Nationaal Lucht- en Ruimtevaartlaboratorium

National Aerospace Laboratory NLR

Executive summary

An Investigation into Standard Instrument Departure (SID) Deviations

Problem area
Standard instrument departures SIDs are used at many airports in the world. A SID provides a transition from the runway end to the en-route airway structure. There are many operational advantages in using SIDs, both for the pilot as for the air traffic controller. Small deviations from the assigned SID occur on almost every SID flown. This is quite normal and poses no immediate threat to flight safety. However large deviations from the assigned SID or flying the wrong SID can be hazardous and may (and have!) lead to: Close proximity to terrain or obstacles; Close proximity to other aircraft; Airspace violations.

Description of work
There can many reasons why an aircraft may significantly deviate from the assigned SID. In this paper these reasons are examined in detail using historical data of significant SID deviation occurrences.

Results and conclusions
Incidents in which a significant deviation from the assigned SID occurred are rare compared to other type of flight safety events. Significant deviation from an assigned SID can result in a degradation of flight safety. Significant SID deviations are caused by a wide variety of factors. However by far the most important causal factor identified in this study is the fact that a wrong SID is used by the flight crew;

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Summary

Standard instrument departures SIDs are used at many airports in the world. A SID provides a transition from the runway end to the en-route airway structure. There are many operational advantages in using SIDs, both for the pilot as for the air traffic controller. Small deviations from the assigned SID occur on almost every SID flown. This is quite normal and poses no immediate threat to flight safety. However large deviations from the assigned SID or flying the wrong SID can be hazardous and may (and have!) lead to: Close proximity to terrain or obstacles; Close proximity to other aircraft; Airspace violations.

There can many reasons why an aircraft may significantly deviate from the assigned SID. In this paper these reasons are examined in detail using historical data of significant SID deviation occurrences.

Incidents in which a significant deviation from the assigned SID occurred are rare compared to other type of flight safety events. Significant deviation from an assigned SID can result in a degradation of flight safety. Significant SID deviations are caused by a wide variety of factors. However by far the most important causal factor identified in this study is the fact that a wrong SID is used by the flight crew. It is more likely that a wrong SID is used by the flight crew when there are similar sounding SID names used at the airport. Also important factors associated with wrongly selected SIDs are inefficient or lack of crew departure briefings, read-back hear-back errors, crew expectation, late departure runway and/or SID change, distracted flight crew, and high workload of the flight crew.

Contents

1 Introduction

"*On April 29, 2001, the Alaska airlines MD-83 was on a flight from Vancouver to Seattle, taking off on runway 08R of Vancouver International Airport. When the clearance delivery controller issued the clearance he incorrectly gave a **Standard Instrument Departure** SID RICHMOND 6. However he wrote down the correct SID, VANCOUVER 2, on both the digital and paper strip. The tower controller, seeing VANCOUVER 2 on his strip, assumed that the Alaska airlines MD-83 would follow that SID. After take-off, the MD-83 turned right to a heading of 140 degrees as called for by the RICHMOND 6 SID. The MD-83 now came into a conflict with a DASH-8 which had taken off ahead, also on a RICHMOND 6 SID. The tower controller noticed the conflict and instructed the MD-83 to turn left. The separation had reduced to 2 nm whereas 3 nm is required.*" Source: NLR-ATSI Air Safety Database.

1.1 Background

A Standard Instrument Departure (SID) is an IFR departure procedure compliant with International Civil Aviation Organization ICAO PANS-OPS (or equivalent) design criteria that provides a transition from the runway end to the en-route airway structure. There are many operational advantages in using SIDs, both for the pilot as for the air traffic controller. For the pilot a relatively complicated route segment may be loaded from a database and flown using the Flight Management System (FMS), whilst being assured of proper clearance from obstacles, ground or other traffic. Air Traffic Control may clear the aircraft for the SID, thereby reducing the need for further instructions during the initial climb phase of the aircraft, greatly reducing the controller workload and frequency congestion.

