CREW TRAINING USING ANIMATION

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Keywords: *animation, safety, simulation, training*

Abstract

This paper is focused on accident prevention, and presents the design aspects of a tool to generate animations from flight data or other sources, providing several examples where these animations can play a significant role in crew training.

1 General Introduction

Huge efforts have always been employed to analyze the causes of aircraft accidents and incidents. The knowledge obtained from these analyzes is widely disseminated by investigation authorities, industries, airlines, air traffic controllers and even passengers. But, according to the chart below, even if the accident rate has decreased as a result of these actions, the absolute number of affected persons may increase as a result of an ever-increasing number of passengers being transported.

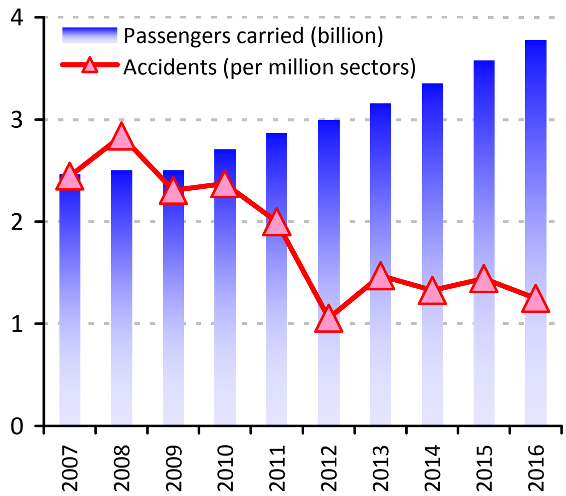

Fig. 1. Decreasing accident rate, together with an increasing number of passengers – adapted from [4].

Thus, new actions are always needed in order to improve overall air safety, in the way it is perceived and required by the community.

The statistics for 2012-2016 Fatal Aircraft Accidents points the two biggest contributing factors in "FLIGHT CREW ERRORS" as "<u>SOP Adherence / SOP Cross-verification</u>" (46%) and "<u>Manual Handling / Flight Controls</u>" (26%) [4] – both can be mitigated through proper training.

One animation tool called "<u>Flyback</u>" was developed at Embraer's Air Safety Department to investigate accidents and incidents. It allows someone to include calculation results and other elements, in order to meet the specific needs of safety-related events, often in a very demanding time frame. As this tool is known to several other departments of the company, the idea of using it to illustrate standard procedures came naturally. Following this approach, it was adapted to cover the situations encountered daily in the operation of the aircraft, from airport familiarization to special procedures, including flight simulator sessions.

Making use of three-dimensional high-definition animations, the professionals involved can have their own perspective of the flight, without spending a single drop of fuel or expensive hours in simulator.

1.1 Learning issues and solutions

Taking into account the dynamics of human learning, <u>experiencing the situation</u> shall produce the best results. But operating an aircraft in abnormal conditions to achieve the best practical result for an issue is not the most advisable or safe way to learn. Thus, a variety of flight simulators have already been developed for this purpose, being very valuable, of course, although not yet so cheap or portable. With a good cost / benefit ratio, the use of animations is an interesting option. While not as immersive as a simulator, they are able to run from home computers to smartphones, literally inside the crew's pocket. And from now on, training programs that are competency- or evidence-based, which maximize the use of simulation, customizable to air carrier operations and that are continually updated based on pilot task-level performance are a must-have [3].

The so-called video modeling techniques are a proven way of empowering people, from children with autism to sports professionals [6]. This technique consists in playing a video of an experienced artist, allowing athletes to watch a skill that is performing correctly. This practice creates a mental representation of the correct skills, so that they are able to physically model or create it. The effect is even greater when the model being visualized is similar to the observer in age, gender and competence. The idea is to ensure that ideal or near ideal performance becomes the image that the athlete uses in mental rehearsal. Using this technique, crew can retrieve the appropriate information while on approach to an unknown or unusual airport, before takeoff or even during the cruise time. The same is true for a failed engine takeoff or a steep approach. The video images shall provide visual cues such as terrain, rivers, roads, buildings and lights, preparing them to fly in visual conditions, for example. Instrument landing condition is even easier to simulate.

With augmented reality, waypoints, charts, paths or any three-dimensional element can be added, and the user can retrieve the information at its own pace and choice.

