

Hypothesis Development in Fire Investigations: Theory and Practice



Fire Investigators of Florida, Inc.

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Objectives

- What is a Hypothesis?
- What Role Do They Play in Fire Investigation?
- What Can I Hypothesize About?
- What Are the “Rules” of Hypothesis Formation?
- How Can They Help Me?
- How Do I Document Hypotheses?



Scientific Method

- “The scientific method ...is a principle of inquiry that forms a basis for legitimate scientific and engineering processes, including fire incident investigation.”

NFPA 921- 2021 ed. §4.3



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Scientific Method

- A Scientific Method is the best process to force the fire investigator to look beyond the obvious; to think about their observations, hypotheses and opinions.
- It is not a magical process to “Absolute truth.”
- It does not prevent others from reaching arguably valid, alternative conclusions.



Scientific Method

- NFPA 1033 (2022) – §4.1.2* The fire investigator shall employ all elements of the scientific method as the operating analytical process throughout the investigation and for the drawing of conclusions.
- See Annex A §A4.1.2 – "...collecting data, then developing and testing hypotheses...Developing hypotheses is an ongoing process...that happens throughout the investigation."



Scientific Method

- NFPA 921 (2021) – and previous editions – presents Scientific Method as a linear, iterative process.



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Recognize the Need (Identify the problem)



Define the Problem



Collect Data



Analyze the Data



Develop a Hypothesis (Inductive reasoning)



Test the Hypothesis (Deductive reasoning)



Select Final Hypothesis

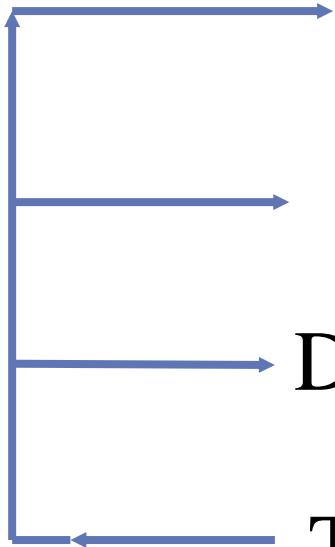


Figure 4.3 NFPA 921 – 2021 ed.

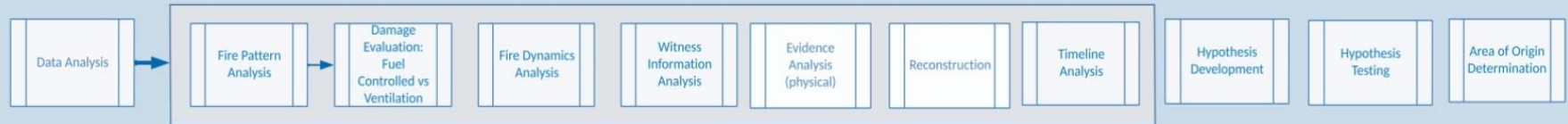
Fire Investigation Process Map

- Released March 14, 2023
- National Institute of Standards and Technology (NIST) in a collaboration between the NIST Forensic Science Research Program and the NIST-administered Organization of Scientific Area Committees (OSAC) for Forensic Sciences (specifically OSAC's Fire & Explosion Investigation Subcommittee).

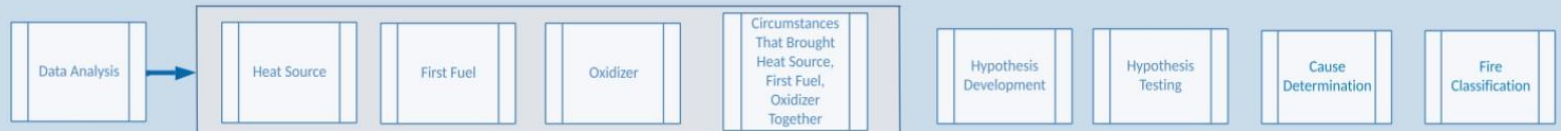


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3000 Origin Determination



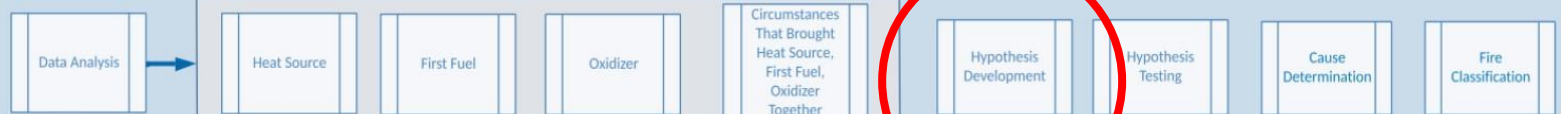
4000 Cause Determination

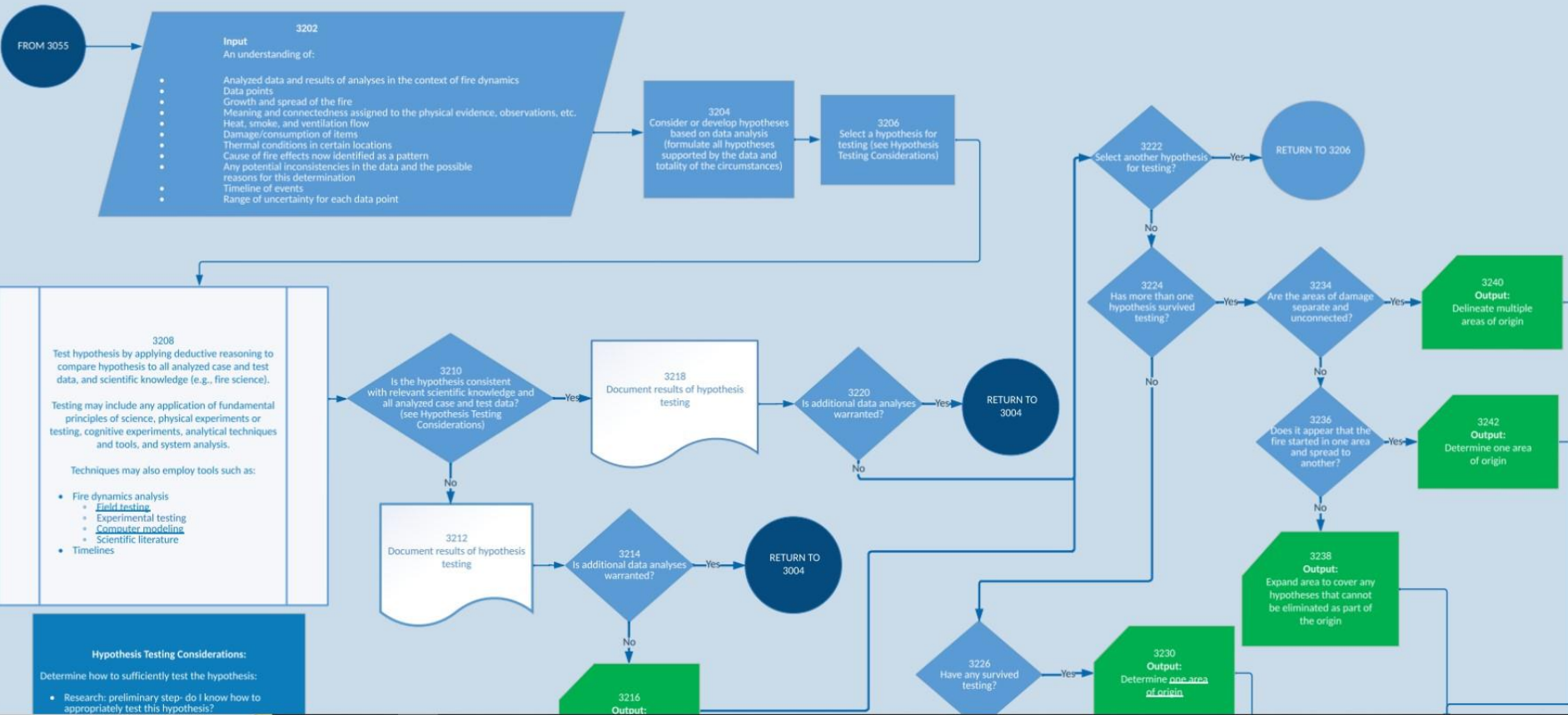


3000 Origin Determination



4000 Cause Determination





Fire Investigation Process Map

- “...the OSAC Fire Investigation Subcommittee does not necessarily support or endorse (as best practices) all of the different steps and paths depicted in this process map.”
- https://www.nist.gov/system/files/documents/2023/03/15/_Fire%20Investigation%20PM%20FINAL.pdf?fbclid=IwAR2vx0UKWGtGQqaXGUrvaoGa2w05H-5RB3D-O0GrM9DdcCmLEBtJXWAjOsg



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Scientific Method

- It is important to understand and apply a systematic approach in order to arrive at a defensible opinion as to the probable origin and cause of a fire.
- It is also important because **METHODOLOGY** is often the first line of attack in adversarial proceedings related to the event.



Scientific Method

- NFPA 921 (2021) Figure 4.3 is a **NORMATIVE** presentation of the methodology.
- It represents how the NFPA 921 Technical Committee believes the process **OUGHT** to flow.
- Not, necessarily, how it is employed in practice.



