Communication

Yak vs. cherry picker: Human factors in an aviation accident

Dirk Pons [1]*

[1] Department of Mechanical Engineering, University of Canterbury, New Zealand. [2]
* Correspondence: Email: Dirk.pons@canterbury.ac.nz e

Abstract: Human factors are the things that go wrong in the interactions between a team of people and a system of technology. This is part of a broader transdisciplinary field called engineering psychology, which as the name suggests, draws from both engineering and psychology. Many, if not most, catastrophic accidents involve a socio-technical interaction, i.e. are not solely due to technology failure. Hence, there is a need to consider human factors in the development or deployment of any technical system. This article is about the human factors involved in an aviation accident in New Zealand between a Yak and a cherry picker. The types of human error are identified, and the barrier bowtie method is used to represent them. The analysis gives different insights into the accident compared to the formal accident report, and better represents the human error characteristics.

Keywords: human factors; error; air show

1. Introduction

Wanaka (New Zealand) hosts an annual air show called Warbirds over Wanaka. In 2018 an accident occurred in the opening sequence whereby a Yakovlev Yak-3M (Yak) aircraft (see Figure 1) collided with a cherry picker vehicle on the airfield. See video of the accident[1] and the Civil Aviation safety briefing report [1]. The present article provides a brief overview, analyses the case using a human-error methodology, and identifies implications for air shows and technical event operations generally.

[1] https://www.youtube.com/watch?v=liZwCz41QhY

Figure 1: Yakovlev Yak 3-M at Wakanka. This is an earlier photo of the same aircraft involved in the accident. Image Bernard Spragg. NZ https://www.flickr.com/photos/volvob12b/13972485511 Public domain.

2 Accident analysis

For a glossary of human error terminology, including emphasised words below, see Appendix A.

Late changes to programme

The air show programme had a late change to the event due to cancellation of another aircraft display, so flying displays by two Yak aircraft were substituted. The event organisers ought to have revised their *risk assessment* for the changed programme, but failed to do so. That was a *violation* of the accepted practice for conducting air shows. Furthermore the change to the programme was not communicated effectively to everyone who needed to know, so people ended up with different expectations of how things were intended to operate (*mental model*). The Yak pilots were explicitly told they could land on the grass. In conflict with that, the cherry pickers had been placed on the grass before they were scheduled to be there.

The bowtie analysis examines what might have been done to *prevent* the cherry pickers ever getting onto the grass, and what might have been done to recovery the situation after they were. For a general approach to developing bowties, see [2].

The overall structure of the bowtie analysis, at a high level of abstraction, is shown in Figure 2. It is a graphical representation of how multiple THREATS or root causes exist and can, if unchecked, lead to an undesired system state which is the ACCIDENT or INCIDENT (called the 'top event'), which in turn can progress to more serious CONSEQUENCES including disaster. Barriers are introduced (not evident at this high level). Proactive barrier are the preventative mechanisms which prevent the threat from progressing to a hazard. There is LOSS OF CONTROL when the threat proceeds to the hazard by overwhelming or evading the barriers. Reactive barriers are the recovery mechanisms that prevent the undesired state (hazard) from progressing to further catastrophe. They recover the situation, by reducing either the severity of the consequence, or its likelihood.

