

DCA24LA330

OPERATIONAL FACTORS

Smoke Simulation Evaluation

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SMOKE SIMULATION EVALUATION

Location: Southwest Headquarters, Wings Building, Dallas Texas
Date: June 16, 2025
Time: 0800 CDT¹
Aircraft: Simulator no. 18

Overall Objective:

- Documentation of visibility limitations using various degrees of simulated smoke lens density to conduct emergency training in simulators and/or FTDs.
- Document any challenges or limitations simulated smoke training may encounter. Including but not limited to operating the airplane on a visual approach while maintaining the localizer and glideslope.
- Document any challenges or the ease of performing selected tasks with the different limiting devices, including the performance of the Smoke, Fire or Fumes checklist up to step 10 and/or Engine Fire or Engine Severe Damage or Separation checklist up to step 5.

Invited Participants:

Brice Banning (IIC²)
Shawn Etcher (NTSB, Operational Factors)
Andy Olvis (FAA – AVP-110³)
Erin Carroll (Southwest Airlines)
John Rummel (Southwest Airlines⁴)
Chris Shaver (SWAPA⁵)
Craig Jakubowski (SWAPA)
John Steinnnes (Boeing)

Additional Participants (if any):

Bob Strahm (Southwest Airlines Chief Technical Pilot)

Evaluation Parameters

The evaluation of the possible workload generated will be based on the Bedford Workload Scale which is a *“uni-dimensional rating scale designed to identify operator’s spare mental capacity while completing a task. The single dimension is assessed using a*

¹ Central daylight time

² Due to a scheduling conflict Mr. Banning was unable to attend.

³ David Gerlach was initially invited but due to retirement, Mr. Olvis was assigned to the group.

⁴ Due to a scheduling conflict Captain Rummel was not able to attend.

⁵ Due to a scheduling conflict Mr. Shaver was unable to attend.

hierarchical decision tree that guides the operator through a ten-point rating scale, each point of which is accompanied by a descriptor of the associated level of workload.

1. The operator rates their workload on a uni-dimensional scale from 1 to 10.
2. The operator is asked on a three-rank ordinal structure whether
 - 1) it was possible to complete the task,
 - (2) the workload was tolerable, or
 - (3) the workload was satisfactory without reduction.

Then, the operator ranks their workload on the respective rating scale end points (1-10) from workload insignificant to task abandoned.

3. This measures whether it was possible to complete the task, if workload was tolerable for the task, and if workload was satisfactory without reduction (Miller, 2001).⁶

