‘ACCIDENT INVESITIGATION WITHOUT THE ACCIDENT’

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Mike is a Professional Engineer with a current pilot’s license and is recognized worldwide as a leading expert in the field of flight recorder analysis. Mike represented Canada as the national expert panel member to the International Civil Aviation Organization’s Flight Recorder Panel. He started in the field of aircraft accident investigation in 1977 and has worked for more than 20 years with the Transportation Safety Board of Canada. For the last 15 years of his career at the TSB, he was the head of the flight recorder and performance laboratory, which he developed for the Board. He was the Flight Recorder Group Chairman on all major accidents in Canada as well as several international accidents during his tenure as the recorder laboratory Head. In 1985 he was responsible for initiating the project that led to the development of the Recovery Analysis & Presentation System (RAPS) that is used by many States flight recorder labs and was eventually commercialized by the TSB.

Mike joined Flightscape in February 2002, a flight safety company specializing in flight sciences and flight data analysis systems. Flightscape maintains and supports RAPS and other product lines for handling flight data. His hands on flight data analysis and investigation experience, lead roles on international committees in flight recording and his technical knowledge bring significant expertise to the Flightscape team.

Abstract:

This paper will discuss the growing trend of airlines wanting to analyze flight data on a regular basis for accident prevention and the numerous similarities to accident investigation. Investigation authorities with substantive flight recorder labs have been analyzing data for years with highly specialized tools that have evolved over many years. This relatively small group of people has gained valuable experiences related to the limitations of flight data and in particular the pros and cons of flight animation. With the recent trend to routinely analyze flight data, there is an increasing demand for flight animation systems within the airlines and a tendency to want automatic tools that require no or little experience on the part of the operator. While flight animation is extremely beneficial, investigators have considerable experience with the numerous associated pitfalls whereby animations can be misleading. The paper will outline some of these pitfalls and stress the importance of the airline and investigation communities learning from each other.

ACCIDENT INVESTIGATION WITHOUT THE ACCIDENT

Introduction:

Flight data volume and availability has come a long way since the beginning days of aviation. Traditionally, accident investigators were the only people who examined flight data in great detail, in aid of detailed investigation. Today, with airlines embracing routine Flight Data Monitoring (FDM) Programs (Note: Flight Data Analysis [FDM] is ICAO nomenclature, Flight Operations Quality Assurance [FOQA] is US nomenclature and FDM is Canadian and some European nomenclature) and the most recent trend for the airlines to use flight animation to replay the data, the domain of flight data analysis is rapidly being driven by the larger airline industry. This paper will argue that the airlines, in many ways, are performing 'accident investigation without the accident', and that there are some significant benefits from learning some of the lessons learned from the relatively small accident investigation community.

A common statement I have heard lately is that FDM Programs and Accident Investigation are not the same and therefore require different tools and there is perhaps a misperception that 'accident investigation' tools are not needed for FDM.

