Resident Pathogens in Systems Engineering: Boeing 737 Max 8 Crashes Case Study

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SUMMARY

The aim of the paper is to present "resident pathogens" or "latent failure conditions" identified in Systems Engineering (SE) practices that led to the two fatal accidents of Lion Air Flight 610 and Ethiopian Airlines Flight 302 involving Boeing 737 Max- 8 airplanes. The accidents led to the tragic loss of 346 lives and incredible pain for the victims' families.

The desktop study included collecting information and data that is publicly available to represent all relevant viewpoints to ensure completeness. The accident analysis uses the Cybernetic Risk Management Model (CRMM) with support from the hybrid Swiss Cheese Model (SCM) and Management Oversight & Risk Tree (MORT) fault tree analytical technique. Resident pathogen metaphor in the Swiss Cheese accident causation model denotes fallible decisions made during the (SE) processes. The methodology incorporates Jens Rasmussen's risk management framework (RMF) augmented by the Heuristics & Biases (H&B) approach to decision making, Thus, the methodology can help to identify latent failures conditions at all levels of the socio-technical system involved in the control of the system -of- interest (SOI).

KEYWORDS

Aerodynamics Stability Complex systems, Accident Analysis, Human, organisational and technical (HOT) Factors, Safety Risk Management

Introduction

Information about the tragic accidents is presented. This information describes the loss events- T and the accident(s) SA1 as per the MORT Manual (Kingston et al, 2009a).

The National Transportation Safety Board Report states thus: "On October 29, 2018, PT Lion Mentari Airlines (Lion Air) flight 610, a Boeing 737 MAX 8, PK-LQP, crashed in the Java Sea shortly after takeoff from Soekarno-Hatta International Airport, Jakarta, Indonesia. The flight was a scheduled domestic flight from Jakarta to Depati Amir Airport, Pangkal Pinang City, Bangka Belitung Islands Province, Indonesia. All 189 passengers and crew on board died, and the airplane was destroyed." National Transportation Safety Board Report (NTSB, 2019a).

"On March 10, 2019, Ethiopian Airlines flight 302, a Boeing 737 MAX 8, Ethiopian registration ET-AVJ, crashed near Ejere, Ethiopia, shortly after takeoff from Addis Ababa Bole International Airport, Ethiopia. The flight was a scheduled international passenger flight from Addis Ababa to Jomo Kenyatta International Airport, Nairobi, Kenya. All 157 passengers and crew on board died, and the airplane was destroyed." (NTSB, 2019a).

(KNKT, 2019) listed nine contributing factors (clause 3.2). that were related to lifecycle Systems Engineering processes of concept definition, system definition, system realisation and systems deployment (INCOSE, 2023, see Figure 2.10). (EAAIB, 2022) stated repetitive and uncommanded airplane-nose-down inputs from the MCAS due to erroneous AOA input, and its unrecoverable activation system which made the airplane dive with the rate of -33,000 ft/min close to the ground was the most probable cause of the accident (clause 3.2). The EAAIB Report listed ten contributing factors (clause 3.2). (BEA, 2023) and (NTSB, 2023) dispute the probable cause of the accident adding that inadequate pilot crew handling of the aircraft before the uncommanded Maneuvering Characteristics Augmentation System (MCAS) activation and the airport management of foreign objects (like birds striking) to be included as well in addition to MCAS related factors.

In terms of aviation occurrences classification by (ASA JSAT, 2014). these accidents are classified as Loss of Control in Flight (LOC-I) accidents. (Bromfield & Jamieson, 2022) did not note the 2014 JSAT paper.

