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H-CoBIT: Human Cognitive Bias Identification Technique for accident Analysis

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Abstract: ***H-CoBIT is a technique initially developed with help of system analyst and designers in safety critical domains to anticipate human involvement failures that may be challenging once the system design becomes operational. This paper outlines and introduces a means of identifying cognitive biases using H-CoBIT method retrospectively (following an accident), where 'human error' is a convenient and all-encompassing explanation given in ninety per cent of cases. This we assert is because existing investigative approaches largely concentrate on observed actions rather than intrinsic thought processes. By teasing out the presence of cognitive bias as a causal factor for incorrect actions, safety recommendations can be made towards their mitigation. Analyzing a real-world case study by anticipating potential cognitive biases using H-CoBIT and comparing the results with the observed biases helped validate that this approach can also be used retrospectively.***

Keywords: ***Human Failures, Accident Analysis***

I. INTRODUCTION

In the field of human factor in safety critical systems, there is a common result that shows the impact of human factors involvement in serious accidents in safety critical domains are high. It is presented as 85% of all accidents in automobiles, 70% of all accidents in U.S. nuclear power plants, 65% in worldwide jet cargo transport and 31% in petrochemical plants are caused by operator errors [1]. With the respect of these figures, some other human factor and safety engineering researchers assert that human cognitive biases contribute most accidents in safety critical systems [2].

Developing an ergonomic system that reduces human errors in critical safety domains, is one of the most significant things that every system engineer/stakeholder seeks as the fundamental goal of considering human factor engineering is to minimize human errors and increase system efficacy during the operators interacting with safety systems [3].

Human errors typically play an essential role in the nature of accident occurrence in safety critical domains, such as nuclear power plants, chemical industries, rail-ways, and avionics systems [4]. Most of these failures are reported and entitled as 'human error' without further investigation (psychological perspective), which may be the root cause of the human error.

Recognizing and identifying human error involvement in an accident does not mean that human error is the only causation of the accident, but every human action error is stimulated by internal errors (psychological errors), such as situation awareness, cognitive bias and mod confusion.

In this paper, we concentrate on errors triggered by cognitive biases, which are deviations from the norm by making incorrect decisions against the stimulus or current situation dealing with the system operators. Using H-CoBIT method [5], we analyze a real-world case study and identify potential human cognitive biases retrospectively.

II. HUMAN INVOLVEMENT FAILURES

Almost 88% of world critical accidents stem from dangerous acts by system operators [6], therefore, it is needed to analyze those human act motivators (psychological perspective).

It is hypothesized that heuristics, such as representatives, availability and confirmation can be the actors trigger cognitive biases [2].

Getting deep insight of human errors, it should be considered on human factors in safety domains, which is multidisciplinary approach that generates information about human capability and their limitations. [7].

Human Factors Analysis and Classification System (HFACS) is one of most accident analysis technique used by investigators in aviation domain. This technique is comprised same levels presented by [4] in his swiss chess model. It consists of organizational influence, supervised factors, precondition for unsafe act and unsafe acts. Since in the unsafe act section include decision, and perception errors; none of these approaches tend to identify cognitive biases, which is the most distorted decision-making factor as below diagram presents the relationship between cognitive biases and unsafe acts [2]

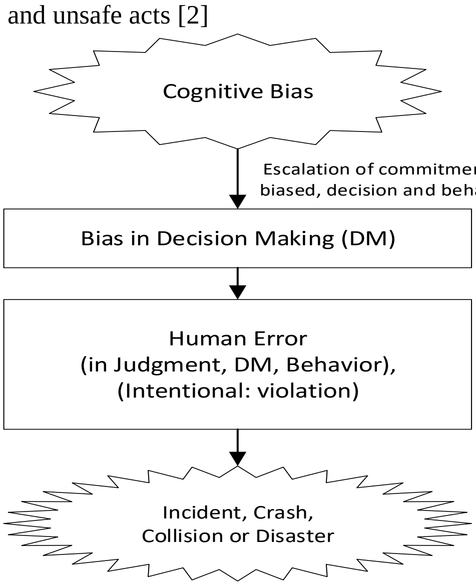

Fig. 1. Relational model between cognitive bias and unsafe acts [2]

