was essentially based on **Ergonomic Criteria**. Ergonomic criteria represent the major ergonomic dimensions according to which interactive software can be detailed or assessed. A definition of each criterion is available in an appendix.

1. Guidance 1.1 Prompting 1.2 Grouping / Distinction of items 1.2.1 Gr / Dist by location 1.2.2 Gr / Dist by format 1.3 Immediate feedback 1.4 Legibility (not studied) 2. Workload 2.1 Brevity 2.1.1 Concision 2.1.2 Minimal actions 2.2 Information density	3. Explicit Control Explicit user actions User control 4. Adaptability 4.1 Flexibility 4.2 User experience 5. Error management 5.1 Error protection 5.2 quality of error messages 5.3 Error correction 6. Consistency 7. Significance of codes 8. Compatibility

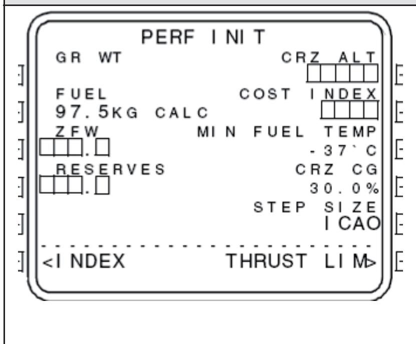
The comparative analysis of procedures highlighted 3 main screens connected with input of weight, speed and takeoff related performance data. The ergonomic inspection was carried out on these three screens.

B777	B747	A340
Perf Init	Perf Init	INIT
Thrust Lim	Thrust Lim	
TakeOff ref	TakeOff ref	TakeOff

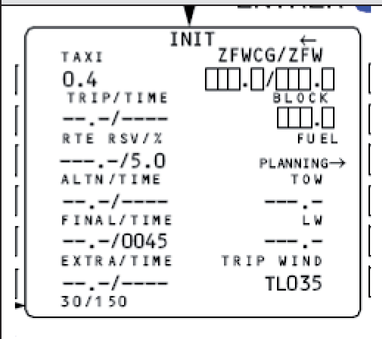
2.2.1 PERF INIT

The PERF INIT and/or INIT screens contained in particular the data relating to weight of the aircraft (load), balancing and fuel (FOB, RESERVES) required to calculate performance.

B777



A340



B747

<u>**Grouping / Distinction of items by format**</u>

The input areas are highlighted using a specific presentation format. The fields to be completed are indicated by boxes matching the maximum number of characters that can be entered.

<u>For the B777:</u>

On this page both the ZFW and reserves, and the COST INDEX, CRZ ALT and CRZ CG must be entered.

<u>For the A340:</u>

On this page both the ZFW and the ZFWCG must be entered.
The boxes are amber coloured indicating that they are required data.
The TOW is indicated in small green characters, indicating that it's an unchangeable calculated value.

<u>For the B747:</u>

As for the B777, on this page both the ZFW and reserves, and the COST INDEX and the CRZ ALT must be entered.

An ambiguity rests in the possibility or entering or not entering the GRWT. As for the other input areas, boxes indicate the maximum number of characters to be entered. It would be a good idea to confirm if this input possibility isn't deactivated depending on the airline.

The CORSAIRFLY procedure states, for example:
Do Not Enter the ZFW into the GRWT boxes. The FMC will calculate performance data with significant errors.

Grouping / Distinction by location

The layout in columns of the items taken into consideration in the calculation of aircraft weight makes sums and comparisons easier.
On the Boeing 777 and Boeing 747 screens, the GRWT calculated by the system is indicated above the measured fuel and ZFW.
On the A340 screen the TOW is indicated under the ZFW and the Block. However, to obtain the TOW it's necessary to subtract the taxi that's located in the other column.

Prompting

No indication is available in the three screens on the status of the data: Forecast or final ZFW and GRWT/FUEL changing during re-fuelling.

Error protection

For the B777 and the B747:
The ZFW field has high and low limits: it's not possible to input values outside these limits.

For the A340:
The range of possible values for ZFW extends from 35.0 to 350 t.

No additional protection is apparently implemented.

Compatibility

The documents used for ZFW input are the flight file (the name can vary depending on the airlines: depending on octave tracking, technical PLN) and the loadsheet.
It is noted that these values can be expressed in some documents in kilograms while input into the FMS is done in thousands of kilograms.
On the other hand, the sequence of the data is not necessarily identical. In fact, on the working documents, you generally find TOW, sum of ZFW and fuel, under these data.

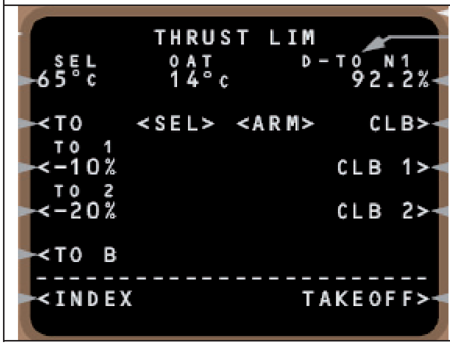
File	FMS
ZFW Fuel TOW TOW	GRWT Fuel ZFW

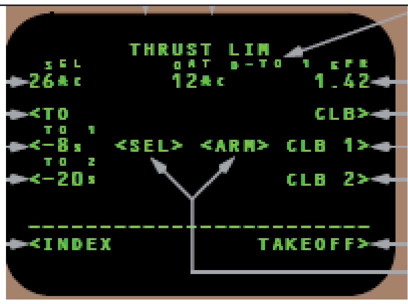
On the B747 and B777 screens the TOW is not indicated. Only the GRWT appears. When the crew has to verify consistency of the GRWT, it has to make a calculation in order to be able to make an approximate comparison with the TOW.

All these items lead to conversions, calculations and manipulations on the part of the pilots. Although individually straightforward, these operations are contributory components to the work load associated with this preparation phase and can therefore be the source of errors.

2.2.2 THRUST LIMIT

The THRUST LIM screens (B777 and B747) enable the crew to enter the theoretical temperature that will allow them to obtain full or reduced thrust for takeoff.





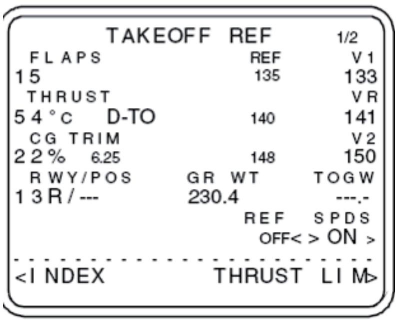
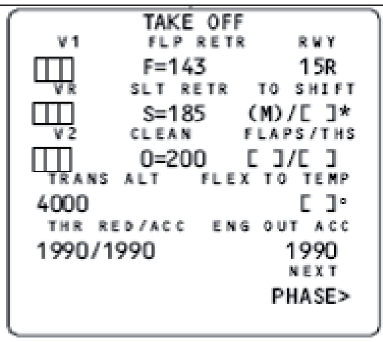
The heading for theoretical temperature is SEL.
If the theoretical temperature selected is greater than ground temperature (OAT) a D is put in front of -TO to specify that a reduced thrust takeoff has been chosen.

Pressing on TO selects full thrust at takeoff.

The items TO1 and TO2 are not used or cannot be entered by crews on certain models; these items nonetheless being part of the information load.

2.2.3 TAKEOFF

The TAKE OFF (or TAKE OFF REF) pages indicate the takeoff parameters, in particular speeds V1, Vr and V2, the flaps and the theoretical temperature .

B777	A340	B747
		

Grouping / Distinction by format

The input areas are highlighted using a specific presentation format. The fields to be completed are indicated either by boxes or by dashes matching the maximum number of characters that can be entered.

For the B777:

The input fields show clearly the distinctions between the data required and those that will be calculated and perhaps modified afterwards (boxes vs dashes).

Regarding reference speeds calculated by the aircraft, the functioning is as follows:
When the parameters required for the calculation have not been entered, dashes are present in place of the values to be entered.
The calculated speeds appear in small characters; when they have been confirmed or modified by the user they then appear in large characters.

The theoretical temperature previously entered is indicated in large characters and can be modified.

For the B747:

The input fields show clearly the distinctions between the data required and those that will be calculated and perhaps modified afterwards (boxes vs dashes).
Regarding reference speeds calculated by the aircraft, the functioning is as follows:
The calculated speeds appear in small characters; when they have been confirmed or modified by the user they then appear in large characters and the notation REF in front of each value is deleted.

For the A340:

The speeds to be entered are indicated by amber boxes as long as a value has not been entered.
The temperature FLEX TO TEMP is entered in this screen.

<u>Grouping / Distinction by location</u>

For the B777:

The presence of unconfirmed reference values on the right of the screen could lead the crew to error in the sense that it is not clear that the system doesn't have confirmed values (possibility for the crew to take off without takeoff speeds input into the system).
When takeoff speeds are the subject of a calculation other than that suggested by the FMS, the reference values could be displayed by default in the centre of the screen while the fields for speed values could remain empty as long as values calculated by the crew have not been entered.

The GWT appears on the PERF INIT screen and on the TAKEOFF REF screen. In both cases it is calculated by the system and can't be entered. The display of this item in the same position on the two screens could allow a reduction in the perceptive load.
On the TAKE OFF REF screen, the positioning in the centre of the screen is an additional indicator to differentiate fields accessible to modification.

<u>Error protection:</u>

B777
The ranges of speed values are from 100 to 300 kt. No additional check on the values is carried out, in particular no check on the sequence of values (V1<Vr<V2).
In the same way no system alert is available to warn the crew of a significant difference between the speeds that it has entered and the reference speeds that were calculated by the system.

A340
The ranges of values accepted for V1, Vr, V2 are from 100 kt to VMO.

The input areas (FLAPS, CG) are distinguished by a different presentation format for these areas. The areas to be completed are indicated by boxes matching the maximum number of characters that can be entered.

Prompting

Given the availability of data, the input of performance data in the FMS is not necessarily done in a linear fashion but may go through a prior step where heterogeneous data (forecast and/or final) are entered. During the final input of the data, the sequence of screens provided in the FMS (PerfInit / thrustLim / TakeOff ref) is not then necessarily suited to the tasks to be performed.

When the pilot is no longer guided by the interface, he must rely on his memory in his choice of pages to display and so does not follow the sequence anticipated by the system. This could lead them to omit certain dependency relationship controls between the data input.

⇒ *These items will be studied in detail in the observations.*

Workload / Minimal actions

A special feature of the B777 screen is that it includes an item of data relating to weight: the GRWT. This display can enable checking until takeoff, this page usually being displayed by the PF. However, and this is also the case for the B747 and the A340, all the information to be entered or checked at the time of obtaining the final weight data is not brought together on the same screen. This could cause errors of omission or non-verification of consistency between data input. In particular, the possibility of inputting the ZFW on the TAKEOFF DATA screen could be studied.

Explicit user actions

The deletion of takeoff speeds by the system is not necessarily explicit for the user.

For the A340:

Amber boxes as long as a value has not been entered.
Each input can be modified as long as takeoff phase isn't active.
If the takeoff runway has changed, the MCDU scratchpad displays CHECK TAKEOFF DATA and the speeds return to amber.

For the B777:

The modification of the theoretical temperature value (SEL) leads to display of the message "TAKEOFF SPEEDS DELETED" which means that the takeoff speeds (V1, Vr, V2) were deleted. The screen that allows the input of new values is "TAKEOFF REF". Although the THRUST LIM screen enables the crew to display the TAKEOFF REF (6R) page, the crew can very well display another screen and update the speeds by means of the 6L button or keypad buttons.

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3 Analysis of incident reports

Based on reading incident reports, this consisted of identifying the HF situations associated with these input errors (time pressure, interface ergonomics, task interruption…).

3.1 Events studied

3.1.1 Criteria selected

The events studied are the listed items for which one of the causes identified is linked to the use of inappropriate takeoff parameters.

3.1.2 List

The following table summarises all the events identified and the associated references.

N°	Registration	Year	Document
1	B757-200 N505UA	1990	http://www.ntsb.gov/ntsb/brief.asp?ev_id=20001212X22410&key=1
2	B767-300 OY-KDN	1999	http://www.hcl.dk/graphics/Synkron-Library/hcl/dokumenter/Redegorelser/1999/49-99-KDN-UK.pdf
3	B747-100F N3203Y	2001	http://www.ntsb.gov/ntsb/GenPDF.asp?id=ANC02LA008&rpt=fa
4	B747-300 ZS-SAJ	2003	http://www.caa.co.za/resource%20center/accidents%20&%20incid/reports/2003/0263.pdf
5	B747-400 9V-SMT	2003	http://www.taic.org.nz
6	B747-200F 9G-MKJ	2004	http://www.tsb.gc.ca/fr/reports/air/2004/a04H0004/a04H0004.pdf
7	B747-400 F-HLOV	2006	http://www.bea.aero/docspa/2006/f-ov061210/pdf/f-ov061210.pdf
8	A330-300 C-GHLM	2002	http://www.tsb.gc.ca/fr/reports/air/2002/a02f0069/a02f0069.asp
9	A321 OY- KBK	2003	Report in Norwegian – request for summary/conclusion in English
10	A340-300 F-GLZR	2004	ITA n°4 : http://www.bea.aero/francais/rapports/rap.htm
11	A340-300 LN-RKF	2005	Chinese report translated into English
12	ERJ190 C-FHIU	2006	Not published

Table 2: List of incidents studied

For each event, a summary was drawn up including a concise description of the event, the causes identified and associated recommendations. These items are reported in an Appendix.

Events 11 and 12 are not analysed in detail, due to a lack of information at the time when the study was carried out.

3.1.3 Descriptive analysis

In total 10 events occurring between 1990 and 2006 were studied. They concerned Airbus (1 x 321, 1 x 330, 1 x 340) and Boeing (1 x 757, 1 x 767, 5 x 747) aircraft. The consequences of these events were as follows:

- 1 aircraft destroyed, 7 crew members killed,
- 8 tailstrikes, of which:
  - 5 QRF,
  - 1 take-off abandoned,
  - 2 flights continued to destination.
- 1 without consequences.

Aircraft equipment used for calculation of takeoff parameters is as follows:

- 6 aircraft equipped with FMS,
  - 4 ACARS queries,
  - 1 manual calculation,
  - 1 laptop.
- 4 aircraft not equipped with FMS,
  - 2 manual calculations,
  - 2 laptops.

This first description highlights the non-specific nature of the aircraft involved, the equipment used or methods employed. This underlines the importance of a summary study to try to highlight weaknesses in the system regarding input of takeoff parameters independently of the aircraft type, the equipment used and the operating airline.

3.2 Approach adopted

The objective of the study is to bring out common factors in all the incidents, enabling a description of how they could have occurred and how it might be possible to remedy them. This is why it was in no way an attempt to redo the analysis of each incident. The study is therefore based on the results of published analyses and does not seek to investigate the incidents in greater depth. For this reason a functional approach was chosen with the aim of highlighting the major functions involved in the input of takeoff parameters.

The FRAM model developed by Erik Hollnagel in 2004 was used as a tool for this study. The model was not used with the aim of making a precise analysis of the incidents, nor was it used to predict the risks associated with a particular context, but it was rather the principles described in the functional approach that were adapted. The model is based on a breakdown of the system into elementary functions.
Six attributes are described for each of these functions (Figure 3):

- I: Input or input data, which is used of transformed to produce the result (output),
- O: Output or output data, which is produced by this function, Constitutes the link with later functions
- P: Pre-condition, in other words the conditions required for this function to be carried out,
- C: Control, which oversees or adapts the function,
- T: Time available to carry out the function,
- R: Resources, which are necessary or consumed to handle the input data (input).

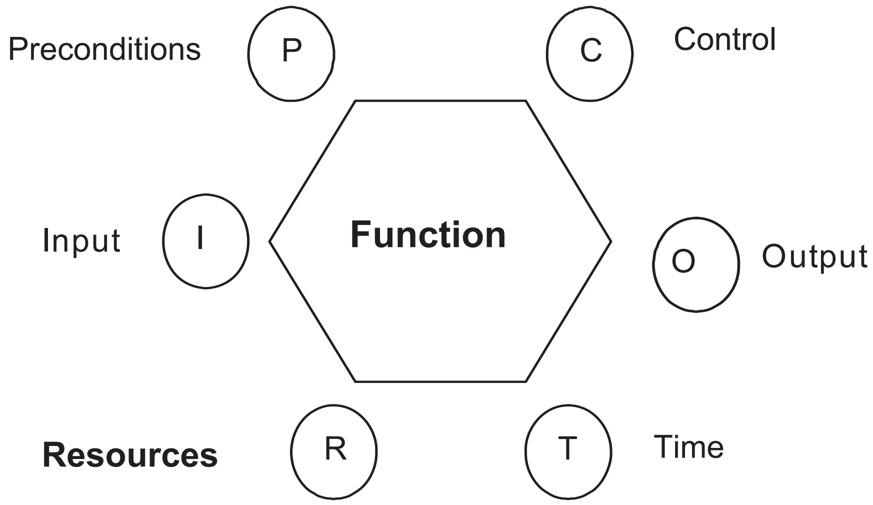


Figure 3: Generic FRAM function

The underlying concept is that each function can be subject to variability. It's this variability that creates a certain flexibility and enables the system to operate. This variability, when combined with the variability in other functions, can also lead to the development of failures causing incidents or accidents. To limit failures, the principle of the method is to determine the measures enabling control and management of the variability of different functions (we talk about barriers).

In the context of this study, the approach adopted was as follows:

1. Read all the incident reports,
2. Draft a reading file with the aim of bringing out:
   - The functions in play,
   - The failures reported,
   - Recovery or non-recovery from the failures,
   - Contextual factors.
3. Schematic summary representation of functions and associated failures,
4. Study of possible barriers enabling the non-propagation of failures.

3.3 Results of analyses

3.3.1 Reading files

The reading files created for each incident are attached in the Appendix.

3.3.2 List of functions identified

The functions identified related to the entire sequence of obtaining, inputting and verifying the data needed for takeoff.

Even if the methods are different depending on the aircraft, equipment and procedures, all functions can be classified into four categories:

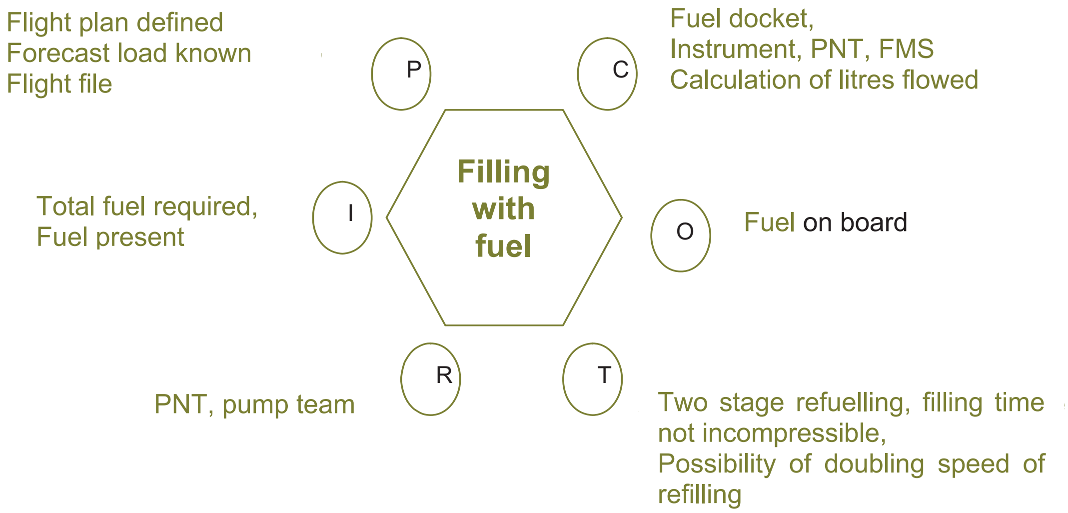
- Obtaining weight data (diagrams in khaki in the document),
- Calculation of takeoff speeds (diagrams in blue in the document),
- Input of parameters into the FMS when it exists (diagrams in purple in the document),
- Display of speeds (diagrams in dark blue in the document),
- Takeoff (diagrams in green in the document),

The functions identified in each of the categories are detailed in the table presented in the appendix.

3.3.3 Obtaining weight data

We make a distinction between refuelling and obtaining the load report (or loadsheet).

Refuelling:



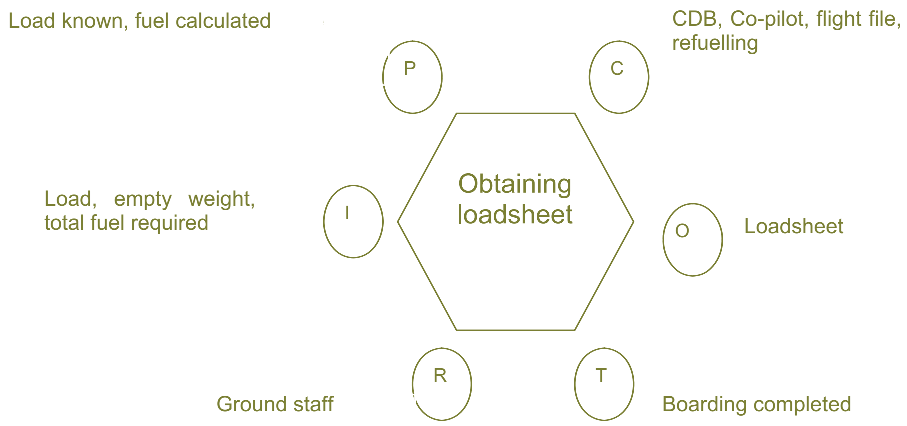
The crew determines the total amount of fuel it needs. From a purely theoretical point of view, it needs its flight file (in particular its flight plan) as well as the aircraft weight.
However, refuelling time being incompressible, it's not possible to imagine going to refuel once the weight is known (in other words, once embarkation is finished). Crews can adopt the following strategy to deal with this variability in the time when load data will be available: estimates can be made on the forecast load data and refuelling is performed separately. The last tonnes are "flowed in" at the end of embarkation when the final load is known.

One of the other elements of variability in this function resides in the communication between ground staff and the aircrew. Depending on stopovers, the procedures adopted are not identical and information doesn't always flow in the best way.

An effective check (even if late) for the on-board fuel value is obtained from equipment on the aircraft: The value for fuel on-board (indicated by the FMS or a gauge) changes in real time depending on the progress of refuelling and possible consumption by the APU. A check can also be carried out on the quantity of fuel flow; in fact the degree of accuracy of gauges is greater when the tanks contain little fuel. The fuel on-board can thus be estimated more accurately by adding the fuel remaining to the quantity flowed.

The effectiveness of this check means that the problem will not reside in this function but more in the link that should exist between this function and obtaining the load sheet (see below).

Obtaining the loadsheet:



The loadsheet or loading report is the reference document needed for the crew to know the aircraft weight and balance.
In particular the data needed are the basic weight, the load and the fuel quantity:

- The fuel quantity isn't obtained directly from quantity of fuel on board, rather it is quantity of the fuel decided on by the crew. This is one of the factors in function variability, the agreement between the fuel considered and that actually on board thus being part of the items to be verified (see Figure 4).
- The load can only be known once embarkation is completed and this is one of the factors creating time pressure.

The time the loadsheet becomes available is one of the main factors in variability. Several versions of this document can follow one another; the forecast report sometimes used for the refuelling decision is eventually replaced by a final version issued to the crew after the completion of embarkation.
The captain is responsible for validating the loadsheet. However, the captain is not necessarily present in the cockpit when it is received (whether electronically or on paper). The loadsheet may therefore be taking into account by only one crew member at the moment of its receipt and then verified later.

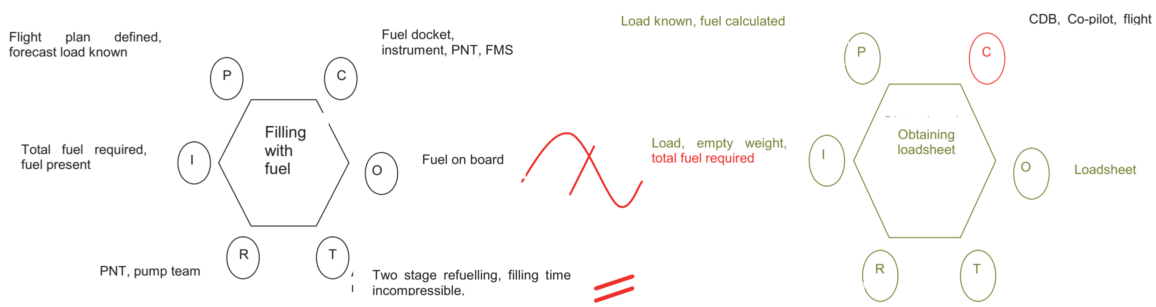
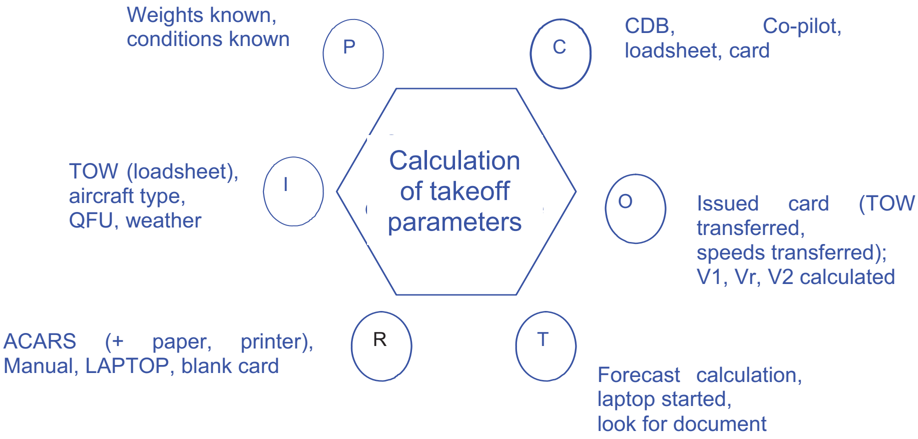


Figure 4: Erroneous link between refuelling and the loadsheet

3.3.4 Calculation of takeoff parameters

Several operating modes exist: speed calculation may be manual or computerised, it may be carried out by the crews (documentation, laptop) or remotely (ACARS transmission, for example).



One of the items in the calculation of takeoff parameters is the takeoff weight. As indicated above, this is sometimes only known late in the process, so the crew sometimes works with forecast values.

