駕駛艙2位組員的工作負荷管理：當自動化增加工作負荷時......

第一代噴射客機的駕駛艙，當時搭配3至5位飛航組員；現代化的客機運送更多的旅客，卻只需要2位飛航組員。檢視領航員的知識與技能，已被「飛航管理系統」(Flight Management System，文後簡稱FMS)鍵盤上的幾個按鍵所取代......

邁德 譯

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當前的數位式「甚高頻」(Very High Frequency, VHF)無線電，很容易經由飛行員與飛機系統進行運作，已經成為非常可靠、數位化控制，以及更加自動化的裝備。導航、通訊，以及系統操作變得如此「簡單」，這些工作已經能結合飛機上2位飛行員的基本操控任務，因此駕駛艙不需要增加任何其他組員。然而，這2位飛行員的操控任務，也和以往多飛航組員的作業方式不同。

有關飛行前的駕駛艙作業，諸如新科技的資料鏈，允許把飛行計畫直接上載輸入FMS，因而避免手動輸入的耗時與容易出錯的過程。運用「電子飛行包」(Electronic Flight Bags，文後簡稱EFB)的電腦程序，計算起飛性能數據，取代以往依賴「厚重書」的紙本來手動計算；相較之下，EFB的流程效率要高出甚多。然而，這些新科技所節省到的時間，卻釋放給新增加的任務所使用。

我在航空公司的飛行任務，包括飛機的外部檢查，而在以前這是飛航工程師的責任；至於載重平衡的數據計算，傳送各種飛航資料給公司，諸如：燃油裝載、乘客數量、延遲代碼等，在以前也都是航務簽派員的責任。在飛行準備階段，飛航組員所擔負的任務類型可能已被改變，但需要完成所有任務的時間卻極為相近，這就反映在飛行與責任的時間限制上。

一旦飛到了天上，他們的飛機就需要執行操控任務，「操作飛行員」(Pilot Flying，文後簡稱PF)負責導航飛行，「監控飛行員」(Pilot Monitoring，文後簡稱PM)則負責通信與系統操作。在正常操控期間，PF和PM在各個飛航階段的任務，在程序中描述的非常清楚，以及責任分配得當。飛航組員妥當運用有效的自動化系統，此時工作負荷的壓力情境，就會留有寬裕的能量給「情境察覺」(Situational Awareness, SA)來維持其有效性。

然而，如果發生非預期的情境而需要額外的注意力，此時工作負荷就會大幅度的增加。有一個很好的案例是，飛機在滑出階段時，遭遇到跑道變更的情境。許多航空公司都擁有雙發動機的飛機，但有的會規定在滑行時，使用單發動機運作；由於這些飛機的最初設計是採用雙發動機滑行，所以需要修改檢查表的順序，而使作業程序變得有些複雜。再加上滑出時遭遇到跑道改變，此時飛航組員的工作負荷明顯地增加。

在PM確定與PF確證新的滑行路線之後，PM必須停止他的主要任務 — 導引和監控PF — 而在FMS上更改離場航線，再從EFB選擇相對應的航圖，然後交互檢查此航線在航圖上與FMS有衝突的航線。接下來，PM必須轉到EFB的起飛性能模式，重新計算新跑道的起飛性能數據，然後

再把資料輸入FMS。

緊接著是PF的作業程序，必須交互檢查這些輸入資料的正確性，以及對更改的離場航線重新提示。在初始的正常滑行階段，突然變成一個高工作負荷的情境，此時可能會發生的疏失，諸如：不正確的滑行路線導致跑道入侵；性能資料的計算錯誤，以及輸入FMS的資料錯誤而導致起飛機尾觸地、或是飛機衝出跑道等意外事故。

有些民航業者採用「威脅與疏失管理」(Threat and Error Management, TEM)策略，其管理步驟中有追尋「威脅」的情境，當確定威脅涉及工作負荷的突然增加，下一個管理步驟即提供改善的措施；諸如：把滑行的飛機完全停住並靜止不動，此時PF就能更有效率地監控PM，如此他們便可完成程序改變的每一個流程。

