Instant-Expertise in Failure Causation:

Developing and Presenting a Network of Causes and Recommendations Extracted from Past Failures

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This material is based upon work supported by the National Science Foundation under Grant No. 1350589.

Research Motivation: Why do projects fail?




- Project failures occur despite systems engineering best practices
  - Project delays, cost overruns, quality concerns, cancellations

Project failures are difficult to study → Advice on project failures is **more easily actionable** → Organizations can use learning from past failures **to improve project performance**

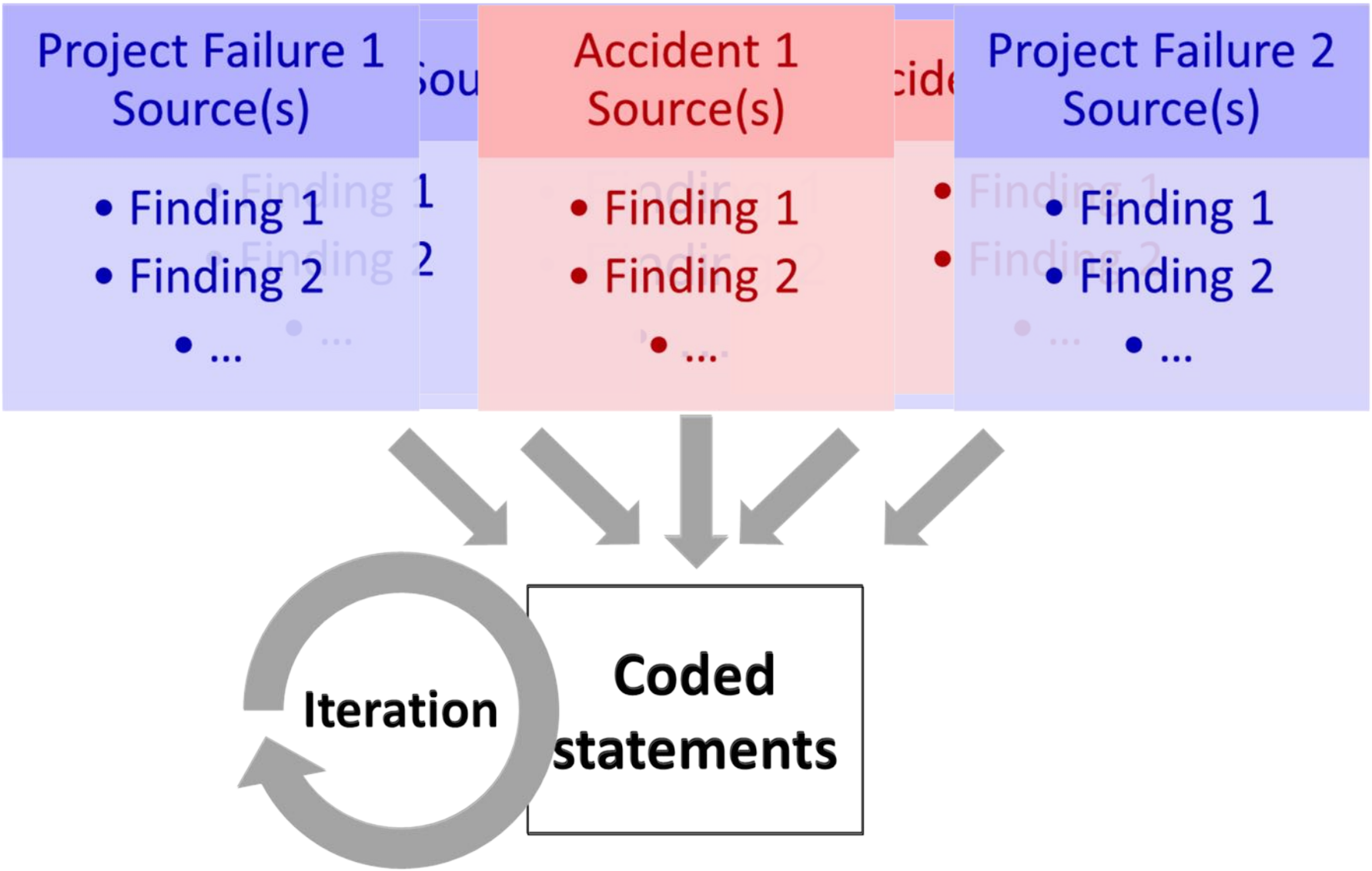
Can we develop a tool to provide actionable advice on project failures based on accident recommendations?

