FLIGHT SAFETY FOUNDATION

LEARNING FROM ALL OPERATIONS

Case Study: Learning With Flight Replay Animations

Flight Safety Foundation

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1. Continuous Learning at Three Levels

The Foundation's approach to Learning From All Operations promotes the value of understanding how work is actually done. Organisations, teams and individuals should recognise how people meet the challenges they typically encounter. Understanding the choices that personnel make when things go well, and why they make those choices, provides insights into why things that usually go well can also occasionally go wrong.

This case study illustrates one possible way that organisations can facilitate individual and team learning through implementing a technological capability for flight replay animations. This learning takes place within an overall continuous learning process at three levels, as explained below.

Learning takes place at individual, team and organisational levels (Flight Safety Foundation, 2021). The results of learning are expressed on the individual level (skills, competence) as well as on the team and organisational levels. On the team and organisational levels, learning is expressed in how work is organised, how the physical environment is structured, which instructions are given, how training is conducted and what's being trained, and which processes and standards are adopted. The interdependencies among the three levels of learning are illustrated in Figure 1.

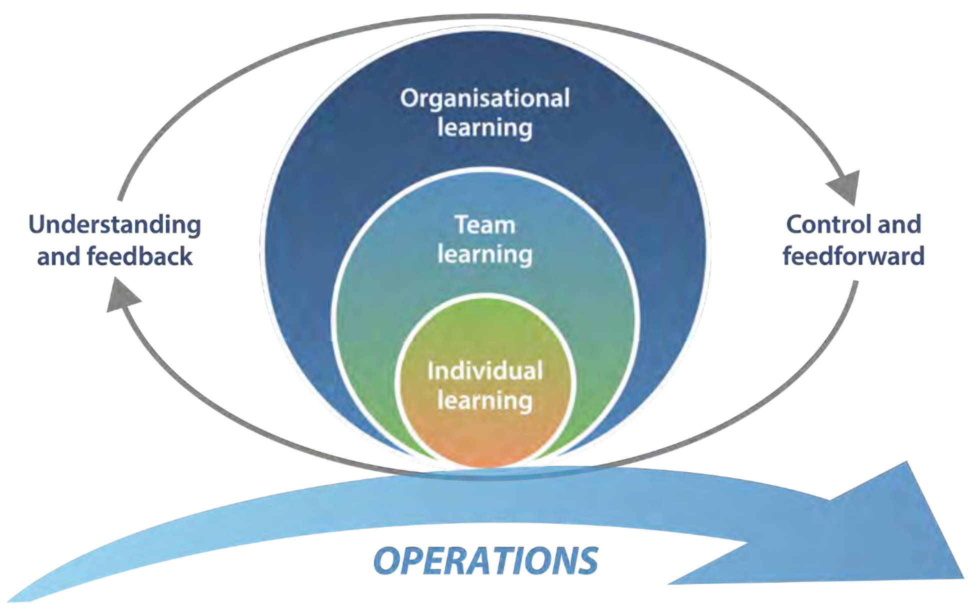

Figure 1: Learning at Three Levels

Individual learning: On the individual level, besides formal training, personnel learn directly from their peers and from their work. In fact, individual learning happens virtually all the time — it can be implicit or explicit, occur as a result of self-reflection on success or failure, and follow easy or difficult tasks. In aviation, this level of learning would apply to the frontline worker, such as a pilot, dispatcher or air traffic controller, as well as a cabin crewmember or a baggage handler.

Team learning: On the team level, learning reflects the experiences of the individuals as well as those of the team as a whole. Time and resources are needed for team learning, but learning is still closely coupled with the actual teamwork and is therefore specific to the given situation. Learning on the team level may, however, also slowly become formalised and subject to organisational policies and procedures. This process changes learning from being direct or personal to something indirect or mediated; the latter requires additional time and resources. A team in this context could include the entire crew of an aircraft, cockpit and cabin, controllers working at a particular facility or at a particular position, or the ramp team.