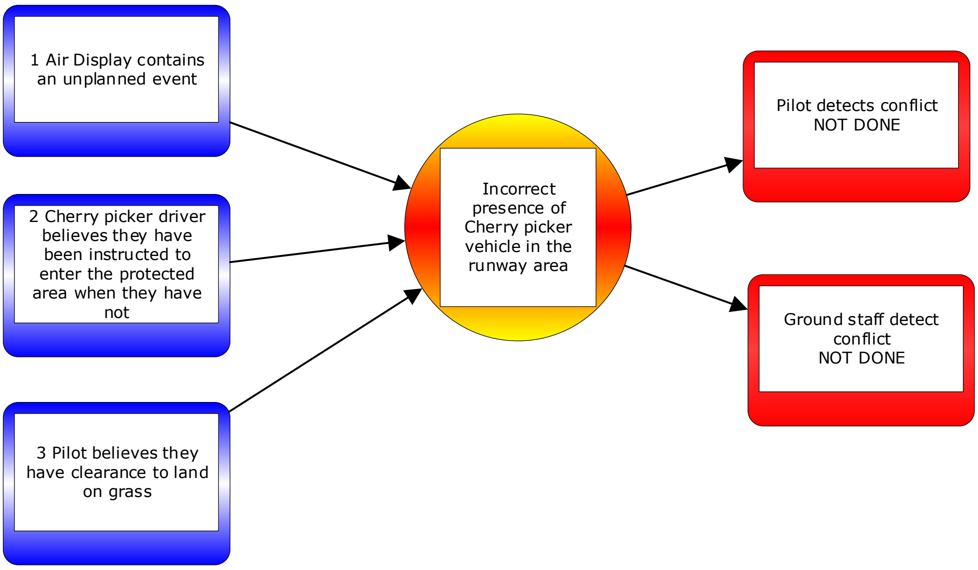

Figure 2: High level bowtie diagram

Threat side

The initiating event was the change in programme. This was followed by an organisational failing to think through the implications and communicate these to everyone affected. The cherry picker drivers believed they had been instructed to enter the grass area. Meanwhile the pilots believed, and received explicit confirmation, that they had clearance to land on the grass. For the prevention side as a whole, most of the failings were misunderstanding, i.e. communication failings.

Introduction of an unplanned event

The sudden change in programme required a substitute event. The changes and their implications were communicated to some people, at least the pilots involved, but not everyone. However the risk assessment was not updated. The new event changed the use of the aerodrome, specifically how the grass between the two runways was to be used. The implications of these changes was either not thought through or not communicated effectively, as seen in people (driver & military manager) working towards the old understanding of what was supposed to happen.

Movement of cherry picker onto the grass area

The cherry picker drivers did their work before it was needed – the machines were not scheduled to be on the grass until later [1]. This was an *anticipation error*. It seems they did not see anything wrong about taking initiative. Perhaps they were unaware of the implications for the changed use of the grass. If the communication had been better, then potentially they (i) might have only moved the vehicles when explicitly instructed, and (ii) been able to challenge the instructions and thereby prevent the accident. The *crew resource management (CRM)* paradigm in aviation encourages junior staff to speak up if they observe possible mistakes by superiors.

Pilots gain explicit approval to use the grass

The display director and the pilots had a common understanding that the pilots were permitted to land on the grass – the pilots explicitly confirmed this. However the military manager did not attend the briefing, and hence operated on a different set of assumptions. They said their 'mental model was that the Yaks would be landing on the sealed runway' [1]. If the communication had been better, then potentially the military manager might have been able to detect the ambiguity of their own *mental model* relative to the news risks imposed. That can be categorised as a *slip*, i.e. an unintended action. It caused them to be unconcerned about the location of the cherry pickers, because they thought the Yak pilots would not use the grass. Also, they did not attend the briefing, which proved to be a *mistake*, because there they would have heard the pilots being given clearance to land anywhere including on the grass. One can also say that the military manager lacked *situational awareness.*

Summary of threats

Taken together, the threat side of the bowtie analysis is shown in Figure 3. The Bowtie method is not specific about the logical connection between the threat strands, and does not include the OR/AND Boolean logic of fault tree analysis (FTA).

