Report

on

Evaluation of VisionSafe EVAS in Cathay Pacific Airways B747-400 Simulator

Summary.

Modern aviation history includes a number of accidents where the crew were unable to see the instruments due to smoke. VisionSafe Corporation provide an Emergency Vision Assurance System (EVAS) consisting of an inflatable unit that displaces the smoke enabling the pilot to see the instruments and the windscreen.

An evaluation of the EVAS was conducted in a B747-400 simulator using dense smoke. The EVAS was capable of being deployed without vision after completing the recommended training. The Inflatable Vision Unit provided the crew with a sufficiently clear view of the instruments to follow ATC instructions to position for a visual final approach to a successful landing. A number of recommendations relating to airmanship considerations for smoke emergencies are included in this report.

References:

A. Report on Evaluation of Simulation of Cockpit Smoke Emergencies in Cathay Pacific Airways Simulators, 20 Feb 2001.

B. Maintenance and User Instructions, Emergency Vision Assurance System, Document Number 8024, Rev 3, 26 Jun 09.

C. Video, "VisionSafeGroundSchoolforWeb", located on Cathay Pacific Intranet, G:\60Shared-FOP\Smoke in the cockpit - EVAS Evalutaion 2011\.

D. Video, "VisionSaferTrainingDemoSim", located on Cathay Pacific Intranet, G:\60Shared-FOP\Smoke in the cockpit - EVAS Evalutaion 2011\

1. Introduction

1.1. Background.

1.1.1 Awareness of emergencies involving smoke in the cockpit has been increasing in recent years due to well-publicised accidents.

1.1.2 The smoke certification tests relate to clearance times once the source of the smoke has been eliminated. Accident history includes cases where the source was not, or could not, be eliminated and the crew were faced with smoke of sufficient density to obscure instruments and controls.

1.1.3 Flight Technical Services Section was tasked to evaluate the Emergency Vision Assurance System (EVAS) equipment manufactured by VisionSafe Corp. (www.visionsafe.com) in a CPA B747-400 Full Flight Simulator.

1.2. Aim. The aims of the evaluation were as follows:

1.2.1. To evaluate suitable locations for installation of the EVAS unit.

1.2.2. Evaluate the crew workload in deploying the EVAS equipment.

1.2.3. Evaluate the field of view, both inside and outside the cockpit, available to the pilot with the EVAS equipment deployed.

1.2.4. Evaluate the ease of executing normal and non-normal procedures related to a smoke emergency from initial smoke onset till aircraft evacuation after a successful landing.

1.2.5. Evaluate the training materials provided and training requirements for line crew for initial and recurrent qualification

1.3. Scope. This assessment did not attempt to consider other systems degradation that may occur as a result of the underlying fire emergency.

2. Conditions Relevant to the Tests

2.1. Description of Equipment.

2.1.1. Simulator. Boeing 747-467 Full Flight Simulator CPA08 was used for the evaluation. This simulator is representative of the Cathay Pacific B744 fleet for the purposes of this evaluation. However, CPA08 is not representative of future B747-8 aircraft in that the sidewall where the EVAS is proposed to be installed will be different on the B747-8.

2.1.2. Smoke Generator. Reference A found that the density of the smoke was insufficient to significantly reduce the visibility in the cockpit. Therefore a portable smoke generator was used to create the smoke during these tests. Two units were supplied by VisionSafe and the smoke density reduced the visibility to about 10cm.

2.1.3. EVAS Equipment. The EVAS was a self-contained system that included:

2.1.3.1.A battery powered blower,

2.1.3.2. A flexible air duct,

2.1.3.3. Inflatable Vision Unit, (IVU).

The blower draws the smoky air through a filter removing the visible particles. This clean air is then sent to the IVU via the flexible duct. The IVU inflates against the windshield and instrument panel. The pilot, wearing the normal crew smoke and oxygen mask can see through the IVU by pressing the smoke mask against the aft panel of the IVU. The entire EVAS system is contained in an aluminium container that is approximately the size of a Jeppesen manual. A more detailed description of the EVAS equipment is included at Reference B.

