找到一個立足點

疲勞風險管理系統（FRMS）在航空維修領域尚無重大進展。

黃德春 譯

美國FAA民航航太醫學機構的一份報告指出，航空維修單位雖有獨特機會使用若干對抗疲勞的最有效方式，但實施正式的疲勞風險管理系統（FRMS）的速度卻相當緩慢。

航空維修人員經常在夜間及未受法規約束的執勤時間工作，這些情況都容易產生疲勞，該報告說。

美國飛安基金會主管技術計畫的副處長及擔任FAA維修疲勞工作小組成員的Rudy Quevedo表示，航空公司的併購和經濟波動已造成許多維修技術人員的壓力增加、工作時間更長，但睡覺的機會卻更少，他們之中有些人還兼職另外一項工作。

Quevedo在東方航空擔任機械員而展開他的職業生涯，他說有的時候他執勤的時間長達24小時；雖然公司並未制定正式的小睡政策，但必要時，他和同事會小睡。

FAA的報告指出，許多維修工作－“尤其是涉及專注的目視注意力，溝通或大量仰賴記憶的工作”－特別容易受到疲勞的影響。

疲勞風險管理系統（FRMS）通常可對付諸如在駕駛飛機的“持續操控工作”中睡著的威脅。然而，該報告說，睡著並非航空維修人員所面臨的主要危害。而最大的威脅乃是涉及疲勞所損害的心理功能，以及它會導致維修疏失的可能性。

「雖然此項差別看似微不足道，但對航空維修的疲勞風險管理卻有重要的意涵，」該報告說，以維修為導向的疲勞風險管理系統和飛航組員的疲勞風險管理系統兩者的方法與目標是不相同的。

例如，由於維修工作的特色乃是「自訂工作步調而非由外部來制定其步調」，因此一位維修機械員在體認到他或她已處在疲勞情況下，必要時，「也許能夠暫停一項工作，犧牲速度以換取準確度或重複一項步驟」。

在某些情況下，維修人員可能也有機會修改工作績

效，或許藉由引進工作單的使用或操作/功能檢查，或在一天當中比較不會疲勞的時段執行要求較高的工作，該報告指出。

此外，該報告說，維修人員通常不會跨越時區，因此不會經歷時差和旅行相關的生理時鐘干擾—這是時常困擾駕駛員和空服員的兩項問題。

因此，該報告補充說，維修組織也許能夠使用更多的解決方案來應付他們的疲勞問題。

該報告引述疲勞風險管理的三項目標：降低疲勞、降低和疲勞有關的疏失或識別疏失並加以改正，以及限制因疏失而造成的損害。

Quevedo表示彈性很重要，絕對限制工作時數實施對下列人員而言可能不是最佳選項：須準時完成額外維修工

作的員工，或了解如何調整工作績效以弭補疲勞的員工。

「最終，必須有疲勞風險管理系統，」他說，「當情況不再一如往常時」它將特別有用。

連續工作52天

降低疲勞的方法包括限制員工的服勤時數（HOS）。美國聯邦航空法規規定只有從事第121部（譯註：指美國籍）航空公司飛機的維修機械員“在任何七個連續工作天內至少需連續休息24小時，或在任何一個曆日月份內，休息等量的時數。”

「事實上，」該報告說，「在連續兩個月期間內，一個人可以連續工作長達52天，而仍然符合法規要求。」

該報告指出，僅有少數幾個國家實施特別限制。例如：

※紐西蘭民航局規定維修人員在執行工作之前至少必須休息八小時，而且在前一個月至少有24小時的休息。

※中國民航總局規定維修人員每天工作不得超過八小時，而且每星期加班不得超過36小時。

依據今年六月份生效的規定，澳洲民航局並未限制工作時數，但卻規定「維修組織若允許受到疲勞影響或對精神有顯著影響物質所削弱的維修人員在航空公司的飛機上執行維修工作即屬違法，」該報告說。

為英國民航局所制定的最佳作法指引－它本身並未規定工作限制－要求含加班在內的12小時輪班不得延長超過13小時，而且每四小時需休息一次。維修人員在兩次輪班之間至少應有11小時的休息，而且他們在一個月之前就應事先被告知排班情況。