Depending on the on-board equipment and procedures, this weight used in parameter calculation is either entered into the ACARS or a laptop or transferred manually. This is one of the determining steps for the whole process of calculation and input of takeoff parameters, as will be seen below in the reported failures.

Other items are taken into account in parameter calculation and relate to conditions external to the aircraft. These conditions (in particular the runway used or the weather forecast) are likely to change practically up until takeoff, which therefore puts on strong time pressure during calculation of parameters. This can influence the effectiveness of procedures providing cross checks between crew members.

Different hardware can be used for these calculations. The unavailability of one of them can lead to a change in operating method and cause significant variability in execution of this function:

ACARS not working,

Laptop battery discharged or not working…

In the same way, the crew's amount of experience in using the equipment appears as another variability factor (for example, failure to understand the parameters stored by default).

In the majority of cases we find emerging from this function the takeoff card (filled in by hand or printed from ACARS or the laptop). The items normally used in the calculations and the speeds obtained will be found on this "card".

Among the 10 events studied, 9 were related to a major failure being produced during execution of this function.

- In 2 cases the failures were linked to the previous flight:
  - Use of landing weight parameters,
  - Use of the previous takeoff weight parameters in the laptop.
- In one case, the manual used for the speed calculation didn't match the aircraft type.
- In 6 cases, the weight used for calculation was erroneous:
  - Input of ZFW instead of TOW into ACARS,
  - Input of ZFW instead of TOW into the laptop,

- Input of ZFW instead of TOW into the laptop,
- Input (and use) of an erroneous TOW on the "card",
- Input (and use) of an erroneous TOW for an ACARS query,
- Remote calculation with an erroneous TOW sent.

These failures highlight the ineffectiveness of controls on this function.

How is the control on this function carried out?
An initial check (simple cross check of input value) may be carried out during input of weight data (in ACARS, in the laptop) or during transfer of the weight to the "card" (in the event of manual calculation). The main element of variability relates here to the availability of two crew members at the time of this input. The task will potentially be carried out by the Co-pilot alone.
Even an input with cross check doesn't guarantee the absence of an error, as one of the studied incidents shows: the captain calls out the value to be input and confirms the input made by the Co-pilot. However, the captain doesn't read the appropriate value, so calls out an erroneous value and the verification of input is ineffective.

The input of the ZFW instead of the TOW may be due to two different types of error:

- The pilot knows he should enter the TOW and takes the ZFW value,
- The pilot thinks he should input the ZFW and inputs the ZFW. In this case it's a matter of erroneous interpretation of system expectations and the heading on the field ("Planned TOW", …), if it's to guide the pilot, is not an adequate barrier.

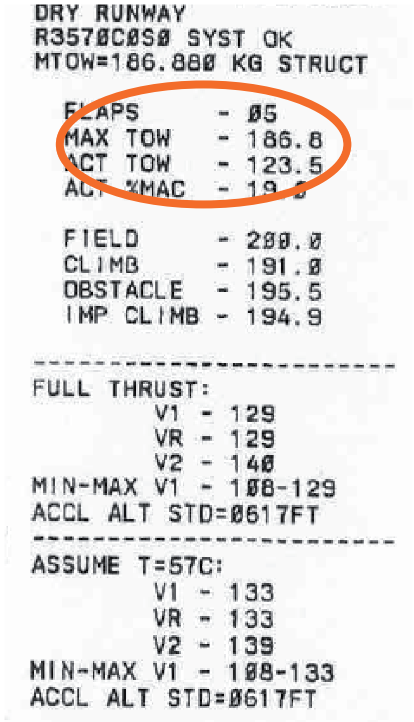
A double calculation (or a later calculation check) could also be used, especially when the calculation is performed manually or using a laptop. However, this double calculation may be disrupted by different contextual elements (unavailability of equipment, late change, time pressure). Finally, for the check to be effective, not only must the calculation be done twice but the selection of input data as well. In one of the incidents studied, the captain carried out a check of the calculation without confirming the TOW and so used the erroneous TOW to check the speeds, and hence obtained the same (erroneous) values as the co-pilot.

Analysis of the speeds obtained is also part of the function control. However, crews don't necessarily have comparison elements enabling them to detect values that are inappropriate for the aircraft, the flight and conditions on the day. On the other hand, elements coming into the speed calculation can have unusual values that will make it difficult for the crew to detect speed values unsuited to the conditions on the day:

- Altitude and elevated temperature,
- Increased QNH, low temperatures.

If there is a "card", the <u>input</u> elements for the calculation function can be verified afterwards (agreement with the loadsheet and/or the FMS).

Some contextual elements can disrupt the verification function.
In 2 events, the TOW is close to the MTOW. It's possible that this could have play a role during verification of data coming from ACARS, the MTOW being displayed just above the TOW. When the crew (or a member of the crew) compares the TOW input into the FMS (or the TOW on the loadsheet) with that taken into account in the speed calculation, he may "mistake" the line and read the MTOW value (close to TOW) instead of the (erroneous) TOW. The crew may thus "find" the value that they're looking for even if it's not in the appropriate place. The diagram below shows an example of an ACARS printout where the TOW and the MTOW are positioned close together.



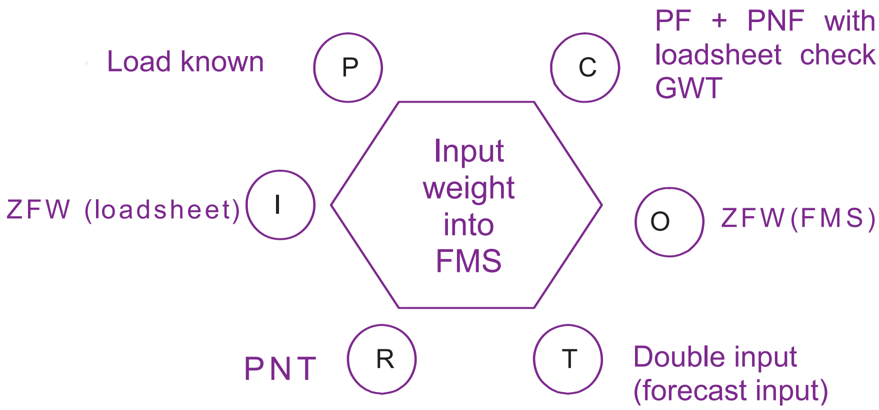
```
DRY RUNWAY
R3570C0S0 SYST OK
MTOW=186.880 KG STRUCT

  FLAPS      - 05
  MAX TOW    - 186.8
  ACT TOW    - 123.5
  ACT %MAC   - 19.0

  FIELD      - 200.0
  CLIMB      - 191.0
  OBSTACLE   - 195.5
  IMP CLIMB  - 194.9

------------------------
FULL THRUST:
         V1 - 129
         VR - 129
         V2 - 140
MIN-MAX V1 - 108-129
ACCL ALT STD=0617FT
------------------------
ASSUME T=57C:
         V1 - 133
         VR - 133
         V2 - 139
MIN-MAX V1 - 108-133
ACCL ALT STD=0617FT
```

Figure 5: Example of ACARS printout

3.3.5 Input of FMS data

When the aircraft is equipped with an FMS, we distinguish on one hand the input of weight without fuel (ZFW) and on the other the input of speeds (V1, Vr, V2).
The "automatic" function of reference speed calculation is available on some FMS.

Input of weight data

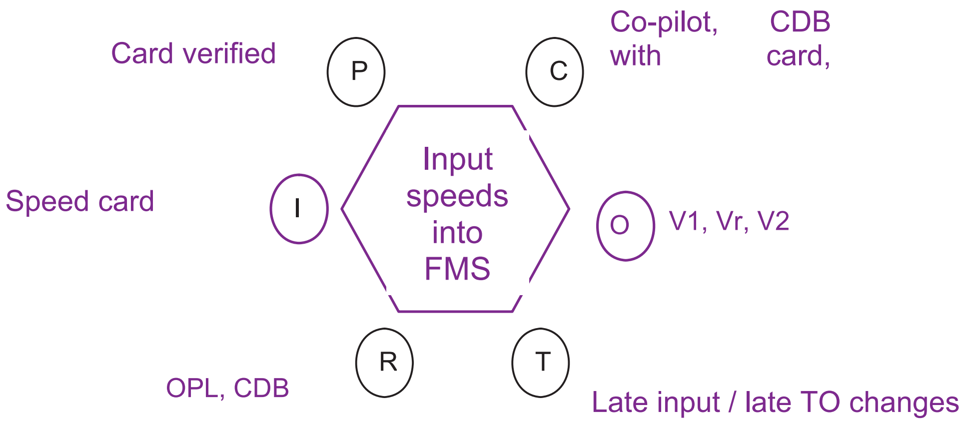


The input of weight data into the FMS relates to weight without fuel.
Depending on data availability (knowledge of the final load in particular), this may be done in two steps, first of all basing it on forecast data. The load can only be known once embarkation is completed and this is one of the factors creating time pressure.

Several elements can allow the correct execution of this function. A consistency check is possible when refuelling is carried out. The GWT can then be transferred to the TOW. A check can be carried out using the loadsheet during its validation.
Once the loadsheet is validated, the empty weight value is usually no longer subject to variation and should not give rise to new input (as opposed to speed values, as indicated below). However, last minute changes can take place and the new input of a weight into the FMS may have

implications for other functions such as that of speed input into the FMS (in some cases the speeds may be reset).

Speed input into the FMS

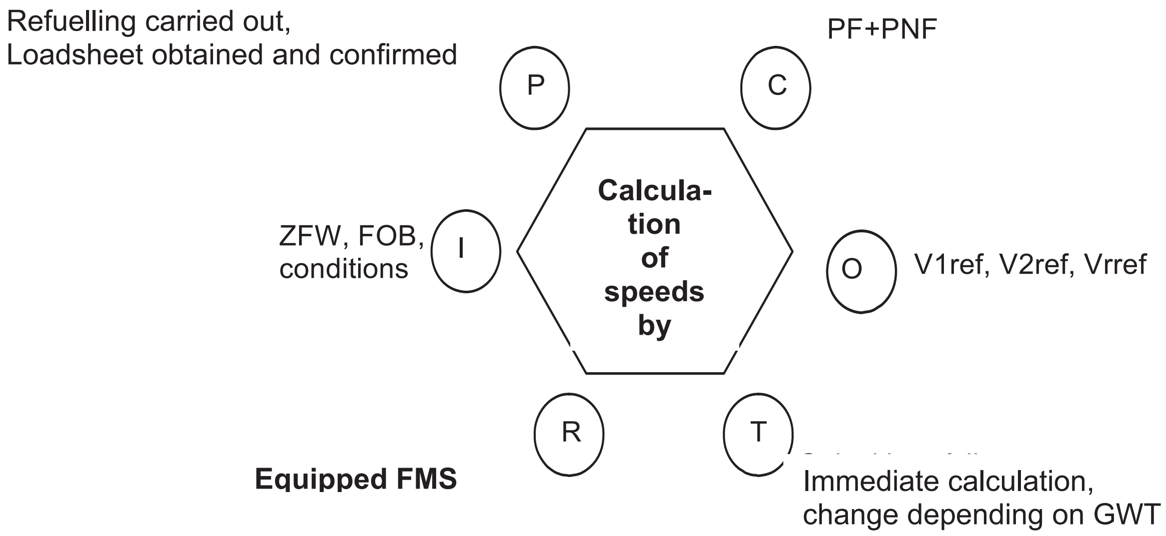


Speed input into the FMS arises from the "Parameter calculation" function. These speeds come from either the takeoff card when there is one or directly from the screen of a laptop.
As we have seen in the description of the calculation function, the late availability of weight data on one hand and on the other the possibility of late changes in conditions outside the aircraft are likely to cause strong time pressure on the input of these items. In one of the incidents studied, following a weight change, the speed data were input by the PNF during taxiing.
Verification of the correct execution of this function may be possible by direct verification with the values shown on the "card" (strict equality, even in the units used).

Failures identified.
In 6 of the 10 events studied, the aircraft was equipped with an FMS. In one of these 6 cases, the major failure was associated with this function. The error related to V1: it was a typing error associated with a late change made without cross-check.

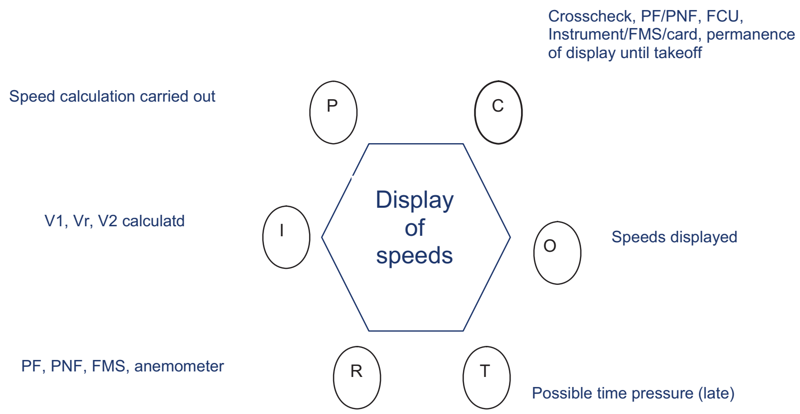
In the other 5 cases, the input speed values were erroneous. The error arose from the parameter calculation function. As during verification of the calculation, the input of these values is one of the steps where inconsistency of the values with the aircraft load and takeoff conditions could be detected. However, simple verification of a match between the elements input and the data shown on the "card" does not allow the error to be detected.

Speed calculation in the FMS



Some FMS can calculate reference speeds V1, Vr, V2. Even if the calculation doesn't take account of all the parameters (such as wet or dry conditions of the runway), even if these speeds are not confirmed, the values could nevertheless be displayed and used during checking of the speed input function.
However, it appeared that this facility was available in two of the events studied but it did not enable the crew to detect errors in speed calculations.

3.3.6 Display of speeds



When the aircraft is not equipped with an FMS, the speeds are transferred by means of an index value on the anemometer.
As in the case of using an FMS, the speeds displayed come from the parameter calculation function. These speeds come from either the takeoff card when there is one or directly from the screen of a laptop. As in the case of the calculation function, the late availability of weight data on one hand and on the other the possibility of late changes in conditions outside the aircraft cause strong time pressure on the input of these items.

Verification of the correct execution of this function may be possible by direct verification with the values shown on the "card" (strict equality, even in the units used).

The relative position of the speed index as well as the redundancy of displays also provides aids to checking the values.

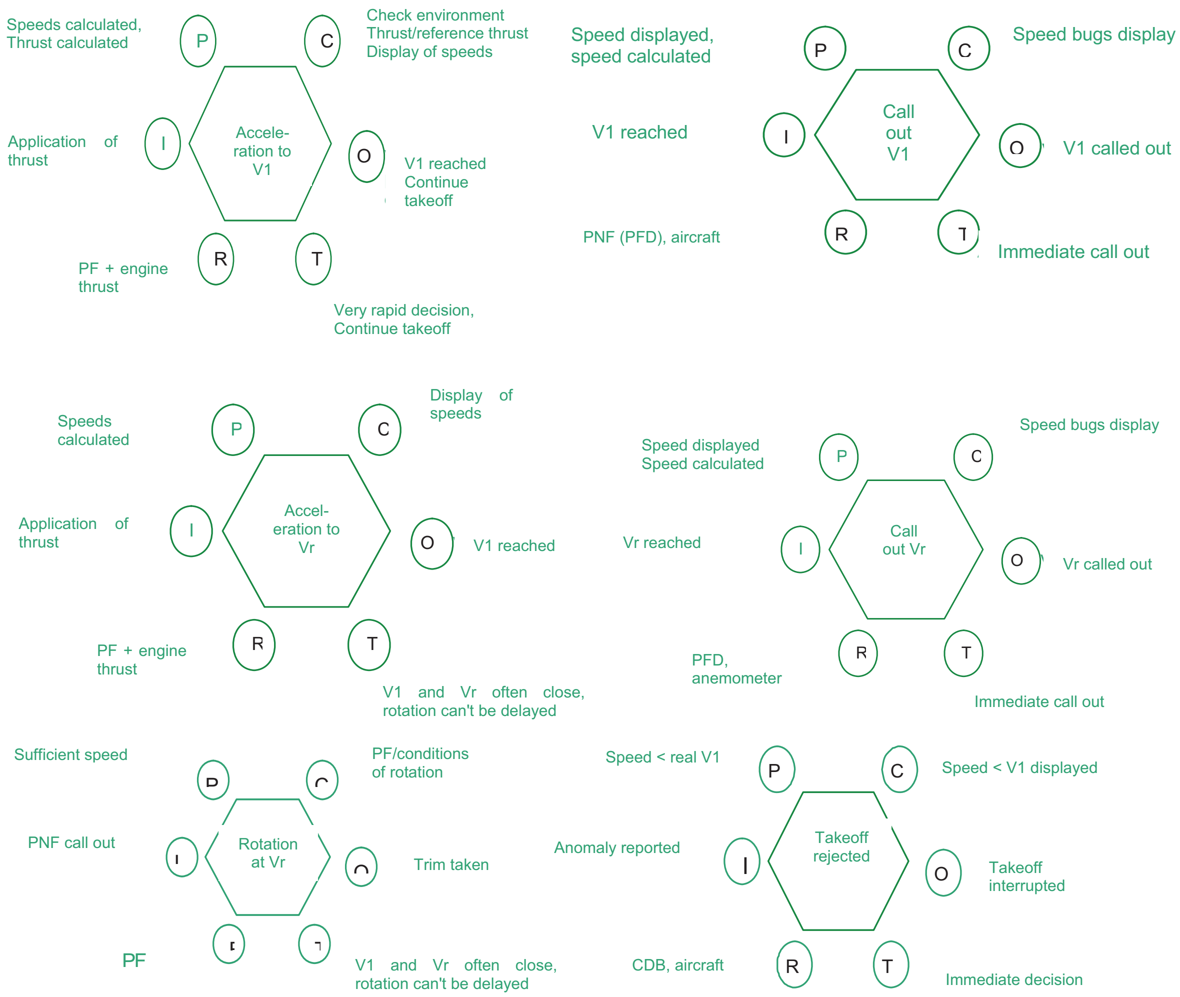
In the 4 cases studied where the aircraft was not equipped with an FMS, these elements did not however enable the detection of errors arising in advance of the parameter calculation function.

3.3.7 Takeoff

The takeoff phase is made up of the following steps:

1. Acceleration to V1,
2. Call out of V1,
3. Acceleration to Vr,
4. Call out of Vr,
5. Rotation at Vr.

The detection of an anomaly before V1 can lead the captain to reject takeoff.

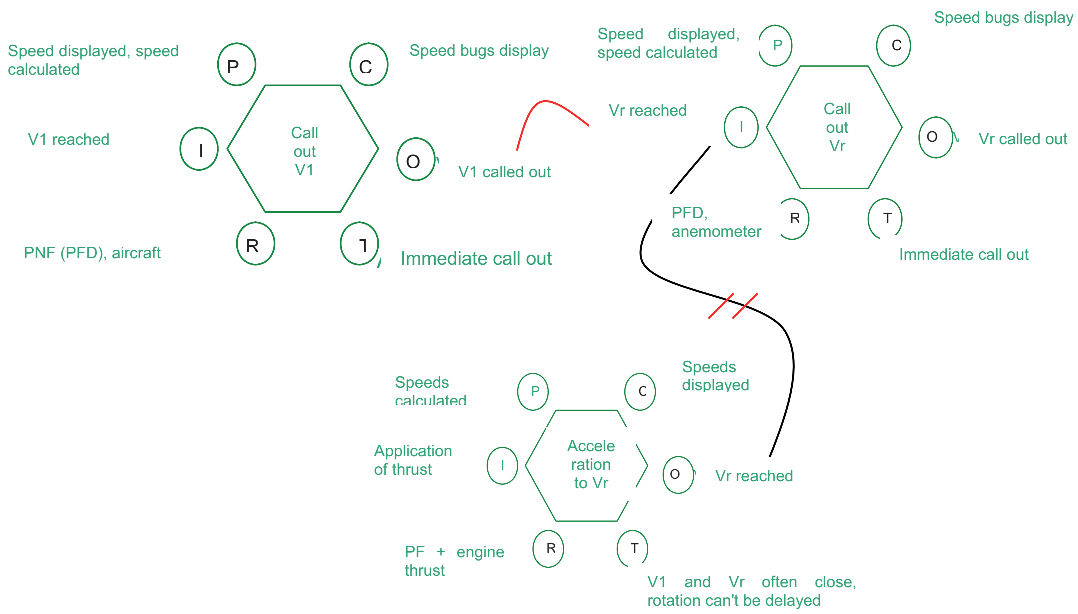


During acceleration to V1, the crew has several elements enabling it to detect an anomaly (see review of Human Factor aspects in the previous chapter). V1 is a reference in the decision to continue or reject takeoff. However, this reference comes from a calculated value and in the

event of an erroneous value safety aspects (either a possible stop before the end of the runway or continuation with an engine failure) are no longer guaranteed.
Contextual elements such as a rolling takeoff can make the detection of unusual aircraft behaviour more difficult.

Depending on the aircraft, V1 may be called out by the PNF (by reading the indication on the PFD or anemometer) or by the aircraft itself.
In one of the incidents studied, the crew noticed unusual aircraft behaviour and took the decision to reject takeoff after V1 was displayed but before the actual V1.

Vr is called out by the PNF (by reading the indication on the PFD or anemometer). The call out cannot be delayed and depends exclusively on the vigilance of the PNF.
In one of the incidents studied, the PNF called out Vr just after V1 while in this case V1 was erroneous and Vr was correct. V1 and Vr being "usually" very close to each other, the PNF may have the habit of making the call out just after reaching V1. The failure arises here from the erroneous link made by the PNF between the achievement of V1 and the achievement of Vr. This underlines the time pressure placed on the PNF as soon as he detects the signal indicating that Vr has been reached as well as the inadequate control of this function. Checking is based on the display of markers on the PFD. The Vr marker is not visible at the start and can be difficult to distinguish from the marker representing V1.



3.4 Summary of failures identified

The previous analysis has highlighted failures reported during the incidents studies. Contrary to the first assumptions made at the start of the study, they do not correspond to "*errors in weight input into the FMS*"; in fact they're not associated directly to the "*Weight input FMS*" function but to the "*Takeoff parameter calculation*" and "*Speed input into the FMS*" functions.

The following table illustrates this observation by distinguishing the correct (in black) and erroneous (in red) weight and speed data for each incident:

		Load sheet	Card	ACARS	Laptop	Main comp	FMS	FMS ref	Anemo meter
N505UA	ZFW	ZFW	ZFW						
	TO	TOW	TOW						
	V1		V1						V1
	Vr		VR						VR
	V2		V2						V2
OYKDN	ZFW	ZFW		MTOW			ZFW		
	TO	TOW	TOW	TOW		TOW	TOW		
	V1		V1	V1		V1	V1		
	Vr		VR	VR		VR	VR		
	V2		V2	V2		V2	V2		
N3203Y	ZFW	ZFW	ZFW						
	TO	TOW	TOW						
	V1		V1						V1
	Vr		VR						VR
	V2		V2						V2
ZSSAJ	ZFW	ZFW							
	TO	TOW	TOW	TOW					
	V1		V1	V1					V1
	Vr		VR	VR					VR
	V2		V2	V2					V2
9VSMT	ZFW	ZFW	ZFW				ZFW		
	TO	TOW	TOW				TOW		
	V1		V1				V1	V1	
	Vr		VR				VR	VR	
	V2		V2				V2	V2	
9GMKJ	ZFW	ZFW	ZFW						
	TO	TOW	TOW		TOW				
	V1		V1		V1				V1
	Vr		VR		VR				VR
	V2		V2		V2				V2
FHLOV	ZFW		ZFW				ZFW		
	TO	TOW	TOW		TOW		TOW		
	V1		V1		V1		V1	V1	
	Vr		VR		VR		VR	VR	
	V2		V2		V2		V2	V2	
CGHLM	ZFW	ZFW	ZFW				ZFW		
	TO	TOW	TOW	TOW		TOW	TOW		
	V1		V1	V1		V1	V1	V1	
	Vr		VR	VR		VR	VR	VR	
	V2		V2	V2		V2	V2	V2	
OYKBK	ZFW	ZFW	ZFW				ZFW		
	TO	TOW	TOW		TOW	TOW	TOW		
	V1		V1		V1	V1	V1	V1	
	Vr		VR		VR	VR	VR	VR	
	V2		V2		V2	V2	V2	V2	
FGLZR	ZFW	ZFW	ZFW				ZFW		
	TO	TOW	TOW	TOW	TOW	TOW	TOW		
	V1		V1	V1	V1	V1	V1		
	Vr		VR	VR	VR	VR	VR		
	V2		V2	V2	V2	V2	V2		

Table 3: Summary of correct and erroneous data

Key points

The key points that emerge from this detailed description are:

- The time pressure related to obtaining the weight data[1],
- Late changes,
- Availability of equipment or human resources,
- Insufficient knowledge of the orders of magnitude enabling the removal of doubt over speed values inappropriate for the aircraft and conditions on the day,
- Controlling functions.

The study of incidents highlights the ineffectiveness of the control functions. The controls are often item by item comparisons. But "one wrong item = one wrong item" is an accurate but inadequate control. In reality there is no overall consistency check.

120

[1] In fact, these data cannot be known with certainty until the last moment (embarkation carried out, refuelling finished). But these functions appear as preconditions for functions related to speed calculation and input of data into the FMS.
This situation can lead crews to adopt strategies (depending on their procedure), such as to carry out preliminary calculations and to input these forecast data.

4 Improvement proposals

The analysis of incidents has highlighted the different functions involved, the variability of these functions as well as the existing controls (more or less effective) enabling these functions to be performed properly. Functional analysis enabled us to show how the variability of certain functions as well as the interdependence of different functions can allow errors to arise and propagate until takeoff.

In the context of flight preparation, the objective of the barriers that we're going to study is to avoid incidents at takeoff due to erroneous takeoff parameters: It's a matter either of having the correct parameters, or of detecting the anomaly before V1 (or even before 100kts), or as a last resort of avoiding tailstrike if the takeoff occurs before Vr.

Different systems enable implementation of these barriers. We will distinguish:

- Physical barriers,
- Functional barriers (controls during item input),
- Symbolic barriers (procedures, guidance) that require interpretive action to achieve their aim,
- Incorporeal barriers (safety policy, user knowledge).