Bedford Workload Scale

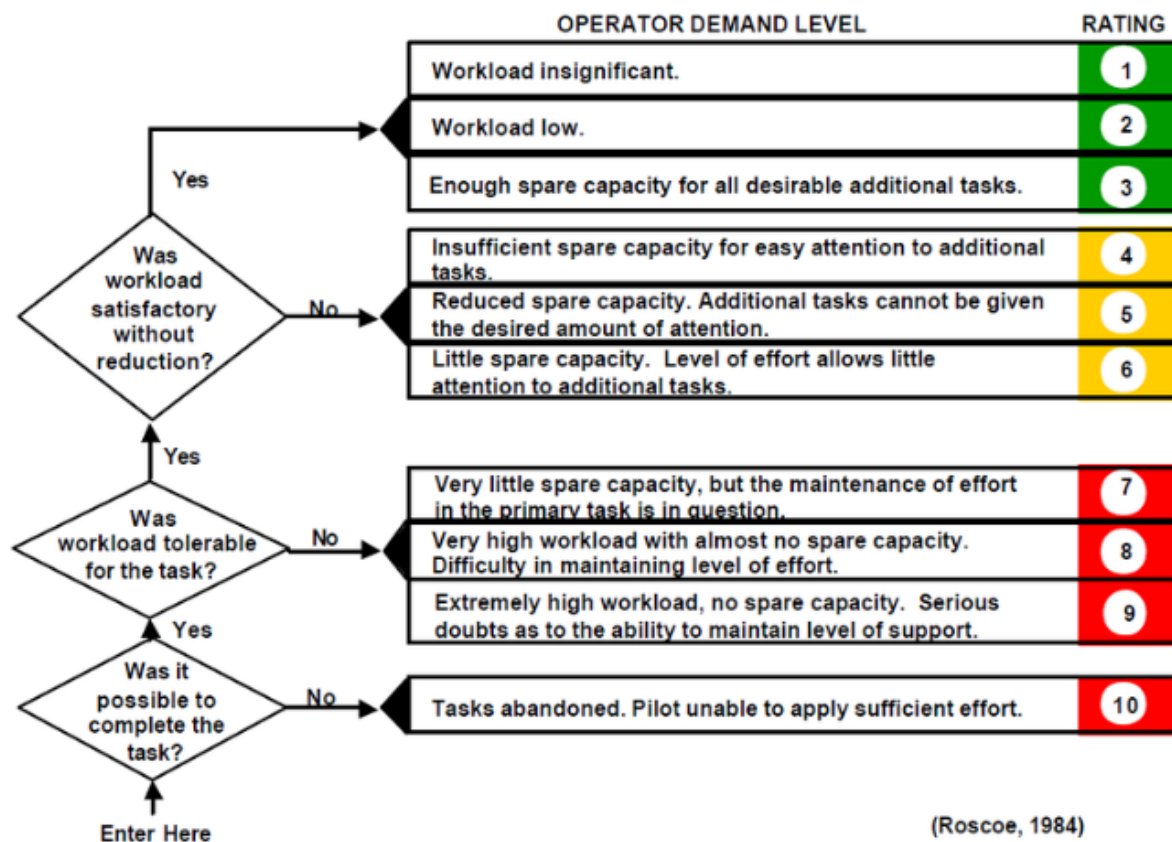


Figure 1: Bedford Workload Scale

The mask inserts came in three IDLH⁷ conditions. The density of those conditions

⁶ Source: [PowerPoint Presentation](#)

⁷ Immediately Dangerous to Life or Health
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was labeled as “*Light Smoke*,” “*Medium Smoke*,” and “*Dark Smoke*.” The mask inserts utilized were designed to be inserted into and removed from specific SCBAs⁸ and were reusable. The inserts were used during firefighting training to simulate the various densities of smoke. There were three separate types of inserts sent (MSA, Scott AV2000, and Scott AV3000), designed for three different SCBAs. The group used only the MSA insert due to its close proximity to fit into the full-face aviation mask the group was using. Although not specifically designed for use in aviation, discussion with the manufacturer of the masks utilized for the test, reported that inserts designed for aviation quick-don masks would need specific millimeter measurements. The measurements would be to develop the insert that would fit into an aviation quick-donning mask securely and accurately into the smoke goggle to eliminate the wear’s ability to see around the smoke lens.

The quick-donning mask used was a Safran MF-004 full face, quick donning oxygen mask with integrated goggles, similar to the picture below. The one-piece mask was required to be donned with one hand in five seconds or less, while accommodating prescription glasses. The overall mask’s dimension was approximately 10 x 9 x 2.4 inches.



Figure 2: Safran MF-004 Full-Face Mask

Setup

- Daytime or Nighttime
- Simulator cockpit dome light off
- VMC⁹ conditions
- HUD¹⁰ (pilots’ discretion)

⁸ Self-Contained Breathing Apparatus

⁹ Visual Meteorological Conditions

¹⁰ Head-Up Display

- MFD/PFD¹¹ set by pilot to normal levels for the condition
- If possible, in flight 10 mile final to ILS 16L at SEA¹².

