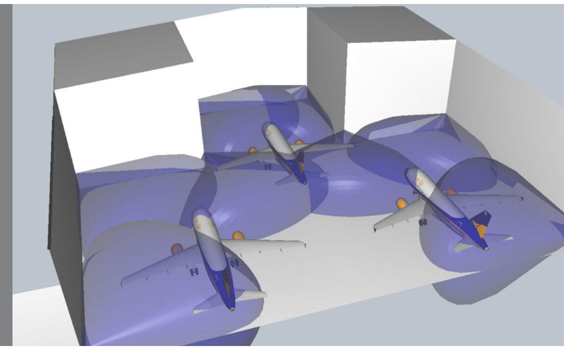
Applying Intelligent Visual Flame Detection in Military Aircraft Hangars

– William Pittman, PhD
Fire and Gas Detection Consultant, Micropack Detection (Americas)

– James McNay BSc MIFireE CFSP MIET,
Director of Consultancy and Engineering, Micropack (Engineering) Ltd



ABSTRACT

Aircraft hangars, and military hangars in particular, combine a set of features that make it both paramount to achieve rapid flame detection and uniquely difficult to do so reliably with a minimum of false alarms. Hangars are frequently occupied by personnel, extremely valuable equipment and aircraft. The hangars, fuel depots and terminals are also necessarily home to large quantities of jet fuel and other hydrocarbons that pose a major fire hazard if released from containment.

Rapid detection and activation of suppression systems is crucial to protecting lives and assets in the event of a fire. Optical flame detection has been applied to aircraft hangars for a number of years as a result. However, aircraft hangars and fuel depots can be difficult places for most optical flame detectors to operate in. A host of possible false alarm sources can cause spurious activations of suppression systems which can, in turn, have expensive or tragic consequences. It is critical that appropriately designed flame detectors are installed with the highest possible level of false alarm immunity and the authors feel that visual flame detectors are better suited for the task than more traditional radiant based detector designs.

The paper details the ways in which intelligent visual flame detectors (iVFDs) can improve the performance of detection systems by reducing the number of false alarms and the number of detectors required to fully cover a hangar. The paper provides results for coverage assessments conducted on a model aircraft hangar to demonstrate the potential for hazard mapping and visual detectors to improve system performance.

KEYWORDS

enclosed spaces, flammable material, fire detection, flame detection, geographic coverage assessment, hazard mapping

INTRODUCTION

The US military maintains by far the largest fleet of military aircraft in the world – over 10,000 aircraft according to one 2015 study.[17] The US Air Force alone operates multiple bases spread out over three continents.[16] Other nations of the world have fewer aircraft and hangars to protect, but many nations still face the challenge of monitoring and protecting hundreds of aircraft spread throughout dozens or hundreds of hangars. These facilities will have to contend with the issues that attend the use, storage, and maintenance of aircraft and stockpiles of jet fuel along with other combustible liquid hydrocarbons. Spills and accidental releases are almost inevitable given the large number of manual transfers that occur via hoses and temporary connections which are far less reliable than fixed piping. These inherent fire risks make any area where aircraft are kept or where fuel is stored and handled ideal locations for installation of optical flame detection systems designed and optimized for that location using 3D hazard mapping.

Optical flame detection should be and has been applied in both civilian and military hangars for years, along with other vehicle refueling and maintenance areas where deemed appropriate. A single hangar can cost anywhere from less than $150,000 to a few million dollars depending on the size of the hangar, the equipment inside, and the type of aircraft it's designed to service.[18] This seems but a pittance however when compared to the costs of the aircraft themselves. A single F-35A Lightning II costs the military about $102 Million as of 2017,[19] which is still lower than the $135-149 million estimated fly-away cost of an F-22 as of 2009.[22] Each of the military's 21 B-2 Spirit bombers cost over $1 billion and would be exceedingly hard to replace.[20,21] This makes protecting the aircraft from damage during a fire paramount, and far more important than protecting the hangar structure itself.

Aircraft can sustain damage in less than a minute when exposed to fire,[18] but the high expansion foam systems that are used to protect them in the event of a hangar fire can take more than two minutes to fill the hangar and suffocate fires near the top of even relatively small aircraft like fighter jets.[23] This race against time makes it critical to detect fires quickly and optical flame detection is ideally suited for this.

Optical flame detectors allow for much more rapid detection of flames than traditional smoke or heat detection systems, especially where aircraft hangars are concerned. The high ceilings of the structures and potential for thermal stratification can significantly delay detection with traditional ceiling mounted detectors in a grid-based array. Optical detectors with wide horizontal and vertical fields of view and detection ranges of 130 ft (40 m) or more can detect small fires over a large section of a hangar in 10 seconds or less.[25,26] Detection with traditional systems can take several minutes or longer to activate or sound an alarm.[24]

Fire Protection Systems for aircraft hangars specifically are handled under the NFPA 409 Standard on Aircraft Hangars.[27,28] which categorizes hangars into four groups or divisions based on the size of the hangars, the height of access doors, and the materials of construction. It provides for performance-based protection of hangars with the requirements for each group sometimes depending on what activities occur inside the hangar. Much of NFPA 409 focuses on what types of fire suppression system are appropriate for use with each group of hangar. It refers to NFPA 72 for guidance on the design of the detection systems.

