Where is my workload? Identifying hot spots

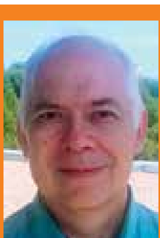
by Patricia Lopez de Frutos and Nicolas Suarez

Today is a normal day in Europe, with normal traffic flows and no incidents. Aircraft are flying through European skies efficiently, following user-preferred routes and keeping to their target times. In this normal situation, nothing seems to go wrong. Nevertheless, the Local Network Position of ACC WXY has detected a possible non-normal situation.

Patricia López de Frutos

holds a M.S. in aeronautical engineering and has a working experience of over 15 years in the ATM business sector. Her area of expertise is focused on validation of future concepts and their impact on performance. Currently, she is a principal research engineer at CRIDA (ATM R&D and innovation Reference Centre). She coordinates CRIDA participation in SESAR Development Phase.

Nicolas Suarez



holds a B.S. in aerospace engineering and has a working experience of over 25 years in the Air Traffic Management (ATM) domain. His area of expertise is focused on the development, assessment and validation of ATM operational concepts and logical architectures. Currently, he is a technical manager in CRIDA (ATM R&D and innovation Reference Centre).

Due to an unexpected weather disturbance, a number of aircraft trajectories have been modified. This situation, combined with a small set of departure delays in airport ABCD will result in a hotspot in sector EFGH in 45 minutes from now. Having identified the hotspot, the Local Network Manager in cooperation with the Regional Network Manager proposes to level cap the flow of aircraft coming into the sector. This solution is also coordinated with the operations control centres of the airlines involved which results in minimum all- round disturbance to the system. This action allows all the aircraft involved to maintain their target times.

As seen from this hypothetical example, the key to identifying and addressing small system disturbances is to correctly identify and deal with hotspots. However this seemingly easy process has a number of challenges. The first one is to identify what is a hotspot.

Hotspots can be defined in a number of ways, but the most useful method is to assess the prospective hotspot in terms of complexity. A hotspot is defined as a location of high complexity where one or more controllers will need to pay extra attention to ensure the safe flow of aircraft. So far so good but, what exactly is complexity? In this context, ATM complexity is understood to be a multidimensional construct that includes static sector characteristics and dynamic traffic factors. These factors can, for example, be physical aspects of the sector, or factors relating to the movement of air traffic through the airspace.

This last paragraph has introduced a key aspect of ATM complexity, its direct relationship with workload, so we are able now to refine our understanding of a hotspot. A hotspot is an area of high controller workload where one or more ATCOs will experience undue pressure if they are to ensure the safe flow of aircraft. Thus, if we are able to determine those areas where ATCO workload is above a certain threshold, we will be able to identify potential hotspots.

Generally speaking, the workload experienced by an ATCO has a range of different components, but from an operational point of view, the most significant feature of workload is the "mental workload".

Mental Workload is defined as a function of the resources required by the cognitive processes that a task demands (cognitive demand) and the mental resources available. In this context, mental overload occurs when there is an excess of task load (cognitive demand) compared to the psychologically available resources that the controller is able to supply. It is assumed that tasks are always performed without reducing safety levels.

Thus the objective of Hotspot detection is met through the estimation of expected workload. This "expected workload" is considered to be a function of the ATCO cognitive resources required to perform a task in a safe and efficient manner.

The Cognitive Demand model is based on the idea that a person engages in five basic cognitive tasks when performing an action – Perception (both visual & auditory), Comprehension, Strategic Thinking, Decision Making and Execution (manual and verbal).

