Building A Better Fire Department

FRI 2007

Case Studies in Extreme Fire Behavior

12-Minutes
On the Fireground

CFBT-US

Not just what and how, but why!

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Ed Hartin, MS, EFO, MIFireE, CFO is a Battalion Chief with Gresham Fire and Emergency Services in Gresham, Oregon and the owner of CFBT-US, LLC a fire service training company specializing in the area of structural fire behavior. Ed has a longstanding interest in fire behavior and has traveled internationally, studying fire behavior and firefighting best practices in Sweden, the UK, and Australia. Ed co-authored *3D Firefighting: Techniques, Tips, and Tactics* a text on compartment fire behavior and firefighting operations published by Fire Protection Publications and has published articles in a number of fire service publications in the US and UK. Ed has also delivered training in compartment fire behavior (CFBT) and tactical ventilation throughout the US as well as in Australia, and Malaysia. The International Association of Fire Chiefs (IAFC) at its 2006 Annual Conference recognized Gresham Fire and Emergency Services compartment fire behavior training (CFBT) program as a finalist for an Award of Excellence.

Ed is a graduate of the National Fire Academy Executive Fire Officer Program and was awarded Member grade in by the Institution of Fire Engineers and Chief Fire Officer Designation by the Commission on Fire Accreditation International.

Ed holds a BS in Fire Service Administration and Master of Science degree in Education. He is currently a doctoral candidate at the Portland State University Graduate School of Education. His research is focused on firefighters beliefs about knowledge and learning with an emphasis on how these beliefs influence the way in which firefighters learn from their experience. Ed will be presenting preliminary results of this research at RE07, the British Fire Service College annual research symposium which will be held in November 2007.

Introduction

Firefighter safety during firefighting operations has seen minimal improvement over the last 30 years despite significant technological advances in personal protective equipment. The average number of fatalities occurring on an annual basis has decreased, but so has the number of structure fires. Equally disturbing has been the increasing rate of fatalities at structure fires as a result of traumatic injury. In a National Fire Protection Association (NFPA) study of firefighter fatalities in structure fires, Fahy (2002) observes that "the death rates for the three major causes of fatal injuries to firefighters while operating inside structure fires [lost inside, structural collapse, and fire progress] have been rising" (p. 10). This same study points to a lack of experience as a potential cause of fireground fatalities due to traumatic injury resulting from rapid fire progress or collapse.

Figure 1. Structural Firefighting Operations

Photo by Jack Hana

Analysis of incidents involving rapid fire progress during both structural firefighting and live fire training points to a lack of understanding about fire behavior and the impact of tactical operations (Grimwood, Hartin, Raffel, & McDonough, 2005). There are a number of approaches to developing this understanding and the adaptive expertise necessary to apply this knowledge under dynamic fireground conditions. Use of case studies is one effective method. Joung, Hesketh, and Neal (2006) report that use of case studies illustrating unsuccessful decision making on the fireground were more effective in developing adaptive performance than study of cases where no errors were made. This research supports the concept of using near miss and firefighter fatality incident reports as a training tool.

Case Study Method

What is a case study? Cases are not simply narratives for entertainment. They are stories with an educational message. Each of the case studies in this article is based on an actual incident where Firefighters were injured or killed by rapid fire development or other extreme fire behavior. The purpose of these cases is not to lay blame or simply identify the mistakes of others; it is to develop an improved understanding of structural fire behavior.

How should you approach learning through the use of case studies? Read the questions to be answered first, this provides you with a framework for understanding the information presented. Second, read the case to get an overall understanding of the incident. Last, examine the incident in detail to answer the questions posed at the start of the case.

One excellent source for case studies are reports prepared by the National Institute for Occupational Safety and Health (NIOSH) on firefighter fatalities. Particularly when fire behavior was a significant factor, the National Institute for Standards and Technology (NIST) Building and Fire Research Laboratory also prepares reports including fire test and modeling data. When using case studies as an element of fire behavior training, the following questions serve as a good starting point for your analysis:

1. Was extreme fire behavior involved in this incident? If so, what type of event happened?

   Look at the reported conditions and observations of individuals involved in the incident. Was this a flashover, backdraft, or smoke explosion? Recognize that it may be difficult to determine based on limited information. If available, NIST fire test and modeling data can shed a great deal of light on the nature of extreme fire behavior phenomena.

2. How did the fire develop and what factors influenced the occurrence of the extreme fire behavior phenomenon?

   As with the question of what happened, this question is complex. Many factors influence fire development and extreme fire behavior phenomena. Think about building factors such as fuel type, fuel load, and ventilation profile, changes in ventilation profile (may be caused by the fire or human action) and actions of firefighting forces.

3. What cues were present that may have indicated potential for rapid fire development?

   Frequently there is limited information on exactly what was observed (particularly by the individuals most impacted by the incident). However, in some cases critical fire behavior indicators are mentioned and/or photographs of incident conditions are included in the reports.

4. Compare and contrast the case study with other cases or events in your own experience. What aspects of these incidents were similar? Which were different?

   Building your knowledge base using case studies is enhanced by integrating this information with your existing knowledge of fire behavior. Often discussion of a case with others results in sharing of personal experience. Expand this discussion beyond simple "war stories" to consider commonalities and differences.

Case Study 1: Keokuk, Iowa

This incident involved an early morning fire in a two-story, wood frame duplex that resulted in the deaths of three children and three firefighters. The fire occurred in the unit on Side Bravo of the structure (See Figure 2). This building was originally constructed in the 1870s as a single family dwelling and divided into two dwelling units in the 1970s. This case study will focus on fire behavior related aspects of this incident. However, this case provides an opportunity to learn a number of other important lessons (see the NIOSH and NIST reports for additional information on the incident).

Figure 2. The fire building viewed from the Alpha/Bravo Corner.

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Photo by Cindy Iutzi (from NIOSH Report F2000-04)

Configuration: The unit involved in the fire had a kitchen, dining room, and living room on floor one and three bedrooms and a bathroom on floor two. Figures 3 and 4 show plan view of the first and second floor of the involved unit. A wall separated the first floor hallway and stairs to the second floor from the rooms on floor 1. There was a door leading from the floor one hallway into the living room (this door was open at the time of the fire). In addition, there was a door from the floor one hallway to the dining room (this door was closed at the time of the fire).

Fuel Profile: Contents were typical of a residential structure and included ordinary kitchen, dining, and living room furniture. Ceilings were covered with combustible wood fiber ceiling tile with the exception of the dining room, which had the original plaster and lath ceiling. Interior walls were covered with gypsum board. However, the walls of the first and second floor hallways, stairwell and bedrooms two and three (see Figures 3 and 4) were covered with wood paneling.

Ventilation Profile: At the time of ignition, there were no ventilation openings. The only air movement would have been due to normal building ventilation and leakage. Prior to the arrival of the fire department a building occupant opened a window in bedroom one on floor two (see figure 4). The front door was opened approximately two minutes after the fire department arrived on scene. The window in the kitchen was composed of small panes with wood framing and failed over a period of time (starting approximately when the front door was opened).

Figure 3. Floor 1 Plan View

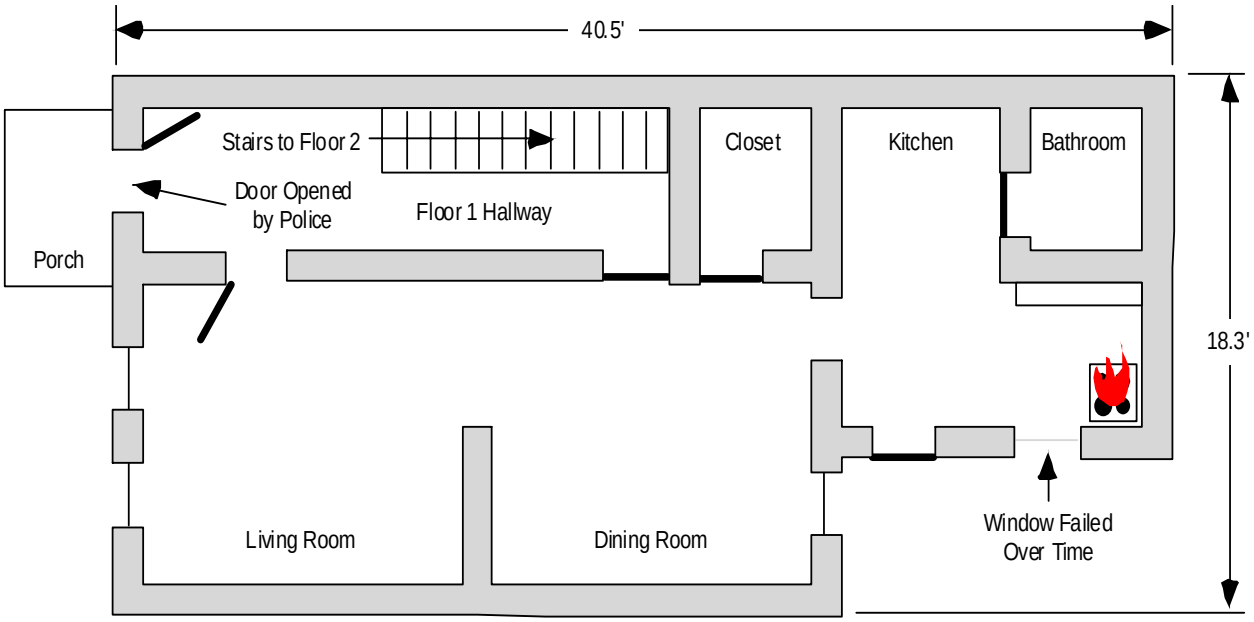
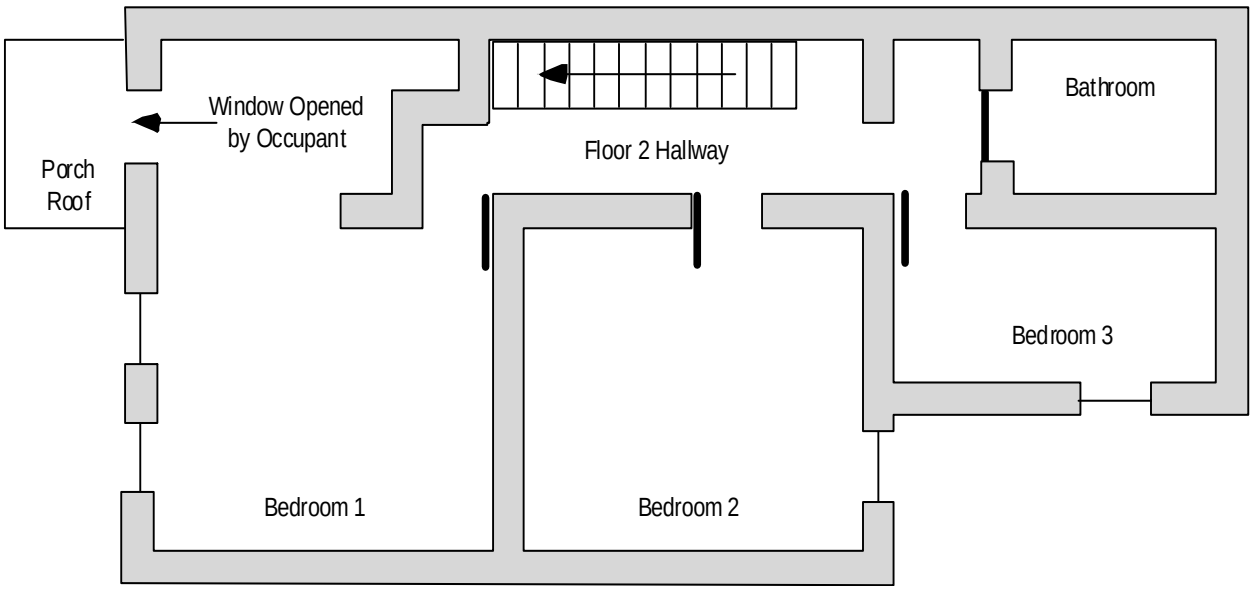


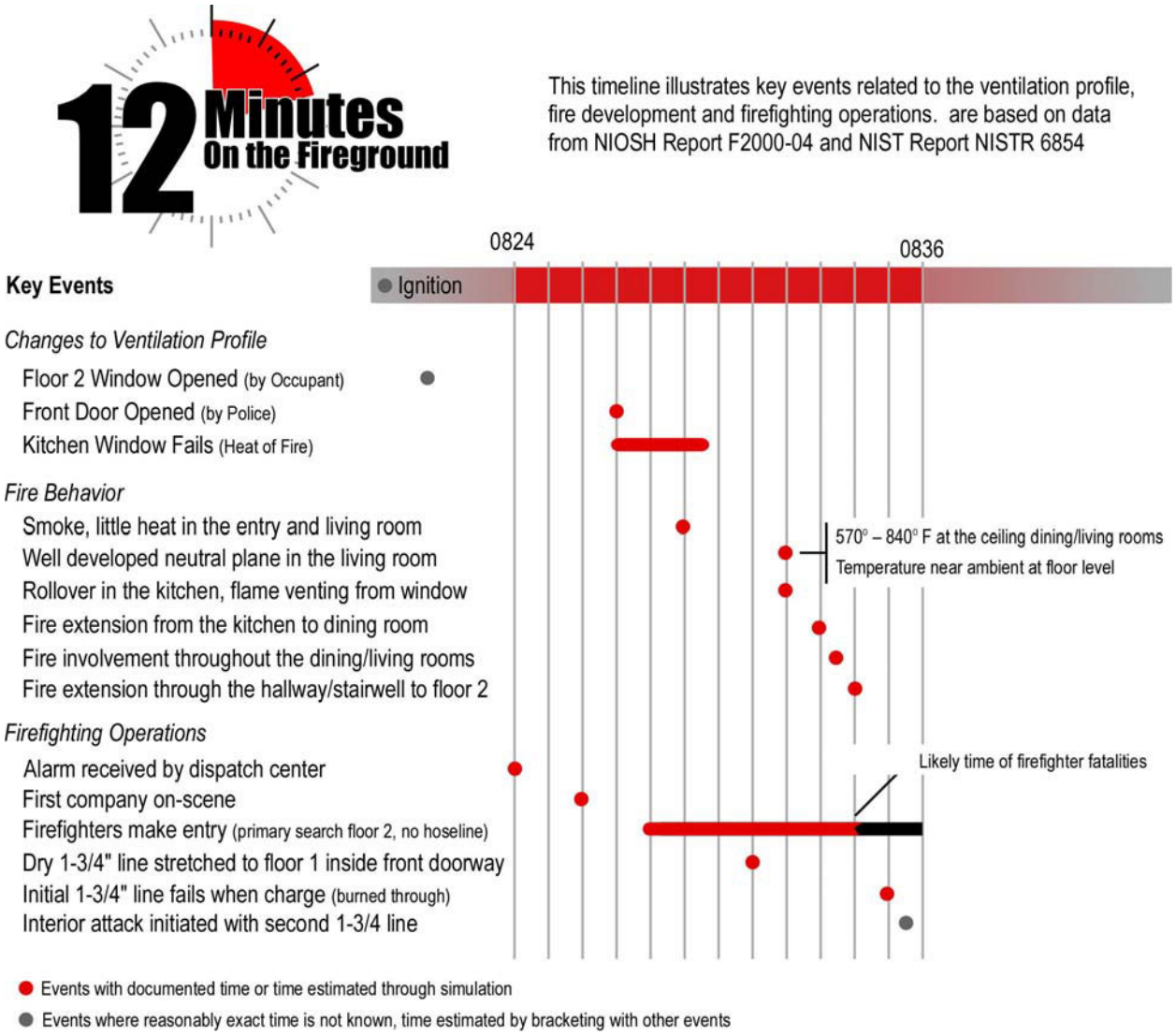
Figure 4. Floor 2 Plan View



Fire Development: The fire originated in plastic materials on top of the stove in the kitchen that was located on floor one of the dwelling. The exact time of ignition and the speed with which the fire may have progressed from incipient to growth stages is unknown. The fire extended from the burning material on top of the stove to interior finish of the kitchen. Firefighters observed that there was smoke, but "no heat" at the first floor level shortly after beginning primary search. While smoke began to spread through the structure shortly after ignition, fire did not extend beyond the kitchen until eight minutes after flaming ignition (estimated to be six minutes after the arrival of the first company). The NIST fire model of this incident is consistent with this observation, showing near ambient temperature at floor level with temperatures between 570^{o} F and 840^{o} F at the ceiling in the living and dining rooms. Between six and eight minutes after the first company arrived on scene, conditions changed radically, with fire rapidly extending sequentially in the kitchen, dining room, living room, floor one hallway and stairway to floor two. Figure 5 illustrates the 12 critical minutes from the time the alarm was received by the dispatch center until 10 minutes after the arrival of the first company.

Initial Tactical Operations: Initial response to this incident was a quint (two personnel), engine (three personnel) and chief. On the arrival of the first company firefighters observed a woman and child trapped on the porch roof and received a report of three children still inside the involved unit. Initial tactical operations involved rescue of the woman and child from the roof (performed by a police officer), primary search, and deployment of a (dry) hoseline to the entry way of the involved unit. Firefighting operations were not initiated until approximately nine minutes after arrival due to the commitment of resources to rescue, primary search, and care of injured occupants.

