Dirección General de
Aeronáutica Civil

MANIFIESTO DE IMPACTO REGULATORIO

PROY- NOM-117-SCT3-2013

ADJUNTO 8.- ESTUDIOS INTERNACIONALES

- **FAA - Regulatory Impact Requirements**
- **EASA - Provision of Scientific Expertise**

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FAA - Regulatory Impact Requirements

U.S. Department of Transportation

FEDERAL AVIATION ADMINISTRATION

Office of Aviation Policy and Plans

Washington, D.C. 20591

REGULATORY IMPACT ANALYSIS

Flightcrew Member Duty and Rest Requirements

PART 117

Final Rule

OFFICE OF AVIATION POLICY AND PLANS

November 18, 2011

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Disposition of Issues Raised by Comments

The following summarizes the FAA's responses to the comments on the economic analysis. These responses address the most substantive comments made in response to the Notice of Proposed Rulemaking (NPRM), including comments made by: Air Transportation Association (ATA), American Airlines, United Airlines, Cargo Airline Association (CAA), Federal Express, United Parcel Service (UPS), National Air Carriers Association (NACA), Atlas Air Worldwide Holdings, Lynden Air Cargo, Omni Air International, Inc., and Southern Air, Inc.

Commenters questioned the base year dollar and analysis period. The final rule analyzes current year (2011) with a two year delay in both benefits and costs. The benefits and costs are presented in a ten year stream and we have provided sensitivity analysis based upon a discount rate of both 7% and 3%. A ten year analysis is sufficient for the costs and benefits to be in a steady state.

The FAA also received comments questioning the validity of the accident set. To address the criticism of using the historical twenty-year analysis period, the FAA narrowed the accident set to the most recent ten years. However, while this approach addressed the issues raised by the commenters, narrowing of the analysis time period reduces the number of accidents/observations available for the benefit analysis. Consequently, while there is a sufficient accident basis to demonstrate a broad benefit basis justifying the cost of this rule, the sparse data does not permit accident analysis for every industry segment.[1] The benefit forecast includes the expected larger

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[1] As discussed in the Regulatory Impact Analysis, the FAA was able to determine the societal benefit of applying this rule to all-cargo operations. The FAA ultimately concluded that this benefit did not justify the costs of requiring all-cargo operations to operate under part 117.

future airplanes and higher load factors. Even though the rate of accidents may have declined in the last ten years, the future consequences may well be more catastrophic.

Commenters questioned that the historical accident rate is significantly higher than the probable accident rate for the period of analysis because accidents have declined in recent years.

The requirements contained in this final rule only address the rates of pilot fatigue. As Table 4 in the Regulatory Impact Analysis shows, the preventable accident rate related to fatigue has not significantly decreased in the last ten years.

The Regulatory Impact Analysis also includes a list of appropriate accidents along with the final Commercial Aviation Safety Team (CAST) scoring. The accident appendix includes detailed fatigue information and the reasoning behind the final CAST scoring.

After considering the comments on the regulatory impact analysis (RIA) for the NPRM, the FAA took a different approach to evaluate the final rule. In the analysis for the NPRM, the FAA attempted to show through statistical analysis and simulation that a broader fatigue problem existed than what could be shown through NTSB accident findings. In response to industry comments objecting to this approach, the FAA Office of Aviation Safety began by narrowing the set of accidents to those with a strong correlation to fatigue and hence narrowed the benefit analysis from a broader fatigue problem to the specific regulatory changes. As a result, the FAA re-examined every accident used in the NPRM and applied the CAST methodology only to the accidents whose likelihood would have been reduced if the requirements in the final rule had been effective prior to the accident. Using this methodology, the FAA re-analyzed the effectiveness of the provisions in the final rule in mitigating accidents where fatigue was identified as a factor in the accident, and removed accident cases that were not closely correlated with fatigue factors from the NPRM. From this exercise, a smaller set of accidents was determined appropriate for further economic analysis of the final rule. With a smaller number of accidents, a simulation methodology was no longer appropriate. Instead, the FAA used a commonly-used benefit methodology. This methodology is grounded in NTSB findings, uses the CAST methodology, and is also transparent and easily reproducible. The methodology is discussed in the full regulatory evaluation.

Industry questioned the use of $12.6 million for a statistical life value.

The use of $12.6 was for a sensitivity test. For the final rule, the FAA uses the $6.2 million as the value of an averted fatality as used commonly by the Department of Transportation.

Commenters also objected to the FAA's assumptions regarding the 25% cost-savings resulting from long-term scheduling optimization in RIA. As the FAA stated in the RIA, the assumption of the long-term schedule optimization factor was dropped because the operation cost was analyzed by the crew pairing optimizer. This different approach estimates operation and scheduling cost of the final rule by building duty and rest time restrictions changing from existing FAA regulations and industry scheduling data into a Cygnus, CrewPairing's (CP) crew scheduling optimization model. Cygnus has been used by more than 30 major airlines worldwide over the past 40 years and is currently used by a number of carriers. CP optimization used constraints contained in the final rule, pooling with the best available industrial data (wages, numbers of flightcrew members sourced from Form 41), to estimate costs of the final rule.

Commenters also contended that the FAA underestimated the NPRM costs related to flight operation in that carriers would be forced to hire new crewmembers and increase flight duty periods (FDP).

The FAA has re-estimated the costs reflecting final rule modifications and used the above-referenced crew scheduling model to better estimate whether the rule would force carriers to hire new crewmembers. The use of a crew pairing optimizer enabled FAA to more accurately model the impacts of the rule on industry crew scheduling costs than was possible during NPRM cost analysis. The data in the final rule RIA included full bid line and pairing information for each flightcrew member, and included both line holder and reserve flightcrew members. The crew pairing optimization did not show a need to hire new crewmembers to comply with this rule because the flightcrew members currently used in reserve allow certificate holders to conduct operations under this rule without hiring additional flightcrew members.

Commenters did not support the costs related to schedule reliability and argued that they were underestimated. One commenter stated the costs would be as high as $9.6 billion. They argued that by excluding the cost of schedule buffering required by multiple provisions of the NPRM, the FAA omitted the major source of cost to the industry.

As stated elsewhere, the FAA has largely removed schedule reliability from this rule. The FAA has instead adopted provisions that limit extensions of the FDP and requires reporting of FDP extensions and activities that were not otherwise permitted by the provisions of §117.11, §117.19 and §117.29 in the Final Rule. Under this amendment, costs to airline carriers are limited to reporting exceptional activities. As such, these costs are expected to be relatively minor. By dropping schedule reliability requirement and limiting the associated reporting burden to flight-duty-period (FDP) extension reporting requirements, the cost in dispute by the commenters became a computer programming cost and was estimated to be about one million dollars.

Some commenters stated the appropriate average wage rate should be $297 per hour.

The FAA notes this wage rate significantly contributed to the industry cost estimates. The $297 per hour wage rate as an average is two times the wage rate from Form 41 and four times the wage rate from the 2010 Census Bureau on the airline industry.

Commenters also argued that the FAA underestimates fatigue training cost described in the NPRM.

All carriers already are required to comply with Public Law 111-216 Section 212(b)(2)(B) with respect to the fatigue risk management plan and training (FRMP). In this final rule, the FAA removed the proposed requirement that pilots receive additional fatigue training that is not required by the FRMP. As such, the FAA expects the cost of fatigue education and training to be largely reduced. The final rule does expand the fatigue education and training requirements to dispatchers and certain members of management. The FAA made this change because air carriers operating under 14 CFR part 121 will be in compliance with the statutory pilot training requirement as part of their FRMPs. Since the final rule extends fatigue training to management and dispatchers, it is expected to be added to existing fatigue risk management education and training program.

Numerous commenters stated that the FAA underestimated the cost of rest facilities due to the loss of first class seating and out-of-service time required for infrastructure installation.

The FAA re-analyzed the facility cost based upon the actual numbers and types of facilities that will need to be put in by querying the inspectors for the fleet of airplanes. The FAA assumed the worst case scenario (all class 1 facilities). The FAA recalculated the number of airplanes needing additional upgraded rest facilities. Based on the existing fleet, the FAA estimates 332 airplanes will need class 1 facilities. In addition, the FAA re-estimated compliance costs of optimizing existing equipment and installing first class facilities. We have also estimated downtime and additional fuel burn costs. The final rule rest facility costs include purchase, design and engineering, physical installation of the facilities on the affected aircraft, downtime impact on revenue, and fuel burn cost. Therefore, the cost of rest facilities was estimated to the full extent in the final rule.

The commenters stated that the FAA's cost analysis does not factor in the costs of the cumulative limits. The FAA notes that all known constraints including existing monthly and annual constraints were imbedded in CP optimization.

The commenters submitted that the FAA assumed for the NPRM that the industry's collective bargaining agreements (CBAs) will be renegotiated to permit carriers to adapt to the new rules without any additional costs to the carriers and also assumes that any short term costs that result from conflicts between the new rule and existing CBAs should not be "counted" as part of the NPRM.

The final rule does not require renegotiation of current CBAs. In the final rule the FAA did not calculate potential gains based on the renegotiation of CBAs. The final rule will give two years buffer for carriers to implement all provisions. The FAA still believes that CBA negotiations could result in a change of economic interests between carriers and crewmembers. Any such change is a transfer of benefits and costs between carriers and bargaining units. Such transfers would be negotiated between parties and transfers do not change the total cost and benefits to society.

Many entities conducting supplemental operations stated that the rule would cause the nature of their operations to significantly change, which would result in lost revenue opportunities or much higher cost, or both.

The FAA adopted significant modifications in the final rule to mitigate the impact on supplemental operations. For example, in the final rule, the FAA made compliance with part 117 voluntary for all-cargo operations. With regard to supplemental passenger operations, the FAA increased both the augmented and unaugmented FDP limits from the NPRM. The FAA also increased the split-duty credit and made that credit easier to obtain. In addition, the FAA notes that section 119.55 provides the mechanism to obtain deviation from existing regulations for military missions. Taken together the FAA has provided substantial flexibility for supplemental operations, and as a result, permits most existing revenue opportunities relative to flight safety risks based on past ten years of NTSB accident findings.

The commenters contend that the FAA assumes, without any evidence, that there will be a reduction in absenteeism due to "improved fatigue management," and that reduced absenteeism costs will offset part of the cost of the NPRM.

The FAA believes that the final rule will improve productivity and reduce absenteeism by the enhanced fatigue management system. CDC's research shows that chronic fatigue can cause illness and even death[2]. Comments and data received from Air Line Pilots Association (ALPA), the largest independent pilots' union in the world, devoting more than 20 percent of its dues income to support aviation safety, validated the FAA's estimation of cost saving from reducing flight-crew members fatigue and absenteeism.

Commenters questioned that there is no justification provided that sick leave use will be reduced by 5%. The FAA has verified this number with labor representatives and the supporting document verifying this information can be found in the docket.

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[2] CDC' s MMWR, Weekly, **February 29, 2008 / 57(08);200-203**

Commenters contended that accidents involving two pilots and a flight engineer should be analyzed separately because in the modern era almost all flights are operated without a flight engineer.

This rule does not distinguish between accidents involving a flight engineer and accidents without a flight engineer because it is difficult to attribute specific amounts of fatigue and accident causality to a flight engineer. More specifically, it is difficult to predict in a fatigue-related accident, how the two pilots would have handled the aircraft in question if a flight engineer had not been present. As such, because it is unclear how much flight-engineer fatigue contributed to past accidents and that this rule does not prohibit flight engineers from working on the flight deck, the Regulatory Impact Analysis used for this rule does not distinguish between accidents involving two pilots and those involving a flight engineer.

Some commenters stated that the FAA simply ignores flight cancellation costs despite the fact that the NPRM will result in substantial increases in flight cancellations.

As discussed above, the FAA calculated the scheduling costs of this rule by running the pertinent data through the Cygnus crew scheduling optimization model. The Cygnus model did not indicate that there would be an increase in cancellations as a result of the changes imposed by this rule. This is because certificate holders will be able to use their existing staff members to cover the scheduled flights.

It was argued by commenters that by excluding the cost of schedule buffering required by multiple provisions of the NPRM, the FAA has omitted the major source of cost to the industry.

There are a few major changes related to crew scheduling made in the final rule from NPRM, which significantly reduced the cost to the industry. The pertinent changes from the NPRM are: (1) a flight extension for unexpected circumstances that arise after takeoff, and (2) the removal of the requirement that "circumstances beyond the control of the certificate holder" have to be present in order to utilize the 2-hour FDP extension for certain unforeseen operational circumstances. Using the crew pairing optimizer to simulate operation schedule, costs that attributable to the final rule were estimated to the full extent, including the cost of schedule buffering.

The commenters further stated that the FAA has omitted the cost estimation attributable to the provision of "three consecutive nights" (section 117.27, NPRM), which is more likely to impact cargo carriers partly because they have a substantial concentration of operation during the night time period and flight crew that are accustomed to night time operations.

As an initial matter, the FAA notes that, based on the cost-benefit analysis, all-cargo operations are not required to operate under part 117. However, based on industry comments the FAA has mitigated the burden to cargo operators who may choose to operate under part 117 by reducing (to two hours) the length of "mid-duty rest" that is necessary to schedule five consecutive nighttime FDPs. Moreover, UPS and FedEx stated in their comments that they currently provide their flightcrew members with a mid-duty breaks that are, on average, two hours long. Because the final rule permits five consecutive nights with two-hour breaks, the impact of the consecutive-night provision on all-cargo operators such as UPS and FedEx will be minimal.

The commenters also argued that, under the FAA's cost-benefit methodology, there is no benefit to limiting duty time below 15 hours.

The FAA agrees the risk of accident prevalence in the 15^{th} hour block and beyond is much greater than that associated with duty times short of the 15^{th} hour block. To evaluate this proposition, the FAA computed ratios of accidents to exposure duty hours (dividing accidents in a sequence of flight hour blocks by pilot exposure duty hours), which substantiated the conclusion that accident risk steeply increases in the 15^{th} hour block and beyond. However, the FAA has also determined that FDPs of less than 15 hours can lead to unacceptably high accident risk. For example, the statistic evidence indicates that the ratios of accidents to block hour rises in a fast rate in the 13^{th} to 14^{th} hour block range. Therefore, the regulation of flight duty time being limited under the 15^{th} hour block is necessary and beneficial.

Allied Pilots Association (APA) generally supported the NPRM but stated that the FAA overestimated computer programming cost, fatigue training costs due to overstated training pay and rest facility installation costs. In addition, APA commented that the FAA underestimated the schedule optimization factor and the agility of air carriers when motivated to achieve efficiency.

The computer programing cost is a very small component of airline operation cost. Since the computer programming cost was estimated based on the market pricing, it was adjusted slightly lower or at about the same level as the FAA gained more accurate market data than that used for NPRM through its software providers. Overall, the operation cost in the final rule was revised and turned out to be lower than that of NPRM. Fatigue training costs was revised to be lower than that of NPRM because of the changes made to the proposed fatigue training requirements by the final rule. The revised rest facility installation cost was also lower than that of NPRM. APA's comment on the overestimation of the NPRM cost was based on the assumption that long-term optimization will occur at much faster rate than implicit in the cost analysis, which would result in more savings in the long run than that in the short run. The FAA agrees that long-term optimization of air carriers could be greater than expected. The FAA believes that the crew scheduling optimizer program provides a better estimate to the final rule.

Therefore, the FAA believes that the final rule cost estimates incorporating crew scheduling optimization model accurately reflect the compliance costs.

ATA's Oliver Wyman analysis on September 14, 2011, "Estimated Job Loss Resulting from Flightcrew Member Duty and Rest Requirements" attached to the ATA petition on Flight, Duty and Rest asserted that the proposed rule would cause nearly 17,000 U.S. airline jobs, which would result in total job losses to the economy of 398,000 jobs.

The FAA believes that ATA's analysis of the jobs impact from the proposed Flight, Rest and Duty rule is inaccurate. ATA's jobs impact analysis is based on its estimate, derived from its analysis of the NPRM, that this rule will cost $19.6 billion over a 10-year period. However, many of the major provisions of the final rule have been significantly altered from the NPRM, and, as discussed elsewhere, the FAA estimates that the final rule will cost approximately $390 million over 10 years. This $390 million cost is significantly smaller than the $19.6 billion cost on which ATA based its job impact analysis. CrewPairing's analysis of the final rule results in no change in pilot employment. Therefore, the FAA does not agree with ATA's job impact findings.

With regard to the accidents that were used to calculate the benefits for this rule, some commenters stated that the ATI 2/16/95 flight (RT2) was a part 91 ferry flight, and that the issues leading to that flight's accident have been addressed by other rulemakings. Consequently, the commenters assert, this flight would not be permitted under current rules.

This comment refers to an accident involving ATI in Kansas City during a nighttime Part 91 engine-out ferry flight in a 4-engine DC-8. Prior to takeoff, the Flight Engineer (FE) had improperly determined the minimum control speed on the ground (VMCG), which produced a value that was 9 knots too low. On the first takeoff attempt, the pilot applied power too soon to the “asymmetrical engine” (the serviceable engine on the side with the failed engine) and was unable to maintain directional control during the takeoff roll. He rejected the takeoff and, in preparation for a second takeoff, the pilot agreed to have the FE advance the throttle on the next takeoff attempt. This conflicted with the prescribed procedure.

At 3,215 feet into the takeoff roll, the DC-8 started to veer to the left. At 3.806 feet, the aircraft rotated with a tail strike but the tail remained in contact with the runway for another 820 feet. At 5,250 feet, the aircraft became airborne and climbed to 100 feet, then sank and crashed. All 3 crew members were killed.

NTSB focused on 2 core issues. First, NTSB found that the crew was flying after a shortened rest break, since rest periods were not required for ferry flights. According to the report, the crew was fatigued from lack of rest and lack of sleep, and from disrupted circadian rhythms. Second, NTSB found that the crew did not have adequate, realistic training in techniques or procedures for a 3-engine takeoff. NTSB added that the crew did not adequately understand 3-engine takeoff, and did not adequately understand the significance of VMCG.