Task

Prior to starting, with the smoke lenses on, measure or obtain an approximate distance the pilot could observe. Although there could be variations of tasks assigned, during this evaluation we need to assess the workload a pilot would perceive and what they would do if in flight. The pilot will be given either engine vibration or given smoke in the cockpit due to any reason not related to engine malfunction. Considering that the simulation will be set on a visual approach to runway 16L, it would be pilot's discretion on the use of the autopilot (A/P) or manual flying as well as if the pilot would initiate a go-around or continue the approach to land and call for the checklist they feel is appropriate and note the reason for that checklist. Those decisions will be noted and the rationale provided by the pilot. However, if the approach is continued, the group will document any course deviation with the 4-light PAPI and any localizer/glideslope deviation. If the pilot elects to go-around, autopilot (A/P) or manual control will be noted plus any deviation from assigned heading/altitude (hdg/alt). Additionally, the pilot, while the simulator is on flight freeze after the initial decision to land or go-around is made, will be tasked with performing either the Smoke, Fire or Fumes checklist up to step 10 or the Engine Fire or Engine Severe Damage or Separation checklist up to step 5, depending on what they called for as the pilot flying.

Initial

The simulator was set up on about a 10-mile final for runway 16L at Seattle Tacoma International Airport (SEA). The MSA Smoke Trainer Masks were trimmed to more closely fit the one-piece full-face mask installed in the simulator. The Public Education mask was not trimmed as it fit into the mask; however, it did allow some areas that a pilot could see around the smoke trainer mask. The initial setup was day VFR. The MSA Smoke Trainer "Light" mask was inserted into the first officer's full-face mask. The Public Education mask was inserted into the captain's full-face mask. The lights were set at the pilot's discretion but during daytime the lights were turned up to maximum. It should be noted that the first officer and captain were both current and qualified on the B-737-8, neither pilot wore corrective lenses.

The first officer described being able to see the overhead switch lights. When a fire test was conducted, the first officer could see the fire lights and the four lightbulbs associated with each fire light but could not see the number. When asked what could be seen on the primary flight display (PFD), the pilot had to lean forward until about 23 inches from the screen and could see the lights on PFD. However, to read the numbers, the pilot had to lean further forward until about 19 inches from the screen to be able to read the

¹¹ Multifunction Display/Primary Function Display

¹² Seattle/Tacoma International Airport, Seattle, Washington
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The screenshot shows the ECDIS interface with the following details:

- Top Panel:** Displays '19.7' and '2000'.
- Main Display:** Shows a vessel icon with 'CMD' and '1260' on the scale. The scale ranges from 0 to 300.
- Bottom Panel:** Shows a heading scale with '211°/16' and '235'.

The captain, who had the Public Education mask, was able to see the HUD and was able to see other details on the PFD, MFD, and engine instruments.

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The second attempt included the captain and first officer, seated in the respective seats. During the second attempt the first officer flew the approach wearing a full-face mask. The approach with little to no vertical or lateral deviation. As the airplane approached decision height the first officer elected to perform a go-around maneuver, due to the fact he could not see the runway with the smoke lenses installed. The go-around was conducted until the turn on the approach, at which point the simulator was placed in flight freeze. The first officer described the workload as tolerable but felt that he had strong support from the pilot monitoring. He classified the workload as a 9 when based on the Bedford Workload Scale.

The third attempt included the captain and first officer, with the captain being the pilot flying. The intent was to fly the approach via the HUD through the landing and the stopping on the runway. The captain was able to see the HUD; hand fly the approach through the landing rollout. Although the captain was able to use the HUD, he was unable to see the runway or centerline until after landing. The workload was classified as 5.

The fourth attempt was conducted with Autoland engaged. The first officer was the pilot flying. The approach was conducted to landing. The first officer described the workload reduction as "huge." He further stated that he was able to see the centerline after landing on the ground. The workload was classified as 7.

The fifth attempt was started on the runway for departure from runway 16L. The flightcrew began the takeoff roll as required by Southwest Airlines procedures. The captain was the pilot flying. About 200 ft above ground level, the No. 2 engine experienced a simulated engine seizure. The first officer put on the full-face mask to perform the Engine Fire, Engine Severed Damage or Separation checklist. The first officer stated that with the smoke lenses on it was hard to see the checklist. He readjusted the map lap which improved slightly but clearly seeing the commands on the checklist was difficult. The airplane was placed on flight freeze and repositioned to a 10-mile final for 16L. The captain got out of his seat and a B737 rated operational factors group member sat in the left seat. The workload was classified, for the pilot monitoring as a 9.