Figure 5. 12 Minutes on the Fireground



Fire Modeling

The NIST report includes output from computer modeling of this incident (this is also available from NIST on CD). This data provides another way to visualize fire conditions. Figure 6 illustrates temperature conditions at various levels within the structure at approximately 0832, six minutes after the arrival of the first company. Figure 7 illustrates conditions one minute later.

Figure 6. Thermal conditions at 0832

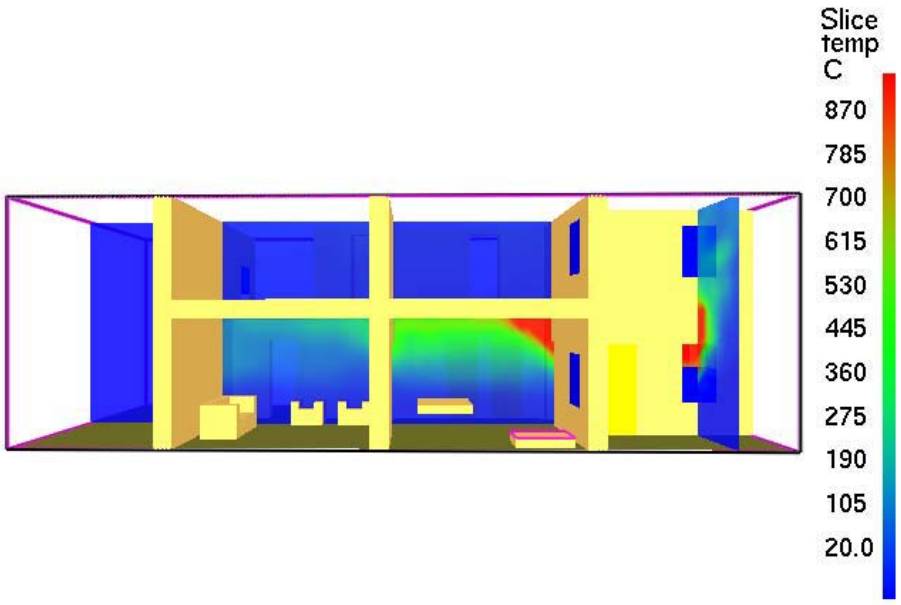
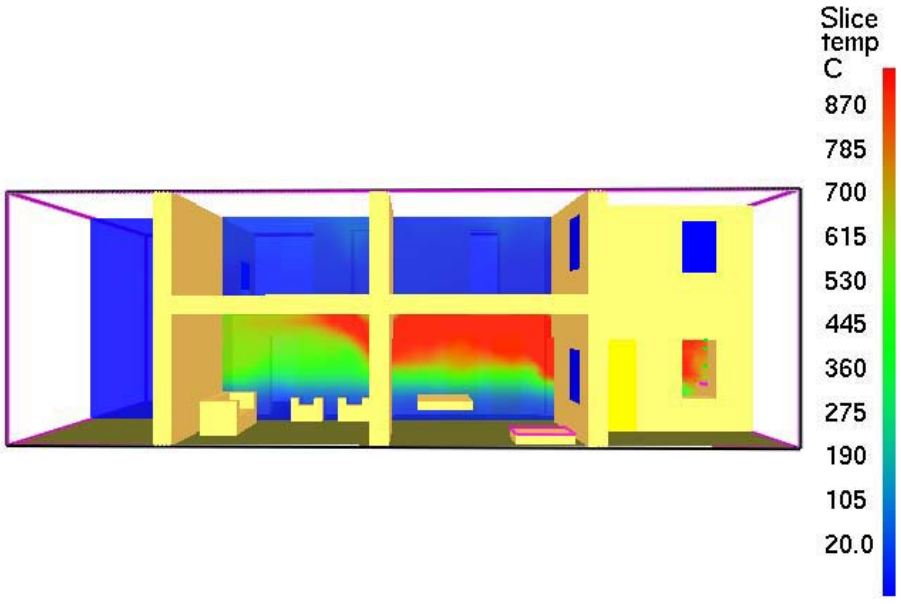


Figure 7. Thermal conditions at 0833



As illustrated by the NIST computer model, thermal conditions changed radically as the fire extended quickly from the kitchen through the dining and living rooms into the hallway and stairwell to floor two.

Case Study 2: Blaina, Wales (UK)

This incident involved an early morning fire in a two-story, mid-terraced house (townhouse). This fire resulted in the deaths of a child and two firefighters in Blaina, Gwent, in Wales (UK). Data for this case was obtained from the Fatal Accident Investigation report conducted by the British Fire Brigade Union (FBU, 1996) and analysis of the incident by Paul Grimwood (1998; personal communication February, 2006). In that this case is situated outside the United States, a brief explanation of deployment, resources, and tactics is likely in order. This area of Wales is served by retained duty (paid on call) firefighters operating from several fire stations each with a pump (engine company). Staffing varies, but on the morning of the incident the first arriving company, pump B031 (Blaina Station 3, Engine 1) was staffed with a sub-officer (Lieutenant), apparatus operator, and four firefighters. In the UK tactical operations are not unlike those used in the US (fire attack, primary search, etc.). However, 19 mm (3/4") and 25 mm (1") hosereels (booster lines) are commonly used for initial attack on contents fires. While deployment and tactical differences are interesting and a great starting point for discussion, don't be distracted from the significant fire behavior lessons presented by this incident.

Figure 8. The Fire Building from Side Alpha

Photo from FBU Report

Construction: The house was built on a concrete slab with concrete block walls with brick veneer on Sides A and C. A concrete block wall also separated the stairwell from the living room and the kitchen from the living room. The second floor was supported by a mix of 75 mm x 175 mm (3" x 7") and 50 mm x 150 mm (2" x 7") joists with weyroc (tongue and groove

particleboard) flooring (thickness not specified). All other internal partitions were fabricated with 50 mm x 100 mm (2" x 4") studs. Interior finish was plasterboard (unspecified thickness). The ceiling had a skim coat of Artex (textured plaster). Windows on floors one and two were 780 mm x 870 mm (36.7" x 34.25") and constructed of unplasticised polyvinyl chloride (UPVC) and glass. Interior doors were lightweight wood with "egg crate" internal separation.

Configuration: The unit involved in the fire had a kitchen and living room on floor one and two bedrooms, bathroom (sink and shower) and water closet (toilet) on floor two. Figures 9 shows a plot plan and plan view of the first and second floor of the involved unit.

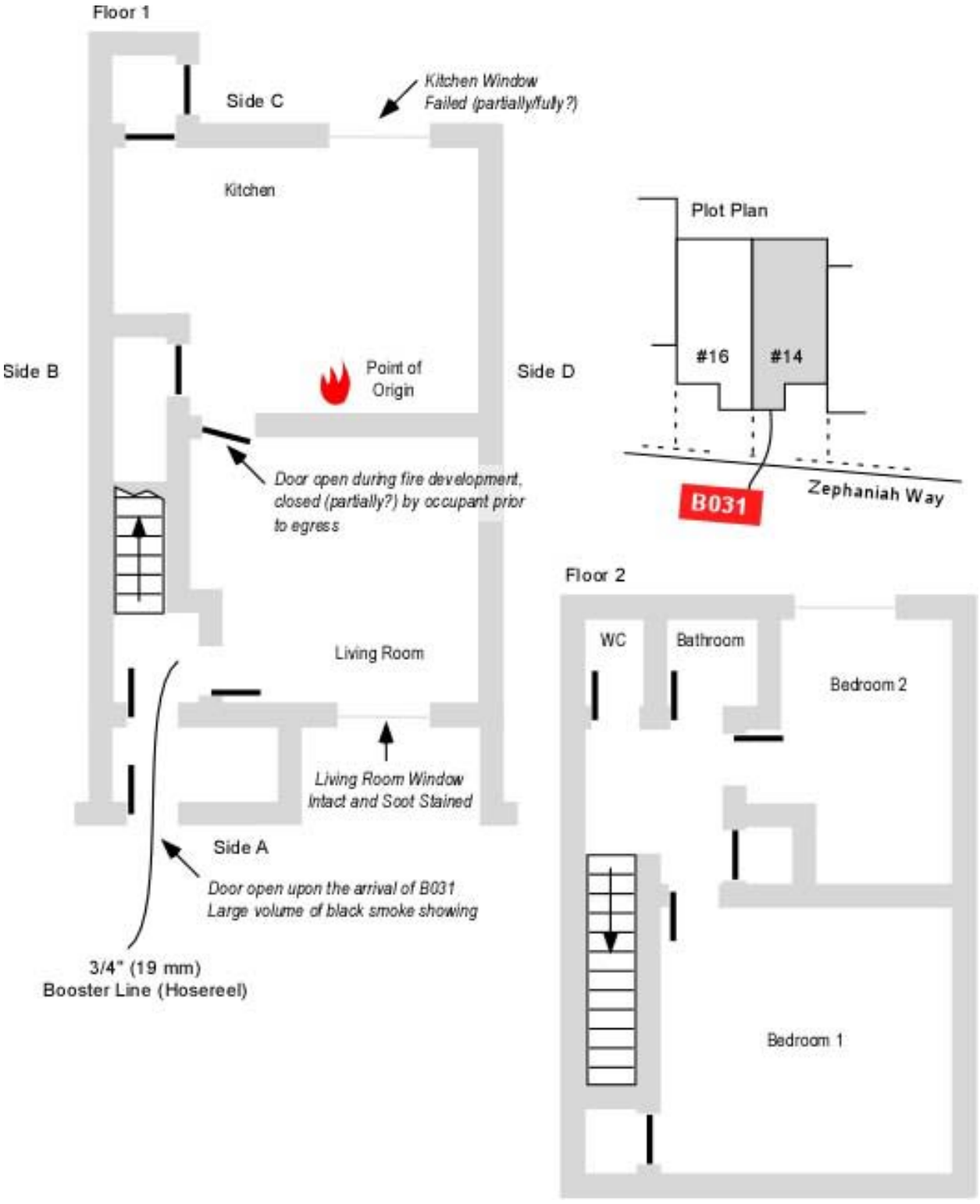
Fuel Profile: Contents were typical of a residential structure and included ordinary kitchen, and living room furniture. The fire originated in clothing located in the kitchen. In addition, all rooms were carpeted. Research conducted by the British Fire College Fire Experimental Unit (FEU) indicated that carpet can contribute significantly to fire load and can have a significant impact on fire development and intensity. This finding is independently supported by research conducted by the National Institute of Standards and Technology (NIST) examining fire development in the deaths of two firefighters during a training exercise in Osceola, Florida in 2002 (Hollenbach, 2002).

Ventilation Profile: At the time of ignition there were not ventilation openings to the exterior of the structure and the door between the kitchen and living room was open. The occupant discovered the fire at approximately 0548 and reportedly closed the door between the kitchen and living room and exited the structure, leaving the front door open. At approximately 0605 (five minutes prior to the arrival of the first company) the kitchen window failed (at least partially) with flames exiting the widow. Smoke pushing from the front door raises the possibility that a gravity current had developed at this opening as well as at the kitchen window (see Figure 3).

The FBU investigative report indicates that the fire breached the ceiling/floor between the kitchen and bedroom two (see Figure 3) at 0615, changing the ventilation profile and related air track. However, subsequent analysis (Grimwood, 2002; personal communication P. Grimwood, Febrary 2006) indicates that the ceiling/floor may not have failed until later in the incident.

Fire Development: The fire originated in clothing located in the kitchen (see Figure 9). The exact time of ignition is estimated at 0537. The speed with which the fire may have progressed from incipient to growth stages is unknown. However, the occupant discovered the fire at approximately 0548 and was able to close (partially?) the door between the kitchen and living room prior to escape. This indicates that the fire had not yet reached flashover. Sufficient heat was developed within the kitchen to cause failure of the kitchen window. This could have occurred fairly early in fire growth, as the melting temperature of UPVC can be as low as 150^{o} C (302^{o} F). This provided an additional, but limited supply of air to support fire growth to flashover within the kitchen. Dr. Martin Thomas of the FEU estimated that post flashover ceiling temperatures in the kitchen were as high as 1000^{o} C (1832^{o} F).

Figure 9. Floor 1 Plan View



Flaming combustion was not observed from the doorway on Side A at the time firefighters entered the structure. However, it is possible that combustion was occurring above the neutral plane and the dense smoke obscured it from the firefighters view. Shortly after 0615 (five minutes after arrival of the first company) there was a deflagration resulting in an immediate transition to flaming combustion on both floors one and two.

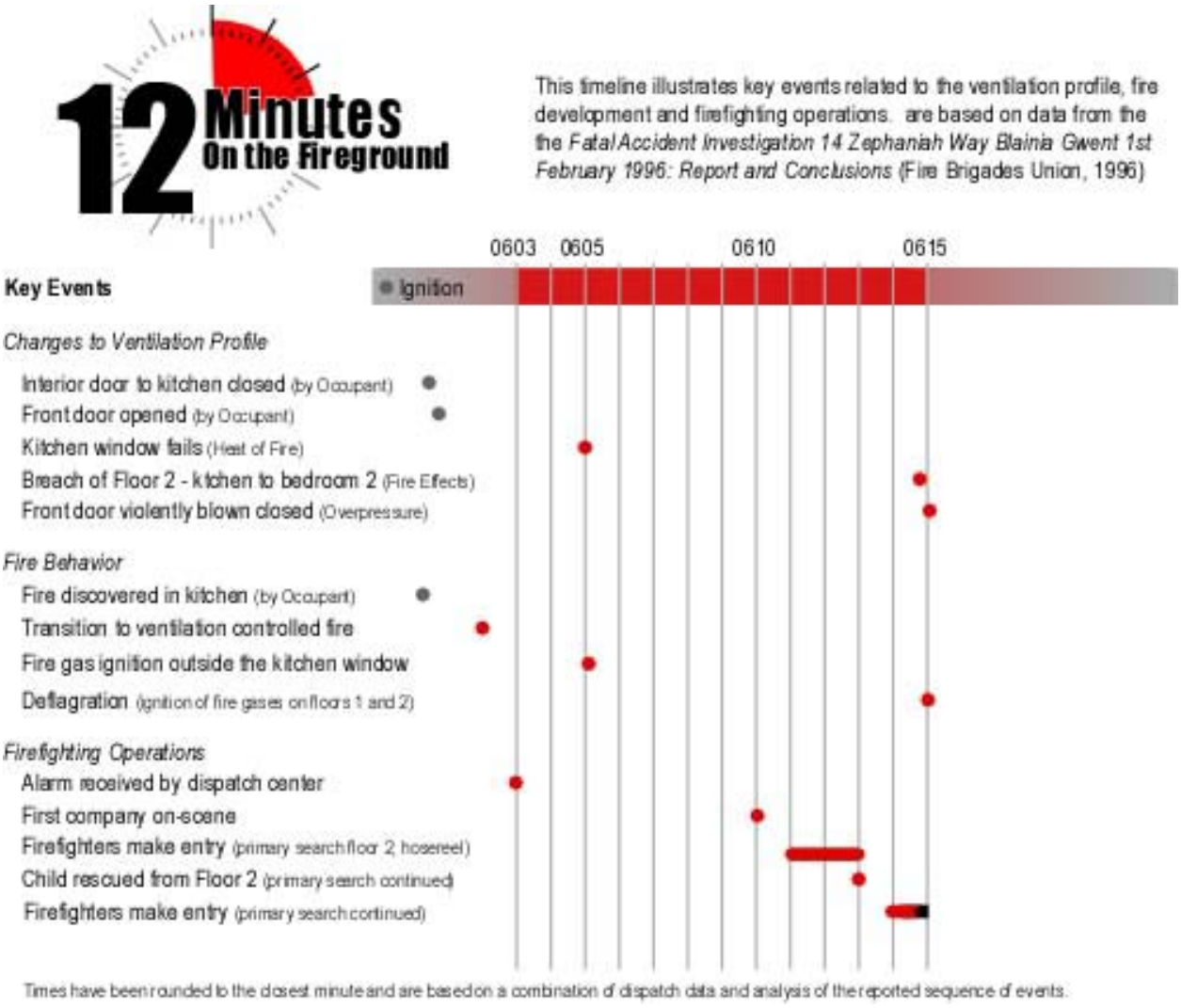
Initial Tactical Operations: Initial response to this incident was a single pump (six personnel) and Station Officer. Upon receipt of additional information that there were persons reported in the building, a second pump (five personnel) was added to the incident. As the first company (B031) arrived on scene, they observed thick, dense smoke from the house drifting across the road. Initial size-up showed a large volume of black smoke from the open front door as well as smoke showing from the eaves. The windows on Side A were intact and showed evidence of condensed smoke (staining of the window glazing). It was apparent that both floors one and two were smoke logged (substantial smoke accumulation within the compartments on each floor).

Bystanders reported that there were children in an upstairs bedroom. Initial tactical operations involved primary search by on floor two, by two firefighters with a hosereel (¾" boosterline). An extension ladder was removed from the apparatus and placed on Side A ready for use. After initiating primary search, the Incident Commander ordered a second hosereel extended to Side C for fire attack (this line was of insufficient length to reach Side C)

Within two minutes, the team conducting primary search exited the structure with an unconscious child. After handing the child off to another firefighter, the search team reentered the structure to continue their search. Smoke continued to push from the front door with considerable volume and velocity. Less than a minute after the search team made their second entry, there was a loud "whoosh" with the fire enveloping floors one and two. The violence of this explosion was sufficient to blow the inward opening front door closed, jamming on top of the firefighters hoseline and preventing their escape. One firefighter observed that the volume of smoke from the front of the house was significantly less immediately after the deflagration. A short time later fire was observed from the windows on Side C, floors one and two.

