飛行員與駕駛艙自動化系統的相關案例學習

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近來有許多媒體針對「自動化系統」(Automated Systems)範疇，發表各種看法、研究，以及觀察等多方面的報導。本論文則討論相關案例的學習，包括自動化系統與飛行員之間的互動，其中涉及到正面與負面影響的學習領域；雖然，本文關注的焦點是飛行員，但有許多案例也適用於飛航管制員的學習。

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案例學習一：自動化系統對安全提升、作業效率，以及飛機的飛航路徑精確管理等方面，都具有重大的貢獻。然而，自動化系統與飛行員之間的互動，仍存在著負面的影響因素；包含下列所述：

- 飛行員有時候會太過依賴自動化系統，以及可能會不願意介入其系統的運作。實際上，他們授權給自動化系統，在自動化的操控之下，有時候會造成與預期飛航路徑的偏離。
- 持續發生「自動飛航模式」(Autoflight mode)的混淆疏失：自動飛航模式的選擇、認知，以及理解等方面，一直是常見的負面影響。
- 我們持續看到「飛航管理系統」(Flight Management System, FMS)的計畫與使用疏失，諸如：錯誤的計畫、錯誤的資料輸入。

案例學習二：自動化系統並不完全「自動化」。

很多時候，我們所謂的「自動化」係指駕駛艙的自動化，或是空中交通管制的自動化。無論如何，這意味著「自動化」是一種單一的系統；事實上，這是有許多不同的自動化系統裝置在飛機上(或是在空中交通管理系統上)，以及那些系統代表著不同的自動化模式與任務。Billings專家在「航空自動化」的書中描述，有三種飛機自動化的類型。第一類是飛機「操控自動化」，或是自動化的功能係在操控與導引飛機(諸如：自動駕駛系統即是操控自動化)。第二類是「資訊自動化」，或是自動化的計算、處理，以及提供相關資訊給飛航組員(諸如：移動式地圖顯示器、警告系統等)。第三類是「管理自動化」，或是管理工作的自動化。

「電子飛行包」(Electronic Flight Bags, EFBs)的運用明顯增加，成為駕駛艙運用資訊自動化的一種導引機制(諸如：電子導航圖)。由於電子飛行包持續增加，其數量與型別的運用設計也同步成長，其中有許多已經影響到飛航路徑的管理。

電子飛行包(以及其他未來的「資訊自動化」系統)，在很多方面都具有潛在的效益，特別是運用在飛航駕駛艙上，就很難找到其他的替代方法。問題是，如果不能適當的運用電子飛行包，也可能會產生負面的影響。它們可能會增加飛行員的工作負荷、增加埋首座艙的時間、分散飛航組員高優先任務的注意力，以及干擾飛航組員的溝通與協調等事宜。電子飛行包與其他「資訊自動化」系統在設計與評估階段，都必須考量這些潛在的負面影響性。

附註：空中交通管理的自動化系統，亦全部屬於「資訊自動化」範疇，同樣必須考量這些類似的潛在負面影響，諸如：工作負荷、干擾分心，以及溝通與協調等因素。

案例學習三：缺乏練習會導致基本知識與技能的退

化。

因為駕駛艙的自動化系統，導致基本飛行技能的退化已經引發關注。依資料顯示，飛行員手動駕駛飛行的知識與技能(包括「駕駛盤與方向舵」，以及認知技能等兩項)，在有些案例中，都被歸屬於脆弱領域的負面影響。雖然，自動化系統不會直接導致手動駕駛飛行的知識與技能退化 — 但缺乏練習就會。當前的自動化系統，並不會阻止飛行員用手動駕駛來操控飛機，而且美國FAA也已發佈編號13002「民航業安全通報」(Safety Alert for Operators, SAFO)，鼓勵航空公司提供飛行員的練習機會，以改善手動駕駛的知識與技能。

