April 3rd, 2018

Fatigue Risk Management in Aviation

- An overview of how fatigue risk is quantified and managed

For the National University of Singapore

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1. Crew fatigue risk and regulation
2. Chronobiology and bio-mathematical modeling of fatigue
3. The crew management process
4. Quantifying and reducing fatigue risk
5. Summary and Q&A

Jeppesen Crew and Fleet Solutions

- **GOT / SIN / YUL / New York**
- **Over 25 years in providing crew solutions**
- **Optimization, striking the best balance between**
  - Cost
  - Productivity
  - Robustness
  - Crew quality-of-life
  - [Flight safety (fatigue risk)]

Jeppesen Crew Solutions touches more than 350,000 crew every day

Crew Fatigue Risk and Regulation

What is fatigue?

” A physiological state of reduced mental or physical performance capability resulting from sleep loss or extended wakefulness, circadian phase, or workload (mental and/or physical activity) that can impair a crew member’s alertness and ability to safely operate an aircraft or perform safety related duties.”

ICAO

Time of day ✚ Time awake ✚ Prior sleep debt

*Fatigue Risk ≈ the risk of a **lapse**, **slip**, **mistake** and/or **violation** by crew as a consequence of reduced alertness, with potentially negative impact on flight safety.*

Why fatigue matters…

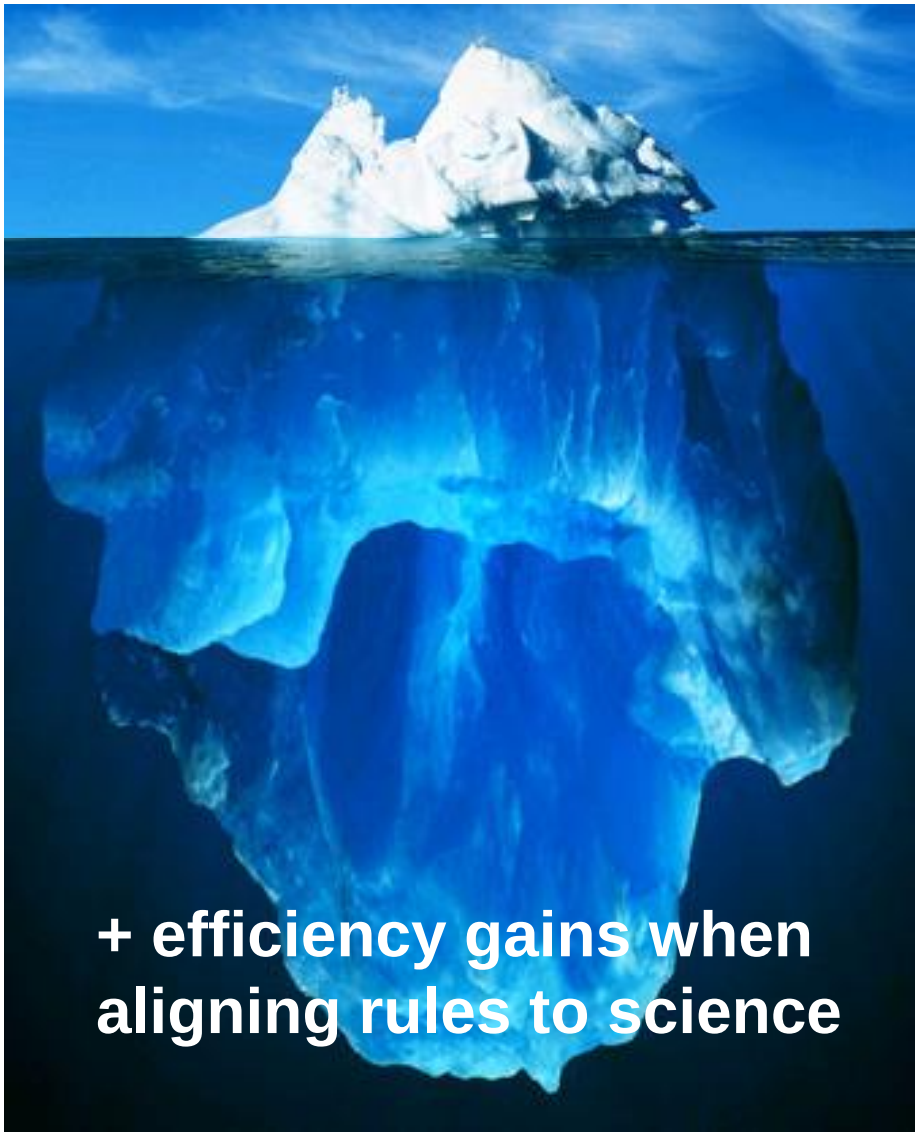
- An estimated 70% of fatal accidents are related to human error
- Fatigue is estimated to contribute to 15-20% of overall accident rate in aviation.

- 1993 Kalitta International, DC-8-61F at Guantanamo Bay, Cuba
- 1997 Korean Air, 747-300 at Guam
- 1999 American Airlines, MD-82 at Little Rock, AR
- 2004 MK Airlines, 747-200F at Halifax, Nova Scotia
- 2004 Corporate Airlines, BAE Jetstream31 at Kirksville, USA
- 2004 Med Air, Learjet35A at San Bernadino, CA
- 2005 Loganair, B-N Islander at Machrihanish, UK
- 2006, 27th Aug, Comair, CRJ100 at Lexington, KY
- 2007, 25th June, Cathay Pacific 747F at Stockholm, Sweden
- 2007, 28th Oct, JetX, 737-800TF-JXF Keflavik airport, Iceland
- Buffalo, Mangalore, AF447?, UPS? …

Why fatigue matters (cont.)

Accidents
Serious incidents

Minor incidents
Well-being
Sickness
Morale
Absenteeism
Recruitment
Attrition
Delays
Fuel inefficiency
Productivity
Reputation
Industrial action
...

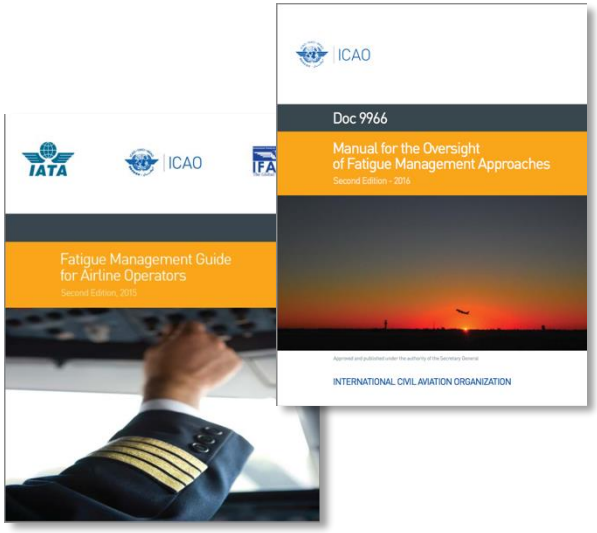


ICAO FRMS guidance material

Prescriptive regulation →
Performance based regulation

Require <u>systems</u> for identification of hazards, risk assessment, and risk mitigation - rather than only compliance with [out-dated or unprecise] rules

So what is an FRMS?