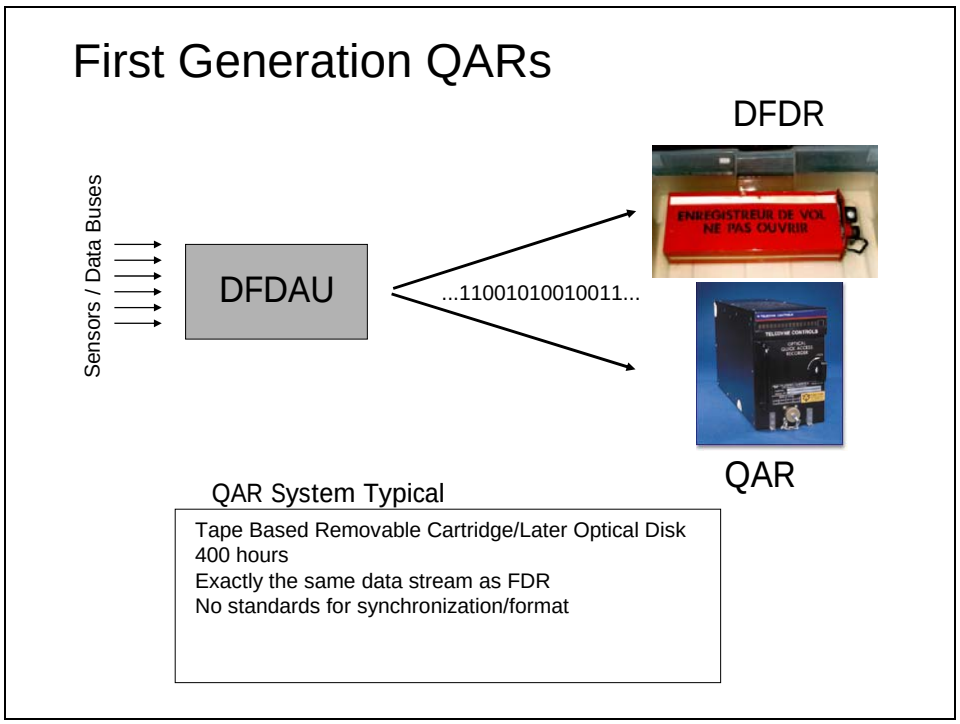
History of Flight Data:

Before exploring this issue, a brief recap of the evolution of flight data is worthwhile. In the early days (1960's) came the metal foil recorder which recorded analog traces of five basic parameters (airspeed, magnetic heading, pressure altitude, vertical acceleration and VHF keying, on a timebase). Then came the digital era (early 1970's), where flight data was digitally recorded on magnetic tape and the FDR name was changed from to DFDR to denote digital FDR (there are no analog FDRs today so the D is not used anymore). Although the military introduced solid state (digital data stored on memory chips) in the 1980's, it wasn't until the early 1990's before solid state memory was acceptable for use in civilian aircraft. The military were able to use solid state before civil aviation because the military recorded typically much less data than civilian aircraft and did not have the same crash survivability requirements as civilian standards, thereby being able to take advantage of early chip designs that did not meet international FDR/CVR standards at the time (Eurocae ED55 & ED56). The digital flight data acquisition unit (DFDAU) provided the data source for the FDR, accepting inputs from various sensors and data busses on the aircraft and 'packaging' them into a serial bit stream that was sent to the FDR.

Some airlines such as British Airways and SAS, were already routinely analyzing flight data for maintenance, prevention, and operational anomalies. In fact, SAS even had two people who's sole job was to sit in front of a magnifying glass and read out foil recorders looking for problems. In these days, no flight animation was available or done and the parameter sets were few in number.

Airlines quickly discovered that to extract data from the mandatory FDR was by no means an easy process. For many, this meant only pursuing the data in reaction to a significant event. The recorder had to be removed from the aircraft and in some cases opened and recertified. Copy processes took hours and were fraught with 'dropouts' or bit errors due to the mechanical nature of the recording system. This inspired the first generation of Quick Access Recorders (QARs) in the early 1970's. They were built with

a removable media (initially tape as well) so that the airline could simply pull out the media and substitute another at any time. In the majority of these early systems, the FDAU sent the *identical* data stream to both the FDR and the QAR simply to facilitate easy access to the data.



Effectively, airlines had two recorders on board the aircraft, one that confirmed to rigorous standards (FDR) and one that conformed to no standards (voluntary) and both recorded the same information.

The data stream in those early days was, by some airlines, not enough, so they asked if they could have more. It is important to note (and it is a very common misconception) that the issue of capacity is rarely an FDR problem; rather it is an acquisition problem. The reason that we did not have larger mandatory parameter lists is because of lack of data availability, not lack of FDR capacity. If the data were to be added to the FDR, it did not help the airline because it was not accessible and any changes to the FDR meant rigorous recertification issues. The data was naturally added to the QAR instead and in some cases a complete additional voluntary FDAU was added to the aircraft which the airline could reconfigure at will to determine which parameters were recorded.

