運用工作負荷數據來管理改變的推行：界定安全工作負荷的極限

這個世界有很多好的建議：聽取使用者的需求；在設計過程中納入作業控管者的意見；辦理正規的人為錯誤分析；提供在不同工作負荷狀態下的高擬真度模擬與其他種種－但是如果這些還是不足時該怎麼辦？

孟磊 譯

2012年間，英國空中交通服務在Prestwick區域管制室成功地導入電子化飛航資訊(EFD)，EFD對於先前的紙本作業而言代表著一個顯著的改變，同時也是英國空中交通服務邁向全面電子化作業旅程的更進一步。

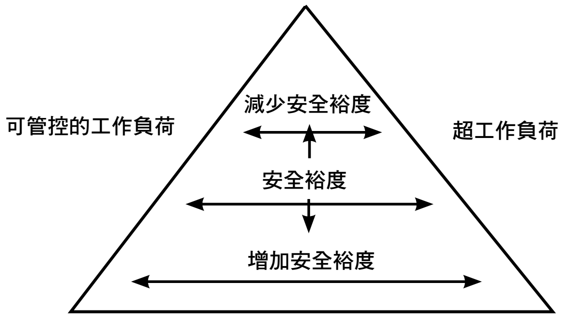
由於系統性質不同(從紙本到螢幕)、工作習慣的改變與在複雜的社會科技系統中對於實際作業的驗證模擬的局限性，在Prestwick區域管制室啟用EFD引發重大的挑戰。

這項作業推行的初次嘗試部分由於工作負荷的因素而暫時收手，不過，也由於一些對於人類表現的明確量測標準的創新做法以及部分管制員與第一線督導人員實質的支持，EFD得以成功地被導入到整個服務作業中。

工作負荷的安全裕度

當要在實際的作業中推行新的技術時，系統中有很多必須加以考量的層面，好比說所牽涉的角色(例如計畫者/執行者/協助者/監督者)、航段的類型、交通流量/複雜度、應變、移交、協調、航機緊急狀況、穩定狀態、多重角色，與合併及分割航段。

而且在評估或驗證模擬環境中的新設計時，由於模擬的擬真度存在著諸多限制(就算是高擬真度的模擬器也是有其限制性的)，在設定的時間內所運行的次數與管制員本身所具備的技能、無法被複製的關鍵角色(例如因為某些模擬器的限制而無法複製的督導角色)、不同系統間的交互聯結(例如獨立的作業)、與實際航班/駕駛員互動的重現、天氣、管制員的經驗與他們對於新系統的經驗/訓練，還有更多不及備載的。



工作負荷增加時對安全裕度的侵蝕

因為這些限制，當新系統被引進到實際作業時，了解在模擬環境中所觀察到的工作負荷安全裕度可能不同於實際世界中是很重要的，所以必須盡快地與盡可靠地界定出在實際世界的系統中，可控制的工作負荷與超工作負荷之間的緩衝區到底有多大。

當啟用新系統時，工作負荷安全裕度的改變被比作固定翼飛行器的所謂“Q”角(當高度增加時，失速速度與超限速度間的差距變小)，當系統是新的而改變又很重大時，要界定出超工作負荷的觸發點變得更加困難，因此可控管的工作負荷與超工作負荷間的差距可能縮小，而成為更難以預期與因應的“懸崖邊緣”。

想要在實際運行中界定與定義出工作負荷安全裕度的改變是極其難以達成的，不過英國空中交通服務就是一直致力於以創新的方法使得因工作負荷增加時而受到侵蝕的

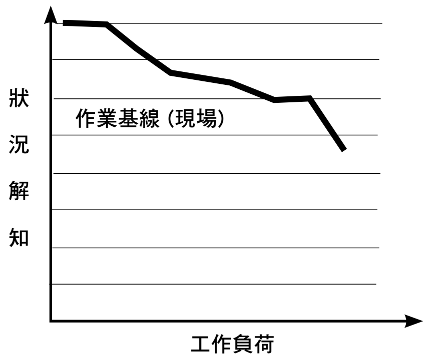
安全裕度能盡快回復。

作者Nic Turley是一位有著超過20年應用人為因素於採購、開發與運用於複雜安全關鍵系統經驗的人為因素專家，在加入NATS之前，Nic任職於參與皇家海軍戰艦、攻擊潛艦與偵查系統開發與重大國防與鐵路採購的大型IT顧問公司，Nic現任NATS 中負責安全文化策略的人為因素部門副主管，同時也是人為因素團隊技術標準的評估員。