There is no question of implementing all these possible barriers:

- Some could prove to be redundant.
- Implementing all the barriers and in particular the symbolic procedural barriers would significantly overburden the preparation phase. Too great a workload could be harmful to the effectiveness of symbolic and incorporeal barriers.
- The feasibility of implementing a barrier must be studied, taking account the actual operational context. This is why one of the objectives of the observations will be to describe the context in order to test the validity of different barriers.

The barriers identified have been defined function by function, they relate to functional, symbolic and incorporeal barriers. They are based on analysis of the incidents, the literature search and ergonomic inspection.

4.1 Physical barriers

A physical barrier physically prevents an event from occurring or physically blocks the effects of an unexpected event.
Certain aircraft are equipped with a tail shoe that could play this role of mechanically protecting the fuselage. Experience has shown that these systems present more disadvantages than advantages.

No additional physical barrier has actually been studied.

4.2 Functional barriers

Functional barriers are intended to limit input errors, handing over basic checks to the automated systems. Functional barriers are very <u>resistant to time pressure and task interruptions</u> since they don't require interpretation on the part of the crew.

Possible barriers relate to:

1. <u>Equipment into which weight values must be input (Laptop, ACARS).</u>

Software controls could be strengthened. The feasibility of the following controls could be studied:

- Comparison of values with similar flights. In the event of a new calculation for the same flight, comparison with the previously calculated values,
- Another means of strengthening the control would be modification of the input function. The possibility of redundancy in data input could be studied: for example it could be the input of ZFW, TOW and FOB.

2. FMS

A strengthening of controls (see existing controls in the ergonomic inspection) could be reviewed:

- For example it could be to check consistency between the 3 speeds input.
- Other controls based on the weight on the day and the conditions on the day could also be studied (with an internal calculation of the orders of magnitude of speeds, for example).

4.3 Symbolic barriers

4.3.1 Systems

In terms of systems, the symbolic barriers could be strengthened:

1. By the calculation and presentation of reference speeds in the FMS.

Only some FMS are currently equipped with this function. Making it general to all FMS could be considered. However, the incidents have shown that the simple presentation of reference speeds by the FMS does not constitute an effective symbolic barrier. Strengthening of this barrier could be considered by providing a warning message in the event of significant differences, or a display of these differences.

2. By the implementation of an independent assessment system for the weight and balance of the aircraft.

Some aircraft are already equipped with such a system ("Weight and Balance" type) enabling independent assessment of the weight and balance of the aircraft. A possible first level barrier consists of displaying this assessment. A second level could consist of querying of this value by the FMS and a comparison with the GRWT values coming from crew input and assessment of the fuel.

4.3.2 Workload

The study of incidents showed the large number of values handled and the relative ineffectiveness of procedural functions associated with controlling these values. The various concepts handled (GWT, TOW, MTOW, ZFW, load, fuel loaded, FOB…), the associated units (kilograms, thousands of kg, tonnes, litres…), the headings used (TOW, Planned TOW…) make their forms too numerous to be held in working memory. Thus the values handled lose their meaning, preventing any comparison with the values for data used in an equivalent context and which could, depending on the level of experience of the pilots, have been retained in long term memory.

Strengthening the symbolic barriers should not be directed towards further burdening of the input and control procedures. Improving the symbolic barriers must go in the direction of reducing the workload, especially the mnemonic load, as well as in the direction of standardisation, enabling a reduction in selection or transposition errors.

Improvements could relate to:

- Standardisation of data manipulated in the different contexts (validation of the loadsheet, input into ACARS, input into the FMS) as well as optimisation of the number of values displayed (for example, consider presenting some differences rather than all the values),
- Standardisation of the representation of data and headings ("card", BLT, ACARS, loadsheet, fuel docket, FMS, TU),
- Optimisation of names (more obvious differentiation: MTOW/TOW),
- Improvement in the presentation of some data. The article by SHERRY (2000) suggests the idea of using a graphic interface to represent the environment. This could relate in part to a graphic representation of the runway with indicators for the place where speeds are reached or a graphic representation of the weight data (in the form of superimposed bar graphs, for example, representing the empty weight, the load, the fuel and the MTOW). This could be considered on the interfaces of the FMS, the "card" and/or the laptop.

The study of incidents showed how non-robust the system was when faced with late changes. And the study by Fenell (2006) showed that the MCDU interface worked well when:
- The pilot's task is directly supported by a function,
- Access to pages and data formats is guided by labels or other visual indications.

This study shows the importance of guidance by the interface and the suitability of the interface for the task. Future systems should be constructed with this in mind. The suitability for late changes could be particularly studied. For example we can refer to late changes in the departure runway, which does not seem to be a task supported by the interface and that requires significant reformulation on the part of the crew.

4.3.3 Overall consistency check

Improvement of symbolic check barriers should not go in the direction of increasing the number of item checks. Item checks are useful for detecting input errors rapidly. However, as the incident analyses show, these checks are not resistant to variability in the availability of resources (of the captain, in particular) and not resistant to interruptions in the task. Checking procedures must allow movement towards an <u>overall consistency check</u>:
- One of the improvement points could consist of a systematic association of weight – speed data,
- The persistence of some representations (those of the "card", loadsheet, FMS), their accessibility and the strict equality of values between the different representations could also leave open the possibility of permanent and relatively easy crosschecking: <u>joint verification of these three representations should</u> enable detection of errors linked to an insufficient weight being taken into account in calculation of speeds. This could be like what has been implemented by some airlines for high-lift flap values, where a check enables comparison of different values (value taken into account for takeoff parameters, value selected on the "handle" for the flaps, value displayed by the system).

4.3.4 Taxiing to takeoff

The check of "V1 call out" and "Vr call out" functions could be strengthened. General implementation of an automatic call out for V1 and implementation of an automatic call out for Vr could be studied. However, particular care must be taken because such as implementation would not be without side effects (impossible to have delayed call out, for example).

A decision support system such as suggested in the Bove (2002) article could also constitute an ultimate barrier. If takeoff is started with an erroneous V1, Vr or inadequate thrust, the system can enable detection of non-nominal behaviour of the aircraft. As for all warning systems, the compromise between efficiency and nuisance can be hard to find. The activation threshold must be defined so as to limit the number of aborted takeoffs, given the associated inconvenience and risks.

4.4 Incorporeal barriers

Implementation of an incorporeal barrier can be more sensitive, the results are less immediate and more difficult to assess. However, in view of the literature analysis and incident analysis, two improvement strategies should be studied.

4.4.1 Orders of magnitude

We have previously seen that the failure of the takeoff parameters to remain in working memory for a long time does not allow the pilot to create in internal representation of the values. This explains why pilots don't (or no longer) possess orders of magnitude of speeds, so making it difficult even in the event of "gross" error to raise a doubt over values incompatible with the flight.
One of the objectives of the symbolic barriers suggested is to encourage storage of values in working memory and their transfer to long term memory. The next idea is to promote consideration of the following problem by the crew: Have we got the appropriate takeoff parameters? The solution should not then be based only on routines and rules but also by access to their experience (see model by Rasmussen, 1983). Of course the ideal would be if the crew was able to formulate the problem by basing themselves on knowledge in long term memory:

> *We have a type X aircraft, so the empty weight is Y.*
> *The reported load is about Z.*
> *We've decided to take on W fuel …*
> *So we have a total of V.*
> *Which we can verify.*
> *Conditions on the day are C1 and C2, so we will have to take off with speeds of around XXXX. Which we can verify.*

This reformulation of the problem could, as necessary, call on a permanent representation in the cockpit showing the orders of magnitude, for example in the form of a summary table giving an acceptable range of V2 compared to conditions on the day, even if this did not cover all eventualities.

4.4.2 Training for emergency situations

Strengthening of operational barriers can be done by improving crew skills. But the few existing studies on flight preparation functions or the fact that in the existing studies the input of takeoff parameters was not considered a critical situation ("observations during training had showed that these tasks did not put pilots to the test", Sarter, 1994) show the difficulty in a simulator of observing the context of takeoff preparation and reproducing all the interactions in order to have a truly ecological approach in the study of this phase. In addition, the results of the study by Stevens (2007) underline the little data relating to the validity of transfer between skills acquired on a simulator during expected situations and their application to unexpected emergency situations (such as stopping takeoff).

4.5 Detailed tables of the different barriers considered

Calculation of takeoff speeds

		Effectiveness	Strengthening
Functional barriers	ACARS Laptop Software control on size of possible values		*Remote calculation and laptop calculation* Software control (comparison with similar flights, for example) Possible redundancy in the input of relevant parameters (e.g. ZFW+TOW+FOB) In the event of a new calculation, comparison with previously calculated data ACARS/FMS link
Symbolic barriers	*Manual* *ACARS* *Laptop with paper "card"* *Laptop without paper "card"*	Double calculation Verification of "card" Cross check during entry of input parameters	Standardisation of systems Standardisation of headings Optimisation of names (more obvious differentiation: MTOW/TOW) Standardisation of data manipulated *Manual* Removal of documentation related to another aircraft Improvement of on-board documentation relating to calculation of takeoff parameters Redundancy of calculation of takeoff parameters Systematic association of weight-speed data Joint verification of FMS/"card"/loadsheet Improvement in presentation of data (weight in particular, graphic presentation, optimisation of number of values displayed, e.g. MTOW/TOW difference) Strengthening of information transfer chain Printing of a "card" using the BLT Standardisation of representation of data ("card", BLT, etc.) Systematic association of Weight-Speed data (simultaneous transfer to the "card")
Incorporeal barriers	Knowledge of orders of magnitude		Improvement in knowledge of orders of magnitude Training

Input of parameters into the FMS

		Effectiveness	Strengthening
Functional barriers	Software control on magnitude of possible values	Insufficient	Strengthening of software control (order of magnitude of values, comparison with usual values …)
Symbolic barriers	Cross checks during input Check by other flight crew Check during takeoff briefing Comparison with speeds on the "card", those supplied by the laptop and/or FMS	Ineffectiveness in the event of previous errors in speeds and ineffectiveness due to variability in the availability of resources and late changes	Suggestion of speeds by the FMS in all cases with warning message in the event of significant differences or display of these differences Revalidation procedure for parameters in the event of late changes Improvement in presentation of data (weight in particular, graphic presentation, optimisation of number of values displayed (e.g. MTOW/TOW difference)) Standardisation of displays (FMS/"card" compatibility) Joint execution of verification operations Optimisation of names (more obvious differentiation: MTOW/TOW) Joint verification of FMS/"card"/loadsheet
Incorporeal barriers	Knowledge of orders of magnitude	Insufficient	Improvement in knowledge of orders of magnitude Knowledge of the origin of differences between calculation by the FMS and other calculation methods

Display of speeds

		Effectiveness	Strengthening
Functional barriers	Position relative to speed indices		
Symbolic barriers	Redundancy of displays (Captain and Co-pilot) Graphic representation of positioning of speeds		Revalidation procedure for parameters in the event of late changes
Incorporeal barriers	Knowledge of orders of magnitude	Insufficient	Improvement in knowledge of orders of magnitude

Takeoff

		Effectiveness	Strengthening
Functional barriers	Position relative to speed indices		
Symbolic barriers			Automatic generation of call out by the aircraft Supply of acceleration times to V1 and Vr and graphic representation of takeoff (with V1 and Vr in particular)
Incorporeal barriers		Insufficient	Knowledge of the value of Vr

5 Study of changes at the design stage

In order to optimise any possible recommendations on the design and certification of systems, it's important to know the future directions being taken by manufacturers on this subject. A questionnaire (included in an appendix) was drafted and sent to the different companies involved (Airbus, Boeing, Honeywell).

Airbus sent the following responses:

A – What are your developments for the FMS relating to takeoff parameters for future aircraft?

The different modifications planned are attached:
Check of ZFW and ZFWCG input ranges.
Init in ZFW and not GW.
V1/V2/Vr input checks compared to VS1G/VMU, VMCA limitations. Check for takeoff speeds that are too low.
Consistency in V1/V2/Vr.
Availability of takeoff speeds.
Verification of aircraft position relative to runway entrance.
Monitoring and feedback functions for the crew are currently under review and a patent application in progress on these subjects.

B – Sequence of FMS pages

None

C – Weight data

Input of ZFW is implemented currently, it will no longer be possible to enter a GW.
A range controller is already planned.
A feasibility study is in progress relating to a system for measuring GW and CG.

D—Speed data

Speed consistency is currently in development as well as proposed limitations for pilot inputs.
The limitations are to do with VS1G, VMU, VMC.
Speed availability will also be offered, meaning verification that the data have been input.

E – Flight conduct and takeoff performance parameters

There is a current project and a patent application is in progress.
Current feasibility studies relating to verification of the takeoff distance compared with runway length. Such a system could be included in an FMS.
The study will identify if it's necessary to have a graphic representation, which has not currently been decided.
Monitoring and feedback functions for the crew are currently under review and a patent application in progress on these subjects.

F – Other comments

None

6 Corsairfly Survey

A questionnaire (see appendix) was designed and distributed to all the pilots at Corsairfly. A total of thirty responses were received; this chapter summarises all the responses gathered by the airline.

The summary relates to 30 responses coming from:

11 Co-pilots: 3 Co-pilots A330
8 Co-pilot B747

19 captains: 7 A330 captains, including one TRE
10 B747 captains including one TRI and three TRE
1 B737 captain
1 TRI captain on an unspecified aircraft type

Question 1 "**During your career with Corsairfly, have you ever recorded that takeoff was or could have been carried out with reduced safety margins because of erroneous parameters?**"

50% of pilots answered yes with the following details:

Weights: 5 cases

- 1 error in basic weight detected after takeoff when re-reading the loadsheet.
- 1 input error (B744) of takeoff weight instead of ZFW into the FMS was not detected before takeoff but during preparation for approach during speed calculations.

There was confusion between the ZFW (1880t) and GW (200t) for a B747 taking off empty with 20t of fuel on-board (this is a rare type of flight for a long-haul crew).

- 1 input error (A330) of ZFW into the MCDU instead of the TOW, detected when Co-pilot was reading speeds following a disagreement with the captain.
- 1 input error (B744) of ZFW instead of GW detected before takeoff when re-reading the FMS during flight compartment preparation procedures
- 1 input error (B744) into the BLT (landing weight confused with takeoff weight) before input into the FMS, detected before takeoff by joint checking of BLT.

Configuration: 2 cases

- 1 error (A330) detected before takeoff during "before takeoff" briefing.
- 1 error (A330) detected during flight compartment verification procedures (before departure briefing).

Speeds: 2 cases

- 1 calculation error for V1, Vr and V2 on conventional B747, detected during " flight compartment verification" procedures using a mental calculation method based on a simple mass/speed ratio (the weight in the calculation being correct). The origin of the error is not specified;
- 1 absence of V2 display (B744) on the MCP (consequently V2 not displayed on PFD) detected during the run to takeoff.

<u>Thrust:</u> 1 case

- 1 error (A330) of thrust display following poor reading of Airbus laptop: use of reduced thrust instead of full thrust. (note: this type of error led to calculation of erroneous speeds.)

By entering the takeoff weight, conditions on the day (flap configuration, runway, weather conditions, etc…) the Airbus laptop will determine the performance values for reduced thrust. From this calculation of theoretical temperature (this is the temperature for which the takeoff weight would be the maximum permitted weight) emerges a reduced takeoff EPR or N1 and speeds V1, Vr and V2, the values of which are noticeably different from those given for an identical weight but at a full thrust. The crew took the values calculated by the Airbus laptop while a reason (not indicated in the statement) required the crew to perform takeoff under full thrust.

<u>Runway:</u> 5 cases

- 1 input error (B744) of the runway in use into the FMS detected before takeoff during the before-takeoff briefing.
- 1 input error (A330) of the runway into the FMS detected before takeoff during the flight compartment verification procedures.
- 1 input error ((B737) of the runway linked to an input error for the airline route (MLA/ORY instead of AGP/ORY) into the FMS, MYA and AGP having QFU 14/32. The error was detected during application of thrust at takeoff with the appearance of the alarm message "verify INS position" after having operated the "switch TO/GA".
- 1 input error (A330) of the runway in use detected before takeoff during the flight compartment verification procedures.
- 1 input error (A330) of the runway linked to an input error for the departure airfield (TFFF instead of TFFR), detected before takeoff during the flight compartment verification procedures.

Question 2 "**what are the principal constraints that you face from preparation until takeoff?**"
The responses were as follows:

- 15 responses relating to time constraints.
- 12 responses relating to the number of outside involvements during preparation and flight compartment verification procedures before leaving the stand.
- 2 responses relating to late knowledge off the final loadsheet (late arrival of the loadsheet on-board).
- 1 response relating to uncertainty over the QFU in use.
- 1 response relating to work overload for training flights.

Question 3 "**what are the principal strategies that you use to deal with these constraints and to ensure that the takeoff parameters are correct?**"
The responses were as follows:

- 1 response relating to input of parameters estimated on the laptop, at the start of flight compartment preparation.
- 2 responses relating to performance calculations depending on the items estimated during flight preparation in operations.
- 2 responses relating to loadsheet validation by the 2 pilots (and not the only captain).
- 8 responses relating to the verification of calculations by having the orders of magnitude in mind and by using a simple "weight/speed" mental calculation rule.
- 4 responses relating to maintaining a closed piloting position during flight compartment verification procedures.
- 2 responses relating to writing calculated values in addition to reading them on the FMS/laptop.

- 4 responses relating to maintaining a closed mental attitude to time pressure ("taking your time however urgent it is").
- 1 response relating to verification of BLT calculations by comparing them with speeds suggested by the FMS (with only V1) after having confirmed the route and the FMS weight by comparison between the PV and FMS unballasting (PROGRESS page).

Question 4 "**Do you have any comments and/or suggestions?**"
The responses were as follows:

- go back to a simplified takeoff card (1 response).
- Calling out the runway read from the ND during the before takeoff briefing (1 response)
- Using 2 BLT (2 responses)
- Implement a runway change/rerouting QRH (1 response).
- Limit manual inputs by pilots (1 response).
- Alternating Captain/Co-pilot in the performance calculation to avoid falling into a routine action (1 response).

7 Observation flights

The objective of the observations was to take account of all operational aspects linked to calculation and input of takeoff parameters into the FMS and to understand the context of the flight preparation phase and factors that could be the origin of errors arising. Observation should enable the analysis of the key items identified during the previous steps and the description of variability in operating methods, data flows and task interruptions.

7.1 Data collection method

During each observation, data were collected by two observers using separate observation charts. One chart was intended to collect data relating more to the operational context (number of people in the cockpit, unusual events, phasing of preparation) as well as all communications and conversations (Figure 6). The second chart was devoted to crew activity, enabling recording of all crew-system interactions, especially data entry into the FMS (Figure 7).

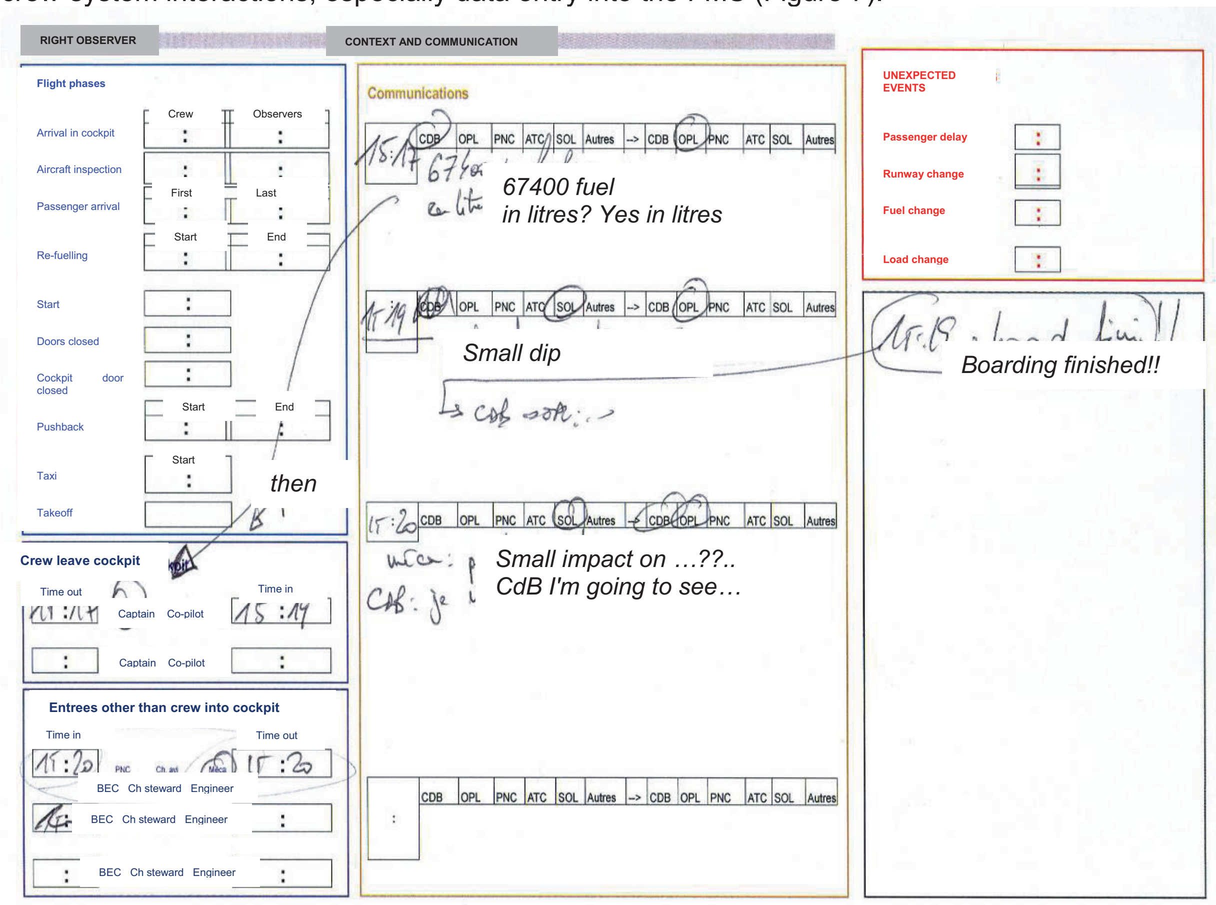


Figure 6: Example of a page from the "context, communication and conversation" observation chart.

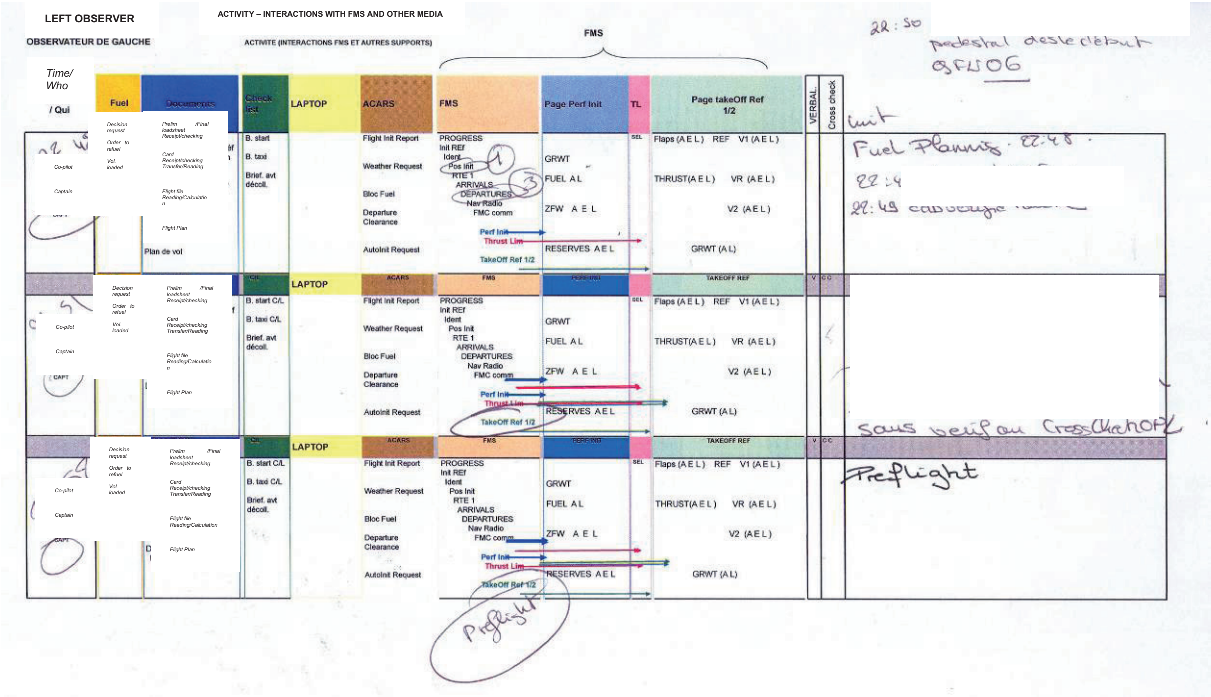


Figure 7: "Activity, crew-system interactions" observation chart.

7.2 List of observations performed

The following table lists all the observations performed. In total, the data were collected on 7 rotations operated on B777, A320, B747 and A330, each including 2 or 3 legs, making a total of 14 flights (see table below).

Rotation	Aircraft type	Flight	Equipment	Code
A	B777	CDG-BEY	FMS+ACARS	1-B777-CDG-BEY
	B777	BEY-CDG	FMS+ACARS	1-B777-BEY-CDG
B	B777	CDG-BEY	FMS+ACARS	2-B777-CDG-BEY
	B777	BEY-CDG	FMS+ACARS	2-B777-BEY-CDG
C	A320	CDG-AMS	FMS	4-A320-CDG-AMS
	A320	AMS-CDG	FMS	4-A320-AMS-CDG
D	B747	ORY-FDF	FMS+Laptop	5-B747-ORY-FDF
	B747	FDF-PTP	FMS+Laptop	5-B747-FDF-PTP
	B747	PTP-ORY	FMS+Laptop	5-B747-PTP-ORY
E	B747	ORY-SXM	FMS+Laptop	6-B747-ORY-SXM
	B747	SXM-FDF	FMS+Laptop	6-B747-SXM-FDF
	B747	FDF-ORY	FMS+Laptop	6-B747-FDF-ORY
F	A330	CDG-BKO	FMS+ACARS	7-A330-CDG-BKO
	A330	BKO-CDG	FMS+ACARS	7-A330-BKO-CDG

Table 4: List of rotations performed.

7.3 Additional observations

An observation chart intended for TREs was designed for Air France (Appendix). The distribution of this chart has been delayed in order to launch the observation campaign once new equipment (especially the laptop) and associated procedures have been implemented.