1. ***Where in your operation are you most likely to suffer your next fatigue related incident or accident?***

2. ***How do you know that?***

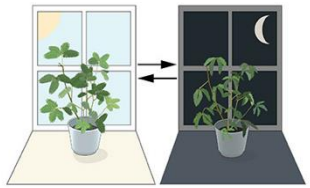
3. ***What do you do about it?***

4. ***How effective is it?***

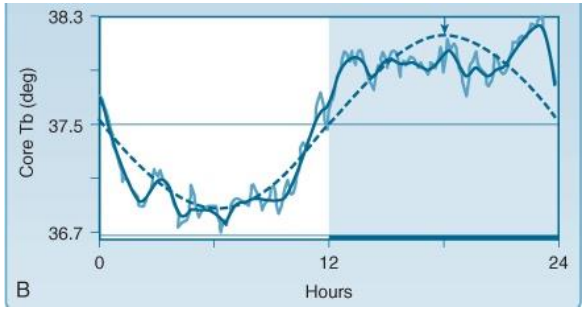
Chronobiology and bio-mathematical Modeling of Fatigue Risk

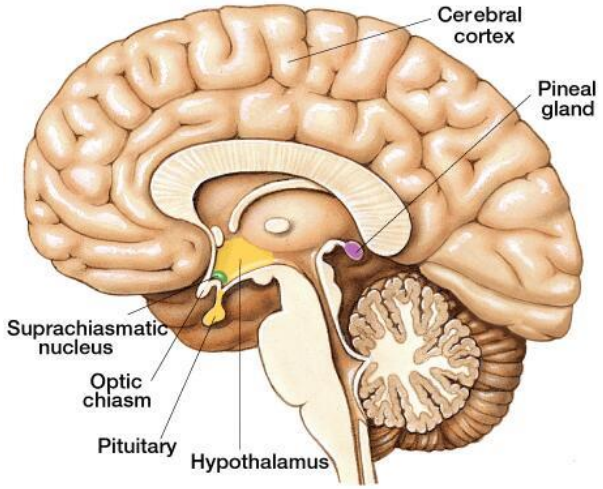
Chronobiology

We are designed to sleep at night



- **Suprachiasmatic nucleus (SCN) +**
- **Retina +**
- **Pineal gland**
  - Affects the modulation of sleep/wake
  - Secretion of melatonin - the ”sleep hormone”
- **Light suppresses the production of melatonin**





The science behind BMMs

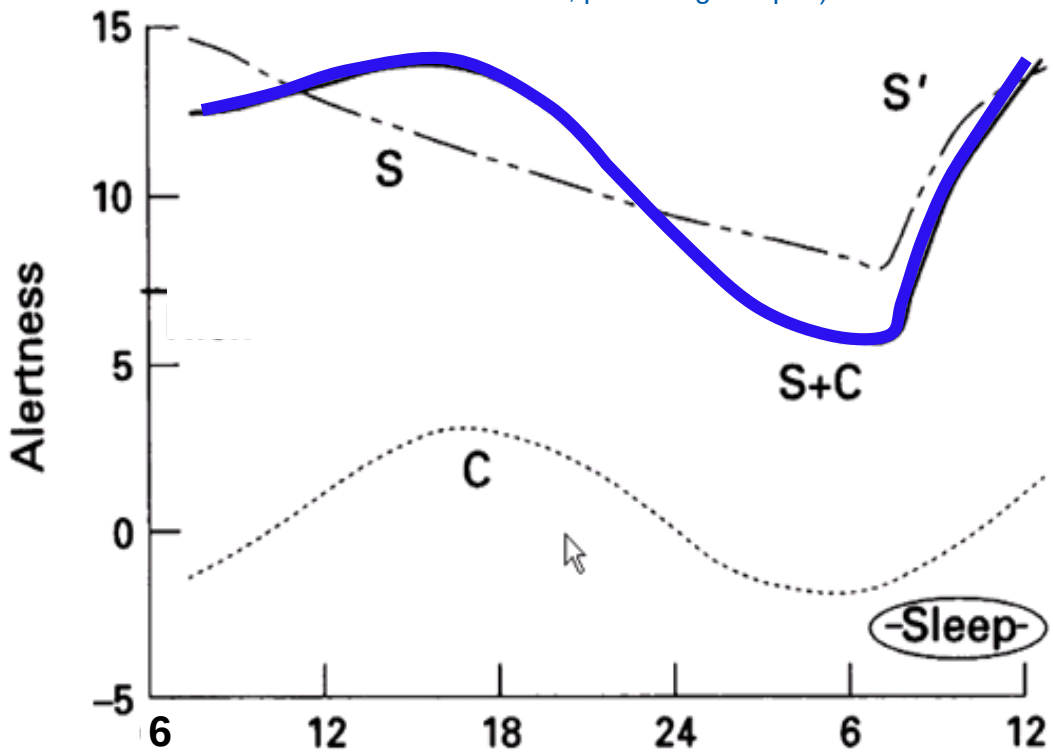
Based on the Three Process Model of Alertness (TPM) by Åkerstedt / Folkard

- Predicts sleepiness

Dominating factors:

- Time of day
- Time since sleep
- Prior sleep deprivation
- NOT duty time or sectors!