飛航管制員擁有機場的「全景」視野，試圖把地面與空中飛機的動態做最好的規劃管理；因此，這是有時候他們會改變起飛跑道，或是離場航線的原因之一。另一個原因，則是變化不斷的氣象條件。雖然這些改變可能有利於飛航管理，但飛航管制員也必須考量到，飛航組員在更改FMS的資料輸入，重新提示新跑道、或是新離場航線等必要程序的所需時間。此外，飛航管制員可能停止滑行中的飛機，提供轉向新跑道的一個機會，結果是飛機靜止不動，以完成駕駛艙內的所有更改程序。歐洲行動計畫的預防跑道偏離(EAPPPRI 2.0)對此情境的認知是，分別提出建議給飛航組員(建議：1.4.10)，以及飛航管制員(建議：1.5.17)。

建議1.4.10	在離場滑行或進場階段，如果時間不夠用來重新規劃FMS/重新提示，飛行員不應該接受跑道變更的提議。這包括離場滑行時，交叉道的變更。

圖1：EAPPRI 2.0 — 對飛航組員的建議。

建議1.5.17	因為離場或進場的交通狀況，而規劃跑道變更時，考慮飛行員將需要準備/重新提示的時間。

圖2：EAPPRI 2.0 — 對飛航管制員的建議。

同樣的原則適用於進場程序。巴黎Charles-de-Gaulle機場是歐洲最繁忙的機場之一，有四條南北向的平行跑道與搭配的兩座南北航廈。通常兩條內跑道用來起飛，兩條外跑道用來落地。這意味著，一旦飛機落地之後，經常不得不等待機場塔台的內跑道(起飛離場)穿越許可。為了達成進場的最好規劃管理，飛航管制員有時候會改變進場程序，從北跑道進場改為南跑道進場，或是反之亦然。

類似的改變發生在起飛離場跑道，將會造成飛航組員的高工作負荷，主要的差別在於飛機的位置不能凍結，無法允許在FMS中改變落地跑道，以及檢視進場與重飛程序。有些飛機的FMS具備稱為「第二飛行計畫」(Secondary flight plan)功能，用來儲存備用機場的進場與重飛程序和航線。「第二飛行計畫」能夠在巡航階段中設置與提示，如果只需要制動幾個按鍵，飛航組員會很容易接受跑道的變更。不幸的是，飛航組員通常選擇內跑道(正常用來起飛)做為「第二飛行計畫」，因為在交通流量低的情況下，他們可以請求「偏側」(Side step)以降落在內跑道上，從而減少滑行到航廈的時間。此外，因預期航班的調度時間會減少，下一個作業部門也可能已經載入其「第二飛行計畫」。因此，即使飛機配備了第二飛行計畫功能，它將包括進場與落地跑道的備用計畫，但從飛航管制員的角度來看，與實際的落差還有一段距離。

所以越早告知飛航組員的跑道變更，他們將越有機會完成一次成功的穩定性進場與落地。從我的角度來看，直線進場的實用指南是，在距離跑道落地端的20浬之內，或是在航線最後順風邊的落地端線之後，就不應該執行落地跑道的變更。這個案例顯示，自動化系統協助減少飛行員的工作負荷，但改變了原來的計畫；此時，自動化系統增加的額外工作負荷，就必須小心地減輕之。

在培復訓階段，「組員資源管理」(Crew Resource Management, CRM)的課程中有工作負荷管理的分析與訓練。傳統的訓練重點是，2位飛行員的協調合作能力；然而，他們與空服員和飛航管制員的協調合作方式，也必須是訓練過程中的一部分。在這裡機長會模擬扮演座艙經理，或是飛航管制員的標準行為模式，以及不利於飛航組員的情境等，以完成這項訓練。幾個星期前，我曾對一位飛航組員進行訓練，在一個主要機場的最後進場階段，當飛到進場航線的10浬位置時，要求他檢查一項輕微的機務故障。在處置問題的過程中，飛航組員的飛行操控從容，也把飛機飛到理想的位置上開始進場；如果處置的情況惡化，最好也不需要飛航管制員的涉入，因為其職責是管理繼續進場的程序。

