



# RAFAEL Investigative Methodology

With an example from:  
**Ethiopian B737-8 (MAX), Aircraft Crash On March 10, 2019**

By Amit Bahat



# Presentation Contents

- Introduction – RAFAEL , me & the case study.
- The whole philosophy in a nutshell.
- RAFAEL Investigative Methodology
- Diving into the example: study of the system & initial failure description.
- The process - illustrated with findings from the Boeing's 737 MAX as an example.
- Iterations: brain storming, initial mind map, PPP evidence, final mind map.
- Explanation of the failure, with a “5 Why” and than a “Why Tree”.
- Local solution (for the MAX).
- Insight wording for Organizational Lessons learned for the stakeholders in the example.
- Key Takeaways.

# Introduction – RAFAEL

- For the last 71 years, a significant contributor to Israel's national security.
- Government owned, innovative, growing and profitable global company that develops, manufactures and supports defense systems at the forefront of technology and mission requirements.
- For the IDF and our world wide customers.



- For additional info. You are welcome to browse our site at [www.Rafael.co.il](http://www.Rafael.co.il) or watch movies on YouTube.

# Introduction - Me

- Mechanical Eng. + MBA With about 35 years of experience, mostly in RAFAEL.
- [As part of my job I guide or head failure investigations and teach the methodology.](#)
- Have previously attended the “Latent Cause Experience” by Bob Nelms and a course named “How to Organize and Run a Failure Investigation” by Dr. Dan Dennies of **Boing** via the ASM (American Society of Materials).

## A little confession:

- My knowledge about planes comes mainly from the passenger seat.
- A failure investigation of this magnitude is like a huge puzzle. However unlike a regular puzzle, we don’t have the final picture in front of us.
- I will be using the example to demonstrate the methodology, with what is known now, from official reports and the media.
- I will do my best to illuminate regions of this complicated MAX puzzle.



# Introduction – The Case Study

## Boeing 737 MAX 8



The US's reputation as the gold standard for aviation safety is at a make-or-break moment, as the 737 Max crashes prompt questions about Boeing's conduct and conflicts of interest. Source: Business Insider

- Many official and “unofficial” investigations are going on in parallel.
- I do not want to give advice or criticize any of them.
- I am using this disaster to demonstrate the methodology.

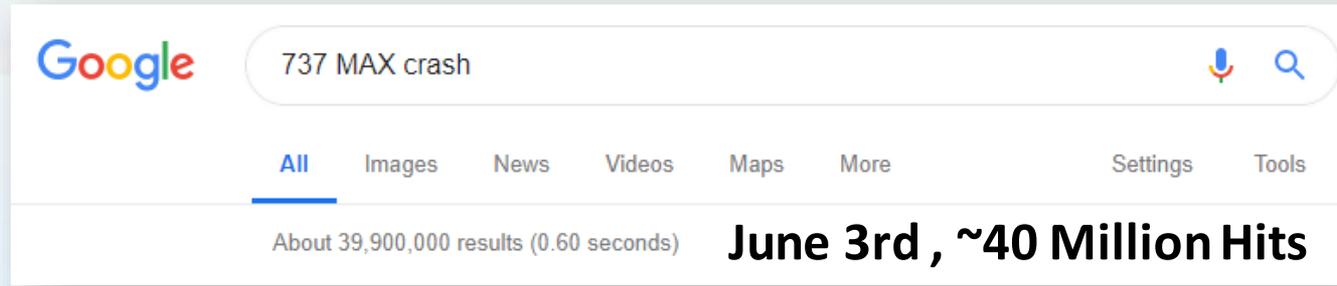
# Background – How was the Max Variant Conceived

## Time line of basic events:

- December, 2010, **Airbus announces** development of A320 neo (new engine option) that would burn about **6 percent less fuel** than the 737NG.
- At the 2011 Paris Air Show, **Airbus sold** a record-setting **667** A320 neos in a **week**. (more orders than the 737s had received in the entirety of 2010).
- Boeing’s interpretation: **existential threat** (from the A320neo).
- July, 2011, **American Airlines** announces it is **buying** 460, **Airbus** and Boeing aircrafts to renew it’s fleet. 100 of, “yet to be lunched and yet to be named 737 variant with **new engines**”.

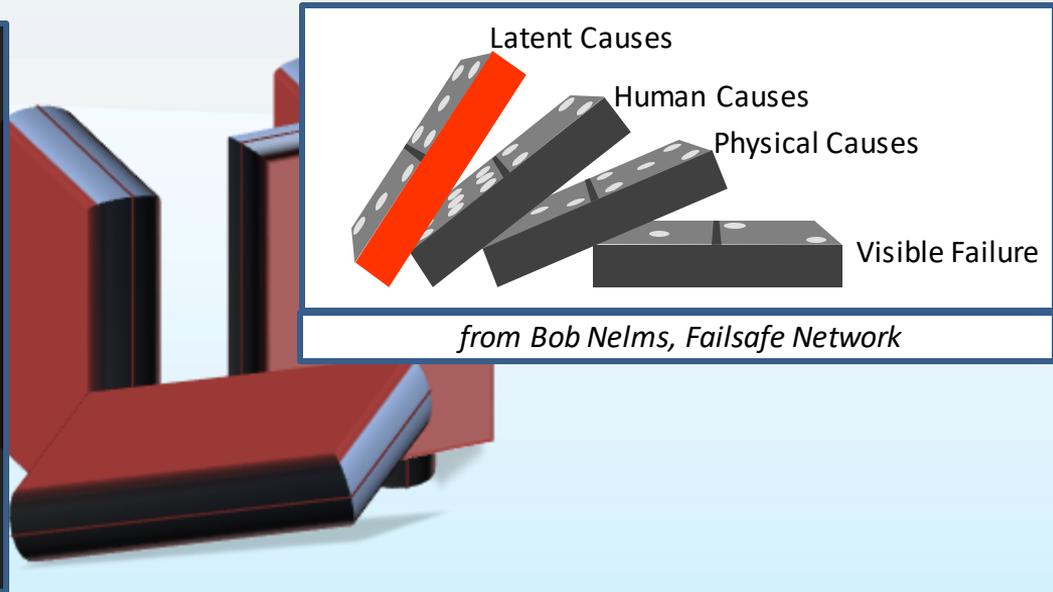
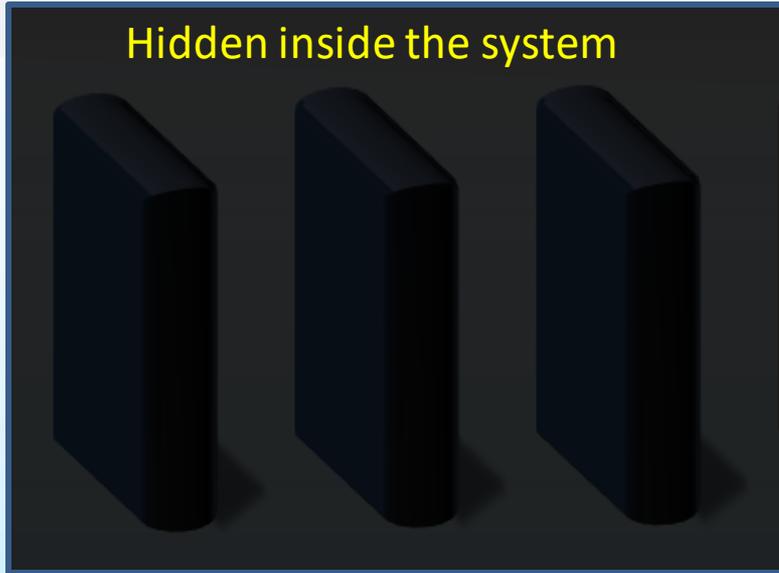
**Boeing’s understanding: the only solution for short TTM & Fuel efficiency.....  
737 platform with new engine.**

# Applicable Documents



1. Indonesian, Lion Air, Boeing 737-8 (MAX) PK-LQP ,Aircraft Accident Investigation Preliminary Report.  
[http://knkt.dephub.go.id/knkt/ntsc\\_aviation/baru/pre/2018/2018%20-%20035%20-%20PK-LQP%20Preliminary%20Report.pdf](http://knkt.dephub.go.id/knkt/ntsc_aviation/baru/pre/2018/2018%20-%20035%20-%20PK-LQP%20Preliminary%20Report.pdf)
2. Ethiopian B737-8 (MAX) ET-AVJ ,Aircraft Accident Investigation Preliminary Report.  
<http://www.ecaa.gov.et/documents/20435/0/Preliminary+Report+B737-800MAX+%2C%28ET-AVJ%29.pdf/4c65422d-5e4f-4689-9c58-d7af1ee17f3e>
3. “How the Boeing 737 Max Disaster Looks to a Software Developer”, By Gregory Travis  
<https://spectrum.ieee.org/aerospace/aviation/how-the-boeing-737-max-disaster-looks-to-a-software-developer>
4. Wikipedia - Ethiopian Airlines Flight 302
5. Letter to Dennis A. Muilenburg, CEO of Boeing, By Ralph Nader (several relevant entries in his blog)  
<https://nader.org/2019/04/25/a-letter-to-dennis-a-muilenburg-ceo-of-boeing/>
6. The many human errors that brought down the 737 MAX, By Darryl Campbell May 2, 2019  
<https://www.theverge.com/2019/5/2/18518176/boeing-737-max-crash-problems-human-error-mcas-faa>

# The Whole Philosophy in a Nutshell



## Main objectives :

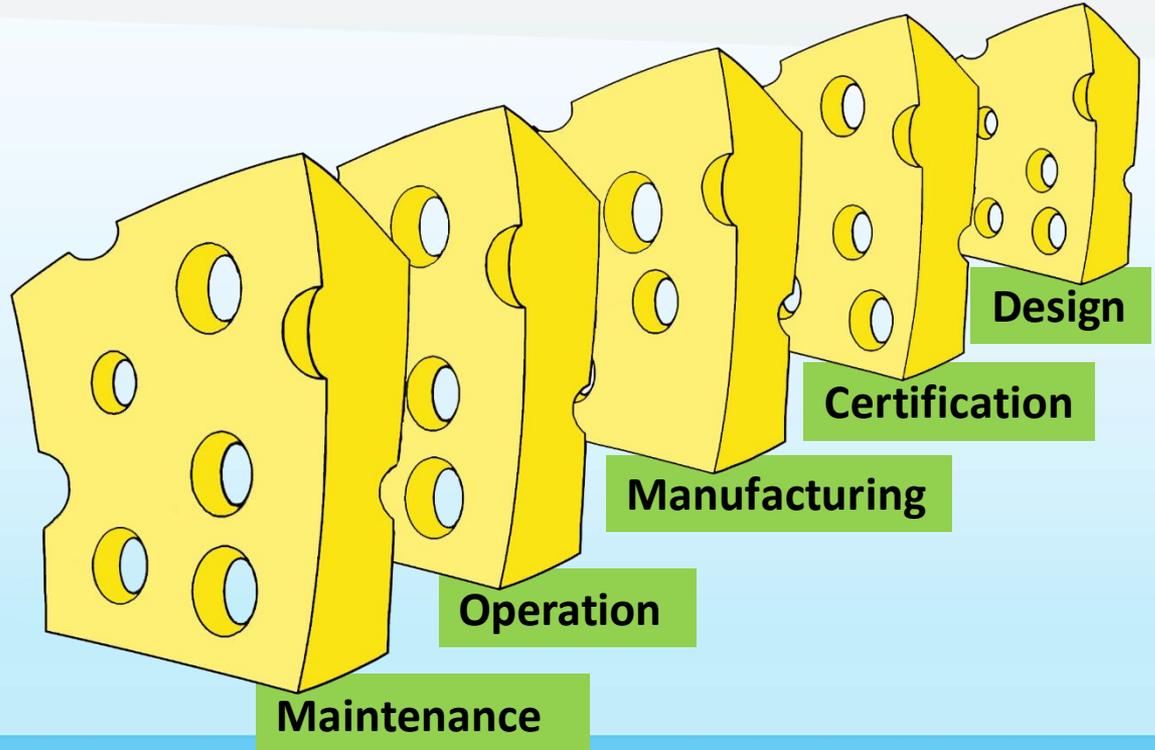
1. Identify the Failure Chain consisting of physical, human and latent root causes.
2. Correctly take care of the local failure.
3. Deduce and publicize lateral insights, and formulate applicable corrective actions to lower our future failure rates.

# Adaptation of Reason's Swiss Cheese Model to Failure Investigation

Holes in the cheese slices symbolize mistakes, and local latent errors or local failures.

Each slice constitutes a partial filter to errors done on previous slices.

Each user may assign slice designations suitable to his specific investigation.

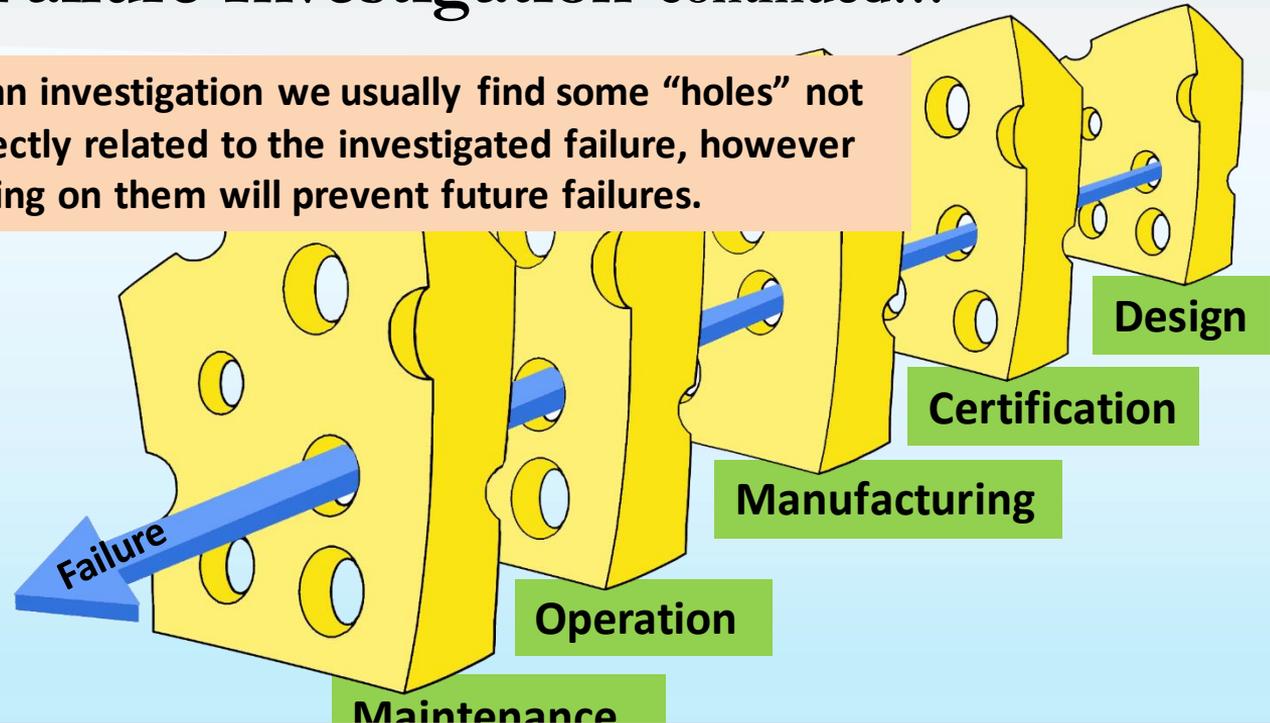


# Adaptation of Reason's Swiss Cheese Model to Failure Investigation continued...

What decreases the number of holes?