A SID is laterally defined by conventional navigation aids (such as VOR, DME, NDB or prescribed headings) or as an area navigation (RNAV) route that consists of a number of LAT/LON waypoints. An RNAV SID may overlay a conventional SID. In addition, SIDs may include a vertical profile, by defining minimum or maximum crossing altitudes at waypoints or fixes along the path. It is worth while to emphasise some characteristics of SIDs:

- The State authority for Air Traffic Control is responsible for the proper design of the SID and publication in the Aerodromes section of the Aeronautical Information Publication (AIP);
- For obstacle clearance, a SID assumes the aircraft will climb with a steady climb gradient of 3.3%, or 200 ft per NM. Where required, a higher procedure design gradient may be published. According to ICAO the aircraft operator is responsible for checking if normal aircraft performance can comply with the higher procedure design gradient (ICAO Annex 6);

- SIDs do not consider the engine failure case while regulations do impose to dispatch the aircraft assuming an engine failure at the most critical moment during the takeoff. Therefore, some high climb gradients required by normal SIDs cannot be achieved in case of engine failure unless the takeoff weight is decreased. The aircraft operator is responsible for the definition of contingency routings for cases where aircraft performance is degraded, such as for engine-out cases.

The SID can be pilot navigated where the pilot is required to use the chart as reference for navigation to the en-route phase. This is often achieved by following a pre-programmed departure procedure from the Flight Management System (FMS) using the flight director (FD) or autopilot. The SID can also be a vectored SID (or radar SID) where ATC provides radar navigational guidance through headings to an assigned route or to a fix depicted on the chart. In this last case pilots are expected to use the SID chart as reference for navigation during radar vectoring.

SIDs are first and foremost designed to comply with obstacle clearance requirements, but are also often optimized to satisfy ATC requirements and may serve as minimum noise routings as well. Small deviations from the assigned SID occur on almost every SID flown. This is quite normal and poses no immediate threat to flight safety. However large deviations from the assigned SID or flying the wrong SID can be hazardous and may (and have!) lead to:

- Close proximity to terrain or obstacles;
- Close proximity to other aircraft;
- Airspace violations.

There can many reasons why an aircraft may significantly deviate from the assigned SID. In this paper these reasons are examined in detail.

1.2 Objectives and scope

The objective of the present paper is to identify the main causal factors related to significant deviations of assigned SIDs. The scope of this study is limited to commercial air transport operations.

1.3 Overview of the paper

In section 2 the incident data analysis is presented and discussed. Section 3 discusses in detail a number of example cases of SID deviations. Finally section 4 and 5 give the conclusions and recommendations respectively.

2 Incident data analysis

2.1 Approach

To meet the objectives of the present study incident data related to significant SID deviations are collected and analysed. A specially developed taxonomy related to the causes and circumstances of SID deviations is applied to the data. Furthermore the outcome of the deviation is also classified (e.g. no safety effect, air proximity, or loss of separation with ground obstacle).

2.2 Data collection

Incident data related to significant SID deviations are obtained from the NLR-ATSI Air Safety Database. This database contains many different sources of aviation safety data. For the present study data from the airline incident database are used as it provides reports on SID deviations often containing information from both the involved air navigation service provider as well as the operator. This database contains over 270,000 flight operational occurrences for the period 1996 to 2005. The data are limited to commercial airline operations. Although the incidents contained in the used database are reported worldwide the majority of the data come from countries in North America and Europe. This reflects the route structure of the operators covered by the incident database.

There is no common definition for what a “significant deviation” is. In the present study a horizontal or vertical deviation of more than 300 ft. from the assigned route is considered significant. However it should be noted that the actual deviation cannot always be found in the available information contained in the incident database. In particular the horizontals deviation is not always mentioned. As the incident was reported it is assumed that the deviation was large enough to be considered hazardous by the pilots and/or air traffic controllers.

The incident database is queried for terms such as “SID deviation”, “wrong SID”, “MAP shift”, “SID blunder” etc. Each result is then manually reviewed to see if the incident is of interest to the present study. If this is the case, the specially developed taxonomy is applied (e.g. assignment of causal factors, type of deviation etc.).

2.3 Results

The final data sample encompasses 345 occurrences in which a significant deviation from the assigned SID occurred. The vast majority (85%) of these incidents occurred in North America and Europe. This is not surprise as most of the operators in the incident database operate in these regions.

Table 1 shows the distribution of the type of deviation that occurred. The results in Table 1 clearly show that the vast majority (71.3%) of SID deviations analysed involve a lateral deviation. In 20% of the occurrences a classical level bust occurred with the majority related to overshooting the assigned altitude. Note that whenever a wrong SID is flown a lateral deviation is selected in the coding process as the first thing that happens when a wrong SID is flown is that the aircraft makes a lateral deviation from the assigned SID.