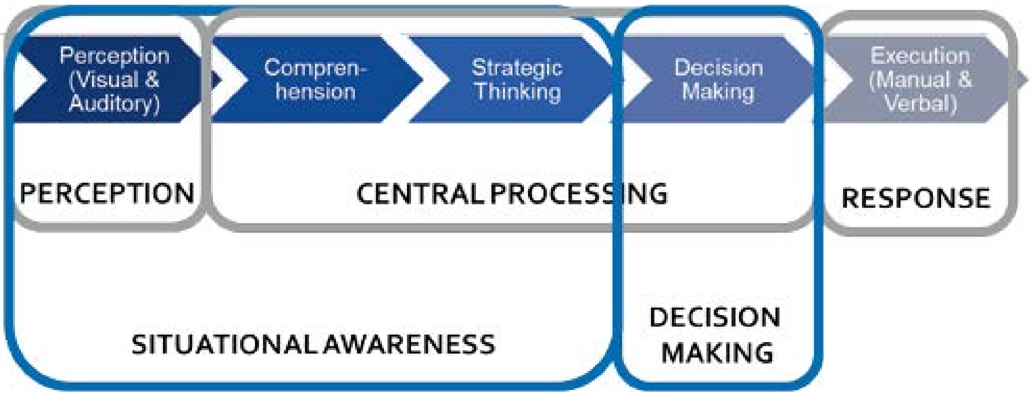


Figure 1 The Cognitive Demand model

The use of these cognitive tasks allows a person to perform high-level mental processes such as the acquisition of situational awareness or the performance of decision-making (Figure 1).

This approach allows us to describe ATCO activities as a set of tasks triggered by those flights under their responsibility. Flight Events, such as sector entry, level changes, conflict detection or vectoring, can be translated into ATC Control Events, thus emulating controller activity (e.g. clearances, conflict resolution by level changes, monitoring, or sequencing). It must be highlighted that ATC Control Events are composed of a temporal sequence of Tasks that the controller performs when an event is occurs – for instance collecting information from the system, coordinating an entry with collateral sectors, listening to the pilot and giving instructions.

Where is my workload? Identifying hot spots (cont'd)

Tasks are performed through elementary actions called Primitive Operator Actions. Each one of these involves different parts of the Cognitive Process such as reach flight strip, fixate object, search with pattern, listen, recall, recognise, select, compare, compute, decide, say a message and type. Primitive Operator Actions are triggered according to the cognitive processes implied in the controller task and result in the use of different cognitive resources with different loads.

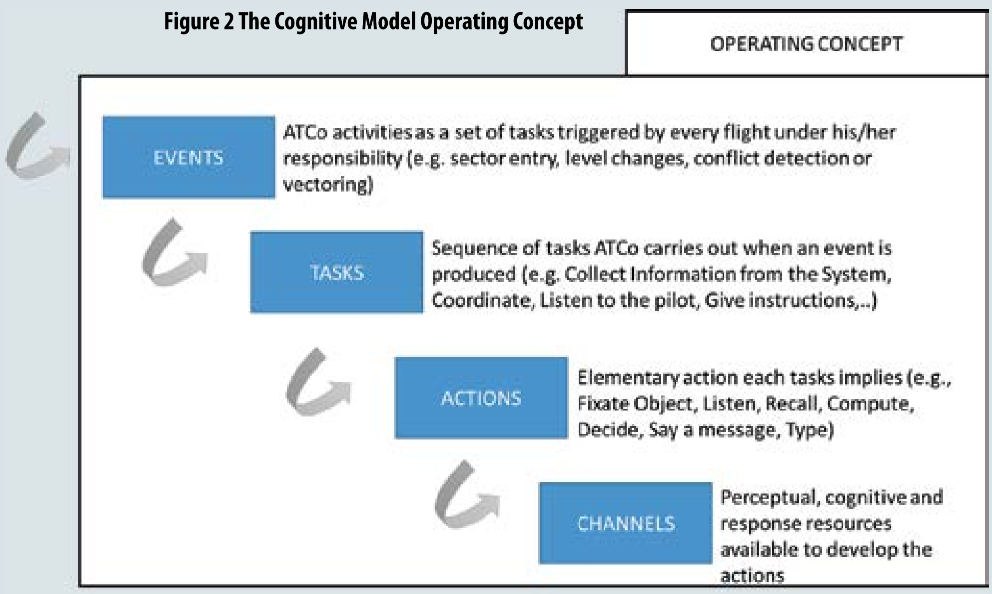
The relationship between ATC Control Events, Tasks, Primitive Operator Actions and cognitive resources is determined by the way in which controllers perform their control actions and constitutes the operating concept used by the Cognitive Model to estimate the required cognitive resource needed to manage a specific traffic situation (Figure 2).