發展

此EFD作業開始於一個內部工作負荷尺規的開發案；在18個月中，針對普雷斯威克與史萬威克的英國空中交通服務中心(包含終端管制與沿路管制)的空中交通管制員日常實際作業中收集了超過18,000份數據點。

第二個量尺則是與工作負荷尺規一同引進的關於管制員的狀況解知，從現場作業中更進一步收集數據點，在同時期中工作負荷與狀況解知的分數被一起評估，作為判斷高於安全程度的狀況解知時的工作負荷等級為何，這提供了一個比較不同系統間所能承受工作負荷等級的方法。



從解讀出高工作負荷分數與狀況解知間的關鍵點在於管制員覺得難以維持一個 “概觀”(在NATS內部用以形容一個人能夠維持充分的狀況解知能力以管控現在與未來預期的交通景況)，如果這個能運作的話，那麼就能在引進新系統時提供一個保護安全裕度的方法：保持工作負荷低於一個已知的關鍵程度可以(理論上)確保狀況解知保持在一個特定可接受的程度以上，使得系統可以持續安全地運作。

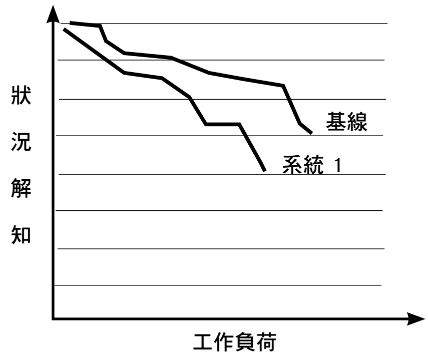
EFD的採用

從服務中暫時停止EFD提供了一個機會，我們有來自於不同來源的數據：模擬；實際作業；推行前模擬；推行中的現場作業與回復到紙本後的現場作業。這些數據庫提供了從初始引進EFD與後續回復到紙本作業時所發生的事件的明確內容。

這意味著我們現在已經對現行的作業型態(基線)有了清楚的 “概念” ，可以互相比較也不會再 “盲目地” 推行了，數據顯示在EFD作業中，在同等工作負荷下，管制員面臨不滿意的狀況解知分數的時間高於現行作業。

有一個非常明確的發現是有關於僅使用模擬中的工作負荷數據而沒有狀況解知指標造成的限制，一個明顯的限制是有關於關鍵工作負荷因素未被複製(例如電話打斷計畫者的作為)，在現場作業中被歸類為高工作負荷的實際交通景況在模擬器中並未能引發管制員相同的工作負荷經驗。

作者Brian Janes現任NATS直屬作業主任之下的獨立人為因素確認主管，Brian 10年前加入NATS，歷任多個技術與人資管理職位，包含人為因素小組的代理副主管，他的技術專長包含使用者介面、互動設計、安全分析與驗證。



在實際服務中再度引進EFD

為了便於將EFD再度引進到實際服務中，必須確認效率與優化以降低任務需求，這些包括：

- 電子化的(前置)協調
- 初始空層的自動化分配
- 自動轉入前段的航向與速度數據
- 數據輸入
  - 航向、空層與速度
  - 協調
  - 大洋空域許可時間

· 減少干擾

這些改變是經由與管制員核心群組密切共事所確認與執行以確保其效率。

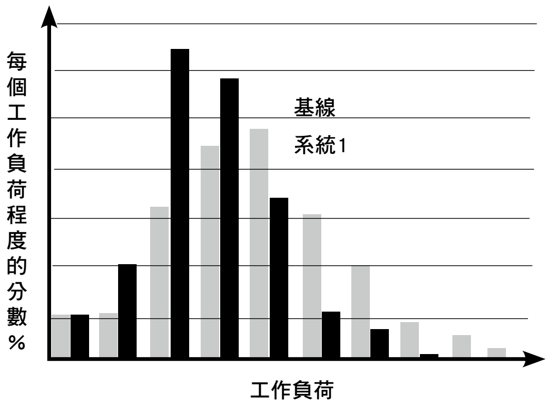
實際作業驗證

EFD被重新引進於一段時間內的限定服務作業中，督導被賦予任務將管制員的工作負荷維持在或低於依據內部工作負荷尺規工具所規範的低-中程度(數據顯示在該工作負荷程度下管制員可以維持良好的狀況解知)。

