Managing Fatigue 2017
San Diego, March 22

A Wider Perspective on Reducing Fatigue Risk in Aviation

- And the importance of metrics

Tomas Klemets, Head of Scheduling Safety, Jeppesen

What is ***fatigue***? And ***fatigue risk***?

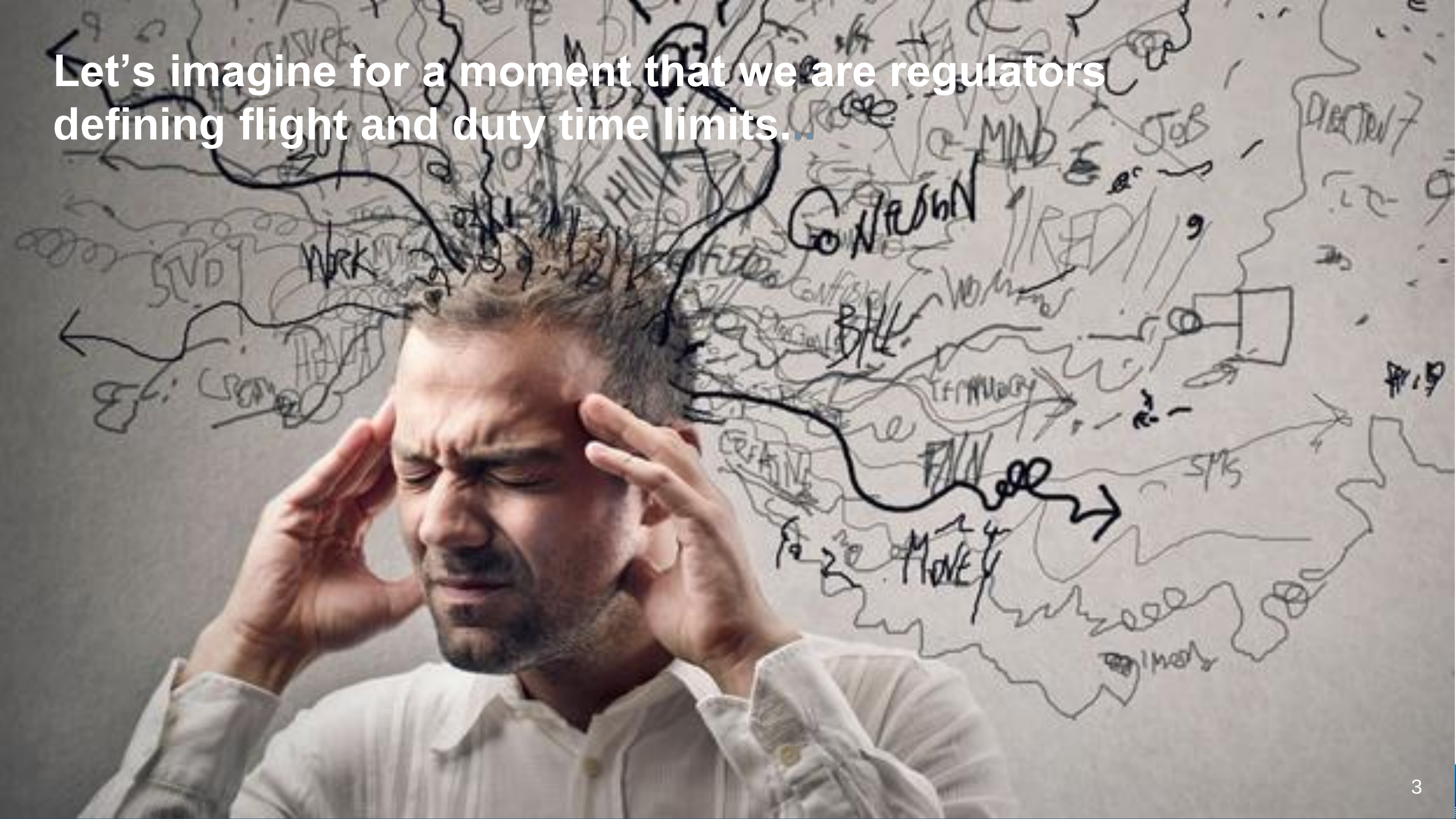
” A physiological state of reduced mental or physical performance capability resulting from sleep loss, extended wakefulness, circadian phase, and/or workload (mental and/or physical activity) that can impair a person’s alertness and ability to perform safety related operational duties.”

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.*

Let’s imagine for a moment that we are regulators defining flight and duty time limits…



We need a quick decision...

In order to reduce fatigue risk, for flight duties starting between 8pm and 5am, should we:

A <u>Increase</u> max flight duty time with 30 minutes, OR

(10h → 10h30m)

B <u>Reduce</u> max flight duty time with 30 minutes?

(10h → 9h30m)

We need a quick decision...