Organisational learning: Learning on the organisational level is typically based on generalised rather than actual experiences. The outcome is usually expressed in terms of the organisation's norms and policies. Furthermore, organisations have a key role in facilitating the individual and team learning which are the drivers for organisational learning. Organisations include airlines, air navigation service providers, aerodrome operators, regulators and other large entities that support the aviation domain.

There are interdependencies across all three levels of learning. It is important to understand that at each level, learning takes place in a different manner. Learning From All Operations refers not only to expanding our understanding of safety-relevant occurrences to include those that go well, but also to expanding learning opportunities at the individual, team and organisational levels. The interdependencies across these levels create opportunities for developing insights about how organisations facilitate or hinder individual learning, about the transfer of learning across levels, and about overall system performance.

2. Using Flight Replay Animation for Individual and Team Learning

Since the incorporation of commercial airline flight data monitoring (FDM) and flight operational quality assurance (FOQA) programs, pilots normally have had the opportunity to review animated flight replays when the safety management system (SMS) personnel required a debrief or the operating pilots themselves requested a review of a specific flight which they operated. When provided, the flight data replay was conducted with guidance from an approved FDM facilitator, often days, if not weeks, after the flight. This time lag allowed for data validation, analysis, and aggregation for the airline. However, for the individual, this time lag created disassociation from the event and less likelihood of accurately remembering what happened.

Through the innovative combination of approved technologies and confidentiality protocols, operators now can partly relocate historical FDM replays from office desktops directly onto the pilots' company-issued electronic flight bag (EFB) in a manner that is compliant with regulations and confidential. The flight replay capability can be made available soon after the completion of the flight. Such capability can be used to facilitate crew debriefing, to support pilot self-reflection and to facilitate training through a timely, tailored and confidential feedback loop. When enabled, each pilot can access his/her own flights.

Secure data, such that only the operating pilot(s) can request access to review their flight profiles can be customised in accordance with company, industry and regulatory stakeholder requirements. This customisation can include defining the time window during which pilots can access their flight replay. If the application uses the aircraft's quick access recorder data transmission via an automatic, wireless process, then for the airline, EFB FDM replay technologies can be easily and efficiently incorporated without any additional installation.

EFB flight replay aims to achieve the goals of improving the effectiveness and efficiency of training, strengthening pilot performance, improving factual understanding, promoting detailed and accurate reporting and, ultimately, improving flight safety. The immediate, objective flight data animation provides pilots with a view into their own performance from the perspective of both the pilot flying and the pilot monitoring. The ability to review the flight in a dynamic, near real-time, self-facilitated manner creates a data/technology-informed opportunity to enhance not only pilot performance, compliance and safety, but also an airline's performance, compliance and safety.

Figure 2: Static image from a representative EFB flight replay

Some airlines that have already incorporated EFB flight replay systems into their programs consider the capability as beneficial and a natural progression of existing safety, operational and training processes. Soon after introducing EFB flight replay capability, one airline noted positive feedback from its pilots, who welcomed the innovative means and opportunities for feedback, self-assessment, knowledge transfer and reinforcement of standard operating procedures and shared mental models.

Reviewing a flight animation is not investigating a flight. It does not need to be a search for "what went wrong". It can serve to support pilots' recall of what happened, organise relevant information and support elaboration, thus, improving learning from their previous flights. In this way, using an EFB flight replay is truly a Learning From All Operations process, enabling learning from everyday situations. For situations that are infrequent but rapidly developing, using EFB flight replay can support recollection of the sequence of events. An example is a traffic alert and collision avoidance system (TCAS) resolution advisory (RA) response. Data indicate that pilots' RA responses can be suboptimal and sometimes incorrect. Because a TCAS RA is a dynamic situation, possibly also involving a reverse RA, it is challenging to accurately recall the moment-by-moment details of everything that happened, along with the order and timing of each detail.

EFB flight replay animation can also be used to support training. For example, after a line training flight, instructors could let the trainees think about the flight, then compare the trainee's perceptions with the recorded event, enabling the trainees to suggest corrective measures themselves or to offer them suggestions for improvement. Instructors could also use flight replay recordings to support a facilitated "talk aloud", during which crews discuss their performance with the instructor and each other during the replay. Such approaches can help instructors understand pilot's competencies (strengths and weaknesses), as well as reinforce or correct the motivations and problem-solving strategies of the trainees.