Cognitive biases are mental errors in judgment under uncertainty caused by our simplified information processing strategies (sometimes called heuristics) and are consistent and predictable (Tversky & Kahneman, 1974), (INCOSE, 2023). Since Tversky and Kahneman's 1974 seminal paper, behavioural decision researchers have identified a large number of biases in human judgment and decision making, each showing a deviation from a normative rule of probability or utility theory (Montibeller &Von Winterfeldt, 2015). When evaluating the results of risk assessments under the managerial review and judgement process, the potential for cognitive biases and heuristics that could influence how decision-makers interpret and deliberate over the results of the risk assessments is to be addressed (Glette-Iversen et al., 2023). Cognitive biases can contribute to incidents, failures, or disasters as a result of distorted decision making and can lead to undesirable outcomes is noted by (INCOSE, 2023). Omission bias in organisations does arise when the phenomenon of emergence is neglected (Reiman & Rollenhagen, 2011). We overestimate the likelihood of good outcomes and underestimate the likelihood of bad outcomes under the influence of optimism bias (Kahneman, 2012), (Montibeller &Von Winterfeldt, 2015). The confirmation bias, or the tendency to look for (and find) information that confirms expectations and disregards information that negates them, might distort probability estimates. Considering the importance of eliciting judgments (probabilities, values, utilities, weights, etc.) in decision and risk analysis, it is somewhat surprising that relative little attention has been previously paid to the possible distortions of an analysis due to these biases(Montibeller &Von Winterfeldt, 2015).

The importance of systemic and organisational performance shaping conditions has been clearly established in the safety literature (Starbuck & Farjoun (Eds.), 2005), (van Kampen, J., et al., 2017), (INCOSE HSI Working Group, 2023). But it is challenging for practitioners from Systems Engineering (including human factors, safety specialists and traditional systems engineers) discipline to identify latent failure types and to find ways to neutralizing the pathogens revealed to improve safety performance (Reason, 1990b) (pp.210-11), (Appicharla, 2006a), (Macrae, 2007). Social and institutional factors are involved in safety risk management (Hutter & Jones, 2006), (Reason, 1990b) (pp. 216) and their contribution to safety risk management is noted (Macrae, 2007). Reason (1990, 1997) has argued that unknown, latent risks are inevitable in all organizations and the primary purpose of risk analysis is to find them and "make them visible" (Reason, 1997, p. 37), (Macrae, 2007). Section 2.3 of the ICAO website "Safety Management System Implementation" states on Accident Causation, thus: "Safety risks can be generated by active failures and latent conditions. The concept of accident causation is an active field of study, and many types of models exist to illustrate the events taking place leading up to an accident." (ICAO, 2018). For definition of active failures and latent failure conditions, (Appicharla, 2023a) may be consulted.

The aim of this paper is to highlight resident pathogens such that systems engineers may identify, reflect and improve the design and delivery process. A significant contribution of the paper is to highlight contribution of cognitive biases underlying decision failures and their contribution to the crashes.

The Methodology for Accident Analysis: The Cybernetic Accident Risk Management Model

At the time of submission for review, Google scholar's search yielded 15,500 hits on the theme of Boeing 737 Max 8 crashes. Due to space constraints, observations on these cannot be presented. However, it is to be noted that the systems approach is underpinned by the idea that safety is an emergent property of socio-technical systems. Interactions within the system are non-linear and produce emergent behaviors that are hard to predict (Rasmussen,1997), Rasmussen' 1997 risk management framework describes various systems levels including: government; regulators; company management; staff; and work. According to Rasmussen, each level is involved in the management and performance of the system. The system requires "vertical integration" to maintain control of hazardous processes and create safe performance.That is, decisions made at the higher levels need to be filtered down to the lower levels and influence practice, and equally feedback from the lower levels needs to filter up and inform the decisions and actions occurring within the higher levels of the system (Grant et al, 2015). These levels need to include professional engineering associations, industry bodies and consultanices as well. (Ball & Boehmer-Christiansen, 2002) noted that many institutions and their associated professions have carved out their own specific approach to safety decision making, sometimes in isolation from other professions, and these are in many cases not consistent with each other.