NFPA 72 and ISA TR 84.00.07 require that selected detectors are appropriate for the application, detecting jet fuel fires, and that the detector layout be chosen based on an appropriate engineering study by qualified individuals.[18] Geographic coverage assessments (GCAs) conducted in a manner consistent with the guidance in ISA TR 84.00.07 are one way, and, in the opinion of the authors, the best way to show that the system has been designed to meet the required level of performance with adequate documentation of the detector layout and expected level of performance. These assessments are sometimes referred to as "hazard mapping."

Military hangars are required to comply with ETL 02-15,[31] which references NFPA 409 among several other NFPA standards, as well as UFC 4-211-01, the Unified Facilities Criteria (UFC) for Aircraft Maintenance Hangars.[32] The 2002 version of ETL 02-15 requires the use of either UV/IR or multi-frequency IR flame detectors proven to be able to detect a fully developed 10 ft by 10 ft (3 m by 3 m) jet fuel fire from roughly 150 ft (45 m) away and that any fire under any aircraft in the hangar must be detectable by at least one optical flame detector. The UFC requires that a fire be confirmed by a second detector or by traditional fire protection systems before foam suppression systems automatically activate.

It is critical that the detectors used produce minimal false alarms and spurious trips, the consequences of which can be dire, even fatal.[29] A fire need not even be real to cause significant disruptions and incur real costs. An investigative piece by the Washington Post in 2015 uncovered several incidents in which foam systems on military aircraft have been triggered, leading to a release of foam. In 2012 a welder set off a fire suppression system and submerged three aircraft in foam. In 2014, six Blackhawk helicopters were covered in foam in Tulsa, OK after an accidental activation caused by the fire security personnel.[29] A spurious foam discharge at Eglin Air Force Base in early 2014 killed one maintenance worker and put three others at great risk.[29] This, of course, represents but a small sampling of the US military's misery with regard to spurious foam system activations. Every time a suppression system activates in response to a false alarm personnel can be placed at risk, money and resources are wasted, and operational readiness is impaired. There is a very real need within the military to have reliable flame detectors installed that will produce the lowest possible number of false alarms and spurious suppression system activations.

However, preventing false alarms in aircraft hangars is, as the preceding examples show, no easy task. This task is currently made all the more difficult by the fact that, under the UFC, the Air Force and the Navy currently require the use of a multi-spectrum infrared (MSIR) flame detector, specifically the Det-tronics X3301. There are multiple ways that the environment in and around the hangar and normal activities in the hangar can trigger a false alarm when using an MSIR detector.

No flame detector is perfect or ideal. No single detector on the market is the best for all applications. However, MSIR detectors are not the latest or the best commercially available detectors or flame detection technology for this application. Intelligent visual flame detectors (iVFDs) can overcome many of the false alarm stimuli that plague MSIR units[1,2] and are, therefore, much better suited to use in aircraft hangars.

THE ADVANTAGES OF INTELLIGENT VISUAL FLAME DETECTION

As noted previously, aircraft hangars have very large doors that are often left open during operating hours to allow for ease of egress for personnel and aircraft. This leaves detectors to contend with sunlight and other challenges from nature, like fog and snow.[1,2,3] While sunlight is generally not expected to trigger false alarms with MSIR units – as it sometimes does with UV, UV/IR and single IR units – some MSIR detectors are significantly impaired by it. The detectors will only be effective at much shorter ranges while the sun is within the detector's field of view (FOV) and may not alarm at all response to a genuine fire. Visual flame detectors do not alarm in response to sunlight and will still work while the sun is within view.

Snow can form a surface for reflecting additional sunlight and desensitizing radiation towards detectors. Fog can enter hangars through doors and windows, absorbing the IR radiation that MSIR detectors depend on, rendering them largely useless.[2] Because water absorbs visible light and near-IR frequencies much less readily than IR radiation, visual detectors can see through much heavier fog, rain or snow than MSIR detectors.[1,2]

Single-frequency IR detectors that only use the 4.2-4.6 micron frequency range to detect hot CO_2 are easily tricked by engine or generator exhaust. This is a significant problem when jet engines and motors associated with maintenance equipment will be used in the hangar frequently.

MSIR detectors can avoid some of these false trips by using reference, or "guard," frequencies to distinguish genuine flames from black-body radiation. MSIR detectors usually use two guard bands to distinguish the sharp narrow peak of a fire from the broad emission spectrum of a black-body radiator.4 The problem encountered here is, while a false alarm should not occur, the detector will suffer significant desensitization in the presence of a black-body radiator. The high levels of background radiation make it harder to distinguish the spike in the 4.4 micron range from all the radiant noise. The detector will take longer to detect a flame or may require the fire to be significantly larger for detection to occur.[3,5] This costs time, which is critical to protect the aircraft in hangars or neighboring tanks in fuel depots.

Visual flame detectors, by contrast, do not use the 4.4 micron frequency and are not fooled or impaired by black body radiators or hot engine exhaust.

Adding perhaps some insult to injury, engine exhaust from jets outside the hangar can still trigger false alarms or cause desensitization in IR or MSIR detectors. The size of the heat signature from the large volume of gas leaving the jets can make the engine exhaust detectable well outside the normal, advertised, range of a detector. Some MSIR units, like the X3301, attempt to combat this issue by having the detector operate in "hangar mode," where-in the detector has a built-in time delay before it goes into alarm. The question can be asked, fairly, why spend the money to install a high-performance detection system that needs to be handicapped with built-in delays to prevent false alarms? Why not just buy a detector that's less prone to false alarms without the need for the time-delay, provided one is available?