Simplified!
(Acclimatisation, afternoon dip, sleep inertia, predicting sleep…)



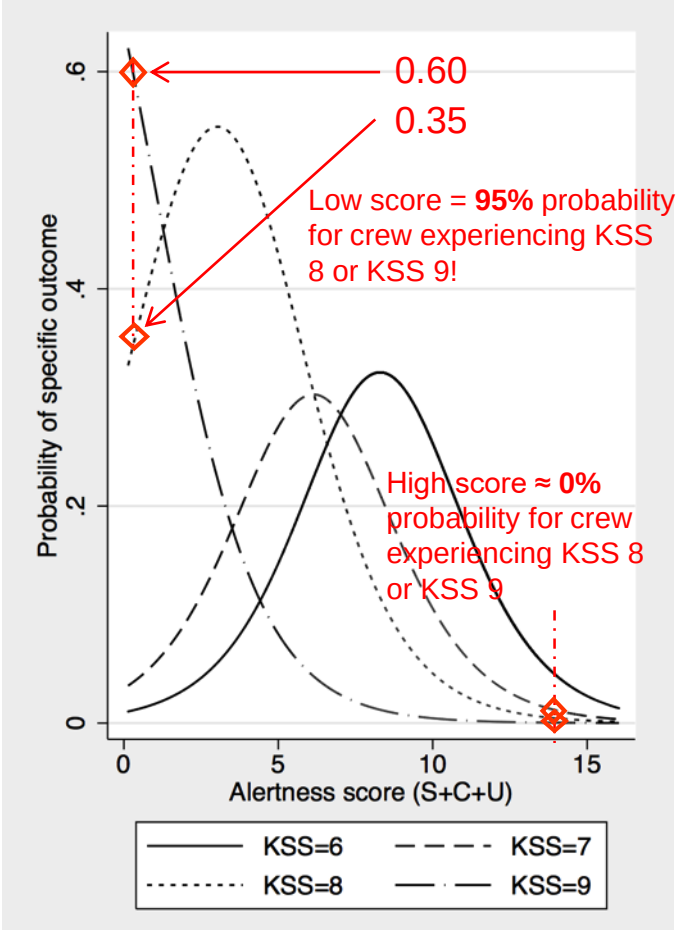
BMM validation

“Proper” model validation has until recently been absent in the industry.

- Not peer-reviewed / published
- Black-box models, secret data
- Small data sets, specific routes
- Known sleep/wake used

The recent validation of TPM; the strongest one ever:

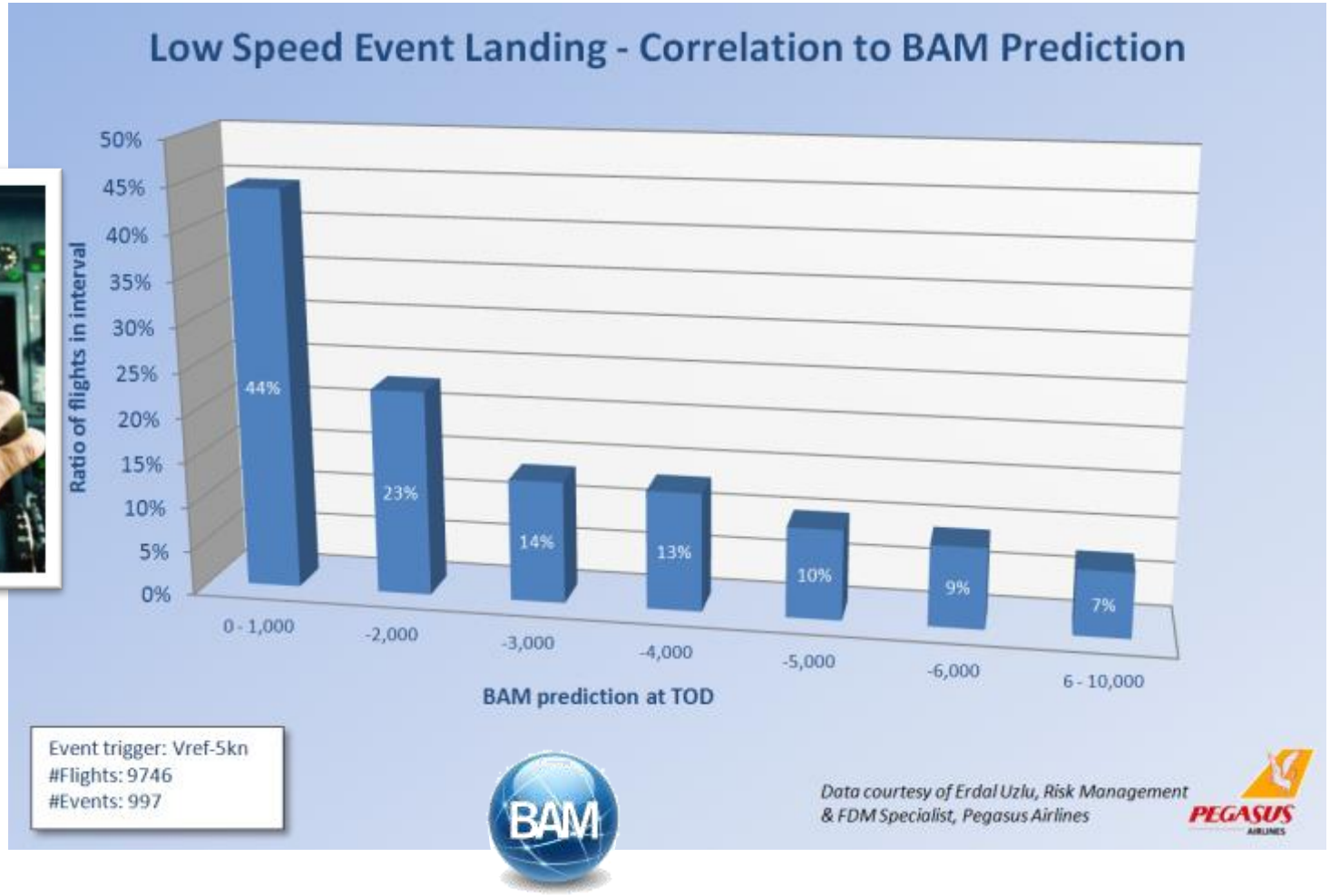
- Peer-reviewed and openly published model equations in PLOS ONE
- Published together with validation data!
- Validation with and without prior sleep
- Large, mixed, sample of aviation data
- Measurement also of variance – not only predicting the average with unknown precision!



