Root Cause Analysis Report

Hindenburg Disaster

sologic root cause analysis

Problem Statement

Report Number	RCA-22-01-2018-271	**RCA Owner**	Chris Eckert
Report Date	1/29/2018	**RCA Facilitator**	Brian Hughes

Focal Point: 36 Fatalities, dozens of injuries, loss of Hindenburg airship

When

Start Date: 1/27/2018	End Date: 1/27/2018
Start Time: 7:25 PM	End Time: 7:30 PM
Unique Timing	While trying to dock after a cross-Atlantic voyage. After delaying landing due to thunderstorms.

Where

	Hangar #1
Other	Naval Air Station Lakehurst, Manchester Township, New Jersey, U.S.
Other	Hindenburg (D-LZ129),

Actual Impact

Safety	36 fatalities	
Safety	Dozens of injuries (actual number unknown)	
	Hastened the demise of travel by airship	
	International incident	
Cost	Complete loss of the airship (2018 dollars)	$68,000,000.00
		Actual Impact Total: $68,000,000.00
Frequency	1 times Overall	
Frequency Note	This was the first and only time a large hydrogen-filled airship crashed/burned.	

Potential Impact

Safety	Potential additional fatalities and injuries

Report Summaries

Executive Summary

The Hindenburg disaster is one of the best-known disasters of the 20th century. Film crews captured virtually the entire event (except the ignition!). And the dramatic images, along with the classic narrative ("Oh the humanity!") are so compelling that generations later, we still cannot look away. Therefore it's a perfect example for a root cause analysis!

The setup for this event is the same as with all Safety events: We start with the fatalities and injuries. In this case, notice that there were three primary means by which people were killed or injured: 1) They were burned, 2) They fell from elevation, and 3) They were struck by debris falling from the burning airship. You will see these listed as "and/or" relationships because in some cases people experienced multiple types of injury.

You should note that "fire" does not appear in the chart until four levels deep. Too often, analysts get impatient and jump to the part of the event they think is the most important. Resist this urge. Take smaller, methodical steps as you put your analysis together and you will find that you develop a more complete, thorough understanding of the event. And you will find that you are less likely to miss something important.

When investigating any fire, start out with a generic template of causes: 1) Oxygen, 2) Fuel, 3) Ignition Source. Yes, it's just the classic Fire Triangle! But it easily transfers to a cause and effect chart. Notice that there were multiple possible ignition sources. In the absence of direct, verifiable evidence, the investigation team must hypothesize alternatives and then, if possible, confirm or refute those hypotheses. Causelink has the option to show a cause as "Disproved." It does this by displaying an "X" through the cause, as well as graying it out slightly. This is how we show our work (versus simply deleting the refuted causes). And it can be very helpful when there is a lot of speculation about what exactly happened and you know you will likely be challenged as to what possibilities you considered.

Cause and Effect Summary

On May 6, 1937, at approximately 7:25PM, the German airship Hindenburg (D-LZ129) caught fire and crashed while attempting to dock at Naval Air Station Lakehurst, in Manchester Township, New Jersey (USA). Of the 97 crew and passengers, 35 lost their lives and many others were severely injured. One person on the ground was killed. The entire event was over within 40 seconds, although diesel fuel from the engines continued to burn for some time afterwards.

Most of the fatalities and injuries were caused by burns. However some were killed/injured when they jumped from the airship while it was still airborne. One grounds person was killed by falling debris. The burns were caused by a massive fire that quickly consumed the entire airship. The Hindenburg used hydrogen to provide lift. Hydrogen is highly flammable, but only in the presence of oxygen. Oxygen and hydrogen were able to mix because of the loss of integrity of the protective outer skin of the airship. This skin was made from cloth that was coated in "dope," which was made from iron oxide and aluminum-impregnated cellulose acetate butyrate - a highly flammable substance. Once the skin caught fire, it burned very rapidly, exposing the internal hydrogen cells. The entire volume of

hydrogen and most of the skin was completely consumed within 40 seconds.

How the skin ignited remains an open question. The most accepted theory is that static electricity, built up from travel through local thunderstorms, built up in different sections of the airship. There could have been a difference in electrical potential between skin panels, or between the skin and the internal metal frame. It is known that static management was an issue with airships of this type. It is unknowable though what actually initiated the spark.

The skin is flammable, but it had to catch fire somehow. It is theorized that the most likely source was venting hydrogen gas ignited by a spark from static discharge. Other theories include a lightning strike, sabotage, and a backfiring engine. Lightning, sabotage, and the backfiring engine were ruled out as being highly unlikely.

