FORUM

Air Safety Through Investigation

OCTOBER-DECEMBER 2020

Journal of the International Society of Air Safety Investigators

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A Boeing 737-800 with 179 passengers and six crew on board took off from Belfast, Ireland, for Corfu with an incorrect thrust set and struck the center approach light for the reciprocal runway. The damaged light was situated 29 meters beyond the end of the takeoff runway. The crew realized as the aircraft's speed approached V_r during the takeoff roll that they weren't accelerating as expected but didn't recognize the reason for the shortfall in aircraft performance (see page 8).

FORUM

ISASI

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AIR SAFETY INVESTIGATORS

INCORPORATED AUGUST 31, 1964

PRESIDENT'S VIEW

INDUSTRY AND ISASI UPDATE

> "I AM SORRY WE COULD NOT BE TOGETHER THIS YEAR, BUT WE MUST STAY CONNECTED TO ONE ANOTHER MORE THAN EVER NOW TO KEEP AVIATION SAFE."

My quarterly "President's View" is based on a video published on the ISASI website in late September. I hope this message finds all of you well and staying as safe as possible as we are living in a challenging time. Our lives have been totally changed by a pandemic spread around the world. We will get through this. I believe, however, that it will be several years before we get back to what we call "normal." The COVID-19 pandemic has taken its toll on the aviation industry at an unprecedented scale. No country is immune from its effects.

The one area of positive news within the industry is the success of cargo operations. As passenger flights have plummeted, cargo still needs to be moved—and all-cargo operations have in some cases seen significant increases in operations. The industry has also seen passenger carriers turn to all-cargo operations with their passenger aircraft.

With all the changes to the industry, proactive, voluntary safety programs have become essential. Operators are not able to rely on past data to inform current operations about the new risks that the industry is experiencing. From increased duty days to changes in training to reduced flying for crews, these safety programs are critical to identifying and mitigating risks.

Reports indicate that there are 16,000 to 30,000 aircraft parked in storage. Air safety through investigation is perhaps even more important now to ensure that stored aircraft are properly cared for, and when they are recertified and returned to service that they are safe to fly.

If world events had been different, we would have had ISASI 2020 in Montréal, Québec, Canada. As you know, our international seminar has been moved to next year. Barbara Dunn and her planning committee are preparing for the 2021 seminar. More information will be available on the ISASI 2021 website.

Our international officer election is complete, and I am happy to announce that Rob Carter from the UK is the new ISASI vice president. Your other executive officials who all stood for reelection will serve another two-year term. Caj Frostell was reelected as international councilor. Steve Dempko was elected president of the U.S. Society. The new officers assumed their duties as of October 1.

I wish to extend my sincere appreciation to Ron Schleede who served as our ISASI vice president for 16 years. He was extremely active in the organization and a true asset to me. I cannot thank Ron enough for all he has done for ISASI. He was instrumental in our seminar sponsorships as well as participating in many projects over the years. Ron will continue to serve as ISASI's representative at the International Civil Aviation Organization and is the Membership Committee chairman.

Ralph Sorrells is the recipient of the Jerome F. Lederer Award for 2020. Ralph recently retired from Mitsubishi where he worked for 39 years and accomplished 39 accident investigations. The award will be presented at the Montréal seminar along with the 2021 winner. I previously announced that we are working on a new electronic membership application. A working group has been formed, led by John Guselli from Australia, and the group is actively developing all features associated with the new form.

Your Society is sound and fully operational. The absence of the 2020 seminar was a financial loss this year of approximately $60,000. We do have sufficient financial reserves to cover the loss. More than 200 ISASI members and 22 corporate members owe dues to the Society. Your dues are needed to reduce our overall loss. ISASI currently has 1,053 active members and 102 corporate members. In addition, we have 124 nondues–paying members (95 life members). The pandemic does not appear to have adversely affected adding new members. Since January 1, 96 new members have joined the Society, with 71 joining since March 1. Perhaps you know of an air safety colleague who would like to join the Society if you asked. In addition, three new corporate members joined this year.

I am sorry we could not be together this year, but we must stay connected to one another more than ever now to keep aviation safe. I pray that you and your families all stay safe and are healthy. ◆

Frank Del Gandio
ISASI President

UNSTABILIZED TAKEOFF TECHNIQUES ON THE A340-300

By Vincent Ecalle, Senior Air Safety Investigator, Bureau d'Enquêtes et d'Analyses (BEA) pour la Sécurité de l'Aviation, France

(Adapted with permission from the author's technical paper Unstabilized Takeoff Techniques on A340-300 *presented during ISASI 2019, Sept. 3–5, 2019, in The Hague, the Netherlands. The theme for ISASI 2019 was "Future Safety: Has the Past Become Irrelevant?" The full presentation can be found on the ISASI website at www.isasi.org in the Library tab under Technical Presentations.—Editor)*

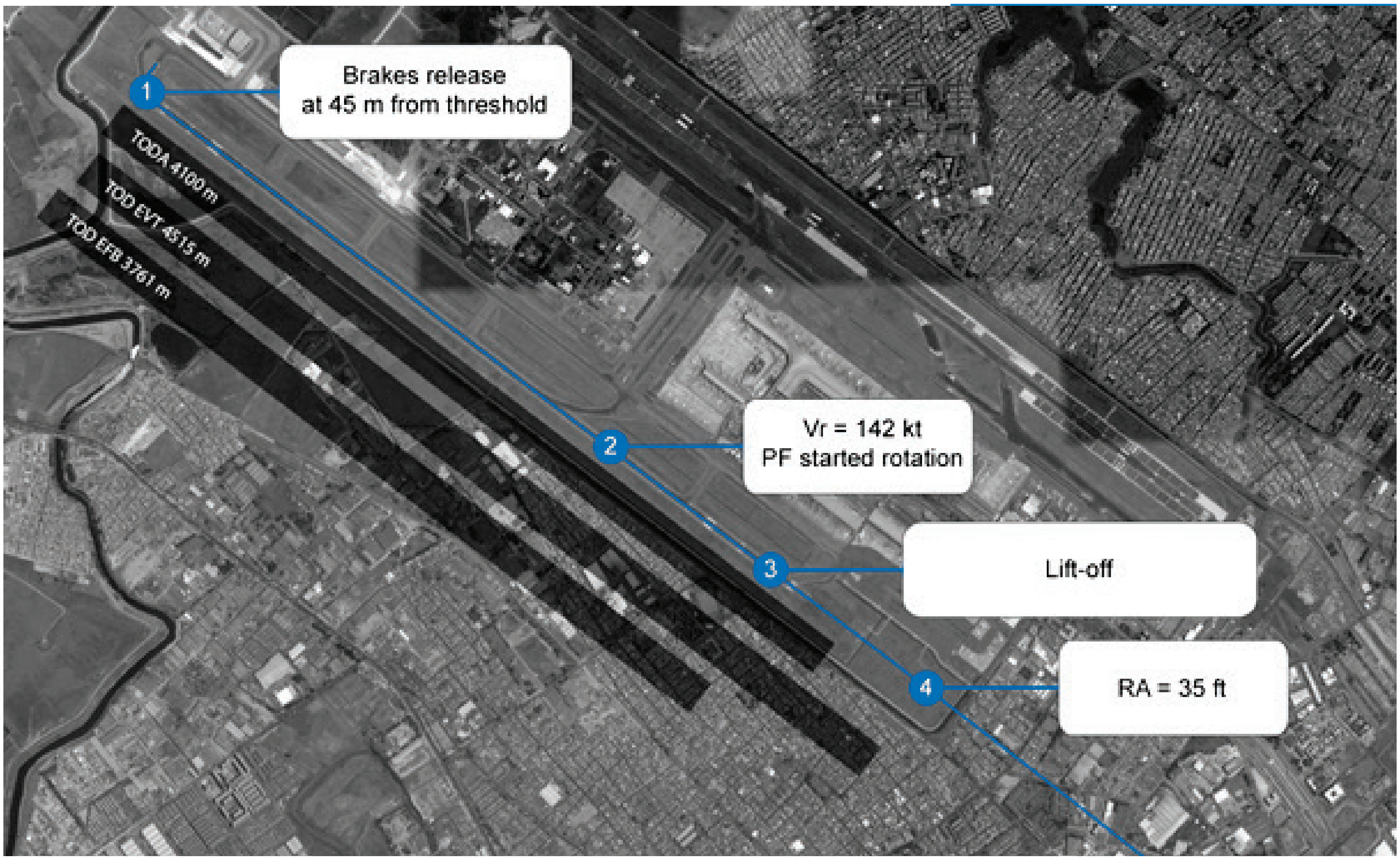


Figure 1. Takeoff distances.

This paper puts into perspective a systemic investigation related to the phase of flight rotation during the takeoff run, which has not been as well documented in terms of safety prevention as other phases, particularly unstabilized approaches.

This investigation focused on risk management and the exploitation of operational data in anticipation of future big data projects such as Data4Safety. It has identified a number of safety concerns and an acceptance of risk that has drifted with time to an unsafe area. It led to seven safety recommendations on the certification of takeoff performance, risk management related to long takeoff runs, and flight data monitoring (FDM) programs.

New investigation techniques were used by including airlines in better identifying and assessing risks that had been underestimated for several years. The in-depth investigation of serious incidents, thanks to the efficiency of Annex 13 and Regulation (EU) No. 996/2010, underlines the proactive safety mission of safety investigation authorities.

Flight AF423 Serious Incident

This serious incident occurred on March 11, 2017, to an Airbus A340-300 operated by Air France-KLM (Flight AF423) during takeoff from El Dorado International Airport in Bogota, Colombia. It was a scheduled flight to Charles de Gaulle Airport in Paris, France, with 268 passengers and 13 crewmembers on board. The takeoff was conducted at night on Runway 13R with a length of 3,800 meters and a clearway extension of 300 meters. When the captain initiated rotation at V_r, the aircraft had already rolled 2,760 meters from the Runway 13R threshold. The rotation rate of the aircraft was low, and all three crewmembers reported hearing the "Pitch, Pitch" audio alarm. When the main landing gear lifted off, the aircraft was only 140 meters from the opposite runway threshold. The aircraft overflew the opposite runway threshold at a radio altimeter height of 6 feet and only had a 12-foot margin with the first obstacle (the ILS antennas).

In accordance with ICAO Annex 13 standards and recommended practices, the GRIAA (Grupo de Investigación de Accidentes, Colombia) delegated the investigation of this serious incident to the BEA and appointed an accredited representative.

Pilot's inadequate rotation technique?

The investigation showed that the serious incident resulted from the pilot's inadequate rotation technique that extended the takeoff distance by 424 meters from the certified theoretical takeoff distance, which included the regulatory safety margins under the operational conditions of the day. This had resulted in a significant increase in the risk of longitudinal runway departure or collision with obstacles.

The investigation showed that had the pilot applied the initial nose-up command typical value recommended by the flight crew training manual (FCTM) (two-thirds rear deflection) and maintained it, it would have been not sufficient to achieve the rotation rate of 3 degrees mentioned in the same document, which was the rotation rate used in the certified performance model.

Due to the absence of crew reports and the lack of takeoff performance monitoring during flight data analysis, the difference between the rotation rates in operations and those taken into account in performance calculations had not been identified by Airbus A340-300 operators.

To better study these discrepancies between certified data and operational data, the investigation exploited FDM data with the support of the A340 operators operating in Bogota, namely Air France and Lufthansa.

To access these valuable records, the BEA had included in this safety investigation the BFU, which appointed an accredited representative supported by Lufthansa's technical advisers, as well as the CIAIAC (Spain), which appointed an accredited representative who was supported by Iberia's technical advisers. The BEA also involved technical advisers from EASA, DGAC, Airbus, and Air France.

FDM study on average rotation rates

For this investigation, Air France and Lufthansa conducted an FDM study on the average rotation rates of their crews from flight data representing about 1,900 takeoffs of Airbus A340-300s from the Bogota airport and about 750 takeoffs from all the airports they serve. They both confirmed a significant difference between the theoretical takeoff performance and those achieved in operation at all airports with similar average rotation rates.

This difference is mainly due to an operational rotation technique resulting in a significantly lower average operating rotation rate than that used in the certified model for calculating aircraft performance. They took safety actions and increased the safety margins for A340-300 takeoffs from airports such as Bogota's El Dorado.

Airbus and EASA also took safety actions during the investigation with regard to the rotation techniques on an A340-300; however, these actions have been deemed as insufficient because they are caught between two risks: a runway overrun/collision with obstacles if the rotation rate is too slow and a tail strike if it is too swift. The industry has dealt with these double-bind risks for years but without addressing them in a holistic manner. The different parties involved in the investigation had a different perception of these risks and their corrective measures. In particular, the BEA focused on improving consistency between takeoff performance in operations, without the use of exceptional piloting capabilities, and the performance data established during certification on the Airbus A340-300.

Certification of Airbus A340-300 takeoff performance

The certification regulations in force when the takeoff performance of the Airbus A340-300 was determined indicated that this performance should be obtained without requiring the use of exceptional piloting techniques or vigilance. The principle of these requirements was, and continues to be, to establish a performance that is representative of what can be reasonably reached in service by crews of average skill.

It must also be possible for the procedures to be consistently executed in service and include allowances for any time delays in their execution. With respect to the takeoff performance, these requirements prohibit higher control force inputs or higher pitch rates than would occur in operational service from being used and that could generate unrealistic takeoff distances.

The fundamental principle of "performance representative of that which can reasonably be expected to be achieved in operational service" can therefore be called into question in the precise case of the A340-300 takeoff performance. In the test flights carried out during the certification campaign and the calculations carried out in retrospect in the conditions of the event, a nose-up input with an unusually high deflection is required to obtain the certified performance.

This nose-up input was significantly different from the "typical" technique mentioned in the A340 FCTM at the time of the event, although the application of the "typical" techniques mentioned in the FCTMs of other airplanes of the Airbus family allowed the certified performance to be reached.

In March 2018, Airbus modified the A340 FCTM and then those of other aircraft types. This revision mentions the rotation rate to be obtained to comply with the certified performance (3 degrees per second) and recommends that crews comply with a four to five second interval between the initial nose-up input and liftoff. Information about the piloting technique to reach the certified performance in a safe and repeatable way is no longer provided. In particular, no information is provided about the "typical" initial input to be applied to reach the expected rotation rate, although the investigation has shown that

Vincent Ecalle

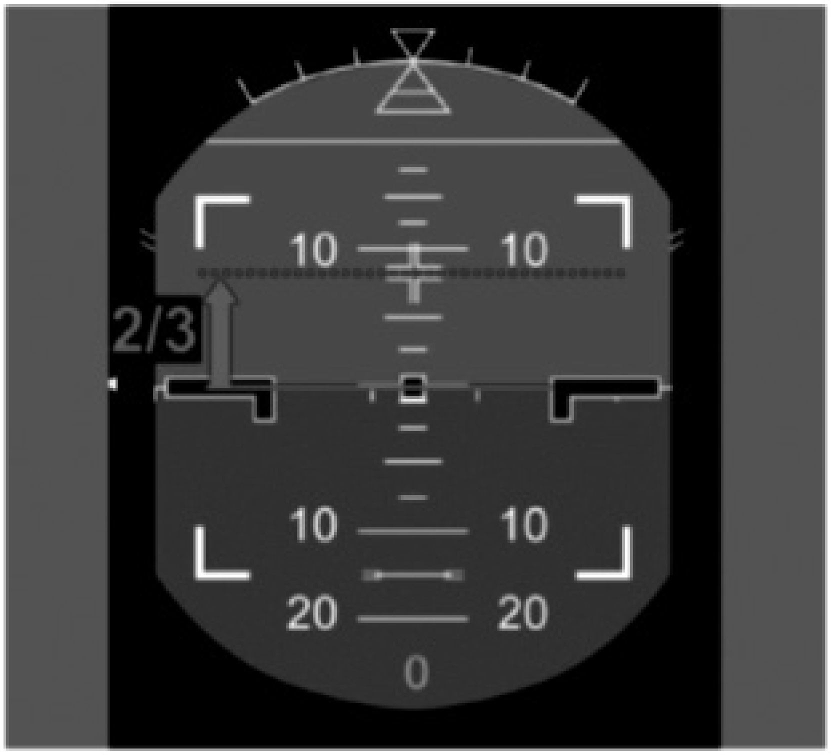
ROTATION

Ident.: PR-NP-SOP-120-00019529.0001001 / 20 MAR 17
Applicable to: ALL

INITIAL STICK INPUT CALIBRATION IN TRAINING

In training, during taxi, the crew may calibrate the appropriate effort and displacement for the initial stick input for rotation (2/3 back-stick), by pulling aft on the stick and observing the position of the stick cross symbol on the PFD, compared to the stick position reference square.