doi:10.7910/DVN/26541, 20 Oct 2014

SRI, Swedish CAA, SAS, Jeppesen

Operational relevance – a real world example

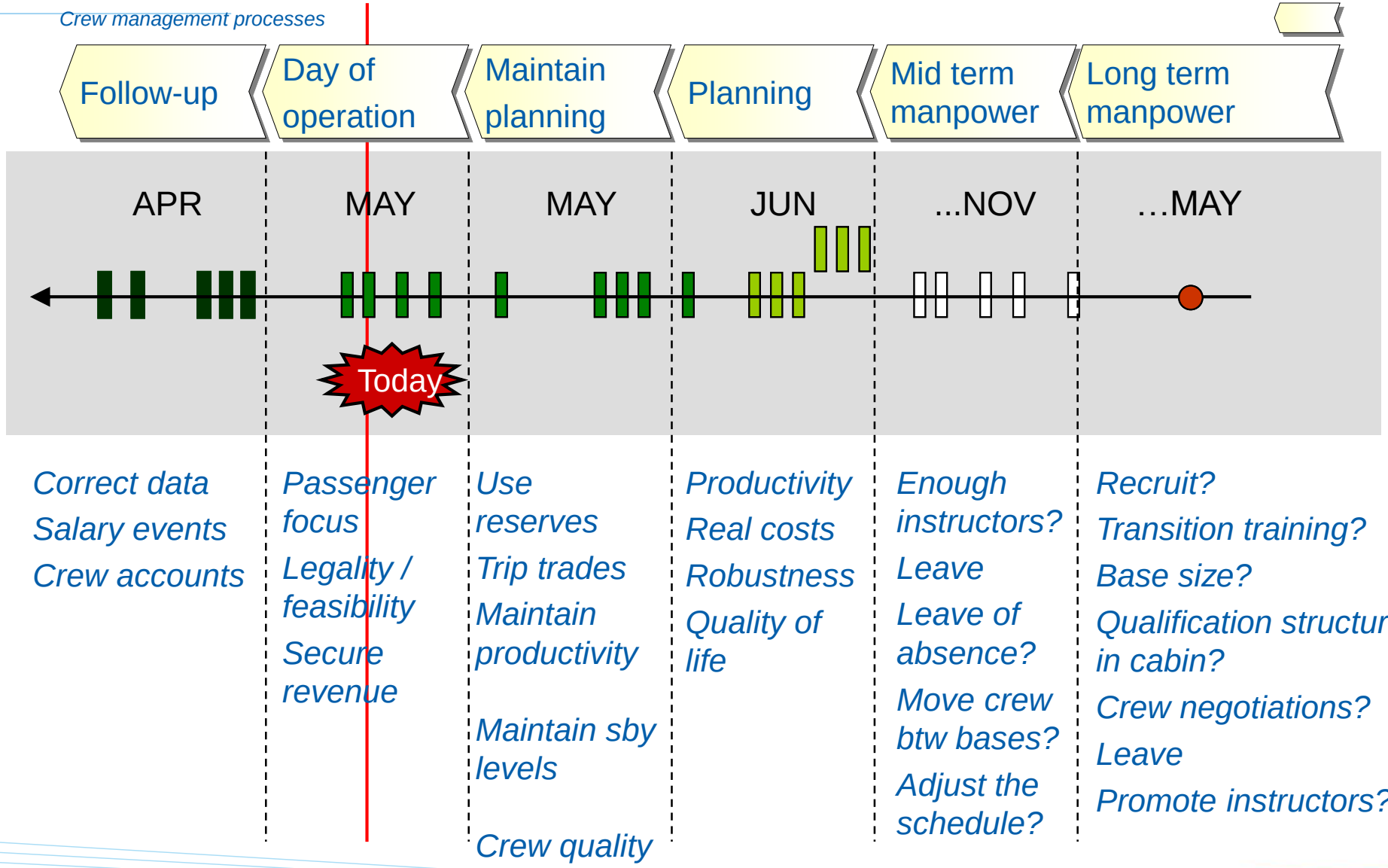


Easy to check model relevance in most airlines.