In response to an NTSB recommendation related to training crews for a 3-engine takeoff ((A-95-39), FAA issued a Flight Standards Information Bulletin (FSIB). The FSIB directed FAA principal operations inspectors to inform their respective operators to take additional measures to ensure: (1) that aircraft manual requirements for engine-out ferry flights are clear; (2) that crew training segments are clearly outlined for engine-out operations; and (3) that operators use only crews specifically trained and certified for engine-out operations. This has become FAA policy and NTSB found the action acceptable and closed the recommendation.

Consequently, the comment is appropriate to the degree that it addresses the issue of training, which is not part of the proposed rule. However, FAA believes that this flight also illustrates the role and risks associated with fatigue, which the FSIB noted above did not address. With or without training in 3-engine takeoffs, NTSB's findings on fatigue in this accident remain pertinent to this rulemaking.

Benefit/Cost Summary

We have analyzed the benefits and the costs associated with the requirements contained in this final rule and our estimates are summarized in table 1. The FAA has made significant changes to the final rule since the NPRM. The training requirement has been substantially reduced because the FAA has determined that pilots are already receiving the requisite training as part of the statutorily required Fatigue Risk Management Plans. The FAA also has removed all-cargo operations from the applicability section of the new part 117 because their compliance costs significantly exceed the quantified societal benefits.[3] All-cargo carriers may choose to comply with the new part 117 but are not required to do so. Since the carrier would decide voluntarily to comply with the new requirements, those costs are not attributed to the costs of this rule. The costs associated with the rest facilities occur in the two years after the rule is published. The other costs of the rule and the benefits are then estimated over the next ten years.

We provide a range of estimates for our quantitative benefits. Our base case estimate is \$376 million (\$247 million present value at 7% and \$311 million at 3%) and our high case estimate is \$716 million (\$470 million present value at 7% and \$593 million at 3%). The total

[3] The projected cost for all-cargo operations is \$306 million (\$214 million present value at 7% and \$252 million at 3%). The projected benefit of avoiding one fatal all-cargo accident ranges between \$20.35 million and \$32.55 million, depending on the number of crewmembers on board the aircraft.

estimated cost of the final rule is $390 million ($297 million present value at 7% and $338 million at 3%).

Table 1: Summary of Benefits and Costs

Total Benefits over 10 Years			
Estimate	**Nominal (millions)**	**PV at 7% (millions)**	**PV at 3% (millions)**
Base	**$ 376**	**$ 247**	**$ 311**
High	$ 716	$ 470	$ 593

Total Costs over 10 Years			
Component	**Nominal (millions)**	**PV at 7% (millions)**	**PV at 3% (millions)**
Flight Operations	$236	$157	$191
Rest Facilities	$138	$129	$134
Training	$16	$11	$13
Total	**$390**	**$297**	**$338**

Benefit Analysis

This rule is intended to address the problem of fatigued pilots flying in Part 121 commercial service. The nature and extent of the problem is such that the NTSB continues to list pilot fatigue as one of the Most Wanted Transportation Safety Improvements. The NTSB recommendations are based on accident investigations and the NTSB safety study on airline safety. The requirements contained in this final rule address both NTSB recommendations and existing public law. This benefit estimate first examines the nature of fatigue, followed by its causes and how it relates to transportation. Second, we summarize some recent findings on fatigue and occupational performance. Next, we look at the magnitude of crew fatigue in Part 121 passenger operations by briefly examining fatigue reports in the context of this final rule. We then re-analyze the likely effectiveness of the requirements contained in this final rule and the potential to decrease these types of accidents in the future. We project a likely number of preventable events that will occur in absence of this final rule. Finally, we estimate the benefits that will be derived from preventing such events. We provide a base case estimate, and a high case estimate, in addition to a threshold/break even analysis.

The Nature of Fatigue

Most fatigue studies agree that, "fatigue refers to a subjective desire to rest and an aversion to further work, coupled with an objective decrease in performance."[4]

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[4] Jones, et al., "Working hours regulations and fatigue in transportation: A comparative analysis," *Safety Science*, Vol. 43, 2005.

Fatigue is characterized by:

- "increasingly frequent lapses in performance,
- general cognitive slowing, including a lowering of optimum performance,
- memory problems,
- time on task decrements, and
- an increasing inability to maintain the vigilance required to perform the tasks required."[5]

Fatigue has been described as "a nonspecific symptom because it can be indicative of many causes or conditions including physiological states such as sleep deprivation….[s]ome describe fatigue in terms of physiological data or 'objective' observations of…decrements in work or performance….or time-related deterioration in the ability to perform certain mental tasks."[6] While physiological criteria related to fatigue can be readily measureable, subjective feelings of fatigue are not directly observable, and in some instances individuals who are exhibiting diminished performance levels also feel confident in their ability to focus and perform assigned tasks.

Causes of Fatigue

A number of factors increase the risk of fatigue. These include:

- Time of day is very important, because the body follows a rhythm over an approximately 24 hour period, often referred to as a circadian cycle

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[5] Jones, et al., "Working hours regulations and fatigue in transportation: A comparative analysis," *Safety Science*, Vol. 43, 2005.

[6] Torres-Harding, Susan and Leonard A. Jason, "What is Fatigue? History and Epidemiology," *Fatigue as a Window to the Brain*, edited by John DeLuca. The MIT Press, 3-18, 2007.

- The amount of recent sleep that a person has received also affects the level of fatigue risk; most people need an average of eight hours of sleep per 24 hour period.
- The number of continuous hours awake also increases fatigue risk, and for most individuals, once the number of continuous hours awake exceeds 17, fatigue risk increases significantly.
- Sleep debt, the difference between the amount of sleep needed to be fully rested and actual sleep, also contributes to fatigue. Sleep debt accumulates over time, and fatigue risk is higher if sleep debt exceeds eight hours
- Work load and time on task can also affect fatigue risk. If work intensity is high and/or there is a long continuous period of time on task, the risk of fatigue increases.

Fatigue and Transportation

The nature of work in the transportation sector makes that sector especially susceptible to risks to performance, vigilance and response to hazards that are associated with fatigue. Workdays of those responsible for the safety of transportation operations can be characterized by long work periods, often at nighttime or early morning hours. Because transportation workers must sometimes rest or sleep away from home, conditions for rest and sleep quality are also important.

Analysts have examined the links between the specific features of work in the transportation industry, including commercial aviation, and the general features of human physiology and fatigue for decades. For commercial aviation, it has been nearly two decades since the first citation of fatigue as a probable cause for a major aviation accident. This accident, the crash of American International Airways flight 808 at Guantanamo Naval Air Station, Cuba, on August 18, 1993, was investigated by the National Transportation Safety Board. Probable causes of the accident identified by the NTSB included "the impaired judgment, decision making, and flying abilities of the captain and flightcrew due to the effects of fatigue…"

As part of the investigation of that accident, NASA researchers and contractors performed an analysis of the links between aviation risks and the effects of fatigue on human vigilance and performance. This research was reported as part of the NTSB report on the Guantanamo Bay accident[7] and later revised for inclusion in an NTSB report on U.S. Department of Transportation efforts to address fatigue issues in Transportation.[8]

This NTSB research and literature summary provides a thorough and well-documented review of these issues. In the 1999 restatement of the research results in the context of addressing fatigue issues in transportation generally, the following summary is provided:

Fatigue, sleep loss and circadian disruption created by transportation operations can degrade performance, alertness and safety. An extensive scientific literature exists that provides important physiological information about the human operator, which can be used to guide operations and policy. For example, there are human physiological requirements for sleep, predictable effects of sleep loss on performance and alertness and patterns for recovery from sleep loss. Additionally, the circadian clock is a powerful modulator of human performance and alertness, and in transportation operations, it can be disrupted by night work, time zone changes, and day/night duty shifts. Scientific examination of these physiological considerations has

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[7] Rosekind, et.al.,"Appendix E: Analysis of Crew Fatigue Factors," Aircraft Accident Report: Uncontrolled collision with Terrain, American International Airways flight 808, Douglas DC-8-61, N814CK, U.S. Naval Air Station, Guantanamo Bay,Cuba, August 18, 1993. Washington D.C., NTSB Report AAR-94/04, pp. 133-144. http://human-factors.arc.nasa.gov/zteam/PDF_pubs/G_Bay/GuantanamoBay.pdf

[8] Rosekind, et.al., "Appendix C: Summary of Sleep and Circadian Rhythms," *Evaluation of U.S. Department of Transportation Efforts in the 1990s to Address Operator Fatigue.* Washington D.C. NTSB Safety Report NTSB/SR-99/01, May 1999, pp.67-81. http://www3.ntsb.gov/publictn/1999/sr9901.pdf

documented a direct relationship to errors, accidents and safety. This scientific information can provide important input to policy and regulatory considerations.

Recent Findings on Fatigue and Occupational Performance

Fatigue is prevalent in the U.S. workforce, with nearly 38 percent of workers in a study reporting fatigue during a two-week period.[9] The National Sleep Foundation conducted a poll in 2008, which found that 29 percent have fallen asleep or become very sleepy while at work and two percent did not go to work due to sleepiness or a sleep problem.[10] Numerous studies have found that fatigue can significantly reduce productivity. A review of published studies on shift work and productivity found a large decrease in efficiency during the night shift, with the low occurring at 3:00AM. On average, the authors found that productivity was five percent lower at night.[11]

A large scale study was conducted at 40 companies and institutions in the Netherlands to investigate the relationship between fatigue and future sickness absence. The presence of fatigue was measured using self-reported symptoms, with employers providing absence data. The study controlled for numerous socio demographic and work characteristics. The investigators found that higher levels of fatigue were statistically significant predictors of both short-term and long-term sickness absence.[12]

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[9] Ricci, et al., "Fatigue in the U.S. workforce: prevalence, and implications for lost productive work time," *Occup Environ Med*, Vol. 49(1): 1-10, 2007.
[10] National Sleep Foundation, "2008 Sleep in America Poll: Summary of Findings."
[11] Folkard and Tucker, "Shift work, safety and productivity," *Occupational Medicine*, Vol. 53, 2003.
[12] Janssen, et al., "Fatigue as a predictor of sickness absence: results from the Maastricht cohort study on fatigue at work," *Occup Environ Med*, 2003, 60(Suppl I): i71-i76.

A study was conducted to estimate fatigue prevalence and associated health-related lost productive time (LPT) in U.S. workers. The investigators found that workers with fatigue were much more likely to report health-related LPT, with a cost of $136.4 billion annually. This amount exceeded health-related LPT reported by workers without fatigue by $101.0 billion.

A study compared the rate of errors made by medical residents working in the ICU on 80 hour weeks versus those on 63 hour weeks. The residents with the shorter work week schedule experienced half the rate of attention failures. The residents with the longer work week schedule made serious medical errors (those causing or having the potential to cause harm to a patient) at a rate 22 percent higher than the residents with the shorter work week schedule.[13]

The railroad industry is at a relatively high risk of fatigue, due to typical 24 hour per day operations. A number of railroads have implemented fatigue countermeasures, which generally reduced absenteeism. For instance, after implementation of fatigue countermeasures for CANALERT, absenteeism decreased from 8.1 to 3.2 percent. After fatigue countermeasures were implemented for the Conrail-Buffalo-Toledo IMPAC project, a statistically significant increase in attendance from 95.21 percent to 98.06 percent was observed.[14] This data demonstrates the potential for fatigue issues, which we will now examine within the specific requirements of this final rule.

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[13] Board on Health Sciences Policy, "Sleep Disorders and Sleep Deprivation: An Unmet Public Health Problem," *The National Academies Press*, 2006.

[14] Sherry, "Fatigue Countermeasures in the Railroad Industry: Past and Current Developments," *Association of American Railroads*, 2000.

ASRS

One can observe fatigue in aviation by examining the Aviation Safety Reporting System (ASRS). The ASRS collects, analyzes, and responds to voluntarily submitted aviation safety incident reports in order to lessen the likelihood of aviation accidents. It is part of a continuing effort by government, industry, and individuals to maintain and improve aviation safety by collecting voluntarily submitted aviation safety incident/situation reports from pilots, controllers, and others.

The data in the ASRS is used to:

- Identify deficiencies and discrepancies in the National Aviation System (NAS) so that these can be remedied by appropriate authorities.
- Support policy formulation and planning for, and improvements to, the NAS.
- Strengthen the foundation of aviation human factors safety research. This is particularly important since it is generally conceded that over two-thirds of all aviation accidents and incidents have their roots in human performance errors.

ASRS assures confidentiality and data cannot be traced back to individual operators. So although we cannot claim the rule could prevent specific ASRS events, it is a useful tool in evaluating and validating the presence of fatigue in Part 121 operations. We performed a query for Part 121 ASRS for Fatigue[15]. Since June of 2009, there were a total of 256 reports where fatigue was cited as a factor. We have neither culled the data nor edited any of the data that was reported to ASRS. The top seven results are listed in Table 2.

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[15] We believe that this is a very conservative assumption because other human factors can reveal fatigue, such as confusion and communications breakdown.

Table 2: ASRS Part 121 Fatigue Reports

Result	Total	Relative %
General None Reported / Taken (No action was taken as a result of the fatigue issue reported)	68	26.6%
General Work Refused (Fatigue caused a worker to refuse an assignment)	21	8.2%
General Maintenance Action (Typically a fatigue event related to a maintenance issue—not related to this final rule).	14	5.5%
Flight Crew Became Reoriented (Confusion related to some type of malfunction.)	10	3.9%
Flight Crew Took Evasive Action (Crew took action to avoid an accident or incident)	8	3.1%
Air Traffic Control Issued New Clearance (Substitute clearance given to get back on track)	5	2.0%
Flight Crew Executed Go Around / Missed Approach	5	2.0%

One captain on an international flight described an onerous flight sequence in the Pacific he believed to be unsafe due to cumulative and predictable fatigue:

"This report concerns a trans-Pacific flight assignment including back to back all night pairings (body clock), two un-augmented inter-Asia segments and 36 hours of flight time. We started the sequence with a 12.7 hour actual flight, single augmented with an hour plus delay on the front end. When we arrived we cabbed to downtown for an additional 1.5 hours on the body before rest. The first internal Asia leg is all night, un-augmented. The return leg is daylight-but all night body time-followed by another 1.5 hour cab ride downtown. The [opportunities for] rest were insufficient to maintain any alertness particularly on the last leg. Both the First Officer and I experienced periods of unintended sleep while at the controls. No amount of coffee or mental discipline was sufficient to stay awake!!! This is unsafe and made more unsafe by requiring: 1. Over 12 hours single augmented on the first leg. 2. Two un-augmented legs on the back side of the clock with long preflight awake hours. 3. Over 8 extra hours of "duty time" in CABS!!! Rework this trip before someone gets hurt. No one in the cockpit for the last 6 hours was at their peak to respond to irregular situations. We weren't even able to stay awake the whole time in the seat".

Even if no anomalies occur during a flight, a fatigued crew may be poorer problem solvers than well-rested crews as noted in the research cited above, and thus add a degree of risk to the system. In addition, taking evasive action and missed approaches because of fatigue are serious safety events indicating substantial risk manifesting in the current system.

Effectiveness

It is usually the case that multiple factors can be identified as causes of specific accidents, and it is seldom the case that a specific rule is 100 percent effective at addressing a variety of accident causal factors. In particular, fatigue is rarely a primary or sole cause of an accident, and therefore this final rule will not likely prevent all future fatigue related accidents. For this final regulatory evaluation, we have established a modified effectiveness ratio to categorize accidents for which fatigue may be a contributing causal factor. This number represents the likelihood the requirements contained in this final rule would have prevented an accident from occurring. It is applied in the calculation of the number of forecasted fatigue accidents, if no action was taken to address the fatigue problem in Part 121 operations.

In its analysis of the effectiveness of the final rule, the FAA reviewed accidents that could have been prevented or could have been influenced by the requirements contained in this final rule. The effectiveness analysis works by assessing the likely capability of the requirements contained in the final rule to have prevented those accidents. As part of this analysis, the Office of Accident Investigation reviewed the accident reports from NTSB and foreign investigative authorities on all accidents where the NTSB cited fatigue or fatigue was thought to be either a cause or factor. This was done in order to assess the likelihood that the provisions of the final rule would have averted those accidents (including positioning flights operating under Part 91).

A consistent definition was applied to the 20-year history as the requirements of the rule apply to all Part 121 operations. As such, we reviewed the accident history for all operations that would currently operate under Part 121. The final analysis will take into account NTSB findings, FAA's independent assessment, and comments to the docket. Some accidents reviewed scored "zero" because fatigue could not be established as a significant factor or because the final rule would not prevent such an event had the requirements been in place today. These accidents were removed from our effectiveness analysis and forecast. Because this final rule does not mandate compliance with Part 117 for all-cargo operations, we also removed them from our final analysis. Anticipated costs and benefits for these operations, were the rule to apply on a mandatory basis, are provided in footnotes to the relevant discussions in this document.

Each accident was then re-evaluated by conducting a scoring process similar to that conducted by the Commercial Aviation Safety Team (CAST), a well-documented and well understood procedure, similar to the NPRM. The FAA Office of Accident Investigation used the NTSB recommendations along with narratives, probable cause, contributing factors and other pertinent data to score the accidents. When these accidents were not well defined in the probable cause or contributing factors statements of the NTSB reports, Accident Investigation used a Joint Implementation Monitoring Data Analysis Team (JIMDAT)-like method. The JIMDAT-type scoring system is from 0 to 5, and the score is based on the likelihood that a proposed action would have mitigated that accident. The level and percentage of effectiveness criteria are detailed in Table 3.