7.4 Analysis method

For each flight, all the items reported on the two observation charts were grouped together and transcribed so as to get a complete chronological picture from arrival in the cockpit (or the start of flight preparation, as appropriate) until takeoff. The following table shows an example of this:

	A	B	C	D	E	F	G	H	I	J
1	UTC	H-mm prév.	H-mm réel	OBSERVATIONS	FMS Gauche	FMS Droit	CDB	OPL	OBS	Autres
148	10:08		0:27	Back end crew call for CdB: missing 2 passengers. Neither Cdb nor back end crew have loadsheet	PERF INIT	RTE 1	oui	oui	oui	
149	10:09		0:26	Co-pilot updates QNH in BLT CdB makes PAX announcement of delay CdB makes PAX announcement of delay	PERF INIT	RTE 1	oui	oui	oui	
150	10:10		0:25		PERF INIT	RTE 1	oui	oui	oui	
151	10:11		0:24	CdB makes PAX announcement of delay 2 mising PAX are not the OBS… Arrival of final loadsheet and info on unloading of 500 kg of freight compared with ZFW given by OPS	PERF INIT	RTE 1	oui	oui	oui	veste orange
152	10:12		0:23	CdB updates ZFW in FMS, inputs 247.5 T and reconfirms GRWT, confirmed by Co-pilot in flight file which adds CG at 19%.	PERF INIT	RTE 1	oui	oui	oui	
153	10:13		0:22	Co-pilot gives BLT to CdB CdB looks at parameters and verifies them in his head, then enters them into the FMS with Co-pilot cross-check on the FMS. CdB enters imaginary T° and verifies associated EPR	THRUST LIM	RTE 1	oui	oui	oui	
154	10:14		0:21	Co-pilot gives BLT to CdB CdB looks at parameters and verifies them in his head, then enters them into the FMS with Co-pilot cross-check on the FMS. Input of speeds (147, 162, 172): "V2 FMS, FMS suggests 148, the difference isn't significant, I'm inputting 147…" same for Vr and V2. NB. Co-pilot doesn't see BLT	T/O REF	RTE 1	oui	oui	oui	
155	10:15		0:20		T/O REF	RTE 1	oui	oui	oui	
156	10:16		0:19	CdB saves data and gives BLT to Co-pilot Back end crew: can we close? CDB: and the 2 PAX? Back end crew: they're here. CdB: Ah! Ok, then we'll close	T/O REF	RTE 1	oui	oui	oui	PNC
157	10:17		0:18		T/O REF	RTE 1	oui	oui	oui	
158	10:18		0:17	Doors closed	T/O REF	RTE 1	oui	oui	oui	
159	10:19		0:16	CdB calls GROUND to be notified of door closure	T/O REF	RTE 1	oui	oui	oui	
160	10:20		0:15	Before start check-list: 247.5, then GROUND interruption. CdB: STDBY to GROUND. After C/L: V1, Vr, V2, both look in FMS NB: C/L made in English	T/O REF	RTE 1	oui	oui	oui	

ORY-FDF (3) / ORY-FDF (2) / ORY-FDF / Feuil1 / FDF-PTP / PTP-ORY

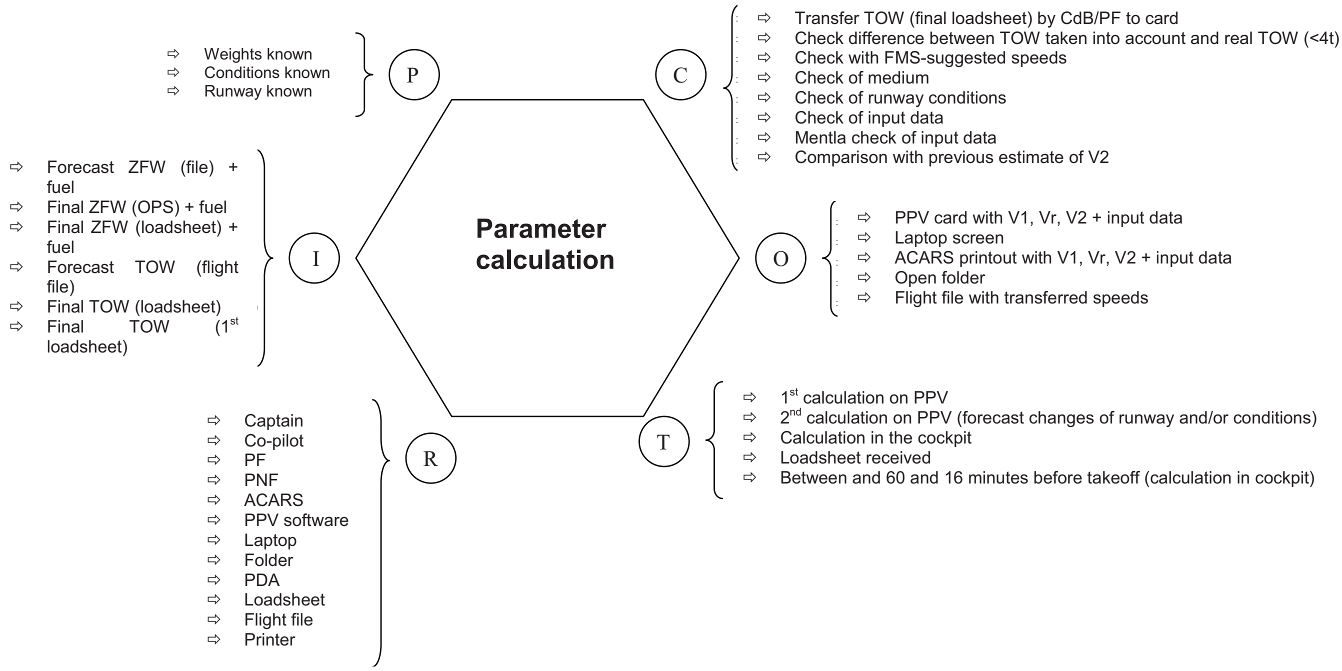
Table 5: Example of chronological table of an observation.

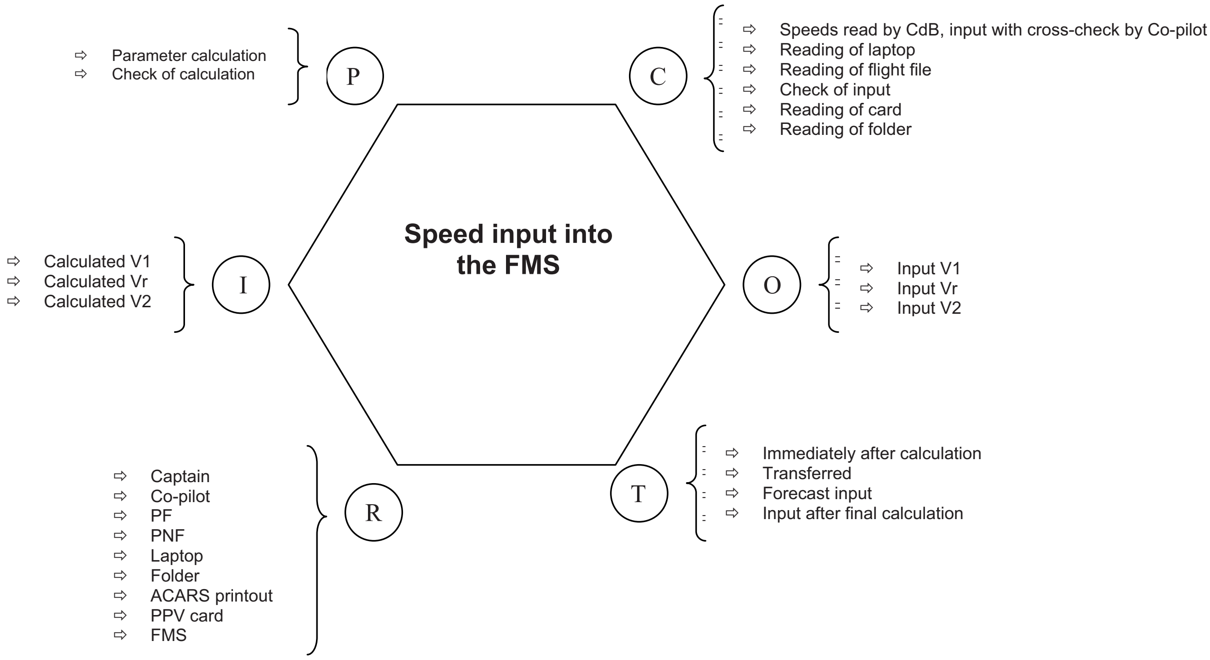
7.5 Results

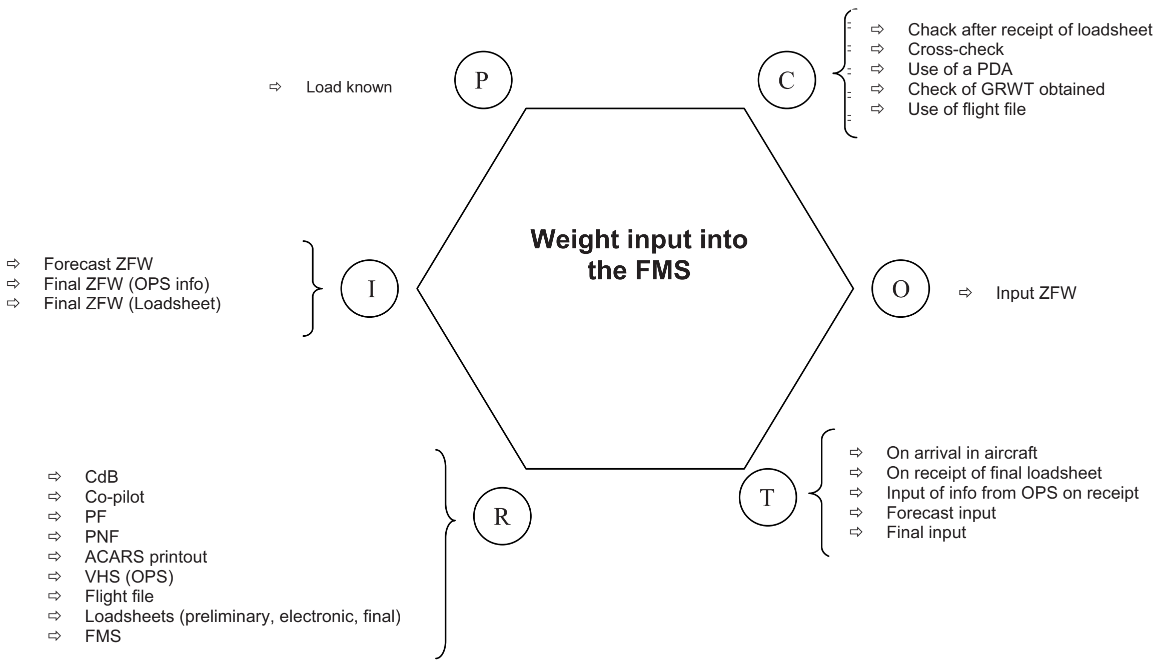
7.5.1 Variability of different operating modes

7.5.1.1 FRAM model

The data coming out of the observations relating to the "parameter calculation", "weight input into the FMS" and "speed input into the FMS" functions were analysed following the FRAM model.
The following figures bring together all the items that were used during the observation flights.







The items relating to temporal aspects, the data input and controls appeared the most interesting to give in detail in order to highlight the variability in different operating modes.

7.5.1.2 Temporal aspects

The following graph describes the basic items that will be reported in the graphs analysing the temporal aspects. All the hour data are expressed relative to the actual takeoff time. Arrival in the cockpit was spread out from 1 hr to more than 2hr30 before takeoff. In reality, for some flights the crew remained in the cockpit during the stopover (as was the case at BEY and FDF before the FDF-ORY leg).

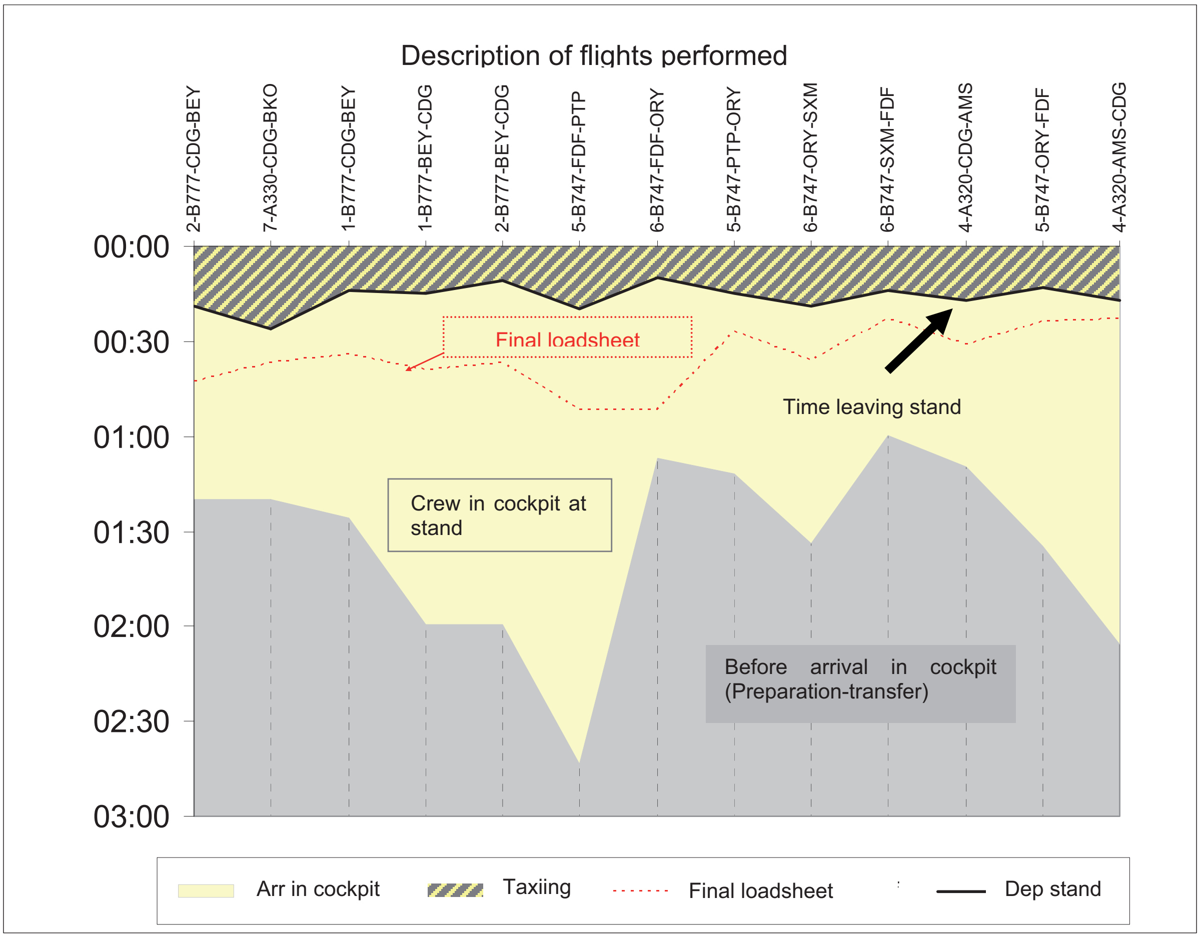


Figure 8: Temporal aspects – basic items

Analysis of the incidents has shown that the parameter calculation step is a critical phase. In most cases erroneous parameters input into the FMS come from errors committed previously due to an inappropriate calculation.

The following graph describes the temporal aspects of all the observations: The ■ symbols indicate the moment (relative to actual takeoff time) at which parameter calculation and possible additional calculations were carried out.

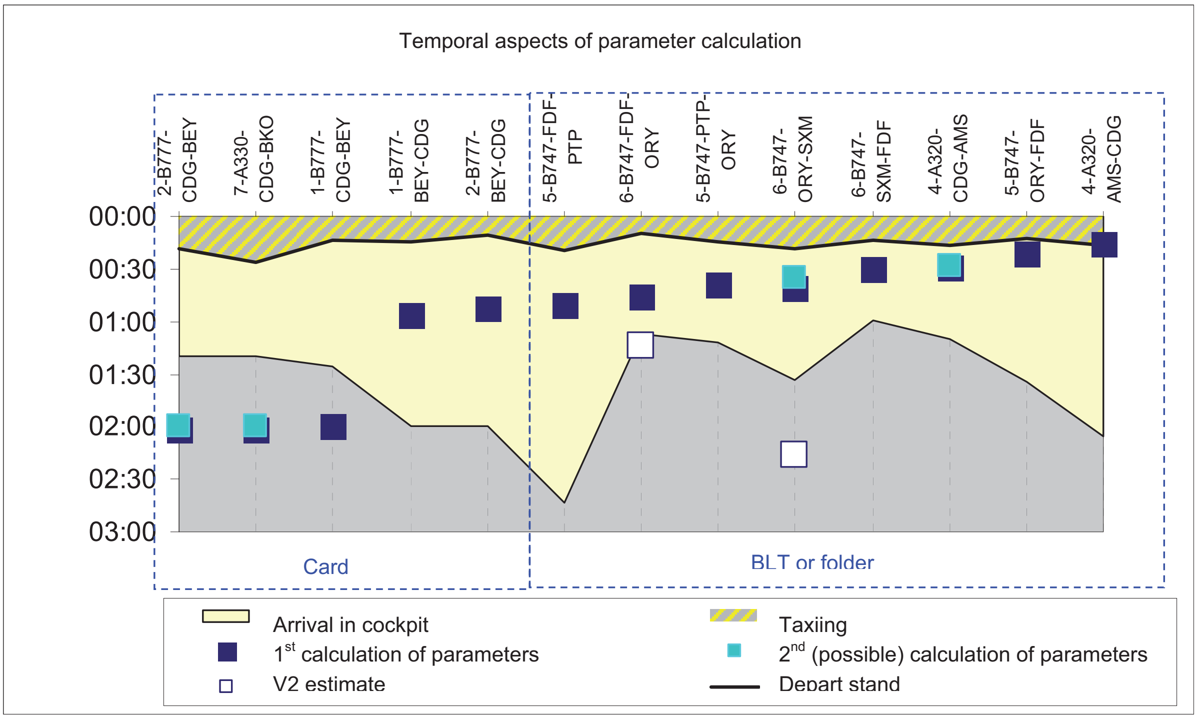


Figure 9: Temporal aspects of the parameter calculation function

This graph highlights the significant variability relating to the moment at which parameter calculation was carried out. We could distinguish the flights for which the calculation was carried out correctly from preparation of the flights with, in two cases, double calculation intended to anticipate several assumptions regarding either the conditions (WET, DRY) or the forecast takeoff runway.
When the calculation was carried out while the crew were in the cockpit, the delay varied from 1hr before takeoff (medium haul return flight) to 16 min for short haul flights.
The two double calculations carried out in the cockpit related to a request to modify the first calculation by the captain: to take account of the tail wind and the choice of a wet runway condition rather than dry.
The estimates of V2 made during preparation related to a personal strategy of a captain who, by a single calculation for this aircraft, can estimate V2 from the takeoff weight.

The permanence of the data medium used for the calculation and the permanence of the input data display have a greater influence than airline procedures on the moment at which the calculation is performed. When the result of the calculation and the input data are presented on a paper ("card" issued by Flight Preparation (PPV) or ACARS output), the calculation is performed further in advance than when the result of the calculation and the input data are presented in a temporary form (open file or laptop switched on).

We found this same distinction if we considered the delay between parameter calculation and input of the resulting values (V1, Vr, V2) into the FMS (Figure 10). When there was no paper document, parameter calculation and input into the FMS were almost simultaneous.
Checking of parameters was performed at the same time since it was not possible to access the input data for the calculation once the laptop had been turned off or the file closed.

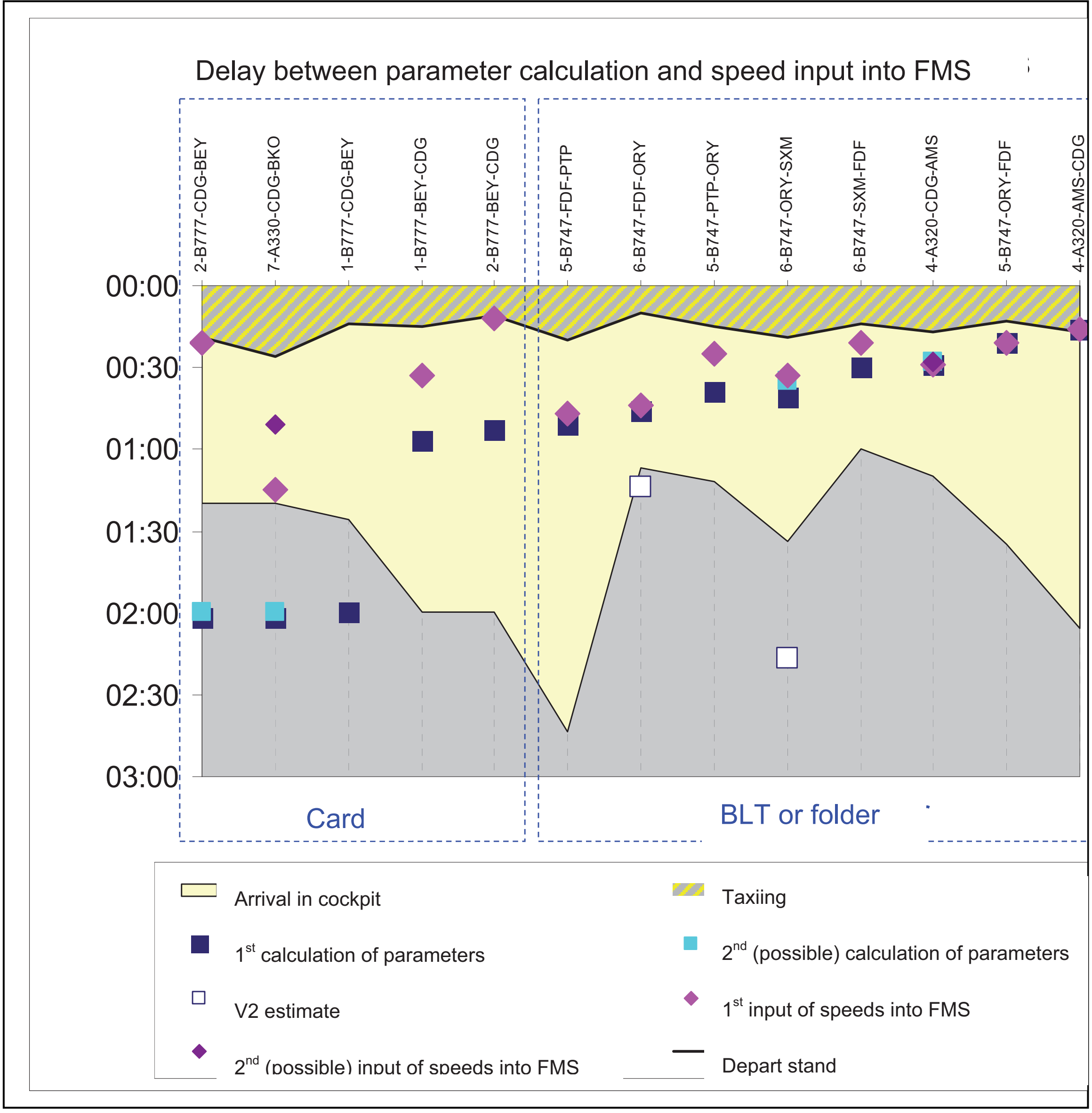


Figure 10: Delay between calculation of speeds and input into the FMS

Figure 10 highlights one flight where input of speeds into the FMS was not performed. During this flight, reference speeds were calculated by the FMS, a "card" was edited by the crew but speeds were not entered into the FMS. During takeoff, the crew used the takeoff card to call out V1 (which would have been called out by the equipment if the speeds had been entered) and Vr. This omission highlights the lack of robustness in the system that enables takeoff to be carried out without input of speeds into the FMS.

Regarding weight data, the final loadsheet is the reference irrespective of the airline or equipment used. The following graph shows the moment in all the observations when the loadsheet is received (dotted line) and the moments when the ZFW is input into the FMS (orange dots).

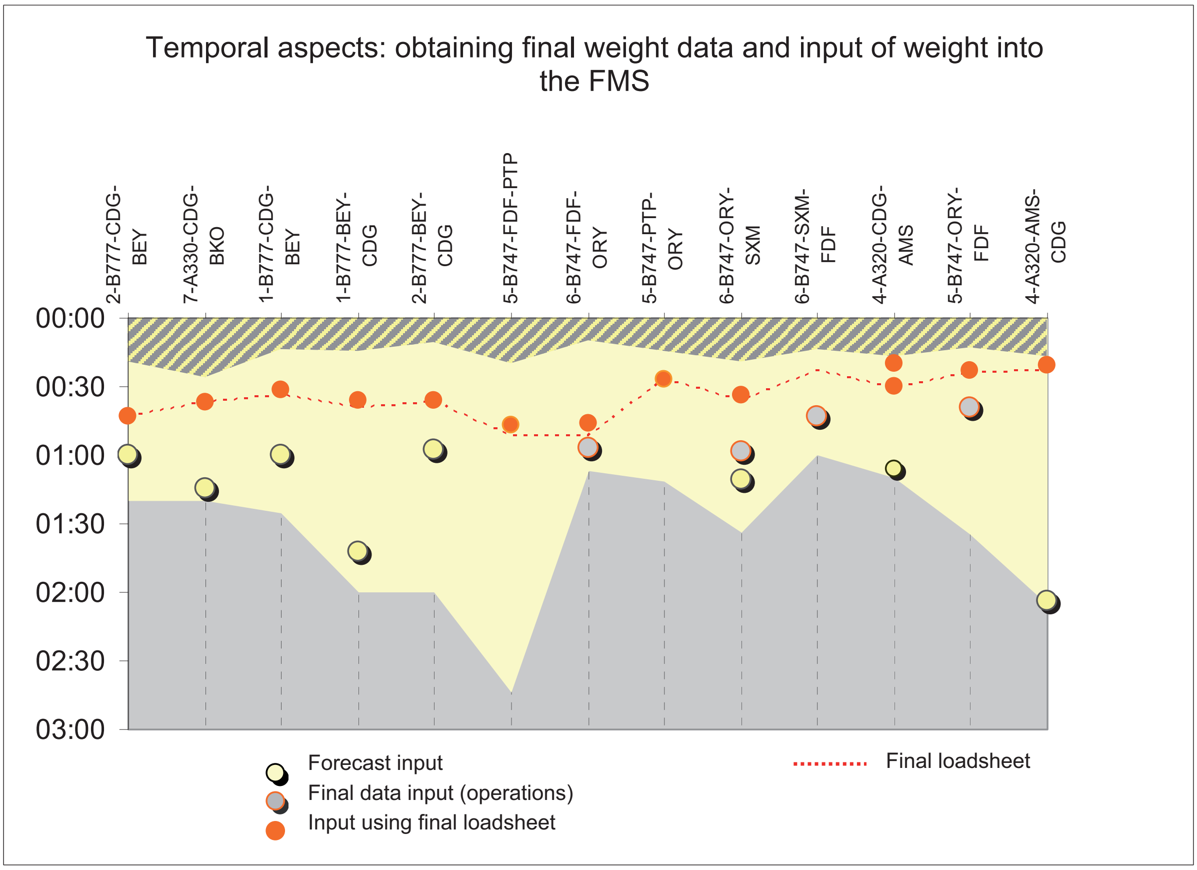


Figure 11: Delay between obtaining final weight data and weight input into the FMS

This graph shows the various strategies regarding input of weight data into the FMS:

In 11 out of 13 cases, the ZFW was entered twice.