Initial rescue efforts supported by a hosereel were unsuccessful due to the intensity of the fire. After the arrival of the second pump (B021) crews were able to gain access to the involved unit supported by a 45 mm (1-3/4") hoseline and remove the two firefighters from the building.

Figure 10. 12 Minutes on the Fireground



Alternative Theory

The fire development scenario presented in the Fire Brigade Union Report (FBU, 1996) was that the door between the kitchen was completely closed and that the backdraft resulted when the fire compromised the ceiling/floor between the kitchen and bedroom two (see Figure 5). Fire development in this case would have been limited by the size of the kitchen window that failed (at least partially) when the fire in the kitchen transitioned from incipient to fully developed.

Review of this case by a number of experienced fire officers and investigators has resulted in another theory of how this fire developed (Grimwood, 2002; personal communication P. Grimwood, Febrary 2006). In this alternate scenario the door between the kitchen and living room was not completely closed, allowing heat and smoke from the developing fire to extend into the living room and to floor two. Firefighters observed smoke pushing under pressure from the front door. This supports the possibility that the occupant may not have tightly closed the doorway between the kitchen and living room. Heat extending from the kitchen through convection, would have increased pyrolysis within the living room and on floor two (to a much greater extent than by conduction through structural members and the limited convection resulting from smoke pushing through the closed door. In this case, the extreme fire behavior would have been caused by a gravity current (i.e. air moving in the lower area of the front door while smoke exited at the top) rather than failure of the ceiling/floor between the kitchen and bedroom two.

While this alternate scenario does not influence the known outcome, rapid fire progress trapping and killing two firefighters, it does have some impact on alternate approaches that may have been taken to prevent the extreme fire behavior that occurred. Consider both possibilities as you work on the study and discussion questions.

Case Study 3: Evanston, Wyoming

This incident involved a fire in a tri-level townhouse that resulted in the deaths of a firefighter and company officer. The mid-afternoon fire occurred in the unit located on Side Delta (see Figure 3). This case study will focus on fire behavior related aspects of this incident. However, this case provides an opportunity to learn a number of other important lessons (see the NIOSH and NIST reports for additional information on the incident).

Figure 11. View of the Involved Unit from Side Alpha

Photo from NIOSH Report F2005-13

Configuration: This 1600 ft^2, tri-level, wood frame apartment building had two levels above ground and a daylight basement (partially above grade on Side C). The first floor was comprised of a single room, divided into living and kitchen areas. A single bedroom and bathroom were located on the second floor.

Figure 12. Void Spaces and Fire Travel-Room in Attic Truss

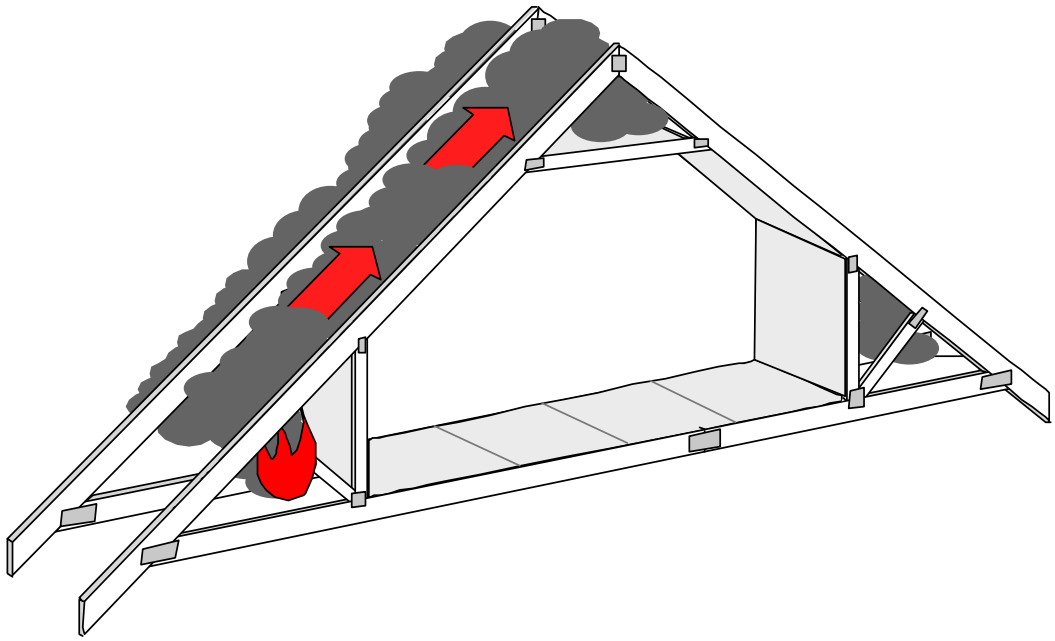
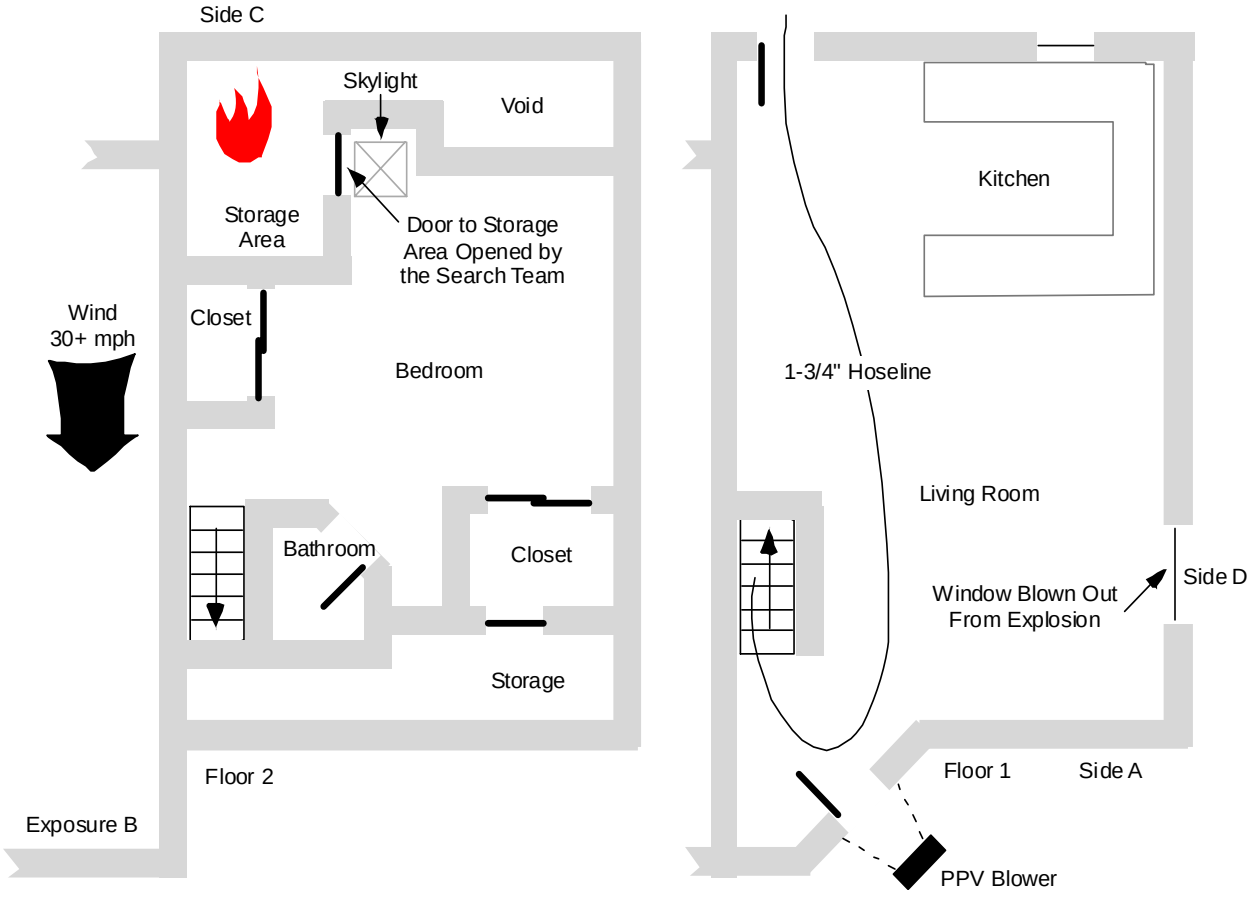


Figure 13. Floors 1 and 2 Plan View



Due to the roofline of the structure (see Figure 3), there were substantial void spaces behind knee walls on the Alpha and Charlie sides of the second floor (see Figure 4). While NIOSH Report F2005-13 emphasizes the void space hazards of this type of truss, similar voids are likely any time a finished room is located directly beneath a pitched roof. The area of fire origin was behind a knee wall (storage area) on floor two (see Figures 4 and 5). The interconnected void spaces behind the knee walls and above the ceiling permitted the fire and hot smoke to surround the rooms on floor two.

Fuel Profile: Contents were typical of a residential structure. NIOSH report F2005-13 made no specific mention of the contents of the attic storage areas.

Ventilation Profile: While not specified in NIOSH report F2005-13, truss spaces are equipped with roof vents, typically providing 1 ft^2 of vent area for each 150 ft^2 of attic floor area. These building vents would have potentially provided limited air supply for fire development within the storage area and void spaces.

It is unknown if either exterior door on floor one was open before the arrival of the fire department. However, Engine 1 the first arriving company opened the door and made entry through the doorway on Side Charlie with a hoseline. At approximately the same time, the Incident Commander observed a small amount of flame from the roof above the door on Side Charlie (see Figure 6).

The Captain from Engine 1 tasked a firefighter to place a positive pressure blower at the door on Side Alpha. Engine 2 stretched a line to this doorway, creating a second opening on floor one. NIOSH Report 2005-13 also discusses the Captain's intention to establish a horizontal exhaust opening on floor two, Side Delta, but found no windows at this location. The report mentions that he observed a skylight on Side Charlie (see Figures 5 and 6). The report did not specify if the Captain vented the skylight.

Fire Development: From its point of origin in the storage area on Side Charlie (Bravo/Charlie corner of the unit), the fire extended throughout the storage area and void spaces on Side C, above the ceiling, and on Side Alpha. Even with the limited ventilation provided by the attic vents, the high wind (30+ mph blowing from Side Charlie) may have accelerated fire development. Fire behavior indicators observed by the first arriving companies included a small amount of flame from the roof peak near the chimney on Side Delta (see Figures 3 and 6) and light colored smoke seeping from the roof shingles and the attic of Exposure Bravo. A short time later flames were observe above the door on Side Charlie (intersection of the involved unit and Exposure Bravo). Engine 2 observed heavy brown smoke filtering down the stairwell as they extended a backup line to the door on Side Alpha. Approximately eight minutes after Engine 1 arrived on scene, an explosion blew the crew from Engine 2 out the door on Side Alpha and caused the window on floor one, Side Delta to fail. Fire and black smoke was blowing out the door on Side Alpha and window on Side Delta. Crews entering the building to attempt a rescue of the crew from Engine 1 encountered fully developed fire conditions on floors 1 and 2.

Initial Tactical Operations: Initial response to this incident was two engines (one with a a Captain and two firefighters and the other a Lieutenant and three firefighters), a truck (Lieutenant and two firefighters), and three additional personnel (Lieutenants) arriving in personally owned vehicles (POV). One of the Lieutenants arrived in his POV and assumed Command just as Engine 1 arrived on scene. Initial reports from bystanders were that children were trapped on floor two. A firefighter (company not specified in NIOSH report F2005-13) placed a PPV fan at the door on Side Alpha. Engine 1 deployed a 1-3/4" hoseline through the doorway on Side Charlie to support primary search. Engine 2 stretched a second 1-3/4" line through the door on Side Alpha and onto the stairwell to back up the crew from Engine 1 while Truck 1 was setting up (tactical assignment not specified in NIOSH report F2005-13).

Figure 14. Alpha/Delta Corner showing the Front Door and Window on Side Delta

Photo from NIOSH Report F2005-13

Figure 15. 12-Minutes on the Fireground

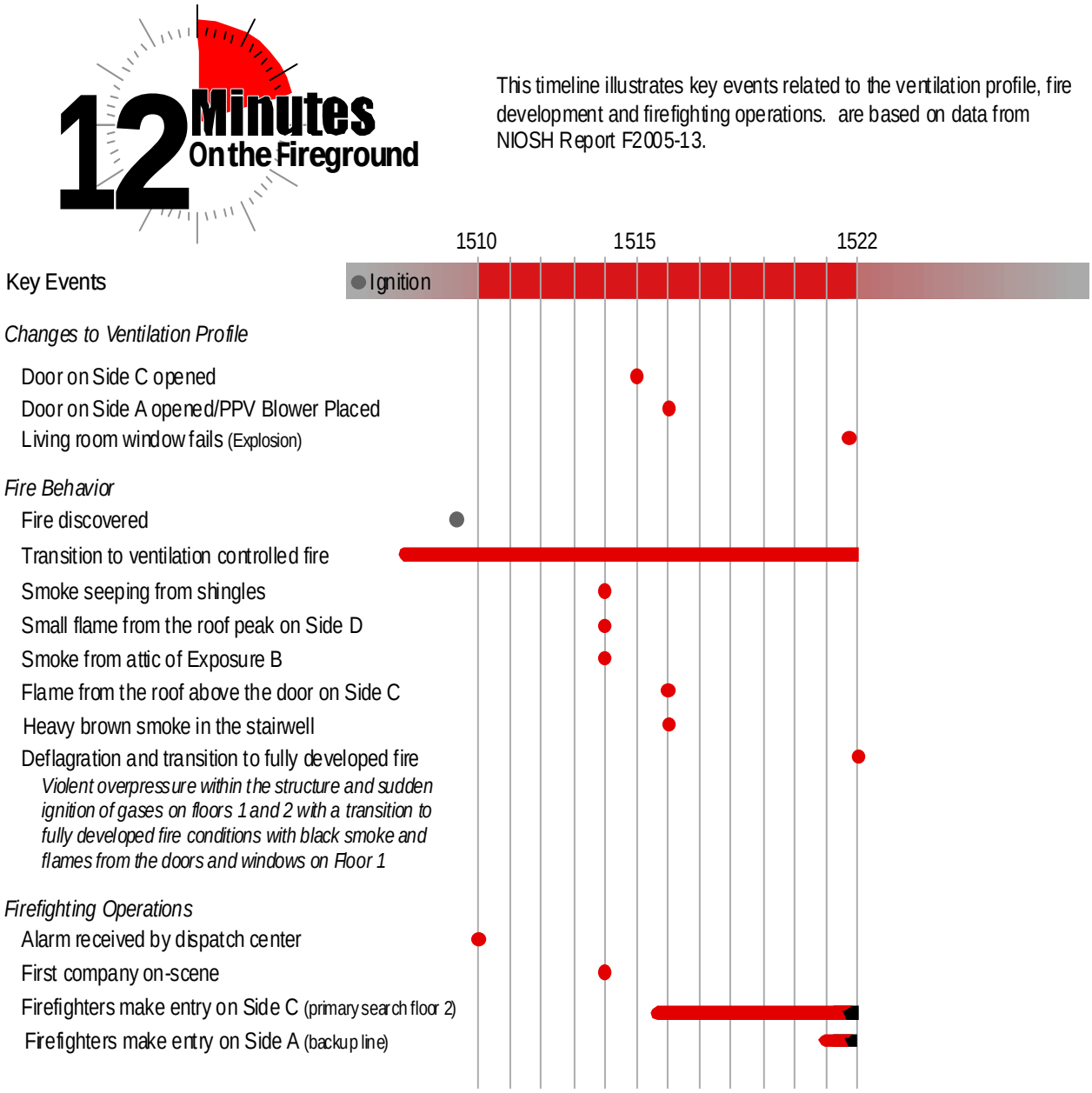


Figure 16. Side Charlie.

Photo from NIOSH Report F2005-13

References

Fire Brigades Union (FBU). (1996). Fatal Accident Investigation: 14 Zephaniah Way, Blaina Gwent 1st February 1997 Report and Conclusions. Surrey, UK: Author.

Grimwood, P. (2002). Compartment Firefighting Strategy and Tactics. Retrieved February 6, 2006 from http://www.firetactics.com/IFE1998.HTM.

Grimwood, P., Hartin, E., McDonough, J., & Raffel, S. (2005). *3D firefighting: Training , techniques, and tactics*. Stillwater, OK: Fire Protection Publications.

Hartin, E. (2005). *Extreme Fire Behavior - Flashover*. Retrieved July 18, 2007 from www.firehouse.com

Hartin, E. (2005). *Fire Development in a Compartment Part I.* Retrieved Retrieved July 18, 2007 from www.firehouse.com

Hartin, E. (2005). *Fire Development in a Compartment Part II.* Retrieved Retrieved July 18, 2007 from www.firehouse.com

Hartin, E. (2005). *Smoke Burns.* Retrieved July 18, 2007 from www.firehouse.com.

Hartin, E. (2006) Extreme Fire Behavior – Backdraft. Retrieved July 18, 2007 from www.firehouse.com.

