



Using CAST for Fire Investigation

Analysis of a 1999 Keokuk, IA Fire

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Problems with Current Investigation Methods

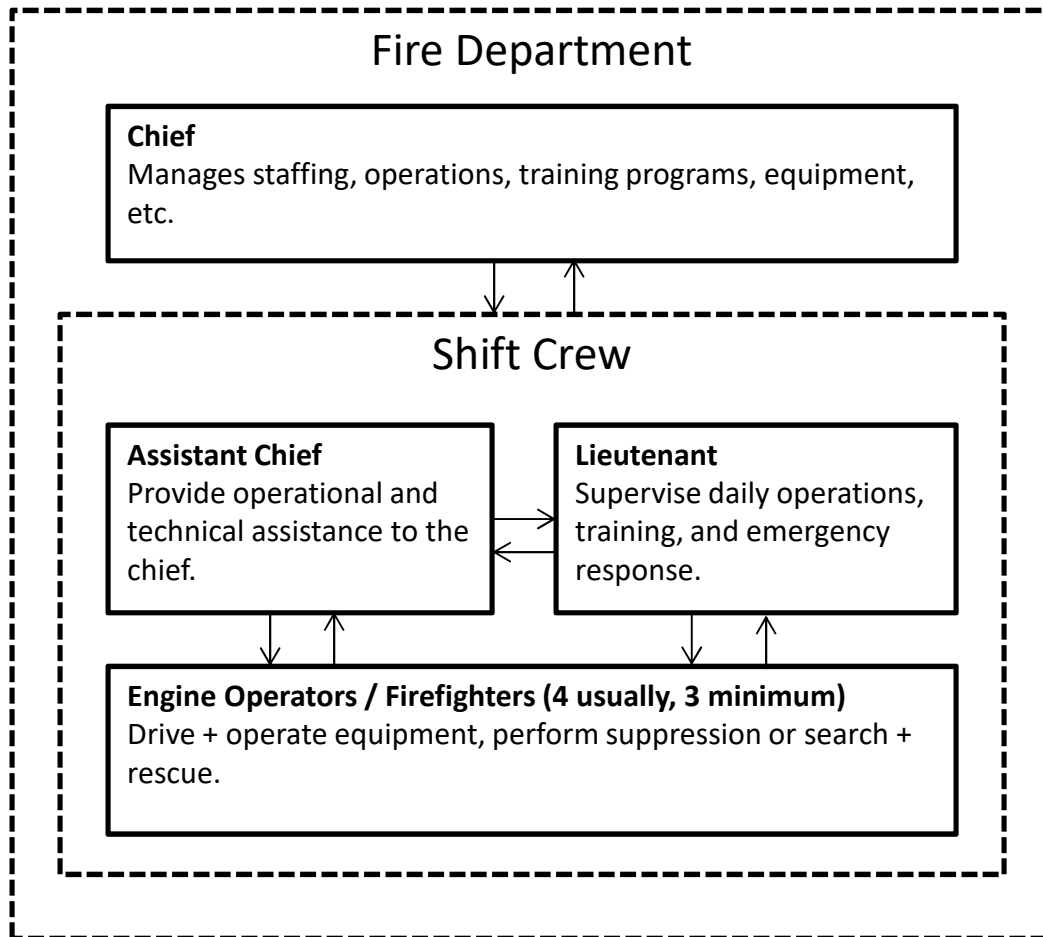
- **BLAME** falls on firefighters and chiefs for making “risky decisions” if they don’t go well; but current approaches do not recognize that such risks may be required for many successful rescues.
- Investigations touch on systemic issues, but **conclusions** focus too narrowly on single issues with obvious solutions.

Keokuk, Iowa Fire

- On December 22, 1999, around 8:24 am, a major apartment fire in a 3-family building spread from the stove to the rest of the unit.
- Occupants (5 total)
 - One adult woman and one child escaped onto the porch roof
 - Three other children remained trapped inside
- Casualties (3 occupants, 3 firefighters)
 - Two infants were removed from the building, but did not live
 - One child and three firefighters were found in the building
- Casualties were caused by sudden flashover, or “near-simultaneous ignition of most of the directly exposed combustible material in an enclosed area”

One of the most widely-studied fires in history.

