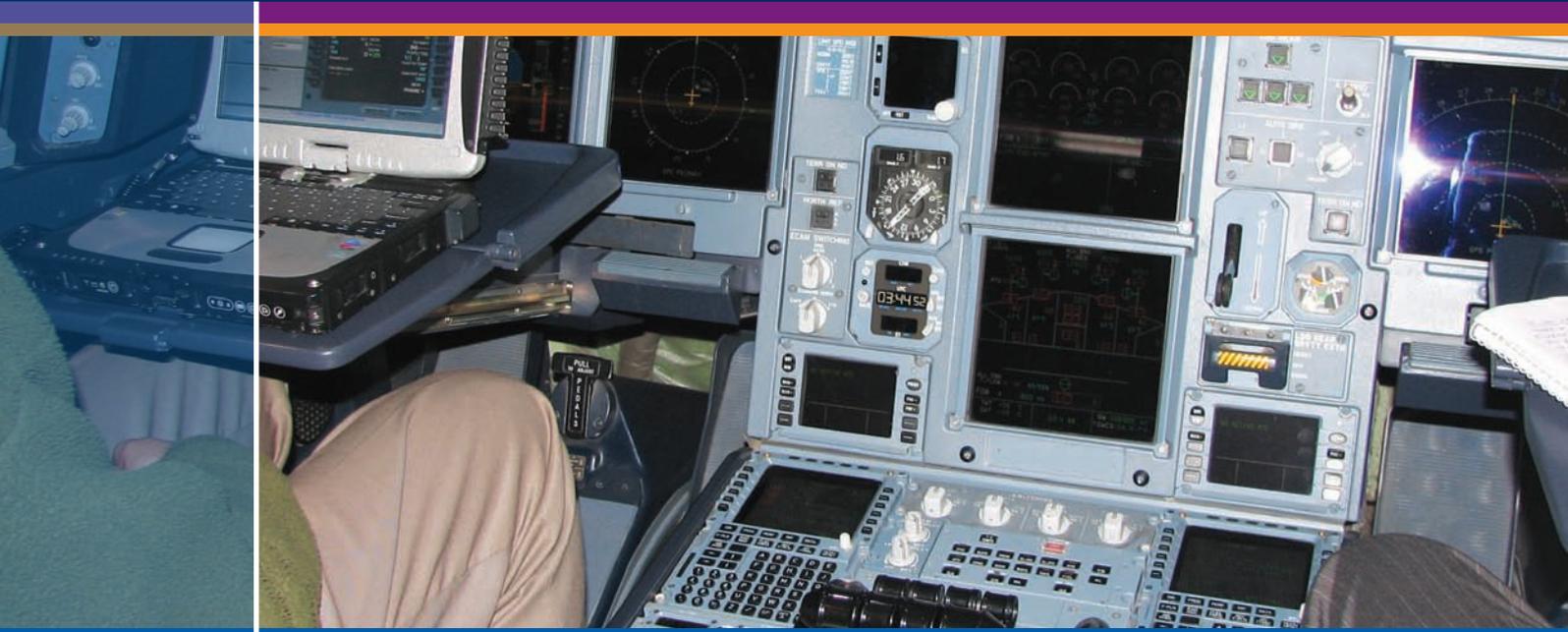




Australian Government

Australian Transport Safety Bureau



ATSB TRANSPORT SAFETY REPORT
Aviation Research and Analysis Report – AR-2009-052

Take-off performance calculation and entry errors:

A global perspective



Australian Government

Australian Transport Safety Bureau

ATSB TRANSPORT SAFETY INVESTIGATION REPORT

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**Take-off performance calculation and entry
errors: A global perspective**

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Figure 9: Photo provided courtesy of Joe Pries (<http://joespriesaviation.net>)

Abstract

Everyday errors such as incorrectly transcribing or inadvertently dialling a wrong telephone number normally have minimal consequences. For high capacity aircraft operation, the consequence of such errors can be significant. There have been numerous take-off accidents worldwide that were the result of a simple data calculation or entry error by the flight crew. This report documents 20 international and 11 Australian accidents and incidents (occurrences) identified between 1 January 1989 and 30 June 2009 where the calculation and entry of erroneous take-off performance parameters, such as aircraft weights and 'V speeds' were involved. Importantly, it provides an analysis of the safety factors that contributed to the international occurrences and suggests ways to prevent and detect such errors.

A review of the international and Australian occurrences showed that these types of errors have many different origins; with crew actions involving the wrong figure being used, data entered incorrectly, data not being updated, and data being excluded. Furthermore, a range of systems and devices have been involved in these errors, including performance documentation, laptop computers, the flight management computer, and the aircraft communications addressing and reporting systems. The consequences of these errors also ranged from a noticeable reduction in the aircraft's performance during the takeoff, to the aircraft being destroyed and loss of life.

The most common contributing safety factor identified related to crew actions (39 per cent), including monitoring and checking, assessing and planning, and the use of aircraft equipment. This was followed by absent or inadequate risk controls (31 per cent), mostly centred on poor procedures, non-optimally designed aircraft automation systems, inappropriately designed or unavailable reference materials, and inadequate crew management practices and training. Common local conditions (27 per cent) involved inadequate task experience or recency, time pressures, distractions and incorrect task information.

Different airlines use, and different aircraft types require, different methods for calculating and entering take-off performance parameters, which means there is no single solution to ensure that such errors are prevented or captured. This report also discusses several error capture systems that airlines and aircraft manufacturers can explore in an attempt to minimise the opportunities of take-off performance parameter errors from occurring or maximise the chance that any errors that do occur are detected and/or do not lead to negative consequences.

THE AUSTRALIAN TRANSPORT SAFETY BUREAU

The Australian Transport Safety Bureau (ATSB) is an independent Commonwealth Government statutory agency. The Bureau is governed by a Commission and is entirely separate from transport regulators, policy makers and service providers. The ATSB's function is to improve safety and public confidence in the aviation, marine and rail modes of transport through excellence in: independent investigation of transport accidents and other safety occurrences; safety data recording, analysis and research; fostering safety awareness, knowledge and action.

The ATSB is responsible for investigating accidents and other transport safety matters involving civil aviation, marine and rail operations in Australia that fall within Commonwealth jurisdiction, as well as participating in overseas investigations involving Australian registered aircraft and ships. A primary concern is the safety of commercial transport, with particular regard to fare-paying passenger operations.

The ATSB performs its functions in accordance with the provisions of the *Transport Safety Investigation Act 2003* and Regulations and, where applicable, relevant international agreements.

Purpose of safety investigations

The object of a safety investigation is to identify and reduce safety-related risk. ATSB investigations determine and communicate the safety factors related to the transport safety matter being investigated. The terms the ATSB uses to refer to key safety and risk concepts are set out in the next section: Terminology Used in this Report.

It is not a function of the ATSB to apportion blame or determine liability. At the same time, an investigation report must include factual material of sufficient weight to support the analysis and findings. At all times the ATSB endeavours to balance the use of material that could imply adverse comment with the need to properly explain what happened, and why, in a fair and unbiased manner.

Developing safety action

Central to the ATSB's investigation of transport safety matters is the early identification of safety issues in the transport environment. The ATSB prefers to encourage the relevant organisation(s) to initiate proactive safety action that addresses safety issues. Nevertheless, the ATSB may use its power to make a formal safety recommendation either during or at the end of an investigation, depending on the level of risk associated with a safety issue and the extent of corrective action undertaken by the relevant organisation.

When safety recommendations are issued, they focus on clearly describing the safety issue of concern, rather than providing instructions or opinions on a preferred method of corrective action. As with equivalent overseas organisations, the ATSB has no power to enforce the implementation of its recommendations. It is a matter for the body to which an ATSB recommendation is directed to assess the costs and benefits of any particular means of addressing a safety issue.

When the ATSB issues a safety recommendation to a person, organisation or agency, they must provide a written response within 90 days. That response must indicate whether they accept the recommendation, any reasons for not accepting part or all of the recommendation, and details of any proposed safety action to give effect to the recommendation.

The ATSB can also issue safety advisory notices suggesting that an organisation or an industry sector consider a safety issue and take action where it believes it appropriate. There is no requirement for a formal response to an advisory notice, although the ATSB will publish any response it receives.

TERMINOLOGY USED IN THIS REPORT

Occurrence: accident or incident.

Safety factor: an event or condition that increases safety risk. In other words, it is something that, if it occurred in the future, would increase the likelihood of an occurrence, and/or the severity of the adverse consequences associated with an occurrence. Safety factors include the occurrence events (e.g. engine failure, signal passed at danger, grounding), individual actions (e.g. errors and violations), local conditions, current risk controls and organisational influences.

ABBREVIATIONS

ACARS	Aircraft communications addressing and reporting system
ADREP	Accident/incident data reporting system (ICAO)
ATC	Air traffic control
ATIS	Automatic terminal information service
ATSB	Australian Transport Safety Bureau
BLT	Boeing laptop tool
CAA	Civil Aviation Authority (United Kingdom)
CDU	Control display unit
CTOP	Computer take-off programme
DTG	Distance-to-go
ECAM	Electronic centralised aircraft monitoring system
ECCAIRS	European Coordination Centre for Accident and Incident Reporting System
FADEC	Full authority digital engine control system
FMA	Flight mode annunciator
FMC	Flight management computer (Boeing)
FMGC	Flight management guidance and envelope computer (Airbus)
FMGS	Flight management and guidance system (Airbus)
FMS	Flight management system (Boeing)
FOVE	Flight operations versatile environment computer system (Airbus)
GWC	Gross weight chart
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
kg	Kilogram/s
kts	Knots
lbs	Pound/s
LPC	Less paper cockpit (Airbus)
m	Metre/s
MAC	Mean aerodynamic chord
MCDU	Multifunction control and display unit
MCP	Mode control panel

MTOW	Maximum take-off weight
MTTL	Module table take-off and landing charts
n	Number
RNP	Required navigation performance
SOP(s)	Standard operating procedure(s)
TODC	Take-off data calculation
TO/GA	Take-off/go-around thrust
TOPMS	Take-off performance monitoring system(s)
TOS	Take-off securing function (Airbus)
TOW	Take-off weight
TORA	Take-off run available
TSB	Transportation Safety Board (of Canada)
WAAS	World aircraft accident summary (Ascend)
V ₁	Decision speed
V ₂	Take-off safety speed
V _R	Rotation speed
ZFW	Zero fuel weight

In July 2004 and December 2006, an Airbus A340-300 aircraft and a Boeing 747-400 aircraft respectively sustained tail strikes as a result of the flight crew (crew) using a much lower than normal take-off weight (TOW) for calculating the take-off reference speeds (V speeds) and thrust setting. In response to these incidents, a working group¹ was established in France to study the processes specifically relating to the use of erroneous take-off performance parameters, and to analyse why skilled and highly training crews were unable to detect these errors.

The final report, titled 'Use of Erroneous Parameters at Takeoff' (published in May 2008), provides a useful insight into the nature of these types of events. This involved reviewing 10 investigation reports and, to identify the various functions, errors and recovery measures involved when obtaining, inputting and verifying takeoff performance data, conducting a pilot survey and observing a number of flights.

Overall, the study determined that these types of errors occur irrespective of the airline, the aircraft type, the equipment, and the data calculation and entry method used. They occur frequently, but are generally detected by the defences put in place at both the organisational (airline) and individual (crew) level (Laboratory of Applied Anthropology, 2008).

As technology evolves, machines become more complex, which in turn affects the way in which humans and machines interrelate. This interaction has created a new set of error modes. In aviation, one such error that continues to surface is the calculation or data entry of erroneous take-off performance parameters (e.g. zero fuel weight (ZFW), TOW, V speeds) utilising systems such as aircraft performance manuals, performance programs on laptop computers, the flight management computer (FMC), and the aircraft communications addressing and reporting system (ACARS). Examples of such errors that have led to accidents include:

- On 24 August 1999, a Boeing 767-383 aircraft, registered OY-KDN, sustained a tailstrike while taking off from Copenhagen, Denmark on a scheduled passenger service. The ZFW had been inadvertently entered into the aircraft TOW prompt in the ACARS (Aircraft Accident Investigation Board Denmark, n.d.).
- On 14 October 2004, a Boeing 747-244SF aircraft, registered 9G-MKJ, attempted to take off from Halifax, Nova Scotia, but overshot the end of the runway, momentarily became airborne and then struck an earth bank. The TOW used to generate the take-off performance data in the laptop computer was from the previous flight (Transportation Safety Board of Canada, 2006).
- On 20 March 2009, an Airbus A340-541 aircraft, registered A6-ERG, sustained a tailstrike during takeoff at Melbourne, Australia. A TOW 100 tonnes below the aircraft's actual TOW was inadvertently entered into the

¹ The working group consisted of representatives from the French air investigation Bureau (the Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile - BEA), Civil Aviation Authority (Direction générale de l'Aviation civile - DGAC), the airlines involved, and the Laboratory of Applied Anthropology (specialists in human factors).

take-off performance software in the laptop computer (Australian Transport Safety Bureau, 2009).

Unfortunately, the above examples are not isolated and despite improvements in automated cockpit systems and robust operating procedures, these errors continue to occur.

1.1 Objectives

Research to date by organisations such as the Laboratory of Applied Anthropology, Boeing and Airbus has provided a valuable awareness of take-off performance calculation and data entry errors. In 2009, the ATSB commenced a research study to not only identify relevant accidents and incidents involving both Australian-registered and foreign-registered high capacity aircraft, but to further explore why these events occur through the identification and analysis of contributing safety factors based on the chain-of-events theory of accident causation concept from Reason (1990).

The purpose of this report was to present a worldwide perspective of accidents and incidents (collectively termed occurrences) involving take-off performance parameter errors. Specifically, the objectives were:

- to provide an overview of these occurrences involving Australian civil registered aircraft and foreign-registered aircraft, between the period 1 January 1989 and 30 June 2009
- to explore the nature of the associated human errors and identify the higher-level safety factors that contributed to these occurrences.

1.2 Report outline

To achieve the above objectives, the report has been structured as follows:

- *Chapter 2* provides a background into the use and determination of take-off performance parameters. This includes briefly defining the different parameters; describing the various methods used by airlines for calculating and entering the parameters; listing the typical errors that may result; and the consequences of erroneous take-off performance parameters.
- *Chapter 3* provides a brief summary and analysis of occurrences relating to take-off performance parameter errors involving Australian civil registered aircraft between the period 1 January 1989 and 30 June 2009.
- *Chapter 4* provides a detailed description of occurrences relating to take-off performance parameter errors involving foreign-registered aircraft between the period 1 January 1989 and 30 June 2009. This includes a broad analysis of the types of errors identified.
- *Chapter 5* uses the Australian Transport Safety Bureau's (ATSB) investigation analysis model to identify the safety factors that contributed to the international occurrences detailed in Chapter 4.
- *Chapter 6* explores ways to minimise some of the common safety factors identified in Chapter 5.

1.3 Methodology

1.3.1 Data sources

Australian occurrences

The ATSB's aviation safety database was searched to identify accidents and incidents relating to take-off performance parameter errors between the period 1 January 1989 and 30 June 2009. The scope was further limited to high capacity air transport operations, which, for the purposes of this report, was defined as operations conducted in an aircraft that is certified as having a maximum capacity exceeding 38 seats or a maximum payload exceeding 4,200 kg.

Accidents and incidents recorded in the ATSB's safety database are categorised based on what happened (occurrence type taxonomy), and if known, why it happened (safety factor type taxonomy). These taxonomies ensure that occurrences reported to the ATSB are classified in a consistent manner, which in turn allows for meaningful analysis and the identification of safety trends.

Generally, like occurrences are categorised the same in terms of what happened, for example, birdstrikes and wheels up landings. However, there are cases where the what or even the why are not alike, despite the fact that the underlying nature of the event is similar. For example, an aircraft may sustain an engine failure (what happened) during flight; however, the reasons why it happened may vary: the pilot incorrectly calculated the required fuel for flight, resulting in fuel exhaustion; engine parts were incorrectly fitted during a maintenance inspection; or an engine component failed due to deformation. Overall, the 'what' happened is the same, however, the 'why' it happened is dissimilar. Conversely, the incorrect calculation of V speeds (why it happened) may result in the aircraft sustaining a tailstrike or the aircraft appearing 'heavy' during the takeoff. In this instance, the 'why' it happened is the same, however, the 'what' happened is different.

The above examples illustrate the complexity of accidents and incidents, and some of the challenges faced when categorising occurrences. Consequently, in order to obtain the most comprehensive dataset of Australian occurrences, a combination of the following parameters was used to interrogate the ATSB's safety database:

- A list of likely occurrence types that described what happened, including: aircraft control, aircraft loading, incorrect configuration, navigation/flight planning, rejected takeoff, stick shaker, tailstrike, and weight and balance.
- A list of likely safety factor types that described why it happened, including: assessing and planning, monitoring and checking, pre-flight inspecting, and using equipment.
- Occurrence descriptions that cited terms such as 'assume, data, FLEX, flight management, FMC, FMS, incorrect, MCDU, miscalculated, performance, tailstrike, TO/GA, transpose, V₁, V_R, V₂, weight, wrong, zero fuel, and ZFW. Variants of these terms were also used.

International occurrences

In order to provide an inclusive list of international accidents and incidents relating to erroneous take-off performance parameters involving commercial jet aircraft between the period 1 January 1989 and 30 June 2009, the following sources were utilised:

- International Civil Aviation Organization (ICAO) provided data from the European Coordination Centre for Accident and Incident Reporting Systems (ECCAIRS) database, which stores occurrence data provided through the Accident/incident Data Reporting (ADREP) System. Data was extracted based on a pre-determined list of event types (what happened), descriptive factors (how it happened), and explanatory factors (why it happened).
- The Ascend World Aircraft Accident Summary (WAAS), researched and published on behalf of the United Kingdom Civil Aviation Authority (CAA), which provides descriptions of accidents involving jet and turbine powered aircraft.
- Accident and incident reports published by international aviation investigation agencies.
- The Laboratory of Applied Anthropology's paper titled 'Use of erroneous parameters at takeoff'.
- Transportation Safety Board (TSB) of Canada's report A06A0096.

1.3.2 Error analysis

In order to provide a broad understanding of the characteristics associated with accidents and incidents relating to take-off performance parameter errors, both the Australian and international datasets were categorised, and subsequently analysed (in sections 3.2 and 4.2), based on:

- performance parameter
- error action
- device.

Performance parameter

The 'performance parameter' refers to the take-off performance parameter that was either, erroneously used to calculate other performance parameters; erroneously entered into an aircraft system; or not updated or checked after a change in flight conditions. The parameters included various weight parameters, take-off reference speeds (V speeds), and runway details.

Error action

The action or inaction that led to erroneous take-off performance parameters. These were specifically coded as:

- *entered incorrectly*: the take-off performance parameter was incorrectly transposed or transcribed into an aircraft system, for example, weight of 242,000 kg was entered instead of 342,000 kg;

- *not updated*: the take-off performance parameters were calculated, but the appropriate aircraft device was not updated;
- *incorrect manual*: the correct performance manual was not available or the incorrect manual was referenced;
- *wrong figure used*: the correct take-off performance parameter was not used during the data entry or calculation phase, for example, the zero fuel weight (ZFW) was used instead of the take-off weight (TOW);
- *not checked*: the take-off performance parameters were not re-calculated or checked after a change in flight conditions;
- *data excluded*: information used to calculate take-off performance parameters were excluded during the calculation stage.

Device

The device refers to the aircraft system that was being used, or should have been used to obtain, calculate or enter take-off performance parameters. Devices included aircraft documentation and charts, take-off data cards, laptop and handheld performance computers, and aircraft systems such as the aircraft communications addressing and reporting system (ACARS) and the multifunction control and display unit (MCDU).

1.3.3 Contributing safety factor analysis

The purpose of a safety investigation is ultimately to enhance safety and identify ways in which similar accidents or incidents can be prevented from occurring in the future. To achieve this, the ATSB has developed a comprehensive investigation analysis framework that seeks to determine what happened, how it happened, and why it happened. This framework consists of a number of processes, one of which is safety factor analysis. Chapter 5 examines the safety factors contributing to the 20 international occurrences to provide some context as to how these events occurred. Due to the limited amount of information available for the Australian occurrences, a safety factor analysis could not be conducted.

A safety factor is defined as (Walker & Bills, 2008, p. 13):

... an event² or condition³ that increases safety risk. In other words, it is something that, if it occurred in the future, would increase the likelihood of an occurrence, and/or the severity of the adverse consequences associated with an occurrence.