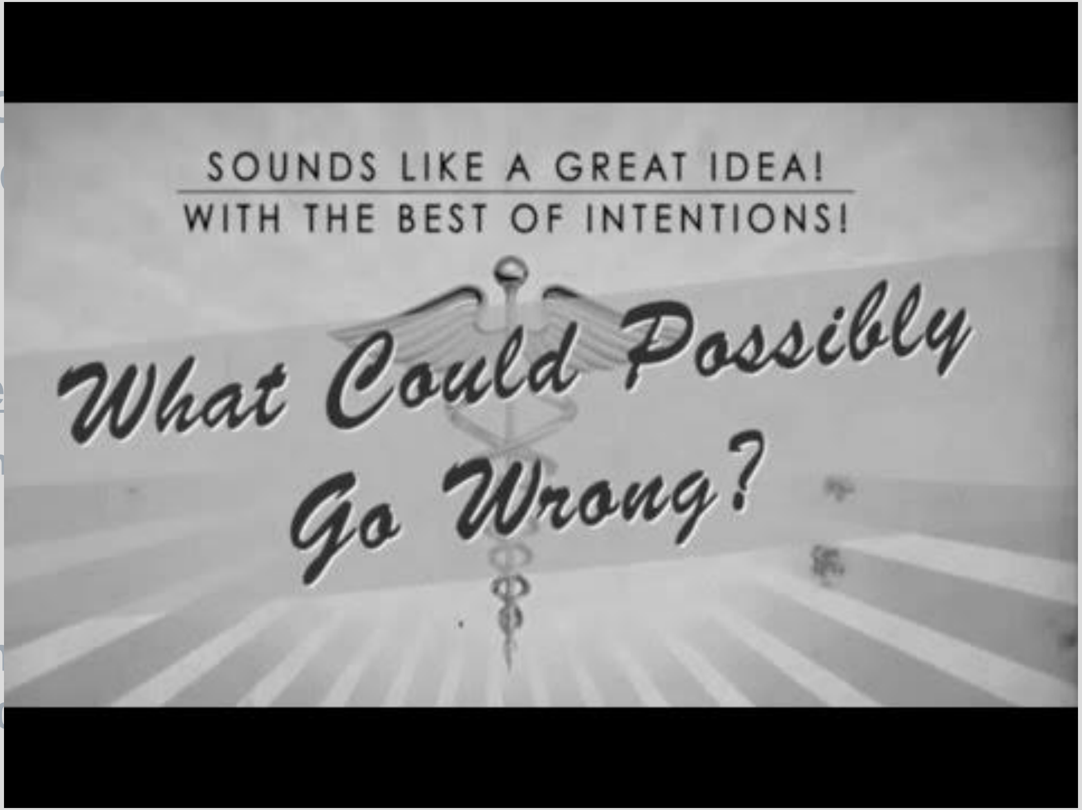
In order to
starting b

A Increase

(10h → 10h

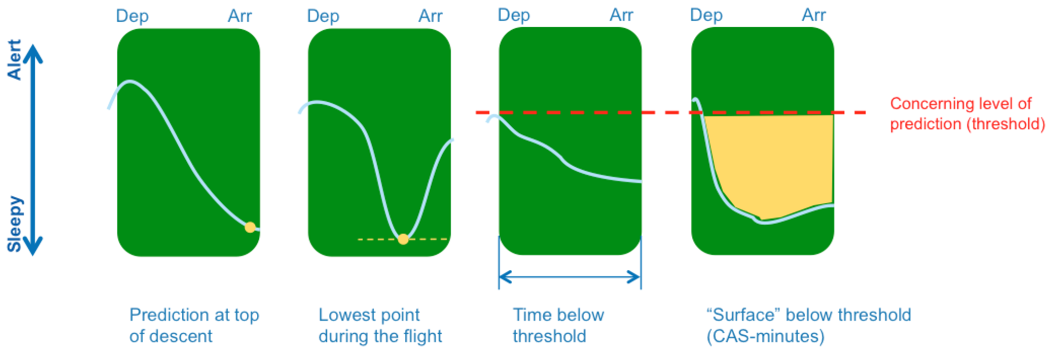
B Reduce n

(10h → 9h3



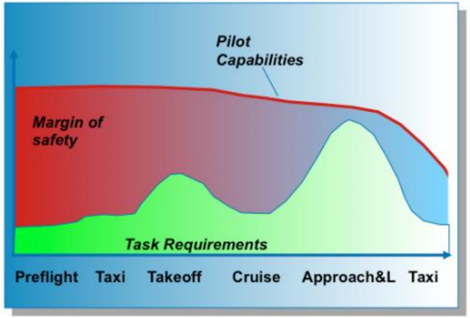
Metrics for more informed decisions

- **Can we quantify fatigue risk?**
- **Perhaps not an absolute quantification, but one allowing us to compare?**
- **Not just one flight – but the overall risk?**
- **We do have validated bio-mathematical fatigue models**
  - Prediction of alertness/fatigue/effectiveness for a population at any point in time

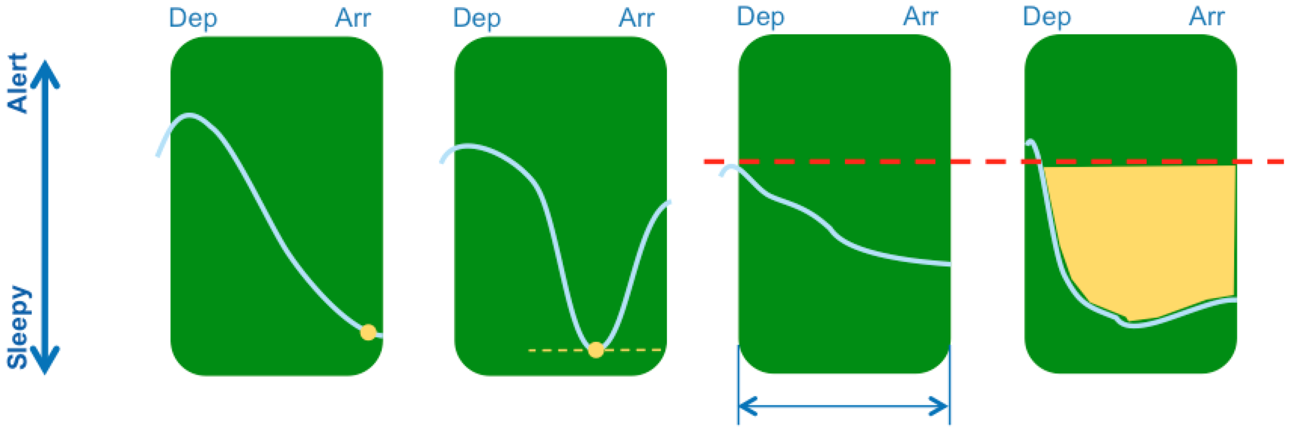


Metrics for more informed decisions

- Starting with one flight



Source: Pilot's Handbook of Aeronautical Knowledge 2004



Concerning level of prediction (threshold)

Prediction at top of descent

Lowest point during the flight

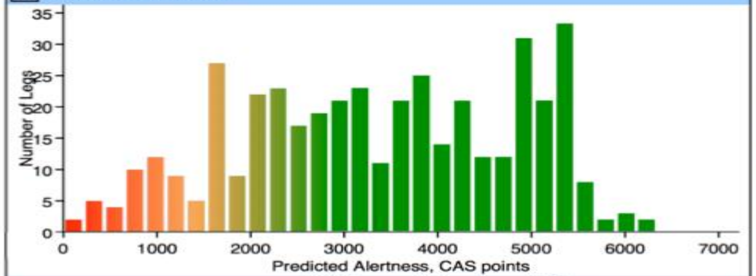
Time below threshold

“Surface” below threshold (CAS-minutes)

But what about a set of flights?

- How much better is the lower distribution?

Alertness Distribution



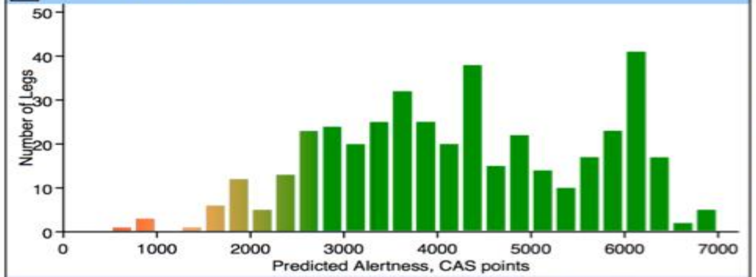
Lowest	AFR	NFR
115	165765	390

Statistics (for worst % of legs)	1%	2.5%	5%	10%
Best alertness:	271	542	971	1492
Average alertness:	193	366	604	921

Alertness Details

Alertness Range	Number of legs
0-249	2
250-499	5
500-749	4
750-999	10
1000-1249	12
1250-1499	9
1500-1749	5
1750-1999	27
2000-2249	9
2250-2499	22
2500-2749	23
2750-2999	17
3000-3249	19
3250-3499	21
3500-3749	23
3750-3999	11
4000-4249	21
4250-4499	25

Alertness Distribution



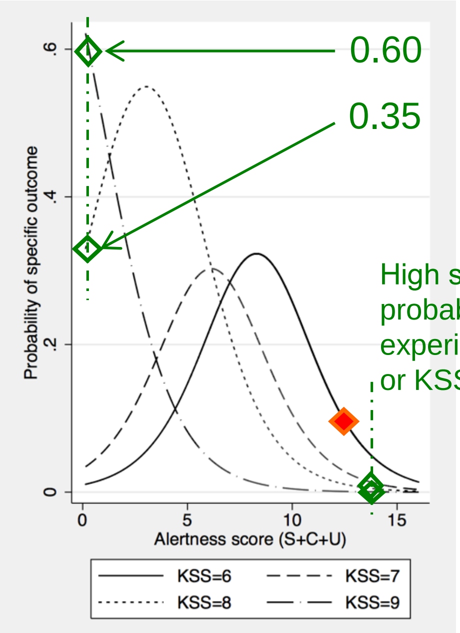
Lowest	AFR	NFR
730	89163	215

Statistics (for worst % of legs)	1%	2.5%	5%	10%
Best alertness:	908	1710	1949	2497
Average alertness:	825	1296	1574	1927