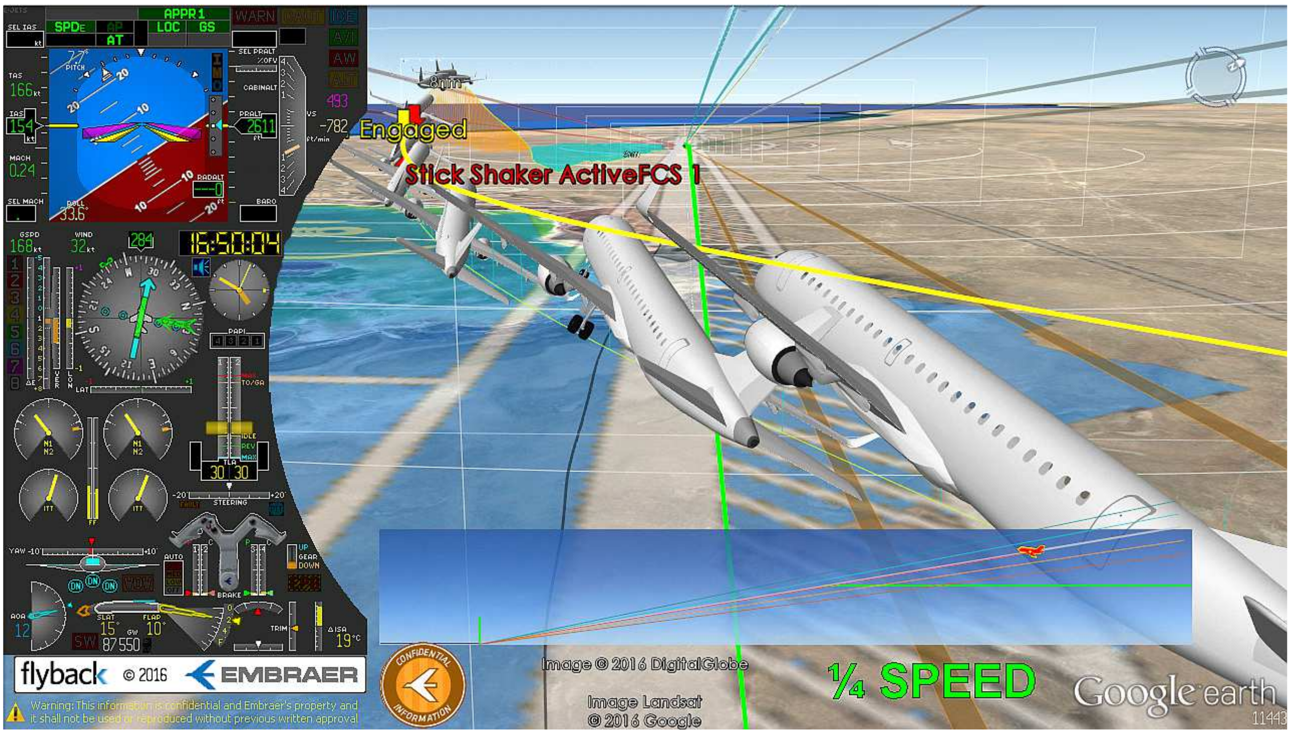

Fig. 2. Step-by-step animation for a stick shaker actuation and the way to recover from it.

1.2 Human aspects

The human brain is roughly divided in three zones. The Reptilian brain (the most primitive one) controls the body's vital functions such as heart rate, breathing, body temperature and balance. It is reliable, but tends to be somewhat rigid and compulsive. The Limbic brain can record memories of behaviors that produced agreeable or disagreeable experiences, and it is responsible for what are called emotions in human beings. It is the seat of the value judgments made, often unconsciously, that exert such a strong influence on the behavior. Finally, the Neocortex is composed of two large cerebral hemispheres that play such a dominant role. It has been responsible for the development of human language, abstract thought, imagination and consciousness, is flexible and has almost infinite learning abilities. Although the cognitive information is processed at the Neocortex, when exposed to stress or fatigue, the brain tends to revert to the Limbic system (where emotions are assigned), then finally to the Reptilian brain (responsible for typical instinctual behaviors).