As will be addressed in more detail shortly, visual detectors like those produced by Dräger, also have wider fields of view and longer effective ranges than many market-leading MSIR detectors, including the X3301. This, combined with their improved immunity to desensitizing environmental factors, makes it possible for each visual flame detector to provide effective and timely coverage to a much larger area.

Because a visual flame detector is essentially a camera with a mechanism to analyze the video and "look" for fires, some models also have the ability to transmit and record video with overlaid boxes to indicate where the fire is thought to exist.7 Remote viewing of the video feed allows personnel to quickly confirm a fire in the event of an alarm or activation of suppression systems. Recordings of the video feed allow investigators to review it and identify the precise origin and cause of a fire. This is particularly useful given that fires tend to destroy much of the evidence of how the fire began, sometimes resulting in so-called "black-hole" fires, with nothing surviving to indicate cause or precise point of origin.8 The cause of many fires remains "undetermined" indefinitely simply because of a lack of definitive evidence.[8,9]

Where an alarm occurs, the video can be reviewed to determine the cause or origin of the fire or to prevent future false activations. This is perhaps the single greatest advantage conferred by visual flame detection over competing optical flame detection technologies. Systems exist on the market that integrate radiant based detectors with cameras to provide video recording capabilities. However, in these systems the detectors and cameras generally exist as separate devices in separate housings, mounted at different locations, with separate connections to a DCS. This all means more things that can break or go wrong, more things to test, diagnose and fix, and higher costs.

The principle weakness of visual based flame detection, the inability to detect fires involving materials that burn with flames that are invisible or nearly invisible, is not expected to be a problem in this application.[1,2,7] Methanol[10] and ethanol[11] are not common jet fuels and are not generally present in aircraft hangars, fuel depots or terminals. The ability to detect hydrogen fires is relevant for NASA and SpaceX as liquid hydrogen is frequently used as a rocket fuel. iVFDs cannot detect hydrogen fires, however, MSIR detectors are also usually incapable of detecting such fires. Some MSIR detectors replace the ~4.4 micron filter with one that is sensitive to wavelengths of around 2.0 microns. This makes those modified units capable of detecting non-hydrocarbon fires like those fueled by hydrogen and silane.[12,13,14,15]

CASE STUDY USING A GROUP I AIRCRAFT HANGAR

To illustrate how using iVFDs in place of MSIR detectors like the X3301 can allow operators to reduce detector counts, and to demonstrate the utility of hazard mapping tools in designing detector layouts, the authors have used a hazard mapping program, HazMap3D, to design detector layouts and conduct coverage assessments on a hypothetical Group I aircraft hangar.

The UFC for aircraft hangars in some cases allows for activation of the foam system in if a single optical flame detector goes into alarm and the system also detects that water is flowing through overhead fire water/sprinkler systems. This analysis will largely ignore this possibility and assume that two optical detectors will need to go into alarm before foam suppression systems are activated.

Thermal stratification and other issues sometimes encountered within structures with very high ceilings – like the 32-65 ft high ceilings see in some hangars – can sometimes delay activation of ceiling mounted smoke and heat detection systems and sprinkler systems by several minutes. These systems therefore most likely will not respond to a fire until well after it has grown quite large. Two optical detectors should easily alarm in response well before that point.

DETECTOR MODELING AND DESENSITIZATION

The analysis will compare the performance achieved by the Det-tronics X3301 to that achieved by the Dräger Flame 3000 and Flame 5000. As noted previously, the X3301 is currently specified for use in the US Military's UFC, making it the obvious choice to represent MSIR detectors as a class in this analysis.

The effective FOV of the detector is one of the most important features of a detector in determining coverage, second, perhaps, only to the effective detection range to a 1 ft^2 (0.1 m^2) pan fire. Table 1 below gives a summary of the maximum FOV achieved by each detector.

Table 1: Effective range and FOV for selected detectors

Detector Model	Detector Type	Field of View (degrees)	
		Horizontal	Vertical
Det-tronics X3301	MSIR	90	75
Dräger Flame 3000	iVFD	120	90
Dräger Flame 5000	iVFD	90	65

As noted previously, the effective range of a detector can be reduced by a wide range of desensitizing environmental factors and it's necessary to account for this loss of sensitivity when assessing the level of coverage the detection system can be expected to provide. There's a method for adjusting the effective detection range of a detector with broad acceptance in the industry that uses three desensitization factors.[1,2] These factors are often called F1, F2, and F3 and adjust the detection range to account for blinding interference sources, the impact of dirty optics and loss of off-axis sensitivity respectively. Table 2 provides a breakdown of the desensitization factors for each detector and the final effective ranges used in the assessment. These values are approved by FM Global and are widely applied in industry. In the case of the X3301, the values of the desensitization factors depend on the sensitivity setting used so Table 2 lists the values for each sensitivity setting individually. The Dräger detectors only have one sensitivity setting. Flame detection with the visual detectors is based on pixel analysis. The number of pixels available for analysis is fixed by the sensor used and the minimum number of pixels required to achieve detection is fixed by the detector's algorithm.