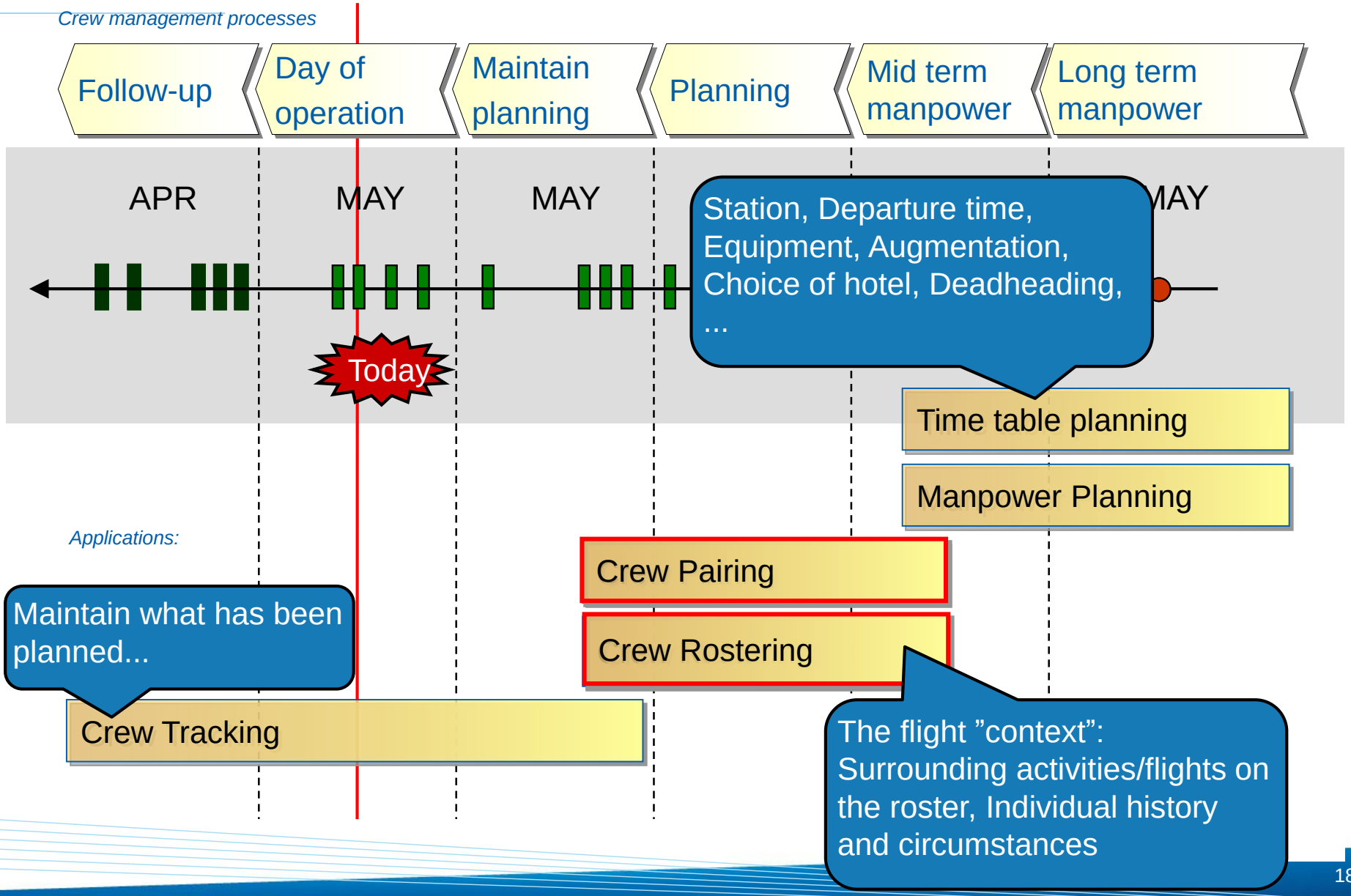
Modeling of the Mangalore Accident

The Crew Management Process

The Crew Management Process/Problem



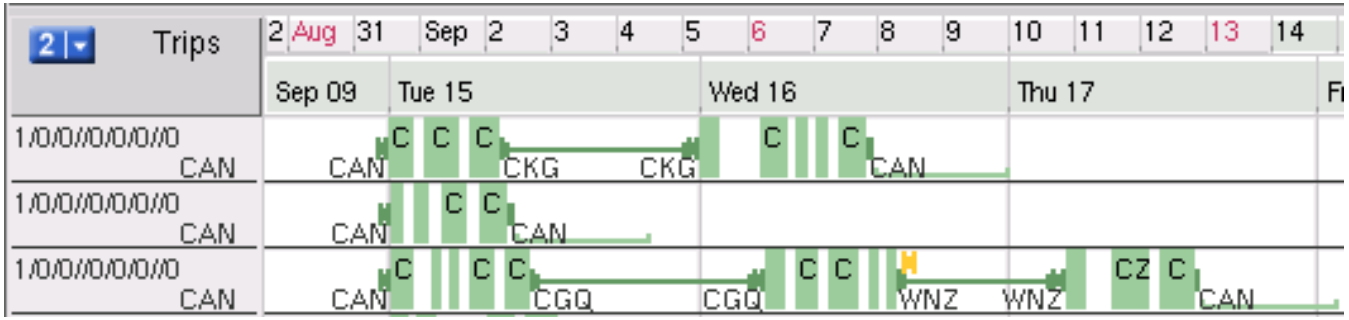
Where to best address fatigue? - *Where it's introduced.*



More on pairings and rosters…

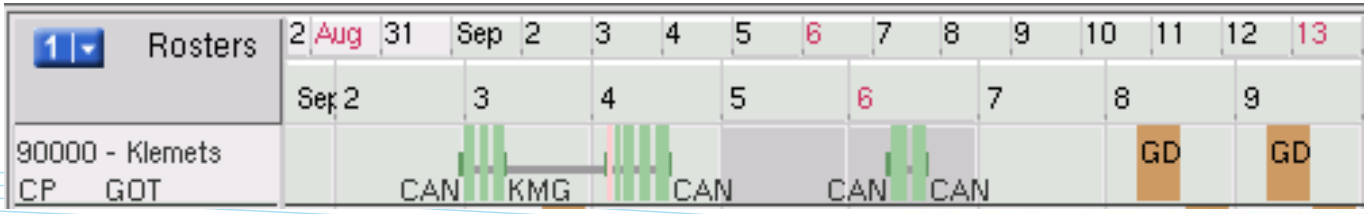
A crew pairing (or a trip) is:

- A sequence of flights starting and ending on home base
- Not associated (yet) with an individual pilot



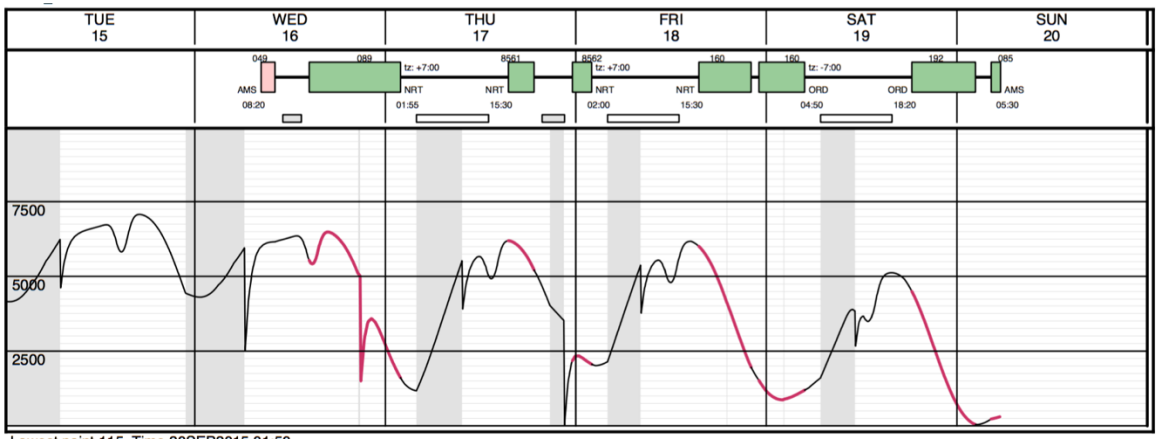
A crew roster (or a crew schedule) is:

- The sequence of activities, such days off, simulators or pairings, assigned to a named crew member