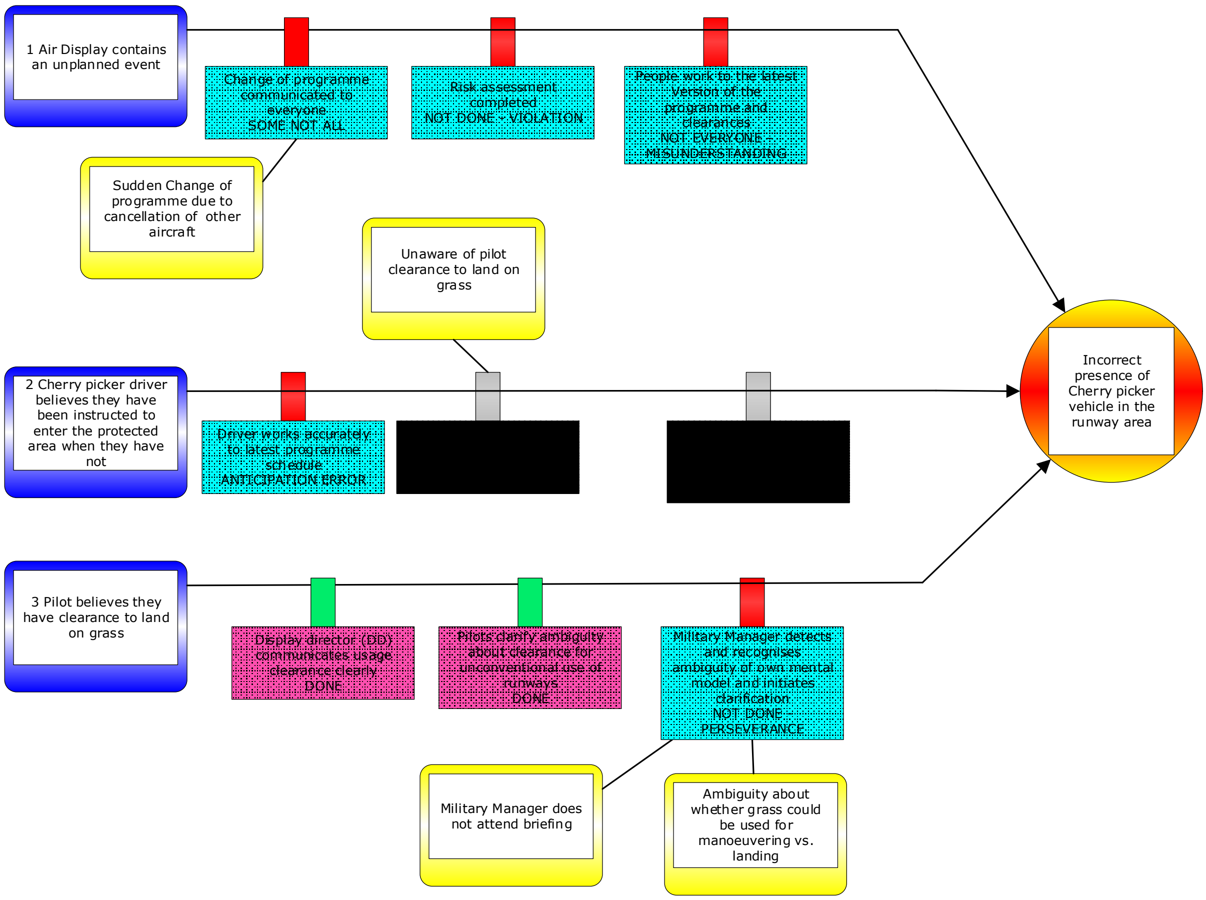

Figure: Bowtie for the input or threat side

The top event is the 'Incorrect presence of Cherry picker vehicle in the runway area', which is a type of runway incursion. This hazard of a vehicle on the runway is well known in aviation as one of the 'Significant Seven' identified by the UK Civil Aviation Authority [3]. In the UK, about 60% of runway incursions involve aircraft, 37% vehicles, and 4% people [4]. The UK CAA has a comprehensive, though general, bowtie analysis on the topic. Hence this is not an unknown hazard for airports. Furthermore the UK CAA specifically identifies runway incursion as a high priority risk for aerodromes, and has worked to produce further guidance for managing this specific risk. For example:

'Where the specific job function requires the driver to operate on the manoeuvring area then additional training on the hazards associated with runways and taxiways is detailed, including use of VHF radio communications with Air Traffic Control, which will require training in the correct use of RTF and standard phraseology.' [4]

Examination of the UK data shows that the dominant factor for runway incursion is failure to follow clearance instructions by pilots and to a lesser extent drivers. This is a problem of poor coordination and people acting in anticipation. Managing runway incursion risk requires communication processes for explicit clearance for both pilots and drivers. It is not clear in the Wanaka case how this was achieved, if at all.