Table 2: Summary of Detector Desensitization Calculation

Detector Model	Detector Type	X	F1	F2	F3	% max range	Effective Range, D
Det-tronics X3301 (L)	MSIR	50 ft (15.2 m)	0.84	0.75	1.0	63%	32 ft (9.7 m)
Det-tronics X3301 (M)	MSIR	100 ft (30.5 m)	0.78	0.75	1.0	59%	59 ft (18.0 m)
Det-tronics X3301 (VH)	MSIR	200 ft (61 m)	0.64	0.75	1.0	48%	127 ft (38.7 m)
Dräger Flame 3000	iVFD	197 ft (60 m)	0.95	0.95	1.0	90%	177 ft (54.1 m)
Dräger Flame 5000	iVFD	145 ft (44 m)	0.95	0.95	1.0	90%	130 ft (39.7 m)

As noted previously, iVFDs are far more resistant to blinding and desensitization than MSIR units. As a result, the Dräger detectors suffer only a 9.75% loss of effective range where the X3301 loses 37-52% depending on the sensitivity setting used.

The FOV cone for the X3301 and Flame 5000 are already accurately modeled in HazMap3D, therefore adjusting for this further is unnecessary and a value of 1.00 is used for F3 for both. It is worth noting, however, that not every commercially available F&G mapping software package uses the accurate, FM Global approved, three-dimensional FOV cones to model each detector. Applying values for F3 other than 1.0 is necessary when using those software tools to account for off-axis sensitivity losses. It is also worth noting that the loss of off-axis sensitivity is far more severe in the X3301 and most IR3 detectors than it is for the Flame 5000 and other iVFDs. Because of this, the FOV of the IR3s tends to be ellipsoidal or circular where the visual flame detector FOV is largely rectangular as shown in Figure 1.

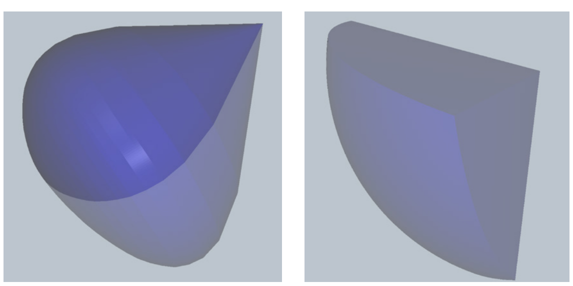


Figure 1: Field of view representations in HazMap3D for the X3301 (Left) and Flame 5000 (right). The images do not use the same scale.

MODEL OVERVIEW

The model aircraft hangar is approximately 295 ft (90 m) wide, 262 ft (80 m) deep in the center, and 165 ft (50 m) deep at the sides with a 75 ft (23 m) ceiling. With a fire zone of approximately 60,000 ft^2 (5,500 m^2) and a room for aircraft with a tail height of more than 28 feet, this hangar would easily be classed as a Group 1 hangar. Figure 2 shows the model hangar and shows that it can accommodate large, “jumbo” jets (or similarly large military aircraft or several smaller jets.

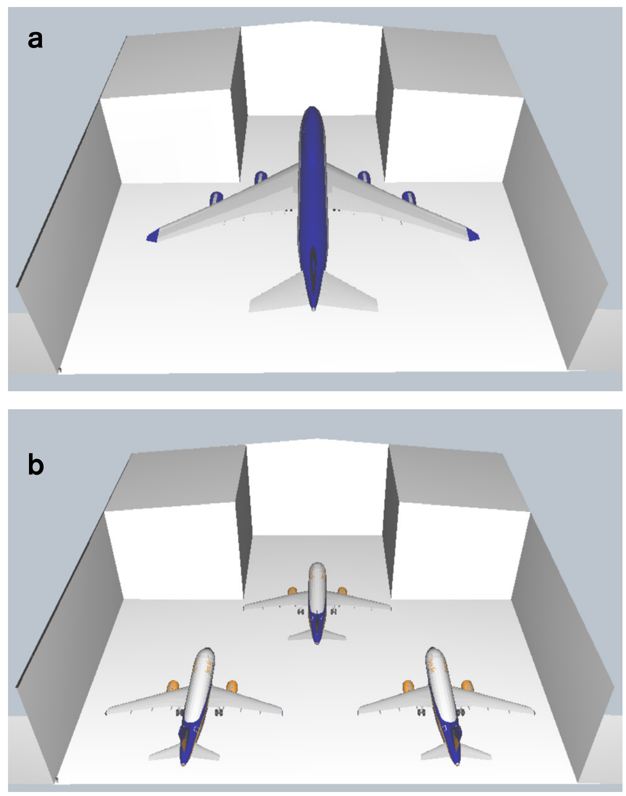


Figure 2: Two versions of the model aircraft hangar with it being used to house a) a single, four-engine, “jumbo” jet or b) three smaller two-engine planes.

The aircraft included in the model are modeled after commercial airliners where this paper is intended to address the requirements of military hangars. However, the overall form factor of large commercial aircraft and larger military cargo planes – like the C-5 galaxy – are sufficiently similar as to allow the authors to use this model for illustrative purposes.

GRADING

The software allows the user to assign a risk grade to equipment or other solid objects, like the aircraft, indicating that fires are thought to be possible in the area surrounding that equipment. How far beyond the piece of equipment the graded area extends can vary with the grade assigned and the standard being used to design the system, but 3-10 ft (1-3 m) is typical. Ungraded areas represent spaces where fire is either not expected, or not expected to result in significant consequences. Figure 3 shows the graded volumes selected for assessment in this case study.