Keokuk Fire Department



- City of about 10,000 people
- 19 full-time members
- 6-person shift crews
- 3 shifts
- Police & fire share a building, dispatcher

Physical Structure (Rear View)



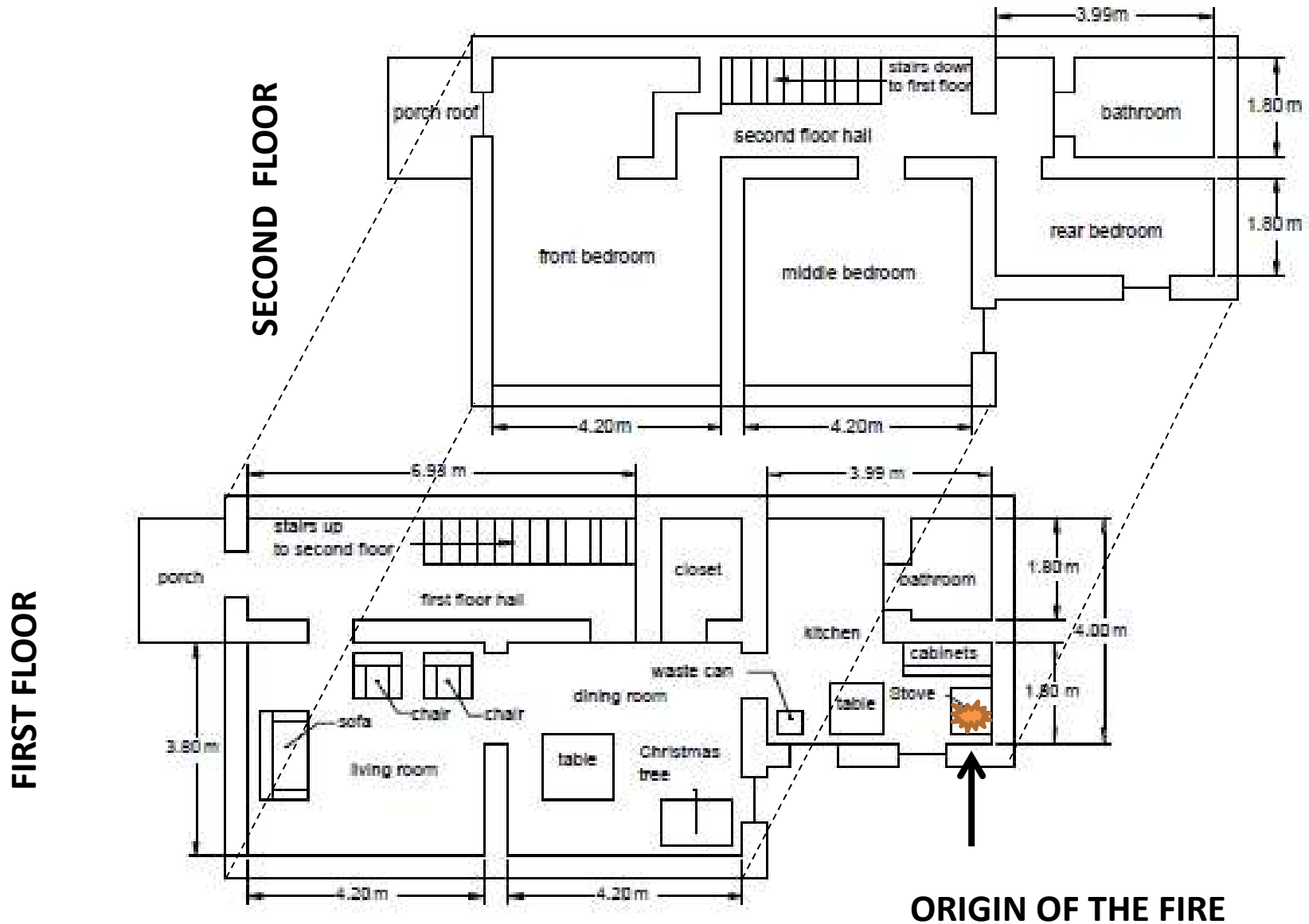
- “Balloon frame” home built in 1870s
- Remodeled in 1970s to create 3 apartments
- Attic and basement not involved in fire