2.2. Test Crew

2.2.1. The test crew included two pilots from FTS Section who were graduates of a test pilot school and experienced in aircraft handling and systems assessment. Both were rated on the B747-400.

2.3. Test Methods

2.3.1. **Qualitative.** This evaluation was generally qualitative in nature.

2.3.2. **Task Difficulty Rating Scale.** Some tests included specific tasks and outcomes so that a quantitative rating could be assigned. Table 1 was used to determine the difficulty rating. The tasks were well defined with specific goals, e.g. “manually fly by attitude reference on the PFD and maintain a desired attitude +/- 1 degree.” Any rating of 2 or 3 were accompanied by an explanation of the pilot compensation required to achieve the task, or reason why task was unachievable. The principles of the Cooper Harper Handling Qualities Rating provided guidance in making these assessments.

2.3.3. **Context of Assessment.** All assessments were made in the context of a “grave and imminent danger” type of emergency, i.e, a greater level of difficulty than encountered in normal operations is expected. However, all tasks were capable of being accomplished by normally trained line crews.

Table 1 - Task Difficulty Rating Scale

Rating	Description
1	Easy to achieve/locate/read/operate, minimal pilot effort required to accomplish task.
2*	Some difficulty encountered to accomplish the task to the defined tolerance. Task achievable.
3*	Unable to complete the task.

***Note:** A rating of 2 or 3 will require further comment on the cause of the difficulty or inability to complete the task.

2.4. Training. Prior to the evaluation the pilots familiarized themselves with the EVAS equipment by reviewing References B, C & D. Additionally VisionSafe staff provided comment during the deployment of the first EVAS unit.

2.5. Safety. The use of smoke in a confined area has safety implications. The IOS operator used the standard simulator oxygen masks which is the same as used in the aircraft. VisionSafe provided respirators fitted with cartridges to remove the smoke contaminants for additional personnel.

2.6. Simulator Crew Oxygen. The simulator did not use pure oxygen in the crew oxygen masks but rather filtered compressed air. The crew oxygen system was checked for serviceability prior to the evaluation.

2.7. Smoke Evacuation. The portable smoke generator produced a much greater amount of smoke than the current smoke generator fitted to the simulator. The simulator smoke evacuation system was confirmed serviceable prior to the tests and the building smoke alarms were disabled.

3. Tests Conducted.

3.1. **Tests Matrix.** A matrix of the tests conducted is included at Annex A. Specific tasks with the associated goals and criteria are included at Annex B.

4. Results and Discussion

4.1. Storage and Location. The EVAS system has yet to be approved for the B747-400 although a Supplemental Type Certificate (STC) is under active development. The installation drawings for the draft STC included two locations, both in the vicinity of the current pilot Nav. Bag or mini Jeppesen stowage. These drawings were based on an aircraft with Electronic Flight Bags (EFB) which includes different cockpit sidewall fittings and may not be applicable to the current Cathay fleet. The major problem with identifying a suitable stowage location was the way the sidewall sloped inwards as it rose. This made it difficult to find a location that would allow the EVAS to be removed easily from the stowage box. Other considerations included access to conduct periodic, (90 day), checks. While no suitable stowage locations were identified without modification to the current sidewall and associated equipment there appeared to be a number of options if modifications were made. In particular the current mini Jeppesen stowage may be suitable if enlarged. Evaluation of this and other options was beyond the scope of this evaluation and further evaluation would be required to identify the best stowage location.

4.2. Deployment.

4.2.1. General. Two deployments were conducted. Prior to the test both pilots had reviewed the video training material supplied by VisionSafe. The initial deployment was done in slow time with some instruction from VisionSafe staff. The second deployment was done with the oxygen mask donned and eyes closed simulating dense smoke. Smoke was not used at this stage so that the deployment process could be observed and evaluated. The entire deployment process requires:

a.) Removal of the IVU from the stowage box, b.) Securing the IVU to the Velcro on the glareshield,

c.) Undo a Velcro tab on the IVU allowing it to inflate,

d.) Assist the inflation of the IVU by unfolding the IVU compartments,

a. One section away from the pilot against the windshield, and

b. The other section towards the pilot against the instruments.