Table 2 lists the frequency of the consequences of a SID deviation. In most cases (87.8%) there was no immediate safety threat. SID deviations resulted in a loss of separation with other traffic in 3.5% of the cases and a loss of separation with ground obstacles in 2.9% of the cases.

Table 3 lists the causal factors identified in the data sample. From all the factors found the factor “wrong SID used by the crew” is by far the most important one as it accounts for 14.9% of all causal factors. No hard conclusions should be made from those factors with a low count.

Table 1: Overview of deviation types.

Type of deviation	Count	Percent
Lateral deviation	246	71.3%
Vertical deviation (overshoot)	66	19.1%
Unknown	30	8.7%
Vertical deviation (undershoot)	3	0.9%

Table 2: Overview of consequences.

Consequences	Count	Percent
None	303	87.8%
Unknown	20	5.8%
Air proximity	12	3.5%
Loss of separation with obstacle	10	2.9%

2.4 Discussion of the results

In this section some of the interesting results presented in section 2.3 are discussed.

One of the first observations that can be made from the list of causal factors is that the vast majority of SID deviations are pilot related. Secondly factors that are related to interface issues are important in the chain of events leading to significant SID deviations. Wrong information or ambiguous information provided to the pilots are examples of this interface problem. Outdated or incorrect FMS databases that are used in an FMS guided departure and outdated departure charts are examples of incorrect data provided to the pilots. Unfortunately pilots often do not have the necessary means or time to check the validity of such information.

Air traffic control also plays a role in SID deviations. For instance the classic readback hearback error occurs often in SID deviations where the pilot reads back the clearance incorrectly and the controller fails to correct the error. Also controllers that issue a departure runway and/or SID change just before takeoff or during taxi-out phase can easily lead to pilots making mistakes.

Another large part of SID deviations is caused by technical problems such failing or improper functioning navigation aids (both on the ground as well on board of the aircraft), autopilot and guidance problems. Interesting is the fact that in a large number of these incidents the technicians were not able to identify what exactly caused the failure of a system. For instance autopilot components were replaced which solved the problem however no fault in these components could be found afterwards.

Table 3: Identified causal factors in SID deviation occurrences.

Causal Factor	Count	Percent (of all factors)
Wrong SID used by crew	69	14.9%
Altimeter setting error	24	5.2%
Inadvertent deviation of SID	23	5.0%
FMS Database error or missing data	23	5.0%
Navigation aids error	21	4.5%
Autopilot error/failure	20	4.3%
Inefficient or lack of crew departure briefings	20	4.3%
Late departure runway and/or SID change	19	4.1%
Crew distracted	18	3.9%
Map shift	18	3.9%
Read-back hear-back error	17	3.7%
Similar sounding SID names	16	3.4%
Incorrect/no flight director commands	15	3.2%
Turbulence	15	3.2%
Crew expectation error	15	3.2%
Aircraft flown in dead reckoning	15	3.2%
Poor programming of departure in the FMS	14	3.0%
Insufficient monitoring by pilots	12	2.6%

Causal Factor	Count	Percent (of all factors)
Intentional deviation of SID	12	2.6%
Departure chart out-of-date or incorrect	9	1.9%
Crew high workload	9	1.9%
Crosswind conditions	8	1.7%
Aircraft performance does not meet SID requirements	6	1.3%
FMS database out of date	5	1.1%
SID flown using conventional navigation aids (raw data), instead of	5	1.1%
Crew misread chart	5	1.1%
Incorrect SID given by ATC	4	0.9%
ATC clearance issued during high workload taxi phase	4	0.9%
SID flown manually (flight technical error)	4	0.9%
Chart susceptible for misreading	4	0.9%
SID coding error	3	0.6%
Ambiguous change in SID clearance	2	0.4%
ATC clearance issued far much in advance	2	0.4%
Complex SID	2	0.4%
Hear-back error	2	0.4%
Inefficient crew inter-cockpit coordination and communication	2	0.4%
ATCO high workload	1	0.2%
High quantity of radio communication with ATC	1	0.2%

From all the causal factors identified in the analysed incident data the factor “wrong SID used by the crew” is by far the most important one. This factor accounts for 14.9% of all causal factors and is found in 20% of all analysed SID deviations. There can be a number of reasons why the pilot used a wrong SID. In Table 4 the factors identified in wrong selected SID related occurrences are listed. This table gives a better understanding of why sometimes a wrong SID is used.