ORIGIN OF THE FIRE

Fire Origin

- One of the four children in the home woke up & turned on the stove, starting the fire
- The child told his mother, who brought him onto the porch roof and tried to rescue the other 3 children
- She was unable to get to the rear bedrooms due to heat, returned to the porch and called for help
- A neighbor called 911 to report the fire

Physical Structure



Summary of Events (1)

- Truck carrying **Assistant Chief (AC)** & an **Engine Operator (EO)** arrived at 8:28 am.
 - EO set up truck while AC called for backup, then began search & rescue.
- Engine arrived with **Lieutenant** and a **second EO**, who set up hoses.
- **Department Chief** and another **fire fighter (FF)** arrived.
- Chief took command, instructed the two EOs to join the AC in search & rescue.

Summary of Events (2)

- Search & rescue team retrieved 2 infants from the house
 - One was transported by a police officer.
 - Second transported by the fire chief, who performed CPR on the way to the hospital
- Lieutenant and FF performed suppression
 - Noticed that line burned through, ground floor was engulfed in flames (flashover)
 - Location of search and rescue team and 3rd child unknown, no further contact with them

Timeline of Events

Table 1. Approximate Incident Timeline

Incident Time	Events	Simulation Time (s)
08:24	First call reporting fire.	0
08:26	Fire fighters arriving on scene	120
08:27	Front door open	180
08:28	Fire fighters on scene requesting back-up	240
08:31	Fire Chief arrives on scene	420
08:33	Second infant removed from house by this time	540
08:34	First infant enroute to hospital.	600
08:35	Second infant enroute to hospital, hoseline burned	660
08:48	Discovered fire fighter on 1 st floor	

Prior Studies We Examined

- NFPA – National Fire Protection Association
 - Standard Fire Investigation
- NIOSH – National Institute for Occupational Safety and Health
 - FFFIP: Fire Fighter Fatality Investigation And Prevention Program
- NIST – National Institute of Standards and Technology
 - Simulation of the fire dynamics & timeline

Prior Study Recommendations

- “Ensure that Incident Command conducts an initial size-up of the incident before initiating fire fighting efforts and continually evaluates the risk vs. gain”
- “Ensure that a trained Rapid Intervention Team (RIT) is established and in position immediately upon arrival”
- “Ensure that adequate numbers of staff are available to immediately respond to emergency incidents”
- “Ensure that fire command always maintains close accountability for all personnel at the fire scene”
- “Ensure that fire fighters wear and use PASS devices when involved in interior fire fighting and other hazardous duties”

CAST ANALYSIS

System Level Accidents & Hazards

- A1: Firefighter death or serious injury.
- A2: Civilian death or serious injury.
- A3: Preventable damage to property.

- H1: Firefighter exposed to dangerous levels of heat, smoke, and exertion.
- H2: Civilians exposed to dangerous levels of heat or smoke.
- H3: Uncontrolled spread of fire to property.

System Safety Constraints

- H1: Firefighter exposed to dangerous levels of heat, smoke, and exertion.
 - SC1: Firefighters must avoid exposure to heat, smoke, or exertion except where the risk is deemed necessary to protect civilians or property.
- H2: Civilians exposed to dangerous levels of heat or smoke.
 - SC2: Firefighters must attempt to remove civilians from areas with dangerous levels of heat or smoke (search & rescue).
- H3: Uncontrolled spread of fire to property.
 - SC3: Firefighters must control fire spread through suppression and ventilation activities.

Police Officers
• Assist with rescues, crowd management and emergency medical transportation.

Dispatch Center
Respond to 911 calls by dispatching appropriate emergency personnel.

Neighbors
Call 911 to report emergency.