案例學習四：「自動化等級」是傳達自動化系統概念的一種有用術語，但可能會很難付諸實行。

很多民航業者對自動化等級的定義是，簡單而制式規定的一種分類等級模式。在獲得訓練的操作經驗，以及實際運用這些制式規定之後，有些民航業者的結論是，這種線性分類的等級定義，係屬於假設性的描述，實際上根本就不存在。自動駕駛系統的各種功能(諸如：自動駕駛、自動導航，自動油門/自動推力、飛航管理系統等)，能夠也可以單獨選用，以及選用不同的搭配組合；因此，各種功能無法簡單的描述其分類等級。基於這種經驗，這些民航業者修改了他們的政策，允許飛行員視情況選用自動化系統的功能合適組合，而不必制式化地定義它們的等級，但最高等級(所有功能都接上)，或是最低等級(所有功能都關閉)除外。

案例學習五：運用飛航路徑管理政策，而不是自動化系統政策。

很多民航業者訂有自動化系統政策，而且他們的重點也有很大的差異。政策範圍從允許飛行員運用任何他們認為合適的自動化功能，到在可能的情況之下，必須運用最高等級的自動化功能。甚至是同一型飛機，製造商所提供的理念與程序是相同的，但在不同的民航業者，卻有明顯的政策差異。這些差異來自於各種理由，其中包括民航業者的獨特歷史、文化，以及作業環境等因素。

無論如何，自動化系統的管理重點，並不會一直與飛機飛航路徑管理的重點整合，因此可能會分散聯合飛航路徑管理任務的注意力。

民航業者必須訂有明確的飛航路徑管理政策，其重點包括(但不僅限於此)如后：

- 政策必須顯著並強調，飛行員在任何時候都負有飛航路徑管理的責任。政策關注的是，飛航路徑管理比自動化系統更重要。
- 確認在適當的機會，執行手動駕駛的飛行操控。
- 確認自動化系統是一種重要的工具(其他工具之一)，用來支援飛航路徑的管理工作，以及提供運用自動化系統的作業政策。

對飛航管制員而言，類似的應用理念是 — 政策關注的是飛航任務，自動化系統只是人類運用的工具之一。

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案例學習六：在正常的操控下，運用自動化系統能降低工作負荷；但在有需求的情境下，可能會增加複雜性與工作負荷。

當前有一段長時間，飛行員經常描述高度自動化的飛機，使其工作負荷降到非常低。這顯示，在很多正常操控下，運用自動化系統可能會降低工作負荷；但在有需求的情境下(諸如：預先計畫好的飛航路徑遭到改變，執行脫離原航向的複雜程序，然後又轉回原航向以恢復程序；或是計畫與驗證「區域導航」(Area navigation, RNAV)進場時，地面滑行的指定跑道遭到改變；或是遭遇非正常或緊急程序時)，運用自動化系統可能會增加飛行員任務的複雜性與

工作負荷。在正常操控下，高度自動化的飛機可能比前幾代的飛機要容易駕駁；但在非正常的情境下，有時候反而會比較不好飛。

案例學習七：當我們必須檢視系統的複雜性，有時候我們就會歸咎於自動化的負面影響。

某些自動化系統的負面影響，係我們能夠確認而歸咎(至少部分)的證據；但從飛行員的角度來看，這些系統與它們的運作本來就具有複雜性，而不是因為系統的「自動化」而簡單視之。複雜性的領域包括：飛行員任務與系統運用的關係、飛行員的人機介面與系統的互動，以及操控涉及某些空域的程序等。未來的空域運作，預期將會變得更加複雜，並預期將會運用更多的自動化系統，以支援基於導航功能需求的操控程序。

案例學習八：小心看待自動化系統，如同另一個飛航組員。

我們聽到「飛行員夥伴」、「電子副駕駛」，以及其他類似名稱的討論。當自動化系統變得越來越有能力時，它們還不是人類。當我們認為自動化系統具有人類特質時，產生一些期望其能力與侷限的錯誤風險，以及過度依賴而導致操控的負面影響(參閱案例學習一)。

案例學習九：飛行員(和飛航管制員)在常規與發展的基礎上，降低安全與操控的風險。

最後的重點是，每天飛行員所飛的航班有數千架次之多，都能安全與有效地完成任務。他們提供適應飛航作業情境的能力，處理操控的諸多威脅，經由其他系統而發現與減輕疏失，降低裝備的限制與故障，以及提供靈活且適當的非常態與非預期的情境處理。