Solutions

SO-0007	**Solution**	Use non-combustible skin material		
	Cause(s)	Outer skin of airship		
	Note	The skin material of modern airships is much less conducive to burning.		
	Assigned		**Criteria**	Passed
	Due		**Status**	Validated
	Term	long	**Cost**	
SO-0008	**Solution**	Use Helium instead of Hydrogen		
	Cause(s)	Hydrogen gas (for lift)		
	Note	Although helium is more expensive, it has a similar lifting capacity to hydrogen and it is not flammable.		
	Assigned		**Criteria**	Passed
	Due		**Status**	Validated
	Term	short	**Cost**	
SO-0009	**Solution**	Ensure effective conductivity throughout all components		
	Cause(s)	Possible ignition: Static electricity?		
	Note	Design needs to ensure that large differences in electrical potential are properly managed and grounded.		
	Assigned		**Criteria**	Not Checked
	Due		**Status**	Validated
	Term		**Cost**	

Team

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Evidence

EV-0004	**Evidence**	The Hindenburg Disaster
	Cause(s)	"High Moor" tactic chosen Airship completely consumed by fire Airship design Airship leaned to the starboard, preventing exit through windows Amount of heat released by H2 Diesel fuel (for engines) Difference in potential between skin and frame Duration of fire (~39 seconds) Elevation too high to survive Possible ignition: Engine failure caused sparks, igniting skin? Fall to ground from elevation Fuel sources (all contributed to the fire) Flammable building/furnishing materials Ground work requires being under the airship Ground worker helping to moor the Hindenburg Ground workers grab the lines and attach to mooring mast High Moor landing involves dragging mooring lines along ground Hydrogen gas (for lift) Ignition possibilities Iron oxide and aluminum-impregnated cellulose acetate butyrate Possible ignition: Lightning igniting venting H2? Material chosen as "doping" component Most were burned No clear escape routes Outer skin of airship Normal travel through air Panels were isolated/insulated by nonconductive cords Passengers/crew jumped to escape the burning airship Passengers/crew were trapped in proximity to fire Political differences... Nazi Germany had many enemies Proximity to O2 (from atmosphere) Possible ignition: Sabotage? Some were trapped in the cabin on the starboard side Some were working inside the hull Static built up in panels Static electrical discharge from skin to frame Possible ignition: Static electricity? Struck by falling debris There were several thunderstorms in the area Combustion time for H2

	Location(s)	http://www.airships.net/hindenburg/disaster/
	Attachment(s)	
	Contributor	
	Type	URL
	Quality	★★★★★
EV-0005	**Evidence**	Hindenburg at 80: An Interactive Look Into the Tragic, Fateful Voyage, by Erik Larsen
	Cause(s)	
	Location(s)	https://www.app.com/story/news/history/2017/04/28/hindenburg-80th-anniversary/100564104/
	Attachment(s)	
	Contributor	
	Type	URL
	Quality	★★★★★
EV-0006	**Evidence**	360 Degree photo mockup
	Cause(s)	
	Location(s)	https://fdwellington.github.io/vrview/?image=R0010915.JPG
	Attachment(s)	
	Contributor	
	Type	Photo
	Quality	★★★★★

Hindenburg Disaster

America/New_York

5/6/1937 06:50 PM

Hindenburg makes final approach

Around 7:00 p.m. local time, at an altitude of 650 feet (200 m), the Hindenburg made its final approach to the Lakehurst Naval Air Station. This was to be a high landing, known as a flying moor, because the airship would drop its landing ropes and mooring cable at a high altitude, and then be winched down to the mooring mast. This type of landing maneuver would reduce the number of ground crewmen, but would require more time. Although the high landing was a common procedure for American airships, the Hindenburg had only performed this maneuver a few times in 1936 while landing in Lakehurst. (From Wikipedia timeline)

5/6/1937 07:09 PM

Airship makes sharp, full-speed left turn to the west

At 7:09, the airship made a sharp full-speed left turn to the west around the landing field because the ground crew was not ready. At 7:11, it turned back toward the landing field and valved gas. All engines idled ahead and the airship began to slow. Captain Pruss ordered aft engines full astern at 7:14 while at an altitude of 394 ft (120 m), to try to brake the airship. (From Wikipedia timeline)

5/6/1937 07:17 PM

Pre-fire manuevers

At 7:17, the wind shifted direction from east to southwest, and Captain Pruss ordered a second sharp turn starboard, making an s-shaped flightpath towards the mooring mast. (From Wikipedia timeline)

5/6/1937 07:21 PM

Mooring lines dropped

At 7:21, while the Hindenburg was at an altitude of 295 ft (90 m), the mooring lines were dropped from the bow; the starboard line was dropped first, followed by the port line. The port line was overtightened as it was connected to the post of the ground winch. The starboard line had still not been connected. A light rain began to fall as the ground crew grabbed the mooring lines. (From Wikipedia timeline)

