European Union Aviation Safety Agency

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RESEARCH PROJECT [EASA.2019.C31]

DELIVERABLE 2.6: EFFECTIVENESS OF THE CURRENT FLIGHT AND DUTY TIME LIMITATIONS IN MAINTAINING ACCEPTABLE LEVELS OF AIRCREW ALERTNESS

Effectiveness of Flight Time Limitations (FTL2.0)

An Agency of the European Union

Disclaimer

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APPROVED BY:	AUTHORS	REVIEWER	MANAGING DEPARTMENT
	Roelen (NLR) Laurie Marsman (NLR) Alwin van Drongelen (NLR)	Jeroen van Rooij (NLR)	A. Rutten (NLR)

EASA:

Irina Petrova, EASA Flight Standards Directorate

Scientific Committee: Barbara Stone, Alexandra Holmes, Kristjof Tritschler

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SUMMARY

Problem area

The research study FTL 2.0 aims to perform a review of the effectiveness of the current flight and duty time limitations and rest requirements contained in Commission Regulation (EU) No 965/2012 in maintaining acceptable levels of aircrew alertness. More specifically, the purpose is to add to the work performed during the first phase of the "Effectiveness of Flight Time Limitation" evaluation (MOVE/C2/2016-360).

This research study includes an assessment of the impact on aircrew alertness of the following aircrew duty periods:

a) Duties of more than 13 hours at the most favourable time of the day;
b) Duties of more than 11 hours for crew members in an unknown state of acclimatisation;
c) Duties including a high level of sectors (more than 6); and
d) On-call duties such as standby or reserve followed by flight duties, specifically focussing on 'other than airport standby'.

It also comprises an assessment of the impact on aircrew alertness of controlled rest: this includes an analysis of the conditions and circumstances under which aircrew members take controlled rest.

Description of work

The current deliverable describes the analyses of how effective the current flight and duty time limitations contained in sub-part FTL of Regulation (EU) 965/2012 are in maintaining acceptable levels of aircrew alertness. It is based on the findings of the data collection as presented in deliverable D2.3 and the results of the FTL1 study.

Results and Application

The conclusions of this report are important for setting up recommendations for improvement of the regulatory requirements.

CONTENTS

ABBREVIATIONS

ACRONYM	DESCRIPTION
D	Deliverable
DLR	German Aerospace Centre
EASA	European Union Aviation Safety Agency
FDP	Flight Duty Period
FRM	Fatigue Risk Management
FTL	Flight Time Limitations and rest requirements
H	Hours
ICAO	International Civil Aviation Organization
KSS	Karolinska Sleepiness Scale
min	minutes
N	number
NLR	Royal NLR - Netherlands Aerospace Centre
ToD	Top of Descent
WOCL	Window of Circadian Low

1. Introduction

1.1 Background

During the adoption in 2014 of the next generation of EU's Flight Time Limitation (FTL) and rest requirements for scheduled and charter airline operations, the European Parliament and the Commission instructed EASA to perform a continuous review of the effectiveness of those requirements.

Article 9b of Commission Regulation (EU) No 965/2012 stipulates that such review shall include an assessment of the impact on aircrew alertness of the following aircrew duty periods:

1. Duties of more than 13 hours at the most favourable time of the day;
2. Duties of more than 10 hours at the less favourable time of the day;
3. Duties of more than 11 hours for crew members in an unknown state of acclimatisation;
4. Duties including a high level of sectors (more than 6);
5. On-call duties such as standby or reserve followed by flight duties; and
6. Disruptive schedules.

1.2 Project description

The first phase of the study on Effectiveness of Flight Time Limitation (MOVE/C2/2016-360), (hereinafter referred to as FTL1), assessed the impact of Flight Duty Periods (FDPs) of more than 10 hours at the less favourable time of the day and disruptive schedules (i.e., early starts, late finishes, and night duties) on aircrew alertness.