希望上述的九項案例學習，將能針對自動化系統激勵出一些實際問題的探討。自動化系統對航空業的安全、效率具有重大的貢獻，我們期望它們在未來能夠越來越好。雖然，我們掌握到飛行員、飛航管制員，以及其他負責安全運作的飛航人員；我們也永遠不要忘記，必須依靠專業人員、妥善訓練，以及合格的飛行員(和飛航管制員)等，在常規的基礎上執行風險降低，才能達成民航系統的安全性與有效性。

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Some lessons learned about pilots and flight deck automated systems

Dr Kathy Abbott

There has been a lot of recent press about various opinions, studies, and views on automated systems. This article talks about lessons learned, including positive lessons and vulnerability areas, with respect to automated systems and pilot interaction. Although the focus is on pilots, many of the lessons also apply to air traffic personnel.

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LESSON 1: Automated systems have contributed significantly to improvements in safety, operational efficiency, and precise management of the aircraft flight path.

However, vulnerabilities exist in pilot interaction with automated systems. These include:

- Pilots sometimes rely too much on automated systems and may be reluctant to intervene. In effect, they delegate authority to those systems, which sometimes results in deviating from the desired flight path under automated system control.
- Autoflight mode confusion errors continue to occur: autoflight mode selection, awareness and understanding continue to be common vulnerabilities.
- We continue to see FMS programming and usage errors, such as mis-programming, data entry errors.

LESSON 2: Automated systems, not “automation.

”Many times, we refer to “automation,” as in flight deck automation or air traffic automation. However, that implies that “automation” is a single system, when the reality is that there are many different automated systems on an aircraft (or in an air traffic management system), and those systems represent automation of different types of tasks. Billings described three categories of aircraft automation. The first was "control automation" or automation whose functions are the control and direction of an airplane (a system such as the autopilot is an example of control automation). The second category was "information automation" or automation devoted to the calculation, management and presentation of relevant information to flight crew members (for example, moving map displays or alerting systems). The third category was “management automation,” or automation of the management tasks.

There is significant growth in the use of Electronic Flight Bags (EFBs) as a mechanism to introduce applications of information automation (e.g., electronic navigation charts) into the flight deck. The number of EFBs is growing. The number and types of applications implemented on these devices are also increasing, many of which affect flight path management.

EFBs (and other future “information automation” systems) have the potential to be beneficial in many ways, and enable applications in the flight deck that would be difficult to provide in other ways. However, EFBs may have negative side effects if not implemented appropriately. They could increase pilot work load, increase head-down time, distract the flightcrew from higher priority tasks, and contribute to crew communication and coordination issues. These potential impacts of EFBs and other “information automation” systems need to be addressed during both design and evaluation.

Note that automated systems for air traffic are all “information automation.” Similar concerns arise with respect to potential issues with workload, distraction, and communication and coordination.

LESSON 3: Lack of practice can result in degradation of basic knowledge and skills.

There has been concern expressed about degradation of basic flying skills because of automated systems in the flight deck. The data show that pilot knowledge and skills for manual flight operations (including both “stick and rudder” and cognitive skills), are a vulnerability area in some cases. However, automated systems do not directly cause degradation in knowledge and skills for manual flight operations – but lack of practice does. The presence of automated systems in an aircraft does not prevent the pilot from flying manually, and the FAA has published a Safety Alert for Operators (SAFO) 13002 that encourages airlines to find opportunities for pilots to practice and refine those skills.

LESSON 4: ”Levels of automation” is a useful concept for communicating ideas about automated systems, but can be hard to put into practice.

Many operators define levels of automation described as a simple hierarchy in a rigid and prescribed fashion. After gaining operational experience with training and operational use of these rigid definitions, several operators concluded that such a description assumed a linear hierarchy that does not exist. The various features of the autoflight system (autopilot, flight director, autothrottle/autothrust, FMS, etc.), can be, and are, selected independently and in different combinations that do not lend themselves to simple hierarchical description. As a result of this experience, those operators revised their policies to allow the pilot to use the appropriate combination of automated system features for the situation, without rigidly defining them in terms of levels, except for the highest (everything is on) or the lowest (everything is off).