From Table 4 it becomes clear that similar sounding SID names are often related in the cases where the pilots selected the wrong SID. It is not a big surprise that pilots select the wrong SID when there are other SIDs available with a similar sounding name. Often the difference is only a single letter or number. For instance ELBA 5B looks very much the same as ELBA 5C and can easily lead to mistakes when selecting one. When using the FMS NAV mode the pilot selects the SID from the FMS database. Depending on the type of FMS a list of runways is presented which has to be selected first after which a list of corresponding SIDs is given. It is also possible that a list of SIDs is listed first which are automatically linked to the corresponding runway. FMS NAV databases always have the SIDs linked with the associated runway. It is often

impossible for the pilots to recognise the fact that they are flying a wrong SID: in the cockpit all instruments indicates that the aircraft is exactly on the pre-defined route! Usually ATC notices such errors much earlier than pilots. It could be expected that similar sounding SID names are mainly used at large airports having many SIDs. However, this is not necessarily the case. Similar sounding SID names are used at many airports around the world regardless of size of the airport operation.
From Table 4 it follows that inefficient or lack of crew departure briefings is also an important factor leading to the use of wrong SIDs. When no crew departure briefing is conducted possible errors in the selected SID may go unnoticed. Departure briefings are sometimes omitted or conducted in less efficient manner when there is a lot of time pressure.
Table 4 shows that the classic readback hearback communication error is also often a causal factor when a wrong SID is flown. In this case the pilot reads back the incorrect SID and the controller fails to notice this.
The crew expectation error is another classical air-ground communication issue which according to Table 4 is also often found when a wrong SID is flown. In this case the pilots assumed that they would be instructed to fly a particular SID (e.g. because they always get this SID or the operational flight plan given by the company mentions this SID). When ATC issues another SID the flight crew still uses the one they expected first. Expectations influence perceptions and therefore underlie potential errors in voice communications.

Table 4: Factors associated in with wrong SID selected deviations.

Associated factors	Count	Percent*
Similar sounding SID names	15	21.7%
Inefficient or lack of crew departure briefings	15	21.7%
Read-back hear-back error	12	17.4%
Crew expectation error	11	15.9%
Late departure runway and/or SID change	6	8.7%
Crew distracted	5	7.2%
Crew high workload	4	5.8%
Chart susceptible for misreading	2	2.9%
Turbulence	1	1.4%
Map shift	1	1.4%
Hear-back error	1	1.4%
ATC clearance issued far much in advance, requiring further re-clearance during high workload taxi phase	1	1.4%
ATC clearance issued during high workload taxi phase	1	1.4%

*of all incidents with wrong SID used by crew.

An altitude deviation or level bust occurred in 20% of all SID deviations analysed. Such events are under the attention of the international aviation community. In Table 5 an overview is given of the factors associated with altitude busts during SID deviations. Altimeter setting error is by far the most important factor in SID deviations that resulted in altitude deviations. This factor is also often identified in other studies on level busts (not limited to SID deviations).

Table 5: Factors related to altitude deviations.

Associated factors	**Count**	**Percent***
Altimeter setting error	24	34.8%
Crew distracted	7	8.0%
Late Departure Runway and/or SID Change	7	8.0%
Autopilot error/failure	6	6.8%
Insufficient monitoring by pilots	6	6.8%
Crew high workload	4	4.5%
SID flown manually (flight technical error)	4	4.5%
Aircraft performance does not meet SID requirements	3	3.4%
Turbulence	3	3.4%
ATC clearance issued during high workload taxi phase	2	2.3%
Chart susceptible for misreading	2	2.3%
Crew misread chart	2	2.3%
Inadvertent deviation of SID	2	2.3%
Incorrect/no flight director commands	2	2.3%
Inefficient or lack of crew departure briefings	2	2.3%
Read-back hear-back error	2	2.3%
Wrong SID used by crew	2	2.3%
Ambiguous change in SID clearance	1	1.1%
ATCO high workload	1	1.1%
Complex SID	1	1.1%
Crew expectation error	1	1.1%
FMS Database error or missing data	1	1.1%
Hear-back error	1	1.1%
High quantity of radio communication with ATC	1	1.1%

*of all incidents which resulted in an altitude deviation.