- Design Simplicity
- Professionalism
- Proper QA
- Proper instructions (assembly, test, operation, maintenance)
- System understanding to all involved
- Motivation
- Learning from failures and acting upon the insights

In an investigation we usually find some “holes” not directly related to the investigated failure, however acting on them will prevent future failures.



What increases the number of “holes”?

shortage in: man power, Budget and time, “**the dirty dozen**” and the opposites of all actions on the “decrease” panel.....

# The Basic Methodology Flowchart

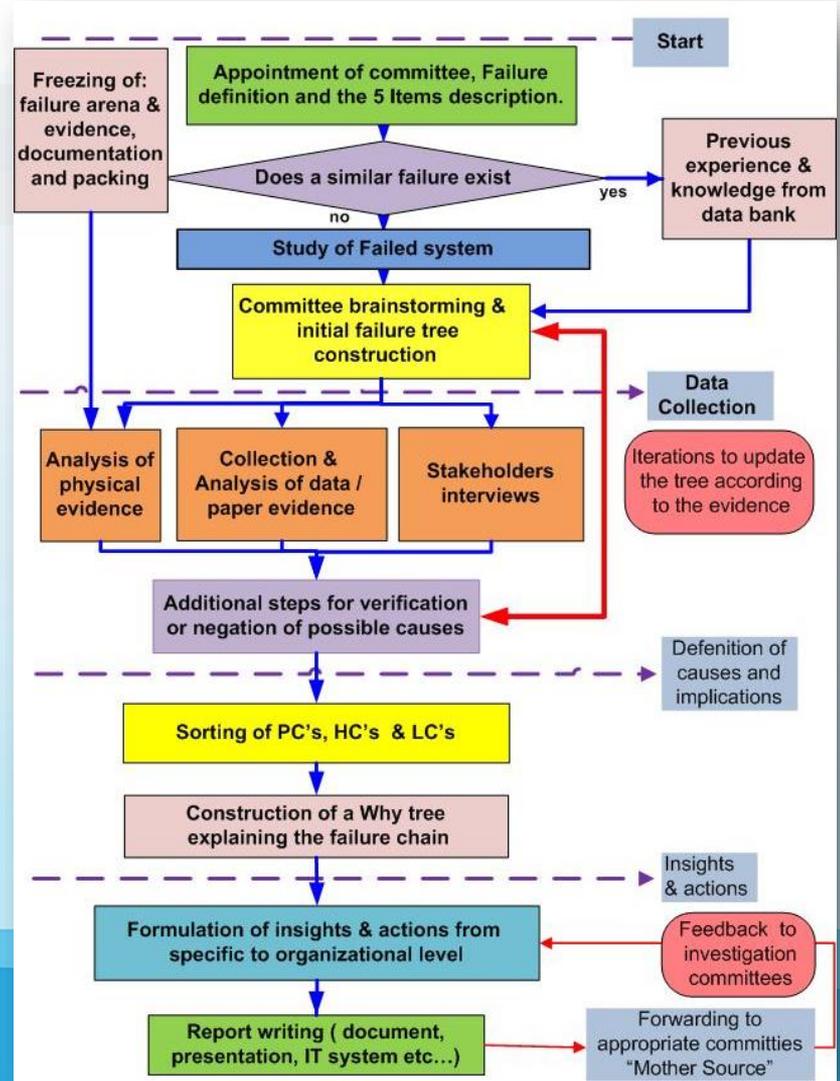
## Stage in Flowchart

Additional text on the dividers:

Notes on the Methodology

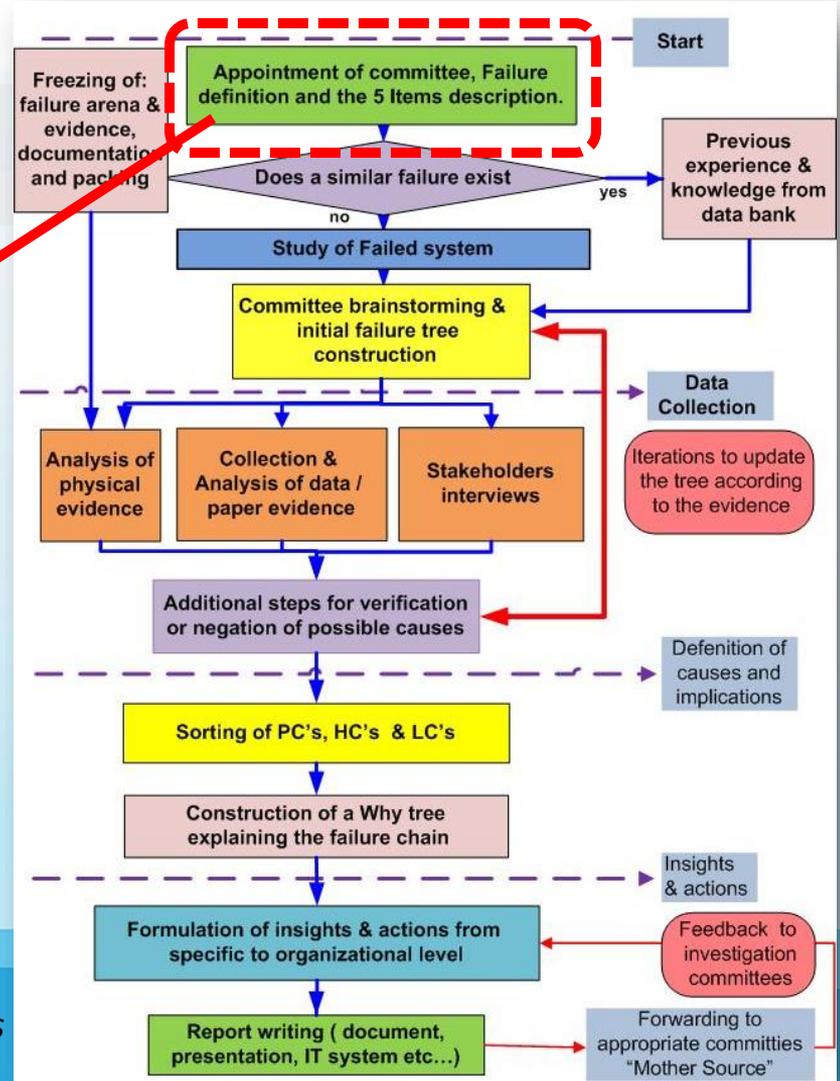
Data pertaining to the example

In RAFAEL we usually do not investigate plane crashes however failures in defense systems are not any less complicated.



# Stage in Flowchart

**Appointment of committee, Failure definition and the 5 Items description.**



*"The 5 Items" from Bob Nelms :ROOTS™ investigative process*

# Committee Appointment & Investigation Question

*Investigation Committee appointed by the Ethiopian Minister of Transport .*

*Working groups were formed as follows:*

- *Operations*
- *Maintenance & Airworthiness group*
- *Power plant group*
- *Autopsy examination group*
- *DFDR and CVR group*

*Investigation Lead Question: Why did the 737MAX crash?*

In RAFAEL committee size, technical expertise and seniority of members, depend on the failure magnitude.

Pain ?

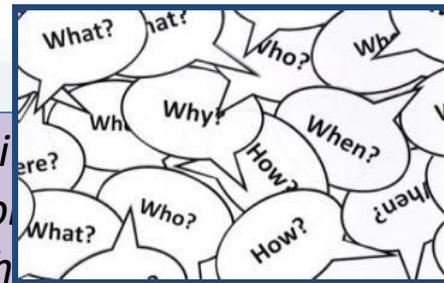
Noise ?

Stain ?

Banana ?



# “The 5 Items”



1. What happened?
2. Who was involved?
3. Where?
4. When?
5. Description

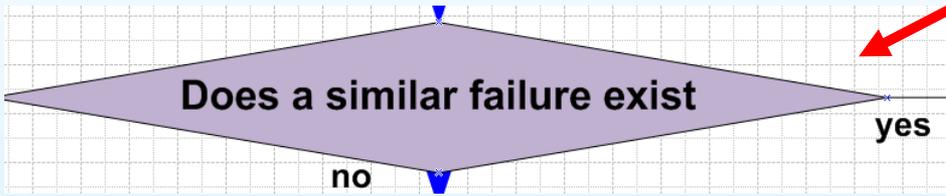
*Due to flight control problems, the Captain requested to return to the departure airport. The crew lost control of the aircraft which crashed near Ejere village.*

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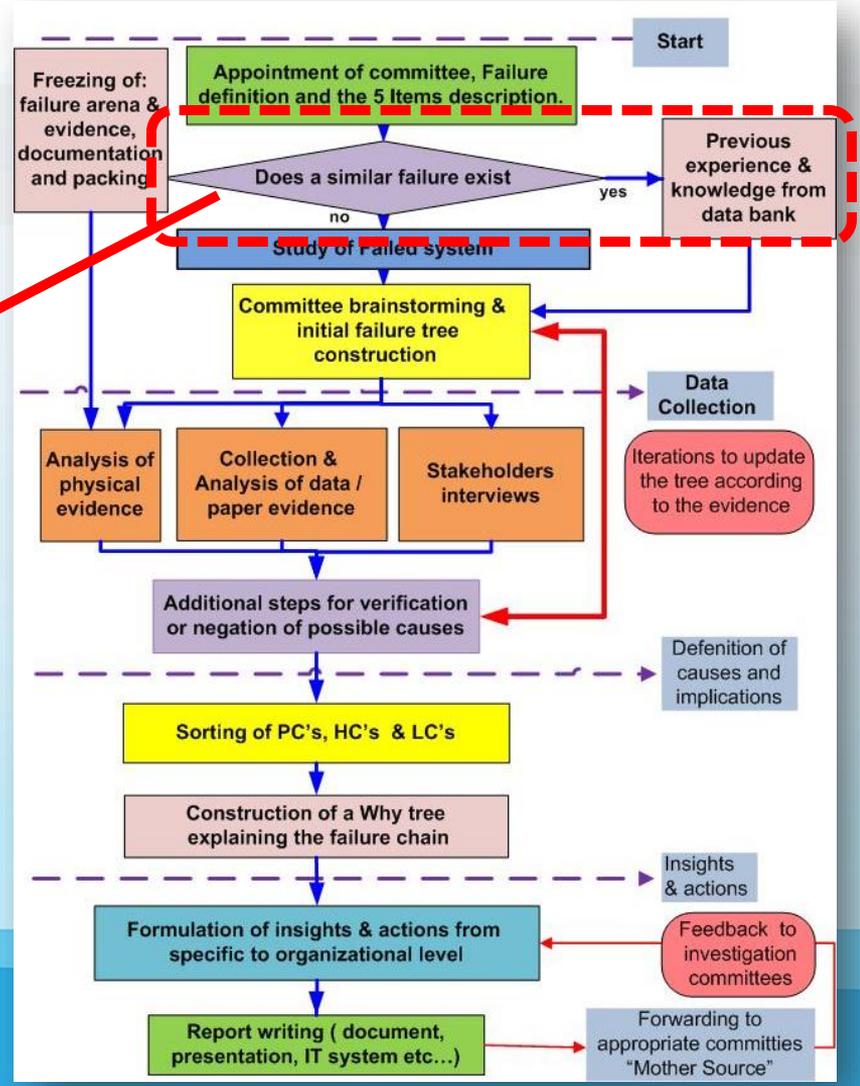
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# Stage in Flowchart



**YES**  
*Unfortunately*



# A similar failure

- October 28, 2018, Lion Air Crash.
- “Flight control problem”.
- From The Digital Flight Data Recorder (DFDR): a continued difference between left and right Angle of Attack (AoA) sensors of about 20° until the “end of recording”.

**AoA sensor malfunction !**



**CNN** World » US | Africa | Americas | Asia | Australia | China | Europe | Middle East | India | UK International Edition + 🔍 ☰

## Extra pilot averted disaster on previous Boeing 737 Max 8 flight - report

By Masrur Jamaluddin, Helen Regan and Jack Guy, CNN  
Updated 1350 GMT (2150 HKT) March 20, 2019



KOMITE NASIONAL KESELAMATAN TRANSPORTASI  
REPUBLIC OF INDONESIA

## PRELIMINARY

KNKT.18.10.35.04

Aircraft Accident Investigation Report

PT. Lion Mentari Airlines  
Boeing 737-8 (MAX); PK-LQP  
Tanjung Karawang, West Java  
Republic of Indonesia  
29 October 2018

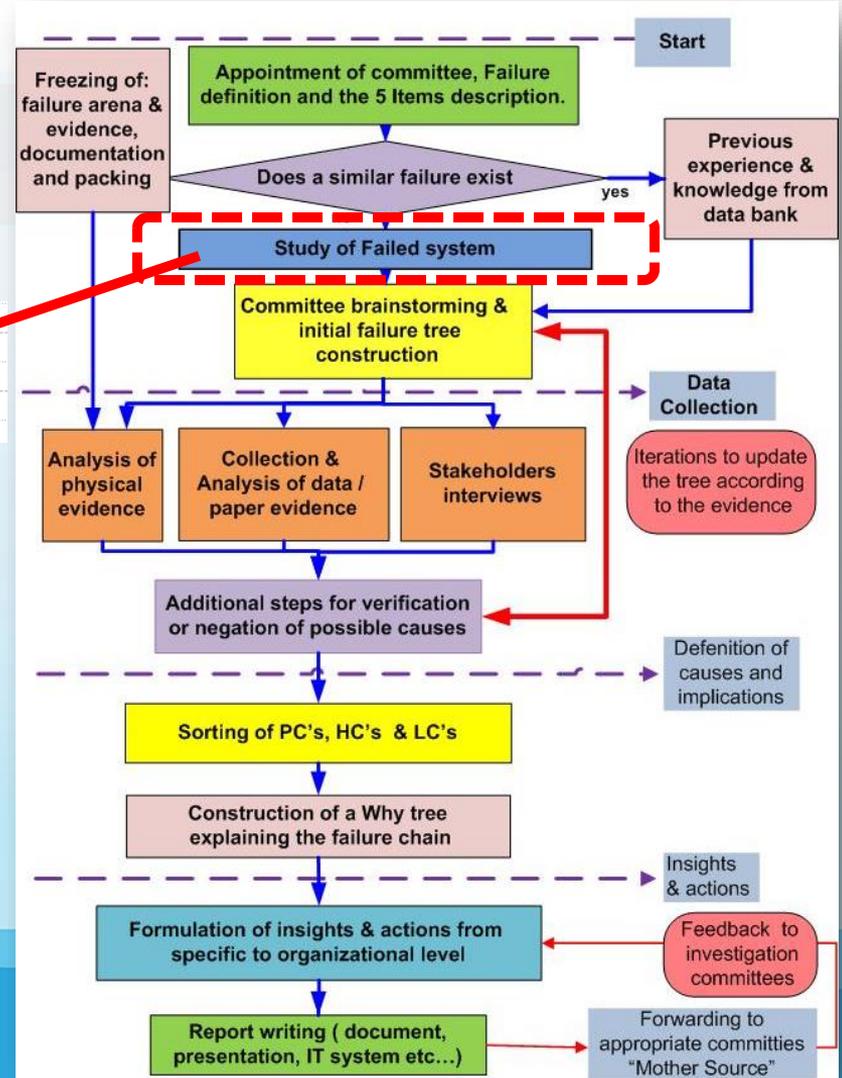
2018

# Stage in Flowchart

## Study of Failed system

The committee has to bridge the gap in knowledge of the failed system.