Walker and Bills (2008) further define a *contributing* safety factor as (p. 15):

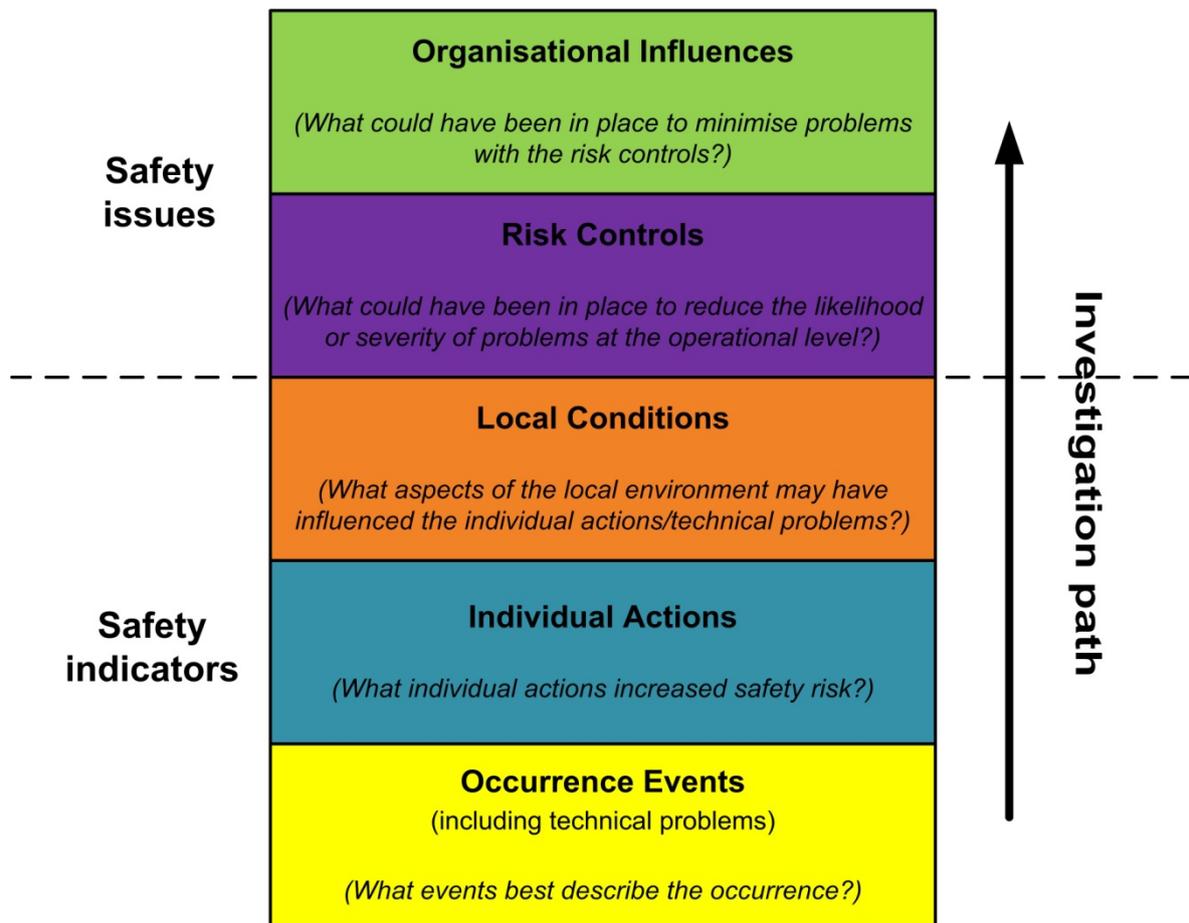
... a safety factor that, if it had not occurred or existed at the relevant time, then either the occurrence would probably not have occurred, adverse consequences associated with the occurrence would probably not have occurred or have been as serious, or another contributing safety factor would probably not have occurred or existed.

² Event: something that happens at a specific point in time.

³ Condition: something that exists for a period of time.

The components of the ATSB’s investigation analysis model (based on Reason’s (1990) chain-of-events accident causation concept), presented as a series of potential safety factors are shown in Figure 1.⁴ The most useful way to identify potential safety factors is to start at the bottom of the analysis model with the occurrence event and work upwards, asking a series of strategic questions. A definition for each of the components in the analysis model is provided in Chapter 5. A complete list of the ATSB safety factor taxonomy is provided in Appendix A.

Figure 1: ATSB investigation analysis model



Source: Walker & Bills, 2008

1.3.4 Limitations

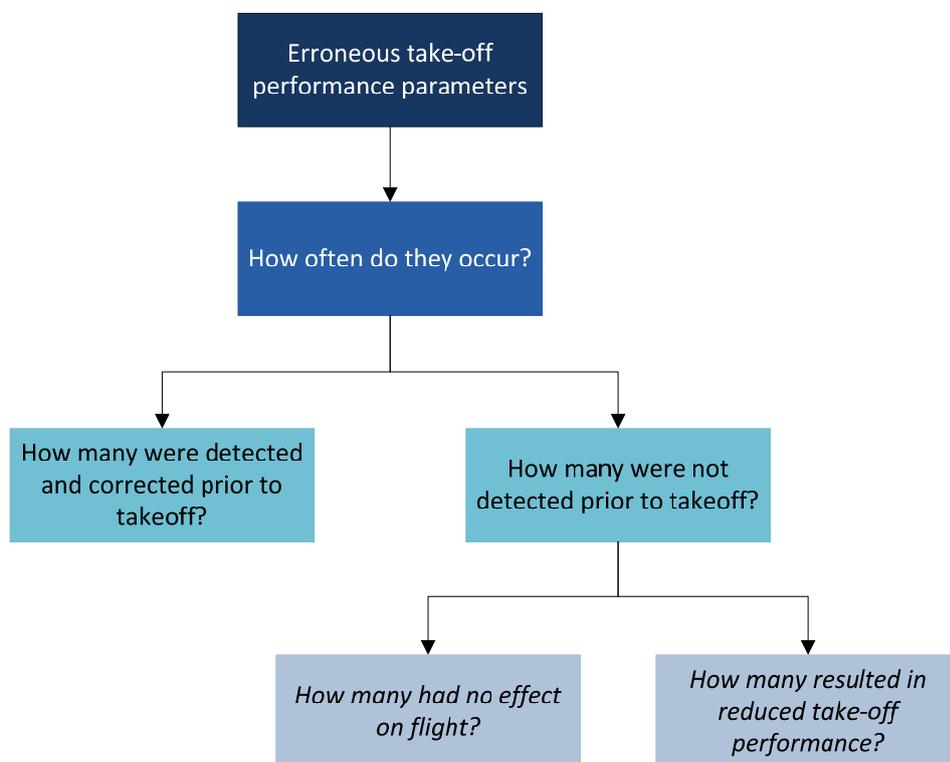
In order to gain an insight into the prevalence of accidents and incidents involving take-off performance parameter errors, it would be ideal to look at the ‘big picture’. One way to do this would involve answering the questions stated in Figure 2.

⁴ Safety issues deal with organisational or systemic-related safety factors, while safety indicators relate to individual or local safety factors.

It can be assumed that errors involving take-off performance parameters occur frequently, however, there are sufficient defences in place, such as checklists, standard operating procedures, automated defences, and the pilot's ability to identify anomalies with the information presented, that provide opportunities for error detection and correction prior to an aircraft taking off. Basically, the protections put in place by manufacturers, airlines and the crew usually work and safety is not compromised. In such instances, agencies such as the ATSB would not be notified, nor would they be required to be notified of such an event. Consequently, the true extent of these events cannot be identified through the analysis of an occurrence database.

The analysis conducted herein does not demonstrate the frequency of these events, but rather, provides an overview of the 'what' and 'why' these events continue to occur.

Figure 2: The 'big picture'



2

TAKE-OFF PERFORMANCE PARAMETERS

From the time the crew arrive at the airport and subsequently enter the cockpit, they are responsible for completing a number of tasks, often concurrently, that may be susceptible to threats and errors. These include, receiving and reviewing flight plans; obtaining weather information; the loading of passengers, cargo and fuel; receiving/preparing load and trim sheets; maintenance requirements; air traffic control clearances; entering data into aircraft systems; completing checklists; and conducting briefings.

Cabin crew, gate agents, dispatchers, ground and ramp personnel, refuelers and maintainers are all working towards the same goal of getting the aircraft off the ground. Their collaboration, both among themselves and with the flight crew requires a high degree of communication. While the exchange of information is essential so that the crew are aware of all progress and/or problems with pre-flight preparations, they are often unpredictable, demand immediate attention, and interrupt and distract the crews' responsibilities (Loukopoulos, Dismukes & Barshi, 2001).

A threat and error management analysis of 4,800 flights by The University of Texas determined that one-third of threats⁵ were related to airline activities. These included ground, ramp, dispatch and cabin related actions; and operational pressures. Of these, 75 per cent occurred during the pre-departure phase of flight; 26 per cent of crew errors⁶ also occurred during this phase⁷ (Helmreich, 2005).

One of the most crucial elements in the pre-flight preparation phase is the calculation and use of take-off performance parameters. This chapter provides an overview of take-off performance parameters, lists the typical errors that have occurred, and details what affect erroneous take-off performance parameters can have on flight.

2.1 The parameters

2.1.1 Take-off reference speeds (V speeds)

Take-off reference speeds, commonly referred to as V speeds, assist pilots in determining when a rejected takeoff can be initiated and when the aircraft can rotate, lift-off and climb away safely given the existing flight conditions. They are defined as follows:

- **V₁: Decision speed** - the maximum speed at which a rejected takeoff can be initiated by the pilot, and the minimum speed at which the takeoff can be continued in the event of an engine failure. If an engine failure does occur after V₁, the takeoff should be continued (Airbus, 2004).

⁵ Threats: events or errors that occur outside the influence of the flight crew, but require attention and management to maintain safety margins (Helmreich, 2005).

⁶ Errors: actions or inactions that result in a deviation from flight crew or operational intentions or expectations (Helmreich, 2005).

⁷ This also included the taxi phase of flight.

- **V_R**: *Rotation speed* - the speed at which the aircraft rotation is initiated by the pilot. This speed ensures that, in the event of an engine failure, lift-off is achievable and the take-off safety speed (V₂) is reached at 35 ft above ground level at the latest (Airbus, 2004).
- **V₂**: *Take-off safety speed* - the minimum speed that needs to be maintained up to the acceleration altitude, in the event of an engine failure after V₁. Flight at V₂ ensures that the minimum climb gradient required is achieved, and that the aircraft is controllable (Airbus, 2004).

2.1.2 Aircraft weights

An aircraft's take-off weight (TOW) and zero fuel weight (ZFW) are crucial values used to determine the V speeds required for takeoff. They are defined as:

- **TOW**: the total weight of the aircraft at the time of takeoff.
- **ZFW**: the total weight of the aircraft excluding the useable fuel. This includes the weight of the aircraft, the pilots, cabin crew, passengers, baggage, cargo, food and water.

2.1.3 FLEX or assumed temperature

Many aircraft are capable of exceeding the minimum performance standards required for operating at certain airports and under the existing environmental conditions. In such cases, conducting every takeoff at maximum engine thrust would place undue stress on the engines and decrease engine life. Consequently, reduced thrust takeoffs are commonly used (Australian Transport Safety Bureau, 2009).

As ambient air temperature increases, the thrust produced by an engine will decrease. By using a temperature higher than the actual ambient temperature, a lower thrust setting for takeoff will result. To do this, an 'assumed' or 'FLEX' temperature is used to calculate the thrust setting. (Australian Transport Safety Bureau, 2009).

2.1.4 The process

Different airlines use, and different aircraft types require, different methods for calculating and entering take-off performance parameters. These may be performed manually or be automated; they may be performed by the crew using performance manuals, the flight management system (FMS), the flight management computer (FMC) or a laptop computer; or remotely by use of the aircraft communications addressing and reporting system (ACARS). The following examples demonstrate the varying methods and processes used to calculate and verify take-off performance parameters.

Performance manuals

The process used by one airline for determining V speeds from performance manuals is as follows. On receipt of the loadsheet, the captain reads out certain information such as the ZFW, TOW and stabiliser trim setting for the first officer to transcribe onto the take-off data card. The first officer writes the TOW in the TOW

box and the ZFW on the bottom of the card. The first officer then references the fuel quantity indicator and writes the take-off fuel weight under the ZFW. Any adjustments to the TOW are made and entered onto the card. The first officer then refers to the airport analysis chart, and using the TOW, determines the V speeds and engine thrust settings. These figures are written on the take-off data card.

The before-start procedure requires the first officer to compute the take-off data and to prepare the take-off data card, and for the captain to check the card and enter the V speeds into the FMC.

The V speeds are entered into the FMC and then displayed on both crew members' primary flight display (PFD). The before take-off procedure then requires the crew to check the engine thrust setting and the crew alert system display, and to check that the correct V speeds are set and appear on the PFD (Transport Accident Investigation Commission, 2003).

Flight management system

The following process, described in the Laboratory of Applied Anthropology's 2008 report, demonstrates how V speeds may be calculated using the FMS. During the FMS initialisation phase, the pilot flying inputs values such as the expected ZFW and selects the take-off thrust setting required, while the pilot not flying verifies the data. The V speeds are then displayed by the FMS. When the refuelling status of the aircraft permits, the crew checks the gross weight⁸ of the aircraft and the V speeds. When the crew receives the final loadsheet, both crew members verify the data. The first officer transfers the TOW onto the take-off data card and compares it with the value on the card. The first officer enters the ZFW into the FMS and compares the gross weight with the loadsheet. The captain reads out the take-off performance parameters and the first officer either confirms, or modifies the V speeds. While completing the 'before start' checklist, the FMS computed data is announced, and during the pre-takeoff briefing, the pilot flying gives a reminder of the take-off parameters (Laboratory of Applied Anthropology, 2008).

Laptop computer

Using a laptop computer to calculate the take-off performance figures involves more steps than the previous processes. The following example is based around the use of one performance program on a laptop computer and is not indicative of the process for all laptop computer calculations.

In preparation for the flight, the first officer listens to the automatic terminal information service (ATIS) and transcribes the information onto the take-off data card. The planned TOW (from the flight plan) and V_{mcg} speed (minimum control speed on the ground, obtained from the quick reference handbook) are also entered onto the card by the first officer.

The first officer then opens up the performance calculation program on the laptop computer. As the program defaults to the information used for the previous takeoff,

⁸ The gross weight is the weight of the aircraft at a given point in time. For this aircraft, the TOW was not indicated on the FMS, only the gross weight appeared. When the crew were required to verify the consistency of the gross weight value, the FMS made a calculation so that an approximate comparison could be made with the TOW (Laboratory of Applied Anthropology, 2008).

the first officer is required to select/over-write with the data pertaining to the current flight. This may include, engine thrust rating, departure airport, runway, runway conditions, and optimum flap setting. If a planned weight is not entered, the maximum TOW will be calculated by the program. If the calculated maximum TOW is less than the planned TOW, a change to the engine thrust rating is needed. The first officer will then verify the ATIS information and data entered into the performance program and selects the 'calculate' button. The maximum allowable TOW for the runway in use will be calculated. If the planned TOW is less than this value, the planned TOW is then entered into the program and the 'calculate' button re-selected.

The program then displays the maximum take-off thrust setting and V speeds. The first officer will transcribe the values onto the take-off data card and delete the actual TOW from the program. In this example, if the loadmaster has entered the load information into the program, the stabiliser trim setting will also appear. The first officer then hands the take-off data card to the captain who cross-checks the ATIS and runway conditions entered and the calculated maximum TOW. The captain then enters the actual TOW into the program and selects 'calculate'. The resultant V speeds are then cross-checked with those entered onto the take-off data card by the first officer.

Before commencing the cockpit flow checks, either the captain or first officer conducts a gross error check of the V_R and V_2 speeds with reference to the high altitude cruise data card. The air speed indicator bugs are then set with the V_1 , V_R and V_2 speeds.

The captain signs the loadsheet, and mass and balance sheet, verifies that the TOW and load distribution are within limits, and transcribes the stabiliser trim setting onto the take-off card. The air speed indicator bugs and engine thrust settings are checked against the values on the take-off data card (Transportation Safety Board of Canada, 2006).

Aircraft communications addressing and reporting system

The crew calculate an estimated TOW based on the final ZFW. The estimated TOW is entered into the ACARS via the multifunction control and display unit (MCDU) interface. A take-off data calculation (TODC) request is then sent via the ACARS datalink to a land-based mainframe computer. The mainframe computer calculates the take-off performance parameters and transmits the results back to the crew via the ACARS. At this stage, no data is entered into the flight management and guidance system (FMGS). When the crew receive the final loadsheet, the actual TOW is verified against the estimated TOW used for the TODC request. If the difference between the two weights is within the prescribed limits, the results of the TODC request are entered into the FMGS. In terms of verifying the aircraft data and calculations, the loadsheet procedures are led by the captain and checked by the first officer, while the TODC procedures are led by the first officer and checked by the captain (Air Accidents Investigation Branch, 2010).

2.2 Typical errors

Calculating and entering take-off performance parameters into aircraft systems involves a number of steps that create potential opportunities for errors. The following list provides examples of the types of errors that have been identified from investigations into related accidents and incidents:

- the ZFW is inadvertently used instead of the TOW
- an aircraft weight is incorrectly transcribed or transposed into an aircraft system or when referencing performance manuals; for example, a weight of 234,000 kg or 224,000 kg is used instead of 324,000 kg
- V speeds are incorrectly transcribed or transposed when manually entered into an aircraft system
- aircraft data from a previous flight is used to calculate the V speeds
- take-off performance parameters are not updated as a result of a change in flight conditions; for example, a change in the active runway or ambient temperature
- selecting the incorrect value from the loadsheet or take-off data card
- using the wrong performance charts for the aircraft type
- inadvertently selecting the wrong table or column/row in the performance charts
- using the incorrect value when referencing the performance charts
- failing to convert values into the required unit of measurement.

2.3 Typical consequences

In the event the above errors are not detected and corrected prior to takeoff, the following adverse consequences may occur:

- *Tailstrike*: when aircraft rotation is initiated at a speed below that required for the aircraft's weight, lift-off may not be achieved. In response, the pilot may increase the nose-up attitude of the aircraft, which may result in the tail contacting the runway.
- *Reduced take-off performance*: during the takeoff, the crew may observe that the aircraft's performance is not as expected; the aircraft may appear 'sluggish' or 'heavy'.
- *Degraded handling qualities*: after takeoff, there may be a reduced margin between the aircraft's actual speed and the stall speed until the aircraft accelerates up to the normal climb speed. If the V_2 speed is also erroneous, this may not occur until after the aircraft passes through the acceleration height (Boeing, 2000).
- *Rejected takeoff*: if the aircraft fails to accelerate or lift-off as expected, the crew may reject the takeoff.
- *Runway overrun*: if the aircraft fails to stop after a rejected takeoff or the aircraft fails to liftoff, the aircraft rollout may extend beyond the end of the runway resulting in an overrun.

- *TO/GA engine thrust*: if the aircraft fails to accelerate or lift-off as expected, the crew may select take-off/go-around (TO/GA) engine thrust (the maximum thrust that the engines will supply).
- *Increased runway length required*: early rotation increases drag and significantly increases the distance from rotation to liftoff (Boeing, 2000).
- *Overweight takeoff*: this may occur if an erroneous TOW is used to determine whether a runway is acceptable for the takeoff (Boeing, 2000).
- *Reduced obstacle clearance*: if the takeoff is commenced at low speed, the aircraft will not achieve the climb gradient required, and the clearance between any obstacles along the take-off path will be reduced.

Between the period 1 January 1989 and 30 June 2009, a total of 11 occurrences involving high capacity air transport aircraft that were reported to the Australian Transport Safety Bureau (ATSB) where take-off performance parameter errors were recorded. These occurrences involved either Australian-registered aircraft (within Australia or internationally) or foreign-registered aircraft in Australia. Of these, 10 occurrences were classified as incidents and one classified as an accident, which was still under investigation at the time of publishing. A summary of the identified occurrences is presented below.

As mentioned in section 1.4.4, the prevalence of erroneous take-off performance parameter events cannot be determined, as those that are detected and corrected prior to takeoff and those where no damage occurs, would not normally be reported. Consequently, these occurrences are likely to be only a sub-set of all these events. Furthermore, a safety factor analysis could not be conducted as only minimal information for each incident was available as these occurrences included only incidents that were not investigated and an accident still under investigation at the time of writing.

3.1 Summary of occurrences

Boeing 747: May 2002

Location: London, UK

During the take-off run, the aircraft's rotation was initiated at a low speed. The rate of rotation was reduced to allow the speed to increase for climb out. A reduction to the V_1 speed due to a wet runway resulted in an incorrect rotation speed (V_R) being entered into the aircraft's flight management computer (FMC).

Boeing 737: November 2002

Location: Townsville, Qld

When preparing the aircraft for departure, the crew were required to read the final loadsheet figures directly from the aircraft communications addressing and reporting system (ACARS) as the ACARS printer was unserviceable. Both crew members selected the ACARS message page on their respective control display unit (CDU) when the final loadsheet was received and the message was acknowledged on the first officer's CDU. The load figures were then read aloud from the captain's CDU and copied onto the take-off data card. When doing this, the flight number was misread and the load figures from the previous flight were used. The zero fuel weight (ZFW) entered into the FMC was about 2.8 tonnes less than the actual ZFW. The error was identified during the preparation of the take-off data card and the FMC was amended accordingly.

Boeing 737: March 2003

Location: Darwin, NT

The crew calculated the take-off performance parameters for a full length runway departure and entered the corresponding V speeds into the FMC. The takeoff was then amended for an intersection departure. The crew briefed on the new V speeds and set their respective airspeed indicator speed bugs. The FMC was not updated with the new V speeds. The crew noticed the error during the take-off run. This resulted in a higher V_R speed being used than that required for the reduced runway length.

Boeing 767: April 2007

Location: Melbourne, Vic.

On arrival at the aerodrome, the crew were advised by engineering personnel that an incorrect performance limit manual was found on board the aircraft. The manual was for a Boeing 767 aircraft with different engines. The crew determined that the take-off performance parameters for the previous two sectors were calculated using this manual. The aircraft model variant name was not written on the specific charts. The crew re-calculated the parameters using the correct performance limit manual and identified that only two V speed values varied, with a maximum difference of 8 kts.

Boeing 737: September 2007

Location: Alice Springs, NT

In preparation for takeoff, the crew calculated the take-off performance data based on a required navigation performance (RNP) departure. While taxiing, the crew were advised by air traffic control (ATC) that there would be a delay for the RNP departure due to an inbound aircraft that required priority. The crew received a revised clearance from ATC to conduct a visual departure. After takeoff, the crew realised that the takeoff data had not been checked or amended to take into account the revised departure clearance.

Airbus A320: November 2007

Location: Cairns, Qld

During the take-off run, the thrust setting applied was not as expected. The captain checked the multifunction control and display unit (MCDU) take-off page and noticed that an incorrect FLEX temperature had been entered. Take-off/go-around (TO/GA) thrust was applied. The takeoff and climb out proceeded normally.

The maximum flex temperature had been entered into the MCDU instead of the actual flex temperature. Both figures were positioned next to each other on the take-off data card.

Airbus A320: March 2008

Location: Launceston, Tas.

The crew incorrectly transposed the take-off safety speed (V_2) onto the take-off data card. During the take-off run, the crew noticed the error and continued the flight. Take-off/go-around thrust was applied and the correct V_2 speed was selected. The crew commented that they must prioritise standard operations, despite other distractions.

Boeing 747: September 2008

Location: Sydney, NSW

While preparing the aircraft for departure, the crew noticed that an error had been made when entering the mean aerodynamic chord (MAC) take-off weight (TOW) into the FMC cruise page. In order to amend the MAC TOW, the crew were required to enter a false ZFW into the FMC, which then allowed the correct MAC TOW to be entered. The correct MAC TOW was entered into the cruise page. At the same time, the first officer recalled hearing the captain state that the correct ZFW was entered into the left FMC. The first officer then entered the MAC TOW and the decision speed (V_1) into the FMC takeoff reference page.