The Wanaka air show organisers had received prior permission from the aerodrome owners to use the full width of the grass for take-off and landing [1]. In practice it appears the organisers collectively lacked a coherent mental model of how this would be operationalised. Some of them treated it as a runway and others not, and hence there was inconsistency regarding what constituted an intrusion risk.

Recovery side

Even when the cherry pickers were on the grass, there was still an opportunity to recover from the situation before it developed into an accident. Unfortunately key opportunities were missed. Either the pilots or the ground based staff could have detected the hazard, but did not.

Pilot avoidance opportunities

It is reasonable to expect pilots to be cognisant that air shows introduce new and unusual hazards compared to routine flying. Hence they need to actively scan for hazards in the air and on the terrain. This calls for heightened vigilance. However flying in formation with other aircraft consumes a great amount of vigilance, and leaves less for other tasks. This is called cognitive burden and can contribute to not perceiving things with the mind that are visible to the eye, especially unexpected objects (perceptual blindness). Unfortunately there is also poor visibility of the ground from the Yak cockpit at landing, which is something of a design failing of many such era aircraft. There is also the odd matter of the pilot's radio transmission not being heard by the tower, which implies another layer of failures somewhere. The CAA report does not elucidate.

Opportunities on the ground

Even before the landing, the flight director had detected the presence of the cherry pickers and asked the vehicle manager to move then away. This was not done, for reasons unreported. The CAA report does not elucidate.

In general, such behaviour can arise from a *lapse,* i.e. forgetting to do something in a sequence, in turn often due to interruption by other task demands. Another general cause can be misunderstanding of the level of compliance required, i.e. whether something is a request or an order. Trying to be polite, such as using the work 'please', is not necessarily a good approach when safety-critical matters are involved.

Either the pilot or the ground based flight directors could have detected that the aircraft was lined up to the cherry pickers, though this is surprisingly difficult to do.

Summary of consequence paths

At this stage all the barriers had been defeated and the collision was ready to happen, see Figure 4. Most of the errors on the recovery side were lack of vigilance. For the complete bowtie diagram see Appendix B.

