Reading the Boeing Alertness Model Predictions

Reading predictions from a bio-mathematical fatigue model may not always be straightforward. How can you identify shifts in the circadian rhythm, sleep inertia, sleep debt and the effects of extended wakefulness and grasp what is resulting in a poor, or a good, alertness score? This document aims to answer those questions, and a few more.

The Alertness Scale

Starting with the scale used by the Boeing Alertness Model (BAM), shown at **A** in the figure, - it is a scale of *alertness* with a range from 0 to 10,000. As shown in the figure, the scale runs in the opposite direction from the Karolinska Sleepiness Scale (KSS), and 0 in alertness, at the very bottom, equals to KSS 9 which is the most severe level of sleepiness. In the upper end of the scale, we have 10,000 which equals KSS 1 - defined as '*extremely alert*'.

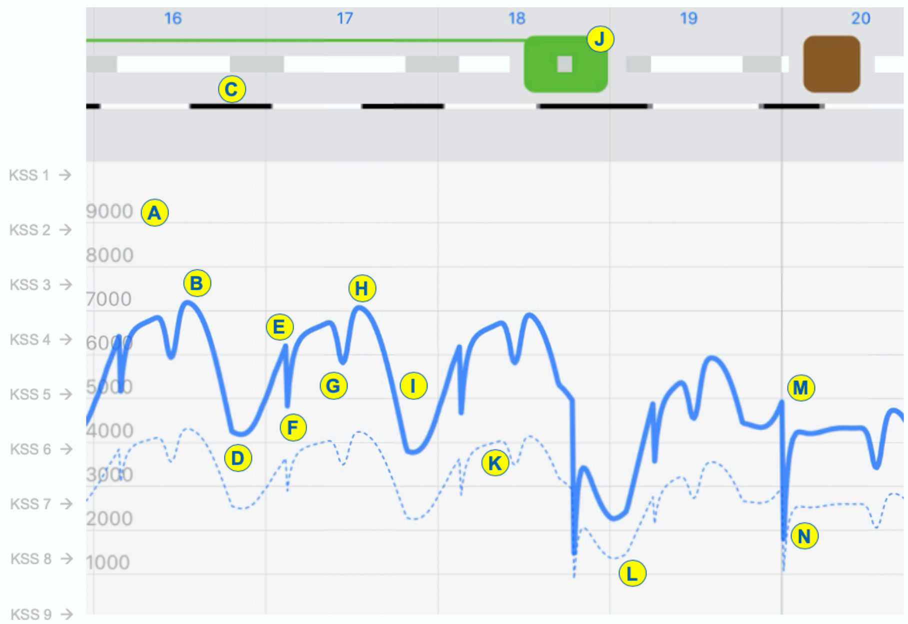
The solid blue line in the figure (**B**) represents the predicted average alertness for a population of crew, given a set of assumptions and given the work/rest schedule seen at the top calendar timeline (**J**), here with dates ranging from the 16th to the 20th.

Sleep and wake

BAM will predict not only alertness, but also sleep/wake as seen at **C** - which is a predicted period of sleep coloured grey. BAM will assume wakefulness during duty, as well as just before and just after duty during an additional period needed for transitioning to and from time off. The prediction of sleep is of course tightly coupled with the prediction of alertness and BAM will use built-in thresholds for the model processes which will 'trigger' sleep onset and awakenings. Looking at **D** in the figure, you see such a point where sleep onset is triggered.

The sleep/wake homeostasis

From **D** to **E,** the predicted alertness improves, which is an effect of the restorative processes active during sleep. The prediction illustrated by BAM during sleep should be read as the alertness level people would be on if woken up at that time. Contributing to the prediction, is both the circadian rhythm and the sleep/wake homeostasis (two different processes) why it could sometimes appear as if the prediction declines during sleep when the two processes interact. However, the 'pure' sleep/wake homeostasis process, sometimes referred to as a sleep reservoir, recovers quickly in the first few hours and then gradually slower - but that is not possible to observe from the combined output in this view. At **E**, another threshold is reached within the model, now triggering awakening.



Sleep inertia

Immediately after waking up there is a 'spike' downwards in the prediction (**F**) showing *sleep inertia*; that first 'grogginess' typically experienced right after waking up. The sleep inertia quickly wears off and the prediction then recovers. The magnitude of the sleep inertia will vary depending on the sleep duration and how likely it is to wake up from deeper phases of sleep. For example, at **N** in the figure it can be seen that the downwards spike is bigger.

