

# Warehouse Fire Detection Test Results – ASD vs Point (spot-type) vs Beam Detectors CASE STUDY

---

## Executive Summary

This Case Study presents results from a series of demonstration tests conducted in Victoria University's warehouse in 2008. Three small fire tests were conducted to illustrate the benefits of a VESDA smoke detector's early warning (EW) and very early warning (VEW) detection capability.

Comparison results between VESDA, point (spot-type) and beam detectors are also included.

# Contents

<b>Background</b> .....	<b>1</b>
<b>Fire Detection Systems Installed</b> .....	<b>2</b>
<b>Spot-type Detectors</b> .....	<b>3</b>
<b>Test Results</b> .....	<b>5</b>
<b>Smoke Trends</b> .....	<b>6</b>
<b>Discussion</b> .....	<b>8</b>
<b>Conclusion</b> .....	<b>8</b>
<b>Appendix A: ASPIRE Results</b> .....	<b>9</b>
<b>Disclaimer on The Provision of General System Design Recommendations</b> .....	<b>10</b>

## Background

A series of fire tests for demonstration purposes to the local (Australian) fire industry was organised by Xtralis, with the assistance of Notifier Inertia, Tyco Fire Security, BlueFire, and FPA Australia, in a Victoria University's (VU) Werribee campus warehouse, shown below (Figure 1).



Figure 1: VU Warehouse.

The purpose of these demonstration tests was to illustrate the smoke detection capability of three detection technologies:

- during the early developing stage of fires; and
- in a challenging environment (warehouse) that promotes smoke dilution due to a high ceiling height, stratification and the action of natural ventilation.

The three technologies compared included VESDA air-sampling (aspirating) detector (ASD), spot-type (point) and beam smoke detectors.

The audience for the tests consisted of fire engineers, fire consultants, architects, installers, end users, and delegates from the department of defence, government, insurance, VU and fire brigade.

## Challenges of Fire Detection in Warehouses

The following challenges in fire detection in warehouse environments are normally encountered:

- Varying fuel loads and ignition sources
  - Large quantities and vertical arrangement of fuel loads make prediction of fire scenarios very difficult
- Dirty environment
  - Performance deterioration of detection systems, which may lead to false positive (nuisance) or false negative (missed) alarms.
- Geometrical and environmental characteristics
  - Smoke dilution due to high ceiling height, stratification, natural/mechanical ventilation, which may lead to delayed detection or false negative alarms.

## Testing Warehouse

The warehouse had the following dimensions:

- Length: 43 m
- Width: 12 m
- Ceiling height: 8 to 8.5 m (central pitch).

The warehouse featured a ventilated ridge traversing the length of the roof. Three roller doors (6 m x 5 m) were located on two adjacent walls.

The effect of wind promoted air movement inside the warehouse through leakages in structural openings and doors. Additionally, poor thermal insulation of the roof and walls was predicted to cause vertical temperature gradients on a warm day leading to stratification (stratification levels were not monitored during the course of the fire tests).

# Fire Detection Systems Installed

## VESDA System

One VESDA LaserPLUS (VLP) detector with a single pipe was installed on the ceiling along the ventilated ridge. The layout of the pipe network is shown below (Figure 2).

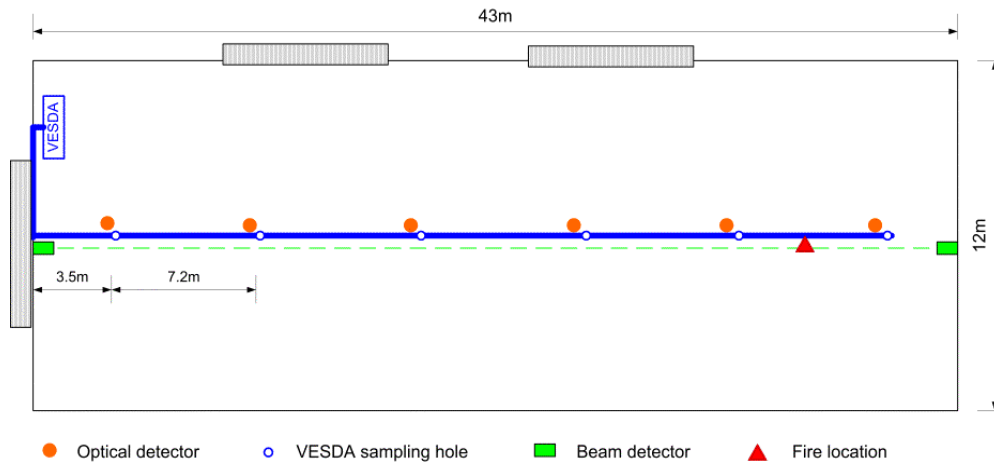


Figure 2: Smoke Detection Systems Layout.