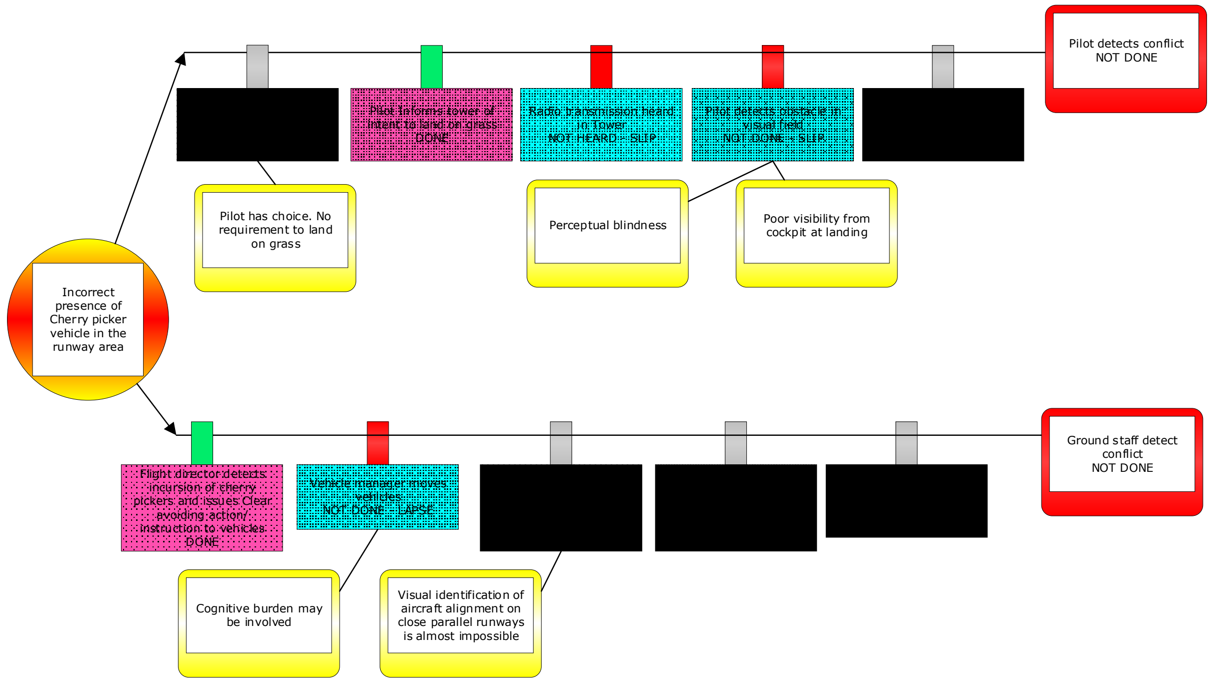

Figure: Bowtie for the consequence or output side

It was fortunate that no-one was killed, not even the pilot, despite the severe damage to the aircraft. That there were no casualties to the wider spectator public was also fortunate, and probably due to the small kinetic and chemical energy involved, see Figure 5.

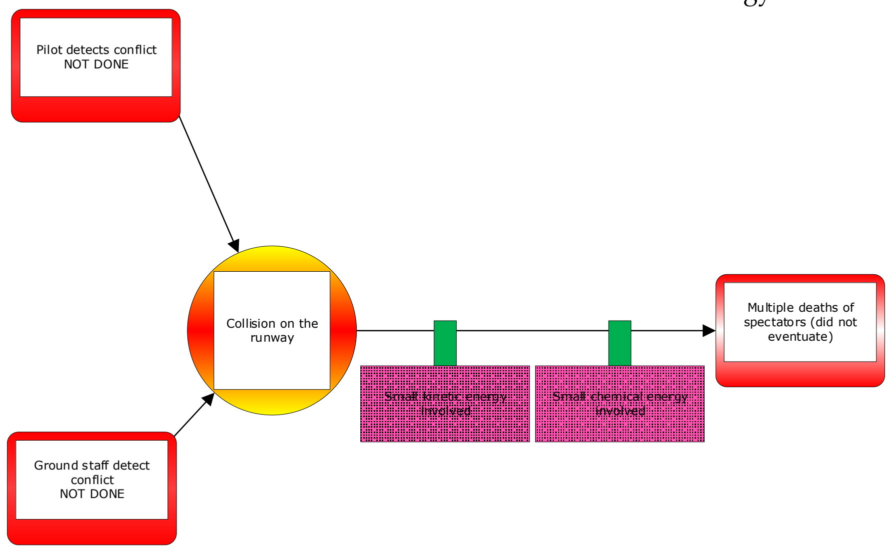

Figure 5: Bowtie for further developments

If this had been the originally planned F16 fighter jet, the outcomes could have been more severe (though that aircraft would probably not have used the grass for landing). See Figure 6 for an example of the significant risks present at airshows.

Figure 6: The pilot of a F-16 ejects at low altitude over an air show. This was an aerobatic manoeuvre that went wrong. The issue was the manoeuvre commended based on an assumed altitude of the airport, but this value was incorrectly specified, so there was insufficient vertical clearance to complete and the aircraft impacted the ground. The pilot managed to eject safely moments before impact. No spectators were harmed. Image: U.S. Air Force photo by Staff Sgt. Bennie J. Davis III, https://en.wikipedia.org/wiki/Aviation_accidents_and_incidents#/media/File:Crash.arp.600pix.jpg Public Domain

3 Implications

There are three implications for project and event management.

