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A Boeing Company

BAM Prediction Power

A summary of outputs and safety performance indicators (SPI) available in the Boeing Alertness Model (BAM)

BAM is the leading bio-mathematical model for aviation in terms of features, performance and validation. The following information summarizes the different outputs available when integrating BAM with an application.

Sleep and alertness

The most fundamental output of BAM is obviously periods of sleep/ wakefulness and the predicted level of alertness. BAM takes as input a chain of activities plus the properties for that chain. A chain here may either be a crew pairing or a crew roster containing a sequence of activities with start- and end-times, etc. Overall chain properties are commute times, habitual sleep duration and diurnal type, etc., that are common for the chain. In pairing construction, as the pairing is shared by many yet still anonymous crew, the company typically assumes properties to be used for their "average" crew member. In rostering, however, it is possible to pass the actual properties of the individual (for example, expressing that "captain Smith has a 2h10m hour commute to work").

The default output of BAM is alertness expressed on the Common Alertness Scale (CAS) that range from zero to 10,000, where zero is the least alert state and thereby the highest fatigue risk. The CAS scale is directly anchored to the Karolinska Sleepiness Scale (KSS) in a way that CAS 0 = KSS 9 and CAS 10,000 = KSS 1. A transformation between CAS and KSS is therefore easily done using this formula:

KSS = 9 - CAS/1250

When being passed a chain of activities, BAM will return the predicted alertness at any point in time asked for. The default setting is asking BAM to provide the 50-percentile (median) prediction for top of descent (TOD) on all active flights. As BAM is aware of its own accuracy, it is possible with an argument to instead, for example, ask for the 90-percentile; the level above which 90% of the crew will be. Also the point in time representing a flight is easily configured. For example, a "cabin crew mode" is available using the average alertness throughout the flight instead of using TOD. On each application call, BAM also responds with an array of the sleep periods predicted, making it easy to use this information for reading out the exact timings predicted for sleep on-set and wake up.

Light conditions

Controlled by an additional argument in the call, BAM will return the local light conditions at location assuming a great-circle transition during flights. The output in this case is -1, 0 or 1 for night, dusk/ dawn and day-time light conditions.

Mitigation strategies

BAM is also able, if initiated by yet another argument in the call, to produce proposed mitigation strategies for a given point in time. BAM will then optimize a sleep/wake pattern and a light-exposure strategy while gauging the effectiveness with the alertness prediction. In this way, BAM is able to produce the "advise" as seen in CrewAlert in the mitigation strategy functionality. The output then includes an array of timings to "seek" or "avoid" aspects such as sleep, light exposure, caffeine, exercise, communication, hydration, protein-rich meals and carbohydrate-rich meals.

Fatigue model components

BAM is capable of returning the activation level of the model subcomponents; meaning the contribution from the circadian rhythm, sleep homeostasis, sleep inertia, etc. Read Fatigue Causes for more information.

Body clock time

BAM continuously predicts acclimatization, gradually "pulling" a persons body-clock time into local time with a gravitational-like function. BAM can therefore answer back at any point in time with the crew members body-clock time, which is helpful when reasoning upon desynchronization.

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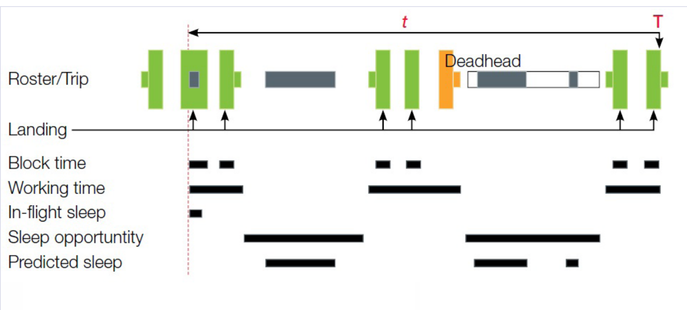
Safety performance indicators

The figures below (on the following page) list the additional SPIs that BAM is able to calculate for easy follow up and buildup of statistics. These SPIs are both roster and model based and suitable for being tracked, for example in the Jeppesen Concert product.

Safety Performance Indicators built into BAM

BAM is able to calculate a large number of different metrics as a function of a chain (pairing or roster) with work/rest activities. The table below summarizes the metrics and definitions available. These metrics are all calculated for a user-specified reference time. The picture illustrates how this reference time (T) and the lead-in period (t) will capture and count various aspects, such as block time, working time, etc.



General Predictive SPIs

SPI	Definition	Unit	Example
A	**Alertness**, predicted level of alertness, expressed in the Common Alertness Scale.	CAS	A=2,761
KSS	**KSS**, predicted level of alertness, expressed in the Karolinska Sleepiness Scale.	KSS	KSS=8.03
LC	**Light Conditions**, conditions at the current time and location on the scale -1= darkness, 1=light, 0=twilight		LC=1
EBCT	**Estimated Body Clock Time**	Time of day	EBCT=16:20
AFR(t)	**Absolute Fatigue Risk,** for all landings in the past *t* hours	AFR	AFR (36:00=773
NFR(t)	**Normalized Fatigue Risk,** for all landings in the past *t* hours	AFR per flight	NFR(36:00)=34