Parameters of the VLP system were:

- Total pipe length: 50 m approx.
- Number of sampling holes: 6
- Sampling hole size: 3 mm
- Endcap size: 3.5 mm
- Sampling hole spacing: 7.2 m
- Maximum transport time: 38 seconds

ASPIRE calculations for the VLP system are included in Appendix A.

The VLP alarm thresholds were set as follows, incorporating a 5 second verification period:

- Alert alarm: 0.05%/m;
- Action alarm: 0.08%/m;
- Fire 1 alarm: 0.2%/m;
- Fire 2 alarm: 2.0%/m.

The VLP alarm verification period was chosen to match the default alarm verification period of spot-type smoke detectors in order to enable similar comparison. Alarm verification periods are recommended in field installations (warehouses), to promote immunity against abnormal fluctuations in ambient background levels due to operational and environmental parameters.

## Spot-type Detectors

Optical spot-type smoke detectors were installed at ceiling level along the ventilated ridge (Figure 2). For comparison purposes, the spot-type detectors were mounted next to the VLP sampling holes (Figure 3).

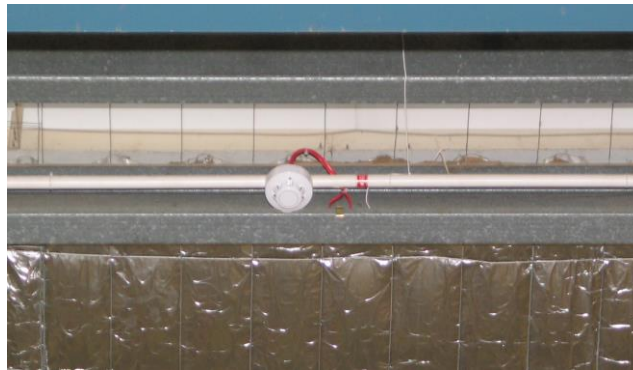


Figure 3: Spot-type Detector and VLP Sampling Hole

The spot-type detector's Fire alarm threshold was set to 1.4%/m (Mode 1 – most sensitive) incorporating a 5 second verification period.

A PROACTIV fire alarm control panel (FACP) was used to log alarm times for each individual spot-type detector and to log the events and alarm times of the VLP detector at the same time.

## Beam Detector

The beam detector emitter and receiver were installed 0.5 m below the ceiling level. For comparison purposes, the beam light-path traversed underneath the ventilated ridge close to the VLP sampling holes and spot-type detectors (Figure 2).

The beam detector was set to its most sensitive Fire alarm threshold, 35%/span, incorporating a 10 second verification period.

## Fire Tests

Three small-scale fire/smoke tests were conducted:

- Smoke pellet burning test;
- N-Heptane fire test;
- Timber burning test.

The fire source location as shown in Figure 2 was placed:

- (i) between the two VLP sampling holes furthest away from the detector, which represents the worst case scenario in terms of activation time (average transport time of approximately 38 seconds),
- (ii) between two spot-type detectors, representing a fair normal case scenario in terms of activation time,
- (iii) directly underneath the light path of the beam detector, which represents the best case scenario.

The fire tests were conducted with the two roller doors alternately open and closed and the tests were repeated over 5 sessions. Details of each test method are described in the following sections.

## Smoke Pellet Burning Test

This test method is a modified scale of the AS 4391-1999 Hot Smoke Test for Smoke Management developed by CSIRO (The Commonwealth Scientific and Industrial Research Organisation, Australia) and Xtralis as a standard performance test method for fire detection systems installed in large open spaces (LOS). This test method utilizes smoke pellets/cartridges as the smoke source which provide a constant smoke release rate, and radiant heaters placed in close proximity provide thermal lift.

For the demonstration tests, varying sizes of smoke pellet (brand Regin) were used, ranging from 3gm (S102) to 18gm (S104). One radiant heater was used to generate a maximum 6kW heat output. The smoke pellet test method is shown below (Figure 4).



Figure 4: Smoke Pellet Test

## N-Heptane Fire Test

This test method is a modified scale of UL 268 and EN54-9 TF5. It simulates a flaming pool fire, with constant heat release rate (HRR). This constant HRR flaming fire generates large size black smoke particles.

