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Fire and explosions at an aerosol warehouse

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Health and Safety Laboratory - Buxton

101 years of fire and explosion testing

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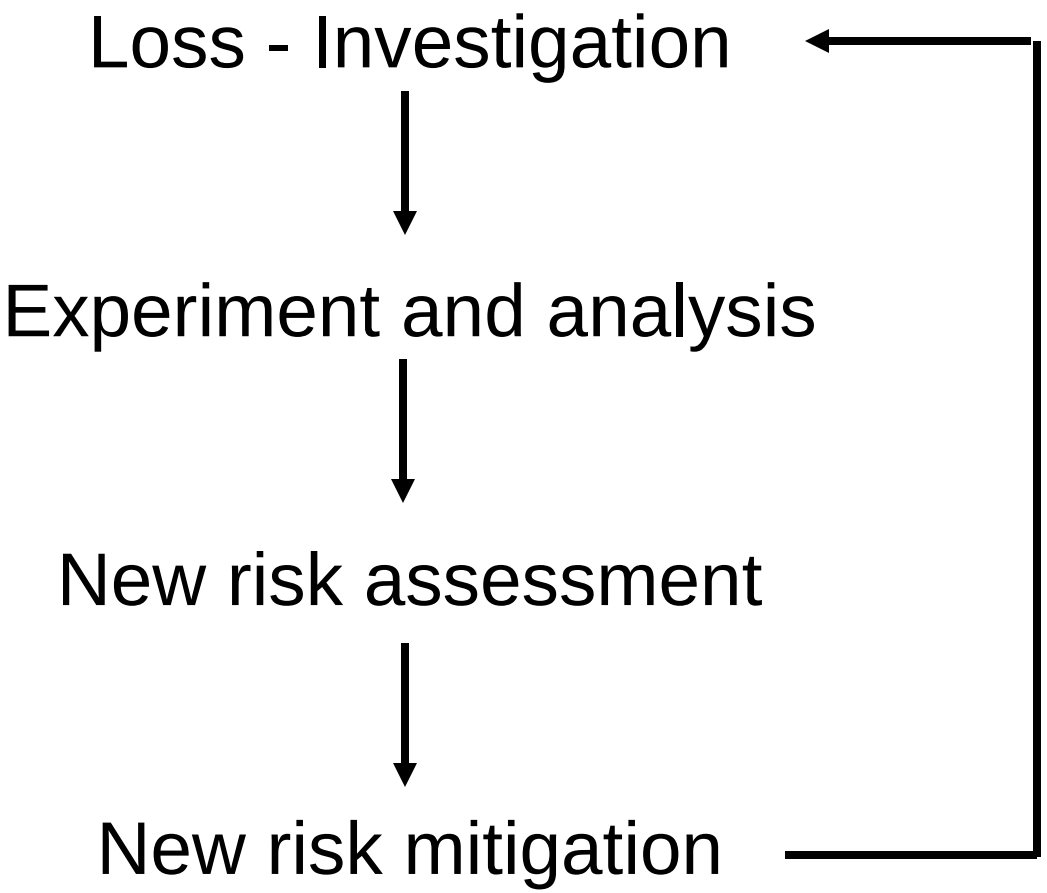
Risk control cycle



IBC fires – Loss and investigation

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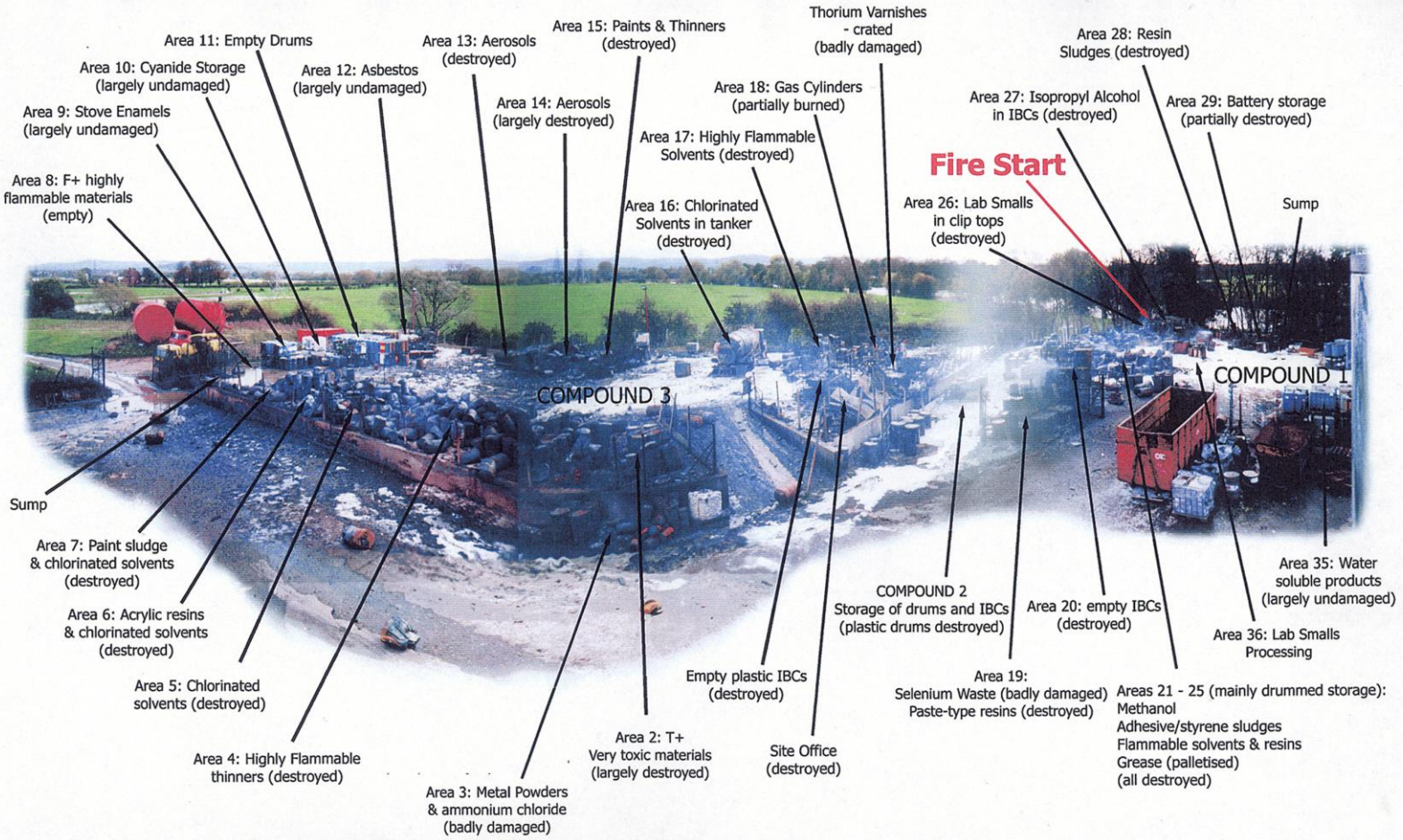