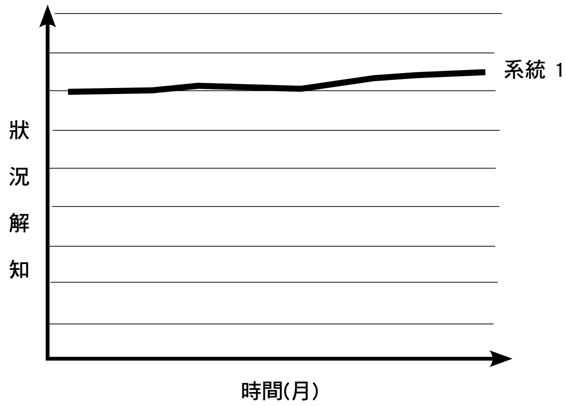
督導們有管控工作負荷的專業(是他們日常工作的一部份)並運用大量的資訊來支援這樣的任務(例如交通資訊；上班管制員人數；航段的組態；特定航段的問題等等)，在每個管制任務時段結束時，管制員報告他們所經歷的工作負荷與狀況解知程度，這些都被回饋到作業經理或督導處以確保工作負荷與狀況解知程度都被維持在可接受的限度內。

為了提供完整的安全保證，在每個EFD作業期間都有一個紙本備份小組，以便在任何時間點回復紙本作業(不管是由督導或管制員所促使)。

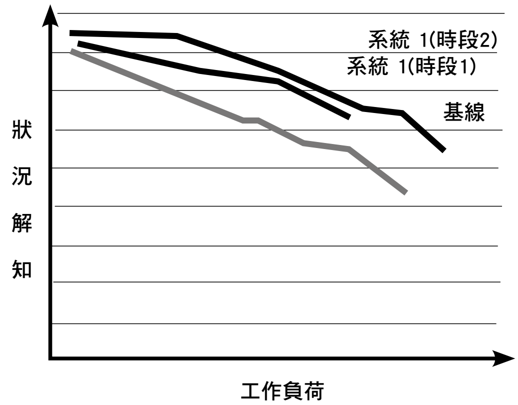
從這些數據，督導可以更清楚地維持管制員的工作負荷在所希望的範圍內，一個緩衝區已被建立，這段期間沒有超工作負荷的報告。



這段期間90%的狀況解知分數是“良好”或以上(非常接近基線的91%“良好”或以上)，整段期間，當工作負荷維持在低或中等程度時，狀況解知分數的提高明顯可見，這被用以指出有關工作負荷緩衝區的逐漸加大，可能由於對新系統熟悉度已提高。



由於“看到”進步的發生，因此可以逐步的提高所規範的工作負荷程度，透過持續的回饋可知狀況解知並未被侵蝕，這個改進可從不同時間點工作負荷/狀況解知曲線圖看見。



在幾個月後，紙本備份被移除而實際作業上EFD的應用持續增加直到所有管制員全時程使用EFD，交通管理也能夠與使用舊系統時達到同樣的等級。

因為這項成功，這個流程被複製到更多計畫(例如iFACTS、2012倫敦奧運、空域改變)，在過去計劃推行中所遭遇的問題(例如超工作負荷)並未再發生，我們現在已有來自實際作業的基線數據(現行系統的運行狀況)、來自模擬的更精確數據、更快的應用於有限的飛航服務(因為我們已知管制員能保持安全的工作負荷程度也有清楚的指標告知何時需要調整這些等級)。通過這個途徑，更大量的數據可以被收集(例如以千為單位的，超過100位以上的參與者)，刻正研究如何擴大運用這項技術於實際作業的監控中。

譯自HindSight 21 Summer 2015

Defining the limits of safe workload

The world is full of good advice: derive user requirements; involve operational controllers in the design process; conduct formal human error analyses; provide high fidelity simulations under varying workload conditions and so on – but what happens when this is not enough?

Nic Turley and Brian Janes

In 2012, NATS successfully introduced Electronic Flight Data (EFD) into the Prestwick Area Control room. EFD represented a significant change from previous paper operations and was another step on NATS' journey towards fully electronic operations.

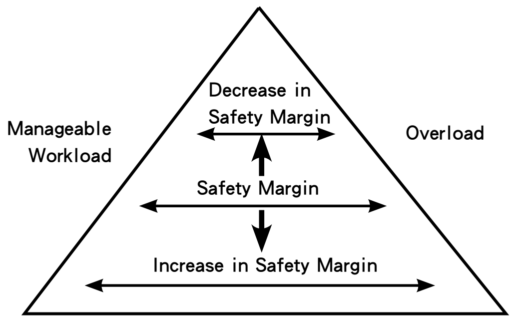
The deployment of EFD at Prestwick posed significant challenges due to the nature of the system (paper to glass), changes to working practices and the limitations of simulations in the validation of complex socio-technical systems for live operations.