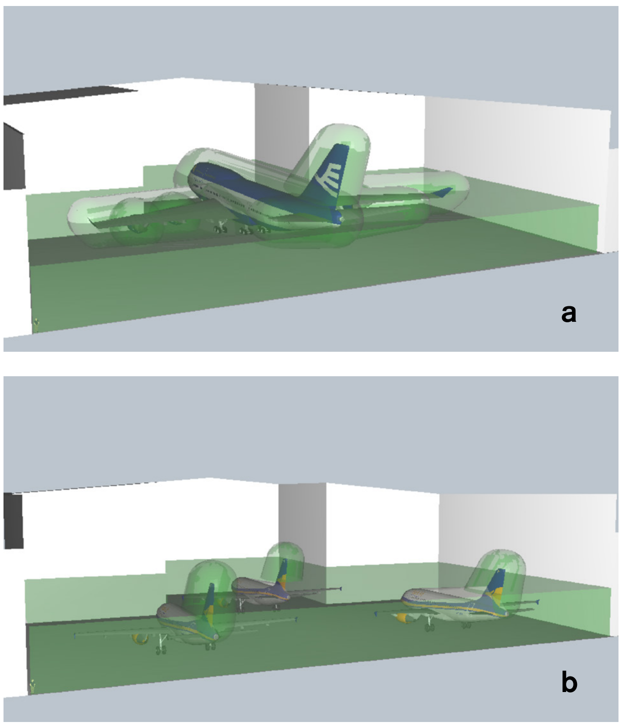


Figure 3: Graded areas for flame detection coverage assessment for a) one large plane or a) a single, four-engine, "jumbo" jet or b) three smaller two-engine planes.

Note that the entire area of the hangar is part of the graded fire zone up to 25 ft (8 m) above the local deck (ALD). The volume within 16 ft (5 m) of the planes that is assigned to the same risk grade, even if that space is more than 25 ft (8 m) ALD. This grading is reasonable given that the principle fire hazard is the ignition and release of liquid hydrocarbons, which can burn on the deck, any surface of the plane or on any other equipment brought into the hangar for fueling or maintenance activities.

Having assigned grades to the areas of interest, detectors can be positioned or repositioned as necessary to achieve the best coverage. Hazard mapping software shines at this stage of the assessment as it allows users to make minor or major changes to detector layouts, run a new assessment and see the changes in coverage, usually in just seconds. This allows for rapid design iteration in pursuit of an optimized layout.

MSIR DETECTOR LAYOUT

A detector layout was designed for the model hangar using the X3301 in the Very High Sensitivity setting. This is the setting generally used for detector in service in military hangars where the aircraft are not allowed to move in and out of the hangar under their own power – the aircraft must be towed into the hangar in these cases. The UFC requires the detectors be kept in the Medium or Low sensitivity settings when aircraft can enter and leave the hangar under their own power. The layout uses eight detectors and is shown in Figure 4.

The FOV cones shown in Figure 4 (and other similar graphics used later) represent the volume in which, baring visual obstruction, the detector should be able to detect a 40 kW RHO fire in 10 seconds or less. That is roughly equivalent to the 1 ft^2 (0.1 m^2) n-heptane pan fire used in FM 3260 testing.

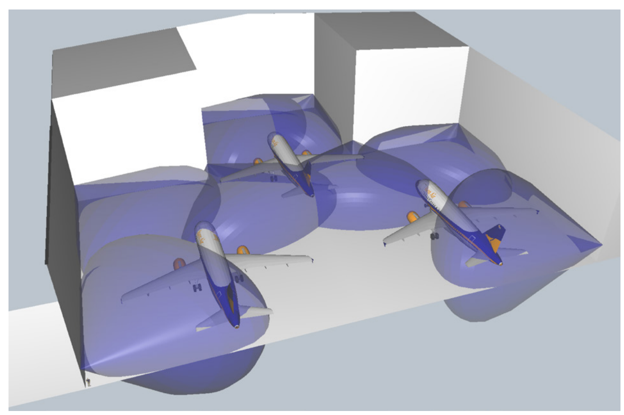


Figure 4: FOV cones for eight Det-tronics X3301 detectors arrayed to cover the model hangar using the "very high" sensitivity setting

There are some aspects of the layout that are admittedly less than ideal. Six of the eight detectors are positioned along the rear walls of the hangar and can see out of the large opening for the hangar doors when they're open. If this hangar were hypothetically positioned with the hangar doors facing a runaway, false alarms could be triggered by planes during take-off. However, the very high hangar ceiling and the dimensions of the hangar make it impossible to achieve good coverage in the middle of the hangar without placing detectors along the back walls. The layout was assessed based on its ability to detect a 90 kW RHO fire, which should roughly correspond to a 2 ft by 2 ft (0.6 m by 0.6 m) JP-4 or JP-5 fire. The results are shown in Figure 5.