CSG Upper Parting Waste Transfer Plant. 30th October 2000

Experiment and analysis

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Easily ignited

Rapid loss of liquid

Risk assessment - Education – Standards - Mitigation

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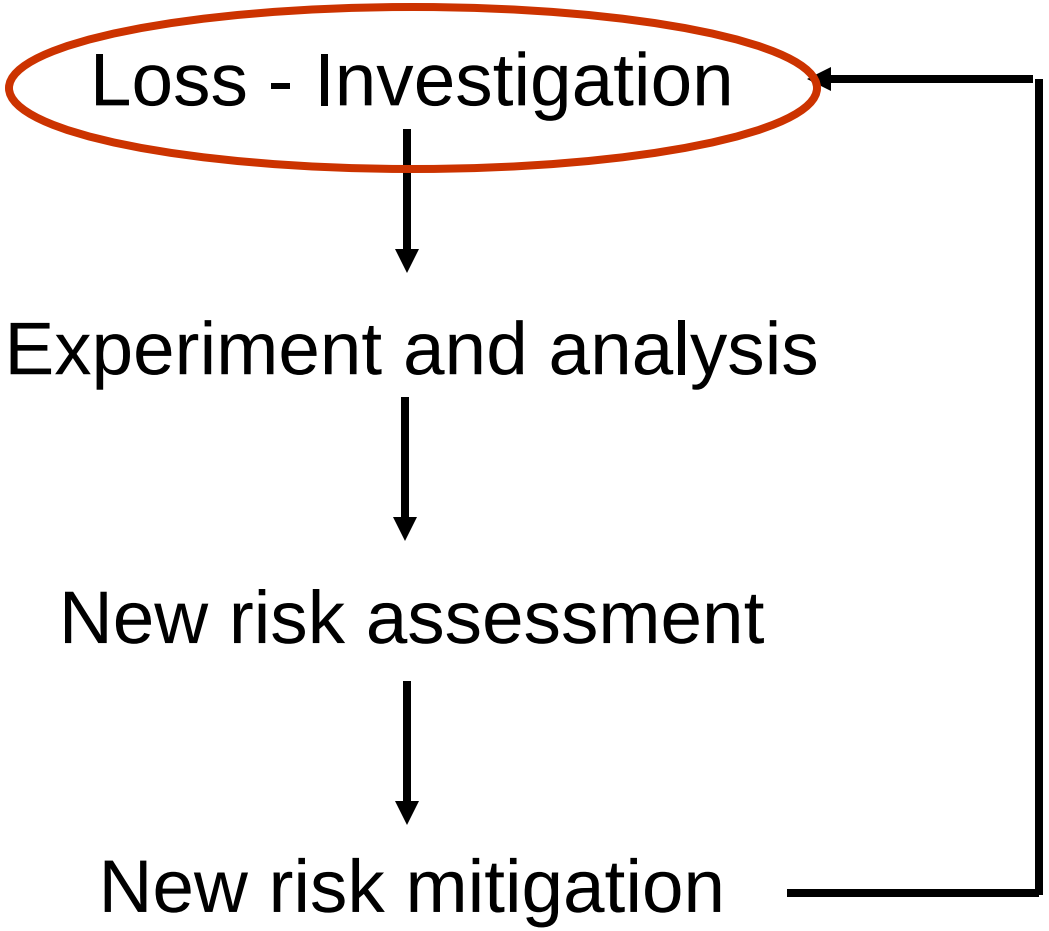
Risk control cycle



Operations prior to the incident

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Warehouse contents

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50-60% Aerosol Anti-perspirants

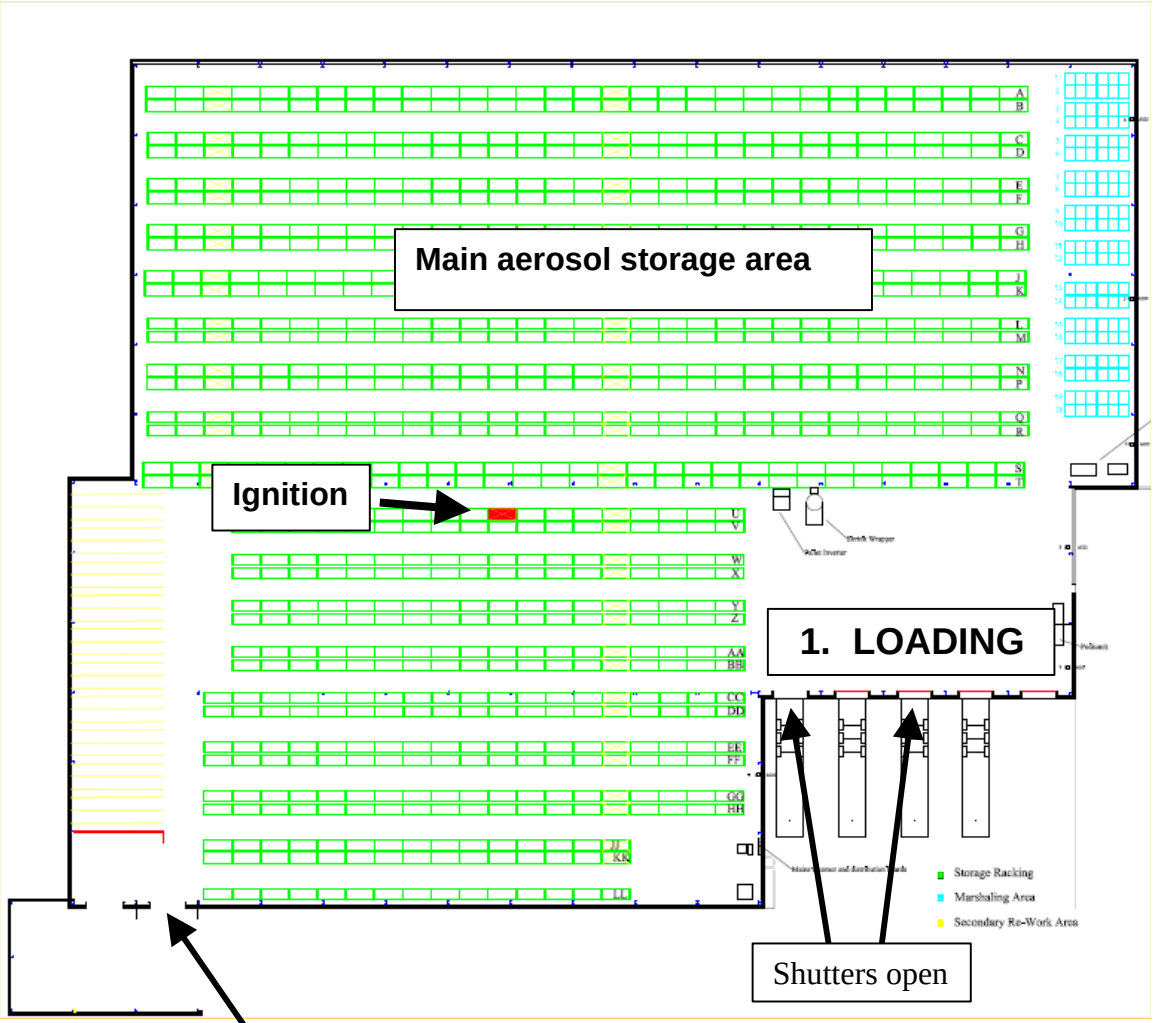
Alcohol and LPG (60%) Approx 4000 pallets

40-50% Low hazard goods

Shampoo, hair colours Approx 4000 pallets

Single point for import from a major European manufacturer. Distribution to the whole of the UK.

