

The Agony and the Ecstasy of Utilizing Safety Data for Modern Accident Prevention and Investigation

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The views expressed in this paper do not necessarily represent the views of the United States, the U.S. Department of Transportation (DOT), or the DOT's Office of Inspector General, or any other Federal agency.

Introduction

With the advent of flight data recording technology, requirements for Safety Management Systems (SMS), and proliferation of voluntary safety reporting, the business of accident/incident prevention and investigation is being transformed from traditional crusty "tin-kickers" who dig out and disseminate lessons-learned from crash sites to a new IT-savvy generation of safety professionals that mine electronic data. But how effective is this transformational approach? How accurate can data analysis get in *predicting* accidents/incidents? How much emphasis of our limited investigative resources should be placed on data mining and analysis? Is this just a panacea, or a legitimate basket in which we should place all of our eggs?

On November 27, 2007, during the kick-off of the *4th Annual International Aviation Safety Forum* hosted by the Federal Aviation Administration (FAA) in Washington, DC, the FAA Administrator at that time spoke these words:

“Aviation no longer is in the business of combing through ashes and wreckage to find answers. SMS will give us the intelligence we need before the problem reaches the headlines. When it comes to risks, the low-hanging fruit is long gone. SMS uses hard data to point us in the direction we need to go. We don’t have to wait for something bad to happen.” [1]

Was this an accurate view six years ago? Is it accurate today? A solid argument can be made that it is not. Tin kicking will always be needed as a major aspect of preventing future accidents, and there is still plenty of low-hanging fruit to pick. And then there is the General Aviation community, which has not yet undergone the same massive data-driven program of the commercial airline industry and must still rely heavily on traditional investigative methods.

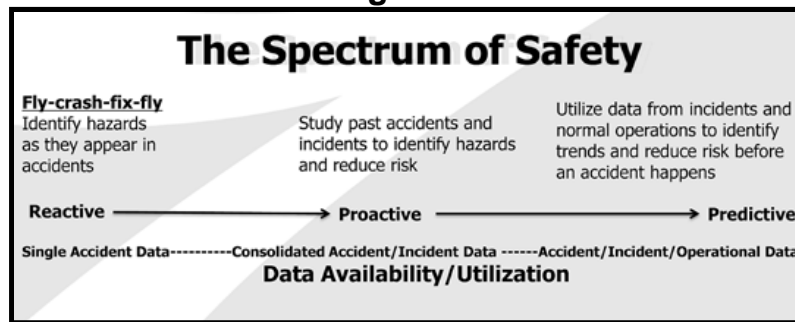
But that’s not to say that data analysis is a wasted effort – quite the contrary. In fact, data mining has played a key in decreasing the airline accident rate over the past two decades. [2][3] More recently, it has helped to quickly solve particularly complex incidents and accidents, such as the Boeing 777 dual-engine roll back and subsequent short landing to a London runway in January 2008.[4] However, data analyses has yet been able to truly “predict” accidents, and it will never replace accident investigation. We should not be lulled into diverting the bulk of our limited resources with mining data instead of following the evidence found at the crash site while using human intuition to solve accidents and prevent future ones.

Defining Expectations: Proactive vs. Predictive

To properly describe and account for the agonies and the ecstasies of data analysis in utilizing safety data for modern accident prevention and investigation, some terms must be established to put things in perspective. Jim Burin of the Flight Safety Foundation effectively laid out a simple scheme in a paper he presented at last year’s 2012 ISASI Seminar, entitled *“Being Predictive in a Reactive World”*, in which he described the differences between being “reactive”, “proactive”, and “predictive.”[5] In the early days of aircraft accident investigation, the industry was mostly “reactive”—waiting until an accident happens and then addressing the

risks. As air safety methodologies matured, the industry became increasingly “*proactive*”—doing something before an accident happens by using data and lessons learned. Now, with the advent of massive amounts of recorded data and voluntary reports, the industry is attempting to be more “*predictive*”—doing something based on potential risk to avert an accident that has not happened (yet). Figure 1 depicts a scale of how these definitions might be viewed.

Figure 1



Source: J. Burin; 2013 ISASI Seminar

But “*predictive*” is a term we should use with great care. Does it mean that the data analysis is so good, a team of air safety prevention specialists can be automatically alerted to stop a taxiing aircraft from taking off? This scenario is reminiscent of Steven Spielberg’s futurist film *Minority Report* -- with Tom Cruise rappelling down to stop an event that hasn’t happened yet, but was foretold through technological means. Or, does “*predictive*” mean that we are simply indentifying a major risk area that will likely result in an accident within a specific segment of aviation at an unknown time and place in the near future. In this latter case, being predictive is achievable, albeit with significant challenges technological advances. We must be cautious not to oversell the benefits of data analysis.