Around this time, solid state memory media recorders were introduced. The advent of solid state was a great advancement in data quality and FDR reliability since there were no moving parts. They were also readily downloadable making them *'quick access'*. I remember being at a Eurocae meeting in Washington in the early 1990's and I said to the QAR manufactures that they need a new name because 'quick access' was no longer a good differentiating term since SSFDRs were also quick access. Many of us thought the QAR would simply die a natural death with the advent of SSFDRs. Why did investigators come to dislike the QAR? The Swissair Flight 111 MD-11 accident off Peggy's Cove in 1998 is a good example. The Swissair 111 FDR was a solid state recorder with 64 words/sec. The QAR was a 384 word/sec tape based unit, arguably

less quick access than the FDR! The FDR survived but the QAR did not. The data was available but it was in the wrong box! The QAR was developed because the FDR was not accessible and has now surpassed the FDR in terms of data quantity. Parameter rules must consider many aircraft types and therefore tend to cater to the lowest common denominator. Additionally, early standards *encouraged* a separate box for fear of adversely affecting the mandatory box. Any change to the mandatory box meant costly certification issues. Airlines on the one hand complained about the costs of additional parameters and on the other hand went to the trouble and expense of recording extra data for their own purposes.

There were some other factors which affected the continued use of the QAR despite logic dictating that it should become a thing of the past. If you added a parameter to the FDR and it the parameter became problematic during routine FDM, regulatory bodies invoked the MEL and grounded the airplane. In the late 1980's, Air Canada actually removed non-mandatory parameters from the FDR because of MEL problems! Operators, still today, do not want to add parameters to the FDR because of the regulatory interpretation of the MEL. The reality is that 99% of parameters today are from a digital data bus and the parameters exist for the operation of the aircraft, not the FDR. The FDR is simply taking advantage of their ready availability. If the airspeed does not work on the FDR for an Airbus A320 for example, it is not an FDR problem, it is an aircraft problem yet some still interpret this as a reason to ground the FDR system. Parameters from digital data busses are incredibly reliable yet the rules were developed from the old days when sensors were dedicated to the aircraft and they have not really been updated.

It makes much more sense to have an integrated system whereby airlines can routinely access the data and the same data set is available to the accident investigator. In some ways it is simply a 'packaging' issue. There was no technical reason why all of the Swissair data going to the QAR could not have also been going to an FDR. There tends to be two different groups in the industry, those who deal with the mandatory FDR and those who deal with the QAR and it is long overdue that they talk to each other.

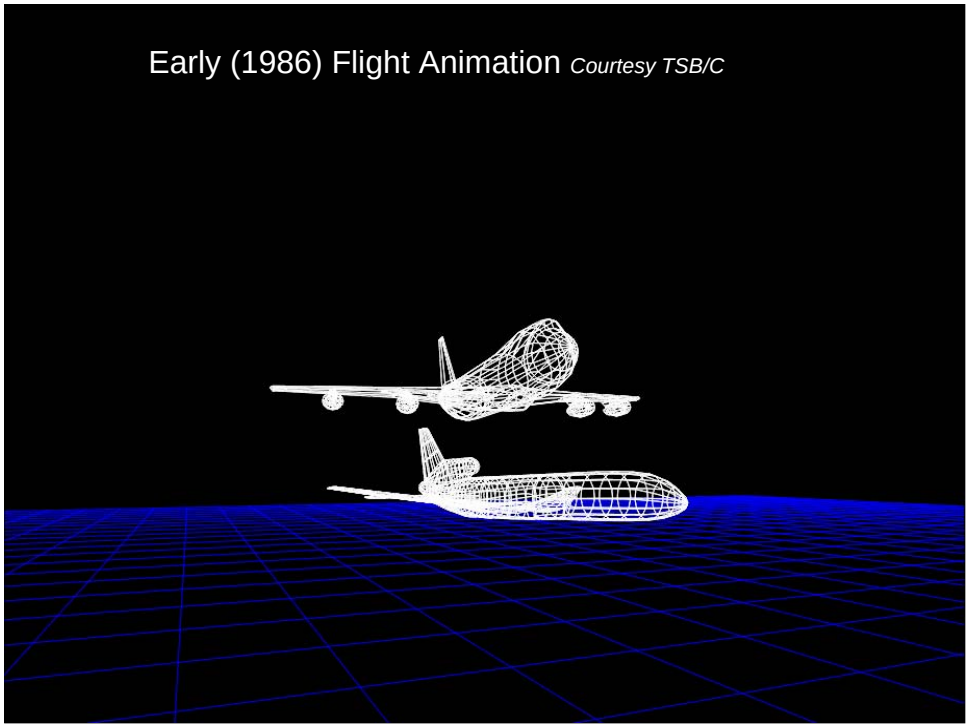
Eurocae ED112 and the recent US Future Flight Data Collection Committee is trying to change history in this regard.