Scientific Method

- Some discussion regarding the existence of THE scientific method.
- Philosopher of science Paul Feyerabend – “anarchy”, “anything goes”, “the tyranny of science”
- “The Scientific Method” as Myth and Ideal [*Sci & Educ* 23, 2069 – 293 (2014).]
- Percy W. Bridgeman (Nobel laureate) – “good deal of ballyhoo about scientific method.” (On Scientific Method from *Reflections of a Physicist*, 1955)



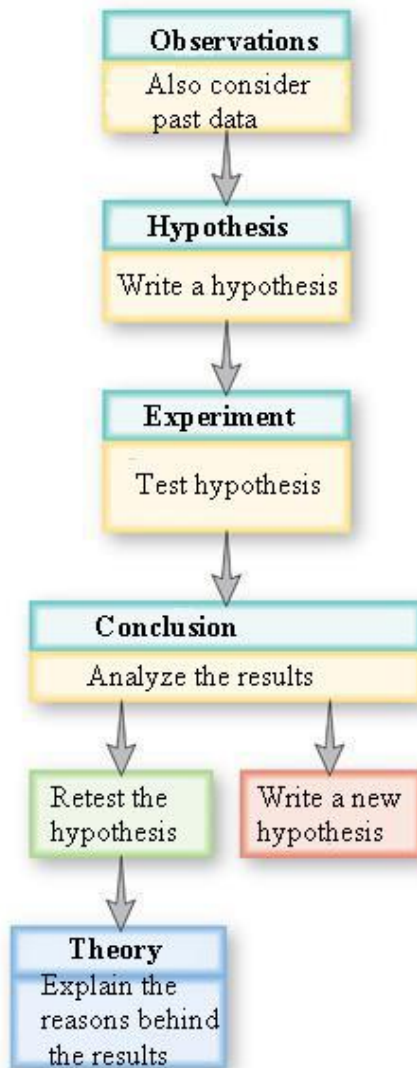
Scientific Method

- “Although no single universal step-by-step scientific method captures the complexity of doing science, a number of shared values and perspectives characterize a scientific approach to understanding nature. Among these are a demand for naturalistic explanations supported by empirical evidence that are, at least in principle, testable against the natural world. Other shared elements include observations, rational argument, inference, skepticism, peer review, and reproducibility of the work. ”
- National Science Teaching Association
Position Statement - Nature of Science



Scientific Method

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Scientific Method

- John Dewey “How We Think” (1910)
 - “Upon examination, each instance reveals...five logically distinct steps: (i) a felt difficulty; (ii) its location and definition; (iii) suggestion of possible solution; (iv) development by reasoning of the bearings of the suggestion; (v) further observation and experiment leading to its acceptance or rejection; that is, the conclusion of belief or disbelief.”



Scientific Method

- The DESCRIPTIVE application of the methodology is more complex and not linear.
- (At least in my mind. I acknowledge that I do not know how everyone thinks and can only describe my process. But I have spoken to colleagues in fire investigation who have similar experience.)



Scientific Method

- NFPA 921 (2021) - §4.3.4 Analyze the Data.
 - “The scientific method requires that all data collected be analyzed.”
 - “This is an essential step that must take place before the formation of the FINAL hypothesis.” (*Emphasis added*)
 - “Analysis of the data is based on the knowledge, training, experience and expertise of the individual doing the analysis.”



Scientific Method

- NFPA 921 (2021) - §4.3.4 Analyze the Data.
 - “The scientific method requires that all data collected be analyzed.”
- This DOES NOT say that ALL DATA MUST BE COLLECTED before analysis or hypothesis formation (as some have argued.)



Scientific Method

- NFPA 921 (2021) - §4.3.4 Analyze the Data.
- What do we ANALYZE the data against?
- What does it mean to “Analyze the Data”?



Scientific Method

Let's Look at a Data Point that has been collected:



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Scientific Method

- What do you think of when you see this piece of data?
- Did you think that the fire may have started on the Interior of the Structure rather than the Exterior?
- Do you need a “guiding statement” against which to analyze the data?





Scientific Method

- NFPA 921 (2021) - §4.3.5 Develop Hypotheses
- Note the change from the 2017 Edition – Hypothesis to Hypotheses - to encourage the idea that multiple hypotheses need to be formed rather than a singular hypothesis.



Scientific Method

- NFPA 921 (2021) - §4.3.5 Develop Hypotheses
- “Based on the data analysis, the investigator produces hypotheses to explain the phenomenon...”



Scientific Method

- NFPA 921 (2021) - §4.3.5 Develop Hypotheses
- “These hypotheses should be based solely on the empirical data that the investigator has collected through observation and then developed into explanations for the event, which are based upon the investigator’s knowledge training , experience and expertise.”



Scientific Method

- NFPA 921 (2021) - §4.3.5 Develop Hypotheses
- By inference, hypotheses are “based upon the investigator’s knowledge, training, experience and expertise”
- These are yours.



Scientific Method

- What is a HYPOTHESIS?
- Since NFPA 921 does not provide a clear definition in Chapters 3 or 4 ...



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Hypothesis

- Guiding Statement
- Provisional Statement
- Speculative Statement
- Testable Statement
- Educated or Informed “Guess”
- “What if...?”



Hypothesis

- NFPA 921 (2021) §18.2 and 19.2 describe hypotheses, based on “data available at the time” as “‘working hypotheses,’ which upon testing may be removed from further consideration, revised, or expanded in detail as new data is collected...”



Hypothesis

- **16th, 17th, 18th Century**
 - Bacon, Newton, Hume
 - *“Hypotheses non fingo”*
 - *“I frame no hypotheses” (roughly)*
 - Physical world; Observable
- **19th Century**
 - Whewell, Pierce, Darwin, Mach, Hertz
 - Postulate unobservable
 - Hypothetico-deductive method



Hypothesis

- Hypotheses are Free!!
- Form as many as you can.
- Form as many as you want.
- The more you form, the better your outcomes.



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Can you form a
hypothesis with only a
“Problem Statement” and
/or minimal Data?



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“Problem Statement”

Fire in a Two-Story Single Family House



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How much analysis was
required to form
hypotheses?



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Admittedly, analysis (based on your knowledge, training, and experience) may happen so quickly as to be almost imperceptible. As a result, hypotheses may sometimes be formed with little analysis.