1 Pay attention to the risk assessment at the planning stages, by approaching it with a wide perspective.

View it as an opportunity to be thoughtful, rather than treat it as a compliance exercise. In complex operations it is unlikely to be adequate to have one large unstructured list of risks. It is better to determine the architecture of the operations, and then identify the risks in each. For an event like an airshow there are different zones, and different schedules of events in each. If one of the zones or events changes, it is necessary to review the risks generated therein. An unstructured list of risks will not make this easy to do, hence the need for an architectural approach. An example of a risk architecture is shown in Figure 7. These items would become category headings in the risk register. For more specifics on air show risk assessment see [5] and [6].

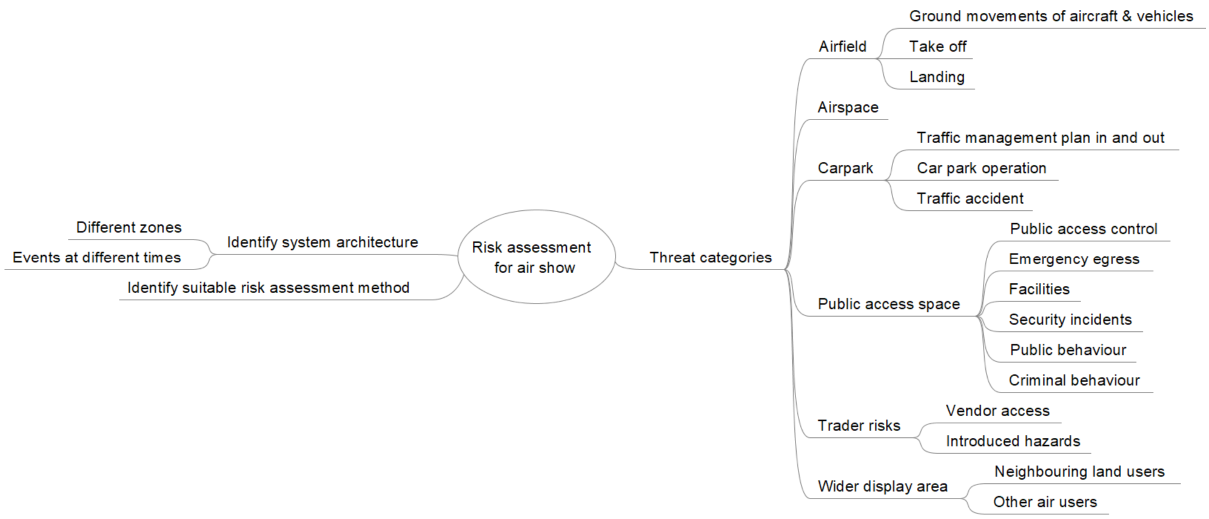

Figure: Possible architecture of a risk assessment for an airshow.

2 Communication is essential, but clarity thereof is critical.

Ask clarifying questions if in doubt of own personal understanding. Ask others to verbally express their understanding of the plan, and reconcile any inconsistencies.

3 Vigilance to hazards is important, and requires a deliberate approach.

Most people will intuitively recognise that. However be wary about distractions, interruptions & demands for attention from other people, and cognitive overload situations (too many demands at once). These are what cause people to forget to do important actions.

Appendix A: Glossary of Human error terminology

agency	The personal attribute of thinking and then committing effort in a deliberate way to achieve goals that one has anticipated.
anticipation error	The performance of an action in anticipation before requested, and without confirming or coordinating with others. Also called implicit coordination.
barrier	These are mechanisms that either prevent a threat from progressing to a hazard (preventative or proactive barriers), or prevent the undesired hazard state from progressing to further catastrophe (recovery or reactive barriers).
cognitive burden	The mental state where too much information or complex task-processing is required to be done at once.
crew resource management	The communication processes used in aviation that encourage junior staff to speak up if they observe possible mistakes by superiors, and ask for clarification of misunderstanding.
hazard	A condition of the system where it is in an undesired dangerous state.