> ED112 – '*With today's solid state technology, significantly increased capacities, readily available data on the aircraft and affordable ground based wireless download capabilities, an integrated crash protected recording system which satisfies both accident investigators and operator's routine playback needs is highly desirable.'*
>
> *'… it is recommended that industry provide operators with solutions that protect the core mandatory list while allowing the operator to change the recorded data (e.g.: additional data, sample rates or resolutions) in the crash protected medium without requiring recertification of the flight recording system.'*

The bottom line is that it is really unacceptable to record more data for routine monitoring of flight data, than for a major accident investigation.

Flight Animation:

Accident investigators have been using flight animation since the early 1980's. Airlines did not because there were no commercial systems at this time and it was relatively expensive to do. Today, flight animation is readily available and numerous systems are commercially available.



Investigators have long known about the benefits and pitfalls of animation and there have been ISASI papers well into the past as they became increasingly popular and controversial in the late 1980's and throughout the 1990's.

Benefits of Flight Animation:

- Assimilate complex information
- Facilitate analysis
- Stimulating and effective means of communication
- Powerful and compelling
- Effective training tool
- Easy to disseminate
- Lend credibility to findings

Pitfalls of Flight Animation:

- Pretty picture syndrome (seeing is believing)
- Fabrication
- Subjective information
- Drawing conclusions without understanding underlying principles
- Misplaced credibility

Accident Investigation Vs Flight Data Analysis Programs:

We all know and understand the elements and reasons why we investigate accidents. FDM programs are very valuable as it makes a lot of sense to study the data *before* things become catastrophic. FDM is a proven concept and is being embraced worldwide. So what is the problem? First let's define an FDM program.

FDM is part of a Safety Management System. It is a systematic collection of flight data for improvement in the areas of:

- Operations
- Maintenance
- Training
- Risk Management

It is effectively an IT system to distribute objective information to reduce operations and support costs and improve dispatch reliability. Above all, it is a system which identifies precursors to accidents. For clarification purposes, I like to break FDM down into tow distinct components:

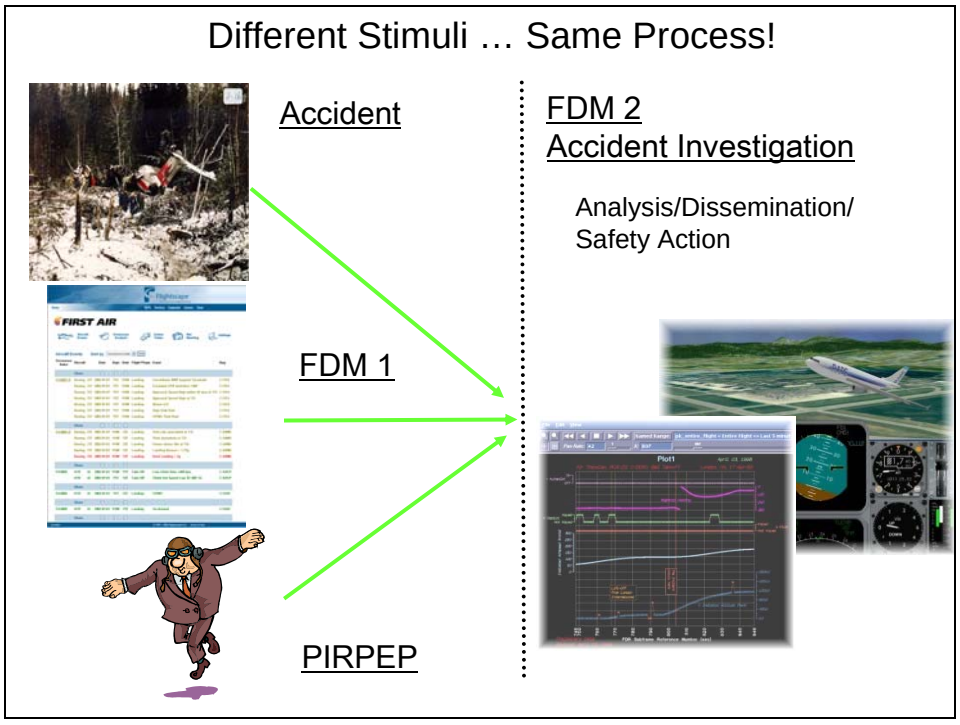
FDM 1 Event Detection

- Routine monitoring of flight data
- Automatic detection of events
- Until recently, plagued with poor quality data
- Outputs statistical database
- Flight Animation not useful
- Examining daily flights in small detail

FDM 2 – Occurrence Investigation

- Examination of a single event(s) in great detail
- Similar to accident/incident investigation
- Flight Animation is very useful for routine events and complex

Regardless as to whether the stimuli to study a flight sequence is an accident, incident, FDM 1 event, or a PIREP, it can be argued that once you perform the study, there should be no difference in the techniques, expertise and tools required. Whether or not the aircraft hits the ground or not has no bearing on the analysis of the data leading up to the event that initiated the analysis. FDM 2 is arguably accident investigation without the accident.



Unfortunately, there is a component of the industry that believes and/or advertises that 'investigation' skills/tools are not necessary for FDM programs in the quest to provide user friendly automatic tools to eliminate the need for expertise. Some believe that you have to be an expert to use an 'investigation' system but you do not need to be an expert to use an 'airline' system. The fact is that the expertise required is not a function of the 'tools' one uses, but rather it is a function of the flight data itself. If you did not need to have expertise to analyze flight data we would not need expert accident investigators.

Many airlines want to routinely animate events for training purposes; just hit a button and up pops the animation. While virtually all software out there can do this, it should be noted that flight animations are actually quite useful for analyzing complex events and understanding and disseminating them. The current limitations of sample rate, resolution, accuracy and number of parameters is such that often significant judgment is required. Accident investigators grew up with lousy tools in the 60's, 70's and 80s and there experience in flight data analysis and the tools used to perform the job grew

together. Today the airline can jump in with very attractive tools that have internally automated many of the steps investigators performed manually. With this automation and marketing of products as automatic requiring little expertise to use comes a significant danger that the judgment is simply lost in the process.