Hartin, E. (2006) Extreme Fire Behavior – Smoke Explosion. Retrieved July 18, 2007 from www.firehouse.com.

Joung, W., Hesketh, B., & Neal, A. (2006). Using war stories to train for adaptive performance: Is it better to learn from error or success? *Applied Psychology*, 55(2). 282-302.

Hollenbach, D. (2002). ACISS Fire Investigation Supplemental Report 02-3753/5. Retrieved Feburary 10, 2005 from http://www.fldfs.com/sfm/bfai/OsceolaDeathReport.htm

Karlsson, B. & Quintiere, J.G. (2000). *Enclosure fire dynamics.* Boca Raton, FL: CRC Press.

Madrzykowski, D., Forney, G., and Walton, W. (2002). *Simulation of the dynamics of a fire in a two-storyt duplex – Iowa, December 22, 1999, NISTR 6854.* Retrieved December 30, 2005 from http://fire.nist.gov/CDPUBS/NISTIR_6854/duplex.htm

National Institute for Occupational Safety and Health (NIOSH) (2000) Death in the line of duty, Report F2000-04. Retrieved December 30, 2005 from http://www.cdc.gov/niosh/pdfs/face200004.pdf

National Institute for Occupational Safety and Health (NIOSH) (2000) *Death in the line of duty*, Report F2005-13. Retrieved March 12, 2006 from http://www.cdc.gov/niosh/fire/pdfs/face200513.pdf

12-Minutes
On the Fireground

Case Studies in Extreme Fire Behavior

CFBT-US

Not just what and how, but why!

Introduction

In order to carry on your business properly, it is necessary for those who practice it to understand not only what they have to do, but why they have to do it…

No fireman can ever be considered to have attained a real proficiency in his business until he has thoroughly mastered this combination of theory and practice.

Fire Protection, 1876
Sir Eyre Massey Shaw
Chief, London Fire Brigade

CFBT-US
Not just what and how, but why!

Dedication

This presentation is dedicated to the firefighters who lost their lives in the incidents we will study during this training session.

Keokuk, Iowa	Blaina, Wales	Evanston, Wyoming
Dave McNally	Kevin Lane	Jacob Cook
Jason Bitting	Stephen Griffin	Robert Henderson
Nathan Tuck		

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Overview

- The rate of firefighter fatalities at structure fires due to traumatic cause has increased over the last 30 years.
  - Lost Inside
  - Structural Collapse
  - Extreme Fire Behavior
- Lack of experience is a potential causal factor in these fatalities.

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Learning Outcomes

- Recognize the hazards presented by extreme fire behavior.
- Explain how the following extreme fire behavior phenomena occur:
  - *Flashover*
  - *Backdraft*
  - *Smoke Explosion*

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Learning Outcomes

- Recognize the significance of fire behavior indicators in each of the following categories:
  - *Building*
  - *Smoke*
  - *Air Track*
  - *Heat*
  - *Flame*

B-SAHF

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Learning Outcomes

- Analyze case studies involving extreme fire behavior to identify:
  - *Type of extreme fire behavior*
  - *Causal factors*
  - *Fire behavior indicators*
  - *Mitigation strategies*

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Not just what and how, but why!

What is Extreme Fire Behavior?

What knowledge and skill becomes critical to your safety when faced with these conditions?

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Extreme Fire Behavior

- Extreme fire behavior involves some form of rapid fire progress.
- These phenomena present a significant threat to firefighter and occupant safety and often result in increased damage.

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Extreme Fire Behavior

- Flashover
- Backdraft
- Smoke Explosion

Many firefighters can define these terms, but do not recognize key indicators and respond appropriately on the fireground.

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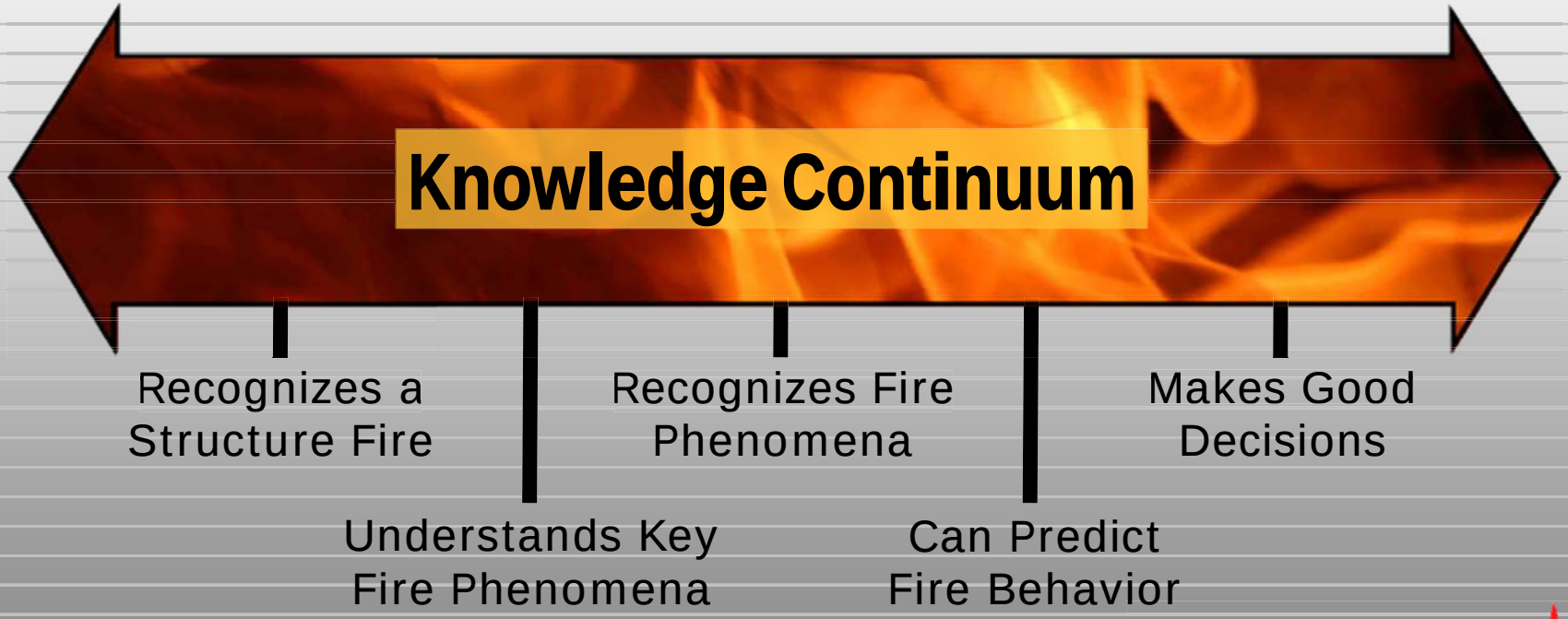
Fire Behavior Knowledge



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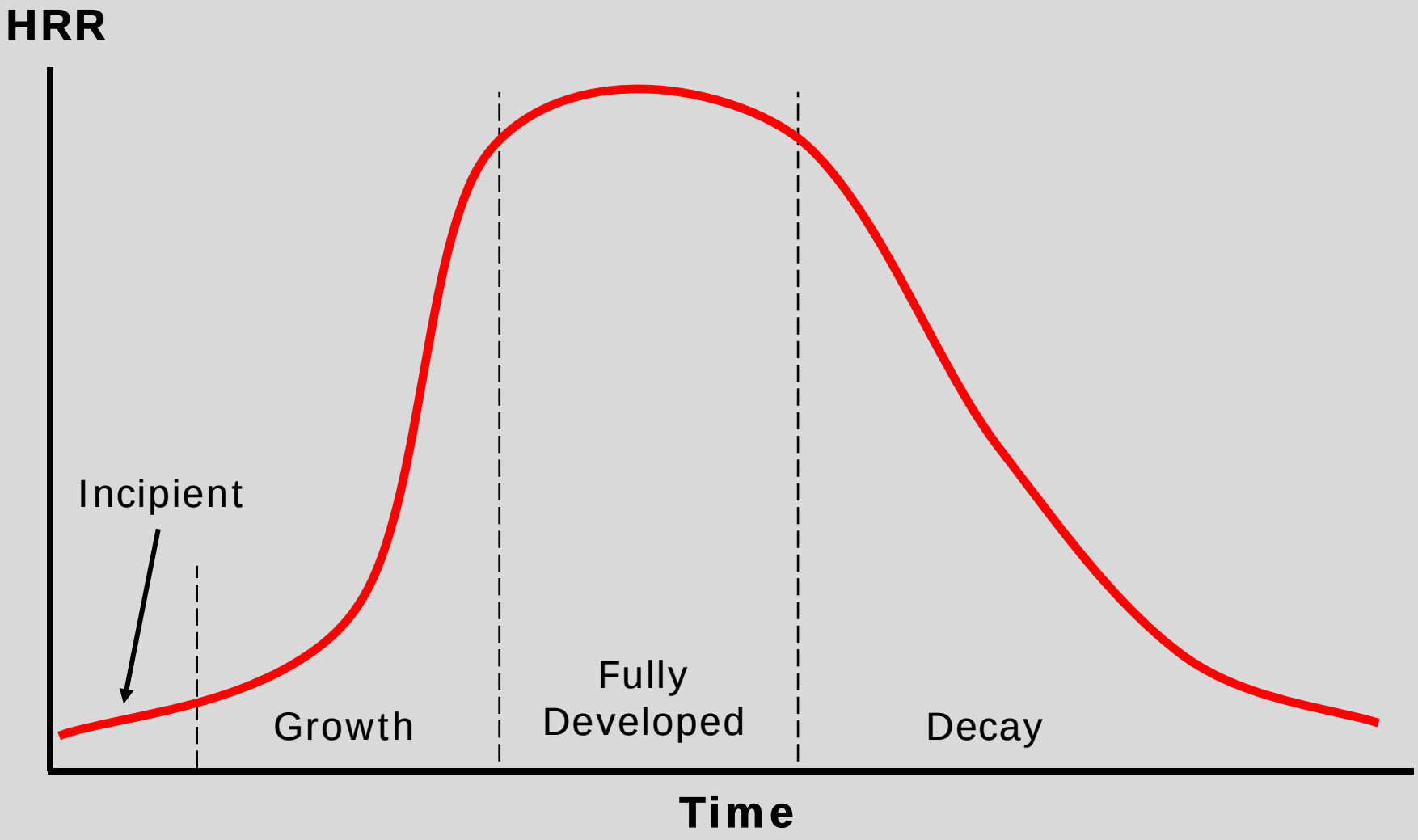
Fire Development



Burning Regime

- Fuel-Controlled

  Fire growth is predominantly limited by the fuel availability and characteristics

- Ventilation-Controlled

  Fire growth is predominantly limited by the available oxygen supply

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Activity

Working Definitions

Develop a common working definition of the following fire phenomena:

- Flashover
- Backdraft
- Smoke Explosion

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Fire Behavior Indicators

- Building
- Smoke
- Air Track
- Heat
- Flame

B-SAHF

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Activity

Fire Behavior Indicators

Identify fire behavior factors in each of the following categories:

- Building
- Smoke
- Air Track
- Heat
- Flame

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Photo 1

Photo 2

Photo 3

Photo 4

Case Study 1

- Listen to the case presentation
- Review the case study materials
- Discuss the questions for each case

You have 12 minutes after the case presentation to complete this assignment

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Keokuk

- How did the fire develop and what factors influenced the occurrence of the extreme fire behavior phenomenon?
- What cues were present that may have indicated potential for rapid fire development?

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Keokuk

- Given the limited resources available, what options did the first arriving companies have to address the need for rapid primary search in conjunction with the potential for rapid fire development?

  How would this differ with the company staffing level and residential fire assignment used by your department?

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Keokuk

- Compare and contrast the case study with events in your own experience.
  - *What aspects of these incidents were similar?*
  - *Which were different?*

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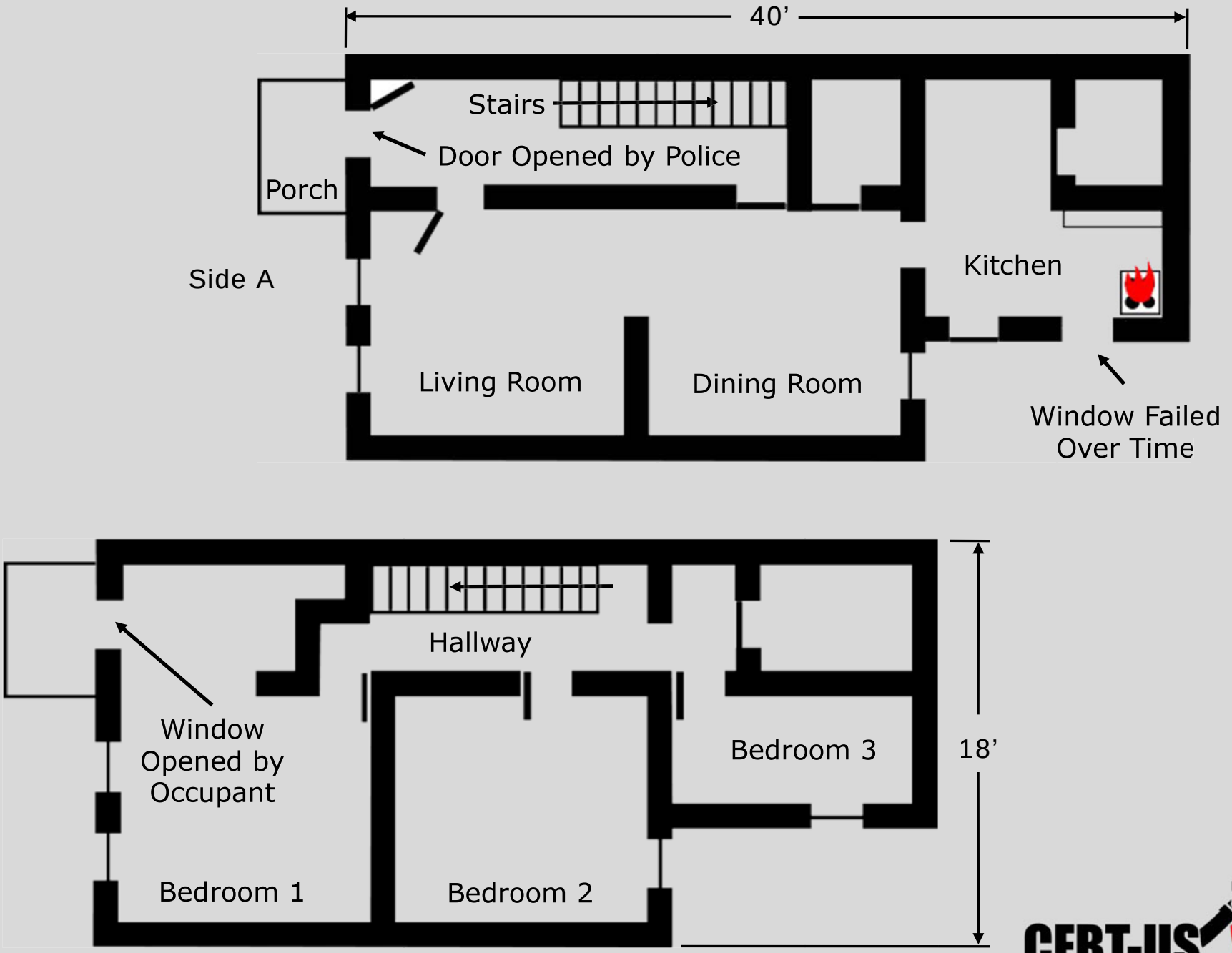

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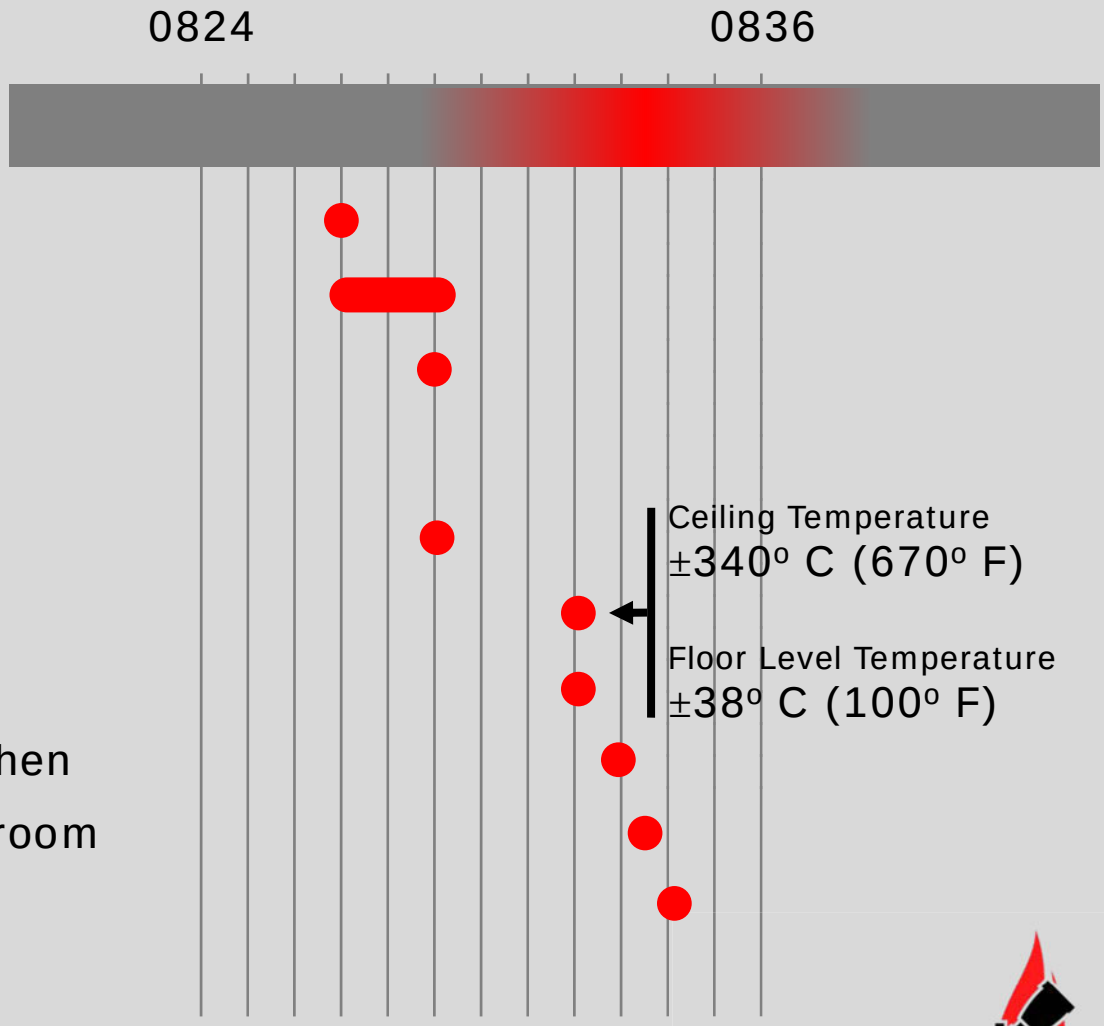
Not just what and how, but why!