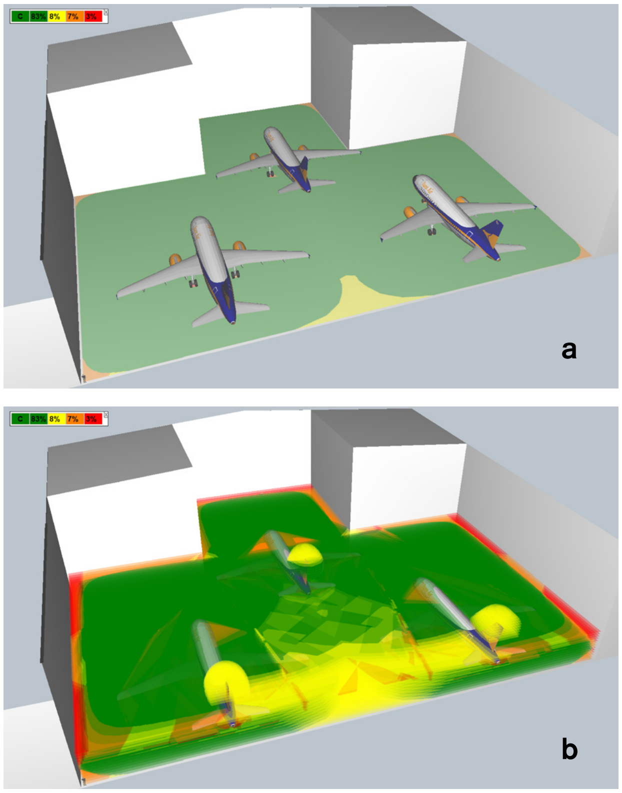


Figure 5: Assessment results for the layout using eight X3301 detectors set to the "very high" sensitivity setting a) at deck level and b) at higher elevations

Some might question the selection of the 90 kW RHO of the 2 ft by 2 ft jet fuel pan fire as the target size for detection where ETL 02-15 requires only that the detector be able to respond to a 10 ft by 10 ft pool fire. However, a fully developed 10 ft by 10 ft pool fire is quite large and does not reflect a fire in the incipient stage. As has been noted previously, the goal of the fire protection system is to detect and respond to the fire as quickly as possible, in the incipient stage – when the fire is still small and damage can be minimized. Tasking the system with looking for fires that are 100 ft^2 does not necessarily accomplish this and certainly does not do so as well as a system that can quickly respond to a 4 ft^2 fire. Additionally, the 2 ft by 2 ft jet fuel fire was used to generate the third-party test data – the effective detection distances – used in this and many other coverage assessments. Few, if any, flame detector performance tests are conducted using fires as massive as the one specified in the ETL. Applying the inverse square law allows for extrapolation of the results using the 4 ft^2 fire for use on larger fire sizes, but, as with all extrapolations, the results become less reliable the further out they're carried.

The results achieved by the 8-detector layout are overall good with 2ooN coverage achieved for 83% of the graded volume and nearly complete 2ooN coverage for the hangar floor. Most of the areas of low coverage are along the outer edge of the hangar and in the middle of the hangar, near the hangar door. Some of this loss of coverage occurs as a result of visual obstruction from the aircraft. Some of it is the result of the limitations in the detector's desensitized effective range.

Covering a hangar of this size and layout becomes considerably more daunting however if it is assumed that the planes will be allowed to enter and leave the hangar under their own power, forcing the detectors to operate using the "medium" or "low" sensitivity setting to comply with the Air Force-specific criteria in section 5.6 of the UFC. Figure 6 shows how the FOV cone for the X3301 shrinks relative to the size of the hangar model when the lower sensitivity settings are used.

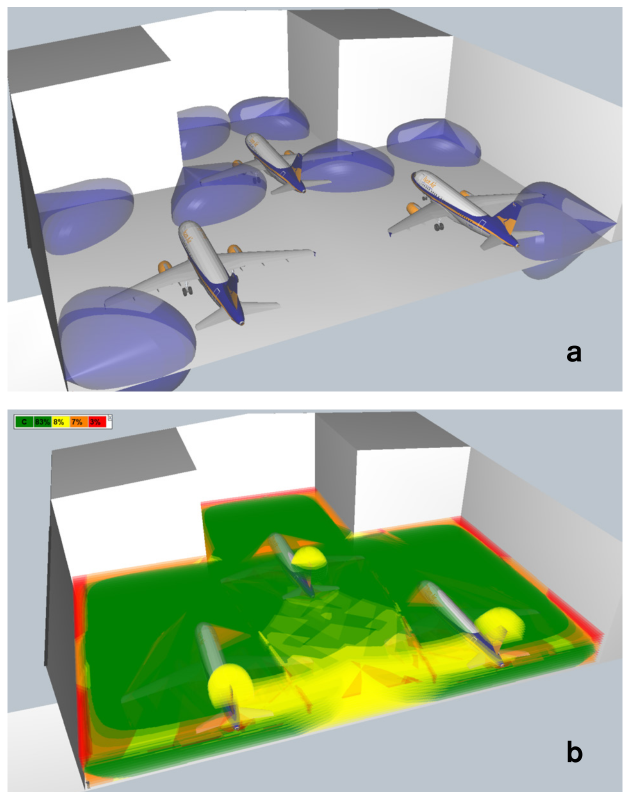


Figure 6: FOV cones for eight Det-tronics X3301 detectors arrayed to cover the model hangar using the a) "medium" and b) "low" sensitivity settings

Figure 6 shows that providing coverage for the hangar is likely to get considerably more daunting for the X3301 in this scenario. Figure 7 shows the results of an assessment using the "medium" sensitivity setting. The results using the "low" sensitivity setting are low enough to not warrant depiction. Table 3 provides a summary of the coverage provided using each sensitivity setting using the eight-detector X3301 layout.