Plan of warehouse



Main aerosol storage area - top right

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Operations prior to the incident

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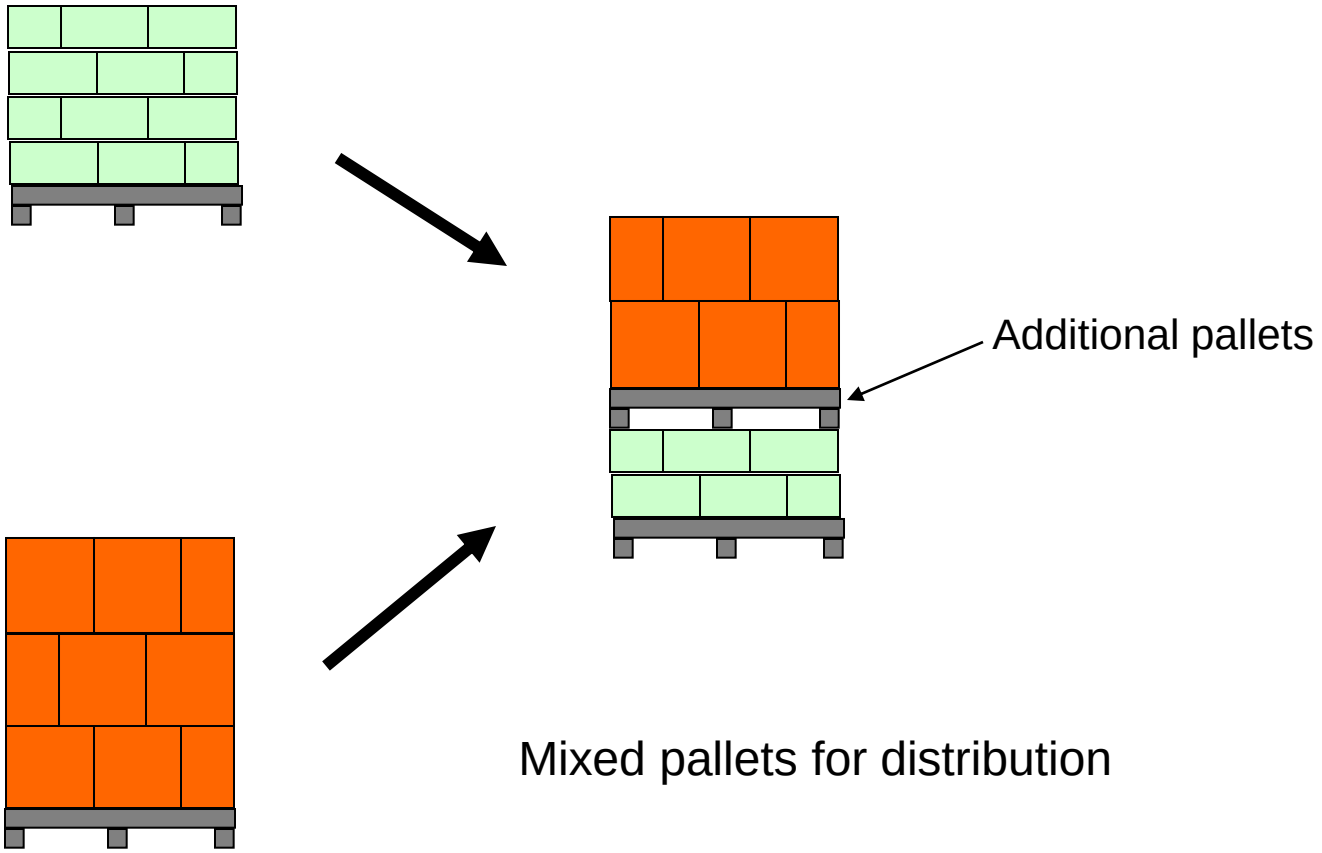
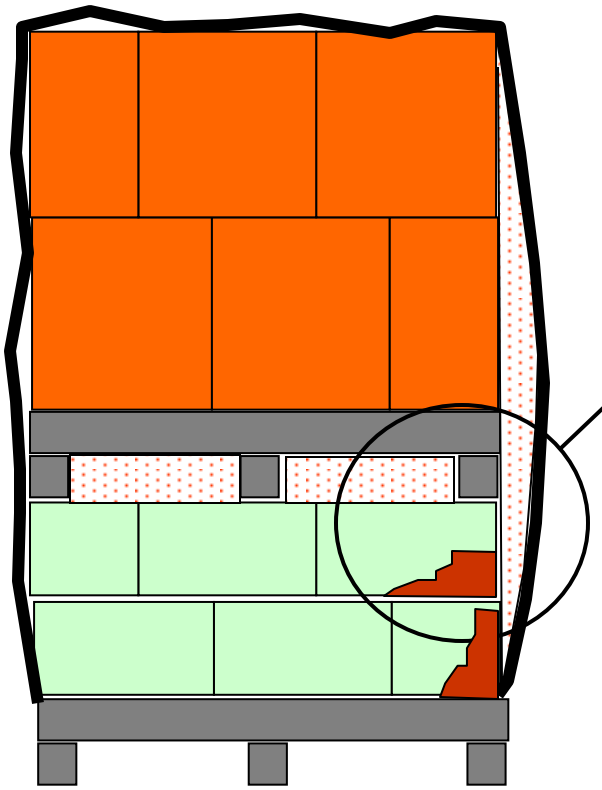
Making mixed pallets for distribution



Complete pallets from supplier

"Every pallet is unique…"

Pallet damaged during assembly



Damage to underlying pallet during stacking.

Cardboard soaked in liquid product (HFL)