For the demonstration tests, a quantity of 100ml N-heptane was ignited in a container (150mm diameter). The burning of the N-heptane liquid is depicted in below (Figure 5).



Figure 5: N-Heptane Fire Test

## Timber Fire Test

This test method is a modified scale of UL 268. This fire initially undergoes smouldering combustion and then transitions to flaming.

For the demonstration tests, a wood crib (3 layers, 9 - 18 timber logs) was ignited. The timber logs were rectangular with length 152mm and width 19mm. Ignition occurred at the crib's bottom through a small pan containing a small amount of denatured alcohol.

The maximum fire size was estimated to be 5kW with 18 logs and 2kW with half the amount of timber logs. The smouldering and flaming combustion stages of the wood crib are shown below (Figure 6).



(a) Smouldering Combustion



(b) Flaming Combustion

Figure 6: Timber Fire Test

## Test Results

### Activation Times

The activation times for all detection systems are shown in following tables.

Table 1: Fire Test Results - Session 1 (25th Feb afternoon)

Test	VLP		Spot Detector	Beam Detector	Remarks
	Alert	Fire 1	Fire	Fire	
Timber (9pcs)	225s	315s	NA	NA	Doors closed
N-Heptane (100ml)	85s	180s	NA	NA	Doors closed
Smoke Pellet (3gm)	72s	90s	90s	NA	Doors closed 5kW heater
Smoke Pellet (9gm)	96s	100s	115s	NA	Doors closed 3kW heater
Timber (9pcs)	96s	NA	NA	NA	Doors closed

NA: No Activation within 10 minutes

Table 2: Test Results - Session 2 (26th Feb morning)

Test	VLP		Spot Detector	Beam Detector	Remarks
	Alert	Fire 1	Fire	Fire	
Timber (9pcs)	180s	192s	NA	NA	Doors closed
N-Heptane (100ml)	78s	155s	NA	NA	Doors closed
Smoke Pellet (3gm)	97s	150s	NA	NA	Doors open
Timber (9pcs)	135s	300s	NA	NA	Doors open

NA: No Activation within 10 minutes

Table 3: Test Results - Session 3 (26th Feb afternoon)

Test	VLP		Spot Detector	Beam Detector	Remarks
	Alert	Fire 1	Fire	Fire	
Timber (9pcs)	210s	280s	NA	NA	Doors closed
N-Heptane (100ml)	115s	175s	NA	NA	Doors closed
Smoke Pellet (3gm)	86s	NA	NA	NA	Doors open

NA: No Activation within 10 minutes

Table 4: Test Results - Session 4 (27th Feb morning)

Test	VLP		Spot Detector	Beam Detector	Remarks
	Alert	Fire 1	Fire	Fire	
Timber (9pcs)	200s	213s	NA	NA	Doors closed
N-Heptane (100ml)	75s	130s	NA	NA	Doors closed
Smoke Pellet (3gm)	66s	81s	NA	NA	Doors open
Smoke Pellet (3+9+18gm)	#	56s	165s	190s	Doors open

NA: No Activation within 10 minutes

#: Invalid data due to high background reading (VLP 0.035%/m) prior to start of test

Table 5: Test Results - Session 5 (29th Feb afternoon)

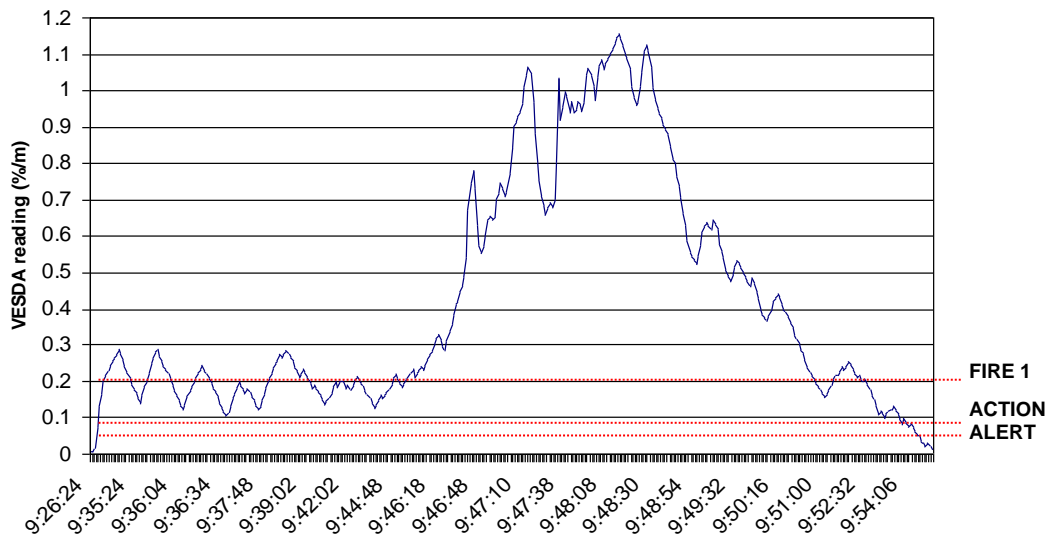
Test	VLP		Spot Detector	Beam Detector	Remarks
	Alert	Fire 1	Fire	Fire	
Smoke Pellet (3gm)	73s	84s	87s	NA	Doors closed
Smoke Pellet (9gm)	96s	124s	NA	NA	Doors open
N-Heptane (100ml)	99s	250s	NA	NA	Doors open
Timber (9pcs)	169s	180s	NA	NA	Doors closed
Timber (18pcs)	190s	520s	NA	NA	Doors open