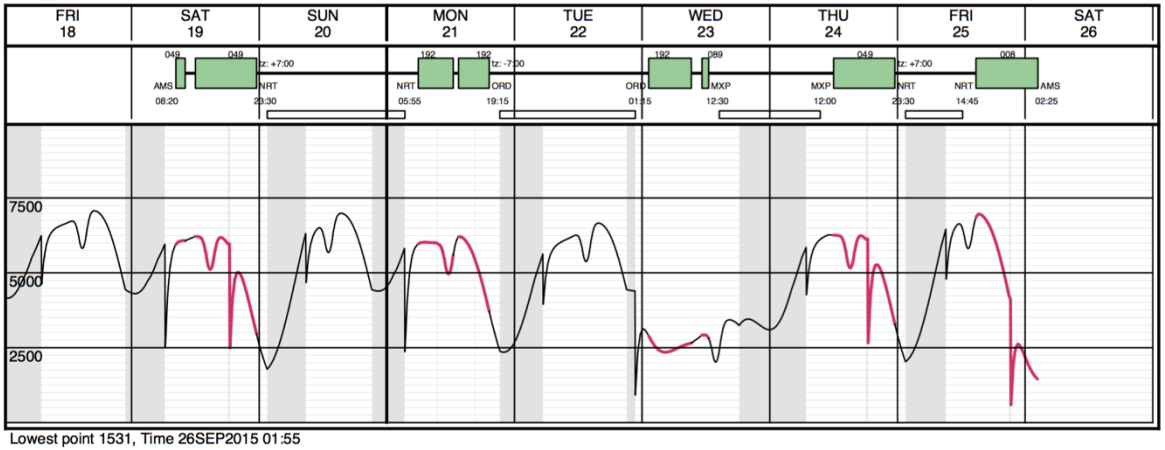


Quantifying and Reducing Fatigue Risk

Alertness prediction → wider risk quantification

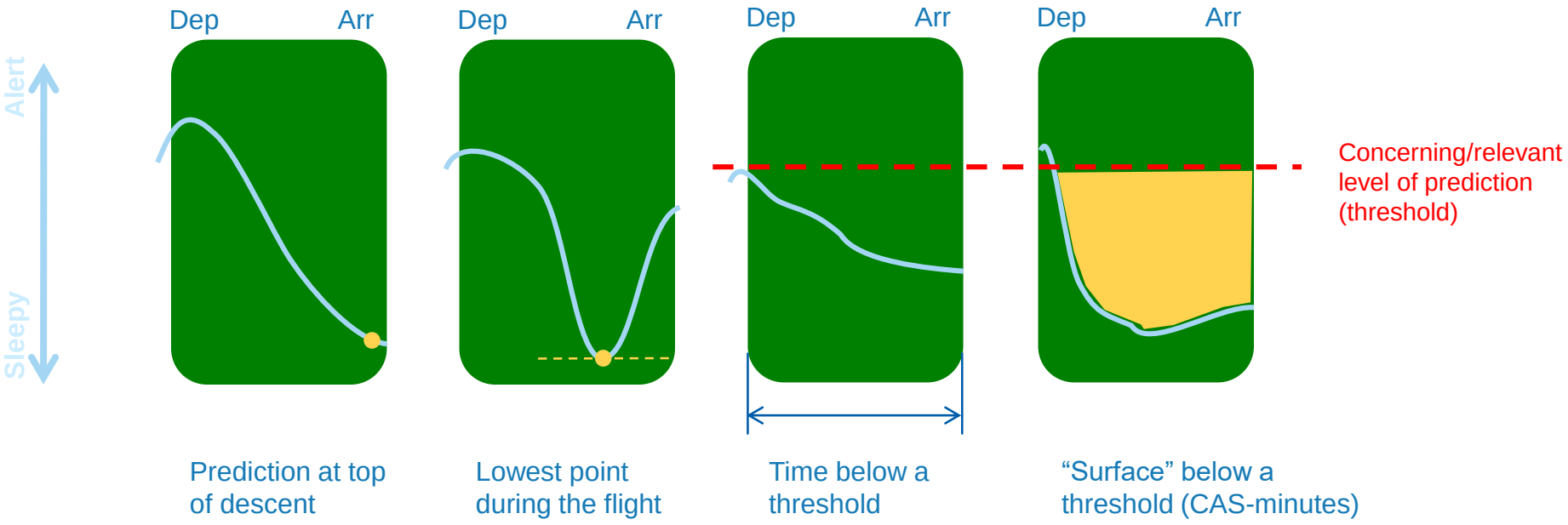


Which crew pairing carries the higher risk?



Lowest point 1531, Time 26SEP2015 01:55

One flight; Fatigue risk = *f* (prediction)

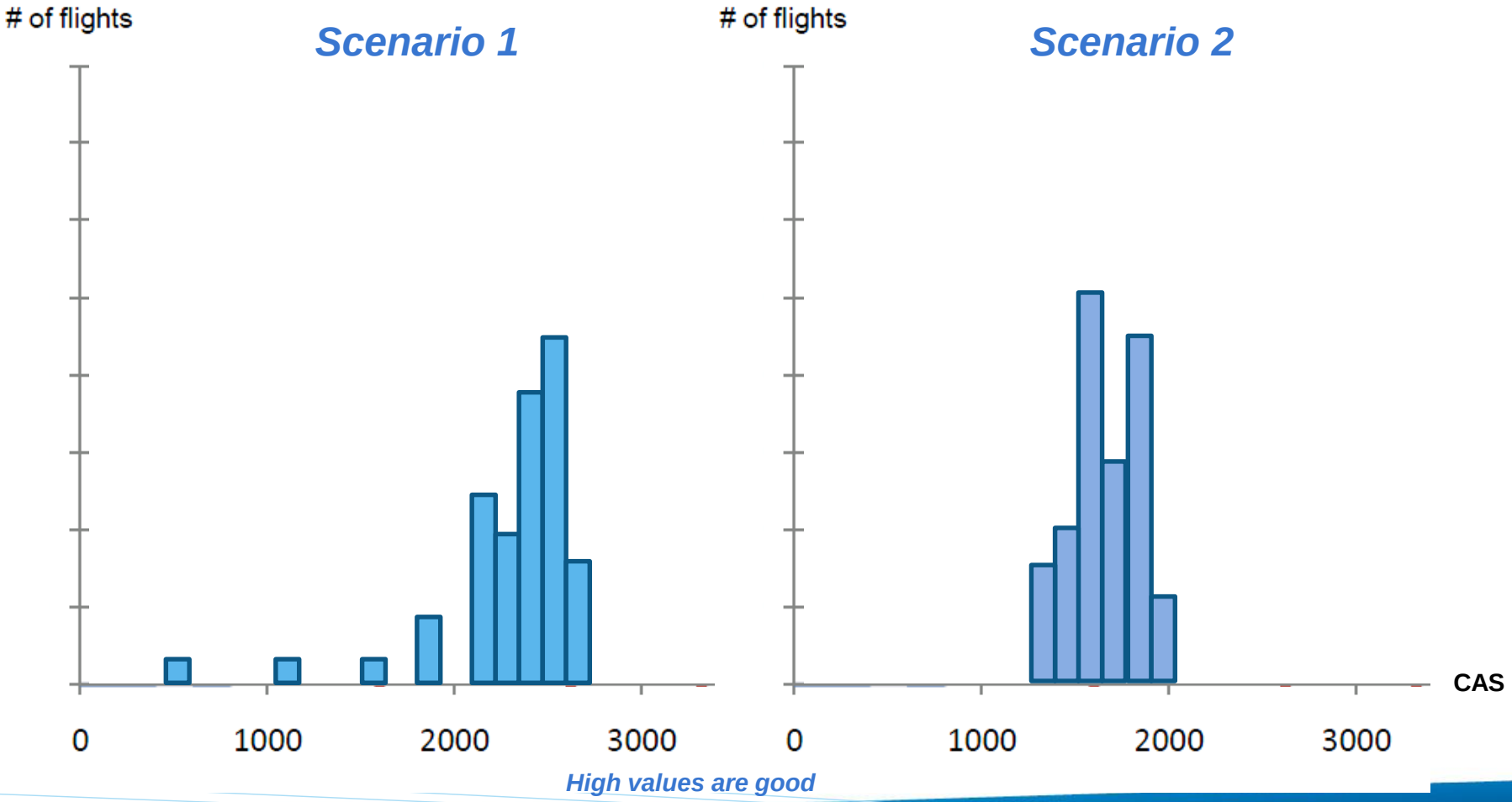


- **For the purpose of planning the sequence of flights when building crew schedules, using any of the above would suffice!**
- **BAM uses the TOD prediction for each flight as default for pilots (configurable). The average of Dep/Arr predictions is used for cabin crew.**