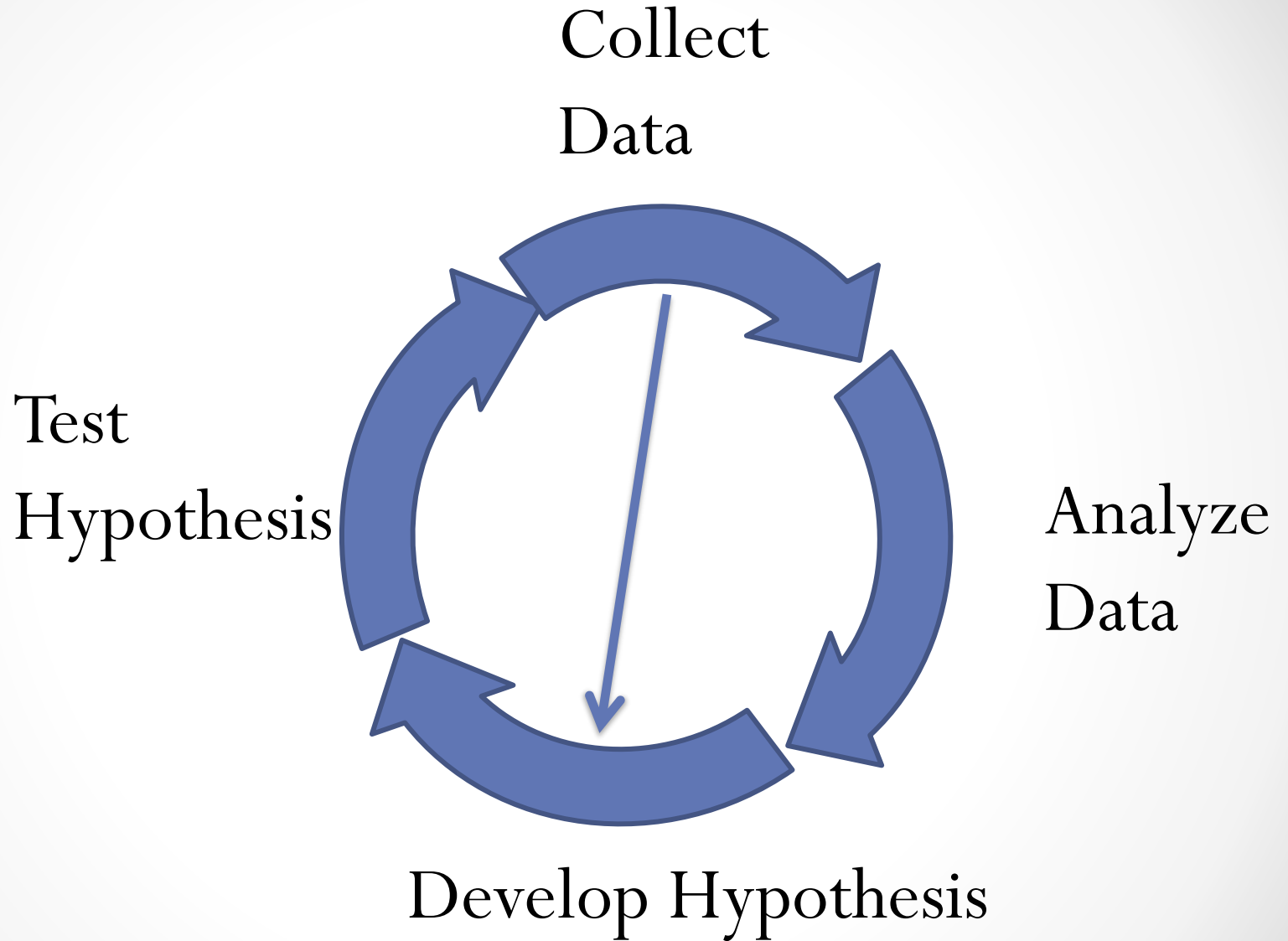


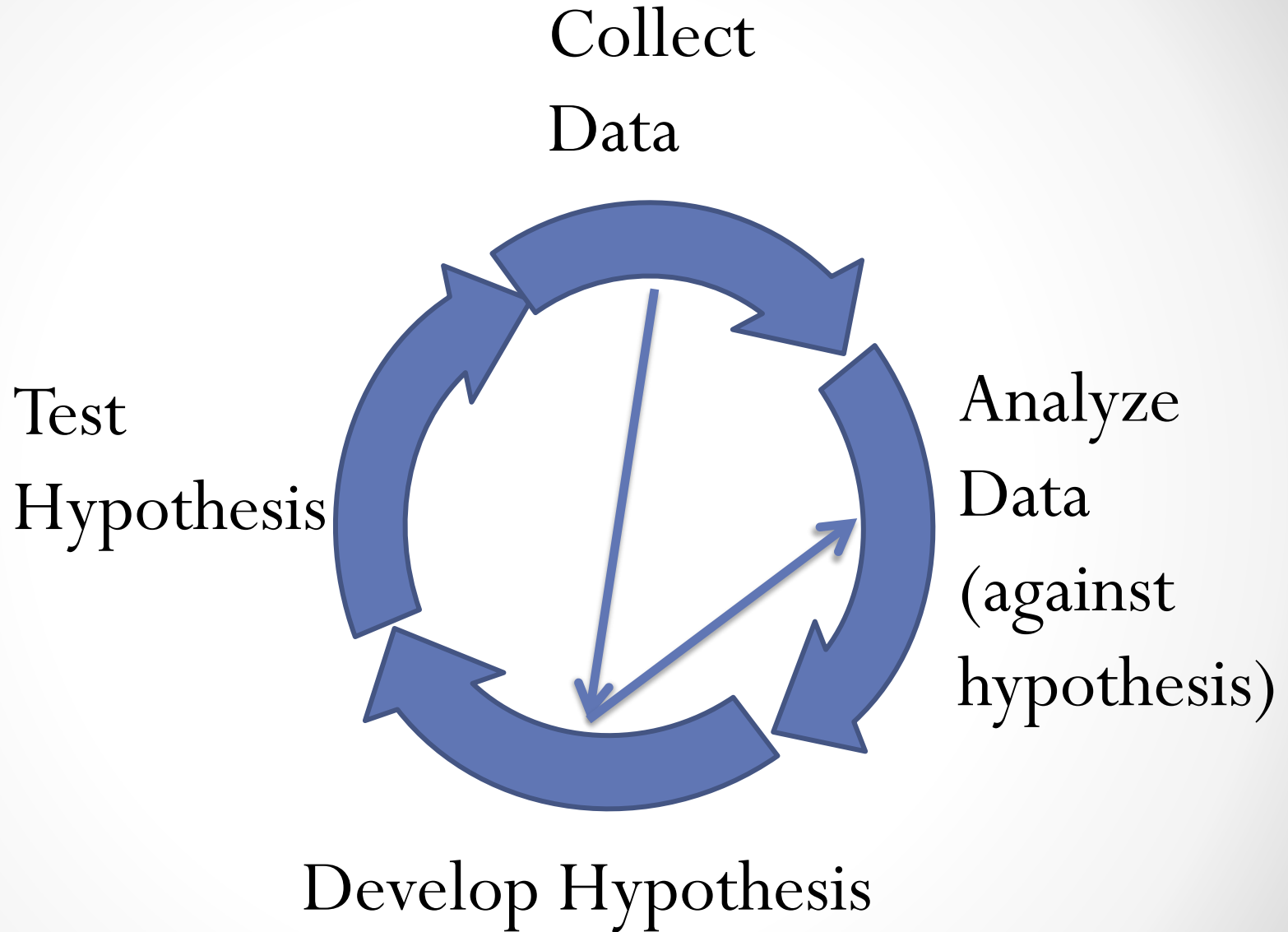
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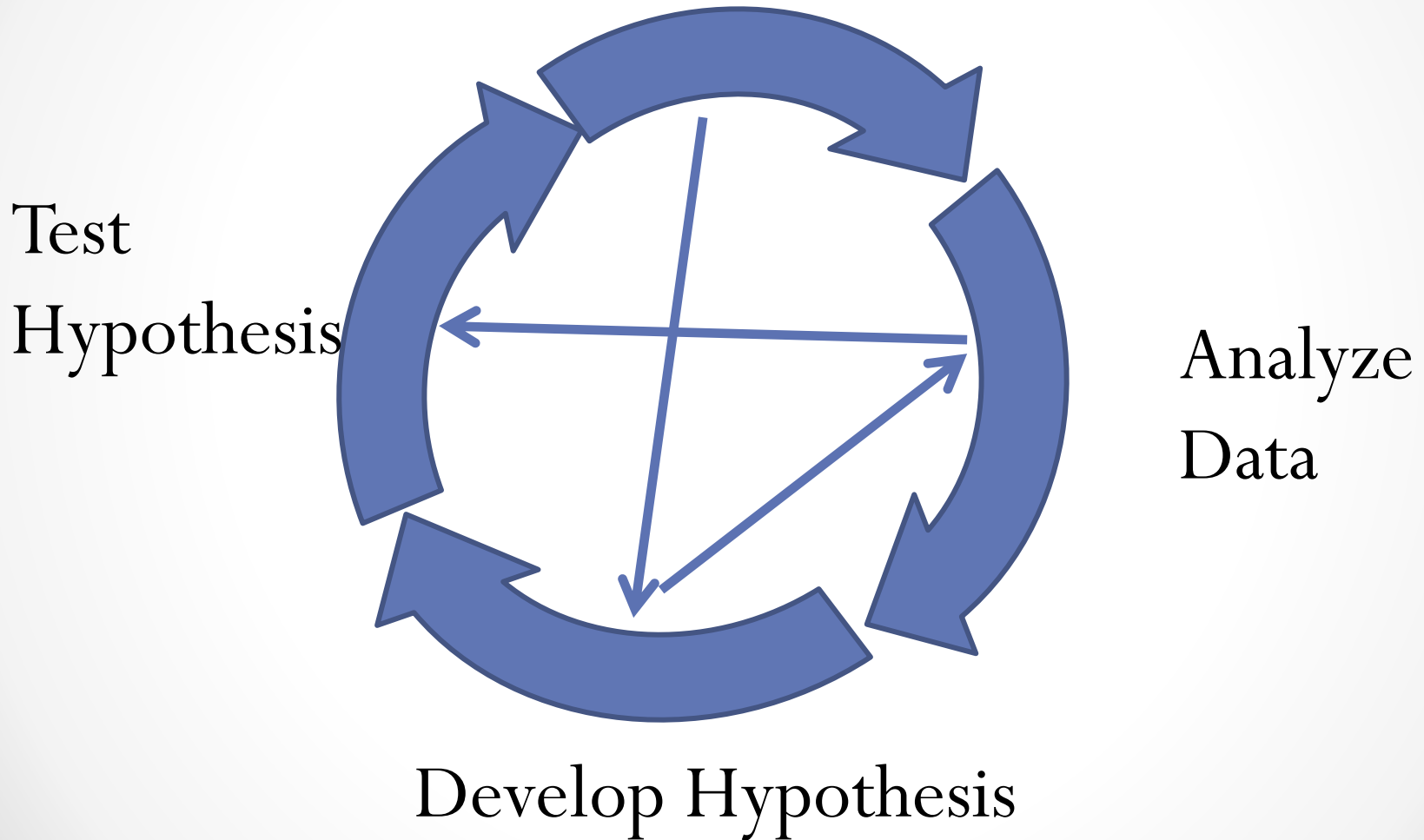
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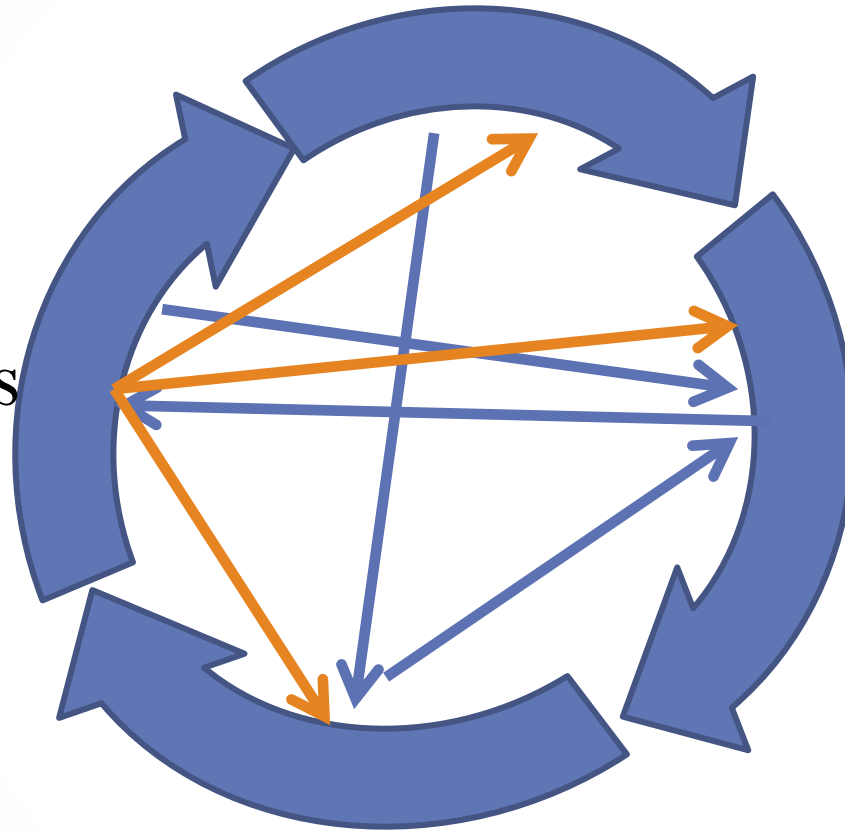
Collect
Data