該項指引雖未納入英國民航局的法規，但卻編入第145部（譯註：維修廠）的一份民航通告（AC），並納入國際民航組織（ICAO）所頒發的指引。

科學排班

降低疲勞的另一種方法乃是科學排班，它包含一軟體模型系統以便估算一特定排班型態可能會造成的疲勞程度。

「軟體模型…能考量警覺性的全天變化和所獲得的睡眠，以便產生某一排班型態可能會造成的疲勞程度之估算，」該報告說，「當被用來做為排班工具時，軟體模型擁有比服勤時數（HOS）限制提供更大彈性之優點。」

該報告引用疲勞稽核（FAID）模型做為範例，指出它考量員工在七天內的工作和休息時間並賦予零和140之間的一個疲勞分數。典型而言，員工得分在80以下時表示他們執行工作“通常是安全的”，該報告說，但分數高於80可能表示一種“不安全的情況”。

然而，該報告補充說，美國FAA的研究顯示分數低到60分仍可能表示和疲勞有關的風險。

疲勞模型通常被用於飛行組員的排班，但該報告並未指名的一家航空公司亦使用疲勞稽核（FAID）來評估維修工作的排班及協助排班設計。

該報告亦引述計畫的20至40分鐘的小睡以做為對抗疲勞的一種主要減輕方法，但承認「以小睡做為維修方面對抗疲勞的措施可能會面臨航空公司和民航主管機構的抵制」。

此外，該報告建議將疲勞相關的教材和可接受的對策提供給員工乃是一個組織能夠影響員工以降低因生活方式而造成疲勞的僅有少數方法之一。

歐洲民航局（EASA）將疲勞納入維修人為因素訓練應涵蓋的主題之中，而且某些民航主管機關，包括加拿大和英國的民航局以及FAA，已頒布疲勞方面的教材－其中有些不只針對維修人員，並且針對他們的督導人員、未從事維修工作的同僚，以及家庭成員。

疲勞風險管理系統的某些指引呼籲工作人員若認為他們太過疲勞而無法遂行其職務時應該請“疲勞休假”，但該報告承認此一觀念可能無法立即被接受。

「各組織需要權衡員工未計畫的缺席所造成的工作中斷和員工在受到疲勞影響下出勤而可能造成的潛在傷害兩者之間的輕重，」該報告說。

第二道防線

由於疲勞不能排除，該報告建議「第二道防線，其目標係為了降低疲勞員工犯錯的機率。」

首先，教導工作人員監控他們的疲勞程度，利用能夠裝在手持裝置或手機的一種疲勞評分計或心理性肌肉運動的績效測試來克服自我認知的不正確性。該報告提及目前被用於卡車行業的各種警覺性監控裝置可能終究會被納入疲勞風險管理系統。

為了降低疲勞程度，工作中的休息－尤其是那些包括短暫行走的休息－能提供暫時的紓解，暴露於新鮮空氣或涼爽空氣與乾燥空氣中也能獲得相同效果，該報告引述稍早的研究。亮光也能降低疲勞和疲勞有關的疏失，而且若能依照準確的時程使用，則各研究已顯示咖啡因能降低疲勞達二小時左右。

以工作為基礎的行動

降低疲勞有關疏失的其他做法著重改變所指派工作的某些方面－這是鮮少受到注意的區塊。

「以工作為基礎的做法係根據此項觀念－維修工作沿著一連續線上產生變化，從極易受到疲勞影響的工作到較少受到疲勞影響的那些工作，」該報告說。「以工作為基礎的做法…會涉及兩項互補的策略：改變執行工作的時機和改變如何執行該項工作。」

研究已找出最容易產生和疲勞有關疏失的工作類型，包括單調或是非常熟悉的工作。其他極容易受到疲勞影響的工作則是檢驗工作，因這些工作需要「極度的、持續專注」，在昏暗環境中所值執行的工作，以及「不正確的完成並不能明顯看出」的那些工作，該報告說。

當多數維修組織在擬定工作班表時並不會考慮一項工作容易受到疲勞影響的程度，但是個別的維修人員有時會有「在一天的某個時間執行工作的非正式基準，」該報告說，指出他們的程序可能涉及在一次輪班的開始執行最具挑戰性的工作。