Many of the causal factors found in this study are related to the way a SID is flown in particular when using a FMS guided departure. It is therefore interesting to have a closer look at FMS departures and its relation to SID deviations. In many commercial aircraft operations SIDs are flown using the FMS (L)NAV mode. This is a lateral autopilot or flight director mode in which the FMS gives input regarding the lateral path to be flown based on a pre-programmed route in the FMS database. The FMS needs to know the position of the aircraft relative to the departure runway to fly a LNAV departure. The FMS can use different types of navigation aids to calculate this position. Depending on the aircraft type/model (L)NAV can be armed on the ground or after reaching a certain altitude (typically 400 ft.). In this last case the aircraft is normally flown in a heading mode until reaching the (L)NAV arming altitude. When LNAV is armed on the ground the aircraft has to be at a certain altitude to pickup the signals from radio navigation aids such as a VOR/DME and DME/DME. If the aircraft has GPS available for navigation the FMS has an accurate position right after liftoff or even earlier. When during an (L)NAV departure navigation aids such the GPS, VOR/DME, and DME/DME are unavailable, the FMS will initially revert to the aircraft Inertial Reference System (IRS) inputs from which LAT-LON coordinates can be calculated by the FMS. The IRS can produce accurate results when flying straight ahead and shortly after an accurate position determination. This is the case directly after lift off as the aircraft position is normally initialised to the LAT-LON co-ordinates of the selected runway when starting the take-off roll. This occurs at TOGA selection or reaching a certain speed, typically 50 kts., when the reference position will be determined by the FMS based on the runway used for takeoff. The FMS database contains the LAT-LON positions of the runway and uses this as its first position. The first part of the SID will always be a straight section as aircraft are not allowed to make turns below a certain altitude (typically 400-500 ft.). If the aircraft has an Attitude Heading Reference System (AHRS) instead of IRS, the FMS can only use this to determine the position of the aircraft based on heading and true airspeed. AHRS works fine for short term navigation purposes as long as there is no (significant) crosswind along the track. When there is crosswind and the aircraft is using AHRS only, a significant deviation from the SID can occur. The analysed incident data show a number of such cases in which the aircraft is flown in dead reckoning. To the pilots this problem goes unnoticed as the navigation display will show the aircraft right on the SID. Sometime after the aircraft receives the first inputs from the ground radio navigation aids a map shift will occur as the aircraft can determine its position much more accurately. To ATC such deviations are difficult to assess as on the radar it could look like the aircraft is flying the wrong SID especially when there are parallel runways. There are also a number of cases identified in the data sample in which during a (L)NAV departure the FD failed or gave wrong commands or in which the autopilot did not work properly.

Properly functioning navigation aids are also required to fly a SID correctly. The analysed data show a number of cases in which this was not the case. Such as the case in which radio beacons like a VOR produced incorrect signals leading to position errors.
Significant deviations from the SID can also occur during an (L)NAV departure when the database in the FMS is outdated or incorrect. The analysed incident data indeed showed a number of such cases. Having an up-to-date database is the responsibility of the operator, update processes are therefore part of the overall quality management within an airline. However, out-of-date NAV databases are less common in SID deviations than incorrect NAV databases. Operators are also responsible for the proper content of the database. Database validity checks may be part of the mentioned quality processes. Alternatively, airlines may obtain their NAV databases from ED-76/DO-200A accredited companies that are certified to supply navigation databases directly to end-users. Navigation database suppliers obtain their source information from worldwide AIPs and NOTAMs. Many of the AIPs are still published in a paper format and errors can easily be made when transferring this information into databases. Analysis of some reported NAV databases problems of different suppliers showed that 10-15% of the errors made in NAV databases are related to SIDs (e.g. wrong names, wrong headings, etc.). These errors could lead to significant deviations from the assigned SID when flying a (L)NAV departure. Many of these errors are only indentified after a SID deviation occurred.

3 Example cases of some serious SID deviation occurrences

In this section some accidents and serious incidents are briefed. These cases reflect some of the causal factors as discussed in the previous section.

CASE 1 (source: ATSB Occurrence Number 200200463. Date: 20 February 2002)
This is an example of a vertical deviation with an air proximity as a consequence. Causal factors in the SID deviation were 'crew distracted' and 'insufficient monitoring by pilots'.