The objective of the second phase of the study on Effectiveness of Flight Time Limitations (EASA.2019.C31) (hereinafter referred as FTL 2.0), is to perform an assessment of the impact on aircrew alertness of the following aircrew duty periods:

FDP1: Duties of more than 13 hours at the most favourable time of the day;
FDP3: Duties of more than 11 hours for crew members in an unknown state of acclimatisation;
FDP4: Duties including a high level of sectors (more than 6) and
FDP5: On-call duties such as standby or reserve followed by flight duties.

In addition, it includes an analysis of the conditions and circumstances under which aircrew members take Controlled Rest (CR).

Two series of deliverables are provided in FTL 2.0:

- D1: deliverables on the work performed in Task 1.1 on the definition of baseline and Task 1.2 on the definition of the target crew population;
- D2: deliverables on the work performed in Tasks 2.1 on the definition of scope and process for the data collection; in Task 2.2 on the data repository; in Tasks 2.3 and 2.4 on the data analyses and benchmark against other reference sources and the synopsis of the results of the previous and current contract including a list of generally applicable performance metrics; as well as in Tasks 2.5, 2.6 and 2.7 on the analysis of effectiveness of prescriptive FTL and the conclusions and recommendations.

1.3 This deliverable

The current deliverable (D2.6) involves an analysis of the effectiveness of prescriptive FTL , contained in Subpart FTL of Regulation (EU) 965/2012, as amended by Regulation (EU) No 83/2014, as well as an analysis of the conditions and circumstances under which aircrew members take CR in accordance with CAT.OP.MPA.210 (a)(3) of Regulation (EU) 965/2012 and taking account of the associated GM1 CAT.OP.MPA.210.

The objectives of this task are:

1) To assess, based on the strength of all the collected evidence, studies, analyses, benchmarks, and the underlying data, whether the examined prescriptive flight and duty time limitations are effective in maintaining acceptable levels of aircrew alertness .
2) To assess, based on the strength of all the collected evidence, studies, analyses, benchmarks, and the underlying data, whether controlled rest is effective and delivers the acceptable level of safety.

The effectiveness of the regulatory measures regarding disruptive schedules are described in the deliverables of study FTL1 already, and resulted in a change in the regulation in that the concept of appropriate fatigue risk management, which already existed in CS.FTL.1.205 for night duties longer than 10 hours, was expanded to include all night and late arrival duties.

2. Safety

2.1 Safety Risk

The ICAO Safety Management Manual (Doc 9859) defines a hazard as a condition or an object with the potential to cause or contribute to an aircraft incident or accident. Fatigue is 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 Manual for the Oversight of Fatigue Management Approaches - Doc 9966). Hence aircrew fatigue is a hazard, and the level of safety risks associated with it are determined by the predicted probability and severity of the consequences or outcomes of potential reduction of alertness and of the ability to perform safety related operational duties.

2.2 Level of risks stemming from aircrew fatigue

According to ICAO Doc 9859 safety is the state in which risks associated with aviation activities, related to, or in direct support of the operation of aircraft, are reduced and controlled to an acceptable level. From the perspective of safety risk management, the required safety level is often established through a risk tolerability matrix that describes the tolerable combinations of the predicted probability and severity of the consequences or outcomes associated with a hazard. Typically, a 5x5 matrix is used, that combines five probability categories and five severity categories (see Figure 2-1). Safety risk severity is defined as the extent of harm that might reasonably occur as a consequence or outcome of the identified hazard (ICAO Doc 9859, section 2.5.4). Typically, for the purpose of safety risk assessments, the description of the extent of harm is based on damage and injuries or fatalities.