Some may fear that pilots using a fast feedback loop through EFB flight replays may develop personal flying techniques that deviate from established procedures. This has not been reported by users of systems that rely on animation technologies, as the animations focus on the process and not only on a performance indicator.

Every pilot employs some level of personal technique in carrying out procedures, because virtually all procedures are inherently underspecified. These "personal flying techniques" are part of how pilots demonstrate resilient performance. The personal flying techniques can, however, have downsides: Such techniques can make it more difficult for crewmembers to predict each other's behaviour, and unvetted techniques may have unintended and unwanted consequences.

Using EFB flight replay can make flight operations more transparent in regard to the presence of personal flying techniques; it can be used to identify these techniques, share them and make them available for rigorous/systematic vetting. Flying techniques are easier and quicker to debrief with animation, either by a crew after their flight, or later, by phone. Those personal flying techniques that have value could become part of standard practice, improving performance for everyone while addressing the predictability challenge described above. In the end, the risk of unknown and problematic personal practices existing for too long in an airline might be reduced.

3. A Personal Example From a Pilot Involved in EFB Flight Replay Implementation

The following example was provided by a pilot involved in supporting an aircraft operator's implementation of EFB flight replay animation capabilities. For this example, we will use the fictitious name "Peter" to refer to this pilot.

Peter has realised during his career that, sometimes, pertinent information is kept at crew levels despite having interesting content for management and the flight safety department. For Peter, the prime reason for not reporting unusual events or safety concerns is not a fear of doing so, but the fact that pilots feel uncomfortable forwarding unclear, incomplete or inaccurate information.

Peter shared a personal example to illustrate his perspective.

A few years ago, during an annual line check, his copilot was intercepting the final approach in a rather "sporty" manner. During this high workload situation, he made the correct procedure callout — localiser (LOC) star/glideslope (G/S) star — indicating the capture of the final guidance.

Peter checked his flight mode annunciator (FMA) and read another indication — heading (HDG)/GS star; immediately, he told the copilot to continue the intercept using raw data and rearmed the approach. Peter had doubts about what he had seen, because the combination of HDG and GS mode should never occur.

Figure 3: Illustration of a doubtful situation

During the debriefing, the instructor, who was seated in the jump seat, told Peter that he saw a strange FMA annunciation, but it disappeared so quickly that he was unable to determine what had happened. As the event did not have an undesired outcome and the aircraft correctly established on the final approach, Peter was not concerned.

As a crew, they were not able to reconstruct exactly what had happened because they were missing elements of the situation. As a consequence, they did not know what to write, so they did not file a report.

Less than 15 days later, the company had an instructors meeting. The technical pilot of the aircraft manufacturer's long-haul fleet warned them that a manufacturer bulletin made their company aware that, with the installed combination hardware/software in their planes, an internal error could result in the loss of the LOC during the capture, leading to a reversion to the HDG mode, but keeping the G/S engaged. This is a potentially dangerous combination.

After this technical explanation, a dozen colleagues in the meeting reported that they had observed such indications.

The chief pilot was angry; he couldn't understand why he had not previously received any report on the issue. The explanation from the affected pilots was that during a task-intensive flight period, close to the ground, there was no time for analysis or troubleshooting. After landing, the pilots had doubts about what they had perceived, and they thought that their observation was probably a misreading or a misinterpretation of the FMA. Being unsure and not having sufficient understanding, the occurrence was left unreported.

A single pilot had forwarded a report. Ironically, this report did not go further, as operational engineering concluded that it must have been a pilot misinterpretation of the FMA, because a combination of HDG and G/S was, according to the books, technically impossible.

After this incident, when working on the replay tool, Peter realised how useful a replay application would have been in such a case. An animation would have allowed the pilots to replay the sequence around the event — if necessary, in slow motion — in a realistic type-specific cockpit, showing all displayed FMA modes and indications. The animation would have immediately confirmed the erroneous flight guidance behaviour.