Various Oversight Groups
Responsible for Standards and Regulations

INCIDENT SAFETY CONTROL STRUCTURE

Note: only control arrows are depicted for simplicity, but feedback & coordination is required throughout the system!!

Chief/ Incident Command
Coordinate FFs (& EMS?) to perform suppression / ventilation / search and rescue / emergency medical. Protect FFs, civilians, and property from harm.

Lieutenant, Engine 3
Lead FFs and engine operators in suppression, ventilation & search + rescue activities.

Assistant Chief
Lead FFs in absence of chief, commanding suppression, ventilation & search + rescue. Protect FFs, civilians, and property from harm.

Fire Fighter #1
• Suppression, ventilation & search + rescue activities as instructed.

Engine Operator, E3
• Operate equipment. Suppression, ventilation & search + rescue activities as instructed.

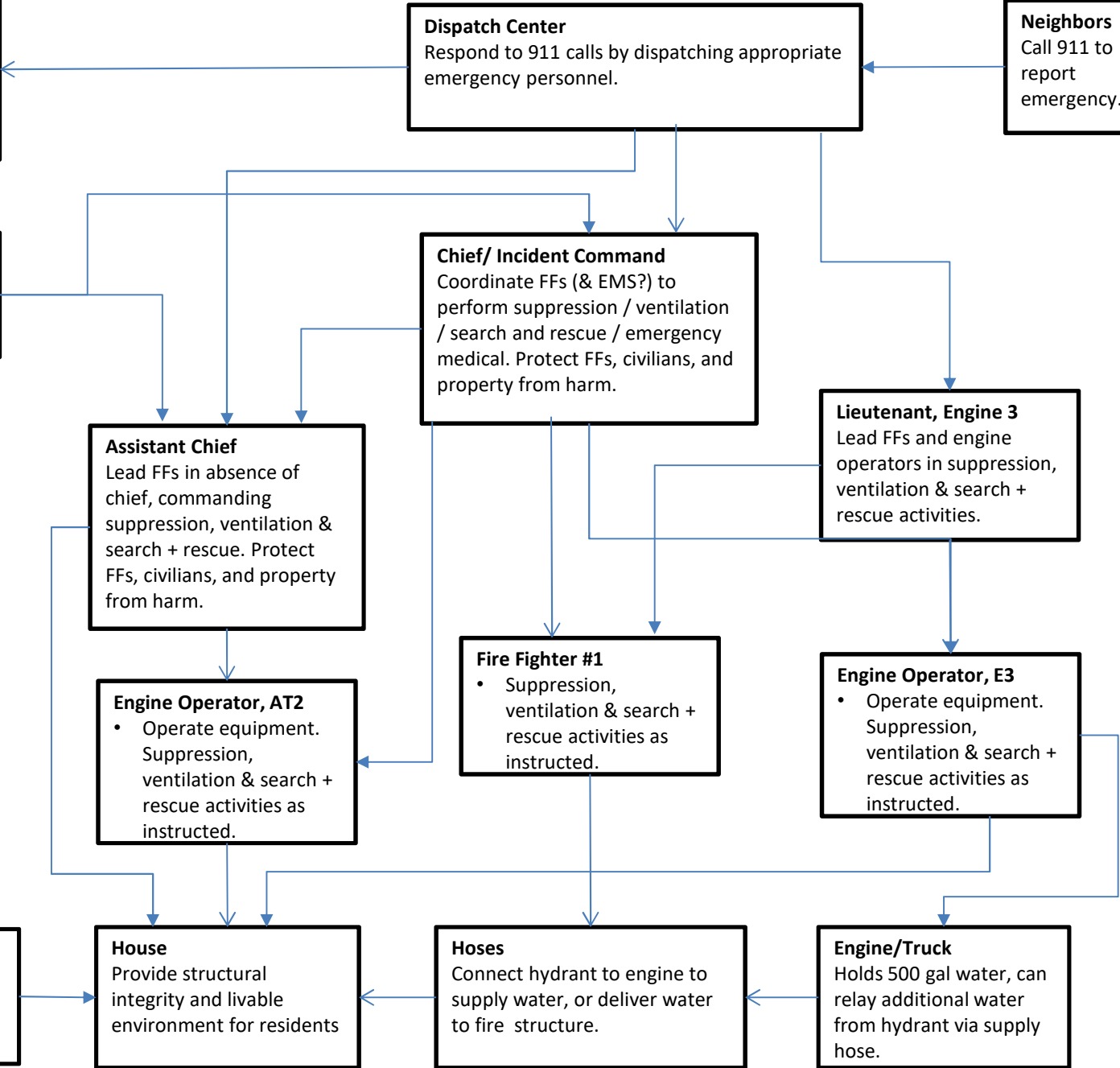
Engine Operator, AT2
• Operate equipment. Suppression, ventilation & search + rescue activities as instructed.