Alertness Details

Alertness Range	Number of legs
500-749	1
750-999	3
1000-1249	0
1250-1499	1
1500-1749	6
1750-1999	12
2000-2249	5
2250-2499	13
2500-2749	23
2750-2999	24
3000-3249	20
3250-3499	25
3500-3749	32
3750-3999	25
4000-4249	20
4250-4499	38
4500-4749	15
4750-4999	22

Fatigue Model Accuracy



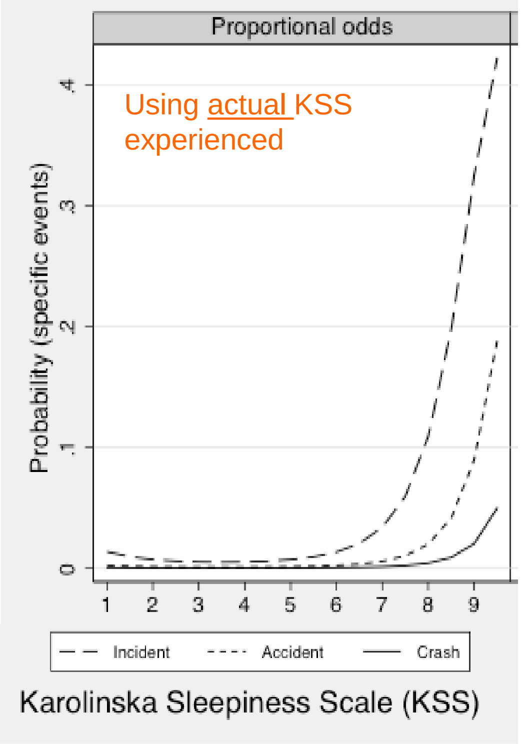
Low score = **95%** probability for crew experiencing KSS 8 or KSS 9!

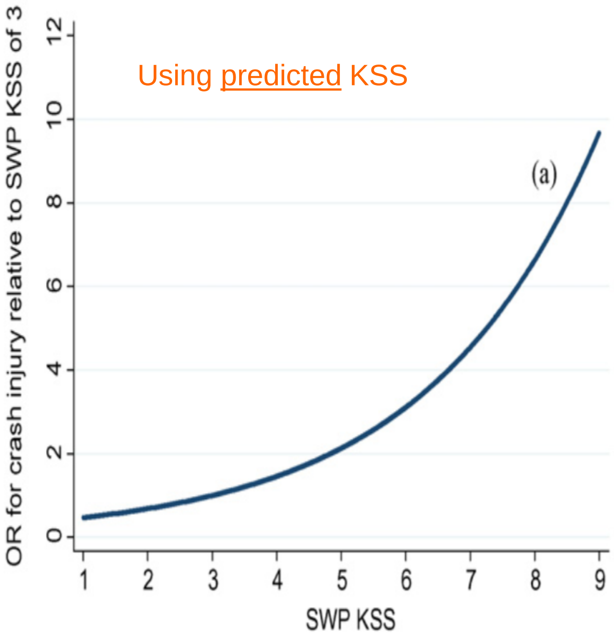
High score ≈ **0%** probability for crew experiencing KSS 8 or KSS 9

doi:10.7910/DVN/26541, 20 Oct 2014
SRI, Swedish CAA, SAS, Jeppesen

- **Reasons for inaccuracy**
  - Models are not perfect (!)
  - Models under-informed
    - Need to predict sleep
    - Habitual sleep length, Diurnal type, Individual commute times etc.
  - Mitigations
  - Social factors
  - Inter-, and intra-individual variation

Fatigue Risk – as a function of KSS

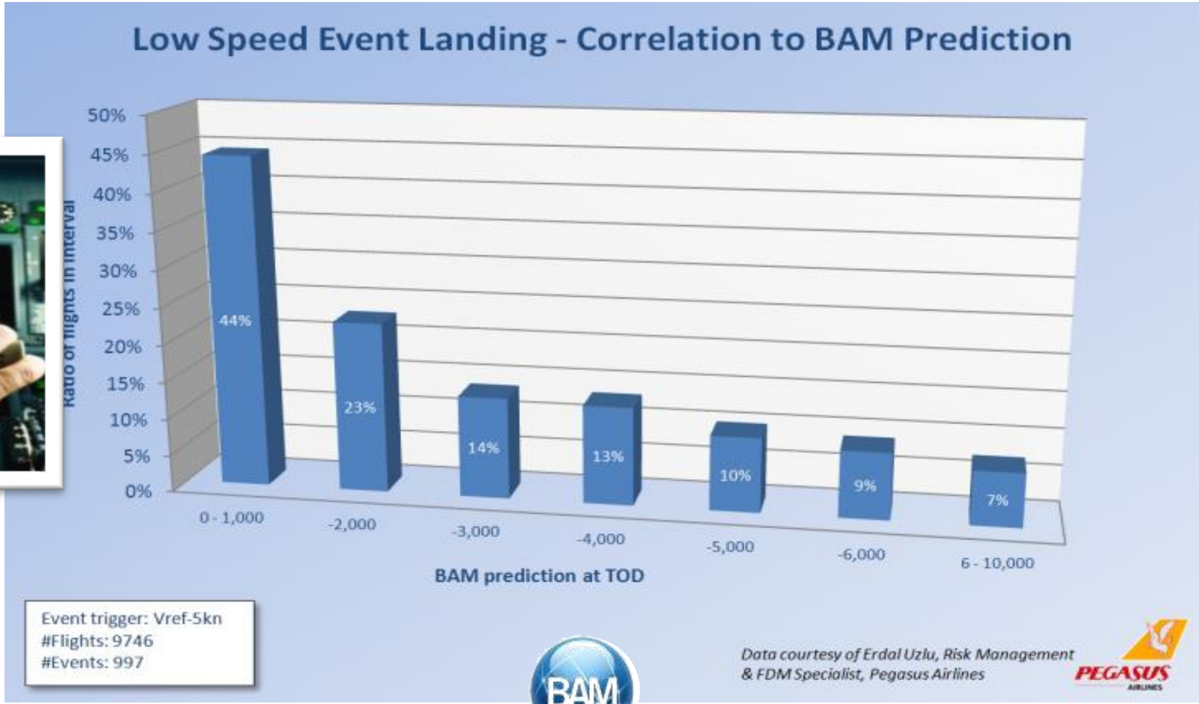




Predicting road crashes from a mathematical model of alertness regulation—The Sleep/Wake Predictor