Shocking situations play a significant role, as they are linked to human survival. That is why aircraft accidents reports are often used for training. But, although this practice is valid, it is not expected that exposing crew to all accident reports that happened in their route will give valid insights for a pleasant and uneventful flight. Note that video modeling techniques also works backwards: if bad performance is shown, bad performance may be expected. In this sense, a video footage for the most critical sections of the flight, with useful information (including good ways to get rid of bad situations), typical sounds and views, will excite their senses and allow the information to be stored and recalled as needed. So, shaping the learning experience with some emotional content (and positively linked to some survival aspects), will be paramount when an unforeseen event disrupts the "routine processing" done by the Neocortex.

Although information which is only read (charts, procedures, manuals) may be rapidly forgotten, audiovisual lessons will last. In a web-based experiment, the audiovisual modality (versus written modality) was found to increase recall of information in both younger and older adults [1]. Together, audio and video create bridges. For example, memories of people's faces, the taste of the wine, the music that was playing, etc, might all be part of the memory of a particular dinner with friends. By repeatedly reactivating or "playing back" this particular activity pattern in the various regions of the cortex, they become so strongly linked with one another, that the memory of the music that was playing can act as an index entry and bring back the entire scene of the dinner party.

1.3 Historical facts

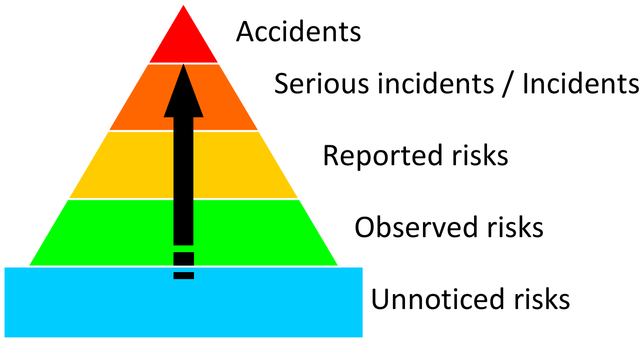

Fig. 3. Accident model (pyramid).

Accidents can be represented as the pyramid top, a place where some predecessors (Serious incidents and Incidents) tend to. Below them, several minor events (Reported risks) can be found. Even below, there is a huge quantity of low relevance events that, although observed, pass unreported. Finally, under this layer, an unknown universe of items that remain unnoticed. Numbers related to each level may vary according to each researcher, but the common idea is that the most relevant events can be avoided if the lower level predecessors are adequately mitigated.

On each level, elements with the potential of combining and getting to the top may be found. Beyond component failures, factors as the growing system complexity and the human-machine interface deserve attention. The results derived from the accident analysis (the facts and the countermeasures) must reach a wider audience, and this is possible through the cheap and practical proposal presented in this article.

2 Objectives

Taking into account the analysis and training needs raised, the application was initially aimed to generating animations using:

- Information from flight data recorders;
- Instrumentation data from aircraft tests;
- Mathematical simulations results;
- Calculations based on performance;
- Data from flight simulator sessions;
- User entered data, as per specific needs.

The video footage produced must collimate the elements in order to allow its comprehension by different audiences: engineers, technicians, pilots, lawyers, analysts, officers etc. Then, some viewing aid may be demanded:

- Relevant readings in a dashboard;
- Specific cues along the flight path;
- Synchronized audio (real or synthetic);
- Moving maps (charts, routes, diagrams);
- Local conditions (sun, fog, rain);
- Field elements (obstacles, buildings etc);
- Moving items (vehicles, other aircraft).

This enhanced vision empowers the analysis and the training given to the crew, this way raising the operational safety level, as initially desired. Following this approach, the goal is to transpose any relevant risk situation into an audiovisual format, offering good ways of overcoming them. Performance data for a particular aircraft model can be used to simulate an operation never performed. This solution allows the prospecting of airports to establish routes within suitable operating conditions.

The generated video files can, for example, become available to the instructors and staff, as well as stored on mobile devices like phones and tablets. Additionally, one can export the data in a specific format and watch to the events using a flight simulator. So, becoming familiar with new routes or understanding an operation in unusual conditions can be done in a quick, cheap and easy way.

3 Methodology and examples

The application software "Flyback", which was originally designed to analyze events from the information recorded in flight data recorders, was used as a base. Sparse figures in tables from recorders or other sources are interpolated to provide a full set of data for each frame. These frames are then translated into Keyhole Markup Language (KML) [5], a notation that follows the guidelines for eXtensible Markup Language (XML) [7] for geographical notation. Such language can be interpreted by a three-dimensional browser, as Google Earth® [2] or other. In this environment, animations can be produced and recorded in current formats such as Windows Media Video (WMV) or other suitable one. Output for flight simulators, from X-Plane® to commercial ones, for example, can also be provided.