12 Minutes On the Fireground

This timeline is based on data from NIOSH Report F2000-04 and NIST Report NISTR 6854.



Changes to Vent Profile

- Floor 2 Window Opened
- Front Door Opened
- Kitchen Window Fails

Fire Behavior

- Smoke with low temperature
- Well developed hot gas layer
- Rollover & flame from window
- Flame extension from the kitchen
- Fire involvement in the living room
- Flame extension to floor 2

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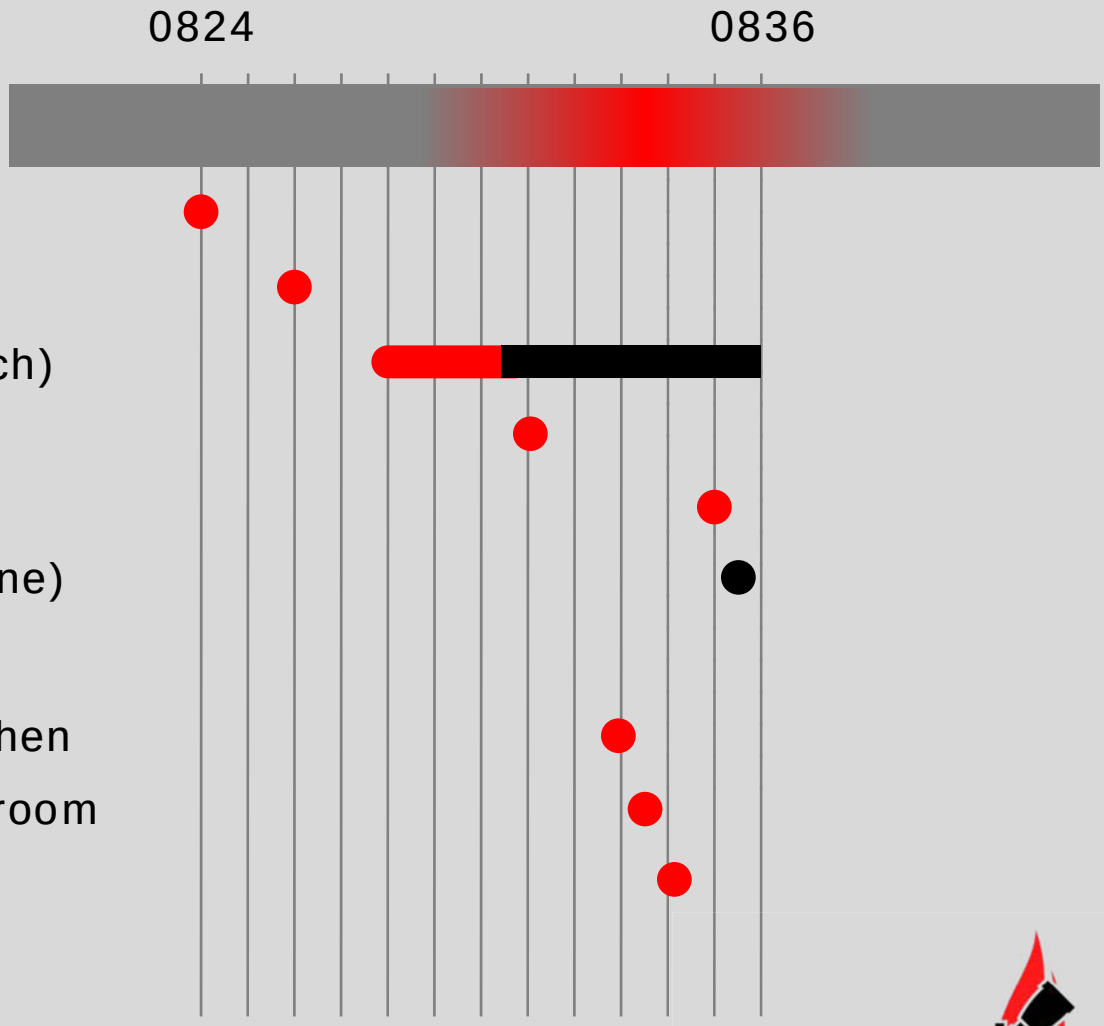
12 Minutes On the Fireground

This timeline is based on data from NIOSH Report F2000-04 and NIST Report NISTR 6854.



Firefighting Operations

- Alarm received
- First company on-scene
- Firefighters make entry (Search)
- Dry line to the front door
- Hoseline charged (fails)
- Interior attack initiated (2nd Line)

Fire Behavior

- Flame extension from the kitchen
- Fire involvement in the living room
- Flame extension to floor 2

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Flashover

- Flashover is the sudden transition from the growth to fully developed stage of a compartment fire.
- Heat from the developing fire and hot gas layer increase the temperature of additional fuel packages within the compartment.
- Sufficient transfer of heat to other fuel packages can result in flashover
  - *Radiant Heat Flux at the Floor: 15-20 kW/m^2*
  - *Temperature: 932^o-1112^o F (500^o-600^o C)*

Activity

Flashover

Watch this demonstration of flashover and watch for:

- *Plume and ceiling jet*
- *Development of the hot gas layer and neutral plane at the door*
- *Pyrolysis and evidence of the extent of heat flux on various fuel packages*
- *Air track*

Another view...

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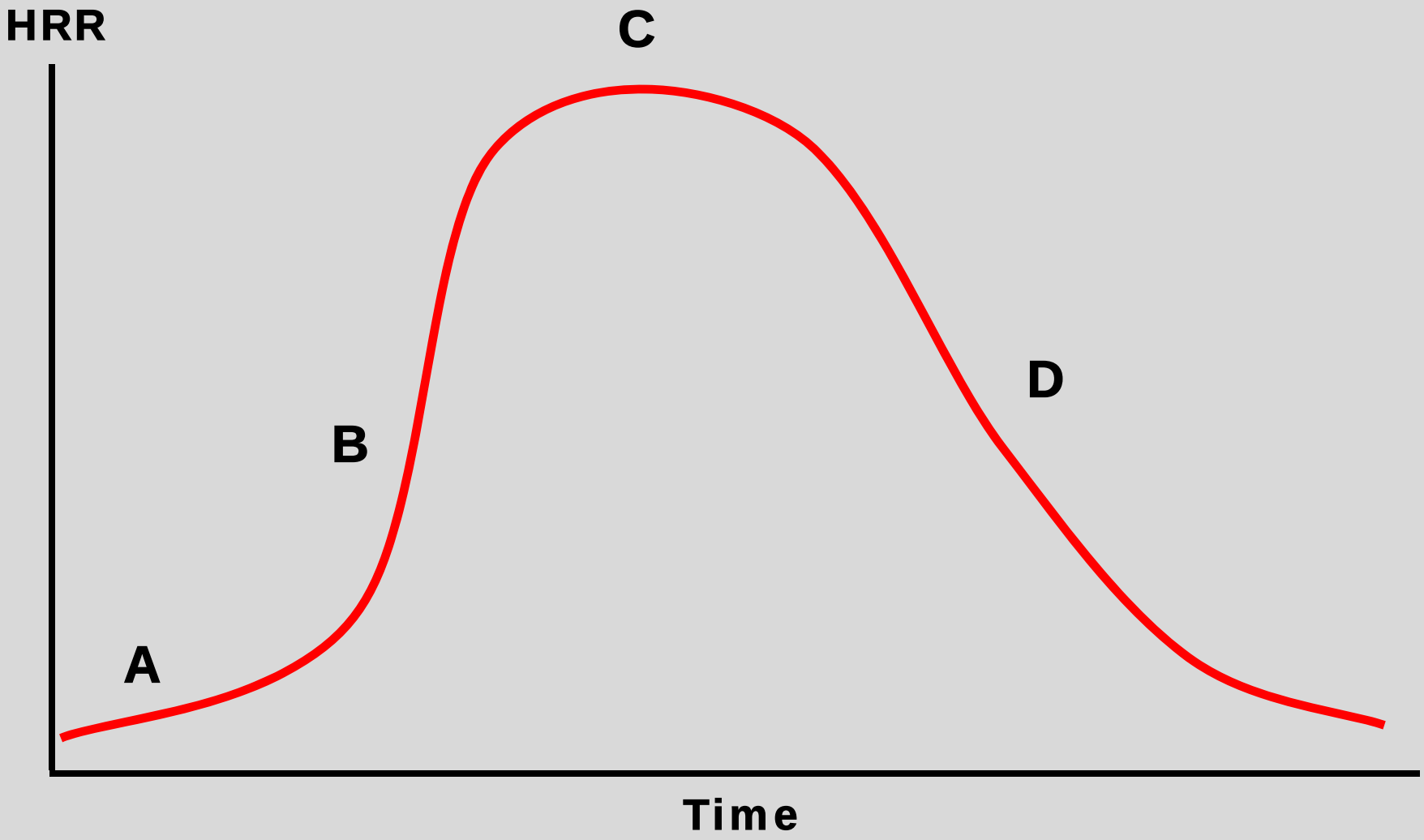
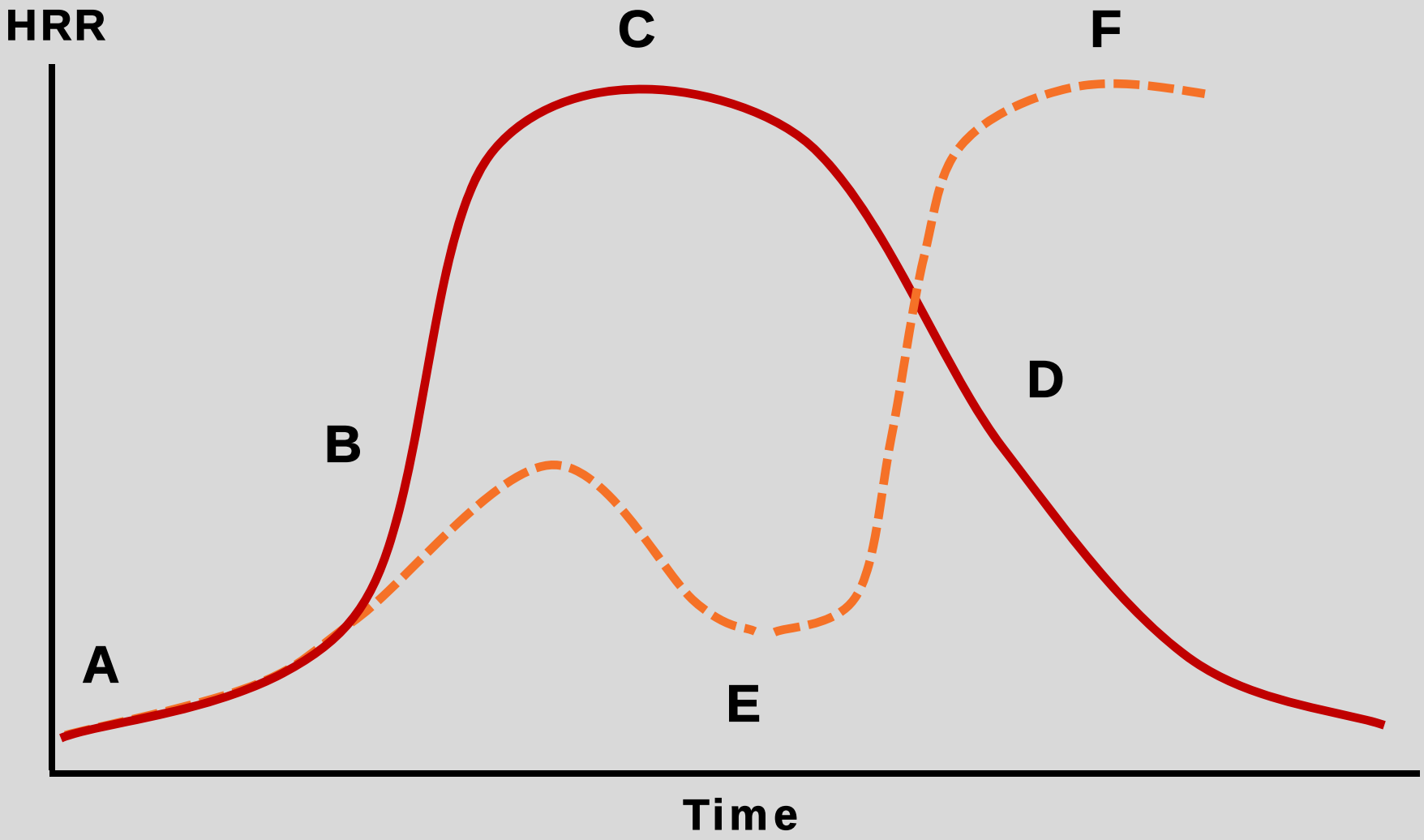

HRR
C
B
D
A
Time

Flashover

- Given adequate ventilation flashover occurs as part of normal fire development
- If ventilation is limited, the fire may become ventilation controlled prior to flashover
- A subsequent increase in ventilation may result in flashover


HRR
C
F
D
B
A
E
Time

Activity

Vent Induced Flashover

These video clips show recreation of conditions involved in the fatality of two firefighters involved in a live fire training exercise.

- *Fuel load included pallets, a polyurethane foam mattress, carpet, and carpet padding.*
- *Describe your observations and explain the observed phenomena*

Another view...

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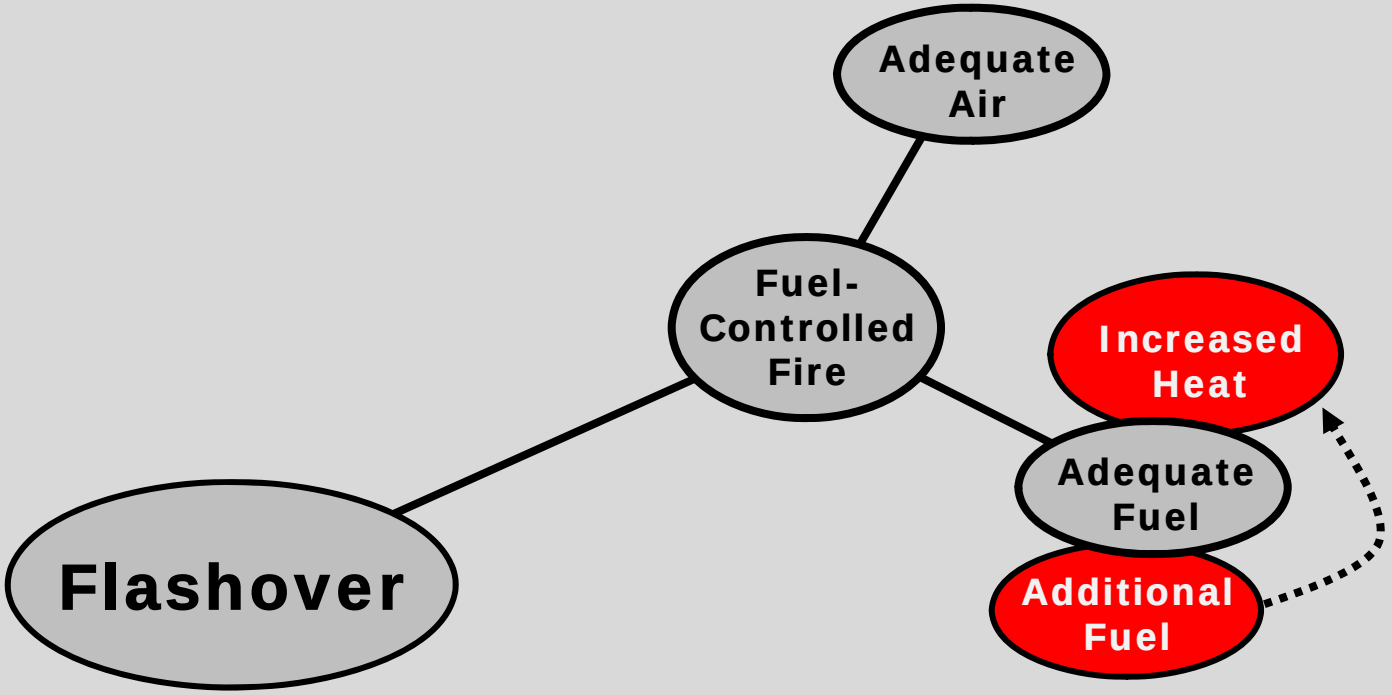
Not just what and how, but why!