Table 3: JIMDAT-Type Scoring System

5	90% effectiveness. The proposed requirement directly addresses the NTSB causal factors and would very likely prevent the accident in the future.
4	75% effectiveness. The proposed requirement directly addresses the majority of the NTSB causal factors and would probably prevent or is likely to reduce the risk of the respective accident, given the circumstances that prevailed.
3	50 % effectiveness. The proposed requirement directly addresses one of several NTSB causal factors and is likely to reduce the risk of the respective accident, given the circumstances that prevailed.
2	35% effectiveness. The proposed requirement generally addresses the NTSB causal factors and is likely reduce the risk of the respective accident, given the circumstances that prevailed.
1	15% effectiveness. The proposed requirement is likely to have reduced the risk of the respective accident, given the circumstances that prevailed.
0	0% effectiveness. The proposed requirement would not reduce the risk of this type of accident in the future.

FAA applied this methodology to each pilot fatigue accident to reach an overall effectiveness ratio for the requirements contained in this final rule. The qualitative assessments ranged from zero (0) to low (1), moderate (3), high (4) and very high (5). The qualitative assessments then were converted to quantitative effectiveness scores as follows: zero; 15%; 35%; 50%; 75%; and 90%.

For this analysis, the FAA presents the quantified benefits and effectiveness analysis for a 10-year period that parallels the cost analysis. Although we only forecast ten years of benefits, we have included a twenty year history of accidents, as these are the circumstances and events which have led to this final rulemaking. Table 4 summarizes the past twenty years of pilot fatigue accidents. The appendices contain a summary of each accident and the corresponding effectiveness analyses.

Table 4: 20 Year Accident History

Date	Location	Service	Carrier	A/C	On Bd	Ftl	Ser	Dam-age	Scenario	Score
07/02/1994	Charlotte, NC	121 Pax	US Air	MD-82	57	37	16	Dest	LOC on Approach; Icing	0.15
02/16/1995	Kansas City, MO	Ferry	ATI	DC-8-63	3	3	0	Dest	LOC in RTO; Engine Out	0.9
12/20/1995	Cali, Colombia	121 Pax	American	B757	164	160	4	Dest	CFIT High	0.35
08/25/1996	JFK, NY	121 Pax	TWA	L1011	262	0	0	Sub	Tail Strike Landing	0.35
01/22/1999	Hyannis, MA	Positioning	Colgan Air (Part 91)	BE-1900	4	0	0	Dest	Hard Landing (BETA)	0.15
05/08/1999	JFK, NY	121 Pax	American Eagle	SF34	30	0	1	Sub	RE Landing	0.5
06/01/1999	Little Rock, AR	121 Pax	American	MD-82	145	11	45	Dest	RE Landing	0.15
10/19/2004	Kirksville, MO	121 Pax	Corporate Airlines as American Connexion	BAE-32	15	13	2	Dest	CFIT Low on Approach	0.75
08/27/2006	Lexington, KY	121 Pax	Comair as Delta Connection	CRJ-200	50	49	1	Dest	Wrong Runway T/O	0.35
02/18/2007	Cleveland, OH	121 Pax	Shuttle America as Delta Connection	ERJ-170	74	0	0	Sub	RE Landing	0.5
04/12/2007	Traverse City, MI	121 Pax	Pinnacle as NW Express	CRJ-200	52	0	0	Sub	RE Landing	0.9
06/20/2007	Laramie, WY	121 Pax	Great Lakes	BE-1900	11	0	0	Sub	LOC Bounced Landing	0.15
02/12/2009	Buffalo	121 Pax	Colgan Air	DHC-8-Q400	49	50	0	Dest	LOC In Flight; RE Landing	0.5
Average										52.5%

Quantitative Benefits

James Reason characterizes major accidents and catastrophic system failures as the consequences of multiple, smaller failures that lead up to the actual accident. It is a “Swiss cheese" model of human error[16] and also a sequential theory of accident causation. Reason's model describes four levels of human failure, each one influencing the next. O*rganizational influences* lead to instances of *unsafe supervision* which in turn lead to *preconditions for unsafe acts* and ultimately the *unsafe acts of operators*. The unsafe acts of operators are where most accident investigations are focused. It is a useful framework to illustrate how analyses of major accidents and catastrophic systems failures tend to reveal multiple, smaller failures leading up to the actual accident. The chances of the exact same circumstances happening again and causing the "same accident" are virtually nil but the possibility of preventing a similar set of circumstances is real.

This sequential "Swiss cheese" formulation is a very appropriate tool for characterizing the circumstances leading up to accidents. The nature of fatigue is such that actions, reactions and the thought processes of fatigued crews are more susceptible to the types of cascading errors of judgment described in the Reason model of catastrophic failure. The requirements contained in this final rule will decrease pilot fatigue and therefore the accompanying accidents that are associated with fatigue. While it is very difficult to accurately attribute all past accidents to one or more causes indisputably, we have developed the average effectiveness measure to apply to the estimates and recognize that there are additional uncertainties with preventing a future fatigue related event. First, we examine an accident that occurred on October 19, 2004:

At about 1937 central daylight time, Corporate Airlines a BAE Systems BAE-J3201, struck trees on final approach and crashed short of runway 36 at Kirksville Regional Airport, in

[16] Reason, 1990

Kirksville, Missouri. The captain, first officer, and 11 of the 13 passengers were fatally injured, and 2 passengers received serious injuries. The airplane was destroyed by impact and a post-impact fire. [17]

Research and accident history indicate that fatigue can cause pilots to make risky, impulsive decisions, to become fixated on one aspect of a situation, and to react slowly to warnings or signs that an approach should be discontinued. Fatigue especially affects decision making, and research shows that people who are fatigued become less able to consider options and are more likely to become fixated on a course of action or a desired outcome. A fatigued pilot might fail to discontinue a flawed approach or might make a risky decision to continue a dangerous approach.

The fatigued crew reported for duty at 0514. The accident was near end of 6th sector on a 'demanding' day. Crew had been on duty 14.5 hours and the PIC is said to have slept poorly night before. The captain was observed resting on a small couch in the company crew room; however, the quality of rest the captain obtained during this time could not be determined. Company pilots stated that the crew room was a noisy meeting area that was not ideal for sleeping.

Additionally, the pilots' high workload during their long day may have increased their fatigue. The accident occurred during the sixth flight segment of the day while the pilots were

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[17] The NTSB evaluated fatigue as a possible factor in this accident and looked at the various circumstances present the day of the accident that might have contributed to the pilots' fatigue. The pilots' available rest time (from about 2100 to 0400) did not correspond favorably with either pilots' reported usual sleeping hours, resulting in much earlier than normal times to go to sleep and awaken. Additionally, the early wakeup call times would have been challenging to both pilots because the human body is normally physiologically primed to sleep between 0300 and 0500.

performing a non-precision approach in low ceilings and reduced visibility. The pilot deficiencies observed in this accident are consistent with fatigue impairment.

Similarly, although the first officer's junior status with the company may have been an issue in his failure to challenge the captain during the approach, he may also have been suffering from fatigue; his failure to monitor and react to the captain's deviations from non-precision approach procedures was consistent with the degrading effects (slowed reactions and/or tunnel vision) of fatigue.

The Safety Board concluded that, on the basis of the less than optimal overnight rest time available, the early reporting time for duty, the length of the duty day, the number of flight legs, the demanding conditions (non-precision instrument approaches flown manually in conditions of low ceilings and reduced visibilities) encountered during the long duty day (and the two previous days), it is likely that fatigue contributed to the pilots' degraded performance and decision-making.

Another fatigue related accident occurred in Traverse City, Michigan on April 12, 2007. The accident occurred well after midnight at the end of a demanding day during which the pilots had flown 8.35 hours, made five landings, had been on duty more than 14 hours, and been awake more than 16 hours. During the accident flight, the CVR recorded numerous yawns and comments that indicate that the pilots were fatigued. Additionally, the captain made references to being tired at 2332:12, 2341:53, and 0018:43, and the first officer stated, “jeez, I’m tired” at 0020:41. Additionally, the pilots’ high workload (flying in inclement weather conditions, and in the captain’s case, providing operating experience for the first officer) during their long day likely increased their fatigue. The aircraft ran off the departure end of the runway during snowy conditions. Although there were no injuries among the 49 passengers, the aircraft was substantially damaged.

As we observe a clear accident history and the accompanying science dealing with fatigue, it is apparent that fatigue threatens aviation safety by increasing the risk of pilot error that could lead to an accident. Fatigue is characterized by a general lack of alertness and degradation in mental and physical performance. Fatigue manifests in the aviation context not only when pilots fall asleep in the cockpit while cruising, but perhaps more importantly, when they are insufficiently alert during take-off and landing. Each flight segment that is flown by a flightcrew member includes a takeoff and a landing, which are the most task and safety-intensive parts of the flight. A flightcrew member whose flight duty period (FDP) consists of a single flight segment only has to perform one takeoff and landing, while a flightcrew member whose FDP consists of six flight segments will have to perform six sets of takeoffs and landings. Because takeoffs and landings are extremely task-intensive, it logically follows that a flightcrew member who has performed six sets of takeoffs and landings will be more fatigued than the flightcrew member who has performed only one takeoff and landing. Reported fatigue-related events have included procedural errors, unstable approaches, lining up with the wrong runway, and landing without clearances. As such, a fatigued crew is dangerous no matter what "type" or segment of operation is examined and the requirements in this final rule will eliminate the distinctions between various operations.

As we have shown, in an airplane accident, there is a series of errors (both causes and factors) that contribute to an accident. Accident scenarios can vary greatly depending on phase of flight, the type of operation, phase of flight and size of the airplane. While pilot fatigue can occur during any stage of flight, takeoff and landing are especially critical times for the crew to exhibit good judgment and sound decision making. The airplane is close to the ground and there is little room for error during these particular phases of flight.

The FAA provides a range of benefit estimates. The base case estimate only looks at the historical events as an exact mirror for the future. The high case estimate assumes that regional carriers will begin flying larger planes. We understand that future accidents, will not be identical to historical accidents but our approach provides a conservative look at the benefits of this rule based on a snapshot of the past.

Here the FAA provides a quantitative benefit estimate of historical-based accidents (base case), and a high case of expected benefits from future averted accidents once this rule is promulgated. Generally our benefit analysis begins using past history as an important reference from which to begin the benefit analysis. We believe the base case benefit estimate, which is based solely on the outcome of past accidents, may be low because today passenger load factors and aircraft size are already greater than they were in the past decade. On the other hand, we also note that this estimate may not fully take into account changes in regulatory requirements that postdate those accidents and that may mitigate the projected risk. As such, our base case estimate represents a snapshot of risk.

Airplane accidents are somewhat random both in terms of airplane size and the number of people on board. For these reasons, projections of future fatalities may be based on future risk exposure, and our projections are typically based on expected distributions around the mean. Our typical scenario incorporates increasing airplane size, expected load factors, and a breakeven analysis. However, our evaluation of the historical accidents showed a disproportionate risk among smaller, regional carriers. Accordingly, as we discuss below, the FAA has decided to base its high case estimate on preventing an accident in a regional jet airplane.

In response to comments, we have reduced the analysis period from the 20 years provided in the proposed regulatory analysis to 10 years here. We received comments disputing the use of a 20 year time frame for accidents stating the accident rate has declined over time. While noting the wide range of operations over the last 20 years, we shortened the accident history to the last ten years. A reduction in the length of the sample period introduces other problems, most importantly with less time there are fewer observations. Observations are important, as the nature of aviation accidents is that while they are rare events, very often these accidents result in severe, high consequences.

The FAA Office of Accident Investigation assessed the effectiveness of this rule to prevent the 6 fatigue-related accidents which occurred on passenger-carrying aircraft in a recent ten year period. This office used the Commercial Aviation Safety Team (CAST) methodology to assign a value to how effective the rule will be at preventing each accident. On average, we expect this rule would have been 52.5 percent effective in preventing the types of accidents had it been in effect over the last 10 years.

Base Case Estimate

The base case estimate only looks at the historical events as a specific reference point. In this estimate the exact number of fatalities for each past event is multiplied by the relative rule effectiveness score to obtain the historical number of deaths that would have been averted with the requirements contained in this final rule, had this rule been in effect at the time. The base case estimate supposes roughly six deaths will be averted annually. Multiplying six annual averted deaths by the $6.2 million value of statistical life equals $37 million annually. In addition, had the requirements been in place at the time of these historical accidents, $2 million in hull damage for each accident would have been averted, which equals $6 million for ten years or $0.6 million annually. When summed over the ten year period of analysis, the base case estimate is $376 million ($247 million present value at 7% and $311 million present value at 3%).

High Case Estimate

Because airplane accidents are relatively rare they are not necessarily representative of actual risk, especially with regard to airplane size and the number of people on-board. In addition, future conditions will be different than they were when the accident occurred. Thus, the base case represents a snapshot of the risk that fatigue introduces in the overall operating environment. It considers neither the forecasted increase in load factors nor the larger aircraft types. The future preventable events that this rule addresses will not exactly mirror the past events because the airplane types, utilization, and seating capacity have changed.

To quantify the expected benefits in the high case scenario, we narrowed the analysis to three of the six historic accidents which were catastrophic (all on board died). In this case the expected number of preventable catastrophic accidents equals the three accidents multiplied by the 52.5 percent effectiveness rate. Thus over a ten-year time period the expected number of preventable accidents is 1.575. Using the Poisson distribution there is roughly a 20 percent chance for no accident; however, there is also a 50 percent probability of two or more accidents.

While the 20 year accident history has a broader range of catastrophic accidents, in the shorter ten year historical period all the three catastrophic accidents were on regional airplanes. We recognize that as regional airplanes are smaller than the ‘typical’ passenger jet, assuming all future accidents would be on a regional jet understates the relative risk across the fleet of aircraft affected by this rule. It does, however, represent historical accidents and may be somewhat representative actual future risk, since the mainline carriers typically have collective bargaining agreements that are already largely reflective of the requirements of this rule. [18]

The average size airplane in the forecast period is a B737/A320 with an expected number of passengers and crew of 123 given a forecasted 142 seat airplane and a load factor of 83 percent.[19] Even though there was a (relatively large) B757 passenger airplane accident in the 20 year history, if one looks at the past 10 years as truly representative of risk, the preventable accident would likely be on a regional airplane.

For the high case the FAA backed away from a benefit outcome based on mean fleet, flight hours, and occupant numbers because ultimately we were persuaded there was information which could not be ignored by the three regional passenger accidents occurring without a mainline passenger accident. For this reason, we selected an 88 seat regional jet (like an ERJ-175) to be the representative airplane for the high case. This size airplane is also consistent with the fact that regional operators are expected to fly somewhat larger airplanes in the future.

The expected benefit from this high case follows a simple methodology for estimating and then valuing the expected number of occupants in a prevented accident. With a total of 0.3 accidents per year over the ten year period multiplied by the 52.5 percent effectiveness rate, the analysis assumes 0.1575 average accidents per year. The estimated occupant value for each averted accident equals the average number of seats (88) multiplied by the load factor of 77% plus 4 crew members for a total of 72 averted fatalities. Each of these prevented fatalities is

[18] It is unusual that collective bargaining agreements would closely mirror regulatory requirements. However, flight and duty limitations are unique because they address both safety considerations, which are regulatory in nature, and lifestyle considerations, which are properly addressed in collective bargaining agreements. Because of the impact of collective bargaining agreements on the number of hours that pilots work, those agreements were considered by the FAA in calculating both the costs and benefits of this rule.
[19] Table 6, FAA Aerospace Forecasts Fiscal Years 2011

multiplied by a $6.2 million value of statistical life. The expected value of a preventable accident equals the sum of the averted fatalities at $446.4 million added to the value of the airplane hull loss ($8.15 million replacement value), for a prevented accident benefit of $454.6 million.[20] Over a ten year period the value of preventing the expected 1.575 accidents equals approximately $716 million ($470 million present value at 7% and $593 million present value at 3%).

Benefit Summary

The new requirements in this final rule will eliminate the current rest and duty distinctions between domestic, flag and supplemental operations as the requirements apply universally to all Part 121 certificate holders conducting passenger operations. The sleep science, while still evolving and subject to individual inclinations, is clear in a few important respects: most people need eight hours of sleep to function effectively, most people find it more difficult to sleep during the day than during the night, resulting in greater fatigue if working at night; the longer one has been awake and the longer one spends on task, the greater the likelihood of fatigue; and fatigue leads to an increased risk of making a mistake. The requirements contained in this final rule and the accompanying analysis are designed reduce the factors that lead to fatigue in most individuals and for all flight crew.

The actual benefits of the final rule will depend upon the type and size of accident that the rule averts. Because we recognize the potential variability in the quantified benefits of this

[20] In contrast, the value of an averted all-cargo fatal accident would range between $20.35 million (loss of hull and 2 crewmembers) and $32.55 million (loss of hull and 4 crewmembers).

final rule, we provide a base case estimate, and a high case estimate. We also note that preventing a single catastrophic accident in a 10-year period with 61 people on board would cause this rule to be cost beneficial. Our base case estimate is $376 million ($247 million present value at 7% and $311 million at 3%) and our high case estimate is $716 million ($470 million present value at 7% and $593 million at 3%).

Cost Analysis

The cost of the final rule to Part 121 passenger air carriers can be categorized into three main cost components: flight operations, training, and rest facilities. Flight operations cost consists of three main sub-components: crew scheduling cost, computer programming of crew management systems cost, and cost saving associated with the need for fewer reserve flightcrew members. Training cost consists of two main sub-components: dispatchers and management fatigue training cost, and curriculum development cost. Rest facilities cost consists of four main sub-components: engineering cost, installation cost, aircraft downtime cost, and increased fuel usage cost. The final rule costs were calculated using industry-provided data whenever possible, along with expert analysis.

The total estimated cost of the final rule is $390 million for the ten year period from 2013 to 2022. The present value is $297 million and $338 million using a seven percent and a three percent discount rate, respectively. The 2013 effective date of the final rule allows two years for carriers to become compliant with the final rule. The FAA classified costs into three main components and estimated the accompanying costs. Data was obtained from various industry sources; the sources of the data used in cost estimation are explained in each section. Table 6 identifies the three main cost components. Flight operations cost accounts for approximately53 percent of the total present value cost of the rule. Rest facilities account for approximately 43 percent of the total present value cost of the rule. Roughly four percent of the costs contained in this analysis are attributable to training. Each of the main cost components are explained in-depth in the following sections of this document.