Accidents are easier to study → Advice given by accident investigators is more easily actionable → Learning on past accidents is used to improve safety and reduce accident occurrences

Case Study Description

	Project Failures				Accidents		
Industry Category	Consumer product	Infrastructure project	Government acquisition	Space Agency	Aerospace	Energy	Infrastructure
Case Example	Xbox 360 quality issues	Boston Big Dig schedule and budget issues	F-35 schedule and budget issues	Hubble quality issue	Alaska 261 crash	Deepwater Horizon oil spill	North Battleford water contamination
Typical Source	Periodical articles	Periodical articles	GAO reports, Periodical articles	NASA reports	NTSB reports	CSB reports	Independent accident reports
# Cases (Break down)	11	6	9	7	9	16	5
# Cases Studied	33				30		

Failure Cause Coding Process



Imperial Sugar Refinery Explosion

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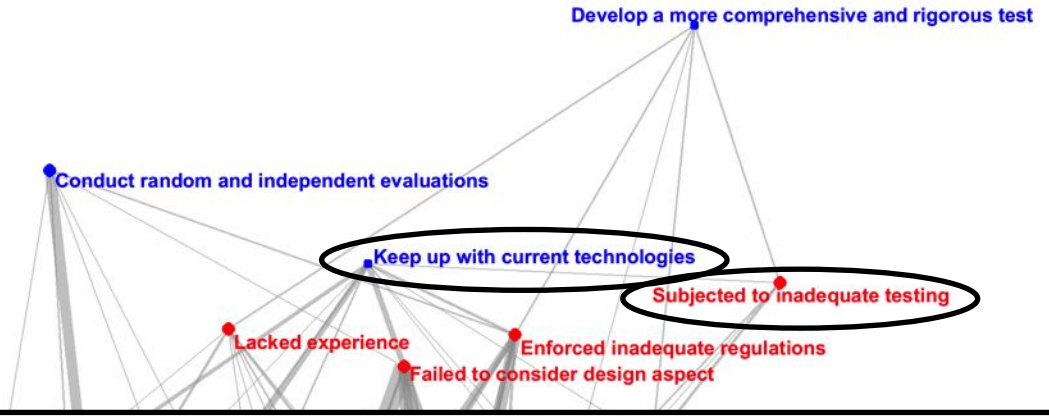
Step 2:
Code Recommendation(s)

Photo Credit U.S. Chemical Safety Board

The Result: A Cause-Recommendation Network



An explosion in a fuel tank after takeoff brought down TWA flight 800. The NTSB concluded that a combination of **a not filling a fuel tank** and running the air conditioning for the aircraft while it waited during a delay **caused an explosive atmosphere to form**. Once in flight, **a short in the electrical system** that measured the amount of fuel in the tank ignited the atmosphere. Investigators found that **the FAA used a flawed test to determine the flammability of aircraft fuel**.

An organization could use these detailed statements for guidance on how to use these cause-recommendation links

Interactive Network Development

- Initially developed the network in Tableau
  - Encountered problems with usability, long loading times, feature incompatibility

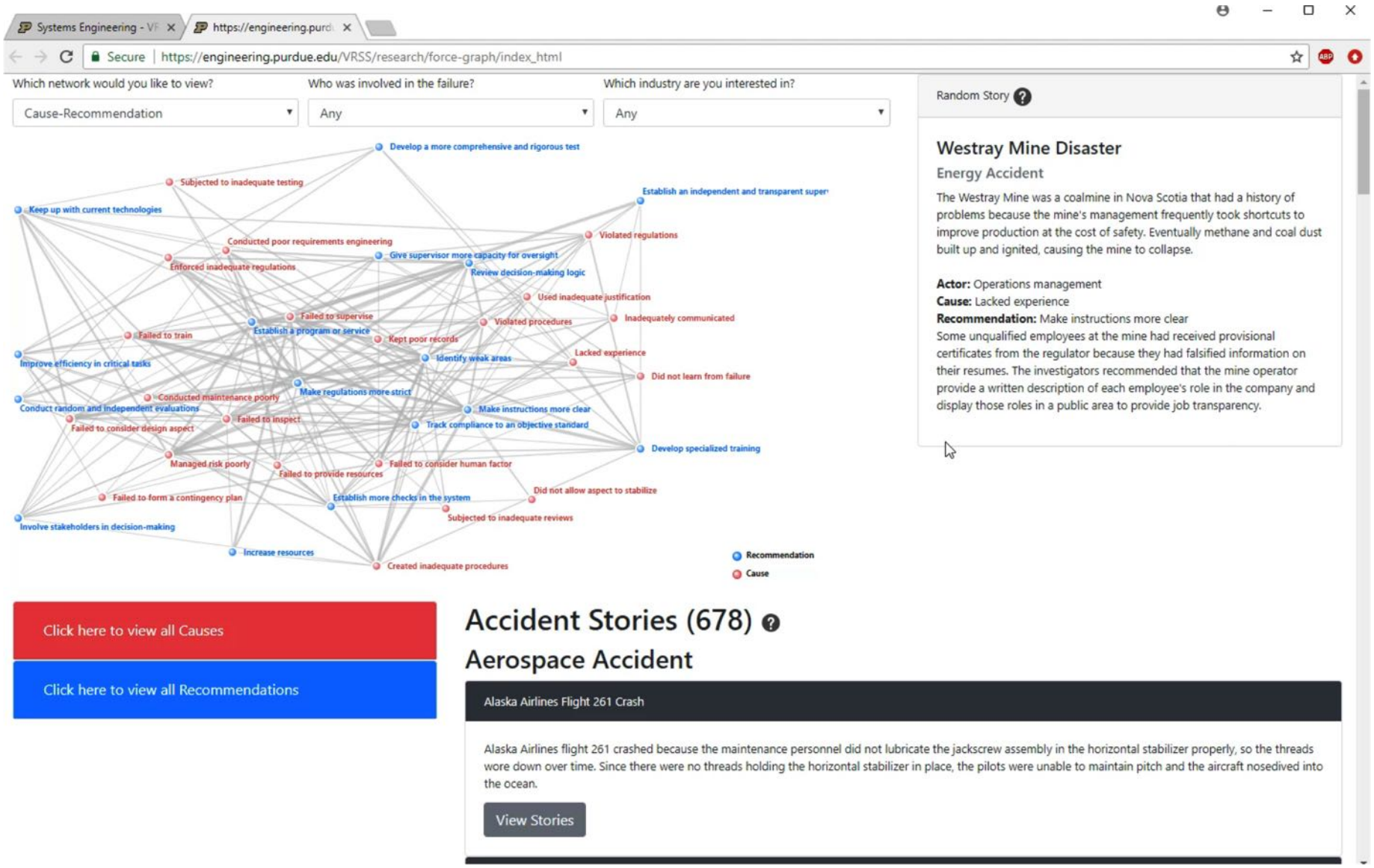
- Commissioned the full-scale network in JavaScript and HTML