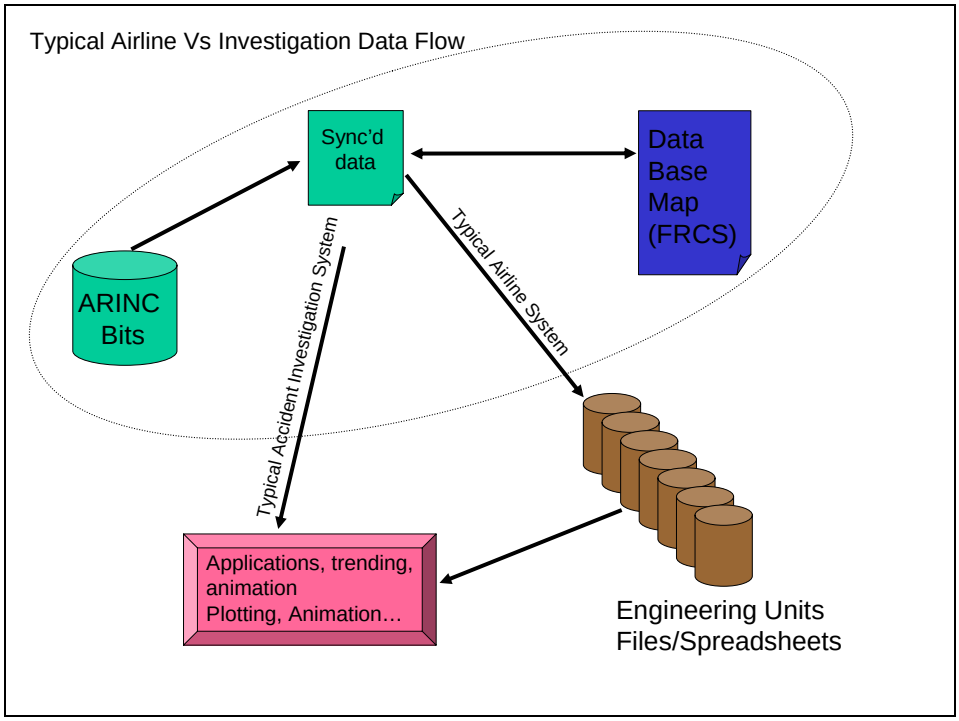
Airline playback systems were originally designed for maintenance and only in recent years have they been used for detailed operational analysis of events, partly inspired by readily available animation capability. Airlines are going to increasingly make operational decisions based on their flight data analysis well beyond this traditional role.

There are many technical examples that illustrate some of the concerns. One example is the problematic trend in the airlines to use Engineering Units (EU) or CSV (Comma Separated Variables or spreadsheets) to pass the data to their analysis/animation systems. The problem with passing EU files is that your analysis/animation tool may be showing you an artifact of the recorded data instead of the real data due to processing that you may be totally unaware of. Investigators use systems that interactively handle the ARINC bit stream data directly. That is all applications interact with the source binary data and convert to EU 'on the fly' as required. Many systems in use by the airlines however cannot accept ARINC data and must first have the data pre-processed by another application so that it is 'readable' by their analysis/animation system. This is largely because handling the ARINC data from the aircraft directly is a significant process in itself. Flight recorder manufactures like to sell boxes and sell hundreds of FDRs for every replay station they sell. Consequently, their replay systems, while they will recover the data, have fairly poor analysis tools. Other companies capitalized on this and developed analysis tools but relied on someone else to perform the actual data recovery.

When you have to pass EU files from one process or system to another as a CSV or spreadsheet file, it becomes problematic to pass all of the recorded parameters. A modern aircraft may have well over a thousand parameters. Imagine an excel spreadsheet 1000 columns wide! In fact you cannot do it in excel due to limitations. What is typically done is only send the parameters you need. Although the person at the other end may normally only want to look at a core set, his ability to 'investigate' the data is compromised because he does not have all of it and he must pre-judge what is important. As a former TSB investigator, I do not like to have to pre-judge what I think I might be interested in. Since investigation systems access the ARINC binary data file which is a relatively small and nicely packaged file already, investigators have access to all of the data all of the time.