FAA’s ASIAS Program – A New Hope

Perhaps the most hopeful *proactive* scheme for aviation accidents – but not yet predictive -- is FAA’s Aviation Safety Information Analysis and Sharing (ASIAS) system. Implemented in 2007, ASIAS collects and analyzes data from multiple databases to proactively identify and address risks that may lead to accidents.[6] The ASIAS program was self-initiated by FAA without regulatory or Congressional prompting. It is a collaborative industry-government information sharing and analysis system that combines, analyzes, and disseminates aviation safety data and

report products. ASIAs accommodates air carriers’ desires to benchmark their safety efforts against industry standards, and it allows government analysis and *some* sharing of data. The system is fed by a wide variety of data sources from both public (non-confidential) and protected proprietary (confidential) aviation data (See Figure 2). Non-confidential data sources include publicly available data such as the NTSB Accident and Incident Reports database. Confidential sources include data from aircraft operators -- including Flight Operations Quality Assurance (FOQA) extracted from aircraft recorders, and voluntary safety reports such as the Airline Safety Action Program (ASAP) submitted by flight crews. These data represent millions of flight data records and textual reports. [6]

Figure 2: ASIAs Data Sources



Source: FAA ASIAs Program Plan, January 2013

Interactions between the FAA and the aviation industry range from analyzing ASIAs data to identifying and recommending risk mitigations. The 20-member *ASIAs Executive Board* assigns teams to conduct studies, receives ASIAs study recommendations, approves all analyses, and sends findings and recommendations to the Commercial Aviation Safety Team (CAST) for a joint decision on whether action is needed by industry or government.[6] The CAST has proven to be a very effective *proactive* safety effort in its own right. It is a U.S. government-aviation industry

partnership, founded in 1998, that has developed an integrated, data-driven strategy to reduce the Nation's commercial aviation fatality rate by analyzing causes of past accidents, identifying areas where changes may have prevented them, implementing promising safety enhancements, and measuring their results.[7] The CAST's goal to reduce the commercial airline fatal accident rate by 80 percent in 10 years has now been achieved – not with sweeping laws or with any single “home run”, but with a series of 76 separate “singles” -- seemingly mundane, low cost “safety enhancements”.[2] Seven of these enhancements resulted from ASIAs. [6][7] The CAST impact is an example of an “ecstasy” associated with data collection and analysis. The CAST's new goal is to reduce this rate another 50 percent by 2025 as compared to the 2010 rate. [3]

FAA has made significant progress with implementing ASIAs. For example, 44 commercial airlines that represent 95 percent of all Part 121 operations in the U.S. are now providing key confidential data from voluntary safety reporting programs to ASIAs, up from only 11 airlines in 2007. As of January 2013, ASIAs had access to about 136,000 ASAP reports as well as the content of nearly 9 million flights of FOQA data. Additionally, the confidential portion of ASIAs now has access to 64 databases (including ASAP and FOQA), up from 46 in 2010. The non-confidential portion of ASIAs includes 142 databases and data standards from publicly accessible sources.[6]

One of the seven “directed studies” from ASIAs addressed the issue of pilots taking off from the wrong runway. This study was initiated shortly after the tragic wrong runway takeoff of Comair Flight 5191 in Lexington, Kentucky on August 2006.[8] The study eventually validated what the news media has already reported only a few days after the accident -- that wrong runway takeoffs was a common error. With access to public information from NTSB, FAA and NASA databases, the reporters found hundreds of cases of pilots trying to take off or land on improper runways since the 1980s.[9] Some within the FAA and ASIAs circles asserted that if ASIAs had been fully up and running prior to Lexington, then the crash would have been prevented. It is easy to assert this after an accident, but “hind sight is 20/20” as they say. The hard part, or “agony” regarding safety data analysis is to identify and prioritize the information needed from a vast sea of data. How would anyone have known that the next fatal accident

would involve a wrong runway takeoff with all of the subtleties of the specific cause and factors that led to Lexington? [10]

The evolution of ASIAS to a more *predictive* tool, as envisioned by FAA, is still several years away. This is due to the challenges – or “agonies” -- associated with deploying technologically advanced and complex capabilities such as:

- querying multiple databases with a single search directive for improved, quicker data searches;
- conducting automated trend/anomaly detection of vulnerabilities (e.g., hazards such as loss of separation between aircraft) based upon digital data;
- developing tools to uncover hard-to-find (not pre-defined) subgroups of flights with higher rates of safety precursor events; and
- fully integrating pilot-controller voice communications data utilizing data fusion capabilities into the ASIAS data set. [6]

After these capabilities are deployed, ASIAS will be a much more powerful *proactive* tool for air safety professionals. However, it may still never be able to truly “predict” specifically when and where the next accident will occur.