The first attempt at deployment was temporarily withdrawn from service due, in part, to workload. However, with the innovative application of some straightforward Human Performance measurements to define the safe limits of workload and some practical support from controllers and front line supervisory staff, EFD was successfully introduced into full operational service.

Safety Margins of Workload

There are many different aspects of a system that need to be considered when implementing new technology into live operations safely and efficiently such as the different roles involved (e.g. Planner/Executive/Assistant/Supervisor), sector types, traffic volumes/complexity, fallbacks, handovers, coordination, aircraft emergencies, steady state, combined roles, and combining and splitting sectors.

Also, when evaluating or validating a new design in a simulated environment, there are limitations due to the fidelity of the simulation (even high fidelity simulators are limited), the number of runs within the allocated timeframe, the number and skillset of controllers available, critical roles that cannot be replicated (e.g. supervisor roles not replicated due to limitations of some simulators), interconnection between systems (e.g. operating as standalone), replication of real life traffic/pilot interaction, weather, the experience of the controllers and their experience/training with the new system. The list goes on.



Erosion of Safety Margin as Workload Increases

Because of these limitations, when new systems are being introduced into service it is important to understand that the safety margins for workload observed in the simulated environment may be different to those observed in the real world. It is therefore critical to identify the size of the buffer between manageable workload and overload in the real world system as quickly and as reliably as possible.

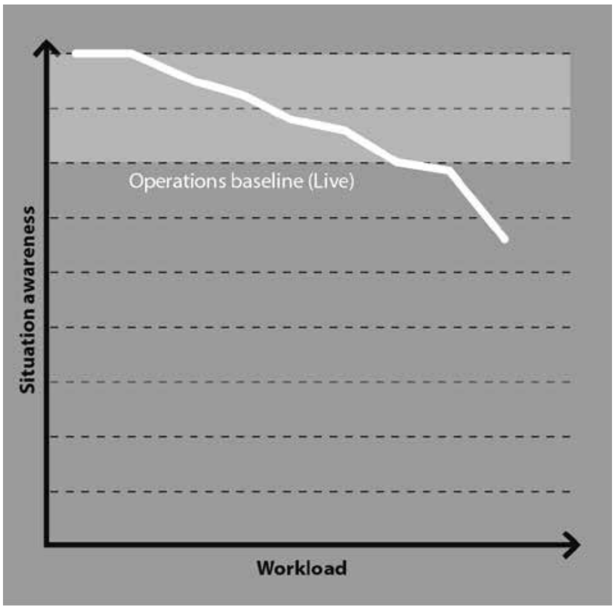
The change in workload safety margins when implementing new systems has been likened to 'Q' corner of a fixed wing aircraft (the margin between stall speed and over speed reduces with increasing altitude). If the system is new and the changes are significant, it is much more difficult to identify the triggers for overload. Therefore the margin between manageable workload and overload may be reduced and become a 'cliff edge' which is much more difficult to anticipate and respond to. Identifying and defining the changes in the safety margins of workload during implementation is extremely difficult to achieve. However, NATS has been working on innovative methods to do just that, making it possible for any erosion of safety margins due to an increase in workload to be restored quickly.

Nic Turley is a Human Factors Specialist with over 20 years' experience in applying HF to the procurement, development and use of complex safety critical systems. Prior to joining NATS Nic worked for large IT consultancies working on the development of Royal Navy warships, attack submarines and reconnaissance systems as well as other major defence and rail procurement. Nic is currently the Deputy Head of HF in NATS and is responsible for NATS Safety Culture Strategy as well as Assessor of Technical Standards for the HF team.

Development

The EFD work began with the development of an in-house workload scale; more than 18,000 data points were collected from air traffic controllers in live operations across NATS centres (Terminal Control and En-Route) at Prestwick and Swanwick over an 18 month period.

A second measurement relating to controller situation awareness was introduced alongside the workload measure and further data points were collected from live operations. Together, the workload and situation awareness scores for the same period provided an insight into the workload levels under which situation awareness remained above what was considered to be a safe level. This then provided a means for comparing the relative tolerance of different systems to varying levels of workload.