- Performed usability testing and received feedback from a usability expert

  Feedback included:

  - Confusing colors
  - Too much information presented at once
  - Information was repetitive

Interactive Web Tool



Is this network useful?

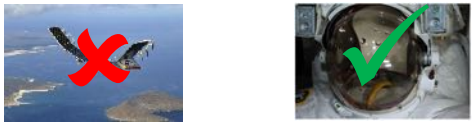
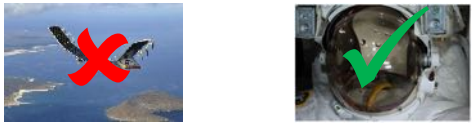
Conducted “usefulness testing” interviews on the network using findings from two NASA failures

Question 1:
What remediation measure(s) would you suggest for NASA’s finding? How would you propose solving this problem?

Question 2:
On a scale of 1 to 10, how useful would your remediation be at alleviating NASA’s finding?

- Each interviewee read findings and answered questions on one failure, then the other (order determined randomly)
- Half of the interviewees used the tool on the second failure

Description of Responses

	Demographic Data	Survey Design	# Collected
			
			
			
			
			
			
			
			

How can we compare recommendations?

We rated each recommendation on four qualities.

	Description

Upper Big Branch Mine Collapse

Baia Mare Gold Mine Cyanide Spill

"A risk assessment study should be carried out of the entire system of remining the old tailings." [United Nations Environment Programme and the Office for the Co-ordination of Humanitarian Affairs 2000, p. 47]

Photo credit Délmagyarország/Karnok Csaba 2000

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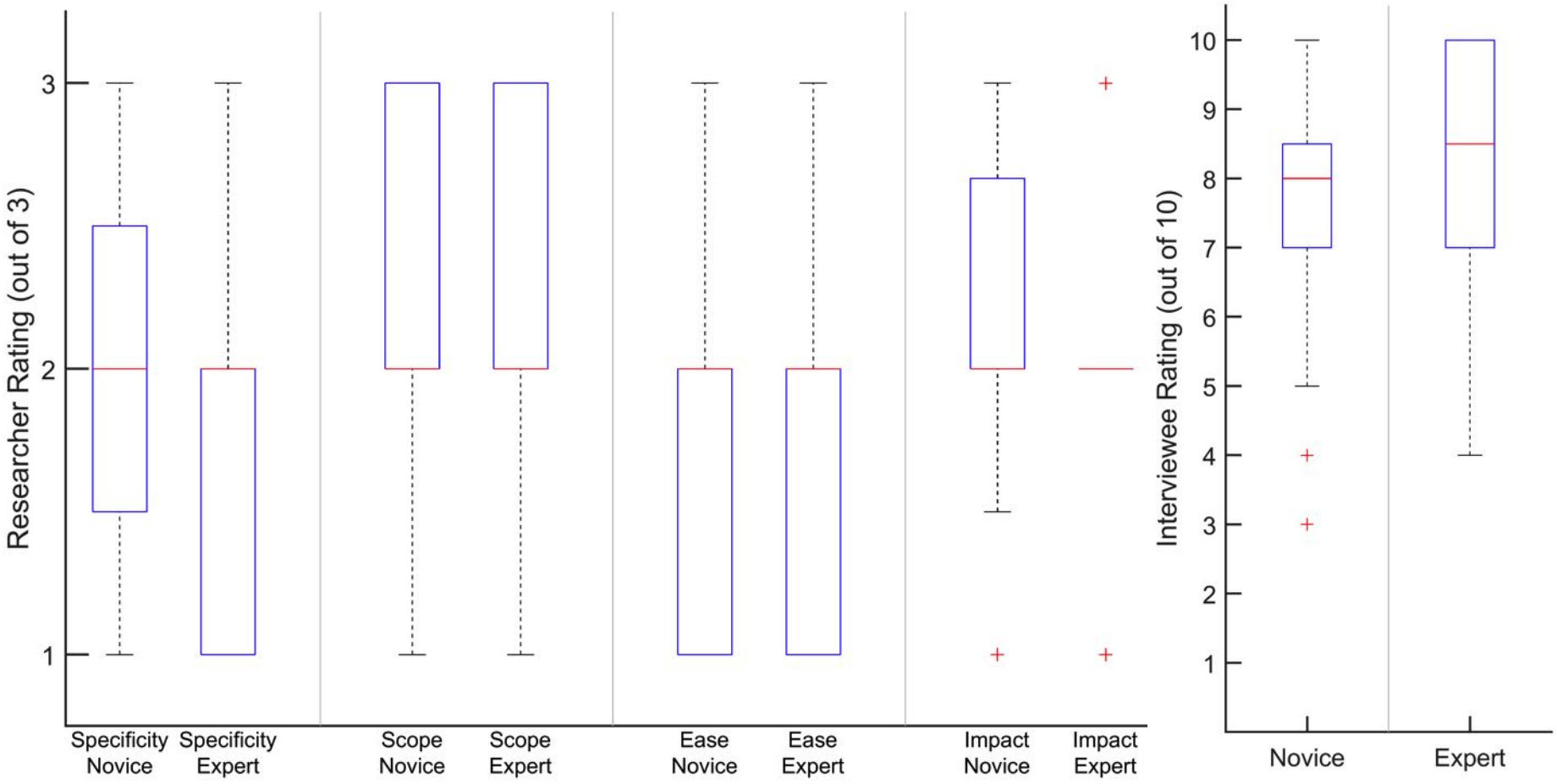
Response Example