Side Stick Input Calibration During Taxi



Note: *the cross is not to be used by PF during the takeoff, whereas the PM can check the validity of the PF initial stick input.*

Figure 2. Extract of the flight crew training manual—standard operating procedures, takeoff.

the nose-up input to be applied is of an unusually high amplitude with respect to other aircraft.

Consequently, it is up to operators to set up the necessary training actions to reach this objective. The effect of a variability of 2 to 3 degrees per second has also been requantified: what was initially a minimal impact is now assessed as a lengthening of the takeoff distance by 300 meters. This infers an increased appreciation of the inevitable variability in the rotation technique in operation, which had not been considered at the time of the certification.

With respect to this variability in service, the two operators associated with the investigation chose to not require their crews to strictly comply with a rotation rate of 3 degrees per second due to the amplitude of the deflection required, which could lead to a greater tail strike risk and to a difficulty in consistently executing the required action, whatever the flight conditions.

Airbus underlined that the additional protections (feedforward order and electronic tail bumper) introduced in 2008 limit this risk and facilitate the "systematic" execution of a takeoff reaching the certified performance.

The differences observed between the certified takeoff performance and that reached in operation require clear communication about the type of change to be made if a piloting technique different from the current common practice was to be selected. Consequently, the BEA recommends that EASA, in coordination with Airbus,

- reexamine the validity of the initial certification hypotheses of the A340-300 takeoff performance,
- take the necessary measures to reestablish consistency between the takeoff performance in operation and that established during certification on the Airbus A340-300,
- examine, with the other primary certification authorities, whether other CS-25 type aircraft are affected by this type of difference in performance and take the corrective measures that may be necessary, and
- manage risks related to long take-

- offs: diminution in the variability of the crews' rotation technique and adoption of restrictive measures.

The safety information bulletin published by EASA in November 2017 sets out the need for each operator to identify, assess, and take the appropriate measures to limit the risk associated with a long takeoff. Operators and training organizations are recommended to implement specific training about the rotation technique while taking into account the introduction of additional risks such as the tail strike.

Air France has set up specific training designed to inform pilots of the risks linked to a slow rotation rate and to train them to apply an initial input of at least two-thirds of the deflection. This measure has resulted in a reduction in the observed variability in the pilots' rotation technique and permits an average continuous rotation rate in operation of around 2.2 degrees per second to be reached.

Additional safety measures taken by Air France and Lufthansa—in particular, the fictitious reduction of runway lengths—have restored sufficient takeoff distance margins to the detriment, however, of the payload to take into account a continuous rotation rate objective in operation that is different from that retained during the A340-300 certification. These measures have proven their effectiveness when they aim to systematize a crew practice.

However, not all Airbus A340-300 operators have necessarily measured the impact of the variability in their crews' rotation technique on their risk management of long takeoffs. Consequently, the BEA recommends that pending measures taken to reestablish consistency between the performance reached in operation and that established by the certification, EASA, in coordination with national oversight authorities, require those operating the A340-300 to set up safety measures to

- reduce the observed variability in the pilots' rotation technique and
- restore sufficient takeoff distance margins by comparing the possible difference between the takeoff performance reached in operations and that established during certification.

Authorities use of flight analysis data

The significant number of years that have elapsed between the entry into service of the A340-300 and the identification of the difference between the certified takeoff performance and that reached in operational situations shows that operators and manufacturer were not fully aware of the impact of this difference on operation safety before the serious incident of March 11, 2017. Yet the European Operator Flight Data Monitoring Working Group that EASA established to facilitate the control of FDM implementation by operators and to help them optimize their use of FDM for safety benefits recommended from 2012 that operators set up monitoring of simple parameters to detect long takeoffs. The investigation showed the importance for an authority to have flight data information available based on the shared analysis of a significant number of flights performed by several operators.

Consequently, the BEA recommends that EASA in coordination with the national oversight authorities

- ensure that European operators introduce in their flight analysis program the indicators required to monitor takeoff performance and at the very least long takeoffs and
- collect and analyze the results of this monitoring in order to produce a report on the actual situation in operations.

Conclusions

This systemic investigation has explored the usage of big data to better understand the operational drift as well as an erroneous perception of risks that had developed along the years within the industry. It has showed a need to improve the exploitation of reporting systems to enhance the detection of these drifts. The use of certification performance data versus operational data was also a key factor, especially when the operators are faced with the double-bind risks during the takeoff run: runway overrun/collision with obstacles versus tail strike. For safer operations, they ended up reducing their payload to increase their safety margins in addition to the existing regulatory requirements, which were deemed inadequate for several airports such as Bogota's El Dorado.

In relation with the theme "Future Safety: Has the Past Become Irrelevant?" the robust "traditional" Annex 13 methods that put emphasis on participation and cooperation by including other states and airlines in the investigation have proven to be very effective to unearth these latent safety issues that had not been detected by big data tools. In this case, past and unchallenged decisions had an impact on safety management. The relevant investigation good/best practices enshrined in Annex 13 and Regulation (EU) No. 996/2010 have promoted the analysis of systemic issues by bridging the silos that had prevented their identification. To improve future safety, an independent process that brings together the key safety actors remains a relevant approach. ◆

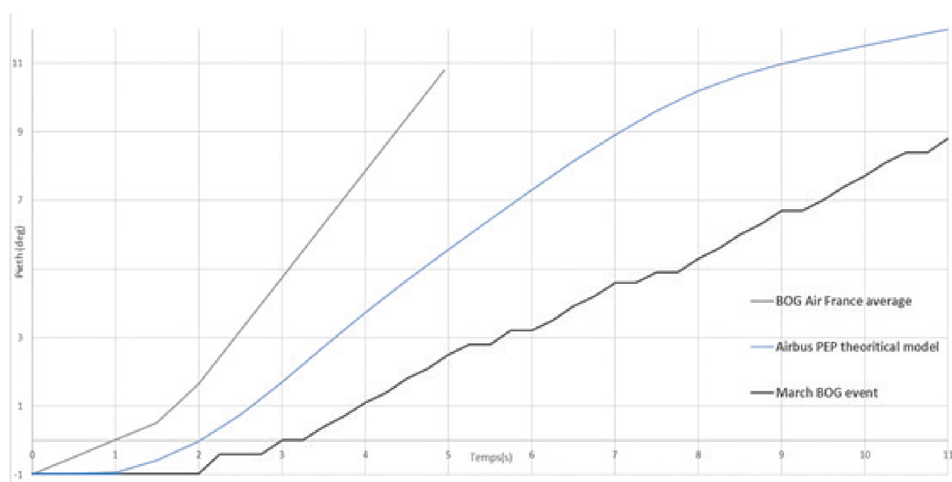


Figure 3. Air France curves.

Figure 1. The damaged approach light.

Erroneous Takeoff Performance

By Steve Hoare, Senior Inspector of Air Accidents, United Kingdom Air Accidents Investigation Branch and Member of the Royal Aeronautical Society

(Adapted with permission from the author's technical paper Erroneous Takeoff Performance: Why the Past Is Still Highly Relevant Today *presented during ISASI 2019, Sept. 3–5, 2019, in The Hague, the Netherlands. The theme for ISASI 2019 was "Future Safety: Has the Past Become Irrelevant?" The full presentation can be found on the ISASI website at www.isasi.org in the Library tab under Technical Presentations.—Editor)*

On July 21, 2017, a Boeing 737-800 with 179 passengers and six crew on board took off from Belfast, Ireland, for Corfu with the incorrect thrust set and struck an approach light for the reciprocal runway. The damaged light was 36 centimeters high and situated 29 meters beyond the end of the takeoff runway, itself 2.6 kilometers long, and ample length for operation of the Boeing.

The crewmembers realized as the aircraft's speed approached V_r during the takeoff roll that they were not accelerating as expected but did not recognize the reason for the shortfall in aircraft performance. After the aircraft became airborne, it climbed away very slowly. It was only when 4 kilometers from the end of the runway that full thrust was applied by the crew.

Although there was no damage to the aircraft, it was the benign nature of the runway clearway, a lack of obstacles in the climbout path, and the absence of significant terrain surrounding the airport that allowed the aircraft to climb away without further collision after it had struck the light. Had an engine failed beyond V_1, the consequences would certainly have been catastrophic with the manufacturer's own modeling confirming a negative climb gradient in this condition.

However, despite the severity and potential consequences of these occurrences, these events continue to occur. A review of notifications received by the AAIB since 2018, representing just one state investigation agency within Europe, includes six reports from commercial carriers in which erroneous data had been used for takeoff; three of these events happened in the first half of 2019.

It is likely that these numbers underestimate the true scale of the issue, especially when the performance degradation is subtle, or when erroneous data leads to an increase in performance because the occurrence may go unnoticed. And, even if it is noted, not all cases are reported.

In the July 2017 occurrence, there were multiple barriers intended to prevent erroneous data from being used at takeoff—such as standard operating procedures (SOPs), which included the cross-checking of data—but these were procedural, human-based barriers that ultimately proved ineffective.

Past takeoff performance events, such as the loss of MK Airlines Flight 1602, provide further evidence of the fragility of human-performed cross-checks and SOPs. These events prove "why the past is still highly relevant today" because, despite rapid advancements in technology and an idea that was first contemplated in the 1970s, for a technological solution to monitor takeoff acceleration, we are still predominantly reliant on humans to identify data entry errors.

However, as technology has evolved in recent years, the AAIB has repeatedly called for a technological solution to monitor takeoff acceleration.

This paper therefore briefly explores the cause of the July 2017 event, discusses the barriers that were intended to pick up on the erroneous data entry, and covers other events in which similar barriers have failed to detect erroneous entries before summarizing a basic takeoff acceleration monitoring system and the effect this would have had on the July 2017 event.

The July 21, 2017, event

The AAIB investigation found that a thrust setting of approximately 81.5 percent N_1 was used for takeoff instead of the correct setting of 92.7 percent N_1.

This was because an extremely low outside air temperature (OAT) had been entered into the flight management computer (FMC) instead of the actual OAT of 16°C. Another entry used by the FMC to

Figure 2. The takeoff roll, showing groundspeeds and the estimated point where V_1 and V_r were attained, and initial climb.

Figure 3. The remains of the main fuselage and No. 4 engine from MK Airlines Flight 1602.

optimize the flight profile is the ambient temperature at the top of climb, and the investigation believes that this figure was mistakenly entered from the flight plan.

The FMC uses the OAT to calculate the value of N_1, which will produce the engine's rated thrust. Given a lower OAT, the engine will require a lower value of N_1 to achieve the engine's rated thrust. Therefore, by entering an incorrect and abnormally low OAT, the FMC calculated a value of N_1 that was significantly below that expected for the environmental conditions on July 21, 2017.

A company engineer, who was on the aircraft's flight deck jumpseat, took this photo, right, prior to the aircraft leaving the stand at Belfast.

This shows a target N_1 of 88.2 percent (text at the top of the engine gauges) prior to the application of any engine derate, which could only be achieved by the OAT entry shown in the FMC photo.

However, this does not fully explain how an N_1 of 81.5 percent was used for the takeoff. One way on the Boeing 737-800 of reducing the takeoff thrust to the minimum required for takeoff, which is common airline practice used to conserve engine life and reduce maintenance costs, is to enter a higher than ambient temperature called an assumed temperature into the SEL (SELected temperature) field of the FMC. The assumed temperature method, as it is known, was regularly used by this airline, and the crew having correctly calculated this temperature entered it into the FMC—which resulted in the target N_1 changing to 81.5 percent for the takeoff.

SOPs and cross-checks as barriers?

The crewmembers, who had both been off duty the day before the flight, said that they were well rested and had only completed two hours and 26 minutes of duty time at the time of departure. Both pilots had also worked together before and knew each other.

The pilots were required to use their own electronic flight bag (EFB), having obtained the latest airport weather, to calculate takeoff reference speeds and the assumed temperature for setting the engine derate. This required the crew to enter an OAT, along with aircraft and other environmental data.

This was performed twice, as the aircraft returned to stand for a nosewheel change as damage was noticed during the first pushback, and during this time the OAT had changed. However, a review of the crew's EFBs showed that both sets of calculations were completed correctly.

It is worth stating here that the calculation performed after the nosewheel had been changed was because of a 1°C change in OAT, which had a negligible effect on the aircraft's performance, but nevertheless increased the opportunity to make an error. In aviation, the use of SOPs that lay down the exact procedure, and even the phraseology to be used, are designed to reduce the chance of making errors, but they cannot cover all eventualities as this example shows.

The EFB values were then transposed into the FMC and cross-checked, a process embedded within an SOP designed to trap errors that have already been made. But neither crewmember noticed that the OAT was incorrect either the first time that the aircraft left the stand or the second time after the nosewheel change. This is possibly because the Canadian crewmembers, who regularly operated in

Figure 4. The cockpit before first leaving the stand.

the cold Canadian winters, were used to seeing low OATs and low N_1 targets on the FMC and engine gauges.

Another serious incident recently investigated by the Japanese Transport Safety Board illustrates a case where predisposition also played a part. This example involved the crew of a Boeing 747-800 freighter that was expecting a departure from Runway 16R in Tokyo, Japan. This was largely because of the much shorter taxi route from where the aircraft was positioned to Runway 16R, than to Runway 16L, but also because of an airport operational policy that stipulated Runway 16R would normally be in use at the time of departure. In this incident, the commander thought that, even if clearance was given to depart from Runway 16L, the lengthy taxi route would give the crew time to reprogram the FMC correctly. However, when the clearance to depart from Runway 16L was given, the lengthy taxi, which was also somewhat more complicated than anticipated, meant that the crewmembers performed their cross-checks. But both pilots failed to notice that, although the departure runway was changed in the FMC, the original engine derate remained selected. The result was that the aircraft passed the end of the runway at 16 feet, and the aircraft's jet blast disabled an airport intrusion detection sensor situated some 450 meters south of the airport. An N_1 of 89.1 percent had been used rather than the required N_1 of 97.2 percent.

Another event reported to the AAIB in 2019 relates to the incorrect selection of departure runway in the FMC, but in this case the incorrect selection was also used for performance planning purposes. However, the selection of FMC departure runway was for a shorter runway than actually used for the departure, which resulted in an increase in takeoff performance. Another operator had also reported a similar error that had been made, involving the same aircraft type, only a few months earlier. In both cases, SOPs and cross-checks designed to detect such anomalies failed to mitigate the error.

A factor that hinders the cross-checking process is significant differences between the presentation of information—whether these are on computer displays or on paper such as a loadsheet. In the AAIB investigation into the July 2017 event, it was established that the layout of the entry page for engine derate information on the FMC (see Figure 5) bears little similarity to the layout of the EFB calculation results page (see Figure 6, page 12). Not only does this hinder any cross-check, but also the transposition of data from one presentation to another.

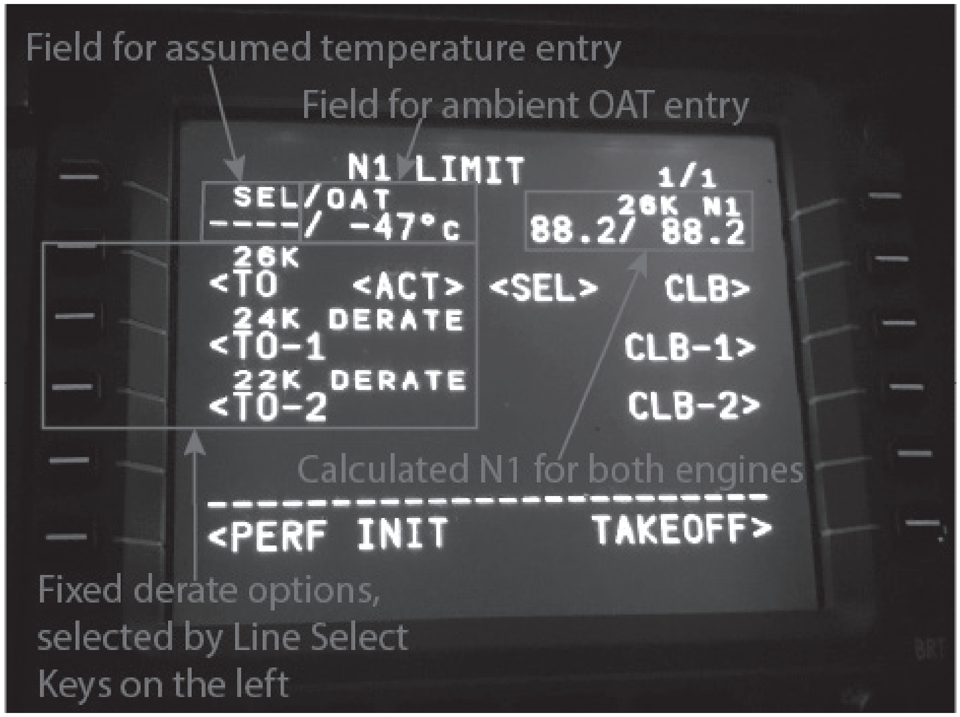


Figure 5. The FMC engine derate page.

For instance, the OAT, pertinent information on which the engines' thrust is based and a required entry on the FMC page, is absent from the EFB results page but instead is entered on a previous screen no longer visible to the crew. The nomenclature used on the EFB also differs from the assumed temperature on the EFB labeled "SEL OAT," whereas on the FMC there are separate fields for the two distinctly different variables "SEL" and "OAT." As all FMC derate data leads to a thrust setting, expressed as an N_1 value and shown on the FMC, one might think that this vital information should be displayed on the EFB, but this is also absent on the results page.

EFBs are not regulated. Instead, approval of an EFB is typically undertaken by the regulator's Flight Operations Department, which, as was the case with the AAIB's investigation, reviews the EFB and the installed applications against its own acceptable means of compliance or advisory circulars—guidance documents, not standards. This document did not define the content or layout of the displayed information—other than that the use of color and entry methods should be consistent—even for safety-critical applications such as weight and balance or performance computations. Instead, it talked about the mounting of an EFB, connections to the aircraft, and the need not to interfere with other aircraft systems.

From all the examples discussed, SOPs and cross-checks as barriers to a takeoff performance event, though generally effective, are often weakened by poor equipment design and rely on well-rested crews and the highest level of attention—even though such checks are carried out many times during a typical duty day.

A technological solution

The loss of a McDonnell Douglas DC-8 in Anchorage, Alaska, in 1970, an accident attributed to braking pressure being applied to the wheels during takeoff, and shortly thereafter a takeoff accident to a Boeing 747 in San Francisco, California, in 1971 that used incorrect takeoff reference speeds significantly raised industry awareness of takeoff performance issues.

During 1971, these events led to the Flight Operations Committee of the Air Transport Association of America to consider the use of existing onboard equipment to assist pilots in judging aircraft acceleration towards V_1. This rationale, incorporating the use of technology, followed on from the DC-8 crash when the U.S. NTSB made a safety recommendation

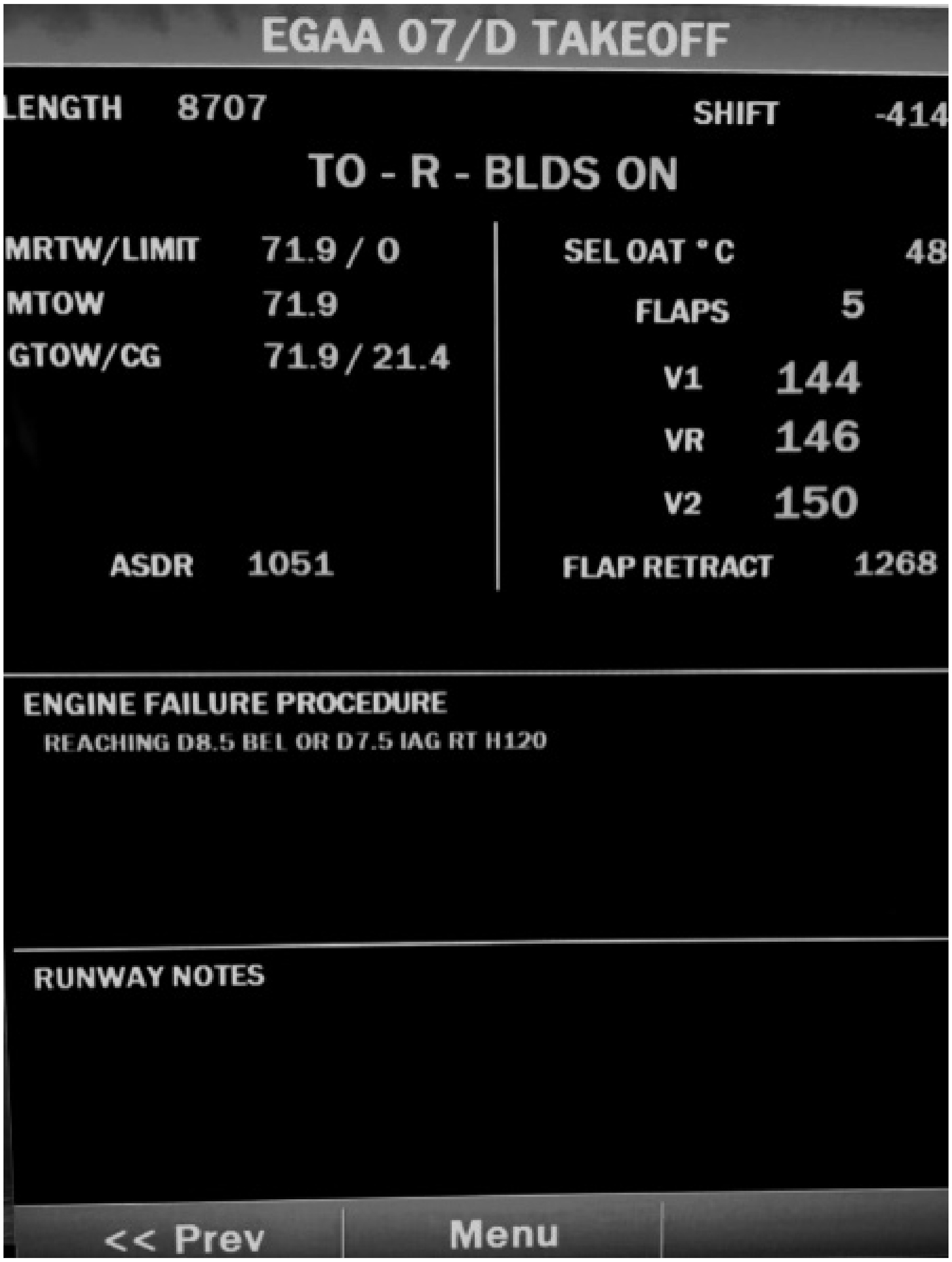


Figure 6. EFB calculation results page.

suggesting that the U.S. FAA "determine and implement takeoff procedures that will provide the flight crew with time of distance reference to appraise the aircraft's acceleration to the V_1 speed."

Fearing the reliability of such a system and the risk of an increased number of high-speed aborted takeoffs, this idea was subsequently discounted until 1982 when a McDonnell Douglas DC-10 crashed in Boston, Massachusetts. The FAA was then requested to "convene an industry-government group that includes the National Aeronautics and Space Administration to define a program for the development of a reliable takeoff acceleration monitoring system."

This was done, resulting in the publication of a technical standard, and several academic and government institutions carried out active research in the area until around 2009. Several promising ideas were tested during this time and generally were met with promising feedback. However, despite first contemplating the use of technology to solve erroneous takeoff performance in 1971, no certified product, other than for some Airbus aircraft, is available today. Yet several state investigation agencies still continue to investigate occurrences that have involved severely compromised takeoff performance, including the crash of MK Airlines Flight 1602.

During the AAIB's investigation into the July 2017 event, an online article was discovered from 2014 that discussed a simple takeoff acceleration monitoring system. The premise of the system was simple: to monitor the aircraft's longitudinal acceleration, once thrust had been set and as the aircraft accelerated, but to warn the crew at a speed well below V_1, where the risk in stopping is low, if the acceleration was less than a predetermined value.

This took advantage of the fact that derated thrust takeoffs have a normalizing effect on the rate of acceleration on takeoff. This is illustrated in the histogram (see Figure 7) showing approximately 73,600 departures for a Boeing 737-800 across a range that covers 93 percent of the aircraft's operating weight and varying climatic conditions.

Across all departures, the data showed a standard deviation in acceleration of only 0.44 knots per second with the median acceleration being 4.1 knots per second. Any skew in acceleration also tended to be in favor of higher accelerations, rather than lower values, meaning any system proposed to detect cases of poor acceleration would benefit. Plotting the same data set but this time against runway length also shows this skew and that a "best fit" line of minimum acceleration required for takeoff could be drawn (see Figure 8).

This confirmed that the minimum acceleration required remained constant for most runway lengths, but an increase was noted as the runway length becomes the limiting factor.

The manufacturer compared the Boeing 737 data with a dataset for the Boeing 777 covering 60,445 departures from 87 worldwide airports to see if these findings would remain true. This data covered airport elevations between sea level and 5,600 feet above sea level, as well as ambient temperatures on takeoff of between -27 and 49°C. The results mirrored the Boeing 737 data, with very low standard deviations in acceleration, further confirming the normalizing effect of derated takeoffs. A second study on Boeing 747 aircraft also reached the same conclusion.

One main advantage of this system is the lack of reliance on any crew-entered data, removing the human fallibility concern regarding SOPs and cross-checks that were noted earlier. However, the biggest advantage of this system is that the software required to perform the acceleration check can be embedded in the aircraft's terrain awareness and warning system, which is required on all large commercial aircraft.

To prove the effect this system would have had on the July 2017 event, the AAIB used a simulator set up with the correct loading, aircraft configuration, and environmental parameters and set an N_1 of 81.5 percent to reflect the actual takeoff conditions. At 75 knots, the system identified that the acceleration was falling below the level of acceleration needed for the length of runway, established from the B-737-800 dataset above, and issued an alert. The takeoff was rejected; and after the simulator had come to a stop, a further 1,670 meters of runway remained ahead—a very different outcome for the same event.

A similar technological solution has also been developed by Airbus, called takeoff monitoring, which is available on later A380s and is under development for the A350. However, the AAIB is not aware of any other aircraft manufacturer that has developed, or is developing, a comparable system.

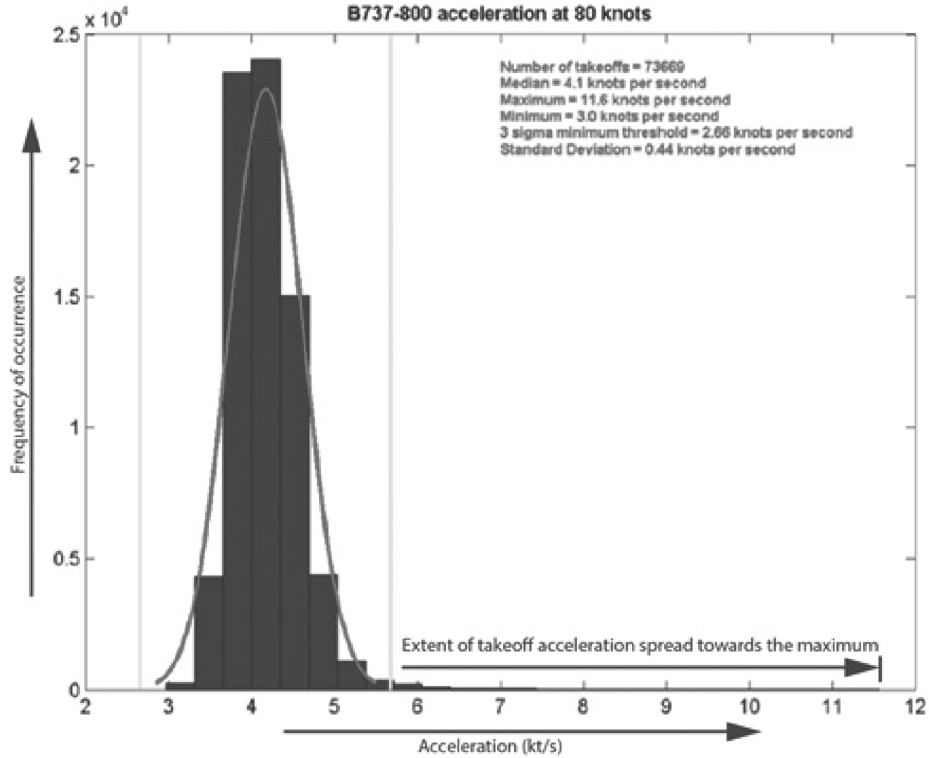


Figure 7. Acceleration histogram of 73,669 Boeing 737-800 departures.

Conclusion

Takeoff performance events continue to occur, as the numbers of notifications to the AAIB alone for this year to date shows. However, the true scale of the problem is hard to establish as cases are not always noticed nor reported. It is likely that these numbers therefore reflect only the tip of the iceberg.

Barriers performed by humans, such as SOPs and cross-checks, are reliant on well-rested crews and the highest level of attention to detail. Often, these barriers are weakened by poor equipment design and a lack of guidance. However, technological solutions already exist or are in active development that could be installed. Further, as this technology can be retrofitted within systems that are already mandated on large commercial aircraft, a greater benefit in safety could be realized.

This is especially true as past events have shown that takeoff performance events are not new and that any strengthening of procedural checks will not necessarily stop these events from reoccurring. A technological solution reliant on minimal, or no, manual data entry could offer a realistic way to identify erroneous takeoff performance and lower this risk. ◆

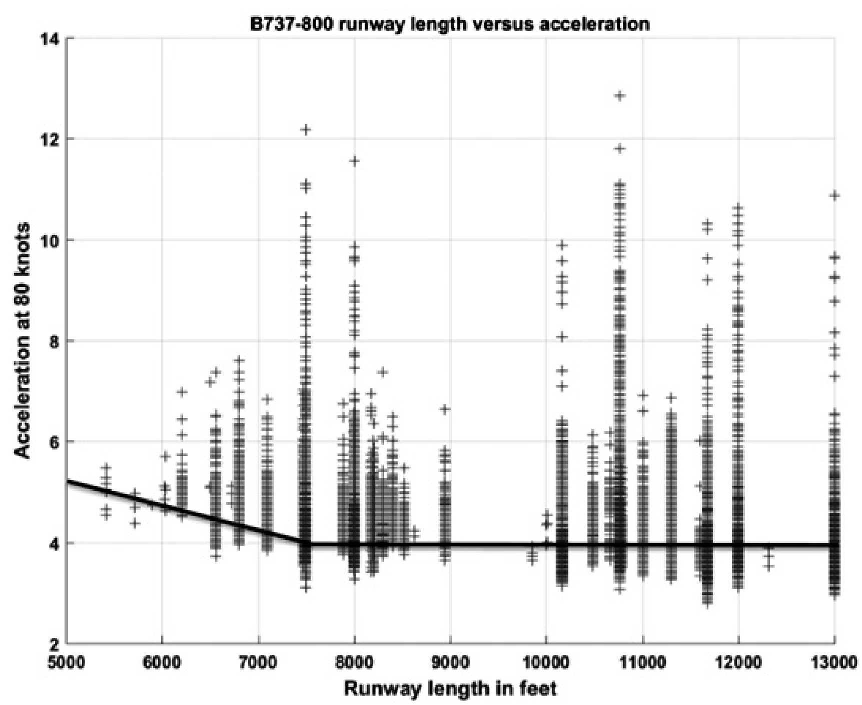


Figure 8. Acceleration rate against runway length for 73,669 Boeing 737-800 departures.

Do We Accept or Can We Avoid: Takeoff Performance Incidents

By Gerard van Es, Aerospace Engineer, Netherlands Aerospace Centre; Martin Nijhof, Flight Safety Investigator, KLM; and Bart Benard, B-747 Captain, Martinair

History

On Nov. 27, 1970, a DC-8-63 operated by Capitol International Airways crashed following an unsuccessful takeoff attempt at Anchorage International Airport. The takeoff was rejected, but the aircraft overran the departure end of the runway and burst into flames. Forty-six passengers and one flight attendant received fatal injuries in the postcrash fire. The accident was caused by the failure of the aircraft to attain the necessary airspeed to lift off during the attempted takeoff due to a lack of acceleration.

In its report on the Capitol crash, the U.S. NTSB recommended, "determine and implement takeoff procedures that will provide the flight crew with time or distance reference to appraise the aircraft's acceleration to the V_1 speed." This recommendation was reiterated in an investigation report involving a Pan Am Boeing 747, which on May 24, 1971, struck the approach lights structure for Runway 19L while taking off from Runway 01R at San Francisco International Airport. The aircraft returned to the airport with only one of its four hydraulic systems left. The accident is best known for its landing and emergency evacuation, during which the aircraft tail tipped, which was captured on film and available on YouTube (nearly 1.9 million views).

Nearly 34 years after the accident at Anchorage, on Oct. 14, 2004, a Boeing 747 freighter collided with an earthen berm supporting an ILS localizer antenna at Halifax International Airport during a failed takeoff attempt. All seven crewmembers were killed, and the aircraft was destroyed. The investigation determined that the aircraft's takeoff speed and thrust setting were too low to enable the aircraft to take off safely for the actual weight of the aircraft. One of the recommendations called for the establishment of a requirement for transport-category aircraft to be equipped with a takeoff performance monitoring system that would provide flight crews with an accurate and timely indication of inadequate takeoff performance. Today, 15 years after the Halifax accident, no operational system exists that can warn the flight crew in the event that takeoff performance is degraded.

Takeoff performance incidents are a special group within takeoff incident and accident occurrences. They are not limited to specific aircraft types or flight operations. They stand out because of the absence of a proper warning system and because the outcome of the majority of these incidents is without damage or loss of life. The outcome of a performance incident can be catastrophic though, but luckily most incidents and accidents have resulted in the airplane just getting airborne before the end of the runway. Even so, the rate of these incidents is alarming; but as the outcome is often without consequence, one might tend to believe that the problem is not that serious.

This paper analyzes the topic of takeoff performance incidents and emphasizes their threat to safety. These incidents therefore require swift action from regulators and the aviation industry. The paper also proposes a practical warning system.

Definition of takeoff performance incidents

Takeoff incidents and accidents take many forms and may be related to improper weight and balance or aircraft configuration (e.g., an improper flap or stabilizer setting). However, within the scope of this article, takeoff performance occurrences are defined as incidents and accidents in which, as a result of a flight crew data input or lack thereof, takeoff is started

- with speeds lower than required (V_1, V_r, and V_2).
- with thrust setting lower than required.
- from an intersection with takeoff data assuming more runway length than is available for that intersection.

Review of incident and accident reports

Tables 1–3, pages 16–18, list 49 incident and accident reports involving erroneous takeoff data. The tables were completed in early July 2019. Reports published after July 15, 2019, have not been included. The reports, spanning the period 1998–2018, have been published by state accident investigation authorities (AIA), and nearly all are available on the Internet. Table 1 lists reports in which the aircraft's takeoff data was calculated for a weight that was significantly lower than the actual takeoff weight (TOW). Table 2 lists reports in which the takeoff thrust setting was lower than required. Table 3 lists reports in which aircraft took off from an intersection with takeoff data assuming more runway length than was available for that intersection.

Although the main focus of the industry is on incidents and accidents of the type listed in Tables 1 and 2, the incidents and accidents listed in Table 3 also have the potential to end in a catastrophic accident.

The reports vary in detail, but the majority provide an accurate account of what happened. The reports listed in Table 1–3 detail a variety of operational consequences:

- Rejected takeoff when abnormal aircraft behavior was sensed during rotation (27).
- Catastrophic accident (20).
- Tail strike during rotation (1, <u>6</u>, 7, <u>10</u>, 12, <u>13</u>, 14, <u>16</u>, 17, <u>19</u>, <u>20</u>, <u>21</u>, <u>23</u>, <u>24</u>, <u>25</u>, <u>26</u>, 27, 28). Damage was substantial for the underlined case numbers. Repair was not deemed economically feasible for case Nos. 6 and 16.
- Many inflight returns following a tail strike.
- Continued pressurized flight with pressure hull damage (7, 40).
- Inflight return due to cabin altitude warning (6).
- Debris on runway that remains operational following a heavy tail strike (with one subsequent aircraft taking off experiencing tire damage) (6).

- APU fire warning following APU damage (24).
- Stick shaker during rotation (6, 10, 14, 16, 24) or initial climb (23).
- Runway overrun (13, 30, 31, 32, 40, 46).
- Aircraft colliding with localizer antenna structure and/or approach lights structure (13, 30, 31, 40, 46).
- Flap retraction at flap retraction speeds based on the erroneous flight management system weight, providing reduced margins to the stall speed.
- Reduced obstacle clearance during takeoff.

Adverse consequences of erroneous takeoff data were not limited to the takeoff phase but may also manifest themselves during approach and landing:

- Stick shaker activation during approach (9).
- Tail strike during landing (28).

For Table 1, the following factors were involved in more than one occurrence:

- The takeoff data was based on zero fuel weight (ZFW) (1, 2, 6, 8, 14, 16, 17, 19, 23, 25, 27, 28) or landing weight (LW) (10, 11). The weight error ranges from 12 to 42.5 percent of the actual TOW.
- The weight error was 10 tons, 100 tons, or 100,000 pounds (3, 4, 5, 12, 13, 16, 21, 24, 26, 28).
- The takeoff data was calculated by dispatch instead of the flight crew (6, 15, 22).

In nearly all incidents, derated/flexible thrust was used. In only a few incidents thrust was increased when it became apparent that takeoff performance was degraded. None of the incidents/accidents involved a contaminated runway. In several occurrences, the flight crew was unaware that a tail strike occurred.

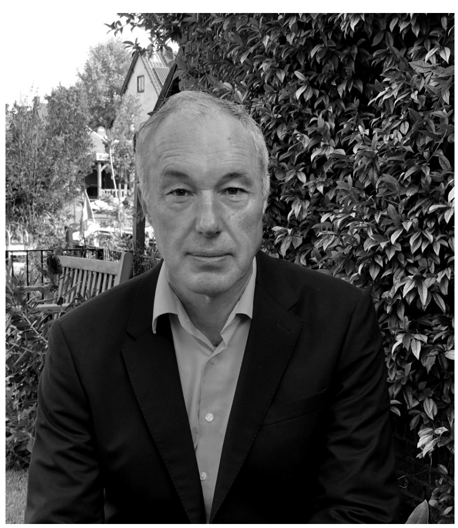
Notes to the tables:

1. All weights mentioned are in metric tons.
2. The following takeoff incidents and accidents were not included in the tables:

- Occurrences in which aircraft acceleration and available runway length were sufficient, but the aircraft was rotated at an improper V_r.
- Occurrences in which a NOTAM was active concerning a runway shortening ahead of the aircraft.
- Takeoffs from the wrong runway.

Gerard van Es

Martin Nijhof



Bart Benard

(Adapted with permission from the authors' technical paper Takeoff Performance Incidents: Do We Accept Them or Can we Avoid Them? *presented during ISASI 2019, Sept. 3–5, 2019, in The Hague, the Netherlands. The theme for ISASI 2019 was "Future Safety: Has the Past Become Irrelevant?" The full presentation can be found on the ISASI website at www.isasi.org in the Library tab under Technical Presentations.—Editor)*

Case No.	Date	Model	Safety Board/ Report No./ Incident or accident	Description
1	28Jul18	Boeing 737-800	AAIB EW/G2018/07/35	• Takeoff data based on ZFW (Δ 12.3 ton / 17.3 % of TOW). • Tail strike causing damage. Aircraft continued to destination.
2	29Mar18	Boeing 787-9	AAII Israel 33/08 Serious Incident	• Takeoff data based on ZFW (Δ 40 ton / 16.6 % of TOW). • Sluggish response upon rotation, takeoff otherwise uneventful.
3	22May15	Boeing 777-200F	BEA F-GUOC report Serious incident	• Takeoff data based on improper weight (Δ 100 ton / 29 % of TOW). • Aircraft took off without further incident.
4	18Sep14	Boeing 737-800	DSB Insufficient thrust setting for takeoff - Serious incident	• Takeoff data based on improper weight (Δ10 ton / 15.9 % of TOW). • Aircraft became airborne 60 m before the runway end.
5	7Jul13	Boeing 777-300	DSB Summary First quarter 2016 - Serious incident	• Takeoff data based on improper weight (Δ 100 ton / 30.4 % of TOW). • Aircraft took off without further incident.
6	16Apr13	Boeing 767-200	CIAIAC A-010/2013 Accident	• Takeoff data based on ZFW (Δ 66.6 ton / 38.8 % of TOW). • Stick shaker activated during rotation. • Fuselage suffered substantial damage and cabin altitude warning activated before aircraft was returned to departure airport. • Aircraft was written off.
7	14Apr12	Boeing 737-300	AAIB EW/C2012/04/03 Accident	• Takeoff data based on TOW previous flight (Δ 6.8 ton / 12.5 % of TOW). • Tail strike, causing damage to pressure hull. Flight continued to destination.
8	29Apr11	Airbus A321	AAIB EW/G2011/04/29 Serious incident	• Takeoff data based on ZFW (Δ 16.9 ton / 19.5 % of TOW). • Takeoff path flight adapted to accelerate, further uneventful.
9	13Oct10	Boeing 717-200	ATSB AO-2010-081 Serious incident	• Takeoff data based on improper weight (Δ 9.4 ton / 20 % of TOW). • Takeoff was uneventful and discrepancy apparently went undetected. Stick shaker activated during approach.
10	4Mar10	Boeing 747-400F	ASC ASC-ASR-11-05 Accident	• Takeoff data based on LW. Weights not mentioned. • Stick shaker activated during takeoff, thrust was increased. • Tail strike, substantial damage.
11	12Dec09	Airbus A340-600	AAIB EW/G2009/12 /04 Serious incident	• Takeoff data based on LW (Δ 86.5 tons / 26.8 % of TOW). • Aircraft took off without further incident.
12	31Aug09	Boeing 777-300	DSB (refer to report 7Jul13) Serious incident	• Takeoff data based on improper weight (Δ 100 ton / 28.8 % of TOW). • Tail strike, minor damage.
13	20Mar09	Airbus A340-500	ATSB AO-2009-012 Accident	• Takeoff data based on improper weight (Δ 100 tons / 27.6 % of TOW). • Tail strike, hit localizer antenna and approach lights structure, suffering substantial damage. Full thrust was applied.
14	13Dec08	Boeing 767-300	AAIB EW/G2008/12/05 Accident	• Takeoff data based on ZFW (Δ 54.4 tons / 31.6 % of TOW). • Aircraft suffered tail strike, superficial damage to tail skid. • Full thrust was applied, stick shaker activated momentarily.
15	28Oct08	Airbus A330-300	AAIB EW/G2008/10/08 Serious incident	• Takeoff data based on improper TOW (Δ 90 tons / 42.5 % of TOW). • Full thrust selected during rotation. Aircraft lifted off within confines of runway.
16	27Oct08	Boeing 747-200F	AAIU Belgium AAIU-2008-18-EBBR Accident	• Takeoff data based on ZFW (Δ 100 ton / 27 % of TOW). • Tail strike, causing substantial damage. Stick shaker during rotation. • Aircraft was written off.
17	10Dec06	Boeing 747-400	BEA f-ov061210 Accident	• Takeoff data based on ZFW (Δ 99 tons lower / 29 % of TOW). • Tail strike, damage to the lower aft fuselage.
18	12Jul06	Embraer 190	TSB A06A0069 Serious incident	• Takeoff data based on improper TOW (Δ 5.9 tons / 12 % of TOW). • Aircraft took off without further incident.
19	24Aug05	Airbus A340-300	CAA China/Scandinavian Airlines Accident report	• Takeoff data based on ZFW (Δ 80 tons / 31 % of TOW) • Tail strike, substantial damage lower aft fuselage.
20	14Oct04	Boeing 747-200F	TSB A04H0004 Accident	• Takeoff data based on improper weight (Δ 114 tons / 32.2 % of TOW). • Tail strike, followed by collision with terrain. • All seven crewmembers suffered fatal injuries. Aircraft was destroyed.

Case No.	Date	Model	Safety Board/ Report No./ Incident or accident	Description
21	14Jul04	Airbus A340-313	BEA Bulletin No.4 - July 2006, Accident	• Takeoff data based on improper weight (Δ 100 tons / 37.7 % of TOW). • Aircraft suffered a tail strike at takeoff, substantial damage lower aft fuselage.
22	04Sep03	Airbus A321	AIBN 40/2004 Serious incident	• Takeoff data based on improper weight (Δ 16.4 tons / 21.5 % of TOW). • Aircraft took off without further incident.
23	22Oct03	Boeing 747-200F	JTSB AA2004-2 Accident	• Takeoff data based on ZFW (Δ 90 tons / 26.2 % of TOW). • Aircraft suffered tail strike at takeoff, substantial damage lower aft fuselage. • Stick shaker activated during initial climb.
24	03Mar03	Boeing 747-400	TAIC 03-003 Accident	• Takeoff data based on improper weight (Δ 100 tons / 28.8 % of TOW). • Tail strike, causing substantial damage and false APU fire warning. • Stick shaker activation.
25	11Mar03	Boeing 747-300	SACAA Ref. 0263 Accident	• Takeoff data based on ZFW (Δ 124 tons / 37.3 % of TOW). • Aircraft suffered tail strike at takeoff, substantial damage lower aft fuselage.
26	28Dec01	Boeing 747-100	NTSB ANC02LA008 Accident	• Takeoff data based on improper weight (45.4 ton / 100.000 lbs / ? % of TOW). • Tail strike causing substantial damage to the lower aft fuselage.
27	24Aug99	Boeing 767-300	Havarikommissionen HCL 49/99 Serious incident	• Takeoff data based on ZFW (Δ 63 300 kg / 33.9 % of TOW). • Takeoff was rejected at a speed of 158 knots. • Tail strike causing minor damage.
28	11Nov98	MD11	NTSB SEA99LA014 Accident	• Takeoff data based on ZFW (45.4 ton / 100.000 lbs / 21.5 % of TOW). • Tail strike during landing due V_{ref} 15 knots too low.

Table 1. Takeoff with Takeoff Data Based on a Lower TOW Than the Actual TOW

Case No.	Date	Model	Safety Board/ Report No./ Incident or accident	Description
29	11Dec18	Embraer 190	AAIB EW/G2018/12/05	• Takeoff with too low thrust setting. • Rotation was delayed, takeoff otherwise uneventful.
30	16Nov17	Boeing 737-700	AIB AIB/AAI/CAS.154 Serious incident	• Takeoff with too low FMS thrust setting. • Aircraft struck approach lights beyond end of runway.
31	21Jul17	Boeing 737-800	AAIB 2/2018 Serious incident	• Takeoff with too low FMS thrust setting. • Aircraft struck eight approach lights beyond end of runway.
32	15Jul17	Boeing 747-8F	JTSB AI2019-2 Serious incident	• Takeoff with too low thrust setting. • Case regarded as equivalent to runway overrun.
33	20Apr16	Boeing 717	ATSB AO-2016-065	• Takeoff with too low thrust setting. • Adjusted thrust setting was reduced by autothrottle. Takeoff uneventful.
34	21Nov10	Boeing 737-700	AAIB EW/C2010/11/06 Serious incident	• Runway change during taxi-out. A too high assumed temperature was inserted. • Aircraft became airborne before the end of the runway.

Table 2. Takeoff with Thrust Setting Being Too Low

Case No.	Date	Model	Safety Board/ Report No./ Incident or accident	Description
35	21Jan17	Airbus A320	ATSB AO-2017-008 Incident	• ATC prevented aircraft from departing from intersection providing less runway than intersection used for takeoff data calculation. (Δ 403 meters).

Case No.	Date	Model	Safety Board/ Report No./ Incident or accident	Description
36	30Aug16	Boeing 777-300	CAA India VT-JEK inquiry Serious incident	• Aircraft departed RWY27L INT S4E, with takeoff data full RWY (Δ 1069 m). • Aircraft airborne with approx. 97 m runway left. No thrust was increased.
37	9May16	Airbus A319	AAIB EW/G2016/03/07 Serious incident	• Aircraft departed INT, with takeoff data assuming full RWY length (Δ 560 m). • Aircraft lifted off closer to runway end than expected.
38	3Dec15	Boeing 737-800	DSB Insufficient thrust setting for takeoff - Serious incident	• Takeoff data were based on runway 03 instead of runway 21 (Δ 1120 m). • Although the flight crew observed there was less runway than expected, thrust was not increased.
39	16Oct15	Airbus A319	AAIB EW/G2015/10/08 Serious incident	• Aircraft departed RWY21 INT U5, with takeoff data for RWY 03 INT N2 (Δ 1120 m). • Aircraft airborne with approx. 213 m runway left.
40	16Sep15	Boeing 777-300	QCAA 001/2015 Accident	• Aircraft departed INT with takeoff data full RWY length (Δ 1000 m). • Aircraft collided with app light structure, puncturing pressure hull. • Unaware of collision flight was continued to its destination.
41	16Jul15	Airbus A319	AAIB EW/G2015/07/11 Serious incident	• Aircraft departed via INT with takeoff data full RWY length (Δ 474 m). • Aircraft airborne with approx. 180 m runway left. No thrust was increased.
42	6Oct14	Airbus A320-200	SUST No. 2256 Serious incident	• Aircraft departed RWY15 INT with takeoff data full RWY length (Δ 1530 m). • Aircraft passed runway end at height of 50 ft. Thrust was increased.
43	14Oct13	Boeing 737-800	ATSB AO-2013-195	• Aircraft departed INT with takeoff data full RWY length (Δ 1116 m). • Takeoff was uneventful.
44	1Oct 13	Airbus A320-200	SUST No. 2246 Serious incident	• Aircraft departed RWY17 INT with takeoff data full RWY length (Δ 1580 m). • Aircraft passed runway end at height of 104 ft. Thrust was not increased.
45	21Jun13	Embraer 190	ATSB AO-2013-112 Serious incident	• Takeoff from intersection providing less runway than required. • Aircraft lifted off within confines of runway.
46	8Dec11	Airbus A340-300	Cenipa IG-556/Cenipa/A/2018, Serious incident	• Aircraft departed RWY10 INT BB, with takeoff data INT AA (Δ 600 m). • Aircraft collided with app light structure and localizer antenna, damaging gear. • Unaware of collision flight was continued to its destination.
47	22Nov11	Boeing 737-400	ATSB AO-2012-020 Serious incident	• Aircraft departed intersection with takeoff data full RWY (Δ approx. 1300 m). • Aircraft was rotated early. Takeoff otherwise uneventful.
48	12Jun11	Airbus A321	ATSB AO-2011-073 Serious incident	• Aircraft departed intersection with takeoff data full RWY (Δ approx. 1090 m). • Aircraft airborne with approx. 450 m runway left.
49	26Sep09	Boeing 777-200	AAIB 4/2010 Serious incident	• Aircraft departed RWY07 INT B, with takeoff data INT A (Δ 695 m). • Aircraft passed runway end at height of 80 ft. Thrust was not increased.

Table 3. Takeoff From an Intersection Providing Less TORA than TORA Used for Calculation of Takeoff Data

Underreporting

The incidents and accidents listed in the tables were investigated by state AIAs. But there is a larger group of incidents involving erroneous takeoff data that has not been subject to investigation by a state AIA. The authors are familiar with about 50 reports between 2000 and 2019 involving erroneous takeoff data. Most of them were reported and filed in a database, while the more serious ones—some of which involve more serious performance deficiencies than described in some of the reports listed in these tables—were subject to an internal company investigation.

Another group of these incidents never gets reported to the operator. There are several reasons that can explain this.

1. Flight crews may simply be unaware that an incident has occurred. For flight crews to file a report on an erroneous takeoff data event, they need to be aware that an incident has occurred in the first place. This awareness does not necessarily exist, as there may still be sufficient runway available at liftoff, thus depriving flight crews from a salient clue that takeoff data is compromised.
2. As a derated takeoff is nearly always performed, the acceleration can be slow, even for relatively low aircraft weights. Also, a greater portion of the takeoff runway is used before the

aircraft becomes airborne. Therefore, slow acceleration and a long takeoff roll may not be interpreted as a takeoff performance incident. It is also not unusual to lift off near the end of the runway, especially not when takeoff performance is known to be critical.

3. Even when flight crews are aware that an incident has occurred, they may deliberately choose not to file a report, depending on factors like outcome and reporting culture. Likewise, operators may decide not to report incidents to state AIAs for the same reasons.
4. Another factor involves risk assessment of an incident, which may be based on its outcome instead of its potential for an accident to occur. This may result in a potentially catastrophic incident not being reported to the authorities.
5. Underreporting (by flight crews to operators and/or by operators to the authorities) thus masks the size of the problem and the actual exposure to what potentially may be a catastrophic accident.

Flight data monitoring filters

Flight data monitoring (FDM) filters able to capture takeoff performance incidents take many forms and range from filters detecting a large in-flight weight change, resulting from a flight crew changing the flight management system (FMS) aircraft gross weight (GW), to filters detecting aircraft acceleration or height above threshold. Depending on the filter used, the use of various databases may be required. But in general, the use of sophisticated filters is rare, as it requires expertise not normally available within the average airline. Also, there is no formal requirement to have filters sensing erroneous takeoff data events.

Most FDM programs are limited, if not incapable, in reliably sensing erroneous takeoff data events. Incident reporting, with all its limitations, therefore remains a vital tool in detecting erroneous takeoff data incidents.

Takeoff incidents and accidents—causal factors

A large variety of factors can result in a takeoff with erroneous takeoff data. These factors include—but are not limited to—simple calculation errors, loadsheet design, electronic flight bag design, FMS page design, and operating procedures. When taking into regard the plethora of systems to calculate takeoff data, variant flying (leaving pilots blind to recognizing abnormal takeoff data), operational pressure, and human factors like distraction and fatigue, it is inevitable that incidents and accidents will continue to occur, no matter how robust the procedures are.

As concluded by the AAIB in its report on an Airbus A340 taking off using takeoff date based on the LW (Table 1, case No. 11): "The loadsheet and takeoff data calculation standard operating procedures developed by the airline were robust and contained numerous cross-checks to ensure takeoff performance data was calculated correctly. Despite this, the crew used incorrect information to calculate takeoff performance and, even though the pilots noticed the high FLEX temperature, it did not prompt them to investigate whether they had made an error."

This clearly indicates the need for an independent warning system.

Initiatives

In the past, several recommendations have been made to develop a takeoff performance management system (TOPMS). Both the Dutch NLR and NASA developed a TOPMS prototype. Nevertheless, these systems were never operationally introduced.

To address the takeoff performance issue, EASA established two working groups (WGs). WG-88 focused on the specification and standardization of onboard weight and balance systems (OBWBS). WG-88 considered this to be a feasible option and is still working on the standards for such a system.

WG-94 focused on developing standards and operational conditions for a TOPMS. WG-94 considered that developing a TOPMS was not feasible due to various factors, including limitations in technology and data availability. WG-94 was concluded in early 2017.

Why is it so difficult to develop a TOPMS? Past initiatives for a TOPMS took into account many variables and aimed at an accuracy level that had the potential for many nuisance warnings to activate. This only introduces new risks.

Table 1, page 16, shows that many of the incidents involving a relatively minor weight error did not have serious consequences. The same is true for many of the unreported incidents. These smaller errors were absorbed by the existing takeoff performance margins, even in the case of maximum thrust deration. The authors therefore believe that detecting small errors should presently not be the aim of a TOPMS, as such systems require a significant larger effort and time to develop. Instead, the focus should be on a system that only warns flight crews in the event of a gross errors.

Unlike an OBWBS, which on many aircraft would require hardware changes for installation, a gross error TOPMS could make use of the existing avionics architecture and thus become available for a large range of aircraft types currently in use.

Another advantage of a gross error TOPMS over an OBWBS is that it is independent: it does not require any flight crew action during the preflight phase.

All gross takeoff performance errors could have been easily detected with a TOPMS. With Dutch airlines having had their fair share of takeoff performance incidents, KLM, Martinair, and the NLR looked at the feasibility of a gross error TOPMS system that provides an alert during the low-speed part of the takeoff run.

The authors believe that the introduction of such a gross error TOPMS is feasible in the near future and propose a system that warns the pilots at the start or early during the takeoff roll (at speeds below 80 knots for a safe reject to be made). The system is not limited to the detection of improper weight inputs or improper FMS speeds, but also issues a warning when takeoff is made from an intersection affording less runway length ahead than required by the takeoff data used.

TOPAP—a simple TOPMS system

The authors propose the following system, referred to as the takeoff performance alerting program (TOPAP). The system is composed of three major steps:

Step 1: Checking FMS weight vs V_2

Takeoff performance entry errors can already be detected while the aircraft is still at the parking bay. However, to prevent nuisance warnings following last-minute changes, it is advisable to do this check when the takeoff is actually started. For a given aircraft weight and flap setting, performance tables can be used to determine minimum V_r and V_2 speeds. For reasons of simplicity, only the minimum V_2 value is used for comparison. If the correct aircraft weight is entered into the FMS, but improper takeoff speeds have been entered (thus including an improper V_2), TOPAP can already perform a first check by comparing the FMS V_2 speed with the V_2 taken from the performance tables. Minimum V_2 is independent from the thrust setting used (thus considering both full and derated thrust settings). The V_2 check therefore provides a valuable means to detect a GW performance error. Several of the incidents in Table 1 could have been avoided if this check had been performed.

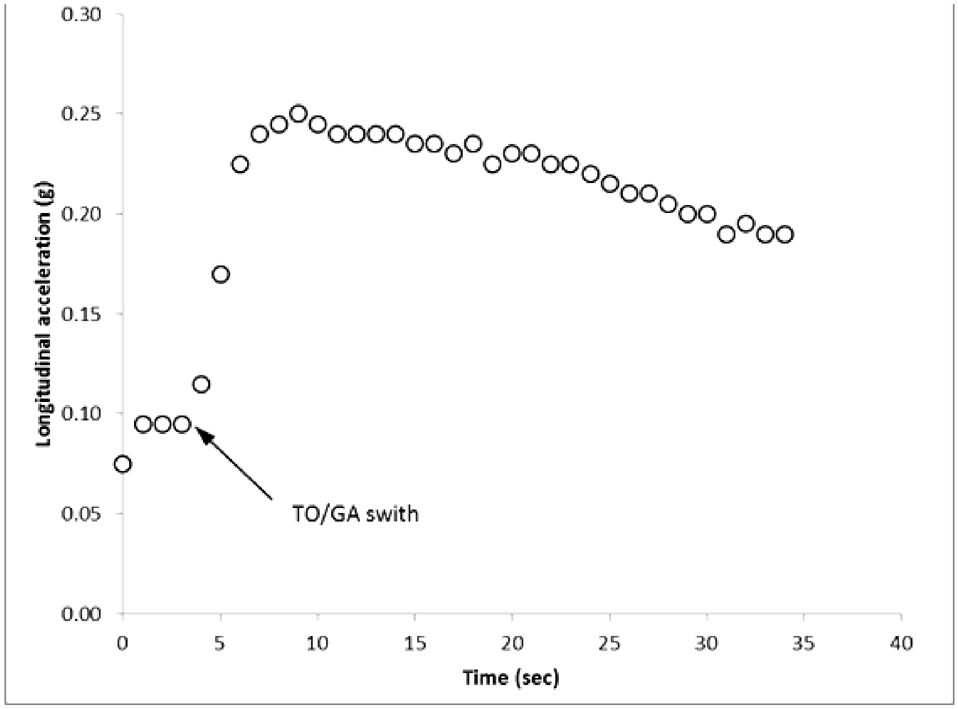


Figure 1: Example of longitudinal acceleration variation with time during the takeoff roll of a jet aircraft.

Step 2: The algorithm estimating the actual TOW

The idea is to have a simple algorithm that is not necessarily taking into account special conditions like contaminated runways but that is still robust enough to be effective as a warning system for detecting large errors in the takeoff weight used for performance calculations under such conditions. The feasibility of a simple algorithm that can determine if the takeoff weight as entered into the FMS by the pilots differs much from the actual takeoff weight was explored by NLR. Some of the results are discussed in this paper. In this approach, the actual takeoff weight is estimated from the onboard recorded longitudinal acceleration, an engine thrust model, an aerodynamic model, estimated slope, and assumed rolling resistance. The following equation is used for the longitudinal acceleration of an aircraft during the takeoff run:

$$a=g/W\,[(T-\mu W)-(C_D-\mu C_L)Sq-W\sin\varnothing]$$

W is the weight of the aircraft, S is the wing reference area, q is the dynamic pressure, CD is the drag coefficient, CL is the lift coefficient, μ is the rolling friction coefficient, and Ø is the runway slope angle (positive for upslope). A large difference between both weights (FMS and actual weight) should trigger an alarm warning the pilots. This is like a Type I TOPM system as defined by SAE. A Type I system compares the achieved aircraft takeoff performance to the aircraft reference performance and indicates to the crew deviations from this reference. It does not have any predictive capability, which makes it much simpler and robust than many of the TOPMS systems studied in the past. The approach is demonstrated here using recorded takeoff flight data of a widebody jet aircraft under a wide variation of conditions.

The takeoff roll is started by advancing the thrust levers to an initial setting as per operating procedures at a low taxi speed. The engines should be stabilized momentarily before pressing the TO/GA switch. This provides uniform engine acceleration to takeoff thrust and minimizes directional control problems caused by asymmetric thrust. Right after pressing the TO/GA switch, the longitudinal acceleration increases rapidly until the target fan speed is reached. After that, the longitudinal acceleration stabilizes and slowly decreases with speed due to the increase in aerodynamic drag and decrease in thrust. An example of the variation of the longitudinal acceleration with time during the takeoff roll of a jet aircraft is shown in Figure 1.

To avoid warnings of improper takeoff weights to be triggered at high speeds, the algorithm should work at the lowest speeds possible. The taxi roll is not really useable to calculate the weight of the aircraft as the acceleration levels are very low and strongly fluctuate, making it difficult to accurately derive the weight of the aircraft. During the takeoff roll, higher and more stable values of the longitudinal acceleration can be found as shown in Figure 1. The data recorded right after pressing the TO/GA switch could be used to calculate the weight of the aircraft. A practical problem is that in order to calculate the engine thrust and aerodynamics forces, the airspeed must be known. At very low speeds, there are no accurate measurements of the airspeed possible.

Typically, from 35–50 knots the airspeed is being measured accurately depending on the aircraft type. This limitation does not apply to the ground speed, which is always recorded even at very low speeds. To obtain airspeeds at low speeds, the measured ground speed could be corrected using an estimate of the wind speed. A soon as airspeed is being recorded, it can be compared to the ground speed. The difference between the true airspeed and ground speed can be used as the wind speed. The true airspeed can then be calculated for much lower speeds. Before reaching 60 knots indicated airspeed (IAS), the algorithm should have calculated the actual weight (best fit) and made a comparison with the FMS weight. When a large difference is detected, the pilots should be warned and the takeoff can be aborted safely at speeds less than around 70 knots. Aborts at higher speeds could be acceptable, although it is desirable to avoid this if possible.

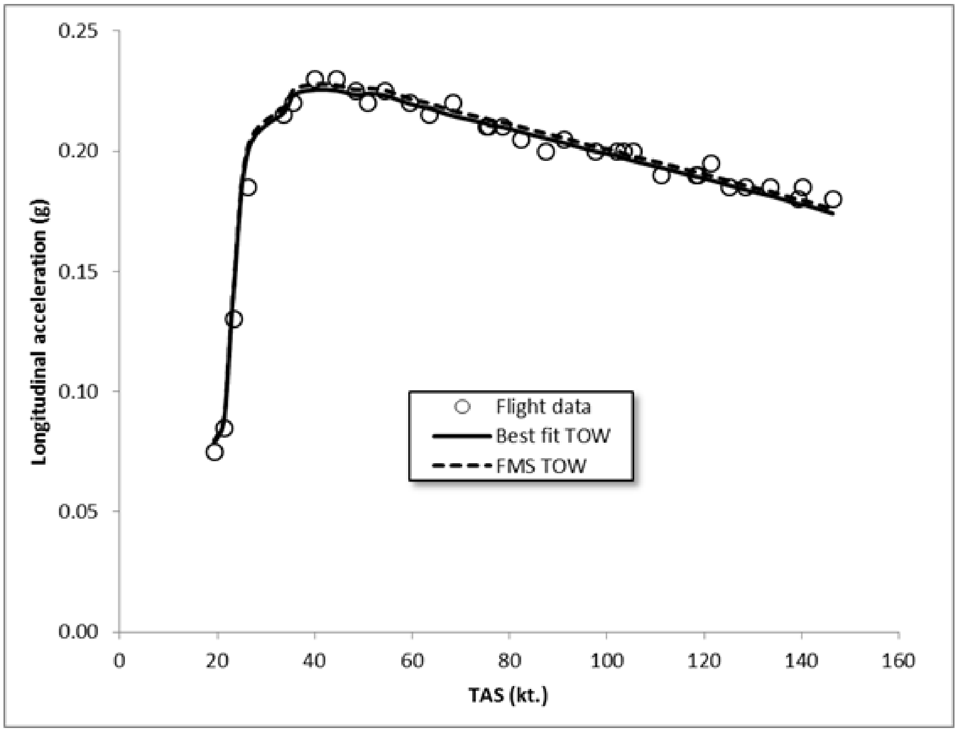


Figure 2. Comparison between recorded longitudinal acceleration, calculated acceleration using FMS TOW, and best fit TOW.

The algorithm compares the calculated longitudinal acceleration to the onboard measured values up to a speed of 55 knots IAS and tries to find a best fit by varying the weight. The effect of fuel burn is ignored, as this will only have a very small influence on the results.

The algorithm was applied to a widebody jet aircraft. For this aircraft, detailed data on thrust and aerodynamics was available, as were recordings of flight data during several takeoffs. The takeoffs were conducted at various airports located at different altitudes and with a wide range of temperatures. Also, the takeoff weight varied from being close to the maximum to very low weights due to short flights between nearby airports. The flight data came from the quick access recorder (QAR). Compared to onboard measurements, the sample rates are much lower for QAR data. However, for demonstration purposes the data is still useful. If the algorithm works for the low sample rate data, it will definitely also work with data recorded at higher frequencies.

Before testing the algorithm, it was first tried using the recorded QAR data of some 50 takeoffs with the time traces starting from the application of the TO/GA switch until rotation. This gave insight in how well the method would work using data from a complete takeoff run. An example is given in Figure 2. This shows the recorded (smoothed) longitudinal acceleration for a widebody jet aircraft during the takeoff run until the start of the rotation. Also shown is the calculated acceleration using the FMS weight and the calculated acceleration using a weight that gave the best fit. In both cases, the simple model for the longitudinal acceleration as presented earlier was used. The recorded N_1 of each engine was used to calculate the thrust. In this example, the FMS weight and the best fit weight compare very well, with a difference of less than 1 percent. For most of the analyzed takeoffs, the difference was less than ±3 percent.

There can be several reasons for differences found between the FMS weight and the calculated weight from the longitudinal acceleration. First, the actual passenger weights and the weight of their carry-on luggage could be different from what was used to calculate the FMS weight (based on regulations). For instance, passengers and their carry-on luggage could be heavier than assumed. The weight of the checked baggage is often measured during the check-in process. This means that the total weight of the checked-in luggage of all the passengers is fairly accurate. The same is true for any cargo on board the aircraft. The engine performance can degrade over time, for example, thrust loss caused by compressor fouling. A recently washed jet engine can produce more thrust at the same throttle setting than an engine that has not been washed. Therefore, the engine thrust calculated from the engine deck could be higher than actually achieved.

The tire rolling resistance coefficient could be different from the assumed value due to differences in tire inflation pressure and effects of ground speed. It is assumed for simplicity that the accelerations at the aircraft's center of gravity and at the accelerometers' location are equal. This will not be the case in the real world. This could introduce some errors in the derived weight if the aircraft experiences a pitch rate or pitch acceleration during the ground roll. Runways contaminated with standing water, slush, or loose snow can induce an additional drag force on the aircraft. Information on the actual contaminant on the runway is not recorded on the QAR. METAR could be used instead; however, this makes the algorithm more complex and more prone to errors.

The takeoffs analyzed were all conducted above outside temperatures of 5°C, making it less likely that snow or slush was present on any of the runways. Standing water is possible but requires a large amount of rain and poor runway drainage characteristics.

Differences in weight can also arise from errors in the used basic empty weight.

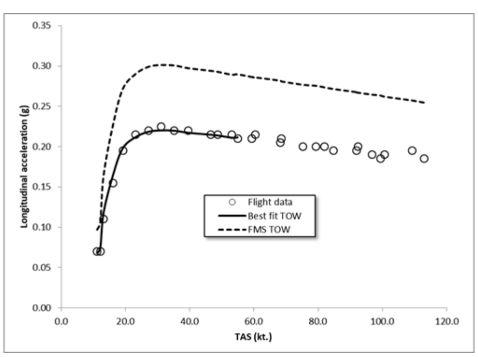


Figure 3. Example of the algorithm for a takeoff started at low speed.

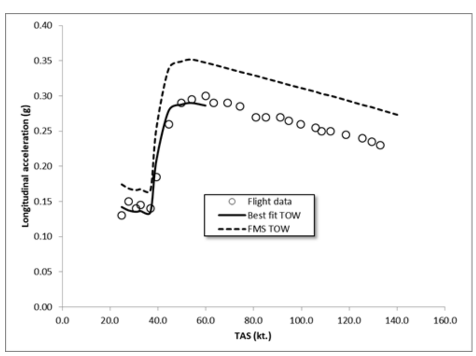


Figure 4. Example of the algorithm for a takeoff started at medium speed.

Aircraft are normally weighed at intervals of 36 calendar months. Alternatively, an operator may choose to weigh only a portion of the fleet every 36 months and apply the weight determined by these sample weighings to the remainder of the fleet. Both methods can introduce errors over time in the basic empty weight that is used to calculate the takeoff weight of a particular aircraft.

Finally, the aerodynamic lift and drag coefficients are conservatively based on the most forward center-of-gravity limit of the aircraft. A more mid-range center of gravity reduces trim drag and increases total lift because horizontal tail download required for aerodynamic balance is reduced.

The small differences in the actual and assumed takeoff weight are mostly covered by the margins taken into account in the performance calculations and should therefore not trigger an alarm. This should only occur for much higher differences in the takeoff weight, more than 15–20 percent. This represents the typical gross weight errors made by flight crews when computing takeoff speeds.

The first example of the algorithm is a case in which the crew used the ZFW for the performance calculations. TO/GA was selected at low speed of around 10 knots in this example. At a speed of around 50 knots, the algorithm estimated that the actual takeoff weight was more than 40 percent higher than assumed. Figure 3, page 21, shows longitudinal acceleration and speed as measured using the onboard inertial reference system compared to the calculated relation using the crew-entered takeoff weight and the fit that the algorithm made. In this example, the aircraft started its takeoff at a low speed.

This gives the algorithm sufficient time and data to estimate the actual takeoff weight. If the aircraft is rolling at a higher speed when TO/GA is applied, there is less time for the algorithm to estimate the actual takeoff weight as the aircraft will accelerate quicker to the target speed of around 60 knots, at which speed the algorithm preferably should start warning the flight crew. An example of such a case is shown in Figure 4, page 21. In this example, the crew selected TO/GA at 40 knots. Still, the algorithm is able to accurately estimate the actual takeoff weight and warn the crew in time of a large difference between the entered weight and the actual takeoff weight (in this example there is a difference of 20 percent).

The examples show that a simple algorithm can give pilots critical warnings well below V_1 in case the assumed takeoff weight is significantly different from the actual takeoff weight.

Step 3: The algorithm checking available runway length

The system discussed so far captures the incidents and accidents presented in Table 1.

The second and third group of takeoff incidents, presented in Tables 2 and 3, pages 17–18, concern occurrences in which takeoff is initiated with a thrust setting being too low or from a wrong entry point allowing less runway ahead than required.

After the pilot has selected TO/GA, the calculated takeoff weight is checked and compared with the entered FMS weight. If no large differences are detected, the system can then check if the engine dry runway takeoff distance for the given conditions (weight, flap, and thrust setting) is sufficient by comparing it to the TO/GA GPS position with the end of the runway. This check will also capture those cases i n which the thrust setting is too low, e.g., due to erroneous OAT or incorrect assumed temperature entries during FMS programming.

The warning system as described is specifically designed to detect gross errors and provide the flight crew with an alert before 80 knots. The system would have captured many of the incidents and accidents included in Table 1–3. The overall system is summarized in Figure 4.

TOPAP limitations

The following limitations apply:

- The system only detects gross errors,
- Obstacles are not taken into account,
- The system only uses runway length based on a dry runway, and
- NOTAM-ed runway shortenings are not taken into account.

Conclusion

Takeoff performance accidents involving loss of life have happened in the past. Despite many incidents and a few accidents, however, there have been no accidents involving loss of life since 2004.

However, the potential for another catastrophic accident involving a large passenger jet is clearly present. The authors believe that it is not a matter of if this will occur, but when. A mid-air collision gave impetus to the development of the traffic collision avoidance system (TCAS), a successful alerting system that is a far more complicated system than the system proposed in this paper. Do we need another major takeoff accident like in the case of TCAS to get things moving? It seems that the need for a TOPMS is not yet fully recognized. And it is questionable if the current movement into the direction of the recommendations for a TOPMS will prevent future accidents. We may just run out of luck. We hope that this seminar can focus the attention of aircraft manufacturers, authorities, airline companies, and investigation agencies to jointly develop a TOPAP that can be installed in most of the airliners in service today. ◆

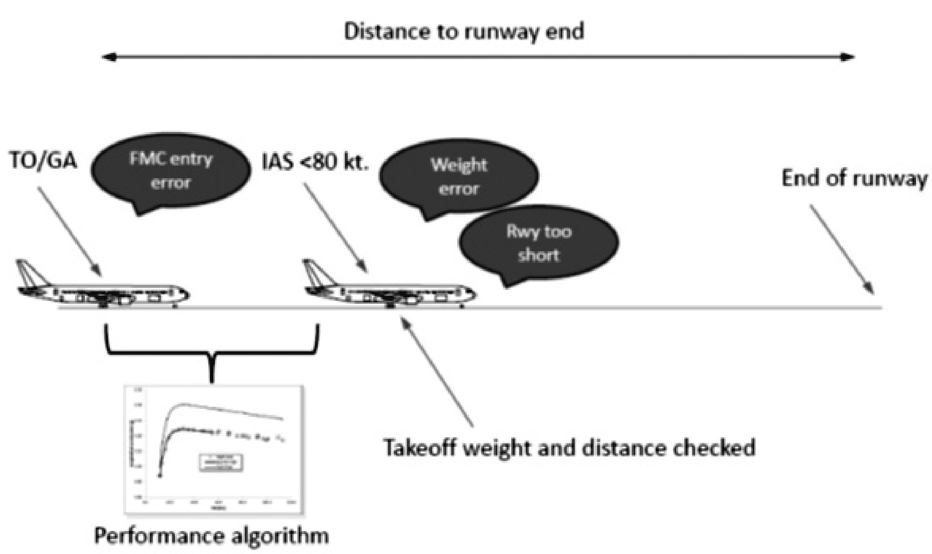


Figure 5. Overview of a simple takeoff performance warning tool.

INATTENTIONAL BLINDNESS AND BIAS DURING VISUAL SCAN

By Capt. Amit Singh, A320 pilot and Fellow of the Royal Aeronautical Society

Visual illusion is a perception of something existing in such a way as to cause misinterpretation of its true nature. It convinces us that the real-life version of the object is untrue or false. The cognitive power of our brain can also create an effect of blindness wherein we do not see obvious and discernible objects in our visual field. In day-to-day life, the term used is "looking without seeing."

Aviation, marine, and automobile occurrences have been recorded that have an element of not sighting the obvious. Investigations in the past have not considered this aspect at all, thereby in a way linking the flight crew to the error. Cognitive ease prefers the mental image of a layout to be seen as it is when it comes into the field of vision. Intuitive thinking prefers to match the two images somehow and introduces biases that affect decision-making. This paper highlights the aspects that can jeopardize safety during critical maneuvers. Simplistic solutions can enhance awareness and consciousness so that even in high workload situations, error is virtually eliminated.

The proverb seeing is believing means that you need to see something to believe it; visible facts cannot be denied. This is a general statement valid for most scenarios, but human psychology warns us that this statement may not be true under a certain set or combination of circumstances.

Two aviation occurrences and one marine occurrence have brought up the question "Why didn't the crew see the obvious?" In any accident/incident, there is no single root cause. There are several contributory causes. A detailed investigation will reveal the probable cause along with the contributory causes. All of the accident/incident investigations analyzed here have one thing in common: certain aspects of the cognitive side of the crew were not investigated from a human factors and psychological view.

1. Taxiway over flight—Air Canada Flight 759 at San Francisco International Airport on July 7, 2017.
2. Risk of collision—A Canadian North

(Adapted with permission from the author's technical paper Inattentional Blindness and Bias During Visual Scan *presented during ISASI 2019, Sept. 3–5, 2019, in The Hague, the Netherlands. The theme for ISASI 2019 was "Future Safety: Has the Past Become Irrelevant?" The full presentation can be found on the ISASI website at www.isasi.org in the Library tab under Technical Presentations.—Editor)*

Capt. Amit Singh

B-737 Flight 9131 and a Jazz Aviation Dash 8-400 Flight 8391 on Aug. 4, 2014.

3. Marine accident—USS *Greeneville* nuclear submarine and Japanese fishing and training trawler *Ehime Maru* on Feb. 9, 2001.

According to a 2007 U.S. FAA report, there were 267 instances of pilots mistakenly landing on a taxiway parallel to a runway in the United States between 1962 and August 2007. These events, identified through U.S. NTSB and Aviation Safety Reporting System databases, occurred at 110 different airports and involved aircraft from the spectrum of operator types. There were multiple occurrences at 44 of the airports, with single occurrences at the remaining 66. It should be noted that the data included only aircraft that had landed on the taxiway; the number of instances of runway/taxiway confusion that were detected prior to landing was likely much higher.

Investigation reports of the two aviation incidents used as examples here had a few commonalities. The captain was the pilot flying, and the first officer was the pilot monitoring under visual conditions. Where there was a parallel runway, it was closed and notified as a notice to airmen (NOTAM). There were parallel taxiways, too. The crews had flown to the airport frequently and were not new to the topography and procedures.

Expectation bias

Purdue University carried out a study of accidents/incidents of landing on wrong runways and wrong airports. One of the reasons for landing on the wrong surface is that the flight crew has a mental picture of the airport and orientation of the runways, and this is compared to what the pilots see outside. The pilots misjudge the time, speed, and distance and finally misidentify the landing surface through distortion of the facts of reality. The pilots are thus disoriented and are inadequately informed by their external visual environment. This happens more often when transiting from instrument conditions to visual conditions.

Visual cognition is limited by the number of computations that the brain can perform. The brain can process only a fraction of the visual faculties in detail and is limited by the inherent ambiguity of information entering the visual system. The brain prioritizes information to reduce the burden. Attention prioritizes stimulus processing based on motivational relevance, and expectations constrain visual interpretation on the basis of prior likelihood.

Expectation is the state of the brain that reflects prior information about what is possible or probable in the forthcoming sensory environment. Expectation leads to faster acquisition and interpretation of the visual input.

Confirmation bias

According to Francis Bacon, once an individual has adopted an opinion either received or self-agreed, he or she draws all things to support and agree with it. This person then neglects or sets aside and rejects any input even though it may outweigh the current opinion. And though there are a greater number and weight of instances to be found on the other side, these are both neglected and despised, or else by some distinction set aside and rejected, so that by this great and pernicious predetermination the authority of these former conclusions may remain inviolate.

People tend to seek information that they consider supportive of favored hypotheses or existing beliefs and to interpret information in ways that are partial to those hypotheses or beliefs; conversely, they tend not to seek and perhaps even to avoid information that would be considered counterindicative with respect to those hypotheses or beliefs and supportive of alternative possibilities.

Sleep deprivation/fatigue

Evidence suggests that certain conditions such as fatigue, sleep deprivation, and cognitive overload predispose decision-makers to use intuitive processes. More biased decision-making resulting in more errors takes place as an outcome of fatigue and sleep deprivation. At the end of 16 hours of being awake, cognitive power is reduced to 75 percent. The impact is in the cognitive function located in the prefrontal cortex, which leads to degraded analytical reasoning and impaired monitoring. There is also an increased tolerance of risk and loss of situational awareness.

Inattentional blindness

Everyone has some awareness of the limited capacity of attention, and our social behavior makes allowances for these limitations. Intense focusing on a task can make people effectively blind, even to stimuli that normally attract attention. When engaged in a demanding task, attention can act like a set of blinders, making it possible for salient, unexpected stimuli to pass unnoticed right in front of our eyes. This phenomenon of "sustained inattentional blindness" is best known from a 1999 study in which observers attend a basketball game while a human in a gorilla suit wanders through the game. Despite having walked through the center of the scene, the gorilla is not reported by a substantial number of the observers. Does inattentional blindness (IB) still occur when the observers are experts and highly trained on the primary task? In computed tomography (CT) lung cancer screening, radiologists search a reconstructed "stack" of axial slices of the lung for lung nodules that appear as small light circles. During a series of experiments conducted with 24 radiologists (mean age 48; range 28–70), they had up to three minutes to freely scroll through each of five lung CTs, searching for nodules as their eyes were tracked. Each case contained an average of 10 nodules, and the observers were instructed to click nodule locations with the mouse. On the final trial, a gorilla with a white outline was inserted into the lung.

In the experiment, 20 of 24 expert radiologists failed to note a gorilla, the size of a matchbook, embedded in a stack of CT images of the lungs. This is a clear illustration that radiologists, though they are expert searchers, are not immune to the effects of IB, even when searching medical images within their domain of expertise. Another study showed that radiologists could miss the absence of an entire bone. Why do radiologists sometimes fail to detect such large anomalies? Of course, as is critical in all IB demonstrations, the radiologists were not looking for this unexpected stimulus. Though detection of aberrant structures in the lung would be a standard component of the radiologist's task, our observers were not looking for gorillas. Presumably, they would have done much better had they been told to be prepared for such a target. Moreover, the observers were searching for small, light nodules.

Selection of landing surface—Air Canada Flight 759

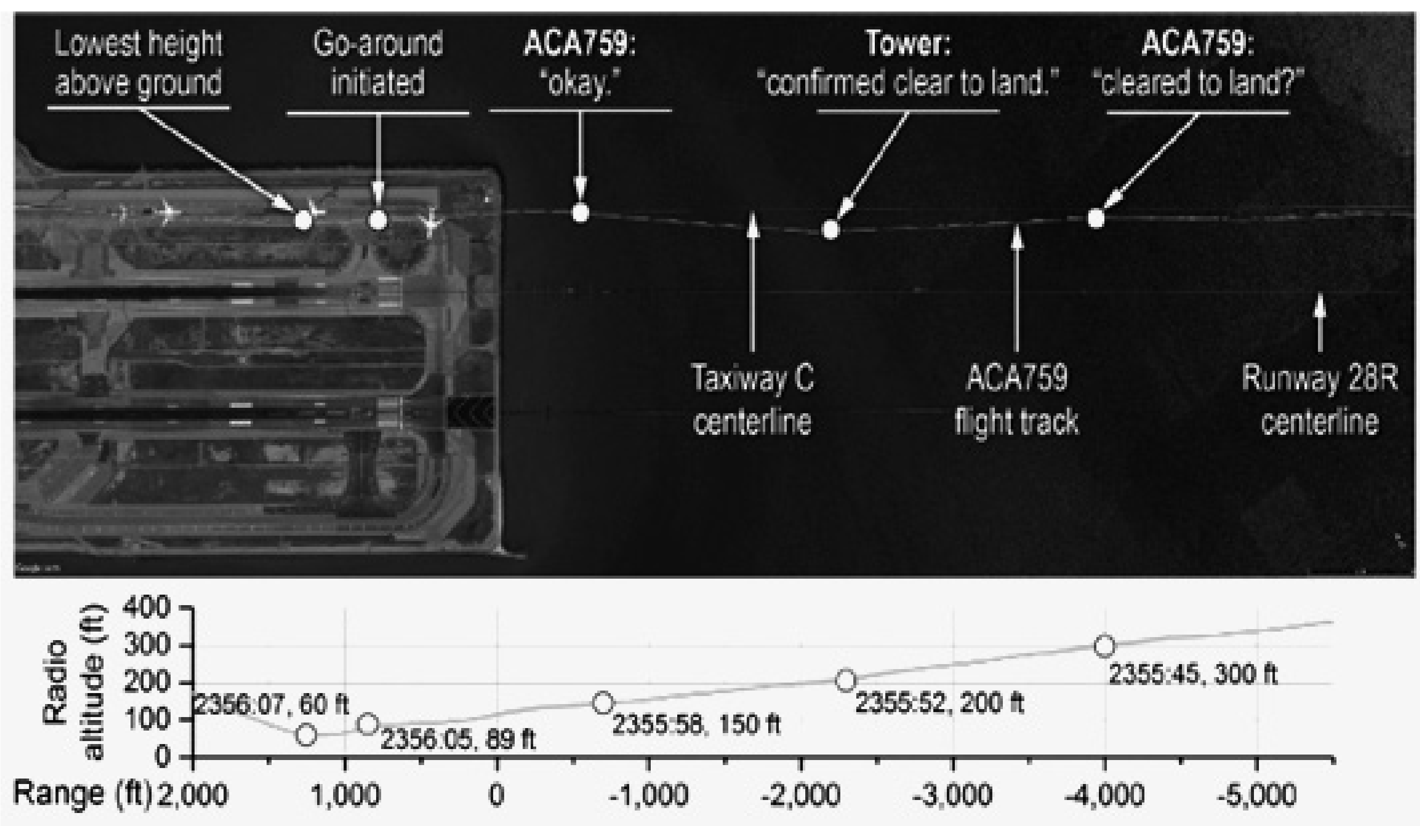
On July 7, 2017, at San Francisco International Airport (SFO), Air Canada Flight 759 executed a visual approach to land on a taxiway followed by a go-around. It was cleared for the quiet bridge visual approach Runway 28R on completion of the standard terminal arrival route (STAR). Runway 28L was closed per the NOTAM. The captain had been awake for almost 16 hours when he was flying the approach. He had flown to this airport several times; thus he had a good mental picture of the airport with two closely spaced parallel runways. The flightcrew members had recent experience flying into SFO at night. The captain reported that he had flown into SFO one or two times during the previous four months. He flew the STAR and at the final descent point transited from instrument to visual reference while at the same time switching off automation.

There was a lighted flashing "X" placed on the closed Runway 28L; but per the NTSB, the flashing rate was too slow to have been noticed by the crew. The crewmembers would have first sighted the landing Runway 28R in front since the approach lights were illuminated. Then they would have seen the parallel taxiway dimly lit but with similar dimensions to that of the runway. In his interview, the captain said that he knew that Runway 28L was closed per the NOTAM. Expectation bias would have set in when only one runway and associated approach PAPI lights were sighted.

Humans use their intuitive decision-making 90 percent of the time, but this increases when they are tired. They resist the analytical part of decision-making. The pilot's mental and real pictures did not match; therefore, he assumed that the currently closed Runway 28L was still open and that the runway in front of him was Runway 28L. Expectation bias lead to confirmation bias. He believed that the lights right of the runway lights were those of Runway 28R, but they were in fact those of the parallel Taxiway C. Despite all the visual evidence that the taxiway did not have approach lights nor did it have a PAPI for vertical descent guidance, the pilot aligned the aircraft trajectory with the taxiway parallel to the runway.

The captain had aligned the aircraft with parallel Taxiway C instead of Runway 28R despite all of the visual illuminations associated with an active runway. The taxiway dimensions were similar to those of the runway, and there was a centerline light similar to what a runway has but green in color as opposed to white runway centerline lights. With this assumption and decision, the mental picture matched what the crewmembers saw in their field of vision ahead of them. Three large passenger jets were taxing on the taxiway, and they had their navigation lights steady, flashing beacons on top illuminated. The crew did not see any of the three aircraft. The preceding crewmembers who landed on

Figure 1. Flight profile of Air Canada Flight 759 at San Francisco International Airport.



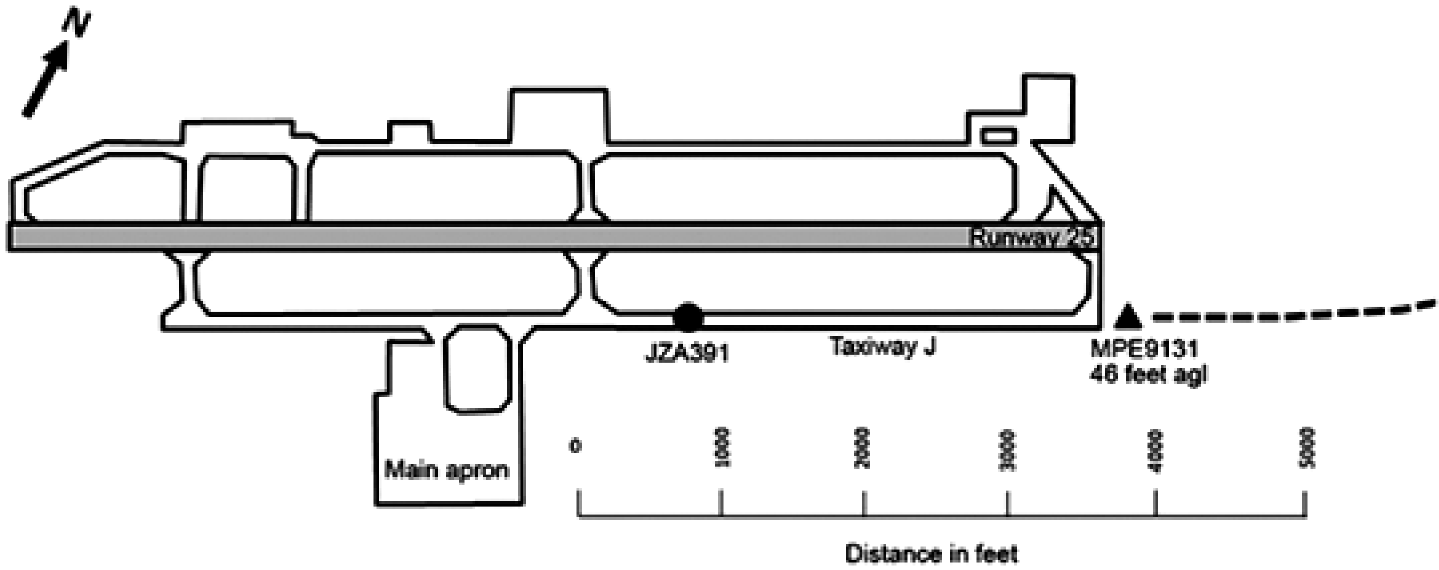


Figure 2. Flight profile of Canadian North Flight 9131 at Fort McMurray Airport.

Runway 28R had sighted the runway number written when the aircraft was 300 feet above the runway. Air Canada Flight 759 could not see any of the three large jets at 300 feet. The crew did see some lights and queried the air traffic controller, who checked Runway 28R visually and on the radar scope for any aircraft and replied that the runway was clear.

The reason the crew did not see the three large passenger jets can be attributed to IB. A fatigued crew had aligned the aircraft with a taxiway due to expectation and confirmation bias. With limited cognitive capacity and analytical skills due to fatigue and biases, the crew also received confirmation from ATC that the runway was clear. During approach to land, the pilot's attention was focused on keeping the aircraft on the lateral and vertical profile, i.e., maintain the centerline and aim for the touchdown point. The crewmembers do not normally expect or look for aircraft on the runway since they assume that ATC is controlling the access to the runway. IB sets in when maximum attention is focused on a particular activity. In this case, the crewmembers were focused on the dimly lit taxiway and trying to fly a vertical profile with limited guidance. As a result, they were blinded to unexpected objects in their field of vision. This is similar to the gorilla in the CT scan experiment that could not be detected because the radiologists did not expect the gorilla to be there and were focused on looking for smaller-sized images.

Canadian North Flight 9131

On Aug. 4, 2014, Canadian North Flight 9131, a B-737, executed a visual approach to land on a taxiway followed by a go-around. The flight crew was preparing for the approach to Fort McMurray Airport in Alberta, Canada, and obtained the weather through the ATIS. Visibility was 4 statute miles with a cloud ceiling of 4,100 feet for Runway 25. The company SOP required an instrument approach when visibility is less than 5 statute miles. The crew decided to carry out a visual approach but set the approach aids for an ILS approach for Runway 25 and carried out an approach briefing accordingly. A regional jet that landed before them asked ATC the reason for using Runway 25 because they were landing into the sun and smoke, making it difficult to see the runway environment. Flight 9131 was given a step descent, instructed to reduce speed, and to fly to a waypoint 12.8 nautical miles from the runway before turning back and being cleared for an ILS approach. When cleared for approach, the aircraft was established on the extended centerline for Runway 25, but was higher than the required vertical profile and at the final approach fix by 2.5 dots. The aircraft had leveled out at the platform height.

At this time, a Dash 8-400 was cleared to taxi via the parallel taxiway and to hold short of landing Runway 25. Flight 9131 leveled out at 3,000 feet (1,800 above airport level) and at 3.5 nautical miles to touchdown, the captain disconnected the autopilot and autothrust followed by a left turn and initiated descent. The pilot aligned the aircraft with the taxiway on the left and descended at a high rate. The glide slope alert was triggered since the aircraft was now below the vertical profile. The glide slope warning stopped when the aircraft was abeam of the threshold but over the taxiway. The crew asked ATC if the runway was clear, and ATC replied that it was. The aircraft descended below 50 feet aligned with the taxiway before the taxiing aircraft announced over the tower frequency that there was an aircraft lined up with the taxiway.

The airport has two parallel taxiways either side of the runway. While approaching Runway 25, Taxiway J is on the left of the runway and runs parallel from the start of the runway but half the width of the runway. Taxiway G is on the right side and is connected with the threshold via a taxiway at a 45-degree angle. The visibility had dropped from 4 statue miles to 2.5 when the approach was started, but the pilots were unaware of it. The approach lights for Runway 25 had not been switched on.

The pilots had completed almost 11 hours of duty and would have been awake for almost 14 to 16 hours. They were unaware of the visibility drop, and the sun was in their eyes—making it even more difficult to locate the runway. With approach lights off, both the surfaces would have looked similar. Taxiway J had been commissioned four months before, and the crew had flown with the new taxiway open but had significantly more experience flying into the airport before the opening of the taxiway.

The mental picture that the crewmembers probably had was from the time they operated before the new taxiway opened. They would have expected Taxiway G and the runway to be left of Taxiway G. Taxiway J is more prominent than G since its positioning is squared to the runway, whereas G starts after the threshold and is linked by a taxiway at a 45-degree angle. The crewmembers were carrying out a visual approach in poor visibility, coupled with the setting sun and no approach lights. They were aligned with Runway 25 but were high on approach and leveled out at 3,000 feet. Since they were expecting the runway to be on the left of the taxiway, and Taxiway J was more prominent than G, they would have decided that Runway 25 was to the left and turned left at 4 nautical miles to touchdown and initiated descent at a high rate.

These actions can be attributed to expectation and confirmation bias, which was seen in the Air Canada incident as well. The aircraft was high on profile at 4 nautical miles to the runway. And since Taxiway J to which the crewmembers had turned toward was half the width of the runway, they perceived that they were even higher. They increased the rate of descent, and at 1,000 feet AAL they were descending at 1,200 feet per minute. They disregarded the glide slope alerts when they crossed the glide slope signal and went below profile due to confirmation bias and reached 50 feet AAL before the beginning of the taxiway or abeam of the runway. There was a Dash 8-400 taxiing on Taxiway J, but the crewmembers did not detect the medium-sized commercial jet since their attention was focused on getting back on profile for landing. But then the crew did notice something and asked ATC if the runway was clear. ATC replied that it was clear since there was no aircraft on the runway. Due to expectation and confirmation bias, the crew was preoccupied with getting back on profile and aligning with the landing surface. This was the probable cause of IB.

An experiment was conducted using a flight simulator and approaches flown under low visibility with a head-up display. There was no need to scan the instruments since all of the relevant information was available through the head-up display. The experiment concluded that a few pilots did not see a large commercial jet on the runway and those who saw the aircraft were almost 2.5 times slower in executing a go-around maneuver.

USS *Greeneville* and *Ehime Maru*

Near Hawaii, the commander of the nuclear submarine USS *Greeneville* ordered a surprise maneuver known as an "emergency deep" in which the submarine suddenly dives. He followed this with an "emergency main ballast tank blow" in which high-pressure air forces water from the main ballasts, causing the submarine to surface as fast as it can. In this maneuver, the bow of the submarine leaves the water surface and comes out of the water. As the *Greeneville* performed this maneuver and the bow surfaced, the crew heard a loud noise and the entire submarine shook. The submarine's bow had surfaced and torn through the Japanese fishing trawler *Ehime Maru*. Within minutes, the trawler sank.

Prior to initiating these maneuvers, the crew and the commanding officer had carried out a visual scan of the surroundings using the periscope. They did not see the huge fishing trawler. The crew and the commanding officer never expected the fishing trawler to be in the area where they were performing the maneuver; therefore, they probably did not see the ship.

Conclusion

The aviation incidents discussed in this paper involved crewmembers who were transitioning from instrument to visual approach. They had long flight duty periods and had enough experience flying to the airport. The probable cause for lateral alignment with the taxiway can be attributed to the mismatch between the mental picture based on past experiences and the visual indications acquired. Expecting the landing runway to be adjacent to a runway/taxiway, expectation bias caused the crewmembers to make the decision to align with the incorrect landing surface. Due to limited cognitive capability at that stage, and probably due to intuitive decisions, the pilots aligned with the taxiway and ignored all obvious and coherent indications of sighting the runway. This indicates confirmation bias, and the crew continued to fly the approach with vertical assistance from internal or external guidance. The reason for not sighting the aircraft on the taxiway was probably due to IB.

This has been proven in the gorilla experiment mentioned earlier in which a life-sized gorilla was unnoticed by many observers during a basketball game and when expert radiologists could not detect a matchbox-sized gorilla in a CT scan. This was the result of increased focus on the primary task and not noticing the unexpected. The pilots in these incidents would not have expected three aircraft on the runway; therefore, they were not looking for them. Instead, they were focused on the landing surface and maintaining the vertical profile at night/poor visibility during a black-hole approach.

These are human cognitive limitations that have also been highlighted in other transport accidents. Crewmembers need to be aware of their limitations, especially when a task demands too much attention and/or when they are fatigued. Awareness of one's limitation, trusting the instruments, and adequately cross-checking with the crew and ATC can help to prevent the bias described in this paper. ◆

NEWS ROUNDUP

ESASI Sets Online Meeting Date, Makes Plans for 2021 Seminar

European Society of Air Safety Investigators (ESASI) President Olivier Ferrante announced that ESASI will hold its annual general meeting online in November and that planning has begun for the next ESASI seminar that will occur in Budapest, Hungary, on March 18–19, 2021. He said, "Given the uncertainty of future travel restrictions and quarantine rules resulting from the COVID pandemic, we are making contingency plans to hold a virtual conference should travel to Hungary not be possible. To help with the planning, we would very much like to know if you are intending to attend the seminar." In addition, the meeting of the military investigator group is scheduled to take place on the afternoon of March 17.

The aim of the seminar is to keep the European air safety investigation community abreast of current developments and evolving best practice in aircraft safety investigation. As in previous years, the seminar will include presentations on case studies, the European environment, challenges of modern air safety investigations, and human factors in aircraft accidents and incidents. ◆

MENASASI Holds Online Seminar

The Middle East and North Africa Society of Air Safety Investigators (MENASASI) held a virtual 2020 seminar on November 18 with an outreach workshop on November 17, reported Tom Curran. The outreach covered crisis management and family assistance. Frank del Gandio gave the seminar opening address, and MENASASI President Khalid Al Raisi welcomed the attendees with an address on the status of MENASASI activities.

The 2020 MENASASI webinar theme addressed the readiness and preparedness of states' accident investigation authorities to carry out their functions while managing adverse challenges by external factors such as, but not limited to, the COVID-19 pandemic and the resulting travel restrictions, governmental quarantine requirements, and the health and safety of investigators. It covered experiences from conducted investigations, lessons learned, solutions to difficult situations, and aspects that could help investigators perform their duties consistent with accepted standards.

The 2020 "in person" seminar, which was scheduled to take place in Cairo, Egypt, will be rescheduled for the same venue during the second half of 2021. This is provisional based on any travel restrictions due to COVID-19.

MENASASI has two new board members: Ismail Kashkash, Saudi Arabia Accident Investigation Board, and Ali Alnaqbi, founder and chairman of the Middle East and North Africa Business Aviation Association.

The regional society is working on a new MENASASI website, which will be available before the end of 2020. ◆

Latin American Society Holds Second Meeting

Latin American Society of Air Safety Investigators Vice President Enriqueta Zambonini reported that the regional society held its second meeting in late September. She noted that the organization developed a new logo, website, and published a page on LinkedIn. Officer elections are planned for December. ◆

ANZSASI Annual Seminar Postponed Until 2021

John Guselli, president of the Australian Society of Air Safety Investigators, announced that the Australian and New Zealand Societies (ANZASI) have rescheduled their joint annual 2020 conference for June 4–6, 2021, at the Novotel Surfers Paradise Hotel.

He noted that the COVID-19 situation in Australia "has deteriorated into one we cannot predict nor accommodate." He added that the postponement "was based on the fact that many local and international delegates may be legally prevented from traveling. In addition, others capable of travel may require a 14-day isolation period prior to and on return to their home states."

Guselli reported that the Royal Melbourne Institute of Technology-RMIT(see page 32) has become an ISASI corporate member. ◆

ISASI ERAU Student Chapter Begin New Semester Activities

Anthony Brickhouse, ISASI student coordinator, reported that Embry-Riddle Aeronautical University (ERAU) is back in full swing. He added that he chose to teach his four classes from home via Zoom. The ERAU (Daytona Beach) student chapter of ISASI continues to be active in the midst of the global pandemic. The officers for the fall 2020 semester are Ukeyvia Beckwith, president; Daniel Policelli, vice president; Donald Ventrice, public relations; and Paige Sharrow, associate advisor.

Due to COVID-19 protocols, the student chapter meetings are via Zoom. This has turned out to be advantageous because hosting guest speakers has become easier to coordinate. The chapter has had an organizational meeting and recently hosted the first guest speaker of the semester: Dr. Diego Garcia, an ISASI member, medical doctor, air safety investigator, and ERAU alumnus. Garcia spoke about the investigation of LaMia Flight 2933. He was on scene and had excellent details. Because the meeting was via Zoom, the lead investigator from the accident, Julian Escheverri, joined from Colombia.

The student chapter will host several guest speakers this semester. The chapter will also be joining in on meetings hosted by the student chapter of ISASI at the Florida Institute of Technology, located in Melbourne, Florida. Their advisor is ISASI member Capt. Shem Malmquist. ◆

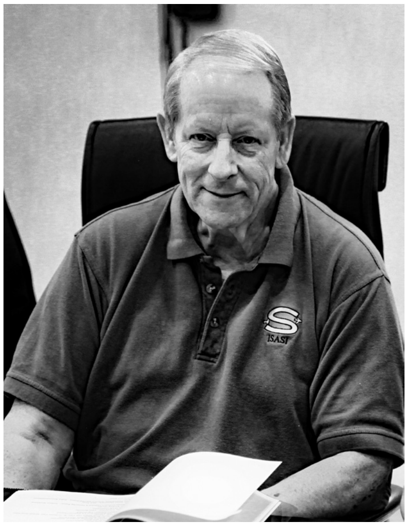
ISASI Seeks Participants for CISM Working Group

ISASI President Frank Del Gandio recently approved the formation of a Critical Incident Stress Management (CISM) Working Group, which is being led by Ashlesh Baichoo from Mali. The group is tasked with developing a working paper for the Society's CISM program to assist and support ISASI members who've faced trauma or high stress due to their work environments. The working group is looking for ISASI members who have CISM experience or training to help formalize the Society's protocol.

Del Gandio said, "All of us who have responded to an air accident or event, with or without fatalities, have at some point experienced difficulty with what we saw, smelled, or uncovered at an accident site—or even just with the pressure and stress of the investigation itself. Asking for emotional support is not easy for many of us."

CISM is a proven protocol originally developed for use with military combat veterans and then expanded to civilian first responders. CISM is now available virtually anywhere there is a need to address traumatic impact in people's lives. Del Gandio added, "Once the ISASI International Council accepts the CISM working paper and a program is in place, I urge you take advantage of this working group's efforts following a stressful investigation, even if you don't think you need help to recover. ISASI members work as part of a team to enhance air safety—we are not alone. We also do not have to face work-related stress and trauma alone."

If you're interested in participating in this new group, please send an e-mail to baichoo@un.org. ◆



Eugene "Toby" Carroll

It is with a heavy heart that I inform you that Eugene "Toby" Carroll passed away of heart complications on October 17. Services were held at the Houston National Cemetery in Houston, Tex., with full military honors on October 28. A mass was celebrated prior to burial. Our sincere condolences go out to Kathy, his wife of 51 years, and his three children and grandchildren.

In lieu of flowers, the family requests that donations be made to the Rudolf Kapustin Memorial Scholarship Fund in Toby's name. These donations may be sent to the ISASI office.

Toby had recently retired as president of the U.S. Society and as the U.S. councilor, positions he held for the last 11 years. He was recognized for his long air safety career and many accomplishments with the 2016 Jerome F. Lederer Award and was a consummate air safety investigator. Toby will be sorely missed by all of us who knew him and by investigators and professional air safety personnel around the world who worked with him.

A summary of Toby's career and air safety achievements appeared in "President's View" in the July-September 2020 issue of *ISASI Forum*. ◆

Frank Del Gandio
President

Former NTSB Chairman Mark Rosenker Dies

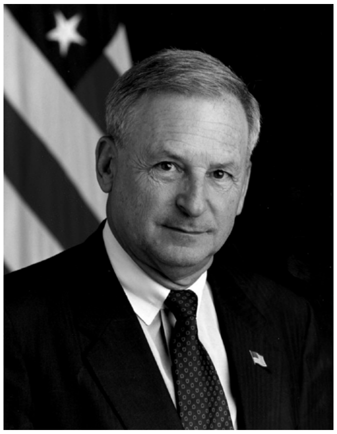
According to *The Washington Post*, Mark Rosenker died on September 26 at a hospice center in Alexandria, Virginia. He was 73. Rosenker was a public affairs specialist who served in Republican presidential administrations in the United States and became an authority on planes, trains, and automobiles. He was confirmed as the 11th chairman of the NTSB in 2006 and served for 4 years under President George W. Bush.

Rosenker chaired the country's accident investigation agency from 2005 to 2009, leading the NTSB through investigations that examined the catastrophic collapse of a bridge over the Mississippi River as well as the plane crash that killed millionaire adventurer Steve Fossett. He later joined CBS News as a radio and television analyst, founded a transportation safety consulting group, and was appointed one of the first members of the Washington Metrorail Safety Commission, an independent oversight group for the regional transit agency.

Rosenker, who had called Metro's worker safety record "unacceptable" during an NTSB investigation of a fatal train accident in 2006, recently completed a term as vice chairman of the safety commission. The group issued a scathing report in September calling Metro's rail operations center a "toxic workplace," with a culture that was "antithetical to safety."

After being appointed to the NTSB in 2003, Rosenker studied train derailments, exploding airplane fuel tanks, and collapsing bridges, trying to find a way to make accidents less likely. He was the face of the federal government's investigation of the Interstate 35W bridge collapse in Minneapolis, Minnesota, which killed 13 and injured 145 when it fell during evening rush hour in 2007. The collapse drew renewed attention to aging infrastructure throughout the United States, with Minnesota Democrats arguing that the state's Republican governor had failed to adequately invest in maintenance. Rosenker's team reached a surprising conclusion, finding that a flaw in the original 1960s bridge design was primarily to blame.

"My job is to call it like it is," he told the Minneapolis *Star Tribune* after announcing his agency's initial findings. "We deal in facts, analysis, and science. Politics, in any way, shape, or form, does not enter into the decisions we make." ◆



Mark Rosenker
Former NTSB Chairman

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WORKING GROUP CHAIRMEN

Air Traffic Services, Darren T. Gaines (Chair) (darren@flyvectorllc.com)
Ladislav Mika (Co-Chair) (ladi.mika@seznam.cz)
Airports, David Gleave (spotwelder@hotmail.com)
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Government Air Safety Facilitator, Marcus Costa (mcosta@icao.int)
Human Factors, William Bramble (bramblw@ntsb.gov)
Investigators Training & Education, Graham R. Braithwaite (g.r.braithwaite@cranfield.ac.uk)
Military Air Safety Investigator, James W. Roberts (james.w.roberts3@boeing.com)
Promotion of ISASI, Daniel Barafani (Chair) (dbarafani@jiaac.gob.ar)
Unmanned Aerial Systems, Tom Farrier (farrierT@earthlink.net)

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WHO'S WHO: RMIT UNIVERSITY AEROSPACE ENGINEERING AND AVIATION

(Who's Who is a brief profile prepared by the represented member organization to provide a more thorough understanding of the organization's role and function.—Editor)

RMIT University and the Australian Transport Safety Bureau (ATSB) announced at the 2019 Australian International Airshow that they had established a strategic partnership to offer a graduate certificate in transport safety investigation, teaching how to manage and lead accident investigations of air, rail, and marine vehicles.

The partnership provides industry in Australia and throughout the Asia-Pacific region with access to high-quality ATSB-sponsored training in transport accident investigation, as well providing a framework to facilitate important transport safety-related research through a credible university-based methodology.

Martin Bean, RMIT vice chancellor and president, noted that the partnership with the ATSB was a historic one. "Together, we will work to improve transport safety throughout the Asia-Pacific region, across aviation, maritime, and rail industries."

Until now, the ATSB has conducted its own nationally accredited diploma of transport safety investigation training in house. But with this collaboration, RMIT and the ATSB ensure the course is industry-relevant and work-integrated and delivered by a highly experienced education provider.

RMIT has extensive expertise in multimodal transport safety systems and experience in industry-focused education. ATSB subject-matter experts with in-depth industry experience are guest lecturers on specialized topics in the program, and the ATSB has advised on the development of the program structure and the course material.

The program is now in its second year, and the first cohort of students has graduated. "Whilst the program, lecturers, and facilities were great, I really appreciated and enjoyed the class dynamics," said 2019 graduate Colin McNamara. "It was richly rewarding to share this experience with such a diverse mix of industry-based personnel alongside actual ATSB investigators."

The graduate certificate in transport safety investigation consists of four courses (or units of study) delivered on the Melbourne City campus. Each course is delivered in a one-week intensive mode combined with online materials to fit around professional obligations.

From left, RMIT Associate Dean of Engineering, Aerospace Engineering, and Aviation, Professor Pier Marzocca; ATSB Commissioner Chris Manning; RMIT Vice Chancellor and President Martin Bean, CBE; and ATSB Program Advisor Linda Spurr at the strategic partnership agreement signing.

What's next?

Following the successful first delivery of the program, RMIT is currently assessing the possibility of introducing a graduate diploma in transport safety investigation as a pathway to extend and deepen studies in the sought-after area of transport safety. This will include subjects on safety management systems, engineering specialist techniques in support of accident investigations, and a range of electives that students can choose from to tailor the program structure to their own learning objectives and professional interests.

"These programs will contribute to addressing an increasing demand in transport safety qualifications and training in the Asia-Pacific region," said Adrian Mouritz, distinguished professor and executive dean of the School of Engineering.

RMIT and the ATSB have an expectation of extending the scope of their ongoing partnership to research opportunities leading to potential master by research and Ph.D. projects in transportation.

The graduate certificate in transport safety investigation sits within the School of Engineering at RMIT, which is renowned for its industry-relevant, high-quality teaching and research, its globally competitive graduates, and its international linkages.

RMIT has a long and proud history in aerospace engineering and aviation education and research, with close to 80 years of experience. RMIT is one of Australia's original tertiary institutions, with an international reputation in education, research, and engagement with industry.

Find out more at rmit.edu.au/schools/engineering. ◆