Fig. 4. Accident analysis example.

The above figure represents an incident by sequentially positioning the aircraft along the trajectory. Recorded data, observer reports, photographic documentation and even a sketch were used to provide the necessary information.

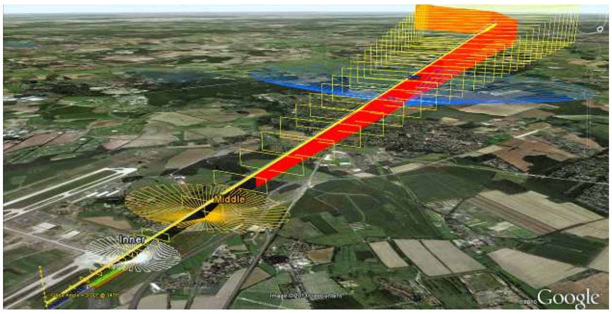

Fig. 5. Antenna radiation pattern.

Accessory elements can be drawn in the environment. Specific routines have been created to generate geometries from a basic set of information. In the figure above, for example, the radiation pattern from the "marker beacon" antennas is represented using standard colors (outer = blue / middle = amber / inner = white).

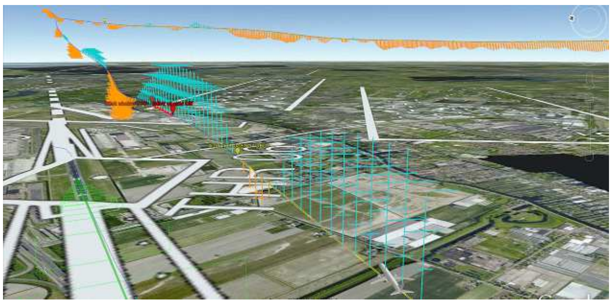

Fig. 6. Actual event animation.

In the previous figure, which relates to a stick shaker actuation during approach, accessory information such as navigation charts were included in the environment. Readings may also be included along the path, enhancing the vision of the event (augmented-reality). In this cited case, the lines projected above and below the flight path represent positive and negative deviations from the glide path, as interpreted by the onboard computer. As the aircraft was much above the proper altitude, the signal presented distortion and multipath, which in turn caused unexpected reactions by the control unit and also by the crew.

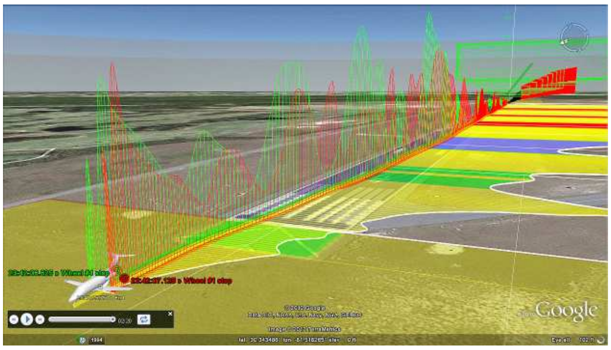

Fig. 7. Runway overrun analysis.

The graphic capabilities also proved useful for runway overrun analysis, as illustrated above. The vertical curves in red and green show the brake pressure for the left and right wheels. This representation brings more visual enhancements than a set of values plotted against time (as usual for such analysis) because it is possible to visually correlate the profiles to the aircraft positioning. The curve drawn horizontally on the ground is an estimate of the distance needed to completely stop the aircraft, calculated for each moment. The colors mean:

- Blue: within lane limits (on runway);
- Green: within paved surface (stopway);
- Yellow: outside the paved surface, but still in obstacle-free region (clearway);
- Red: danger of collision with obstacles.

In the top view shown in next figure, it is clear that the aircraft, in most of the path, would not be able to stop inside the paved surface boundaries. The runway lies on the x-axis for all curves. Landing is from left to right.

