Loss of Space Shuttle Challenger

Root Cause Analysis Case Study

Cause Mapping® Method

Problem Solving • Root Cause Analysis

Cause Mapping® Steps

1. Problem — Specifics, Impact to Goals
2. Analysis — Timeline, Cause-and-Effect: 3-, 5-, 6-, 7-, and 20-Why *Cause Maps*
3. Solutions — Action items to prevent recurrence

NASA Image

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Michael J. Smith | Dick Scobee | Ronald McNair

NASA Image

1. Problem

What	Problem(s)	Challenger exploded, Shuttle disaster, Loss of life, Breakup on 1st stage ascent
When	Date	January 28, 1986
	Time	11:39 AM EST
	Different, unusual, unique, (specific to this incident)	Coldest launch at ~34° F, freezing temps that morning, 10th flight of the Challenger, multiple delays in launch date, teacher onboard shuttle, high wind shear aloft
Where	Facility, site, area	NASA, Kennedy Space Center, Cape Canaveral, FL, Pad LC-39B
	Equipment	Challenger Space Shuttle, Flight STS-51-L
	Task being performed	First stage ascent, throttle up

Impact to each GOAL

Safety	Loss of 7 crew
Vehicle	Loss of Challenger
Mission, Schedule	2.5 year halt to shuttle program
Environmental	Debris, fuel, chemicals in Atlantic
Customer	Loss of Halley's Comet camera (CHAMP), Loss of SPARTAN-203 satellite for astronomy research.
Labor, Time	Debris recovery, investigation, corrective actions (hours)

This incident $3.5 billion

Frequency	First time, loss of shuttle and crew

Timeline

Year	Date	Time (Eastern)	Description
1983	April 4		First Challenger flight, STS-6, 6th overall mission
1985	December 18		Planned Columbia launch, delayed, first of 7 delays
1986	January 12		Columbia launch, STS-61-C, 7th flight, 24th overall
			Planned Columbia landing delayed 3 times in 2-days
	January 18		Columbia landed at Edwards, AFB in California
1986	January 22-27		Planned Challenger launch, 6 delays in 6 days
	January 27	afternoon, evening	NASA meetings with Morton Thiokol regarding temps
	January 28	11:38 AM, T - 0	Challenger launch, STS-51-L, 10th flight, 25th overall
			36 F at launch (15 F colder than any previous launch)
		+ 0.678 secs	First puffs of smoke from right booster aft field joint
		+ 2.733 secs	Last puffs of smoke
		+ 57.788 secs	First evidence of burn through plume from booster
		+ 73.213 secs	Explosion of External Tank, Challenger broke up
		+ 98 secs	Crew module peak altitude of 65,000 feet
		+ 2-min 45 secs	Crew module contacted water
	June 6		Challenger Investigation Report released
1988	September 29		Return to Flight, Discovery STS-26, LC-39B

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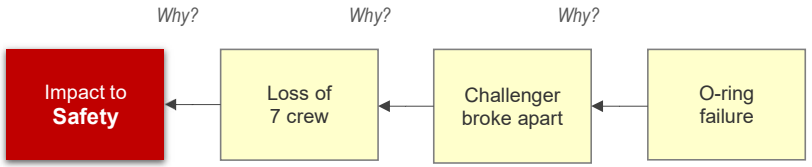
Loss of Space Shuttle Challenger

Step 2. Cause-and-Effect Analysis - Simple

Don't overlook the benefit of starting with a simple 3- to 5-Why even on complex problems.