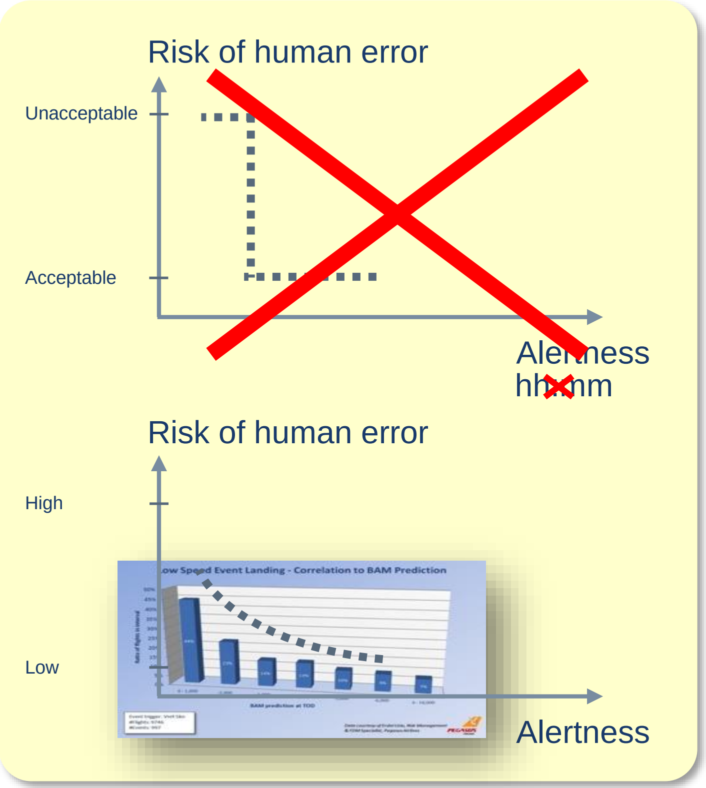
Torbjörn Åkerstedt[a,*], Jennie Connor[b], Andrew Gray[b], Göran Kecklund[a]

A Real World Example



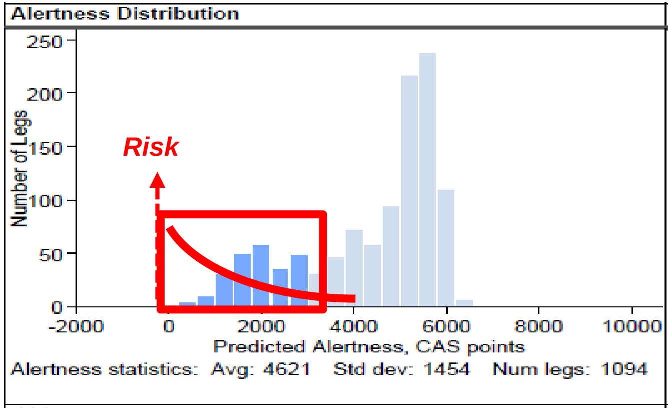
BAM

The Risk of Human Error
(Lapses, Slips, Mistakes, and 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

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

Proposed metrics for overall risk

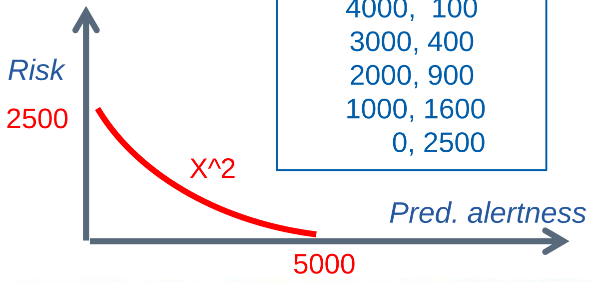
- **AFR, Absolute Fatigue Risk**
  - A weighted sum over all flights, with an accelerating weight as the prediction approaches zero
  - ✓ Detailed representation of risk, as we know it.
  - ✗ Becomes a bit abstract.

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

- **NFR, Normalized Fatigue Risk.**
  - AFR divided over number of flights.

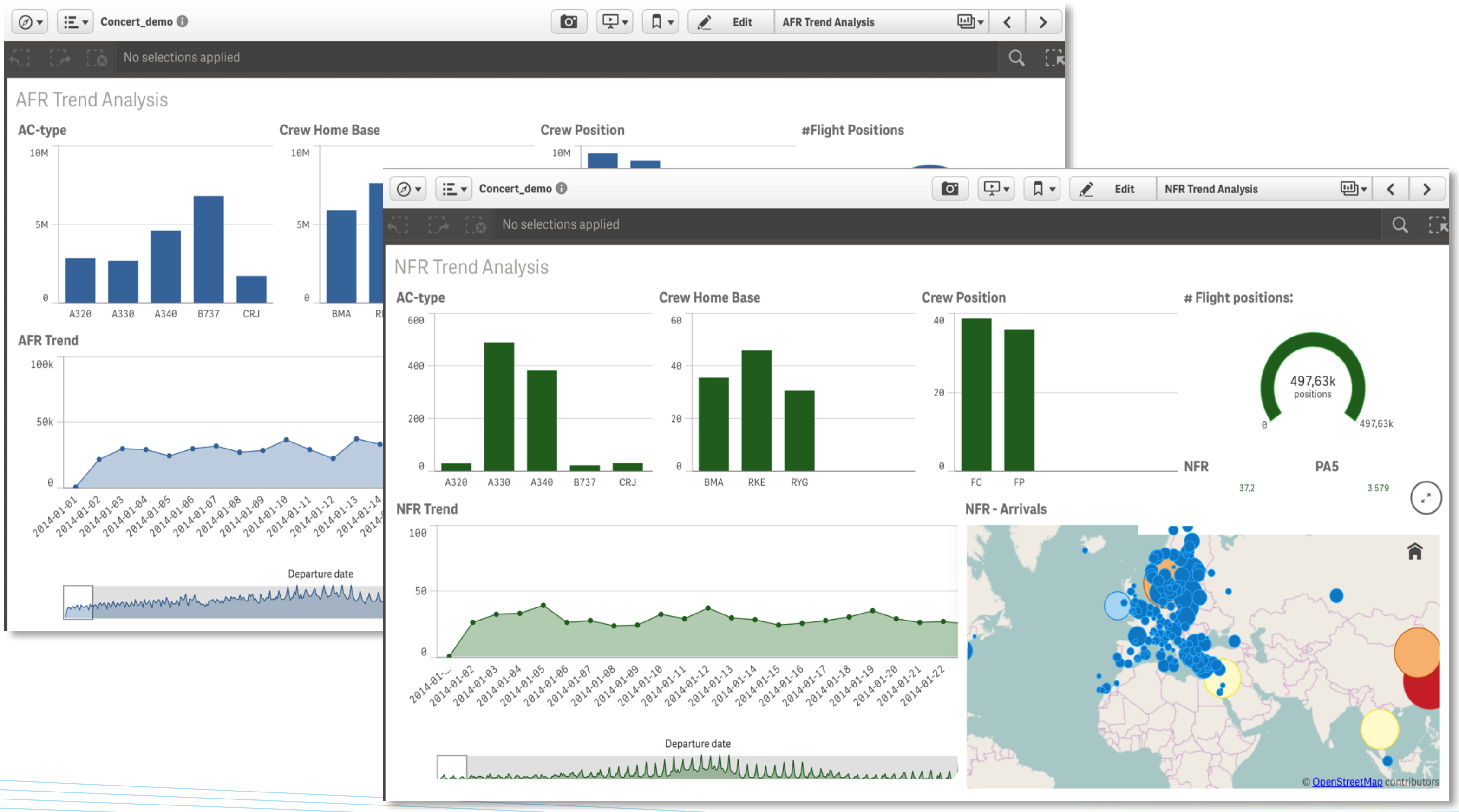
Good for spotting trends and picking out base/rank/fleet/station with the relatively highest, or shifting, risk.

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).