- Some crews entered a forecast ZFW on their arrival in the cockpit and entered a final ZFW after receiving the loadsheet. This first input could be dictated either by airline procedures or by a personal strategy enabling verification of the flight plan based on unballasting calculated by the FMS.

- On several flights we observed a first input a few minutes before obtaining the final loadsheet. In this case it was input of the final ZFW obtained not from the loadsheet but communicated (orally) directly by operations. A second input (either identical or slightly different) was then generally carried out when the final loadsheet was received.

In one case, two weight inputs took place based on the final loadsheet. The crew had actually asked for a change to the loadsheet, the base weight not being correct on the first occasion. The second input took place only 4 minutes before leaving the stand.

7.5.1.3 Variability of input data

From a purely theoretical point of view, it's the final TOW that should be used to calculate parameters. In this case parameter calculation must necessarily be carried out after receipt of the final loadsheet. But Figure 12 shows that this wasn't the case in 5 flights out of 14.

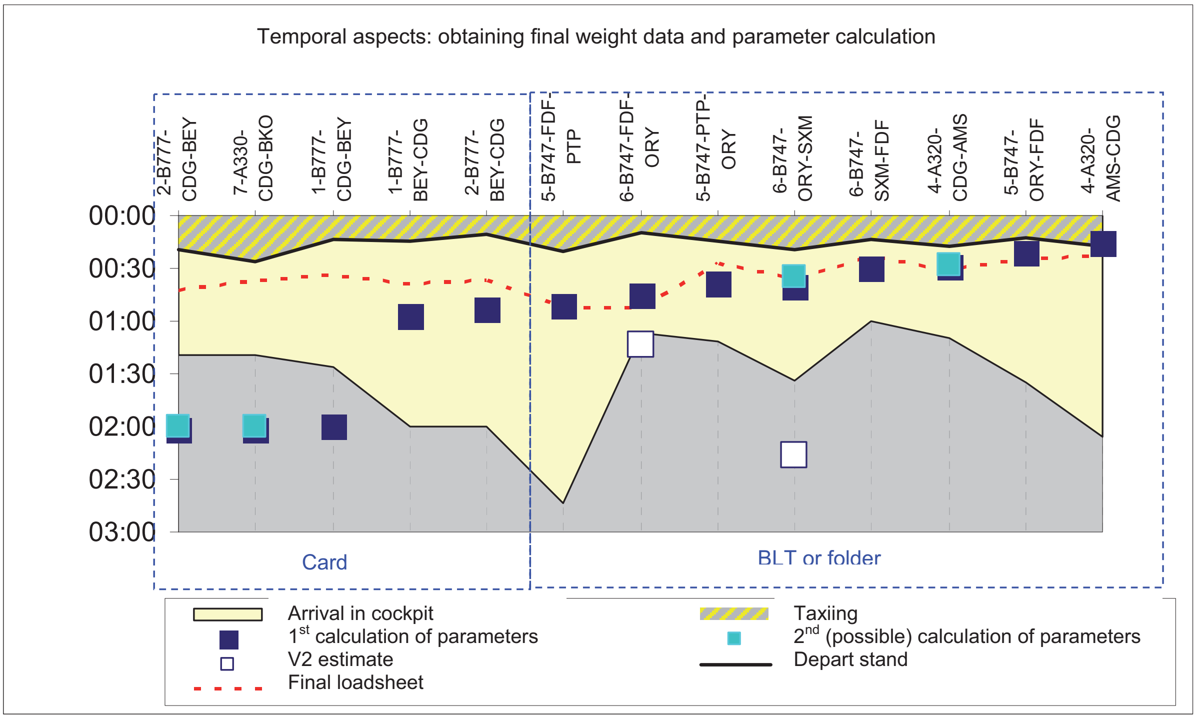


Figure 12: Temporal aspects – Obtaining final weight data and parameter calculation

This led to detailed study of the input data actually used in parameter calculation.
The following figure show the input data used for parameter calculation and weight input functions into the FMS. They highlight the wide range of weight data handled:

- Fuel
- Forecast ZFW
- Final ZFW
- Forecast TOW
- Final TOW.

They also underline different operating methods and lead to a detailed examination of the controls carried out on these functions.

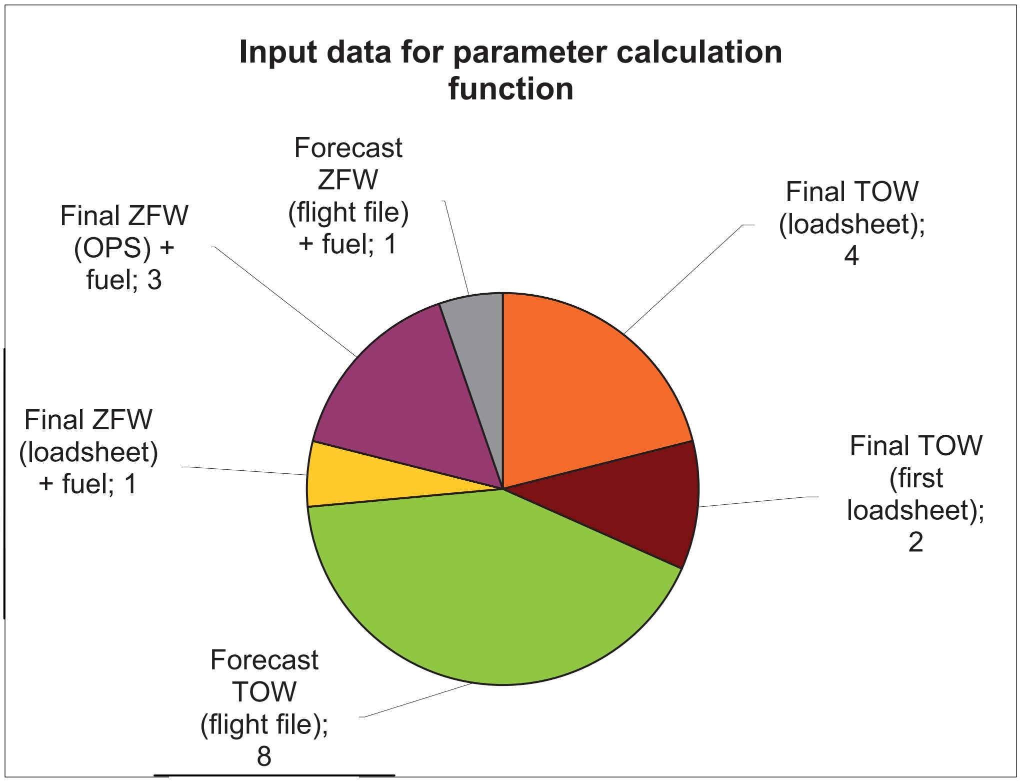


Figure 13: Input data for the parameter calculation function

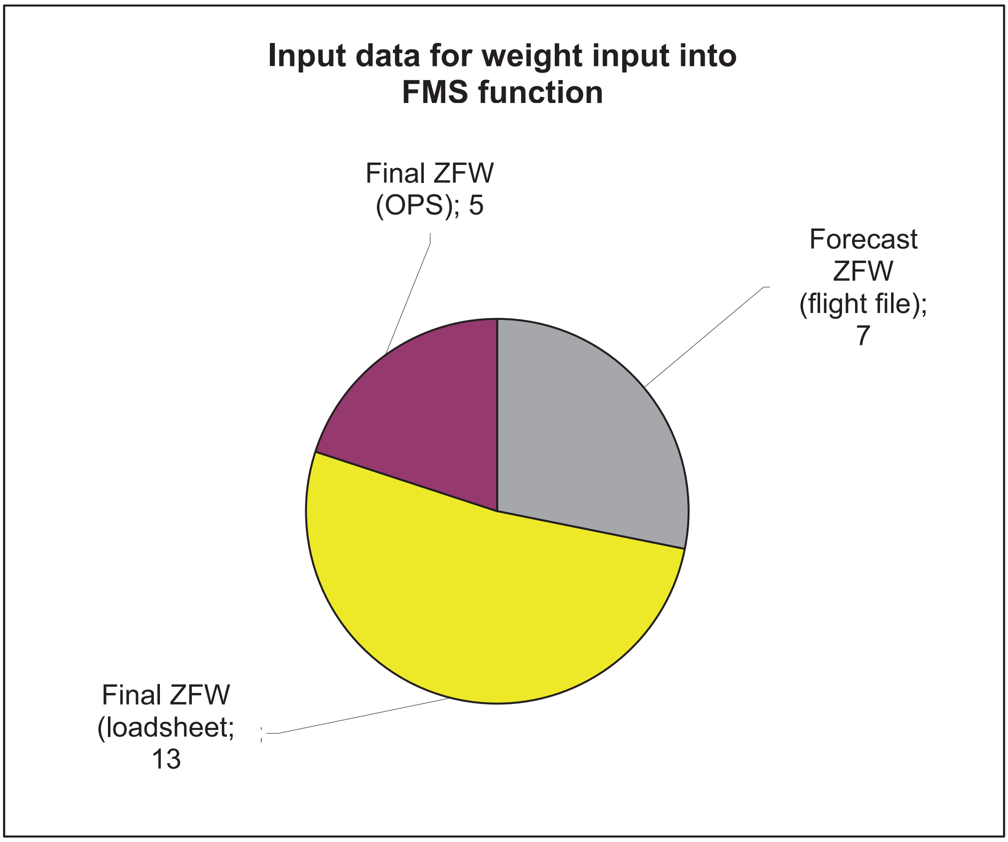


Figure 14: Input data for the weight input into the FMS function

7.5.1.4 Variability in controls

Parameter calculation
For all the flights carried out the following table describes the items relating to controlling of the parameter calculation function.

Flight	Control
1-B777-BEY-CDG	No comparison with FMS values (very different)
1-B777-CDG-BEY	Transfer TOW (final loadsheet) to "card" Check difference between TOW taken into account and real TOW (<4t) No check of speeds suggested by FMS Card placed in available location (and used) until takeoff
2-B777-BEY-CDG	Transfer TOW (final loadsheet) No check of speeds suggested by FMS
2-B777-CDG-BEY	Card put away during runway confirmation by ATC (didn't match)
	Transfer TOW (final loadsheet) No check of speeds suggested by FMS
4-A320-AMS-CDG	Captain
4-A320-CDG-AMS	Captain (with folder) modifies calculation to take account of tail wind
	No check
5-B747-FDF-PTP	Captain: explicit comparison with values suggested by FMS
5-B747-ORY-FDF	Captain with BLT (checks input data in his head) and explicit comparison with values suggested by FMS
5-B747-PTP-ORY	Captain with BLT (checks input data in his head) and explicit comparison with values suggested by FMS
6-B747-FDF-ORY	Captain: explicit comparison with values suggested by FMS and comparison with estimate of V2
6-B747-ORY-SXM	Captain with BLT (input data check, changes "WET" condition)
	Captain: explicit comparison with values suggested by FMS and comparison with estimate of V2
6-B747-SXM-FDF	Captain with BLT (input data check)
7-A330-CDG-BKO	Captain checks conditions ("WET"), "card" tidied as doesn't match
	Captain checks conditions ("DRY")

Table 6: Controlling parameter calculation function

Controllng parameter calculation breaks down into two parts:
- input data checking,
- checking consistency of the speed data obtained.

Observations showed that depending on the cases the emphasis was put on one or other of these aspects but rarely on both.

When a paper document was used, input parameter control could be carried out afterwards. In particular the final TOW could be transferred to the document for comparison with the TOW taken into account in parameter calculation. However, observations showed that this was not always the case (1-B777-BEY-CDG and 7-A330-CDG-BKO). When a paper document was used, as we have seen before, a greater or lesser time could elapse between parameter calculation and their input into the FMS. During the observations, in the cases where a paper document (takeoff card) was used and where speeds were suggested by the FMS, the consistency check between calculated speeds and speeds suggested by the FMS was not explicitly carried out.

When a laptop was used, the observed controls took place just before the captain input the speeds into the FMS. Emphasis was given to comparison of the speeds obtained with those suggested by the FMS, the input data being checked "in the head". In fact, the organisation of tasks to be carried out by the captain at this time was such that the handling of a third medium (such as the final loadsheet) appeared difficult.
On the other hand, observations showed that in the two cases where an input parameter did not match (accounting for a tail wind, "DRY" conditions rather than "WET"), checking of the other parameters was partly carried out.

- No new cross-check when a tail wind was taken into account.
- No transfer of the final TOW to the second "card" chosen.

Speed input into the FMS
The following table describes controls carried out during speed input into the FMS by one of the crew members.

Flight	Control
5-B747-ORY-FDF	Speeds read out by Captain, input crosschecking with Co-pilot, Co-pilot doesn't see BLT
5-B747-FDF-PTP	Speeds read out by Captain, input crosschecking with Co-pilot, Co-pilot doesn't see BLT
5-B747-PTP-ORY	Speeds read out by Captain, input crosschecking with Co-pilot, Co-pilot doesn't see BLT
6-B747-ORY-SXM	Speeds read out by Captain, input crosschecking with Co-pilot, Co-pilot transferred speeds to his flight file
6-B747-SXM-FDF	Speeds read out by Captain, input crosschecking with Co-pilot, Co-pilot transferred speeds to his flight file
6-B747-FDF-ORY	Speeds read out by Captain, input crosschecking with Co-pilot, Co-pilot transferred speeds to his flight file
2-B777-CDG-BEY	Captain dictates speeds and checks input by Co-pilot with the "card"
2-B777-BEY-CDG	Captain dictates speeds and checks input by Co-pilot with the "card"
1-B777-CDG-BEY	No speeds input
1-B777-BEY-CDG	Captain dictates speeds and checks input by Co-pilot with the "card"
7-A330-CDG-BKO	Captain reads the "card" and inputs, Co-pilot checks input in the FMS
4-A320-AMS-CDG	Captain inputs from file, Co-pilot checks input in the FMS
4-A320-CDG-AMS	Co-pilot reads values from the file, no check by the captain
	Captain reads values from the file and checks input by Co-pilot

Table 7: Controlling speed input function into FMS

Table 7 highlights the fact that the input of speeds into the FMS is performed with crosschecking by the crew. However, in several cases this check was limited to verifying that "what was read was really entered". In fact, whether with a laptop or a printed "card", it was noted that in several cases the crew member responsible for carrying out the verification did not see the medium used for data input. This could lead some pilots to adopt their own strategy to make up for this lack, as was the case for the Co-pilot on rotation 6 who routinely transferred the parameters coming from the BLT to his flight file.

7.5.2 Data flows and the use of different media

The following figure shows all communications relating to fuel, weight and speed data from all the observations.

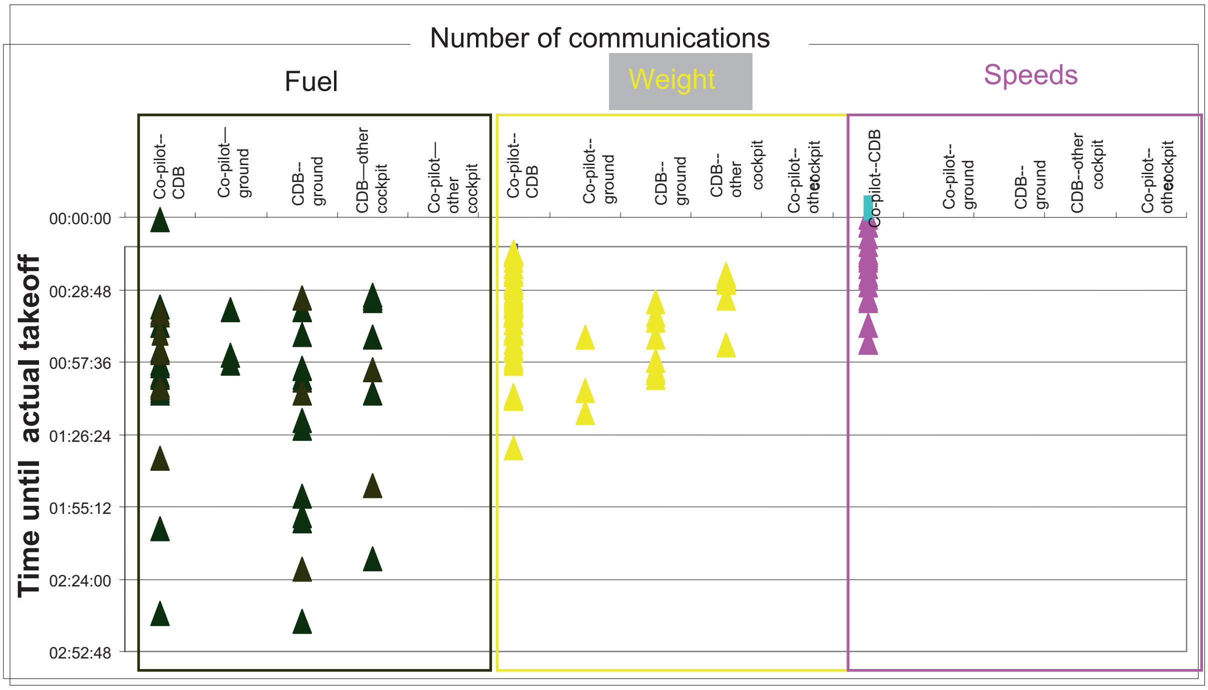


Figure 15: Communications relating to fuel, weight and speed data.

Figure 15 shows that generally communications relating to fuel take place before those relating to weights which take place before those relating to speeds. Another important item involves the number of different contacts. The figure shows that there were a large number of contacts for fuel, as there were exchanges:

- between crew members,
- With the person on the ground responsible for re-fuelling,
- With people in operations wanting to know the crew's decision about fuel requirements,
- With the person bringing the fuel docket to the cockpit for signature.

Communications relating to weight data took place:

- Between crew members,
- With operations personnel by radio,
- With the person bringing the loadsheet for signature by the captain.

Communications relating to speed data took place exclusively between the members of the crew.

The following graph shows manipulations (reading aloud, writing and inputting) of fuel, weight and speed data.

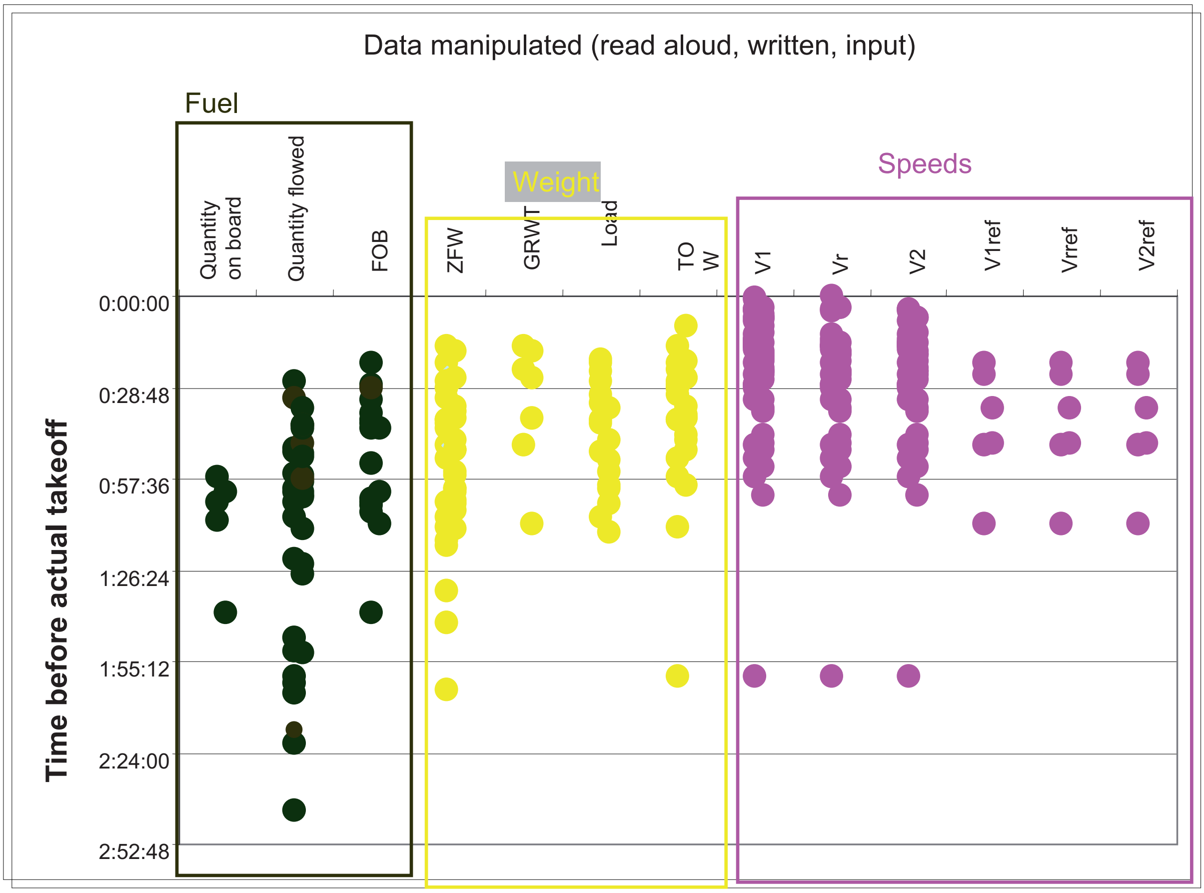
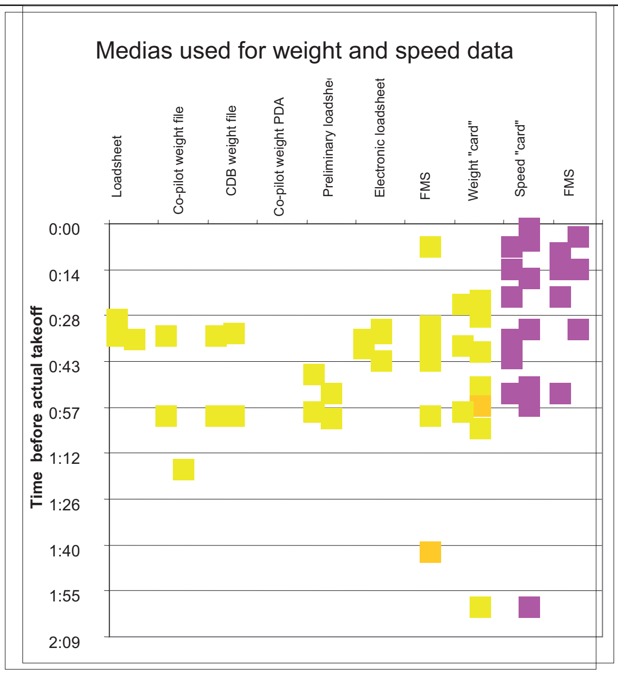


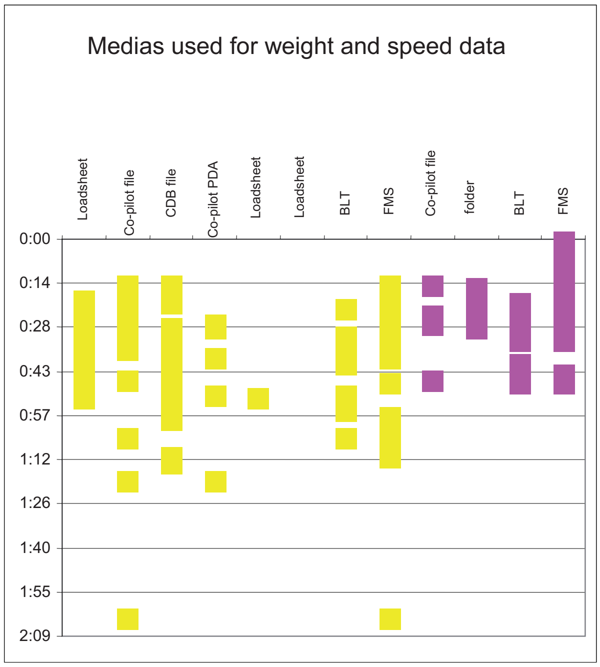
Figure 16: Data manipulated

This figure highlights the fact that the speed data manipulated related exclusively to V1, Vr and V2, and where appropriate speeds suggested by the FMS (V1ref, Vrref, V2ref). For weight data, the figure shows that crews manipulated not only the ZFW and the TOW but also the GRWT and load. The fuel data handled were in relation to the quantity initially on-board, the quantity flowed and the total quantity requested.

This figure is to reconcile the number of media handled (see the two following figures).



Editing of a paper document for calculation of parameters ("card")



Use of a laptop or documentation for calculation of parameters

Figure 17: Media used for weight and speed data.

The observations relating to the data manipulated highlight the variety of weight data used, the level of accuracy, the validity and the formats used. These variations depend on the contact or the medium used.

The observations have also shown that communications relating to speeds are numerous until takeoff although in some cases only one medium (the FMS) is available for these values. This is why calling out these speeds at the time of the last C/L or briefings should not be considered as a final verification but only as a means for the crew to memorise them.
The observations have shown (Figure 17) that some crews refer to the takeoff "card" during these last briefings or C/L.