因此結論是，除非事先聲明發生「飛行異常」(PAN)，或是「快來幫我」(MAYDAY)等緊急狀況，很少授權給飛航管制員來處理這些類似的情境。較少發生的情況是，訓練飛航管制員以協助飛航組員，提供適合的待命點，或雷達導引來達成飛航任務；因此，飛航組員在一開始的瞬間，就能做好疏失管理的程序。

譯自Hind Sight 21, Workload Second Edition, Summer 2015, EUROCONTROL.。

Workload management in a 2-man flight deck: when automation increases the workload...

While the flight deck of first generation passenger jet aircraft hosted a 3 to 5 man crew, modern versions need only a 2 man crew and transport many more passengers. The knowledge and skills of the navigator are replaced by a few keystrokes on the keypad of a Flight Management System (FMS)...

Captain Dirk De Winter

Captain Dirk de Winter

has over 11,000 hours flying time gained over the last 22 years. He started as a cadet pilot with SABENA in 1987 flying Boeing and Airbus aircraft.

Before starting his flying career Dirk obtained a Masters degree in Electronic Engineering from the University of Brussels. Since January 2009 Dirk has been working part-time at EUROCONTROL.

The now digital VHF radios are easily operated by the pilots and aircraft systems have become extremely reliable, digitally controlled and much more automated. Navigating, communicating and system operation have become so “easy” that these tasks can now be combined with the primary aircraft control tasks of the two pilots without any other flight deck occupant. However these two pilots are not working in the same way as the larger crews used to.

During the pre-flight cockpit preparation, new technologies such as datalink allow the uploading of the flight plan straight into the FMS, thus avoiding the time consuming and error-prone process of manual entry. The use of computer programs on the electronic flight bag (EFB) to calculate the takeoff performance data instead of the old manual process relying on a paper “weight book” has certainly made this process more efficient. However the time saved by these new technologies has freed-up time for new tasks. In the airline I fly for, this includes the external aircraft inspection which was previously done by the flight engineer, and the calculation of weight and balance data previously done by the despatcher who also sent various flight data such as the fuel uplift, passenger numbers and delay codes to the Company. In the flight preparation phase, the type of tasks undertaken may have changed, but the time required to complete them all has remained very similar and this is reflected in the flight and duty time limitations.

Once in the air, in addition to their aircraft control tasks, the Pilot Flying (PF) takes responsibility for navigation and the Pilot Monitoring (PM) takes responsibility for communication and systems operation. During normal operations, the procedures and tasks for the PF and PM in the various flight phases are well described and evenly distributed. With good use of the available automation, the level of workload is such that spare capacity to maintain situational awareness is available.

However if an unexpected situation occurs which requires extra attention, the workload can increase considerably. A good example is a runway change during the taxi-out phase. Many airlines perform single engine taxi on their twin-jets and these are slightly more complex and change the order of set-ups and checklists because these aircraft were originally designed to taxi on two engines. Adding a taxi out runway change to this significantly increases the flight crew workload. After the PM has verified the new taxi routing and confirmed this with the PF, he needs to stop his primary task – guiding and monitoring the PF – to make the changes to the departure routing in the FMS, select the corresponding chart from the EFB and then cross-check the routing in the FMS against the routing on the chart. Next, the PM needs to go to the take-off performance module in the EFB to recalculate the performance data for the new runway and enter these into the FMS. Afterwards the PF must cross-check these entries and re-brief the changes to the departure routing. An initially normal taxi phase suddenly turns into a high workload phase where errors such as an incorrect taxi routing could lead to a runway incursion or errors in the performance calculation or FMS data entry could lead to a tail strike or even a runway excursion.