Collect
Data

Test
Hypothesis

Analyze
Data



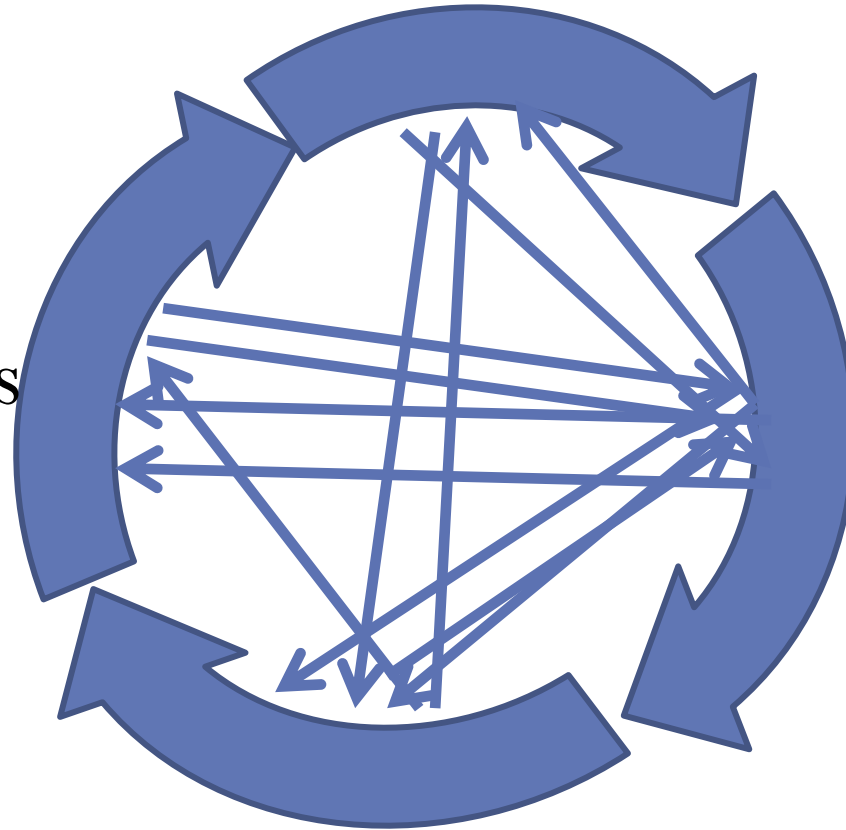
Develop Hypothesis

Collect
Data

Test
Hypothesis

Analyze
Data

Develop Hypothesis



Passive v. Active Hypothesis Development

- Passive –hypotheses that form as soon as data is received through an almost instant analysis of data filtered through knowledge, training and experience.
 - Some may be formed, analyzed, refuted and forgotten just as quickly. REMEMBER THESE.
- Active – those hypotheses formed based on specific data.
 - Formed to Support and Refute other hypotheses.
 - Formed to account for reasonable causes in area of origin.



Passive v. Active Hypothesis Development

- Active Hypothesis Development
 - Tentative statements formed deliberately, based on observations from a particular scene, to help direct further specific action, research, or testing to answer questions.



Passive v. Active Hypothesis Development

- Hypothesis Prompts
 - Reference Material
 - NFPA 921
 - Scientific Protocols for Fire Investigation
 - Ignition Handbook, Electrical Fires and Explosions



What can we Hypothesize About?

- There are a myriad of issues at a fire scene for which hypotheses can be formed.
- Each hypothesis can lead to multiple, related hypotheses.
- Sequential Hypotheses where the outcome of one hypothesis can lead to new hypotheses.



What can we Hypothesize About?

- Origin
- Cause
- Growth
- Spread
- Attribution



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What can we Hypothesize About?

- Who
- What
- Where
- Why
- When
- How
- If
- Could



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What can we Hypothesize About?

- **Fire Origin**
 - Interior v. Exterior?
 - Exterior
 - Which side?
 - Mulch bed?
 - Smoking?
 - Utility Entrance?
 - Interior?
 - Utilities?

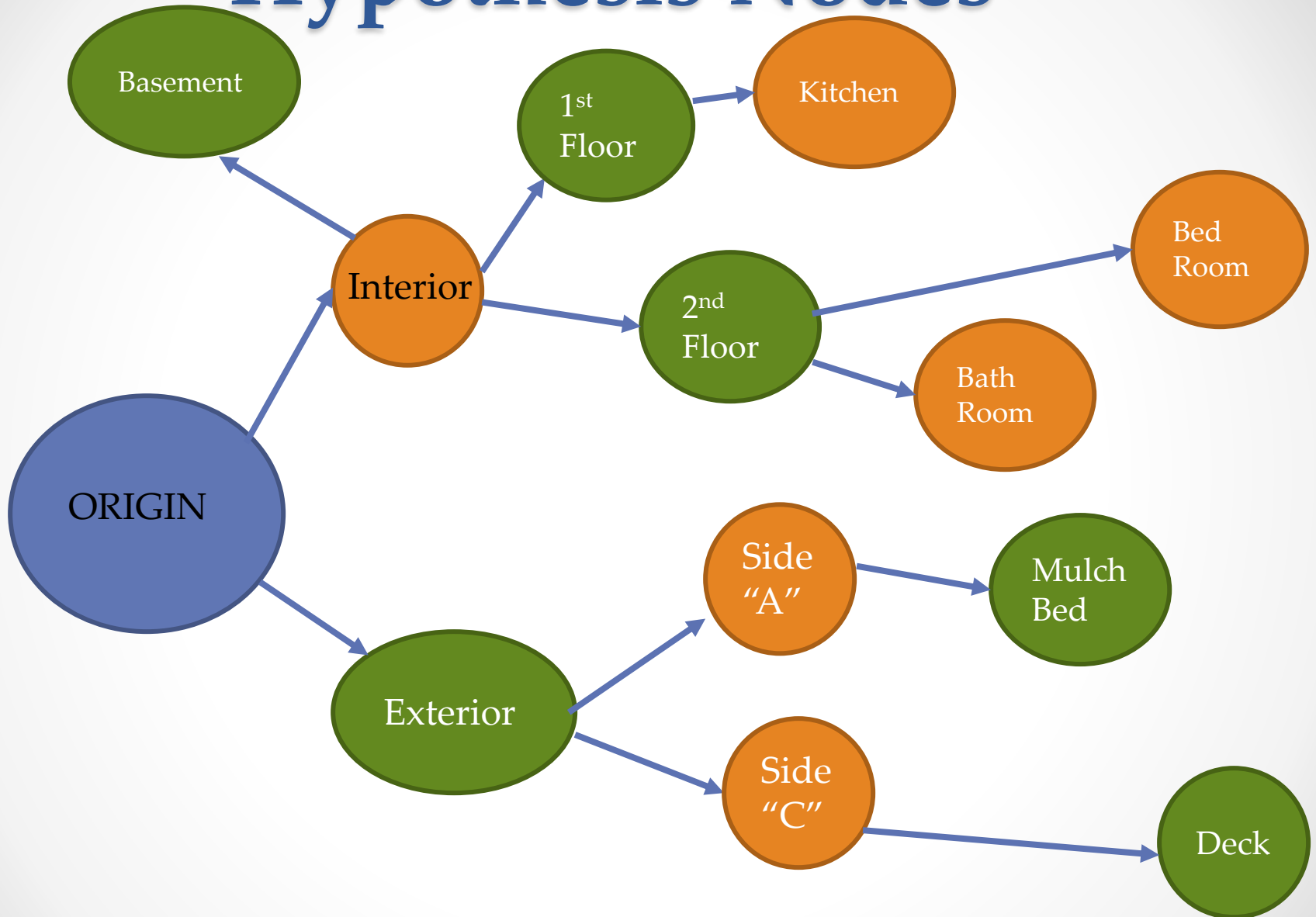


Scientific Method

- NFPA 921 (2021) – Chapter 18 Origin Determination
- §18.1 “...one of the most important hypotheses that an investigator develops and tests during the investigation.”
- If the origin isn't correct, the subsequent cause determination will be incorrect.



Hypothesis Nodes

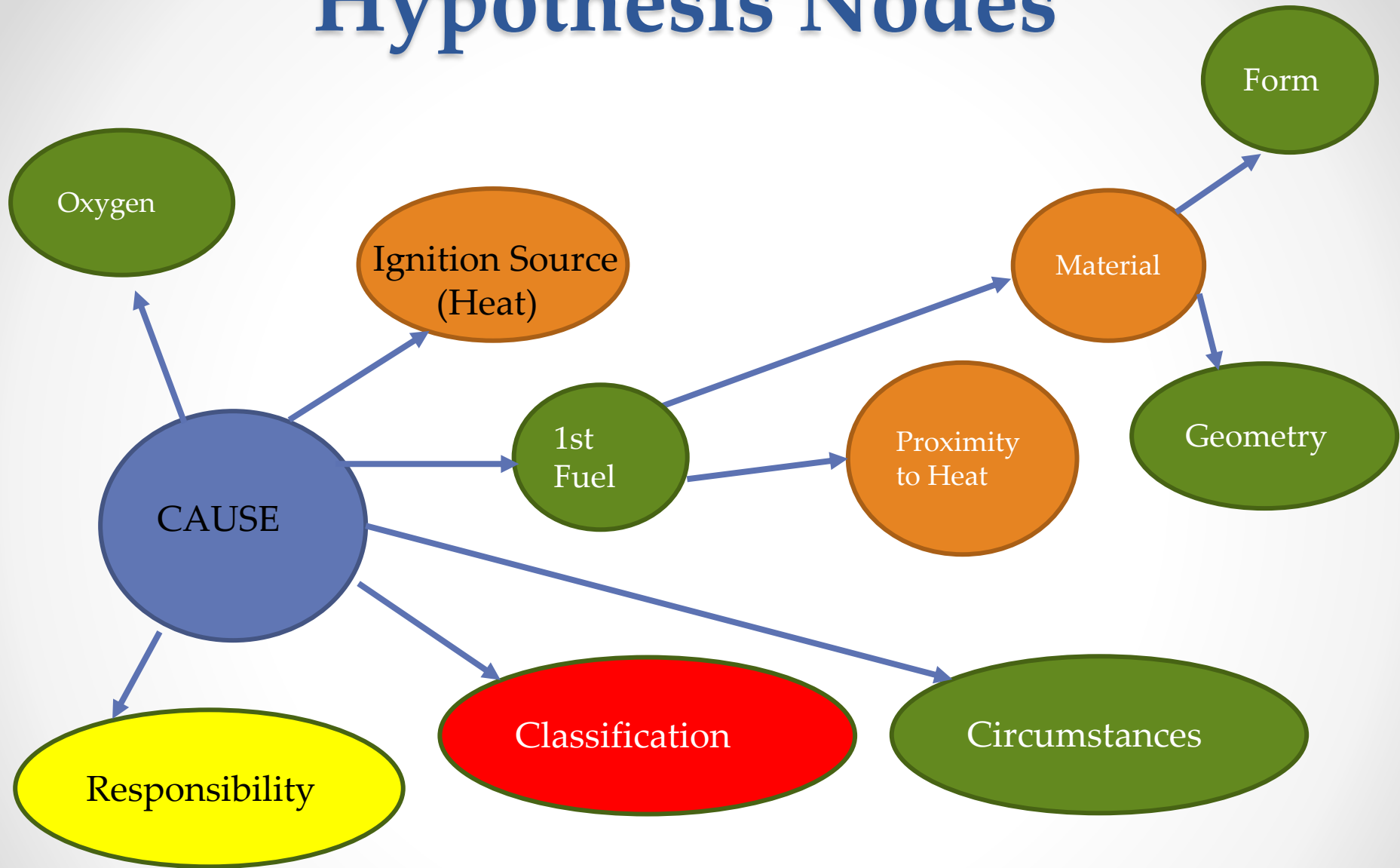


What can we Hypothesize About?