Next: A metric for an set of flights...

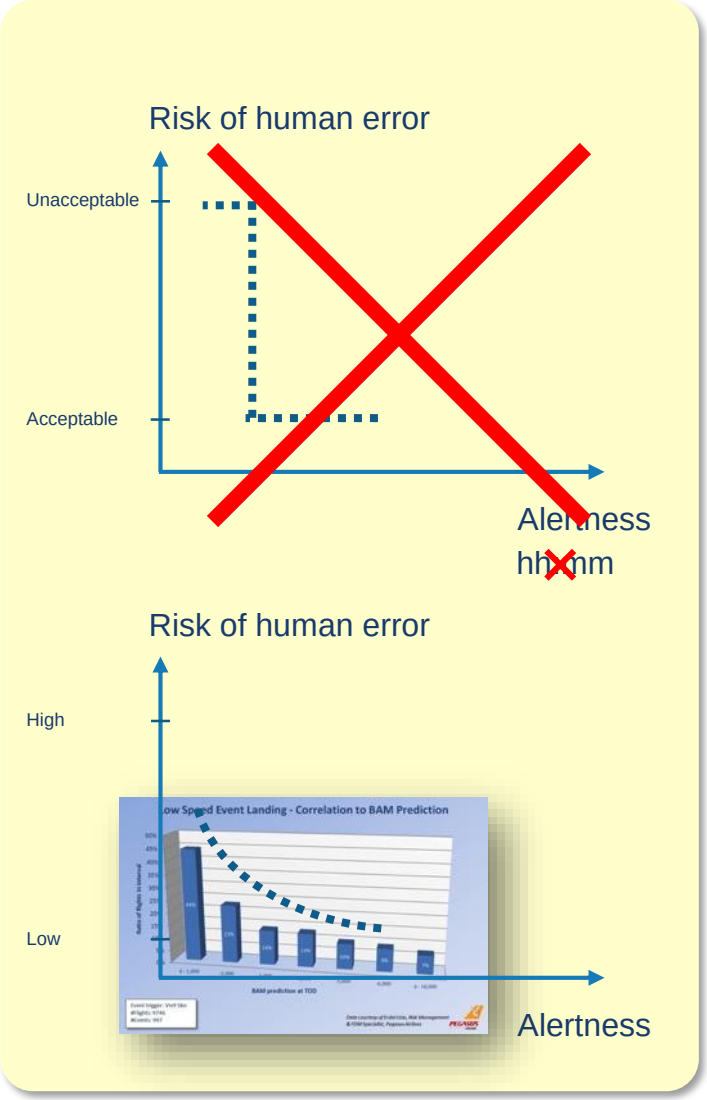
Recognizing that <u>low</u> levels of alertness are bad... – what would be a relevant metric for comparing the two outcomes are below?

And which one is the best from a safety perspective? ***(note: the same data used)***



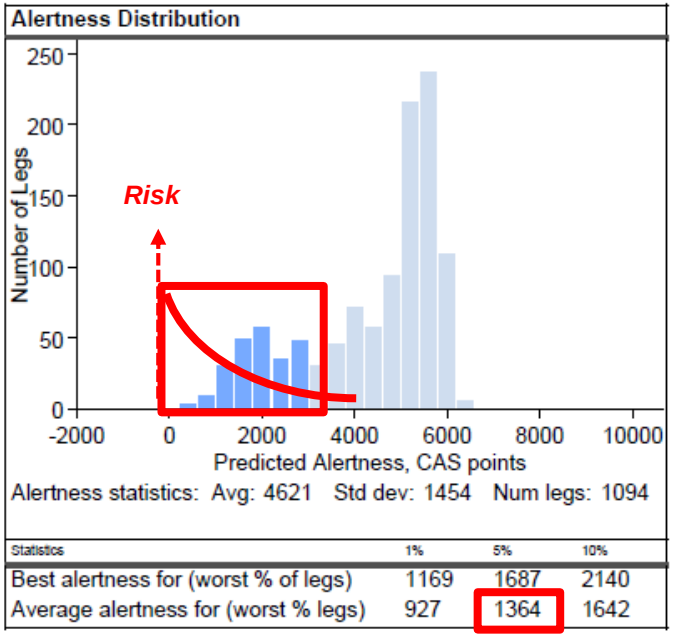
High values are good

The Risk of Human Error (Lapses, Slips, Mistakes, Violations)...



Alertness Distribution

Scenario file: FA20110620_01
Model: BAM Version: 1.1.6 Unit: CAS-50
Created: 15Aug2011 16:42:50 By: klemets2



Statistics	1%	5%	10%
Best alertness for (worst % of legs)	1169	1687	2140
Average alertness for (worst % legs)	927	1364	1642

PA5

The operational risk for the airline is the sum of risk contributions of all the flights (in the tail of the distribution).

Metrics (1)

CAS, The Common Alertness Scale

- Anchored to KSS such that KSS1 = 10k, KSS2 = 8750, KSS9 = 0.
- [Proposed to all model vendors as "*least bad common denominator*" but adaption is low.]

The model prediction (good proxy for risk of human error at a certain time)

PA5 (Protected level of alertness at a 5% level)

- The average level of alertness for the 5% worst flights. (Predicted at top of descent).
- ✓ Reflects the tail of the risk distribution. Easy to understand.
- ✗ Does not work for a small number of flights

Shows overall "risk profile" on a set of flights

High numbers are good (alertness)

Metrics (2)

AFR, Absolute Fatigue Risk

- A weighted sum over all flights of a risk growing exponentially from 5000 CAS and down (number of 100-points steps squared).
- ✓ Detailed representation of risk, as we know it.
- ✗ Becomes a bit abstract.