Safety Risk		*Severity*				
Probability		*Catastrophic* *A*	*Hazardous* *B*	*Major* *C*	*Minor* *D*	*Negligible* *E*
Frequent	5	5A	5B	5C	5D	5E
Occasional	4	4A	4B	4C	4D	4E
Remote	3	3A	3B	3C	3D	3E
Improbable	2	2A	2B	2C	2D	2E
Extremely improbable	1	1A	1B	1C	1D	1E

Figure 2-1. Example safety risk matrix from ICAO Doc 9859 Safety Management Manual

To classify the risks stemming from aircrew fatigue, a similar risk matrix can be used with severity levels corresponding with fatigue levels (KSS scores). This leads to a risk tolerability matrix that combines KSS values and the probability of occurrence of these KSS values on top of descent (ToD) of the last sector of a flight duty period. In scientific studies and aviation operational practice, KSS ≥7 is suggested as a threshold for fatigue risk. This leads to the severity classification as shown in Table 2-1.

Table 2-1. Severity classification based on KSS levels.

Fatigue level (KSS)	Risk severity level
1-3	Negligible
3-5	Minor
5-7	Major
7-8	Hazardous
8-9	Catastrophic

This classification can be used in a fatigue risk tolerability matrix that combines KSS values and the probability of occurrence of these KSS values on top of descent of the last sector of a flight duty period.

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The question whether the current FTL are effective in maintaining an acceptable level of safety will be investigated by means of looking at the relevancy of the main elements of FTL and comparing the probabilities for high aircrew fatigue (KSS ≥7) in the various types of flight duty periods studied.

3. Relevancy of the principles regulating FTL and rest requirements

3.1 Main principles of Subpart FTL

The prescriptive FTL limits and rest requirements of subpart FTL are based on the following main principles:

- The maximum basic FDP for acclimatised aircrew shall be limited as a function of the start time of the duty;
- The maximum basic FDP for acclimatised crew shall be reduced due to WOCL encroachment and workload (the number of sectors);
- The maximum FDP for aircrew in an unknown state of acclimatisation shall be less than the maximum basic FDP for acclimatised aircrew and shall be further reduced as function of the number of sectors;
- The combination of other standby and FDP may not lead to more than 18 hours awake time;
- The minimum rest period before an FDP shall be at least as long as the preceding duty period, or 12 hours, whichever is greater.

In the following sections, the relevancy of these main principles is described in the context of the outcomes of the FTL2.0 study.

3.2 Relevancy of limiting the maximum basic FDP duration for acclimatised crew as a function of the start time of the duty and workload (the number of sectors)

Under Regulation (EU) 965/2012, particularly in relation to flight time limitations (FTL) and FDP, the WOCL (Window of Circadian Low) is a crucial factor in managing fatigue. The idea is that if a Flight Duty Period (FDP) starts at a more favourable time of the day—typically when the crew is well-rested and alert— it should not extend into the WOCL and therefore may be with the longest duration without additional fatigue mitigation measures compared to duties with other starting times. However, starting duties at the most favourable time of the day does not necessarily mean these duties should not encroach the WOCL. But if a favourably timed FDP does extend into the WOCL, it may require additional mitigation. Therefore, in FTL 2.0 the analysis is focused on duties that for various operational reasons last for more than 13 h and for which no additional fatigue mitigation measures are currently foreseen.

The results of the data analysis of duties >13 hours starting at the most favourable time of day (FDP1) and duties >11 hours for crew members in an unknown state of acclimatisation (FDP3) demonstrate that FDP duration is an important determinant of fatigue. It was found that the probability of high fatigue increases with FDP duration.

The results of the study into duties including many sectors showed that the number of sectors and FDP duration both contribute independently to the probability of high levels of fatigue. Since both the number of sectors and the FDP duration contribute to the probability of high levels of fatigue, higher values of one variable may be counteracted with low values of the other variable. Overall, the probability of high levels of fatigue can be decreased by reducing or restricting both the number of sectors and FDP duration. The data analysis also demonstrated that the probability of high fatigue (KSS ≥7) increases with the number of sectors, and that there is a higher probability for high fatigue in FDPs with >6 sectors in comparison with FDPs with 1-6 sectors. Although there no clear inflection point (threshold) was found, results suggest a possible deviation from the gradual increased risk of high fatigue between duties of 4 and 5 sectors.