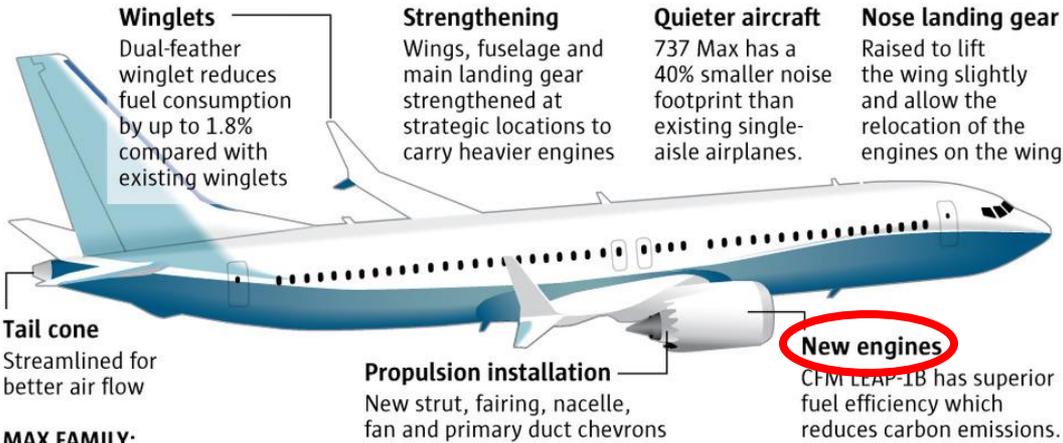
- *Boeing 737 MAX 8, 4<sup>th</sup> Gen. Entered service in 2017.*
- *New LEAP-1B Engines manufactured by CFM International. much **larger**, quite & fuel efficient.*
- *New Software package , **MCAS***



# System Study

## - Info. from "Manufacturer"

### What is new on Boeing's 737 MAX



**MAX FAMILY:**

**737-MAX 7**

Wingspan: **117 feet, 10 inches**  
 Length: **116 feet, 8 inches**  
 Passengers: **172 (maximum seating)**

Source: Boeing

**737-MAX 8**

117 ft., 10 in.  
 129 ft., 8 in.  
 189 (maximum seating)

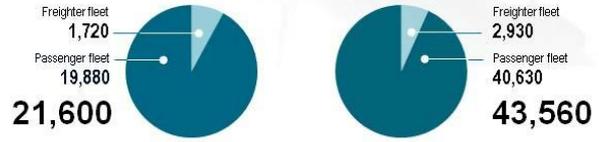
**737-MAX 9**

117 ft., 10 in.  
 138 ft., 4 in.  
 220 (maximum seating)

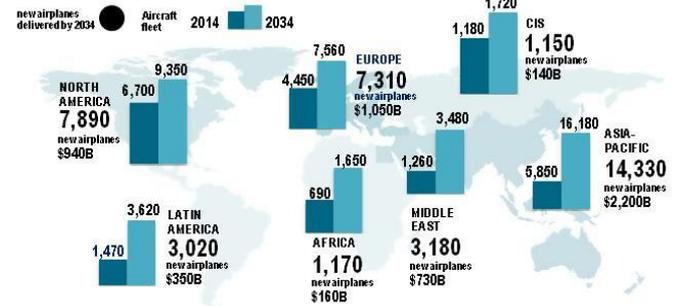
MARK NOWLIN / THE SEATTLE TIMES



**WORLD FLEET TO DOUBLE IN SIZE OVER THE NEXT 20 YEARS**  
 38,050 new airplanes / \$5.6 trillion



**EMERGING MARKETS TO LEAD THE GROWTH**



**NEW AIRPLANES TO BE DELIVERED BY 2034**

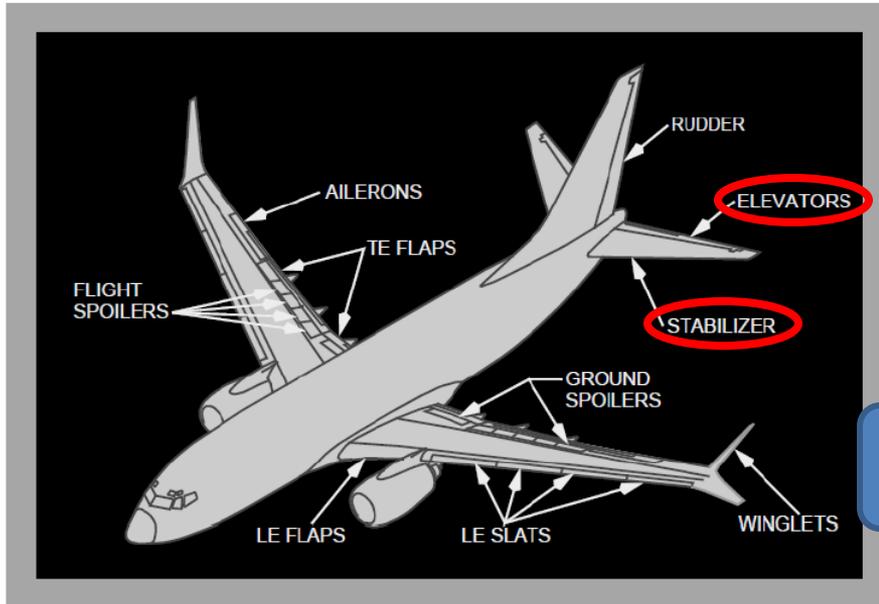


## 1.6.2 AIRCRAFT FLIGHT CONTROL SYSTEM DESCRIPTION

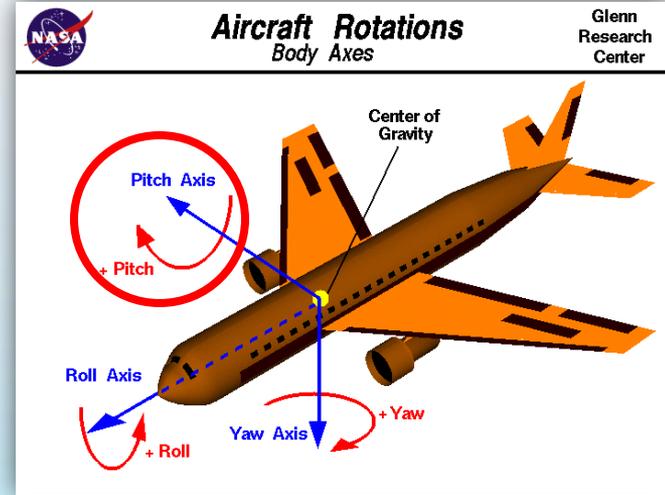
### Introduction

The primary flight control system uses conventional control wheel, column and pedals linked mechanically to hydraulic power control units which command the primary flight control surfaces; ailerons, elevators and rudder. The flight controls are powered by redundant hydraulic sources; system A and system B.

### Flight Control Surfaces Location



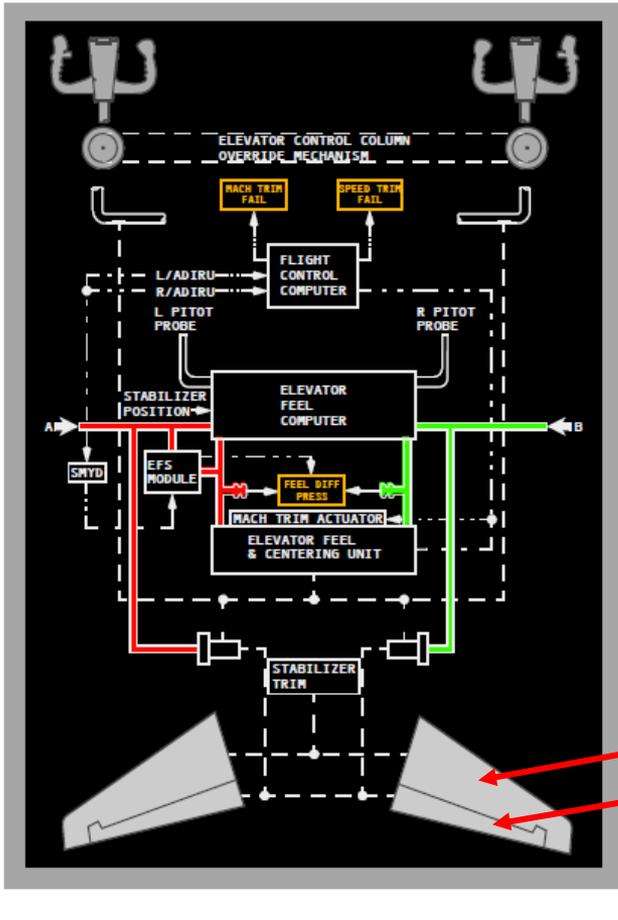
Further explanation



Pitch up = Nose up = ascent  
 Pitch down = Nose down = Descent

From the Ethiopian Accident Investigation Preliminary Report

## Pitch Control Schematic



# Pitch Control Schematic

## Pitch Control

- The pitch control surfaces consist of **hydraulically powered elevators** and an **electrically powered stabilizer**. The **elevators** are controlled by forward or aft movement of the control column. The **stabilizer** is controlled by **autopilot trim** or **manual trim**.

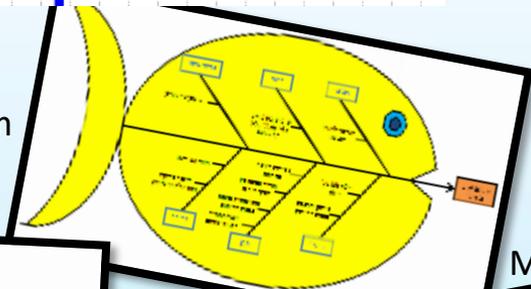
- Stabilizer
- Elevator



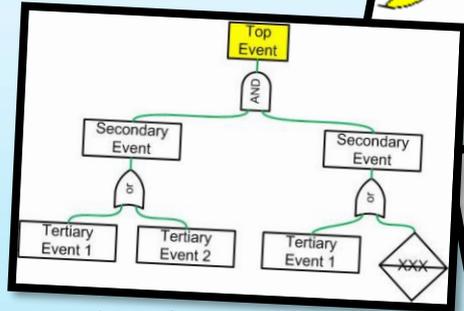
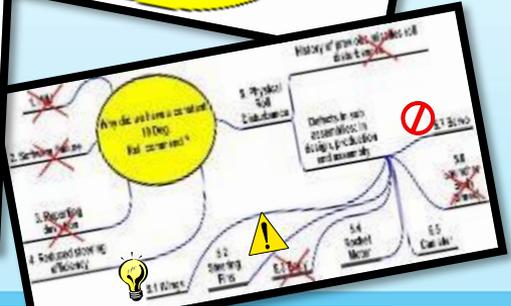
# Stage in Flowchart