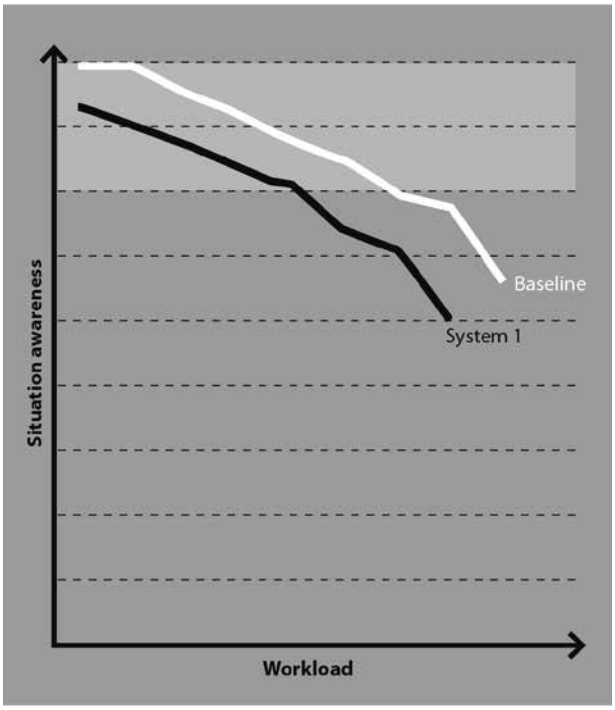
The observed link between high workload scores and situation awareness scores appeared to be related to the point at which the controllers found it difficult to maintain the 'picture' (a term used within NATS to describe the capacity of the individual to maintain sufficient situation awareness to manage current and future anticipated traffic scenarios). If this was the case then this would provide a means for protecting safety margins during the introduction of a new system: keeping workload levels below a known critical level would (theoretically) ensure that situation awareness would remain above a desired critical level and thus enable continued safe operation of the system.

Application to EFD

The temporary withdrawal of EFD from service provided an opportunity. We had data from a number of sources: simulations; live operations; pre implementation simulations; live operations during implementation and live operations post-reversion to paper. These data sets provided a clear insight into the events which took place following the initial introduction of EFD and the subsequent reversion to paper operations.

This now meant we had a clear 'picture' of the current operational profile (baseline) to compare against and were no longer implementing 'blind'. Data showed that the percentage of time that controllers were experiencing non-satisfactory situation awareness scores was higher for EFD than the current operating system at similar levels of workload.

One very clear finding related to the limitations of using workload data alone from simulations in the absence of situation awareness indicators. A clear limitation of the simulations related to key workload factors not being replicated (e.g. phone calls interrupting planner actions). Live traffic scenarios, which would be classed as high workload in live operations, did not invoke the same workload experience for controllers in the simulator.



Brian Janes is currently Head of Independent Human Factors Assurance at NATS reporting to the Operations Director, Safety. Brian joined NATS 10 years ago and has held a number of technical and people leadership positions including Acting Deputy Head of the Human Factors Group. His technical skills include User Interface and Interaction Design, Safety Analysis and Validation.

Introducing EFD back into live service

In order to facilitate the introduction of EFD back into live service, efficiencies and improvements were identified in order to reduce task demand. These included:

- Electronic (Forward) coordination n Auto population of initial levels
- Carry forward of previous sector heading and speed data
- Data entry
  - Heading, level and speed
  - Co-ordinations
  - Oceanic clearance times
- Strip interactions

The changes were identified and implemented through working closely with a core team of controllers to ensure they would be effective.

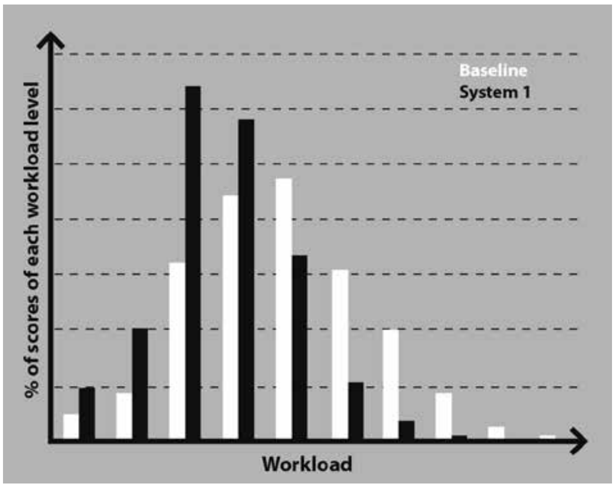
Live Ops Validation

EFD was reintroduced during a period of Limited Operational Service. The supervisors were tasked with maintaining the workload of the controllers at or below LOW-MODERATE levels as defined by the in-house workload measurement tool (data showed that this was the level at which the controllers could maintain good situation awareness).