NA: No Activation within 10 minutes

## Smoke Trends

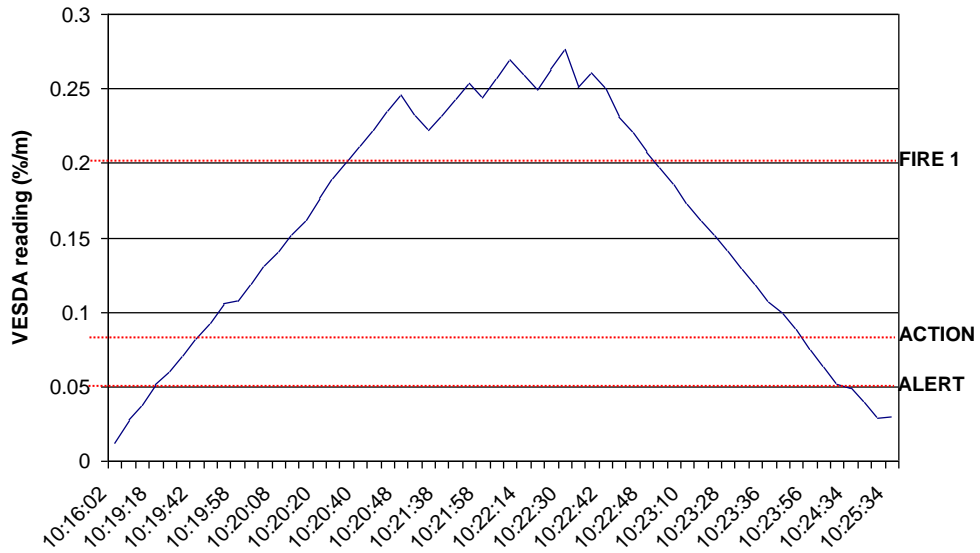
The VLP smoke trends for some fire tests are shown in the following figures:

- Timber fire test: Figure 7.
- N-heptane test: Figure 8.
- Smoke pellet test: Figure 9.



No activation of spot-type and beam detectors during the test

Figure 7: VLP Smoke Trend of Timber Fire Test (Session 4).



No activation of spot-type and beam detectors during the test

Figure 8: VLP Smoke Trend of Heptane Fire Test (Session 2).