A Boeing B737-800 (B737) was cleared to Melbourne, Australia via the Sydney RWY 34R MARUB THREE standard instrument departure (SID) to 5,000 ft. A Boeing B767-338ER (B767) was inbound to Sydney from Auckland, NZ, and had been cleared to descend to 6,000 ft with a vector to a right downwind leg for RWY 34R. As the aircraft approached each other 12 NM east of Sydney, an infringement of the radar separation standard occurred.

The pilot in command of the B737 was the handling pilot for the sector and was manually flying the aircraft while tracking via the SID. He had recently completed retraining on the aircraft after having not flown the type for 10 years.

After take-off, the B737 entered clouds and encountered turbulence as it climbed through 3,500 ft. The pilot in command was monitoring the aircraft's weather radar and stated that he became distracted while assessing the meteorological conditions. Although the co-pilot gave the 1,000 ft to assigned altitude call at 4,000 ft, he was also observing the weather situation and did not monitor the flight instruments as the aircraft approached the assigned altitude. The B737 continued to climb above 5,000 ft and reached 5,700 ft before the pilot in command descended the aircraft back to the assigned level. During the descent the aircraft's traffic alert and collision avoidance system issued a Traffic Alert.

The departure controller issued a turn instruction to the crew of the B737 for avoidance action and an evasive turn instruction to the crew of the B767, in addition to providing traffic information on the B737. Recorded radar data indicated that lateral separation between the aircraft reduced to 2.8 NM with a vertical separation of 900 ft. The required radar separation standard was 3 NM laterally or 1,000 ft vertically.

At the time of the infringement, the B737 was being manually flown by the pilot in command who was distracted from his primary task of controlling the aircraft's flight path. The distraction occurred as he monitored the weather radar and assessed the meteorological conditions that the aircraft was encountering during the climb. The engagement of an autopilot would have reduced the pilot in command's workload and enabled him to monitor the weather situation while the auto-flight system levelled the aircraft at the assigned altitude. Crew coordination did not provide a defence against human error in this occurrence, as the co-pilot did not monitor the aircraft's flight path as it approached the assigned altitude.

CASE 2 (source: report accident investigation commission, government of Nepal, Date: 07 July 1999).

Case 2 provides an example of a lateral deviation with a complete loss of separation with the ground as a consequence resulting in a fatal crash. Causal factors in the SID deviation were 'SID flown manually (flight technical error)' 'inefficient crew inter-cockpit coordination and communication', "Inefficient or lack of crew departure briefings" and "Wrong SID flown".

A Boeing 727-243 aircraft operating a cargo flight from Kathmandu to New Delhi took off from Kathmandu Tribhuvan International Airport Nepal. The aircraft was cleared to takeoff from runway 20 and fly a DHARKE 1A SID. After take off the aircraft the aircraft proceeded overhead the Kathmandu VOR/DME and commenced a climbing right turn. The aircraft then rolled out on a heading between 253 – 260 degrees magnetic and levelled off momentarily. The aircraft then continued the climb and proceeded across the 4 DME arc prior to commencing a shallow right turn. As the aircraft was in a 10 degree bank right turn at 4.4 DME crossing the KTM VOR/DME the GPWS sounded "Terrain Terrain Whoop Whoop Pull Up Pool Up. The stick shaker activated 11 seconds after the initial GPWS warning as the speed dropped below 171 KIAS. The GPWS "Terrain Terrain Whoop Whoop Pull Up" activated three more times during the next 30 seconds, prior to impact. The aircraft impacted the side of a hill and was destroyed killing all on board.

The investigation determined that the crew after take off did not adhere to the published Standard Instrument Departure (SID) procedure for runway 20 at Kathmandu, Nepal. The investigation revealed that an incomplete departure briefing was given by captain while other cockpit activities were in progress. The briefing was incomplete regarding the critical information on the DHARKE 1A or 1B SID in that there was no mention of the minimum airspeed (180 knots) authorized to be flown or alternatively the corresponding aircraft flap configuration for the speed restriction (Flaps 5), emergency procedures, or the specific routing of each SID including the 4 DME. Furthermore the briefing contained the option to fly the DHARKE 1A if they were at 7.500 feet ASL by the "270" radial which was contrary to a specific and clear company directive dated 6 October 1998, that all company aircraft will fly the DHARKE 1B SID. The captain in his briefing also stated that it would be a noise abatement departure, even though the company did not use noise abatement procedures at Kathmandu, and there are none published or required. Despite these deviations from standard operating procedures and omissions in the SID briefing by the captain, none of the crew questioned the captain about his departure briefing. This may suggest that none of the crew were fully conversant with the company instructions on the SID to be flown, the actual SID procedures (no noise abatement), or the consequences of deviating from the published SID. During the taxi, the aircraft was cleared to Delhi via the flight planned route to climb and maintain FL310, DHARKE 1A departure, which the co-pilot accepted. Although the captain had briefed earlier for an expected DHARKE 1B SID, there was no further discussion between the crew when the co-pilot accepted the DHARKE 1A SID.

