OIL & GAS

Vapour Cloud Explosions - How the Buncefield and Jaipur Incidents Changed our Understanding

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Overview

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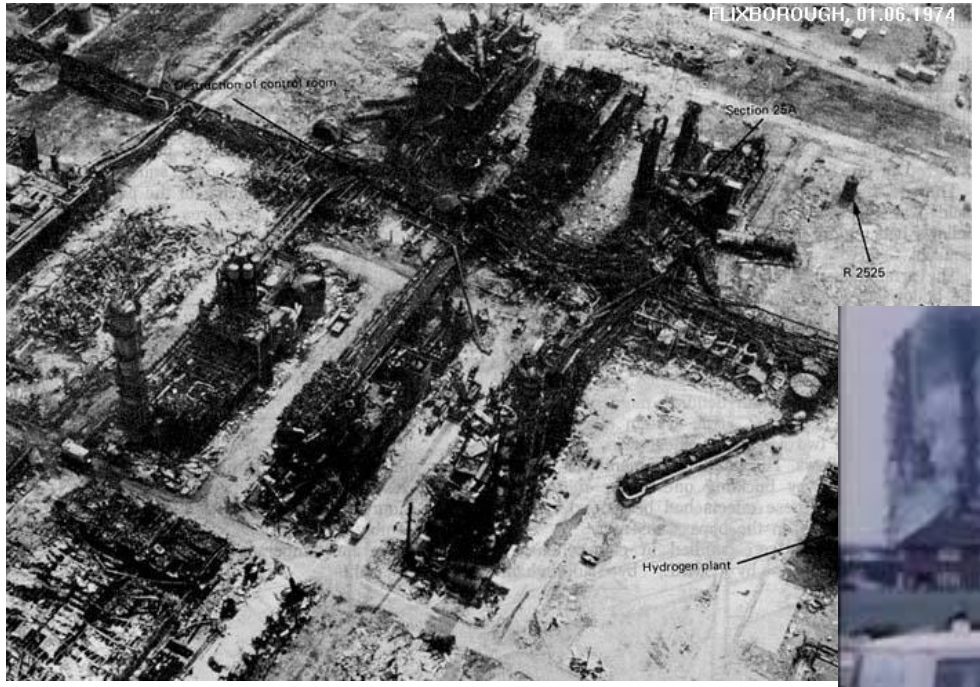
- Background on early research
- Accepted assessment methodology
- Buncefield and Jaipur incidents
- Implications

‘Unconfined’ Vapour Cloud Explosions

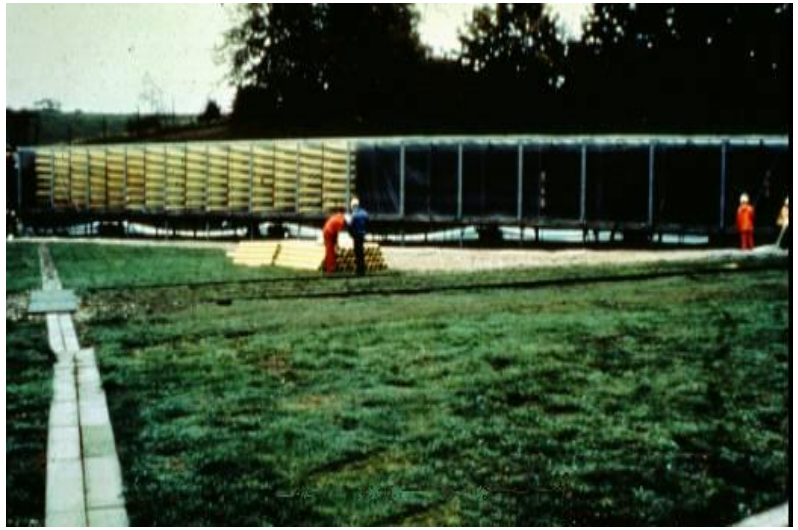
- Major explosions in the 2nd half of the 20th century where the gas/vapour cloud was not confined
- No understanding of the cause of damaging pressures
- A key incident for the UK was in Flixborough in 1974