**Committee brainstorming & initial failure tree construction**

Ishikawa or Fishbone Diagram

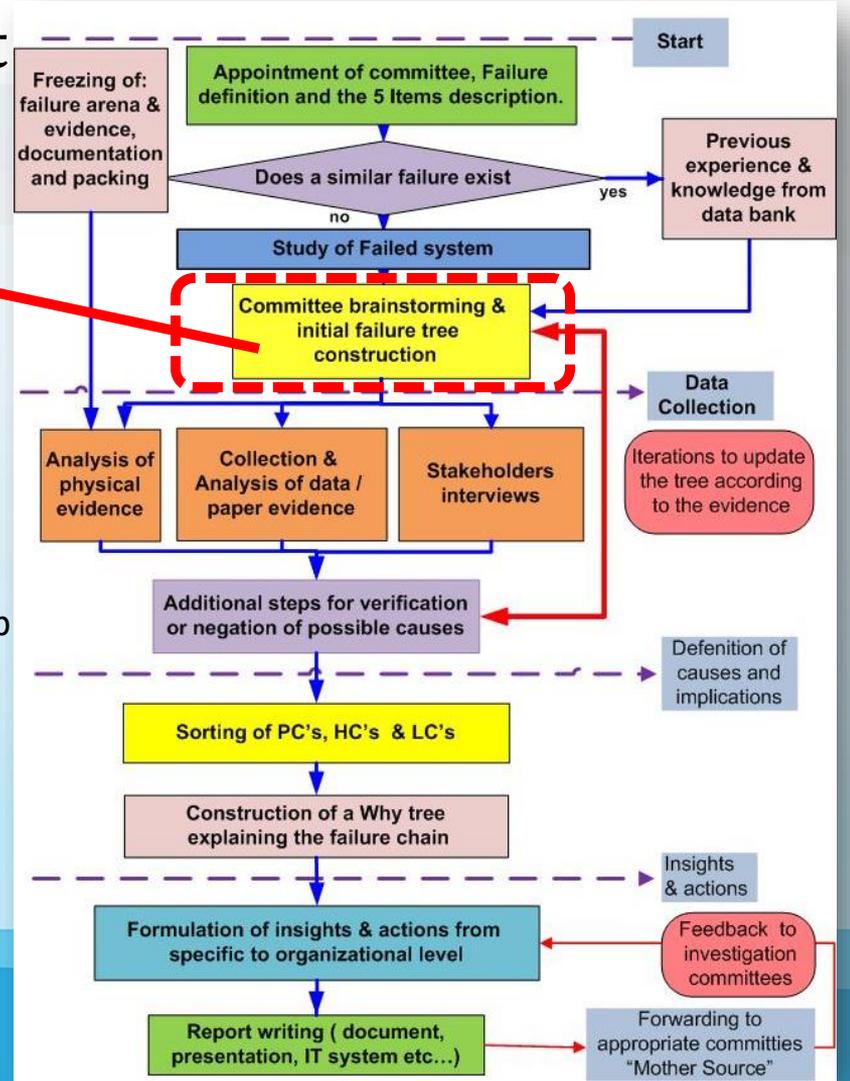


Mind Map

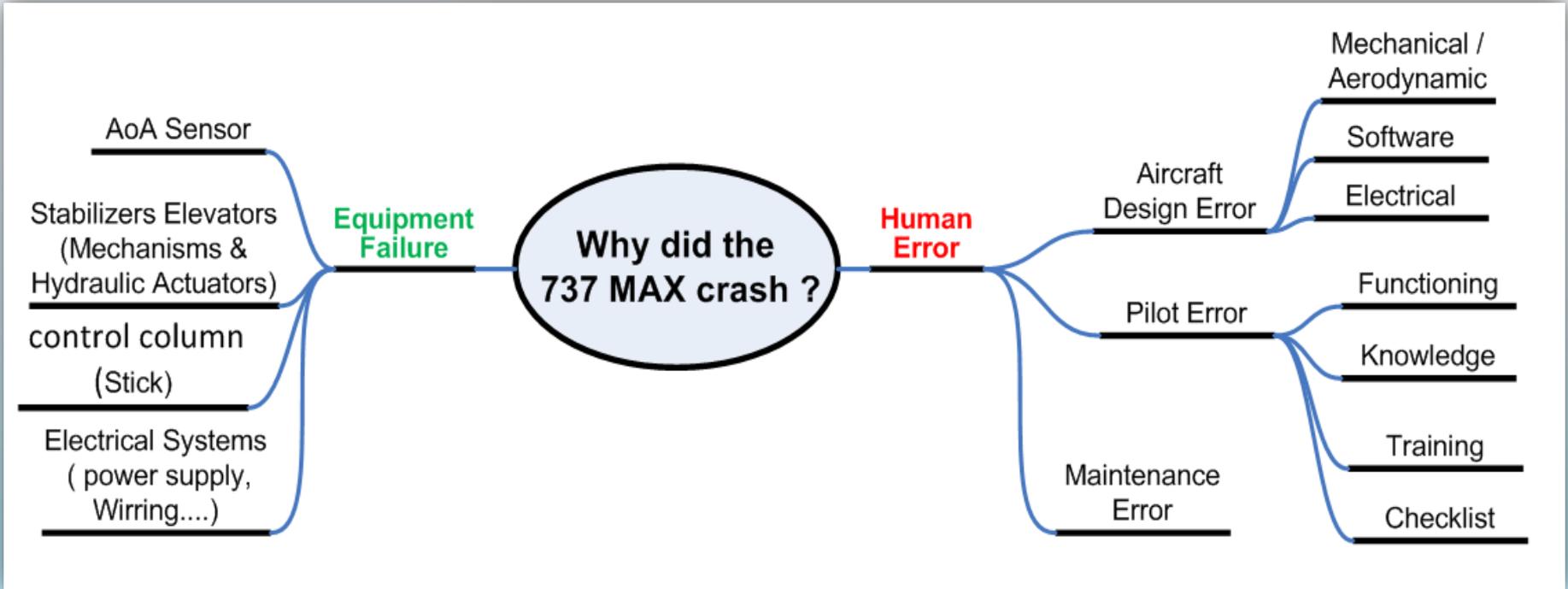


Logical Fault Tree

My preference is a **Mind Map** because it encourages brainstorming.



# Initial Failure Tree (Mind Map)





# Stage in Flowchart

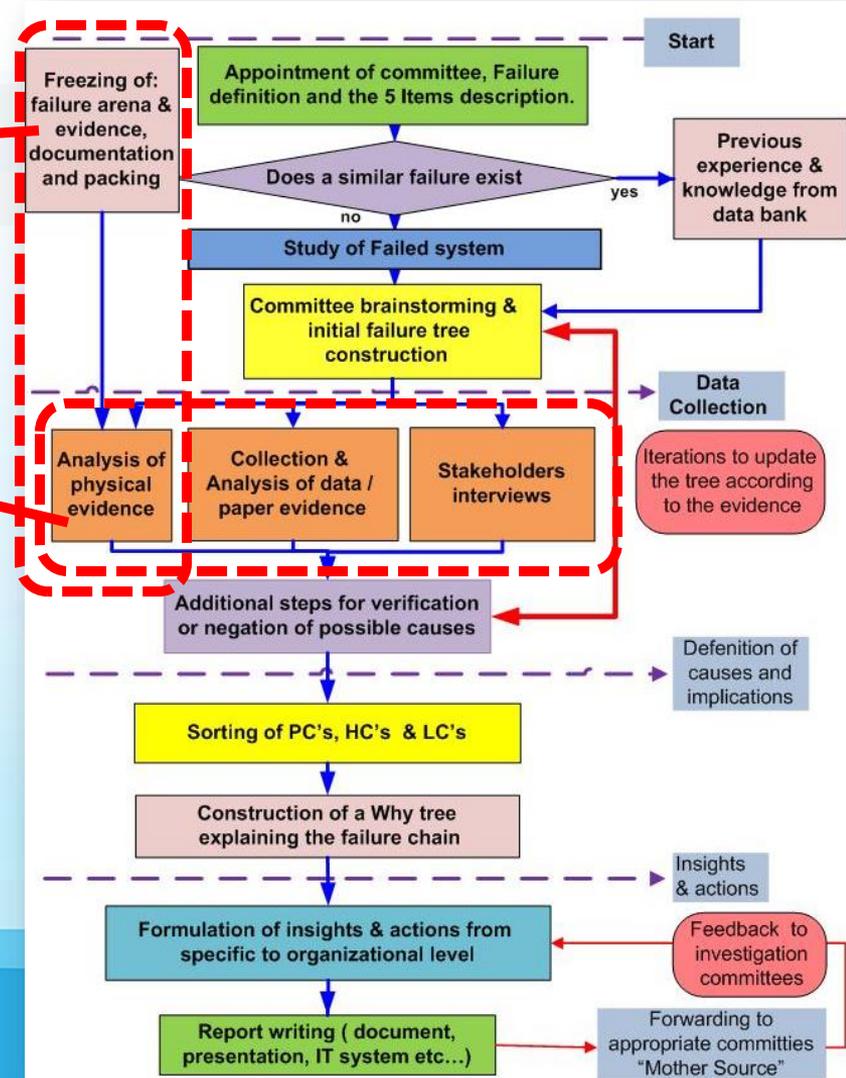
Freezing of: failure arena & evidence, documentation and packing

Analysis of physical evidence

Collection & Analysis of data / paper evidence

Stakeholders interviews

*Parts from the crash site & examinations of parts and systems from intact planes.  
Papers from: development, certification, operation documentation etc.  
People: stakeholders like: Boeing & FAA engineers, Pilots & experts....*



# Sample PPPs

## Evidence from Crash Site



Close view of the crater before excavation

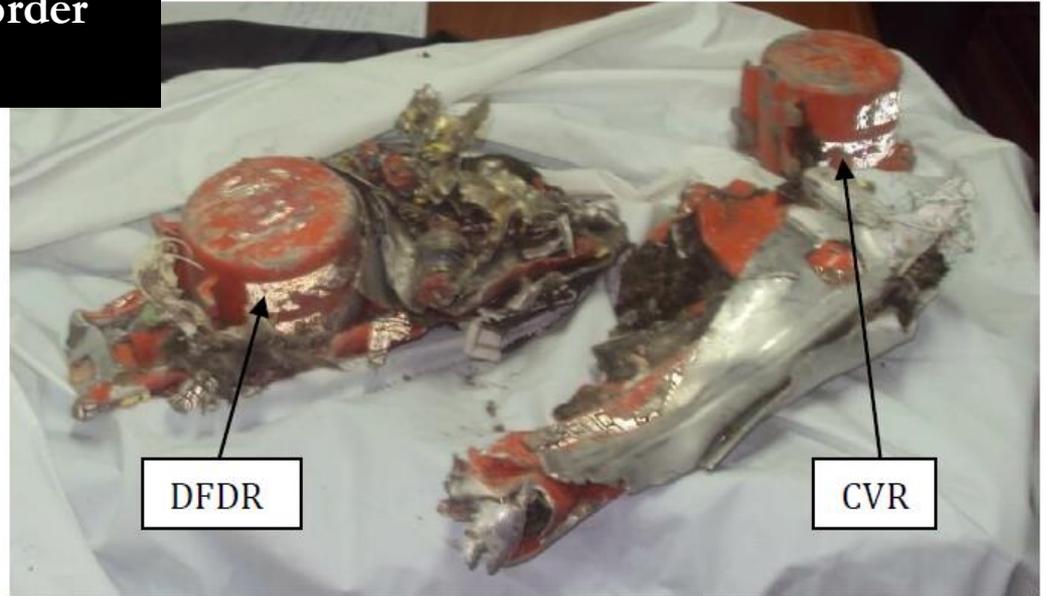


Top view of the crater

# Evidence From Crash Site....cont.

## Black Boxes

- DFDR – Digital Flight Data Recorder
- CVR – Cockpit Voice Recorder

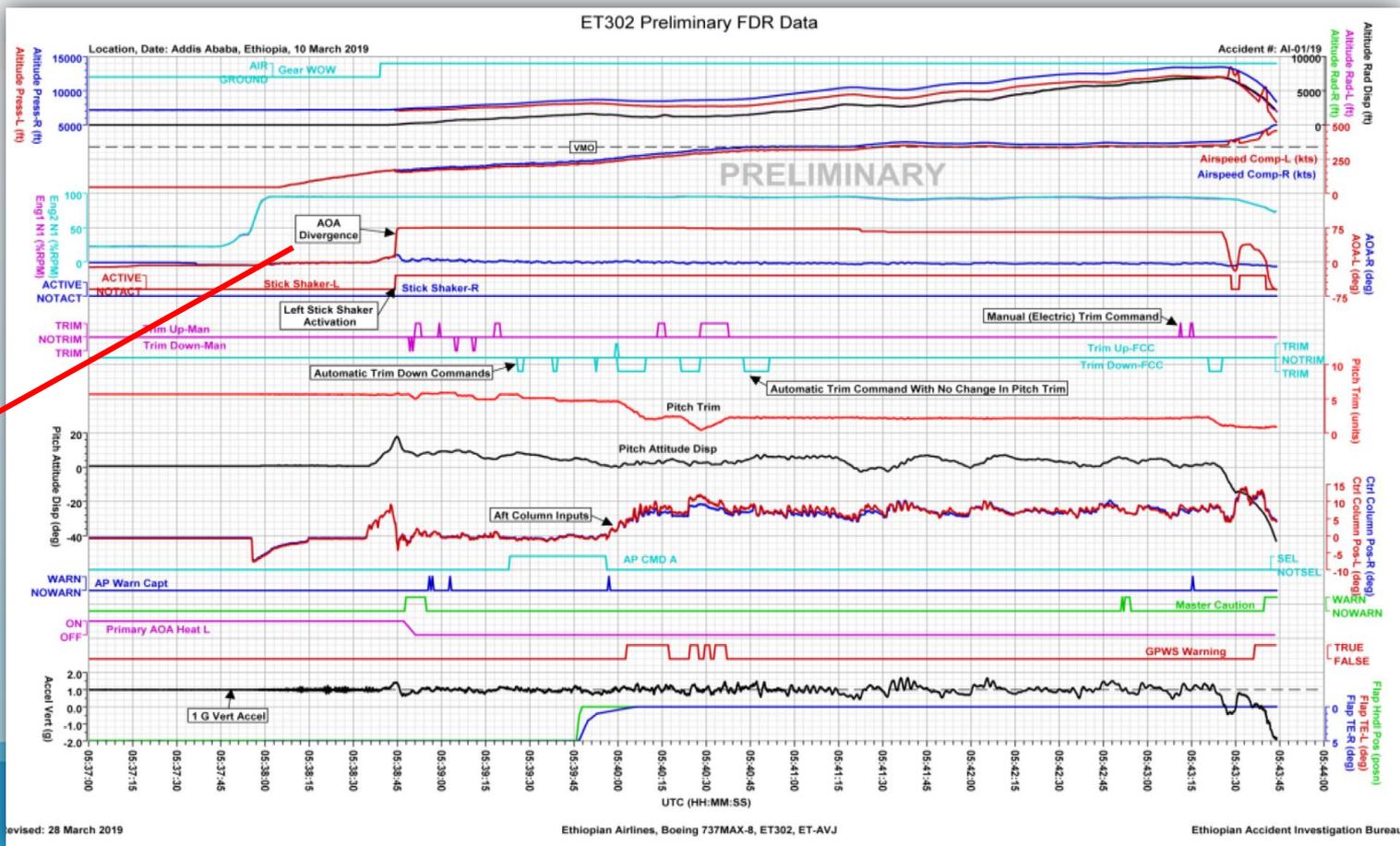


DFDR and CVR as discovered on the accident site.

# Sample PPPs - Paper

Relevant  
 Data  
 from the  
 DFDR

**AoA  
 Divergence**



Revised: 28 March 2019

Ethiopian Airlines, Boeing 737MAX-8, ET302, ET-AVJ

Ethiopian Accident Investigation Bureau

# Sample PPPs – AoA Sensor

- Initiate AoA study.

“ There are at least 140 instances since the early 1990s of sensors on U.S. planes being damaged by jet-ways and other ground equipment, or striking birds in flight”.  
- Bloomberg News -



# Sample PPPs - Paper

## Aircraft + Crew data

- Aircraft had 1330.3 hours with a total of 382 cycles (flights) at the time of the accident.