Table 6: Cost Summary

Cost Component	Nominal Cost (millions)	PV at 7% (millions)	PV at 3% (millions)
Flight Operations	$236	$157	$191
Rest Facilities	$138	$129	$134
Training	$16	$11	$13
Total	**$390**	**$297**	**$338**

Flight Operations Cost

The flight operations cost component of the final rule is composed of three sub-components: crew scheduling costs, crew management system computer programming costs, and cost savings of reduced reserves due to reducing fatigue. Table 7 provides a summary of the three sub-components of the flight operations cost. The derivations of sub-component costs are explained in-depth in the following sections of the document.[21]

[21] Operators might be able to reduce their flight operations costs by developing and implementing a fatigue risk management system (FRMS). The FAA is not imposing an FRMS program requirement on Part 121 carriers, but does allow carriers the FRMS option. Carriers might develop an FRMS program as an alternative to the final rule flightcrew member duty and rest requirements when the crew scheduling cost savings equal or exceed the costs of the FRMS program. Carriers might do this for ultra-long flights, which have flight times over 16 hours. FRMS is optional and would only be implemented by an operator if their compliance costs could be reduced as FRMS only provides cost relief. We did not estimate this potential savings as we do not know how many operators would use FRMS and the cost of FRMS has a wide range.

Table 7: Summary of Flight Operations Costs

Flight Operations Cost Sub-Component	Nominal Cost (millions)	PV Cost (millions)
Crew Scheduling	$ 440	$ 289
Computer Programming	$ 8	$ 7
Reducing Fatigue Saving	($ 211)	($ 138)
Total Flight Operations	**$ 236**	**$ 157**

Note: Numbers may not sum to total due to rounding-off error.

Crew Scheduling

Overview

Numerous commenters objected to FAA's assumptions regarding the 25 percent cost-savings resulting from long-term scheduling optimization in the NPRM. To address these concerns, the FAA estimated the scheduling compliance costs using a commercial crew scheduling program. The final rule's impact on crew scheduling costs was evaluated using Cygnus, a pairing and bid line optimizer developed by CrewPairings, Inc.[22]. Part 121 passenger air carriers provided actual crew schedule data to the FAA for assistance in the cost analysis of the Flightcrew Member Duty and Rest Requirements Rulemaking. Each carrier provided data for one or more "cases". A case is defined as a carrier fleet, which usually consists of one aircraft type. In some of the cases, the carrier schedules multiple aircraft types using the same pool of flightcrew members; the methodology in this regulatory impact analysis mirrors actual carrier practice.

[22] Cygnus has been used by more than 30 major airlines worldwide over the past 40 years.

In total, carriers provided data for eight cases. We believe these are representative of the Part 121 air transportation industry. Mainline passenger carriers were represented with two short-haul, narrow-body aircraft cases and two long-haul, wide-body aircraft cases. Regional passenger carriers were represented with two cases.[23] Cargo carriers were represented with one short-haul, narrow-body aircraft case and one long-haul, wide-body aircraft case.

In addition to the eight cases based on actual carrier fleets, a synthetic supplemental carrier case was created because no supplemental carriers provided crew schedule data. Creation of the synthetic supplemental carrier involved modification of the cargo wide-body case. The flight schedules and crew bases of the cargo wide-body case were retained because cargo carriers consist of the major share of supplemental carriers. The cargo carrier collective bargaining agreement (CBA) rules were replaced with those reflecting a representative supplemental carrier CBA. The representative supplemental carrier CBA reflected rules from a number of actual supplemental carrier CBAs. These changes reflect the impacts of this final rule on actual supplemental passenger carriers operating wide-body aircraft with route structures similar to the cargo carrier wide-body aircraft case.

The crew schedule data consisted of one scheduling period (month) per case. The specific periods varied by carrier, based on data availability. The data included full bid line and pairing information for each flightcrew member, and included both lineholder and reserve flightcrew members.

[23] Most regional carriers operate code-share flights for a number of mainline partners; crew scheduling is usually performed separately for each mainline partner. This analysis was conducted using the same process as the actual carrier, so each regional carrier case represents a sub-fleet.

The use of a pairing and bid line optimizer enabled the FAA to more accurately model the impacts of the final rule on industry crew scheduling costs than was possible during NPRM cost analysis. The pairing and bid line optimizer has been used worldwide by all types of airlines for their own crew scheduling needs and addresses the optimizer and scheduling limitations in the NPRM cost analysis. Due to this extensive real-world experience, results for these eight cases can be expected to accurately portray the impacts of the final rule on crew scheduling costs for the cases studied, without making assumptions about potential optimization by carriers.

Crew Scheduling Analysis

Accurately analyzing the final rule's impact on crew scheduling costs for the eight cases required isolating the final rule's impact from the impacts of various contractual, management, and discretionary crew scheduling practices. The pairing and bid line optimizer was first calibrated to ensure that it was capable of creating crew schedules identical to the crew schedules provided by the carriers. After calibration, existing federal regulations relevant to flightcrew member scheduling were removed from the optimizer and replaced with the final rule requirement. Changes in crew scheduling cost could then be attributed solely to the final rule.

The first step in optimizer calibration was receiving and formatting the input data from carriers for use in the optimizer. The input data included flight schedules, aircraft flow information, production pairings, regulations, and the carrier's rule set (contractual, management, and discretionary rules) from the carriers' crew management systems. Carrier rule sets included parameters for crew bases, maximum/minimum flight time, rest time, duty time, and ground time to allow aircraft changes. The bid lines and pairings that were received directly from the carriers in this first step are referred to as the "production solution." Since no modifications were made to the production solution by the FAA or the optimizer, the production solution accurately represents the current crew scheduling environment, including all regulatory, contractual, management, and discretionary rules.

Once the production solution was established, the bid lines and pairings were set aside. The optimizer was run using only the flight schedules, aircraft flow information, federal aviation regulations and the carrier's rule set. The optimizer then created its own bid lines and pairings, which are referred to as the "Baseline solution." The Baseline solution was compared to the production solution using a number of metrics, such as the amount of credit hours, duty periods, hotel room nights required, distribution of time among crew bases, number of aircraft swaps, etc. Once the Baseline solution was identical or virtually identical to the production solution, the optimizer was deemed calibrated for each of the cases.

Calibration of the optimizer verified that the optimizer could accurately reproduce the crew scheduling process at each of the carriers. The Baseline solution could be substituted for the production solution at each carrier with no change in crew scheduling cost.

To determine the impact of the final rule, the regulations in the Baseline solution were replaced with the final rule. All provisions of the final rule were implemented in this analysis, including maximum flight time, maximum flight duty time, minimum rest time, and cumulative limits. All other, non-regulatory rules from the Baseline solution were retained. Using these inputs, the optimizer created bid lines and pairings referred to as the "final rule solution."

Since the only difference between the Baseline solution and the final rule solution was the substitution of the final rule for the existing regulations, the change in cost between the solutions is solely attributable to the final rule. Eight industry groups were created for the final rule cost analysis. Three cargo groups were dropped from final rule cost estimates. The two short-haul passenger cases were combined for the passenger narrow-body group. The two long-haul passenger cases were combined for the passenger wide-body group. The two short-haul passenger and two long-haul passenger cases were combined for the passenger integrated group. The two regional cases were combined for the regional group. The synthetic supplemental case was renamed the supplemental group. Table 8 lists the number of flightcrew members per industry group used in the crew pairing analysis, in the determination of the compliance cost for the final rule.

Table 8: Flightcrew Members per Industry Group

Industry Group	Flightcrew Members
Passenger Integrated	4,173
Passenger Narrow-body	2,622
Passenger Wide-body	1,551
Regional	540
Supplemental	806

For each industry group, the change in cost between the Baseline and final rule solutions was divided by the number of flightcrew members in the Baseline solution to determine the monthly final rule crew scheduling cost per flightcrew member for that group. The final rule crew scheduling cost is valued by summing the change in credit hour cost, per diem cost, and hotel cost from the Baseline solution to the final rule solution. The annual final rule crew scheduling cost per flightcrew member was calculated by multiplying the monthly cost by 12. Table 9 presents the monthly and annual final rule cost per flightcrew member for each group.

Table 9: Final Rule Crew Scheduling Cost per Flightcrew Member

Industry Group	Final Rule Monthly Cost per Flightcrew Member	Final Rule Annual Cost per Flightcrew Member
Passenger Integrated	$22	$264
Passenger Narrow-body	$98	$1,176
Passenger Wide-body	-$107	-$1,284
Regional	$84	$1,008
Supplemental	$1,261	$15,133

The final rule crew scheduling cost per flightcrew member in Table 9 includes crew salary, per diem, and hotel costs. Crew salary is calculated by multiplying the change in credit hours from the Baseline solution to the final rule solution by the estimated average credit hour cost per flightcrew member. Estimated average credit hour cost per flightcrew member was calculated using Bureau of Transportation Statistics Form 41 data[24] and other industry data.

Item 51230, Pilots and Copilots, from Schedule P-5.2 was used to determine the total flightcrew cost by carrier and by aircraft type. Block hours by carrier and by aircraft type were taken from the AirHoursRamp item in the Air Carrier Summary Data, T2: U.S. Air Carrier Traffic and Capacity Statistics by Aircraft Type report. Total flightcrew cost data and aircraft block hour data were both summed for each of the five industry groups. The industry group sum of total flightcrew cost was divided by the industry group sum of aircraft block hours for each of the five industry groups. These calculations resulted in the average total flightcrew cost per aircraft block hour.

[24] Data is from 1Q 2010 through 3Q2010, the most recent data available as of April 2011.

To determine the average cost per block hour for an individual flightcrew member, it was necessary to divide the average total flightcrew cost per aircraft block hour by the average number of flightcrew members per flight. The average number of flightcrew members per flight was estimated using data provided to the FAA by a number of carriers.

Several steps were necessary to convert from the average cost per block hour per flightcrew member to the average credit hour cost per flightcrew member. First, estimated credit hours per flightcrew member per month by industry group were derived from analysis of AIR Inc. Salary Survey data. The AIR Inc. Salary Survey provided estimated credit hours per flightcrew member per month for 29 carriers. Each of these carriers was assigned to one of the industry groups. Weighted average estimated credit hours were calculated using carrier block hour data from Schedule T2: U.S. Air Carrier Traffic and Capacity Statistics by Aircraft Type carrier block hours from the Air Carrier Summary Data database. Next, actual crew scheduling data provided by a number of carriers to the FAA was analyzed to determine the average flightcrew member number of block hours per month for each of the industry groups. Dividing the average flightcrew member block hours per month by the average flightcrew member credit hours per month resulted in a ratio of block hours per month to credit hours per month, for each of the industry groups. The average cost per block hour per flightcrew member was multiplied by the ratio of block hours per month to credit hours per month to result in the average credit hour cost per flightcrew member for each of the industry groups.

The approach to calculating the average credit hour cost per flightcrew member presented in Table 10 addresses NPRM comments made by several commenters. Commenters stated that the salary data used in the NPRM RIA "does not approximate current, real world flight crew unit costs…"[25] ATA suggested that the FAA use DOT Form 41 data for calculation of crew salary costs. The approach to crew salary costs presented in Table 10 responds to this comment by using the most recent 2010 DOT Form 41 data available as of April 2011 for the calculation of average credit hour costs per flightcrew member. This approach does not include payroll taxes because these represent a transfer cost. This approach also does not include pension and benefit costs, because these costs will not be affected by the marginal change in credit hours attributable to the final rule.

Table 10: Average Flightcrew Member Cost per Credit Hour

Industry Group	Average Flightcrew Cost per Block Hour	Average Flightcrew Members per Flight	Average Flightcrew Member Cost per Block Hour	Weighted Average Estimated Credit Hrs/Month	Average Flightcrew Member Block Hrs/Month	Ratio of Credit Hrs/Month to Block Hrs/Month	Average Credit Hour Cost per Flightcrew Member
Passenger Integrated	$481	2.24	$214	78	59	0.76	**$163**
Passenger Narrow-body	$417	2.00	$209	82	60	0.73	**$153**
Passenger Wide-body	$629	2.67	$236	60	59	0.98	**$231**
Regional	$179	2.00	$89	82	48	0.59	**$53**
Supplemental	$712	2.16	$329	71	44	0.61	**$201**

Table 10 summarizes the steps used to calculate the average monthly credit cost per flightcrew member. First, the number of flightcrew members in the Baseline solution of each case was summarized by industry group. Next, the change in credit hours from the Baseline solution to the final rule solution was calculated. The result was multiplied by the average

[25] Comments of the Air Transport Association of America, Inc. in the matter of Notice of Proposed Rulemaking for Flightcrew Member Duty and Rest Requirements, Docket No. FAA-2009-1093, November 15, 2010.

flightcrew member cost per credit hour[26] to calculate the final rule credit hour cost. The final rule credit hour cost per flightcrew member was necessary to have for extrapolation of the crew scheduling cost to the industry; this was calculated by dividing the final rule credit hour cost by the number of flightcrew members in the Baseline solution and is shown in Table 11.

Table 11: Average Monthly Credit Hour Cost per Flightcrew Member Calculation

Industry Group	Baseline Solution Flightcrew Members	Change in Credit Hours from Baseline Solution to Final Rule Solution	Average Flightcrew Member Cost per Credit Hour	Final Rule Credit Hour Cost	Final Rule Credit Hour Cost per Flightcrew Member
Passenger Integrated	*4,173*	*723*	*N/A*	*$29,854*	***$7***
Passenger Narrow-body	2,622	1,758	$153	$268,664	**$102**
Passenger Wide-body	1,551	-1,035	$231	-$238,809	**-$154**
Regional	540	94	$53	$4,953	**$9**
Supplemental	806	4,642	$201	$930,922	**$1,155**

Note: The passenger integrated group is the combined passenger narrow-body and passenger wide-body groups.

Per-diem costs were calculated by multiplying the change in time away from base (TAFB) from the Baseline solution to the final rule solution by the appropriate per diem rate. Because flightcrew members at some carriers receive different per diem rates based on whether TAFB is domestic or international, the pairings summary in each of the solutions provided domestic and international TAFB separately. The per diem rates used in this analysis were a weighted average of carriers reporting per diem rates in the 2006-07 AIR, Inc. Salary Survey. The data was categorized by operator type (freight, passenger, and regional) since per diem rates

[26] Average flightcrew member cost per credit hour calculation is shown in Table 10.

do not differ by aircraft type operated. Weighted averages were calculated using T2: U.S. Air Carrier Traffic and Capacity Statistics by Aircraft Type carrier block hours from the Air Carrier Summary Data database. Table 12 shows the weighted average hourly per diem rates by operator type used in this analysis.

Table 12: Hourly Per Diem Rates by Operator Type

Operator Type	Weighted Average Domestic Per Diem Rate	Weighted Average International Per Diem Rate
Passenger	$1.94	$2.28
Regional	$1.60	$1.99
Supplemental	$2.06	$2.28

Table 13 summarizes the steps used to calculate the average monthly domestic per diem cost per flightcrew member. First, the number of flightcrew members in the Baseline solution of each case was summarized by industry group. Next, the change in domestic TAFB hours from the Baseline solution to the final rule solution was calculated. The result was multiplied by the weighted average domestic per diem rate to calculate the final rule domestic per diem cost. The final rule domestic per diem cost per flightcrew member was necessary to have for extrapolation of the crew scheduling cost to the industry; this was calculated by dividing the final rule domestic per diem cost by the number of flightcrew members in the Baseline solution.

Table 13: Average Monthly Domestic Per Diem Cost per Flightcrew Member Calculation

Industry Group	Baseline Solution Flightcrew Members	Change in Domestic TAFB Hours from Baseline Solution to Final Rule Solution	Weighted Average Domestic Per Diem Rate per Hour	Final Rule Domestic Per Diem Cost	Final Rule Domestic Per Diem Cost per Flightcrew Member
Passenger Integrated	4,173	7,488	$1.94	$14,557	**$3**
Passenger Narrow-body	2,622	3,625	$1.94	$7,048	**$3**
Passenger Wide-body	1,551	3,863	$1.94	$7,510	**$5**
Regional	540	9,960	$1.60	$15,972	**$30**
Supplemental	806	3,159	$2.06	$6,509	**$8**

Table 14 summarizes the steps used to calculate the average monthly international per diem cost per flightcrew member. First, the number of flightcrew members in the Baseline solution of each case was summarized by industry group. Next, the change in international TAFB hours from the Baseline solution to the final rule solution was calculated. The result was multiplied by the weighted average international per diem rate to calculate the final rule international per diem cost. The final rule international per diem cost per flightcrew member was necessary to have for extrapolation of the crew scheduling cost to the industry; this was calculated by dividing the final rule international per diem cost by the number of flightcrew members in the Baseline solution.

Table 14: Average Monthly International Per Diem Cost per Flightcrew Member Calculation

Industry Group	Baseline Solution Flightcrew Members	Change in International TAFB Hours from Baseline Solution to Final Rule Solution	Weighted Average International Per Diem Rate per Hour	Final Rule International Per Diem Cost	Final Rule International Per Diem Cost per Flightcrew Member
Passenger Integrated	4,173	6,637	$2.28	$15,120	**$4**
Passenger Narrow-body	2,622	1,030	$2.28	$2,346	**$1**
Passenger Wide-body	1,551	5,607	$2.28	$12,774	**$8**
Regional	540	-16	$1.99	-$31	**$0**
Supplemental	806	9,759	$2.28	$22,270	**$28**

The final rule domestic per diem cost per flightcrew member column from Table 13 and the final rule international per diem cost per flightcrew member column from Table 14 were summed to calculate the final rule per diem cost per flightcrew member. The results are shown in Table 15.