Prior to pushback, the second officer noticed that the V_2 speed on the mode control panel (MCP) (168 kts) differed from the speed in the FMC (158 kts). The second officer investigated the discrepancy and discussed it with the other crew members.

The captain stated that he was using new bifocal glasses and when looking at the FMC he was unable to see the MCP clearly through the upper portion of the glasses. It was assumed that an error was made when entering the speed into the MCP and the speed on the MCP was changed to 158 kts.

During the takeoff, the aircraft appeared to feel 'lighter' than normal. The captain later observed a discrepancy with the fuel and time estimates on the FMC. The captain explored the situation and discovered that the ZFW entered in the FMC was incorrect; the ZFW was updated accordingly.

Simulations performed by the airline determined that the aircraft was rotated about 13 kts below the correct speed. The crew were only required to manually calculate V_1 , as V_R and V_2 were automatically generated by the FMC. Consequently, any change to the ZFW figure in the FMC resulted in a change to V_R and V_2 .

Airbus A320: October 2008

Location: Rockhampton, Qld

When the crew selected the take-off thrust, no information appeared on the flight mode annunciator (FMA). At about 80 kts, the captain (pilot flying) called 'no FMA' and the takeoff was rejected. At the same time, an alert appeared on the electronic centralised aircraft monitoring (ECAM) system. The crew determined that an incorrect FLEX temperature had been entered into the MCDU.

While taxiing the aircraft for departure, the temperature on the automatic terminal information service had changed to 26 degrees, which was higher than the FLEX temperature set (21 degrees). This situation would have resulted in the full authority digital engine control (FADEC) system being set at maximum continuous thrust,

while the thrust levers were set to FLEX for takeoff. The error was not detected by the crew when completing the checklist as there was only a requirement to compare the MCDU and upper ECAM display, not the take-off data card, where the temperature values were written.

Airbus A320: May 2008

Location: Sydney, NSW

In preparation for departure, the crew inadvertently used the take-off performance data for an Airbus A321 aircraft instead of an Airbus A320 aircraft; the data for both aircraft were similar. It was reported that the aircraft type was written in a small font on the front page of the reference document and title area on the take-off performance page.

Airbus A340: March 2009

Location: Melbourne, Vic.

The following summary is based on the preliminary results of the ATSB's ongoing investigation, released on 18 December 2009.

On 20 March 2009, the crew of an Airbus A340-541 aircraft arrived at the aircraft about 1 hour before the scheduled departure time.

About 30 minutes later, they received the final loadsheet via the ACARS, with a TOW of 362.9 tonnes. Shortly after, the first officer entered a TOW of 262.9 tonnes into the Airbus less paper cockpit (LPC) electronic flight bag system.

The first officer recorded the resultant figures on the flight plan and handed the LPC computer to the captain for cross-checking. The captain checked the take-off performance figures and entered the figures into the flight management and guidance system (FMGS) through the captain's MCDU. The captain's figures were then cross-checked with the figures recorded by the first officer.

During the takeoff, the captain called for the first officer to rotate. The first officer attempted to rotate the aircraft, but it did not respond. The captain called 'rotate' again and the first officer applied a greater nose-up command. The nose of the aircraft raised and the tail made contact with the runway. The aircraft did not begin to climb. The captain selected TO/GA thrust and the aircraft commenced a climb.

After establishing a positive climb gradient, the crew received a message on the ECAM system indicating a tailstrike. The crew notified ATC and advised that they would be returning to the departure airport. While reviewing the aircraft's performance documentation in preparation for landing, the crew noticed that a TOW 100 tonnes less than the actual TOW had been inadvertently entered into the LPC, resulting in low V speeds. (ATSB investigation AO-2009-012)

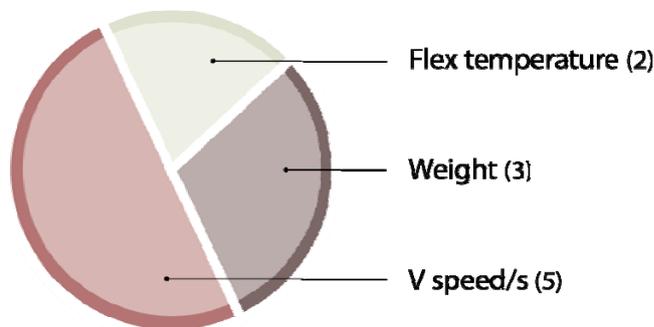
3.2 Australia in perspective

Due to the small number of occurrences identified in this study, minimal data analysis was conducted. Furthermore, the 10 incidents analysed were based on the pilots' reported account of the event without verification from other sources.

3.2.1 Performance parameter

The specific take-off performance parameter leading to the occurrences was identified in 10 of the 11 occurrences. Of these 10, half were related to errors involving V speeds (n = 5). This was followed by aircraft weights, accounting for three occurrences. Of this, two were related to the ZFW and one related to the aircraft's TOW. There were two occurrences where an erroneous FLEX temperature was used (Figure 3).

Figure 3: Take-off performance parameter

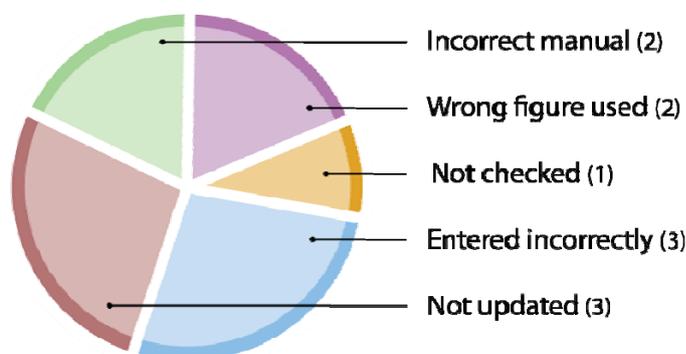


3.2.2 Error action

Figure 4 describes the nature of the action, or inaction that subsequently led to the erroneous take-off performance parameters.

Take-off performance parameters entered incorrectly or not updated, each accounted for three of the 11 occurrences identified. This was followed by those involving the use of an incorrect manual or the wrong figure, each accounting for two occurrences. The take-off performance data for one occurrence was not checked after a change in flight conditions.

Figure 4: Error action

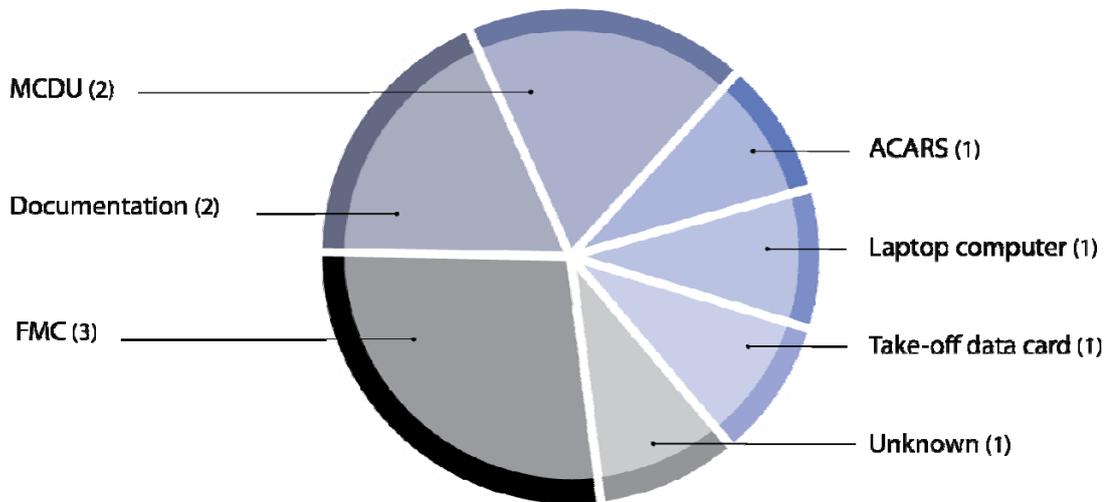


3.2.3 Device

The type of device or aircraft system that was used, or should have been used to calculate and/or enter the take-off performance parameters was identified in 10 of the 11 occurrences. There was insufficient information for one occurrence to determine the device.

The most prevalent device was the FMC, accounting for just over a quarter of the occurrences. This was followed by documentation (aircraft performance manuals) and the MCDU, each accounting for two occurrences. The use of the ACARS, laptop computer, and take-off data card all recorded one occurrence each (Figure 5).

Figure 5: Device

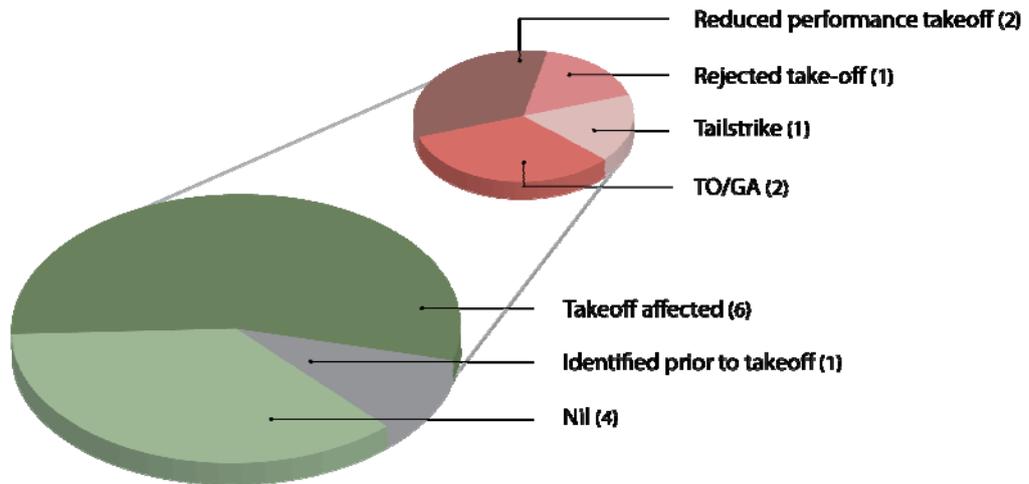


3.2.4 Consequence

Of the 11 occurrences identified, six had some consequence or effect on flight, ranging in severity from the crew noting that the aircraft felt different to that normally experienced, to the aircraft sustaining substantial damage from a tailstrike. In two cases, TO/GA thrust was applied by the crew and one occurrence resulted in a rejected takeoff being conducted. In one occurrence, the error was identified prior to the aircraft departing and the remaining four occurrences had no effect on flight (Figure 6).

No injuries were reported in any of the Australian occurrences reviewed in this report.

Figure 6: Consequence



3.2.5 Change in conditions

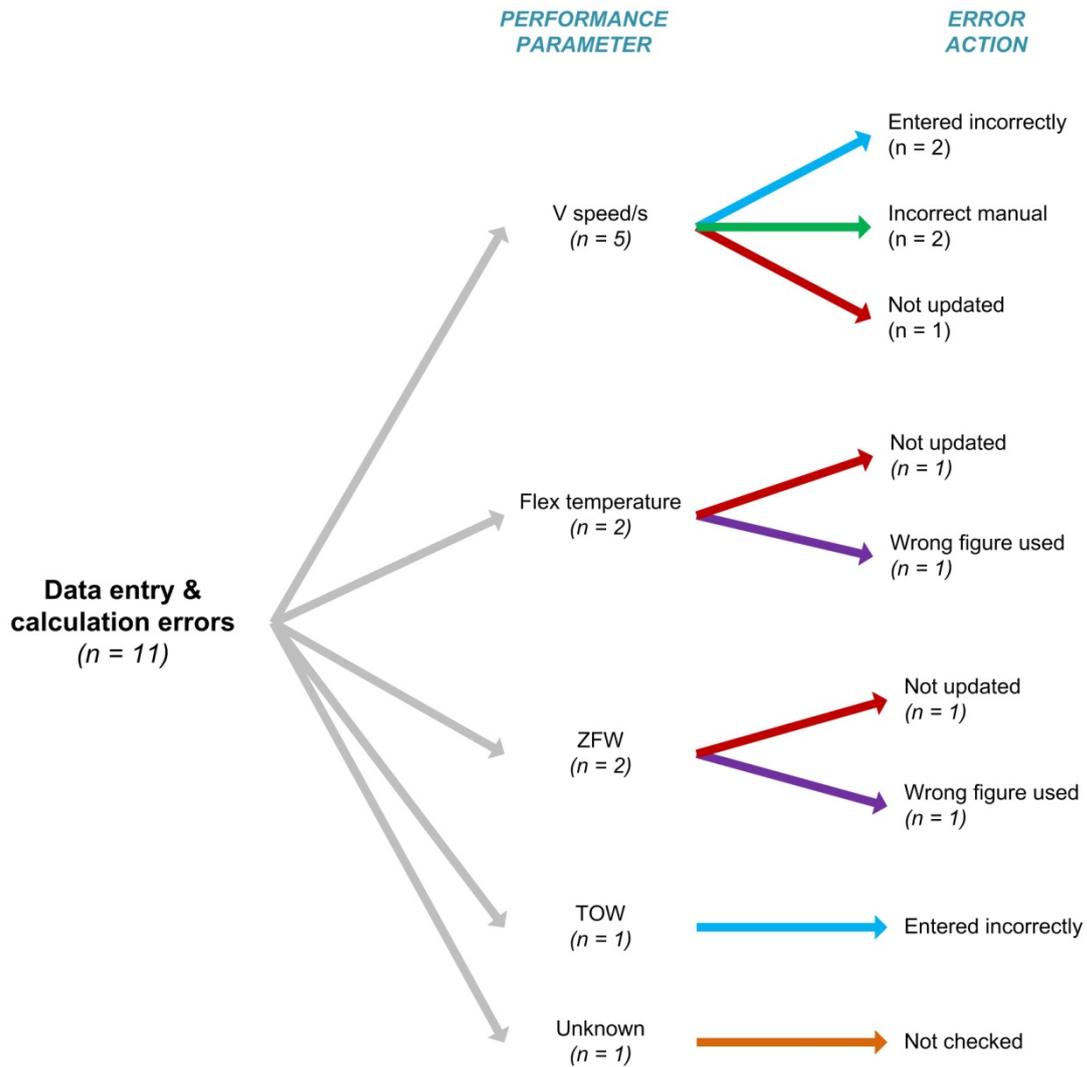
A change in operational or environmental conditions was recorded in six of the 11 occurrences. This change necessitated the crew to either check, amend and/or update the take-off performance parameters previously calculated. These included:

- the ambient temperature increasing above the FLEX temperature
- a change from an RNP departure to a visual departure
- a change from a full-length runway departure to an intersection departure
- MAC TOW re-calculation using a ZFW work-around
- an unserviceable ACARS printer requiring verbal transcription
- a change in V speed/s due to a wet runway.

3.2.6 Summary of Australian data

Figure 7 shows that while only a small number of occurrences were identified between the period 1 January 1989 and 30 June 2009, data entry and calculation errors involving take-off performance parameters are quite varied in nature. They can involve V speeds, aircraft weight's and flex temperatures; and data can be entered incorrectly, the wrong figure used, not checked or updated, or an incorrect manual is referenced. There is a multitude of relationships that can be potentially formed, and along with the various ways take-off performance parameters can be calculated or entered into aircraft systems, the task of minimising these events is ever more challenging.

Figure 7: Summary of Australia data, 1 January 1989 to 30 June 2009



4 INTERNATIONAL DATA

A total of 20 occurrences were identified between the period 1 January 1989 and 30 June 2009 where the calculation or entry of erroneous take-off performance parameters were cited as contributing to commercial jet aircraft accidents and incidents involving foreign registered aircraft outside Australian territory.

Below is a summary of each occurrence. Some information contained in the original report may not be presented here; for a detailed description of each event refer to the relevant investigation report.

4.1 Summary of occurrences

4.1.1 Boeing 727: August 1989

Location: New Orleans, US

Report: http://www.nts.gov/nts/brief.asp?ev_id=20001212X22410&key=1

History of the flight

On 25 August 1989, a Boeing Company 727-231 aircraft, registered N52309, was to be operated on a scheduled passenger service from New Orleans to New York, US with seven crew and 142 passengers on board.

In preparation for departure, the flight engineer completed his portion of the take-off data sheet and handed it to the captain. The captain anticipated a departure from runway 10 (9,228 ft in length) and calculated the take-off performance parameters accordingly. The crew received a taxi clearance from air traffic control (ATC), with runway 19 (7,000 ft in length) the assigned runway for takeoff. The use of runway 19 was also mentioned in the automatic terminal information service (ATIS).

During the takeoff, the aircraft became airborne from the safety area of the departure end of runway 19. The aircraft's left main landing gear struck a lighting control box.

Contributing factors

The following factors were identified throughout the subsequent investigation:

- The crew calculated the take-off performance parameters based on runway 10 instead of runway 19, resulting in the aircraft being about 6,800 lbs (3,085 kg) over the runway limit weight and an incorrect flap setting being applied.
- The airline's procedures did not assign the take-off performance data calculations to a specific crew member.
- The airline's procedures did not provide for a cross-check of the take-off data calculations by another crew member.
- There was no provision in the airline's procedures for verifying that the departure runway is one for which the take-off data calculations were based on.

4.1.2 Boeing 757: January 1990

Location: New York, US

Report: http://www.nts.gov/ntsb/brief.asp?ev_id=20001212X22410&key=1

History of the flight

On 16 January 1990, the crew of a Boeing Company 757-222 aircraft, registered N505UA, were preparing the aircraft for a scheduled passenger service from New York to Denver, US. Onboard the aircraft were two crew, five cabin crew and 169 passengers. During the flight preparation stage, the first officer inadvertently calculated the take-off performance data based on Boeing 767 data. The speeds were not verified by the captain. Both pilots set their respective airspeed bugs with the incorrect V speeds. During the takeoff, the aircraft was over-rotated, resulting in a tailstrike. The flight was continued to the destination.

Contributing factors

The following factors were identified throughout the subsequent investigation:

- The first officer's improper use of the aircraft's flight manual, which resulted in the incorrect calculation of the V speeds.

<i>Take-off performance data</i>		
Data	Required	Used
V ₁	145 kts	115 kts
V _R	148 kts	118 kts
V ₂	152 kts	129 kts

- Inadequate supervision by the captain regarding the verification of the take-off data.

4.1.3 Douglas DC-8: March 1991

Location: New York, US

Report: http://www.nts.gov/ntsb/brief.asp?ev_id=20001212X16675&key=1

History of the flight

On 12 March 1991, a Douglas DC-8 aircraft, registered N730PL, was being operated on a non-scheduled cargo flight from New York, US to Brussels, Belgium.

In preparation for takeoff, the flight engineer calculated the V speeds and horizontal stabiliser trim setting. The captain and first officer did not confirm the data. During the takeoff, the captain (the pilot flying) noticed that the force required to rotate the aircraft was greater than normal and that at the V speeds calculated, the aircraft would not fly. In response, the captain rejected the takeoff. The crew were unable to stop the aircraft within the remaining runway length. The aircraft struck the instrument landing system equipment, the landing gear collapsed and all four engines were torn away. The aircraft was destroyed in the ensuing fire.

Contributing factors

The following factors were identified throughout the subsequent investigation:

- The flight engineer calculated the take-off performance data based on a take-off weight (TOW) of 242,000 lbs (109,771 kg) instead of 342,000 lbs (155,131 kg).
- Shortcomings were identified in the airlines crew training program, and questionable scheduling of qualified, but marginally experienced crew for the accident flight.

Figure 8: N730PL accident



Source: Photograph provided courtesy of Joe Pries (<http://joepriesaviation.net>)

4.1.4 Boeing 767: August 1999

Location: Copenhagen, Denmark

Report: <http://www.skybrary.aero/bookshelf/books/1284.pdf>

History of the flight:

On 24 August 1999, a Boeing 767-383 aircraft, registered OY-KDN, was scheduled to operate a passenger flight from Copenhagen, Denmark to Tokyo, Japan. Onboard the aircraft were 181 passengers and 10 crew members, including the captain, first officer and relief pilot. The relief pilot was not assigned any duties for the takeoff or landing phases of flight.

Prior to engine start, the first officer entered the runway in use, temperature, and other flight details into the aircraft communication and reporting system (ACARS). The TOW was not entered as the crew had not yet received the loadsheet. The loadsheet was subsequently delivered and the captain entered the zero fuel weight

(ZFW) into the flight management system (FMS) using the multifunction control and display unit (MCDU).

The first officer noted the ZFW, TOW, planned landing weight, fuel figures and passengers numbers. The first officer then entered the ZFW into the aircraft TOW prompt in ACARS. This data was then sent to the mainframe computer where the take-off performance calculations were made and transmitted back to the crew and printed out.

The relief pilot noticed that the mean aerodynamic chord (MAC) was 7.0 %, which did not appear to be correct. According to the loadsheet the MAC was 19.0%; the first officer amended the ACARS accordingly. The crew checked the new print out and determined it was correct. The captain entered the V speeds into the FMS.

During the takeoff, the tail skid pad came into contact with the runway. The aircraft failed to become airborne and the captain rejected the takeoff.

Contributing factors

The following factors were identified throughout the subsequent investigation:

- The first officer entered the ZFW into the ACARS instead of the TOW, resulting in low V speeds.

<i>Take-off performance data</i>		
Data	Required	Used
TOW	186,800 kg	123,500 kg
V ₁	166 kts	133 kts
V _R	166 kts	133 kts
V ₂	172 kts	139 kts

- The first officer had a limited amount of experience on the Boeing 767.
- The first officer had previously flown a McDonnell Douglas MD-80 aircraft, where the ZFW was the take-off input parameter.
- The crew checked the take-off performance data on the second print; however, their attention was focused on the MAC value and not the incorrect TOW and V speeds.
- The layout of the ACARS print out could have resulted in a misinterpretation of the TOW, with the crew possibly believing ‘they had found the value they were looking for’, but at the wrong location.
- The crew’s normal procedures may have been interrupted by the relief pilot observing the MAC value discrepancy, which in turn, may have stopped the crew from checking the remaining take-off data.
- The first officer could have been experiencing some stress due to the delayed departure.