The results of the data analysis of flight duties starting at the most favourable time of day (part of FTL2.0), demonstrate that the start time of the FDP (time of day) is not strongly related with the probability of high fatigue at ToD of the last sector for these FDPs. The importance of FDP duration seems to overpower any effect of FDP start time.

The results of the data analysis of flight duties starting and ending at the less favourable time of day (early starts and late arrivals) and fully encroaching the WOCL (night duties) (FTL1) demonstrate that for these FDPs the start time of the FDP does influence the probability of high fatigue at ToD of the last sector.

These combined results lead to the conclusion that the basic set-up in the regulation of limiting the maximum basic FDP duration for acclimatised crew as a function of the start time of the duty and workload (the number of sectors) is sound.

3.3 Relevancy of reducing the maximum FDP duration for aircrew in an unknown state of acclimatisation as function of the number of sectors

For aircrew in an unknown state of acclimatisation, the probability of high fatigue increased with FDP duration. It was also observed that FDPs of a long duration (more than 9 hours) that are flown by aircrew in an unknown state of acclimatisation resulted in higher levels of fatigue when the FDP coincided with the night (2:00 – 5:59) as defined by the time at the place of arrival, which corresponded to the home base in the FTL2.0 dataset. The point estimates of the probability of high fatigue at ToD of these 'overnight' FDPs of more than 11 hours flown by crews in an unknown state of acclimatisation are the highest observed during the study (close to 0.7) albeit with a fair amount of uncertainty due to the low number of observations. These flights were predominantly flights returning overnight from North/Central America and the Caribbean. Because the crews were in an unknown state of acclimatisation, by definition it cannot be determined exactly how the timing of these flights relates to the Window of Circadian Low (WOCL) of these crews.

Additionally, sleep duration in the past 24 hours was a significant predictor of fatigue at last ToD of FDPs flown in an unknown state of acclimatisation.

Because the study only included FDPs flown by crews in an unknown state of acclimatisation with a maximum of 3 sectors, the number of sectors was not identified as a significant factor for aircrew in an unknown state of acclimatisation. The effect of the number of sectors was however clearly demonstrated for crew in a known state of acclimatisation (see previous section) and it is realistic to assume that the number of sectors affect crews in an unknown state of acclimatisation in a similar way.

Taken together, these results confirm the principle that is used in the regulation where the maximum FDP for crew members in an unknown state of acclimatisation is less than that for acclimatised crew members, and that the maximum FDP duration for crew members in an unknown state decreases with number of sectors.

3.4 Relevancy of 18 hours awake time cap for standby duties

Results from the data analysis indicate that high fatigue levels (KSS ≥7) appear to occur rather infrequently with 'other than airport standby' FDPs. The results of the data analysis showed that fatigue levels for FDPs assigned during 'other standby' were quite similar to those observed for corresponding FDPs scheduled in normal duty rosters. This result suggests that assigning an FDP during 'other standby' does not lead to higher fatigue than scheduling a similar FDP in the duty roster.

In addition, the findings suggest that the 18 hours awake time cap could be working effectively. However, higher fatigue during FDPs assigned during 'other standby' seems to be associated more closely with prior sleep and sleep-to-awake time ratio than with prior time awake. This suggests that the 18 hours cap rule may not be effective in preventing fatigue in cases where the amount of prior sleep is reduced (see deliverable D2.3 for more information). This result emphasises the importance of Fatigue Risk Management (FRM) in combination with the prescriptive FTL regulations.

3.5 Relevancy of requiring that the minimum rest period before an FDP shall be at least as long as the preceding duty period, or 12 hours, whichever is greater.

The results of the data analysis show that (longer) sleep duration in the past 24 hours is a strong and consistent predictor of (lower) fatigue. This confirms the importance of a rest period of a minimum duration preceding a flight duty period, as required by the current regulation.

3.6 Relevancy of controlled rest as a measure against unexpected fatigue

According to CAT.OP.MPA.210, if unexpected fatigue is experienced, a controlled rest procedure may be used if workload permits. Controlled rest means a period of time 'off task' that may include actual sleep during a flight duty period.