Table 15: Average Monthly Per Diem Cost per Flightcrew Member

Industry Group	Final Rule Domestic Per Diem Cost per Flightcrew Member	Final Rule International Per Diem Cost per Flightcrew Member	Final Rule Per Diem Cost per Flightcrew Member
Passenger Integrated	$3	$4	**$7**
Passenger Narrow-body	$3	$1	**$4**
Passenger Wide-body	$5	$8	**$13**
Regional	$30	$0	**$30**
Supplemental	$8	$28	**$36**

Hotel costs were calculated by multiplying the change in required hotel room nights from the Baseline solution to the final rule solution by the average hotel room cost. The hotel room costs used in this analysis were included in data provided to the FAA and differ by carrier. Table 16 summarizes the final rule monthly hotel cost per flightcrew member by industry group.

Table 16: Cost Components of Monthly Final Rule Cost per Flightcrew Member

Industry Group	Final Rule Monthly Credit Cost per Flightcrew Member	Final Rule Monthly Per Diem Cost per Flightcrew Member	Final Rule Monthly Hotel Cost per Flightcrew Member	Final Rule Monthly Cost per Flightcrew Member
Passenger Integrated	$7	$7	$8	**$22**
Passenger Narrow-body	$102	$4	-$8	**$98**
Passenger Wide-body	-$154	$13	$34	**-$107**
Regional	$9	$30	$46	**$84**
Supplemental	$1,155	$36	$70	**$1,261**

Extrapolation of Crew Scheduling Analysis

All Part 121 passenger air carriers in the U.S. air transport industry were categorized into one of the five industry groups based on how closely the carrier resembled one of the five industry groups. A number of metrics such as operating authority, aircraft fleet, aircraft utilization, markets served, collective bargaining agreements, etc. were examined to determine which of the five industry groups each carrier most closely resembled. Table 17 lists the number of air carriers in each group and the number of flightcrew members in each group.

Table 17: Final Rule Cost Analysis Industry Groups

Industry Group	Part 121 Carriers	Flightcrew Members
Passenger Integrated	7	36,013
Passenger Narrow-body	16	12,128
Passenger Wide-body	1	150
Regional	40	20,668
Supplemental	3	1,267
Total	**67**	**70,226**

Source: Adapted from FAA VIS, December 2010

The number of flightcrew members presented in Table 17 reflects the number of flightcrew members listed on each Part 121 carrier's operating certificate in the FAA's Vital Information Subsystem (VIS) as of December 2010. The total industry final rule cost would be overstated if extrapolation was based on the number of VIS flightcrew members because not all of these flightcrew members are lineholders. Each carrier employs a significant number of reserve flightcrew members. The FAA estimated that reserves comprise 15 percent of flightcrew members for the average Part 121 passenger air carrier based on APA published information[27]. Thus, the extrapolation of the crew scheduling analysis to the Part 121 passenger air transportation industry used the number of flightcrew members (lineholders) shown in Table 18 to determine the final rule crew scheduling cost.

[27] "The Reserve System – A Quality of Life Nightmare," page 16, Flightline, Allied Pilots Association, December 2010/January 2011.

Table 18: Reserve-Adjusted Flightcrew Members by Industry Group

Industry Group	Flightcrew Members Adjusted for Reserves
Passenger Integrated	30,611
Passenger Narrow-body	10,309
Passenger Wide-body	128
Regional	17,568
Supplemental	1,077
Total	**59,692**

Note: Numbers may not sum to total due to rounding-off error.

The number of flightcrew members in each industry group shown in Table 18 was multiplied by the appropriate annual cost per flightcrew member (Table 16) to extrapolate the estimated cost to the Part 121 passenger air transportation industry, as shown in the "Preliminary Annual Crew Scheduling Cost" column in Table 19. In 2010, there were eight Part 121 carriers that conducted both all-cargo and passenger operations. For those carriers, the number of passenger revenue departures as a share of total revenue departures in 2010 as reported in Database T1: U.S. Air Carrier Traffic and Capacity Summary by Service Class from the Bureau of Transportation Statistics was used as the share of crew scheduling costs attributable to the final rule. The "Final Annual Crew Scheduling Cost: Adjusted for Passenger Flights Only" column in Table 19 presents the annual, nominal crew scheduling costs by industry group.

Table 19: Annual Crew Scheduling Costs

Industry Group	Final Rule Annual Cost per Flightcrew Member	Reserve-Adjusted Flightcrew Members	Preliminary Annual Crew Scheduling Cost (millions)	Final Annual Crew Scheduling Cost Adjusted for Passenger Flights Only (millions)
Passenger Integrated	$264	30,611	**$8**	**$8**
Passenger Narrow-body	$1,176	10,309	**$12**	**$12**
Passenger Wide-body*	-$1,284	128	**$0**	**$0**
Regional	$1,008	17,568	**$18**	**$18**
Supplemental	$15,133	1,077	**$16**	**$7**
Total	**N/A**	**59,692**	**$54**	**$44**

* Some flights that currently require four flightcrew members could be completed with three flightcrew members under the final rule.

Note: Numbers may not sum to total due to rounding-off error.

Table 20 presents the nominal and present value (at seven percent discount rate) crew scheduling cost for the entire passenger-carrying portion of the industry for each year of the ten year period of analysis[28]. Each table contains all crew scheduling cost components, including crew salary, per diem, and hotel costs.

[28] The projected cost for all-cargo operators associated with crew scheduling was $286 million over 10 years in nominal costs and $188 million in present value costs.

Table 20: Ten Year Crew Scheduling Costs

Year	Nominal Cost (millions)	PV Cost (millions)
2014	$ 44	$ 38
2015	$ 44	$ 36
2016	$ 44	$ 34
2017	$ 44	$ 31
2018	$ 44	$ 29
2019	$ 44	$ 27
2020	$ 44	$ 26
2021	$ 44	$ 24
2022	$ 44	$ 22
2023	$ 44	$ 21
Total	**$ 440**	**$ 289**

Note: Numbers may not sum to total due to rounding-off error.

Limitations of Crew Scheduling Analysis

The FAA believes that carriers will be able to reduce much of the cost shown in Table 20. Carriers will engage in additional network optimization to reduce crew scheduling costs, which the FAA is unable to quantify at this point. In the long run, this may involve re-timing flights, changing schedule frequency, and entering or leaving markets. However, there may also be costs associated with these actions such as changes in aircraft utilization and revenue losses. At this time, the FAA has not estimated potential long-run optimization of crew scheduling costs.

The final rule economic costs are best measured as society's willingness to be compensated for consumption opportunities forgone as a result of resources being diverted to the production of improved aviation safety. Because these opportunity costs are difficult to estimate, our estimates of crew scheduling costs reflect, for the most part, financial costs that will be incurred by affected air carriers. These financial costs are likely to overstate the economic costs of the proposed rule.

A large part of estimated crew scheduling costs is increased compensation to flightcrew members for the additional time spent in avoiding pilot fatigue. These compensation costs will reflect economic costs only if flightcrew wage rates are accurate measures of the forgone value of goods and services that could otherwise be produced. However, it is likely that flightcrew members will be able to use some of the time spent avoiding fatigue in productive activities, including the production of leisure activities. Our cost estimates do not include offsets for the value of these activities.

Increased per diem cost estimates do not include offsets that are likely to occur. For example, meals consumed on the road by flight crew members are substitutes for meals that would otherwise be consumed at home. Resource savings (the value of labor and food used to produce meals at home in this example) are not reflected in our cost estimates. Similarly, the costs associated with increased hotel expenses do not include offsets for at-home savings that will likely occur—e.g., reduced energy and water consumption and avoided cleaning costs.

Computer Programming

Carriers will incur computer programming costs as they will need to update their crew management systems and their schedule optimization systems with the constraints imposed by the final rule.

A one-time cost will be incurred in 2013 as carriers update their crew management systems. Crew management system update costs were estimated for each individual carrier, based on the number of flightcrew members listed on the carrier's operating certificate.

Carriers were assigned to one of three groups based on the number of flightcrew members. Costs vary with size of carriers, estimated by the number of person-days and staff costs. Person-days required to perform the system update were estimated about 400, 160 and 80 days for large (more than 1,000 flightcrew members), average (250 to 1,000 flightcrew members) and small (less than 250 flightcrew members) carriers, respectively. A daily professional staff cost was estimated approximately $625. Table 21 presents the nominal and present value of crew management system update costs[29].

Table 21: Crew Management System Update Costs

Year	Flightcrew Members	Carriers	Cost per Carrier	Nominal Cost (millions)	PV Cost (millions)
2014	>1,000	16	$250,000	**$ 4**	**$ 3**
	250-1,000	21	$100,000	**$ 2**	**$ 2**
	<250	30	$50,000	**$ 2**	**$ 1**
Total		**67**		**$ 8**	**$ 7**

Note: Numbers may not sum to total due to rounding-off error

Cost Savings from Reducing Flightcrew Members Fatigue

The final rule is designed to reduce the risk of fatigued flightcrew members by limiting the maximum number of hours they are permitted to be on duty, the number of hours they actually fly during duty periods, and by ensuring that they receive adequate rest periods before

[29] The projected cost for all-cargo operations associated with computer programming was $2 million in nominal cost and $1 million in present value cost.

reporting for duty. According to CDC, "chronic sleep loss is an under-recognized public health problem that has a cumulative effect on physical and mental health. Sleep loss and sleep disorders can reduce quality of life and productivity, increase use of health-care services, and result in injuries, illness, or deaths."[30] It is expected that the final rule will result in better-rested flightcrew members, and reduce wage loss. The final rule will reduce flight crew member fatigue, thus reducing the use of sick time. When a flightcrew member is scheduled for duty and calls in sick or fatigued, the carrier must use a reserve flightcrew member to complete the scheduled duty. The final rule will reduce the use of reserve flightcrew members to cover fatigue-induced sick call-ins by flight crew members, which will reduce the flight operations cost associated with fatigue issues for carriers.

While the precise share of current sick time attributable to fatigue is unknown, it is most likely greater than zero. Similarly, while the precise amount by which the final rule will reduce sick time is unknown, it is also most likely greater than zero. Labor representatives have informed the FAA that the estimated sick time that is used due to fatigue is approximately five percent. In light of this information, the FAA assumes, for the purposes of this analysis, that sick time accounts for five percent of total industry flightcrew member pay. Total industry flightcrew member pay was calculated by multiplying the average flightcrew member cost per credit hour from Table 10 by the estimated number of credit hours per month[31] and multiplied by 12 for each carrier to calculate total annual industry flightcrew member pay.

[30] CDC's MMWR, Weekly, February 29, 2008 / 57(08);200-203.

[31] Estimated number of credit hours per month by carrier was taken from the 2006-07 U.S. Airlines/Corporate Salary Survey published in AIR Inc.

In 2010, there were eight Part 121 carriers that conducted both all-cargo and passenger operations. For those carriers, the number of passenger revenue departures as a share of total revenue departures in 2010 as reported in Database T1: U.S. Air Carrier Traffic and Capacity Summary by Service Class from the Bureau of Transportation Statistics was used as the share of cost savings attributable to the final rule.

The final rule is expected to reduce the use of sick time by five percent. The nominal value of the cost savings is approximately $211 million ($138 million present value) over the ten-year period of analysis.[32] Table 22 presents the annual cost savings.

[32] The projected cost savings to all-cargo operators was estimated at $48 million nominal value over 10 years and $32 million in present value.

Table 22: Reducing Flightcrew Members Fatigue Cost Savings

Year	Nominal Cost Savings (millions)	PV Cost Savings (millions)
2014	$ 21	$ 18
2015	$ 21	$ 17
2016	$ 21	$ 16
2017	$ 21	$ 15
2018	$ 21	$ 14
2019	$ 21	$ 13
2020	$ 21	$ 12
2021	$ 21	$ 11
2022	$ 21	$ 11
2023	$ 21	$ 10
Total	**$ 211**	**$ 138**

Note: Numbers may not sum to total due to rounding-off error

Flight Operations Cost Summary

The total flight operations cost is composed of the additional crew scheduling costs (flightcrew member salary, hotel, and per diem), plus the computer programming costs, and less the cost savings from reducing flightcrew members fatigue. The net nominal value of the total flight operations cost for the period of analysis is approximately $236 million, with a present value of $157 million[33]. Table 23 presents the annual nominal and present value total flight operations cost.

[33] The projected cost to all-cargo operators associated with flight operations is $240 million in nominal cost over 10 years and $158 million in present value.

Table 23: Total Flight Operations Cost

Year	Nominal Cost (millions)	PV Cost (millions)
2014	$ 30	$ 27
2015	$ 23	$ 19
2016	$ 23	$ 17
2017	$ 23	$ 16
2018	$ 23	$ 15
2019	$ 23	$ 14
2020	$ 23	$ 13
2021	$ 23	$ 12
2022	$ 23	$ 12
2023	$ 23	$ 11
Total	**$ 236**	**$ 157**

Note: Numbers may not sum to total due to rounding-off error.

Rest Facilities

The final rule establishes maximum flight-duty period limits for augmented operations that are dependent on the start time of the flight duty period, the number of flightcrew members assigned to the flight, and the class of rest facility installed on the aircraft. The final rule establishes detailed specifications for each of the three classes of rest facilities. Class 1 rest facilities are most conducive to reducing the risk of fatigue in augmented operations; accordingly, the maximum flight duty time permitted for augmented operations conducted with Class 1 rest facility-equipped aircraft is greater than the maximum flight duty time permitted for augmented operations conducted with either Class 2 or 3 rest facility-equipped aircraft. The definitions of the rest facilities are as follows:

- A Class 1 rest facility is a bunk or other surface that allows for a flat sleeping position and is located separate from both the flight deck and passenger cabin in an area that is temperature-controlled, allows the crewmember to control light, and provides isolation from noise and disturbance.
- A Class 2 rest facility is a seat in an aircraft cabin that allows for a flat or near flat sleeping position; is separated from passengers by a minimum of a curtain to provide darkness and some sound mitigation; and is reasonably free from disturbance by passengers or crewmembers.
- A Class 3 rest facility is a seat in an aircraft cabin or flight deck that reclines at least 40 degrees and provides leg and foot support.

There are four sub-components of the rest facility cost component of the final rule. The first sub-component consists of the rest facility design and engineering costs. The second sub-component consists of the cost resulting from the physical installation of the facilities on the affected aircraft. The third sub-component is the value of the aircraft downtime required to install the rest facilities. The final sub-component is additional aircraft fuel consumption cost due to the weight of the rest facilities. The following paragraphs discuss how the FAA estimated each of the rest facility cost sub-components, and Table 24 details the final cost of each of these sub-components. The total rest-facility cost is approximately $138 million ($129 million present value[34].)

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[34] We assumed costs of engineering, installation and downtime incur in two years prior to the compliance of the final rule and fuel cost incurs for a 10-year period.

Table 24: Rest Facility Cost Overview

Rest Facilities Cost Sub-Component	Nominal Cost (millions)	PV Cost (millions)
Engineering	$ 12	$ 11.5
Installation	$ 99	$ 96
Downtime	$ 12	$ 11.5
Fuel	$ 15	$ 10
Total Rest Facilities	**$ 138**	**$ 129**

Engineering

During NPRM cost analysis, the FAA obtained detailed cost estimates from two supplemental type certificate (STC) holders. For this final regulatory evaluation we have delineated between engineering and kit/installation costs, as the engineering cost per operator would be a one-time, non-recurring cost for each type (make and model) of aircraft. We continue using the data provided by the STC holders as the basis for engineering and installation. The engineering costs are non-recurring, design costs. These consist of system, development, engineering, analysis, and certification costs. We conservatively use the engineering cost of $0.5 million per make/model as estimated by the STC holders. Accordingly, there will be roughly 24 different designs at $0.5 million per design (make/model). The actual engineering cost will not be incurred until 2014, one year after the implementation of the rule (2013) because the final payment will not occur until successful demonstration of the STC on all of the aircraft. As such, the estimated engineering cost is approximately $12 million ($0.5 million x 24), or $11.5 million present value at 7% discount rate.

Installation

Based upon public comments in response to the NPRM, the FAA has refined the estimate of the number of aircraft that will require rest facility installation. The FAA now estimates, based on data collected from FAA inspectors, that 223 aircraft will need crew rest modifications to comply with the final rule.[35] This is an increase from the estimate of 104 aircraft in the NPRM cost analysis. However, it is lower than the estimates of some NPRM commenters. The FAA believes that the final rule estimate of 223 aircraft represents the worst case scenario because aircraft will be re-optimized based upon current configurations. The FAA estimates that, any additional aircraft, beyond the approximate 223 aircraft used in this analysis, will already have adequate rest facilities. Once the additional 223 aircraft have rest facilities installed, each fleet will be re-optimized for the most efficient use. As such, we conservatively assume all of these 223 aircraft will have a Class 1 facility installed for an upper-bound estimation.

We continue to use the equipment and labor cost provided by an STC holder for our estimate of installation costs to the carriers. The kit and the installation for each of the individual airplanes will cost roughly $350,000 and $95,000, respectively. As such, the total cost of each installation will be roughly $445,000 ($350,000 + $95,000). When multiplied by the affected fleet of 223 aircraft, the total facility installation cost will be approximately $99 million ($445,000 x 223), or $96 million present value at 7% discount rate.

[35] All aircraft used in augmented operations by carriers conducting both all-cargo and passenger operations are included in this analysis, since it is not possible to identify whether aircraft are used exclusively in all-cargo operations.

Downtime

Commenters indicated that an aircraft could be out of service for two weeks during rest facility installation. The FAA estimates the cost to Part 121 operators for this potential additional planned time out of service, or *downtime,* to install the rest facilities. STC designers have indicated that with proper planning, a modifier can install rest facilities in two to four days. We conservatively use a four-day estimate for the calculation of the downtime cost. The FAA conservatively assumes that if an aircraft was to be out of service for any part of a day, that airplane would be out of service for the entire day.

For this analysis, the FAA uses the opportunity cost of capital to approximate the planned downtime cost to the operators. Using guidelines prescribed by the Office of Management and Budget, the FAA uses seven percent as a proxy for average annual rate of return on capital. The FAA uses $69 million as the estimated market value of an aircraft[36] for downtime in this analysis. The yearly opportunity cost of capital per aircraft would be $4.83 million, roughly $13,233 per day. When multiplied by the affected fleet (223 aircraft) and the days out of service (4 days), the downtime cost for the fleet is $12 million (223 x 4 x $13,233), or $10 million present value.