4.1.5 Boeing 747: December 2001

Location: Anchorage, US

Report: http://www.nts.gov/nts/brief.asp?ev_id=20020114X00069&key=1

History of the flight

On 28 December 2001, the crew of a Boeing Company 747-128 aircraft, registered N3203Y, made a scheduled fuel stop at Anchorage, Alaska in preparation for the final leg of the flight to Travis Air Force Base, US.

During the stop, about 100,000 lbs (45,360 kg) of fuel was uploaded. The crew failed to take into account the additional fuel uploaded, and inadvertently used the performance cards from the previous landing for the takeoff. During the takeoff, the aircraft sustained a tailstrike resulting in substantial damage.

Contributing factors

The subsequent investigation determined that the probable cause of the accident was the crew's inadequate pre-flight planning and the fact they had not calculated the weight and balance for the takeoff.

4.1.6 Airbus A330: June 2002

Location: Frankfurt, Germany

Report: <http://www.tsb.gc.ca/eng/rappports-reports/aviation/2002/a02f0069/a02f0069.pdf>

History of the flight

On 14 June 2002, an Airbus 330-343 aircraft, registered C-GHLM, was operating on a scheduled passenger service from Frankfurt, Germany to Montreal, Canada with 13 crew and 253 passengers on board.

While preparing the aircraft for the flight, the crew received the initial load figures from the ACARS and entered the TOW (222,700 kg) and V speeds into the MCDU. Shortly after, the crew received the final load figures with a revised TOW of 221,200 kg. During pushback or taxi, the pilot not flying inserted the final load figures and V speeds into the MCDU. When doing so, a V₁ speed of 126 kts was entered instead of 156 kts. The crew did not detect the error. During the takeoff, aircraft rotation was initiated at 133 kts. Due to over rotation the aircraft sustained a tailstrike.

Contributing factors

The following factors were identified throughout the subsequent investigation:

- An erroneous V₁ speed was entered into the MDCU. The error was not detected by the crew.
- The V speeds were re-inserted into the MCDU, although this was not required as the speeds initially provided by the ACARS were valid for any aircraft TOW between 219,100 and 223,600 kg.

4.1.7 **Boeing 747: March 2003**

Location: Johannesburg, South Africa

Report: <http://www.caa.co.za/resource%20center/accidents%20&%20incidents/reports/2003/0263.pdf>

History of the flight

On 11 March 2003, a Boeing Company 747-300 aircraft, registered ZS-SAJ, was scheduled to depart Johannesburg, South Africa on a scheduled passenger service to Sao Paulo, Brazil.

During flight preparations, the crew were distracted with the auxiliary power unit (APU), which failed to provide sufficient airflow into the cockpit and cabin area. They were also advised by ATC of an expected 45-minute delay. When given a start clearance from ATC, the delay was reduced to 30 minutes.

The flight engineer received the aircraft loadsheet and inadvertently entered the ZFW into the handheld performance computer instead of the TOW. The resultant V speeds were transferred onto the take-off data card. The captain checked the V speeds as the first officer, who normally did this, was busy. Both pilots set the speed bugs on their respective airspeed indicators. During the take-off run, the captain sensed that the aircraft was nose heavy. In response, the rotation was delayed by 15 kts. After becoming airborne, the captain felt that the aircraft was sluggish and he requested more thrust. At the same time, the flight engineer stated that the aircraft was sinking. The captain kept the aircraft's nose down to gain more speed and the aircraft climbed away. The crew were notified by ATC that the aircraft had sustained a tailstrike.

Contributing factors

The following factors were identified throughout the subsequent investigation:

- The flight engineer unintentionally entered the ZFW instead of the TOW into the handheld performance computer.
- The crew were distracted by problems associated with the APU, and the 45 minute delay by ATC suddenly reduced to 30 minutes.

4.1.8 **Boeing 747: March 2003**

Location: Auckland, New Zealand

Report: <http://www.taic.org.nz/>

History of the flight

On 12 March 2003, a Boeing Company 747-412 aircraft, registered 9V-SMT, was being prepared for a scheduled passenger service from Auckland, New Zealand to Singapore. Onboard the aircraft were the captain, two first officers, 17 cabin crew and 369 passengers.

About 1 hour prior to the scheduled departure, the crew commenced preparing for the flight. The aircraft had been refuelled with a predetermined amount of 100,000 kg; however, during flight planning, the crew determined that extra fuel was required. An additional 7,700 kg was needed, but only 4,500 kg was uploaded into the centre fuel tank by the refueler.

The crew boarded the aircraft and about 15 minutes prior to departing, they realised that the centre tank had not been refuelled with the required amount. They subsequently requested the additional fuel and a revised loadsheet. The final loadsheet was delivered to the crew at about the same time the aircraft was scheduled to depart. The loadsheet showed the ZFW as 230,940 kg and the TOW as 347,340 kg. The flight was delayed by about 13 minutes.

The captain referred to the loadsheet and called out certain information such as the ZFW, TOW and stabiliser trim setting for the first officer to write on the take-off data card. The first officer then referred to the aircraft's fuel quantity indication and wrote the take-off fuel weight under the ZFW on the card. When doing so, the first officer wrote 247,400 kg in the TOW box, 231,000 kg in the ZFW box and 116,000 kg of take-off fuel on the bottom of the card. The first officer normally added these figures together to verify the TOW. He also added 2,000 kg to the TOW for an atmospheric pressure correction adjustment. The adjusted TOW was 249,900 kg, which the first officer wrote on the card.

Figure 9: Take-off data card

FLAP	B747-400		RWY
20	SQ 286	DATE	23L
	APT NZAA	ELEV +23'	
ATC	TO / TO1 / D- 52 T/O EPR <u>1.34</u>		ATIS
	V ₁ <u>1 23</u>		
	V _R <u>1 30</u>		
	V ₂ <u>1 43</u>		
STAB TRIM 6.6	TOW 247.4	OAT 22 °C	
POB 389	QNH CORR 2.0	QNH 1009	
OM 27.12.99	ADJ TOW 249.4		
	ZFW 231.0 [fuel] 116		FORM SOPS 111A

Source: Transport Accident Investigation Commission, 2003

Using a TOW of 250,000 kg, rounded up, the first officer referenced the airport analysis chart and obtained the V speeds. In accordance with the aircraft

manufacturer's before-start operating procedures, the first officer computed the take-off data and prepared the take-off data card, and then passed the card onto the captain to verify the data. The captain did not verify the TOW and subsequently used the incorrect TOW to verify the V speeds.

The captain checked the onboard fuel value on the flight management computer (FMC) with the required fuel weight. As the weights were similar, he entered the ZFW from the loadsheet into the FMC. The FMC automatically added the ZFW with a computed onboard fuel weight to display a gross weight. The captain verified that the FMC calculated gross weight corresponded with the TOW from the loadsheet. The captain manually entered the V speeds calculated by the first officer into the FMC, replacing the V speeds values automatically calculated by the FMC.

The captain placed the take-off data card and airport analysis chart on the centre pedestal. Normally, the second first officer (third pilot) would cross check the card data and computations, however, he stowed the airport analysis chart without verifying the data. At this time, the third pilot was explaining the departure delay to the operation's station manager.

During the takeoff, the first officer called 'V₁' when the aircraft's speed reached 123 kts and called 'rotate' when it reached 130 kts. At 132 kts, the captain initiated the rotation for lift-off and the tail struck the runway, scraping for about 490 metres before becoming airborne.

Contributing factors

The following factors were identified throughout the subsequent investigation:

- The first officer incorrectly wrote a TOW of 247,400 kg on the take-off data card instead of 347,400 kg. He then referred to the airport analysis chart and used the incorrect TOW to determine the V speeds.

<i>Take-off performance data</i>		
Data	Required	Used
TOW	347,340 kg	247,400 kg
V ₁	151 kts	123 kts
V _R	163 kts	130 kts
V ₂	172 kts	143 kts

- The captain did not verify the correct TOW and used the incorrect weight to confirm the V speeds.
- The delay due to refuelling may have put pressure on the crew to hurry their preparations.
- The captain was experienced, but had only recently converted to the Boeing 747-400; the first officer was considered experienced on type, but relatively inexperienced overall.
- Prior to flying the Boeing 747-400, the captain had been flying the Airbus A340 aircraft, where a typical V_R speed was 138 kts.
- There were no specific duties assigned to the third pilot. The use of this pilot was at the captain's discretion.

- There was no policy to compare the take-off data card V speeds with those automatically computed by the FMC. However, it was common practice for the pilots to reconcile the figures between the two sources.
- The FMC did not challenge V speed discrepancies between what was automatically computed with what was manually entered.

4.1.9 Airbus A321: September 2003

Location: Oslo, Norway

Report: <http://www.trm.dk/graphics/Synkron-Library/hcl/dokumenter/Redegorelser/2003/70-03-KBK-foreloebig-UK.pdf>

History of the flight

On 4 September 2003, the crew of an Airbus A321-232, registered OY-KBK, were preparing the aircraft for a scheduled flight from Oslo, Norway to Copenhagen, Denmark. During the pre-flight preparations, the crew were unable to calculate the take-off performance data using the ACARS as the datalink was not operating.

The crew contacted the airline's duty flight operations officer at Oslo requesting assistance. The duty officer was unable to help the crew as the portable computer used to complete the task was not working. The captain then requested that the dispatch office in Copenhagen be contacted and make the necessary calculations. The captain relayed the aircraft's TOW (76,400 kg), runway in use and current weather conditions over the radio for the flight operations officer in Oslo to pass on to Copenhagen.

The flight operations officer noted down the values provided by the captain, but reportedly only passed on the runway in use, wind and QNH⁹ to Copenhagen as they already had access to the former information, with the exception of the runway in use. The flight operations officer then received a fax from Copenhagen with the completed calculations.

The person at Copenhagen who received this information stated that a TOW of 60,000 kg was also provided. He then reportedly telephoned Oslo to confirm the TOW as he believed it to be too low. The flight operations officer reportedly confirmed that 60,000 kg was correct. The take-off data calculations were made and then faxed to Oslo.

The flight operations officer contacted the crew via radio and relayed the values from the fax. Both crew members took notes while listening to the call. The captain then read back all the values and received confirmation that they were correct. The crew queried the low V_1 value, however, they were satisfied that it was correct as the value read back was confirmed. The first officer entered the V speeds and FLEX temperature into the aircraft's flight management guidance and envelope computer (FMGC).

During the takeoff, the first officer noticed that the aircraft's response was sluggish. Once airborne, the crew observed that the V_2 speed bug on the primary flight

⁹ QNH is the altimeter subscale barometric pressure setting to provide altimeter indication of altitude relative to mean sea level.

display was lower than normal. The aircraft's speed was accelerated to 250 kts and the climb out continued.

Contributing factors

The following factors were identified throughout the subsequent investigation:

- The take-off calculations were based on a TOW of 60,000 kg instead of 76,400 kg, resulting in low V speeds.

<i>Take-off performance data</i>		
Data	Required	Used
TOW	76,400 kg	60,000 kg
V ₁	151 kts	118 kts
V _R	156 kts	127 kts
V ₂	159 kts	131 kts

- There was no procedure for manually calculating take-off data when the datalink was not operational.
- The flight operations officer had received training in the use of the laptop and current take-off data computer program; however, these skills were rarely used. An investigation conducted by the airline determined the flight operations officer and other employees did not have sufficient knowledge and proficiency with respect to take-off calculations for the Airbus aircraft.
- The airline's investigation also determined that it was not clear as to what services were provided by the various support departments.
- The FMGC did not suggest default V speed values based on the TOW entered into the system.

4.1.10 Boeing 747: October 2003

Location: Tokyo, Japan

Report: http://www.mlit.go.jp/jtsb/eng-air_report/JA8191.pdf

History of the flight

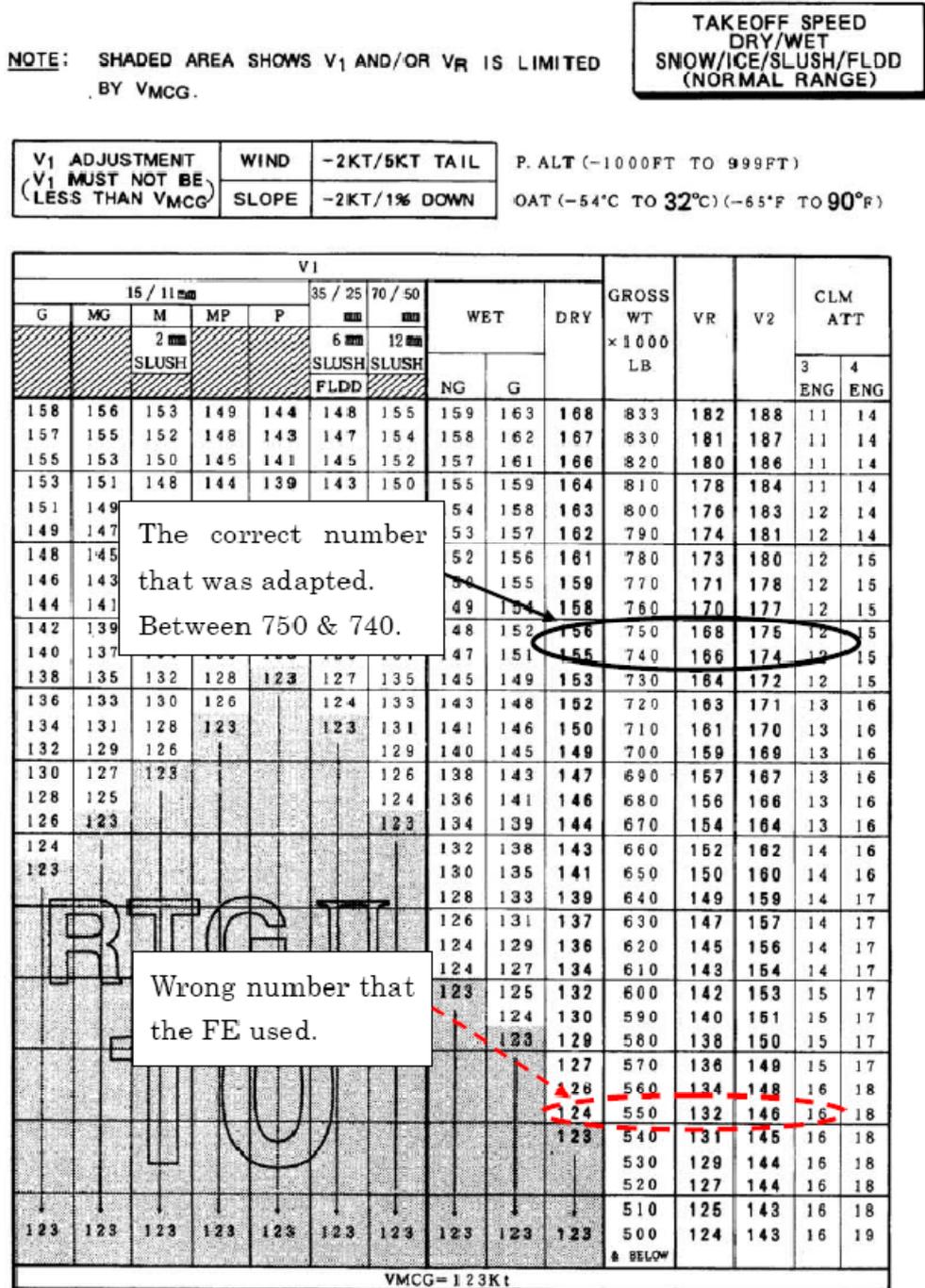
On 22 October 2003, a Boeing Company 747-200F aircraft, registered JA8191, was scheduled to operate a cargo flight from New Tokyo International Airport, Japan to Anchorage, US. Onboard the aircraft were the captain, a foreign pilot training for first officer, the flight engineer, and the first officer.

On arrival at the aircraft, the flight engineer noticed that loading of the aircraft was behind schedule. The load planner provided the weight and balance manifest to the crew and the flight engineer prepared the take-off data card. The flight engineer wrote down the ZFW (552,700 lbs – 250,705 kg) and the estimated landing weight (579,800 lbs – 262,997 kg) in the margin on the flight engineer record. The aircraft's TOW was 745,000 lbs (337,932 kg).

When obtaining the V speeds from the relevant take-off charts, the flight engineer used a TOW of 550,000 lbs (249,480 kg) (Figure 10). The flight engineer typically

verified the data by doing a reverse lookup, reading the TOW from the speeds, but as he didn't want to delay the flight any further, the check was not done.

Figure 10: Take-off performance chart



The flight engineer handed the take-off data card to the captain, and the airspeed bugs on the airspeed indicator were set.

During the taxi, the crew completed the taxi and take-off checklist, which involved setting and cross-checking the airspeed bugs against the take-off data card.

During the takeoff, the trainee pilot called ‘ V_R ’ and the captain applied aft pressure on the control column at the standard rotation rate. The captain felt that liftoff took longer than normal.

When passing 3,000 ft on climb, the stall warning stick shaker activated. The captain responded by reducing pitch and asking the flight engineer to re-check the take-off performance data. It was noted that the V_2 value used was about 28 kts less than what was required. The aircraft was returned to the airport, where the engineers found abrasions on the lower part of the aft fuselage, indicating a tailstrike occurred during the takeoff.

Contributing factors

The following factors were identified throughout the subsequent investigation:

- The flight engineer had determined the V speeds based on the ZFW of 249,480 kg instead of a TOW of 337,932 kg. The flight engineer had written the ZFW value on the flight engineer record and this value remained in his mind.

<i>Take-off performance data</i>		
Data	Required	Used
TOW	337,932 kg	249,480 kg
V_1	156 kts	124 kts
V_R	168 kts	132 kts
V_2	175 kts	146 kts

- The flight engineer did not verify the take-off data as the flight was running behind schedule.
- The captain, training pilot, and first officer did not doubt or cross-check the V speed values presented on the take-off data card.
- The trainee pilot stated that aircraft weight always used in simulator training was 530,000 lbs (240,408 kg).
- The trainee had previously used kilograms as a unit of measurement in his home country instead of pounds, and did not immediately detect the mistake in the numbers.
- From the operations manual it could be determined that the flight engineer was responsible for preparing the take-off data card, but there was mention of who was responsible for confirming the data.

Source: Aircraft and Railway Accidents Investigation Commission, 2004

4.1.11 Airbus A340: July 2004

Location: Paris, France

Report: <http://www.bea.aero/ita/pdf/ita.004.pdf>

History of the flight¹⁰

On 14 July 2004, an Airbus A340-300 aircraft, registered F-GLZR, was being prepared for a passenger service, departing from Charles de Gaulle Airport, France. In preparation for the flight, the crew received an expected TOW of 268,600 kg, which was close to the aircraft's maximum take-off weight (MTOW) of 271,000 kg. The TOW, rounded up to 270,000 kg, was used to submit a take-off data calculation request via the ACARS. The resultant take-off performance parameters were verified by the crew.

Shortly after, the crew were advised that the TOW was 5,200 kg less than that previously provided, resulting in a TOW of 264,800 kg. As the change in weight was greater than 5,000 kg, the crew were required to submit a new ACARS request. When entering the revised TOW into the ACARS via the FMGS interface, a weight of 165,000 kg was inadvertently entered. This weight was close to the ZFW of 164,480 kg. The resultant V speeds and FLEX temperature were then entered into the FMGS. The captain confirmed the parameters; however, he did not detect the error as he read the MTOW from the ACARS printout instead of the TOW.

During the takeoff, the pilot flying reported the aircraft feeling heavy and noticed that the V_2 speed was slower than the V_{LS} speed (the lowest selectable speed, which provides an appropriate margin above the stall speed); take-off/go-around thrust was not applied. The aircraft sustained a tailstrike, with the fuselage remaining in contact with the runway for a distance of about 100 metres.

Contributing factors

The following factors were identified throughout the subsequent investigation:

- A weight similar to the ZFW was inadvertently entered into the ACARS instead of the actual TOW, resulting in low V speeds.

<i>Take-off performance data</i>		
Data	Required	Used
TOW	265,000 kg	165,000 kg
V_1	143 kts	129 kts
V_R	153 kts	131 kts
V_2	161 kts	137 kts

- The FMGS would accept unrealistic low V speeds without challenge.
- The FMGS did not compare the V_2 and V_{LS} speeds, despite the fact that both values were known before takeoff.

¹⁰ The following information is based on a translation of the Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile's (BEA) investigation report. Some information may have been omitted or incorrectly interpreted through the translation process.

- The presentation of the parameter values on the ACARS printout may have led to some confusion in reading between the TOW and ZFW.
- The take-off briefing procedures did not require a comparison between the TOW and speed characteristics.

4.1.12 Boeing 747: October 2004

Location: Halifax, Canada

Report: <http://www.tsb.gc.ca/eng/rapports-reports/aviation/2004/a04h0004/a04h0004.pdf>

History of the flight

On 13 October 2004, a Boeing 747-244SF aircraft, registered 9G-MKJ, was planned to operate a multi-stage non-scheduled international cargo flight departing from Luxembourg. The flight plan was as follows:

Date	Departure	Destination
13 October	Luxembourg	Bradley International Airport, Connecticut, US
14 October	Bradley, US	Halifax International Airport, Nova Scotia, Canada
	Halifax, Canada	Zaragoza, Spain
	Zaragoza, Spain	Luxembourg

The crew complement for the flight consisted of two captains, one first officer, two flight engineers, a loadmaster and a ground engineer.

Prior to departing the hotel in Luxembourg, the crew were advised that the aircraft would be delayed due to its late arrival at Luxembourg and late preparation of the cargo. During loading, the loadmaster noted that some of the pallets were contaminated. The loadmaster and another company employee commenced cleaning the pallets, but so not to delay the flight any further, this was continued enroute.

The aircraft departed Luxembourg at 1556 and arrived at Bradley at 2322, where the cargo was offloaded. The loading of the cargo at Bradley was delayed due to an inoperable aircraft cargo loading system. The crew remained on the aircraft during the stopover. With a change in crew (captain and flight engineer), the aircraft departed Bradley on 14 October 2004 at 0403.

The aircraft arrived at Halifax and loading of the aircraft was commenced. During this time, two crew members were observed sleeping in the upper deck passenger seats.