Cause Mapping® Method
Problem Solving • Root Cause Analysis

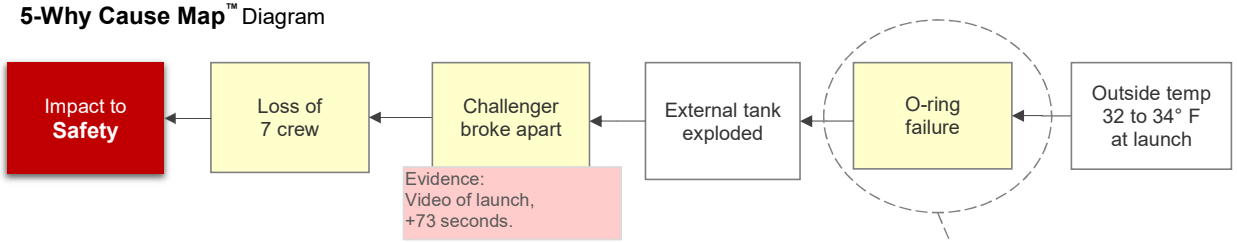
3-Why Cause Map™ Diagram



O-Ring Failure
Equipment

Here is a simple explanation of why the Challenger disaster happened. This 3-Why analysis is accurate, but it's not complete. As more information becomes available, it can expand into a 6-Why to reveal more detail about the incident.

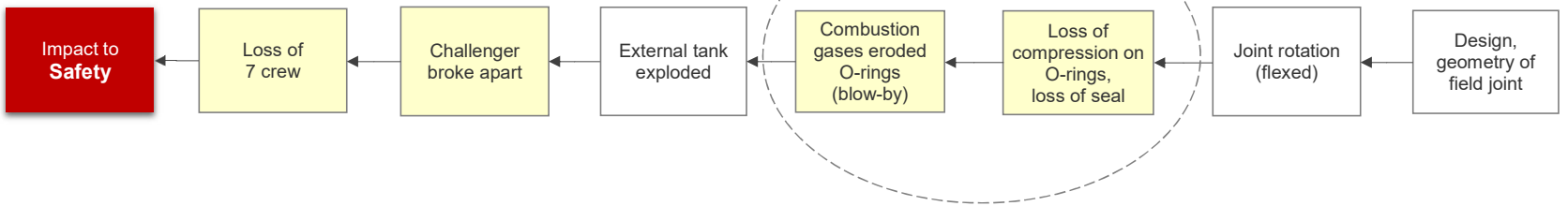
5-Why Cause Map™ Diagram



Temperature
Environment

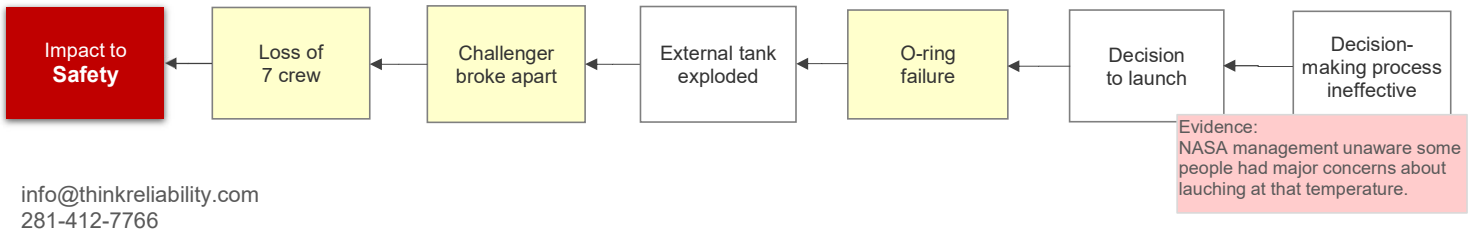
"O-ring failure" in the 5-Why is accurate, but too generic. Specifically, compression on the O-rings was reduced allowing hot, pressurized combustion gases to blow-by and erode both the primary and secondary O-rings. The wording of the causes in the 7-Why is more specific to provide a clearer explanation of what actually happened.