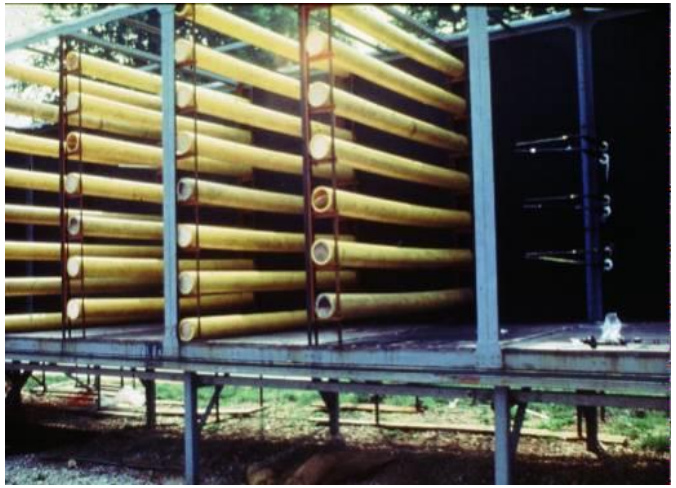


Effect of Process Congestion

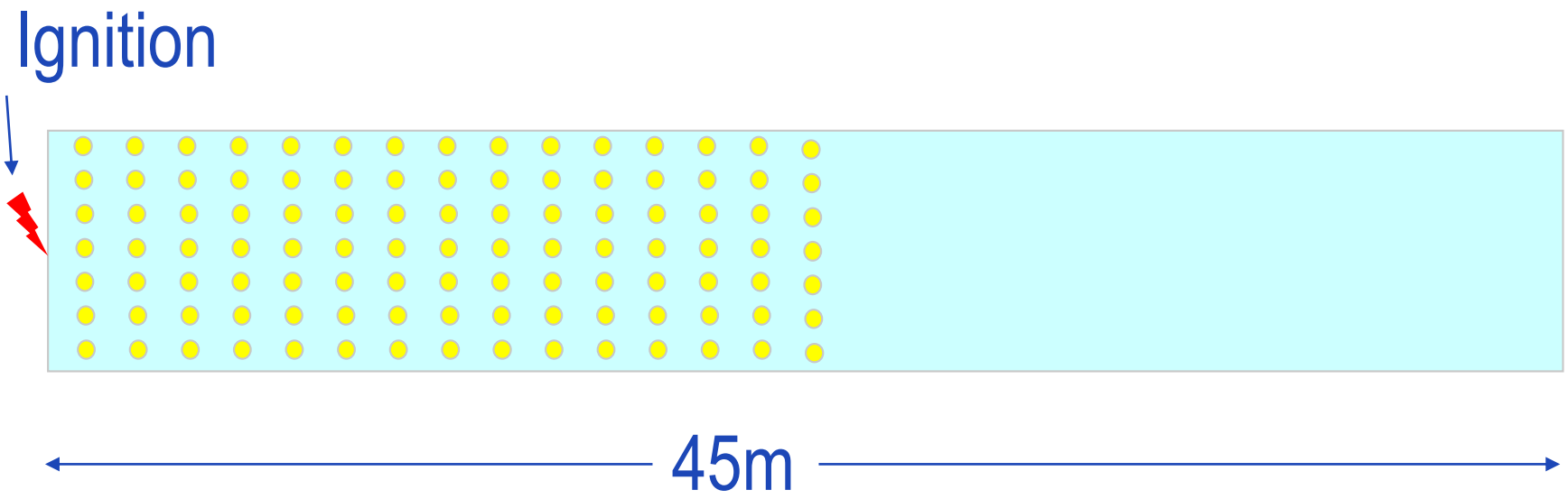
- One characteristic was that clouds usually engulfed congested process areas

- Research examined the effect of pipework in the gas cloud
  - Conducted ~1980-1986
  - No computer models
  - Simple regular obstacle arrangement
  - Parameter variations easily specified