We can now model ATCO activities in terms of the tasks associated with the operating concept used to provide the control service over an area, but we still need to translate the model into "something" that can be used to obtain a number. To accomplish this, we must determine how the performance of tasks affects cognitive demand.

Cognitive Demand is calculated using Wickens' algorithm. When Tasks overlap in time, the Total Cognitive Resource Demand depends on two factors, the resources demanded per task and a "conflict" component when two tasks compete for the same pool of resources. The Multiple Resource Model postulates separate resource pools in terms of three dimensions of information processing so that when two tasks use the same pool of resources there is a conflict and a higher cognitive demand results.

Wickens' algorithm allows us to estimate cognitive demand using a set of flight events and control events. Furthermore, this algorithm permits us to use different operating concepts depending on traffic features and environmental context.

Figure 2 The Cognitive Model Operating Concept



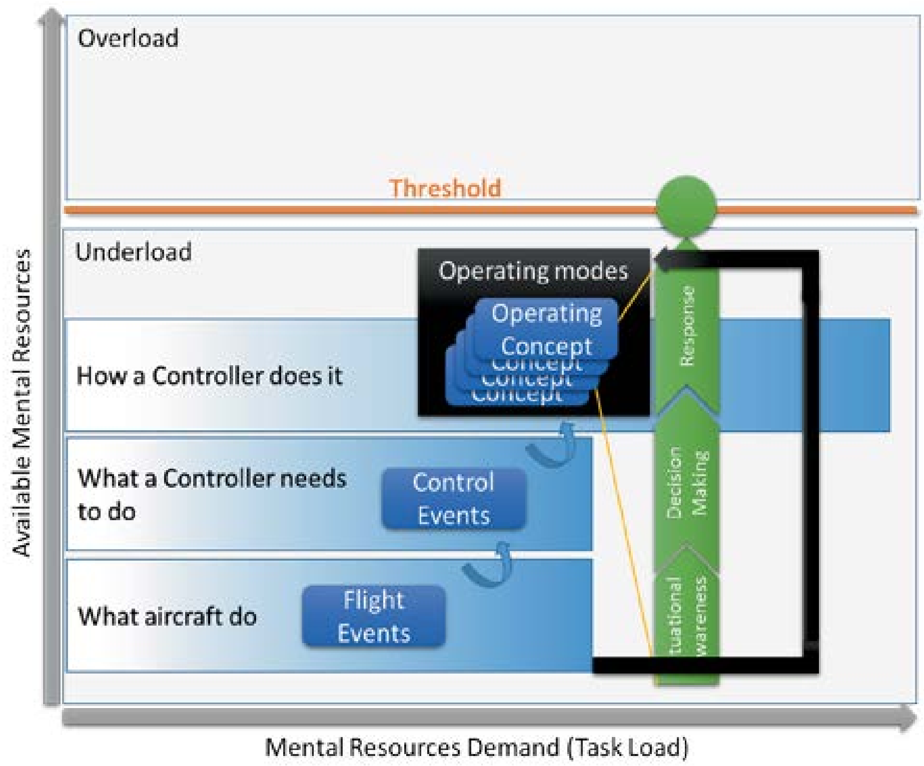
There are three basic concepts that we need to implement (figure 3):

- **Cognitive Demand (Task Load):** the physical and mental activity required to deliver perceptual actions, cognitive actions and motor skills. To model this concept it is assumed that Flight Events result in ATC Control Events that are driven by an underlying Operating Concept and that their implementation requires a specific set of cognitive resources.
- **Available Mental Resources:** the mental resources that an ATCO has available to provide the control service, considering only a fixed amount of base resources. The psychological factors experienced during a controller's shift such as fatigue, stress and satisfaction with work done shape the available resources.
- **Threshold:** the value beyond which Cognitive Resource Demand (Task Load) exceeds the Available Mental Resources. This is where a direct impact on safety begins and the ATCO will need to be trained to cope with these situations or be supported by technology. Currently the Cognitive Model assumes a fixed amount of available resources.