7-Why Cause Map™ Diagram



Booster Joint
Design

6-Why Cause Map™ Diagram



People
Management Decision

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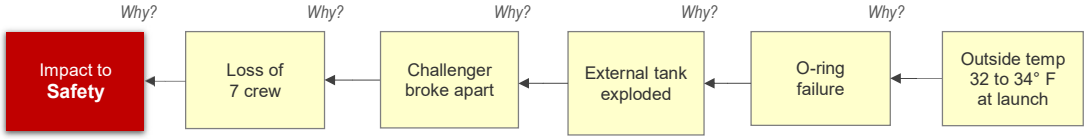
Step 2. Cause-and-Effect Analysis - More Detailed

Cause Mapping® Method

Problem Solving • Root Cause Analysis

5-Why Cause Map™ Diagram

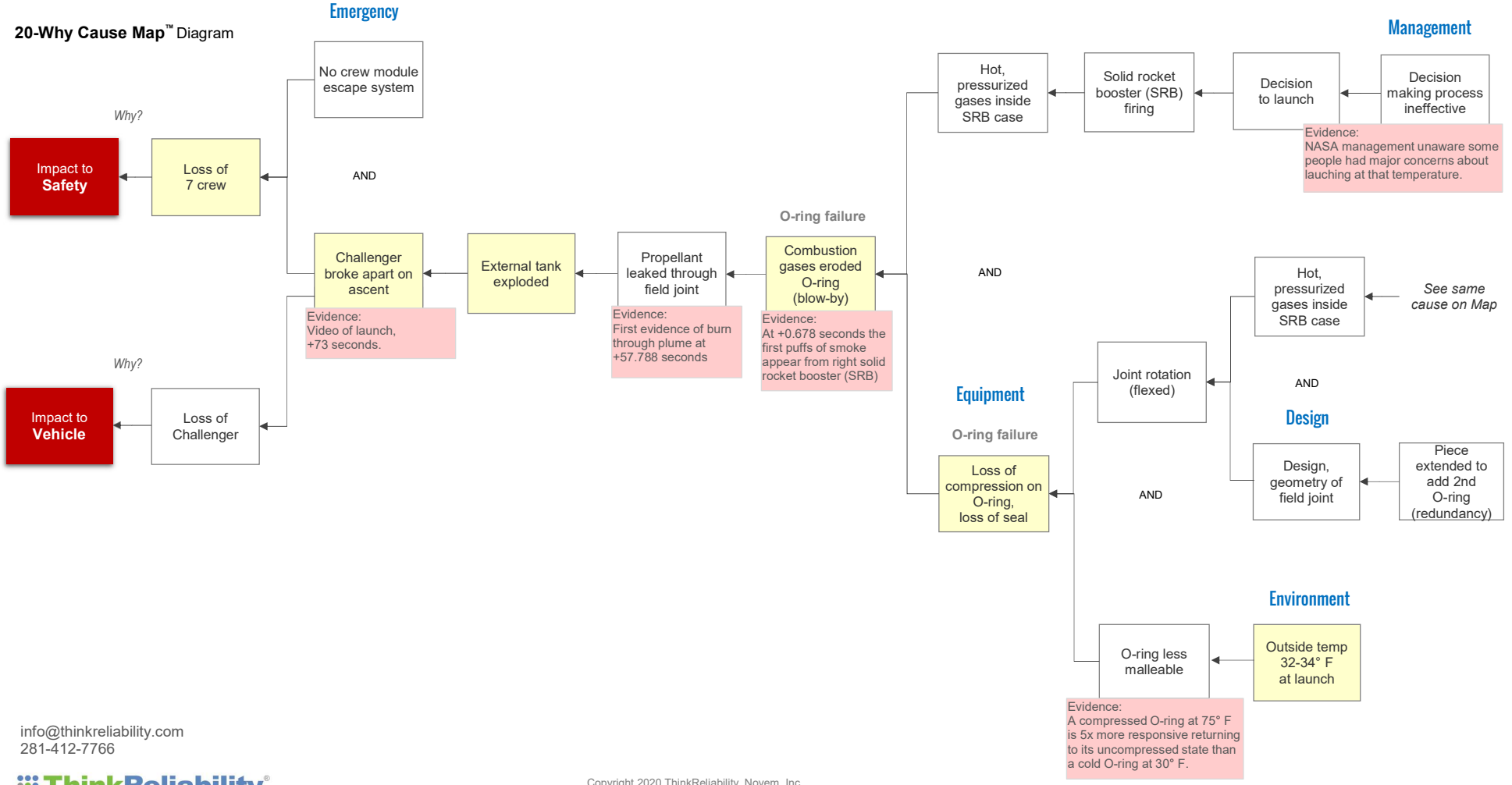


Improve the Way People Communicate

The 20-Why *Cause Map* diagram below shows how four different people may each argue their point assuming they are "right." Each of the linear cause-and-effect analyses may be accurate, but none of them are complete. The input from each person needs to be validated with evidence then combined into a more complete explanation of the issue.