Finding from the NASA Report:

The spacesuit had filled with water on the previous EVA, but there was not a lot of time before the next EVA. So, the ground team decided to perform the next EVA without finding out what had happened. They wanted to avoid initiating a lengthy formal risk assessment process, which in may have found the real source of the water and avoided the dangerous scenario.

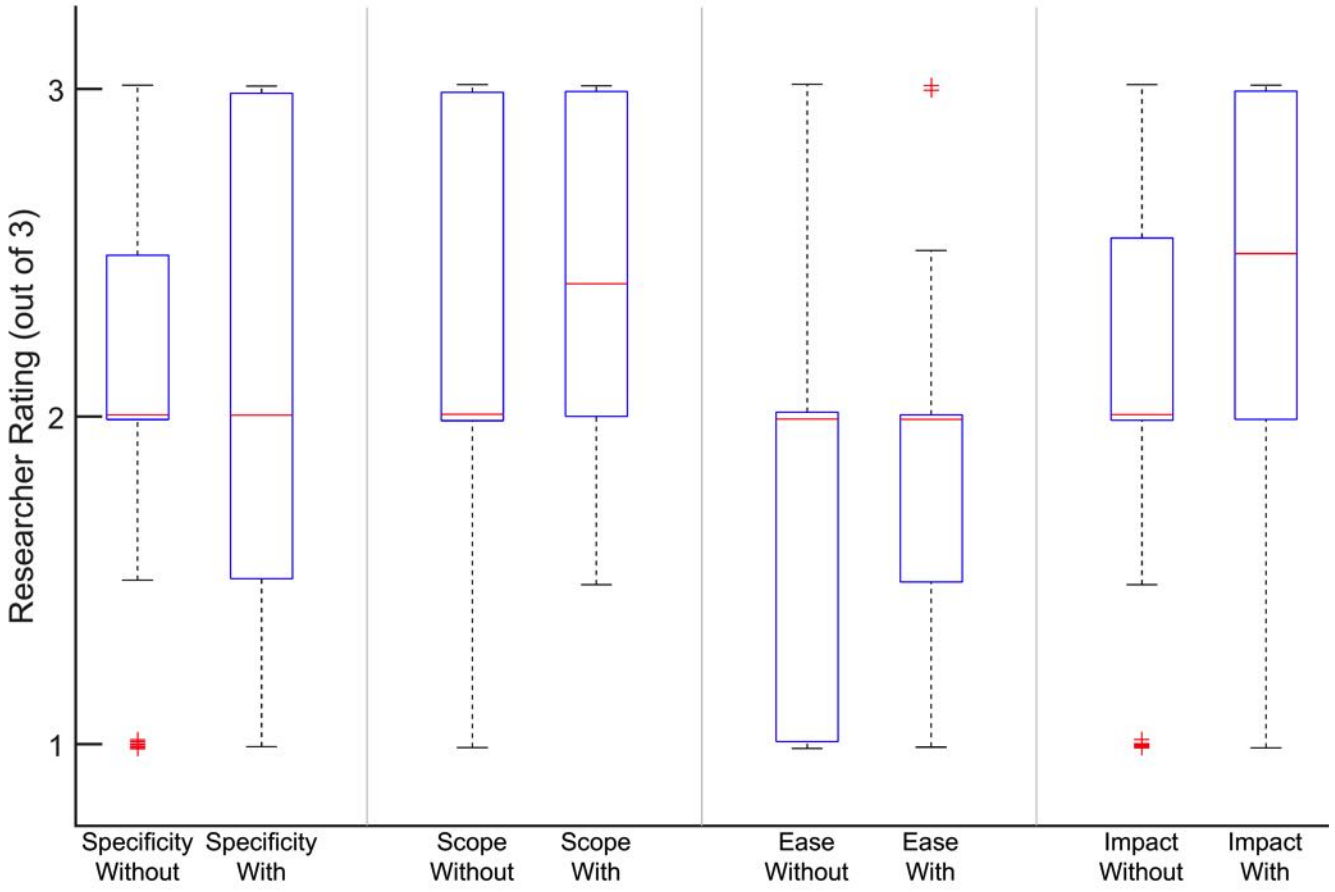
Responses (from novices)	Self	Specificity	Scope	Ease	Impact
They should consider all the possibilities					

