NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety
Washington, D.C. 20594

Attachment 35 - SEA Smoke Simulator Results

OPERATIONS/HUMAN PERFORMANCE SUPPORT TO THE U.S. ACCREDITED REPRESENTATIVE

DCA10RA092

Simulator Test Results for UPS B747 Flight 6 Accident (NTSB # DCA10RA092)

Simulator: CAE Model 7000 Boeing 747-400F configuration
Airport (simulated): Seattle, WA (SEA), Alternate Portland, OR (PDX)
Participants (6):

Simulator Operator:	Tom Lange – Boeing
Left/Captain Seat:	Darren Straker – GCAA
Right/F/O Seat:	Martin Hinshaw – IPA
Observers:	Katherine Wilson, Bill English – NTSB
Test Director:	David Lawrence – NTSB

Date/Time: December 1, 2010/0500 PST[1]
Objectives:

1. To document crew procedures and the aural and visual alerts/messages that occur during pack failure and main deck fire events.

2. To document how crew performance is affected by modifying the font size of crew checklists and various lighting configurations, by removing outside visual references, and during single pilot operations.[2]

Notes:

- The crew consisted of 1 GCAA pilot (non-rated B747) sitting in the left/Captain's seat and 1 UPS B747 rated line captain sitting in the right/First Officer's seat.
- For the main deck fire scenarios, Seattle (SEA) was used to simulate Dubai (DXB) and Portland (PDX) was used to simulate the diversion option of Doha. Based upon FDR data, the SEA 210 radial at 120 miles (PBD01) was used as the point for initiation of the main deck cargo fire.
- The simulator was configured with UPS oxygen masks and smoke goggles.
- Only UPS checklists/procedures were used to complete scenarios.
- Smoke was generated via an internal system to the simulator and a handheld smoke generating device.[3]
- Task times are approximate to the minute and were noted when necessary.

Task 1 - Setup

Initial Setup

- FMS Flight plan - SEA-SEA/210/120DME (PBD01)-HNL[4]
- Departure/Destination - SEA/HNL
- Alternate - PDX
- Weight - 750,000 pounds
- Autopilot - Engaged, standard VNAV climb to FL320

[1] All times listed are Pacific Standard Time (PST) unless otherwise noted.
[2] The purpose of this test was not to conduct a systems verification check or replicate any degraded flight control functioning.
[3] See Appendix A for more information on simulator set up/clean up and smoke generation.
[4] Honolulu International Airport, Honolulu, Hawaii

- Config - Clean
- Altitude -20,000 feet
- PF/PM - F/O will be PM and Captain will be PF
- Weather - Night VFR, calm winds (preset for all tasks)
- Sim Position - Instructor: take a “snapshot” of Task 1 position

Procedure

1) Boeing provides simulator safety briefing.
2) Observer/pilot occupant cockpit familiarization.

Note: Task complete when simulator occupants briefed

Task 2 - Pack Failure

Initial Setup

- Weight - Normal Climb to FL320
- Autopilot - Engaged
- Config - Standard
- Pressurization - Auto

Task 2 - Pack Failure

Procedure	Notes
1) Simulator motion "on".	Time: 0649
2) Pack 1 failure.	Time: 0653 Captain was PF; Pack Failure checklist accomplished by F/O.
3) Document visual/aural alerts.	No aural alerts noted; "Pack 1" message appeared on EICAS in top right.
4) Time from pack failure to status message.	Status message appeared on EICAS about 20 seconds after failure initiated.
5) Transfer control; complete QRH items.	F/O became the PF about 1 minute 5 seconds after the start of the failure. Crew turned on dome light to complete checklist.
6) Time for pack to reset and status message alert to extinguish.	Time: 0655 Status message extinguished about 2 minutes 25 seconds after initiation of QRH.
7) Task complete when Pack 1 resets. Freeze simulator.	