Alertness, Risk
>=5000, 0
4000, 100
3000, 400
2000, 900
1000, 1600
0, 2500

Monitoring Fatigue Risk

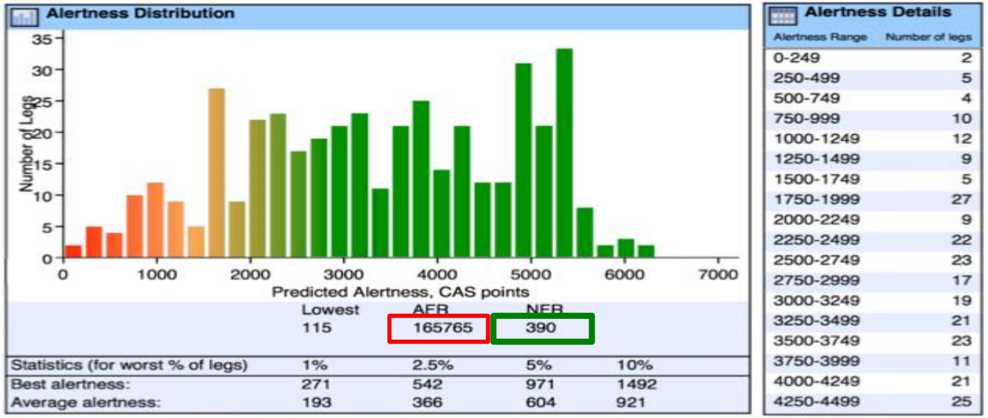


Control of Fatigue Risk

- “Normal” planning rules/focus w/o any true guidance on human physiology

- Same rules but <u>also</u> using a BMM providing an incentive during planning to avoid poorly planned flights.

- Same data. Same rules. Almost identical crew efficiency.
  But much lower risk.



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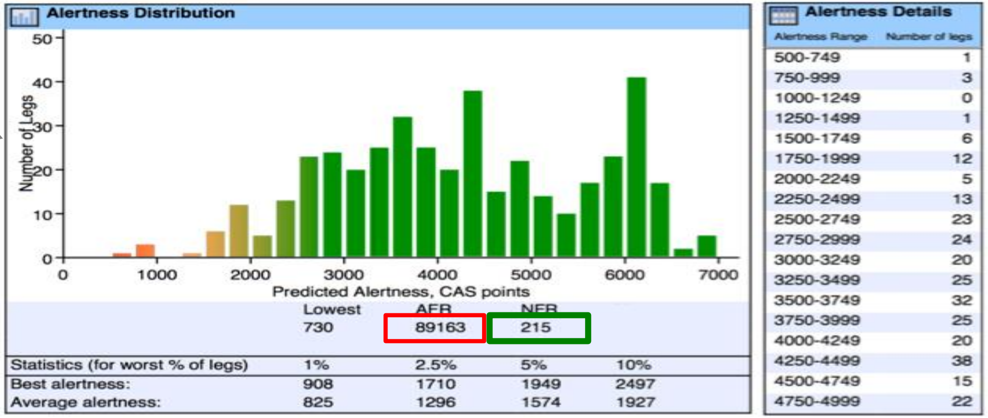

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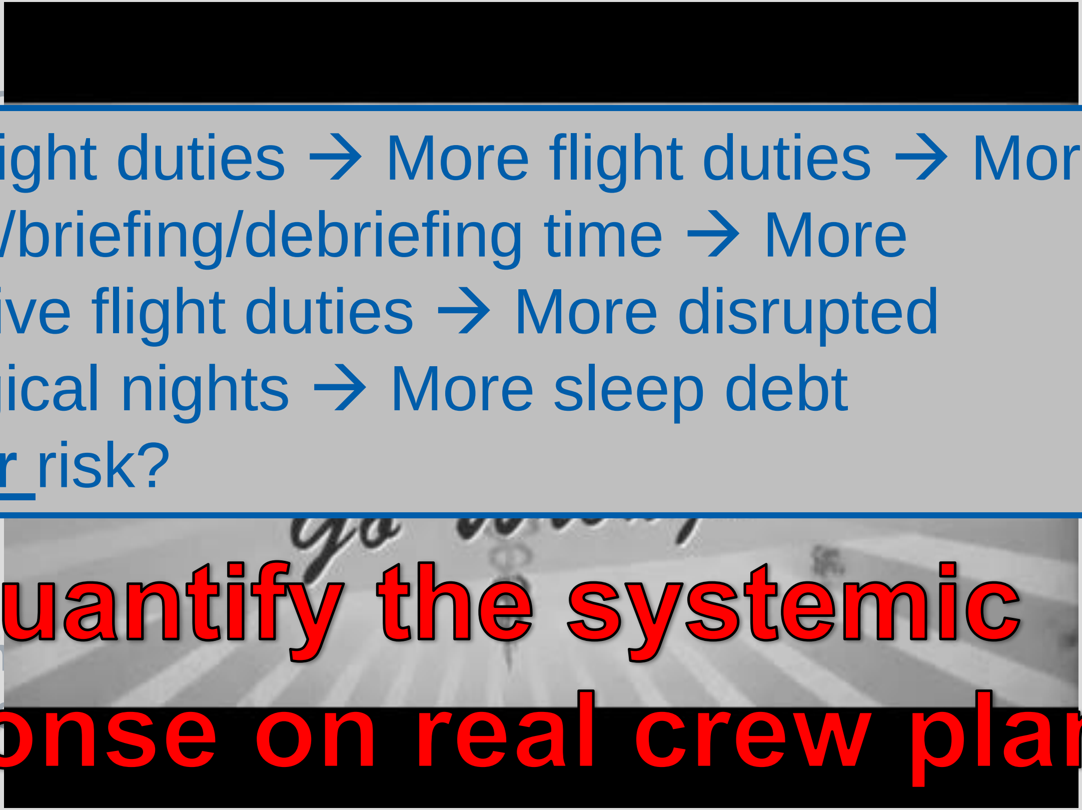
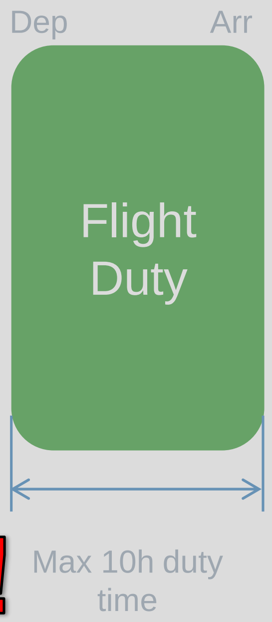


Shorter flight duties → More flight duties → More commute/briefing/debriefing time → More consecutive flight duties → More disrupted physiological nights → More sleep debt → **<u>Higher</u>** risk?

B Reduce m

(10h → 9h3

Quantify the systemic response on real crew plans!



Summary

- **Traditional rules are blunt instruments. So are cut-offs based on bio-mathematical models**
- **Output from fatigue models can be used to effectively monitor, prevent and reduce fatigue risk exposure**
- **The industry would benefit from standards for predictive risk metrics, such as AFR and NFR here presented.**
  – What you can't measure…
- **Gains are significant...**
  – From max 60h to 70h...