Systemic view of accident causation is the norm where agencies such as the Australian Bureau of Air Safety Investigation (BASI) and the Transportation Safety Board of Canada have seen the great opportunity afforded by James Reason's organisational accident approach to identify deeper systemic causes (Braithwaite, 2010). The BASI was the first to use Reason's model for all its major reports, directing attention to organisational factors underlying aviation accidents (Hudson, 2003). The idea that human error is a symptom of system failure may be traced back to Justice Peter Mahon's examination of the circumstances behind the loss of an Air New Zealand DC10 aircraft with 257 fatalities on the slopes of Mount Erebus in 1979 (Braithwaite, 2010). Dr Rob Lee, Director of BASI, Captain Dan Maurino, Jean Paries, Captain Jeremy Butler, and Captain Bertrand de Courville are few professionals who are credited with promoting the Swiss Cheese Model in the aviation sector (Reason,J., et al, 2006), (Appicharla, 2006a). Reason argued that the safety level of any organisation could be evaluated from a limited set of indicators, based on an analogy between the breakdown of complex technological systems and the aetiology of multiple -cause illnesses such as cancer and cardio-vascular diseases(Reason, 1990b), (Larouzee & Le Coze, 2020). Like cancer or heart disease, industrial accidents result from a combination of factors, each of which is necessary but not sufficient to overcome the technical, human and organisational defences of the industrial system defences (Reason, 1990a). Criticism of the Swiss Cheese Model were taken up by (Reason et al, 2006) and answered. One of the criticisms is that misapplication of the model can shift the blame backwards, from a 'blame the pilot' to 'blame the management' culture and may obscure real human factors concerns at the front line. However, as (Reason et al, 2006) argued that the fact that deterministic causal connection between latent conditions and accidents cannot easily be identified (particularly before the event), does not rule out that efficient prevention policy can be based on addressing latent conditions. Drawing upon convergence between disciplines of decision research, organisational theory, safety management and accident causation identified by (Rasmussen,1997) and assuming the hypothesis that system safety, accident analysis and occupation safety research need a common approach (Appicharla, 2006a) used the MORT to identify latent failure conditions to meet the challenges of the Railway Safety Directive 2004/49/EC (No longer in force) (EU, 2004) in response to an internal research brief by RSSB for a Systems Engineering solution to identify missing safety measures at the duty-holders interfaces. (Appicharla, 2010c) revealed the results of application of the Methodology over five-year period at RSSB in the form of the latent failure conditions that can contribute to future railway accidents like the lockout protection system, ABCL types of level crossing, permissive working operations, axle counters and train detection systems. These hazard warnings were neglected and safety critical incidents as identified in the Hazard Analysis Reports manifested in the railway operations later. One of them accident(s) foreseen was analysed by (Appicharla, 2011) and the 2011 paper presented failings at the regulator level as well. Later, in 2017, the Heuristics and Biases (H&B) approach was integrated into the Methodology and (Appicharla,v2021c) presented the application of the Methodology to the 2017 Cambrian ERTMS Incident. The Regulatory and System owner awareness of Common Safety Method: Risk Assessment LTA is noted in the section 2c of the paper and this state of affairs is prevailing since 2007. (EU, 2016) (Recast of Directive 2004/49/EC) is in force and calls for integration of human, organisational ad technical factors. (The UK HSE, 2003) provides guidance how to manage the impact of organisational change on their control of the hazards for chemical plants.

The 2017 Cybernetic risk management model (see Figure 1) uses the hybrid Swiss Cheese Model (SCM) (Reason et al, 2006) and (MORT) terminology under the lens of socio-technical systems & 1997 Risk Management Framework(RMF) (Rasmussen,1997), control system theory vide barrier model (Ashby, 1956) cited in (Appicharla, 2006a),and H & B approach (Reason, 1990b) and (Kahneman, 2012) to explain accident causation. The Systems Engineering framework is made up of SCM as an explanatory mechanism (see accident equation (1)) and modelling the latent causal factors with the help of the MORT, the "resident pathogens" (including human, organisational, social, institutional and technical factors) are studied in the paper using the hybrid MORT & SCM model. The concept of emergent properties plays a significant role in accident analysis (Appicharla, 2006a), (Appicharla, 2010c). The Energy Barrier Trace Analysis (Table I) of the MORT Manual and its similarity with the Swiss Cheese Model (Reason et al, 2006) can be seen in (Appicharla, 2011) with discussion of biases like optimism bias play in decision making and neglect of other biases was noted as well.