Vapour accumulation within the wrapped pallet

Example of surviving site Flexi-truck

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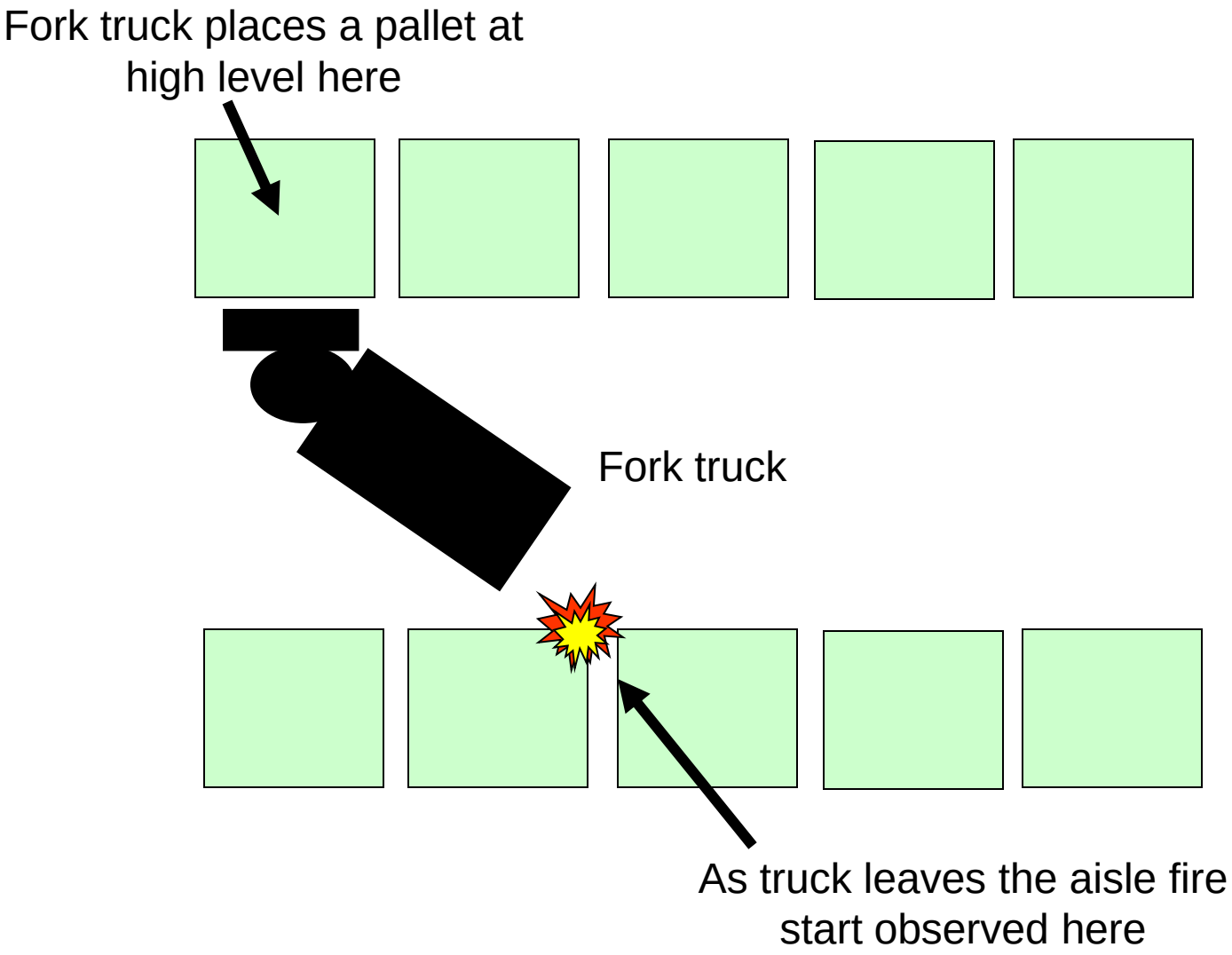
Witness evidence on ignition sequence



Early stages of fire development

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"The fire was right at the bottom of the pallet , about a foot in height and 2 or 3 inches across" **Witness A**

"It was a yellow fire, orange lazy flame coming up the pallets right at the corner facing into the aisle. The flame was a foot from the ground and was not very big, not reaching the top of the pallet which was about shoulder height." **Witness B**

Witness B took a small foam extinguisher from a truck and emptied it on the fire. Initially the visible flame was knocked down but Witness C reports that seconds later flames broke out again. Witness B then heard a popping noise that he recognised as the failure of an aerosol. Both men then ran out of the building.

Witness C reported his final impressions of the fire as he left the building.

"..*the fire had started to spread to adjacent pallets on either side of it and above. It was spreading surprisingly quick and was beginning to spread towards pallets opposite. You could hear popping and rumbling. This all happened over seconds. There was thick dense black smoke which was spreading up and along the ceiling."* **Witness C**

Explosion 80 seconds after fire alarm operation

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"I would have ran about 10m out of the gate when I heard the building go. This would have been 10-15 seconds from having left the building. As I ran from the building you heard rumbling and cracking building up, getting louder and louder. The rumbling and cracking did not stop for ages. However when I was running from the building there was one big boom." ***Witness C***

"The noise got faster and faster until we heard a bigger bang. We saw a blast of air across the yard with smoke in it." ***Witness A***

"There was loads of cardboard coming out through the roof, along with smoke and flames, this all again seeming to happen shortly after I left the building." ***Witness C***

Location and views of cameras

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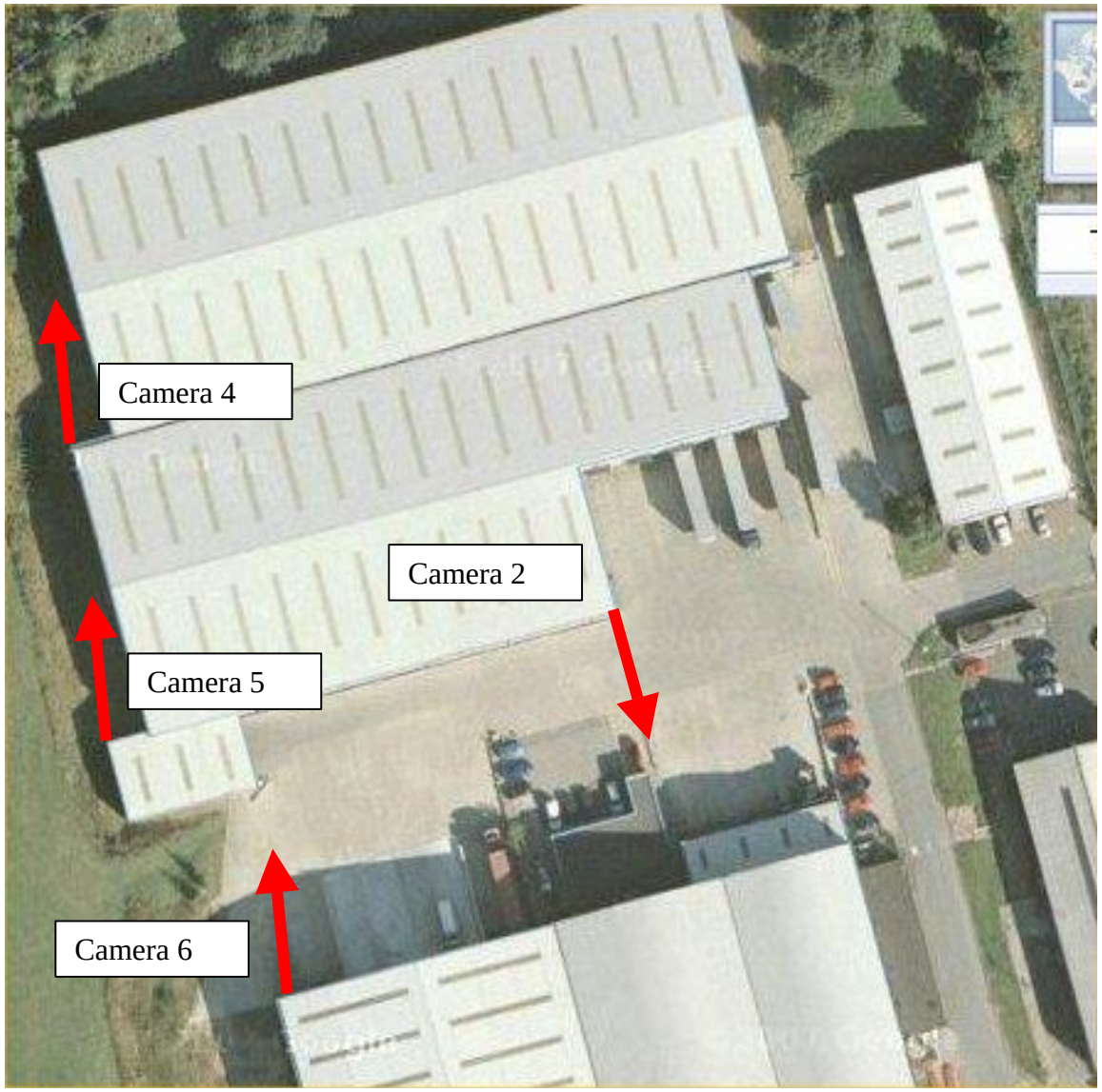