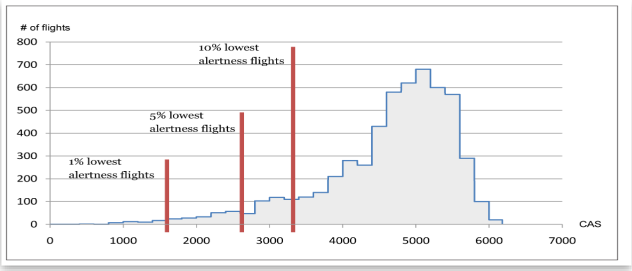

Thank you!

Backup slides from here onwards

The ”Comprehensive Study” 2011 - preconditions

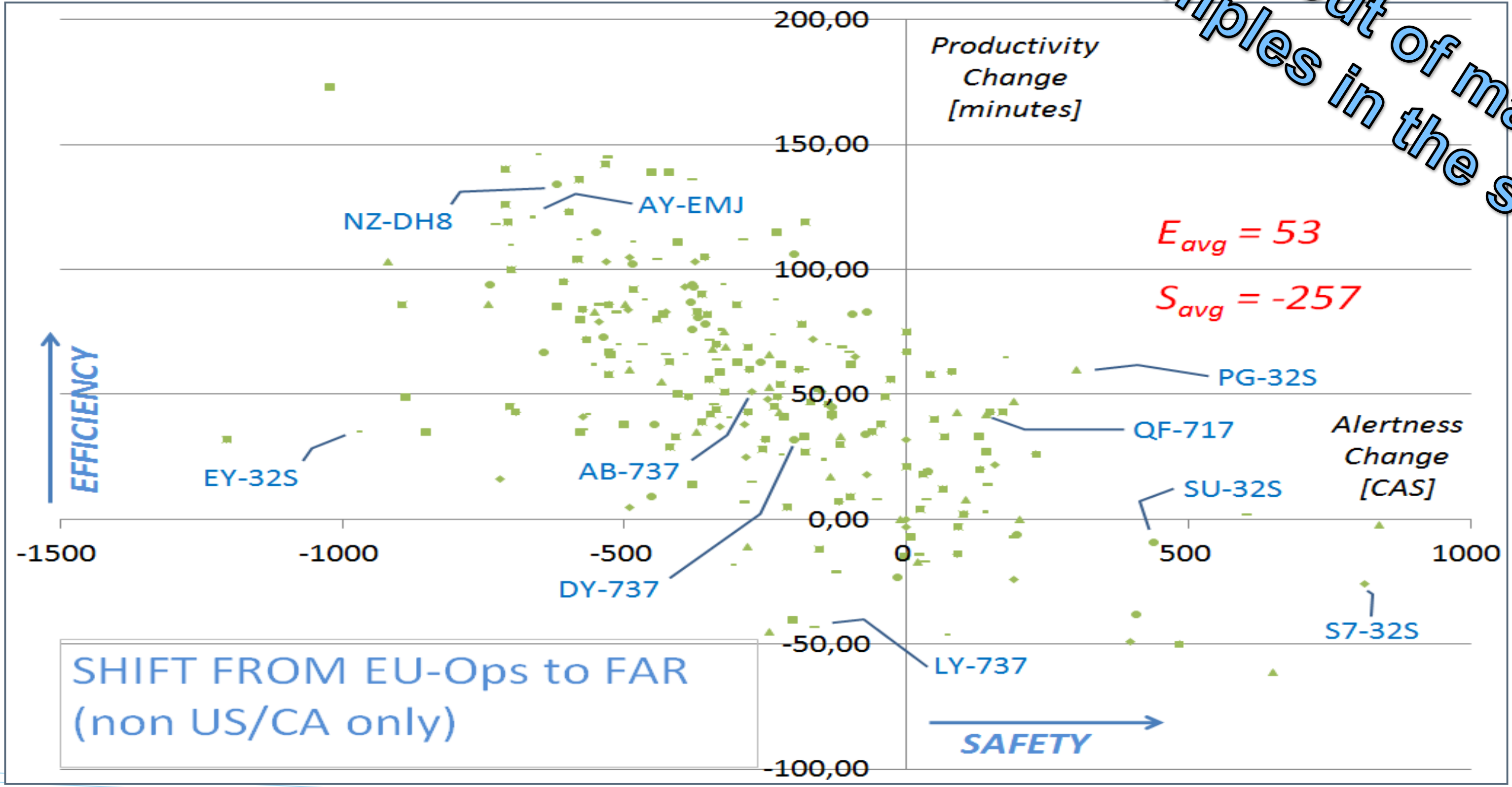
See
GPA_white_paper_word_v1.0.pdf

- **OAG data for May 2011.**
  - Over 300 planning problems selected, all >200 flights/week
- **Only two-pilot operation**
- **Applying only flight time regulations**
- **Optimal base-distribution of crew.**
- **Aircraft rotations built using FIFO algorithm.**
  - Crew may always follow A/C in turns
- **Deadhead only on own carrier**
- **Pairing construction, striving for efficiency**
  - Minimizing synthetic for US and CA operators
  - Maximizing productivity elsewhere
  - Basic, normal, planning constraints limiting e.g. A/C changes.
- **Evaluation using BAM 1.6.1**
  - PA5 used as main KPI for the safety of a solution
- **In total over 2100 plans built consuming some 4000 CPU hours**



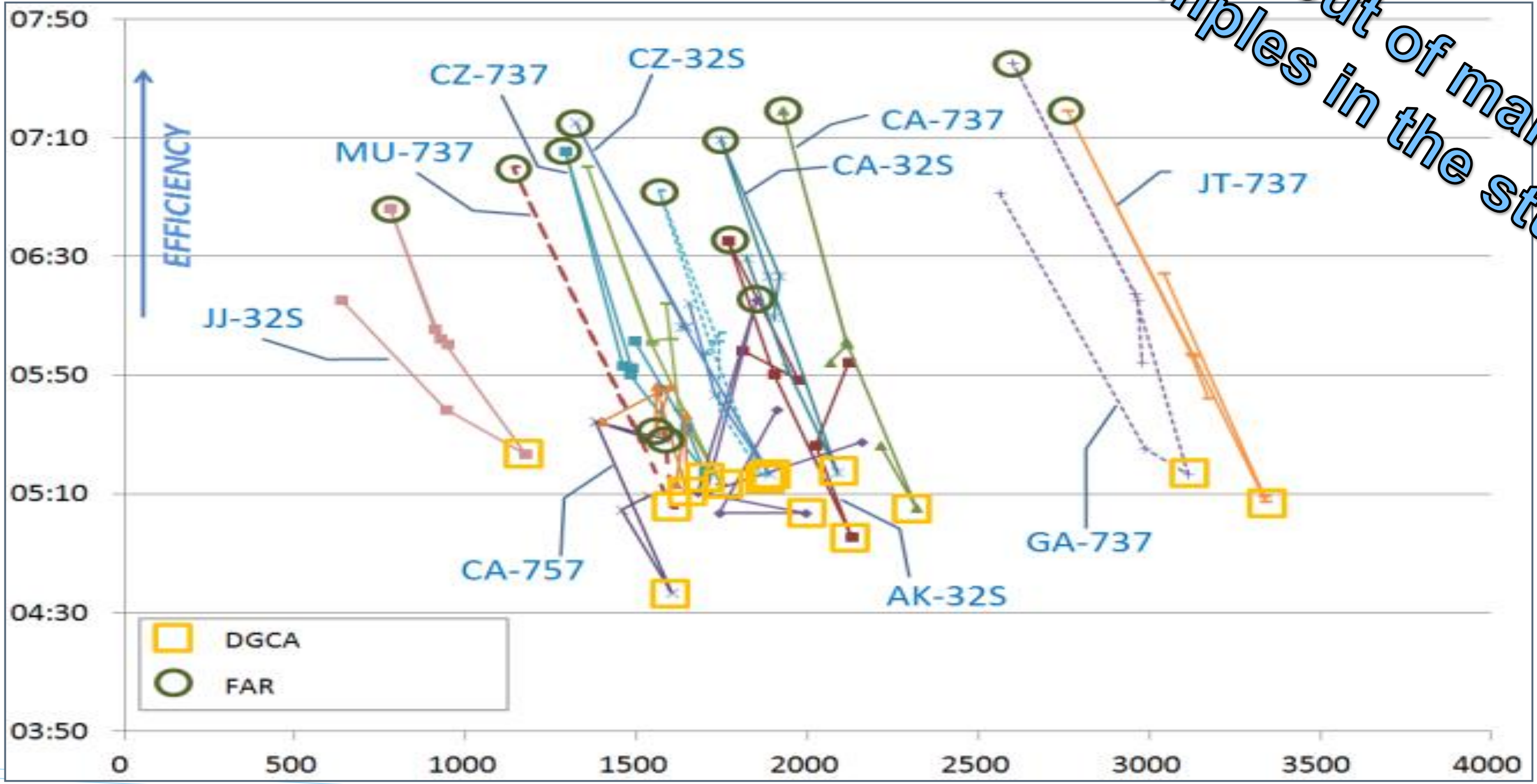
What if changing from EU-Ops to FAR?