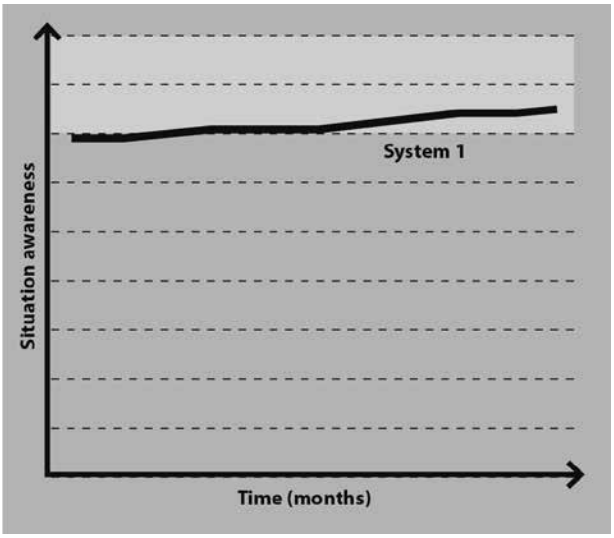
Supervisors have expertise in controlling workload (as part of their day job) and use a large amount of information to support this task (e.g. traffic information; number of controllers present; sector configurations; specific sector issues etc.). At the end of each controlling session, controllers reported the actual level of workload and situation awareness they experienced and this was fed back to operational managers and supervisors to ensure that workload and situation awareness had remained within acceptable limits.

To provide complete safety assurance, a paper back-up team was utilised during each period of operating with EFD. This allowed reversion at any point (either prompted by the supervisor or the controllers).

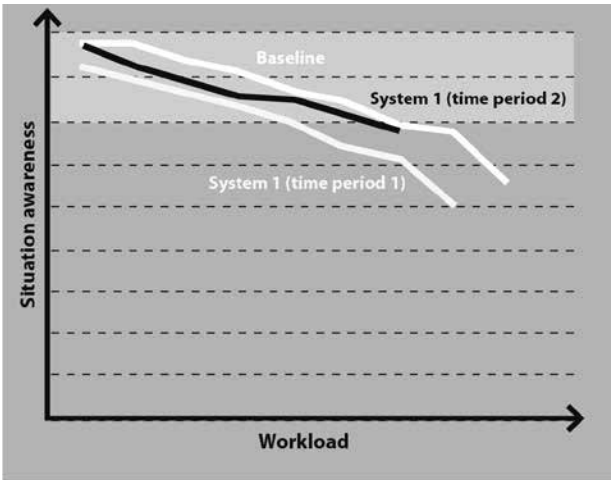
From the data it became clear that the supervisors were able to maintain the workload of the controllers within the desired range. A buffer had been built in and during this period there were no overload reports.



90% of the situation awareness scores during this period were 'Good' or above (very similar to baseline scores of 91% 'Good' or above). Over time, as workload was maintained at a low to moderate level, an increase in situation awareness scores was observed. This was taken to indicate a gradual increase in the buffer relating to workload, possibly resulting from increased familiarity with the new system.



Being able to 'see' the progress taking place allowed for increases in the defined workload level at a gradual rate, with constant feedback that situation awareness wasn't being eroded. The improvements could be seen when looking at the workload/situation awareness profiles at different points in time.



After a few months, the paper back-up was removed and the utilisation of EFD in live operations continued to increase until all controllers were using EFD on a full time basis and traffic was able to be managed at the same levels as when the previous systems were in use.

Due to this success, this process was repeated on further projects (e.g. iFACTS, the London 2012 Olympic Games, airspace changes). Previous issues encountered during project implementation (e.g. overloads) were not experienced. We now have baseline data from live operations (how the current system performs), more accurate data from simulations, and limited operational service applied sooner (as we know the levels of controller workload to maintain safety and clear indicators when these levels need to be adjusted).

The approach also allows significant amounts of data to be collected (e.g. in the 1000s, with 100+ participants). Investigation to broaden the use of this technique for live operations monitoring is currently being explored.

From HindSight 21 Summer 2015