LESSON 5: Use a flight path management policy, instead of automation policy.

Many operators have an automation policy, and they vary significantly. The policies range from allowing the pilots to use whatever they consider appropriate, to policies that require use of the highest level of automation possible for the circumstances. Even operators of the same airplane type, which are supported by common, manufacturer-based philosophy and procedures, differed markedly from each other. These differences are because of a variety of valid reasons that include the operators’ unique history, culture and operational environment.

However, the focus on management of automated systems was not always well integrated with the focus on managing the flight path of the aircraft, and may distract from the tasks associated with flight path management.

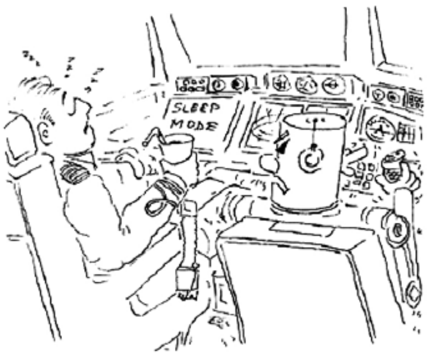
Operators should have a clearly stated flight path management policy that includes (but is not limited to) the following:

- The policy should highlight and stress that the responsibility for flight path management remains with the pilots at all times. Focus the policy on flight path management, rather than automated systems.
- Identify appropriate opportunities for manual flight operations.
- Recognise the importance of automated systems as a tool (among other tools) to support the flight path management task, and provide operational policy for the use of automated systems.

For air traffic personnel, a similar idea applies - focus the policy on the aviation task, with the automated systems as tools for the human to use.

LESSON 6: Use of automated systems can reduce workload during normal operations but may add complexity and workload during demanding situations.

Pilots often described long periods of time in modern, highly automated aircraft where workload was very low. It appears that use of automated systems may reduce workload during much of normal operations, but during demanding situations (e.g., certain phases of flight when the pre-planned flight path is changed, such as being vectored off a complex procedure, then vectored back on to resume the procedures, or programming and



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verifying an RNAV approach, change of runway assignment during taxi, or during non-normal or emergency procedures), use of the automated systems may add complexity and workload to the pilots tasks. In normal operations a highly automated airliner may be easier to fly than previous generations of aircraft but, in a non-normal situation, it sometimes is comparatively harder.

LESSON 7: Sometimes we attribute vulnerabilities to automated systems when we should look at complexity.

Some of the vulnerabilities we identify with automated systems can be attributed (at least partially) to the fact that these systems and their operations are inherently complex from the pilots' perspective, rather than simply because the systems are "automated." Areas of complexity include pilot tasks related to use of the systems, the pilot-machine interface and interaction with the system, and operating with certain airspace procedures. Future airspace operations are expected to be more complex and are expected to use more automated systems to support Performance-Based Navigation operations.

LESSON 8: Be cautious about referring to automated systems as another crewmember.

We hear talk about "pilot's associate," "electronic copilots" and other such phrases. While automated systems are becoming increasingly capable, they are not humans. When we attribute human characteristics to automated systems, there is some risk of creating false expectations about strengths and limitations, and encouraging reliance that leads to operational vulnerabilities (see Lesson 1).

Last but not least, LESSON 9: Pilots (and controllers) mitigate safety and operational risk on a regular and ongoing basis. Pilots fly thousands of flights every day that are conducted safely and effectively. They provide the ability to adapt to operational circumstances, deal with operational threats, detect and mitigate errors by others in the system, mitigate equipment limitations and malfunctions, and provide flexibility and adaptability to address non-routine and unanticipated situations.

I hope these lessons will stimulate some discussion about the practical aspects of automated systems. Automated systems have contributed significantly to safety and efficiency of the aviation system, and we expect them to do so increasingly in the future. However, we hold the pilots, controllers, and other humans in the aviation system responsible for its safe operation. We should never forget that the safety and effectiveness of the civil aviation system rely on the risk mitigation done by professional, well trained and qualified pilots (and controllers) on a regular basis.

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