Task interruptions

Flight	Observed interruptions
1-B777-CDG-BEY	Co-pilot passes final loadsheet to Captain and makes calculations on his flight file Captain goes to transfer the weight to the "card" and is interrupted by a call on a portable phone about the fuel pb erroneously entered through ACARS
1-B777-BEY-CDG	Takeoff -43 min: Co-pilot→Captain we'll takeoff in Vnav Lnav on demand… Back end crew (BEC) interruption (Back end crew display in place) Takeoff -2 min: Back end crew→Captain requests oxygen for PAX Captain reply→ prepare for takeoff
4-A320-CDG-AMS	
4-A320-AMS-CDG	
5-B747-ORY-FDF	Captain departure briefing… interruption for FMS update Takeoff -15 min: Before start check-list: 247.5 the GROUND interruption Captain: STDBY to GROUND.
5-B747-FDF-PTP	"Pre-flight C/L Co-pilot: "Oh yes, we've got the special ACARS… I'm continuing the C/L" Captain sends an ETD by ACARS = 21h30
5-B747-PTP-ORY	GROUND --> Captain: 95,200 litres flowed, can we disconnect? During ACARS query by Captain for receipt of F-PLN Captain --> GROUND: Stand By I recall you Co-pilot begins departure briefing MECA waits for end of departure briefing before leaving Pre-flight C/L Co-pilot: "Haven't we had the weight breakdown yet?" Captain: "No, we'll do the pre-flight" TOW = 228.2 + 87 = 315.2. Co-pilot approves Co-pilot takes out the BLT and says: what have you got for the TOW? 315 tonnes 2. Co-pilot passes BLT to Captain who puts it on the pedestal because the final loadsheet arrives.
6-B747-ORY-SXM	1:16 Captain verifies the loaded route 1:16 Back end crew→Captain: interruption to bring the bottle of water 1:15 Co-pilot and Captain verify ATIS issuing 1:15 Captain enters departures 1:15 interruptions by the stewardess 1:15 Captain: so it really is the 26th 1:01 Captain verifies the route and detects the runway 24/26 error; error linked to Back end crew interruption
6-B747-SXM-FDF	
6-B747-FDF-ORY	01:04 Captain interrupted by OPS 0:59 Captain requests departure from the tower 0:59 Captain interrupted by Co-pilot about the fuel (89t740 on-board + 250 l and we'll disconnect)
2-B777-CDG-BEY	0:37 Each with jeppesen files Captain→ I assumed a 26 if ever it was the 27th... 0:35 I have verified the limits (interruption * 2) 0:35 Captain: I'll start again!
2-B777-BEY-CDG	0:53 Back end crew→Captain OK to leave 0:52 Captain reads "card" (Back end crew interruption)
7-A330-CDG-BKO	

7.6 Summary of results from observations

The previous tables show that the crew's tasks (communication, data and media used) relating to weights and speeds increase when departure approaches.

Observations have shown that the final loadsheet is actually the reference source, whatever the airline and the equipment used. Obtaining this document is the determining step that influences calculation and input of takeoff parameters into the FMS. Making these final data available late generates a great number of tasks to be carried out in a limited time and creates time pressure. To deal with this, airlines and crews adopt different operating methods.

For weight data, in most cases it leads to double data input. The first input is performed using forecast or supposedly final data issued from a medium other than the final loadsheet. The observations highlight the large amount of weight data used, their level of accuracy, validity and formats used depending on the contact involved or medium used.

The most significant variability related to parameter calculation. Observations showed multiple sources of input data used (loadsheet, ACARS, radio contact).
The medium used (paper or otherwise) has an impact on the moment at which calculation and input of speeds into the FMS were carried out. When there was no paper copy, parameter calculation and input into the FMS were almost simultaneous. Control of parameters was performed at the same time since it was not possible to access the input data for the calculation once the laptop had been turned off or the file closed.

Observations highlighted certain weaknesses in the controls used. Control of parameter calculation breaks down into two parts: checking of input data and consistency checking of the speed data obtained. Depending on the particular case, priority was given to one or other of these aspects but rarely both. Input of speeds into the FMS is performed with crosschecking by the crew. However, whether with a laptop or a printed "card", in several cases the crew member responsible for carrying out the verification did not see the medium used for data input. So the check was limited to verify that "what was read was really entered".
Observations showed that there was no control based on a comparison of the three principle media: the final loadsheet, the takeoff card or laptop, and the FMS.

CONCLUSION

In conclusion, the study brought to light the following items:

- The variety of events show that the problem of determining and using takeoff parameters is independent of the operating airline, of the aircraft type, of the equipment and of the method used,

- Errors relating to takeoff data are frequent. They are generally detected by application of airline operating modes or by personal methods, such as mental calculation,

- The cases studied reveal that failures correspond to the "calculation of takeoff parameters" and "input of speeds into the FMS" functions, but do not correspond to errors in the "weight input into the FMS" function,

- In several cases, the ZFW was entered instead of the TOW into the performance calculator,

- Half the crews who responded to the survey carried out in one of the airlines taking part had experienced errors in parameters or configuration at takeoff, some of which involved the weight input into the FMS,

- Pilots' knowledge of the order of magnitude of these parameter values, determined by empirical methods, is the most frequently cited strategy used to avoid significant errors,

- Input of the weight used in parameter calculation, in whatever medium it may be (by ACARS, in a computer, manually), is one of the determining steps in the process of takeoff preparation. It's this, by affecting both the thrust and the speeds, that determines takeoff safety,

- The real-time availability of the final weight information a short time before departure obliges the crew to perform a large number of tasks, inputs and parameter displays under strong time pressure,

- Checks on the "takeoff parameter calculation" function can be shown to be ineffective because they consist of verifying the input of the value but not the accuracy of the value itself,

- In the same way, the check of data featuring on several media often proves to be ineffective. It's often limited to item by item comparisons. If the item is wrong, the check is correct but inadequate because it doesn't cover overall consistency. In particular, there is no comparison between values for takeoff weight given in the final loadsheet, on the takeoff paper or electronic "card" and in the FMS,

- The reference speed values suggested by some FMS can be easily changed. They do not enable routine detection of prior calculation errors,

- The FMS studied allow insertion of weight and speed values that are inconsistent or outside the operational limits of the aircraft concerned. Some accept an omission to enter speeds, without the crew being alerted,

- The weight values manipulated by crews before the flight can appear, depending on the documents or software, under various names or acronyms and in different units and formats for the same data, which makes them too difficult to memorise,

- Time pressure and task interruptions are frequently cited in surveys as common factors contributing to errors. The observations showed that the crews' work load increases as the departure time approaches and that the normal operation actions of the captain were all the more disrupted,

- During the takeoff run, the possible decision to reject takeoff based on an erroneous V1 no longer guarantees safety margins,

- On cockpit display screens of the PFD-type, the marker representing Vr is not displayed at low speed. Further, it can be difficult to distinguish it from the marker representing V1, especially when the two values are similar.

- In several cases, crews perceived abnormal airplane behaviour during takeoff. Some took off “normally”. Others were able to adopt different strategies: stopping takeoff, increasing thrust, delayed rotation.

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ANNEXES

Detailed list of events used by the working group

DETAILED LIST OF EVENTS USED BY THE WORKING GROUP	
Date Place Aircraft Operator	**Report reference / Summary / Analysis**
16/01/1990 New York B757-200 N505UA United Airlines	**Reference:** http://www.ntsb.gov/ntsb/brief.asp?ev_id=20001212X22410&key=1 **Incident:** Tailstrike due to excessive rotation by the PF (Co-pilot). Continuation of flight to destination despite feeling a jolt. Erroneous use of documentation by the Co-pilot (performance data for 767 instead of 757). No verification by captain V1 = 115 kt (-30 kt), Vr = 118 kt (-30 kt), V2 = 129 (-23 kt) **Recommendations:** None (factual report by NTSB) **Corrective actions** by airline not known.
24/08/1999 Copenhagen B767-300 OY-KDN SAS	**Reference:** http://www.hcl.dk/graphics/Synkron-Library/hcl/dokumenter/Redegorelser/1999/49-99-KDN-UK.pdf **Serious incident:** Strike by rear fuselage landing pad at rotation followed by halting of takeoff. TPG tyres and brakes damaged. Input by Co-pilot PF (undergoing airline training) of ZFW instead of TOW for ACARS query of takeoff performance calculation. Captain PNF. The 3rd pilot recorded an MAC error between the weight breakdown and the result supplied by the ground station. Correction of MAC then new ACARS for modified parameter calculations. Focussed on MAC error (that Co-pilot had not entered during ACARS query), no-one identified the other errors linked to the ZFW and TOW. The special feature of the day (TOW = MTOW) and display of the takeoff data, presenting the MTOW and the TOW one above the other, do not enable easy identification of an input error. Takeoff at reduced thrust with imaginary T = 57°. Calculated speeds 33kt less than speeds expected with the correct TOW. Co-pilot previously on MD80, taking ZFW as the input parameter. Time pressure because flight late. Boeing 767: FMS alarm only if TOW > MTOW No check of parameters by captain before ACARS query. **Recommendations:** - Order of magnitude of flight data: flight time, weights (ZFW, trip fuel, TOW), and T/O and LDG speeds. - Change in display of T/O data to avoid reading and input errors. **Corrective actions:** - Information on possibilities for error during T/O data calculation. - Software change: alarm if input TOW differs by ± 8 t from the average TOW for the relevant route (here, Copenhagen to Tokyo))
28/12/2001 Anchorage B747-100F N3203Y Evergreen	**Reference:** http://www.ntsb.gov/ntsb/GenPDF.asp?id=ANC02LA008&rpt=fa **Incident:** Tailstrike and continuation of flight (PEQ not aware of strike) Use of previous landing weight parameters. The crew "forgot" to take account of 45.4 tonnes of fuel added during the stopover.

	Recommendations: None (factual report by NTSB).
14/06/2002 Frankfurt A330-300 C-GHLM Air Canada	**Reference:** http://www.tsb.gc.ca/fr/reports/air/2002/a02f0069/a02f0069.asp **Serious incident:** Tailstrike followed by QRF flight Special feature of the crew: 2 flight crew are A330-qualified captain and TRE. The flight captain (PF, left seat) subjected the Co-pilot (PNF, right seat) to a test During flight preparation, the PNF input weight/Vref data through ACARS (forecast TOW of 222.7t). The final data reported a weight at takeoff of 221.2t. For this small difference it was not necessary to re-input the speeds because these were identical to the speeds initially input. Despite this, these speeds were re-input by the PNF during the pushback, at the same time as the weight. The PNF input a V1 of 126 kt instead of 156 kt. Before T/O, the PF read the speeds on the MCDU. Neither of the two pilots noticed the anomaly. At takeoff, the PNF called out V1 when the index appeared, then Vr immediately afterwards, through habit, which was actually about Vr – 30 kt (Vr of 157 kt). We don't know when and how the situation was detected and corrected. **Recommendations:** None **Corrective actions:** no information
11/03/2003 Johannesburg B747-300 ZS-SAJ S A A	**Reference:** http://www.caa.co.za/resource%20center/accidents%20&%20incid/reports/2003/0263.pdf **Serious incident:** Tailstrike at rotation signalled by ATC. QRF after dumping fuel. Error of 121 t: ZFW instead of TOW input by OMN into the laptop. Erroneous speeds written on the card. Speeds displayed by pilots and verified by comparison with takeoff card. Takeoff EPR = 1.44 (-0.14). Climb EPR = 1.42 (-0.05) V1 = 123 kt (- 31 kt), Vr = 123 kt (- 41 kt), V2 = 142 kt (- 29 kt) "Nose heavy" felt at the "rotation" call out. Rotation delayed by 15 kt, equivalent to Vr – 26 kt. Thrust increased to EPR = 1.58, the aircraft not accelerating normally. Contributory factors: Lapse of concentration in the flight compartment, heat (APU INOP) + time pressure (delay of 45 min reduced to 30 min). **Recommendations:** Better knowledge of on-board calculators + data checking methods. Procedures to be put in place to avoid errors in concentration…
12/03/2003 Auckland B747-400 9V-SMT Singapore Airlines	**Reference:** http://www.taic.org.nz **Serious incident:** Tailstrike + QRF, landing overloaded. Significant damage to rear of fuselage. Error of 100 t on the takeoff card: TOW: 247.4 t instead of 347.4 t. Error not detected by Captain (PF) who has used the ZFW for a weight breakdown to verify data to be input into the FMS. The FMS calculated different values (from 15 to 30 kt) for V1, Vr and V2, which had been deleted and replaced by the Captain with erroneous values written by the Co-pilot on the card. The 3rd pilot, busy, had not verified the card as he usually did. Note that the card does not contain a specific field for ZFW and FOB. EPR = 1.34 (- 0.07) iso 1.41, V1 = 123 kt (- 28 kt), Vr = 130 kt (- 33 kt), V2 = 143 kt (- 29 kt) Factors identified: - Non-verification of TOW by Captain on the card. Use of erroneous TOW to verify speed calculations. - Acceptance by FMS of speeds input by Captain, although very different to those that the system had calculated. - The Captain did not question these differences in speeds. - The Captain used the weight breakdown to verify the TOW calculated by the FMS rather than the TOW written on the card by the Co-pilot and which was wrong. But it's this card that was used to correct the speeds from the FMS.

	- The 3rd pilot had not verified either the card or the calculations because he was distracted (discussion with stopover manager). **Recommendations:** for Honeywell, via NTSB (see appendix 2, Boeing and SIA (the latter having accepted and implemented everything): - Boeing thinking about modifications to be made to the FMC but has no solutions for the problem of manual input "above" the automatically calculated values. - SIA has made crews aware of cross-checks and strengthened this aspects in simulator sessions and specified the role of the 3rd pilot on the affected flights.
04/09/2003 Oslo A321 OY-KBK SAS	**Reference:** Report in Norwegian- conclusion in English **Incident** without either technical or operational consequence. During flight preparation, the crew noted that the ACARS was not working. They sent the takeoff parameters by radio to the operations office in Oslo, which sent them by telephone to the operations office in Copenhagen where the calculations are carried out. The origin of the error is not known but it seems that a TOW of 60t had been sent to Copenhagen instead of 76.4t. The person responsible for calculations at Copenhagen stated that he had requested confirmation from Oslo when he realised that this TOW was unusually low. The calculated speeds were sent to the crew in the opposite route (fax + radio). The captain (PNF) checks and the operations office confirms. The crew found V1 unusually low (V1 = -33kt, VR = -29 kt, V2 = -28kt) but remained confident in view of the fact that the check had been confirmed. At rotation, the Co-pilot (PF) felt a heaviness. Immediately after takeoff, the crew noticed that V2 was less than the VLS. They accelerated to 250 kt. **Recommendations:** training procedures and methods for personnel in the operations office.
14/07/2004 Paris-CDG A340-300 F-GLZR Air France	**Reference:** ITA n°4: http://www.bea.aero/itp/events/ita4/ita4.pdf **Serious incident:** Tailstrike followed by QRF flight. Following a change in weight just before departure, the Co-pilot issued a new takeoff card. He input a takeoff weight with an error of 100t (note: the weight input was close to the ZFW). The captain verified the parameters but did not detect the error because by mistake he read the MTOW, which was on the card, instead of the takeoff weight (note: these two weights were very close). V1 = 129 kt = VMCG (-14 kt), Vr = 131 kt = VMCA (- 22 kt), V2 = 137 kt (- 24 kt) The FMS did not suggest takeoff speeds. V_{LS} information is not available to the ground. From takeoff, the PF noticed that V_{LS} was greater than V2. TOGA thrust was not used. Low vertical speed (700 ft/min) during acceleration. **Recommendations:** In the form of *lessons* in the ITA bulletin. **Corrective actions** by operating airline: modifications to procedures to make checking more reliable.
14/09/2004 Halifax B747-200F 9G-MKJ MK Airlines	**Reference:** http://www.tsb.gc.ca/fr/reports/air/2004/a04H0004/a04H0004.pdf **Accident:** Collision with an obstruction at takeoff: 7 crew members killed Recent use of the BLT without government approval. No specific PEQ training. "Gross error verification" procedure to adjust the Vr and V2 cursors using a high altitude cruise table. Probable cause: Calculations by the BLT. Use of values (takeoff thrust and speeds) based on data based on the previous takeoff that appeared when the BLT started up, namely – 113 t. <u>Contributory factor:</u> Crew fatigue; Max TSV in 24 h exceeded with 2 crews (the highest of the ICAO…). **Recommendation** to Transports Canada in liaison with ICAO, FAA and EASA, to instigate a requirement for takeoff performance monitoring equipment in transport aircraft.

24/08/2005 Shanghai Pudong A340-300 LN-RKF SAS	**Reference:** Chinese report, translated into English. **Serious incident:** Tailstrike followed by depressurisation after takeoff. QRF flight after dumping fuel. Takeoff on QFU 35. Co-pilot PF. Input by Co-pilot into the FMS of speeds corresponding to the ZFW (179.3 t) instead of TOW (259.7 t). No verification by the captain. V1 = 129 kt (- 14 kt), Vr = 130 kt (- 25 kt), V2 = 139 kt (- 23 k) Thrust readjusted at the request of the captain who felt "something unusual"… **Recommendation:** To use updated data for the weight breakdown and carry out verifications.
12/07/2006 Edmonton ERJ190 C-FHIU Air Canada	**Reference:** Investigation in progress. **Incident** without either technical or operational consequence. EFB: input of weight of fuel present (before re-fuelling): 3.7t vs 10.2t. TOW: 41.7t which is -5.9t. FLEX thrust of 84.9% vs 90%. Detection + correction of MCDU but manual input of erroneous speeds. V1 = Vr = 137 kt (-12 kt), V2 = 140kt (-11kt). At rotation the crew "felt" reduced performance. <u>Contributory factors:</u> **-** Increased work load following a technical problem requiring the aircraft to be powered down. - Several task interruptions for the crew.
10/12/2006 Paris-Orly B747-400 F-HLOV Corsairfly	**Reference:** http://www.bea.aero/docspa/2006/f-ov061210/pdf/f-ov061210.pdf **Serious incident:** Tailstrike at rotation. QRF flight after dumping fuel. Use of BLT in preference to FMS. Input into BLT: ZFW instead of TOW (- 99 t) EPR = 1.33 for an imaginary T of + 58 °C, which is - 0.07. V1 = 120 kt (- 27 kt), Vr = 127 kt (- 32 kt), V2 = 140 kt (- 29 kt) At takeoff, rotation delayed by +5 kt, equivalent to Vr – 27 kt. Aircraft felt "heavy" + brief triggering of stick vibrator. Reduction of trim and readjustment of thrust (maximum takeoff). At 35 ft reached V2 – 3 kt (166 kt). **Recommendations:** None **Corrective actions** by the airline operator relating to data verification procedures and methods.

Fiches de lecture des articles

Title	**understanding takeoff speeds**				
Type	Briefing Notes	**Interest for the study**			***
First Author (s)	Airbus	**Year**		**PDF**	
Reference	http://www.airbus.com/store/mm_repository/safety_library_items/att00003116/media_object_file_FLT_OPS-TOFF_DEP_SEQ07.pdf				

Key Words	Tailstrike, erreurs FMS

Objective	Donner aux pilotes et aux compagnies des éléments pour comprendre les problèmes liées aux vitesses de décollage

Results	Concernant les facteurs humains mis en jeu, Airbus précise que les changements de dernière minute, la pression temporelle ou une charge de travail élevée peuvent être à l'origine d'erreurs dans le calcul des vitesses. La charge de travail du PF pendant les phases de taxi ou de pushback étant élevée, les crosschecks peuvent être difficiles. Airbus attire l'attention sur le fait que en cas de problème survenant avant V1, l'attention du PNF peut être focalisée sur le problème et lorsque l'avion n'est pas équipé d'un système d'annonce de V1 automatique, le PNF peut ne pas effectuer l'annonce.
Comments	Briefing note très générale
Potential Implications of the results	Cette briefing note conforte ce qui a pu être identifié par ailleurs dans l'étude mais n'apporte pas réellement d'éléments nouveaux.

Abstract	

Title	**Erroneous takeoff reference speeds**				
Type	Guidelines	**Interest for the study**			***
First Author (s)	Boeing	**Year**	2001?	**PDF**	
Reference	http://www.boeing.com/commercial/aeromagazine/aero_11/erroneous_story.html				

Key Words	Tailstrike, erreurs FMS

Objective	Donner un guide pratique pour limiter les erreurs de saisie des paramètres de décollage

Results	L'étude Boeing définit les différents types d'erreurs susceptibles de se produire en supposant que les valeurs en entrée sont exactes : - erreur de conversion de données - erreur de sélection de la masse sur l'état de charge - erreur de touches lors de la saisie (masse ou vitesse) - erreur de sélection de champs lors de la saisie (PerfInit ou takeOffref) - Erreur de sélection du tableau en cas de calcul manuel - Erreur en utilisant le tableau - Erreur de sélection des flaps Au niveau de la magnitude des erreurs, Boeing précise que : Les FMS ont des modèles qui font que si l'on entre une ZFW trop faible, l'erreur est détectée. Par contre, les marges sont telles que l'on peut entrer une ZFW à la place du GW. Les conséquences des erreurs peuvent être un toucher de queue ou un arrêt décollage à trop haute vitesse. Il est à noter que d'autres effets passent inaperçus mais pourraient avoir des conséquences graves s'ils étaient couplés avec une panne moteur par exemple. Les pratiques recommandées sont les suivantes : Donner des valeurs de poids justes à la personne chargée de déterminer les vitesses de décollage Présenter les données de poids dans un format clair et non ambigü Etablir des procédures pour gérer la pression temporelle et les opérations hors séquence Toujours entrer ZFW dans les avions équipés de FMC Etablir des procédures fiables pour vérifier les opérations manuelles Etudier la possibilité d'un couplage ACARS/FMS (entrée des données par uplink)
Comments	Le document insiste sur les problèmes de saisie du GW qui est une

	fonction qui peut être maintenant désactivée. Boeing a changé toutes ses procédures précisant que la procédure normale est de saisir le ZFW et non le GW.
Potential Implications of the results	Boeing propose un guide détaillé des bonnes et mauvaises pratiques concernant la saisie des masses et le calcul des paramètres de décollage. IL s'agit de principes généraux qui pourront servir lors de la validation des recommandations issues de l'étude.

Abstract	The occurrence of human error while establishing takeoff reference speed has caused tail strike, highspeed RTOs, and other instances of degraded performance. These errors can occur in a variety of ways. Operator procedures are the primary means for eliminating these errors. Establishing proper procedures can reduce these errors by helping flight crews avoid situations that make the initial error more probable. These procedures must also ensure that any error that does occur is caught and corrected before it can cause a problem during takeoff or initial climb. The primary method for eliminating error is to ensure that comprehensive, independent verification steps are accomplished at key points where a manual task is performed. Operators are encouraged to review each step of their process and make adjustments to address any deficiencies they may uncover. Boeing has developed a risk assessment checklist as a tool for this review. Operators should also consider two automation features that eliminate known points of error input. One is the ACARS/FMC communications feature, which is available on most current-production airplanes. The other feature is the option to disable FMC GW entry, which will become available with future FMC software updates

Titre	The effect of an advisory system on pilots' go/no-go decision during take-off				
Type	Etude en simulateur	Intérêt pour l'étude			* *
Auteur	BOVE	Année	2002	PDF	Oui
Référence	Journal paper/ Reliability Engineering & System Safety				

Mots clés	Go/no Go decision

Objectif	Test du prototype d'un système d'alerte de monitoring du take off

Taille et caractéristique de l'échantillon		20 pilotes 320/330/340
Facteurs	Décision de poursuivre ou d'arrêter le décollage	
Méthode	Fixed Based simulator!!! Système testé : ATOMS 6 scénarios avec et sans ATOMS : Situation nominale Problème de freinage Feu moteur Problème moteur + Feu Masse erronée faible accélération mais qui reste dans les marges de sécurité prédéfinies. Alerte ATC NB : Le scénario débute alors que les données de masse et vitesses sont déjà entrées dans le FMS.	

Résultats	Pour le scénario étudié, pas d'impact du système d'alerte sur la poursuite ou non du décollage. Il s'agissait de déterminer si la présence du système dans un cas où les marges de sécurité diminuait pouvait avoir un effet de bord et influencer l'équipage dans le sens d'un abandon de décollage. Ce qui n'a pas été le cas pour les 10 équipages participants. Les autres résultats ne sont pas significatifs pour l'étude. A noter : Les résultats doivent être considérés avec prudence, l'utilisation d'un simulateur fixe pour la phase de décollage limitant les facteurs pouvant influencer la prise de décision des pilotes
Commentaires	Cet article est intéressant dans l'approche que l'auteur adopte pour décrire les facteurs pouvant influencer la décision de poursuivre ou d'arrêter le décollage. Les premières parties de l'article sont en effet consacrées à une description des aspects principaux de la phase de décollage puis aux problèmes de traitement de l'information et d'évaluation des risques sur les décisions de continuer ou

	d'interrompre le décollage. L'auteur met en relief le fait que la décision doit être prise sous pression temporelle alors qu'elle implique des risques élevés. Elle doit être basée sur des informations incomplètes, complexes et changeant dynamiquement. L'auteur distingue trois phases conduisant au rejet ou non du décollage : 1) le diagnostic, le diagnostic se fait à partir : - d'évènements discrets - de signaux continus - l' "écoulement" visuel en dehors du cockpit - Les petites secousses au roulage (ou plutôt écarts entre les secousses) - Le système vestibulaire - L'indicateur de vitesse : la différence entre la vitesse actuelle et la vitesse dans 10s est une mesure de l'accélération instantanée - Le taux d'accroissement de la puissance moteur Les pilotes peuvent avoir des difficultés à interpréter ces signaux car d'autres facteurs viennent influencer le temps nécessaire au décollage (masse, température, altitude…) 2) le pronostic Il s'agit d'être capable de faire des inférences fiables Par exemple projeter que l'accélération actuelle est suffisante Il peut être difficile de voir ou d'estimer la fin de la piste (les pilotes n'appliquent pas forcément la bonne force de freinage) Surestimation ou sous estimation en fonction de la visibilité des côtés 3) la prise de décision. Le diagnostic et le pronostic vont conduire à la prise de décision : rejeter ou continuer le décollage. Les facteurs qui peuvent influencer la décision au profit d'une poursuite du décollage sont : - V1 on peut décoller avec un seul moteur, - Possibilité d'augmenter la poussée, - Incertitude possible sur le calcul de V1, En effet, V1 est considérée comme la référence dans la prise de décision : avant V1 on peut s'arrêter après non. Si un des éléments ayant servi au calcul de ces vitesses est inexact (par exemple si les moteurs ne délivrent pas la poussée adéquate), V1 calculée ne correspondra pas à une interruption de décollage effectuée en toute sécurité.
Implications potentielles des résultats	Ce type de système peut constituer une ultime barrière. Si le décollage est entamé avec une V1, Vr erronées ou une poussée inadéquate, le système peut permettre de détecter un comportement non nominal de l'avion. Comme pour tout système d'alerte, le compromis entre efficacité et nuisance peut être délicat à trouver. Le seuil de déclenchement doit être défini de façon à limiter le nombre de décollages avortés étant donnés les dérangements et risques associés.