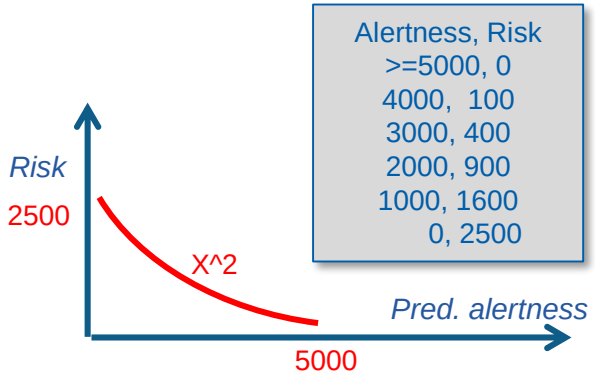
Good for identifying the part of operation at highest (overall) risk.

NFR, Normalized Fatigue Risk.

- AFR divided over number of flights.

Good for spotting trends and picking out base/rank/fleet/station with the relatively highest, or shifting, risk.

So; An operation keeping it's structure but doubling in size will have 2 times the AFR (double risk for fatigue related incident/accident) but the same NFR (risk profile).

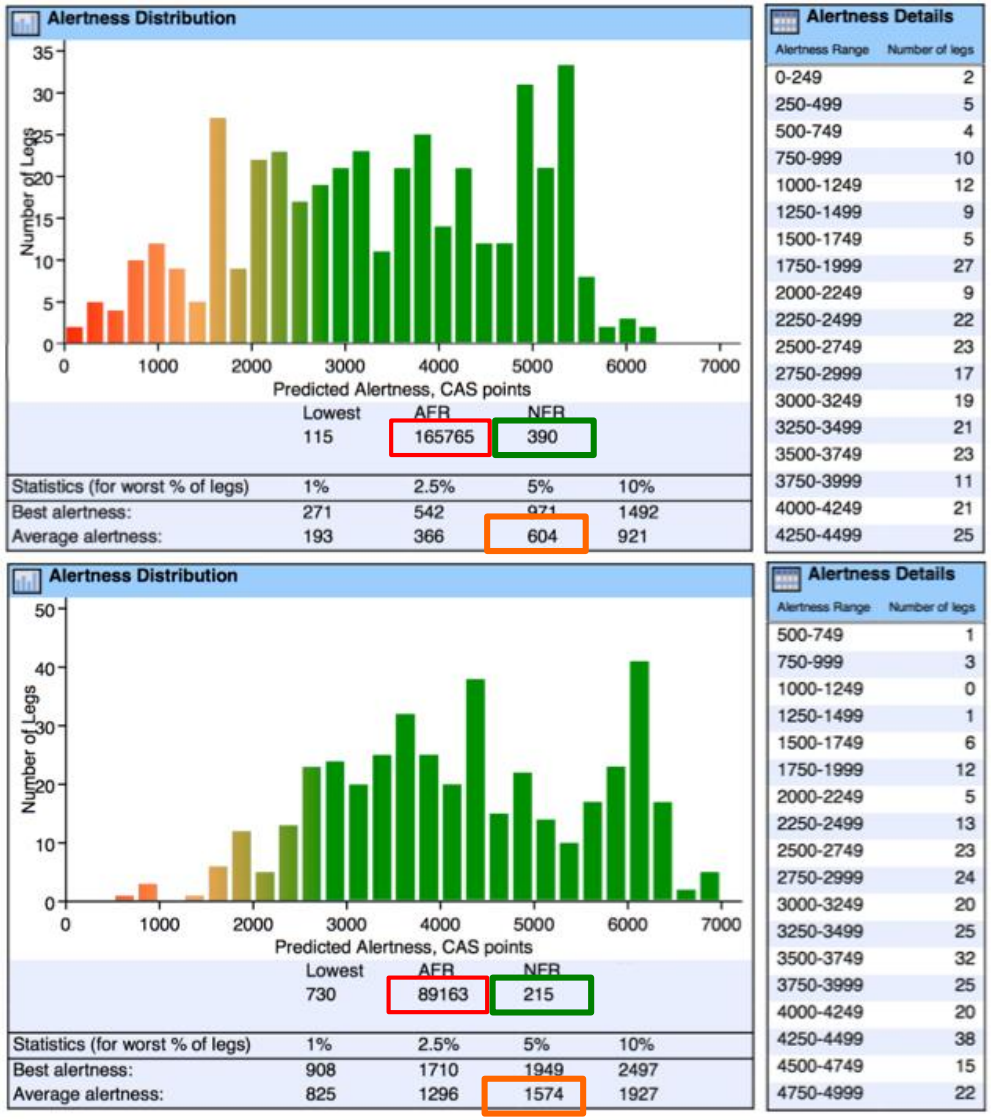


Low numbers are good (risk)

Used in practice in planning of full solutions

Sometimes easy to see in the end result...

…but to find the better solution you need this metric also guiding the optimizer…



Jeppesen FRM News Flash APR'16

www.jeppesen.com/frm

Fatigue Risk Management tools that make a real difference

Wideroe Among the First with FRMS and a Derogation

Wideroe, the largest regional airline in Scandinavia with 3,000 staff and 41 Dash-8 aircrafts, has become one of the first operators in Europe to gain approval for their FRMS.

"*The Boeing Alertness Model is one of the cornerstones of our FRMS, providing us with an additional layer of safety on top of regulation. Using BAM we have been granted a derogation by EASA to allow 70 hours duty per seven days instead of the 60 hours stipulated in the new FTLs. This derogation is based on our additional precautions introduced to exceed the equivalent level of safety*", says Aleksander Wasland, Chief Pilot, at Wideroe.

Tomas Klemets, Head of Scheduling Safety at Jeppesen, adds: "*It is highly satisfactory to see operators now embracing science and using it in a more direct way in their operations, to supplement less accurate rules-only approaches. Wideroe is one of the first operators to perform a solid quantification of risk in short haul operations and build a detailed safety business case. We are very happy to see that our optimization technology, in combination with BAM, enabled this development.*"

Summary and Q&A

- **Fatigue risk is real**
- **Crew rosters play an important part in building risk**
- **The crew management process is complex, and governed by regulatory rules (still) poorly aligned with human physiology**
- **Fatigue risk can be predicted and quantified using BMMs**
- **BMMs can be used for planning crew better, opening up for**
  - Reducing crew fatigue risk
  - Higher crew efficiency

Questions?

www.jeppesen.com/frm