One out of many examples in the study



Some absolute numbers – APAC

One out of many examples in the study



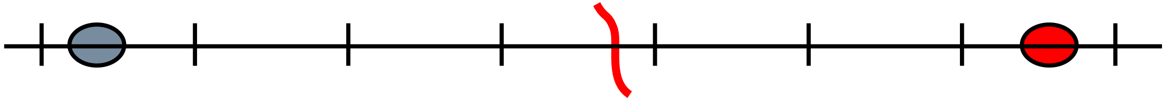
Conclusions of the study

- Fatigue is significantly linked to the business model of the operator.
- FTLs in current form do not limit fatigue effectively.
- Current FTLs have a more significant effect on efficiency than on fatigue risk.
- FAR allows for the highest efficiency, but is also the FTL least protective from fatigue.
- DGCA is the most protective FTL for fatigue risk but is generally most restrictive on efficiency.
- Fatigue models are needed to provide direction <u>within</u> FTLs. And also for improving them…

The Misalignment btw Fatigue and Work load…

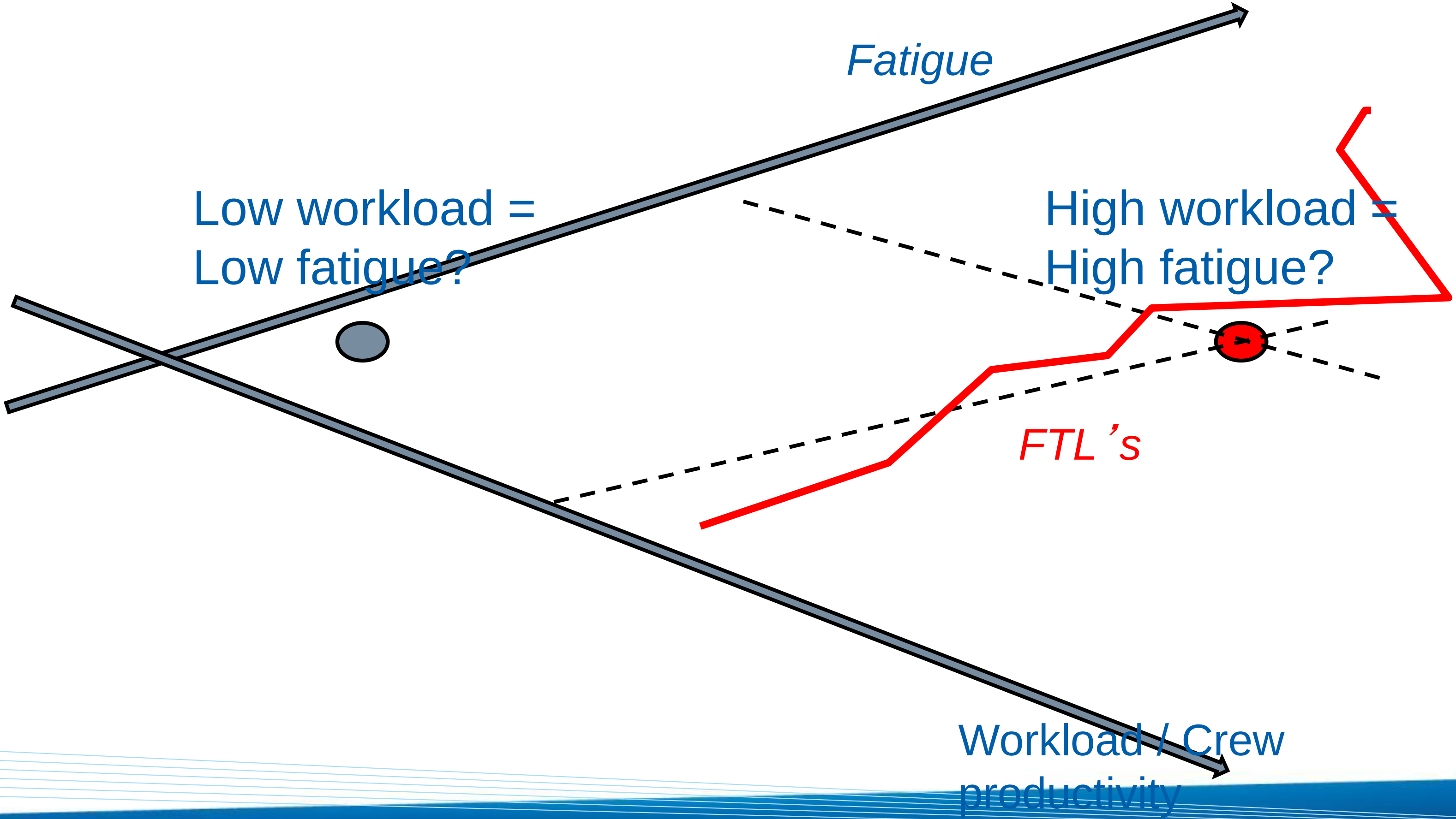
Low workload =
Low fatigue?

High workload =
High fatigue?