Prior to first explosion

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12:54:20

12:54:38

Effects of the first explosion on cameras

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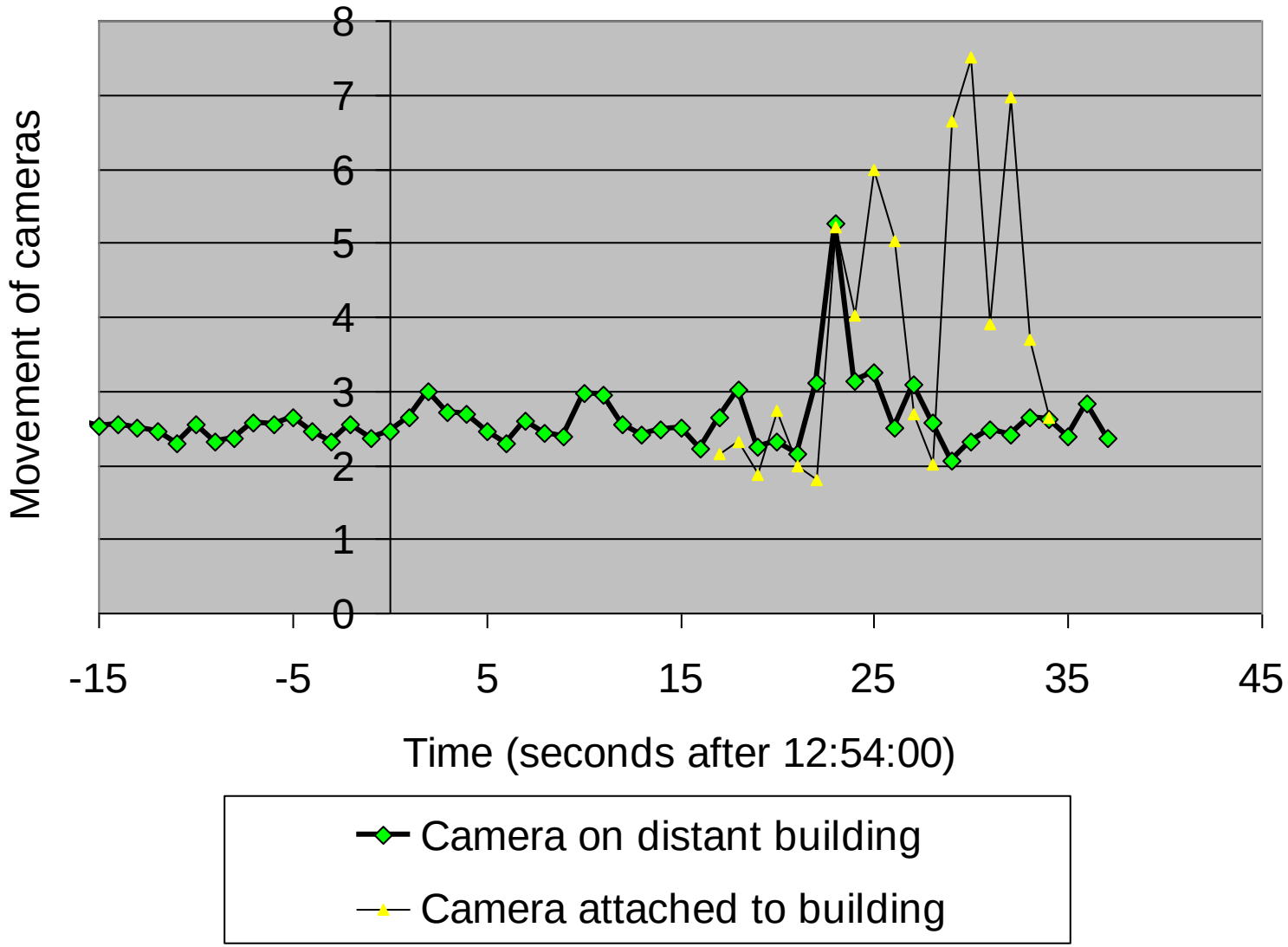

30 seconds after the first explosion

110 seconds after fire alarm

12:54:50

A rapidly developing fire forces smoke out of the open shutter at the West end of the warehouse

12:54:51

Which blows in front of Camera 2

Venting early in the fire (after the first explosion)

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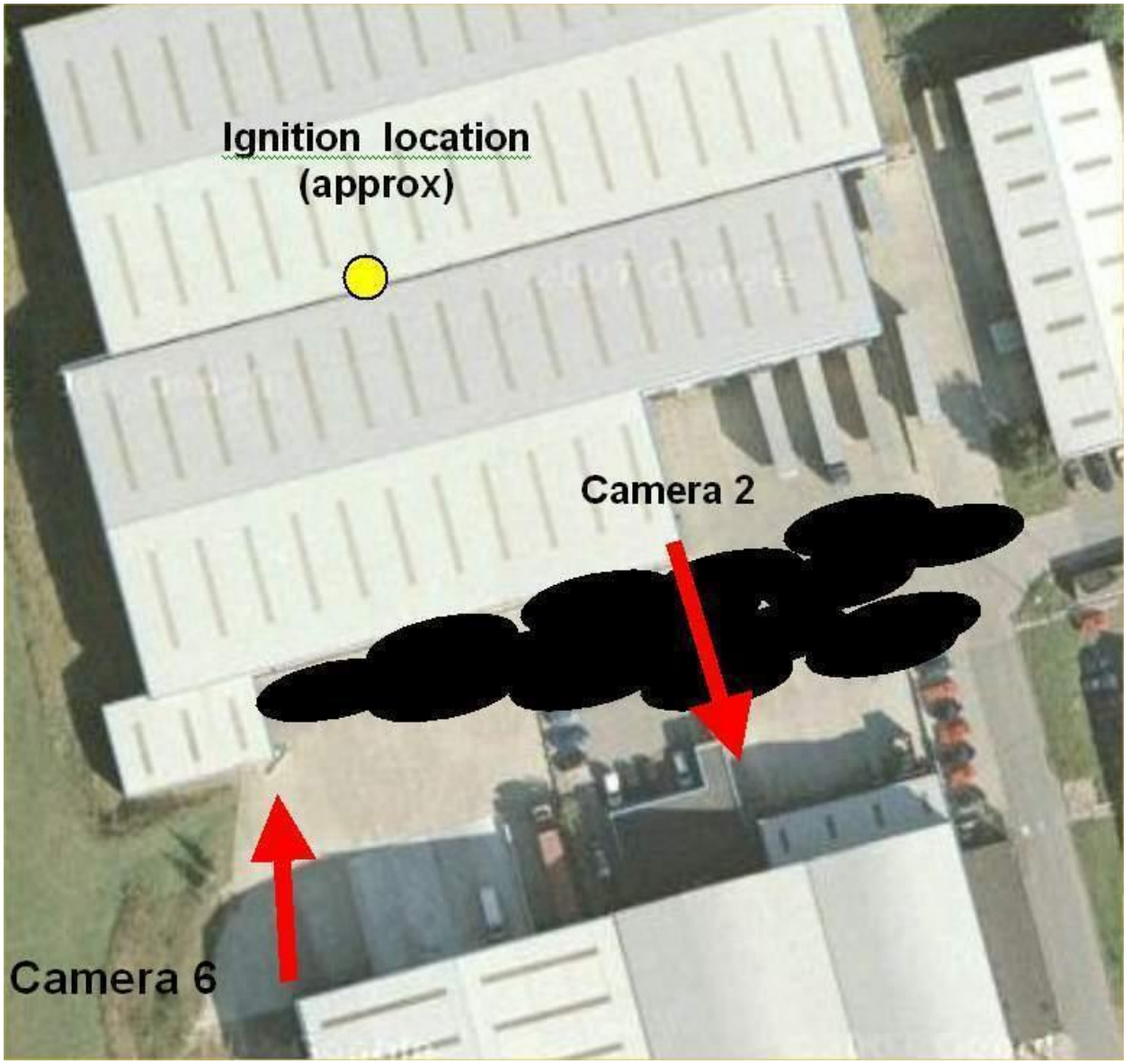