Other “agonies” that exist with ASIAS involve challenges that are much more near-term. For example, FAA is struggling with non-standardized data collection practices, incomplete or inaccurate information, and difficulties with processing data a uniform manner as a result of deficiencies from the data that ASIAS receives from airline safety reporting programs. Further, because FAA’s initial focus for ASIAS was on safety data from commercial airline operations, ASIAS does not yet incorporate substantive data from other segments of the industry such as general aviation operations. FAA is beginning to include these data, as well as increasing the types of voluntary safety data from air carrier programs already in the program, in an effort to further enhance the safety benefits that ASIAS could provide to all aviation sectors. [6]

Moreover, access to the full capabilities of ASIAS has been limited. The data is closely guarded by the ASIAS Executive Board and the results of these analyses are shared with ASIAS

participants *only* through high-level executive summary reports and industry information sharing venues. Other aviation communities may also share in these analyses, but only when approved by the ASIAs Executive Board. In fact, FAA does not yet allow its own inspectors access to ASIAs confidential data (i.e. FOQA, ASAP) despite the fact that these data could provide them visibility into safety issues experienced by other similar air carriers and aircraft fleets, resulting in more focused and effective oversight. FAA is planning to expand access to its inspectors, but the effort has been slow apparently due to concerns that air carriers will be reluctant to continue volunteering information for fear of reprisal from their regulators. However, these fears are mostly unfounded, as the data can be sanitized and aggregated.

Even the NTSB, a non-regulatory independent body, had to work hard for nearly two years to convince FAA and stakeholders to allow it to obtain specific ASIAs data in the wake of accident A written agreement was finally struck this past November allowing the NTSB to initiate written requests for ASIAs information related to aircraft accidents involving U.S. air carriers that occur in the United States. [11] The NTSB has agreed it will not publicly disclose ASIAs information it receives via the process unless the ASIAs Executive Board agrees. The data is to be de-identified and aggregated. The agreement also does not allow any of the parties to use aggregate FOQA, ASAP, ATSAP or other non-publicly available data to measure an individual data contributor's performance or safety.

The justification behind this “close hold” safety data philosophy is to ensure that airlines and other reporting entities remain confident that their confidential data will be adequately protected and not come back to support punitive actions against them. However, a reasonable balance must be found between protecting the data to prevent a “chilling effect” while allowing more safety professionals greater access as a force multiplier for safety analyses and, ultimately, safety improvements.

Heinrich’s Triangle – Turned on its Side

Another caution for the next generation of investigators and aviation professionals is to be mindful on not becoming overly obsessed with data from previous incidents that may portend an accident with similar characteristics. Known as the “Heinrich Pyramid” scheme --

in which safety events of varying severity could be represented in a pyramid, has been a stalwart in the field of safety for decades (See figure 3). In 1931, American industrial engineer Herbert W. Heinrich published an empirical finding that for every accident in a workplace that causes a major injury, there are 29 accidents that cause minor injuries and 300 accidents that cause no injuries. The reasoning behind this scheme is simple: many accidents share common root causes, and therefore, addressing more commonplace accidents that cause no injuries can prevent accidents that cause injuries. [12] This finding is well known in our profession, especially within the context of SMS, in which one of the four major SMS components is “data collection and analysis”. [13]

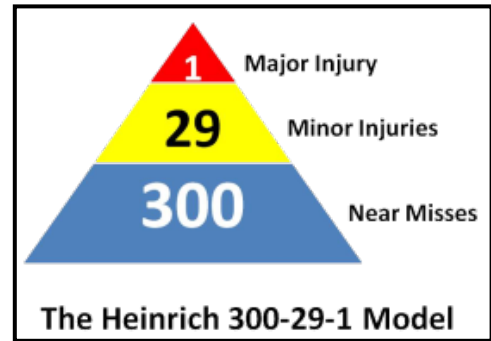


Figure 3

However, Heinrich’s Law has proven to be invalid in several types of aviation operations. According to research conducted last year by staff at the Imperial College London’s Transport Risk Management Center, many accidents have occurred with “sudden failures” that had nothing to do with any previous trend of incidents. One example cited was with flight operations involving helicopters that service the oil and gas industry. [14] For the most part, this industry is very safety conscious, due to its competitive nature and the arduous environment in which it operates. The industry has driven the safety requirements for helicopters that operate worldwide, especially in the North Sea, where operators must abide by a British requirement for Mandatory Occurrence Reporting (MOR) to meet the critical element of the ICAO-mandated SMS program. The researchers examined the correlation with occurrence reports and accidents, and the results were startling. Between 1997 and 2010, there were 10 off-shore helicopter accidents, and 789 incidents reported under MOR. Each accident was analyzed, along with the previous 2 years of MOR data – the conclusion of the research revealed that the MOR data analysis could not have predicted the accident that preceded them. [14]