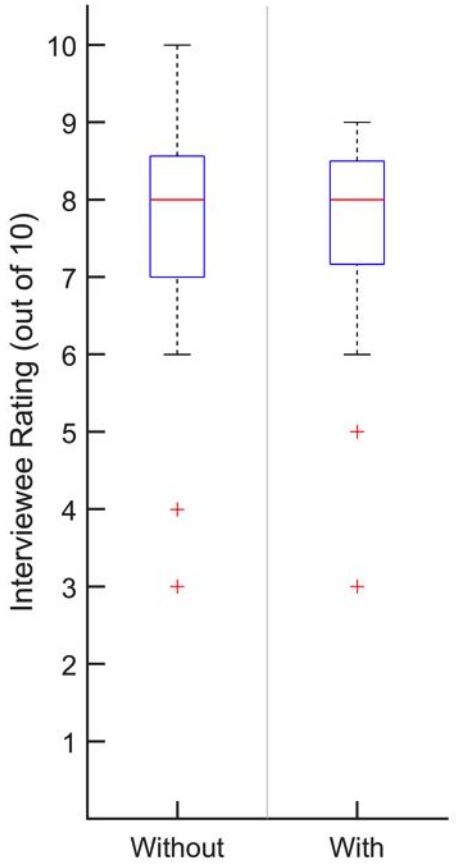
Boxplot of Expert and Novice Data



Novice recommendations had somewhat higher scores but they had less confidence than experts

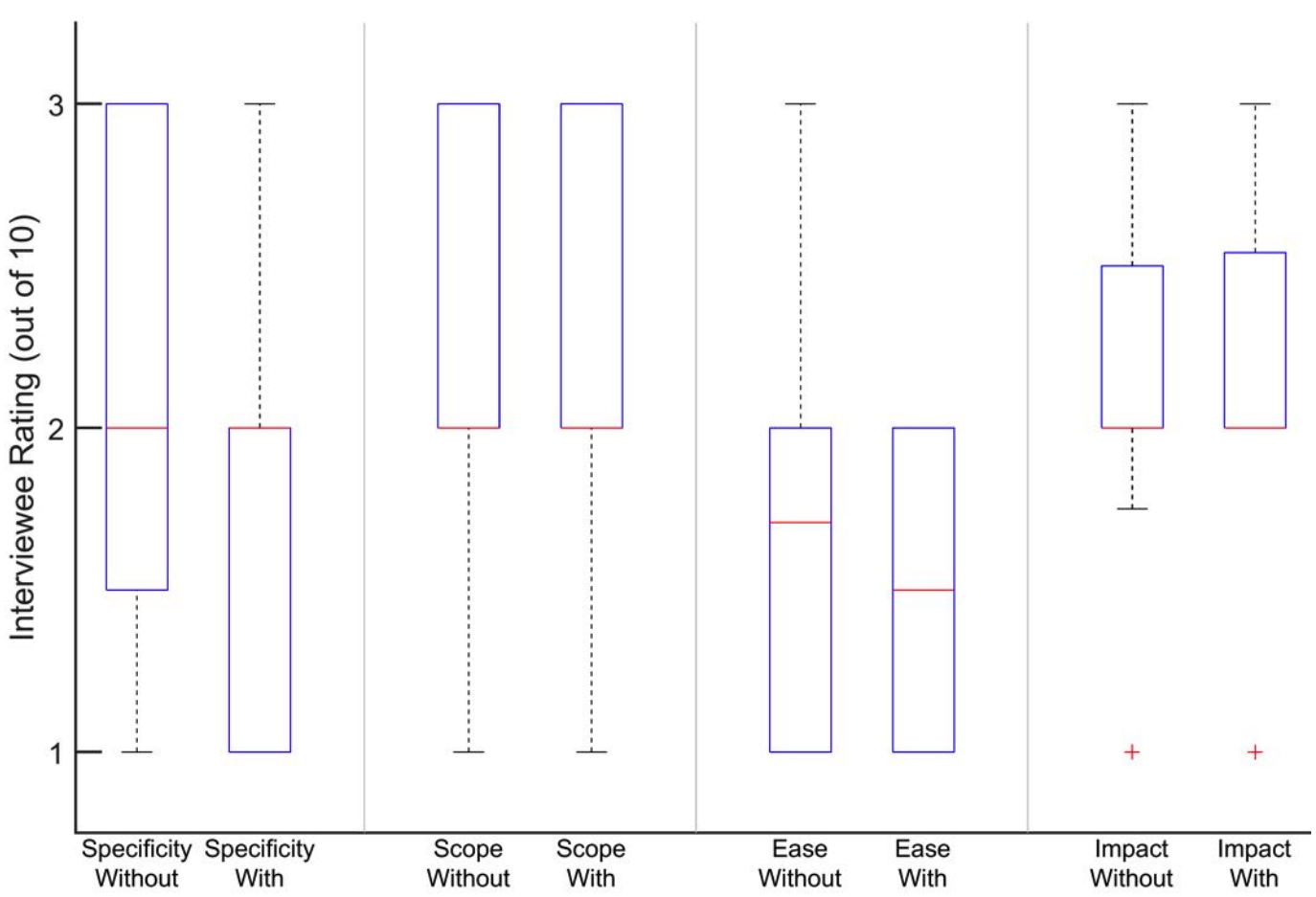
Boxplot of Novice Data (Helios failure)