Fuel Consumption Costs

We have analyzed the costs associated with the design and installation of Class 1 rest facilities. We assume the rest facilities will be installed in the most efficient manner possible, with no impact on passenger seats or the revenue that they generate. As such, we do not estimate

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[36] November, 2010 The Airline Monitor. This number represents the appraised value of a 767-300. p.33

loss of revenue from a Class 1 rest facility, because as defined by the rule, the facilities will be located separate from both the flight deck and passenger cabin, and will not necessarily require the removal of passenger seats. For example, a Class 1 rest facility can be located in aircraft belly or overhead area, neither of which requires the removal of passenger seats. Although there will be no revenue impact, there will be an additional cost that will add to the aircraft operating costs due to the estimated additional impact of weight changes on each aircraft. Estimates for the additional incremental weight impact are used to calculate the additional fuel consumption for the affected fleet.

The estimated cost of fuel reflects the most recent forecast using data from the 2011 FAA Aerospace Forecast. We use the fuel consumption methodology as derived from the FAA's guidance, Economic Values for the FAA Investment and Regulatory Decisions along with the estimated average fuel cost of approximately $2.85 per gallon. To calculate the additional annual cost of fuel per aircraft, we multiply the 300 additional pounds by the fuel consumption factor of .005 gallons per hour per pound (consistent with a two-engine, wide-body aircraft) and arrive at 1.5 gallons per hour per aircraft. This product is then multiplied by the average annual flight hours per aircraft of 2,380[37] and finally by the cost of fuel ($2.85) to arrive at the total annual estimated additional cost of fuel per aircraft of $6,763. When multiplied by the affected annual fleet (223 aircraft), the annual incremental fuel consumption cost is approximately $1.5 million. When summed over the period of analysis, the total estimated cost for fuel is approximately $15 million (1.5 x 2,380 x 223 x $2.85 x 10) or $10 million present value.

[37] DOT, Form 41

Fatigue Training

In accordance with the Airline Safety and Federal Aviation Administration Extension Act of 2010, Section 212, each air carrier conducting operations under 14 CFR part 121 must have submitted a fatigue risk management plan (FRMP) to the Administrator for review and acceptance. A FRMP is an air carrier's management plan outlining policies and procedures for reducing the risks of flightcrew member fatigue and improving flightcrew member alertness. In this final rule the FAA kept the requirement for pilots to receive fatigue training, but eliminated the incremental cost of compliance because the operators are already in compliance with FRMP. The final keeps the requirement for management and dispatchers to have fatigue training and the requirement for curriculum development and keeps the costs for these requirements. Again, the FAA made this change as air carriers under 14 CFR part 121 will be in compliance with the statutory pilot training requirement as part of the FRMP's. This rule change reduces the nominal training cost requirement to $16 million.

The final rule requires that dispatchers and upper management having operational control over flightcrew members be given fatigue training. The number of dispatchers in the U.S. air transportation industry is equal to approximately three percent of the number of pilots. The number of management personnel (immediate supervisors and schedulers) is estimated to be about nine percent of flightcrew members. Therefore, the total number of dispatchers and management personnel required to receive fatigue training is estimated to be approximately 12 percent of total flightcrew members.

The estimated total cost of the proposed fatigue training requirements for dispatchers and management personnel over the ten year period from 2013 to 2022 is $16 million or $11 million in present value.

In addition carriers will incur a one-time cost to develop fatigue training curriculum. According to industry standard, curriculum development takes three hours for each hour of course required. Therefore, the time needed to develop the initial training curriculum will be fifteen hours and the time needed to develop the recurrent training curriculum will be six hours. The FAA assumes that the wage rate of the curriculum developer is approximately $100 per hour. Each of the 67 Part 121 passenger air carriers will need to develop its own curriculum. The total cost of curriculum training is $140 thousand or $120 thousand in present value.

Thus the training cost requirement for management and dispatchers plus curriculum development cost equals $16 million and $11 million in present value.

Cost Analysis Summary

The present value cost of the final rule to Part 121 passenger air carriers over the ten-year period of analysis is $390 million ($284 million present value). Flight operations account for approximately 53 percent of the nominal total cost; crew scheduling cost is the largest sub-component of flight operations cost. Rest facilities account for roughly 43 percent of the nominal total cost; rest facility installation is the largest sub-component of rest facilities cost. Roughly 4 percent of the nominal cost of the final rule is attributable to training. All final rule cost components were calculated using industry-provided data whenever possible, along with expert analysis.

Table 25: Cost Summary

Cost Component	Nominal Cost (millions)	PV at 7% (millions)	PV at 3% (millions)
Flight Operations	$236	$157	$191
Rest Facilities	$138	$129	$134
Training	$16	$11	$13
Total	**$390**	**$297**	**$338**

Note: Numbers may not sum to total due to rounding-off error.

Cost-Benefit Summary

The total estimated cost of the final rule over 10 years is $390 million ($297 million present value at 7% and $338 million at 3%).[38] We provide a range of estimates for our quantitative benefits over the same period. Our base case estimate is $376 million ($247 million present value at 7% and $311 million at 3%) and our high case estimate is $716 million ($470 million present value at 7% and $593 million at 3%). We also note that preventing a single catastrophic accident in a 10-year period with 61 people on board would cause this rule to be cost beneficial.

[38] The projected cost for all-cargo operations is $306 million ($214 million present value at 7% and $252 million at 3%). The projected benefit of avoiding one fatal all-cargo accident ranges between $20.35 million and $32.55 million, depending on the number of crewmembers on board the aircraft.

Accident Appendix

1. Accident DCA94MA065

Date: 7/2/1994

July 2, 1994 in Charlotte, NC

A/C: MD-82, N954VJInjuries: 37 Fatal, 16 Serious

Accident Summary: Aircraft collided with trees and a private residence near the Charlotte/Douglas International Airport, Charlotte, North Carolina (CLT), shortly after the flightcrew executed a missed approach from the instrument landing system (ILS) approach to runway

Probable Cause: Probable cause was determined to be the flightcrew's decision to continue an approach into severe convective activity that was conducive to a microburst: 2) the flightcrew's failure to recognize a windshear situation in a timely manner, 3) the flightcrew's failure to establish and maintain the proper airplane attitude and thrust setting necessary to escape the windshear; and 4) the lack of real-time adverse weather and windshear hazard information dissemination from air traffic control, all of which led to an encounter with and failure to escape from a microburst-induced windshear that was produced by a rapidly developing thunderstorm located at the approach end of runway.

Flight Crew/Fatigue Related Information: The captain was off duty for 3 days before the beginning of the accident trip. On the morning of June 28, 1994, he flew with his National Guard squadron, which is based at Wright Patterson Air Force Base Ohio, near his home. On the day of the accident he awoke about 0455 drove to the airport in Dayton Ohio, and departed on a flight to Pittsturgh at around 0745. The reporting time for the trip that included the accident flight was 0945, and the departure time for LGA was at 1045. The first officer flew a 4-day trip that ended around 0930 on July 2. On the day of the accident, he arose about 06 I5 and flew the leg to Pittsburgh that departed St. Louis at 0810. He arrived in Pittsburgh at 0030.

SCORE: 0.35 Fatigue could have affected FO's performance (PF). PIC, who was off-duty preceding 3 days, was much less vulnerable to fatigue, but he too had already had a long day. Accident occurred 14 hours into PIC's day. He awoke at 0455, drove to Dayton from home, then flew to PIT to begin duty day. Accident occurred at 1843, at end of third of 4 scheduled legs. His long day may have contributed to his failure to make 2 standard call-outs on approach at 1000 AGL & 100 AGL. As NTSB notes, failure to make these call-outs contributed to PIC's loss of situational awareness, his directing FO to go-around "to the right" instead of following runway heading as directed, & directing FO to "push down" after FO had initiated 15-degree nose-up & right banking turn.

FO was more vulnerable to fatigue. His duty day ended June 30 at 2230 at Blountsville, TN. NTSB report does not say when that duty day began, nor when FO awoke that day. At Blountville, he went to bed at 0130 & awoke at 0900. His next duty day ended at STL at 2040 EDT. He went to bed at 2230 & awoke at 0615 on accident day. He then flew to PIT & began pairing with accident PIC. Like PIC, FO was nearly 14 hours into his day when accident occurred. He was PF on PIT-LGA leg & on accident leg from CAE. Fatigue could have contributed to incomplete pre-flight brief, failure to maintain sterile cockpit below 10,000 feet, approach briefing in which he omitted field elevation, FAF altitude, DH, & MAP altitudes, all of which NTSB noted had contributed to lack of situational awareness by both pilots. Finally, all the above contributed to crew's choice to initiate non-standard go-around. Other factors were important, including ATC performance, A/C's inadequate windshear algorithm, & abnormally severe windshear. In short, hard to justify a high score, but equally hard to argue that fatigue was irrelevant.

2. Accident DCA95MA020

Date: 2/16/1995

NTSB Identification: DCA95MA020, Air Transport International

February 16, 1995 in Kansas City, MO

A/C: DC-8-63, N782AL Injuries: 3 Fatal

Accident Summary: Aircraft was destroyed by ground impact and fire during attempted takeoff.

Probable Cause: Probable cause was determined to be loss of directional control by pilot in command during the takeoff roll, flightcrews lack of understanding of the three-engine takeoff procedures and their decision to modify these procedures and the failure of the company to ensure that the flight crew had adequate experience, training and rest to conduct the non-routine flight

Flight Crew/Fatigue Related Information: Safety board believes the captain and other crew members were experiencing fatigue at the time of the accident. The captain's performance in the accident reveals many areas of degradation in which fatigue is probably a factor. Accident report notes a demanding Delaware -Germany overnight round trip flight (6 time zones crossed) and a daytime rest period which caused disruptions in circadian rhythms. Additionally, the captains last rest period was repeatedly interrupted by the company. Report also notes that since flight was non-revenue flight, it was under different duty rules and the same flight, were it a revenue flight, would have been illegal given the rest periods the crew had.

SCORE: 0.9 Fatigue was a significant problem in this accident. With or without crew's inadequate training & knowledge of 3-engine T/O, NPRM would preclude this crew from this ferry trip. Also, all 3 crew performed poorly & all 3 likely were fatigued, per NTSB, & all 3 exhibited "performance degradation" symptomatic of fatigue (difficulties in setting proper priorities & continuation of T/O attempt despite disagreement & confusion on important issues).

3. Date: 12/20/1995

NTSB Identification: DCA96RA020, American Airlines

December 20, 1995 in Cali, Colombia

A/C: B757-200, N651AA Injuries: 160 Fatal, 4 Serious

Accident Summary: Aircraft crashed 38 miles north of Cali, Columbia into mountainous terrain during a descent under instrument flight rules

Probable Cause: Probable causes were determined to be the flight crew's failure to adequately plan and execute the approach to runway 19 at SKCL and their inadequate use of automation; Failure of the flightcrew to discontinue the approach into Cali, despite numerous cues alerting them of the inadvisability of continuing the approach; The lack of situational awareness of the flightcrew regarding vertical navigation, proximity to terrain, and the relative location of critical radio aids; Failure of the flightcrew to revert to basic radio navigation at the time when the FMS-assisted navigation became confusing and demanded an excessive workload in a critical phase of the flight.

Flight Crew/Fatigue Related Information:

At 2138 CFIT at 9000; peak at 9190. Night VOR/DME approach from MIA; 2 hrs late. PIC concerned to get cabin crew on ground to meet AAL rules on cabin crew rest (for next day return flight). Cali in long N/S valley; high terrain west & east. Cleared to Cali VOR; readback "cleared direct," entered "direct;" way points go off display. Later cleared to interim Tulua VOR. Expecting “direct,” crew became unsure of location. CVR shows crew fumbled with charts & Tulua ID, but already past Tulua. When crew finally entered Tulua, A/C began turning back to Tulua; PIC overrode. Then ATC offered direct approach from north (was 01; now 19). Crew rushed to get down. Put in single-letter ID for ROSO, but Colombia has 2 navaids with single-letter "R." Per ICAO, software defaults to "R" with more traffic (well north at Romeo VOR--Bogota); had to punch in all 4 letters for ROSO. Again A/C began turning back. Crew now very confused & they knew it. FO (PF): "where are we?" PIC says go S/SE – now east of valley, 13 miles off course & below terrain between A/C & Cali. Now more confused; reading DME to ROMEO, thinking it was ROSO. Stepped down early, configured to land as GPWS sounded. Pulled up but did not retract spoilers; slow climb (184 knots at impact). Hit east slope nose up, skidded over top & down west side. Both pilots, 6 FA & 152 pax fatal; 4 pax serious.

CAUSE per Colombian CAA: 1. crew's failure to adequately plan & execute approach to runway 19 & inadequate use of automation; 2. Failure to discontinue approach, despite numerous cues; 3. lack of situational awareness regarding vertical navigation, proximity to terrain, & relative location of critical radio aids; 4. Failure to revert to basic radio nav when FMS-nav became confusing & demanded excessive workload. Factors: 1. crew's ongoing efforts to expedite approach & landing to avoid potential delays from exceeding company duty time limits; 2. execution of GPWS escape maneuver with speed brakes deployed; 3. FMS logic that dropped all intermediate fixes from display(s) upon execution of direct routing; 4. FMS-generated nav information that used different naming convention from that published in nav charts."

SCORE: 0.35 Crew certainly would have been tired, despite being first of their duty tour. PIC had been awake close to 17 hours & FO had been awake at least 15 hours (14 & 17 hours are key thresholds in fatigue). Yet even if each had been operating earlier in their day, they likely would not have sorted out confusion created by single-letter identifier for Rozo & Romeo. Yet more rested crew may have avoided readback-hearback error related to “direct” with interim way points. Crew clearly knew they were very confused & that they were uncertain of their position in rugged terrain. More alert crew might have responded more appropriately, either by climbing above terrain to sort things out, or by reverting to radio nav until they re-established their position, or may have recognized that over-ride of northbound turn had pushed them across ridge line, east of valley. Though crew certainly would be tired, fatigue was less than a show-stopper. Key factors would have remained with or without alert crew: non-radar environment; confusion from multiple identifiers; self-induced pressure; unexpected change to unfamiliar step-down approach at night in mountainous terrain; & significantly delayed flight. The requirements might have led to avoiding confusion or to more appropriate response to confusion.

4. NTSB Identification: NYC96FA174, TWA

August 25, 1996 in JFK, NY

A/C: L-1011, N31031 Injuries: None

Date: 8/25/1996

Accident Summary: Aircraft was substantially damaged when the tail struck the runway, while landing at John F. Kennedy International Airport, Jamaica, New York (JFK).

On arrival in JFK area, wx was ¼-mile in fog, scattered at 200, & temp/dew of 66/66F. Crew expected 4R, but before reaching FAF, 4R went below minimum & ATC offered 4L (still above minimum). PIC accepted & FO (PF) transitioned to 4L. Inspection methods from Lockheed & adopted by TWA did not adequately specify how to check slat drive system for slack.

But crew failed to reset altimeter bug for new runway (100 feet higher than 4R). PIC also missed several required call-outs on approach & no charts for 4L were on board. When PF asked for charts, PIC said "just fly the approach." A/C was slow & unstable throughout approach & when altimeter read 50 feet (in fact 150 feet), A/C began to flare. FO recognized they were high & pushed nose over. On landing, A/C had tail strike & substantial damage. Failure to reset altimeter & absence of charts were fundamental in this accident.

Probable Cause: Probable cause was determined to be the failure of the flight crew to complete the published checklist and to adequately cross-check the actions of each other, which resulted in their failure to detect that the leading edge slats had not extended and led to the aircraft's tail contacting the runway during the computer-driven, auto-land flare for landing.

Flight Crew/Fatigue Related Information: The captain reported that he had difficulty adjusting to disruptions in his sleeping schedule, and for this reason did not bid to fly international routes. According to his sleep schedule, he had been awake about 24 hours at the time of the accident and reported that he that he felt, ""awful, just tired and exhausted."" The first officer said that the captain attempted to rest during the cruise portion of the flight to JFK, with his head back in the seat, but that there were visiting crewmembers in the cockpit and the captain might not have received good rest. In addition, the captain commented that he had not slept well in the hotel.

The first officer reported that he had flown the LAS layover trip several times during July, and had learned the importance of good sleep for flying it. He reported that he had in excess of 14 hours of rest in the scheduled 24 hours of off duty, which was split over two periods. At the time of the accident he had been awake for over 9 hours following a rest in excess of 5 1/2 hours.

The flight engineer reported that she had not slept well in the hotel on the layover. Additionally, she reported that she felt rested when the accident trip began; however, at the time of the landing she was getting tired

SCORE: 0.35 Had crew been better rested, they may not have missed altimeter reset, may have recognized or acted upon unstable approach, or may have gone around, as required by company procedures when not stable at 500 feet. NPRM's treatment of night operations may have affected this flight. Conversely, crews have made similar errors when well rested & flying at mid-day. FAA believes that avoidable fatigue contributed to crew's failures on approach.

5. NTSB Identification: NYC99LA052, Colgan Air

January 22, 1999 in Hyannis, MA

A/C: BE-1900, N215CJ Injuries: None

At 1719 (dusk), Beech 1900D by Colgan substantially damaged on landing at HYA. No injury to PIC, FO & 2 employees as pax on positioning flight from BOS to HYA in IMC. Started taxi at BOS at 1600. T/O & en route uneventful. But RVR at HYA went below minimum while en route. Wx was 100-foot ceiling in fog, with variable winds at 3 knots.

On arrival at HYA, PIC performed 2 missed approaches. Before trying 3rd approach, he advised tower & pax that this was last shot, or they return to BOS. On third approach, both PIC & FO visually acquired runway. FO said PIC lined up with centerline & requested flaps. FO said A/C "floated at 20 feet over runway at normal transition when I heard PIC taking power levers over flight idle gate by sound of engine/props.' This placed prop in 'BETA' range. A/C then started to sink, & PIC pulled back on control yoke.