「在多數大型組織內，〔維修人員〕對他們在輪班的工作時機之掌控是有限的，但領工、領班、或計畫人員對在一天的某個時段執行某項工作可能會有若干影響。」

某些工作能夠「不受疲勞影響，或經修改以便降低發生和疲勞有關疏失的可能性或增加此類疏失會被偵測到的可能性，」該報告說，並提到加拿大民航局建議在執行容易受到疲勞影響的工作時應使用下列不受疲勞影響的策略：

※在嚴密監督下工作；

※以成雙或小組方式工作；

※工作輪替；

※使用檢查表；

※使用有經驗的人員來支援新人；以及

※在換班時實施任務提示。

來自其他來源的建議要求制式化的自我檢查，操作或功能檢查，或對如下工作實施獨立檢驗：特別容易受到疲勞影響的工作或在昔日曾經因為疲勞而致執行不正確的那些工作。其他研究呼籲已休息的人員去檢查在生理時鐘低潮時段－當地時間0300與0600之間－所執行的工作。

將傷害降至最低程度

體認到儘管努力要防止和疲勞有關的疏失之發生，但它們還是會出現；該報告說「最後一道防線」應限制這些疏失所造成的損害。

「將傷害降至最低程度和在先前段落所描述的干預行動不同，因為前者的焦點是在疏失後果的嚴重性，而非疏失的機率，」該報告說。「就維修疲勞方面而言，將傷害降至最低程度涉及不讓最疲勞的人員插手在安全方面最重要的工作。」

該報告說，例如，飛行操縱系統的工作不會分派給在生理時鐘低點的維修人員，但會將較不重要的工作分派給他們。「此項做法不會防止維修人員在他們被分派的工作上產生和疲勞有關的疏失，但會降低該項疏失的可能後果。」

該報告說雖然在許多案例中，服勤時數（HOS）限制和科學排班模型已被分開使用並且被視為解決工作疲勞時只能選擇其中的一種方法，但可將它們納入單一專案計畫中。服勤時數限制可建立服勤時間的“外部界線”而科學排班模型則形成在界線以內的特定排班基礎。

「除了服勤時數（HOS）限制之外，一個維修的疲勞風險管理系統將包括一系列的干預措施俾處理派工、工作環境和人員執勤的健康狀態，」該報告說。「不論使用何種疲勞風險管理做法，組織所有階層的承諾很重要。上級管理階層有責任明確陳述疲勞的政策，包括在公正文化之下如何處理和疲勞有關的事件。」

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Finding a Foothold

FRMS has not yet made major inroads in aviation maintenance.

Linda Werfelman

Aviation maintenance organizations have been slow to implement formal fatigue risk management systems (FRMS), despite their unique opportunities to employ some of the most effective types of fatigue countermeasures, according to a report by the U.S. Federal Aviation Administration (FAA) Civil Aerospace Medical Institute.[1]

Aviation maintenance personnel work in conditions that are conducive to fatigue, often at night and with unregulated duty hours, the report said.

Rudy Quevedo, Flight Safety Foundation deputy director of technical programs and a member of the FAA Maintenance Fatigue Working Group, said airline mergers and general economic upheaval have resulted in increased stress, longer work hours and fewer opportunities for sleep for many maintenance technicians, some of whom have taken second jobs.

Quevedo, who began his career as a mechanic for Eastern Airlines, said that at times, his shift extended for 24 hours or longer, and that, when necessary, he and his colleagues took short naps, although the company had no official napping policy.

The FAA report noted that many maintenance tasks — "especially those involving intense visual attention, communication or a heavy reliance on memory" — are especially susceptible to fatigue's effects.

FRMS usually addresses the threat of falling asleep during a "continuous-control task" such as piloting an aircraft. However, falling asleep is not the primary hazard facing aviation maintenance personnel, the report said. Instead, the greatest threat involves fatigue-impaired mental functioning and the possibility that it will lead to

maintenance errors.

"This distinction, while seemingly trivial, has important implications for fatigue risk management in aviation maintenance," the report said, adding that it follows that the methods and goals of a maintenance-oriented FRMS will differ from those of a flight crew FRMS.

For example, because maintenance tasks typically are "self-paced rather than externally paced," a maintenance technician who recognizes that he or she is fatigued "may be able to pause a task, trade speed for accuracy or repeat a step, as necessary," the report said.