The Accident Risk Management Model describes how the unsafe outcomes occur as a result of:

- Less than adequate (LTA) development/application of standards related to systems engineering, safety engineering, human factors, and domain related standards or omission of hazard analysis at the standard preparation, hazards not controlled by standards (Rasmussen et al,1994), (Starbuck & Farjoun, (Eds.), 2005),(Appicharla, 2006a), (Appicharla, 2010c), (Koopman, et al, 2019);
- LTA responses to the disturbances due to Heuristics and Biases(Reason, 1990b), (Reiman & Rollenhagen, 2011), (Kahneman, 2012), (Appicharla, 2023a). (Tuccio, 2011) drawing upon NASA Human Factors Experts study, showed that at least 19 aviation accidents over a ten-year period from 1991 through 2000 can be attributed to heuristics and recommended that pilot training should adopt these concepts. This open access article is a helpful reading to understand heuristics and biases from accident analysis perspective and enable us to reframe our thinking about the concept of Human error.
- LTA Business policy and its implementation and its integration with risk related policies (Starbuck & Farjoun, (Eds.), 2005). Use of pre-trained models can also increase levels of statistical uncertainty and cause issues with bias management, scientific validity, and reproducibility (NIST, 2023) (pp.38),(Koopman & Widen, 2023).
- LTA Safety Risk management practices of System Definition, Hazard Identification, Risk Analysis and Implementing Risk Controls Options, and Assurance Management(Appicharla, 2006a), (FAA , 2017), (Rasmussen,1997). Attention to management of desired emergent properties is needed and efforts to prevent unwanted or undesirable ones must be taken (Siemieniuch & Sinclair, 2014).
- LTA Learning from Accident Investigation, risk assessments and other public inquiries due to biases in accident investigation(Reason, 1990b), (Leveson.2011) and/ or LTA

analyses of past accident scenarios that do not serve to describe the socio-technical context within which accidental flow of events are conditioned and ultimately take place (Rasmussen & Svedung, 2000)(pp.17). Attribution error, Hindsight bias and Outcome bias may impact our learning of right lessons from past accidents (Appicharla, 2023a);

- Finally, LTA philosophy of ALARP decision making, LTA Oversight process/ LTA business/mission analysis (INCOSE, 2023). Affect and other heuristics may have an adverse impact on ALARP decision making by injecting biases (Ale et al, 2015), (Langdalen et al, 2020). Does the risk exceed an acceptable level (e.g., regulatory standards, action levels)—the "As Low As Reasonably Practical" (ALARP) test? (Smith, 2013). (The UK HSE, 2001) recognises any informed discussion on the risk decision-making process quickly raises ethical, social, economic and scientific considerations(clause 13). (Adam & Thompson, 2002) concluded attempts to manage risk that a) ignore the rewards of risk taking, and/or b) exclude significant stakeholders, and/or c) fail to appreciate the type of risk it is sought to manage, are unlikely to succeed.

Accident Analysis Results

In accordance with (ASA JSAT, 2014). the SCM and the MORT EBTA, and using the accident analysis procedures described in the MORT User Manual, and following the application examples stated in (Appicharla, 2021c) and (Appicharla, 2024b), we describe the accident(s), thus:

> Loss of Control – Inflight (LOC-I) hazard (SB1) + loss of 346 lives (SB2) + Less than adequate control by Socio-technical system in control (Omissions & oversight)

The following are significant latent failure conditions that led to the fatal crashes:

MORT code S/M. Oversight and Omissions (Kingston et al, 2009a) (pp. xvi -1): LTA Specific Control Factors) S-1[1] & LTA Management System Factor: M-37: LTA regulatory oversight & functioning, and certification): Excessive Federal Aviation Administration (FAA) delegation of certification functions to Boeing on the 737 MAX eroded FAA's oversight effectiveness and the safety of the public. Boeing's Authorised representatives (ARs)—Boeing employees acting as representatives of the FAA or performing certification functions on behalf of the FAA—were impaired from acting independently of the company about the certification of the 737 MAX(Defazio & Larsen, 2020)(pp.57). "DOT OIG Audit Report AV-2016-001 stated "FAA Lacks an Effective Staffing Model and Risk-Based Oversight Process for Organisation Designation Authorization (ibid)(pp.59). Technical design flaws, faulty assumptions about pilot responses, and management failures by both Boeing and the FAA played instrumental and causative roles in the chain of errors that led to the crashes …that resulted in the tragic and preventable deaths of 346 people. Both crashes involved Boeing 737 MAX airplanes (ibid)(pp.5). The latent failures investigated at Boeing Board level were presented by (Appicharla, 2023a). Omission bias (Reiman & Rollenhagen, 2011), Confirmation bias due to AH and inadequate mental model of the regulatory problem space (Reason, 1990b) is asserted here.

MORT Code MA3 Risk Management System LTA/ MB3. Risk Analysis Process LTA. a1. Concepts and Requirements LTA. b5-45. Specification of Requirements LTA: c11-45(Kingston et al, 2009a) (pp.45): System (1)-engineered system (737 Max-8 aircraft), system (2)-the Boeing SE Life Cycle Project Management System, and system (3)- the Boeing Enterprise Process and Innovation System monitoring, the SE Life Cycle Project Management failed. LTA adequate system definition made up of three systems (INCOSE, 2023) (section 1.3.4). Overconfidence bias is asserted here (Reason,

[1] The numbers after the hyphen refer to the MORT Manual page numbers and letters with numbers before hyphen refer to the MORT Manual nodes/code.

1990b)(89). LTA Safety standards: (Lopes, 2024) uncovered four main limitations in safety assessment guidance that contributed to the accidents: (a) limited integration of human factors and safety, (b) limited guidance for identifying assumptions, (c) limited ability to capture non-failure based causal scenarios, and (d) limited ability to understand complex nonlinear causal relationships.

-do- SB3-5 Barriers & Controls LTA : ***SC1-5 Control of Work & Process LTA: SD1-5 Technical Information LTA:a2-8 data collection LTA: b5-8 Use of Previous Accident/Incident Information LTA? b6-8 Learning from employee/contractor's personnel experience LTA :*** The FAA TARAM analysis showed that even with the FAA's Emergency Airworthiness Directive but without a fix to MCAS, there could be more than 15 fatal 737 MAX crashes over the estimated 30-year lifetime of the fleet, then estimated to be 4,800 aircraft, resulting in over 2,900 deaths Defazio & Larsen, 2020)(pp.210). Boeing did not learn that its design was flawed, or that it had made mistakes, but blamed industry-wide assumptions regarding pilot response time (ibid) (pp.231). Subject matter experts were overruled in some cases(Cantwell, 2021). This shows 'insensitivity to predictability due to RH' (Kahneman, 2012), (Appicharla, 2023a). Even after the fatal Lion Air crash, Boeing maintained that its "rationale" for removing references to MCAS from the 737 MAX training manual was still "valid and Boeing asserted that the addition of MCAS on the 737 MAX did "not affect pilot knowledge, skills, abilities, or flight safety (ibid))(pp.27). In 9 of the 18 events, flightcrew training played a role (ASA JSAT, 2014) (pp.4). The past accidents such as AF447 (2009) (Oliver et al., 2017), and TK 1951 (2009) (Appicharla, 2023a) highlight the cases where the pilot(s) reliability in handling the stall situation would be critical. AF447 (2009) shows Inappropriate Control Inputs (Oliver et al., 2017), and TK 1951 (2009) shows effects of single sensor-based architecture (Appicharla, 2023a) leading to Inappropriate Control Inputs as a contributing factor(s) (ASA JSAT, 2014) (pp.5).