Registration Number:	ET-AVJ	Aircraft Category:	Transport	Manufacturer:	© CFM International
Aircraft Serial Number:	62450	Number of Engines:	2	Type/Model:	LEAP-1B28B1
Aircraft Manufacturer:	Boeing Commercial Aircraft	Seating arraignment:	Multi-Class	Serial Number-1 engine:	602722
Model:	737-8 (MAX)	PAX Seating Capacity:	160	Time Since New:	1330 hours
Engine Manufacturer:	CFM International	Max. T/O Weight:	82,190 kg	Cycles Since Install:	382 cycles
Engine Model:	LEAP-1B28B1G05	Total Time:	1330.3 hours	Cycles Since New:	382 cycles
Manufactured Year:	2018	Total Cycles:	382	Serial Number-2 engine:	602695
Aircraft Type:	Fixed Wing Multi-Engine	Aircraft Owner:	Ethiopian Leasing (5-737) LTD	Time Since New:	1330 hours
Engine Type:	Turbo Fan			Cycles Since Install:	382 cycles
				Cycles Since New:	382 cycles

- Captain** : 29 years old, Total flight experience :8122 hours, 1417 in B737, 103 on the MAX.
  - The pilot's **license allowed** him to act as **pilot-in-command** on the 737 MAX .
  - had a first-class **medical certificate** with no limitations
- First-officer**: 25 years old, Total flight experience :361 hours, 207 in B737, 56 on the MAX.
  - The first-officer's **license allowed** him to act as **first-officer** on the 737 MAX .
  - The first-officer had a first-class **medical certificate** with no limitations .

# Sample PPPs - Paper

- Section 2.6 of the Flight Operations Manual, "Operational Irregularities", in use by Ethiopian Airlines at the time of the crash was dated November 1, 2017 and did not include this Bulletin.
- **Did the pilots : know about it?, Memorized it? Practiced it?**
- **And still no mention of the MCAS (by Boeing)???**

Boeing Believed 737 M...  
https://www.thedailybeast.com

**DAILY BEAST** JOIN

ASUS ZenBook 13/14

**A DAMNING TIMELINE**

**Boeing Told 737 MAX Pilots to Follow Instructions After First Fatal Crash. They Did and Died Anyway.**

Clive Irving  
Updated 04.04.19 6:51PM ET  
Published 04.04.19 1:02PM ET

**BOEING**

Operations Manual Bulletin  
for  
Ethiopian Airlines

124-2207 

Number: ETH-12

**IssueDate: November 6, 2018**

**Subject: Uncommanded Nose Down Stabilizer Trim Due to Erroneous Angle of Attack (AOA) During Manual Flight Only**

**Reason: To Emphasize the Procedures Provided in the Runaway Stabilizer Non-Normal Checklist (NNC).**

Information in this bulletin is recommended by The Boeing Company, but may not be FAA approved at the time of writing. In the event of conflict with the FAA approved Airplane Flight Manual (AFM), the AFM shall supersede. The Boeing Company regards the information or procedures described herein as having a direct or indirect bearing on the safe operation of this model airplane.

THE FOLLOWING PROCEDURE AND/OR INFORMATION IS EFFECTIVE UPON RECEIPT

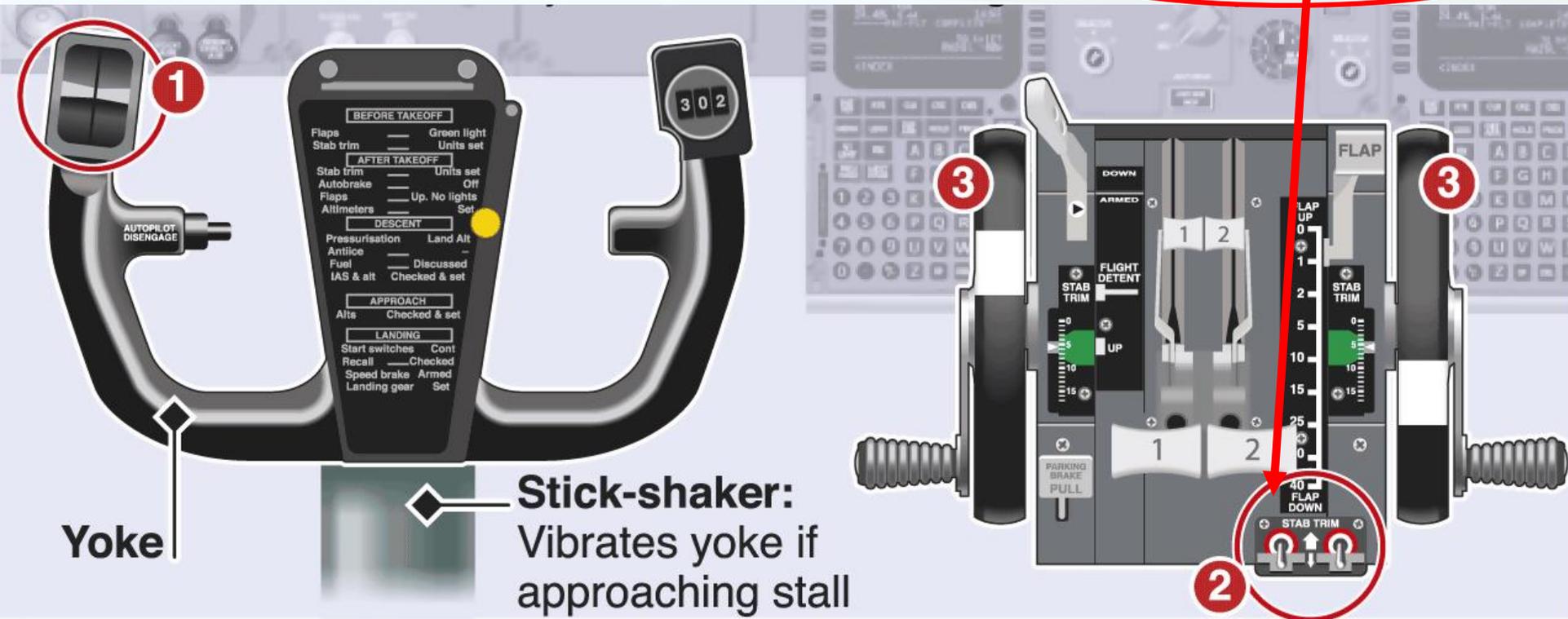
attention to an AOA failure condition that can occur **during manual flight only**. This bulletin directs flight crews to existing procedures to address this condition. In the event of erroneous AOA data, the pitch trim system can trim the stabilizer nose down in increments lasting up to 10 seconds. The nose down stabilizer trim movement can be stopped and reversed with the use of the electric stabilizer trim switches but may restart 5 seconds after the electric stabilizer trim switches are released. Repetitive cycles of uncommanded nose down stabilizer continue to occur unless the stabilizer trim system is deactivated through use of both STAB TRIM CUTOUT switches in accordance with the existing procedures in the Runaway Stabilizer NNC. It is possible for the stabilizer to reach the nose down limit unless the system inputs are counteracted completely by pilot trim inputs and both STAB TRIM CUTOUT switches are moved to CUTOUT.

# Pilot Controls

1. Trim Switches

3. Stabilizer manual trim wheels

2. STAB TRIM - Cutout Switches



**Yoke**

**Stick-shaker:**  
Vibrates yoke if  
approaching stall

# Sample PPPs – Paper - FAA

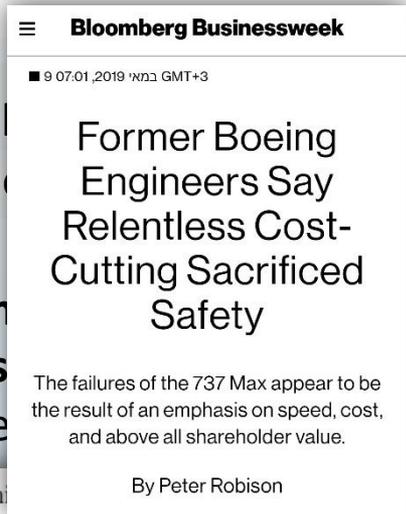
- The 30 pages list of changes for the “**type certificate**” **does not mention MCAS.**
- In it’s **FMECA** the “**failure condition**” assigned to **MCAS** was “**hazardous failure**” and not “**catastrophic failure**” (condition that can endanger the aircraft and its passengers).
- Even with this designation the system is required to have at least **2 levels of redundancy**, with a chance of failure of less than 1 in 10 million.
- **MCAS does not meet this standard.**
- FAA did not catch the fact that. **On paper, MCAS was supposed to move the horizontal stabilizer 0.6 degrees at a time. In reality, it was “could move it as much as 2.5.**



**Type Certificate** = Certification for a new model “by similarity” after review of differences.  
**FMECA** = Failure Mechanisms Effects & Criticality Analysis (to identify and treat risky features during the design phase).

# Sample PPPs - People

- Juan Browne, a 777 pilot with over 40 years of flying experience. “It a wonder, **did Boeing engineers themselves really understand how much authority they built into this system?**” ...”MCAS” – will explain soon.
- Alex Fisher, a retired British Airways pilot. **Boeing couldn’t just slap an** on the airplane. **Aerodynamic changes require a lot of design and test** right. **Boeing needed** something precisely targeted, carefully calibrated in effect. It needed **software**.



An Ethiopian Airlines pilot told senior Boeing executives before one of its Boeing Co. 737 Max jets crashed that more training and better communication to crew members was needed to avert a repeat of a similar disaster involving a Lion Air flight.

According to emails and documents reviewed by Bloomberg News, the pilot in December urged his superiors to bolster training on a 737 Max flight-control feature so crews would be better prepared for what the Lion Air pilots encountered in October before plunging into the Java Sea, killing all aboard.

“It will be a crash for sure” if pilots struggling with a malfunction of Boeing’s flight-control system on the 737 Max also encountered, for example, a cockpit warning that they were flying too close to the ground, the pilot, Bernd Kai von Hoesslin, wrote in a Dec. 13 email.

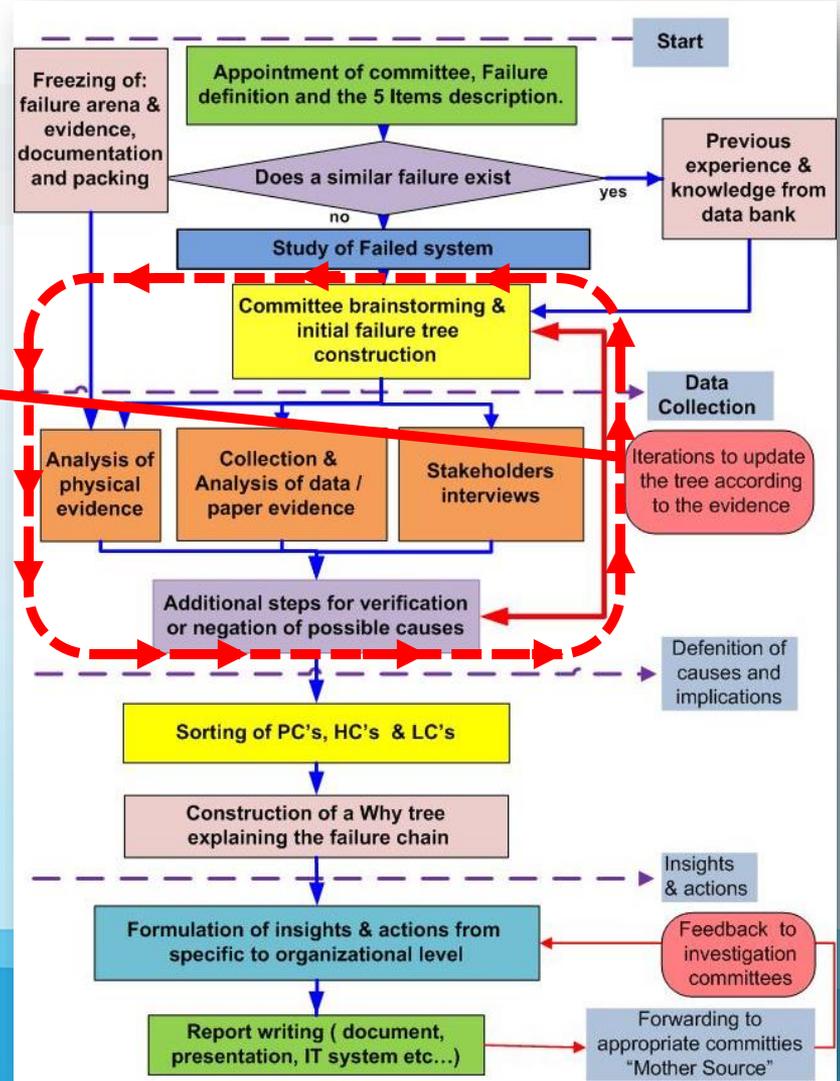


# Stage in Flowchart

Iterations to update the tree according to the evidence

Iterations expanding and invalidating branches in the failure tree according to PPP findings +  
 Initiation of additional steps for verification or negation of possible causes (Relevant tests and simulations as required)