Approx 55 seconds after the first explosion

135 seconds after fire alarm

12:55:17

A rapidly developing fire forces smoke out of the open shutter at the West end of the warehouse

12:55:16

Which blows in front of Camera 2

Approx 150 seconds after the fire alarm – A second larger explosion

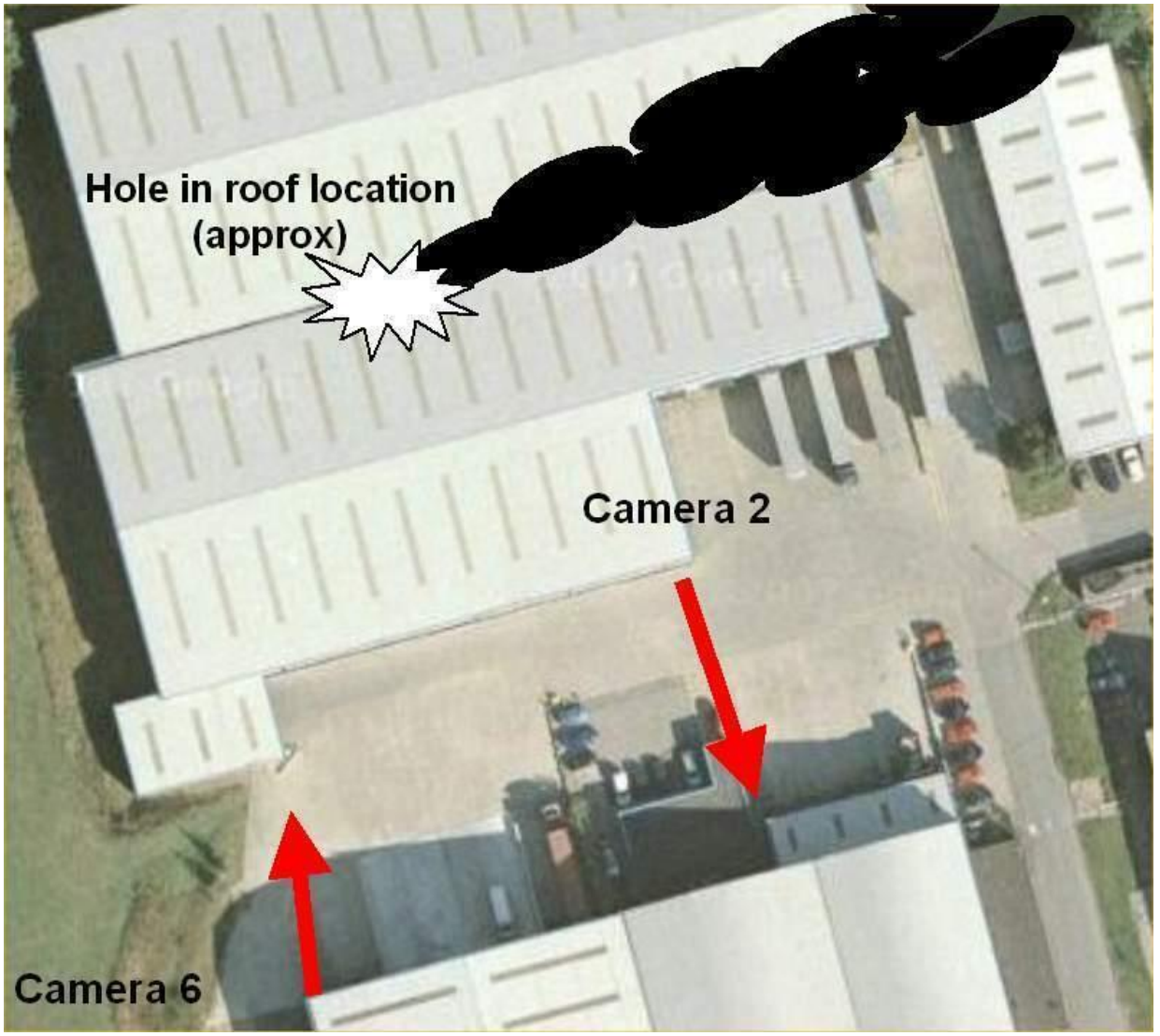
12:55:37

A large hole in blown in the roof cladding and smoke clears around other vents

12:55:57

The view of cameras attached to the building is permanently shifted

Venting after second explosion



Overturned section of roof cladding

(above the area where the fire started)

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Overturned section of roof cladding

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Summary of approximate time-line

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-1 (?) minute	Ignition
0	Operation of the fire alarm
40 seconds	Last witnesses leave
80 seconds	First explosion – very rapid fire escalation
110 seconds	Building smoke-logged to low level
150 seconds	Second explosion – portion of roof blown off

Safety Planning and analysis prior to the incident

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- Fire modelling with CFAST (ultra-fast fire growth assumed)

- Calculated time available (for escape) before smoke logging **350 seconds.**

- No need for special attention to escape from mobile access platforms (scissor lifts) which were in routine use.

Safety lessons

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- Unprotected fork lift trucks are potent sources of ignition
- There are numerous potential ignition scenarios:
  Collisions, loose aerosols on the floor, leaks, repacking faults
- The rate of fire growth and smoke–logging is extremely rapid.
  As a rule of thumb everyone needs to be out in 100 seconds.
- Mass explosions occur very quickly: these are capable structural effects and can trigger almost instantaneous increases in burning area
- Results from conventional zone-modelling should be treated with great caution.
- In some circumstances there maybe potential for a very severe mass explosion - large enough to affect property nearby.