- **Fire Cause**
 - Ignition Source
 - First Fuel Ignited
 - Oxygen (Ventilation)
 - Circumstances
 - Classification



Hypothesis Nodes



Sequential / Derivative Hypotheses

- The “answer” to one hypothesis generates additional hypotheses that need to be addressed.
- Was the Door Open or Closed?
 - If Closed – Would the fire become Ventilation Limited?
 - If Open – Is the pattern near the door Ventilation Induced?



What can we Hypothesize About?

- Fire Cause
 - Ignition Source
 - “Competent”?
 - First Fuel Ignited
 - Form? Geometry?
 - Oxygen (Ventilation)
 - Circumstances



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What can we Hypothesize About?

- Fire Origin
 - The more hypotheses about the origin that we create, the better our chances of determining the probable Origin.
 - Do I have Witness Information and/or Electronic Data?
 - What do Fire Effects and Patterns indicate at this scene?
 - What role does Fire Dynamics play in determining this fire's origin?



What can we Hypothesize About?

- **Fire Cause**

- The more hypotheses about the cause, especially the ignition source, that we create, the better our chances of determining the probable Cause.
- First Fuel?
- Ignition Source?
- Oxidizer? (This one's usually the easiest!)
- Circumstances, conditions or agencies?



What can we Hypothesize About?

- **Witness Statements**
 - Can we form hypotheses about a witness's statements?
 - Can we evaluate the witness statement **AS A HYPOTHESIS?**
 - Can we apply a “Scientific Method” to witness statements?
 - **NOTE** – This is not saying that the witness statement evaluation **IS “Science”**.



Witness Statements

- What data do we have to support a witness's statements?
- What data do we have to refute a witness's statements?
- Does the witness statement make any predictions about the fire that can be independently tested?
 - “When I opened the door, the fire got bigger.”



What can we Hypothesize About?

- **Classification**
 - Chapter removed from 2021 Edition of NFPA 921
- **Responsibility**
 - Depends on the scope of your work.



“Forcing” Ourselves to Hypothesize

- Hypothesis development should be an active process.
- Force ourselves to ask questions.
 - But, what if...
- Turn around! Look elsewhere!
 - Just when you think you’ve settled on an origin...
 - Look Up...Look Down...
 - Walk the scene again...Slowly



“Forcing” Ourselves to Hypothesize

- **Visualize Fire Growth and Spread from Alternate Origins**
- **Do Any of the Alternatives Provide Better Convergence with Observed Damage?**



What can we Hypothesize About?

- Almost every section of NFPA 921 Can Generate Hypotheses.
- Can we Hypothesize that we Need More Data Before Forming a Hypothesis?
 - Sure. But, isn't that a hypothesis?



Testable Hypotheses

- NFPA 921 (2021) - §4.3.6 Test the Hypotheses (Deductive Reasoning) –
”...compares the hypothesis to all known facts as well as the body of scientific knowledge associated with the phenomenon relevant to the specific incident.”



Testable Hypotheses

- NFPA 921 (2021) - §4.3.6 Test the Hypotheses (Deductive Reasoning) – “...compares the hypothesis to all known facts* as well as the body of scientific knowledge associated with the phenomenon relevant to the specific incident.”

*Emphasis added



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Testable Hypotheses

- **NFPA 921 (2021) - §4.3.6 Test the Hypotheses (Deductive Reasoning) –**
"Testing of a hypothesis should be designed to disprove, or refute, the hypothesis. This may also be referred to as falsification of the hypothesis. Working to disprove a hypothesis is an attempt to find all the data or reasons why the hypothesis is not supported or not true, rather than simply finding and relying on data that supports the hypothesis or why the hypothesis is true."



Testable Hypotheses

- §19.6.4 Means of Hypothesis Testing
 - Scientific Literature (§19.6.4.1)
 - Fundamental Principles of Science (§19.6.4.2)
 - Physical Experiments or Testing (§19.6.4.3)
 - Cognitive Experiments (§19.6.4.4)



Testable Hypotheses

- §19.6.4 Means of Hypothesis Testing
 - Time Lines (§19.6.4.5)
 - Fault Trees (§19.6.6)
 - Additional Techniques (§19.6.4.7)
 - Mathematical Modeling (§21.4)



Testable Hypotheses

- Testing can be :
 - Physical Experiments
 - Cognitive Analysis
- Which do you think is used more often in fire investigation?



Fire in a Two-Story Single Family House

- Hypothesis – Fire Origin in Basement
- Analytical Testing –
- Is there a basement?
- Do we observe fire damage in the basement?



Fire in a Two-Story Single Family House

- Analytical Testing –
- Would principles of fire dynamics predict the spread of this fire upward?
- Is there fire damage above the basement?
- Is there a path from the basement?



Falsifiable Hypothesis

- **Karl Popper**
 - *The Logic of Scientific Discovery* (1934)
- **Demarcation in Science**
 - “Science” vs. “Pseudo-science”
 - Marxism and Freudianism
 - Falsifiable vs. Verifiable



Falsifiable Hypothesis

- “A hypothesis is scientific if and only if it has the potential to be refuted by some possible observation.”
 - Popper, *Conjecture and Refutation*, 1963



Falsifiable Hypothesis

- Note that there are philosophical arguments opposing Popper's Falsifiability (Feyerabend, Lakatos, Quine, Duhem, Kitcher)
- Understand that no hypothesis will ever be "certain" under this approach; Only that it hasn't been falsified.



Falsifiable Hypothesis

- Fire Investigators render an opinion based on NFPA 921 defined “Level of Certainty”
- 921 (2021) §4.5.1 defines the highest level of certainty as “Probable” (“more likely than not”, “greater than 50 percent”)



Falsifiable Hypothesis

- The truth of a statement is, at best, contingent.
- Looking for refutational data serves to help us **ELIMINATE** hypotheses, not to prove them.
(There likely will never be absolute proof)



Falsifiable Hypothesis

- In order to be “Falsifiable” there must be some conditions under which the hypothesis would be, or could be, false.



Falsifiable Hypothesis

- **Does the Hypothesis Itself Generate the Opposite Hypothesis?**
 - Hypothesis – The Door was Open During the Fire.
 - Hypothesis – The Door was Closed During the Fire.
- **Is Support for One Hypothesis a Refutation of the Other Hypothesis?**





Falsifiable Hypothesis

- Are there conditions such that the hypothesis can be shown to be refuted?
- Hypothesis – Origin in basement.
Data – No Basement! Hypothesis REFUTED.
Data – No fire damage in basement and no reasonable passage of fire from basement to damage. Hypothesis REFUTED.



Falsifiable Hypothesis

- Hypothesis – Electrical Failure Ignition

Data – No Electricity! Hypothesis REFUTED.

Data – No fire damage at or near fixed electrical wiring consistent with known causation – arc tracking, high resistance connections, mass loss, etc. – at or near origin . Hypothesis REFUTED. (Or, at least, not supported.)

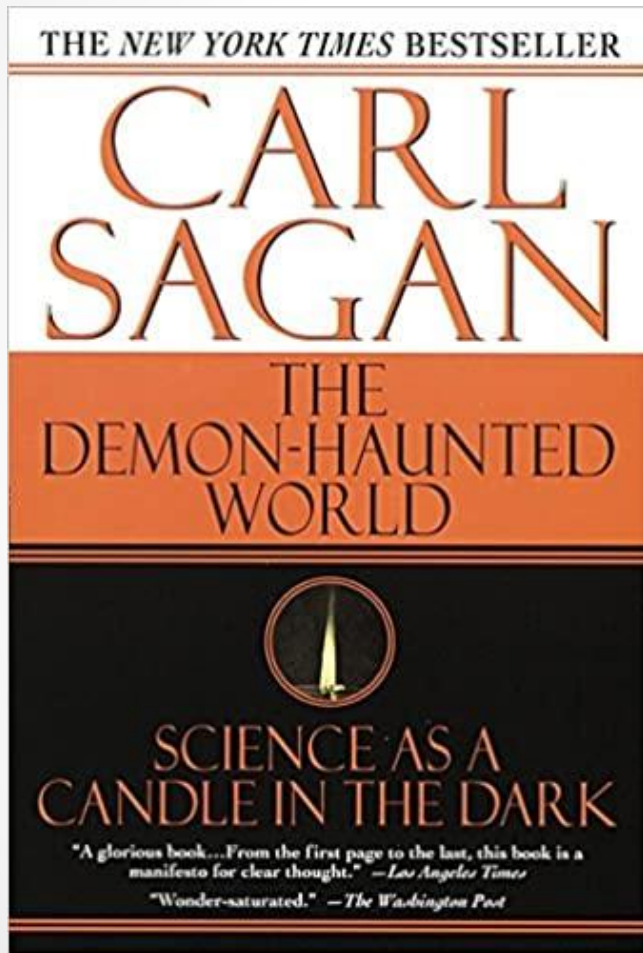


Falsifiable Hypothesis

- This approach does provide some protection from the claim of Confirmation Bias and/or Expectation Bias. (More later.)