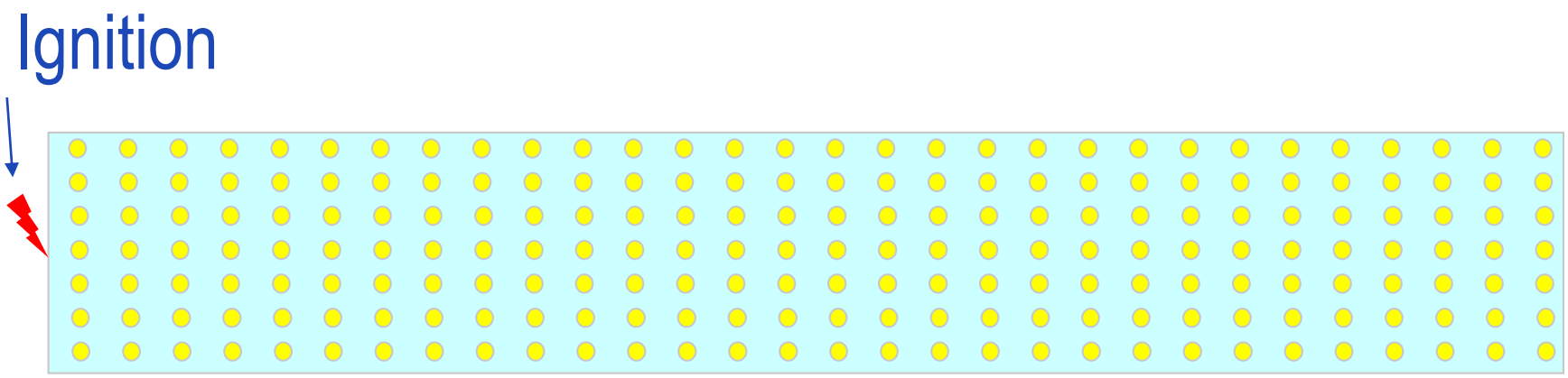


Experimental Arrangement



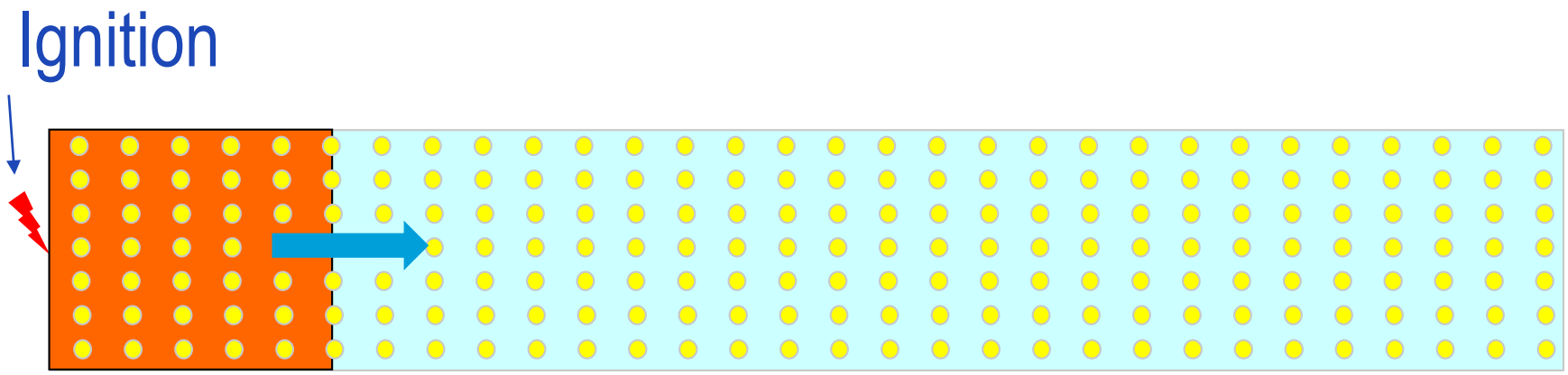
Natural Gas – Half full of Pipes

Extended Pipework Region



Cyclohexane – Full Pipes

Natural Gas with Initial Confinement

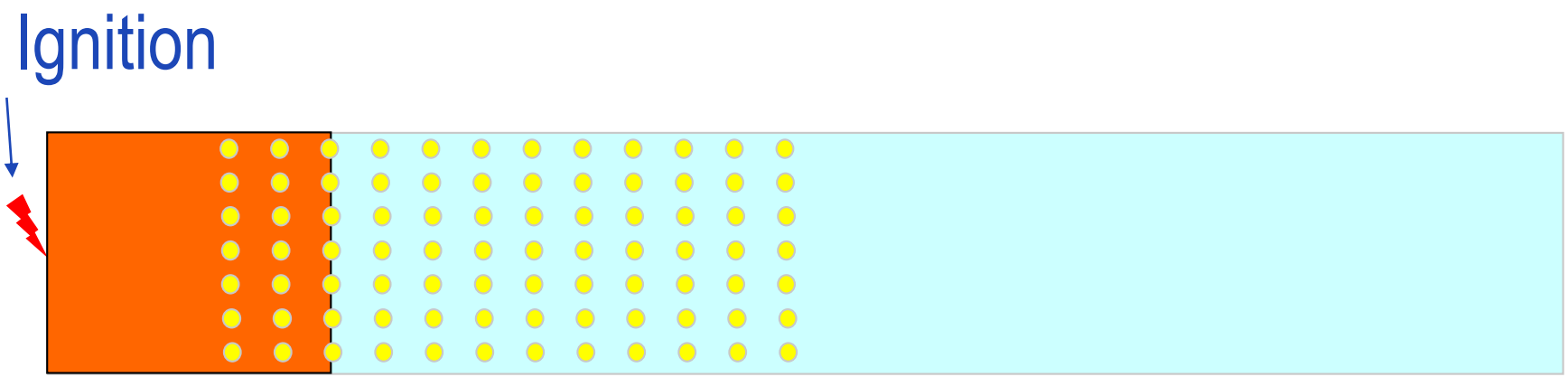


Maximises flow through pipes giving rapid flame acceleration