	Often involves a progressive evolution of system state from threat, to hazard, to accident, to harm.
hierarchy of hazard control	The preferred way to reduce risk is to eliminate the risk, and if that is not possible then minimise it.
lapse	Operator forgot information or to perform an action that was intended.
mental model	Personal construct of cause and effect. More specifically, a set of personal understandings of how a system is working, and thought expectations of how it ought to behave in response to own actions. It may be partly subconscious and implicit. It invariably includes assumptions and simplifications, some of which may be unquestioned or even wrong.
mistake	Inappropriate decision- operator decided what action to take, and performed it, but it was an inappropriate choice in the first place
misunderstanding	A failure to correctly understand the meaning or intent of the other person.
motivation	The personal willingness to exert agency. motivation as the combined effect of a chain of three factors: (i) expectancy - that exertion of effort will result in performance, (ii) instrumentality- whether that performance will result in reward or punishment, and (iii) valence - the extent to which that reward or punishment is important to the person.
over-alignment	Excessive conscientiousness towards accomplishment of organisational objectives. A factor in perverse agency.
perceptual blindness	The cognitive failing of not perceiving things with the mind that are visible to the eye, especially unexpected objects. Also called inattentional blindness.
perseverance	Persistent acceptance of a false belief, leading to inappropriate actions. Also called fixation. Involves a lack of de-biasing of mental model, and ignoring disconfirmatory evidence. The latter is a mostly subconscious process of ignoring evidence that is inconsistent with the mental model.
perverse agency	The application of poor judgement whereby the protagonist persists (by showing decisiveness, action, and commitment) with an unwise course of action and willing assumption (personal acceptance) of risk that others would consider unreasonable, to achieve what they feel is a good objective [7].
prevention	Actions that prevent a potential threat from developing into a hazardous event. Eventuation of the hazard is also called loss of control. Much of risk management is directed to prevention via the hierarchy of hazard control.
recovery	Actions that prevent an occurring hazardous event from developing into a full accident.
risk assessment	Systematic and documented evaluation of the potential adverse outcomes, and identification of treatment actions, typically per ISO 310000 [8]. For airshow risk assessment see https://www.skybrary.aero/index.php/Air_Display_Safety

situational awareness	Dynamic awareness how threats may evolve. More specifically, (i) the ability to recognise potential threats originating in the environment, (ii) comprehend their meaning & implications, and (iii) anticipate how those threats may evolve over time and affect the future state of the technology system. The environment may be external events (e.g. weather changes), or information presented by the technical system in its current state. The 'situation' is both the current state of the technical system and the stressors that the external environment is throwing at it. Involves a mental model.
slip	Operator performed an action they did not intend.
Swiss cheese	The idea that individual barriers have different deficiencies and none on their own can totally prevent the accident from occurring. Certain unfortunate combinations of events can defeat all the barriers and cause the hazard to emerge.
vigilance	The action of keeping alert for suddenly emergent hazards.
violation	Operator knew what procedure to follow, but did not. Lack of compliance.