The overall deployment process took 75 seconds from completion of donning the crew oxygen mask to the IVU being sufficiently inflated that the pilot was instructed to open his eyes. At this point the ND and PFD were clearly visible and it was possible that in a smoke filled cockpit the instruments would have been readable earlier. Complete inflation took approximately another 15 seconds. The evaluation pilot was able to assist the unfolding and inflation, based on the video training and with eyes closed, to achieve a successful deployment. The deployment process involved a number of steps but these were logically sequenced and, with the appropriate training, line crew would be able to deploy the IVU in a smoke filled cockpit.

4.2.2. Initial Deployment Actions. The initial step in any deployment was removal of the stowage box lid. This required separating a Velcro secured tab on the top of the box allowing the lid to be removed exposing the IVU. During the blind deployment there was some fumbling as the pilot located the tab, separated the Velcro, removed the lid and located the IVU, taking 12 seconds. VisionSafe reported the lid assembly was being redesigned to make the initial actions simpler and quicker. Once the lid was clear the IVU was easy to locate and the low pullout forces, (less than the oxygen masks forces), made deployment easy to complete with one hand.

4.3. Recommended SMOKE & FUMES Initial Actions. VisionSafe recommends that once smoke is detected in the cockpit the crew don oxygen masks, complete the QRH Recall Actions then remove the IVU and mount it on the glareshield. However, inflation is not initiated unless the smoke is confirmed to be a threat to vision. This would simplify the initial deployment steps as the pilots could see what they were doing. If the smoke density increased while the crew completed the QRH actions the IVU could be deployed quickly and possibly with the assistance of vision. If the EVAS is installed on CX aircraft, initial deployment should be included as an additional Recall Action with a note that the IVU should be inflated if smoke density threatens vision of the instruments.

4.4. Control Column Interference. When the IVU is fully inflated one section extends from the pilot's face to the instrument panel and comes in contact with the control column. During one deployment the AP was left disengaged to observe the extent of unwanted control inputs from the IVU. Throughout the deployment the bank angle deviated about 10 degrees and the pitch angle deviation was negligible. These deviations were small and may have been unrelated to the IVU contact. During normal operations the AP would be engaged and much greater control column force would be required to override the AP. If the AP was disengaged, possibly due to the emergency, the risk of flight path deviation due to inadvertent control input during deployment is very low. Furthermore, during hand flying exercises with the IVU deployed, the pilot was aware of the IVU but its influence on control input was negligible. When fully deployed the IVU comes in contact with the control column but has no adverse affect on control of the aircraft.

4.5. Cockpit Field of View (FOV). With the IVU fully inflated the PFD and ND were easily viewed. While there was some distortion due to the added transparency layers on the IVU and oxygen mask visor, all symbology on the PFD and ND were sufficiently readable to complete the necessary flying tasks. The IVU bag was quite flexible, even when fully inflated, which allowed the pilot to move it to observe other indications. Specifically, the FMC CDU display and keyboard could be brought into view. The F/O's IVU could be moved to confirm Landing Gear and Flap indications on the Upper EICAS. In a serious smoke emergency time is limited and it is reasonable to expect ATC assistance to land. The information visible on the PFD and ND should be sufficient to follow instructions to a successful landing. The ability to see other panels such as the CDU was an added advantage that would help in the absence of ATC or to augment ATC. The internal FOV was sufficient to monitor sufficient flight instruments to control the aircraft.

4.6. External Field of View. The external FOV was limited to directly ahead by that part of the IVU that inflated between the glareshield and the windshield. The visual acuity was reduced by the additional multiple transparencies of the smoke mask and the IVU. The assessment was limited by the simulator visual system which was over 20 years old and generally of a lower brightness and contrast than the real world. Nevertheless, there were sufficient details and a sufficiently wide field of view to visually acquire the runway at ranges of 3-5 NM in 20kt crosswind conditions when positioned on a straight in approach. This would enable crew to follow ATC instructions to acquire the runway at a sufficient range to complete the approach themselves.