The aircraft was refuelled with 72,062 kg uploaded, to provide a total of 89,400 kg of fuel on board. The ground engineer checked the aircraft fuelling panel and signed the fuel ticket. He then went to the main cargo deck to assist with loading.

Once the loading had been completed, the ramp supervisor retrieved the cargo and flight documentation from the upper deck. While the loadmaster was completing the documents, the ramp supervisor went to the cockpit and noticed that the first

officer was not in his seat. About 10 minutes later, the ramp supervisor left the aircraft with the completed documentation.

The aircraft was taxied to the runway and during the takeoff the aft fuselage momentarily contacted the runway. Several seconds later, the fuselage contacted the runway again with greater force. Contact with the runway continued to about 825 ft beyond the end of the runway, where the aircraft became airborne. The lower aft fuselage then struck an earth bank supporting the instrument landing system antenna and the tail separated from the aircraft. The rest of the aircraft continued forward until it struck terrain. The aircraft was destroyed by the impact forces and subsequent fire. All seven of the crew members received fatal injuries.

Contributing factors

The following factors were identified throughout the subsequent investigation:

- *Flight data recorder comparison*

The flight data recorder information for the take-off at Halifax was compared with the takeoff at Bradley to identify any similarities. This comparison identified that the rotation speed and flap setting for both flights were about the same, however, at Bradley the aircraft reached V_R 13 seconds before that recorded for the Halifax takeoff, indicating a higher rate of acceleration. Furthermore, the initial pitch rate for the Bradley takeoff was 1.2 degrees per second and the aircraft climbed away about 4 seconds later, with the pitch angle increasing to 6 degrees. For the Halifax takeoff, the initial pitch rate was 2.2 degrees per second, with the aircraft lifting off near 10 degrees. This eventually increased to 14.5 degrees.

The take-off data for Halifax was nearly identical to that for the takeoff at Bradley, indicating that the Bradley TOW (239,783) kg was used to generate the performance data for Halifax. The calculated TOW for Halifax was 353,800 kg.

- *Boeing laptop tool (BLT)*

In order to calculate the take-off performance data, landing performance data, and weight and balance information for a flight, the crew were required to use the Boeing Laptop Tool (BLT), which was located on the upper deck of the aircraft.

It was likely that the use of the wrong TOW came from the misuse or misunderstanding of how the BLT software functioned. When the BLT program was launched, the data for the previous flight would populate all of the fields, in this case, the data for Bradley. These fields would then need to be updated with the data for Halifax. If the user opened up the weight and balance page, and then returned to the take-off performance page, the TOW already in the system would automatically populate the planned weight on the take-off and performance page, which was 240,000 kg for Bradley. If the user was unaware of the software's reversion feature or did not notice the change, and they selected the 'calculate' button, the resulting V speeds and thrust settings for the takeoff at Halifax would have been based on the data for Bradley. If these figures were written on the take-off data card with the correct TOW of 353,300 kg, it is likely that the error would have gone unnoticed.

- *Other factors identified*
 - It was likely that an independent check of the take-off data card was not performed by the crew as required by the standard operating procedures (SOPs).
 - The crew did not conduct a gross error check in accordance with the SOPs.
 - The crew were at their lowest level of performance due to fatigue, which may have increased the probability of error when calculating the take-off performance parameters, and degraded their ability to detect the error.
 - Crew fatigue and the dark take-off environment contributed to a loss of situational awareness.
 - The airline did not provide formal training on the use of the BLT, nor did they have a testing program.

4.1.13 Airbus A340: August 2005

Location: Shanghai-Pudong, China
Report: http://multimedia.jp.dk/archive/00062/Klevan-rapporten_pd_62785a.pdf

History of the flight

On 24 August 2005, an Airbus A340-300 aircraft, registered LN-RKF, was being prepared for a scheduled passenger service from Shanghai-Pudong International Airport, with 12 crew and 244 passengers onboard. About 30 minutes prior to the scheduled departure, the crew received the preliminary load information via the ACARS that indicated a ZFW of 179,110 kg and a TOW of 259,514 kg. As the captain was temporarily away from the cockpit, the pre-flight preparations had been delegated to the second officer. When entering the data into the ACARS take-off data calculation (TODC) computer, the ZFW was used instead of the TOW. Soon after, the final loadsheet was received; the TODC was not updated.

When the captain arrived, the majority of the pre-flight preparations had been completed. The flight plan was completed by the first officer. The captain checked the loadsheet and flight plan, and then signed the plan.

The second officer read-out the TODC speeds to the captain, who then entered them into the MCDU. The captain observed that the difference between the V_1 and V_R speeds was small; however, no further action was taken. The captain believed that the last line of defence was incorporated into the ACARS TODC, similar to that previously experienced when he had flown the Boeing 767.

The captain and first officer verified the take-off data calculations prior to departing the gate and while taxiing, but the error was not detected.

During the takeoff, liftoff was not achieved as expected. Additional control inputs were made and the aircraft's fuselage contacted the runway. Take-off/go-around thrust was applied by the first officer at the same time the aircraft became airborne.

Contributing factors

The following factors were identified throughout the subsequent investigation:

- The ZFW was inadvertently entered into the ACARS TODC instead of the TOW, resulting in low V speeds. The error went undetected by the crew.

<i>Take-off performance data</i>		
Data	Required	Used
TOW	259,514 kg	179,110 kg
V ₁	143 kts	129 kts
V _R	155 kts	130 kts
V ₂	162 kts	139 kts

- The second officer did not have immediate access to the flight plan to confirm the aircraft's TOW.
- The ACARS TODC computer requires input of the TOW, while the MCDU requires input of the ZFW.
- The captain was temporarily pre-occupied.
- All crew members were previously qualified on the Boeing 767 aircraft, where the TOW was similar to the ZFW of an A340.
- The take-off data was calculated by a crew member who was not responsible for checking the data or entering it into the MDCU.
- The data was entered into the TODC computer using a third MCDU, which was not visible to the other two crew members.
- The captain and first officer were also qualified on the Airbus A330 aircraft where the V speeds and thrust settings are lower than that of the A340.
- The V speeds were verbally provided to the pilot flying. The printed calculations were not shown.
- The ACARS TODC software would accept unrealistic low weights and mismatched V speeds without challenge.
- The duties of the second officer were not clearly defined by the airline.

4.1.14 Embraer 190: July 2006

Location: Edmonton, Canada

Report: <http://www.tsb.gc.ca/eng/rapports-reports/aviation/2006/a06a0096/a06a0096.pdf>

History of the flight

On 12 July 2006, an Embraer 190-100 aircraft, registered C-FHIU, was being operated on a scheduled flight from Toronto to Edmonton, Canada and return. On arrival at Edmonton, the aircraft was powered down to clear a fault message. As the aircraft servicing was to be completed with only battery power, the captain (pilot not flying) left the cockpit to supervise refuelling and servicing of the lavatory

system. At the same time, the first officer (pilot flying) was completing the pre-flight walk around inspection.

The first officer returned to the cockpit and calculated the preliminary take-off performance data using the captain's laptop computer. The captain's computer was used as the first officer's laptop power cord was defective. When inputting the data, the first officer entered the weight of the fuel on board at the time (3,700 kg) instead of the planned fuel for departure (10,200 kg). The resulting TOW and V speeds were transcribed onto the flight plan.

The captain returned to the flight deck and assumed his responsibilities as pilot not flying and entered the preliminary take-off performance data into the FMS.

The crew received their clearance from ATC and completed the pre-flight fuel check, which involved comparing the fuel gauge indication with the flight plan. Shortly after, the crew were advised that water was overflowing from a coffee maker in the galley. The first officer communicated with the flight attendant to resolve the problem. At the same time, the captain was advised that the departure runway had changed. The captain recalculated the take-off performance data to reflect the runway change. The updated data was compared with the previous data. As the new data was similar to the previous data, the captain did not identify the incorrect fuel weight or TOW. The new thrust and V speeds were entered into the FMS.

During taxi, the crew received the final load data. These values were compared to the flight plan and accepted as the values were within the prescribed company tolerances.

During the takeoff, the crew noticed that the aircraft's pitch response was different from normal and the aircraft felt out of trim and slow to respond. Soon after, the crew reviewed the performance data on the laptop computer and noted the discrepancy.

Contributing factors

The following factors were identified throughout the subsequent investigation:

- An incorrect aircraft weight was used to calculate the take-off performance data. The error was not detected by the crew, resulting in the aircraft taking off with lower than required thrust and V speeds.

<i>Take-off performance data</i>		
Data	Required	Used
Fuel on board	10,200 kg	3,700 kg
TOW	47,600 kg	41,700 kg
V ₁	149 kts	137 kts
V _R	149 kts	137 kts
V ₂	151 kts	140 kts

- The requirement to power down the aircraft and the laptop computer power cord defect increased the crew's workload and interrupted their process for preparing the aircraft for departure. This resulted in the crew deviating from the airline's SOPs.

- The pilot flying calculated the take-off performance data. The SOPs required the pilot not flying to calculate the data and the pilot flying to verify the data before being transcribed onto the flight plan.
- The SOPs required the crew to transcribe the data onto the flight plan; however, there was no designated location on the plan for the figures. This made it difficult for the crew to compare the calculated take-off performance figures with the planned figures.

4.1.15 **Boeing 747: December 2006**

Location: Paris, France
Report: Transportation Safety Board of Canada - Aviation Safety Advisory A06A0096-D1-A1

History of the flight

On 10 December 2006, a Boeing 747-400 aircraft, registered F-HLOV, was being prepared for a scheduled passenger service from Paris-Orly airport, with 15 crew and 563 passengers onboard. On arrival at the aircraft, the crew found that the battery of one of the two BLT's used to calculate the take-off performance parameters was flat; consequently, the second BLT (operating on battery power) was used.

During the pre-flight preparations, the first officer noted a fault message relating to the hydraulic circuit. Discussions with the ground mechanic determined that the issue was being dealt with.

When determining the take-off performance parameters for the flight, the captain provided the first officer with the ZFW from the weight and balance sheet, which he increased by 1.6 tonnes, and the TOW. The first officer then entered the ZFW into the FMS. The TOW was entered into the BLT and the take-off performance parameters calculated. The first officer handed the BLT to the captain to cross-check the calculations. The BLT then went into standby and the captain handed it back to the first officer who unintentionally turned it off, thus erasing the entered data. At the same time, the captain was dealing with the hydraulic failure issue with the mechanic in the cockpit.

When the new data was being entered into the BLT, the captain inadvertently called out the ZFW instead of the TOW. A weight of 242,300 kg was entered into the BLT instead of 341,300 kg. The captain entered the resultant BLT data into the FMS, replacing the values automatically calculated by the FMS. The first officer then verified that the BLT and FMS values were identical.

The captain entered the assumed take-off temperature into the FMS and queried the reduced thrust value with the first officer. The first officer justified these figures by the fact that the QNH was high and the temperature was low.

The crew performed a rolling takeoff and did not detect that the aircraft's acceleration was lower than normal. At the V_1 speed, the crew noted that there was a reasonable amount of runway length still available and they began to doubt the V speeds. The captain (the pilot not flying) elected to delay the aircraft's rotation.

When the first officer began the rotation, he immediately noticed that aircraft appeared heavy. The aircraft's pitch was increased slowly, but the stick-shaker

activated. The first officer responded by reducing the aircraft's nose-up attitude and applying full take-off power. Ground personnel noticed smoke during the aircraft's rotation.

After the takeoff, the crew suspected a problem with the calculated V speeds and increased the retraction speeds for control surfaces by 20 kts.

Contributing factors

The following factors were identified throughout the subsequent investigation:

- The ZFW was inadvertently read aloud and subsequently entered into the BLT instead of the TOW, resulting in V speeds that were too low.

<i>Take-off performance data</i>		
Data	BLT calculation	FMS calculation
TOW	242,300 kg	341,300 kg
V ₁	120 kts	147 kts
V _R	127 kts	159 kts
V ₂	140 kts	169 kts

- The BLT was not connected to the aircraft's power source and it went into standby mode.
- The captain was dealing with a hydraulic failure at the time the take-off performance calculations were being calculated.
- After the data had been entered into the FMS, there was no requirement for a comparison to be made with the TOW and the flight limitations.
- There was no requirement to compare the data entered into the BLT with the data entered into the FMS.

4.1.16 Airbus A340: March 2007

Location: Paris, France

Report: <http://www.tsb.gc.ca/eng/rapports-reports/aviation/2006/a06a0096/a06a0096.asp>

History of the flight

On 28 March 2007, an Airbus A340 aircraft, registered F-GLZP, was being prepared for takeoff from Charles de Gaulle International Airport, France. The crew had initially planned to conduct a reduced thrust takeoff. However, due to a 5 kt tail wind, this was changed and the take-off performance parameters were re-calculated. When entering the V speeds, an error was made, resulting in the V_R speed being 20 kts lower than required. During the takeoff, the pilot flying delayed the aircraft's rotation.

<i>Take-off performance data</i>		
Data	Required	Used
V ₁	131 kts	131 kts
V _R	151 kts	131 kts
V ₂	159 kts	159 kts

4.1.17 Boeing 747: June 2007

Location: Singapore

Report: http://app.mot.gov.sg/DATA/0/docs/mot_content/2%20Jun%202007.pdf

History of the flight

On 2 June 2007, a Boeing 747-300 aircraft, registered HZ-AIT, was to be operated on a scheduled passenger service from Changi Airport, Singapore to Riyadh, Saudi Arabia. The first officer and flight engineer arrived at the aircraft and received a briefing from the handling agent's dispatcher. The captain arrived shortly after and the briefing was repeated. During the brief, the dispatcher advised the crew that runway 20C had been shortened, which was not reflected in the company's Notice to Airmen. The flight engineer had also listened to the ATIS, which stated that the runway in use was runway 20C and the take-off run available (TORA) was 2,500 m. The full length of the runway was 4,000 m.

The crew then calculated the take-off performance data using the computer generated module table take-off and landing (MTTL) charts provided by the dispatcher. The MTTL charts, for certain flap setting, allowed the crew to determine a zero wind TOW limit corresponding to a particular outside air temperature value and direction of takeoff (runways 02C/02L/20C). The table spread over two pages, with the runway length information appearing only on the second page of the MTTL charts.

The crew reported that the MTTL charts provided were different from what they normally received, which contained the outside air temperature versus the TOW limits data for one particular runway and runway length. As the first officer was not familiar with the new format of the MTTL charts, he consulted the captain. The

captain identified the correct column on the chart corresponding to the reduced runway length; however, the first officer incorrectly read the take-off data from the column applicable for a full runway length take-off. The first officer did not notice the runway length on page 2 of the chart.

The crew contacted ATC, requesting a clearance for flight level 330. At this stage, ATC informed the crew twice that they should expect runway 20C and that the TORA was 2,500 m. The crew received a clearance from ATC to line up on runway 20C and were again advised that the TORA was 2,500 m, before receiving a clearance for takeoff.

During the takeoff, the crew noticed the red runway-end lights and the flight engineer also reported that he sensed that the aircraft was too low and was expecting to feel or hear the aircraft hit the lights. The crew reported that they did not feel or hear anything during the takeoff, however, the runway end marker board lights turned off shortly after the aircraft became airborne. A subsequent inspection determined that the marker boards were badly damaged.

During the takeoff, a group of workers were doing runway re-surfacing work at the end of runway 20C. The workers reported that when the aircraft flew overhead, it was low enough that their reaction was to squat down.

Figure 11: Damaged runway end marker board lights



Source: Air Accident Investigation Bureau of Singapore, 2008

Contributing factors

The following factors were identified throughout the subsequent investigation:

- The first officer determined the aircraft TOW limit using the full runway length available column on the MTTL chart instead of the reduced runway length column.
- The captain did not cross-check the first officer's calculations.

- There was no requirement by the airline for the crew to cross-check each other's calculations.
- The crew were not familiar with the new format of the MTTL charts as they weren't informed of the change.
- The first officer only referenced the first page of the MTTL chart, and consequently, did not notice the runway length figure for the particular column being referenced.

4.1.18 **McDonnell Douglas MD83: September 2007**

Location: Östersund, Sweden

Report: http://www.havkom.se/virtupload/news/RL2009_14e.pdf

History of the flight

On 9 September 2007, a McDonnell Douglas MD83 aircraft, registered OE-LRW, was being prepared for a charter passenger flight from Åre/Östersund Airport, Sweden to Antalya Airport, Turkey with six crew and 169 passengers onboard. For the flight, the crew were responsible for the loading instructions, preparing the load and trim sheet, and performance calculations.

The crew had elected to use runway 30 with a tail wind as this runway allowed for a higher TOW than the runway in the opposite direction. In preparation for the flight, the crew obtained the maximum permitted TOW for runway 30 using gross weight charts (GWC). According to the load and trim sheet, the aircraft's actual TOW was 70,169 kg, while the maximum permitted TOW for runway 30 was 70,651 kg (uncorrected).

These charts also provided information relating to the V speeds and took into account the physical data of the aircraft, the height of the aerodrome above sea level, the actual aircraft TOW according to the load and trim sheet, wind, temperature, air pressure, runway conditions, and the wing flap setting required for takeoff. When determining the maximum permitted TOW, the tail-wind and current atmospheric air pressure conditions were omitted.

During the takeoff, the captain felt that the aircraft rotation was heavier than normal. A slow rotation was conducted to avoid a tailstrike and the aircraft became airborne at the end of the runway. After rotation, the aircraft had to be trimmed more to the rear than normal. A subsequent inspection determined that the aircraft had struck the approach lights.

The captain later reported that he believed the take-off performance calculations were based on the wind information provided in the weather forecasts and could not remember the actual wind direction provided by ATC. The first officer could not remember why he had made the calculations based on zero wind.

In addition, a number of baggage items in the forward cargo compartment were not included in the weight calculations. When loading of the aircraft was completed, the handling agent provided the captain with a verbal report. According to the agent, he advised that there were 29 bags in the forward cargo compartment, which were not included on the load and trim sheet. The captain believed that the agent stated that there was only a 'few' bags in the compartment.

The captain told the handling agent that he would make the necessary changes to the load and trim sheet. The corrections were not made as the captain believed that the airline's regulations stated that corrections were not required for values less than 500 kg. The manual only stated that if the weight changes were less than 500 kg, a new load and trim sheet was not required, however, the changes did need to be included on the existing sheet. The aircraft was 3,148 kg heavier than the maximum allowable weight for the prevailing conditions.

Contributing factors

The following factors were identified during the subsequent investigation:

- The weather and wind conditions were not included in the calculations for determining the maximum allowable TOW.
- Loading instructions were communicated verbally between the crew and ground staff, resulting in a difference of understanding with respect to the additional baggage in the forward cargo compartment.
- An analysis of the takeoff determined that the aircraft rotation was initiated late and too low a rotation rate was used.
- Due to the seasonal requirements of charter flights, the pilot group was not homogeneous, with pilots from different backgrounds and differing periods of employment. This resulted in high demands on the management and safety guidance within the airline to ensure a high level of safety was maintained and to prevent an undesirable culture from developing.

4.1.19 Airbus A330: October 2008

Location: Montego Bay, Jamaica

Report: http://www.aaib.gov.uk/sites/aaib/publications/bulletins/november_2009/airbus_a330_243_g_ojmc.cfm

History of the flight

On 28 October 2008, the crew of an Airbus A330-243 aircraft, registered G-OJMC, reported for duty at Sangster International Airport, Jamaica to operate a passenger service to London, UK. During pre-flight preparations, the crew (captain, first officer and a supernumerary pilot) were unable to locate the aircraft's performance manual. The captain contacted the flight dispatch department via telephone and requested that the take-off performance data be calculated using the Airbus flight operations versatile environment (FOVE) computer system. The captain relayed the relevant information to the dispatcher to enter into the FOVE system. The resultant figures were then read back to the captain. The telephone was then handed over to the first officer and this process repeated. Both the captain and first officer reported receiving the same take-off performance figures. These figures were then entered into the FMGS.

During the takeoff, the aircraft appeared to accelerate as expected. After passing 100 kts, the first officer called 'V₁' and 'V_R'. The captain was surprised by the quick succession of these calls. The first officer called 'rotate' and the captain pulled back on the sidestick. When doing so, the aircraft did not appear to feel right

and the captain immediately applied TO/GA thrust. The aircraft became airborne and climbed away.

After completing the after take-off checklist, the crew checked the take-off performance figures against the data contained in the flight crew operating manual. This comparison identified significant differences between the two.

Contributing factors

While the exact source of the error could not be identified, the following factors were identified by the subsequent investigation:

- A TOW of 120,800 kg was used by the dispatcher instead of 210,183 kg to calculate the take-off performance parameters resulting in erroneous V speeds.

<i>Take-off performance data</i>		
Data	Required	Used
TOW	210,183 kg	120,800 kg
V ₁	136 kts	114 kts
V _R	140 kts	114 kts
V ₂	147 kts	125 kts

- The function in the FOVE computer to calculate the green dot speed¹¹ was disabled. If the green dot speed from the FOVE computer was provided to the crew, this figure could have been used to compare the green dot speed automatically generated by the FMGS as a gross error check.
- The procedure for calculating and verifying the FOVE calculations were not completely carried out. The airline's procedures stipulated that the dispatcher was required to obtain the input data from one of the crew members and enter it into the FOVE computer. Both the input figures and resultant data are then read back to that crew member. The dispatcher was then required to hand over the FOVE computer to a second dispatcher, who would then go through the same process with a different crew member. If a second dispatcher was not available, the duty pilot was contacted, who had his own FOVE computer, and the second calculations were to be made.

4.1.20 Boeing 767: December 2008

Location: Manchester, UK

Report: http://www.aaib.gov.uk/publications/bulletins/july_2009/boeing_767_39h_g_oan.cfm

History of the flight

On 13 December 2008, a Boeing 767-39H aircraft, registered G-OOAN, was scheduled to fly from Manchester Airport, United Kingdom to Montego Bay, Jamaica. On board the aircraft were 11 crew and 254 passengers.

¹¹ Green dot speed: the best lift to drag ratio speed.