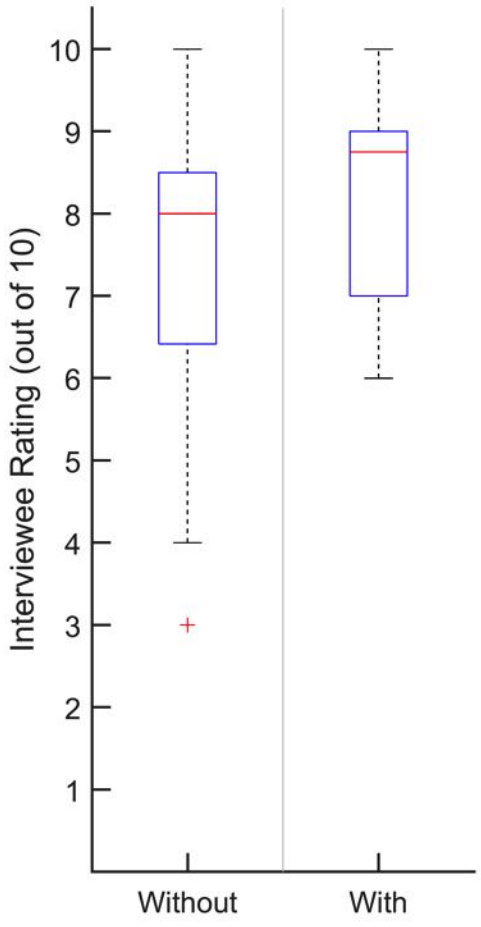




- The novices were more comfortable with this failure in general
- The tool helped with scope and impact
- Self-confidence was not really helped

Boxplot of Novice Data (Water Intrusion failure)





- The novices were less comfortable with this failure in general
- The tool made ease a bit worse
- Self-confidence was really helped

How Do the Responses Differ Qualitatively?

- Experts did not distinguish between subtleties of findings

  Experts are effective at framing design problems, make decisions quickly, and are more wedded to their own previously developed design concepts than novices [Kim & Ryu, 2014].

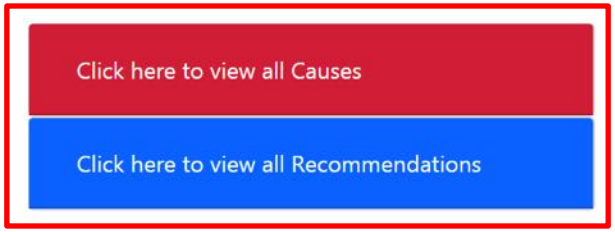
Conclusions and Future Work

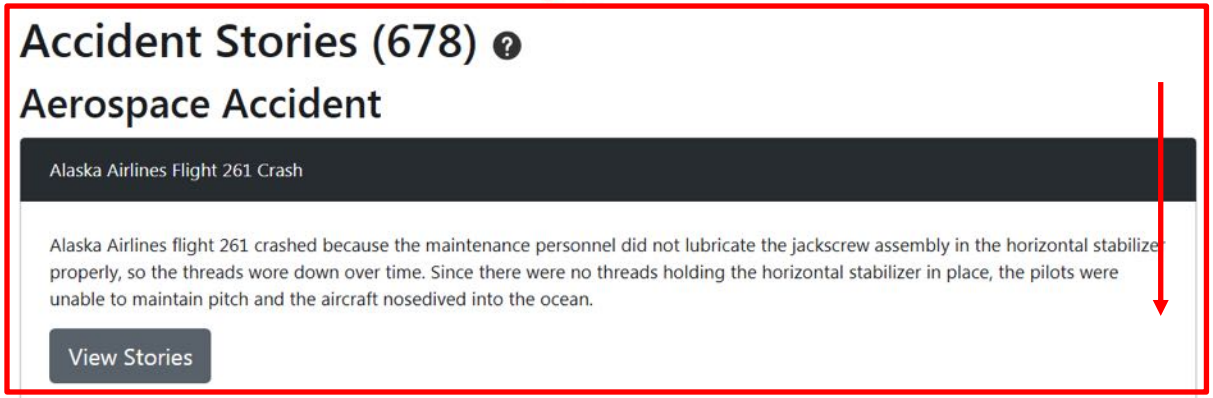
- Continue analyzing results of usefulness interviews

  Determine:

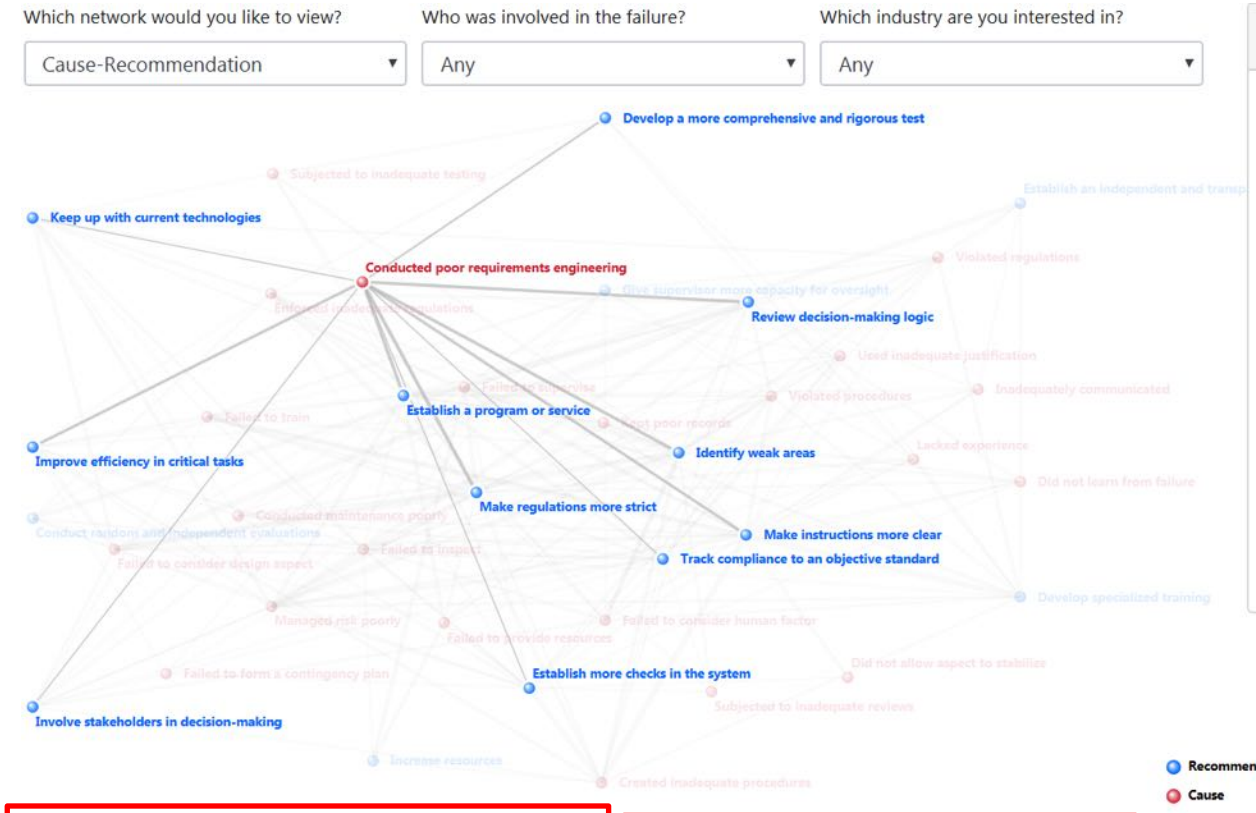
  - Whether the tool caused “fixation”
  - Whether the tool better helped the novices who had less systems engineering experience (control for # classes, months worked, etc.)

Interactive Web Tool





Functions: User Node Selection



Random Story

Pike River Mine Disaster

Energy Accident

The Pike River coalmine in New Zealand suffered an explosion in 2010 that killed 29 miners and exploded three more times over the course of 9 days before it was permanently sealed.

Actor: Designers
Cause: Conducted poor requirements engineering
Recommendation: Keep up with current technologies
The mine did not have enough methane sensors throughout its ventilation system, and thus the control room did not have an accurate measurement for how much methane was in the mine's air. The investigators recommended that the regulator require mine operators to have modern equipment and facilities, including technology for monitoring underground atmospheric conditions.

Selected Node

Conducted poor requirements engineering

Actor(s) in the organization did not lay out the needs, attributes, capabilities, characteristics, or qualities of the system well.

Click here to view all Causes

Click here to view all Recommendations

Accident Stories (35)

Aerospace Accident

Challenger Space Shuttle Disaster

The Space Shuttle was a reusable spacecraft that launched vertically with the aid of two solid rocket boosters (SRBs) and a large fuel tank that detached from the spacecraft before it reached orbit. The SRBs were comprised of multiple segments, and two rubber O-rings sealed the gaps between these segments to prevent the extremely hot gases from escaping. Despite unusually cold temperatures on the morning of the launch, the Challenger was cleared for launch. The O-rings were too cold to expand and fill the gap between the SRB joints and hot gases escaped from one of the motors, damaging the nearby components and causing the spacecraft to disintegrate.

View Stories

Functions: Expanding Stories and Nodes

Selected Node

Conducted poor requirements engineering

Actor(s) in the organization did not lay out the needs, attributes, capabilities, characteristics, or qualities of the system well.

Click here to view all Causes

Conducted poor requirements engineering
Actor(s) in the organization did not lay out the needs, attributes, capabilities, characteristics, or qualities of the system well.

Conducted maintenance poorly
Actor(s) in the organization failed to perform maintenance on a component or subsystem.

Created inadequate procedures
Actor(s) in the organization developed a deficient procedure, for instance maintenance, manufacturing, or emergency procedures.

Did not allow aspect to stabilize
Actor(s) in the organization did not allow a system aspect like personnel, design, or requirements to stabilize before moving forward with the project.