5/6/1937 07:25 PM

Time of Ignition

At 7:25 p.m. Witnesses saw the fabric ahead of the upper fin flutter as if gas was leaking. Others reported seeing a dim blue flame moments before the fire on top and in the back of the ship near the point where the flames first appeared. Other eyewitness testimonies suggest that the first flame appeared on the port side just ahead of the port fin, and was followed by flames which burned on top. Commander Rosendahl testified to the flames in front of the upper fin being "mushroom-shaped". One witness on the starboard side reported a fire beginning lower and behind the rudder on that side. On board, people heard a muffled detonation and those in the front of the ship felt a shock as the port trail rope overtightened; the officers in the control car initially thought the shock was caused by a broken rope. (From Wikipedia timeline)

6:51 PM 6:52 PM 6:53 PM 6:54 PM 6:55 PM 6:56 PM 6:57 PM 6:58 PM 6:59 PM 7:00 PM 7:01 PM 7:02 PM 7:03 PM 7:04 PM 7:05 PM 7:06 PM 7:07 PM 7:08 PM 7:09 PM 7:10 PM 7:11 PM 7:12 PM 7:13 PM 7:14 PM 7:15 PM 7:16 PM 7:17 PM 7:18 PM 7:19 PM 7:20 PM 7:21 PM 7:22 PM 7:23 PM 7:24 PM

Chart Key
- Transitory
- Non-Transitory
- Transitory Omission
- Non-Transitory Omission
- Undefined
- Chart Quality Alert
- Focal Point
- Evidence
- Notes
- Solutions
- Tasks

36 Fatalities, dozens of injuries, loss of Hindenburg airship

AND OR

Most were burned

Amount of heat released by H2

a

Airship completely consumed by fire

Fuel sources (all contributed to the fire)

Proximity to O2 (from atmosphere)

END

Terminated because:
Other causal paths more productive

Hydrogen gas (for lift)

END

Terminated because:
Other causal paths more productive

Solutions

Use Helium instead of Hydrogen

Criteria Pass Status Validated

Although helium is more expensive, it has a similar lifting capacity to hydrogen and it is not flammable.

Outer skin of airship

Iron oxide and aluminum-impregnated cellulose acetate butyrate

Material chosen as "doping" component

?

Solutions

Use non-combustible skin material

Criteria Pass Status Validated

The skin material of modern airships is much less conducive to burning.

Diesel fuel (for engines)

END

Terminated because:
Other causal paths more productive

Flammable building/furnishing materials

END

Terminated because:
Other causal paths more productive

Ignition possibilities

OR

Possible ignition: Static electricity?

Static electrical discharge from skin to frame

Difference in potential between skin and frame

Static built up in panels

AND OR

Normal travel through air

END

Terminated because:
Other causal paths more productive

There were several thunderstorms in the area

END

Terminated because:
Other causal paths more productive

Panels were isolated/insulated by nonconductive cords

Airship design

END

Terminated because:
Other causal paths more productive

Solutions

Ensure effective conductivity throughout all components

Criteria ⚠ Status Validated

Design needs to ensure that large differences in electrical potential are properly managed and grounded.

Possible ignition: Sabotage?

Political differences... Nazi Germany had many enemies

?

Possible ignition: Lightning igniting venting H2?

END

Terminated because:
Disproven

Possible ignition: Engine failure caused sparks, igniting skin?

END

Terminated because:
Disproven

Duration of fire (~39 seconds)

Combustion time for H2

END

Terminated because:
Other causal paths more productive

Connects to:

a Airship completely consumed by fire

Passengers/crew were trapped in proximity to fire

Some were working inside the hull

END

Terminated because:
Other causal paths more productive

Some were trapped in the cabin on the starboard side

Airship leaned to the starboard, preventing exit through windows

END

Terminated because:
Other causal paths more productive

No clear escape routes

END

Terminated because:
Other causal paths more productive

Fall to ground from elevation

Passengers/crew jumped to escape the burning airship

END

Terminated because:
Other causal paths more productive

Elevation too high to survive

END

Terminated because:
Other causal paths more productive

Struck by falling debris

Ground worker helping to moor the Hindenburg

END

Terminated because:
Other causal paths more productive

Ground work requires being under the airship

"High Moor" tactic chosen

?

High Moor landing involves dragging mooring lines along ground

END

Terminated because:
Other causal paths more productive

Ground workers grab the lines and attach to mooring mast

END

Terminated because:
Other causal paths more productive