In the FTL1 study it was observed that in-flight napping occurred in 31% of night duties longer than 10 hours. Results from the FTL2.0 study showed that 38% of the pilots reported using controlled rest during any of their flights within the measurement period, which confirms the relatively frequent use of controlled rest, i.e. controlled rest was taken by many pilots.

The results of the FTL2.0 study show that, while controlled rest is intended for mitigation of unexpected fatigue, in almost 30% of the observations, controlled rest was applied to prevent the occurrence of expected fatigue as well.

The analyses also show that the use of controlled rest is rather expected by flight crew in the following cases :

- a return (inbound) flight to home base as part of a westward rotation,
- a flight crossing multiple time zones
- a night flight in comparison to day or evening (defined by the reference time); and
- being in an unknown state of acclimatisation (X-state).

It is likely that experienced crew are aware of the combinations of flight characteristics that may result in the occurrence of high fatigue during the FDP and therefore may anticipate the use of controlled rest.

The results of the data analysis show that in general there was no difference in the occurrence of high fatigue (KSS ≥7) on top of descent of the last sector in FDPs in which controlled rest was used in comparison to matched FDPs without controlled rest occurrences, although a significant difference was observed when looking at high fatigue across the entire FDP. This result suggests that controlled rest helps reducing the likelihood of high fatigue at top of descent, given the fact that it is well known that prior sleep is a strong determinant of fatigue. Previous literature also showed that controlled rest can be an effective in-flight fatigue-mitigation strategy (D2.5).

EASA's guidance material on controlled rest (GM1 CAT.OP.MPA.210) states that a controlled rest period should not be longer than 45 minutes, and sleep within that period should be limited to approximately 30 minutes. When comparing the reported instances of controlled rest to this guidance material, 6 controlled rest periods (7.5%) were longer than 45 minutes (although duration of the controlled rest period was not always reported). From the 80 reports on sleep duration, 20 controlled rest instances (25.0%) included a sleep period longer than 30 minutes. The guidance material also states that after the 45-minute period, there should be a period of 20 minutes to overcome sleep inertia during which the control of the aircraft should not be entrusted to the flight crew member, and that at the end of this recovery period an adequate briefing should be given. The reports on crew rest did not contain information on adherence to the 20-minutes sleep inertia and briefing guideline, but anecdotal information suggests that this guidance is not always followed. The guidance material does not provide information on how to operate in case of an emergency while one of the crew members is taking controlled rest or is in the recovery period.

4. Adequacy of regulatory fatigue mitigation measures

4.1 Introduction

The preceding chapter considered whether the basic principles regulating FTL and rest requirements are relevant. This chapter considers whether the prescriptive FTL and rest requirements are adequate in maintaining an acceptable level of crew alertness. If a measure is both relevant and adequate it is considered to be effective.

For the purposes of FTL 2.0, probabilities of high fatigue levels (KSS ≥7) for the different FDPs are compared with the probability of high fatigue for daytime FDPs (the baseline). A higher likelihood of KSS ≥7 observed for an FDP of interest, when compared with the baseline, is an indication that a given regulatory limit of the first FDP might not be adequate.

4.2 Comparison of probabilities of high fatigue

A direct comparison of the results from the different FDP of interest must be made with caution due to differences in the number of observations, the limited number of observations for some categories and the fact that descriptive results are based on mixed design (see D2.3 and D2.5 for more information). Nevertheless, a comparison of the probability of high fatigue for the various FDPs, as shown in Figure 4-1 (which is also presented in D2.5) provides relevant information.