4.7. Flying Tasks. An extensive evaluation of flying tasks was made by conducting the exercises defined in Annex B. In all cases the EVAS provided a sufficiently clear view of the PDF and ND to enable the pilot to fly to a level of accuracy similar to normal conditions. In general, the most flying tasks could be completed with a Difficulty Rating of 1, as defined in Paragraph 2.3.2 and Table 1. A line crew, faced with a cockpit obscured by smoke, would be able to control the aircraft sufficiently well to follow ATC guidance to position for a final approach in visual conditions.

4.8. **Final Approach and Landing.** The evaluation was conducted on the basis of the final approach and landing being conducted in visual meteorological conditions. The runway was generally visible by 5 NM with some conditions reducing this to 3 NM. The more limiting case was a daylight scene where the simulator's low scene contrast and brightness were not fully representative of the real world. A slight tendency to over control in roll was noted when making small corrections to track the centreline, (Difficulty Rating 2). This was similar to a 'black hole' approach where the lack of peripheral cues are similar to the limited FOV of the IVU. Nevertheless, successful visual approaches were conducted in 20kt of crosswind and moderate turbulence. Once in the flare the lack of peripheral cues became apparent requiring "flare by numbers" technique rather than the correct technique using peripheral cures, (Difficulty Rating 2). An emergency landing due to smoke could well be overweight, and possibly fast, requiring the landing to be achieved by checking the rate of descent rather than a normal flare to a smooth touchdown. The combination of the IVU and radio altitude provided sufficient cues to successfully land the aircraft and decelerate to a full stop.

4.9. **Smoke Mask Fogging.** Cathay aircraft are fitted with full face oxygen masks. During the evaluation both pilots experience a slow deterioration in visual acuity only to discover that it was not due to smoke but internal fogging of the smoke/oxygen mask. When the fogging was purged full visual acuity was regained. The simulator uses filtered compressed air rather than pure oxygen as in the aircraft. The higher water content of the compressed air probably makes the fogging worse in the simulator. However, both evaluation pilots conduct airworthiness test flights in the aircraft and regularly use the oxygen masks during these flights. Fogging is observed regularly during test flights and would reasonably be expected during a smoke emergency. Crews must be made aware of the probability of the oxygen mask fogging and the necessary actions to clear the fog.

4.10. **QRH Use.** The IVU has panels either side and below the section where the pilot observes the instruments. An approach plate or QRH can be placed in these panels for checklist reading. An attempt was made to action the QRH "Smoke and Fumes" Non Normal Procedure (NNP) using these panels. The combination of multiple transparency layers, low light level and close positioning made the checklist difficult to read. An alternative location, especially for older crew, who may require reading glasses but are not wearing them in this emergency, is to place the QRH between the forward part of the IVU and the windshield. During the evaluation this proved to be too far away to be readable in the ambient light and multiple transparencies. The process of identifying the correct page when only able to read the QRH via the side panels was time consuming. It required a number of steps in selecting an approximate page, noting the page number, then a further selection by counting pages. The Smoke and Fumes NNP has a number of decision points often leading to further page changes. In a smoke emergency requiring the use of EVAS the primary tasks are to maintain control of the aircraft and land ASAP. In this situation the crew workload in achieving these primary objectives would leave little time for auctioning the QRH when it was only readable via the IVU. The inclusion of the IVU panels for the QRH or approach plates was a thoughtful addition but of little benefit within the scope of the evaluation. Nevertheless, crews should be made aware of this feature as it may be useful in some circumstances.