Natural Gas – With Initial Confinement

Confinement and Congestion

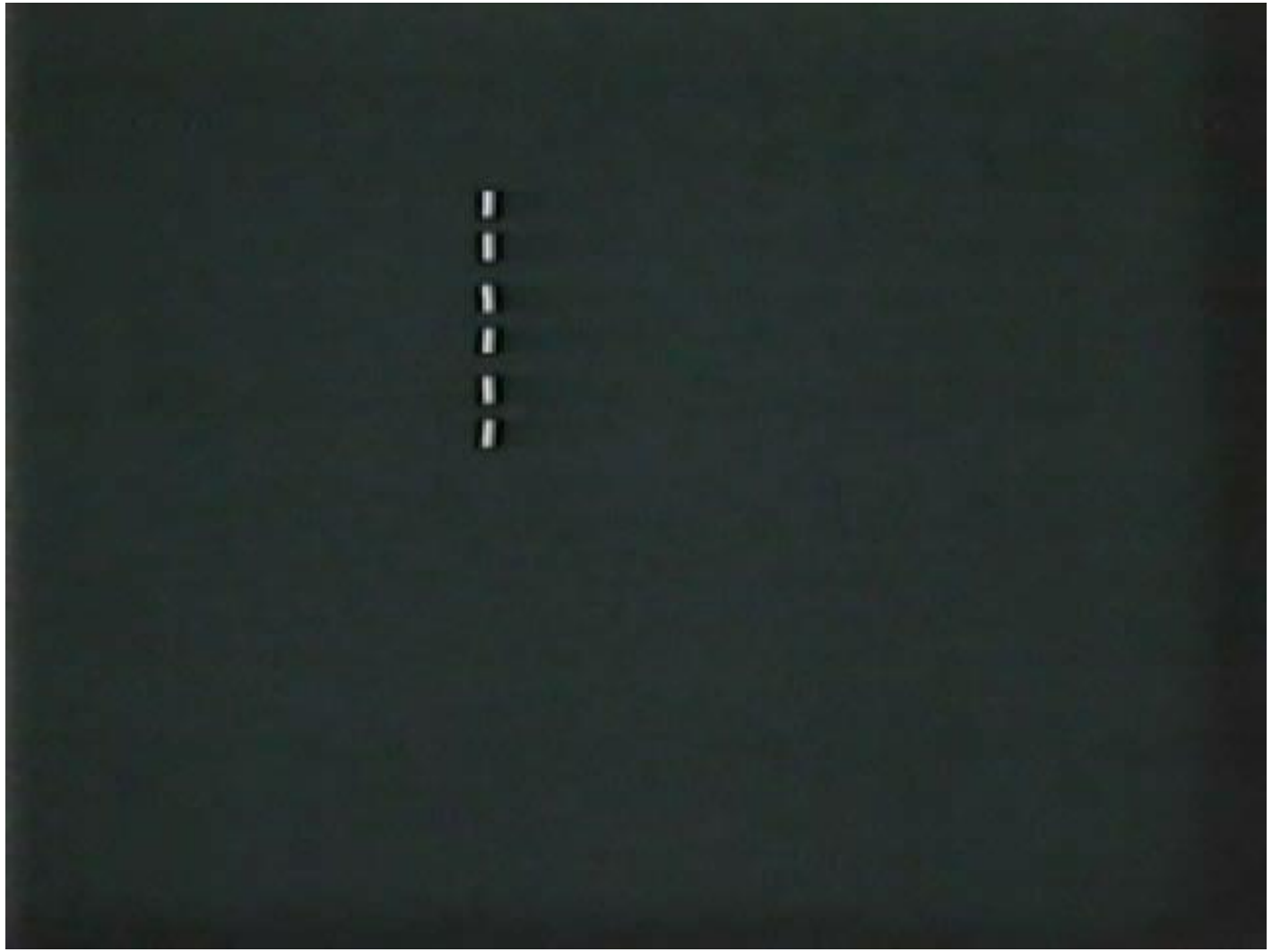
Cyclohexane and Propane



Cyclohexane

Slow Motion

- Deflagration to Detonation Transition (DDT)
  - Flame speed ~Mach 2
- Detonation sustained through remainder of cloud
  - 1.8 km/s (~Mach 5.5)