The sixth attempt was flown using the HUD by the group member. The approach was flown and was stabilized. The pilot flying classified the workload as a 3 on the Bedford Workload Scale. One thing noted was that when the group member placed on the full-face mask he was required to use both hands to adjust his reading glasses while placing on the mask.

The seventh attempt was flown from takeoff with a bird strike leading to a Load Reduction Device activation. After the simulated bird strike the airplane vibrated for a few seconds and then began reducing the severity of the vibrations. The first officer put on the full-face mask simulating that smoke entered the cockpit. He performed the Engine Fire, Engine Severe Damage or Separation checklist. As part of the Southwest procedure

the pilot flying would guard the engine thrust lever of the operating engine, and the engine cutoff switch for the operating engine when the checklist called for the pilot monitoring to confirm. The first officer performed the checklist while the captain used the autopilot. The airplane was vectored downwind to runway 16L. Once the crew was ready to begin the approach, the flight was turned to a 130-degree heading about 25 mile final for the approach. During the vectoring there was still a noticeable vibration through the airframe which added to the challenges of reading and performing the checklist. The flight continued to and landed on runway 16L during rollout the vibration subsided. The pilot monitoring classified the workload based on the Bedford Workload Scale as a 9.

The conditions were switched to night VFR and the airplane was placed on a 10-mile final to runway 16L. The captain was in the left seat and the first officer in the right seat. The first officer described the few as "much easier" to see; however, the lighting had to be adjusted. The captain also adjusted his lighting to a dimmer setting on both the HUD and the cockpit lights. When the first officer was reading the checklist, he had the Quick Reference Handbook about 12 inches from his goggles. It was also observed that the captain was seated in his normal position and was not exhibiting any requirement to lean forward to see the HUD or his displays. The pilot flying classified the workload as based on the Bedford Workload Scale as 6 and the pilot monitoring classified the workload as 5.

The captains full-face mask smoke lens was replaced with the MSA Smoke Trainer Mask - Dark. The lens restricted visibility to the point that the captain was unable to see any instruments, HUD, or anything. The group chairman also tried the full-face mask and like the captain was unable to observe any indication, as well as attempted to get close to the HUD but would block the projection making the HUD unusable.

The captains full-face mask smoke lens was replaced with the MSA Smoke Trainer Mask - Medium. In night conditions with the sim lighting set for normal operations and the captain was able to see the HUD, flight instruments and engine instruments. The lens was removed from the captain mask and placed in the first officers full face mask. The first officer was able to observe the overhead panel switches and indications, engine instruments, flight displays, and the checklist. The pilot monitoring described the MSA Smoke Trainer Mask - Medium at night similar to the workload and visibility of the MSA Smoke Trainer Mask - Light during the daytime. The pilot monitoring described the workload based on the Bedford Workload Scale as 9.