Similar research was cited involving a review of British MOR data for *all* types of helicopter operations from 1995 thru 2004.[15] In one study, the researcher identified that while only 10

percent of the filed reports corresponded to private flights, such operations sustained 47 percent of all helicopter accidents in the same period. It was also noted that human factors issues were only causal to 17 percent of the reported occurrences, but human factors were attributed to 76 percent of the accidents. The opposite was found in regard to airworthiness failures, which corresponded to 98 percent of the MORs, but only 16 percent of the accidents.

This demonstrates that our new generation of accident investigators should take into consideration the specific types of flight operations involved in the accident, and to identify any and all complex operational variables and human factors. The more complex, the less likely that Heinrich's pyramid should be applied. These accident types are characterized by multiple, rare and non-linear combination of factors which are often not evident in routine incidents.[14]

The Needs and Limitations of Data

The aforementioned British researchers, as well as other research conducted by the MITRE Corporation and others, also discovered other important aspects – agonies -- associated with the usefulness of data analysis:

- In one research study conducted by the British Royal Air Force (RAF), a bias was identified towards the reporting of technical issues. From the over 4,800 RAF occurrence entries of 2007, only 65 were related to human factors.[16]
- Data that is overly general will not provide many interesting results. For example, researchers noted that while the NASA Aviation Safety Reporting System (ASRS) has been extensively de-identified to protect pilots, this de-identification results in the loss of the details needed to find subtle patterns. [17]
- Varying data collection practices and taxonomies prohibit the melding of data from many different sources. [17]
- Information embedded in report narratives is very difficult to glean and categorize. [17]
- Finding associations and distribution patterns in data is difficult because of having too many results returned by the tools. This leaves the analyst with the task of going

through a large amount of findings and separating the ones that are relevant, unusual, surprising, or in any other way “interesting”. [17]

Recently published audit reports and testimony performed by the U.S. Department of Transportation’s Office of Inspector General also pointed out additional “agonies” of utilizing safety data. For example, this past February, they found that FAA’s policies and procedures to identify and report on losses of separation between aircraft are limited by incomplete data and implementation challenges. [18] They also found that FAA lacks an accurate baseline of the actual total number of separation losses that occur. In addition, they found deficiencies with the use of a new air traffic operational error reports database, and concerns regarding data collection and analysis due to inadequate staff, training, and familiarization. This is consistent with other previous research which indicates that informing data collectors about the needs of downstream data facilitates the generation of higher quality data. [17][18]

Another DOT Inspector General audit report from August 2012 indicated that FAA’s wildlife strike database provided “an incomplete picture of the total number and severity of wildlife strikes that occur,” hindering the effectiveness of FAA’s efforts to mitigate the increasing hazards of bird strikes. [19] The auditors cited an FAA-contracted study in 2009 that concluded only 39 percent of actual wildlife strikes were reported and as many as 36 percent of the events involving wildlife in FAA’s Accident/Incident Data System were not captured in its wildlife strike database. The auditors also found that, because strike reporting is voluntary, airports varied in how frequently they chose to report strikes to FAA. For instance, they found that at one large airport, 90 percent of the airport’s recorded strikes were reported in FAA’s strike database while another medium-sized airport reported only 11 percent of its strikes. [19]

Data Analysis to Help Solve Accidents

Because of the proliferation of safety data, the next generation of investigators can now turn to data mining and analysis to assist them in solving complex accidents. This “ecstasy” was demonstrated with the investigation of an accident that occurred on January 17, 2008, when a Boeing 777-236ER landed short of the runway during approach to London Heathrow Airport from Beijing, China. [4] At 720 feet above the ground, the right engine stopped responding to

autothrottle commands for increased power and instead “rolled back” on power. This was followed by a roll back of the left engine seven seconds later, resulting in a loss of airspeed and the aircraft touching down some 330 meters short of the runway. The physical evidence at the crash site, and even the waterfall of parameters from the flight data recorder, did not yield obvious clues. So, the British AAIB underwent a data mining exercise.