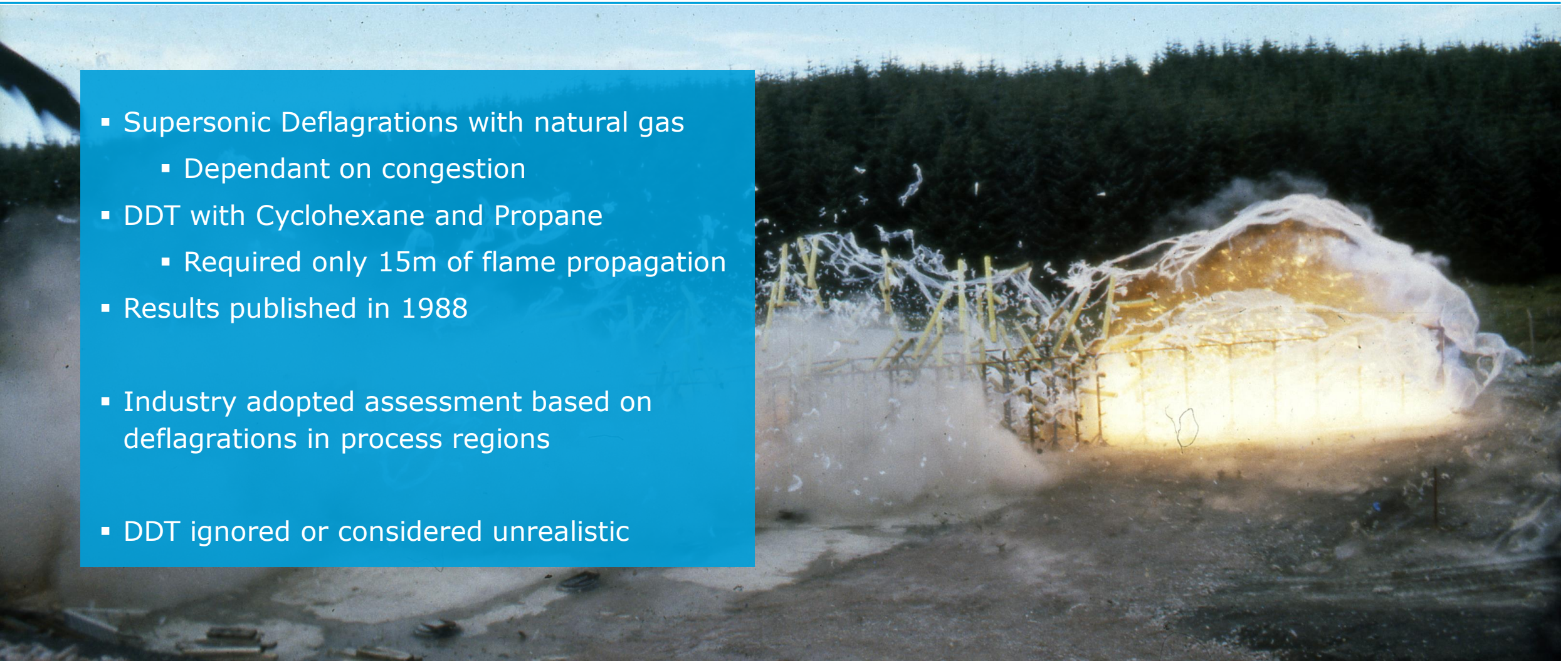
Deflagration to Detonation Transition

Summary – Late 20th Century

- Supersonic Deflagrations with natural gas
  - Dependant on congestion
- DDT with Cyclohexane and Propane
  - Required only 15m of flame propagation
- Results published in 1988

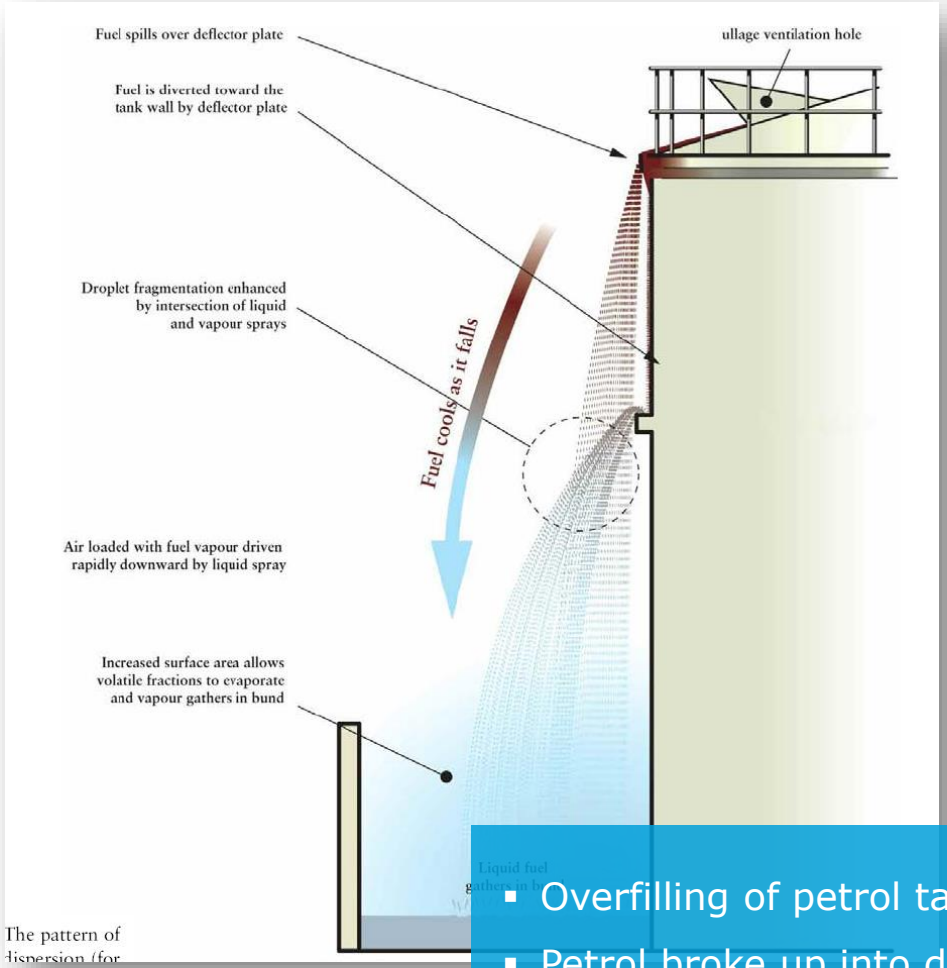
- Industry adopted assessment based on deflagrations in process regions

- DDT ignored or considered unrealistic



Buncefield – December 2005

Vapour Cloud



- Overfilling of petrol tank in calm conditions
- Petrol broke up into droplets as it fell from tank roof, generating vapour
- Vapour cloud extended offsite

Jaipur – October 2009

- 1000Te of petrol spilled as a ‘geyser’ from the tank outlet pipe
- Break-up of liquid into droplets enhanced vapour generation
- In calm conditions, vapour cloud spread to cover most of the site (an area 3 times that of the Buncefield cloud)

Characteristics of Buncefield and Jaipur Incidents

- Very little process congestion on sites
- Dense vapour cloud covering large area
- Widespread severe blast damage through most of the vapour cloud
- Does this indicate a detonation of the cloud?
- More on pressure damage from Bassam Burgan tomorrow

Directional Indicators

- Observed throughout clouds in Buncefield and Jaipur incidents
  - Bent or leaning lampposts
  - Trees scorched on one side
  - Branches on trees snapped and bent over in one direction
  - Scoured paintwork on one side of posts