Résumé	Résumé original :

The take-off phase of modern airliners is a relatively critical phase of flight. Thus, about 12% of all civil aviation accidents happen during take-off. In this paper we describe results of an experimental study of a prototype cockpit advisory take-off monitoring system designed to help pilots to make better and safer go/no-go decisions in the case of abnormal events during take-off. We describe, first, the basic aspects of the take-off task and, second, some of the information processing and risk assessment problems involved in making go/no-go decisions at high speeds during take-off. Third, we describe a prototype advisory take-off monitoring system (ATOMS), which as the result of a research project, has been designed to improve pilots' judgement of acceleration and deceleration during the take-off roll. Fourth, we report on results of an experimental study of this prototype system in a full-flight simulator — results that indicate that ATOMS has a promising potential to improve take-off safety. Finally, we discuss implications of the experimental results for systems support for pilots during take-off.

Title	**Difficult Access: The Impact of Recall Steps on Flight Management System Errors**				
Type	Expérimentation	**Interest for the study**			*
First Author (s)	Fenell	**Year**	2006	**PDF**	
Reference	THE INTERNATIONAL JOURNAL OF AVIATION PSYCHOLOGY, 16(2), 175–196				

Key Words	FMS, recall steps, access errors

Objective	

Sample sizes and characterization		22 C130 pilotes (peu expérimentés sur le système)
Factors	Format errors Insert errors Verify errors Access errors	Définition d'une tâche de rappel : la tâche ne possède pas de signaux visuels tels qu'un label saillant ou un message. Sinon on parle d'une tâche de reconnaissance. -
Method	20 tâches liées au FMS (radio, navigation, plan de vol) analysées à partir d'un modèle cognitive enregistrement vidéo des actions instructions verbales	

Results	La majorité des difficultés concernent l'accès à la bonne fonction (erreur d'accès). Les erreurs sont plus nombreuses lorsqu'il n'existe pas un réel mapping entre la tâche à effectuer et les fonctionnalités du FMS. Le pilote doit dans ce cas reformuler ce qu'il doit effectuer et faire appel à sa mémoire pour accéder à la bonne page initiale. Si le guidage est de plus insuffisant, les erreurs d'accès se multiplient.
Comments	
Potential Implications of the results	Les erreurs étudiées dans cette expérimentation ne concernent pas des tâches relatives à la saisie des paramètres de décollage. Elles montrent cependant les erreurs liées aux taches de saisie de plan de vol. Pendant la phase de préparation, les problèmes d'accès aux pages peuvent provoquer une augmentation de la charge de travail et laisser peu de place à la mémorisation d'autres éléments tels que par exemple les masses de l'avion.

Abstract	This study examines flight management system (FMS) tasks and errors by C–130 pilots who were recently qualified on a newly introduced advanced FMS. Twenty flight tasks supported by the FMS were analyzed using a cognitive stage model (Sherry, Polson, Feary,&Palmer, 2002) to identify steps with the potential for errors. If a step

	was found not to have visual cues such as labels or prompts for the required action sequence it was identified as a recall step and a potential source of difficulty. If the action was supported by salient labels and prompts it was identified as a recognition step. Actual pilots using an FMS were observed and performance and errors categorized into the related task step. The greatest amount of observed difficulty was accessing the correct function, labeled as an access error. This process was found to be particularly vulnerable to recall problems. Pilots had the likelihood of .74 for committing an access error on tasks with 2 recalled access steps. This is compared to .13 for 1 recalled access step and .06 for no recalled access steps. Errors associated with formatting, inserting, or verifying entries were less common than access errors; however, these errors primarily occurred on tasks in which recall steps were required for the related step.Atotal of 93% of the format errors, 80% of the insert errors, and 81% of the verify errors occurred on the tasks that did not have good recognition support for each associated step. On a positive note, experience with the new FMS in the preceding 6 months was correlated with a decrease in overall errors, $r(22) = -.42$, $p < .05$, and a decrease in errors associated with inadequate knowledge to accomplish a required step, $r(22) = -.61$, $p <. 01$.

Titre	**Response time to reject a takeoff**				
Type	Etude en simulateur	**Intérêt pour l'étude**			* *
Auteur	Harris	**Année**	2003	**PDF**	
Référence	Human factors and aerospace safety				

Mots clés	Go/no Go decision, response time

Objectif	

Taille et caractéristique de l'échantillon	16 pilotes	
Facteurs	Temps de réaction	
Méthode	Aerosoft 200 flight trainer (747-200) V1= 141 knots (dry conditions) Les participants étaient PF 8 scénarios avec des appels à interrompre le décollage aux vitesses suivantes 60, 80, 90,100,120,130, 135 ou 141 kts NB : les participants ne connaissent pas la vitesse à laquelle a lieu l'appel à interrompre le décollage.	

Résultats	Sur 114 essais, 9 cas où le décollage a été poursuivi. Les temps de réponse diminuent avec la vitesse au sol mais augmentent une nouvelle fois à l'approche de V1. Les réponses moyennes correspondent bien à ce qui peut être écrit pour la certification mais lorsque l'on se rapproche de V1, l'écart type augmente. Attention donc aux cas extrêmes.
Commentaires	Le calcul des distances d'accélération et de stop pour les aspects certification du FAR/JAR 25 est central pour déterminer les marges de sécurité au décollage. Dans le calcul de V1, on doit prendre en compte le temps de réaction de l'équipage, le temps d'application des freins, le temps de fermeture des thrust levers et le temps de déploiement des spoilers. Pour mener à l'action, plusieurs étapes sont nécessaires : 1) Identification du problème, 2) Analyse et décision 3) Appel à rejeter le décollage 4) Perception de l'appel 5) Cross check avec V1

	6) Décision 7) Action Dans la certification, on parle des RTO en cas de panne moteur, mais les pannes moteur sont impliquées dans une minorité des RTO. Pour les actions simples, les temps de réaction se décomposent en 1. encodage de l'information, 2. sélection de l'action, 3. exécution. Pour les stimulus simples les temps de réaction sont de 140 à 160 ms pour l'auditif et de 180 à 200 ms pour le visuel.
Implications potentielles des résultats	

Résumé	Résumé original :

Rejecting a takeoff at high speed in a airliner is a risky manoeuvre, however, if the decision is not made in a timely manner, at high speeds there is the strong possibility of overrunning the runway. The responses times to reject a takeoff were measured in a flight simulator at a variety of speeds using 16 professional pilots. It was observed that as speed on the runway increased, response times decreased, up until a point just before V1 ('the go/no go decision speed). At this point response times increased dramatically. The results are discussed within the context of the current aircraft certification parameters. Suggestions for further research are made, particularly with respect to extending this work to examine whole crew response time when rejecting a takeoff.

Titre	**How a cockpit remembers its speeds**				
Type		**Intérêt pour l'étude**			***
Auteur	HUTCHINS	**Année**	1995	**PDF**	Oui
Référence	Cognitive science				

Mots clés	MEMORY

Objectif	Etude de la mémorisation des vitesses d'atterrissage dans le cockpit : Appliquer l'approche classique de la science cognitive à une unité plus large qu'une personne.

Taille et caractéristique de l'échantillon	N/A	
Facteurs	N/A	N/A
Méthode	N/A	

Résultats	N/A
Commentaires	L'auteur s'intéresse à la façon dont les vitesses d'atterrissage sont mémorisées dans le cockpit. La mémorisation des vitesses est décrite selon trois approches : Une approche procédurale Une description cognitive des représentations et process en dehors des pilotes Une description cognitive des représentations et process interne pilotes Hutchins décrit les différentes représentations des valeurs de vitesses en les distinguant selon leur permanence, des plus durables (ex : cartes de correspondances vitesses/Masses) aux plus éphémères : Verbalisations… Ses descriptions montrent que si ces vitesses sont mémorisées à l'échelle du cockpit elles ne le sont pas forcément par les pilotes même en mémoire de travail.
Implications potentielles des résultats	Il est assez aisé de procéder à un parallèle entre les vitesses d'atterrissage et les paramètres de décollage. Les notions mises en évidence par l'article montrent que la présence des différents supports de représentation des vitesses permettent une mémorisation à l'échelle du cockpit mais pas forcément à l'échelle du pilote. Dans le cas des vitesses de décollage, les indications sur le PFD (ou les speed bugs sur l'anémomètre), le carton de décollage, les valeurs saisies dans le FMS sont autant de représentations qui permettent que les vitesses soient "connues" dans le cockpit. Suivant les stratégies et les modes opératoires choisis par les pilote, la présence de ces représentations rend la mémorisation des vitesses (même à court terme) non nécessaire. Par exemple, l'annonce de la vitesse de rotation est plus basée sur une reconnaissance graphique que sur la mémorisation de la valeur. L'absence de présence prolongée de ces valeurs en mémoire de travail ne

	permet pas au pilote de se créer une représentation interne des valeurs et diminue les possibilités de stockage en mémoire à long terme. Ce qui explique pourquoi les pilotes ne possèdent pas (ou plus) d'ordre de grandeur des vitesses, rendant ainsi difficile même en cas d'erreur "grossière", le lever de doute sur des valeurs incompatibles avec le vol.

Résumé	Résumé original : "Cognitive science normally takes the individual agent as its unit of analysis. In many human endeavors, however, the outcomes of interest are not determined entirely by the information processing properties of individuals. Nor can they be inferred from the properties of the individual agents, alone, no matter how detailed the knowledge of the properties of those individuals may be. In commercial aviation, for example, the successful completion of a flight is produced by a system that typically includes two or more pilots interacting with each other and with a suite of technological devices. This article presents a theoretical framework that takes a distributed, socio-technical system rather than an individual mind as its primary unit of analysis. This framework is explicitly cognitive in that it is concerned with how information is represented and how representations are transformed and propagated in the performance of tasks. An analysis of a memory task in the cockpit of a commercial airliner shows how the cognitive properties of such distributed systems can differ radically from the cognitive properties of the individuals who inhabit them."

Title	**Pilot Interaction with cockpit automation II : An experimental study of Pilots'Model and Situation Awareness of the Flight Mangement system**				
Type	Expérimentation	**Interest for the study**			
First Author (s)	Nadine B. Sarter	**Year**	1994	**PDF**	
Reference	THE INTERNATIONAL JOURNAL OF AVIATION PSYCHOLOGY, 4(1), 1–28				

Key Words	

Objective	Vol en simulateur qui contient plusieurs études destinées à reveller les modèles mentaux des pilotes du FMS

Sample sizes and characterization	20 pilotes expérimentés	
Factors	-	-
Method	Simulateur Part-task Vol individuel (B737) Initialisation du FMS non incluse L'une des tâches concerne l'interruption de décollage.	

Results	Sur la tâche concernant l'interruption de décollage, lorsque l'avion atteint 40 nœuds, on interroge les pilotes sur ce qu'ils feraient pour annuler le décollage. Le but étant d'étudier leur maîtrise du fonctionnement des auto - throttles. Les résultats montrent que 80% se trompent dans leur réponse. Ceci révèle les manques existants dans le modèles mentaux des pilotes sur la structure fonctionnelle de l'automatisme dans les situations anormales sujettes à pression temporelle. Ces résultats ainsi que ceux obtenus sur les autres tâches montrent que : - Il existe des manques dans la compréhension des pilotes des automatismes - l'interface ne facilite pas la compréhension du pilote de l'état du système - les pilotes ne sont pas forcément au courant de ces manques L'auteur souligne que les problèmes ne sont pas inhérents au système mais plus aux limitations dans la façon dont les pilotes et l'automation sont plus ou moins bien intégrés dans un système cognitif distribué.
Comments	Il est intéressant de noter que l'étude n'a pas inclus volontairement l'initialisation des performances car *"les observations lors de l'entraînement avaient montré que ces tâches ne mettaient pas à*

	l'épreuve les pilotes. L'étude a préféré se concentrer sur les tâches en vol, les tâches au sol étant moins sujettes à la pression temporelle et aux tâches concurrentes." Ceci montre la difficulté d'observer en simulateur le contexte de préparation des décollages et de reproduire l'ensemble des interactions afin d'avoir une approche vraiment écologique dans l'étude de cette phase.
Potential Implications of the results	-

Abstract	Technological developments have made it possible to automate more and more functions on the commercial aviation flight deck and in other dynamic high-consequence domains. This increase in the degrees of freedom in design has shifted questions away from narrow technological feasibility. Many concerned groups, from designers and operators to regulators and researchers, have begun to ask questions about how we should use the possibilities afforded by technology skillfully to support and expand human performance. In this article, we report on an experimental study that addressed these questions by examining pilot interaction with the current generation of flight deck automation. Previous results on pilot–automation interaction derived from pilot surveys, incident reports, and training observations have produced a corpus of features and contexts in which human–machine coordination is likely to break down (e.g., automation surprises). We used these data to design a simulated flight scenario that contained a variety of probes designed to reveal pilots' mental model of one major component of flight deck automation: the Flight Management System (FMS). The events within the scenario were also designed to probe pilots' ability to apply their knowledge and understanding in specific flight contexts and to examine their ability to track the status and behavior of the automated system (mode awareness). Although pilots were able to "make the system work" in standard situations, the results reveal a variety of latent problems in pilot–FMS interaction that can affect pilot performance in nonnormal time critical situations.

Title	When Does the MCDU Interface Work Well?				
Type	Modélisation	Interest for the study			*
First Author (s)	SHERRY	Year	2000	PDF	
Reference	American Association for Artificial Intelligence (www.aaai.org)				

Key Words	

Objective	Ce papier propose un modèle des interactions qui pourrait être utilisé dans la conception des futures interfaces du cockpit.

Results	Une précédente étude a montré que l'interface du MCDU marche bien quand : La tâche du pilote est supportée directement par une fonction L'accès aux pages et les formats de données sont guidés par des labels ou d'autres indications visuelles. L'interaction peut être décrite par 5 étapes : 1. Reformulation 2. Accès à la bonne interface 3. Formatage des données à entrer 4. Insertion des données 5. Vérification des données insérées Chaque étape est effectuée soit par un rappel en mémoire à long-terme de l'action à effectuer soit par une reconnaissance de certaines indications de l'environnement. La reconnaissance est plus robuste et plus rapide. En particulier, la reconnaissance est plus robuste aux interruptions de tâches, à la surcharge de charge de travail. La conception des futurs systèmes doit être guidé par deux grands principes : - Etablir les tâches et sous-tâches de la mission qui sont supportées par automation - Ajouter des labels, prompts et des feedback suffisants pour permettre aux pilotes de réaliser les 5 étapes décrites précédemment. Le recours à une interface graphique peut être utile si : - Pour les étapes de reformulation et de vérification. Une représentation graphique peut faciliter la représentation de l'environnement. - Les autres étapes peuvent être facilitées grâce à

	l'utilisation de boites de dialogue ou de menus déroulants
Comments	Etude menée en collaboration avec Boeing et Honeywell.
Potential Implications of the results	Cette étude montre l'importance du guidage de l'interface et de l'adéquation de l'interface à la tâche. Ceci est particulièrement vrai pour les interactions liées à la phase de préparation du vol ou les interruptions de tâche peuvent être nombreuses. Si des recommandations de conception sont établies à la suite de l'étude, ces éléments devront être pris en compte. On peut citer par exemple le changement piste au départ qui n'est pas une tâche directement supportée par l'interface et qui demande une reformulation importante de la part de l'équipage. L'article suggère d'autre part l'intérêt de l'utilisation d'une interface graphique pour la représentation de l'environnement. Ceci pourra rejoindre des recommandations dans le sens d'une représentation graphique de la piste avec des indicateurs de l'endroit où les vitesses sont atteintes ou encore une représentation graphique des données de masse (sous forme de barres graphiques superposées par exemple représentant la masse à vide, la charge, le carburant et la MTOW)

Abstract	The Multi-function Control and Display Unit (MCDU) has been identified as a source of issues pilots have transitioning to glass cockpits. Several aircraft manufacturers and avionics vendors have committed to replace the MCDU with graphical user-interfaces in the next generation of commercial aircraft. A cognitive task analysis of pilot-MCDU interaction, described in this paper, has identified that pilot failure to complete mission tasks using the MCDU is not a sole consequence of the physical dimensions or layout of the device. Instead, the MCDU interface works adequately when a given pilot task: (1) is supported directly by a function provided by the automation, and (2) the access of MCDU pages, and format and entry of data, are prompted by labels and other visual cues (and not by memorized actions sequences). Pilot tasks not supported directly by automation, and/or pilots tasks that rely on memorized action sequences are difficult to learn and likely not to be used effectively in the field.

Title	SKILL DECAY ON TAKEOFFS AS A RESULT OF VARYING DEGREES OF EXPECTANCY				
Type	Expérimentation	**Interest for the study**	*		
First Author (s)	Stevens	**Year**	2007	**PDF**	
Reference					

Key Words	Expectancy, rejected takeoff.

Objective	Estimer si les compétences acquises en simulateur sur des évènements attendus (tels que des arrêts décollage) sont bien transférées en situation réelle lorsque les évènements sont inattendus.

Sample sizes and characterization		147 étudiants 14 pilotes
Factors	Temps de reaction Déviation par rapport à la ligne centrale	Prévisibilité manipulée
Method	PC based-simulator	

Results	Dans les deux études les performances se dégradent lorsque les participants ne s'attendent pas à la survenue de l'évènement : - pour les temps de réponse pour les 2 types de participants - pour la déviation pour les étudiants
Comments	
Potential Implications of the results	Les résultats de cette étude soulignent le peu de données existant concernant la validité du transfert entre les compétences acquises en simulateur lors de situations attendues et leurs applications aux situations d'urgence inattendues. Ceci met en relief les difficultés à former les équipages à la phase de préparation du vol et notamment à la prise de décision d'arrêt oude poursuivre le décollage.

Abstract	It is generally assumed that skills trained and assessed in a simulator will transfer to the line. However, there is a class of maneuvers that demand an immediate response to an unexpected event (e.g., rejected takeoffs) for which such transfer can be questioned and for which there is little or no empirical data to support a transfer assumption. Thus, we have completed a series of studies aimed at investigating the effects of expectancy on performance for unanticipated events in a laboratory situation with undergraduate college students and experienced pilots. Our participants were trained on both normal and rejected takeoffs and the expectancy for a rejected takeoff was manipulated in each study. There were two primary measures of performance on rejected takeoff trials: the amount of time it took the participant to close down the throttle after engine failure and the maximum deviation from center line achieved while bringing the aircraft to a stop. T-tests indicated that there was a significant degradation in throttle performance for both studies (all *ps*<.05) and in maximum deviation from center line performance for one of

	the studies (p<.001). Thus, it is questionable whether the assumption that performance on events that occur in high expectancy conditions will transfer to low expectancy conditions is valid.

Fiches de lecture des incidents

OY-KBK : A321, 04/09/2003 à Oslo.

1. Questions :

- Dans quel(s) cas V1 et Vr sont elles significativement différentes ?

2. Types d'erreurs :

Erreur de calcul des vitesses :

- Transmission des paramètres de décollage entre l'avion, Oslo et Copenhague. Erreur de 16 tonnes sur la TOW parvenue à Copenhague. Détection par Copenhague d'une valeur anormalement faible de la TOW, mais confirmation par Oslo.

- Calcul des vitesses. Calcul avec une TOW erronée. Fourniture de vitesses incohérentes avec l'avion / le vol.

- Saisie de vitesses dans le FMS. Collationnement de vitesses erronées. Absence de lever de doute sur les vitesses anormalement basses.

3. Eléments contextuels :

- ACARS INOP. Utilisation de procédures détournées (radio + fax). Risque d'erreur lié aux transmissions successives des données.

4. Détection / Récupération de l'erreur :

- Lourdeur à la rotation.
- V2 < VLS
- Accélération à 250 kt.

5. Conséquences :

- Sans Objet.

C-GHLM : A330-300, 14/06/2002 à Francfort

1. **Questions :**

- Les vitesses saisies sur le FMS 330/340 disparaissent-elles lorsque l'on change d'autres paramètres (CG, TOW, ZFW…) ?
- Existence d'un carton décollage papier (affichage de l'impression ACARS) ?
- Sur quelle vitesse porte l'alarme MCDU <100 kt (V1, Vr) ?

2. **Types d'erreurs :**

Erreur de saisie (touche) sur la V1 :

- Saisie des paramètres du décollage dans le FMS. Erreur de 20 kt sur V1. Non détection par l'équipage de la masse erronée.

- Annonce de Vr. Annonce prématurée. Non détection de l'écart entre V1 et Vr. Non observation de l'absence du symbole de représentation de Vr.

3. **Eléments contextuels :**

- Qualification de l'équipage. 2 TRE, l'un contrôlant l'autre. Modification possible des comportements lors des vérifications croisées.

- Changement tardif de la masse au décollage. Nouvelle saisie des paramètres. Erreur de saisie de V1.

- Proximité habituelle des vitesses V1 et Vr. Ecart significatif entre V1 et Vr. Non détection de l'erreur de vitesse.

- Utilisation de la documentation disponible. Utilisation de références provenant de sources multiples. Non vérification d'une cohérence globale.

- Superposition habituelle de V1 et Vr sur le PFD. Association erronée des deux vitesses. Annonce de Vr à la suite de celle de V1.

- Alerte FMS si et seulement si V1<100 kt.

- Valeurs V1, Vr, V2, proposées par le FMS.

4. **Détection / Récupération de l'erreur :**

- Non détection par l'équipage. Info par PNC et ATC.

5. **Conséquences :**

- Toucher du fuselage arrière.
- QRF après attente.

F-GLZR : A343, 17/07/2004 à CDG.

1. Questions :

- Rôle / fonction du PNT de renfort pendant la préparation du vol ?

2. Types d'erreurs :

Erreur de saisie de la TOW pour le calcul des vitesses.

- Saisie de la TOW pour interrogation ACARS. Erreur de 100 tonnes sur la TOW. Absence de vérification par l'équipage.

- Calcul des vitesses par l'ordinateur central. Calcul avec une TOW erronée. Fourniture de vitesses incohérentes avec l'avion / le vol.

- Saisie de vitesses dans le FMS. Saisie de vitesses erronées. Non détection par le FO de valeurs de vitesses incohérentes avec l'avion / le vol et vérification par le CdB des vitesses insérées à partir de la valeur de masse erronéedu carton erroné.

- Briefing avant décollage. Lecture de la MTOW à la place de la TOW sur le carton. Non détection de l'écart entre la TOW mesurée et affichée sur le SD et celle prise en compte dans le calcul des vitesses par acars.

3. Eléments contextuels :

- Ecart de 5 tonnes par rapport à la masse prévisionnelle. Edition d'un nouveau carton par ACARS. Erreur de saisie sur la TOW lors de l'interrogation ACARS.

- Présentation des informations de masse sur l'impression ACARS et valeurs de MTOW et TOW proches. Association erronée des deux masses. Vérification de la MTOW au lieu de TOW.

- Valeurs V1, VR, V2, non proposées par le FMS.

- Expérience de l'équipage. Expérience faible sur l'avion et sur le système FMGS. Lecture inappropriée du carton décollage.

- Présence d'un 3^{e} PNT sans fonction définie à bord.

4. Détection / Récupération de l'erreur :

- Sensation d'accélération lente.
- Comportement anormal de l'avion perçu par PF : lourdeur. Action sur le manche amplifiée.
- Bruit sans choc et raclement perçu par PNC.

5. Conséquences :
- Fuselage éraflé.
- QRF après vidange 1 heure.

9V-SMT : B 747-400, 12/03/2003 à Auckland

1. Questions :

Sans Objet

2. Types d'erreurs :

Erreur sur la TOW.

- Réalisation du carton décollage. Erreur de 100 tonnes sur la TOW. Non détection par le FO de la masse erronée.

- Calcul des paramètres à l'aide de la documentation. Utilisation d'une TOW erronée. Détermination des vitesses incohérentes avec l'avion / le vol.

- Report des vitesses sur le carton décollage. Report de vitesses erronées. Non détection par le FO des vitesses incohérentes avec l'avion / le vol.

- Vérification du «carton». Absence de vérification de la TOW et utilisation d'une TOW erronée pour vérifier les vitesses. Non détection par le CdB. de paramètres de décollage (V + TOW) incompatibles avec l'avion / le vol.

- Saisie des vitesses dans le FMS. Saisie de vitesses erronées. Non détection par la CdB des écarts entre les vitesses proposées par le FMS et celles du «carton». Non détection par le FMS de valeurs de vitesses significativement différentes de celles calculées par le FMS.

3. Eléments contextuels :

- Retard du vol. Pression temporelle. Précipitation des actions et vérifications pendant la préparation du décollage

- Landing weight proche de TOW-100. Valeur erronée de la TOW proche de celle du landing weight. Confusion possible du TOW erroné et du landing weight.

- Procédure personnelle du FO. Mise en œuvre inefficace (erreur de calcul possible). Non détection par le FO d'erreurs sur la TOW.

- Copilote de renfort en jump seat pendant la préparation du vol avec une fonction définie. Tâche non effectuée. Non détection des erreurs de masses et vitesses.

- Utilisation de la documentation disponible. Utilisation de références provenant de sources multiples. Non vérification d'une cohérence globale.

- Valeurs V1, Vr, V2, proposées par le FMS.

4. Détection / Récupération de l'erreur :

- Stick shaker à la rotation. Maintien de l'assiette jusqu'au décollage. Non détection du tail strike par les 3 PNT. Alarme feu APU après décollage.

5. Conséquences :

- Toucher du fuselage arrière.
- QRF après vidange carburant. Atterrissage en surcharge.

F-HLOV : B 747-400, 10/12/2006 à Orly

1. Questions :

Procédure PROCEDURES NORMALES SUPPLEMENTAIRES / BOEING LAPTOP TOOL (B-02b-17-2)

« l'équipage vérifie la cohérence du GRWT. »

- En quoi consiste la vérification de la cohérence : où est lu le GRWT, comment est il vérifié ?
- Annonce VR par le Capt. PNF ? Rotation « spontanée » de l'OPL ?