Figure 4: Animation of a situation

In addition, the animation would have helped determine whether the FMA mode change was the result of a voluntary crew action, an erroneous pilot manipulation, or an automation glitch.

In companies using a replay tool, improved understanding of events by individual pilots appears to promote reporting. For example, at one airline, an increase in pilot reporting of flap overspeed occurrences was noted following the implementation of flight replay technology.

Peter is convinced that by reducing doubts at the individual and crew levels about what happened, the willingness to forward information, the degree of details and the pertinence of the reports will be greatly enhanced.

To be most effective, such a replay tool should be available immediately after the flight to provide an opportunity for review while pilots' memories of the events are still fresh.

Having factual data to report is a clear benefit, but a replay tool also could provide insight into crew elements such as situational awareness, perception issues, startle effects and workload — information that is not available today with traditional FDM/FOQA data crunching. EFB flight replays can provide data that are also potentially valuable indicators of possible threats.

In the previous example, had pilots reported the automation's behaviour, airline management would most probably have been informed of the FMA anomaly much sooner. As a consequence, the aircraft manufacturer and the training and operations departments could have begun looking for appropriate mitigating measures in a more timely fashion.

4. Feedback From a Pilot Using EFB Flight Replay

The following feedback was provided during an interview with a pilot from an aircraft operator that uses EFB flight replay animation capabilities. For this example, we will refer to this pilot using the fictitious name "Mike".

The company started using EFB flight replay technology when Mike had just finished his type rating, and was about to start his line training. Mike received an introduction to the application and downloaded it onto the company-provided iPad.

For Mike, the value of the tool was discovered when he started flying the jet himself. By using the application, a pilot can select a flight, save a clip and replay it. The tool provides a choice to select a replay time — for example, from takeoff or landing, and clips of different lengths: 1,5 minutes for a short clip, and 5 minutes for a long clip. In cockpit view, pilots can see flight controls and displays, and they can see the control column and the rudder pedals in separate inserts. The app shows the pilot's flight control inputs and displays. On an approach clip, pilots can see the flaps selections and continuous descent approach; pilots can see when the speed brakes are selected and the associated speeds, and when the gear is lowered.

On the landing page, the pilot can see where the aircraft touched down — e.g., 380 m (1,257 ft) past the threshold; it took 1,450 meters (4,757 ft) from that point to slow down to 37 kt at the runway exit point. The pilot can see that after 500 m (1,640 ft) and 2,8 seconds, the first reverser was deployed.

Mike recalled an experience with the tool that occurred during line training. The event he recalled happened around a week into his training and involved a landing. It was not a perfect landing but a bit of a "struggle". It was a full-flaps approach to one airport which is normally quite straightforward, but there was a significant crosswind. In Mike's airline, pilots are limited for the first 500 hours, to a crosswind which is lower than the aircraft maximum limit. During the event, the landing "just did not seem right" and the captain took over control and landed the aircraft. Afterward, the captain gave Mike some tips. Although the tips "made sense" he could not fully comprehend them until he checked the application on his iPad and saw what had happened during the approach. He was able to see how he focused on a single parameter and lost his scan. On the app, the pilot can see parameters which would be observable to his or her copilot, and Mike could see how one of them caused the intervention by the line training captain. He realised his attention was channelled elsewhere, and could see the glide slope deviating — for him, it was clear he was concentrating on one thing instead of scanning all parameters; his scan broke down.

Mike shared another story, when he was done with line training but still had fewer than 500 hours, so he still had the crosswind limitation. There was a low-pressure system over the country with lots of high crosswinds, so he was not able to fly but was monitoring. He appreciated seeing how the captain handled the crosswind. Later, he re-watched the flights and he could virtually "re-live" the events, thinking how he could try to do the same things that his captain did.

After line training, Mike continued to use the EFB flight replay for different scenarios, especially weather-related events. Pilots can use the flight replay animation to perform a debrief after a flight. Also, they can contact each other and have a virtual meeting to discuss their flight, or they can discuss it with the same crewmember the next time they fly together.