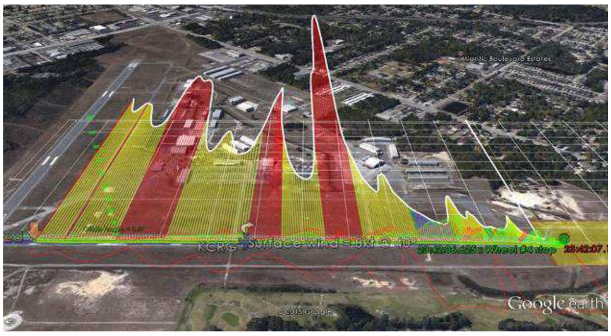

Fig. 8. Runway overrun analysis.

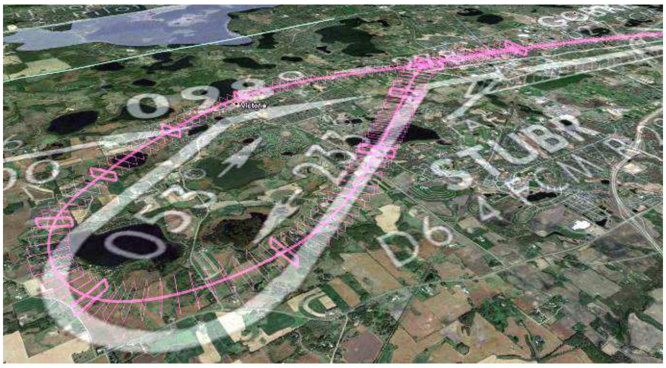

Fig. 9. Planned route over navigation chart.

Talking about prevention, it is possible to represent the planned route from a chart, such as in the above figure. Combined with real flight data, it is possible to analyze the adherence to pre-established spatial limits.

Fig. 10. Animation running on "X-Plane®".

The application also allows generating files that can be interpreted by flight simulators, either in desktop computers, or in commercial systems, helping evaluating solutions, at least preliminarily.

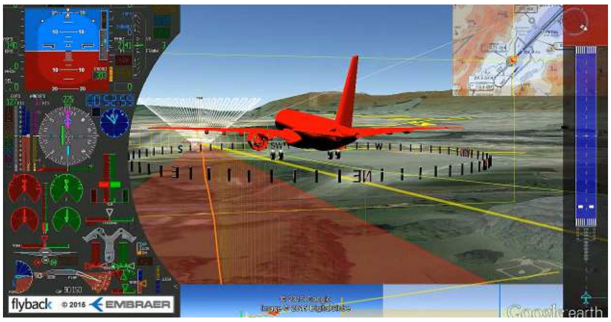

Fig. 11. Dashboard, top view, profiles...

The figure above shows readings of some of the most relevant parameters in a panel (at left), including attitudes, engine data, control surfaces etc. A representation of the relative position to the runway can also be displayed (at right). The top view, on a map or navigation chart section, is shown in the upper right corner. In the bottom, the vertical profile is shown, including the theoretical and the real slopes, which may also be shown in the 3-D environment view. A compass drawn around the aircraft also provides a visual guide for heading.

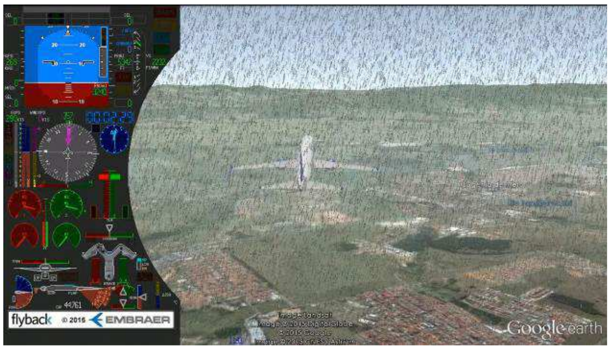

Fig. 12. Presenting ambient conditions.

Ambient conditions such as rain and fog, as well as elements such as snow, cracked windshield etc., are also possible to be created from a few tweaking parameters.

Fig. 13. Sun positioning.

The position of the sun can be manually defined using geographic browser settings, or linked to the event occurrence time.

Fig. 14. Pilot's perspective.

Animation can be generated from the pilot's point of view, including a representation of the Head-Up Display (HUD), together with the dashboard. This view has proved very useful in training pilots by recreating the environment from their own point of view, as well as when checking testimonies or even depositions during discovery processes.

Fig. 15. Simultaneous animations.