Some operators employ the Threat and Error Management (TEM) process which seeks to identify the 'threats' involved with such a sudden increase in workload and offer mitigation measures such as bringing the aircraft to a full stop and remaining stationary so the PF can more effectively monitor the PM as they complete every step of the change process.

Controllers have a “big picture” view of the airport and are trying to optimise the aircraft movements both on the ground and in the air which is one reason why they sometimes change departure runways or departure routings. Changing weather conditions are another. Whilst this is likely to also be beneficial for the flight involved, controllers should consider the time needed by the flight crew to make the necessary changes in the FMS and re-brief the new runway or departure routing. Additionally they might offer an opportunity to stop the aircraft en route to the new runway so that all consequences on the flight deck can be accomplished whilst the aircraft is stationary. The European Action Plan for the Prevention of Runway Excursions (EAPPPRI 2.0) acknowledges this issue and proposes recommendations for flight crew (REC 1.4.10) and air traffic controllers (REC 1.5.17).

1.4.10	During taxi departure or during approach, Pilots should not accept a runway change proposal if time to re-programme the FMS / re-brief is not sufficient. This includes a change of departures intersection.

Figure 1: EAPPRI 2.0 – Recommendations for Aircraft Operators

1.5.17	When planning a runway change for departing or arriving traffic, consider the time a pilot will require to prepare / re-brief.

Figure 2: EAPPRI 2.0 – Recommendations for Air Traffic Controllers

The same principle applies to approaches. Paris Charles-de-Gaulle airport; one of the busiest airports in Europe, has two pairs of parallel runways with the terminal buildings in between the Northern and Southern runway pairs. The two inner runways are usually used for takeoff and the two outer runways are usually used for landing. This means that once landed, aircraft often have to hold short of the inner (departure) runway to await crossing clearance from the tower controller. To optimise the arrival sequence, controllers sometimes change the approach from the Northern to the Southern runway or vice versa. Like a change in departure runway, this generates a high workload for the flight crew with the major difference that the aircraft position can't be frozen to allow for a change of the landing runway in the FMS and a review the approach and go-around procedure. Some aircraft have a FMS functionality called "secondary flight plan" to store the routing for the approach and go-around procedure for an alternate runway. This "secondary flight plan" can be set up and briefed during the cruise and if required activated with just a few keystrokes making it easier for the crew to accept a runway change. Unfortunately crews often choose to enter the inner (normally the take off) runway into the "secondary flight plan" because in low traffic situations they could request a 'side step' to land on the inner runway and thereby reduce taxi-in time. Also, in anticipation of a short turnaround, the next sector might have already been loaded into the "secondary flight plan". So even if the aircraft is equipped with this secondary flight plan functionality, it's far from sure that it will contain the amended approach and landing runway which the controller has in mind. So the sooner the flight crew is advised of this runway change, the more chance there is that the flight crew will be able to complete a successful stabilised approach and landing. In my view, practical guidance for a straight-in approach is that the landing runway should not be changed once the aircraft is within 20 track miles of the threshold or beyond a late downwind position abeam the landing threshold. This case shows that automation assists in reducing pilot workload but that when there is a change to the original plan; automation creates extra workload that requires careful mitigation.

In recurrent training, workload management is analysed and trained as part of the crew resource management (CRM). Traditionally, the focus is on how the two pilots cooperate.

However the way they cooperate with the cabin crew and ATC should also be part of the training process. Here a Training Captain would simulate normal cabin manager or air traffic controller behaviour and not facilitate the flight crew to complete the exercise. A few weeks ago, I had a flight crew under training who requested a hold on a 10 mile final to a major airport in order to investigate a minor technical problem. Whilst this makes the navigation task of the flight crew easier and places the aircraft in an ideal position to start the approach if the situation deteriorates, it is not necessarily an optimal position for the controller who has to manage his arrival sequence.

Consequently, there's little chance a controller would authorise such a request without the prior declaration of a PAN or MAYDAY. In lesser situations, controllers are trained to assist flight crew and facilitate the navigation by offering suitable holding fixes or radar vectoring so that the flight crew can swiftly begin the failure management process.

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