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. **Increase** max flight duty time with 30 minutes, OR
   (10h $\rightarrow$ 10h30m)

B. **Reduce** max flight duty time with 30 minutes?
   (10h $\rightarrow$ 9h30m)
We need a quick decision...

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   (10h → 9h30m)
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

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<th>Alert</th>
<th>Sleepy</th>
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- Prediction at top of descent
- Lowest point during the flight
- Time below threshold
- "Surface" below threshold (CAS-minutes)

Concerning level of prediction (threshold)
But what about a set of flights?

- How much better is the lower distribution?
Fatigue Model Accuracy

- **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

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

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

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SRI, Swedish CAA, SAS, Jeppesen
Fatigue Risk – as a function of KSS

Using actual KSS experienced

Using predicted KSS

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

Torbjörn Åkerstedt, Jennie Connor, Andrew Gray, Göran Kecklund
A Real World Example

Low Speed Event Landing - Correlation to BAM Prediction

Event trigger: Vref-Skm
#flights: 9746
#Events: 997

Data courtesy of Erdal Uzlu, Risk Management & FDM Specialist, Pegasus Airlines
The Risk of Human Error
(Lapses, Slips, Mistakes, and Violations)...

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.

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

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

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

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

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

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

We need a quick decision...

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

- Increase max flight duty time with 30 minutes, OR
- Reduce max flight duty time with 30 minutes?

<table>
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<tr>
<th>Flight Duty</th>
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<td>Max 10h duty time</td>
<td>10h</td>
<td>9h30m</td>
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Shorter flight duties $\Rightarrow$ More flight duties $\Rightarrow$ More commute/briefing/debriefing time $\Rightarrow$ More consecutive flight duties $\Rightarrow$ More disrupted physiological nights $\Rightarrow$ More sleep debt $\Rightarrow$ **Higher** risk?

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

- 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

\[ E_{\text{avg}} = 53 \]
\[ S_{\text{avg}} = -257 \]

SHIFT FROM EU-Ops to FAR (non US/CA only)
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 within 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…

Fatigue

Low workload = Low fatigue?

High workload = High fatigue?

FTL’s

Workload / Crew productivity
Operator objective (in part) – crew productivity

Fatigue

FTL’s

Workload / Crew productivity
Fatigue (Risk) Management – if done right…

- Increased productivity (not allowed today despite being safe)
- Increased safety (allowed today despite being unsafe)
- Workload / Crew productivity
The value of an FRMS approach

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