Task 3 – Main Deck Fire

Initial Setup

- Departure Point - SEA
- Destination - SEA/270/120 DME
- Alternate - PDX
- Weight - Standard, Normal Climb Thrust Setting
- Autopilot - Engaged
- Config - Clean
- Altitude - 20,000 feet + (during climb to FL320)
- Sim config - Continued flight after pack one reset, normal climb
- Pack one - Reset to operational
- PM/PF duties - PM (Captain) will run all checklists, radio calls, and MCP inputs

Task 3 – Main Deck Fire Scenario

Procedure	Notes
1) Initiate Main Deck Cargo Fire upon arrival at PBD01.	Time: 0659 Aural alarm.
2) Don O2 masks/goggles; establish communications.	Time: 0700 Pilot notes goggles a bit tight and irritating after 10 minutes of wearing. Periphery was limited and had to push goggles closer to face to get greater periphery. Pilot notes the emergency switch was easy to find but the normal/100% switch hard to find and he thought it was on opposite side of mask.
3) Use current MDF checklist. **NOTE: DO NOT press the "Depress" switch**[5]	Time: 0701 Transfer control – Capt. is PM; F/O is PF Pilot notes that while crews don oxygen masks in flight, they do not communicate while wearing the mask because they wear the mask when they are single pilot. Pilots only communicate while wearing the mask during initial training. 0702: pilots depress MDF button. 17 seconds later, visual alert on EICAS.
4) Initiate smoke in simulator.	Time: 0702
5a) Time MDF alert to start of checklists.	Less than 2 minutes.
5b) Time MDF alert to don O2 masks/goggles.	Less than 1 minute.
6) Task crew to divert to SEA via FMS entries.	Time: 0704 SEA Runway 34R (ILS 110.3, 343° inbound) 11 FMS entries made. Pilot also changed destination.
7) Pilots reach separately for smoke evacuation handle.	Time: 0708 Both pilots easily found the smoke evacuation handle. PF believed airplane was at 10,000 feet, however, they were still descending through FL190. The displays were visible to observers not wearing goggles but PF could not see displays through smoke and goggles. PM noted that he could not see PF.
8) Give multiple radio calls.	Pilots had to lean to see panels. One pilot stated that he could not see the screen. Crew had communication issues and said it was hard to remember that it was not a hot mic in the mask. One pilot indicated that his hand was "tied up" to activate the mic. Pilots noted that they could see better with the dome light off. PM asked for an altitude from ATC.
9) Task complete upon arrival to 10,000 feet. Freeze simulator.	

[5] Pushing the DEPRESS switch would evacuate smoke from the simulator.

Task 4 – Visibility Drills

NOTE: This task occurred during the descent phase of the previous task (Task 3).

Initial Setup

- Simulator position - Position freeze aircraft during descent in Task 3 (if required, no later than 10,000 Feet)
- Masks/goggles - On
- Dome light - On
- Checklist - Provide crew with larger font checklist
- Flashlight - Provide crew with hand-held flashlight

Task 4 – Visibility Drills

Procedure	Notes
1) Ensure simulator is smoke-filled.	Time: 0713
2) Compare current/larger font MDF checklists (dome light on).	Current checklist: Pilots could not read QRH through smoke. Larger font: Pilots indicated that it was still hard to see but it was easier than the smaller font. Both pilots indicated dome light on was worst for reading checklists.
3) Identify visible primary flight displays/MCP/FMS and radio panels.	PF could read displays if he put his head close. He could see "bits and pieces" of the PFD but no specific information. He could not see what he was dialing on the MCP. PM could feel the buttons of the MCP but could not see anything. He could see the blue background of the PFD but not details.
4) Identify visible EICAS status messages and visual warnings.	PM could see that the CDU had green lettering and could only make out a few letters.
5) Compare current/larger font MDF checklists (dome light off).	Both pilots said it was easier to view the checklists without the dome light on.
6a) Compare current MDF with larger font checklist (simulated daylight).	Both pilots said it was a little better to view the checklists without the dome light on but they could not make it out.
6b) Identify visible primary flight displays/MCP/FMS and radio panels (simulated daylight).	MCP caught smoke under panel lip which did not occur on the PFD. PM noted that he could see the green lettering of the CDU/FMC better through the smoke but it was still not readable. PF noted that the pressure from the O2 band on back of head was starting to hurt.

Procedure	Notes
7) Compare current/larger font MDF checklists (white flashlight).	PF noted that the smoke and the background of the checklist were the same color (white) so text was hard to see. Also with the white flashlight the contrast made it hard to read. Like “high beams” or “white out”.
8) Compare current/larger font MDF checklists (flashlight with red filter).	PF said the larger lettering was easier to read because better contrast. PM said he could see more lettering with larger font and red filter. When lots of smoke, size didn’t matter. But when the smoke cleared slightly, PM said larger font was more visible (a few letters could be seen and a word could be inferred).
9) Task complete when crew observations are complete. Freeze simulator.	