Maintenance personnel also may, in some cases, have opportunities to modify task performance, perhaps by introducing the use of task cards or operational/

functional checks or performing demanding tasks at times of day when fatigue is less likely, the report said.

In addition, the report said, maintenance personnel usually do not travel across time zones and therefore do not experience jet lag and travel-related disruption of their circadian rhythms — two problems that often plague pilots and flight attendants.

As a result, the report added, maintenance organizations may be able to employ a greater number of solutions to their fatigue problems.

The report cited three objectives of fatigue risk management: reducing fatigue, reducing the number of fatigue-related errors or identifying the errors and correcting them, and limiting the harm caused by errors.

Flexibility is crucial, Quevedo said, adding that an absolute limit on the number of hours worked might not be the best option for either an employer that has extra maintenance work that must be completed on time or employees who understand how to adjust their task performance to compensate for fatigue.

"Eventually, there'll have to be FRMS," he said, adding that it would be especially useful "when it's not business as usual."

'52 Days Straight'

Methods of reducing fatigue include limiting an employee's hours of service (HOS). U.S. Federal Aviation Regulations say only that maintenance technicians working on Part 121 air carrier aircraft must be off duty for "at least 24 consecutive hours during any seven consecutive days, or the equivalent thereof, within any one calendar month."

"In effect," the report said, "a person could work up to 52 days straight, in a period of two consecutive months, and still be in compliance with the regulation."

Only a few countries apply specific limits, the report said. For example:

- The New Zealand Civil Aviation Authority says that maintenance personnel must have had at least eight hours off duty before performing work and at least four 24-hour periods off in the preceding month.
- The Civil Aviation Administration of China says maintenance personnel may work no more than eight hours a day and 40 hours a week. Under special circumstances, they may work as long as 11 hours a day, but monthly overtime may not exceed 36 hours.

The Civil Aviation Safety Authority of Australia, under regulations that took effect in June, does not limit work hours but instead "makes it an offense for a maintenance organization to permit a maintainer who is significantly impaired by fatigue or a psychoactive substance to carry out maintenance on an airline aircraft," the report said.

Best practices guidelines developed for the U.K. Civil Aviation Authority (U.K. CAA) — which does not itself prescribe work limits — call for 12-hour shifts that, with overtime, should be extended to no longer than a total of 13 hours, with a work break every four hours. Technicians should have at least 11 hours off between shifts, and they should be informed of their work schedules a month in advance.[2]

While not incorporated into U.K. CAA regulations, the guidelines were included in an agency advisory document for Part 145 operators and in guidance issued by the International Civil Aviation Organization.

Scientific Scheduling

Another method of reducing fatigue is scientific scheduling, which incorporates a software modeling system to estimate the level of fatigue likely to result from a specific scheduling pattern.

"Software models ... can take into account circadian variations in alertness and sleep obtained, to produce an estimate of the fatigue level that may result from a particular shift pattern," the report said. "When used as scheduling tools, software models have the advantage of offering greater flexibility than HOS limits."

The report cited the Fatigue Audit InterDyne (FAID) model as an example, noting that it considers employee work and break times for a seven-day period and assigns a fatigue score of between zero and 140. Typically, employees who score less than 80 are

"generally safe" to perform their jobs, the report said, but scores of more than 80 may indicate an "unsafe condition."

The report added, however, that research by the U.S. Federal Railroad Administration has indicated that scores as low as 60 may indicate fatigue-related risks.

Fatigue models generally have been used in flight crew scheduling, but one airline, which the report did not name, also has used FAID to evaluate maintenance work schedules and to help in schedule design.

The report also cited planned naps of 20 to 40 minutes as a key mitigation for fighting fatigue but acknowledged that "napping as a fatigue countermeasure in maintenance may face resistance from airlines and regulators."

In addition, the report suggested that providing employees with educational material about fatigue and acceptable countermeasures is one of only a few methods by which an organization can influence employees to reduce fatigue that results from lifestyle choices.

The European Aviation Safety Agency includes fatigue among the topics that should be covered in maintenance human factors training, and some civil aviation authorities, including Transport Canada, the U.K. CAA and the FAA, have published educational material on fatigue — some of it aimed not only at maintenance personnel but also at their supervisors, non-maintenance co-workers, and family members.