Simultaneous animations are also possible, as illustrated above. In this case, two landings at different times on the same runway are shown. They were combined to allow a visual comparison of the differences between the two procedures.

It is also possible to generate the ideal profile for a given procedure, to be checked against the one executed, to detect the significant differences. Slow motion and frame by frame camera repositioning are available throughout the entire trajectory.

Fig. 16. Simultaneous animations.

In the figure above, different take-off procedures are illustrated. The differences between them can be clearly seen.

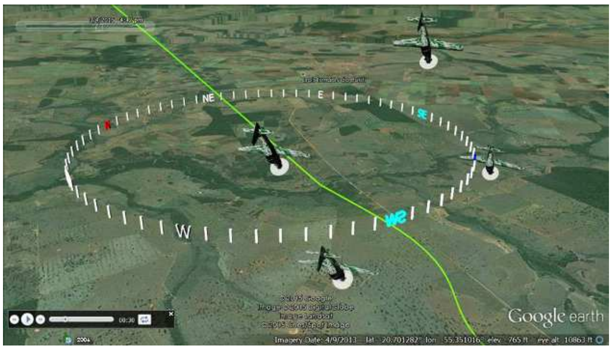

Fig. 17. Formation flights.

Simultaneous animation is paramount for studying formation flights.

It is possible to combine information for each aircraft, as well as generate camera paths by selecting one as a reference. Briefings can be richly prepared prior to the execution. Interesting perspectives can be obtained for singular events, such as pilot ejection. The costs and risks involved are much smaller to generate an animation than to record a real video.

Fig. 18. Pilot ejection.

In the figure below, an approach with two other aircraft in the vicinity (placed in the center of the spheres, a visual aid given the small size of these elements) is analyzed. The paths, viewed from above, are shown in detail in the lower right box. The point of view of any of the pilots can be used as reference in order to get the visual fields for them during the event.