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A. Keg worth air accident

"In 1989 Boeing 737-400 crashed as it was approaching to east Midlands airport, which left extreme damages and loss of lives. This is one of human cognitive bias induced accidents recorded. The most significant contribution of this accident is engine failure and flight crew's poor decision making. The investigation of the accident analysis shows that crew correctly completed engine shut down procedure but unintentionally shut down a wrong engine Shortly after the aircraft flew, it had been seen that fan blade broke off and the aircraft experienced extreme vibration felt by the crew, fumes and smoke drawn into the aircraft through air-conditioning system. Investigations and analysis from cockpit voice recorder VCR presented that there had been crew's decision hesitancy in determining which engine is failed. Flight captain asked the flying pilot, which engine is getting fault? He replied 'it is the le…it's the right one. This hesitation shows the poor decision of the flying-pilot and as a consequence, the right hands' engine power throttled back that led the engine totally shut down" [8]. Shutting down wrong engine caused to reduce the vibration and the smoke emerging from the left engine, that led the crew believe they took the correct decision as they shut down the right engine. Then flight crew decided to make an emergency landing as they contacted to the ATC and ATC gave green light to land appropriately. Flight crews started descending, they reduced the power of the left engine and the vibration reduced. Then 10 minutes later, crew decided to increase the power to maintain aircraft's altitude in the final stage of the descend but vibration increased again to an extremely high levels and the power of the left side engine lost along with fire warning sounded. Crew decided to restart right hand side engine to maintain descending but did not manage to do this as the aircraft crashed into the grounded".

B. Three Mile Island

"According to [9] it was on March 28, 1979 when Three Mile Island incident happened. The system was working at 97% power, when minor failures in the auxiliary cooling circuit made the temperature ascend to a point that the core reached at dissolving point and was seriously harmed. It was 4.00 am the point at which the site plant encountered the failure in its optional cooling system. As initial cause occurred around one hour earlier, human operators were attempting to clean a stuck polisher that sift the contaminations through of the secondary feed water system. Ordinarily, the polishers are simply flushed by shooting beads into the blocked pipe in the polisher to get it out, yet this standard technique did not work. Rather the operators choose to unsettle the water by utilizing compacted air; accidently they utilized instrument air framework, which controls pneumatically worked valves of the plant. As the water line conveyed more weight than the instrument air framework, the water started to work its way into air framework until it arrived at the valve control funneling. Hence, this caused almost every valve in the feed water system to close in a split second, and it therefore caused the feed water pumps and condensate pumps to trip at around 4:00 am" [2].

"As [10] hypothesized contribution of Three Mile Island (TMI) with cognitive biases as arguing that the system operators didn't see the failure of the nuclear reactor in view of the availability heuristic (i.e., Halo impact), which biases our decisions by moving our thoughts and beliefs about one attribute of something to other irrelevant attribute. System operators should likewise have hopefully accepted that such a minor slip by of not opening the valve of the optional water feed pumps would not prompt a significant disaster (optimistic bias stems from overconfidence)".

C. Air France 447 Crash

"According to [11] report, "on June 1, 2009, demonstrated an Airbus A-330, managed by Air France, collapsed in a deadly accident, while crossing the Atlantic Ocean on its way to France. The airbus was en-route flight, advancing the inter-tropical convergence zone ITCZ. crew detected that there was a line of thunderstorms ahead. The aircraft was on autopilot at the moment as the first pilot was the pilot flying. He was concerned about the weather ahead, and wanted to climb, but the aircraft was carrying too much load enough to be heavy. The flight captain did not appear concerned about the weather and a few minutes prior to facing the thunderstorms, he chose to take his crew rest, getting the pilot-not-flying forward. The pilot-not-flying had quite a bit more experience than the pilot flying in the right seat".