6. Types d'erreurs :

Confusion, lors du 2^{e} calcul des paramètres du décollage, ZFW / TOW (ZFW annoncée au lieu de la TOW) ➔ ZFW saisie dans BLT dans le champ *Planned Weight* (TOW). ➔ V1 (-27), Vr (-32), V2 (-29) BLT sont erronées. Valeurs FMS écrasées :

- Lecture du TOW par Capt. (lecture ZFW à la place) Non détection par l'équipage de l'écart des valeurs par rapport à celles (correctes) annoncées lors de la première saisie.

- Saisie du TOW dans BLT par FO (saisie de ZFW à la place de TOW). Non détection de l'écart par le FO des valeurs par rapport à celles (correctes) annoncées lors de la première saisie. Acceptation par le système BLT d'une valeur significativement différente de la valeur précédemment entrée, et incohérente avec le vol.

- Calcul des vitesses par BLT (calcul des vitesses avec le ZFW comme TOW). Fourniture des vitesses par le BLT incohérentes avec l'avion / le vol.

- Saisie des vitesses dans le FMS (saisie des vitesses erronées). Non détection par le Capt. des écarts entre les vitesses proposées par le FMS et le BLT. Non détection par le FMS de valeurs de vitesses significativement différentes de celles calculées par le FMS.

7. Eléments contextuels :

- Batterie d'un BLT HS. Utilisation d'un seul BLT. Vérification croisée des données entrées impossible.

- Mise en veille. Perte des données entrées. Répétition de toute la procédure de calcul des paramètres du décollage.

- Message de panne hydraulique. Traitement par Capt. pendant la saisie des données dans le BLT par le FO. Possible impact sur la séquence de préparation / vérification du décollage.

- QNH élevé et T° basse. Interprétation erronée de la différence des T° fictives BLT / FMS. Non détection des erreurs sur les paramètres de décollage.

- Rolling take-off. Effet de masque sur les performances d'accélération de l'avion. Non détection de la faible accélération.

- Valeurs V1, Vr, V2 proposées par le FMS.

8. Détection / Récupération de l'erreur :

Longueur de piste restante à V1 jugée anormalement importante par le Capt et doute sur les vitesses de décollage. Annonce différée de la rotation.

Sensation de lourdeur de l'avion par l'OPL. Augmentation de l'assiette. Déclenchement du vibreur de manche. Pleine poussée par l'OPL.

Non détection du toucher de queue.

Observation de fumée par un véhicule de piste.

9. Conséquences :

Toucher de queue à la rotation
Poursuite du décollage
QRF
Dommages sur fuselage

N3203Y: B 747-100, 28/12/2001 à Anchorage

1. Questions :

- La masse de l'avion dépendait-elle seule du ravitaillement en fuel ?

2. Types d'erreurs :

Erreur sur la masse de carburant.

- Réalisation du carton décollage. Report des données figurant sur le carton atterrissage. Non prise en compte de la masse de carburant ajoutée
    - Calcul des vitesses au décollage. Calcul des vitesses avec une masse erronée. Non détection par l'équipage des vitesses incohérentes avec l'avion / le vol.

3. Eléments contextuels :

- Equipage à trois.
- Vol cargo. Variabilité des masses en fonction des vols. Ordres de grandeurs des vitesses au décollage variables.
- Absence de FMS.

4. Détection / Récupération de l'erreur :

- Tailstrike non ressenti ni détecté jusqu'à l'arrivée à destination.

5. Conséquences :

- « Substantial Damages »

9G-MKJ : B747-200F, 14/09/2004 à Halifax.

1. Questions :

2. Types d'erreurs :

Erreur de calcul des vitesses associées au décollage

- Calcul des vitesses dans le BLT. Utilisation des paramètres de masse du décollage précédent. Fourniture de vitesses par le BLT incompatibles avec l'avion / le vol.

- Remplissage du carton décollage. Report de vitesses erronées. Non détection de l'écart entre la masse utilisée pour le calcul du BLT et la masse au décollage.

- Affichage des vitesses sur l'anémomètre. Utilisation de vitesses erronées. Non détection par l'équipage du positionnement inadéquat pour ce vol / cet avion.

3. Eléments contextuels :

- Utilisation du BLT. Prise en compte de données par défaut non maîtrisé. Calcul de vitesses avec une masse entrée pour un vol précédent.

- Vol par étapes.

4. Détection / Récupération de l'erreur :

- Sans Objet

5. Conséquences :

- Perte de contrôle en vol, collision avec le relief en bout de piste.

ZS-SAJ : B 747-300, 11/03/2003 à Johannesburg

1. Questions :

Sans Objet

2. Types d'erreurs :

Confusion ZFW / TOW : utilisation de laptop pour le calcul des vitesses. Saisie du ZFW au lieu de TOW. Report des vitesses erronées sur le «carton» puis mauvais placement des index de vitesses.

- Saisie de la TOW dans le laptop. Utilisation de la ZFW. Non détection par l'OMN de la masse erronée.
- Calcul des paramètres par le laptop. Calcul avec la ZFW au lieu de la TOW. Fourniture de vitesses par le laptop incohérentes avec l'avion / le vol.
- Report des vitesses sur le carton décollage. Report de vitesses erronées. Vérification par le CdB à la place du FO. Non détection par le CdB et l'OMN de vitesses incohérentes avec l'avion / le vol.
- Affichage des index de vitesse sur l'anémomètre. Choix Report de vitesses erronées. Non détection par l'équipage du positionnement inadéquat pour ce vol / cet avion.

3. Eléments contextuels :

- Service ATC perturbé. Pression temporelle. Précipitation des actions et vérifications pendant la préparation du décollage
- APU INOP. Chaleur dans le poste et distractions de l'équipage. Répartition des tâches perturbée et conditions de préparation du décollage dégradées.
- Altitude et température élevées. Absence de prise en compte. Non détection par l'équipage des vitesses de décollage incohérentes.
- Equipage à trois.
- Pas d'utilisation du FMS.
- 5+15+137 POB.

4. Détection / Récupération de l'erreur :

- Perception d'un comportement inhabituel de l'avion au cours de la rotation. Décision de différer la rotation de 15 kt.

5. Conséquences :

- Toucher du fuselage arrière.
- QRF après vidange carburant.

N505UA : B 757-200, 16/01/1990 à New York

1. Questions :

Sans Objet

2. Types d'erreurs :

Erreur de calcul des vitesses.

- Utilisation du manuel. Utilisation des performances d'un autre avion. Non détection par le FO des écarts de performance entre l'avion concerné (B757) et les références utilisées (B767).

- Confirmation de la détermination des vitesses. Non effectué. Non détection par le Capt. de l'erreur de calcul.

- Affichage des index de vitesse sur l'anémomètre. Choix des vitesses erroné. Non détection par l'équipage du positionnement inadéquat pour ce vol / cet avion.

3. Eléments contextuels :

Inconnus…

- Pas d'informations concernant l'expérience / la formation de l'équipage (change-t-il souvent d'avion, est-il bi-qualifié ?)

4. Détection / Récupération de l'erreur :

Rotation excessive. Perception d'une secousse au décollage

5. Conséquences :

Poursuite du décollage et du vol.
Dommages fuselage arrière et bouclier de pressurisation.

OY-KDN : B 767-300, 24/08/1999 à Copenhague

1. Questions :

Sans Objet

2. Types d'erreurs :

Confusion ZFW / TOW lors de l'interrogation ACARS du calcul des paramètres au décollage. Utilisation de ZFW dans le champ TOW. Retour Acars avec MAC différent de l'état de charge. Nouvelle interrogation comprenant la MAC (cette fois) et toujours ZFW au lieu de TOW. Retour ACARS avec MAC conforme à l'état de charge et V1 (-33), Vr (-33) et V2 (-33) toujours erronées :

- Saisie de la TOW pour interrogation ACARS. Utilisation de la ZFW. Compréhension erronée par le FO des attentes du système.

- Envoi des données par ACARS. Utilisation de la ZFW à la place de la TOW. Non contrôlé par le Capt.

- Calcul des paramètres par l'ordinateur central. Calcul avec la ZFW au lieu de la TOW. Fourniture de vitesses par l'ordinateur central incohérentes avec l'avion / le vol.

- Vérification des données ACARS. Détection de l'erreur de MAC par le 3e homme. Absence de vérification par l'équipage des autres données.

- Saisie de la MAC pour interrogation ACARS. Utilisation non modifiée de la ZFW à la place de la TOW. Non détection par l'équipage de l'erreur de masse.

- Vérification des données ACARS. Vérification inadéquate de la masse. Confusion (possible ?) avec la MTOW.

- Saisie de vitesses dans le FMS saisie de vitesses erronées Non détection par le Capt et le FMS de vitesses incohérentes avec l'avion / le vol. Non vérification par l'équipage pendant le taxi.

3. Eléments contextuels :

- Retard du vol. Pression temporelle. Précipitation des actions et vérifications pendant la préparation du décollage

- Expérience du copilote. Expérience préalable sur MD80, route training sur 767 et première utilisation complète du FMS. Confusion TOW/ZFW

- Indisponibilité de l'état de charge lors de la préparation. Interruption lors de la saisie des données ACARS. Séquence de saisie perturbée (notamment absence de saisie de la MAC)

- Présentation des informations de masse sur l'impression ACARS et valeurs de MTOW et TOW proches. Association erronée des deux masses. Vérification de la MTOW à la place de la TOW.

- PNT de renfort en jump seat pendant la préparation du vol sans fonction définie. Interruption de la séquence normale de préparation. Vérification des paramètres de décollage perturbée.

- Valeurs V1, Vr, V2 non proposées par FMS

- Alerte FMS uniquement si TOW>MTOW.

4. Détection / Récupération de l'erreur :

- Perception d'un comportement inhabituel de l'avion au cours de la rotation. Décision d'interrompre le décollage après la V1 affichée (mais avant la V1 réelle)

5. Conséquences :

- Toucher du patin arrière
- Pneus et freins TPG endommagés

Définition des critères ergonomiques

Cohérence/homogénéité

Le critère Homogénéité/Cohérence concerne la façon avec laquelle les choix de conception de l'interface (codes, dénominations, formats, procédures, etc.) sont conservés pour des contextes identiques, et sont différents pour des contextes différents. Des interfaces cohérentes sont plus faciles à apprendre et à utiliser. À l'inverse, des interfaces « incohérentes » sont plus difficiles à utiliser et peuvent entraîner des erreurs de procédures.

Problème de guidage

Incitation

Le terme « Incitation » a ici une définition plus large que celle qu'on lui confère généralement. Ce critère concerne les moyens mis en œuvre pour amener les utilisateurs à effectuer des actions spécifiques, qu'il s'agisse d'entrée de données ou autre. Ce critère englobe aussi tous les mécanismes ou moyens faisant connaître aux utilisateurs les alternatives, lorsque plusieurs actions sont possibles, selon les états ou contextes dans lesquels ils se trouvent. L'Incitation concerne également les informations permettant aux utilisateurs de savoir où ils en sont, d'identifier l'état ou contexte dans lequel ils se trouvent, de même que les outils d'aide et leur accessibilité.

Concisions et actions minimales

Le critère Actions Minimales concerne la charge de travail quant aux actions nécessaires à l'atteinte d'un but, à l'accomplissement d'une tâche. Il s'agit ici de limiter autant que possible les étapes par lesquelles doivent passer les utilisateurs.

Lisibilité

Le critère Lisibilité concerne les caractéristiques de présentation des informations sur l'écran pouvant entraver ou faciliter la lecture de ces dernières (luminance des caractères, contraste caractères-fond, taille des lettres, espacement entre les mots, espacement entre les lignes, espacement entre les paragraphes, longueur des lignes, etc.).

Compatibilité

Le critère Compatibilité concerne l'accord pouvant exister entre les caractéristiques des utilisateurs (mémoire, perceptions, habitudes, compétences, âge, attentes, etc.) et des tâches, d'une part, et l'organisation des sorties, des entrées et du dialogue d'une application donnée, d'autre part. De plus, la Compatibilité concerne également le degré de similitude entre divers environnements ou applications.

Gestion des erreurs

Le critère Gestion des Erreurs concerne tous les moyens permettant d'une part d'éviter ou de réduire les erreurs, et d'autre part de les corriger lorsqu'elles surviennent. Les erreurs sont ici considérées comme des saisies de données incorrectes, des saisies dans des formats inadéquats, des saisies de commandes avec une syntaxe incorrecte, etc.
Trois sous-critères participent à la Gestion des Erreurs : Protection Contre les Erreurs, Qualité des Messages d'Erreurs et Correction des Erreurs.

Densité de l'information et groupement distinction des items

Le critère Densité Informationnelle concerne la charge de travail du point de vue perceptif et mnésique, pour des ensembles d'éléments et non pour des items.

Le critère Groupement/Distinction par le Format concerne plus particulièrement les caractéristiques graphiques (format, couleur, etc.) permettant de faire apparaître l'appartenance ou la non appartenance d'items à une même classe, ou encore permettant d'indiquer des distinctions entre classes ou bien encore des distinctions entre items d'une même classe.

Sondage Corsairfly

Corsairfly

Plusieurs accidents et incidents se sont produits au décollage, en particulier sur des avions de nouvelle génération, à la suite d'insertion de données erronées dans les systèmes d'aide à la conduite du vol.

Compte tenu de la fréquence et de la gravité des événements, le BEA a engagé une étude afin de proposer des actions concrètes pour prévenir le renouvellement de telles erreurs.

L'étude menée en collaboration avec les compagnies Air France et Corsairfly est composée de 4 phases principales :

- Analyse des incidents et accidents,
- Entretiens/Questionnaires avec des équipages,
- Observations sur le terrain,
- Etude des évolutions au stade de la conception.

C'est dans ce cadre que nous vous proposons de répondre au questionnaire suivant.

Vous êtes   OPL ☐   CdB ☐   TRI ☐   TRE ☐

Type avion   B747 ☐   A330 ☐

Ancienneté en tant que pilote (années) ☐

Expérience Glass cockpit (années) ☐

QUESTION 1 : Au cours de votre carrière à Corsairfly, vous est-il arrivé de constater que le décollage a été (ou aurait pu être) effectué avec des marges de sécurité réduites en raison de paramètres erronés ?

Si oui, quels paramètres étaient erronés ?

Masses	☐	Configuration	☐
Vitesses	☐	Piste	☐
Poussée	☐	Bretelle d'alignement	☐

Merci de préciser si vous étiez CdB ☐ OPL ☐ PF ☐ PM ☐

et le type avion B737 ☐ B747 ☐ A330 ☐

Merci de décrire également les circonstances en précisant si l'erreur a été détectée avant, pendant ou après le décollage.

QUESTION 2 : quelles sont les principales contraintes auxquelles vous êtes confrontés de la préparation jusqu'au vol ?

QUESTION 3 : quelles sont les principales stratégies que vous utilisez pour faire face à ces contraintes et vous assurer que les paramètres de décollage sont corrects ?

QUESTION 4 : avez-vous des remarques et/ou des suggestions ?

Merci de remettre ce questionnaire dans le casier n°149 Wilfrid LEGAULT.

Grille d'observation TRE

Grille d'observation des paramètres de décollage

Date	Jour		Mois		Année	
Type avion	A320 (A318, A319, A321)	A330	A340	B737	B747	B777
Type Vol	LC	MC	CC			
Composition de l'équipage	CdB	OPL1	OPL2	OPL3		
Qui est PF au départ ?	CdB	OPL1	OPL2	OPL3		

Edition informatique du carton de décollage

Première édition

Effectuée par CDB OPL1 OPL2
A quel moment PPV Préparation avion Après mise en route
Vérifiée/ validée CDB OPL1 OPL2
Plus tard Simultanément
Données vérifiées? Conditions de calcul Résultats
Météo / Piste /bretelle / TOW — Vitesses / T° fictive / N1
La charge prise en compte est -elle égale à
celle initialement prévue
tendance affichée
valeur actualisée par téléphone par le CLD
autres (précisez)

Deuxième édition

Effectuée par CDB OPL1 OPL2
A quel moment PPV Préparation avion Après mise en route
Vérifiée/ validée CDB OPL1 OPL2
Plus tard Simultanément
Données vérifiées? Conditions de calcul Résultats
Météo / Piste /bretelle / TOW — Vitesses / T° fictive / N1
La charge prise en compte est -elle égale à
celle initialement prévue
tendance affichée
valeur actualisée par téléphone par le CLD
autres (précisez)

Inscription manuscrite de la masse sur le carton

Première saisie

Effectuée par CDB OPL1 OPL2
A partir de Suivi Octave
Loadsheet préliminaire
Loadsheet définitive
LMC
annoncée à voix haute Oui Non
Vérifiée ensuite par CDB OPL1 OPL2
A partir de Suivi Octave
Loadsheet préliminaire
Loadsheet définitive
LMC
annoncée à voix haute Oui Non

Deuxième saisie

Effectuée par CDB OPL1 OPL2
A partir de Suivi Octave
Loadsheet préliminaire
Loadsheet définitive
LMC
annoncée à voix haute Oui Non
Vérifiée ensuite par CDB OPL1 OPL2
A partir de Suivi Octave
Loadsheet préliminaire
Loadsheet définitive
LMC
annoncée à voix haute Oui Non

Aperçu: page 1 sur un total de 1

Préparation FMS

Donnée de Masse : ZFW

Première saisie

Insérée par CDB OPL
en cross check Oui Non
A partir de Suivi Octave
Loadsheet préliminaire
Loadsheet définitive
annoncée à voix haute Oui Non
Quand Préparation préliminaire poste
Réception loadsheet préliminaire
Réception loadsheet définitive
LMC
Autre

Valeur vérifiée ensuite ?

Par CDB OPL
en cross check Oui Non
A partir de Suivi Octave
Loadsheet préliminaire
Loadsheet définitive
Annonce CDB
annoncée à voix haute Oui Non

Modification

Insérée par CDB OPL
en cross check Oui Non
A partir de Suivi Octave
Loadsheet préliminaire
Loadsheet définitive
annoncée à voix haute Oui Non
Quand Préparation préliminaire poste
Réception loadsheet préliminaire
Réception loadsheet définitive
LMC
Autres (Précisez)

Valeur vérifiée ensuite ?

Par CDB OPL
en cross check Oui Non
A partir de Suivi Octave
Loadsheet préliminaire
Loadsheet définitive
Annonce CDB
annoncée à voix haute Oui Non

Données de vitesses : V1, VR, V2

Première saisie

Insérées par CDB OPL
en cross check Oui Non
A partir de Carton
Autres (Précisez)

Modification

Insérées par CDB OPL
en cross check Oui Non
A partir de Carton
Autres (Précisez)

Données de vitesses : V1, VR, V2

Première saisie

Insérées par	CDB		OPL	
en cross check	Oui		Non	
A partir de	Carton Autres (Précisez)			
	annoncée à voix haute	Oui	Non	

Valeurs vérifiées ensuite

Insérées par	CDB		OPL	
en cross check	Oui		Non	
A partir de	Carton Autres (Précisez)			
	annoncée à voix haute	Oui	Non	

Modification

Insérées par	CDB		OPL	
en cross check	Oui		Non	
A partir de	Carton Autres (Précisez)			
	annoncée à voix haute	Oui	Non	

Valeurs vérifiées ensuite

Insérées par	CDB		OPL	
en cross check	Oui		Non	
A partir de	Carton Autres (Précisez)			
	annoncée à voix haute	Oui	Non	

Briefing avant décollage

Rappel par le PF des paramètres de décollage

Effectué oui ___ non ___

Données abordées par le PF, vérifiées par le PNF en se basant sur

Volets ___ Tempé fictive ___ V1, VR, V2 ___

Volets	PF	PNF	Tempé fictive	PF	PNF	V1, VR, V2	PF	PNF
FMS			FMS			FMS		
carton			carton			carton		
Loadsheet			Loadsheet			Loadsheet		
Octave			Octave			Octave		
PFD			PFD			PFD		
de mémoire			de mémoire			de mémoire		
ne sais pas								

ZFW ___ TOW ___ Fuel ___

ZFW	PF	PNF	TOW	PF	PNF	Fuel	PF	PNF
FMS			FMS			FMS		
carton			carton			carton		
Loadsheet			Loadsheet			Loadsheet		
Octave			Octave			Octave		
PFD			PFD			PFD		
de mémoire			de mémoire			de mémoire		
ne sais pas								

Rappel par le CDB de V1 dans son briefing sécurité

en se basant sur

FMS ___
carton ___
Loadsheet
Octave
PFD ___
de mémoire
ne sais pas ___

Avez-vous noté des évènements particuliers/imprévus lors de la préparation du vol?

Comment qualifieriez-vous la pression temporelle lors de la préparation relativement à un vol moyen/normal?

Très faible	Relativement Faible	Normal	Relativement Elevé	Très Elevé

Comment qualifieriez-vous la charge de travail du CDB pour les "opérations annexes" à la préparation du vol relativement à un vol moyen/normal??

Très faible	Relativement Faible	Normal	Relativement Elevé	Très Elevé

Comment qualifieriez-vous le nombre d'interruptions dues à des entrées dans le cockpit ou à des communications avec le sol comparativement à un vol moyen/normal?

Très faible	Relativement Faible	Normal	Relativement Elevé	Très Elevé

Questionnaire Concepteurs

A N T H R O P O L O G I E   A P P L I Q U E E

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Téléphone : 01 42 86 20 41 - 01 42 86 20 39 - Télécopie : 01 42 61 53 80
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1 - Contexte de l'étude

Depuis quelques années plusieurs accidents et incidents graves se sont produits au décollage, en particulier sur des avions de nouvelle génération, à la suite d'erreurs d'insertion de données dans les systèmes d'aide à la conduite du vol.
Compte tenu de la fréquence et de la gravité des événements, le BEA a engagé un processus de réflexion avec les parties concernées afin de proposer des actions concrètes pour prévenir le renouvellement de telles erreurs.
Dans ce contexte, le BEA et la DGAC coordonnent un groupe de travail auquel collaborent les compagnies Air France et Corsair. Le Laboratoire d'Anthropologie Appliquée (LAA) est chargé de mener l'étude Facteurs Humains. Cette étude s'appuie pour une large part sur l'analyse d'événements, des observations en vol et des entretiens. Dans le cadre de cette étude, nous souhaiterions appréhender la problématique sous l'angle de la conception au travers d'un questionnaire diffusé auprès des experts concernés.

2 - Questionnaire

Nom :……..   Société/département : ……….. ..Fonction occupée : …………..

A - Quelles sont les évolutions des FMS concernant les paramètres de décollage sur les futurs avions?

B – Enchaînement des pages FMS

Voyez-vous des raisons de faire évoluer la logique d'enchaînement des pages de saisie et de consultation des données de masses et de vitesses ?

C - Données de masse

Parmi les possibilités de saisie de masse suivantes quelles sont celles qui seront implémentées ?
Pourquoi ?
Saisie du ZFW
Saisie du TOW
Saisie du GRWT
Quelles sont celles que vous préconiserez ? Pourquoi ?

Les systèmes comporteront-ils des contrôles des valeurs (min, max) des masses saisies ?
Un système de mesure autonome du GROSS WEIGHT de type Weight and Balance est-il prévu ?

D - Données de vitesse
Les systèmes comporteront-ils des contrôles des valeurs (min, max) des vitesses saisies ?
D'autres contrôles sont-ils envisagés ? Par exemple contrôle de cohérence entre les vitesses ($V1 \leq Vr < V2$…)
Un calcul des vitesses par le système est-il envisagé ?
Dans l'affirmative, une alerte est-elle envisagée sur les différences entre vitesses de référence proposées par l'avion et vitesses saisies par l'équipage?

E – Conduite du vol et paramètres de performance au décollage
Quel type d'information est-il envisagé pour informer l'équipage des conséquences sur la conduite du vol des paramètres de décollage qu'il a saisis ? Quels seraient les systèmes concernés ?

L'utilisation d'une représentation graphique est-elle envisagée ?
Des systèmes d'aide à la décision lors du décollage sont-ils étudiés ?

F – Autres commentaires :

Merci de renvoyer ce questionnaire à : fanny.rome@univ-paris5.fr
ou par fax au : 0142615380

Eventuellement, seriez-vous d'accord pour que nous vous contactions pour compléter ces réponses ?   Oui ❑ Non ❑
Si oui à quel numéro peut-on vous joindre ?

A N T H R O P O L O G I E   A P P L I Q U E E

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1 – Context of the study

For several years, accidents and severe incidents have occurred during the takeoff, particularly with new generation aircraft, due to the insertion of erroneous data.
Because of the frequency and the severity of these events, the BEA has initiated a think-thank with the impacted actors in order to propose practical actions to prevent the occurrence of such erroneous actions.
In this context, the BEA and the DGAC coordinate a working group for which collaborate two French Airlines: Air France and Corsairfly. The Laboratory of Applied Anthropology (LAA) is in charge of the Human Factors aspects. The study is based on events analysis, line observations and interviews. As part of the study, we wish to integrate the design aspects by the means of a questionnaire addressed to the involved experts.

2 - Questionnaire

Name :…….. **Company : ……….. ..** **Role : …………..**

A – What are the main FMS evolutions related to the takeoff parameters in the future aircraft?

B – Sequence of FMS screens

Do you think that the sequence of FMS screens referred to the insert and reading of weight and speeds data has to be changed? Why?

C – Weight data

Between these different possibilities of weight data input, which of them will be implemented? Why?
Input of ZFW
Input of TOW
Input of GRWT
Which of them will you recommend? Why?

Will systems integrate controls of the input values (min, max)?
Is an autonomous system enabled to evaluate the GROSS WEIGHT such as the Weight and Balance planned?

D – Speed data

Will systems integrate controls of the input speed values (min, max)?
Are other controls planned? e.g. coherence control among the speeds ($V1 \leq Vr < V2 \ldots$)
Is an automatic calculation planned? If so, is it planned to inform the crew to the eventual differences between the reference speeds proposed by the aircraft and the input of the crew?

E – Managing of flight and performance takeoff parameters

Which kind of information is planned to notify to the crew the impacts of the inserted takeoff data on the Flight Managing? Which systems would be affected?

Is it planned to use a graphical interface?
Are Decision aid systems considered?

F – Additional remarks?

Thanks to send back this questionnaire to: fanny.rome@univ-paris5.fr
fax:+33142615380
Would you agree to be eventually contacted to complete your answers?
Yes ❑ No ❑
If so, may you let us your phone number: