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**A global safety deficiency
False glide slope capture affecting aircraft**

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Title:

Safety Alert on False Glide Slope captures effecting various aircraft models. A potential safety deficiency identified by investigation

Abstract:

A serious incident occurred at Eindhoven Airport (Netherlands) in May 2013. A Boeing 737-800 performed a go-around while using the Instrument Landing System (ILS). The flight crew reported a False Glide Slope capture as the reason for the go-around.

At first the occurrence report did not really gain much attention but when the investigation progressed it turned out to be a safety deficiency on a global scale. Following flight tests it was found that a potential serious weakness in the automatic systems and logic used was discovered that effected many aircraft types and perplexed many pilots in the past.

The Dutch Safety Board finalised the investigation with recommendations in two Final Reports. The first report deals with the event "Stick shaker warning during ILS approach Eindhoven Airport" and a second report, "Pitch-up Upsets due to ILS False Glide Slope", deals with the explanation of the pitch-up response of aircraft on a global scale.

The author

Mr. Michiel Schuurman is a Senior Air Safety Investigator for the Dutch Safety Board. He joined the safety board in 2005. His key responsibility at the Board include conducting accident investigations, performing accredited representative duties, analysing flight recorder data and other electronic recorded data which is not limited to Aviation. He is currently also an Assistant Professor at the faculty Aerospace Engineering Delft University of Technology The Netherlands. In the Structural Integrity and Composites group he is responsible for teaching the Masters course Forensic Engineering.

Michiel holds a Master's Degree in Aeronautical Engineering from faculty of Aerospace Engineering Delft University of Technology. He has was trained in accident investigator at the NTSB training centre Washington D.C. and at the Kirkland Albuquerque New Mexico. Also he has received technical training on various aircraft types including Boeing and Fokker aircraft.

How is began

On May 31st 2013 a Boeing 737-800 received radar vectors for the arrival and approach to the landing runway at Eindhoven Airport. During vectoring the aircraft's speed was high and its vertical position remained approximately 1,000 feet above the descent profile up to the moment of pitch-up upset. During the approach a 30 knots crosswind at 2,000 - 3,000 feet on base leg and a tailwind on final approach contributed to the aircraft being closer and higher to the runway than normal. The influence of the crosswind and tailwind on the flight path remained unnoticed by both the air traffic controller and the flight crew. At approximately 1,300 feet the captain informed the FO that it was very unlikely a successful landing would be possible and they should prepare to make a go-around.

At approximately 1,060 feet and 0.85 NM from the runway threshold the aircraft captured the 9 degree False Glide Slope. The aircraft pitched up rapidly and the engine N1 increased from 30% to 90% on both engines in order to maintain the selected airspeed. Finding this behaviour unexpected, the Captain called for a go-around. The pitch further increased to approximately 24.5 degrees nose up and the stick shaker warning activated. Almost at the same time the TOGA button was pushed once by the First Officer and the autopilot was deactivated. The aircraft landed safely after the go-around.

Background

Similar events

To get better understanding of the event a database search was performed to find similar occurrences. A search in the European databases found four other events which occurred between 2011-2013. In the United States NASA runs the Aviation Safety Reporting System (ASRS). A search performed in this database with the search for pitch-up upsets, attributable to the false Glide Slope phenomena, revealed 19 similar events.

Analysing this ASRS event in more detail it was shown that a distinction could be made between Glide Slope events from above and below. The 19 pitch-up upset events above the Glide Slope attributed to the main cause of a False Glide Slope. For statistical purposes a problem is attributed to each event for analyses purposes. The ASRS assessment of these events is not definitive but the database suggests that human factors and navigation facility equipment plays a major part (Figure 1).

ILS glide slope antenna

The Glide Slope antenna is situated to one side of the runway touchdown zone. The centre of the Glide Slope signal is arranged to define a Glide Path of approximately 3 degrees above touchdown ground level. The Glide Slope receiver on the aircraft measures the difference in the depth of modulation of the 90 Hz and 150 Hz signals similarly to that of the Localizer (Figure 2). For a standard 3 degree Glide Path the relative signal strength of the "Fly Up" (150 Hz) command and the "Fly Down" (90 Hz) command is equal (Null).

Five types of Glide Slope antenna systems are used worldwide, three of which are Imaging Type antennas. These three types are referred to as Null Reference, Sideband Reference, and Capture Effect or M-array (Figure 9). The two non-Imaging Type antennas are the Endfire and Waveguide. The non-Imaging Type ILS Glide Slope antenna systems were excluded from the investigation because they are infrequently used.

The Key outcomes

Flight tests

The Dutch Safety Board conducted test flights to measure the ILS-signal field characteristics of the M-array (Capture Effect) antenna. The Sideband and Null Reference antenna were measured by the Federal Aviation Administration (FAA) in the United States, at the request of the National Transportation Safety Board.

By closely examining the ILS signal characteristics the investigation shed new light on the False Glide Slope. The first False Glide Slope type is a False Null. This glide path resembles the normal 3 degree Glide Slope signal (Null) but is actually either at the wrong location in space or has a steeper angle. Following a False Null signal will result in an aircraft having a higher than normal descent rate. The second type of False Glide Slope that can be distinguished is the Signal Reversal. This Signal Reversal is 'unstable' as the ILS signal changes from "Fly Down" to "Fly Up". When the autopilot is engaged in the appropriate mode, the "Fly Up" signal will result in a command to pitch-up the aircraft (Figure 3).

Measurements performed on the three Imaging type category ILS Glide Slope antenna systems revealed two different Glide Slope signal characteristics.

- a. Signal reversal sometimes occurs at approximately 6 degree Glide Path angle.
- b. Signal reversal always occurs at the 9 degree Glide Path angle.

Accessible information for the aviation community and received wisdom for flight crew and air traffic controllers did not make a distinction between two types of False Glide Slope; False Null and Signal Reversal. As a result the False Glide Slope phenomenon was not fully understood. Based on these results and the multiple similar events in the past the Safety Board published a Safety Alert in November 2013. The Safety Alert warns pilots of a potential hazard when ILS approaches from above the 3 degree Glide Slope are performed in autoflight resulting in unexpected and severe pitch-up upset. Following the Safety Alert the industry and several aviation authorities worldwide have taken actions to prevent re-occurrence.

Certified volume of operation

ICAO mandates that Radio Navigation aids of all types which are available for use by aircraft engaged in international navigation shall be the subject of periodic ground and flight checks. Ground measurements cannot completely assure the quality of the signal in space due to the environmental

effects of terrain, man-made obstructions, Radio Frequency Interference (RFI), and reflective surfaces such as snow, water and other aircraft. The use of specially equipped aircraft, precisely positioned (laterally and vertically), is the only effective method of evaluating a signal-in-space or instrument flight procedure. Flight inspection certifies instrument approaches and ensures that an aircraft at the lowest authorized altitude is guaranteed to be safe from ground obstacles.

Flight inspection is traditionally based on in-flight measurement of the signal in space produced by air navigation systems on board a calibration aircraft. During flight inspections the 3 degree ILS Glide Slope signal is inspected in different ways, including at a prescribed flight offset, to verify a valid 3 degree Glide Slope signal.

The inspected area is normally situated between 0 and 10 NM from the runway threshold and approximately 35 degrees left and right of the runway heading (Localizer). The ILS antenna system is checked and if required adjusted at least once a year.

The measurements to determine the Glide Slope field as were done for this investigation were not part of a normal Flight Inspection. Flight Inspection is performed on the 3 degree Glide Path. Above an angle of 5.25 degrees, the Glide Slope field characteristic is neither checked, nor is this required by ICAO regulations. This means that when flying above the 5.25 degree Glide Path the aircraft is flying beyond the reliability envelope which is certified and periodically checked by Flight Inspection (Figure 3

Aviation Safety Management System

ICAO mandates all Contracting States to implement a State Safety Program (SSP) wherein aviation organisations are required to establish a Safety Management System (SMS). SSP and SMS are complementary. The European Union adapted the ICAO requirements for Safety Management in Regulation (EU) 290/2012 and Regulation (EU) 965/2012. In some cases this regulation pre-dated the events described in this investigation. The overall SMS structure for all organisations is based on the following four components, also known as "pillars of the SMS".

The level of development and implementation of SMS depends on the size, nature and type of operation. Depending on the number of aircraft and destinations an operator can have thousands of flights per week, with hundreds of safety reports being filed. All these safety reports must be captured, assessed and analysed to identify risks if further investigation and corrective actions is warranted.

Safety Management Systems "4 pillars"

- Safety Policy:
 - Management Support
 - Responsibilities & Authorities
- Safety Risk Management:
 - Proactive Hazard Identification
 - Risk Assessments and Control Measures
 - Corrective and Preventive Actions

- Safety Assurance:
 - Process Evaluation
 - Safety Performance Monitoring
- Safety Promotion:
 - Safety Communications and Culture
 - Safety Training

SMS methodologies were applied and resulted in data being captured in the mandatory state occurrence databases and Operators' SMS databases. However the investigation indicated that due to event coding and insufficient detail in the event descriptions, the complexity of the occurrence was not identifiable.

The initial mandatory reports into to the involved State occurrence database were not always appended with the results of the follow-up investigations conducted by the operators. Furthermore the root-cause of the events was not identified during the operators investigation. The result was that due to the absence of valuable additional background information, the possible detection of a safety deficiency in the future became remote. As the investigated safety management systems are mainly driven by statistical analysis, a limited number of reports is statistically insignificant and on that basis no action was required.

Despite SMS methodologies and previous investigations, the reported pitch-up upset incidents occurred in airspace which is not part of the ILS ICAO certified volume of operation. None of the parties identified this latent safety deficiency.

This investigation has shown that despite the implementation of SMS the global aviation system was unable to 'connect the dots' when related serious incidents occurred. On a national level occurrences are analysed mathematically and the identified risk indicators are monitored and serve as the present Safety State. As has been shown in this investigation, the unidentified or misidentified indicators which in some cases are mathematically insignificant, but nonetheless important, are not dealt with in current SMS occurrence report analyses methodology. This shows that new techniques and information sharing strategies are required to be embedded in safety management systems to search for and identify latent safety risks at present and in the future.

It could be argued that a more holistic systems approach in risk identification might be a way to supplement current SMS occurrence report analyses methodology in the future. As an example, in the fourth quarter of 2013 the Flight Safety Foundation and MITRE1 announced collaboration in creating Transform Global Aviation Analytics. The background to the collaboration was given as the complexity of today's global air navigation system; the analysis of diverse types of data is essential to correlate accurately multiple attributes, which in combination have the potential to identify systemic vulnerabilities that elevate safety risks. This is an example of a possible approach in addressing the safety challenge of the future. Unidentified or misidentified indicators, which in some cases are mathematically insignificant but nonetheless important, are not dealt with in the current SMS framework. The large amount of reports and information available has meant that the currently implemented SMS occurrence reporting analyses framework, using mathematical methodologies and assessments, might be reaching its potential limit for safeguarding safety.

Conclusion

In conclusion the Pitch-up upset events were reported to European national occurrence databases and the voluntary NASA ASRS database. Analysis of similar events and database analyses suggests that aircraft pitch-up upsets have occurred with a variety of aircraft model types and manufacturers. The pitch-up upsets were attributed to ATC equipment failures and Human Factors. But analyses of the data indicates a difference between aircraft flying above or below the glide slope. This was not included in the analyses performed.

In conclusion by closely examining the ILS signal characteristics the investigation shed new light on the False Glide Slope myth. A 'reversal of knowledge' was required to identify an issue resulting in aircraft pitch-up upsets.

The implemented SMS and its methodology has certain flaws which can be improved. A potential enhancement can be made through a holistic approach of using knowledge, experience and data to identify new potential safety issues which have not yet occurred.

As a result of the investigation the Dutch Safety Board formulated 6 recommendations. The recommendations focus are on changes being implemented in short and long term in the area of training, operational (stabilised approach criteria) and technical measures to prevent re-occurrence. Furthermore the Dutch Safety Board made recommendation to enhance current occurrence reporting and analyses and take measures to achieve the goal of the system to identify potential safety deficiencies in a timely manner.

Reference

www.safetyboard.nl [Aviation > Stick shaker warning on ILS final / Aviation > Pitch-up upset due to ILS False Glide Slope]