-do- a2. Design and Development LTA: b9. Human Factors (Ergonomics) Review LTA: c29-49. Did not Predict Errors: LTA consideration of Human Factors in system design, operation and maintenance, and certification processes: (INCOSE, 2023) (2.3.4.6)(3.1.4) Human Systems Integration LTA. Automation Confusion/Awareness (ASA JSAT, 2014): The FAA has provided guidance that pilots should be able to respond to uncommanded MCAS activation condition within four seconds (Defazio & Larsen, 2020) (pp.24). Unfortunately, had the EICAS been installed on the Lion Air or Ethiopian Airlines flights, some experts believe it may have helped to alleviate pilot confusion—a contributing factor in both of those accidents(ibid)(pp.47). The Boeing OMB did not indicate to flight crews that they may experience multiple alerts at once leading to cognitive confusion and mental overload, often referred to as the "startle effect" (ibid)(pp.195). LTA Flight Crew Alerting: Boeing did not make the angle of attack (AOA) Disagree alert functional to indicate the significant difference between the two AOA sensors. As a result, Boeing did not contribute to adequate situational awareness of Lion Air Flight 610 piloting crew(ASA JSAT, 2014)(pp.5). (NTSB, 2006) stated that the functional implications of failures that could result from human interaction with airplane systems and components are not analyzed in safety assessments. The Safety Board is concerned that human interaction failures are not addressed in the assessment of safety-critical system. The FAA March 2002 and the HF Guidance by (Yeh et al 2016) cited in (NTSB, 2019b) and (ASA JSAT, 2014) findings were omitted by both FAA and Boeing. (Leggett, 2020) described the four themes of regulatory failures, system design, and pilot training crisis including a doctoral thesis of Dr Karlene Petitt. She is described as an experienced pilot based in the US. She has become a vocal critic of airline safety culture, drawing on research carried out for her doctoral thesis. Omission/Out of sight out of mind bias due to AH is asserted here(Reiman & Rollenhagen, 2011), (Reason, 1990b).

-do- b8-46 Energy Control LTA: c24-47 Controls and Barriers LTA: b22-53 Design Acceptance & Change Control Process LTA: c38-53 Engineering Studies LTA: Safety Risk Management LTA: The

Single & Multiple Failure (S& MF) analysis process LTA: The MORT Fault tree does not have a tree branch to deal with the safety culture and safety management aspects under the a2 Design and development processes is to be noted. Therefore, b22 -53 and c38-53 branch are considered for Safety Risk Management aspects. The S &MF analysis process was led by a Boeing Systems Engineering team along with relevant stakeholders was carried out (NTSB, 2019a). The failure analysis was "completed prior to the design change to MCAS control law during flight test and not reevaluated." This did not entail a "process violation or non-compliance (Defazio & Larsen, 2020)(pp.209). These controllers (decision makers) who from their local perspective strove to meet their programme objectives of 'Operational commonality' and 'Amended certification (ATC) requirements prepared the latent pathway(s) to accident(s) (Defazio & Larsen, 2020), (Reason, 1990b). Confirmation bias to program objectives of 'Operational Commonality', 'Energy Efficiency' and 'Amended certification (ATC)' is asserted here, (Reason, 1990b), (Teal, 2014), (Montibeller &Von Winterfeldt, 2015).

-do- b22-53 Design Acceptance & Change Control Process LTA: c43-54 Change Review Procedure LTA: In 2011, facing a competitive threat from Airbus's new, more fuel efficient, single-aisle A320 aircraft, Boeing believed it did not have time to create a new plane from scratch (Project Yellowstone was shelved under customer pressure) (Defazio & Larsen, 2020) (pp.39). LTA business and mission analysis & management (INCOSE, 2023) (2.3.5.1). (NTSB, 2019a) documents how Aerodynamic stability and statutory requirements drove the Boeing team to re-apply the LTA MCAS solution. "Boeing failed to appropriately classify MCAS as a safety-critical system, concealed critical information about MCAS from pilots, and sought to diminish focus on MCAS as a "new function" in order to avoid increased costs, and "greater certification and training impact." (Defazio & Larsen, 2020). Boeing had tremendous financial incentives to ensure the MAX program met this goal. In December 2011, Boeing agreed to pay Southwest Airlines $1 million per MAX airplane that Boeing delivered to Southwest if its pilots were unable to operate the 737 NG and 737 MAX interchangeably due to any reason. In addition, if the FAA required more than 10 hours of pilot training and/or required flight simulator training, Boeing would reimburse SWA for any direct training expense that exceeded 10 hours Defazio & Larsen, 2020)(foot notes -814 to 821).