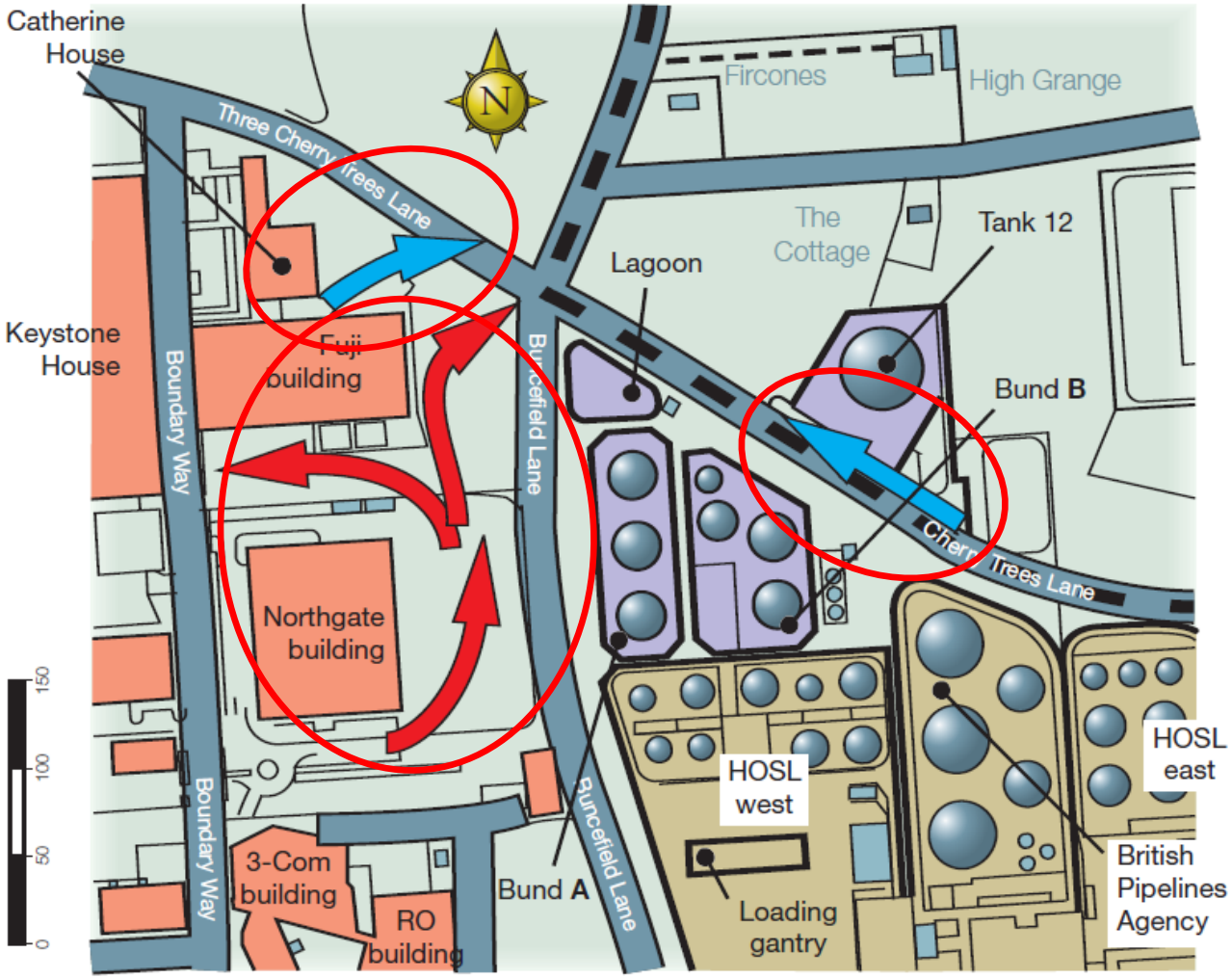





Initial Investigation

- Early Buncefield report gave initial assessment of the directional indicators
- Suggested <u>three</u> explosion events!! (Indicated by the red and blue arrows)

