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The System Theoretic Accident Modelling and Process (STAMP) of medical pilot knock-out events: Pilot incapacitation and homicide-suicide

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ABSTRACT

After the Germanwings flight 4U9525, mental health issues of pilots have been raised as a hazard to flight safety. Pilot homicide-suicide, as a special subtype of pilot incapacitation, can be examined at different levels of commercial aviation. We extended the System Theoretic Process Analysis (STPA), based on the System Theoretic Accident Modelling and Process (STAMP), to pilot behaviour to investigate how these knock-out events may be encountered in the whole system. Several safety actions have been identified to prevent hazardous pilot behaviour caused by medical incapacitation and homicidal-suicidal behaviour at different levels of the system. Pilot incapacitation is already handled very well in practice with respect to the regulations and procedures in current usage. In contrast, the prevention of pilot homicide-suicide is currently managed by aeromedical decision-making regulations and pilot support programs. The design of the flight deck compartment door and the balancing of privacy laws and public safety remain trade-offs amid a medical risk.

1. Introduction

Pilot suicide became a hot topic in the media when Germanwings flight 4U9525 crashed into the French Alps at 24 March 2015. In 2016 about 12.6% of airline pilots met the depression threshold and 4.1% reported suicidal thoughts (Wu et al., 2016). A descriptive cross-sectional study provided results from pilots (N = 1848) who took part in an anonymous web-based survey. Hundreds of pilots (n = 233) are currently flying and managing depression. A smaller number of pilots even reported suicidal thoughts (n = 75) from the sample surveyed. The First Officer (FO) of Germanwings flight 4U9525 was diagnosed with depression and was on duty the same time. It is argued that a more transparent and caring environment in commercial aviation could have prevented the tragedy (Hussain et al., 2015). This environment ranges from mental health assessment in the future to possible pilot support programs for mental and social issues (European Aviation Safety Agency [EASA], 2016b). In capturing this far-reaching environment of commercial aviation, we applied the System Theoretic Accident Modelling and Process (STAMP) together with its accompanying hazard analysis technique, the System Theoretic Process Analysis (STPA) to medical pilot knock-out events (Leveson, 2014). Medical pilot knock-out events include pilot incapacitation and pilot homicide-suicide as well as other forms of malady. These events are manifest in anomalies of pilot behaviour. We consider both types of medical events in detail in the next sections because they are critical to flight safety.

1.1. Pilot incapacitation

The ICAO defines in-flight pilot incapacitation in general as any reduction in the medical fitness of a pilot to a degree or of a nature that is likely to jeopardize flight safety (International Civil Aviation Organization [ICAO], 2012, I-3-1). Operationally this is any physiological or psychological state or situation that adversely affects performance. It represents an emergency situation because it includes a

Abbreviations: AAIU, Air Accident Investigation Unit Ireland; ATC, Air Traffic Control; ATSB, Australian Transport Safety Bureau; BEA, Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile; CIAIAC, Comisión de Investigación de Accidentes e Incidentes de Aviación Civil; DA, Decision Altitude; EASA, European Aviation Safety Agency; ECA, European Cockpit Association; FCOM, Flight Crew Operating Manual; FE, Flight Engineer; FO, First Officer; ICAO, International Civil Aviation Organization; PF, Pilot Flying; PM, Pilot Monitoring; SARPs, Standard and Recommended Practices; STAMP, System Theoretic Accident Modelling and Process; STPA, System Theoretic Process Analysis; UCAs, Unsafe Control Actions; UAE GCAA, UAE General Civil Aviation Authority

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significant potential for injury, loss of life, and/or severe damage of aircraft (Burian, 2008). The redundancy of two pilots on-board is lost. Thus, it is a time critical event which the remaining pilot must deal with immediately to minimize the likelihood for an accident and loss of life of the incapacitated pilot as well as the crew and passengers on board. In-flight incapacitation, as medical event, can emerge from several sources. It is primarily due to an adverse health condition of the pilot without any other factors being involved. If an external factor resulting from a technical incident causes an in-flight incapacitation the predominant event is categorized in different terms. Examples are an in-flight fire or a rapid decompression event causing hypoxia (Allison et al., 2017). We excluded these incidents and accidents from analysis because they differ in nature and causation.

An incapacitation is operationally classified as either “obvious” or “subtle” (ICAO, 2012). The obvious subtype is easy to detect because it manifests in distinct and apparent damages of health. It appears suddenly or insidiously. For example, the Captain of flight BA 5390 (Pilot Flying, PF) was sucked out of the aircraft when the window blew out due to a rapid decompression event during cruise (Air Accident Investigation Branch, 1992). Two cabin crew members secured the Captain while the FO took over control and landed the aircraft safely. A pilot can handle a sudden and obvious incapacitation more easily than a subtle incapacitation with an insidious time course of onset. The predictors of a subtle incapacitation occur frequently partial in nature and are much harder to detect. The pilot might look healthy although he is not able to conduct his duties on a good and safe level. Even the pilot himself might not be aware of his own health symptoms and reduced operational capacity. Similarly, a pilot incapacitated cognitively may be characterized as “mentally disoriented, mentally incapacitated or obstinate, while physically able and vocally responsive” (ICAO, 2012, I-3-6). Predominantly psychological and pathological issues cause a “cognitive” incapacitation. A complete loss of function can occur in all cases. Effective operational monitoring is needed to control this risk which can lead to a loss of control and operational hazard.