Main gear struck ground & fractured during +2.9G touchdown, which occurred 2500 feet beyond approach end of 5,252 foot runway. Ran off right side of runway, 4700 feet beyond approach end & stopped. To place throttles in BETA, it was necessary to lift power levers over flight idle stop. Flight manual included warning: 'Do not lift power levers in flight.'

On accident day, PIC reported for duty at 0535, with first departure from HYA at 0620. He returned to HYA at 0920, after 3 flights & 2:31 flight time. Then with different FO, PIC T/O for Boston at 1100. They flew 5 more flights for 3:53 flight hours, then returned to BOS at 1540.

Probable CAUSE: PIC's improper placement of power levers in BETA position while in flight. Factors: fog & dusk conditions.

SCORE: 0.15 Accident report summarizes only Captain's flight day, not his preceding 72 hours. Clearly had a long day & difficulty getting into HYA did not help. Started taxi at BOS 12.5 hours into duty day for flight to HYA, so he needed to be on ground at HYA within half-hour to beat new NPRM max duty day. May have precuded this PIC from this flight (or not – close call). Also, though better rested PIC may have handled flare better, others have pulled throttle & props into beta. Fatigue might help explain PIC's decision to take 3 shots at landing below mimium,

6. NTSB Identification: NYC99FA110, American Eagle

May 8, 1999 in JFK, NY

A/C: SF34, N232AE Injuries: 1 Serious

Accident NYC99FA110

Accident Summary: Aircraft sustained substantial damage during landing at John F. Kennedy International Airport (JFK)

Probable Cause: Probable cause was determined to be the pilot-in-command's failure to perform a missed approach as required by his company procedures. Factors were the pilot-in-command's improper in-flight decisions, the pilot-in-command's failure to comply with FAA regulations and company procedures, inadequate crew coordination, and fatigue

Flight Crew/Fatigue Related Information: On May 6, 1999, the captain went off duty about 2030, drove home, and was asleep about 2300. On May 7, 1999, he awoke about 0700. He attempted to nap about 1200, but was unsuccessful. He reported for duty about 2200. The first officer was off duty on May 6, 1999. He departed Las Vegas, Nevada (commuting on a jumpseat) at 1230, and arrived at JFK about 1730. He ate, then rested in the pilot's crew room, but did not sleep. There was a 3 hour time difference between Las Vegas and JFK. The trip sequence scheduled the pilots to depart JFK at 2246, arrive at BWI at 2359, on May 7, 1999; and depart BWI for JFK at 0610 on May 8, 1999. They were provided with individual rooms at a local hotel, approximately 10 minutes from the airport. Due to a takeoff delay at JFK, the flightcrew did not arrive at BWI until 0025. They arrived at the hotel about 0100. The captain stated that he was asleep by 0130. He awoke at 0445 for the scheduled 0530 van ide back to the airport. The first officer stated that he was asleep between 0130 and 0200. He received a wake-up call at 0445. During post-accident interviews, both pilots stated that they were fatigued.

At 0702, SF34 by American Eagle substantially damaged on landing at JFK; 1 pax serious; no injury to 26 pax, FA & 2 pilots. En route from BWI uneventful. On arrival in NY area, crew completed checklists & briefings for runway 04 when ATC advised crew that RVR for 04 was 1,600. Crew needed 1800 so ATC cleared them to holding fix at 4,000. While flying toward holding fix, RVR increased. ATC offered crew ILS approach, but advised that they might be too high. PIC accepted clearance nevertheless. Controller asked if crew could make approach from their position. PIC said yes & continued entire approach with excessive altitude, airspeed, & rate of descent, while remaining above glide slope. This violated company procedures & FAR 91.175. Crew then failed to respond to 4 audible GPWS warnings. During approach, FO failed to make required callouts, including missed approach callout. Landed 7,000 feet beyond approach end, at 157 knots, & overran.

During interviews, both pilots said they were fatigued. Crew was working continuous duty overnight schedule. Continuous duty overnights (CDO) at American Eagle identifies trip sequence that is flown during late night hours, extending into early morning hours, with significant elapsed time period between one arrival & next departure. Since break between flights is not sufficient to qualify as free from duty rest period, crew remains continuously on duty, though carrier may have provide hotel room for rest.

On May 6, PIC went off duty at 2030, drove home, & was asleep at 2300. On May 7, he awoke at 0700. He tried to nap about noon but was unsuccessful. He reported for duty at 2200. FO was off duty on May 6. He departed LAS (commuting on jumpseat) at 0930 local time on May 7 (1230 EDT) & arrived at JFK at 1730. He ate then rested in crew room, but did not sleep. Trip sequence scheduled crew to depart JFK at 2246, arrive BWI at 2359, & then depart BWI for JFK at 0610 on 5/8. They were provided with individual rooms at hotel 10 minutes from airport. But, due to delays at JFK, crew did not arrive at BWI until 0025. They arrived at hotel at 0100 & PIC was asleep by 0130. He awoke at 0445 for scheduled 0530 van ride back to airport. FO said he was asleep between 0130 and 0200. He received wake-up call at 0445. CAUSE: PIC's failure to perform missed approach as required by company procedures. Factors:

PIC's improper in-flight decisions, failure to comply with FARs & company procedures, inadequate crew coordination, & fatigue.

SCORE: 0.5 Crew likely was tired, & helps to explain why crew did little right on or before the approach. Yet, the requirements would not reach the practice of "Continuous Duty Overnight, but it would have reached the FO's continuous day starting with his commute. This would not have helped PI, but it might have ensured at least one alert crewmember.

7. NTSB Identification: DCA99MA060, American

June 1, 1999 in Little Rock, AR

A/C: MD-82, N215AA Injuries: 11 Fatal, 45 Serious

Accident DCA99MA060

Accident Summary: Aircraft crashed after it overran the end of runway

Flight Crew/Fatigue Related Information: The captain went to sleep about 2200 the night before the accident and slept until between 0700 and 0730. On nonflying days, he would typically go to sleep between 2130 and 2200, wake up about 0515, and leave for work about 0600. On May 30, 1999, the first officer traveled from his home outside Los Angeles, California, to Chicago. The first officer indicated that he had been commuting from his home to the Chicago-O'Hare base for about 3 months and that, as a result, he was adjusted to the central time zone. The first officer indicated that he was involved in routine activities while in the Chicago area. He went to bed between 2000 and 2200 the night before the accident and woke up about 0730.

The board found that at the time of the accident (2350:44), the captain and the first officer had been continuously awake for at least 16 hours. Also the accident time was nearly 2 hours after the time that both pilots went to bed the night before the accident and the captain's routine bedtime (between 2130 and 2200), meaning their circadian systems were not actively promoting alertness. The Safety Board concludes that the flight crew's degraded performance was consistent with known effects of fatigue.

CAUSE: failure to discontinue approach when severe thunderstorms & associated hazards to flight operations had moved into airport area, & crew's failure to ensure that spoilers had extended after touchdown. Factors: flight crew's (1) impaired performance resulting from fatigue & situational stress associated with intent to land under the circumstances, (2) continuation of approach when company's max crosswind component was exceeded, & (3) use of reverse thrust greater than 1.3 engine pressure ratio after landing.

SCORE: 0.15 FO was 5 months into 1-year probation & paired with Chief Pilot from ORD base. But FO later testified of good working relationship with PIC & said rank of Chief Pilot was no barrier. Accident occurred 14 hours into duty day & nearly 17 hours after awakening. Long day & disrupted flight into & from DFW. FO showed signs on CVR of recognizing that landing was not a good idea, but PIC focused on landing. Was this fatigue or task fixation? Would more rest have made recently hired FO more willing to speak up to PIC-Chief Pilot? Call-outs were made & SOPs indicate crew was engaged. Perhaps a less worn-out PIC would have considered diverting (or not), or may at least have responded to implied warnings from tower. Would have exceeded the requirements contained in this final rule by 12 minutes at impact; may have changed sequence before T/O (had to be released by 2316 - - 2304 might have made a difference).

8. NTSB Identification: DCA05MA004, Corporate Airlines as American Connection

October 19, 2004 in Kirksville, MO

A/C: BAE-32, N875JX Injuries: 13 fatal, 2 Serious

Accident AAR0601

Accident Summary: Aircraft struck trees on final approach and crashed short of runway.

At 1937 on LOC/DME final at Kirksville in IMC, hit trees at 33 feet QFE on center line 1.3 NM out. WX: wind 020 at 6, visibility 4, mist & 300 overcast. On final, PIC (PF) maintained constant descent of 1200 FPM until impact (met company SOP but exceeded that recommended by FAA for descent below 1000 AGL). At MDA, PIC said 'I can see ground there' (as PF, he should have been on instruments). Continued through MDA & asked FO 'what do you think?' FO: 'I can't see (expletive).' Seconds later PIC said 'yeah, there it is. Approach lights in sight' just as GPWS called "200" & FO announced 'in sight, continue'. (Both looking out window; nobody on instruments). Never recognized low altitude until seeing trees 2 seconds before impact. Wx complicated approach but crew never seemed too concerned about wx. Flew approach in casual fashion & lack of professionalism: no sterile cockpit (casual conversation); non-standard phraseology; humming; etc. PIC known for sense of humor & was said to 'emphasize fun in the cockpit'.

Crew was fatigued: reported for duty at 0514. Accident was near end of 6th sector on 'demanding' day in IMC. Crew had been on duty 14.5 hours & PIC is said to have slept poorly night before. PIC commuted from home in NJ to STL & FO commuted from Ohio. Reported for duty at 1345 on 10/17 (2 days before accident). Flew 3 flights in 8-hour duty day & arrived at over-night destination (Quincy) at 2125. On 10/18, departed Quincy at 1415 after more than 15 hours off. Flew 3 flights & 6:20 duty day. Arrived at over-night destination in Burlington at 1945. On 10/19, duty day began at 0514 after 9 hours off. Departed BRL at 0544 to STL &

arrived 0644. Next 2 flights cancelled due to wx. T/O for round-trip from STL-Kirksville (IRK) at 1236. Landed STL at 1745.

Probable Cause: failure to follow procedures & improper non-precision instrument approach at night in IMC, including descent below MDA before acquiring runway environment. Factors: non-standard callouts; unprofessional demeanor; & crew fatigue.

Probable cause was determined to be the pilots' failure to follow established procedures and properly conduct a non-precision instrument approach at night in IMC, including their descent below the minimum descent altitude (MDA) before required visual cues were available (which continued un moderated until the airplane struck the trees) and their failure to adhere to the established division of duties between the flying and nonflying (monitoring) pilot

Flight Crew/Fatigue Related Information: Captain reportedly did not sleep well the night before the accident but did not report feeling tired. He was later observed resting on a couch the morning of the accident. First officer reportedly did not have any trouble sleeping the night before the accident and the day of the accident seemed alert and happy.

However, the flight crews rest time (2100-0400) did not correspond favorably with either ones sleeping patterns and at the time of the accident, they had been on duty 14.5 hrs and it had been 15 hrs since their last rest period. The board suggests that the pilot deficiencies observed could be consistent with fatigue impairment

SCORE: 0.9 Accident flight T/O STL at 1842 for IRK on 6th flight of day after 6:14 flight time & 14.5-hour day already. Long, brutal day in IMC that started with limited rest period. Crew was familiar with each other & with IRK. WX & PIC's established practice of "fun in the cockpit" also were factors. Fatigue had to be a big player, though PIC's history of "fun in cockpit implies other issues. The requirements in this final rule would have precluded this crew from taking this flight.

9. NTSB Identification: DCA06MA064, Comair as

August 27, 2006, Lexington, KY

A/C: CRJ-200, N431CA Injuries: 49 Fatal, 1 Serious

Accident AAR0705

Date: 8/27/2007

Accident Summary: Aircraft crashed during takeoff from Blue Grass Airport, Lexington, Kentucky.

At 0607 Comair 5191 crashed on T/O from Blue Grass Airport (LEX) for ATL. A/C ran off end of Runway 26 & was destroyed by impact forces & post crash fire. T/O wrong runway; had been cleared to T/O on Runway 22. PIC, FA & all 47 pax fatal; FO serious. Threshold for 22 & 26 are close & common taxiway had construction near thresholds, possibly inviting confusion in darkness after short taxi from nearby terminal. Also, sole controller in tower turned away after clearing A/C for T/O (A/C was the only active A/C on the airport).

Runway 22 had minor construction work underway preceding week with NOTAM for "some" lights out. Crew also appeared behind the curve early: approached wrong RJ on ramp (corrected by ramp staff); called Toledo tower rather than LEX (corrected by tower); called wrong flight number (corrected by tower); & vocally ran through checklist on taxi so quickly NTSB had to slow CVR read-out to understand it. Crew then taxied onto darkened, closed short runway (26). Initiated rolling T/O, further reducing chance to recognize wrong runway, crossed intersection with active runway, lighted 7,000-foot Runway 22, 500 feet from start of rolling T/O on 26, continued & rotated just as they ran out of pavement. Ran onto grass & nose lifted slightly (with main gear tracks deepening in grass) just as A/C struck perimeter fence, then rolled at high speed into trees & burned out. PIC, FA & 47 pax fatal; FO serious. CAUSE: crew's failure to use available cues & aids to identify A/C's location on airport surface during taxi & their failure to cross-check & verify that A/C was on correct runway before T/O. Factors: crew's non-pertinent conversation during taxi, which resulted in loss of positional awareness, & FAA's failure to require that all runway crossings be authorized only by specific ATC clearances.

Probable Cause: Probable cause was determined to be s the flight crewmembers' failure to use available cues and aids to identify the airplane's location on the airport surface during taxi and their failure to cross-check and verify that the airplane was on the correct runway before takeoff

Flight Crew/Fatigue Related Information: The captain and the first officer received more than the minimum required rest periods during their respective trips in the days before the accident, and their flight and duty times in the week and month before the accident would not have precluded them from obtaining adequate sleep. Also, both pilots had only been awake for about 2 hours at the time of the accident. Two factors in the pilots' schedules just before the accident could have been associated with the potential development of a fatigued state: acute sleep loss and circadian disruption - The captain and the first officer also awakened on the day of the accident at a time when they would normally be asleep.

Overall, The Safety Board concludes that, even though the flight crewmembers made some errors during their preflight activities and the taxi to the runway, there was insufficient evidence to determine whether fatigue affected their performance

SCORE: 0.35 Fatigue likely was not an issue for PIC (PNF) but it may have affected FO's performance (PF). FO began his duty tour on 8/25 at JFK. He drove that morning to FLL near his home for flight to JFK. Departed FLL at 0559 & arrived JFK at 0832. NTB does not note when FO awoke, but it likely would have been around 0400 to reach his 0559 departure at FLL. His duty day then began with flight from JFK to ROC at 1305. Return flight to JFK T/O at 1600 but crew had to divert to BDL for fuel & did not land at JFK until nearly 2000. Due to late arrival, crew was asked to reposition A/C to LEX. Departed gate at 2130 but were not able to T/O until 2300; arrived at LEX at 0140. FO reached his hotel at 0210 on 8/26. By the time he got to bed, FO would have had nearly a 23-hour day. On 8/26, FO had day off. He told his wife that morning by phone that he had "slept in" & planned to go to bed early that night. Phone records, hotel key cards, & credit card records indicate normal day of activity through at least 1830 on his rest day, when FO paid for meal in hotel restaurant (probably asleep no earlier than 2000). On 8/27 he & PIC reported for duty at 0515. FO likely had same wake-up call as PIC (0415).

Though FO had free day before accident, 8/25 was 23-hour day, with very late time to bed, followed on 8/27 by very early start to his day. Despite "sleeping in" on 8/26, FO would have been coping with sleep deficit. This could partly explain his confusion or inattention prior to departing gate. It also could have made him more vulnerable to visual confusion caused by minor construction & related barriers, & his failure to respond to visual cues of unlighted runway & crossing active runway that was fully lighted. Yet other factors also may explain these failures. For example, FO had flown into LEX 2 nights before when "lights were out all over the place." That was at end of his 23-hour day; neither he nor that Captain apparently recognized that outages had been NOTAMed on 8/25. On morning of accident, runway end identifier lights were out of service. Closeness of 2 runway ends with single taxiway also increases risk of wrong runway T/Os. Finally, with terminal close to runway ends, taxi time was short, increasing percentage of head-down time, at least for PNF. The requirements would have precluded FO from taking positioning flight & extending very long duty day on first day. This may have averted the entire scenario.

10. NTSB Identification: DCA07MA072, Shuttle America

February 18, 2007, Cleveland, OH

A/C: ERJ-170, N862RW Injuries: None

Accident AAR0801

Accident Summary: Aircraft overran the end of the runway during a landing in snowy conditions and stuck an ILS antenna and fence, and the nose gear collapsed.

Flight Crew/Fatigue Related Information: The day of the accident, the captain had been awake for all but about 1 hour of the previous 32 hours; he stated that his lack of sleep affected his ability to concentrate and process information to make decisions and, as a result, was not "at the best of [his] game." The captain also reported that he had insomnia, which began 9 months to 1 year before the accident and lasted for several days at a time. From Feb 11-14 the first officer flew a total of 18hrs 27 mins. On Feb, he started a 3-day 6-leg trip and by the 18th, his total flight time was 11 hrs 50 mins. At the time of the accident, the first officer had been on duty about 9 hrs 15 mins with a total flight time of 5 hrs 30 mins. The first officer agreed to be the flying pilot because of the captain's references to fatigue and lack of sleep the night before.

A contributing factor to the accident was the pilot's fatigue which affected his ability to effectively plan and monitor the approach and landing. The Safety Board concludes that the captain was fatigued, which degraded his performance during the accident flight.

CAUSE: failure to execute a missed approach when visual cues for runway were not distinct & identifiable. Factors: (1) crew's decision to descend to ILS DH instead of localizer (glideslope out) MDA; (2) FO's long landing on short, contaminated runway & crew's failure to use reverse thrust & braking to max effectiveness; (3) PIC's fatigue, which affected his ability to effectively plan for & monitor approach; & (4) carrier's failure to administer attendance policy that permitted crew to call in as fatigued without fear of reprisals.