BREAK

Procedure

1) Set simulator on position freeze
2) Push “Depress” switch to evacuate smoke
3) Exit simulator and allow cab to clear of smoke
4) Reset sim position to Task 1 “Initial Setup”
5) Provide crew with larger font MDF checklist

Task 5 – Alternate MDF

Initial Setup

- Sim Position - Instructor: reposition sim to Task 1 "snapshot"
- FMS Flight plan - SEA-SEA/210/120DME (PBD01)-HNL
- Departure/Destination - SEA/HNL
- Alternate - PDX
- Weight - ~750,000
- Autopilot - Engaged, standard VNAV climb to FL320
- Config - Clean
- Altitude - 20,000 feet
- PF/PM - F/O will be PM and Captain will be PF
- Weather - Night VFR, calm winds (preset for all tasks)

Note: Full face mask[6] installed in simulator during break and used for remaining scenarios.

Task 5 – Alternate MDF Checklist

Procedure	Notes
1) Initiate a Main Deck Cargo Fire upon arrival at PBD01.	Time: 1037 35.5 seconds from alarm to pack message on EICAS. Volume of intercom was turned down to see how long it would take crew to notice reduced speaker volume. Neither pilot recognized that the volume knob was turned down after they donned the O2 masks. Observers could hear both pilots through both speakers, but the volume was noticeably lower than before.[7]
2) Initiate smoke in simulator.	
3) Don O2 full face masks/goggles; establish communications.	Communications established 55 seconds after start of scenario. Pilots note full face mask easier to don and more comfortable. Control transferred by 14 seconds from start of scenario.
4) Use MDF checklist with **larger** font. **NOTE: DO NOT press the "Depress" switch.**	Captain is PM; F/O is PF. PM distracted from checklist because of ATC radio calls for about 1:44. Dome light on.
5a) Time MDF alert to start of checklist.	PM grabbed checklist 7 seconds after start of scenario. Time from MDF arm to pack message: 35.5 seconds.
5b) Time MDF alert to don O2 masks/goggles.	Masks donned 33 seconds after start of scenario. Actual donning took 6 seconds. Pilots could make out blue on PDF and green displays best. PF could not see MCP. PF could not make out any details with black background and said status messages on EICAS were too small to read.

[6] See Appendix B for pictures

[7] According to the FCOM, turning the volume down on the intercom is not affect the speaker volume, which is only influenced by the speaker volume knob.

Procedure	Notes
6) Divert to PDX. Provide vectors for an approach to PDX runway 10R. (ILS 110.5, 101° inbound)	Dome light turned off. PM again distracted by ATC radio calls. 6 FMS entries to divert.
7) Attempt autoland at PDX.	3:09 into scenario, aft cargo fire alarm occurs. Pilot notes that he can't see what the alarm is. Crew was leaning to see panels. PM asking ATC for DME and altitude.
8) Task complete at instructor's discretion (no later than 15,000 feet). Freeze simulator.	PF noted he had better vertical vision but not lateral/peripheral vision when wearing the full face mask. Mask more comfortable than separate system. PM noted he had better lateral and vertical vision. Pilot in right seat could lean forward as far as the altitude window on MCP. Pilot in left seat could lean forward as far as the heading window on MCP.

Task 6 – Visibility Drills 2

Initial Setup

- Simulator position - Position freeze aircraft
- Masks/goggles - On; full face mask used
- Dome light - Off
- Checklist - Provide crew with larger font checklist
- Flashlight - Provide crew with hand-held flashlight

Task 6 – Visibility Drills 2

Procedure	Notes
1) Ensure simulator is smoke-filled.	Dome light off. Pilot had difficulty finding MDF checklist because of small tabs on QRH.
2) Compare current/larger font MDF checklists (dome light).	Small: PM said dome light not much better than using the white flashlight. Large: PF said the white background of the checklist with the white smoke made it difficult to read. PM said dome light refracted the light.
2) Compare current/larger font MDF checklists (white flashlight).	Small: PF said smoke was more reflected with the white light. PM said white light was a lot worse. Large: PF said the white light was reflected on the smoke. PM said he could not make out the black writing.