Research priorities – Vapour cloud formation

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Examples of important release scenarios:

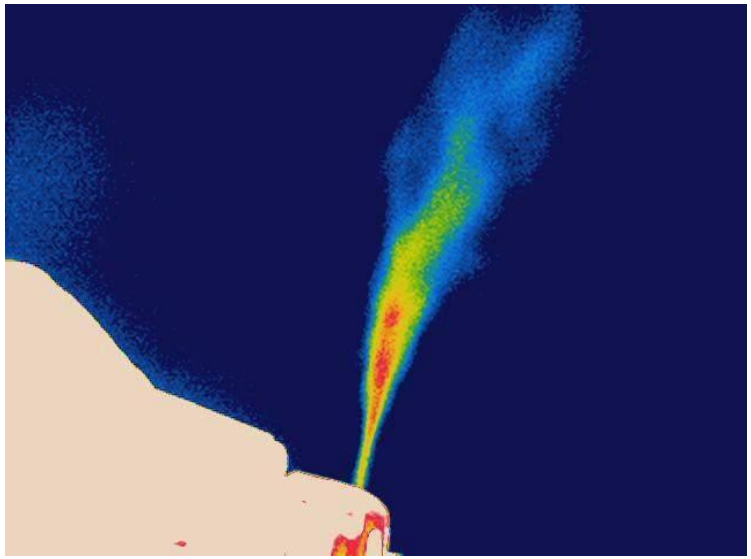
•Can puncture

•Can run-over

•Leaking can in shrink/stretch wrapped pallet. Piercing of the wrapping.

•Dropped pallet

•Speared pallet



IR cameras tuned to hydrocarbon spectral frequencies provide a powerful means to follow the cloud and identify which parts are flammable.

Videos would be valuable for training. And in the choice/design of FLTs

Understanding why mass explosions occur

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Conventional fuels

Wood

Card

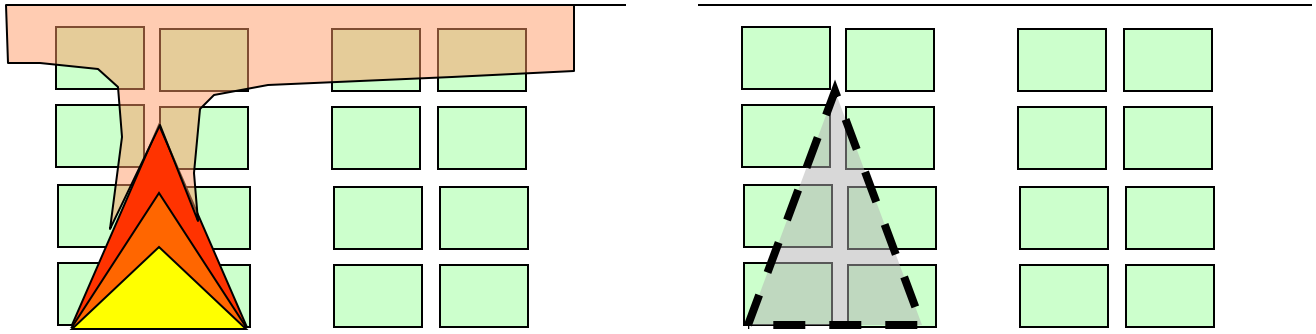
Plastic

Production of fuel vapours at above about 320°C

Aerosol cans

Failures above about 80°C

Understanding why mass explosions occur



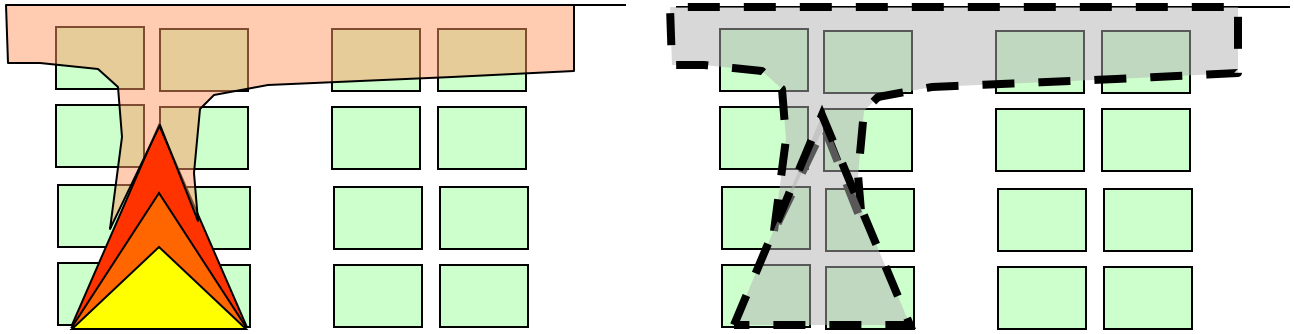
Conventional fire

Cardboard

Wood

Plastic

Area producing fuel vapours >320°C



Aerosol fire

Area producing fuel vapours >80°C

How could aerosols fuel ultra rapid fire development?

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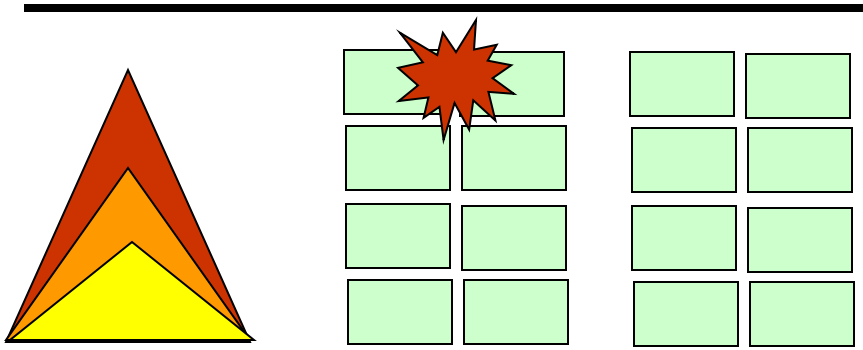
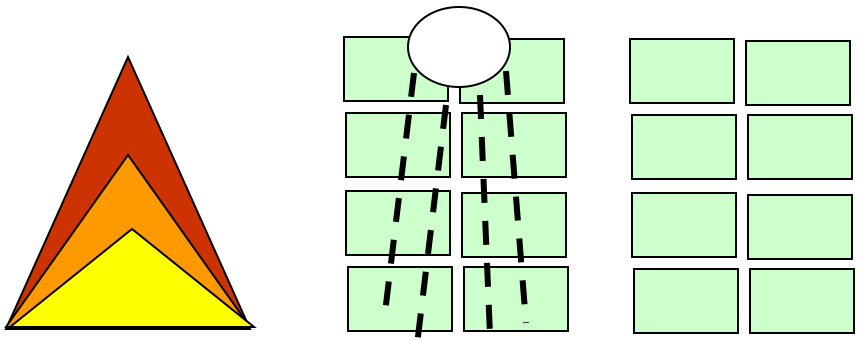
Immediate ignition



Fire is transitory and effects a small area at high level

Delayed ignition



Liquid spray from bursting aerosols rains out affecting lower levels

Understanding why mass explosions occur

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Conventional fuels

•Volatiles are usually only produced where there is a flame

•If the temperature is high enough to drive off volatiles there will not be enough oxygen left to form an explosible mixture

Aerosols

•Flammable liquids and gases can be released at some distance from the flames.