Prior to receiving the loadsheet, the crew entered the required information into the computer take-off programme (CTOP) (laptop computer), with the exception of the aircraft TOW, which was required from the loadsheet. When later entering the required weight information, the ZFW was inadvertently entered instead of the TOW. The calculated V speeds and thrust setting were then entered into the FMC. The aircraft was pushed-back from the gate about 15 minutes late.

While taxiing, it began to rain heavily and the temperature engine anti-ice was required to be on. The first officer re-calculated the V speeds using the CTOP and informed the captain that there was no change to the speeds. The crew's attention was also focussed on the taxi, due to works in progress on some of the taxiways. The captain was paying particular attention to their taxi route as he was not familiar with the airport.

During the takeoff, the captain elected to delay the V₁ call by 10 to 15 kts due to a sluggish acceleration as he believed the aircraft may have been heavier than calculated. The first officer rotated the aircraft slowly. The tailskid message on the engine instrument and crew alerting system (EICAS) illuminated momentarily, indicating a tailstrike. In response, the captain applied full power. Soon after, the stick shaker activated briefly. The aircraft continued to climb away.

Contributing factors

The following factors were identified throughout the subsequent investigation:

- The ZFW was entered into the CTOP instead of the TOW, resulting in significantly lower V speeds than required for the aircraft's actual weight.

<i>Take-off performance data</i>		
Data	Required	Used
TOW	172,351 kg	117,951 kg
V ₁	143 kts	124 kts
V _R	154 kts	133 kts
V ₂	160 kts	138 kts

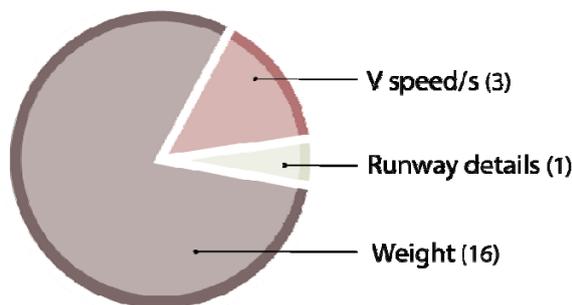
- The captain had flown a number of sectors in an empty Boeing 767 aircraft prior to the incident flight; consequently, the slow V speeds did not trigger an alert.
- The crew were distracted by the works in progress on the taxiways and were particularly attentive to the taxi routing.
- The delay in pushback led to a time pressure.

4.2 International perspective

4.2.1 Performance parameter

While half of the Australian occurrences analysed in section 3.2 involved the incorrect calculation or input of V speeds, they accounted for only four of the 20 international occurrences. The incorrect calculation or input of weight parameters accounted for the greatest proportion, with 16 occurrences, of which 14 were related to the aircraft's TOW and two involved the fuel on board weight (Figure 12). In one case, the incorrect runway details were used during the calculation of the take-off performance parameters.

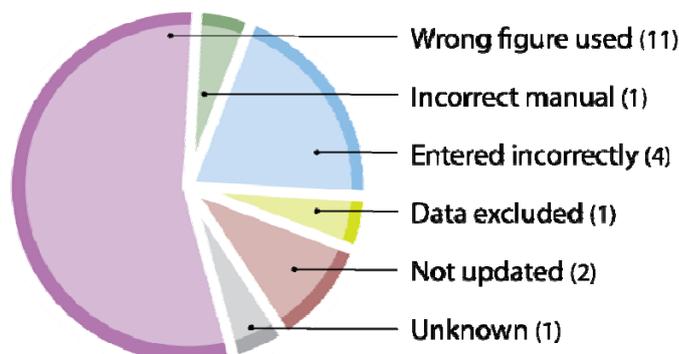
Figure 12: Take-off performance parameter



4.2.2 Error action

The most prevalent type of crew error identified was when the wrong figure was used, accounting for over half (n = 11) of the occurrences. These included, entering the ZFW into an aircraft system instead of the TOW, using the TOW from the previous flight, and entering the fuel on board at the time instead of the planned fuel for departure. The second most common error action related to take-off performance parameters being entered incorrectly, accounting for four occurrences, followed by parameters not updated, which corresponded to two occurrences. The remaining three were equally divided between cases, where data was excluded, the incorrect manual was used, and one occurrence where the exact source of the error could not be determined (Figure 13).

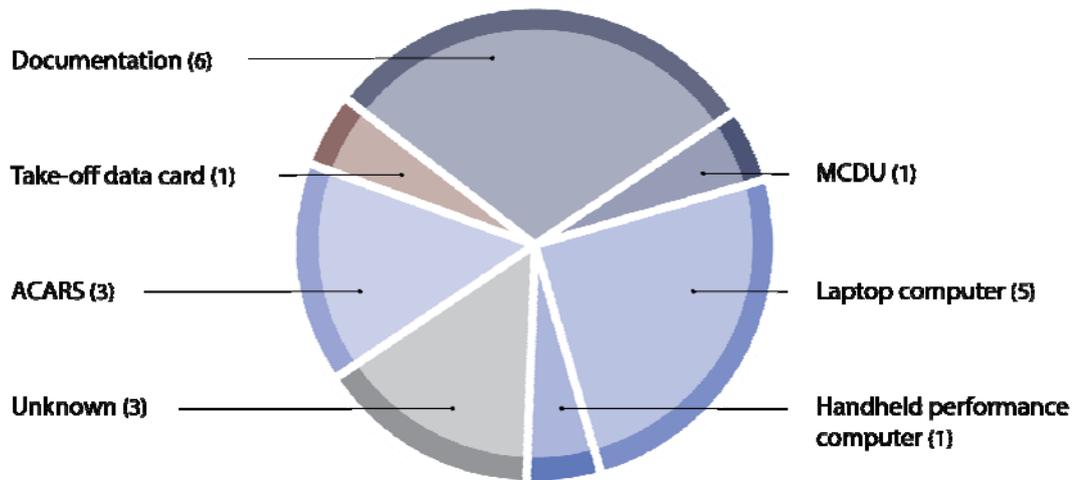
Figure 13: Error action



4.2.3 Device

Figure 14 shows that the most common devices involved in the calculation or entry of erroneous take-off performance parameters related to aircraft documentation and the laptop computer, accounting for six and five occurrences respectively. Documentation errors included using the wrong weight to determine the V speeds from aircraft performance charts, using the wrong chart, or not taking into account certain flight conditions when determining the maximum permitted TOW. In three occurrences, the device could not be determined, and in another three cases, the ZFW was entered into the ACARS instead of the TOW. The use of the MCDU, handheld performance computer¹², and take-off data card, each accounted for one occurrence.

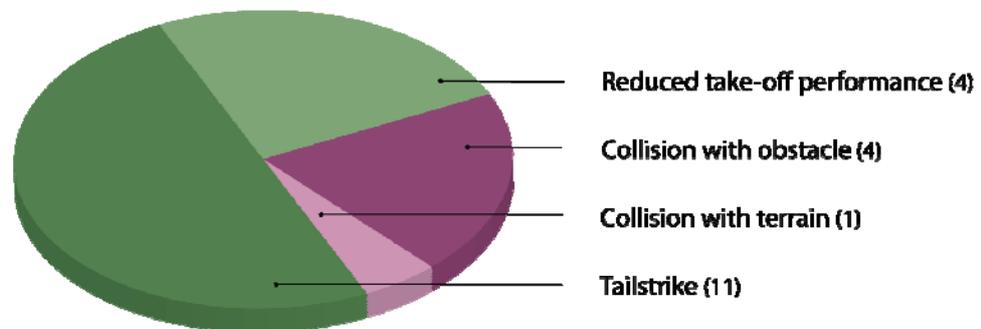
Figure 14: Device



4.2.4 Consequence

All 20 of the international accidents and incidents recorded some effect on flight. Over half resulted in a tailstrike (n = 11), while one-fifth resulted in a reduced take-off performance (n = 4). These included the crew noticing that the aircraft's response during the takeoff was slow to accelerate, the aircraft felt heavy, and the pitch response was different from normal. The aircraft colliding with an obstacle or terrain, accounted for four and one occurrence respectively (Figure 15).

Figure 15: Occurrence consequence



¹² Insufficient information was available in the investigation report to determine if the 'handheld performance computer' was a laptop computer or a different device.

4.2.5 Change in conditions

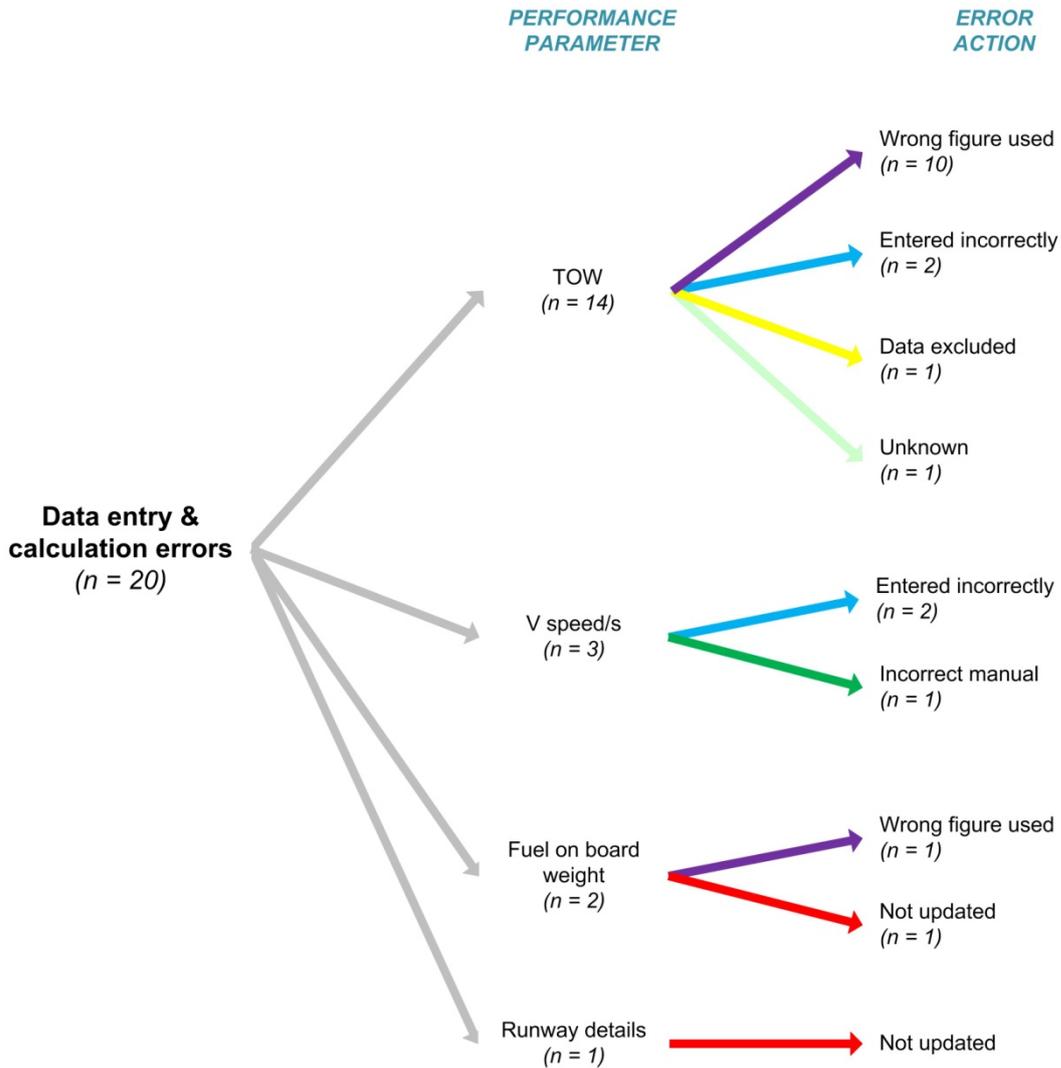
A change in operational and environmental conditions was determined in nine of the 20 occurrences. These included:

- the planned runway in use differed from the actual runway in use
- the crew noting that the MAC percentage did not appear correct; the correct MAC was then entered into the ACARS
- the crew received a revised loadsheet with an updated TOW
- the ACARS datalink was not operating and the crew were required to obtain the take-off performance data by other means
- take-off performance calculations entered into the laptop computer were inadvertently erased; the data required re-insertion
- the crew elected not to conduct a reduced thrust takeoff due to a tail wind
- the aircraft performance manual was not available and the crew were required to obtain the take-off performance data by other means
- a change in weather conditions required the engine anti-ice system to be selected.

4.2.6 Summary of international data

The broad analysis of the international data paints a slightly different picture when compared with the Australian data. The most common error for the international data involved an aircraft's TOW, while the Australian occurrences commonly cited erroneous V speed/s. Despite this, Figure 16 demonstrates the varying nature of these types of occurrences and the multitude of ways the same error can occur. Like the Australian data, it highlights the fact that the error path is not uniquely linear, that is, the path is not the same for like occurrences.

Figure 16: Summary of international data, 1 January 1989 to 30 June 2009



The following sections provide an analysis of the safety factors contributing to the 20 accidents and incidents identified between the period 1 January 1989 and 30 June 2009, involving foreign registered commercial jet aircraft operating outside Australian territory. These factors were coded by the authors using the Australian Transport Safety Bureau's (ATSB) safety factor model (shown in Figure 1 on page 16), based on the results of the subsequent investigation.

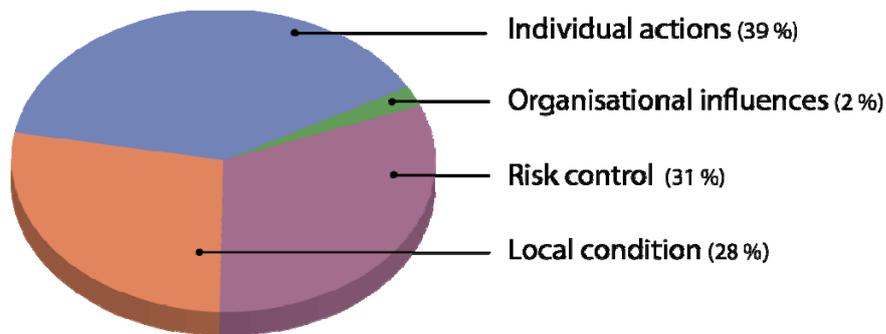
Due to the limited amount of information available for the Australian data, a safety factor analysis of the 11 occurrences could not be conducted.

5.1 All safety factors

A contributing safety factor is an event or condition that increases safety risk which if it had not occurred or existed at the relevant time, then either the occurrence would probably not have occurred, adverse consequences associated with the occurrence would probably not have occurred or have been as serious, or another contributing safety factor would probably not have occurred or existed (Walker & Bills, 2008).

A total of 131 contributing safety factors were identified from the 20 accidents and incidents (Figure 17). Of these, 39 per cent were related to individual actions ($n = 51$). This was followed by risk controls, accounting for 31 per cent ($n = 41$) and local conditions, accounting for 28 per cent ($n = 36$). Organisational influences accounted for two per cent ($n = 3$).

Figure 17: All contributing safety factors



5.1.1 Individual actions

Individual actions refer to observable behaviours performed by operational personnel (flight crew, dispatcher, etc) that increase safety risk (Walker & Bills, 2008).

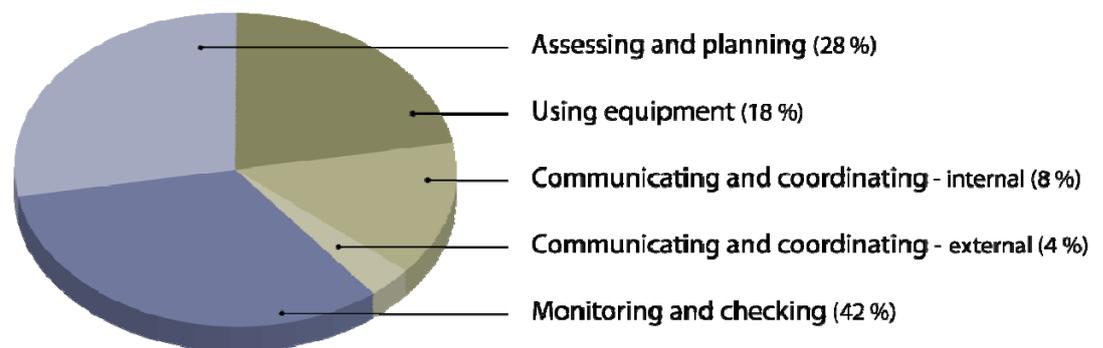
The largest proportion of all safety factors classified was related to individual actions, accounting for 51 of the 131 total factors identified. One occurrence reported actions by personnel other than the flight crew. This involved the calculation of take-off performance data by dispatch, which was not independently

verified by another dispatcher or by the duty pilot as required by the standard operating procedures.

The remaining 50 individual actions specifically related to aircraft operation actions by the flight crew. As show in Figure 18, these included:

- *monitoring and checking*, accounting for 42 per cent. These involved crew actions associated with the verification or cross-checking of take-off data computations not being completed by the crew.
- *assessing and planning*, accounting for 28 per cent. These involved problems associated with assessment and planning activities including inadvertently using the zero fuel weight (ZFW) instead of the take-off weight (TOW) to obtain the V speeds from the take-off performance charts, V speeds obtained from the incorrect performance chart, and calculating take-off performance parameters based on anticipated conditions and not the actual conditions.
- *using equipment*, accounting for 18 per cent. These related to actions associated with the use of equipment for aircraft operations, with the exception of aircraft handling. Examples of this include the ZFW being entered into an aircraft system instead of the aircraft's TOW, and the fuel on board being entered into the laptop computer instead of the planned flight fuel.
- *communicating and coordinating (internal)*, accounting for 8 per cent. These involved actions associated with communicating relevant operational information within the crew of an aircraft, such as the ZFW being read out aloud instead of the TOW, and the pilot flying conducting the pilot not flying duties.
- *communicating and coordinating (external)*, accounting for 4 per cent. These involved actions associated with communicating relevant operational information to personnel external to the aircraft. This included a misunderstanding between the crew and ramp personnel regarding the number of bags in a cargo compartment, and a breakdown in communication between ground personnel.

Figure 18: Aircraft operation individual actions



5.1.2 Local conditions

In this analysis, local conditions refer to those conditions on the flight deck that increase safety risk through their influence on individual actions. Local conditions

include characteristics of the individuals and the equipment involved, as well as the nature of the tasks being conducted (Walker & Bills, 2008).

As shown in Figure 19, of the 36 contributing local conditions identified, the most prevalent type related to task demands, accounting for 61 per cent (n = 22). This was followed by knowledge, skills and experience, accounting for 33 per cent (n = 12) and personal factors, accounting for 6 per cent (n = 2).

Figure 19: Local conditions

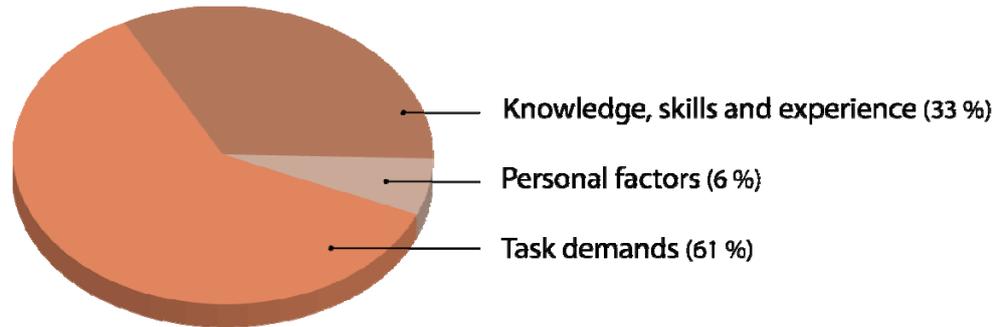


Table 1 provides a breakdown of the three categories. The most common specific local condition identified was task experience or recency, accounting for 31 per cent of all local conditions. This refers to situations where an individual did not have a sufficient amount of total or recent experience to conduct the task appropriately. This also includes being unfamiliar with a task or procedure, and negative transfer influences from other aircraft types or flights.

The second most prevalent local condition related to situations where the properties of an individual's task demands influenced performance (other task demands factors), accounting for 22 per cent. This was followed by situations where the demands to complete a task or tasks by a specific time influenced the ability of an individual to perform effectively, accounting for 14 per cent (time pressure). Distractions and incorrect task information (operational information was not provided or contained significant omissions or inaccuracies), accounted for 11 per cent each.

Table 1: Type of local conditions

Factor	Examples	Number
Knowledge, skills and experience		
<i>Task experience/recency</i>	<ul style="list-style-type: none"> crew had previous experience on another aircraft type, which had similar weights and V speeds to the erroneous values crew were marginally experienced for the flight 	11
<i>Equipment knowledge/skills</i>	<ul style="list-style-type: none"> operations officer had completed training on the laptop computer, but these skills were rarely used 	1
Task demands		
<i>Other task demand factors</i>	<ul style="list-style-type: none"> there was a strong emphasis placed on the ZFW by the company as this weight often restricted long haul flights crew were interrupted by the relief pilot to discuss a mean aerodynamic chord (MAC) value discrepancy 	8
<i>Time pressure</i>	<ul style="list-style-type: none"> 45 minute delay reduced to 30 minutes delayed departure 	5
<i>Distractions</i>	<ul style="list-style-type: none"> captain was distracted by a hydraulic failure crew were distracted by mechanical problems with the auxiliary power unit 	4
<i>Incorrect task information</i>	<ul style="list-style-type: none"> performance manual not onboard the aircraft information on shortened runway not provided on the Notice to Airmen 	3
<i>High workload</i>	<ul style="list-style-type: none"> increased workload due to a number of technical and operational issues 	1
<i>Task completion pressure</i>	<ul style="list-style-type: none"> crew tried to complete the task using their own methods to meet production targets 	1
Personal factors		
<i>Preoccupations</i>	<ul style="list-style-type: none"> crew were preoccupied by ground staff (not related to the operation of the flight) 	1
<i>Fatigue</i>	<ul style="list-style-type: none"> crew were at their lowest level of performance due to fatigue 	1
Total		36

5.1.3 Risk controls

Risk controls refer to those measures put in place by an organisation to facilitate and assure safe performance of the aircraft operation that are absent, inadequate or failed and so increase safety risk (Walker & Bills, 2008).