Procedure	Notes
3) Compare current/larger font MDF checklists (flashlight with red filter).	Small: PF could differentiate words better through smoke. PM could tell there was writing but could not read the text unless there was a break in the smoke. When dome light turned on and red flashlight used, PM said it was better because it penetrated the smoke better. Large: PF could make out main words better. PM said it was better and more readable. Both pilots said with dome light on and red flashlight it was much easier to see/penetrated smoke better.

Task 7 – Ditching/Single Pilot CRM

Initial Setup

- Simulator position - Position from Task 5 (10,000 feet)
- Autopilot - Engaged
- Masks/goggles - On
- Pilot duties - F/O will be PF, Captain will not participate in this task
- Config - Clean
- Altitude - 10,000 feet
- Dome light - Off

Task 6 - Ditching/Single Pilot CRM

Procedure	Notes
1) Initiate smoke generation in the simulator.	Time: 1109
3) Place simulator motion to "on".	
2) F/O completes "Ditching" QRH action items.	Time: 1113 Crew dumped fuel. Turning up brightness of PFD helped visibility some. PF stated he was completing items from memory because he could not see anything.
4) Task F/O to ditch aircraft.	
5) Task complete at instructor's discretion (Do not allow aircraft to impact). Freeze simulator.	

Pilot Observations and Conclusions:

Donning of the emergency oxygen mask (UPS standard):

i. Straight forward, however, determining the position of the oxygen selector with the mask on is difficult without experience
ii. Changing the selector from a predetermined position to an alternative position – e.g., from normal to 100% in an emergency condition is only possible if all other tasks are terminated and the crew member concentrates on the specific task of manipulating the selector.
iii. Changing from normal or 100% to emergency flow is a task that requires detailed familiarity as it is performed without visual reference. It is an acquired skill that requires repetitive practice to familiarize the procedure as an instinctive reaction.
iv. Prolonged operations with the mask on can be difficult to sustain due to the build up of sweat effecting the mask placement; it was also noted the due to the high stress a noticeable build up of saliva affects the mask functioning (it requires clearing from the mask)
v. Two piece smoke goggle/mask take longer to put on.
vi. A lot more "action" is required to move switches in position for the smoke prevention.
vii. Two piece is harder to adjust once on, because you can't adjust the mask without removing the goggle because the goggle strap hold the mask strap against the head and won't allow the mask band to expand to allow a different fit.

Donning of the emergency oxygen mask (full face):

i. Straight forward, simple process without the complication of also donning the mask and performing the mask clearing procedure(see below).
ii. Similar difficulty exists for determining the normal,100% and emergency switch positions.
iii. One piece mask is a lot faster to put on. The extra time can be used to set up audio panel.
iv. One piece is a lot more comfortable. You can move the mask for a better fit and both, the mask and goggle, stay together, never breaking seal.
v. The vision on the bottom half of the goggle is far superior in the full face. It allows to see the center console without putting your chin against your chest or even pulling down on the hose to see and that takes a hand that you may not have available for that task.
vi. It feels lighter, and maybe that is due to the fact there is NO hot spots on your head since only one strap holds both, the mask and the goggle.

Donning of the emergency goggles:

i. Problematic to get the goggles to fit and then sit on the oxygen mask. The oxygen mask retainer prevents the goggle attachment strap from seating properly.
ii. The smoke goggle strap, applies pressure to the oxygen mask strap against the skull and creates hot spots that are distracting after 5 minutes.
iii. There is a prerequisite that the wearer has to know that the mask selector top vent has to be pulled down to provided the goggle clearing function.
iv. Performing the goggle clearing function is not intuitive, but is a learned process which is not easily performed in a high stress, multi tasked environment.
v. Lateral and downward vision lost when goggles put on.
vi. Difficult to see radio panels comfortably with the mask and goggles on. Had to pull mask down to see radios.