MSA Smoke Trainer Mask - Light



Figure 4: MSA Light Smoke Density
MSA Smoke Trainer Mask - Medium

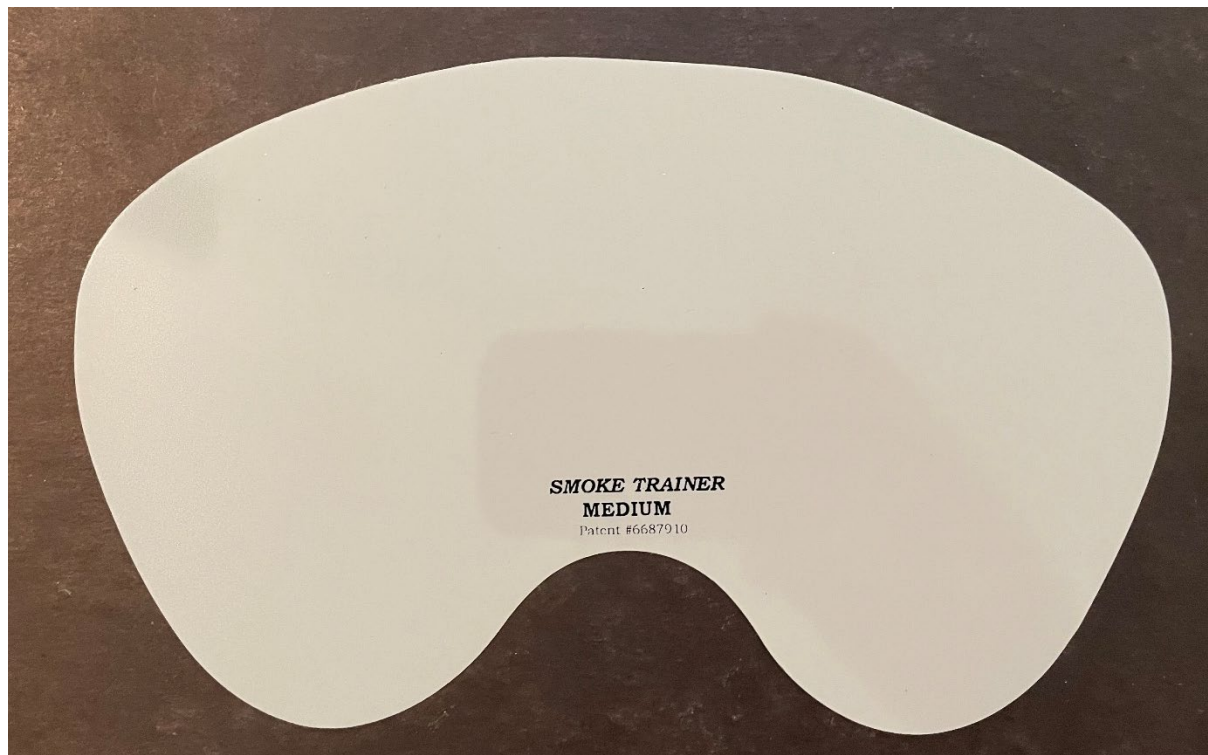


Figure 5: MSA Medium Smoke Density
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MSA Smoke Trainer Mask - Dark



Figure 6: MSA Dark Smoke Density

Public Education



Figure 7: Public Education (similar to Light Smoke Density)

Additional Masks sent but not evaluated

The following masks were also sent but were not evaluated due to time constraints. Scott AV2000 - Light, Medium, and Dark