Another more serious problem with passing EU files around for analysis is the time element. Two parameters that are both recorded at one sample per second are actually not sampled at the *same* time within the second. There is a relative offset based on the word location. For example aileron position and control wheel, while both sampled once per second, will be offset from each other by as much as just under a second. In order to maintain the timing resolution of the original data, the EU file must be incremented at intervals coincident with the data frame rate. For example, a 64 word/sec rate would require the data printed out in 1/64 time intervals to maintain the same time resolution for each parameter. This means that if you want to look at 25 hours of data using EU files, you would need 64 lines of data for each second. To pass 25 hours of all of the flight data to someone in an EU file format maintaining the recorded accuracy would require a spread sheet 5,760,000 lines long and 1000+ columns wide! If you move to a 256 or

512 word/sec recording, the numbers get even more impractical. Instead, shortcuts are taken by prejudging what parameters the analysis or animation system needs and by truncating the data all to the nearest second. The NTSB and other investigation agencies have given papers on how important it is that we be able to trace data latency. They are talking about latencies within the second for the most part. For all of these systems out there that truncate the data to the nearest second, there is no point in worrying about latency – you have already reduced the accuracy well beyond the latency concerns. This is simply unacceptable for accident investigators who have expertise in flight data analysis. Systems that can process the ARINC data on the fly do not suffer from this problem and they will display the data at precisely the times it was recorded.



While in many flight animations, it will not matter that the data is inaccurate in the time domain as there are lots of smoothing processes going on internally (a whole other paper) and the animation is being used to look at a relatively simple, routine event. However, should the team come across a more complex event, it is human nature that they will try to use the tools they have to do the work. This has already happened where an airline has run incidents through their 'automatic' tools before the investigation authority even has the data. If we believe that FDM is accident investigation without and accident investigators are not willing to compromise data quality and have stringent standards, why is it acceptable at the airlines? The answer is it shouldn't be and, like the QAR dilemma, it is another example of how history has got us to a place that we do not really want to be and it is very hard to undo.

Aircraft manufactures are also becoming aware of this growing problem as airlines will frequently wish to send data to them for assistance in troubleshooting something. They send a CSV file and the analysts at the other end do not get all the parameters, do not get the proper time resolution, and do not have the ability to check the EU conversion process if they suspect a problem. The EU conversion process has many opportunites for error, especially with parameters infrequently analyzed and one should never accept

the EU data as factual. Since the ARINC data file is magnitudes smaller to send and has no compromises, it does not make much sense to be passing EU files and manufacturers are starting to ask that the airlines please send the raw data, not some artifact of the data in which they have no way of assessing its validity.

Summary:

ICAO Annex 13 Appendix D recognizes the difference between an 'airline' facility and an 'investigation' facility and recommends States use investigation facilities. This was written by the ICAO FLIREC Panel because some States started taking the recorders to airline facilities after a major accident and other States with significant recorder labs felt that this could compromise an investigation. This was written before FDM programs were popular. With the FDM evolution, ICAO will need to revisit this as the stakes have gone up as airlines can now have a flight animation done very quickly. If it is not accurate or misleading, it is very hard to backtrack once people have seen it. The golden rule of accident investigation is to get it right before disseminating the results. With the accessibility of 'automatic' flight animation systems and the manner in which some systems process the data, combined with philosophies that purport that you do not need any expertise to generate animations, we are setting ourselves up to compromise this golden rule.

As airlines make more and more decisions based on routine flight data, it will become increasingly important that similar standards or data recording, extraction and processing that have evolved from years of accident investigation are applied to the rest of the industry.

With flight animation becoming more and more being a popular part of FDM programs, airlines will almost certainly go down the same path the investigation labs have already gone down and eventually demand the same tools and require the same expertise. If you are using animations for training, you still need to make sure that it is right – you can't always jump from the data to training with the investigation part in the middle! The investigation part may be trivial for routine events but will not be trivial for complex events. When is the transition whereby the investigation expert is required and will you know when you have crossed it? Like most things in life, nothing is free. The proper solution is to make sure you treat the data with the respect it deserves and develop an expertise and thorough understanding of the process you are operating.