Establishing Communication:

i. Without a hot mic function, crew communication is achieved through either the control column mic switch (left hand Capt/right hand FO) or the RT/INT switch on the radio panel (right hand/left hand). One pilot indicated that it depended on what he was doing at the time as to which switch was used. With the task breakdown and crew functioning during an emergency, the necessity to arrest the task, perform the communications requirement and continue with the assigned task is diverting and the synchronization of the crew tasks can become problematic to crews unfamiliar with the drills required.
ii. In the absence of a defined verbal command or confirmation, non-verbal associative actions were observed to complete the assigned task or drill.
iii. In multi-task functioning environments, the communication switching is not an intuitive function.
iv. An associative problem with the communication switching is the cessation of the assigned task for the duration of the communication requirement. In a high task load situation, this is a diversion activity inside the CRM procedure.
v. Without a clear role and function differentiation in the CRM process, i.e. PM verses PF responsibility, this task completion as per the non normal checklist is not a priority (based on observation).
vi. When going to either system (1piece/2 piece) you must set up the audio panel, and that does take some time to establish communication. You are as fast as your partner, and you can't establish communication until the last person comes on. Just like the HOT AUDIO for the 121.5 radio, I would like to see when the mask is pulled out, audio panel is set up for operation. Forces volume and speaker on.

Maintaining Communication:

i. In a normative flight deck environment without degraded visual acuity, communications are straight forward as the crew can refer to task actions through verbal and non verbal commands – pointing for example.
ii. In a smoke degraded cockpit without line of sight to the other crew member with high demand on task completion and ergonomic limitations imposed by utilizing one hand to periodically manipulate the mic switch(s), task completion and communication functions are counterproductive. It was observed that following a specific command – speed break extend – if the command was not completed as the task was enunciated, the PF made the action to complete the task
iii. In the multitasked environment each crew member performed the allocated task up until one crew member considered a new task priority took precedence over the current tasking, eg MCP inputs versus comms with ATC.
iv. Not having hot mic is a huge handicap. You are now communicating in a "bad" environment and you have to change habits. Every time you want to say something to your crew, it takes one hand and a button. You can't just have a duplex conversation like you would normally have. Not having the hot mic options adds a lot of effort and confusion to the existing problem. Communication is KEY to this non normal and not being able to talk while using your hands for other tasks, adds to the emergency.
v. Without hot mic, the PM ends up doing the checklist without verbalizing what he is doing to save time on accomplishing the procedure but also leaving the PF out of the loop on what the PM is doing. You can't see what the person is doing and you can't hear either and that is a bad combination.

Visual Clarity:

i. In normal crew function modes a response to an alert message is ‘Visualize, Comprehend, React, Solve’. If it is not possible to visualize the message (reading the EICAS), the resulting chain of the problem solving is rendered redundant. It is possible to comprehend an audible warning in a visually

degraded environment, but with the specific fault or error message being visible, the possibility to solve the problem is seriously diminished.

ii. Inter-crew functioning in a completely smoke filled cockpit compromises the safety and failsafe loop as non-linear task completion in conjunction with elevated task demands will ultimately arise in the two crew members functioning independently

iii. Checklist reading in a degraded cockpit was problematic. In the case of UPS6, the aircraft departed prior to CET, climbing on a westerly heading. This is significant as the cockpit conditions would have been dusk, with ambient solar illumination. On the return, post CET, descending easterly, there would have been less or no solar illumination. As the juncture between the external light source and the cockpit light requirements may have meant that the checklist started in relatively bright conditions, in a smoke filled cockpit, it was determined that turning off the dome light aided the checklist reading as the light was not refracting through the smoke.

iv. Reading the checklist in twilight conditions, smoke in the cockpit visual acuity is enhanced with a red filtered light as the definition of the black printed words are easier to differentiate in a smoke filled cockpit.

v. It was noted that the Flight Management Computer (FMC) green on black illumination was easier to distinguish

vi. It was noted that blue – as on the PFI – was easier to distinguish than surrounding colors

vii. The large scale non normals checklist was easier to read that the standard checklist, particularly under red light

viii. In the thickest smoke, only Braille will help. What bigger font does to you, if there is any "break" in the smoke, it allows you to see more letters (group), therefore part of words. From that you can deduct what the action on the checklist is for the next step.

ix. Larger font allows the finger to hold the position on the checklist where you just were able to catch a glimpse and wait for the next break in the smoke waves, to continue reading the checklist.

x. Smoke is like fog and it can go from RVR 0 - 2400. So the term smoke doesn't cover the spectrum to describe what you can do or are able to see. When smoke was zero zero, I would not see ANYTHING outside my plastic visor, light or no light.

xi. Except for the ZERO ZERO big font can make the difference in accomplishing the checklist faster and accurately.

xii. Having ink that can reflect with little light might help in a dark cockpit (for electrical loss checklist at night) and smoke environment checklist.

xiii. For newer aircrafts that have checklists on a MFD, the smoke or electrical QRH might still need to be on a card so you can see.

xiv. It was very apparent that the dome light (white and bright) refracted in a major way, and basically turn the cockpit into a "flash". It is like driving in fog/heavy snow fall and using the high beams.

xv. Softer color, light red allowed light to see what we were doing but did not blind us. A red dome light might be a good option.

xvi. Flash light with a red lens also worked better, but with this environment of having one hand to hold the push to talk, and the other a flashlight, you have nothing else to do the job.