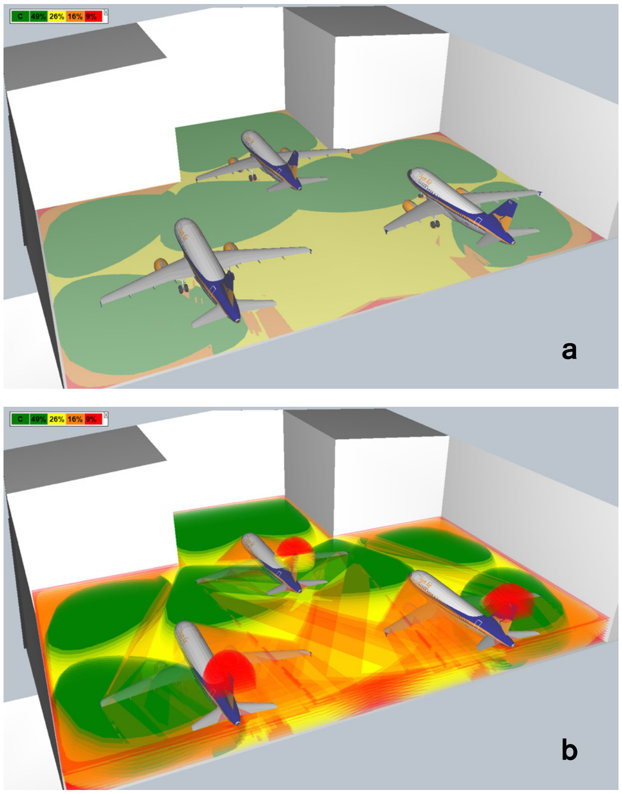


Figure 7: Assessment results for the layout using eight X3301 detectors set to the "medium" sensitivity setting a) at deck level and b) at higher elevations

Table 3: Summary of Assessment Results for the eight-detector X3301 layout using different sensitivity settings

	2ooN coverage of Target Fire Size	Delayed 2ooN Coverage	1ooN coverage	No Effective Coverage
Low	-	-	31%	69%
Medium	49%	26%	16%	9%
Very High	83%	8%	7%	3%

Figure 7 shows that, using the "medium" setting, most of the hangar floor will still have 2ooN coverage, albeit for fire sizes that are larger than the 90 kW RHO specified. This means that the system will still ultimately activate the fire suppression systems, but activation will be delayed to some extent while the fire grows – this could prove costly. Using the "low" sensitivity, there is effectively no 2ooN coverage as the fire will have to grow unacceptably large before two detectors will alarm in response to it. In this scenario the system is therefore not expected to activate the fire suppression systems in the hangar until the fire has spread and the damage incurred could be extensive by that time.

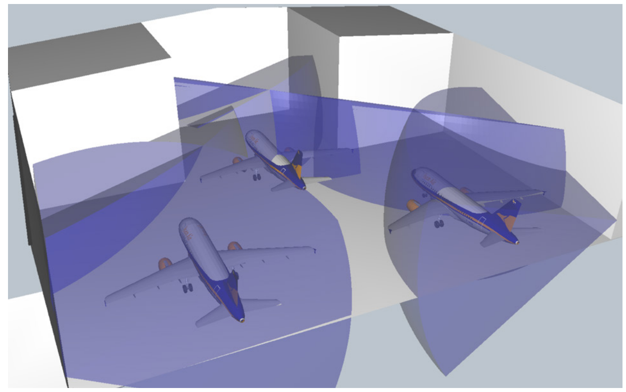


Figure 8: FOV cones for six Dräger Flame 5000 detectors arrayed to cover the model hangar

COVERAGE ACHIEVED USING IVFDS

Figure 8 shows a six-detector layout using Dräger Flame 5000 detectors. This layout eliminates two of the detectors in the X3301 layout, simply because they're no longer necessary for covering the middle of the hanger as the assessment results in Figure 9 show. A similar visual has not been provided using the Flame 3000. The range and FOV of that detector is so large and the FOV cones overlap to such a degree that it becomes difficult to distinguish the different FOV cones.

The six-detector Flame 5000 layout achieves 87% 2ooN coverage and provides at least 1ooN coverage for all but 1% of the graded volume. Even with two fewer detectors, the Flame 5000 layout achieves better coverage than the eight-detector X3301 layout, even on the "very high" sensitivity setting, including at deck level.

The coverage provided using iVFDs becomes even better when using the Dräger Flame 3000. Using six Flame 3000 detectors, 2ooN coverage rises to 93% when using the same layout as shown in Figure 8.

For context, Figure 10 shows the coverage achieved using six X3301s in the same layout as for the iVFDs. Table 4 summarizes and compares the coverage achieved by the Flame 3000, Flame 5000, and X3301 in the "very high" setting using identical six-detector layouts.