The *Cause Mapping* method provides a simple way for people to analyze complex problems. Something as catastrophic as the Challenger disaster can begin with a simple 3- to 5-Why that expands into as much detail as needed. Each causal path on the Map provides opportunities to add layers of protection to reduce the risk of future incidents.

20-Why Cause Map™ Diagram



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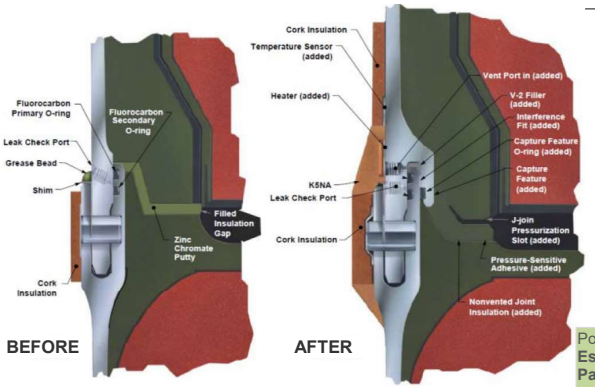
Step 3. Solutions

No.	Solution (Recommendation)	Cause	Work Process
1	Establish Safety Advisory Panel to develop launch commit criteria.	Decision made to launch	Launch Criteria
2	Redesign joint with captured fit.	Joint rotation, (flexed)	SRB Design, Field Joint
3	Redesign joint with 3rd O-ring.	Loss of compression on O-ring, loss of seal	SRB Design, Field Joint
4	Test a full range of operating conditions and temperatures.	O-ring less malleable	SRB Design, Field Joint
5	Add a crew escape system.	No crew module escape system	Emergency Egress

Solid Rocket Booster (SRB) Field Joint Design



NASA Image

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20-Why Cause Map™ Diagram

Possible Solution: **Add a crew escape system.**

No crew module escape system

Evidence: Launch escape system was part of Apollo program, not the space shuttle design.

NASA Image

Why?

Impact to **Safety**

Loss of 7 crew

AND

Challenger broke apart on ascent

External tank exploded

Propellant leaked through field joint

Combustion gases eroded O-ring (blow-by)

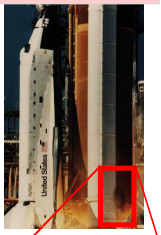
Evidence: Video of launch, +73 seconds.

NASA Image

Evidence: First evidence of burn through plume at +57.788 seconds

NASA Image

Evidence: At +0.678 seconds the first puffs of smoke appear from right solid rocket booster (SRB)



NASA Image

Why?

Impact to **Vehicle**

Loss of Challenger

Hot, pressurized gases inside SRB case

Solid rocket booster (SRB) firing

Decision to launch

Possible Solution: **Establish Safety Advisory Panel to develop launch commit criteria.**

Decision making process ineffective

Evidence: NASA management unaware some people had major concerns about lauching at that temperature.

AND

Possible Solution: **Redesign joint with captured fit.**

Joint rotation (flexed)

Hot, pressurized gases inside SRB case

See same cause on Map

AND

Possible Solution: **Redesign joint with 3rd O-ring.**

Loss of compression on O-ring, loss of seal

AND

Design, geometry of field joint

Piece extended to add 2nd O-ring (redundancy)

Possible Solution: **Test a full range of operating conditions and temperatures.**

O-ring less malleable

Outside temp 32-34° F at launch

Evidence: A compressed O-ring at 75° F is 5x more responsive returning to its uncompressed state than a cold O-ring at 30° F.

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