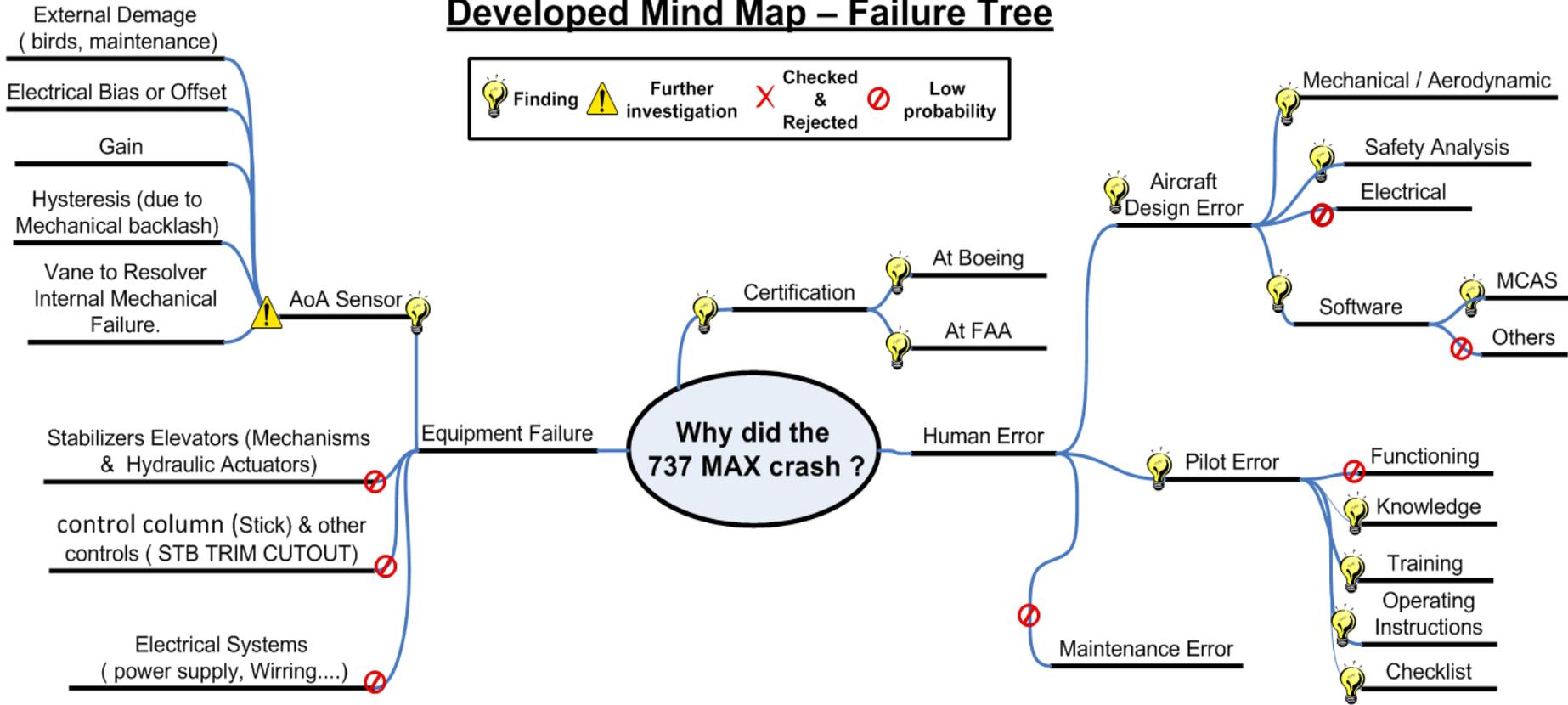
In-process updating of the Failure Tree



# Final Mind-Map (for demonstration only)

## Developed Mind Map – Failure Tree

 Finding 
  Further investigation 
  Checked & Rejected 
  Low probability

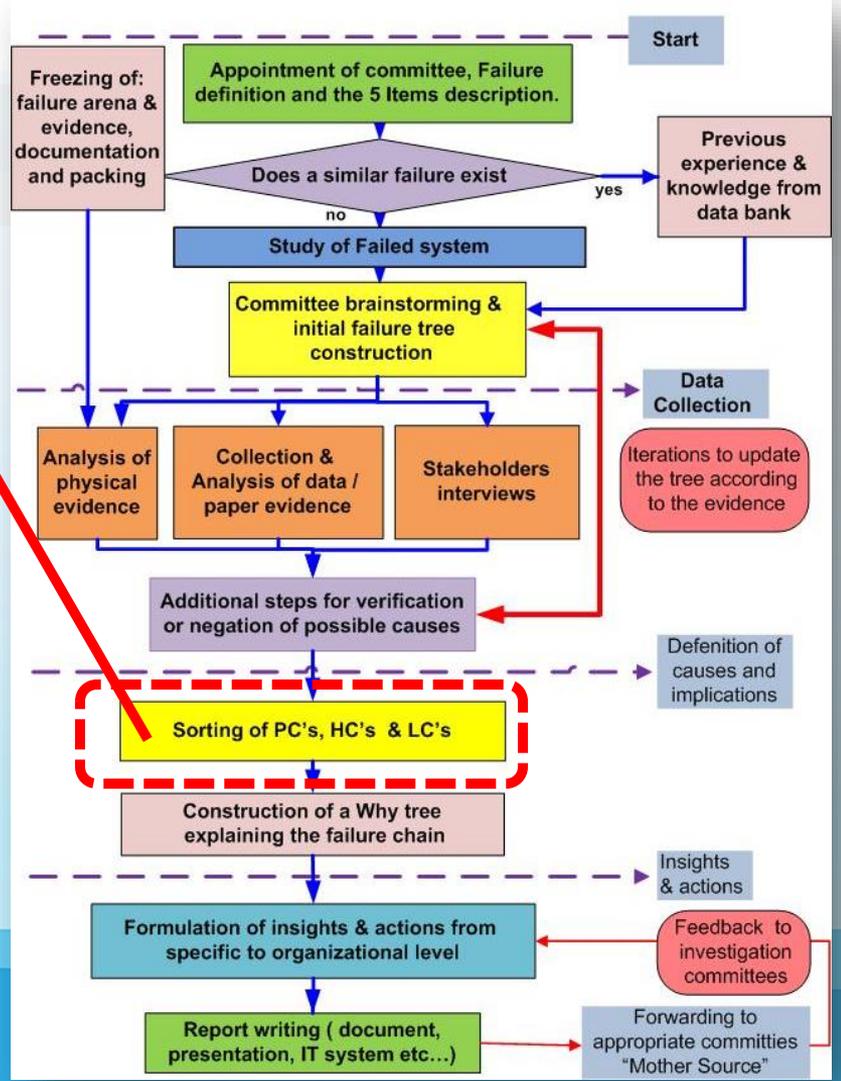


## Sorting of PC's, HC's & LC's

Sorting main findings according to the 3 categories: Physical Causes, Human Causes, Latent Causes



*Explanations and Summary of relevant findings*



# Boeing Engineering Challenge:



Engine is Larger and positioned up and well in front of the wing

- The engines on the original 737 are 40 inches in diameter. On the Max 69 inches.
- **The problem** - Centerline difference of over a foot. The meaning: **no sufficient ground clearance.**
- **The solution** - extension of the engine up and well in front of the wing. **PC**
- **The problem** - Engine nacelles far in front of the wing causes a **significant lift, particularly at high angles of attack.** With a long moment arm from the plane's C.G. **PC**
- **The solution** – MCAS, **PC**
- **The problem** – MCAS....

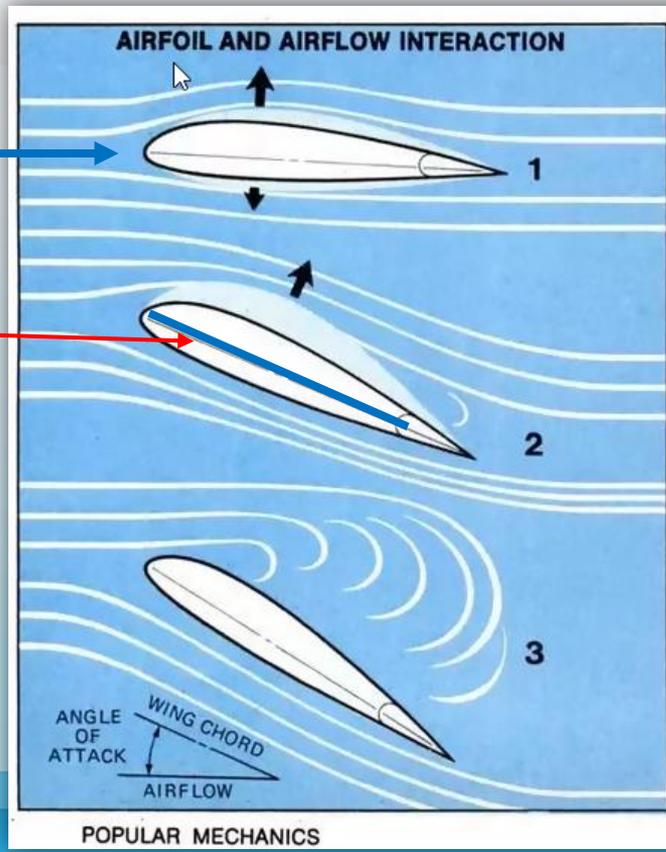
Further explanation on next slides...

# Angle of Attack (AoA) & Stall Explained

- “**Angle of attack**” – angle between:  
Airflow and Wing Chord
- At too high an angle, flow breaks away from the wings upper skin. Lift diminishes catastrophically and we get a **stall**.
- **A Stall** – a condition where the wing Lift diminishes.

Airflow direction

Wing chord



“Angle of attack” refers to relationship of wing chord to direction of oncoming airflow. At low angle of attack, airflow is smooth and moderate lift is the result.

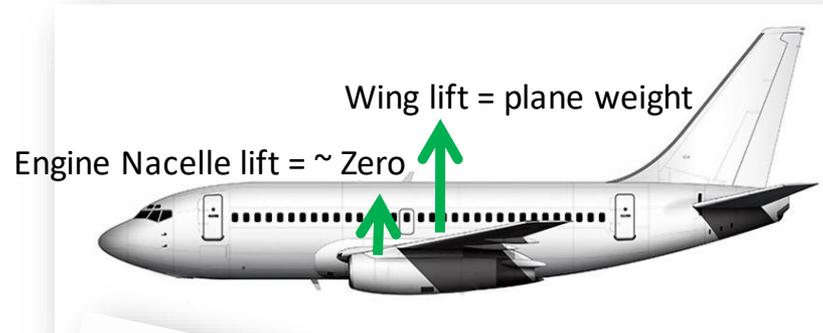
As angle of attack is increased, lift forces build to a peak, then the airflow begins to move away from the wing, starting near the trailing edge and going forward until...

... Stall occurs! At too high an angle of attack, flow breaks away from entire surface. Depending on wing design, it can destroy lift instantly without warning.

# Lift as a Function of AoA - All passenger planes

For explanation purposes:  
Elevators are controlled by forward or aft movement of the control column.  
for each increment in the pilot's command to raise the aircraft nose, the nose will move up 1 degree.

## Aircraft close to Level Flight = cruise



## Aircraft ascending, after takeoff



No engine pitching force because their center of pressure is close to the wing's center of pressure.

# Lift as a Function of AoA - 737 MAX

For explanation purposes:

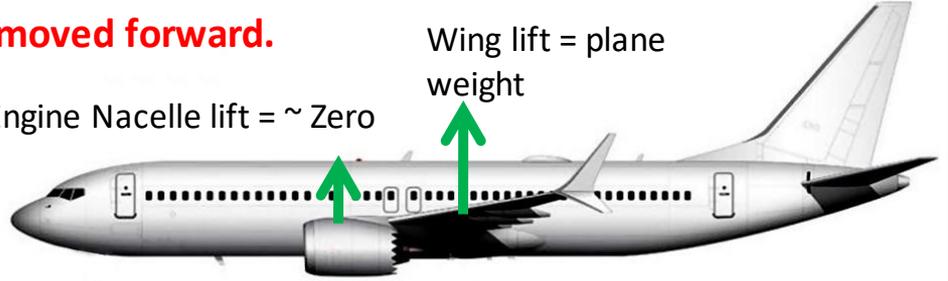
- for the first increment in the pilot's command to raise the aircraft nose, the nose will move up 1 degree.
- Second increment the nose will move up 2 more degrees.
- Third increment the nose will move up 4 more degrees.
- **Increased tendency to get into a stall.**

Aircraft close to Level Flight = cruise

**Engines moved forward.**

Engine Nacelle lift = ~ Zero

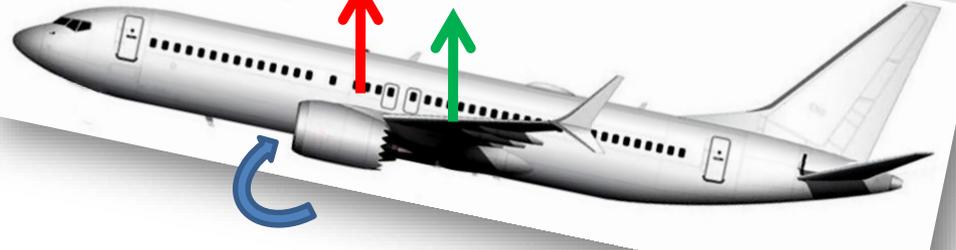
Wing lift = plane weight



Aircraft ascending, after takeoff

Engine Nacelle lift = substantial and increases with angle

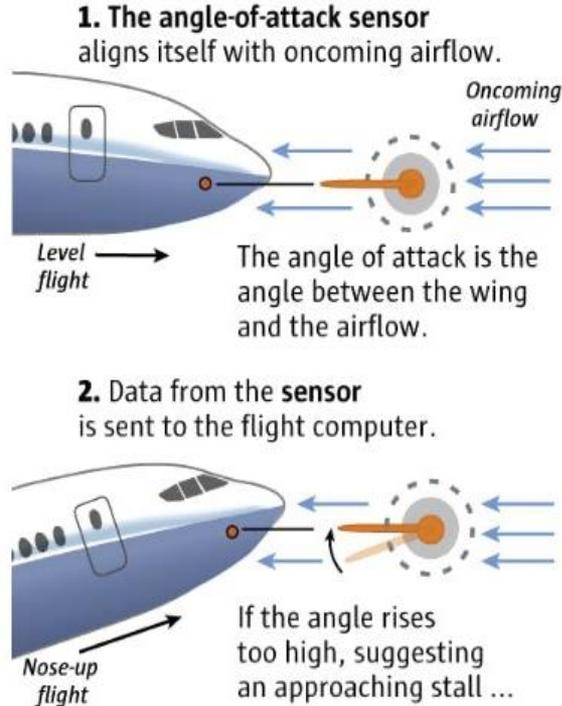
Wing lift = ~ plane weight



Engines pitching force proportional to it's size & distance from the wing's center of pressure.

- MCAS is not mentioned in both preliminary crash investigation reports!
- **MCAS relies on input from a single AoA sensor.**
- **Design spec.** - capable of moving the stabilizer **0.6 degrees** at a time.
- After test pilot feedback **updated** to move **2.5 degrees** at a time.
- Change “not fully examined by the FAA”.

## How the MCAS (Maneuvering Characteristics Augmentation System) works on the 737 MAX



... the **MCAS** activates.