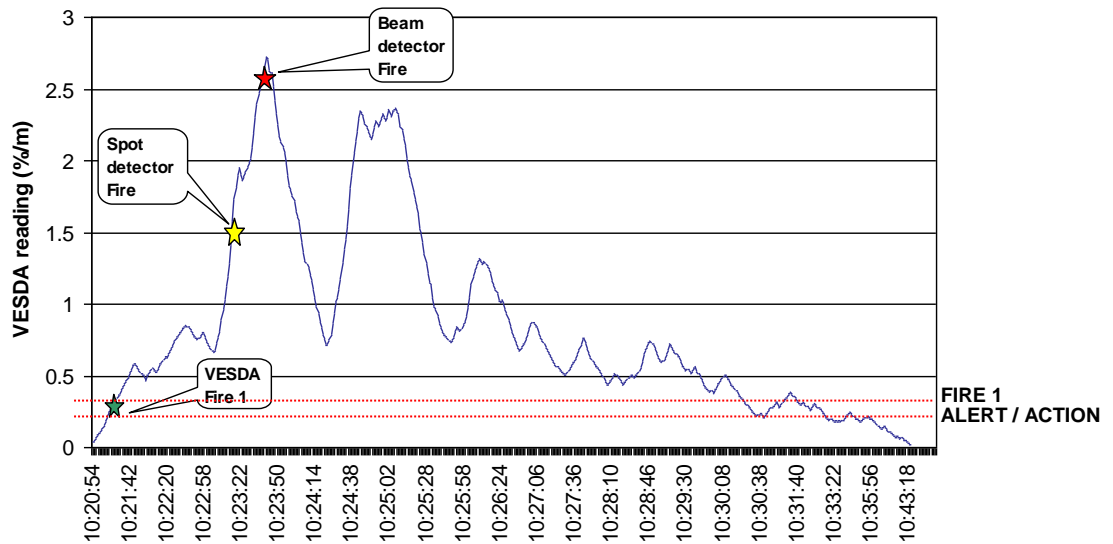


Figure 9: VLP Smoke Trend of Smoke Pellet Test (Last in Session 4)

## Discussion

As evident from Tables 1-5, with all fire types the VLP detector outperformed the spot-type and beam detectors in terms of reliability and faster activation.

In addition, VLP activation times were consistent. For the closed doors scenario, the VLP Alert alarm times for the timber fire test (9 pcs) ranged from 169 to 225 seconds with an average value of 197 sec.

For the open door scenario, (representing normal warehouse operating conditions), the VLP activation times were faster compared to the closed doors scenario, which was attributed to the action of natural ventilation transporting smoke particulate faster to the VLP sampling ports. The VLP average Alert alarm time decreased to 117 seconds.

During the smoke pellet tests, which consisted of a constant heat release rate (radiant heater), the VLP activation time became more consistent and unaffected by the door status. The VLP Alert time ranged from 66 to 97 seconds with an average value of 79 seconds. Similarly in the N-heptane tests, a flaming pool fire, VLP Alert times ranged from 75 to 115 seconds with an average of 90 seconds.

The spot-type detectors failed to activate during the timber and N-heptane tests, whereas activation was observed in 3 out of 7 smoke pellet tests. The beam detector failed to activate to all fire types except during one smoke pellet test (Smoke Pellet (3+9+18gm), Session 4), which greater quantity of smoke produced.

With all fire scenarios (fire types, doors status) the VLP Alert time was between 1 to 4 minutes. Considering the very small fire size of all the tests (2 to 20 kW), the VLP detector proved to be capable of providing early warning (EW) detection during the incipient stage of fire event. Detection at this stage allows time for investigation, manual intervention and, if necessary, suppression with (for example) a portable extinguisher. Early detection and multiple levels of alarm allow reduction in the cost of false/nuisance alarms, should the smoke event in fact be benign. Most importantly, it also allows reduced risks of a threat developing into a large fire, the risks to life safety and the consequential losses to assets, premises and business continuity.

## Conclusion

As the fire tests at the VU warehouse have demonstrated, the VESDA system provided reliable early warning (EW) detection by successfully detecting the fire incidents in their early developing (smouldering) stage with heat outputs between 2 to 20 kW.

Spot-type and beam detectors failed to detect the incipient fires, showed poorer activation time for larger fires and generally showed poor consistency of performance in the more challenging environment of the warehouse. In particular, spot-type detection performance was greatly affected by environmental conditions such as air velocity and temperature in their vicinity. This explains why spot-type detectors issued alarms in fire tests comprising high heat release rates which contributed to a higher smoke plume velocity towards the spot detector.

The VESDA detector's consistent performance makes it a suitable and reliable fire safety solution in warehouses and in general LOS applications. Furthermore, the stable and repeatable performance of VESDA detectors is critical in PBD practices, where quantified performance is imperative.

# Appendix A: ASPIRE Results

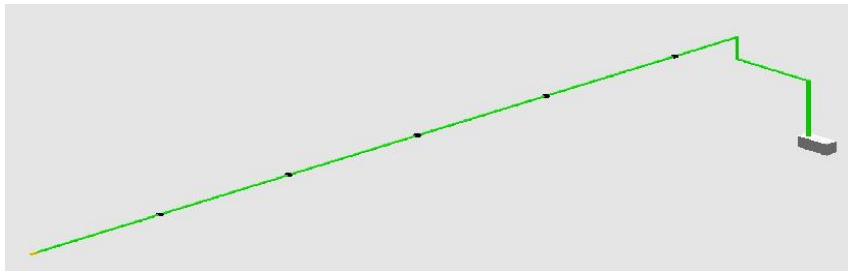
## Installation Data Pack for VU Warehouse Demo

Pipe Type Asiapac  
 Date 2/13/08  
 Units Metric  
 Altitude 0.0m  
 Designed with Hole Sizes 3.0;3.5mm

### Detector : [The Detector]

Flow Calculations found there were problems with this detector. Check below for errors (marked with !?) or warnings (marked !).