<u>CASE 3</u> (source: UK **AAIB Bulletin No: 4/98 Ref: EW/C97/9/5. Date: 30 September 1997)**
Case 3 is an example of a lateral deviation with an air proximity as the consequence. Most likely causal factor was 'inefficient crew inter-cockpit coordination and communication'.

A B737 was planned to operate a scheduled passenger service from London (Stansted) to Dublin. The crew contacted the Stansted ground control frequency to acknowledge receipt of the relevant ATIS and requested ATC clearance. A BUZAD FOUR ROMEO Standard Instrument Departure (SID) was allocated, as expected, and a transponder setting was also given. The BUZAD FOUR ROMEO SID requires that, after take off, the aircraft should climb straight ahead and, at 11·5 DME from Brookmans Park (BPK), which is coincident with the 160° radial from Barkway (BKY), the aircraft should turn right to intercept the BKY 175° radial inbound to BKY by 8 DME from BKY. The aircraft is then required to proceed inbound towards BKY. Separate routing instructions then apply for the remainder of the SID. The initial altitude constraint for this SID is to cross the 5 DME point from BKY at3,000 feet.
The commander was to be the handling pilot for this leg. He therefore set the navigation aids as follows: BKY VOR on navigation box1, BPK VOR on navigation box 2, 355° was set on both omni-bearing selectors (OBSs) and both remote magnetic indicators (RMIs) were set to dual VOR. These navigation aids were then checked by both pilots for the correct aural identification.

Meanwhile control of a BAe 146, on a scheduled passenger service from Edinburgh to London City Airport, had been passed to the North East sector of the London Terminal Control Area (LTCA) and the aircraft was descending to FL70 on a radar heading of 120°M; this heading would take it about4 nm to the north east of BPK. This same controller was also responsible for the Stansted departures at that time.

The B737 took off from Stansted and climbed straight ahead as the BAe 146, descending through FL 90, was 21 nm to the west maintaining the radar heading of 120°M. Stansted handed the B737 over to the departure controller as the aircraft was passing through 1,500 feet, however, due to the amount of radio traffic on the new frequency, contact was not established until one minute later by which time the flaps were raised and the aircraft had levelled at 3,000 feet. At this time the aircraft was already one nautical mile past the start point for the right turn towards BKY required by the SID. The BAe 146 had by now been cleared to descend to 4,000 feet. When the crew of the B737 called level at 3,000 feet it was climb to FL 70 and the speed restriction of 250 KIAS below FL 100 was removed. The aircraft recommenced the climb but maintained the runway heading until when an altitude of 4300 feet and 6·8 nm from BPK the aircraft commenced a right turn. Just as this aircraft entered the turn the ATC controller instructed avoidance instructions to both aircraft.. The two aircraft passed at the closest proximity of 0.91 nm horizontally and 200 feet vertically.

Analysis of the incident has been unable to determine the exact reason for the SID deviation of the B737. According to the investigation it is most likely that there was a significant breakdown in the management of the cockpit resources on the flight deck during this departure, particularly with regard to the requirement for the pilot non-flying to monitor the performance of the pilot flying.

CASE 4 (Source: AAIB Bulletin: 1/2008 EW/C2006/10/10. Date: 3 October 2006)
Case 4 is an example of a lateral deviation with no consequences. The cause was a' navigation aids error'.