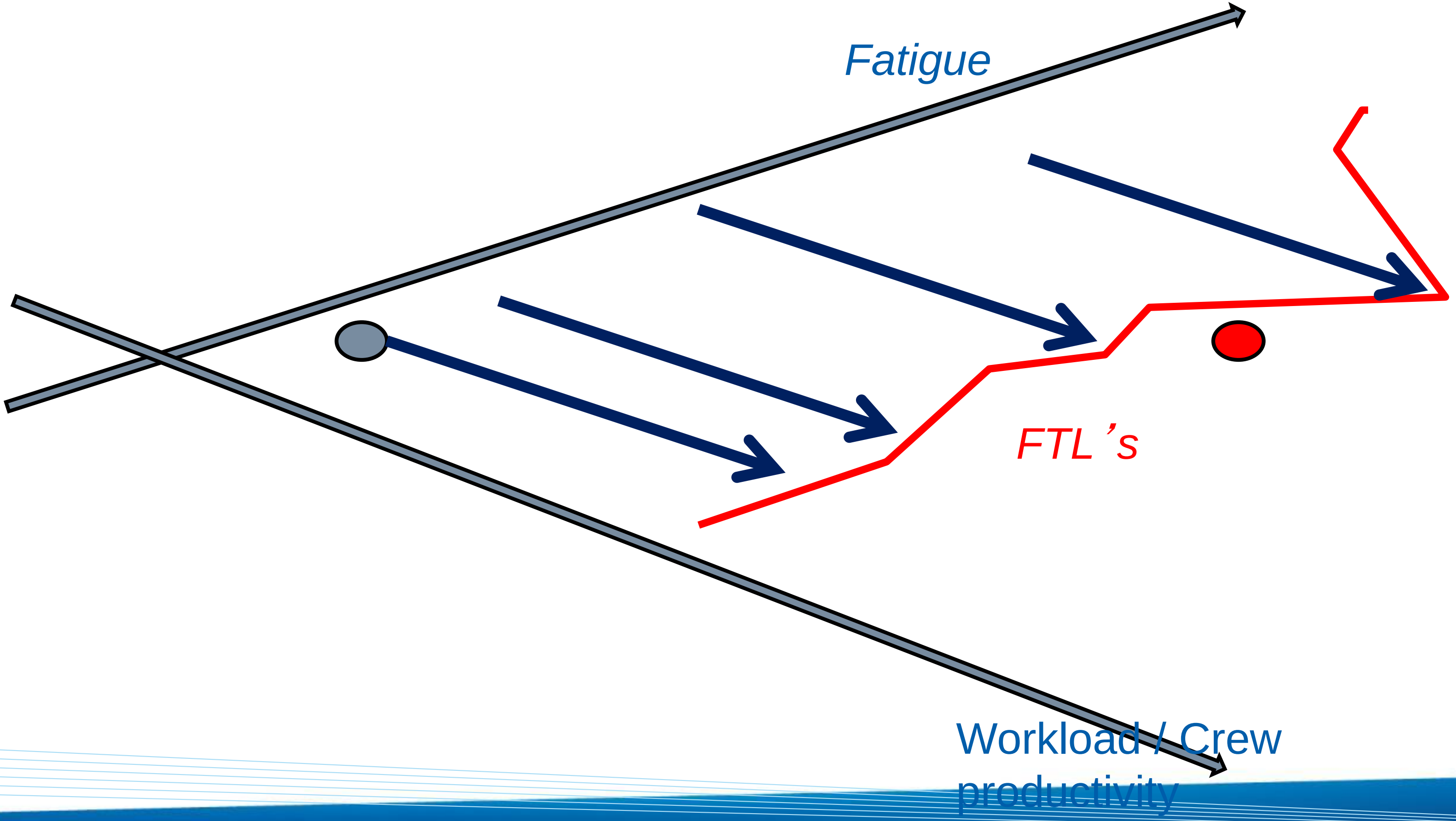


FTL’s: FAA, EASA, CASA, CAAC, national CAA’s...

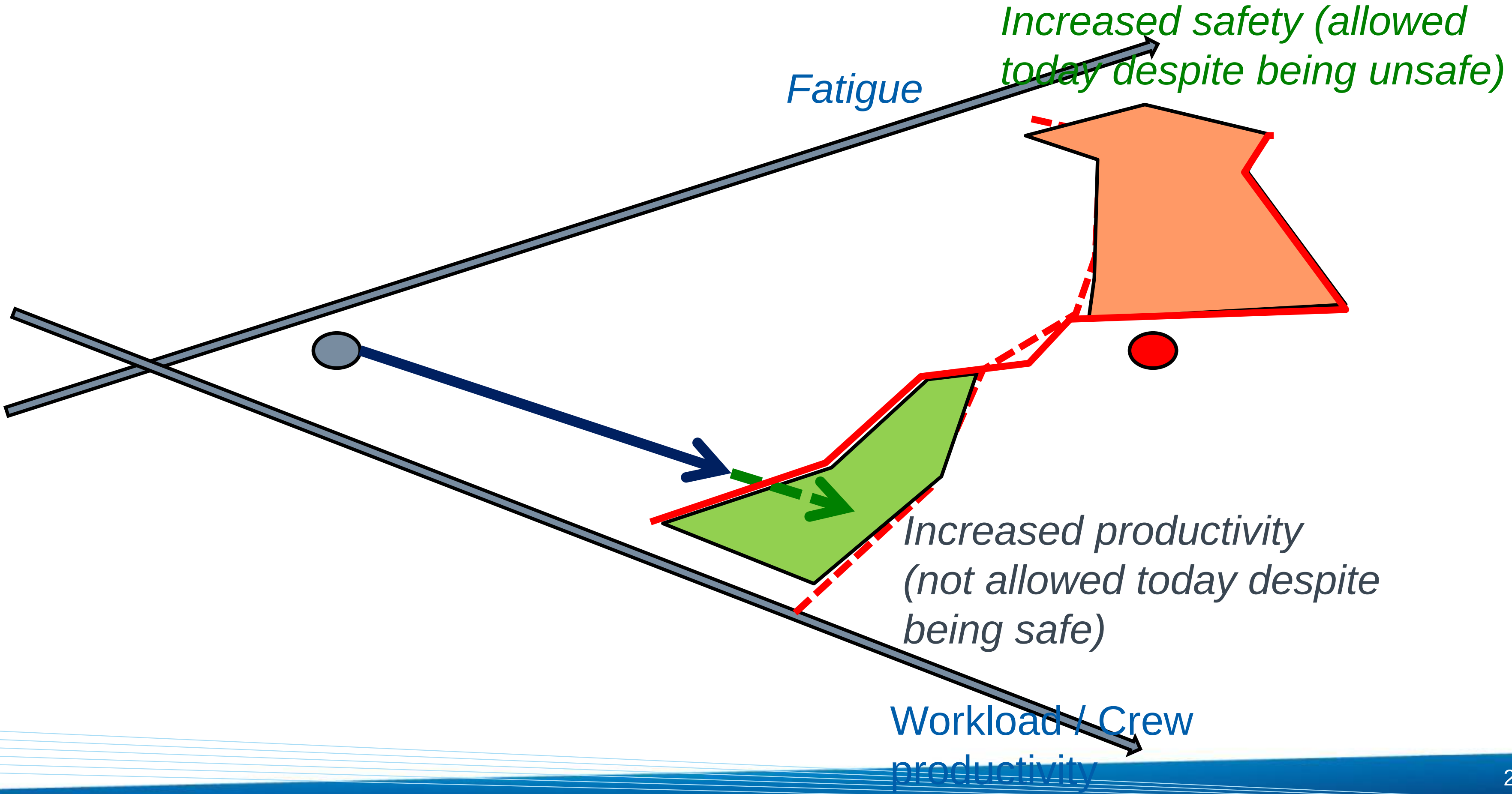
The Misalignment btw Fatigue and Work load…



Operator objective (in part) – crew productivity



Fatigue (Risk) Management – if done right…



The value of an FRMS approach

- Safety (lower risk of incidents/accidents)
- Crew quality of life
- Compliance / liability / goodwill
- Crew efficiency!