Prediction during physiological day

Acclimatisation will happen gradually inside BAM, mainly driven by time-zone difference between the predicted body clock time and local time. During physiological day, not necessarily local day, the circadian process will elevate the alertness scores and after sleep inertia has dissipated all the way up to **H**, the alertness

Learn more about what we offer: www.jeppesen.com/frm

JEPPESEN
A Boeing Company

prediction is fairly constant. This with the exception of the afternoon 'dip', or siesta opportunity, seen at **G**, which typically is around 2:30pm for people of intermediate diurnal type (neither morning, nor evening type of person).

The *acrophase* (peak) of the circadian rhythm is similarly visible at **H**, and located around 5:30pm in body clock time. Acclimatisation, a shifting phase of the circadian rhythm, is most easily spotted in the prediction graphs by comparing the timing of the afternoon dip from one day to another. In the figure, the dip is significantly earlier on the 17th, which happen to be a Singapore layover, compared to on the 20th where re-acclimatisation to CET is well underway.

Dropping off…

After H in the figure, a downswing in the circadian rhythm will interact with long wakefulness and the prediction will quickly drop off (ass seen at **I**) and eventually reach a level that again will trigger sleep onset in the model, for many at around 11pm, and a new period of recovery will start.

Variance…

The solid line is, as explained, the average prediction for a population. This means that approximately half of the individuals will be above that level, and about half below. As a reminder of this inherent variance (in all models), and as BAM is self-aware of the prediction accuracy, the dotted line (**K**) is indicating the 90-percentile; a level which 90% of the population is predicted to be above. As seen, the gap between the two lines is smaller at more fatiguing 'states' (compare the gap at **K** vs. at **L**). At more alert states you can also see, for the same reason, that the prediction for the average population (the solid line) will rarely go above 7,000. A population of people is on average, during good conditions, typically scoring themselves between KSS 3 and 4.

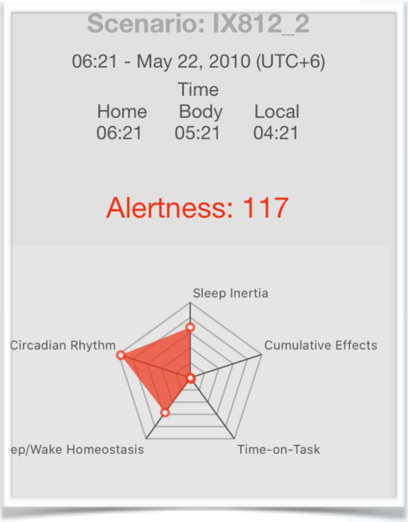
Sleep debt

A premature awakening, before full recovery has been achieved, is seen at **M** in the figure. Compare the level of alertness at that time with the level at **E** that has a spontaneous awakening not caused by duty 'forcing' crew out of sleep opportunity, and you can see in this example that the score is some 1500 points lower on the alertness scale at **M**. That *sleep debt* will be carried forward and eventually need to be 'repaid' by additional sleep. As sleep is more restorative when a person is sleep deprived, the pay-back ratio is however better than 1:1 - as more time will be spent in the deeper sleep phases.

After the forced awakening at **M**, and a shortened sleep period, you can see that the predicted level of alertness on the 20th is lower than on other days but still on a fairly 'decent' level - upheld by the circadian rhythm that comes to rescue the score.

More tools and additional reading

As noticed above, some experience is required for easily reading the output score from BAM. Luckily, there are good built-in features in most of Jeppesen tools (such as CrewAlert Pro) serving you more detailed information - like the 'spider chart' illustrated here.



There are also training courses and plenty of additional material to digest as referenced below. Good luck.

—-

Further reading:

- Fatigue Causes
- Assignment-centric Performance Indicators
- BAM Safety Performance Indicators
- BAM Technical Fact Sheet
- Aligning Rules With Human Physiology
- The secret behind pro-active risk reduction
- CrewAlert Fatigue Mitigation Functionality
- A best practice for quantifying fatigue risk

Learn more about what we offer: www.jeppesen.com/frm

JEPPESEN
A Boeing Company