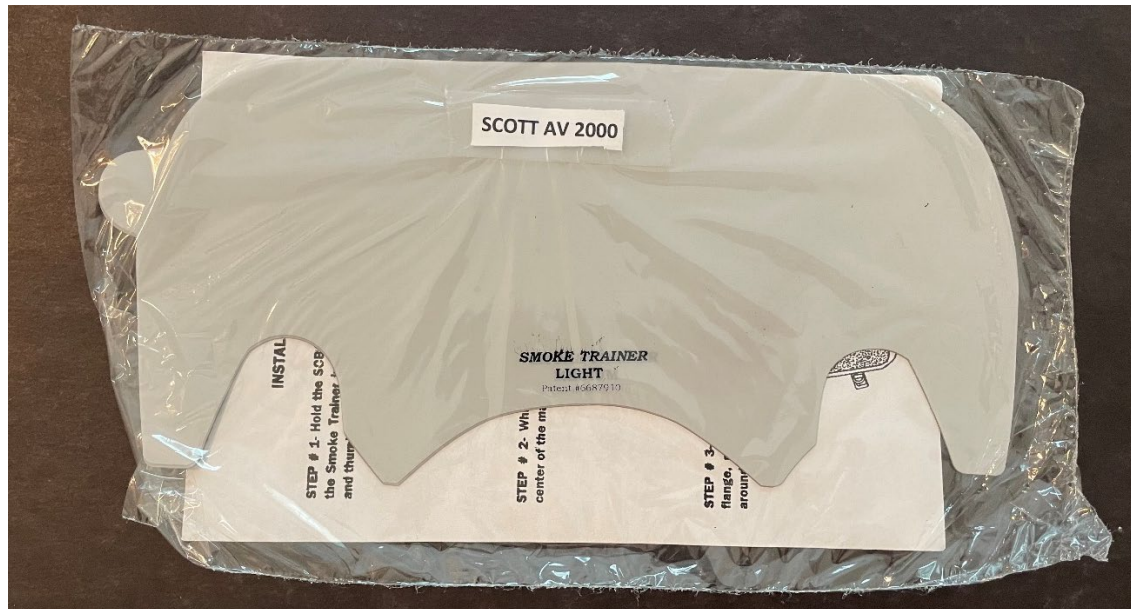


Figure 8: Scott AV2000 pack of three

Scott AV3000 - Light, Medium, and Dark



Figure 9: Scott AV3000 pack of three

Conclusion

During the testing it was determined that the MSA Smoke Trainer Mask - Dark was not something that could be used in the simulator as it limited visibility to a point too low for anyone to see any indications. However, the MSA Smoke Trainer Mask - Medium, and - Light, as well as the public education masks could be used in the right conditions not as a first look maneuver but as an educational scenario to assist pilots with being exposed to simulated smoke indications. However, it should be considered that if lenses like these or different ones are used it needs to be lenses that are designed to fit in the respective full-face mask. Additionally, it would be a useful tool to train crews on dealing with smoke; however, if it were too hard to observe the instrumentation could result in a negative training event. Additionally, considering smoke training has not been used with simulated smoke events, this indicates that there are possible means to expose flight crews to simulated smoke events.

Engine Fire or Engine Severe Damage or Separation

8.2

DO NOT USE FOR FLIGHT

737 Flight Crew Operations Manual

ENGINE FIRE or Engine Severe Damage or Separation

Condition: One or more of these occur:

- Engine fire warning
- Airframe vibrations with abnormal engine indications
- Engine separation
- Engine failure with smoke or fumes in the flight deck or cabin.

- 1 Autothrottle (if engaged) Disengage
- 2 Thrust lever
(affected engine) Confirm Close
- 3 Engine start lever
(affected engine) Confirm CUTOFF
- 4 Engine fire switch
(affected engine) Confirm Pull

To manually unlock the engine fire switch, press
the override and pull.
- 5 **If** the engine fire switch or ENG OVERHEAT light is
illuminated:

Engine fire switch
(affected engine) Rotate to the stop
and hold for 1 second

▼ Continued on next page ▼

8.2

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Smoke, Fire or Fumes

8.12

DO NOT USE FOR FLIGHT

737 Flight Crew Operations Manual

Smoke, Fire or Fumes

[Without Aux Fuel Tanks.]

Condition: Smoke, fire or fumes occur.

- 1 Diversion may be needed.
- 2 Don oxygen masks and set regulators to 100%, as needed.
- 3 Don smoke goggles, as needed.
- 4 Establish crew and cabin communications.
- 5 Choose one:
 - ◆ **Engine failure or airframe vibrations with abnormal engine indications exist:**
 - ▶▶ **Go to the ENGINE FIRE or Engine Severe Damage or Separation checklist on page 8.2**
 - ■ ■ ■
 - ◆ **Engine has *not* failed and airframe vibrations with abnormal engine indications do *not* exist:**
 - ▶▶ **Go to step 6**
- 6 BUS TRANSFER switch OFF
- 7 Advise the cabin crew that the cabin lighting will be extinguished, but passenger reading lights will continue to work.
- 8 CAB/UTIL switch. OFF
- 9 IFE/PASS SEAT switch OFF
- 10 RECIRC FAN switches (both) OFF

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