With a limited air supply, the fire growth will move from a fuel-controlled state one that is ventilation-controlled

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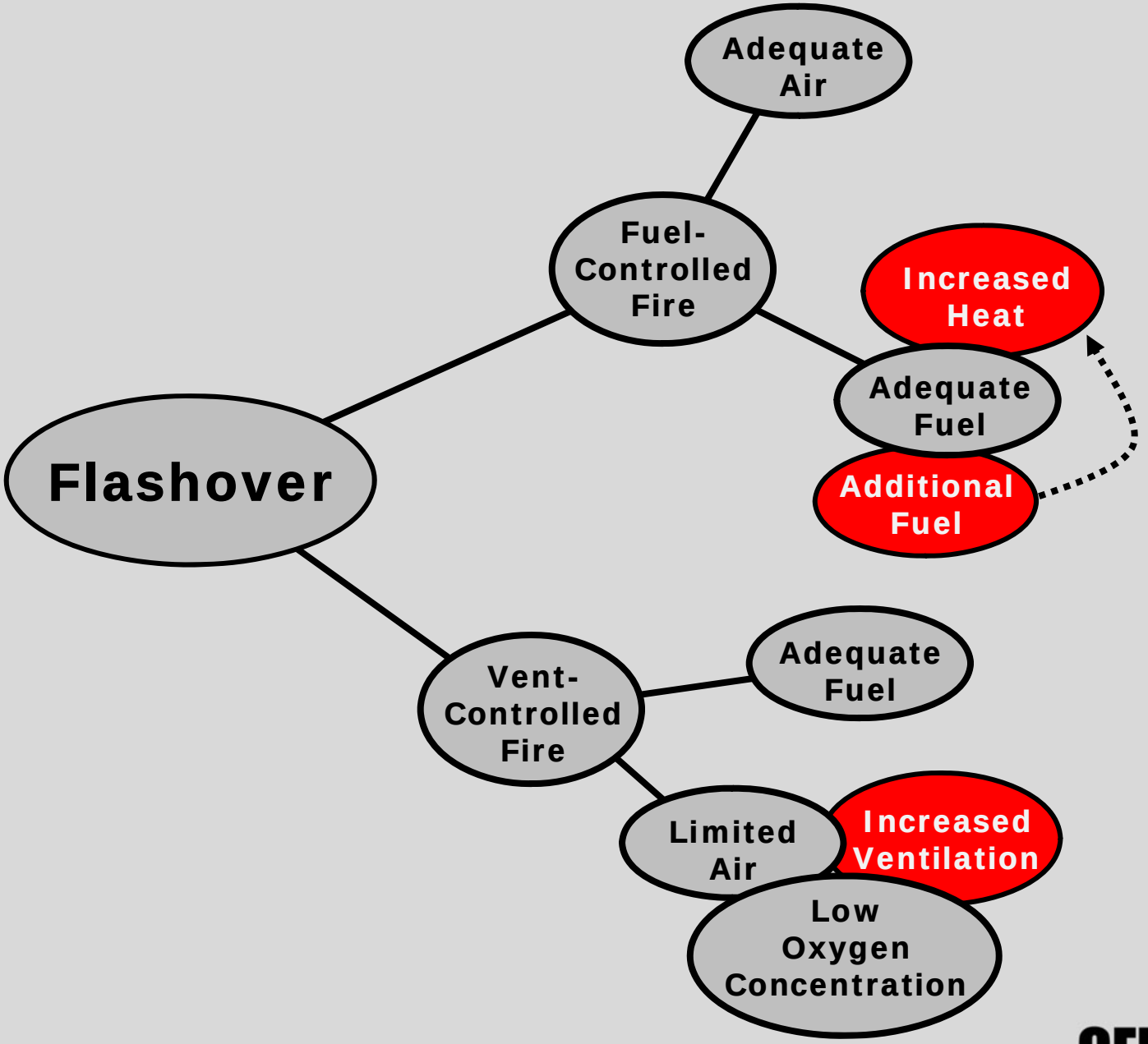

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Activity

FBI-Flashover

Develop a list of fire behavior indicators that would assist in predicting flashover potential.

- *Exterior indicators*
- *Interior indicators*

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Case Study 2

- Listen to the case presentation
- Review the case study materials
- Discuss the questions for each case

You have 12 minutes after the case presentation to complete this assignment

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Blaina

- Was extreme fire behavior involved in this incident? If so, what type of event happened?
- How did the fire develop and what factors influenced the occurrence of the extreme fire behavior phenomenon?
- What cues were present that may have indicated potential for rapid fire development?

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Not just what and how, but why!

Blaina

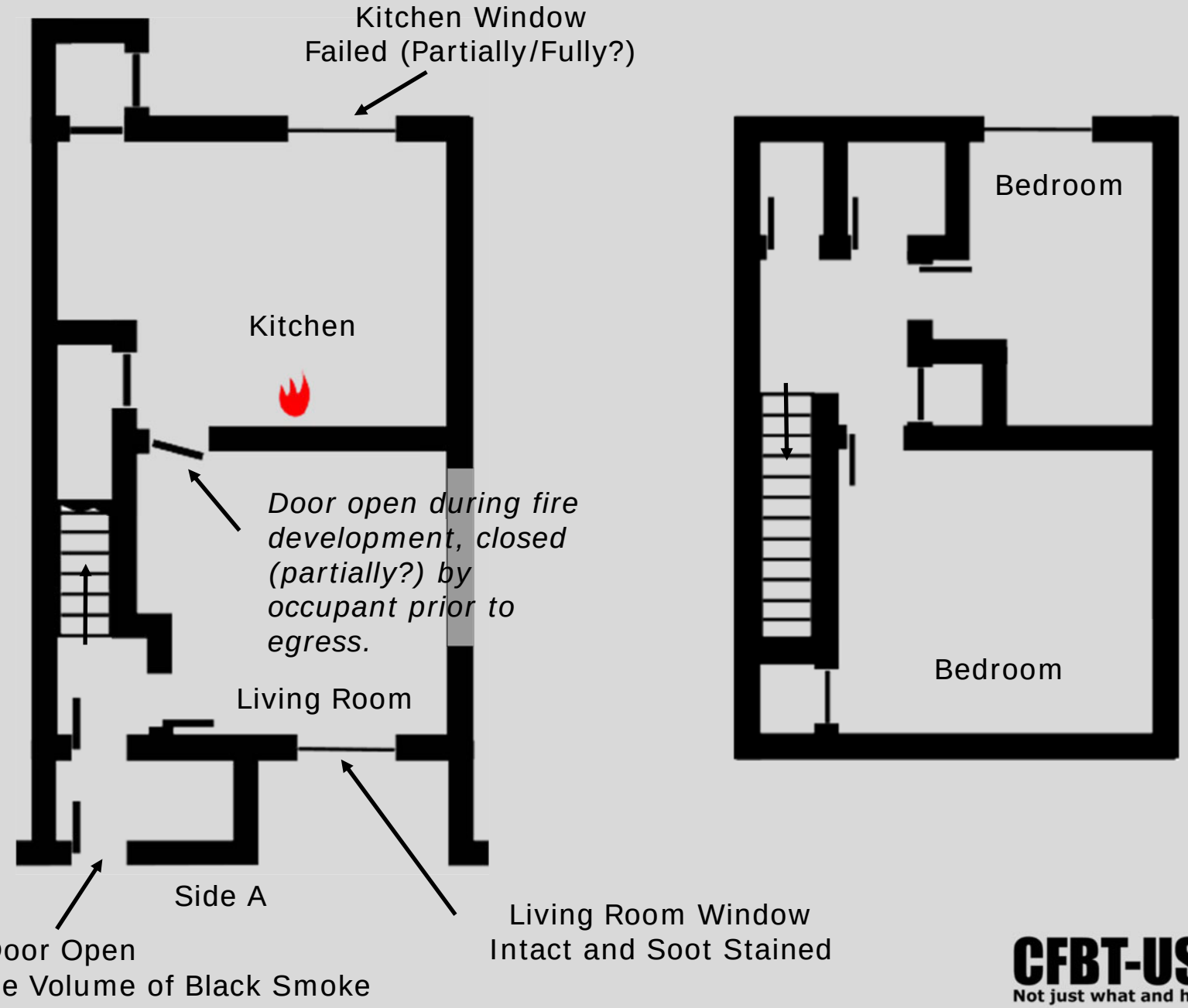
- Given the limited resources available, what options did the first arriving companies have to address the need for rapid primary search in conjunction with the potential for rapid fire development?

  How would this differ with the company staffing level and residential fire assignment used by your department?

Blaina

- Compare and contrast this incident with the circumstances and events in Keokuk.
  - *What aspects of these incidents were similar?*
  - *Which were different?*
- Compare and contrast these the case study with events in your own experience.
  - *What aspects of these incidents were similar?*
  - *Which were different?*

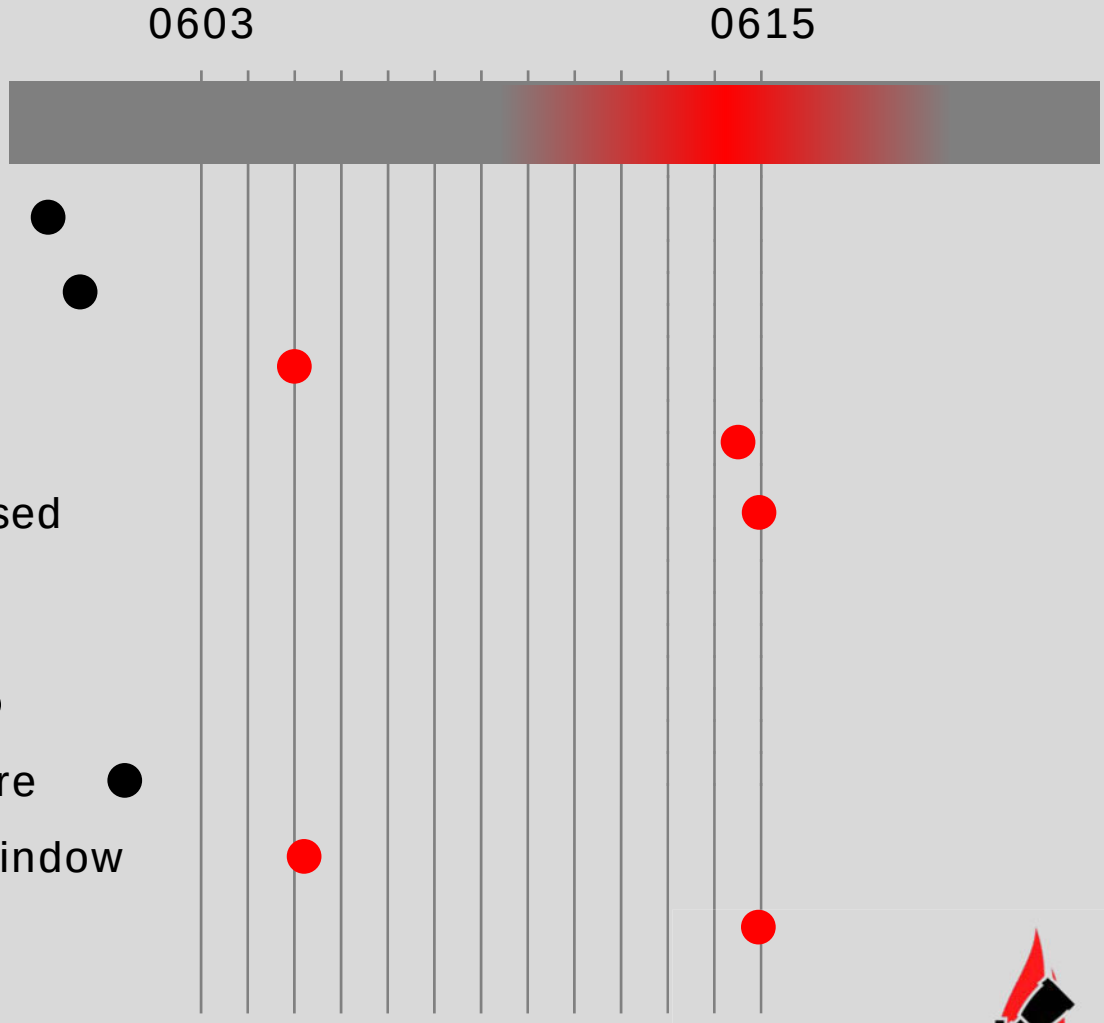
CFBT-US
Not just what and how, but why!



CFBT-US
Not just what and how, but why!

12 Minutes On the Fireground

This timeline is based on data from the *Fatal Accident Investigation 14 Zephaniah Way Blainia Gwent 1st February 1996: Report and Conclusions* (Fire Brigades Union, 1996.



Changes to Vent Profile

- Interior Kitchen Door Closed
- Front Door Opened
- Kitchen Window Fails
- Breach of ceiling/floor
- Front door violently blown closed

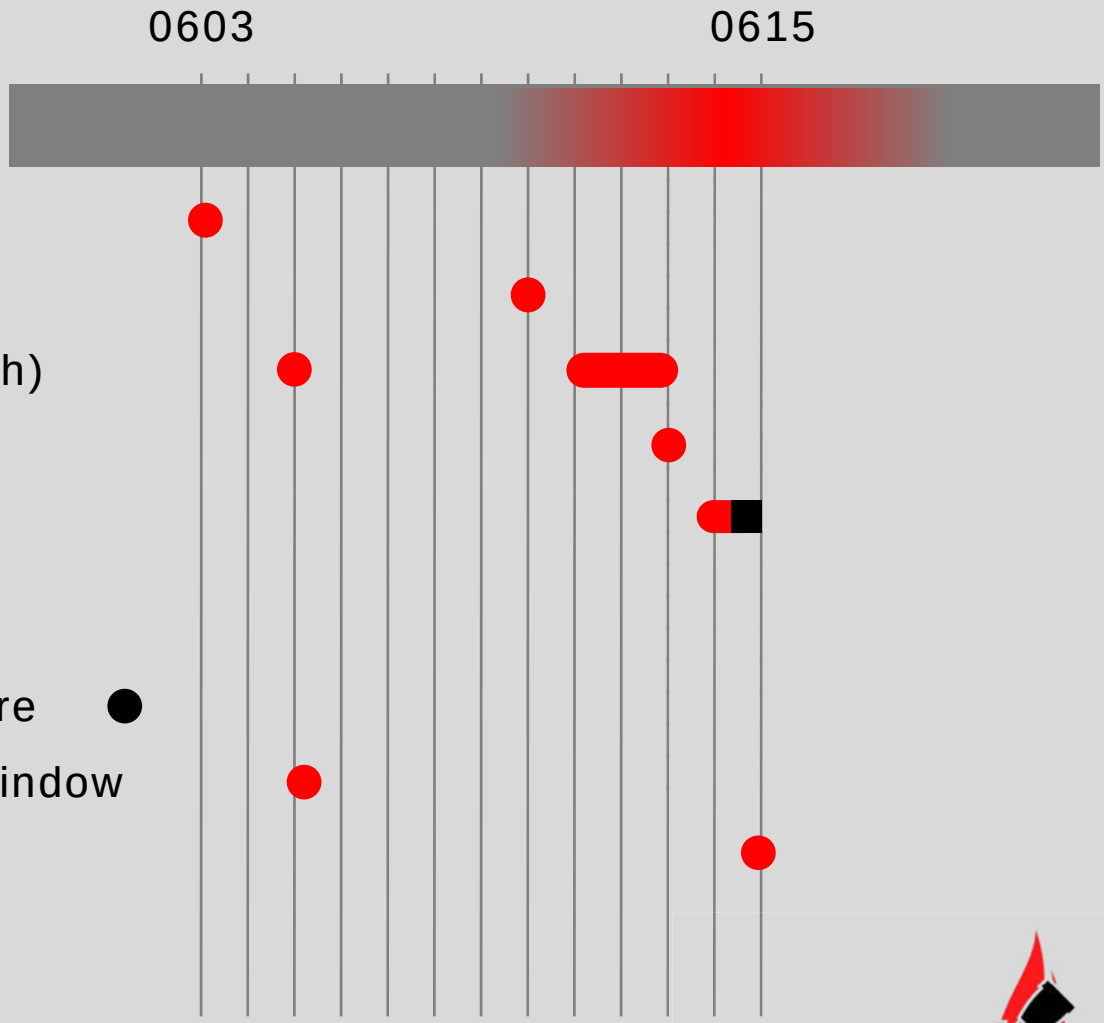
Fire Behavior

- Fire discovered (kitchen)
- Transition to vent controlled fire
- Fire gas ignition outside the window
- Deflagration inside the unit

CFBT-US
Not just what and how, but why!