The intent of the data mining activity was to identify any parameters or a combination of parameters that were unique to the accident flight. Initial analysis of the accident flight identified that certain features were unusual or unique when compared to a small number of flights having operated on the same route and under similar atmospheric conditions. However, it was difficult to place a statistical significance on these findings alone due to the small sample size. Unencumbered with any existing British data access problems, the AAIB obtained and analyzed an additional 175,000 flights of Boeing 777s, and the AAIB identified that the accident flight was unique among 35,000 Rolls-Royce powered flights in having a combination of the lowest cruise fuel flow, combined with the highest fuel flow during approach while at the lowest temperature on approach. Just two flights from 142,000 Pratt and Whitney powered aircraft flights had these features.

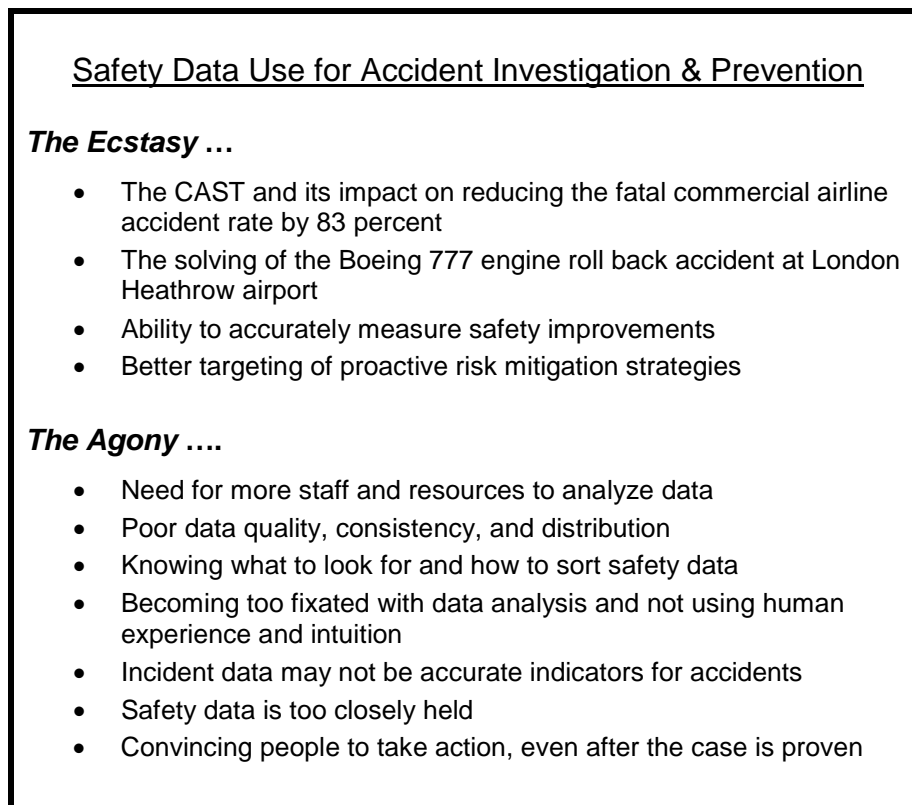
As a result of the AAIB’s data collection and analysis efforts, the investigation identified that the reduction in thrust was due to restricted fuel flow to both engines. It was determined that this restriction occurred at the engines’ fuel oil heat exchanger. Accreted ice from within the fuel system released, causing a restriction to the engine fuel flow at the face of the exchange, on both of the engines. Ice had formed within the fuel system, from water that occurred naturally in the fuel, while the aircraft operated with low fuel flows over a long period and the localized fuel temperatures were in a specific area. The AAIB issued 18 Safety Recommendations from the investigation to enhance the certification and operations of air carriers.

According to the AAIB report, the data mining process “... was largely complementary to the laboratory testing that had been ongoing during the course of the investigation, with features identified from the data mining being incorporated into laboratory tests and similarly, laboratory results being applied to the data analysis.” [4]

Conclusion

There is no doubt that more safety data, and the analysis of that data, leads to better risk management in aviation or any other endeavor. Data analysis can also significantly aid in solving accidents. However, we must keep in mind the challenges (i.e. agonies) of this analysis, while recognizing the benefits obtained (i.e. ecstasies) with realistic expectations (See figure 4).

Figure 4



Our next generation of accident investigators cannot substitute methodical post-accident “tin kicking” efforts with sitting in front of a computer mining for data in comfortable office. A balance of both will be needed. Accident investigations bring together diverse groups of experts in a focused and structured environment. This synergy of human experience and motivation cannot be matched by a database. Not yet, anyway. Regardless, even with all the evidence -- whether it be from the crash site or a supercomputer -- perhaps the most challenging “agony” is convincing the decision-makers to take the action needed to prevent the next accident.

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