Occupants
Maintain smoke detectors, use caution with stove...

House
Provide structural integrity and livable environment for residents

Hoses
Connect hydrant to engine to supply water, or deliver water to fire structure.

Engine/Truck
Holds 500 gal water, can relay additional water from hydrant via supply hose.



CAST – Physical Process

- Constraints violated:
 - exposure of civilians & FFs to heat and smoke; uncontrolled spread of fire
- Physical controls:
 - Smoke detectors to alert residents & emergency responders
 - 500 Gal water in engines; supply lines from hydrant to engine; attack lines from engine; ventilation activities
 - Protective clothing; oxygen tanks & masks; PASS devices

CAST – Physical Process

- Failures, Inadequate Controls, & Unsafe Interactions:
 - Lack of smoke detectors
 - Rapid spread through balloon-frame house;
 - Water stored in engine not immediately used; skipping supply line could have started suppression sooner
 - Attack line burned through
 - Rear window was vented, but went only to a closed bathroom
 - Oxygen tanks ran out; possible failure of PASS devices & limited design range
- Context
 - Balloon-frame home may not have been up to modern codes
 - Instructions require running supply lines in case stored water runs out
 - Search and rescue was prioritized over suppression & ventilation
 - Limited time, limited manpower

Assistant Chief

- Safety Responsibilities
 - Perform size-up, request backup if needed
 - Begin suppression, ventilation, and search & rescue as appropriate while following guidelines
- Unsafe Decisions
 - Entered building alone (violated 2-in, 2-out)
 - Prioritized search and rescue over suppression
 - “Size-up” may have been inadequate

Assistant Chief

- Process Model Flaws
 - Believed the children could be rescued before flashover occurred
 - Thought additional time spent on suppression or size-up would hurt their chances of survival
- Context
 - Extremely limited personnel
 - Could not easily obey 2-in, 2-out and had to make decisions fast to try to save the children
 - The mother of the children was present and visibly distressed

Chief (Incident Command)

- Safety Responsibilities
 - Assign responsibilities to firefighters at the scene.
- Unsafe Decisions
 - Left the scene of the fire to transport the second infant to the hospital.
 - Lost track of victims performing search & rescue.
 - Did not order a Rapid Intervention Team until after victims had been missing for some time.

Chief (Incident Command)

- Process Model Flaws
 - Believed it was safe to briefly leave the scene while driving a few minutes to the hospital.
 - Perhaps did not realize flashover occurred.
- Context
 - Search and rescue began before the chief arrived, AC was already inside.
 - The hospital was only 3 minutes away.
 - Without adequate EMS personnel on site there was no one else to perform CPR on the second infant on the way to the hospital.

Oversight Organizations

- Responsibilities:
 - Write rules and guidelines
- UCA:
 - Created rules that don't work for all fire departments (2-in-2-out)
- Process Model Flaw:
 - Believe rules will improve safety
- Context:
 - Rules often written in response to losses
 - Large departments from urban settings have most influence on rule making

New Conclusions

- Behavior of Chief & Assistant Chief *made sense in context*, and would have been seen very differently if they had led to a “heroic rescue”
- One-size-fits-all rules do not work! Small departments operate have very different needs & limitations
- Using CAST suggests different priorities (better physical controls, creation of standard operating procedures, etc.) than traditional approaches