4.11. Airmanship Considerations.

4.11.1. Non Normal Checklist – Non Recall Actions. Airline crews are trained to complete checklist items, including recall actions, in a methodical and disciplined manner involving crosschecking. A smoke filled cockpit could make the crosschecking impossible. Furthermore, the Smoke and Fumes, and Smoke Removal NNP contains many decision points which may be difficult to read let alone identify the next step on the correct page, making it impractical to compete. These two NNP have only one memory item however airmanship would suggest that crews be aware of other critical steps and how to identify the switches by feel. Specifically, the UTILITY power switches and the EQUIPMENT COOLING selector. While there is no suggestion that these should be recall items, this knowledge could assist clearing the smoke in a life threatening situation. Check and Training crew should encourage an awareness of the initial steps in the Smoke and Fumes, and Smoke Removal NNPs and how these could be actioned in a smoke filled cockpit.

4.11.2. Location of Secondary Controls. During the approaches, landing gear and flap selections were made without visual reference. While both controls were easy to locate, it was possible to place the flap lever in the wrong detent. The selector assembly has gates and airmanship would suggest crews should be aware of the location of the gates and how they would confidently select the correct flap in a smoke filled cockpit.

4.11.3. Mode Control Panel (MCP) Selections. The exercises were manually flown with and without the Flight Directors (FD). The FD modes and commands were selected from the MCP which was obscured by smoke. The MCP has pushbutton switches which are identical in shape and operation, and rotary selectors which are uniquely identifiable by shape and knurled knobs. In normal operations crew visually identify the correct button or rotary selector. Airmanship would suggest that crews be familiar with the different shaped rotary selectors and from them be able to locate the required pushbutton. The correct selector could then be confirmed by the PFD indications.

4.12. Smoke Generator. The simulator was fitted with a smoke generator for simulating smoke and volcanic non-normal scenarios. Reference A found that the smoke was thin and while suitable for its intended use could not simulate dense smoke that could obscure instruments and controls. A portable smoke generator was used to successfully generate dense smoke to reduce visibility to about 20cm. The dense smoke deposited an oily film on the simulator surfaces and required a significant cleaning effort by the simulator technicians. Dense smoke is desirable for realistic training and Cathay Pacific should carefully consider the possibility of contamination in the purchase of future smoke generation equipment.

4.13. Training. A smoke emergency is time critical and crew must have the knowledge to correctly deploy the EVAS equipment. Deployment involves a number of steps which are not difficult but need to be completed correctly. The VisionSafe videos provide good instruction however, the evaluation crew believe all crew should complete a full deployment, preferably as part of a LOFT smoke scenario to an emergency landing. Recurrent training should include a review of the training video.

4.14. Simulator Training Equipment. The EVAS is designed as a single use unit and would normally be returned to the factory for checking and repacking after use. This is not practical for crew training use however, VisionSafe advised they can provide the necessary training to Simulator Engineering staff for local repacking after deployment. Frequent deployment and repacking has the potential do damage the IVU. VisionSafe provide training units where the transparent panels are secured by Velcro allowing easy replacement.

5. Conclusions and Recommendations.

5.1. The EVAS equipment evaluated enabled a suitably trained pilot to successfully deploy the unit without the aid of vision.

5.2. In a smoke filled cockpit it enabled the pilot to see the primary flight and navigation instruments sufficiently well to fly the aircraft to a position where a visual final approach could be completed.

5.3. The external vision was sufficient to complete the landing visually to full stop.

5.4. The following recommendations are made as a result of the evaluation.

5.4.1. Further evaluation is required to establish the best stowage location. (Para. 4.1)

5.4.2. If the EVAS system is installed the SMOKE AND FUMES NON NORMAL PROCEDURE should include a memory item to position the IVU on the glareshield. (Para. 4.3).

5.4.3. If EVAS is installed crew training should include a full deployment of the equipment in the simulator, ideally as part of a LOFT smoke scenario. Recurrent training should include, as a minimum, reviewing the training video. (Para. 4.13).

5.4.4. Crews must be made aware of the probability of the oxygen mask fogging and the necessary actions to clear the fog. (Para. 4.9)

5.4.5. Check and Training crew should encourage an awareness of the initial steps in the Smoke and Fumes, and Smoke Removal NNPs and how these could be actioned in a smoke filled cockpit. (Para. 4.11.1)

5.4.6. Crews should be aware of the flap selector gates so that the correct flap can be selected without visual reference to the selector if necessary. (Para. 4.11.2).