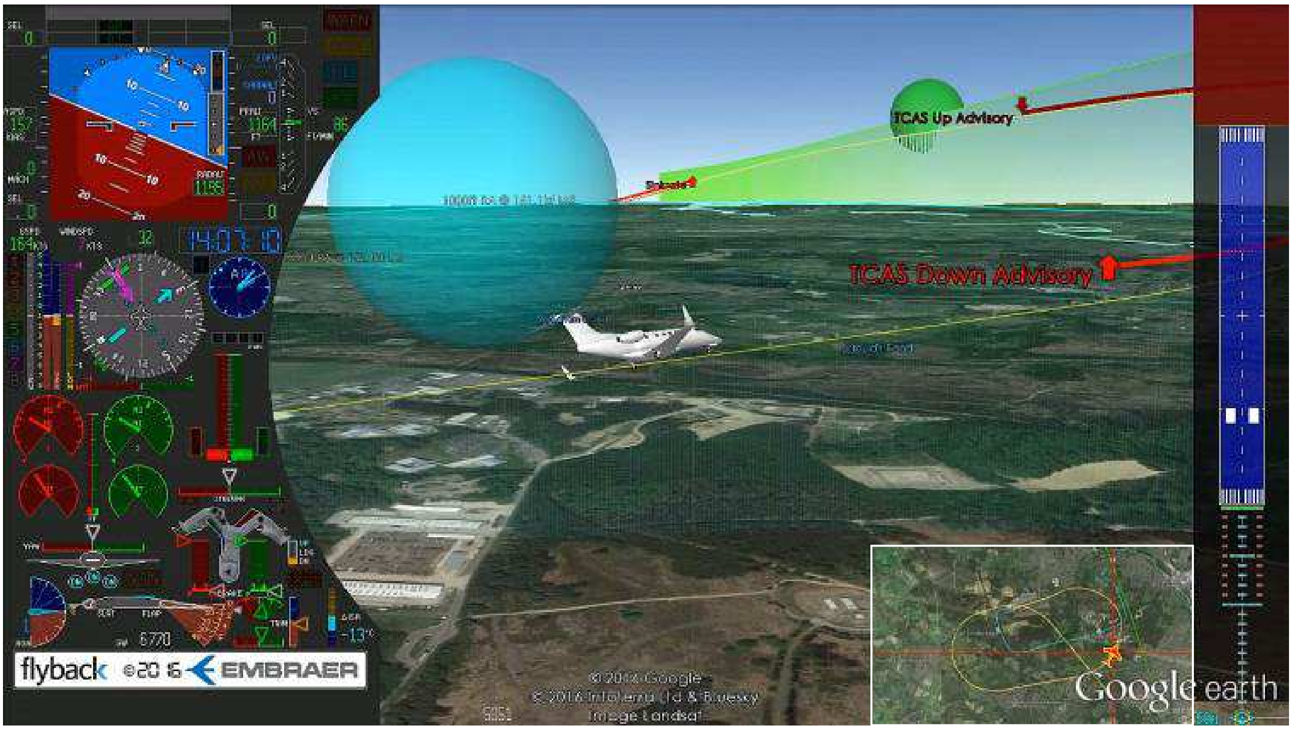

Fig. 19. Simultaneous animation in real event.

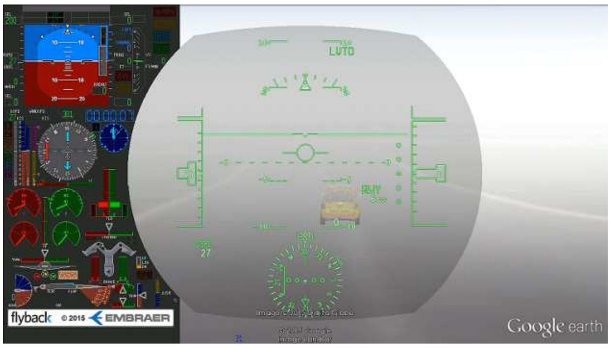

Fig. 20. Low visibility takeoff.

Practical applications include special procedures such as Low Visibility Takeoff (LVTO). In this case, the fog was added as an environmental factor, as well as another vehicle (the "follow-me" car). Note the corresponding information on the Head-Up Display ("LVTO" on the upper center region of the screen, and a circular guide, in the center). This animation was used by an operator to support the process of procedure certification by the national authority.

Fig. 21. Fog effect tuning.

Tweaking the effects is possible, such as fog intensity and color gradient, as well as the instants for the gradual start and end of the effect.

To enrich the visual experience, taking full advantage of the geographical navigator, it is possible to generate real three-dimensional visualization files (for compatible monitors). In this case, two videos are generated, with the camera positioned with an offset to the left and to the right, then combined through a video editor. Even ordinary videos can produce a 3-D effect when viewed on monitors that provide three-dimensional enrichment, which is a very interesting feature.

Fig. 22. 3-D visualization.

A typical example for an instruction video is shown below: an engine failure event during takeoff at Santos Dumont airport in Rio de Janeiro, Brazil.

Fig. 23. Single engine takeoff.

Fig. 24. Single engine takeoff – external view.

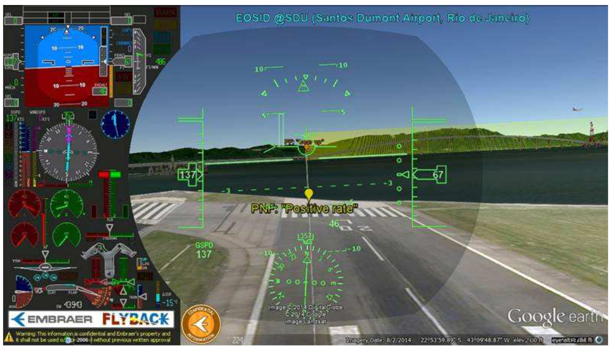

Fig. 25. Single engine takeoff – pilot view.

The figures above illustrate three different camera views. Note the visual cues, like the bridge just ahead. The yellow numbers on the sides of the runway indicate its remaining length. The map in the upper right corner provides visual indication of the trajectory. The video containing visual references, enhanced with standard operational procedure speeches and other sound effects, is a documented reference to the crew. It can be shown in the classroom and also viewed immediately before takeoff.

Fig. 26. Unstable approach.

The figure above presents an approach beyond the current criteria for stability. These videos can be generated in a safe manner using calculated data to illustrate situations that would be risky if performed under real conditions.

Fig. 27. Standard approach.

A standard approach video, with elements to make it easier to understand, is shown above. Visual cues are included, such as flashing lights, roads, buildings, and other geographic references. The position of the sun may be relevant. Air traffic, which may exist in normal situations, can also be added.