**3. MCAS** automatically swivels the **horizontal tail** to lift the plane's tail while moving the nose down.



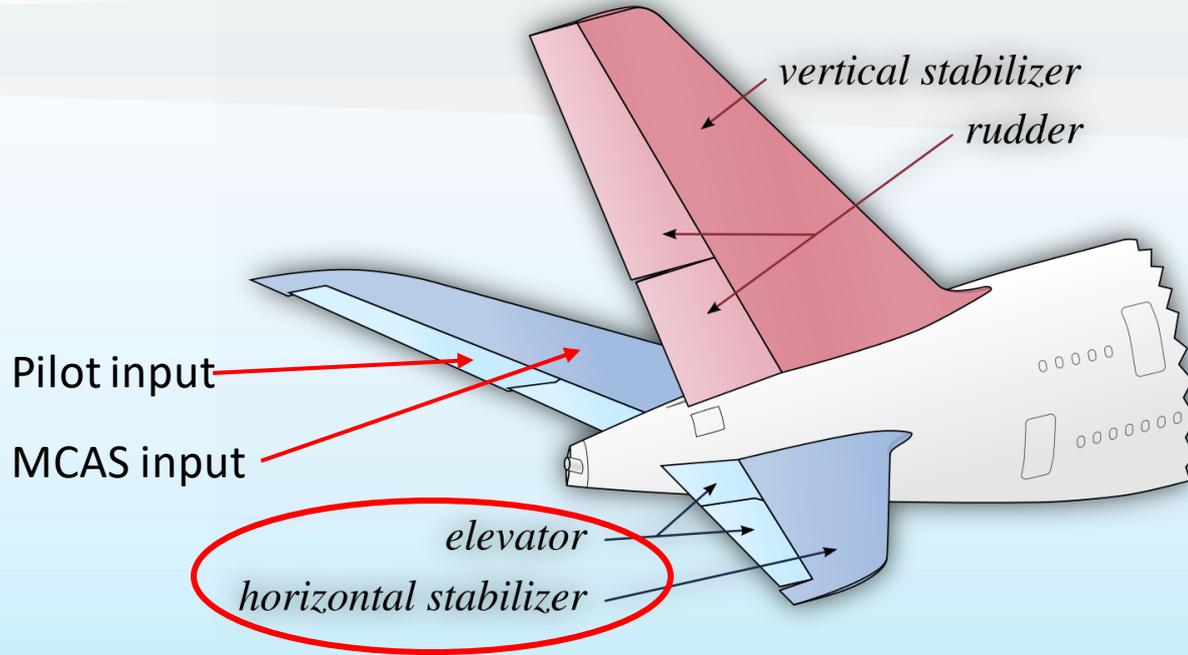
**Horizontal tail**

In the Lion Air crash, the angle-of-attack sensor fed false information to the flight computer.

Sources: Boeing, FAA, Indonesia National Transportation Safety Committee, LeeHam.net, and The Air Current

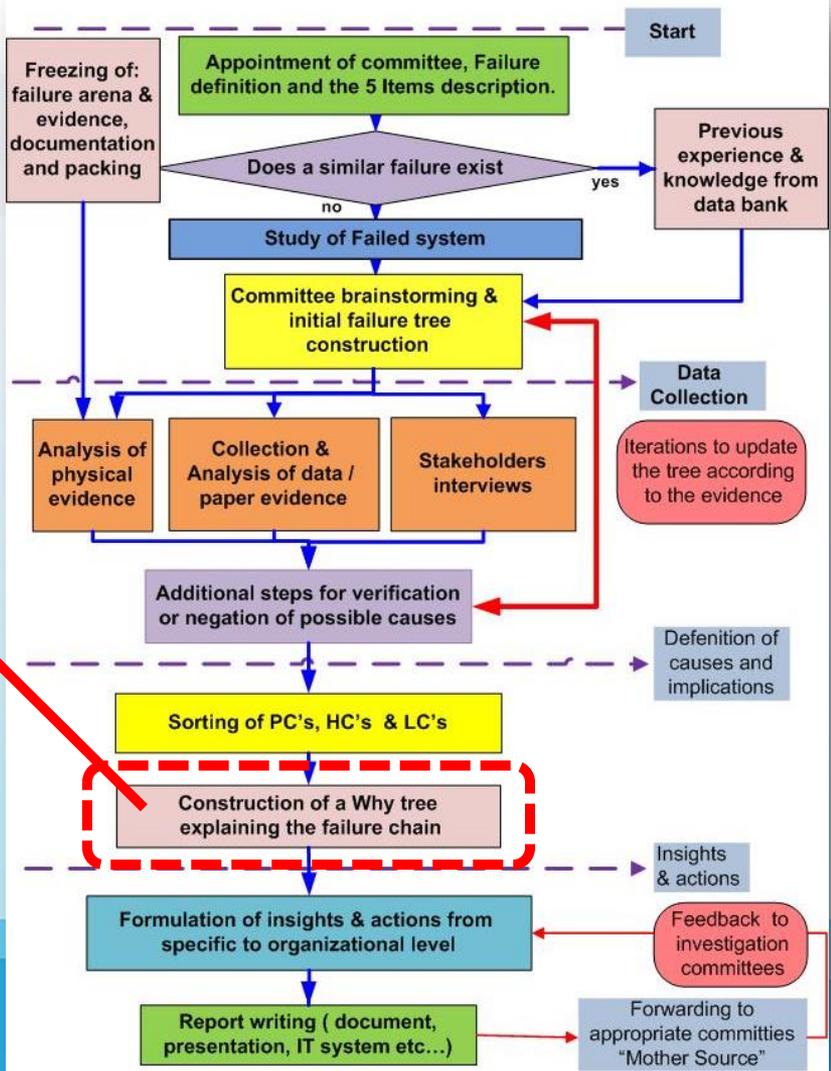
Reporting by DOMINIC GATES,  
Graphic by MARK NOWLIN / THE SEATTLE TIMES

# MCAS Continued



the MCAS system directs the 737Max's **stabilizer**; pilot input, however, affects the **elevator**, which is located on the opposite edge of the tail-fin. A pilot can be applying full *opposite* input into the stabilizer, and the physics are such that the stabilizer — the part under control of the automatic system — **can overcome the inputs of the pilot.** **PC**

# Stage in Flowchart

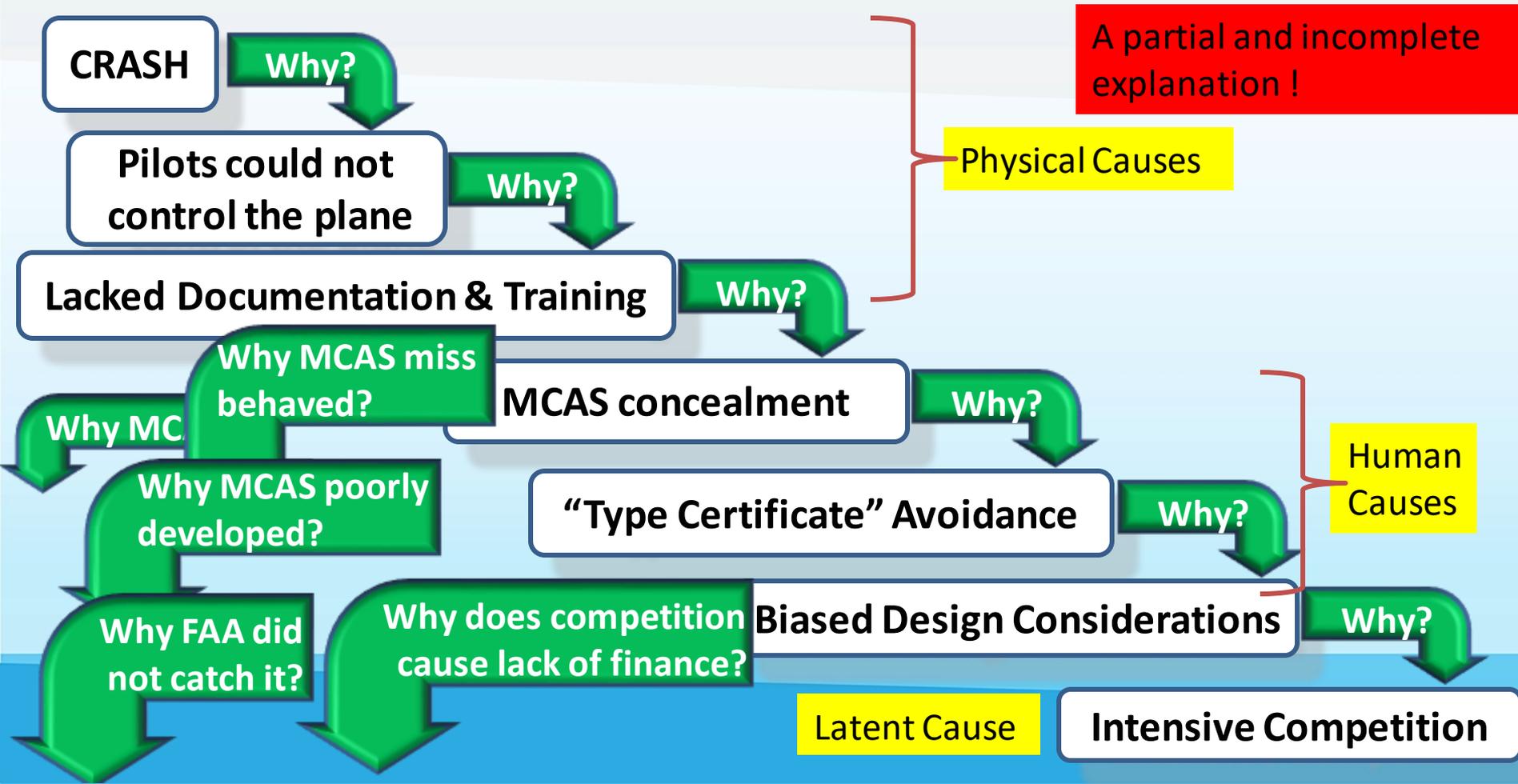


**Construction of a Why tree explaining the failure chain**

*For our example a "5 Why" explanation and than the "Why Tree"*

**"Why Tree" A method to explain the whole picture with visual connections between the relevant causes. (Hopefully on 1 page)**

# A Sample of a “5 Why” Explanation Chain



# A simple

WHY

WHY

WHY

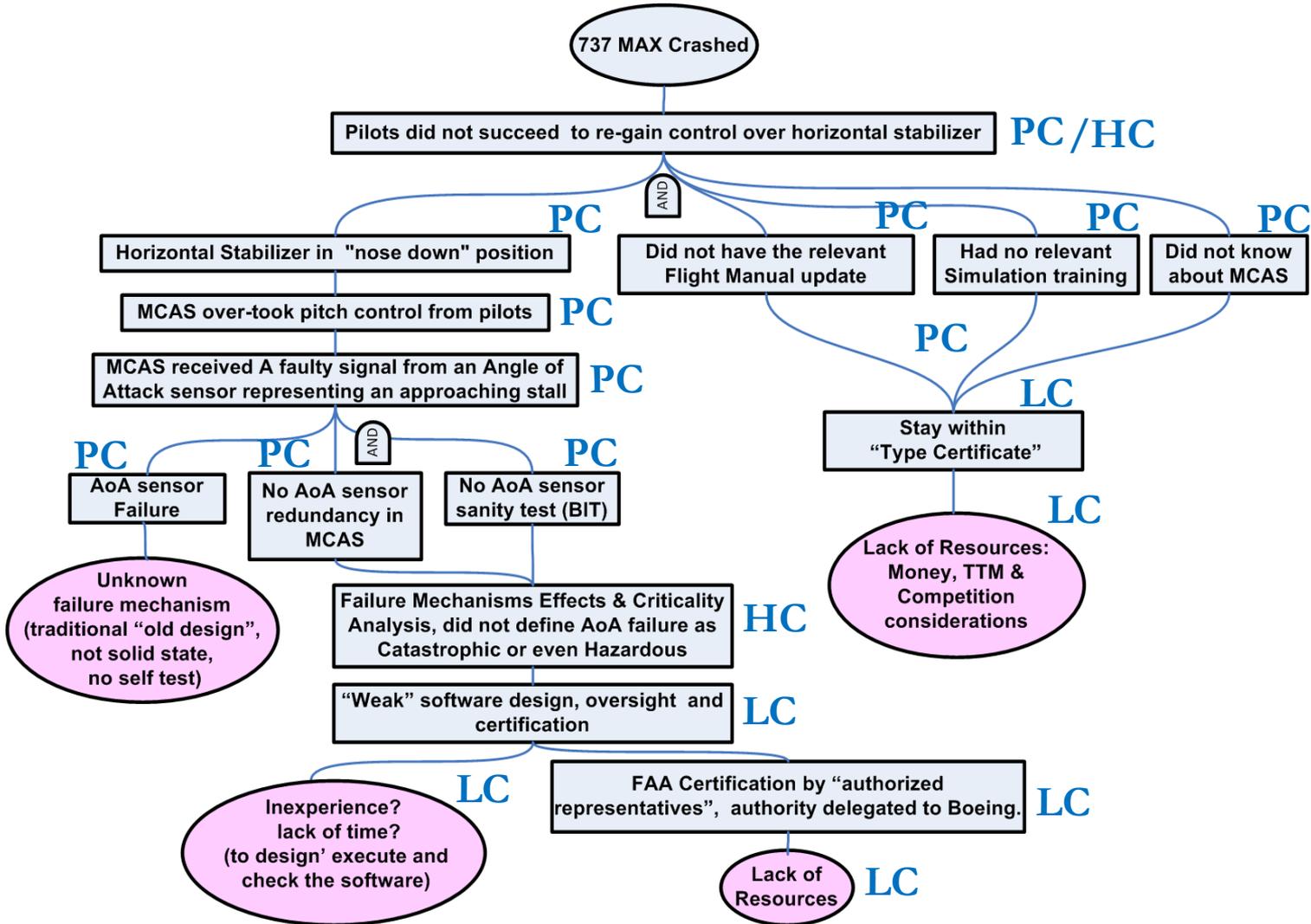
WHY

WHY

WHY

WHY

WHY



# Stage in Flowchart

## Insight wording

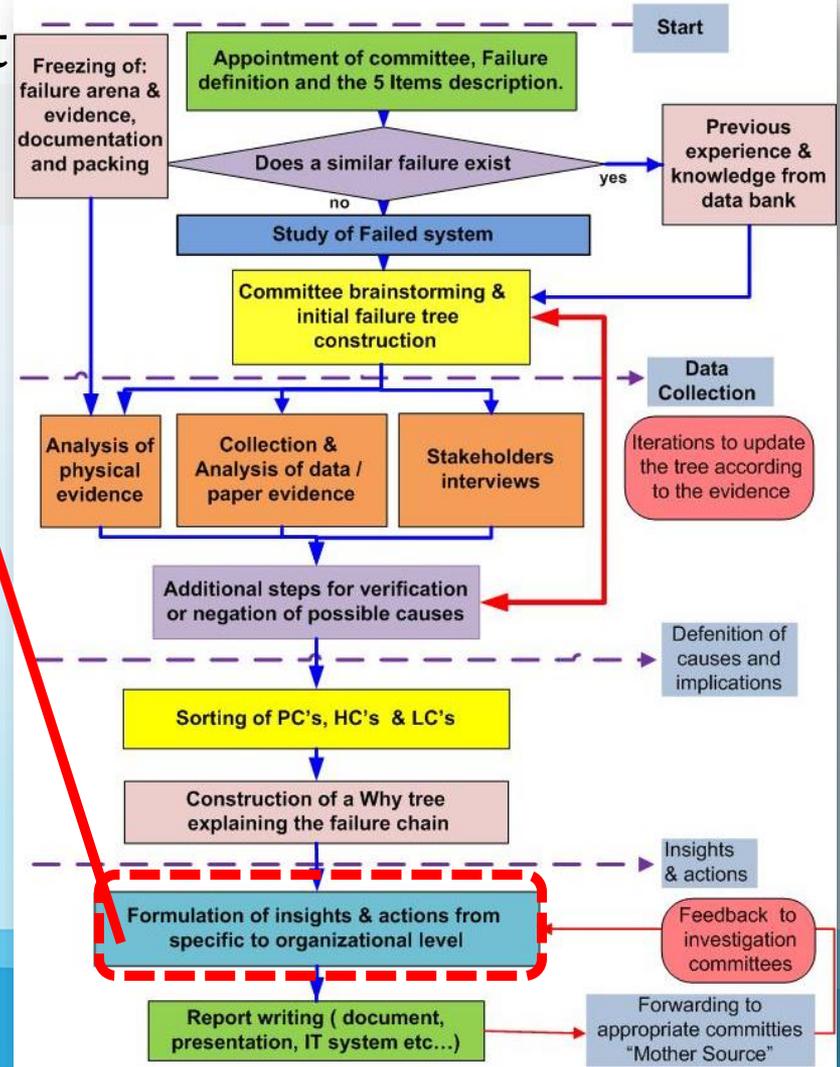
- Association
- Recommendation
- Justification