Timely 2ooN coverage achieved by the X3301 drops to 70% with the elimination of two detectors, falling well below the coverage achieved by the iVFDs with the same detector count. If the 14% of the graded volume with delayed 2ooN coverage is added in, the 84% coverage is close to the 2ooN coverage provided by the Flame 5000, but still falls shy of it. It is also perhaps worth noting that the area of delayed 2ooN coverage in the center of the

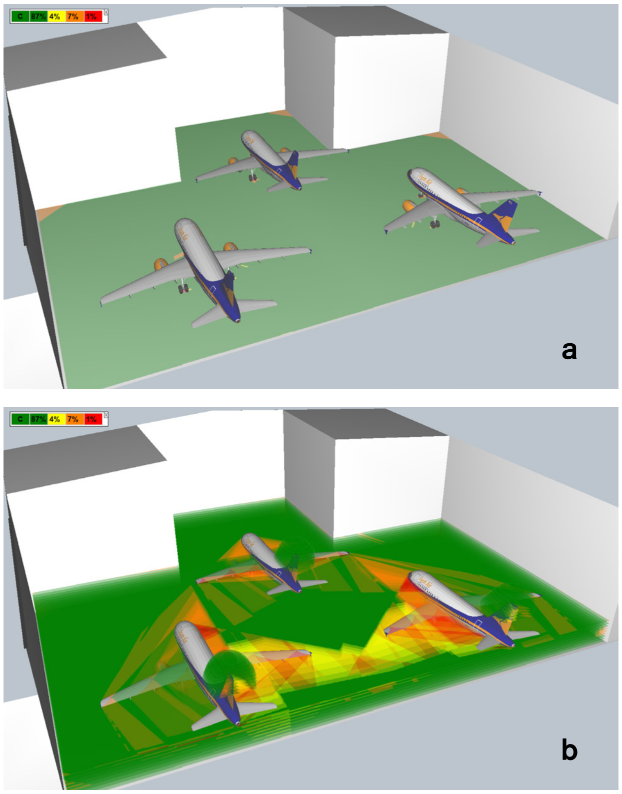


Figure 9: Assessment results for the layout using six Flame 5000 detectors a) at deck level and b) at higher elevations

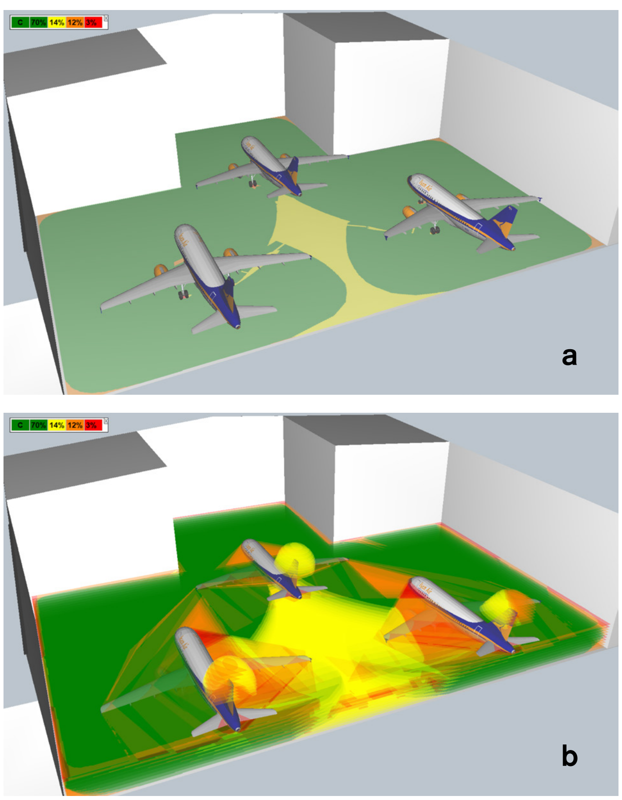


Figure 10: Assessment results for the layout using six X3301 detectors set to the "very high" sensitivity setting a) at deck level and b) at higher elevations

hangar is the result of the limited effective range of the X3301 after desensitization, not the result of obstruction from the planes. This layout can never be depended on to provide timely activation in response to a 90 kW RHO flame in the center of the hangar. The Flame 3000, on the other hand, can detect a 90 kW RHO fire at a distance of roughly 81 m, even after desensitization. So if two Flame 3000 have an unblocked line-of-sight to the fire, the system will go into alarm in a timely fashion.

Table 4: Summary of Assessment Results Using Selected Optical Flame Detectors

	2ooN coverage of Target Fire Size	Delayed 2ooN Coverage	1ooN coverage	No Effective Coverage
Det-tronics X3301 (VH)	70%	14%	12%	3%
Drager Flame 5000	87%	4%	7%	1%
Drager Flame 3000	93%	-	6%	1%

CONCLUSIONS

Optical flame detectors have recognized utility in improving the performance of fire suppression systems in aircraft hangars and protecting the extremely expensive vehicles and equipment inside them. The multi-spectrum infrared detectors – the Det-tronics X3301 in particular – currently dominate aircraft hangar installations and military hangar systems in particular as use of the X3301 is currently required in the US military's UFC. However, MSIR detectors are not the newest optical flame detection technology or the one that is best suited to this application. The hangar environment is so potentially bedeviling to MSIR units that the UFC requires that the X3301 operate in "hangar mode" when used in aircraft hangars. In this mode it operates with a built-in time delay, to help reduce the likelihood of false alarms. This precaution is unnecessary using iVFDs.

Intelligent visual flame detectors can achieve detection at longer ranges with fewer false alarms than MSIR units, even when the MSIR units are set to higher sensitivity settings. This ultimately means that iVFDs can provide adequate coverage to larger hangars with fewer detectors, which lowers upfront and maintenance costs. When MSIRs are used in lower sensitivity settings, as is sometimes required by the UFC, the MSIRs completely fail to provide adequate, effective coverage, regardless of the number of detectors used. This can be and has been tested and verified using hazard mapping software.

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