Appendix B: Complete bowtie

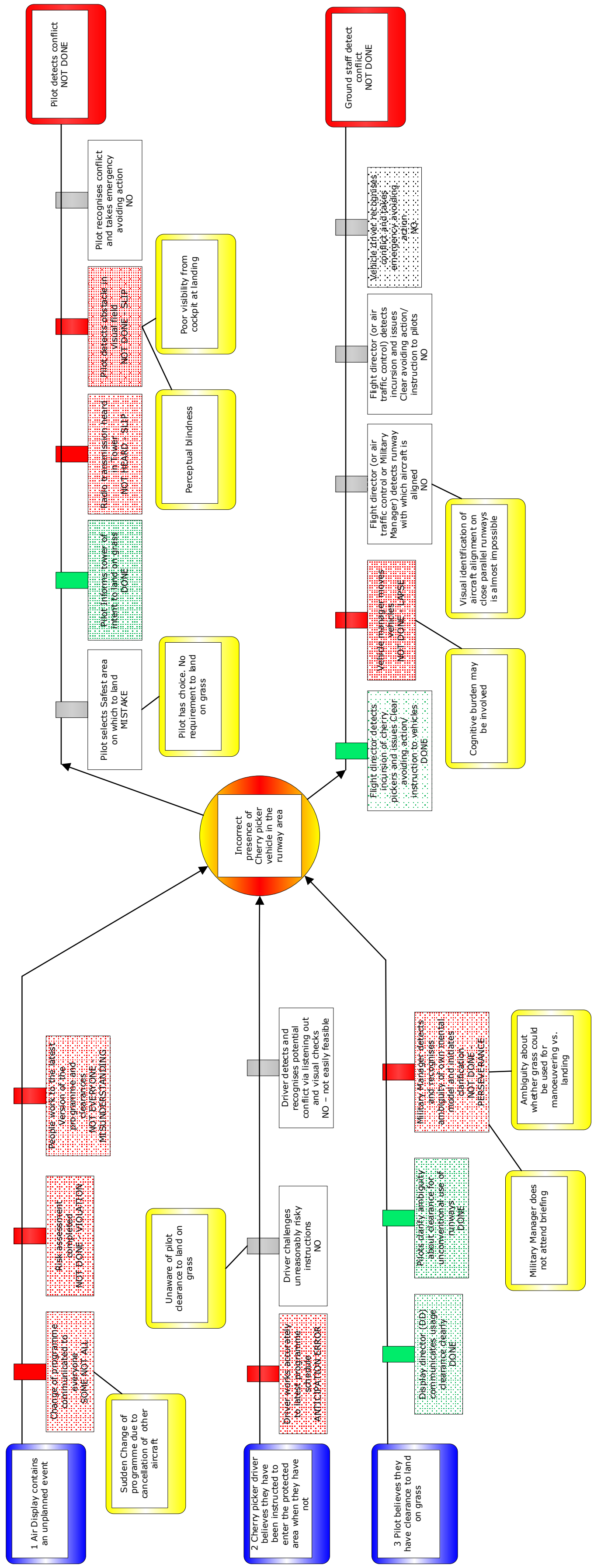

Figure B1: Complete bowtie

Supplementary Materials: The following are available online at www.mdpi.com/xxx/s1, Figure B1: Complete bowtie.

Funding: This research received no external funding.

Conflicts of Interest: The authors declare no conflict of interest

References

1. CAA NZ, *Yakovlev Yak 3M ZK-YYY Collision with ground equipment Warbirds overWanaka Air show 31 March 2018.* Civil Aviation Authority of New Zealand, 2019. **CAA Safety Investigation Brief 18/1592**.
2. Aust, J. and D. Pons, *A Systematic Methodology for Developing Bowtie in Risk Assessment: Application to Borescope Inspection*. Aerospace, 2020. **7**(7): p. 86.
3. CAA, U., *Bowtie document library.* Civil Aviation Authority (GB), last accessed 2020. https://www.caa.co.uk/Safety-initiatives-and-resources/Working-with-industry/Bowtie/Bowtie-templates/Bowtie-document-library/.
4. CAA UK, *CAA 'Significant Seven' Task Force Reports.* Safety Regulation Group, 2011. **CAA PAPER 2011/03**.
5. Skybrary, *Air Display Safety.* Flight Safety Foundation, 2020. https://www.skybrary.aero/index.php/Air_Display_Safety.
6. Davis, J., *Airshow risk assessment.* British Air Display Association, 2016. http://www.bada-uk.com/wp-content/uploads/2016/02/FDD-5-Risk-Assessment-BADA-16.pdf.
7. Ji, Z., D. Pons, and J. Pearse, *Why Do Workers Take Safety Risks?—A Conceptual Model for the Motivation Underpinning Perverse Agency.* Safety, 2018. **4**(2): p. 24.
8. ISO 31000, *Risk management - Principles and guidelines* 2009, International Organization for Standardization.