LTA Systems Engineering application: LTA (MCAS) Systems Knowledge; invalid source data (ASA JSAT, 2014)(pp.4): The MORT Fault tree does not have a tree branch to deal with the Systems engineering and Systems thinking aspects under the a2 Design and development processes is to be noted. Based on the admission of John Hamilton, the then-Chief Engineer, that one of the two MCAS design requirements (no objectionable interaction with the piloting of the airplane and not interfere with dive recovery) were not met, the Report concluded that MCAS was poorly designed, not adequately tested, and had received flawed oversight by the FAA (Defazio & Larsen, 2020)(pp.120). The huge error of omission is that Boeing failed to disclose the existence of MCAS to the pilot community(Defazio & Larsen, 2020) (pp. 206). Omission bias due to AH is concluded (Reason, 1990b). (Campbell, 2019) noted that Boeing 737 Max 8 is a perfect example of the cross purposes at which business, technology, and safety often find themselves. With its bottom line threatened, Boeing focused on speed instead of rigor, cost-control instead of innovation, and efficiency instead of transparency. The FAA got caught up in Boeing's rush to get the Max into production, arguably failing to enforce its own safety regulations and missing a clear opportunity to prevent these two crashes.

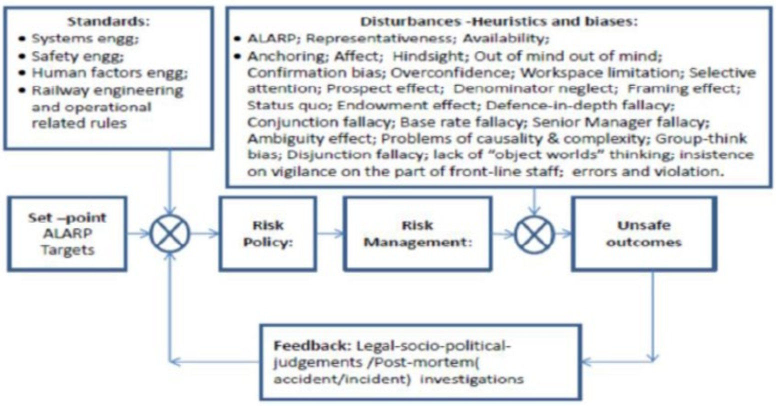

Figure 1: The Cybernetic Risk Management /Accident Risk Management Model

LTA Systems Thinking concepts and their application: Concepts of emergent properties (Hitchins, 2007), like system safety (Appicharla, 2006a), (Leveson, 2011), affordance of harm (Appicharla, 2011), inadequate communication of Systems Knowledge(ASA JSAT, 2014), and Cognitive biases (such as rankism in decision making) (Jackson, 2018) to assure better situational awareness, design and control (Defazio & Larsen, 2020), (Checkland,1981) were not part of shared mental models (Senge,1990b) of the FAA and Boeing Systems Engineering teams. Omission and confirmation biases due to AH and RH is asserted here(Reason, 1990b).

Brief discussion: The paper did not discuss the active failures of flight crew and the debate between the BEA, NTSB and the EEAIB on the question of flight crew errors due to space constraints. The role of deadheading pilot in previous flight to the Lion Air Crash is discussed by (Defazio & Larsen, 2020) and other inadequacies in maintenance activity by (KNKT), 2019). (Jackson, 1997) may be consulted to learn how the Integrated Project Teams (IPT) and other SE concepts are linked to certification and design process. (Defazio & Larsen, 2020) provided evidence for the confirmation bias hypotheis when the Boeing's own simulator tests showed that pilot response far exceeds(ten seconds in the case of one pilot) the four seconds requirements and leads to catastrophic results.

Conclusion

Resident pathogens identified in Systems Engineering (SE) practices that led to the two fatal accidents that can be addressed were presented.

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