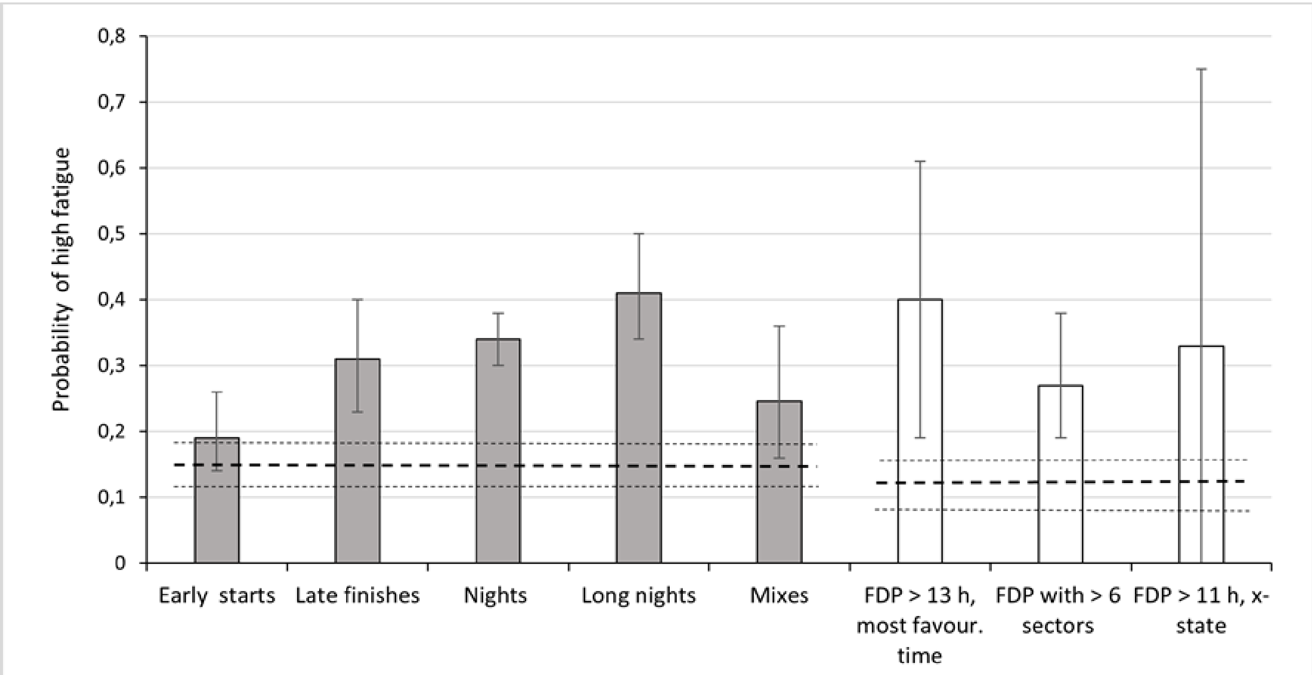

Figure 4-1. Probability (95% confidence interval) of high fatigue (KSS ≥7) at last ToD by FDP of interest. The grey bars denote the FDPs of interest in the FTL1 study and the white bars the FDPs of interest in the FTL2.0 study. The vertical error bars indicate 95 % confidence intervals of the FDPs of interest. The thick dashed horizontal lines denote the corresponding probability of all daytime FDPs collected in the FTL study in question and the thin dashed lines the related 95% confidence intervals.

All FDPs of interest have a higher probability of high fatigue than corresponding daytime FDPs. The probability of high fatigue during daytime FDPs (as shown as the horizontal dashed line in the figure) determined in FTL1 and FTL2.0 are quite similar, despite the different time periods of the study and the difference in the participating airlines. This suggests that the result for daytime FDPs is sufficiently robust to be used as a baseline for comparison.

The results show that the highest probability of high KSS at ToD occurs at FDPs of long duration: FDPs of more than 10 hours at the less favourable time of day (long nights in Figure 4-1) and FDPs of more than 13 hours at the most favourable time of day. The probability of high fatigue of FDPs of more than 11 hours with aircrews in an unknown state of acclimatisation is a bit lower, but is based on few observations resulting in quite some uncertainty (as indicated by the 95 % confidence interval represented by the thin vertical error bars in Figure 4-1). The point estimates of the probability of high fatigue at ToD of 'overnight' FDPs of more than 11 hours flown by crews in an unknown state of acclimatisation are the highest observed during both FTL projects (probability close to 0.7).