Falsifiable Hypothesis

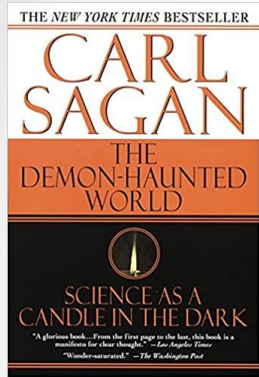


- *Demon Haunted World* – Carl Sagan (1995)
- “Dragon in my Garage” scenario



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Falsifiable Hypothesis



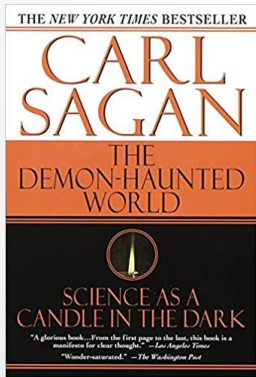
- There is a dragon in my garage.
- TEST – Let's see it.
- *Ad hoc* – She's invisible
- TEST – Spread Flour on the floor
- *Ad hoc* – This dragon floats (of course!)
- TEST – Infrared Camera to detect invisible heat
- *Ad hoc* – Heatless fire



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Falsifiable Hypothesis

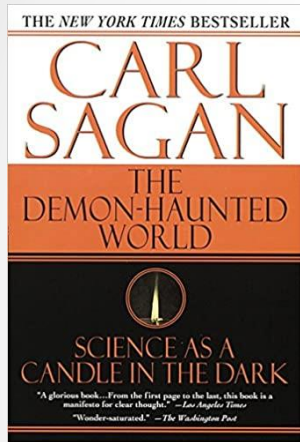
- "Now what's the difference between an invisible, incorporeal, floating dragon who spits heatless fire and no dragon at all? If there's no way to disprove my contention, no conceivable experiment that would count against it, what does it mean to say that my dragon exists? **Your inability to invalidate my hypothesis is not at all the same thing as proving it true.**"



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Falsifiable Hypothesis

- The hypothesis is testable
- But, because of *ad hoc* caveats, it is unable to be falsified.



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Hypotheses

- **NFPA 921 (2021) - §4.3.6.1 “Any hypothesis that is incapable of being tested either physically or analytically is an invalid hypothesis. A hypothesis developed based on the absence of data is an example of a hypothesis that is incapable of being tested. The inability to refute a hypothesis does not mean that the hypothesis is true.”**



Hypotheses

- What people think / say about hypothesis development is important to us.
- Experts may use the term “invalid hypothesis” to dismiss opposing hypotheses.



The “INVALID” Hypothesis

- §4.3.6.1 is used to attack an investigator's methodology by claiming that their hypothesis is “invalid” and a violation of “THE SCIENTIFIC METHOD”.
- Especially in “Incendiary” fires where an ignition source may have been removed, lost, undiscovered, or destroyed



Incendiary Hypotheses

- This section has been used to claim that a hypothesis of an ignition source removed, destroyed, or not found at the scene (match, lighter, etc.) is not a testable (or falsifiable) hypothesis and, therefore, methodologically unsound.
- “INVALID”



Incendiary Hypotheses

- This argument attempts to dismiss the “Incendiary Cause Hypothesis” on purely methodological grounds.
- The argument is that “First and Foremost, the hypothesis is ‘invalid’ and any actions, decisions or opinions based on such a hypothesis cannot be valid.”



The “INVALID” Hypothesis

- Can a “Provisional” or “Speculative” Statement be “Invalid”?
- The hypothesis is a thought, idea, proposal, speculation or provisional statement on which to base further action.
- It cannot, in and of itself, be “invalid”. (Only unsupported or refuted.)



Incendiary Hypotheses

- Is such a hypothesis, in fact, “untestable” either physically or analytically?
- Can an empirical test be designed to see if a transient ignition source (match, lighter, etc.) is competent to ignite a proposed first fuel?



Incendiary Hypotheses

- Is such a hypothesis, in fact, “falsifiable”?
- Are there conditions under which the “Incendiary Hypothesis” can be refuted or falsified?



Incendiary Hypotheses

- Can tests be designed to see if materials found at the scene are capable of being ignited by a theoretical ignition source (such as the open flame from a match, lighter, torch or flare)?
- §19.4.2 Ignition Source Analysis
 - Is my hypothesized ignition source “competent” to ignite hypothesized first fuel?



Incendiary Hypotheses

- Does your knowledge, training and experience support the hypothesis that a competent ignition source can be removed from a scene after ignition?
- Does your knowledge, training, experience, or expertise include instances of incendiary fires where evidence of the ignition source has been moved, removed or destroyed?



Incendiary Hypotheses

- If you cannot locate physical evidence of an ignition source at an identified origin, do you immediately form the opinion that the fire is of incendiary origin?
- Do you seek other hypotheses and data to explain the ignition source?
 - Lightning Strike?



Incendiary Hypotheses

- **§19.4.4.3 There are times when there is no physical evidence of the ignition source found at the origin, but where an ignition sequence can be logically inferred using other data.**



Incendiary Hypotheses

- §19.4.4.3 provides examples. The list is not exclusive.
 - Diffuse fuel explosions and flash fires
 - Ignitable liquid residue (without innocent explanation)
 - Multiple fires (non-communicating)
 - When trailers are observed
 - Fire was observed or recorded at/near inception.



Incendiary Hypotheses

- **NFPA 921 (2021) - §4.3.6.1 “... based on the absence of data ...”**
- **Is the fire itself data?**
- **Fire requires the presence of an ignition source (Heat).**
- **921 Definition of “Fire Cause” includes “...circumstances, conditions or agencies...”**



Hypotheses “Absent Data”

- Darwin and “gemmules”
- Mendeleyev and “missing elements” (gallium, scandium, germanium)
- Dirac and anti-matter
- “Phlogiston”



Bias and Hypotheses

- §4.3.9 Expectation Bias – “...premature conclusion without having examined or considered all of the relevant data.”
- §4.3.9 Confirmation Bias – “...rely(ing) only on confirming data that support the hypothesis...the investigator relies exclusively on data that supports the hypothesis and fails to look for, ignores or dismisses contradictory or nonsupporting data.”



Bias and Hypotheses

- Bias is easy to accuse.
- A whole class could be spent on discussions regarding biases.
- Everyone who forms an opinion has done so based on the weighing of the value of data.



Bias and Hypotheses

- The essence of both claims of bias is that the investigator did not examine or consider alternative hypotheses.
- The more hypotheses that are formed, documented, analyzed and articulated, the easier it is to counter claims of bias.



Who cares how hypotheses are formed?

- Regardless of how a hypothesis is formed (whether it follows NFPA 921's linear rules, requires analysis or not), the important part of a hypothesis is whether it can be supported or refuted by the data.



Methodology

- To Be Clear:

I (Steven Avato) am not advocating for Methodological ANARCHY* in fire investigation.

* - As described by Paul Feyerabend in “*Against Method*”



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Methodology

- **IMPORTANT CAVEATS!**
 1. This is not to say that METHODOLOGY is not important!
 2. Analyzing a Hypothesis against Data that both Supports AND Refutes a Hypothesis is important.



Scientific Method (Cause)

- NFPA 921 (2021) - §19.2.1
Consideration of Data “...determine which hypotheses fit all of the credible data available.”



The “Final” Hypothesis

- As previously noted, all “scientific” statements are contingent and subject to falsification.
- Balance between “Rush to Judgement” and “Analysis Paralysis”
- At some point, we may need to make a judgment or form an opinion based on the data we have.



The “Final” Hypothesis

- Case by case basis.
- Depends on your confidence and ability to justify your opinion.
- Must be able to articulate your opinion.
 - Not enough to just write a report



The “Final” Hypothesis

- When you are confident that you have gotten all of the data that you are going to get.
- What if I am not going to get any more data?
- What if more data comes up later?



The “Final” Hypothesis

- Do NOT conflate “hypothesis” with “Final Hypothesis”.
- A hypothesis can be formed any time during the process.
- “Final Hypothesis” is the end result of all of the previous hypotheses combined in a “final” statement.



The “Final” Hypothesis

- “The testing process needs to be continued until all feasible hypotheses have been tested, and one is determined to be ***uniquely consistent*** with the facts and with the principles of science.” [emphasis added]



NFPA 921 (2021 Edition), §4.3.6 Test the Hypotheses
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“New” Data

- Does Data Support or Refute Hypothesis?
 - SUPPORTS
 - Look for more data.
 - REFUTES
 - Re-evaluate Hypothesis
 - Re-evaluate data
 - Discard Hypothesis
 - Form New Hypotheses



Irrefutable Facts

- Make sure to include hypotheses that consider critical scene observations.
- Irrefutable Fact – victim was located in First Floor bathroom.
 - Corroborated by Fire Personnel who located and removed the victim.



Irrefutable Facts



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Irrefutable Facts

- Do your hypotheses about critical, irrefutable facts converge with other hypotheses?
- Hypothesis Consistency
 - Does any part of your explanation of the incident conflict with other parts?
 - If you change one hypothesis, does it impact other hypotheses?



CAUTION

- Do Not Let the Hypothesis Alone Become Fact Without Data.
- Avoid allowing the final hypothesis to be a tautology.
 - Circular – “This fire is incendiary due to the fact that it was intentionally ignited under circumstances where there should not have been a fire.”



CAUTION

- “The first principle is that you must not fool yourself, and you are the easiest person to fool.”

- Richard Feynman

Nobel Laureate – Physics

(1974 CalTech Commencement)



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Methodology

- Methodology provides a framework for the conduct of the Fire Investigation.
 1. Provides a systematic approach.
 2. Allows the Investigator to critically analyze their thinking regarding an investigation.



Hypothesis Exercise

- Look at the following Photo and think about your IMMEDIATE thoughts.



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Hypothesis Exercise

- Can you form Hypotheses as to origin?
- Did you collect ALL of the DATA BEFORE forming the hypotheses?
- What would these hypotheses encourage you to do?
- Where would you look for more data?



Hypothesis Exercise

- Collect More Data.
- Form More Hypotheses.
 - Could the fire effect / pattern be ventilation induced?
- Force yourself to look for other potential areas of origin.
- Is anyone ready to render an opinion as to origin and cause based on this data alone?