"The two pilots talk about the approaching weather. Pilot not flying also did not appear to be particularly concerned about the line of weather. Because it is common for an experienced airplane pilot, as crossing such lines of weather at cruise altitude is quite common and rarely results in any problem. When the plane reached the line of weather, they immediately experienced unknown turbulence, and then an area of high-altitude ice crystals. Those ice crystals were of sufficient quantity to block all three of the aircraft's pitot tubes, causing a substantial data loss that resulted in the autopilot disconnection and the loss of the airplane's displays, as well as a combination of electronic alert messages as various systems depended on airspeed. At the time when autopilot disengaged, the aircraft was somewhat below the target height of 35,000 feet. The pilot flying pulled back on the controls to raise the nose, and throughout the following 20 seconds, the nose kept on pitching up to around 12 degrees. In spite of the fact that this is over the ordinary pitch angle for the altitude, it is not a considerably high pitch, and in fact, is significantly lower than the climb attitude after takeoff. Most likely it is not shocking that the crew was not worried about the pitch attitude, although they were concerned that the airplane was climbing. The alter of pitch attitude was slow enough that it would not have been particularly noticeable"

III. ACCIDENT ANALYSIS USING H-COBIT

In this research study, it is commenced literature review on human involvement critical accidents in safety critical systems, then we choose air France 447 crash as case study to validate and check whether H-CoBIT method can be used to identify potential human cognitive biases. As previous proposed H-CoBIT [5] method for predictive analysis, we also claim that there are no obstacles impede H-CoBIT to be used as a retrospective analysis.

In line with the validating process, we conducted experiments with different group participants in different times giving a same case study.

Normally H-CoBIT method places a great amount of dependence upon the judgment of team-based approach using systematic guidewords[5] that help stimulate imaginative thinking to focus on analyzed tasks.

In this process of analysis, the accident investigators require to be able to use the method simply to identify potential cognitive biases that led to the accident. The participants were allocated into three groups. Each Group consisted of 5 graduate students with different educational backgrounds. All participants have been trained for the H-CoBIT methodology. They have been taught how method and its materials are used. They had taken 8 hours class session as they had no previous experience of any H-CoBIT methodologies used and the given case study.

Air France 447 crash is a case study that focuses on one of the main causes of aviation disaster in 2009 as we detailed in section II. This case study was considered one of human factor incidents triggered by human cognitive biases. This case was chosen as it was deemed to be representative of typical human cognitive biases, since it has been hypothesized six potential cognitive biases contributed to the accident [11].

On the basis of these six cognitive biases, we set event sequence diagrams (ESD) of the Air France 447 as an experiment of validating our H-CoBIT method. Then the participants investigated the potential cognitive biases by not having any background knowledge about the cause of the incidents. The results found from participants compared with the hypothesized results in the case report. Then the result of participants was analyzed finding number of Hit rates, misses and false alarms using sensitivity detection theorem [12].

Conducting retrospective analysis with H-CoBIT, certain activities should be performed to identify the potential causes of the accidents (cognitive biases). Unlike H-CoBIT predictive Analysis[5], accident investigators use event sequence diagram after reliable accident report described. Below diagram is H-CoBIT retrospective analysis flowchart.

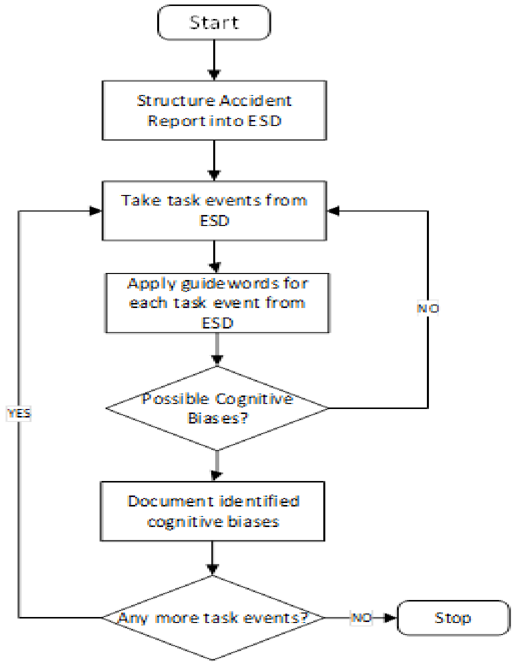


Fig.2. H-CoBIT retrospective analysis Flowchart

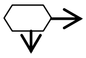
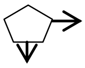
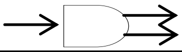
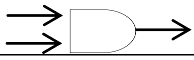
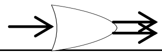
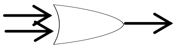
Step 1: Nominate H-CoBIT Team – As the main objective of this approach is to analyze and identify potential cognitive biases, it is required to have first H-CoBIT team leader who is experienced using with H-CoBIT technique in order to be the approach reliable and efficient. H-CoBIT team leader will help the rest of the team to guide how the system would be applied. The nominated H-CoBIT team should consists of team leader, accident investigation expert, operation team leader, system engineer, and record keeper which we demonstrated their roles in below table-I.