Did not learn from failure
Actor(s) in the organization did not take past failures into account and a similar problem occurred.

Enforced inadequate regulations
A regulator (e.g., the FAA) enforced deficient regulations. This causal action captures writing deficient regulations as well as implementing regulations poorly.

Accident Stories (35)

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View Stories

Actor: Development management
Cause: Conducted poor requirements engineering
Recommendation: Identify weak areas
Problem reporting requirements for the space shuttle program were not concise and failed to get critical information to the proper levels of management. The investigators recommended that NASA take energetic steps to eliminate the tendency to fail to provide full and timely information bearing on the safety of flight by changing personnel, organization, of indoctrination.

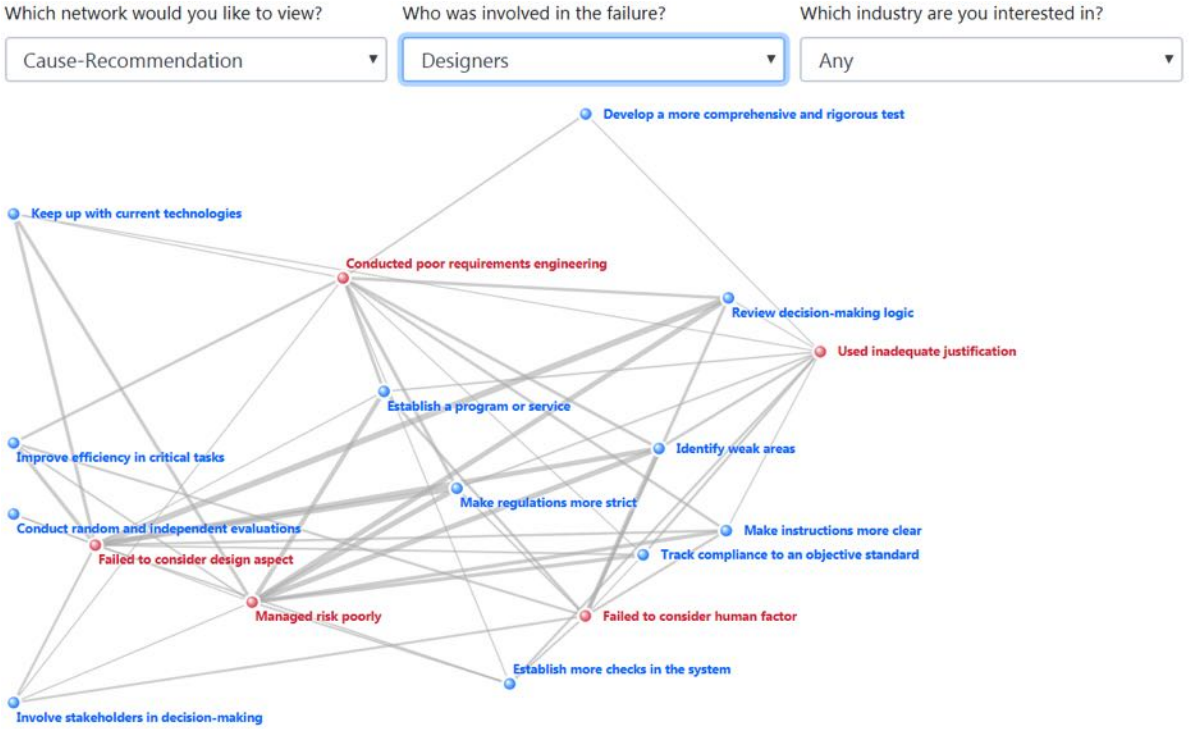
Actor: Development management
Cause: Conducted poor requirements engineering
Recommendation: Review decision-making logic
NASA committed the shuttle to a rapid flight schedule, which meant that they did not identify and address critical anomalies found on a flight before the next flight. The investigators recommended that NASA establish a flight rate that is consistent with its resources, that limits the pressures caused by factors like payload changes that affect schedules and crew training.

Columbia Space Shuttle Disaster

On its 28th launch, Space Shuttle Columbia's leading edge was struck by a piece of foam insulation that had detached from its external tank. The damage was so severe that it compromised the integrity of the shuttle's thermal protection system and the shuttle disintegrated on re-entry, killing its ocupants.

View Stories

Functions: Sorting the Network by Actor



Random Story

Alaska Airlines Flight 261 Crash

Aerospace Accident

Alaska Airlines flight 261 crashed because the maintenance personnel did not lubricate the jackscrew assembly in the horizontal stabilizer properly, so the threads wore down over time. Since there were no threads holding the horizontal stabilizer in place, the pilots were unable to maintain pitch and the aircraft nosedived into the ocean.

Actor: Designers
Cause: Failed to consider design aspect
Recommendation: Identify weak areas
The jackscrew assembly designers did not account for the loss of the threads as a single-point failure mode and thus did not include a fail-safe mechanism in the design. The NTSB recommended that the industry conduct a systematic engineering review to eliminate the effects of a total thread failure in the horizontal stabilizer jackscrew assembly and evaluate the horizontal trim systems of all other aircraft to identify designs that have a single-point failure mode.

Recommendation
Cause

Click here to view all Causes

Click here to view all Recommendations

Accident Stories (117)

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