Risk controls accounted for 41 of the 131 safety factors identified. Of these, 46 per cent (n = 19) were related to problems with the useability or availability of aircraft equipment and 37 per cent (n = 15) involved problems with the design, delivery or availability of procedures, checklists or work instructions used by operational personnel.

Factors relating to problems with the design, administration or effectiveness of human resource management controls that have a relatively direct influence on the performance of operational personnel (people management) accounted for 10 per cent (n = 4). The remaining seven per cent (n = 3) were related to issues with the design, delivery or availability of training provided to operational personnel (Figure 20).

Figure 20: Risk controls

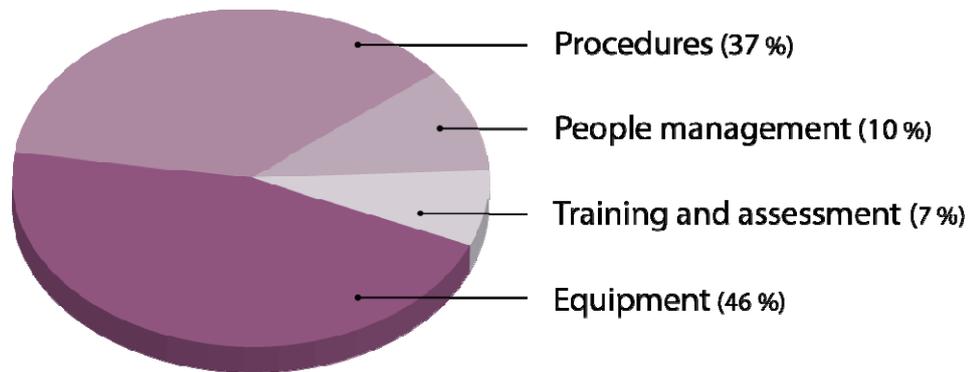


Table 2 provides examples of the typical risk control factors identified from the 20 international occurrences; a detailed breakdown of equipment factors is also provided.

The largest number of issues associated with aircraft equipment related to problems with the design of automated systems, accounting for 22 per cent of the total number of risk control factors. This was followed by problems associated with the design or availability of tools or materials, leading to personnel not being able to perform their tasks safely or effectively, which accounted for 17 per cent of risk controls.

Table 2: Type of risk controls, 1 January 1989 to 30 June 2009

Factor	Examples	Number
Equipment		
<i>Automation</i>	<ul style="list-style-type: none"> • system accepted mismatched values without challenge • TOW was the input value for the aircraft communications addressing and reporting system (ACARS); the ZFW was the input value for the multifunction control and display unit (MCDU) • the system was configured in a way that prevented the crew from conducting a gross error check 	9
<i>Tools and materials</i>	<ul style="list-style-type: none"> • the crew did not have immediate access to the flight plan • the presentation of parameter values may have lead to some confusion when reading varying weights 	7
<i>Other equipment factors</i>	<ul style="list-style-type: none"> • ACARS datalink was not working • dispatch portable computer not working 	2
<i>Workspace environment</i>	<ul style="list-style-type: none"> • the third MCDU was located in a position not visible to the captain or first officer 	1
Procedures		
	<ul style="list-style-type: none"> • procedures did not require the crew to cross-check take-off calculations • procedures did not specify who was responsible for calculating take-off data • duties/responsibilities of the second officer in pre-flight preparations were not defined • no procedure to compare data entered into the laptop computer with data entered into the flight management system (FMS) 	15
People management		
	<ul style="list-style-type: none"> • flight and duty time scheduling • crew pairing practices 	4
Training and assessment		
	<ul style="list-style-type: none"> • no formal training and testing was provided on the use of the performance calculation system • shortcomings in the flight crew training program 	3
<i>Total</i>		41

5.1.4 Organisational influences

Organisational influences refer to absent or inadequate conditions that should be in place to establish, maintain or otherwise influence the effectiveness of an organisation's risk controls (Walker & Bills, 2008).

Of the 131 safety factors identified relating to the 20 international occurrences, only three involved organisational influences. Specifically, these involved two factors relating to safety management processes and one for organisational characteristics.

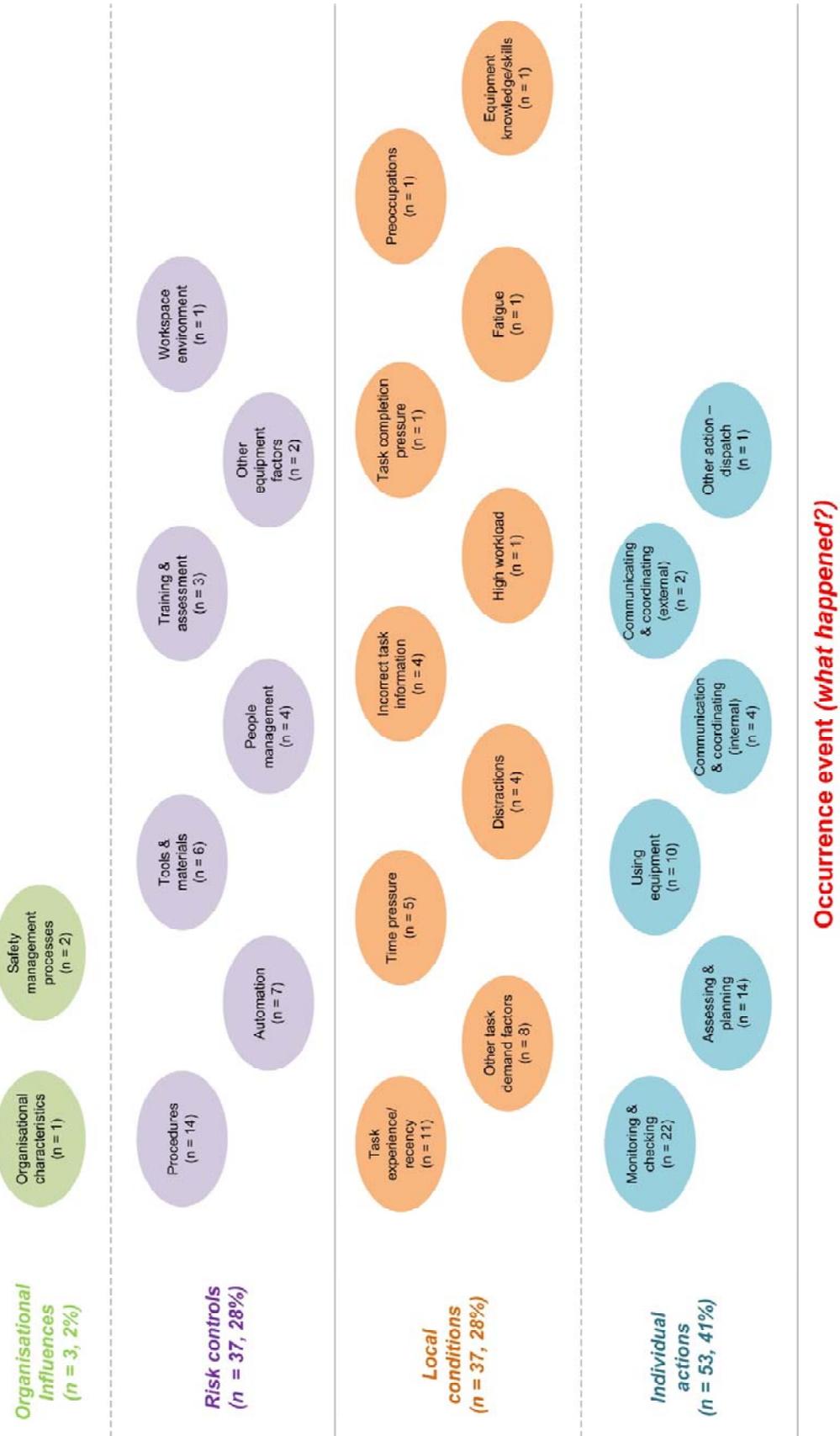
These included:

- the crew were not recruited in accordance with company's normal procedures
- the airline failed to detect that the software used to calculate the take-off performance data did not have an inbuilt reasonability check
- the services provided by the airline's support departments were not clear.

5.2 Safety factor map

Figure 24 provides a pictorial representation of all of the safety factors identified from the 20 accidents and incidents involving commercial jet aircraft operating outside Australian territory between the period 1 January 1989 and 30 June 2009.

Figure 21: Contributing safety factor map



It is part of human nature that, despite our best intentions, errors will occur. Errors involving take-off performance parameter calculations and data entry probably occur frequently, but in most cases, there are sufficient defences in place to detect these errors prior to the aircraft leaving the gate. However, as there is varying take-off performance parameter calculation methods used by airlines, different aircraft involved, and different aircraft systems used to calculate and enter take-off performance parameters, there will never be one solution for minimising or eliminating these errors.

Chapter 5 of this report used the Australian Transport Safety Bureau's (ATSB) safety factor analysis model to provide some background on why these events occur. The following provides some suggestions for minimising the opportunities of take-off performance parameter errors from occurring.

6.1 Risk controls

6.1.1 Procedures

Standard operating procedures (SOPs) are widely recognised as necessary for safe aviation operations (Federal Aviation Administration, 2003). They are one of the key defences used to ensure that there is a safe outcome for all phases of flight (Transportation Safety Board of Canada, n.d.).

Problems associated with procedures, checklists or work instructions were identified in 14 of the 131 safety factors. These covered the following areas:

- no procedures in place to compare or independently verify the take-off performance parameter values with other sources such as, comparing the data entered into the laptop computer with that automatically calculated by the flight management computer
- no requirement for the calculations made by one crew member to be cross-checked by another crew member
- no requirement to cross-check all of the take-off performance parameters, for example, a cross-check of the V speeds was required, but not the aircraft's take-off weight (TOW)
- the roles and responsibilities of crew members, including the third or relief pilot, were not clearly defined with respect to calculating and verifying take-off performance calculations
- no procedure in place for calculating take-off performance data when the primary system used to conduct this task was unavailable.

For airlines, it is important to look at the ways errors can be introduced into the process and determine if the procedures currently in place prevent these errors from occurring or provide sufficient opportunities for errors to be detected. Procedures need to take into account the entire process and recognise that errors may occur at all stages of pre-flight preparation.

Ideally, procedures relating to the calculation and entry of take-off performance parameters should take into account the following:

- An independent calculation or cross-check of the take-off performance data is conducted by another crew member
- where possible, the data is verified using multiple sources
- when verifying the data, both the values used to make the calculations and the values that are calculated are checked
- there are procedures in place in the event the primary aircraft system used to calculate take-off performance parameters is unavailable
- the roles and responsibilities of all crew members are clearly delineated.

In addition, Boeing has developed a risk assessment checklist to assist airlines in assessing the adequacy of their process, in particular, those relating to the calculation of V speeds. The checklist divides the process into six key areas:

- determine the zero fuel weight (ZFW)
- determine gross weight; communicate weights to flight crew
- include complete information for deriving V speeds
- cross-check manual operations
- set speed bugs.

Each stage asks a series of questions, rates the degree to which the error may affect the flight, and provides examples of the 'best', 'good' and 'poor' practices. Boeing recommends that airlines use this checklist to review their SOPs and address any resulting deficiencies (Boeing, 2000).

6.1.2 Automation

Seven safety factors were identified where problems with the design of the aircraft's automated systems affected their usability and made it easier for crew errors to occur, or difficult to detect errors that did occur. These included:

- systems requiring different input values, for example, the aircraft communications addressing and reporting system (ACARS) required input of the TOW while the multifunction control and display unit (MCDU) required input of the ZFW
- no inbuilt function to alert the user that the values entered were unrealistically low or mismatched (compared with the values already calculated by the system)
- a system function that would have allowed for a cross-check of the 'green dot speed' was not activated
- the system reverted to the information entered for the previous flight.

Software design

To address some of the issues detailed above, when designing aircraft systems such as the flight management computer (FMC) or performance software on handheld performance and laptop computers, manufacturers and software developers should consider standardising input values and implementing reasonability checks where possible.

In one incident, a low TOW was entered into the ACARS, which subsequently resulted in a V speed that was too low. At the time, the ACARS returned a warning only if the TOW entered was greater than the aircraft's maximum TOW. As a result of this incident, the airline modified the take-off data computer software so that a warning would be issued to the crew if the TOW differed more than 8,000 kg from the normal average TOW for that particular route (Aircraft Accident Investigation Board Denmark, n.d.).

As part of the Laboratory of Applied Anthropology's study (2008), a questionnaire was distributed to various companies, including Airbus, to ascertain what developments had been planned for the flight management system (FMS) relating to take-off parameters in future aircraft. Airbus responded stating that on newer FMSs, it was no longer a requirement to enter a gross weight into the FMS, only the ZFW. Furthermore, when V_1 , V_R and V_2 are entered, they would be compared with V_{SIG}^{13}/V_{MU}^{14} and V_{MCA}^{15} limitations to check if the V speeds are too low. The Laboratory also proposed a number of suggested controls that could be explored, including strengthening software controls, such as comparing the values entered into the system with similar flights or, if new calculations are made for the same flight, these values are compared with those previously calculated.

In the case of the Boeing 747 aircraft accident at Auckland International Airport in 2003 (9V-SMT), the V speeds were calculated based on the wrong TOW. The V speeds were then manually entered into the FMC, replacing the V speeds automatically calculated by the system. As the FMC did not take into account all of the necessary take-off parameters (for example, non-normal conditions or improved climb performance), the airline used the airport analysis charts to determine the V speeds rather than those automatically produced by the FMC. While the speeds displayed by the FMC are generally within 3 kts of those calculated using the charts, the system was not programmed to challenge any discrepancies between the V speeds manually entered and those automatically calculated. The Transport Accident Investigation Commission (TAIC) (2003) recommended to Boeing that it implement an FMS software change on all Boeing aircraft to ensure that any V speed or gross weight entries that are mismatched by anything other than a small percentage are either challenged or prevented.

While software enhancements may provide an additional line of defence, it is important to recognise that there may be associated limitations. In response to TAIC's recommendation, Boeing stated that this software check would be ineffective at preventing a large number of erroneous V speed events if an incorrect weight was entered into the FMC. Furthermore, the software could challenge the

¹³ The stall speed under 1 g vertical acceleration.

¹⁴ The minimum unstick speed. It is the calibrated minimum airspeed which the aircraft can lift-off the ground and continue flight.

¹⁵ The minimum control speed at which an aircraft can be controlled in the air.

speeds entered, even if they were entered correctly. This in turn may result in the crew inadvertently using the FMC calculated V speeds, which may be incorrect. Another issue raised by Boeing related to those instances where the manually calculated speeds, which take into consideration more variables, would genuinely differ from the FMC calculated speeds, resulting in nuisance warnings. With this, the effectiveness of the warnings may be reduced, thus defeating their original purpose. However, Boeing stated that they were exploring the possibility of checking that the V_R speed manually entered was not significantly lower than that automatically calculated by the FMC.

In addition to the recommendation from TAIC, the Laboratory of Applied Anthropology (2008) also suggested that all FMSs should be equipped to calculate and present V speeds to the user and provide a warning message in the event of significant differences, or display these differences.

Airbus take-off securing function (TOS)

The use of erroneous take-off performance parameters has prompted Airbus to develop a software package that automatically checks the data entered into the FMS for consistency. Known as the 'take-off securing function' (TOS), the system has the capacity to check the ZFW and V speeds entered into the FMS against a set of predefined criteria and display a caution message via the MCDU if these values are outside these limits (Airbus, 2009).

System cross-check

Where more than one system is available for calculating take-off performance parameters, system manufacturers and airlines should consider provisions for cross-checking the data between both sources. For example, the V speeds automatically calculated by the FMC may be entered into the handheld performance or laptop computer and compared with those values calculated by the computer. If the values differ by a certain margin, the program warns the crew that a difference has been identified. Alternatively, the crew could enter the ZFW, fuel load and TOW into the computer. The computer then adds the ZFW and fuel load figures to determine the TOW. This figure could then be compared with the TOW initially entered. This check would assist in identifying those errors where the TOW is incorrectly entered into a handheld performance or laptop computer.

6.1.3 Tools and materials

Factors associated with the availability or design of tools and materials such as flight plans, take-off data cards and performance charts were identified in six instances. These involved:

- the presentation of the values led to some confusion when reading certain values
- the crew were not provided with a full set of flight documentation
- the format of performance charts were changed without the crew being notified
- there was no designated position on the flight plan or take-off data card for values to be written

- runway information was not presented on all take-off performance calculation chart pages.

Flight plans and take-off data cards should be designed so that all of the relevant performance figures have a designated location. In one occurrence, the investigation determined that had there been a specific area on the flight plan, adjacent to the planned figures, to write the calculated performance data, the discrepancy between the planned TOW and the TOW used to calculate the performance data would have been easier to identify (Transportation Safety Board of Canada, n.d.).

Performance data such as the TOW or ZFW should be presented clearly and unambiguously to reduce the possibility of the wrong figure being selected. To distinguish between these two values, Boeing has revised their standard loadsheet to highlight the ZFW and inserted the note 'Enter ZFW into FMC' (Boeing, 2000).

6.2 Local conditions

6.2.1 Task/experience recency

Cases where an individual did not have sufficient experience to perform a task or where previous experiences were applied to a new and similar task were identified in 11 occasions. These included:

- crews had previous experience on a different aircraft type that had similar weights or V speeds to the erroneous values used, for example, the crew had previously flown a Boeing 767 where the TOW was similar to the ZFW of the Airbus A340
- the pilot had recently flown an empty aircraft of the same type; consequently, the low V speed did not trigger an alert
- the pilot/s were relatively inexperienced on the aircraft type
- the pilot/s were relatively inexperienced overall
- the erroneous TOW used was similar to the TOW used in simulator training
- the pilot previously used kilograms as a unit of measurement; the aircraft weights were in pounds
- the flight operations officer did not have sufficient knowledge/proficiency regarding take-off calculations for the aircraft type.

Negative transfer

In a number of instances, the pilots' performance was inhibited by previous experiences when they inadvertently reverted back to what they were more familiar with.

The Laboratory of Applied Anthropology (2008) recognised that if take-off performance parameters failed to remain in the pilot's working memory for a long time, they would be unable to create an internal representation of the values. Pilots would no longer possess an order of magnitude, making it difficult to question values incompatible with the flight.

The report stated that implementing symbolic barriers (procedures and guidance that require interpretive action to achieve their aim), such as the calculation and representation of V speeds on all FMS, may encourage the storage of values in pilots' working memory and the subsequent transfer into the long term memory. With this, crews could draw on their knowledge to question if they had the appropriate take-off performance parameters by formulating the following based on knowledge in the long-term memory¹⁶:

- we are flying a *Boeing 747* aircraft, with an empty weight of *190,000 kg*
- the reported load is about *45,000 kg*
- we are carrying about *115,000 kg* of fuel
- our take-off weight is *350,000 kg*, which we can verify
- conditions on the day are *clear* and the *outside air temperature is 22 degrees Celsius*, so the V speeds will be around *150 kts (V₁)*, *165 kts (V_R)* and *175 kts (V₂)*, which we can verify.

To complement the above, a physical representation showing the orders of magnitude could be located in the cockpit. For example, a summary table that provides the acceptable range of V₂ values for a variety of conditions. While it would not be possible to cover all circumstances, it would allow for a quick gross error check.

The above barriers suggested by the Laboratory of Applied Anthropology would provide a useful mechanism for minimising negative transfer as they would re-affirm the task at hand and assist in ensuring that pilots have the correct mental model of the flight details and take-off performance parameters.

Crew pairing

Ideally, an airline's crew rostering practices should be designed in a way such that every crew compliment consists of, at a minimum, a captain or first officer who is very experienced on the aircraft type. The International Air Transport Association's (IATA) operational safety audit (IOSA) program assesses the operational management and control systems of an airline. As part of this, IATA recommends that airlines should provide guidance and criteria in their operating manuals to ensure that scheduling processes preclude inexperienced crew members from operating together. While it may be difficult to define 'inexperienced', it generally refers to a minimum number of hours on a particular aircraft type after the completion of initial training/qualifications. The purpose of this is to prevent two newly trained or inexperienced pilots from operating together until they have achieved a determined level of experience on a particular aircraft type (International Air Transport Association, 2010).

¹⁶ The information shown in italics is for illustrative purposes only.

6.3 Individual actions

6.3.1 Monitoring and checking

Monitoring and checking activities was the most common individual action related contributing safety factor identified, accounting for 22 of the 53 individual actions. Examples of these included:

- the crew did not identify the incorrect value
- an independent check of the data was not conducted
- the gross error check was not conducted
- performance data was not verified by the other crew member/s
- discrepancy in values not queried
- discrepancy in values queried, but not checked
- discrepancy in one value checked, while other performance parameters were not checked
- cross-check with other sources was not conducted
- performance data was verbalised to the captain; a physical print-out of the data was not provided
- the crew did not recognise that the V_2 speed bug was lower than normal
- the crew did not detect that the V_R speed (indicated by a blue circle) was unusually removed from V_1 on the primary flight display.

A line operations safety audit conducted by the University of South Australia (Thomas, Petrilli & Dawson, 2004) provided a systematic analysis of error detection processes of airline crews operating jet aircraft, primarily on short-haul operations. The results of the study, based on data collected from a sample of 102 sectors, identified that captains were more effective in detecting errors compared with the first officer, detecting on average twice as many errors. This not only suggests that the captain is an essential component in error detection, but also highlights the potential role experience plays in monitoring other's actions in the cockpit. Furthermore, as shown in Table 3, the results of the Thomas et al. (2004) study indicated that errors are more likely to be detected by the person not responsible for creating the error, with 38.4 per cent of the errors made by the first officer detected by the monitoring actions of the captain and only 14.9 per cent of the errors made by the captains detected by the first officer.