## Background info.

*Who are the Stake Holders in this Failure?*

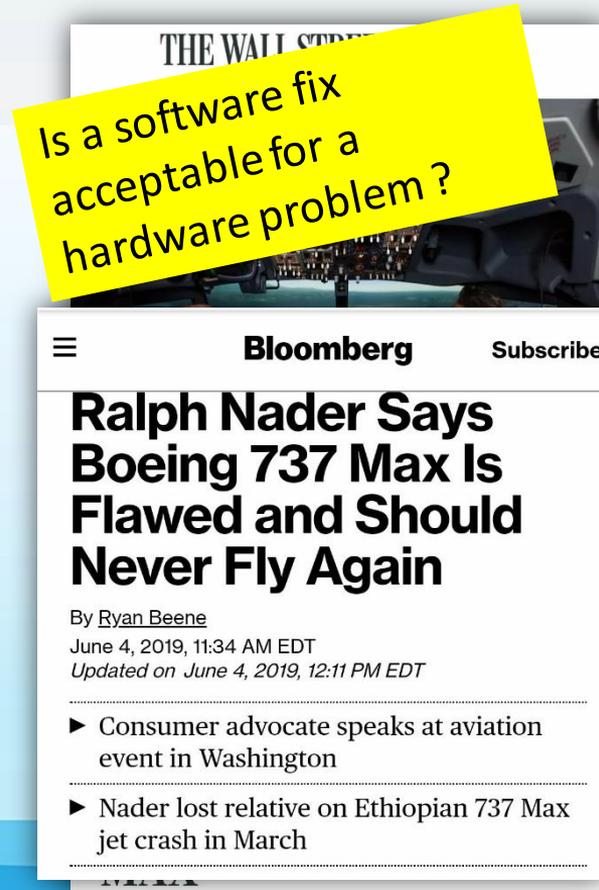
- Boeing Management & Employees **Insight**
- Pilots **Insight**
- FAA + DOT personnel, airline Companies, investors, the competition.....
- Passengers **Insight**

Insight effectiveness is measured by action initiated and it's result.



# The Emerging Local Solution (Not from Boeing)

- The flight control system will **collect data from 2** Angle of Attack **sensors** (instead of 1).
- The Optional “**AoA Disagree**” alarm will be added to the primary flight display.
- When data from the 2 sensors disagree by more than 5.5 degrees, **MCAS won't activate** and the “AoA Disagree” alert the pilots.
- **MCAS will only activate once** for each indication of “too high” angle of attack.
- The movement of the **Horizontal Stabilizer under MCAS will never exceed a pilot's ability to override it** and enable aircraft climb.
- Pilot will undergo **training (including simulation)** and testing.



THE WALL STREET

**Is a software fix acceptable for a hardware problem ?**

**Bloomberg** Subscribe

## Ralph Nader Says Boeing 737 Max Is Flawed and Should Never Fly Again

By [Ryan Beene](#)  
June 4, 2019, 11:34 AM EDT  
Updated on June 4, 2019, 12:11 PM EDT

- ▶ Consumer advocate speaks at aviation event in Washington
- ▶ Nader lost relative on Ethiopian 737 Max jet crash in March

Association

Recommendation

Justification

Senior engineers and managers in companies developing hazardous products (HRO's), have to personally verify performance of FMECA and appropriate corrective actions, in order to reduce probability of tragedy, avoid damaging their firm's reputation and financial stability.

Boeing Mismanagers Forfeit Your Pay and Resign: An Open Letter to Boeing CEO  
Dennis Muilenburg  
April 26, 2019  
Ralph Nader

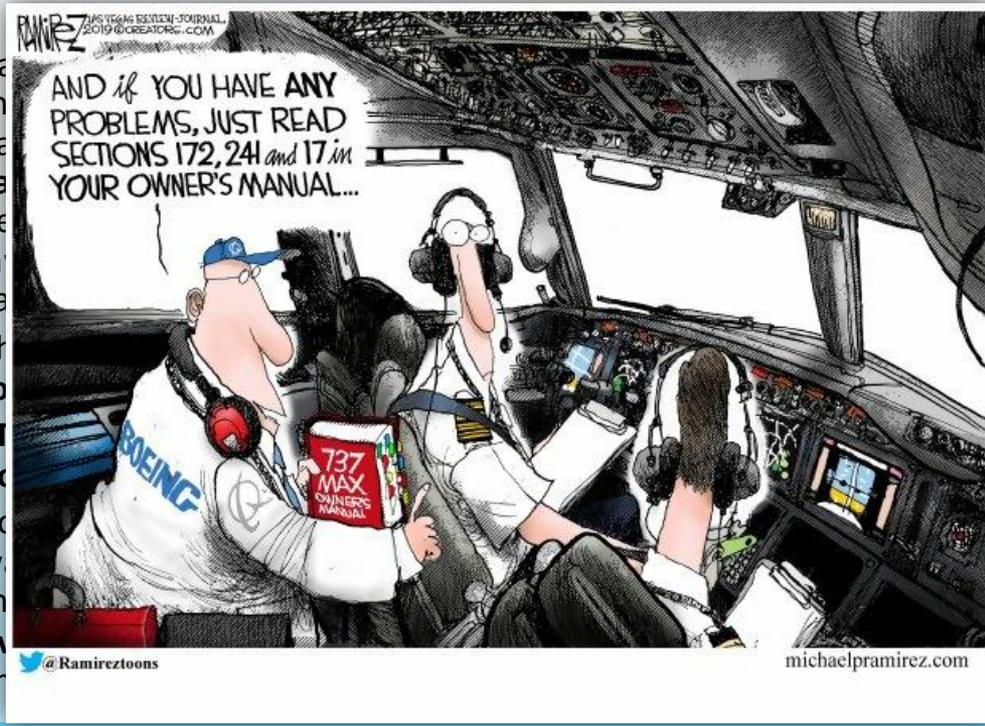
MCAS was directly responsible and that Boeing would fix its responsibility to eliminate this and we know how to do it."

Boeing can run but it's run  
By Leonard J. Marcus and  
Updated 1404 GMT (2204 HK1) March 27, 2019

Boeing CEO says he'd put family on 737 Max 'without hesitation'  
By Bradford Betz | Fox News  
May, 30 2019



When in doubt about your knowledge or flying proficiency, insist on receiving proper information and training, before agreeing to fly a new type of plane.

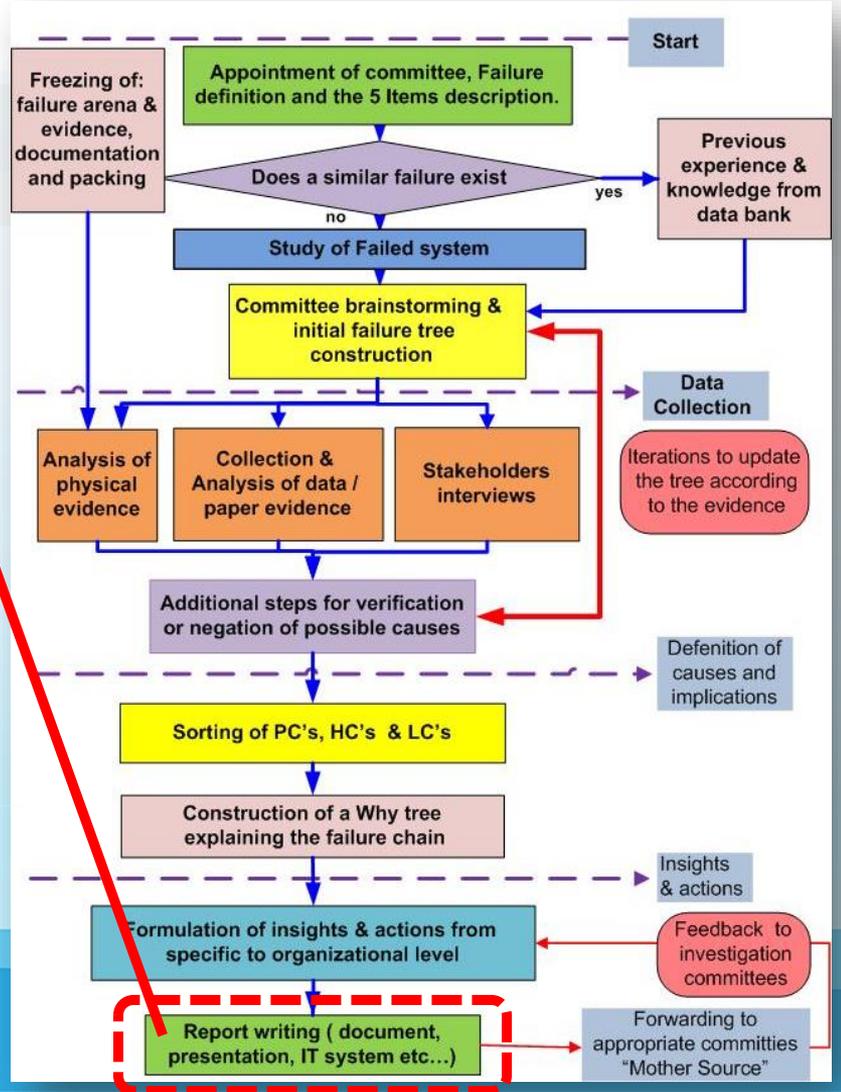


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**Report writing ( document, presentation, IT system etc...)**

"This report, by its very length, defends itself against the risk of being read."  
Sir Winston Churchill

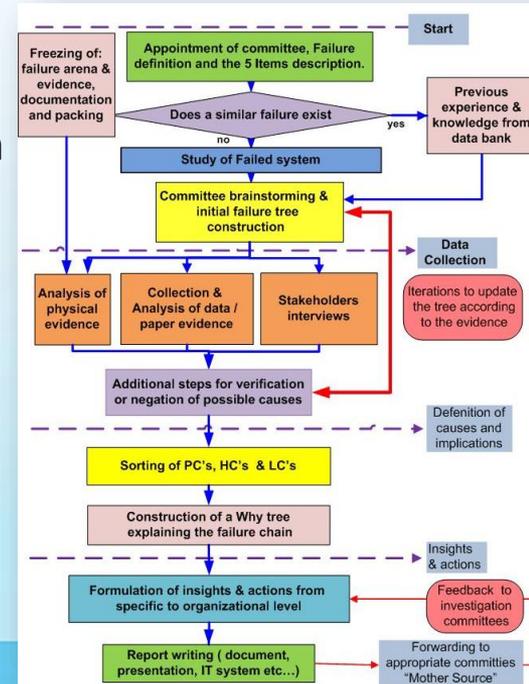
Churchill's quote is my excuse for not talking about the report.



# Key Takeaways for Failure Rate Reduction

We have operated RAFAEL's method, and in a short time reached a structured explanation of a complicated and unfamiliar case.

- Failure investigation should be done **methodologically**.
- It should include: a **failure tree**, identification of **physical, human** and **latent causes** and a **structured explanation** of the failure chains or web.
- The real value of an investigation is to refine **lateral insights**, define **corrective actions** and **assimilate** them.



# Passengers

Paris Air Show is this week! How many orders Boeing will get this year?

CBS, morning news, May 31, 2019

Even if Boeing 737 Max jets are cleared to fly, Americans may not get on board

## UNLIKELY TO FLY ON A 737 MAX IN THE FIRST SIX MONTHS OF ITS RETURN

Category	Percentage
BUSINESS PASSENGERS	47%
LEISURE PASSENGERS	55%

**NOT CLEAR FOR TAKEOFF**  
 STUDY: 1 IN 5 AMERICANS WOULD FLY ON BOEING 737 MAX

CTM | CBS

**YAHOO! NEWS**

### Nobody wants to fly on the disastrous 737 Max, even if Boeing fixes it

By Mike Wehner  
 BGR News June 5, 2019, 3:21 PM UTC

**Bloomberg** Subscribe

Technology

### Boeing 737 Max Seen as 'Airplane Non Grata' by Wary Travelers

By Mary Schlangensten  
 4:20:58, 2019 ביוני GMT+3

- ▶ Atmosphere, UBS surveys reflect anxiety as grounding drags on
- ▶ At least 20% say they will avoid jetliner in first six months

Confidence in the 737 Max or in all Boeing Planes ?



# Passengers – Remove Your Fear

Copyrighted Material

**REMOVE YOUR FEARS AND CONCERNS BEFORE YOUR NEXT FLIGHT**

**REMOVE BEFORE FLIGHT**

When in need of a commute, use airline travel, in order to obtain maximum life expectancy.



WRITTEN BY AVIATION PASSENGER  
 WRITTEN BY AIRLINE PILOT LAURA EINSETLER

- 40,000
- 957
- 200
- $40,000 / 200 = 200$
- $365 / 200 = \sim 2$

40,000 US road accident fatalities:  
 40,000 / year.

- Global yearly average aircraft accident fatalities (calculated from the last 10 years of data): 957 / year.
- If an average crash kills 200 people than the **death toll on the roads is equivalent to 200 aircraft crashes a year**, in the USA, roughly a crash every 2 days!!!

**Personal Conclusion:** on my way home from here, the riskier parts of my journey are: driving to Denver's airport and driving home from TLV.

Death Toll	Year
1040	2018
399	2017
629	2016
898	2015
1328	2014
459	2013
800	2012
828	2011
1130	2010
1108	2009
952	2008

Deaths per year according to ACRO and Bureau of Aircraft Accident Archives data, as of

May we all have safe journeys by all means of transportation.



May we all have only solvable failure investigations with beneficial insights.