The implementation of these three components results in a system that is able to estimate the workload using commonly available information such as flight events and operational inputs.

Up to this point, the reader will have noticed that there is a strong theoretical emphasis in this approach. So the question that we now need to pose is can we build an experimental sys-

Figure 3 The Mental Workload Model System Framework



tem that implements this approach? The answer to this question lies in our ability to develop an appropriate logical architecture and an associated set of operational requirements. This architecture defines the principles that support the estimation of the workload (Figure 4).

We believe that the use of Cognitive Demand to assess the workload is a viable approach for the identification of hotspots. This approach has a distinct advantage presenting the hotspot in terms of high workload areas that require special effort from ATCOs. The models and systems required to implement this approach already exist and are being used by ENAIRE and CRIDA and are under evaluation as part of the SESAR programme.

Additionally, analysis of validation data from the mental workload model indicates that there is a need to upgrade the mental workload model to take into account the variability of human behaviour under the different traffic patterns and dynamic environments that are the Operating Modes. This will be achieved by introducing dynamic thresholds, enhancing the definition of operating modes and developing situational awareness and decision-making process models. Psychological factors sush as fatigue, stress and emotion will be integrated to complete the model as part of future projects.

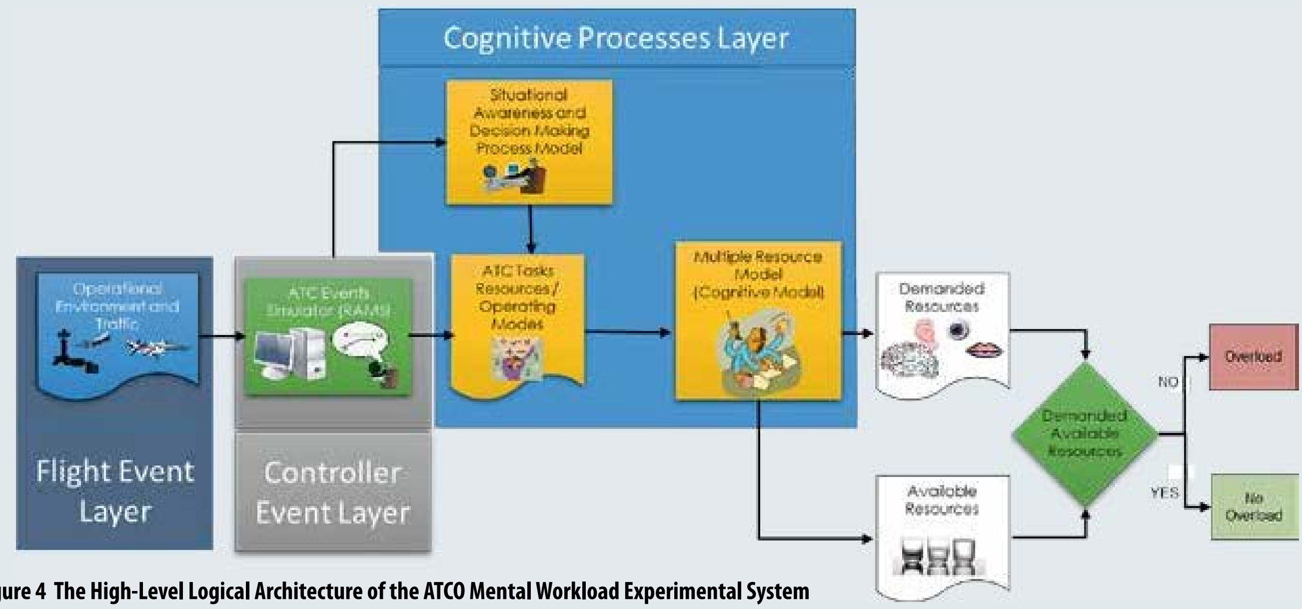


Figure 4 The High-Level Logical Architecture of the ATCO Mental Workload Experimental System