Table 3: Percentage of errors detected by the monitoring pilot

	<i>% of errors detected by the monitoring pilot:</i>	
	First officer	Captain
<i>Error created by:</i>		
Captain	14.9	15.8
First officer	6.3	38.4

Note: The above table was adapted from Thomas, et al. (2004)

In addition to the above, the study also identified that only a small number of errors were detected by the aircraft's warning systems and through the use of checklists. These findings illustrate the significance of monitoring and checking activities, and highlight the need for airlines to have multiple defences in place to provide crews with opportunities to detect any errors made in the calculation or entry of take-off performance parameters. To achieve this, airlines and crews should consider the following:

- *Procedures:* airlines should provide robust procedures that require crews to cross-check and verify take-off performance parameters. This may include one crew member cross-checking the V speeds entered into the MCDU or FMC by the other crew member; the independent calculation of take-off parameters by two personnel, either two crew members or a crew member and dispatch; or the use of two different sources to determine the values, such as the handheld performance or laptop computer and FMC (Boeing, 2000).
- *Complying with procedures:* in a number of occurrences, the procedures were in place, but were not followed by the crew. In this instance, it is imperative that crews complete the appropriate procedures and do not allow other factors, such as delays or distractions to inhibit their performance. If a procedure or checklist is interrupted and there is some doubt as to what items have been completed, start again.
- *Check the values:* if discrepancies in values are identified, crews should take the time to verify all of the data, including both the input and output values; airlines should be supportive of this action and ensure that operational requirements do not compromise safety.

6.3.2 Using equipment

Errors relating to the entry of weights or V speeds into systems such as a handheld performance or laptop computer, ACARS, FMS, flight management computer/flight management and guidance system (FMC/FMGS), and MCDU were identified in 10 of the 131 safety factors. Specifically, these included:

- the ZFW was entered instead of the TOW
- an incorrect weight or V speed was entered
- the fuel on board weight at the time was entered instead of the planned fuel weight
- the laptop computer was either misused or misunderstood, resulting in the TOW for the previous flight being used.

As mentioned in section 6.1.2, the provision for inbuilt reasonability checks in aircraft systems would assist in alerting the crew to the possible entry of erroneous values. Furthermore, it is crucial that when critical values are entered into a system, they are independently verified by another crew member. Crews should also be appropriately trained in the use of performance software programs and be aware of any limitations.

6.4 Detecting degraded take-off performance

Take-off performance monitoring systems

In October 2004, a Boeing 747 aircraft (9G-MKJ) collided with terrain during the takeoff from Halifax International Airport, Nova Scotia as a result of erroneous V speeds and thrust setting. During the take-off run, the crew did not recognise that the aircraft's performance was significantly degraded until a point at which their response was insufficient to prevent the accident. The subsequent investigation by the Transportation Safety Board of Canada recognised that despite over 30 years of industry effort, there is no acceptable industry 'in-cockpit' defence that provides crews with the necessary information to indicate that the aircraft performance is insufficient to safely execute the takeoff. As a result, the Board recommended that (Transportation Safety Board of Canada, 2006):

The Department of Transport, in conjunction with the International Civil Aviation Organization, the Federal Aviation Administration, the European Aviation Safety Agency, and other regulatory organizations, establish a requirement for transport category aircraft to be equipped with a take-off performance monitoring system that would provide flight crews with an accurate and timely indication of inadequate take-off performance.

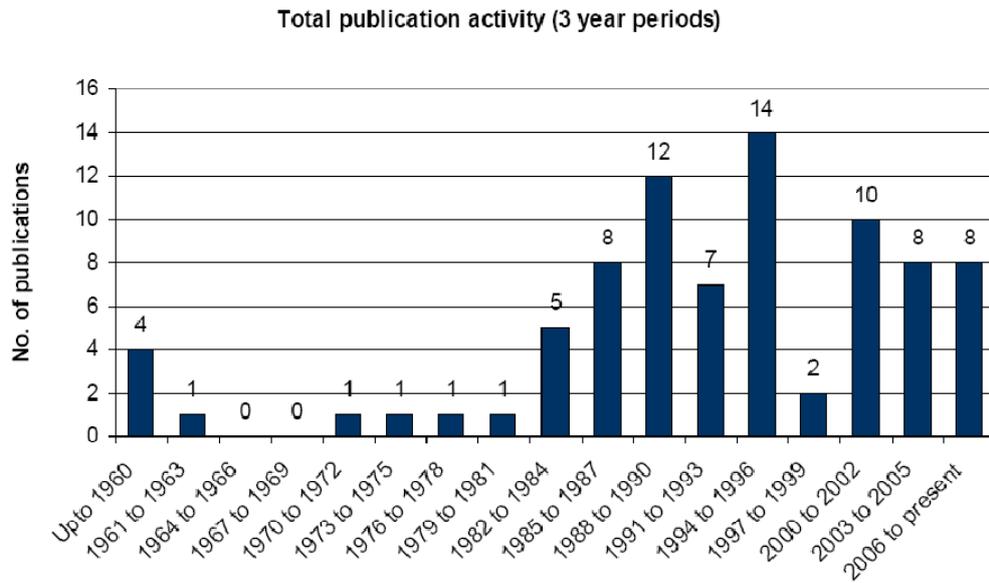
While the above recommendation does not preclude data entry and calculation errors relating to take-off performance parameters from occurring, Transport Canada (Department of Transport) agreed that a take-off performance monitoring system(s) (TOPMS) would provide a significant safety benefit. However, before regulatory authorities establish a requirement for the fitment of TOPMS, a certified system would need to be developed (Transport Canada, 2010).

Basically, a TOPMS, which assists pilots in determining whether to continue or reject the takeoff, can be defined as (Brown & Abbasi, 2009, p. 7):

...a system which automates the pilot monitoring of DTG [distance-to-go], for the same purpose – to sense, in a timely fashion the development of insufficient acceleration, which would extend the takeoff roll, perhaps precipitously.

In 1954, the National Advisory Committee for Aeronautics (NACA) published a technical report that evaluated a prototype cockpit instrument designed to indicate a loss in aircraft performance during takeoff. A literature search of published research on TOPMS by Brown & Abbasi (2009) has shown that since this time, countless attempts have been made to develop such a system (Figure 22).

Figure 22: Frequency of published research into TOPMS



Source: Brown & Abbasi, 2009

The aviation industry’s continued persistence in advancing TOPMS is indicative of the systems safety benefits, however, the accuracy and integrity required for TOPMs was not available until the late 1990s when digital processing became accessible in the cockpit. Despite this, solutions put forward have been too complex and demanding on the pilot/s. A simple system that confirms that the takeoff is progressing as required is needed, one that is as easy to read and understand as the fuel gauge in a car (Cranfield University, 2007).

Runway distance remaining indications

The concept of take-off performance monitoring is not new. For many years the military have been using runway distance remaining signs (RDRS) (also known as ‘distance-to-go’ (DTG) markers boards) indicating the runway distance remaining in thousands of feet. On takeoff, pilots can use RDRS to check expected versus actual aircraft acceleration prior to rotation. The US Federal Aviation Administration currently recommends that RDRS are installed on all runways used by jet aircraft (FAA, 2004). Lobby groups such as the Airline Pilots Association and industry experts have urged the FAA to make RDRS compulsory for all airports in the United States that receive regular public transport services (Rogers & Cook, 2007). However, neither the International Civil Aviation Organization nor the Civil Aviation Safety Authority (Australia) require or recommend airport operators to install RDRS at the side of runways.

An in-cockpit runway awareness and advisory system (RAAS) based on the enhanced ground proximity warning system (EGPWS) has been developed by Honeywell. Similar to the RDRS concept, this system informs pilots of the remaining runway length during a takeoff run.

Despite advanced aircraft systems and robust operating procedures, accidents continue to occur during the take-off phase of flight. The takeoff is recognised as one of the most, if not the most, critical stage of flight, as there is limited time and options available to the flight crew for managing abnormal situation such as insufficient airspeed. This has been highlighted by the accident statistics that show between the period 2000 and 2009, 12 per cent of fatal accidents involving the worldwide commercial jet fleet occurred during the takeoff, despite the fact that this phase of flight accounts for about only one per cent of the total flight time.

This report documented accidents and incidents (occurrences) that have resulted from take-off performance parameter data being incorrectly calculated or entered into aircraft systems. This in turn has resulted in pilots attempting to rotate and/or lift the aircraft off the ground at a speed slower than what is required. Although there have been numerous occurrences recorded, there have been (and continue to be) many more occasions where identical crew errors have been made, but have had no consequence on the safety of the takeoff. This is because adequate systems have been in place to successfully capture these errors before the take-off run was commenced. In fact, it is likely that the error was identified and corrected even before the aircraft had been pushed back from the gate.

Experience shows that the calculation and entry of erroneous take-off performance parameters have many different origins. The data parameters involved in these errors have included weights (take-off weight, zero fuel weight, gross-weight), V speeds, and runway details. Crew errors concerning these parameters have included the wrong figure being used, data entered incorrectly, data not being updated when conditions changed, data being excluded, and incorrect references being used. Furthermore, a range of systems and devices have been involved in these errors, including performance charts and manuals, laptop and handheld computers, flight management computers (FMC), aircraft communications addressing and reporting systems (ACARS), multifunction control and display units (MCDU), and take-off data cards.

The safety factor analysis of the 20 international occurrences showed that many factors have been identified at all levels of influence. At the pilot level, monitoring and checking, assessing and planning, and the use of equipment were the main types of factors identified. Common local conditions identified were inadequate task experience or recency, time pressures, distractions, and incorrect task information. Absent or inadequate risk controls identified mostly centred on poor procedures, non-optimally designed aircraft automation systems, inappropriately designed or unavailable material used in calculations, inappropriate crew management practices, and inadequate crew training.

Due to the immense variation in the mechanisms involved in making take-off parameter calculation and entry errors, there is no single solution to ensure that such errors are always prevented or captured. This report has discussed several error capture systems that airlines and aircraft manufacturers can explore. These include: appropriate crew procedures, especially those involving cross-checking; aircraft automation systems and software design involving the entering and checking of data; the provision of, and design of flight documentation and performance charts; and adequate crew pairing that accounts for aircraft-type experience for all crew

operating the aircraft. At the same time, pilots need to ensure procedures are followed even when faced with time pressures or distractions.

The results of this study, and that from other related research, have recognised that these types of events occur irrespective of the airline or aircraft type, and that they can happen to anyone; no-one is immune. While it is likely that these errors will continue to take place, as humans are fallible, it is imperative that the aviation industry continues to explore solutions to firstly minimise the opportunities for take-off performance parameter errors from occurring and secondly, maximise the chance that any errors that do occur are detected and/or do not lead to negative consequences.

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APPENDIX A: ATSB SAFETY FACTOR TAXONOMY

	Level 1		Level 2		Level 3
	Occurrence Event				
I	Individual Action	I1	Aircraft operation action	I1.1	Pre-flight inspecting
				I1.2	Assessing and planning
				I1.3	Aircraft handling
				I1.4	Using equipment
				I1.5	Communicating and coordinating – Internal
				I1.6	Communicating and coordinating - External
				I1.7	Monitoring and checking
				I1.8	Other aircraft operation action
		I2	Aircraft maintenance action	I2.1	Inspecting
				I2.2	Replacing, repairing, and installing
				I2.3	Using incorrect parts
				I2.4	Completing documentation
				I2.5	Other aircraft maintenance action
		I3	ATS action	I3.1	Assessing and planning
				I3.2	Using equipment
				I3.3	Communicating
				I3.4	Handover / takeover
				I3.5	Monitoring and checking
				I3.6	Other ATS action
		I4	Other action	I4.1	Cabin safety action
				I4.2	Facilities maintenance action
				I4.3	Ground handling action
				I4.4	Passenger action
				I4.5	Other action
T	Technical failure mechanism	T1	Fracture		
		T2	Wear		
		T3	Corrosion		
		T4	Deformation		
		T7	Software / firmware anomaly		
		T8	Other		

	Level 1		Level 2		Level 3
L	Local Condition	L1	Personal factors	L1.1	Physical limitations
				L1.2	Health-related condition
				L1.3	Fatigue
				L1.4	Alcohol/drugs
				L1.5	Motivation/attitude
				L1.6	Stress/anxiety
				L1.7	Preoccupations
				L1.8	Spatial disorientation
				L1.9	Other personal factors
		L2	Knowledge, skills, experience	L2.1	Task knowledge/skills
				L2.2	Task experience/recency
				L2.3	Equipment knowledge/skills
				L2.4	Other knowledge, skills, experience factors
		L3	Task demands	L3.1	High workload
				L3.2	Task completion pressure
				L3.3	Time pressure
				L3.4	Distractions
				L3.5	Incorrect task information
				L3.6	Other task demand factors
		L4	Social environment		
		L5	Workspace environment	L5.1	Workspace lighting
				L5.2	Noise
				L5.3	Temperature/humidity
				L5.4	Air quality
				L5.5	Other workspace environment factors
		L6	Physical environment	L6.1	Light conditions
				L6.2	Runway/movement area surface
				L6.3	Other physical environment factors

	Level 1		Level 2		Level 3
		L7	Weather conditions	L7.1	Visibility
				L7.2	Wind
				L7.3	Windshear
				L7.4	Turbulence
				L7.5	Icing conditions
				L7.6	Other weather conditions
R	Risk Control	R1	Equipment	R1.1	Displays/controls
				R1.2	Workspace equipment
				R1.3	Tools and materials
				R1.4	Warning/detection systems
				R1.5	Protection/rescue systems
				R1.6	Automation
				R1.7	Other equipment factors
		R2	Facilities/infrastructure	R2.1	Aerodrome lighting
				R2.2	Aerodrome signage
				R2.3	Runway design
				R2.4	Navigation aids
				R2.5	Other facilities/infrastructure factors
		R3	Procedures		
		R4	Training and assessment		
		R5	People management		
		R6	Technical failure management	R6.1	Design
				R6.2	Manufacture
				R6.3	Maintenance
				R6.4	Operation
O	Organisational Influence	O1	Safety management processes		
		O2	Organisational characteristics		
		O3	Regulatory influences		
		O4	Other external influences		

APPENDIX B: LIST OF AUSTRALIAN OCCURRENCES

ATSB reference number	Performance parameter	Error action	Device	Consequence	Aircraft damage	Occupant injuries
200202486	V speed/s	Entered incorrectly	Flight management computer	Reduced take-off performance	Nil	Nil
200205710	Zero fuel weight	Wrong figure used	Aircraft communications addressing and reporting system	Identified prior to takeoff	Nil	Nil
200301351	V speed/s	Not updated	Flight management computer	Nil	Nil	Nil
200702657	V speed/s	Incorrect manual	Documentation	Nil	Nil	Nil
200706051	Unknown	Not checked	Unknown	Nil	Nil	Nil
200707509	Flex temperature	Wrong figure used	Multipurpose control and display unit	TO/GA thrust applied	Nil	Nil
200802068	V speed/s	Entered incorrectly	Take-off data card	TO/GA thrust applied	Nil	Nil
200806012	Zero fuel weight	Not updated	Flight management computer	Reduced take-off performance	Nil	Nil
200806692	Flex temperature	Not updated	Multipurpose control and display unit	Rejected takeoff	Nil	Nil
200808440	V speed/s	Incorrect manual	Documentation	Nil	Nil	Nil
AO-2009-012	Take-off weight	Entered incorrectly	Laptop computer	Tailstrike	Substantial	Nil

APPENDIX C: LIST OF INTERNATIONAL OCCURRENCES

Aircraft registration	Performance parameter	Error action	Device	Consequence	Aircraft damage	Occupant injuries
N52309	Runway details	Not updated	Documentation	Collision with obstacle	Minor	Nil
N505UA	V speed/s	Incorrect manual	Documentation	Tailstrike	Substantial	Nil
N730PL	Take-off weight	Entered incorrectly	Documentation	Collision with obstacle	Destroyed	Minor
OY-KDN	Take-off weight	Wrong figure used	Aircraft communications addressing and reporting system	Tailstrike	Minor	Nil
N3203Y	Fuel on board weight	Not updated	Unknown	Tailstrike	Substantial	Nil
C-GHLM	V speed/s	Entered incorrectly	Multipurpose control and display unit	Tailstrike	Substantial	Nil
ZS-SAJ	Take-off weight	Wrong figure used	Handheld performance computer	Tailstrike	Minor	Nil
9V-SMT	Take-off weight	Entered incorrectly	Takeoff data card	Tailstrike	Substantial	Nil
OY-KBK	Take-off weight	Wrong figure used	Laptop computer	Reduced take-off performance	Nil	Nil
JA8191	Take-off weight	Wrong figure used	Documentation	Tailstrike	Substantial	Nil
F-GLZR	Take-off weight	Wrong figure used	Aircraft communications addressing and reporting system	Tailstrike	Minor	Nil

Aircraft registration	Error category	Performance parameter	Error action	Device	Consequence	Aircraft damage	Occupant injuries
9G-MKJ	Calculation	Take-off weight	Wrong figure used	Laptop computer	Collision with terrain	Destroyed	Fatal
LN-RKF	Data entry	Take-off weight	Wrong figure used	Aircraft communications addressing and reporting system	Tailstrike	Substantial	Nil
C-FHIU	Data entry	Fuel on board weight	Wrong figure used	Laptop computer	Reduced take-off performance	Nil	Nil
F-HLOV	Calculation	Take-off weight	Wrong figure used	Laptop computer	Tailstrike	Minor	Nil
F-GLZP	Data entry	V speed/s	Entered incorrectly	Unknown	Reduced take-off performance	Nil	Nil
HZ-AIT	Calculation	Take-off weight	Wrong figure used	Documentation	Collision with obstacle	Nil	Nil
OE-LRW	Calculation	Take-off weight	Data excluded	Documentation	Collision with obstacle	Nil	Nil
G-OJMC	Unknown	Take-off weight	Unknown	Unknown	Reduced take-off performance	Nil	Nil
G-OOAN	Data entry	Take-off weight	Wrong figure used	Laptop computer	Tailstrike	Minor	Nil

APPENDIX D: ADDITIONAL OCCURRENCES

Subsequent to the accidents and incidents detailed in Chapter 4, the following occurrences were also identified, but are outside the reporting period of 1 January 1989 to 30 June 2009, or relate to a different phase of flight.

Boeing 747: July 1971 (N747PA)

On 30 July 1971, a Boeing 747 aircraft, registered N747PA, collided with the runway 19L approach light system structure while taking off from San Francisco International Airport, United States (US).

The investigation determined that the initial pre-flight preparations for the flight were based on a departure from a closed runway. When a change to an active runway was made, the takeoff reference speeds were not re-calculated for the existing conditions. Other factors identified included:

- the airport conditions were not checked prior to the pre-flight planning
- the performance manual calculations for runway 01R were based on the full runway length
- the takeoff reference speeds were set on the air speed indicator bugs for a takeoff on runway 28L
- the closure of runway 28L and partial closure of runway 01R were not included in the Notice to Airmen

Lockheed L1011: May 1998

In preparation for landing, the crew inadvertently transferred the passenger weight in kilograms onto the load sheet, which required the weight in pounds. The error was not detected and the landing reference speed (V_{Ref}) was based on a weight 21,985 lbs less than the actual landing weight. During the landing, the rate of descent in the flare did not reduce as expected. The pilot flying increased the aircraft's pitch attitude to about 13 degrees. The aircraft landed with a steep nose up attitude and the tail made contact with the runway.

McDonnell Douglas MD-11: November 1998 (N801DE)

On 11 November 1998, a McDonnell Douglas MD-11 aircraft, registered N801DE, was being operated on a scheduled passenger service from Cincinnati to Portland, US. During the landing on runway 10R at Portland, the aircraft sustained a tailstrike. None of the 11 crew members or 113 passengers was injured.

A subsequent investigation determined that the weight entered into the flight management system during the approach and landing sequence was 100,000 lbs less than the aircraft's actual landing weight of 392,000 lbs. The exact nature of the error was not determined, however, it was likely that the crew either incorrectly transcribed the takeoff gross weight, or entered the empty weight into the zero fuel weight prompt, or entered the zero fuel weight into the takeoff gross weight prompt. As a result, a final approach speed of 136 kts was used, instead of 151 kts.

Boeing 777-300: September 2009

Just prior to the scheduled boarding time, the aircraft was repositioned, resulting in a delay. During pre-flight preparations, the crew were discussing a minimum equipment list (MEL) item in the passenger cabin, which led to a number of interruptions. The crew were also notified of a last minute change relating to the cargo, requiring re-calculation of the take-off performance parameters. The crew attempted to call dispatch over the radio; however, they were unable to make contact due to frequency congestion. The pre-flight preparations were continued, but an incomplete takeoff briefing was given and the takeoff reference speeds were not cross-checked. During the takeoff, the aircraft was rotated at V_R ; the tailskid made contact with the runway. The V speeds were calculated based on the ZFW instead of the actual TOW. The ZFW was about 100 tonnes less than the TOW.

Airbus A340: December 2009 (G-VYOU)

In preparation for flight, the crew received a late change to the ZFW and subsequently requested a new flight plan. This resulted in the loadsheet and performance procedure being completed out of sequence. The crew received the amended loadsheet and entered the expected landing weight of 236.0 tonnes into the TODC instead of the actual TOW of 322.5 tonnes. This data was sent via the ACARS to a central computer where the take-off performance calculations were made and returned to the crew. The resultant V speeds were entered into the FMGS, along with the correct ZFW and fuel on board. The crew noticed that the FLEX temperature provided was unusually high, but this did not prompt them to check the TODC. During the takeoff, the pilot flying noted that the aircraft's acceleration was slightly lower than normal and the rotation was slightly sluggish and nose heavy. After rotation, the aircraft settled at the V_{LS} speed, which prompted the pilot flying to reduce the pitch attitude. The rate of climb was also low, between 500 and 600 feet per minute. Take-off/go-around thrust was not applied. During the climb, the crew referenced the TODC and realised the error.

The following factors were identified by the airline:

- The crew entered the expected landing weight into the TODC instead of the TOW.
 - The crew were subject to time pressures.
 - The late change to the ZFW disrupted the loadsheet and performance procedure.
 - The landing weight entered into the TODC was similar to the TOW of an Airbus A340-300, which the crew also flew.
 - The airline's procedures stipulated that the crew make an initial TODC request using the estimated TOW. The preliminary data received from this request was not entered into the FMGS. On receipt of the final loadsheet, the actual TOW would be checked against the estimated TOW. If the difference was within the prescribed limits, the TODC data initially requested would be considered valid and entered into the FMGS.
- Due to the change in the ZFW, the crew elected not to calculate an estimated TOW for an initial TODC request. They used the actual TOW obtained from the loadsheet.

- As there was no TODC request from the crew using an estimated TOW, a gross error check could not be made against the TOW on the loadsheet.