Table-I: H-CoBTI team and its role

H-CoBIT team leader	the leader should have enough and complete knowledge of H-CoBIT technique and how it is applied to guide the team in a way they can analyze the task simply.
Accident investigator expert	this person should be specialist of human factor and has experienced accidents analysis and how to investigate potential errors triggered by the accident.
Operating team leader	operating leader is the person responsible for conducting the investigation analysis, he leads the operating team and analyze the incident with help of H-CoBIT team leader
System engineer	since it is investigated and analyzed potential human deviation in a specific domain, either in aviation or any other safety domains, it should be there a domain expert of what is being investigated or analyzed.
Record keeper	this person is among the team, and he is assigned to keep the record and write down any documentations during analysis

Table-II: ESD symbols of evens[13]

Category	Symbol	Annotation
Initial Event		Beginning event of the sequence diagram.
Deterministic Delay Event		The delay time is fixed.
Random Delay Event		The delay time is random number.
Action State event		The likelihood of each action state is expressed by probability or random number
Comment Event		Providing information of the development of the event sequence.
Termination Event		End state of event sequence diagram

Time Condition		The direction of the event sequence is influenced by even time
Action Correctness Condition		The direction of the event sequence is influenced by event state.
Output AND gate		The occurring of one input event will lead to multiple output events occurring
Input AND gate		Output event will not occur until all input events occur.
Output OR gate		The occurring of one input event will lead to multiple exclusive output events occurring.
Input OR gate		Any of the input events occulting will lead to the output event occurring

Step 2: Structure Accident Report into Event Sequence Diagram – As H-CoBIT analysis team requires clear and simple accident report, it should be re structured the natural language text (accident report) into event sequence diagrams that will help the team to understand and re-describe event sequences carried before accident happed. This analysis technique also provides to team a way that human operators may perform erroneous activities.

In this step 2, H-CoBIT team applies accident report as an input and then restructures into Event Sequence Diagrams (ESD). Below are graphical representations of ESD that we use accident investigation with H-CoBIT method. Below diagram is ESD of air France 447 crash that we derived from the [5] report.

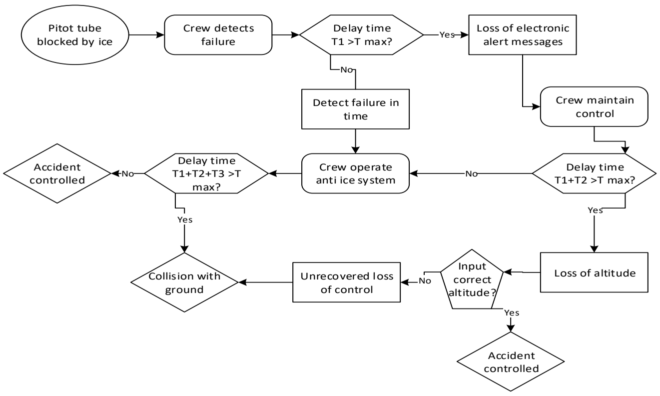


Fig. 3. Event sequence diagram of Air France 447 crash

Step 3: Guidewords – In this step, H-CoBIT team will perform task analysis by taking task events from the event sequence diagram illustrated from the accident being under analysis. They take each failed event (command events) from the ESD. Then H-CoBIT team will consider each related H-CoBIT guideword to the task type from the ESD. Then the team will assess whether guidewords could have impact on the task steps being analyzed. Therefore, if a cognitive bias is deemed, the team will execute on step 4 else they will go back to step 2 and take task step from it.

Table-III: Guidewords [5]

Guidewords	***Generic Meaning***
Equate	To associate stimuli with thoughts, beliefs and experiences.
Encode	To encode information structurally in wetware which cannot be erased or ignored.
Focus	Concentrate on specific information while ignoring the other parts (what you see is all there is WYSIATI).
Distract	Prevent someone from giving full attention to something/Unable to concentrate because of preoccupied mind.