Under Regulation (EU) 965/2012, particularly in relation to flight time limitations and FDP, the WOCL is a crucial factor in managing fatigue. If an FDP starts at a more favourable time of the day—typically when the crew is well-rested and alert— it should not extend into the WOCL (typically between 02:00 and 06:00 in the home base time zone) and therefore may have the longest duration compared to duties with other starting times. However, under the current regulation, FDPs with a duration of 13 hours or more (for non-augmented crew) will extend into the WOCL if they start after 13:00. These duties can therefore be also categorised as duties of long duration ending at the less favourable time of day.

In order to determine whether additional mitigation measures are needed, the FDPs of more than 13 hours starting at the most favourable time of day were subdivided into non-disruptive duties with end times before 23:00 (1), late finishes with end times between 23:00 and 01:59 (2) and duties partially encroaching the WOCL with end times after 01:59 (3). Perhaps surprisingly, the descriptive results of FDPs longer than 13 hours in the subcategories 2 and 3 show a lower probability of high fatigue at ToD than for subcategory 1. This result should however be treated with caution because of the low number of observations for subcategory 3. The use of controlled rest might also be an explanation for the lower probability of high fatigue at ToD for duties of long duration partially encroaching the WOCL when compared with daytime duties of long duration. Controlled rest was used in 43% of all FDPs of more than 13 hours partially encroaching the WOCL, while for daytime FDPs of long duration this percentage was 23%. Controlled rest was shown to be an effective mitigation strategy for high fatigue during crucial phases of the flight, such as ToD of the last sector (D2.5).

5. Conclusions

The combined results from the data analyses lead to the conclusion that the basic set-up in the regulation of limiting the maximum basic FDP for acclimatised crew as a function of the start time of the duty and workload (the number of sectors) is sound.

The results from the data analyses indicate the appropriateness of the principle that is used in the regulation where the maximum FDP duration for crews in an unknown state of acclimatisation is less than that for acclimatised crews, and that the maximum FDP duration for crews in an unknown state of acclimatisation decreases with the number of sectors.

The findings suggest that assigning an FDP during other standby does not lead to higher fatigue than scheduling a similar FDP in the duty roster. The 18-hour awake time cap for the combined duration of 'other than airport' standby and FDP may not be effective in preventing fatigue in cases where the amount of prior sleep is reduced.

Sleep duration in the past 24 hours is a strong and consistent predictor of fatigue: longer sleep duration results in lower levels of fatigue. This confirms the importance of a rest period of minimum duration, as required by the current regulation.

Controlled rest is used during many flights and results from the data analysis suggest that controlled rest could help to reduce the likelihood of high fatigue at top of descent. The data also show that while controlled rest is primarily intended as a measure against *unexpected* fatigue, it is regularly being used to prevent *expected* high fatigue as well. With respect to the maximum length of controlled rest and sleep duration during the rest period, the guidance material is not always followed. Future research should shed more light on the adherence to the 20-minutes sleep inertia and briefing guideline.

The highest probability of high fatigue levels on top of descent occurs during flight duties of long duration: FDPs longer than 10 hours starting at the less favourable time of day, FDPs longer than 13 hours starting at the most favourable time of day and overnight flight duties longer than 11 hours with a crew in an unknown state of acclimatisation. Because of the complex interactions of factors influencing the probability of high levels of fatigue, additional further restrictions on maximum flight duty periods and numbers of sectors could be ineffective. Effective mitigation measures must be tailored to the specifics of the operation. Appropriate fatigue management principles should therefore be applied to optimise crew alertness on flights of long duration.

European Union Aviation Safety Agency

European Union Aviation Safety Agency

Konrad-Adenauer-Ufer 3

50668 Cologne

Germany

Mail EASA.research@easa.europa.eu

Web www.easa.europa.eu

An Agency of the European Union