Assumed direction of explosion

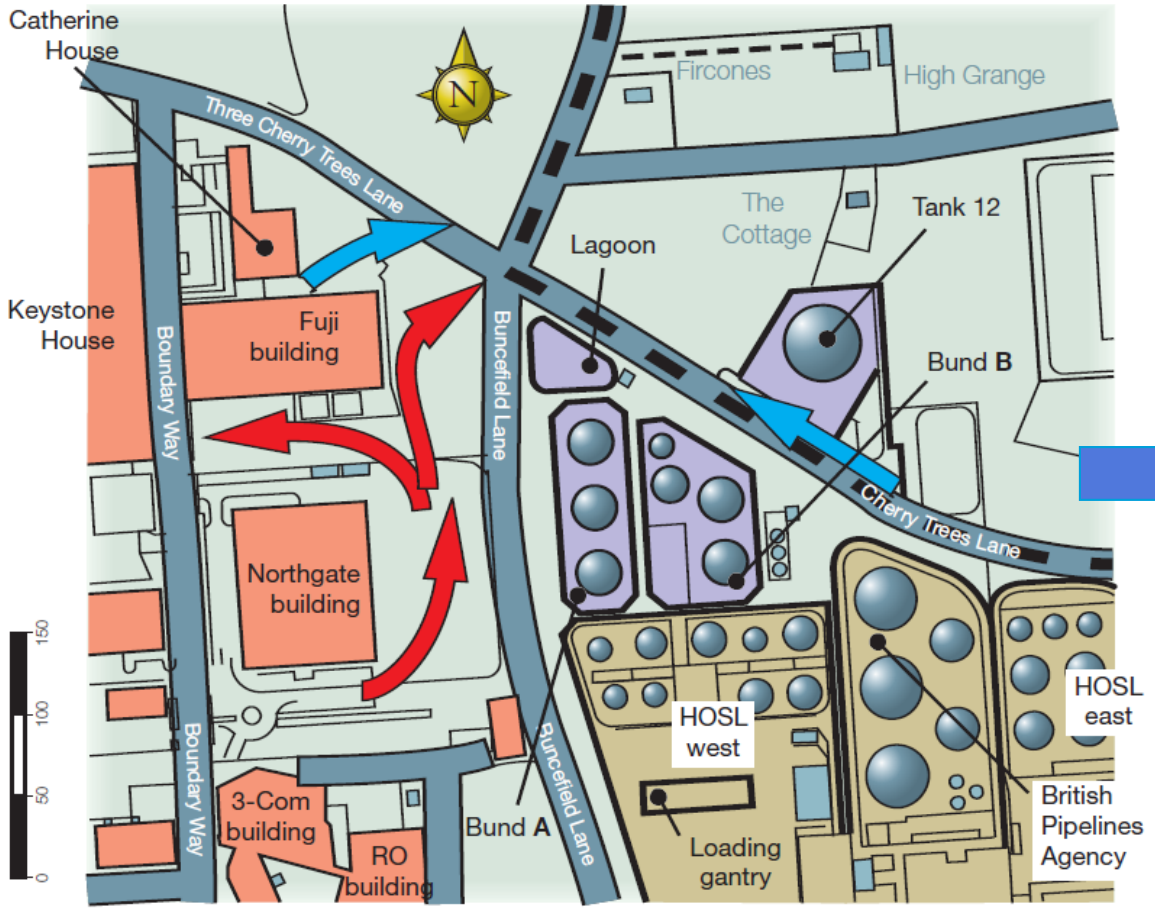


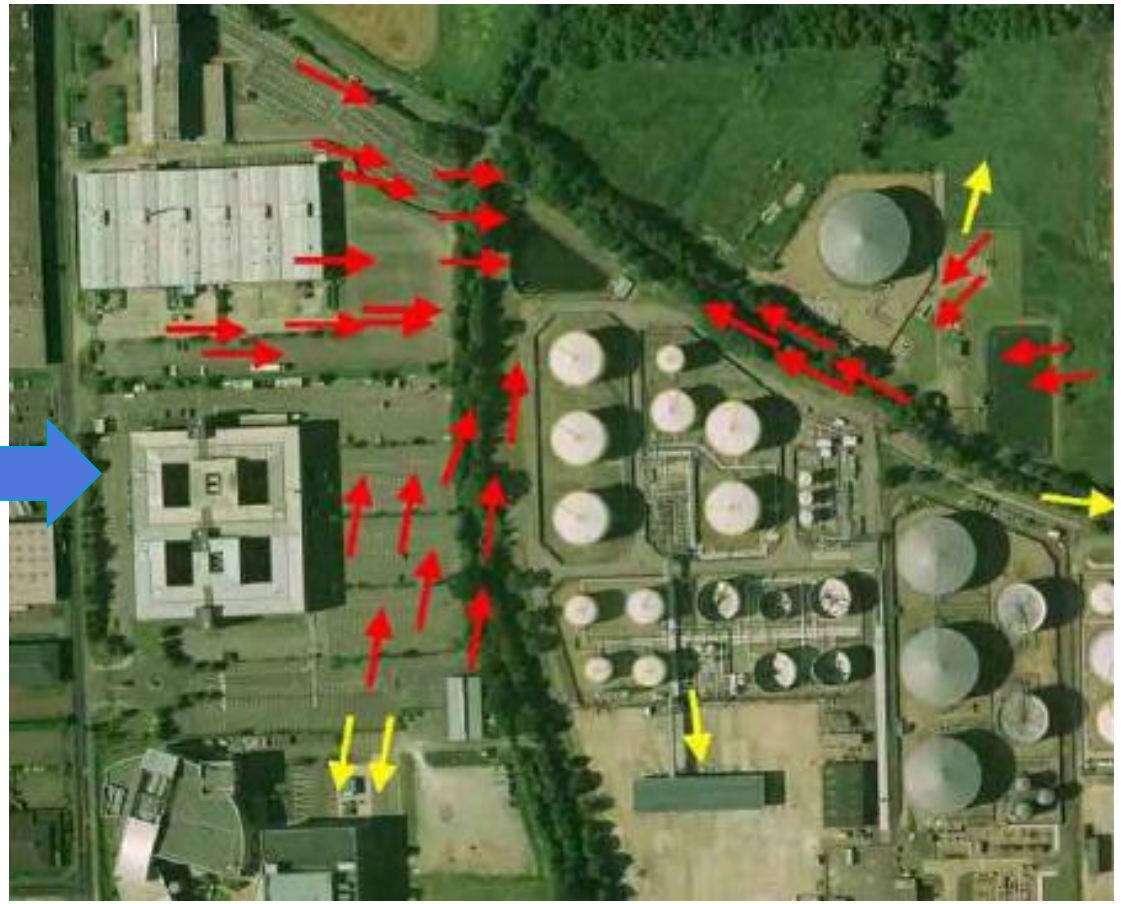
Directional Indicators

- Experimental work showed significant reverse flow
- Modelling confirmed net force in reverse direction