12 Minutes On the Fireground

This timeline is based on data from the *Fatal Accident Investigation 14 Zephaniah Way Blainia Gwent 1st February 1996: Report and Conclusions* (Fire Brigades Union, 1996.



Firefighting Operations

- Alarm received
- First company on-scene
- Firefighters make entry (search)
- Child rescued from floor 2
- Firefighters re-enter (search)

Fire Behavior

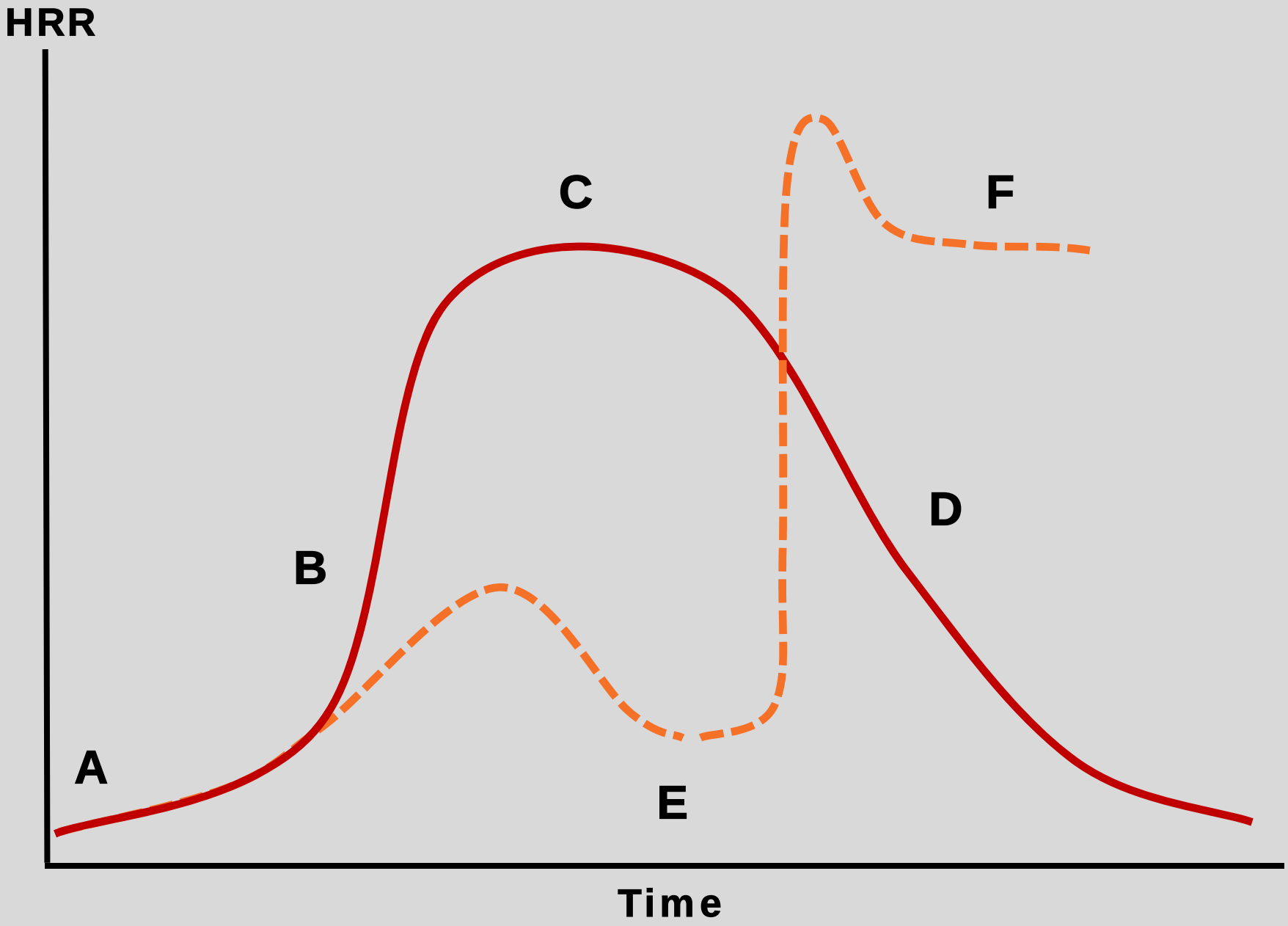
- Transition to vent controlled fire
- Fire gas ignition outside the window
- Deflagration inside the unit

CFBT-US
Not just what and how, but why!

Backdraft

- Backdraft is where an under-ventilated fire receives a sudden supply of air and an ignition source causes the mixing fire gases to ignite, sometimes with explosive force
- Backdraft may present itself in either a sustained fire where large amounts of gases have accumulated, but more likely in a brief 'flash' (non-sustained) fire

CFBT-US
Not just what and how, but why!


HRR
A
B
C
D
E
F
Time

Activity

Backdraft

This video clip illustrates a backdraft in a window cell.

- *Watch closely for fire behavior indicators that may point to backdraft potential*
- *Why do you think there is a difference in outcome in this series of demonstrations?*

A comparison, backdraft on the fireground!

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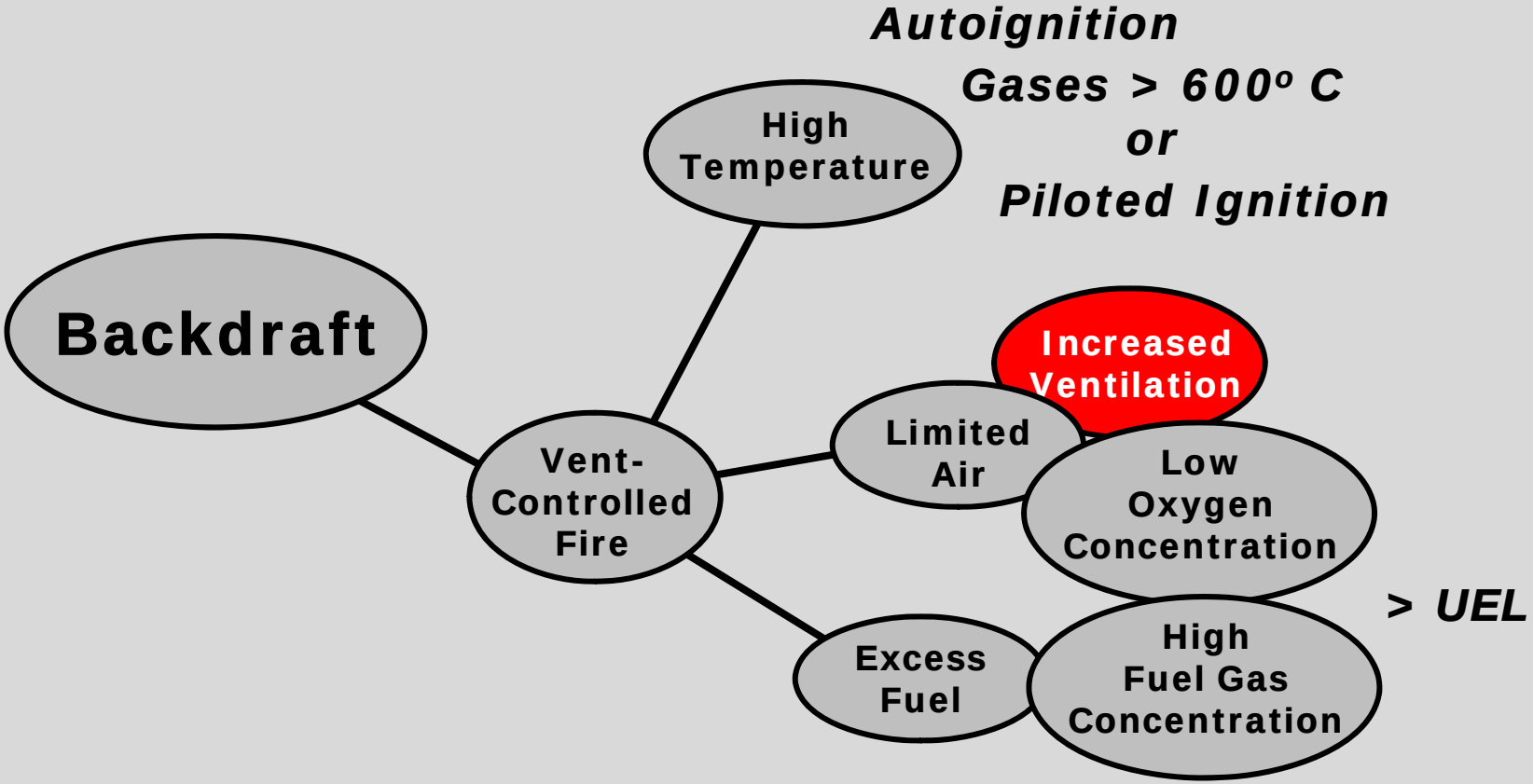
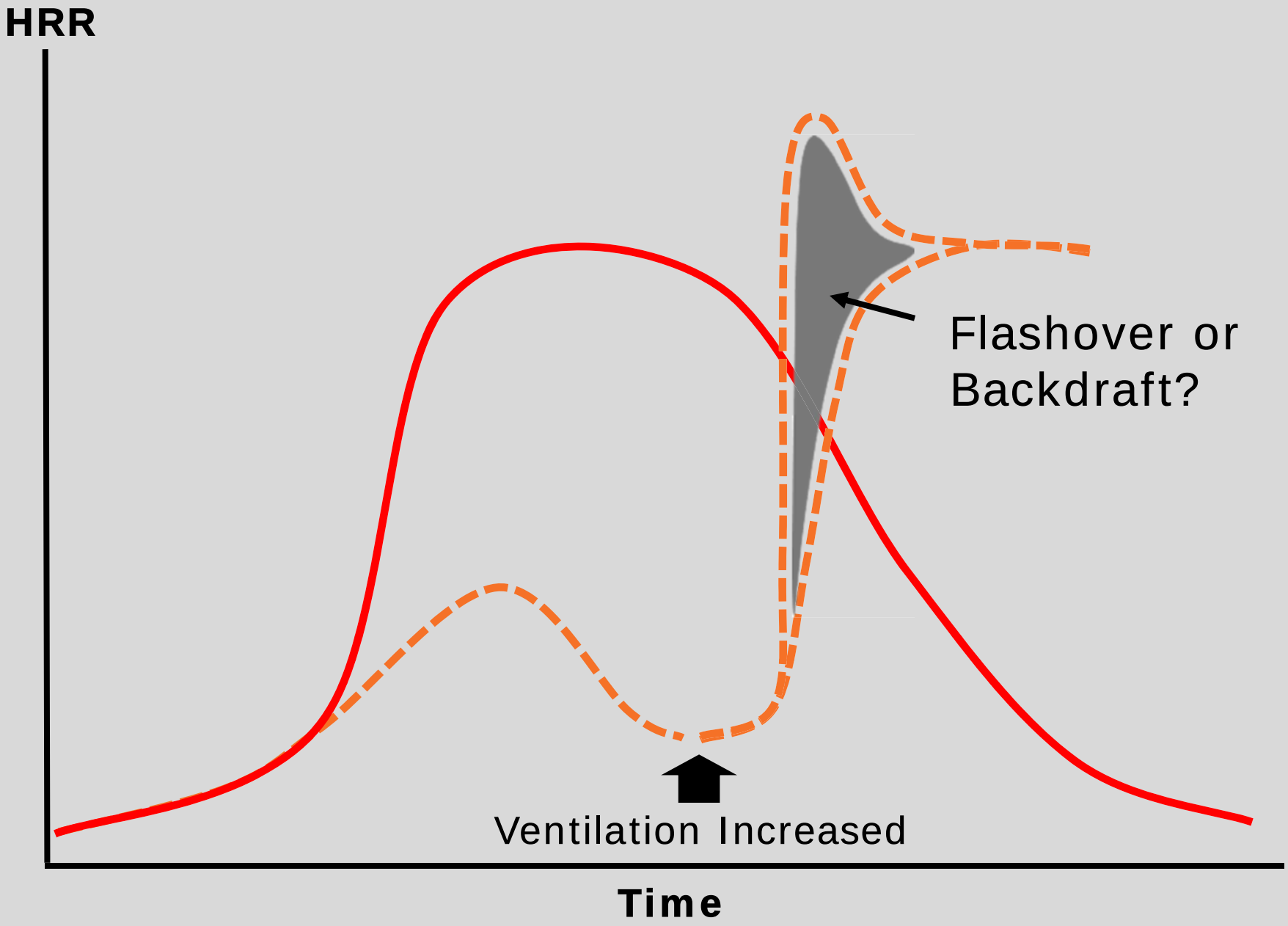
Not just what and how, but why!



CFBT-US
Not just what and how, but why!


HRR
Flashover or
Backdraft?
Ventilation Increased
Time

Sequential Effects

- A fire in a compartment may or may not reach flashover…
- Transient fire behavior in and of itself does not generally result in a sustained increase in fire intensity. However…

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Sequential Effects

- Fire in the basement of a five-story, heavy timber meat packing plant
- Yellowish brown smoke pushing with high velocity from floor four
- A backdraft followed horizontal ventilation of floor four
- Flashover of all floors lead to full involvement with extension to other buildings

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Activity

FBI-Backdraft

Develop a list of fire behavior indicators that would assist in predicting backdraft potential.

- *Exterior indicators.*
- *Interior indicators*

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Case Study 3

- Listen to the case presentation
- Review the case study materials
- Discuss the questions for each case

You have 12 minutes after the case presentation to complete this assignment

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Evanston

- Was extreme fire behavior involved in this incident? If so, what type of event happened?

  Might there have been more than one event or more than one explanation for what happened?

- How did the fire develop and what factors influenced the occurrence of the extreme fire behavior phenomenon?
- What cues were present that may have indicated potential for rapid fire development?

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Evanston

- Given the limited resources available, what options did the first arriving companies have to address the need for rapid primary search in conjunction with the potential for rapid fire development?

  How would this differ with the company staffing level and residential fire assignment used by your department?

Evanston

- Compare and contrast the Evanston incident with those in Blaina and Keokuk.
  - *What aspects of these incidents were similar?*
  - *Which were different?*
- Compare and contrast these the case study with events in your own experience.
  - *What aspects of these incidents were similar?*
  - *Which were different?*

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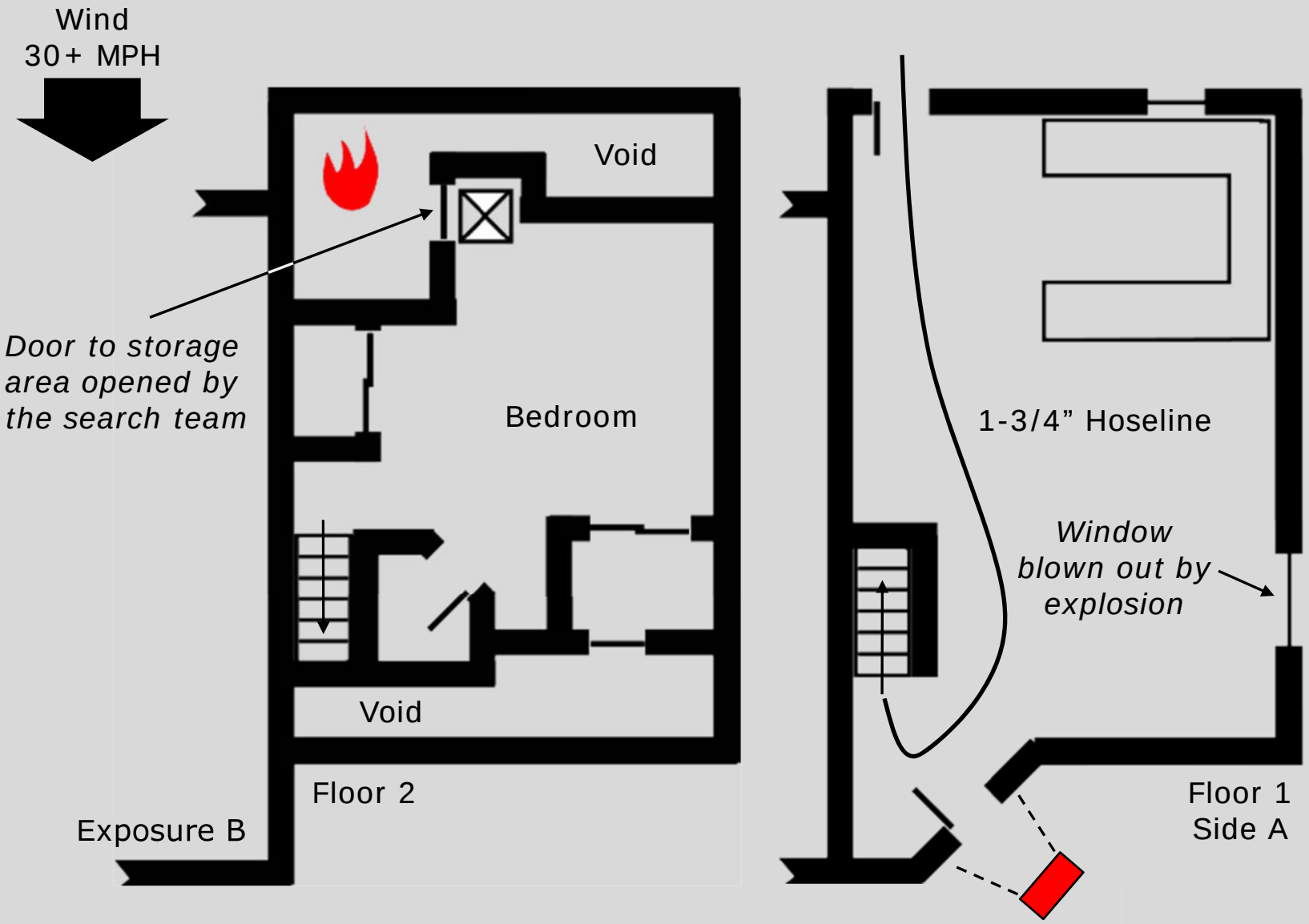