The aircraft intended to depart London City Airport (LCY) on a non-scheduled flight to Brussels. Prior to departure, while stopped at holding point Mike (Hold M) at LCY the pilots observed AHRS and HDG red flags on both Primary Flight Displays (PFDs), indicating that the Attitude and Heading Reference System (AHRS) had failed and that heading indications were unreliable. The pilots commented that this was a “known fault” at LCY which they thought was associated with “metal in the taxiway pilings”. After lining up on Runway 28 the flags disappeared without further action. However, after departure, the pilots found that they were unable to control the aircraft in heading using the autopilot because neither of the heading selector bugs would move in response to rotation of the heading selector control. They observed a difference of 60º between the heading indicated on PFD 1 and PFD 2 and the combined standby instrument indicated a heading of 15º less than that shown on PFD 1. A red FD flag was displayed on both PFDs and both flight directors were unavailable. In accordance with the Emergency Procedures section of the Quick Reference Handbook (QRH) the pilots selected AHRS 1 as the source for both sets of flight instruments but found that this system did not operate normally for a further 10 minutes. They decided to return to LCY and were given radar vectors in order to do so. The aircraft landed without further incident. It transpired that several similar incidents had previously occurred with other aircraft and there have been similar incidents subsequent to this one. The cause of the problem was identified as strong magnetic anomalies in the holding area for Runway 28.

CASE 5 (Source AAIB Bulletin: 11/2007 EW/C2006/10/07. Date: 6 October 2006)
Case 5 is an example of a vertical deviation (undershoot) with no consequence. Causal factors were ‘crew misread chart’ and ‘inefficient crew inter-cockpit coordination and communication’, and “high workload’.

A Boeing 737 was cleared to depart from Runway 05 at London Stansted Airport, Essex, on a ‘Dover Five Sierra’ Standard Instrument Departure for Istanbul Ataturk Airport, Turkey. The co-pilot was the pilot flying for this sector and he briefed the commander on the departure. Soon after takeoff the aircraft was observed in a “steep” nose-down attitude. It then flew level, at 500 ft aal (900 ft amsl), for approximately 6 nm before being instructed to climb immediately to 5,000 ft amsl. Having been given further climb clearances, the aircraft subsequently reached its cruising level and later landed at Istanbul Ataturk Airport without further incident.

The commander stated that this was the first time he had operated from Stansted, but he had operated from London Heathrow Airport and Manchester Airport on “numerous” occasions without incident. He added that, even though the initial level-off altitude seemed “unusual”, he believed that the vertical profile of the ‘DVR 5S’ SID did not allow for an unrestricted climb to 5,000 ft amsl due to the note on the plate of ‘Initial climb straight ahead to 850’ [500 ft aal]’. He thus believed that the initial level-off altitude was 900 ft amsl, as briefed by the co-pilot prior to departure. He additionally believed that they would be given further clearance to climb from the en-route controller.

After takeoff the autopilot failed to capture the pre-selected altitude of 900 ft. As a result, the commander said he took control of the aircraft manually and, having flown above 900 ft, descended back to 900 ft. Once level at 900 ft amsl, the commander was “slightly alarmed” at the height and realised something was wrong. Even though he realised the aircraft was below the Minimum Safe Altitude (MSA) of 1,800 ft amsl, he was not overly concerned as he was in VMC. At this point, he said, his workload was very high.

4 Conclusions

From the results presented in this paper the following conclusions are made:

- Incidents in which a significant deviation from the assigned SID occurred are rare compared to other type of flight safety events;
- Significant deviation from an assigned SID can result in a degradation of flight safety. In 6.4% of the analysed incidents in this study a loss of separation with other traffic or ground obstacles occurred;
- Significant SID deviations are caused by a wide variety of factors. However by far the most important causal factor identified in this study is the fact that a wrong SID is used by the flight crew;
- It is more likely that a wrong SID is used by the flight crew when there are similar sounding SID names used at the airport. Also important factors associated with wrongly selected SIDs are inefficient or lack of crew departure briefings, read-back hear-back errors, crew expectation, late departure runway and/or SID change, distracted flight crew, and high workload of the flight crew.

5 Recommendations

- It is recommended to disseminate the findings of this study to the aviation community including aircraft operators, air navigation providers, civil aviation authorities, unions (pilot and controller), accident investigation organisations.
- From the database analysis that is presented in this paper it is apparent that by far the most important causal factor for significant SID deviations is the fact that a wrong SID was programmed in the Flight Management System by the crew. Intervention strategies should therefore be focussed on this factor. An example of a potentially efficient intervention strategy may be the recent introduction of a datalink Pre-Departure Clearance (PDC) at some major airports in Europe and the US. Although primarily introduced to alleviate frequency congestion on delivery frequencies, the use of PDC can affect errors made with similar sounding SID names, readback-hearback errors and flight crew expectation errors, together responsible for more than half of the SID deviations found in this study.
- It is strongly recommended to avoid the use of similar sounding SID names.