Re-interpret as opposite direction of explosion

Directional Indicators - Buncefield



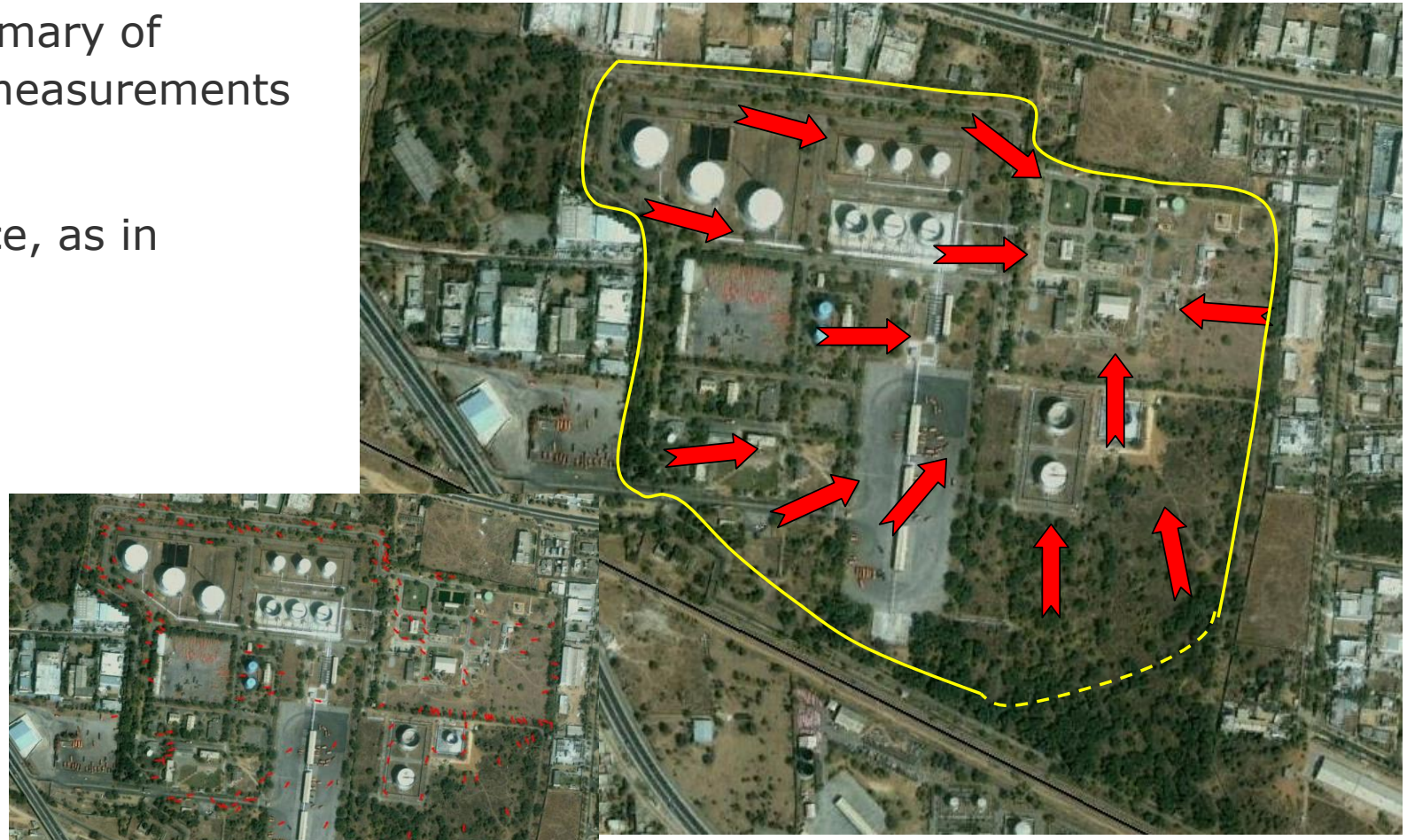


Red inside cloud, Yellow outside cloud

Red arrows point to location of DDT

Directional Indicators - Jaipur

- Large red arrows show summary of many directional indicator measurements
- Point towards a single source, as in Buncefield
- Indicates location of DDT



Other Vapour Cloud Explosion Incidents

- Recent publication of a review of VCE incidents*
- Evidence consistent with DDT in most major VCEs
  - Pressure damage
  - Directional indicators

** G. Chamberlain, E. Oran, A. Pekalski, Detonations in industrial vapour cloud explosions, Journal of Loss Prevention in the Process Industries, Volume 62, November 2019, 103918*

So is this Very Bad News?

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- First reaction can be '*I can't design against for a 20bar detonation pressure*'
- So it looks like very bad news

- However, current good practice will minimise the risk:
  - Prevention or minimising release or spill is even more important
  - Separation of occupied buildings from process area (minimises effect on design strength)
  - Reducing potential for flame acceleration
  - Maintaining safety critical systems to original design intent

- In the end, this is reality, we need to deal with it

Summary

- All the elements of the Buncefield and Jaipur VCEs were understood before the events
- VCE assessment methods avoided this 'uncomfortable truth'
- What has changed is our willingness to accept DDT as a reality in VCE incidents

Thank you

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