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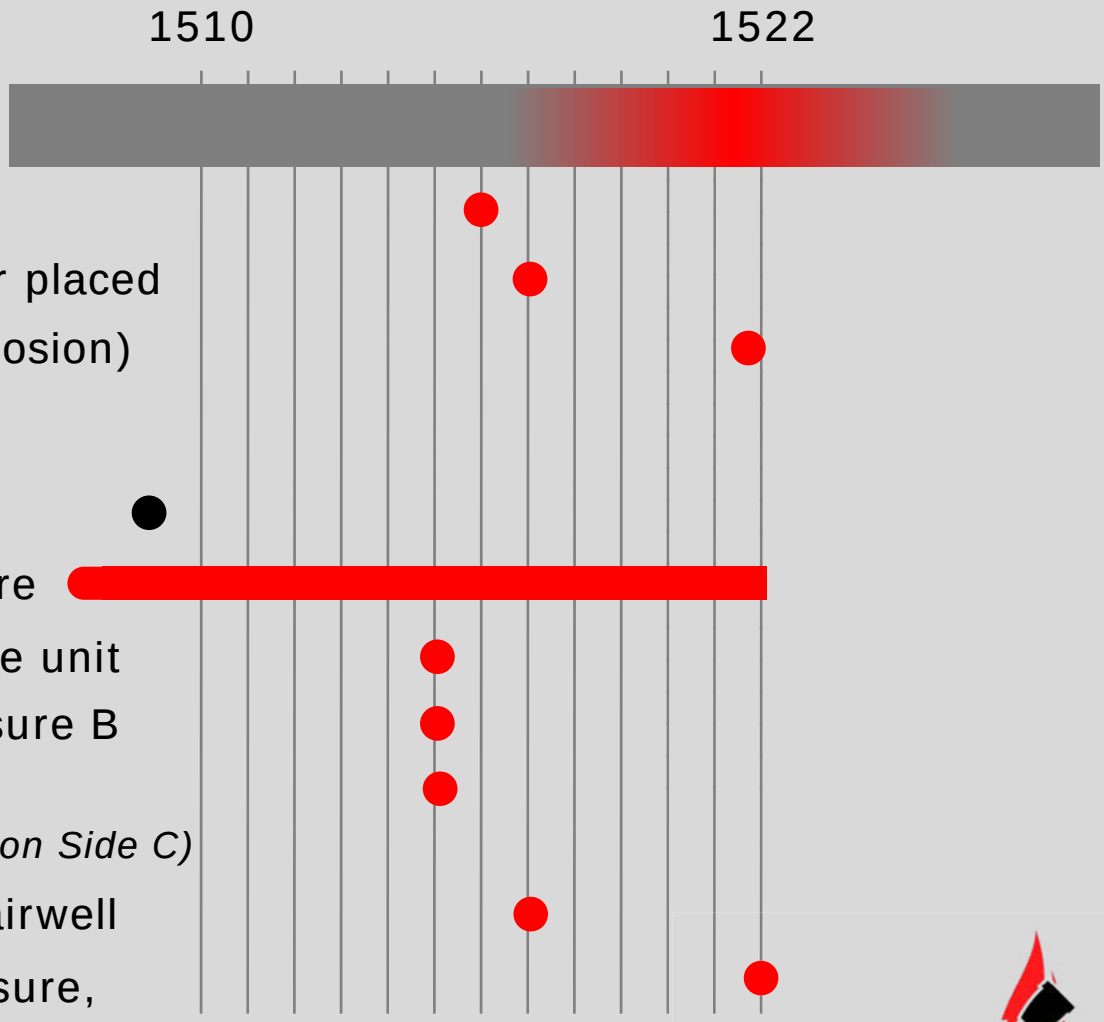
Not just what and how, but why!

12 Minutes On the Fireground

This timeline is based on data from NIOSH Report F2005-13.



Changes to Vent Profile

- Door on Side C opened
- Door on Side A opened/blower placed
- Living room window fails (explosion)

Fire Behavior

- Fire discovered (kitchen)
- Transition to vent controlled fire
- Smoke from the roof of the fire unit
- Smoke from the attic of Exposure B
- Small flame from the roof
  (at the peak and above the door on Side C)
- Heavy brown smoke in the stairwell
- Deflagration, violent overpressure, & transition to a fully developed fire

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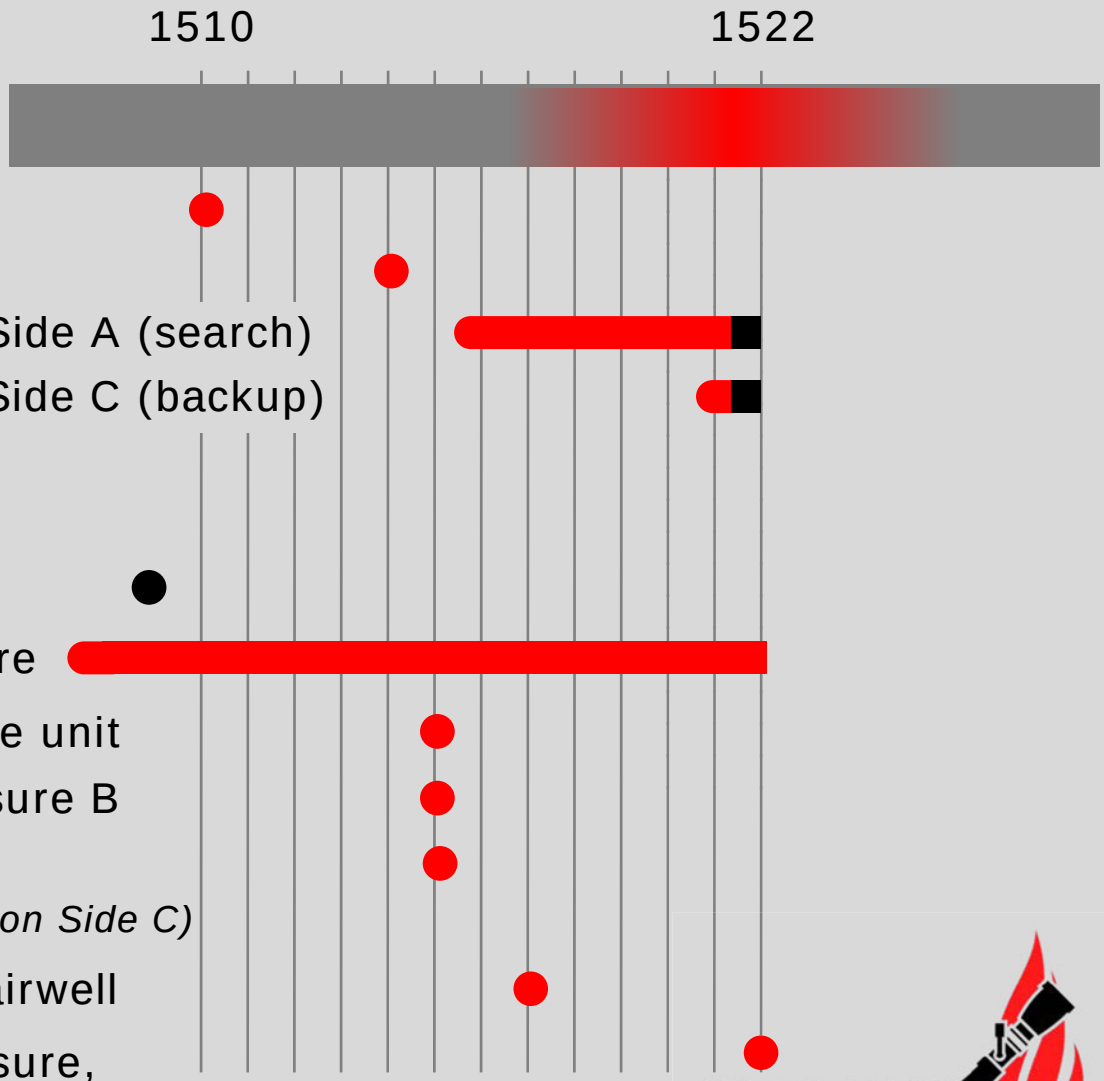
12 Minutes On the Fireground

This timeline is based on data from NIOSH Report F2005-13.



Firefighting Operations

- Alarm received
- First company on-scene
- Firefighters make entry from Side A (search)
- Firefighters make entry from Side C (backup)

Fire Behavior

- Fire discovered (kitchen)
- Transition to vent controlled fire
- Smoke from the roof of the fire unit
- Smoke from the attic of Exposure B
- Small flame from the roof
  (at the peak and above the door on Side C)
- Heavy brown smoke in the stairwell
- Deflagration, violent overpressure, & transition to a fully developed fire

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Not just what and how, but why!

Smoke Explosion

- Smoke Explosion involves ignition of an accumulated mass of flammable fire gases existing in a room or compartment
- The ignition source may be flames, embers, or may even be unrelated to the fire.
- Addition of oxygen is not necessary as the gases already mixed with air and within their flammable range

A smoke explosion is similar to ignition of propane or natural gas inside a structure

Activity

FBI-Smoke Explosion

Develop a list of fire behavior indicators that would assist in predicting potential for a smoke explosion.

- *Exterior indicators.*
- *Interior indicators*

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Variables

- What changes in the fire environment could result in a step or transient event such as flashover, backdraft or smoke explosion?
- What are the basic variables in a compartment fire?

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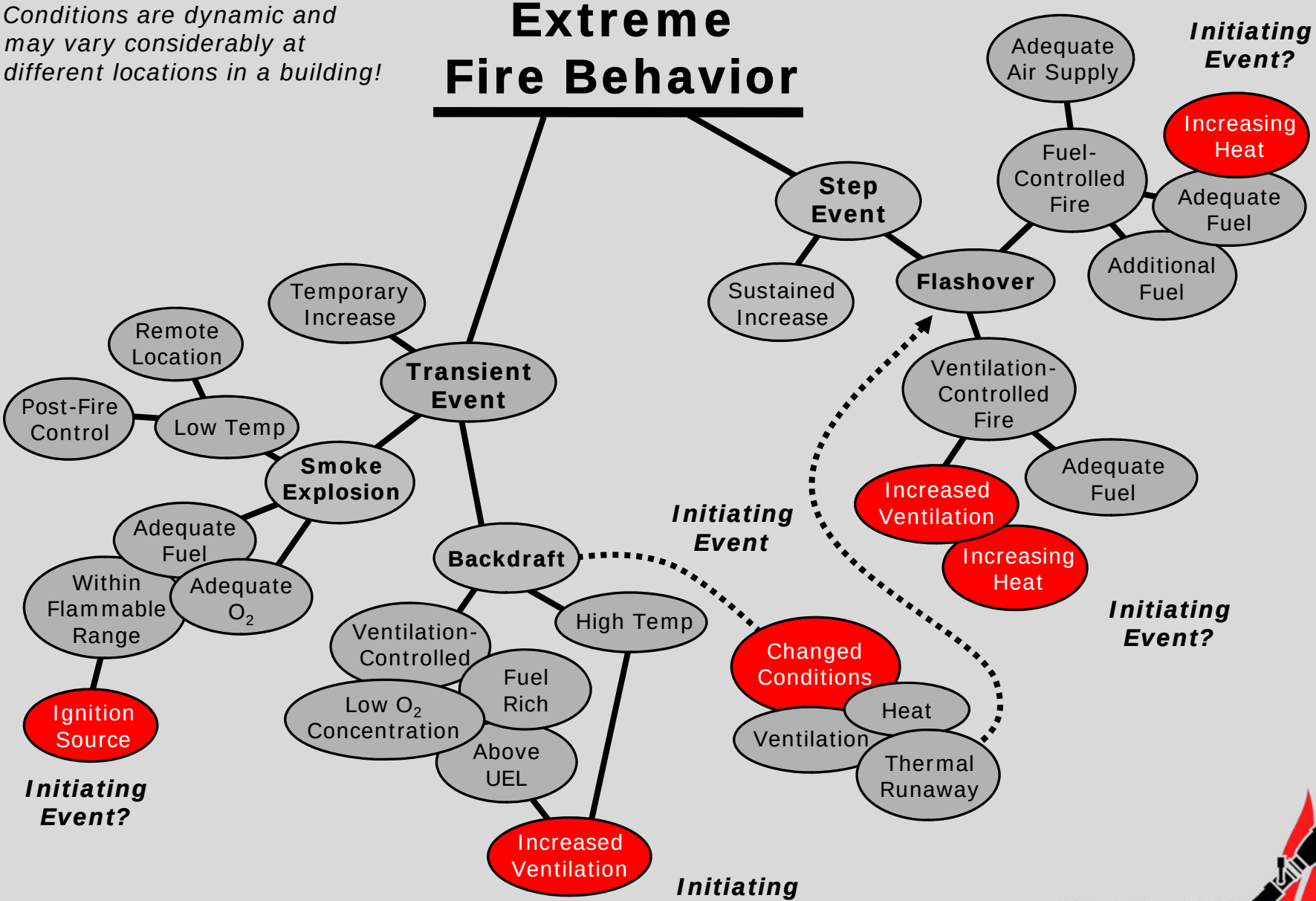
Conditions are dynamic and may vary considerably at different locations in a building!

Extreme Fire Behavior



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Acknowledgement

CFBT-US would like to thank the following individuals for their assistance in reviewing and validating this training program.

Training Officer Chris Baird
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Queensland Fire Rescue

Station Officer John McDonough
New South Wales Fire Brigades

Paul Grimwood
London Fire Brigade (Ret.)

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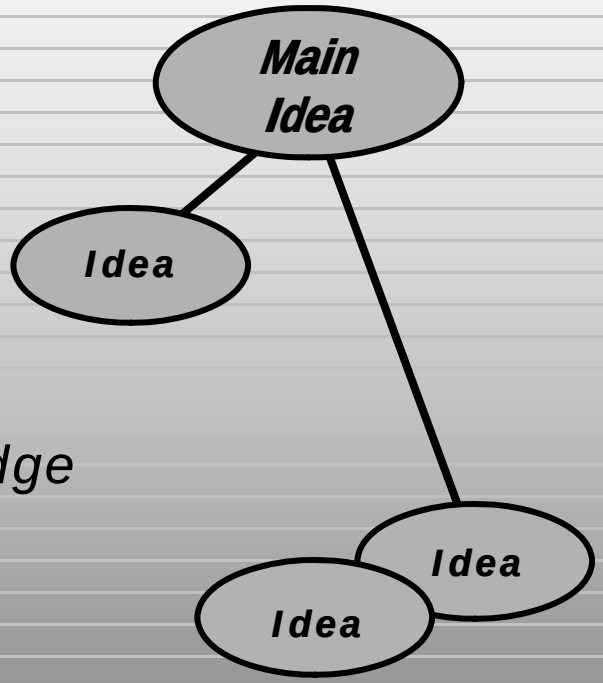
Cluster Maps

Knowledge represented in graphic format

- *Generate ideas*
- *Design a complex structure*
- *Communicate complex ideas*
- *Integrate new and old knowledge*
- *Assess understanding*



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Ed Hartin, MS, EFO, MIFireE, CFO

Ed Hartin, MS, EFO, MIFireE, CFO is a Battalion Chief with Gresham Fire and Emergency Services in Gresham, Oregon and the owner of CFBT-US, LLC a fire service training company specializing in the area of structural fire behavior. Ed has a longstanding interest in fire behavior and has traveled internationally, studying fire behavior and firefighting best practices in Sweden, the UK, and Australia. Ed co-authored *3D Firefighting: Techniques, Tips, and Tactics* a text on compartment fire behavior and firefighting operations published by Fire Protection Publications and has published articles in a number of fire service publications in the US and UK. Ed has also delivered training in compartment fire behavior (CFBT) and tactical ventilation throughout the US as well as in Australia, and Malaysia. The International Association of Fire Chiefs (IAFC) at its 2006 Annual Conference recognized Gresham Fire and Emergency Services compartment fire behavior training (CFBT) program as a finalist for an Award of Excellence.

Ed is a graduate of the National Fire Academy Executive Fire Officer Program and was awarded Member grade in by the Institution of Fire Engineers and Chief Fire Officer Designation by the Commission on Fire Accreditation International.

Ed holds a BS in Fire Service Administration and Master of Science degree in Education. He is currently a doctoral candidate at the Portland State University Graduate School of Education. His research is focused on firefighters beliefs about knowledge and learning with an emphasis on how these beliefs influence the way in which firefighters learn from their experience. Ed will be presenting preliminary results of this research at RE07, the British Fire Service College annual research symposium which will be held in November 2007.