Cockpit Resource Management:

i. When the cockpit visual clarity was compromised the task and roles between the PF and the PM also exhibited a reduction in efficiency.

ii. The communications function when task loaded are not a priority due to the ergonomic constraints of mic switching and freeing up one hand for the task is counter intuitive and counterproductive to the

task completion – e.g., MCP task completion verses ATC comms or reprioritizing associated tasks which can then be unintentionally discarded

Conclusions

i. It is imperative that when cockpit visual clarity is compromised, clear and defined task and role differentiation between the PF and PM are understood and reinforced through adequate training.
ii. Crews should be very familiar with the functioning of the oxygen mask selectors and the switching options, including the mask venting function
iii. Turning off the dome light aids text differentiation in smoke + twilight conditions
iv. EICAS messages that cannot be read are a fundamental flaw in the smoke filled cockpit checklist design philosophy
v. Reversion to a variation of single pilot CRM appears to be a standard reaction to a lack of communication in multi crew operating environments. It would be advisable that if 1 crew member goes into a single pilot CRM state of cognitive functioning, that the actions performed are enunciated (as per normal 1 pilot CRM) to provide a clue to the PM, or non handling pilot, that a command decision has been made and the PM should revert to a passive or supernumerary role.
vi. Training for worst case scenario emergency flight management should be predicated on the requirement to perform an immediate landing with degraded cockpit visibility and communications. This should be a rehearsed procedure with the decision points clearly established through repetitive training
vii. Checklists should be fully representative of the reality of the emergency they are attempting to mitigate.

Appendix A

Smoke Test in Boeing simulator, Bldg 25-01, Tukwila, WA Nov-Dec 2010
Simulator utilized: CAE Model 7000 B747-400F configuration

-Smoke generation is provided through 2 simulator malfunctions:

--Electrical: 3 panel areas of smoke production

--Air Conditioning: Smoke production from each of the three Packs

-Smoke generation is for training purposes to introduce realism (fumes and wispy smoke); does not restrict visibility.

When utilizing malfunctions generating smoke, the building fire detection panel goes into by-pass for that particular simulator.

-When accomplishing the Fire Main Deck non-normal checklist, the DEPRESS switch was not pushed. Doing so would evacuate the smoke from the simulator.

Additional smoke was required for the purpose of the GCAA/NTSB test. For the smoke generation scenarios, a smoke generator approved for certification flight tests was used – See the information below:

The Smoke generator is a Colt, model COLT4BASIC. The fluid is Corona Type 100A.

http://msds.web.boeing.com/cics/suw1/s11ow003 Search for MSDS# 108720

The simulator has ventilation that could allow Colt-generated smoke to escape from the simulator and possibly be vented to the simulator bay. During the smoke scenarios, utilizing the Colt smoke generator, the Boeing Fire Department was on-scene to monitor for any smoke. To prevent an interruption in training from the other simulators, the building's smoke and fire detection panel was placed in by-pass, and the on-scene firefighters visually monitored the 747F simulator.

The smoke generator was not able to completely fill the simulator with smoke because of the required simulator ventilation. The smoke was effective, however, by placing the generation nozzle in the area of interest, as in, which pilot was to accomplish which task. This appeared to be an effective method in simulating a dense smoke environment.

After the tests were completed, the simulator smoke evacuation fans were used to eliminate the smoke from the simulator and to prevent smoke from entering the simulator bay. The fans required approximately 10 minutes to evacuate the smoke.

At the completion of the smoke scenarios, simulator maintenance personnel required almost one hour of clean-up time. The smoke generation fluid leaves a film on many of the surfaces, as well as the mirror from the visual generation system.

Appendix B

Use of full face mask in the simulator.