Therefore, H-CoBIT team analyze and extract potential cognitive biases using above mentioned predefined guidewords [5]. As the flowchart diagram details, H-CoBIT team take task events from the diagram. For instance, when pitot tube blocked by ice and the aircraft got turbulence pilot flying felt that something went wrong but they did not response with time required

(T_{max}) – is the time required to respond to the system while T is the response time. Because the pilot **FOCUSED** on the weather conditions and expected turbulence due to the thunderstorm he entered. Therefore, *attentional tunneling and expectation bias* developed. another cognitive bias experienced by the crew is when they missed electronic alert messages from the flight display and failed to maintain control. The flight captain and the co-pilot overestimated that the situation will be normal, and the pilot flying overcomes soon, they both **EQUATED**

pilots flying experience with their thoughts and beliefs. Therefore, overconfidence bias and confirmation bias were developed in this case. Again, after crew failed to maintain control, the lost altitude, and pilot flying **DISTRACTED** fluctuating indicators and thrusted incorrectly (inserted incorrect values) that led to unrecovered loss of control and finally collided with the ground.

Step 4 Cognitive Bias Documentation – In this stage, the team is wrapping up and record the potential cognitive biases identified during the analysis. The team will record the data H-CoBIT table which consisted of six columns namely, task type, external error mode, cognitive failure (guideword with parameters), failure descriptions, and identified cognitive biases.

Table-IV: Extracted Cognitive biases

Comment event	E.E.M	Guideword	Parameter	Failure Description	Cognitive Bias
Loss of electronic alter messages	Checking error	**Focused**	On thunderstorm ahead	Pilot flying gives more attention to weather concerns and anticipating turbulence	• ***Attentional Tunneling*** • ***Expectation bias***
Loss of altitude	Communication error	**Equated**	Their thoughts and beliefs with PF experience	Captain and co-pilot filed to hand over the control and overestimated the situation	• ***Overconfidence bias*** • ***Confirmation bias***
Unrecovered loss of control	Action Error	**Distracted**	Fluctuating indicators	Pilot flying gave more attention to fluctuating indicators and the worried condition	• ***Attentional bias***

Step 5: Safety Recommendations – As the main goal of conducting accident investigation is to prevent not occurring again similar incidents, H-CoBIT method suggests design safety recommendations at the final stage, when the team correctly identified the causes of the investigated accidents. In this paper, we are not going present safety recommendations as the focus is identifying cognitive biases retrospectively.

IV. RESULT

Since this paper focuses and demonstrates that H-CoBIT method can be used retrospectively, we hereby present the result of the experiment that we have conducted during validating the reliability of the method when it is used for the retrospective analysis. As we have mentioned above, we used signal detection theory to analyze the consistence and the reliability of the method using below formula below.

$$\text{SI} = \frac{\left(\frac{Hit}{Hit + Miss}\right) + \left(1 - \frac{\text{False Alarm}}{Falase\ Alarm + Correct\ RFejection}\right)}{2}$$

The measurement scale of the sensitivity index is from 0 to 1 as the method reliability and consistence will be reflected to how the SI approaches to 1. Therefore, if the result of sensitivity index closes to 1, it will be considered that the method reliability and consistence is high. Below table 4.2 summarizes first time experiment results, such as, frequency of hit rates, misses, false alarms, sensitivity index and the mean score of each result.

Table -V: Mean score of H-CoBIT Sensitivity Index

	Team 1	Team 2	Team 3	Mean Score
Hit Rate	0.83	0.66	0.66	0.72
Misses	0.16	0.33	0.33	0.27
False Alarm	0.15	0.15	0.20	0.16
Sensitivity Index	0.83	0.75	0.72	0.76

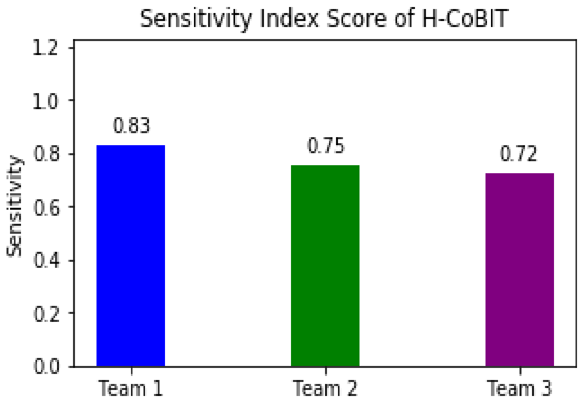


Fig. 4. SI Score of the three group participants

This above figure 4 shows the sensitivity index mean score of the three group participants. The data shows that the participants of team 1 correctly identified more cognitive biases and missed fewer biases than the participants of other teams. Therefore, if theses participants would be human factor experts or would have taken more hours of learning as they did before, their score will be higher than this.