•Liquids may rain out at some distance from the fire

•The mixture of hot air and released fuels flowing away from the fire can be explosible.

Research priorities

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Test data required

What is the response to pallets of aerosols to engulfment in gas in the temperature range 100-300°C?

What is the rate of can failure?

How stable are pallets? Are there sympathetic failures?

How much liquid rains out?

Follow on analysis

How would released liquids affect on-going fire development?

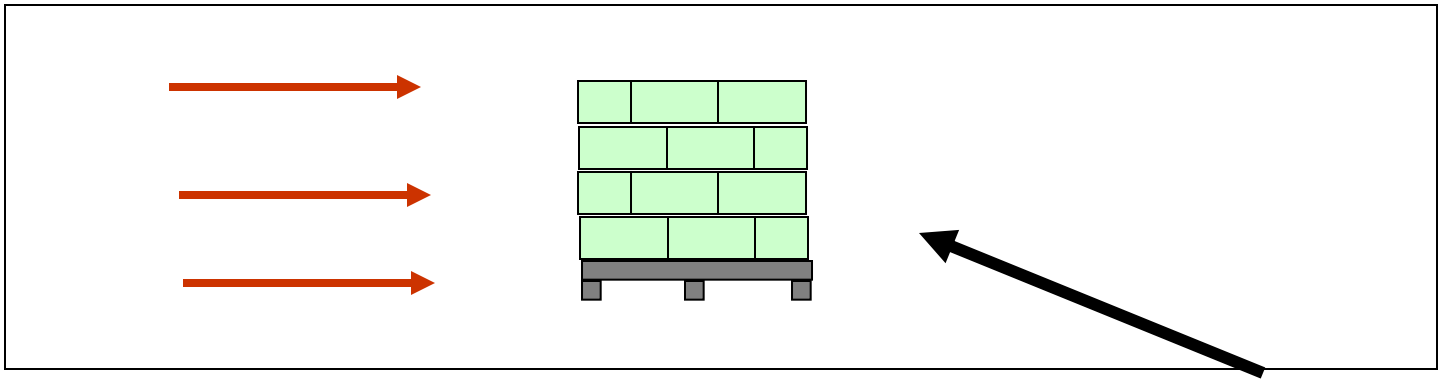
What gas concentrations would occur in the ceiling?

What areas of the warehouse could become filled with explosible gas?

What would be the consequences of explosions?

How effective would sprinklers be in mitigation?

Schematic of test arrangement



Hot gas flow

Pallet or half-pallet scale sample

Pallet response:

Video/IR video

Gas analysis

Mass loss

Thermocouple arrays

The rate of can failure is critical

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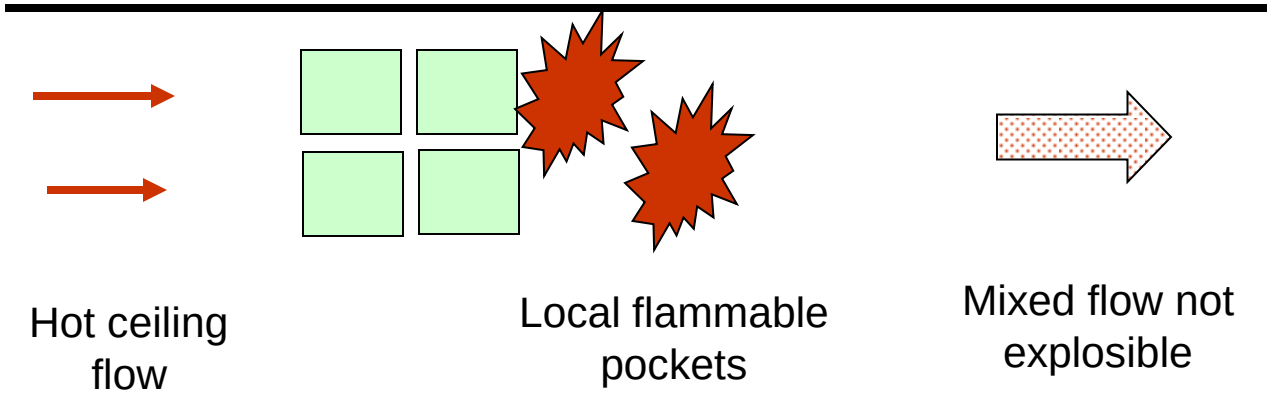
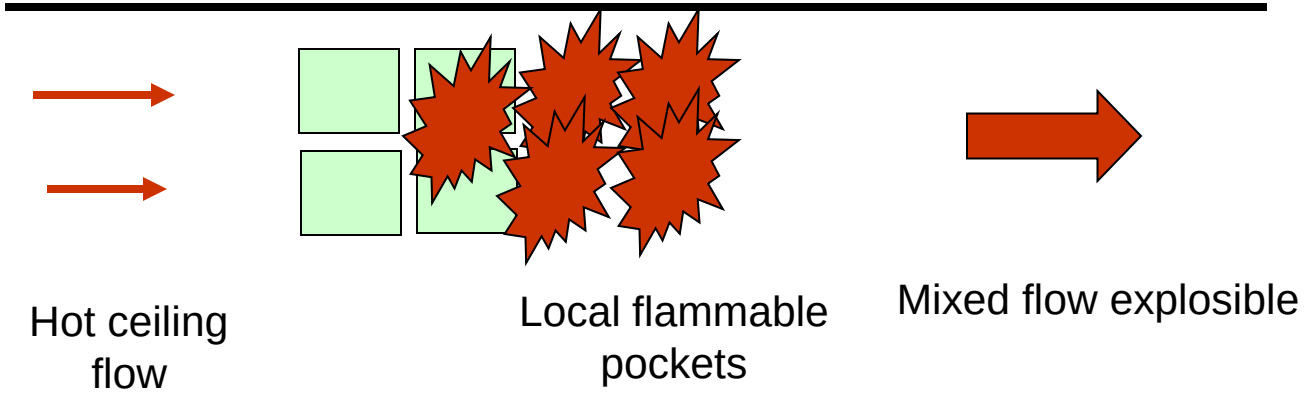
Low rate of can failure



High rate of can failure



Summary

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- Unprotected forklift trucks are a serious risk in aerosol stores
- Fire growth in aerosol stores can be extremely high
- Even in large buildings escape times can be as low as 100 seconds
- Mass explosions can occur in aerosol fires – causing structural effects and rapid fire escalation
- The severity of explosions depends on the type and layout of products.
- Generally occupiers are not aware of any of the above - and have an incorrect view of the level of risk
- Research on gas cloud formation would be valuable in FLT choice and operator training

- Sprinklers may provide valuable reductions in risk
- Research on the behaviour of palletised aerosols in hot gas flows is needed