5.4.7. Crews should be aware of the different MCP rotary selector shape and feel so that they can be correctly identified without visual reference if necessary. Furthermore, the identical pushbuttons on the MCP should be identifiable by their location reference the rotary selectors. (Para. 4.11.3).

5.4.8. Dense smoke is desirable for realistic simulator training and Cathay Pacific should carefully consider the possibility of contamination in the purchase of future smoke generation equipment. (Para. 4.12).

JO'Halloran

John O'Halloran
Test Pilot,
1st August 2011

Annexes:

A. Test Matrix
B. Table of Specific Tasks

Test Matrix

Serial	Test	Conditions	Method/Tasks
	(a)	**(b)**	**(c)**
1	Installation	No Smoke	Qualitative assessment of installation, location and impact on normal crew operations. Tasks will include normal crew equipment such as nav bags and cockpit procedures. Assessment of impact of installation will be conducted throughout the evaluation.
2	Deployment	Initially smoke off, in slow time to become familiar with the EVAS. Without Crew Mask	Familiarization
3		Smoke off, in real time with crew mask ON	
4		Smoke ON, or with eyes closed simulating thick or irritating smoke, crew mask ON	Qualitative Assessment of ease of deployment.
5		Smoke ON, masks ON as part of the LOFT exercise	

Serial	Test	Conditions	Method/Tasks
	(a)	(b)	(c)
6	Inflight assessment	Smoke ON, (continuation of step 5 with a reposition to airborne.) Mask ON, EVAS deployed Exercises not conducted in real time.	Assessment of field of view: • Critical instruments, PFD & ND • Other instruments, Standby Inst., MCP, CDU etc. • Outside visual scene
7			Access, use and readability of QRH.
8			Conduct specific flying tasks assigning Difficulty Ratings. • Speed & Altitude tasks • Heading tasks • Visual app tasks.
9	Line Oriented Flying Task (LOFT)	Reposition to top of climb. (may require HDG slew to point away from origin). Introduce smoke, return to land at destination using masks and EVAS applying normal LOFT CRM. Continue until evacuation after landing.	Don masks, deploy EVAS. Vectors from ATC (IOS operator) to achieve visual at 5 nm from runway. Applicable Checklists.

Table of Specific Tasks

Serial	Task	Goal	Criteria / Tolerance
	(a)	**(b)**	**(c)**
1	Don mask, deploy EVAS with dense smoke, OR with eyes closed simulating dense or irritating smoke.	Achieve correctly deployed EVAS such that PFD and forward outside view is attained.	Achieved without undue difficulty in a timely manner.
2	In manual flight, with reference to the PFD, using normal attitude flying techniques conduct the following exercises. This is not part of the LOFT exercise and time is not a critical factor.	Accelerate to and maintain a speed of MMO/VMO.	MMO/VMO to MMO/VMO -5
6		Maintain altitude while decelerating from VMO to Vref 30. This exercise to be conducted below 5,000 ft.	Altitude +/- 200 ft
7		Conduct turns using 30 deg AOB and maintain heading.	Bank angle +/- 5 deg Heading +/- 5 deg
8		On finals, in the approach configuration, make heading adjustments of 2 degrees and maintain heading.	+/- 2 degrees heading
9		On finals in the approach configuration maintain a rate of descent of 800 ft/min	+/- 200 ft / min

Serial	Task	Goal	Criteria / Tolerance
	(a)	**(b)**	**(c)**
10		Conduct a visual approach to a successful landing from 5NM.	Achieve a normal touchdown within the first 2,000ft of the runway.
11		Conduct a visual side step approach to a successful landing from 5 NM	Achieve a normal touchdown within the first 2,000ft of the runway.
12	QRH use	Access the QRH, identify relevant checklist and read all steps including decision path over multiple pages.	Be able to read complete procedure. Note: Actual QRH steps may not be able to be completed due to density of smoke.