Hypothesis Exercise

- Hypotheses about Ignition Source?
- Hypotheses about First Fuel Ignited?
- Hypotheses about Cause?
- Hypotheses about Classification?









Hypothesis Exercise

- How quickly did you form hypotheses?
- Did you have ALL of the data when you formed the hypotheses?
- Did you think you would need more data before settling on an explanation regarding origin and cause?



Hypothesis Exercise

- Per NFPA 921 (2021) - Hypotheses are based on your “knowledge training, experience and expertise.”
- Is your experience that reasonable hypothetical fire origins are vast but finite?
- Is your experience that reasonable hypothetical fire causes are vast but finite?
- Can you form hypotheses without ALL empirical data?



Hypothesis Exercise

- 5:30 PM a report of a kitchen fire is dispatched in a multiple-occupancy, multi-story apartment building in your local area.



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Scientific Methodology, Hypotheses and Science in Testimony

- *Methodology will almost certainly come up.*
 - *Be prepared to ARTICULATE the process and how you applied it.*



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Scientific Methodology, Hypotheses and Science in Testimony

- **Do you agree that NFPA 1033 is a standard and describes the minimum qualifications for a fire investigator?**
- **Do you meet those qualifications?**
 - **Yes – Expert opinion may be rendered.**
 - **No – Fact Witness?**



Scientific Methodology, Hypotheses and Science in Testimony

- ***As a Fire Investigator :***
 - ***Are you an expert in “Fire Science”?***
 - ***If the answer is “NO” – how do you expect a court to accept your “expert opinion” testimony?***
 - ***If the answer is “YES” – then be prepared to answer basic questions about fire science.***



Scientific Methodology, Hypotheses and Science in Testimony

- ***As a Fire Investigator :***
 - ***Are you a “Scientist”***
 - “I am not a scientist. I have never been a scientist. A lot of these questions are scientific questions that are, you know, ... although I may have a basic understanding or I did have a basic understanding of them, you know. At this time, you know, I have not looked at any of these, nor as not being a scientist, memorized any of these things.”

(Deposition Testimony of public sector fire investigator included in *in Limine* motion. Testimony of two fire investigators were excluded resulting in dismissal of charges. As reported by John Lentini on LinkedIn and <http://www.forumworld.com/arson-investigations>)



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Science, Scientific Methodology and Hypotheses in Testimony

- ***As a Fire Investigator :***
 - ***Are you a “Scientist”***
 - ***How do you define “Scientist”?***
 - ***Merriam- Webster – “a person learned in science and especially natural science : a scientific investigator”***



Science, Scientific Methodology and Hypotheses in Testimony

- **As a Fire Investigator :**
 - **Are you a “Scientist”**
 - **If you answer “Yes” be prepared to answer questions about fire science.**
 - **If you answer “No” be prepared to answer questions about why you should be considered an expert with a “reliable” opinion.**



Science, Scientific Methodology and Hypotheses in Testimony

- ***Fire Science – “The body of knowledge concerning the study of fire and related subjects (such as combustion, flame, products of combustion, heat release, heat transfer, fire and explosion chemistry, fire and explosion dynamics, thermodynamics, kinetics, fluid mechanics, fire safety) and their interactions with people, structures and the environment.” NFPA 1033 §3.3.13***



Science, Scientific Methodology and Hypotheses in Testimony

- How much “Fire Science” do you need to know?
- NFPA 1033 §4.1.7
- NFPA 1033 Annex A, §A 4.1.7



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Science, Scientific Methodology and Hypotheses in Testimony

"An investigator who cannot name the basic units of energy or power, or explain the difference between energy and power, is not an expert, and is not qualified. The same goes for an expert who thinks the air around us is 92 percent oxygen, or one who cannot describe the simplest of all combustion reactions, the burning of hydrogen in air to produce water. The author once witnessed the exclusion of a fire marshal when the judge said, "I'm sorry. If you don't know H₂O, you will not be rendering opinion testimony in my courtroom."

"What Fire Litigators Need To Know in 2017", John J. Lentini
The SciTech Lawyer, Vol. 13, Number 4 Summer 2017



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Science, Scientific Methodology and Hypotheses in Testimony

- **Energy v. Power**
- **Radiant Heat Flux**
- **Pyrolysis**
 - **Is it reversible?**
- **Combustion of Methane? (CH₄)**
 - **(Not in NFPA 921)**
- **Three Modes of Heat Transfer**



Science, Scientific Methodology and Hypotheses in Testimony

- Questioning is designed to either provide validation to your testimony or to show that you are not “scientific” enough for your opinion to be reliable.
- Do NOT overstate your certainty.
 - PROBABLE
 - AVOID “Scientific” or “Engineering” Certainty.



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NATIONAL COMMISSION ON FORENSIC SCIENCE

NIST
National Institute of
Standards and Technology
U.S. Department of Commerce

Views of the Commission Regarding Use of the Term “Reasonable Scientific Certainty”

Subcommittee
Reporting and Testimony
Status
Adopted by the Commission

Date of Current Version	22/03/16
Approved by Subcommittee	29/01/16
Approved by Commission	22/03/16

Commission Action

On March 22, 2016, the Commission voted to adopt this Views Document by a more than two-thirds majority affirmative vote (86% yes, 7% no, 7% abstain)

Note: This document reflects the views of the National Commission on Forensic Science, and does not necessarily represent the views of the Department of Justice or the National Institute of Standards and Technology. This document does not formally recommend any action by a government entity, and thus no further action will be taken upon its approval by the Commission.

Overview

It is the view of the National Commission on Forensic Science (NCFS) that legal professionals should not require that forensic discipline testimony be admitted conditioned upon the expert witness testifying that a conclusion is held to a “reasonable scientific certainty,” a “reasonable degree of scientific certainty,” or a “reasonable degree of [discipline] certainty.” The legal community should recognize that forensic scientists, medical professionals and other scientists do not routinely use “to a reasonable scientific certainty” when expressing conclusions outside of a courtroom context. Forensic science service providers and forensic science medical providers should not endorse or promote the use of this terminology. The Commission recognizes the right of each jurisdiction to determine admissibility standards but expresses this view as part of its mandate to “develop proposed guidance concerning the intersection of forensic science and the courtroom.”

Views of the Commission

Forensics experts are often required to testify that the opinions or facts stated are offered “to a reasonable scientific certainty” or to a “reasonable degree of [discipline] certainty.” Such statements have no scientific meaning and may mislead factfinders when deciding whether guilt has been proved beyond a reasonable doubt. “Outside of the courts, this phrasing is not routinely used in scientific disciplines. Thus, in prescribing a different standard for admissibility in *Daubert v. Merrell Dow Pharmaceuticals*, 509 U.S. 579, 590 (1993), the Supreme Court

Science, Scientific Methodology and Hypotheses in Testimony

- NFPA 921 as “Authoritative” or a “Standard of Care”?
- Are there any portions of NFPA 921 that you disagree with?



Hypotheses in Testimony

- *Michigan Millers Mutual Insurance v. Janelle R. Benfield* [93-1283-CIV-T-17(A)]
- Fire investigated in July 1992 in Sarasota, Florida (US)
- *Daubert* Motion Testimony from January 24 & 25, 1996
- Investigator retained by the Plaintiff (Michigan Millers)



Michigan Millers v Benfield

- Investigator “The first thing that we always accomplish is make a visual observation of the structure of the building that’s going to be examined...So this is just representative of the front view of the residence ... and we did not see any fire damage in this particular photograph.”

I – Investigator P – Plaintiff’s Attorney (D) – Defendant’s Counsel

C- Court

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Michigan Millers v Benfield

- Are there hypotheses regarding Origin and / or Cause implicit in this statement?
- "... and we did not see any fire damage in this particular photograph."



Michigan Millers v Benfield

- (I) “Well, from the fire damage that we see, that we just have some contents , basically the chair and tables, that was located in the dining room had been fire damaged. As you can see the walls around this area really has suffered nothing other than smoke damage. So the fire was very isolated to a small area. We found no other area in the residence at all where any actual fire damage occurred...”



Michigan Millers v Benfield

- Are there hypotheses regarding Origin and / or Cause implicit in this statement?
- “... We found no other area in the residence at all where any actual fire damage occurred.”



Michigan Millers v Benfield

- (I) “This is a photograph of the kitchen, which is just to the rear of the dining area. Again, it was just to document the damage and the extent of the smoke and the heat damage. ...”
- (P) “Okay. Was there any actual flame or fire damage in this area?”
- (I) “No there was not.”



Michigan Millers v Benfield

- Does this statement support a hypothesis?
Refute a hypothesis?
- It appears to support a hypothesis that the fire originated outside of the kitchen area and refute a hypothesis that the fire originated in the kitchen.



Michigan Millers v Benfield

- (I) “This is a photograph after I had removed the chairs and cleaned a lot of the debris off the floor and actually sifted through the debris to determine specifically if in fact there was a power cord, an electrical appliance, some other accidental source of ignition for the fire. And I found none or observed none during that examination. ...”



Michigan Millers v Benfield

- (P) “What about the chandelier or the light fixture above or near the table?”
- (I) “I found no indication that it had any role in the ignition of the fire...”
- (P) What about in your interview with Ms. Benfield? Did she indicate to you anyone smoking in there, for instance, the morning of the fire or anything like that?”
- (I) Exactly the opposite. There were no smokers related to be in the house.”



Michigan Millers v Benfield

- Hypotheses?
 - Power Cord
 - Other Electrical Appliances
 - Other Accidental Sources of Ignition
 - Chandelier
 - Smoking Material
- Incendiary Hypothesis
 - Support – Lamp Oil Bottle Found on Floor



Michigan Millers v Benfield

- Under Cross Examination by the Defendant's Attorney, the Investigator agrees that he (I) would "hold (himself) out as an expert in the area of fire science."
- Then asked – several times - to explain to the jury what the "scientific method" is.
- (D) "And in the case of Ms. Benfield's residence, did you apply the scientific method?"
- (I) "Yes, I did."



Michigan Millers v Benfield

- (D) “So then certainly in accordance with these definitions...you developed hypotheses?”
- (I) “Yes, I did.”
- (D) “And you tested them?”
- (I) “Yes, I did.”