Some FRMS guidelines call for workers to take "fatigue leave" if they believe they are too fatigued to perform their duties, but the report conceded that the concept may not be readily accepted.

"Organizations need to weigh the potential disruption caused by an unplanned absence with the potential harm that could result when an employee reports for duty impaired," the report said.

A 'Second Line of Defense'

Because fatigue cannot be eliminated, the report recommended "a second line of defense, with the objective of reducing the probability of error among fatigued workers."

First, workers are taught to monitor their level of fatigue, overcoming the inherent inaccuracy of self-perception by using a fatigue rating scale or psychomotor performance tests that can be installed on hand-held devices or smartphones. The report noted that various alertness monitoring devices now being used in the trucking industry may eventually be incorporated into an FRMS.

To reduce levels of fatigue, work breaks — especially those that include a brief walk — can provide temporary relief, as can exposure to fresh air or cool, dry air, the report said, citing several earlier studies. Bright light also can reduce fatigue and fatigue-related errors, and caffeine, if used according to a precise schedule, can reduce fatigue for about two hours, studies have shown.

Task-Based Action

Other efforts to reduce fatigue-related errors emphasize changing some aspect of the assigned task — an area that has received relatively little attention.

"Task-based approaches are based on the idea that maintenance tasks vary along a continuum, from tasks that are highly susceptible to fatigue to those that are less susceptible," the report said. "Task-based approaches ... can involve two complementary strategies: changing when the task is performed and changing how it is performed."

Research has identified the types of tasks most prone to fatigue-related errors, including tasks that are monotonous or very familiar. Others that are highly susceptible are inspection tasks, tasks that require "intense, continuous concentration," those performed in a darkened environment and those in which "incorrect performance is not immediately obvious," the report said.

Most maintenance organizations do not consider the fatigue-susceptibility of a task when they develop work schedules, but individual maintenance technicians sometimes have "informal norms concerning the time of day at which tasks are performed," the report said, noting that their procedures may involve performing the most

challenging tasks at the beginning of a work shift.

"In most large organizations, [maintenance personnel] have limited control over the timing of tasks throughout their shift, yet crew leads, foremen or planning personnel may have some influence on the time of day at which certain tasks are performed," the report said. "It is critical, therefore, that such personnel have an awareness of the effects of fatigue on human performance."

Some tasks can be "fatigue-proofed," or modified to reduce the likelihood of fatigue-related errors or to increase the likelihood that such an error will be detected," the report said, noting that Transport Canada has recommended that the following fatigue-proofing strategies be used when performing tasks that are susceptible to fatigue:

- Work under close supervision;
- Work in pairs or teams;
- Rotate tasks;
- Use checklists;
- Use experienced personnel to provide support for new personnel; and,
- Conduct briefings when shifts turn over.

Recommendations from other sources call for formalized self-checks, operational or functional checks, or independent inspections for tasks that are especially susceptible to fatigue or those that have been performed incorrectly in the past because of fatigue. Other research calls for rested personnel to check work that has been performed during the window of circadian low — between 0300 and 0600 local time.

Minimizing the Harm

Recognizing that fatigue-related errors occur despite efforts to prevent them, the report said that a "final line of defense" should limit the damage that results from these errors.

"Harm minimization differs from the interventions described in the preceding sections, as the focus is on the severity of the error's consequences, rather than the probability of error," the report said. "Harm minimization in the context of maintenance fatigue involves keeping the most safety-critical tasks out of the hands of the most fatigued people."

The report said that, for example, work on flight control systems would not be assigned to maintenance personnel during their circadian low point, but they would instead be given other, less critical tasks. "This approach does not prevent maintainers from making a fatigue-related error on whatever task they are assigned but reduces the likely consequences of that error."

The report said that although, in many cases, HOS limits and scientific software scheduling models have been used separately and viewed as competing methods of addressing workplace fatigue, they can be incorporated into a single program. HOS limits can establish the "outer bounds" of duty times while scientific scheduling models form the basis of specific schedules within the bounds.

"In addition to HOS limits, an FRMS for maintenance will include a range of interventions addressing the task, the work environment and the fitness for duty of personnel," the report said. "Whatever approach to fatigue risk management is applied, commitment from all levels of the organization is essential. Upper management has a responsibility to state a clear policy on fatigue, including how fatigue-related incidents will be dealt with under a just culture."

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