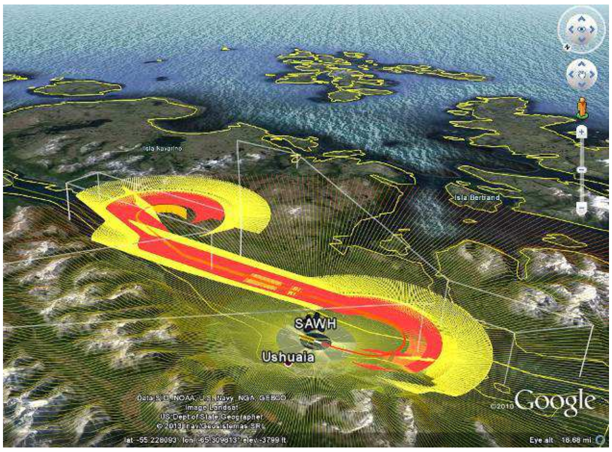

Fig. 28. Airfield prospecting.

It is possible to check the feasibility for new routes, combining geographic information with aircraft performance data, thus optimizing the operation from the point of view of payload.

The previous figure and the next one show projections corresponding to possible alerts of proximity to the ground, in two levels.

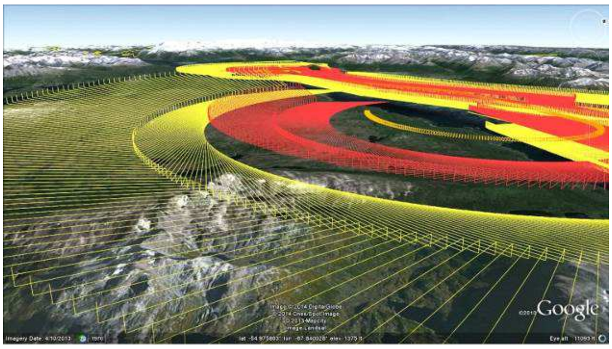

Fig. 29. Airfield prospecting - detail.

Fig. 30. Real crash animation.

Lessons learned from real cases, which can be broken down into recommendations, can also be illustrated. In the figure above, all the information was collected from public reports.

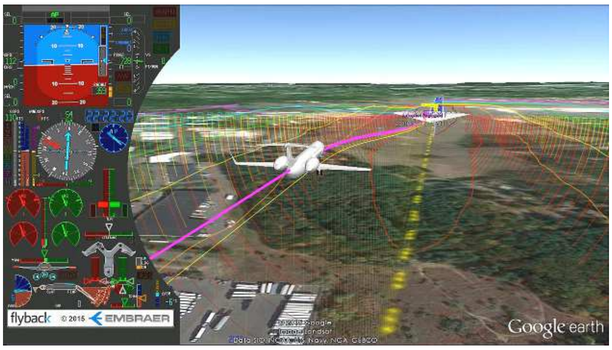

Fig. 31. Noise emission assessment

In order to comply with the legislation, the routes can be evaluated for noise emission, and a visual representation of the levels can be done.

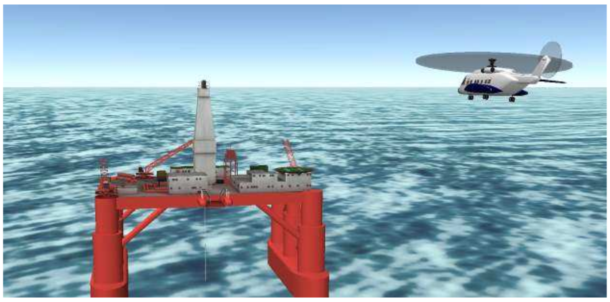

Fig. 32. Application for rotating wing aircraft.

Fig. 33. Ship operation animation.

In fact, animation solution applies to many types of vehicles, in all transportation modals.

4 Conclusion

The initial premise, which was to provide training in an accessible and practical language, using reliable information, was fully met. Although the application has been developed for fixed wing aircraft, it can be quickly adapted to helicopters, ships or other vehicles, even the unmanned ones, each with its own list of needs.

Possible uses also include briefings and debriefings for general, commercial, defense and even agricultural aviation. Several videos have already been produced to support the analysis of events related to operational safety, development of aeronautical systems, training certification, prospecting of routes, simulation of procedures, new business surveys etc. Thus the possibilities of use are still far from exhaustion, because the ease of generating solutions according to customer needs has always been the key point of this solution.

4 References

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