5. Using Flight Replay for Organisational Learning

Flight data animations come in two forms, both of which are valuable yet differ in their use and benefit to flight safety. The first form comes from an individual flight. As described above, that is useful to the individual pilot and the crew. This is also useful if the flight experiences an anomaly and the pilot or airline seeks to better understand the aircraft state and hence gain better overall situational awareness in hindsight.

While airline data security protocols prevent disclosure of proprietary flights, a demonstration case study is shared by an airline that leverages the use of Google Earth, an open-source platform. In this instance, an operator was having issues regarding ground-proximity warning system (GPWS) terrain warnings on an area navigation (RNAV) approach into an airport. Airplanes in one of the operator's fleets encountered terrain warnings due to the algorithms of the software calculating terrain closure based on the aircraft's trajectory, position and groundspeed. As the aircraft was making the turn from north to west (base to final), the GPWS system was activating.

Flight data analysts undertook a four-step process to animate the flights.

Step 1: A Google Earth image of the area was chosen (Fig. 5, below).

Figure 5: Google Earth image of the area of interest

Step 2: The appropriate approach plate was superimposed on the Google Earth image, and its transparency was set to retain terrain features (Fig. 6, below).

Figure 6: Google Earth image with overlayed approach plate

Step 3: The aircraft's GPS (ADS-B) positioning was overlaid onto the approach chart (Fig. 7, below).

Figure 7: Google Earth image with overlayed approach plate and aircraft positions

Step 4: Data markers were created to highlight where the aircraft was configured, and where the GPWS warning happened (Fig. 8, below).

This flight also triggered a false unstable approach, depicted in yellow on Figure 8, below. It is important to note that thorough validation must be done to ensure that an event such as an unstable approach is valid. High density altitudes, short turns to final and many other variables can contribute to spurious events such as this one.

Figure 8: Google Earth image with overlayed approach plate, aircraft positions and data markers

In the final analysis, the carrier determined that the aircraft was flying the RNAV procedure correctly, but as the aircraft was pointed northeast on base to final, the logic of the GPWS "look ahead" was activating the terrain warning. The flight animation program enabled that determination, and a company notice to airmen (NOTAM) was created to make pilots aware of this threat on arrival into that airport.

The second form of organisational learning from flight data animations pertains to aggregate animations. This is a powerful tool for identifying, analysing and remedying issues pertaining to airspace. Aggregate flight data tracks are used for a myriad of purposes, including noise studies and procedure design.

In Figure 9 (p. 10), flight tracks were used to analyse approaches to Runways 19L and 19R at an airport. After the tracks were obtained, flight data analysts colour-coded the approaches based on stability. Green tracks were stabilised approaches, red tracks were unstabilised.

As can be seen, the aircraft that were vectored close in to the airport (or self-directed after being cleared for the visual) had a much higher rate of unstabilised approaches than aircraft that were vectored to a further-out final. A simple animation such as this makes a compelling case when an airline works with an air traffic control facility to adjust procedures.

As a final point, note the one approach starting from the upper right corner that remained red for its duration. Outliers like this can be very valuable in data analysis. First, a data outlier might represent an invalid data signal. Second, an outlier might represent undesired performance (e.g., the aircraft remained fast and/or high for the entire approach). Third, an outlier might represent desired exceptional performance based on context (e.g., following a declared emergency due to passenger illness, the aircraft flies the approach above normal airspeed). Thus, we should not assume that all outliers are necessarily undesired. Regardless, outliers represent an important opportunity for learning.