Type VESDA LaserPLUS  
 Endcap Usage Create a Balanced Design  
 Application Default  
 Aspirator Speed 4200rpm  
 Fire Threshold 0.200%/m  
 Temperature 20.0°C  
 Absolute Pressure 1013.5hPa  
 System Flowrate 40.4l/min  
 Manifold Pressure 362Pa  
 Total Pipe Length 50.50m  
 Number Of Sample Points 6  
 Maximum Transport Time 90sec  
 Minimum Hole Flow Rate 2.0l/min  
 Inverted Detector No



### Pipe:[New Pipe]

Total Pipe Length 50.50m  
 Ambient Pressure 0Pa  
 Sector Pressure 362Pa  
 Number Of Sample Points 6  
 Pipe Flowrate 40.4l/min

### Section1

Pipe Diameter 21.0mm

#		Distance m	Relative m	Direction	Hole Diameter mm	Capillary Length m	Transport Time sec	Pressure Pa	Flow l/min	Flow %	Hole Sensitivity %/m	Diameter mm	Capillary Diameter mm	Intersection Pressure Pa
-	Bend	5.00	5.00	L	-	-	-	-	-	-	-	-	-	-
-	Bend	9.00	4.00	U	-	-	-	-	-	-	-	-	-	-
-	Bend	11.00	2.00	B	-	-	-	-	-	-	-	-	-	-
1	Hole	14.50	3.50	-	3.0	-	8	316	6.7	16.5	1.212	21.0	-	-
2	Hole	21.70	7.20	-	3.0	-	11	298	6.5	16.0	1.248	21.0	-	-
3	Hole	28.90	7.20	-	3.0	-	15	283	6.3	15.6	1.280	21.0	-	-
4	Hole	36.10	7.20	-	3.0	-	20	271	6.2	15.3	1.308	21.0	-	-
5	Hole	43.30	7.20	-	3.0	-	27	263	6.1	15.0	1.329	21.0	-	-
6	Endcap	50.50	7.20	-	3.5	-	38	256	8.7	21.5	0.930	21.0	-	-

---

## Disclaimer on The Provision of General System Design Recommendations

Any recommendation on system design provided by Xtralis is an indication only of what is considered to be the most suitable solution to meet the needs of the common application environments described.

In some cases, the recommendations on system design provided may not suit the unique set of conditions experienced in a particular application environment. Xtralis has made no inquiry nor undertaken any due diligence that any of the recommendations supplied will meet any particular application. Xtralis makes no warranty as to the suitability or performance of any recommendation on system design. Xtralis has not assessed the recommendation on system design for compliance with any codes or standards that may apply nor have any tests been conducted to assess the appropriateness of any recommendations on system design. Any person or organization accessing or using a recommendation on system design should, at its own cost and expense, procure that the recommendation on system design complies in all respects with the provision of all legislation, acts of government, regulations, rules and by-laws for the time being in force and all orders or directions which may be made or given by any statutory or any other competent authority in respect of or affecting the recommendation on system design in any jurisdiction in which it may be implemented.

Xtralis products must only be installed, configured and used strictly in accordance with the General Terms and Conditions, User Manual and product documents available from Xtralis. Xtralis accepts no liability for the performance of the recommendation on system design or for any products utilized in the implementation of the recommendation on system design, aside from the General Terms and Conditions, User Manual and product documents.

No statement of fact, drawing or representation made by Xtralis either in this document or orally in relation to this recommendation on system design is to be construed as a representation, undertaking or warranty.

To the extent permitted by law, Xtralis excludes liability for all indirect and consequential damages however arising. For the purposes of this clause, 'consequential damage' shall include, but not be limited to, loss of profit or goodwill or similar financial loss or any payment made or due to any third party.

Recommendations on system design are provided exclusively to assist in design of systems using Xtralis products. No portion of this recommendation on system design can be reproduced without the prior approval in writing of Xtralis. Copyright and any associated intellectual property in any such recommendations on system design or documentation remains the property of Xtralis.