(The investigator is later questioned about the testing of the “Incendiary” hypothesis, to include chemical testing and heat release rate calculations.)



Michigan Millers v Benfield

- (D) “(Investigator) was asked to define the scientific method and he could not even define them. He was given several opportunities to define it. Finally, I gave him the scientific method definition to which he agreed.”
- (D) “(Investigator) was asked to advance one hypothesis for which he tested and he declined.”



Michigan Millers v Benfield

- The Court ruled that the Investigator's testimony be stricken.
- (C) "Here the witness has testified that he examined the debris after the fire, and using his years of experience, but not telling us how, he was able to determine the cause and origin of this fire. Accordingly, he concludes that where he cannot determine the cause or origin of the fire, it is his opinion that it was intentionally set, an arson."



Michigan Millers v Benfield

- (C)“He cites no scientific theory, applies no scientific method. He relies on his experience. He makes no scientific tests or analyses. He does not list the possible causes, including arson, and then using scientific methods exclude all except arson. He says no source or origin can be found on his personal visual examination and, therefore, the source and origin must be arson.”



Michigan Millers v Benfield

- Illustrates that it is not merely enough to conduct a methodologically sound investigation, but to be able to ARTICULATE the methodology – especially the hypotheses considered and how the data either supported or refuted the hypothesis.



Documenting Hypotheses

- ▶ Documentation may be guided by Department / Company policies / procedures and should be followed by the investigator.

(I'm just describing options and not making specific style recommendations.)



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Documenting Hypotheses

- ▶ Documentation is based on the data collected, observations made, hypotheses formed, opinions, etc. at the time the report is written!!

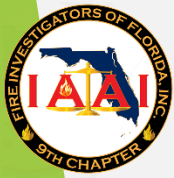


Documenting Hypotheses

- ▶ **“Recommendation: Fire and explosion investigation reports should include all data collected, all hypotheses formulated, details of the testing process for each hypothesis, and the conclusions of the investigation.”**

OSAC Technical Guidance Document 005, Strengthening Fire and Explosion Investigation in the United States: A Strategic Vision for Moving Forward, p. 99, April 2021

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Documenting Hypotheses

- ▶ NFPA 1033, §4.6.1 Prepare a written report...so that the report accurately reflects the facts, data and scientific principles on which the investigator relied; clearly identifies and expresses the investigator's opinion and conclusions and contains the reasoning by which each opinion or conclusion was reached..."



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Documenting Hypotheses

► How do I document the numerous hypotheses typical of a fire scene examination?

Photographs

Visual Media

Audio Recordings

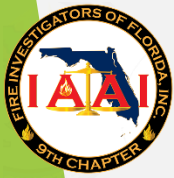
Written Reports



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Documenting Hypotheses

- ▶ Can we enumerate ALL of the “possible” hypotheses typical of a fire scene examination?
- ▶ Narrow down to those most relevant to THIS fire.



Documenting Hypotheses

► Direct.

- List each hypothesis considered.

► Indirect.

- Describe observations and the hypotheses they support or refute.



Documenting Hypotheses

- ▶ **The Documentation of the hypotheses can be either in a separate section of the report or addressed in a scene processing section – especially in the case of the Indirect style.**



Direct Documentation

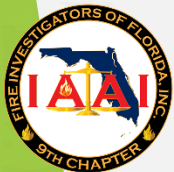
“During the course of this scene examination, I considered the following hypotheses regarding the fire’s origin:

- 1) The fire originated on the exterior south wall of the structure.**
- 2) The fire originated on the interior in the family room on the north side of the structure....”**



Direct Documentation

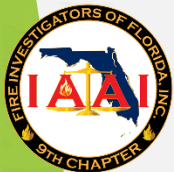
Each hypothesis in the list should then be addressed with data that either supports or refutes the hypothesis.



Direct Documentation

“1)The fire originated on the exterior south wall of the structure.

Damage consistent with fire venting is observed above the window on the south wall. There is no visible fire damage on the exterior siding below the window. The observed damage above the window, as opposed to below, is more consistent with fire venting from an interior fire than from an exterior origin.”



Direct Documentation

“2) The fire originated on the interior in the family room on the north side of the structure.

This hypothesis is supported by”

“However, fire damage was observed on the exterior of the structure below the north family room’s east window. This damage appears to be from falling debris from fire extension into the roof via the eaves”



Indirect Documentation

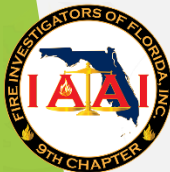
“On the south wall of the first floor living room was a duplex electric outlet. Examination of this XYZ Brand, 110-V receptacle reveals no indication of mass loss, arc damage, or discoloration of the ground strap. The neutral and hot bus are intact and pristine. The neutral, hot and ground terminal screws and associated wiring are undamaged. This observation is inconsistent with a high resistance connection fire causation hypothesis.”



Indirect Documentation

The statements imply BOTH data supporting the hypothesis AND a counterfactual statement.

The description “no indication of mass loss, arc damage, or discoloration of the ground strap... This observation is inconsistent with a high resistance connection fire causation hypothesis” provides a statement of data that you would EXPECT to see if the hypothesis were correct.



Indirect Documentation

That is, if the Hypothesis of an outlet origin were correct, you would EXPECT to see SOME indication of mass loss, arc damage, or discoloration of the ground strap.



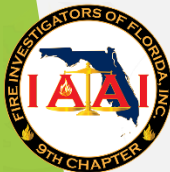
“En masse” Hypothesis Documentation

- ▶ **Addressing all relevant hypotheses in a single statement.**
- ▶ **May address hypotheses regarding origin and cause in a single statement.**
- ▶ **Save report writing time and space.**



“En masse” Hypothesis Documentation

“Examination of the garage of the structure reveals no fire interior damage, no discernable fire patterns and/or effects indicative of fire origin or cause.”



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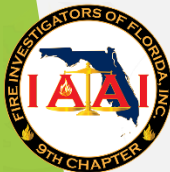
“En masse” Hypothesis Documentation

Implicit in this type of statement are hypotheses that the garage, basement, etc. was a potential origin of the fire, in which a cause might have been found, but there was no data to support a viable origin or cause hypothesis.



“En masse” Hypothesis Documentation

The investigator must still be prepared to “tease out” and articulate in a court proceeding some of the hypotheses contained within their statement.



“En masse” Hypothesis Documentation

These areas should still be documented to support that statement. Within reason.

(A fire originating on the 22nd floor of a 30-story high rise may not require detailed photos of floors 1 through 20 to illustrate the origin hypothesis.)



“En masse” Hypothesis Documentation

Photographs

The author should still be able to articulate included hypotheses and the support / refutation.



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UNITED STATES DISTRICT COURT FOR THE DISTRICT OF MASSACHUSETTS

**UNITED STATES OF AMERICA,
v. JAMES HEBSHIE, Defendant.**

(Criminal No. 02cr10185-NG)

MEMORANDUM AND ORDER RE: MOTION TO VACATE
CONVICTION

November 15 2010



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Documentation of Resource Material

Books, articles, training material, testimony, etc. may be used to support or refute a hypothesis.

May be specific or general.



Documentation of Resource Material

SPECIFIC –

**“NFPA 921 (2021 ed.) §3.3.121
Incendiary Fire.”**



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Documentation of Resource Material

GENERAL –

“During the course of this investigation, the following sources were consulted as references, when analyzing data, or cognitively testing hypotheses:

NFPA 921 (2021 ed.)...”*

***Example statement only**

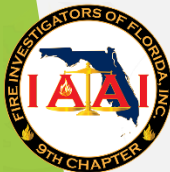


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Documentation of Resource Material

Direct –

Based on the examination of this scene, the probable cause of the fire is ... NFPA 921 (2021), §4.5.1 States “Probable. This level of certainty corresponds to being more likely true than not. At this level of certainty...”



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Documentation of Resource Material

Indirect –

Based on the examination of this scene, the probable cause of the fire is ... (NFPA 921 [2021], §4.5.1 describes “probable” as the highest level of reasonable certainty on which an investigator can report an opinion.)



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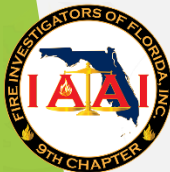
Documentation of Resource Material

- ▶ **In-text citations**
- ▶ **Footnotes**
- ▶ **Endnotes**
- ▶ **Reference List / Bibliography**



Documentation of Testing

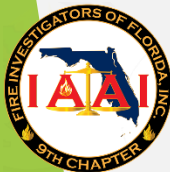
- ▶ **Guidance can be found in NFPA 921 (2021), Chapter 21 Failure Analysis and Analytical Tools**
- ▶ **§21.5 Fire Testing**



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Documentation of Testing

- ▶ ****Destructive Testing of actual fire scene materials should be avoided at all costs and especially where only one test item exists****
- ▶ **Exemplars – document location obtained, make, model, etc.**
- ▶ **Take more than you need to protect items for others to test.**



Inconsistent Data

- ▶ **Origin §18.7.2 - “It is unusual for a hypothesis to be totally consistent with all of the data.”**
- ▶ **Cause §19.7.2 - “It is unusual for all data to be totally consistent with the selected hypothesis.”**
- ▶ **“Not all data in an analysis has the same value.”**



Summary

- Hypothesis Development is critical to the application of a scientific methodology in fire incident investigation.
- Hypotheses are FREE! Form as many as you like.
- Some hypotheses will be supported, so seek refutation.
- Some hypotheses will be refuted, so form more.



Summary

- At the end of the “day”, select the hypothesis that is most consistent with all of the available data. Then see how that hypothesis meshes with all of the other hypotheses for consistency.
- Be prepared to defend your hypothesis with data and analysis. How and when you formed a hypothesis is not as important as the ability to support it.



Summary

- Be prepared to articulate your final hypothesis.
- Don't expect absolute certainty.



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[Problems with 'the scientific method' | Science News for Students](#)

[Q: Do Scientists Really Use the "Scientific Method?" | NSTA](#)

[Scientific sensemaking supports science content learning across disciplines and instructional contexts \(pitt.edu\)](#) 2019