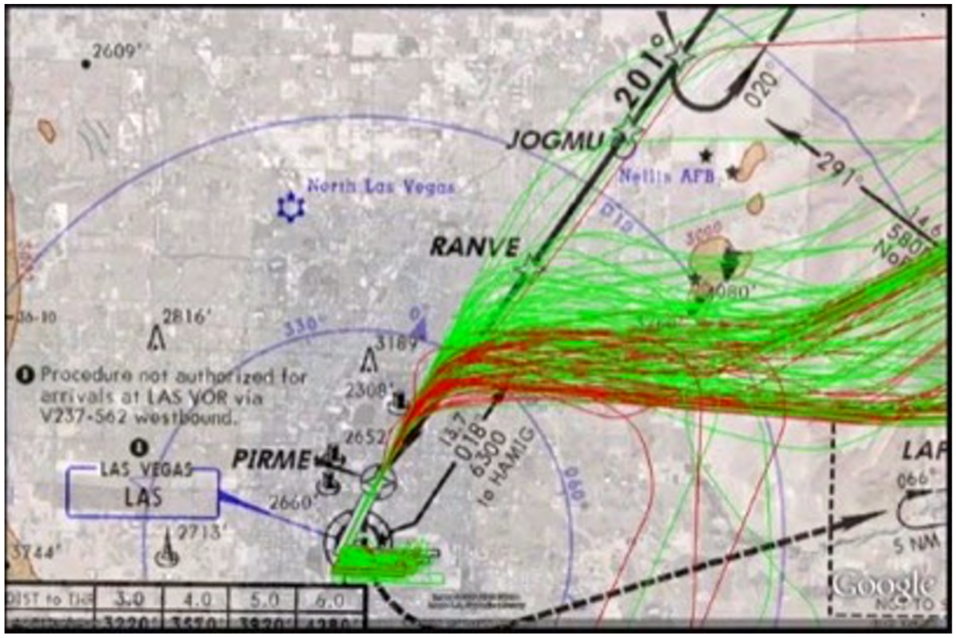

Figure 9: Aggregated animations for multiple flights

6. Flight Data Animation's Limitations

While animation of flight data for individual pilots is an exciting development given the back-drop of the new data ecosystem we are entering, it does not come without important considerations and areas of caution. First, flight data animations are recreated in day visual flight rules (VFR) conditions. While this is convenient for visual reference, these conditions don't always exist in real-world operations. Pilots fly in all weather conditions, day and night. A day VFR animation makes it easy to see the horizon, which is a luxury many loss of control (LOC) events did not have.

Second, research has shown a severity bias when it comes to slowing down a replay. In a study, researchers found that slowing down motion made actions seem more intentional (Caruso et al., 2016). Aviation is a real-time endeavour, and pilots reviewing their data must remember that they were not afforded the luxury to "freeze the sim" while conducting a live flight.

Third, while it may seem easy to imagine a perfect recreation of flight animation, this is rarely, if ever, the case. The quality of the flight replay is highly dependent on the recorded parameters on the aircraft, the so-called data-frame. The data frame defines which parameters are recorded and at what frequencies.

Some aircraft will, for example, record a master caution, while others are only able to record a master warning. TCAS traffic advisories (TAs) are also frequently not recorded; on a playback of a TCAS RA event, this might be confusing for the crew. Giving the flight crew a video playback without guidance might give the impression that what is seen on the playback is the only true scenario. Crews using the replay software should be educated about the background of the data and made aware that not everything that is seen in the animation is necessarily complete or even correct.

Finally, it is critical that protections exist for pilots and airlines, should they adopt this technology (Norman, 2022). In an SMS, an airline must continually identify and mitigate hazards.

Having access to personal flight data in privacy is touted as a major psychological selling point for pilots. Yet, the same data is used by the FDM/FOQA program and is available to management. Clear boundaries must be set, and clear policies must be communicated to all.

7. Conclusion

A tool such as flight replay software can facilitate Learning From All Operations. What's more, it can facilitate learning at the individual and team levels, and thus contribute to learning at the organisational level. While a review of flight animations has been used historically to understand "what went wrong," it can also be used to support pilots' memories for what happened, organisation of relevant information and elaboration that reinforces learning. Pilots can use these tools to, among other things, support event reporting, learn individually from their own and their co-pilot's behaviour, and to support crew debriefs after a flight. By supporting reflective debriefing and active learning, such a tool has the potential to lead to improved performance and enhanced safety at all three levels.

8. Acknowledgements

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