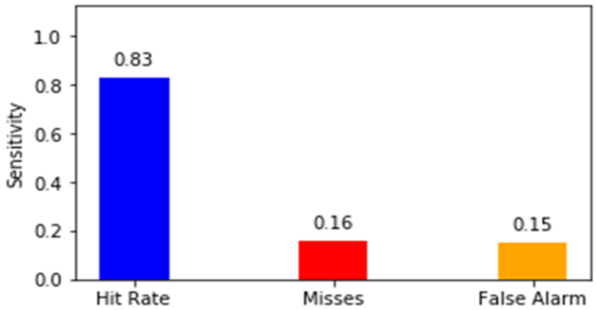


Fig. 5. Team 1 experimental results

The second above figure 5 presents number of hit rates, misses, and false alarms that group participants of team 1 made for their experimental test. The figure shows that team one hit 83.3% of cognitive biases and missed 16% from the observed data while 15% marked as false alarm.

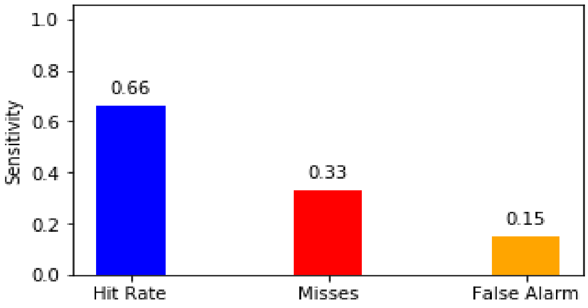


Fig. 6. Team 2 experimental result

From above figure 6, shows number of hit rates, misses, and false alarms that group participant of team 2 identified during their experiment using H-CoBIT. This data demonstrates that team 2 correctly identified 66% of the cognitive biases experienced during the case study report and the team missed 33% of an existing cognitive bias in the case study while they identified 15% as false alarm. Therefore, the data shows that H-CoBIT method can be correctly identify potential human cognitive biases.

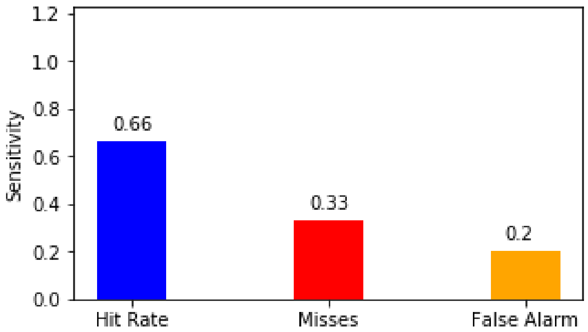


Fig. 7 Team experimental result

In this figure 7 shows that team 3 hit 66% same as team 2 identified but showed more false alarm rates than teams with the rate of 20%.

V. CONCLUSION

Performance and efficiency of accident investigation strategies play an important role in mitigating potential human failures in safety critical domains. A comprehensive approach for identifying and analyzing potential cognitive biases is paramount important for critical accidents. Consequently, this research paper offers significant advances on previous studies of human cognitive bias identification method (H-CoBIT), which is used for predictive analysis using HTA and guidewords while this study shows that H-CoBIT can be used retrospective analysis (accident investigation). Achieving that we used same conceptual framework for incident analysis but slightly changed the system description. We used accident reports and event sequence diagram (ESD) as an input of the method while the rest processes such as using guidewords and elicit cognitive biases are conducted through same process. Finally, using H-CoBIT for retrospective analysis in safety critical systems contribute accident analysts and investigators to come up with countermeasures and safety recommendation to mitigate occurrence of future accidents with similar causes. Work presented here therefore contributes to the field of HFE and Human Reliability Analysis (HRA) for cognitive bias mitigation. Specifically, we introduce a means of identifying cognitive biases retrospectively (i.e. as possible contributory factors in an accident).

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