Every kind of commercial aircraft is built to be occasionally operated by only one pilot according to CS 25.1523 (EASA, 2015b, Table 1). Hence, every Flight Crew Operating Manual (FCOM) contains a crew incapacitation procedure among the abnormal and emergency procedures for case of need (e.g. Airbus, 2003). Personnel licensing addresses medical aspects to following extent to prevent in-flight incapacitation due to medical reasons (Evans et al., 2016). Airline transport, commercial, and multi-crew pilots have to check and renew their medical certificate (class 1) every 12 months. If they at least 60 years of age they have to renew it every 6 months. The same rule accounts for commercial pilots who are at least 40 and engaged in commercial single-crew operations and carry passengers. The 1% forms the basis for aeromedical decision making during this certification process in several countries (ICAO, 2012). It should limit the appearance of cases of incapacitation resulting in a fatal accident to 1 in 10^9 flying hours (Evans, 2016). On the basis of this rule, and calculated down to an individual pilot in commercial multi-crew operations, it does mean that for one commercial pilot on duty the maximum risk of a case of incapacitation per annum is at one percent. This rule included only cardiovascular diseases (Evans and Radcliffe, 2012). Nonetheless, physical health is addressed in all aspects in aeromedical examinations whereas the cognitive mental status is only examined if suspected. The latter is mainly left to self-report by the pilot.

In practice, the occurrence of an in-flight incapacitation is thankfully very rare (Hinkelbein et al., 2008). A systematic analysis could not be undertaken because the studies reviewed varied in their methodology that, together with a low incidence rate, made precise calculation impossible (Australian Transport Safety Bureau [ATSB], 2016; DeJohn et al., 2006; Evans and Radcliffe, 2012; Newman, 2007). There were 36 in-flight incapacitations of commercial pilots in UK in 2004 (Evans and Radcliffe, 2012). About 37% of them were due to cardiovascular events, 14% were due to cerebrovascular events whereas the remaining half events arose from predominantly psychiatric issues. Other causes of pilot incapacitation are to a large extent gastrointestinal illnesses (ATSB, 2016; Bureau d’Enquêtes et d’Analyses pour la sécurité de l’aviation civile [BEA], 2011). During flight, the “two communication” rule is applied to detect especially subtle incapacitations before they critically affect operations. It says that a flight crew member should be watchful for any signs of a subtle incapacitation at any time (ICAO, 2012). This can become apparent in a crew member not responding appropriately to verbal communication. Examples are deviations from standard operating procedures or standard flight profiles, delayed reactions or no reaction. In the case of pilot incapacitation, the crew has to execute the aforementioned crew incapacitation procedure (e.g. Airbus, 2003). The pilot calls the cabin attendant as soon as possible to immediately take care of the incapacitated pilot. An

Table 1
The regulations regarding the minimum flight crew in commercial aviation.

Regulator	Type	Text
ICAO (SARPs)	Operational	**“7. Flight crew experience, training and checking** 7.1 The State of the Operator shall prescribe the minimum flight crew experience required for night/IMC operations by single-engine turbine-powered aeroplanes 7.2 An operator’s flight crew training and checking shall be appropriate to night and/or IMC operations by single engine turbine-powered aeroplanes, covering normal, abnormal and emergency procedures and, in particular, engine failure, including descent to a forced landing in night and/or in IMC conditions.”[a]
ICAO (SARPs)	Airworthiness	“**G.2.7 Flight crew limitations** The flight crew limitations shall include the minimum number of flight crew personnel necessary to operate the aeroplane, having regard, among other things, to the accessibility to the appropriate crew members of all necessary controls and instruments and to the execution of the established emergency procedures.”[b]
EASA		“**CS 25.1523 The minimum flight crew […]** must be established (see AMC 25.1523) so that it is sufficient for safe operation, considering – (a) The workload on individual crew members; (b) The accessibility and ease of operation of necessary controls by the appropriate crew member; and (c) The kind of operation authorised under CS 25.1525. The criteria used in making the determinations required by this paragraph are set forth in Appendix D. […] **Appendix D** Criteria for determining minimum flight crew […] (b) Workload factors. […] (10) Incapacitation of a flight-crew member whenever the applicable operating rule requires a minimum flight crew of at least two pilots.”[c]

Notes. The structure of the table was guided by the structure of the international agencies.
[a] Annex 6 to the Convention on International Civil Aviation. Operation of Aircraft (ICAO, 2010, Appendix 3, p. 2).
[b] Annex 8 to the Convention on International Civil Aviation. Airworthiness of Aircraft (ICAO, 2005, IIIB-G-1).
[c] CS25 (EASA, 2015b, 1-G-2, 1-App D-1).