Time Beyond Limit SPIs

SPI	Definition	Unit	Example
WTL(t)	**Working Time above Limit**, sum of working time exceeding *x* continuous hours in the past *t* hours (working time calculation includes in flight sleep as well as briefing and debriefing and connection time).	Real time	WTL(10:00, 168:00)=2:30
BTL(t)	**Block Time above Limit**, sum of block time exceeding *x* continuous hours in the past *t* hours (Includes in flight sleep).	Real time	BTL(10:00, 168:00)=4:30
SOTL(t)	**Sleep Opportunity Time below Limit**, sum of sleep opportunity time shorter than *x* continuous hours in the past *t* hours.	Real time	SOLT(12:00, 168:00)=3:30
PTAL(t)	**Predicted Time Awake above Limit**, sum of predicted time awake exceeding *x* continuous hours in the past *t* hours.	Real time	PTAL(16:00, 168:00)=11:20
PSTL(t)	**Predicted Sleep Time below Limit**, sum of predicted sleep time shorter than *x* continuous hours in the past *t* hours (afternoon naps and in flight sleep excluded).	Real time	PSTL(8:00, 168:00)=4:30

Time in period breakdown SPIs

SPI	Definition	Unit	Example
WT(t)	**Working Time**, active working time past *t* hours (Includes in-flight sleep as well as briefing and debriefing and connection time).	Real time	WT(168:00)=71:20
BT(t)	**Block Time**, time operated in the past *t* hours (Includes in-flight sleep).	Real time	BT(168:00)=31:20
IST(t)	**In flight Sleep Time**, estimated and/or actual in flight sleep in the past *t* hours.	Real time	IST(168:00)=6:00
SOT(t)	**Sleep Opportunity Time**, total sleep opportunity in the past *t* hours.	Real time	SOT(168:00)=71:20
PST(t)	**Predicted Sleep Time**, total predicted sleep time in the past *t* hours.	Real time	PST(168:00)=43:10

Miscellaneous SPIs

SPI	Definition	Unit	Example
MIN(t)	**Minimum Alertness**, lowest alertness during block time operated in the past *t* hours (in flight sleep and sleep inertia excluded).	CAS	MIN(48:00)=1,132
PFA(t)	**Predicted Forced Awakenings**, number of forced (non-spontaneous) awakenings in the past *t* hours.	Int	PFA(168:00)=3:00
MS(t)	**Missing Sleep**, difference between predicted sleep and expected sleep in the past *t* hours (Expected sleep is calculated using habitual sleep length).	Real time	MS(168:00)=2:45
TZS(t)	**Time Zone Span**, maximum time zone span over time zones in the past *t* hours (Example: id airport visited furthest to the west is located in UTC-5 and the airport most to the east is in UTC+5:30; the total span is 5+5:30=10:30).	Real time	TZS(168:00)=2:00
AS(t)	**Acclimatization Span**, maximum time span of predicted re-acclimatization (west/east) in the past *t* hours.	Real time	AS(168:00)=3:16
SOTD(t)	**Sleep Opportunity Time in Darkness**, sum of sleep opportunity time in darkness in the past t hours	Real time	SOTD(72:00)=19:20

Block Time SPIs

SPI	Definition	Unit	Example
BTBL(x,t)	**Block Time Below Limit**, block time (excluding any in flight sleep and sleep inertia) operated below predicted alertness score of *x*, in the past *t* hours	Real time	BTBL(2,000, 168:00)=3:10
BTD(t)	**Block Time Operated in Darkness**, sum of block time (excluding any in flight sleep and sleep inertia) operated below predicted alertness score of *x*, in the past *t* hours.	Real time	BTB(168:00)=21:20
BTW(t)	**Block Time during WOCL**, sum of block time operated falls within WOCL in the past *t* hours (Includes in flight sleep). WOCL is defined as 02:00-06:00 in body clock time).	Real time	BTW(72:00)=3:13

Landing SPIs

SPI	Definition	Unit	Example
L(t)	**Landings**, number of landings in the past *t* hours.	Int	L(168:00)=5:00
LBL(x,t)	**Landing Below Limit**, number of landings operated below a predicted alertness score of *x*, in the past *t* hours.	Int	LBL(2,000, 168:00)=2:00
LD(t)	**Landing in Darkness**, number of landings during darkness in the past *t* hours.	Int	LD(168:00)=3:00
LW(t)	**Landings in WOCL**, number of landings that fall within WOCL in the past *t* hours (WOCL is defined as 02:00-06:00 in body clock time.	Int	LW(168:00)=3:00

Take-off SPIs

SPI	Definition	Unit	Example
T(t)	**Take-offs**, number of take-offs in past *t* hours.	Int	T(168:00)=5:00
TBL(x, t)	**Take-offs Below Limit**, number of take-offs operated below a predicted alertness score of *x*, in the past *t* hours.	Int	TBL(2,000, 168:00)=2:00
TD(t)	**Take-offs in Darkness**, number of take-offs during darkness in the past *t* hours.	Int	TD(168:00)=3:00
TW(t)	**Take-offs in WOCL**, number of take-offs that fall within WOCL in the past *t* hours (WOCL is defined as 02:00-06:00 in body clock time.	Int	TW(168:00)=3:00

Learn more about BAM Prediction Power at jeppesen.com/frm