SCORE: 0.5 A better rested PIC likely would have flown this leg, & likely would have increased chances of going around. However, it but probably would not have changed confusion over glideslope & ILS DH versus localizer MDA. Either way, the requirements would have enabled PIC to opt out of flight.

11. NTSB Identification: DCA07FA037, Pinnacle as Northwest Express

April 12, 2007, Traverse City, MI

A/C: CRJ-200, N8905F Injuries: None

Accident AAR-0802

Date: 4/12/2007

Accident Summary: Aircraft ran off the departure end of the runway during snowy conditions.

Probable Cause: Probably cause was determined to be the pilots' decision to land at TVC without performing a landing distance assessment, which was required by company policy because of runway contamination initially reported by TVC ground operations personnel and continuing reports of deteriorating weather and runway conditions during the approach. This poor decision making likely reflected the effects of fatigue produced by a long, demanding duty day, and, for the captain, the duties associated with check airman functions

Flight Crew/Fatigue Related Information: The accident occurred well after midnight at the end of a demanding day during which the pilots had flown 8.35 hours, made five landings, been on duty more than 14 hours, and been awake more than 16 hours. During the accident flight, the CVR recorded numerous yawns and comments that indicate that the pilots were fatigued. Additionally, the captain made references to being tired at 2332:12, 2341:53, and 0018:43, and the first officer stated, "jeez, I'm tired" at 0020:41. Additionally, the pilots' high workload (flying in inclement weather conditions, and in the captain's case, providing operating experience for the first officer) during their long day likely increased their fatigue.

SCORE: 0.9 Crew was clearly tired & had been on duty 15 hours as of accident time & 12:44 hours at pushback; The requirements would have precluded this crew from taking this flight.

12. NTSB Identification: DEN07LA101, Great Lakes Airlines

June 20, 2007, Laramie, WY

A/C: BE-1900D, N253GL Injuries: None

Accident DEN07LA101

Date: 6/20/2007

Accident Summary: The airplane landed long, bounced, and touched down again. The captain tried to slow down and turn the airplane off the runway on to a taxiway at high speed. During the turn attempt, the airplane departed the runway and the airplane's right propeller struck the top of an electrical box that powered the runway approach lighting system.

Probable Cause: Probable cause was determined to be The pilot's improper decision, his misjudgment of his speed and distance, and his failure to perform a go-around resulting in the airplane overrunning the runway and striking an electrical box. Factors contributing to the accident were the failure of the crew to perform proper crew resource management, the first officer's failure to intervene before the accident occurred, and the electrical box.

Flight Crew/Fatigue Related Information: Only mention of flight crew schedule is the crew was on the third day of a three-day trip, which had started in Cortez, Colorado, that morning at 0520. The crew had flown from Cortez to Denver, Colorado, to Farmington, New, Mexico, back to Denver, then to Laramie, and then to Worland.

SCORE: 0.15 Given number of days & segments flown, the accident occurred precisely at NPRM's proposed limit of 11-hour duty day. The requirements might have made a difference.

13. NTSB Identification: DCA09MA027, Colgan Air as Continental Connection

February 12, 2009, Clarence Center, NY

A/C: DHC-8-400Q, N200WQ Injuries: 50 Fatal

Accident DCA09MA027

Accident Summary: Aircraft crashed into residence 5 nautical miles northeast of the airport and was destroyed by impact and post-crash fires.

At 2217 Dash 8-Q400 by Colgan Air as Continental Connection crashed on ILS approach to runway 23 at BUF 5 NM NE of airport in Clarence Center. FO arrived EWR on red-eye from West Coast via MEM at 0623. First flight @ 1300 cancelled. Accident flight delayed; T/O EWR at 2120. Newly upgraded PIC (110 hours in M/M); FO (PF) had 700 hours in type. Steady, non-pertinent chatter enroute & throughout approach. FO notes little knowledge of icing. Other pilots describe light-moderate rime icing b/ 6,500 & 3,500 but none at 2,300. Accident A/C was in icing 9 minutes. De-icing system was "on" (which increases speed at which crews get low-speed cue, but does not affect actual stall speed).

At 22:15:14 BUF Approach cleared flight for ILS approach to runway 23 (acknowledged). At 22:16:02, engine power levers were reduced to flight idle & Approach instructed crew to contact Tower. Crew extended gear & auto flight system captured ILS 23 localizer. PIC then moved engine conditions levers forward to max RPM position as FO acknowledged instructions to Tower. At 22:16:28 FO moved flaps to 10°, & 2 seconds later stick shaker activated (warning of impending stall) & autopilot disconnected, with ”disconnect” horn sounding until impact. Stickpusher then activated (to correct actual stall). Crew added power to 75% torque. At 2216:37, FO told PIC that she had put flaps up; airspeed now 100 knots, & roll angle reached 105 degrees right wing down before A/C began to roll back to left & stick pusher activated second time (about 2216:40). Roll angle then reached 35 degrees left wing down before A/C began to roll again to right. FO then asked whether she should put gear up; PIC responded “gear up” with expletive. Pitch & roll had reached 25 degrees nose down & 100 degrees right wing down, when A/C entered steep descent. Stick pusher activated third time (at 2216:50), followed by impact. All 4 crew & 45 pax fatal; 1 ground fatal. (Not an icing accident.)

Both pilots likely were significantly fatigued. Both pilots were based at EWR. PIC lived near Tampa & FO lived near Seattle. Neither had “crash pad” at EWR & both regularly used crew room to sleep. PIC tried to bid trips that ensured some nights in hotels at out-stations. At EWR he usually slept in crew room. FO always slept in crew room at EWR & was open about it.

PIC, recently upgraded, commuted to EWR on 2/9 from TPA; arrived EWR at 2005 & spent night in crew room. Phone records & log-ins to crew tracking system indicate he got little sleep. Reported for duty at 0530 on 2/10, flew 3 flights & arrived at BUF at 1300& had hotel room. Left hotel at 0515 on 2/11 to report at 0615. Again flew 3 flights & returned to EWR at 1544; spent rest of day & night in crew room. Again, phone, tracking system & contact with others indicate very little sleep.

FO commuted to EWR from SEA. She awoke on 2/11/ at 0900, arrived at PDX at 1730 for FedEx flight to MEM; arrived MEM at 0230 EST (2230 PST); had about 90 minutes of sleep on flight. She then T/O MEM at 0418 & arrived EWR at 0623, sleeping for "much of" 2-hour flight. At EWR, she spent day in crew room & napped, but phone, tracking system & conversations show she got little sleep.

On 2/12, crew was scheduled for 3 flights: EWR-ROC; ROC-EWR; & EWR-BUF. First 2 cancelled due to winds at EWR & ground delays. Dispatch estimated 1910 departure for accident flight. Multiple delays; pushed back at 1945 & finally T/O 2120 for BUF. FO noted multiple times that she was not feeling well & before T/O said she was "ready to be at hotel" at BUF.

CAUSE: Captain's inappropriate response to activation of stick shaker, which led to stall from which A/C did not recover. Factors: (1) crew's failure to monitor airspeed in relation to rising position of low-speed cue, (2) crew's failure to adhere to sterile cockpit procedures, (3) PIC's failure to effectively manage flight, & (4) Colgan's inadequate procedures for airspeed selection & management during approaches in icing conditions. NOTE: NTSB Cited fatigue in findings, but not in causal statement because NTSB said it could not determine "the extent of their impairment & degree to which it contributed to performance deficiencies." But clearly suggests it did contribute. NOTE: NTSB was divided on the issue, with some arguing that the overwhelming issue was skills-based: pulling up to 30 degrees, not pushing power up all the way even well into the stall, and thereby missing several opportunities to allow the aircraft to fly out of the stall. In short, debate is this: though the crew clearly was fatigued, would the outcome have been any different if the same crew were better rested?

Flight Crew/Fatigue Related Information: On the day of the accident, the captain was scheduled to report to EWR at 1330. Because his duty period on February 11, 2009, had ended about 1544, he had a 21-hour, 16-minute scheduled rest period before his report time. However, at 0310 on February 12, the captain logged into Colgan's CrewTrac computer system. This activity would have meant that he had, at a minimum, a 5-hour opportunity for sleep followed by another sleep opportunity of about 4 hours. During the 24 hours that preceded the accident, the first officer was reported to have slept 3.5 hours on flights and 5.5 hours in the crew room.

At the time of the accident, the captain would have been awake for at least 15 hours if he had awakened about 0700 and for a longer period if he had awakened earlier. The accident occurred about the same time that the captain's sleep opportunities during the previous days had begun and the time at which he normally went to sleep. The first officer had been awake for about 9 hours at the time of the accident, which was about 3 hours before her normal bedtime. The captain had experienced chronic sleep loss, and both he and the first officer had experienced interrupted and poor-quality sleep during the 24 hours before the accident

The pilots' failure to detect the impending onset of the stick shaker and their improper response to the stick shaker could be consistent with the known effects of fatigue. The NTSB concludes that the pilots' performance was likely impaired because of fatigue, but the extent of their impairment and the degree to which it contributed to the performance deficiencies that occurred during the flight cannot be conclusively determined

SCORE: 0.5 Accident had many issues, but fatigue clearly was one of them. Both pilots had to be exhausted when they initiated approach to BUF. PIC was completing 4th day since awakening on 2/ 9. He had opportunity for quality sleep only on night of 2/10, & that was cut short with departure from hotel at 0515 on 2/11. Both pilots essentially stayed up all night on 2/11, with no opportunities for deep sleep, then found themselves operating late-night flight after day-long cancellations & delays. At one level, any rule that might have diminished this crew's fatigue could have been a show-stopper with a high score. However, crew had other basic problems. PIC clearly was not well versed in stall recognition nor response to stall (never went to full power, which likely would have enabled the aircraft to fly out of the stall in at least 2 points during the sequence). Same lack of recognition & knowledge appears true of FO; she raised flaps during a stall. Being well rested would not have provided this crew with any more skill than they already had, it would not necessarily have averted the chatter sustained throughout flight, nor would it necessarily have led crew to enter proper ref speeds for conditions. BUT more rest may have at least kept them tuned in enough to monitor airspeed. That alone could have averted the entire scenario. However, too many other fundamental issues to score above 50%.

Dirección General de
Aeronáutica Civil

MANIFIESTO DE IMPACTO REGULATORIO

PROY- NOM-117-SCT3-2013

EASA - Provision of Scientific Expertise

European Aviation Safety Agency

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M.B.SPENCER Ltd

Provision of Scientific Expertise to submit an assessment of the NPA on Flight Time Limitations (FTL) and to provide guidance and advice to the FTL Review Group: Final Report

Mick Spencer

Cover + ii + 31 pages

June 2011

List of contents

1 Introduction

1.1 This report has been prepared by Mick Spencer for the European Aviation Safety Agency (EASA) under the terms of contract number R.2011.C03.

1.2 A previous interim report provided an assessment of the 14 top issues identified in the Notice of Proposed Amendment (NPA), and of 15 additional issues, formed into eight questions, that were submitted for consideration at a later date. The substance of that earlier report has been carried across, with a few minor changes, to the present report. However, the original order has been amended at the suggestion of EASA in order to keep together questions that covered similar topics. This has necessitated some reorganization and rewording of the original text.

1.2 Other changes and additions have been made to cover some further issues arising from the three-day meeting of the FTL Review Group in Cologne 17-19 May 2011, and to clarify some of my previous answers. The main changes are the following:

i. the discussion relating to the definition of a home base has been slightly extended (Section 2.2);

ii. the section on commander's discretion (5.1) has been expanded at the request of EASA, in response to additional material provided by ECA;

iii. Section 5.2 on short-term replanning has been completely rewritten;

iv. the discussion of rolling 12-monthly limits (Section 6.3) has been extended to address a specific issue raised during the Review Meeting;

v. the discussion of disruptive schedules (Section 9.1) has been broadened to include transitions from earlies to nights;

vi. some changes have be made to the sections on acclimatization (9.2 and 9.3), for the purpose of clarification;

vii. two additional topics raised during the Review Meeting are discussed in Section 11;

viii. the key issues identified and discussed during the Review Meeting have been summarized in a separate section.

ix. an Appendix has been added to provide a more detailed discussion of time-zone changes and acclimatization.

1.3 In responding to many of these questions, it has been possible to draw on the results from a large number of studies that have been carried out into the sleep, circadian rhythms and fatigue of aircrew related to their patterns of work. On some issues, however, there is very little information that is directly available from studies. Where this is the case, it has generally been possible to provide some limited guidance based on a broad understanding of the issues involved. The overall objective has been to present, from an independent standpoint, a critical evaluation of the various topics to assist EASA in the evaluation and further development of the proposal.

1.4 In the following text, the 14 original issues / questions) are represented by the abbreviations Q1, Q2,…, Q14, and the additional questions by AQ1, AQ2,…, AQ8.

2 Home Base

2.1 The definition of a Home Base (Q1)

2.1.2 The proposed definition allows a home base to be a multiple airport location, provided that (i) the distance between any two airports does not exceed 50km and (ii) the relevant travelling time does not exceed 60 minutes in normal conditions. There is also provision for the time to return to the initial airport from the final point of landing to count as positioning.

2.1.3 Although there are no studies that have investigated this question specifically, there are possible fatigue implications related to the additional travelling time that may be required between the two airports or between home and a more distant airport. Travelling time is a factor that can affect subsequent levels of fatigue by reducing the time available for rest and extending the continuous period of wakefulness associated with the Flying Duty Period (FDP).

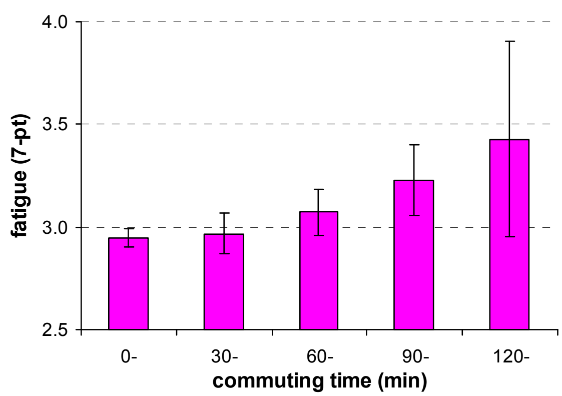

Figure 1: The effect of commuting time on fatigue (7-pt Samn-Perelli)

2.1.4 The effect of commuting time on subsequent levels of fatigue has been shown in a diary study of 158 pilots on short-haul routes between the UK and the continent of Europe [Spencer & Robertson, 2000]. After correcting for other significant factors such as the length of duty and the time of day, their fatigue rating at the end of each flight was positively correlated with commuting time ($p<0.001$). The increase in fatigue associated with one hour of commuting was roughly equivalent to the increase associated with an extra hour of flying (Figure 1). Similar effects have been reported in studies of railway workers, where it has been recommended that alternative arrangements be made if the travelling time exceeds 90 minutes [Robertson et al., 2010].

2.1.5 These results lend support to the guidance contained in CAP 371 that ‘if the journey time from home to [the] normal departure airfield is usually in excess of 1½ hours, crew members should consider making arrangements for temporary accommodation nearer to base'. However, the proposed definition of a home base could then allow potentially for a further hour of travelling time, up to a total of 2½ hours, which would be excessive.

2.1.6 This question, therefore, needs to be addressed alongside the issue of travelling time, and the current proposal should be amended to ensure that, if multiple airports are permitted, additional provision is made to restrict excessive commuting times. The proposed provision for the return time to the original airport to count as positioning should be retained as a necessary protection for the subsequent rest period.

2.2 Home Base (AQ8)

2.2.1 Based on the conclusions of the previous section, multiple airports should not be used to extend the travelling time beyond a reasonable limit (e.g. 1.5 hours). If this limit is exceeded due to the provision for multiple airports, then the additional time, whether before or after the FDP, should count as positioning.

2.2.2 There was some concern expressed at the Review Meeting that the intentions behind the definition of a home base could be circumvented if an operator were able to change a crew member's home base frequently or without adequate notice. In extreme cases, this could be used to evade the requirement for a positioning flight. It may therefore be necessary to include further provisions in the regulations to protect the integrity of a home base.

3 Flight Duty Period (FDP)

3.1 Maximum FDP (AQ1)

3.1.1 It is well recognized that duties of the same duration starting at different times of day can have a differential effect on the development of fatigue and sleepiness. In particular, alertness levels overnight cannot be sustained for as long as they can during the day. The Haj operation (see Paragraph 3.6.3) has provided a unique opportunity to make a direct comparison between this time-of-day effect, as exactly the same flight was carried out at times equally spaced around the 24-hour clock.

3.1.2 Table 1 is based on the results from that operation, extrapolated where necessary, and shows the length of duty at different times of day, rounded to the nearest hour, associated with similar levels of fatigue. The cut-off point corresponds approximately to a probability of 10% that both pilots in a two-crew operation would record a level of eight or more on the Karolinska Sleepiness Scale [Åkerstedt & Gillberg, 1990]. Scores of eight or more are known to be associated with a high frequency of microsleeps [Gillberg et al., 1994].

3.1.3 These results are broadly consistent with those from both laboratory studies of irregular work-rest patterns [Minors et al., 1986] and other aircrew studies. However, higher levels of fatigue have been reported for overnight flights, especially those departing late in the evening [Powell et al., 2008]. For this reason, many would argue that the overnight limit of 10 hours should apply equally to duties starting earlier in the evening.

report time	23-1	1-3	3-5	5-6	6-7	7-8	8-12	12-14	14-17	17-23
duration of duty (h)	10	9	10	11	12	13	14	13	12	11

Table 1: Limits for maximum FDP based on the Haj operation

3.1.3 Figure 2 shows a comparison between these limits and those proposed in the NPA (Table 36)without any extension. There is close agreement throughout most of the 24-hour period, and they only differ by more than an hour for a two-hour period during the very early morning. The Haj limits are more generous for duties starting in the late morning, allowing 14 hours, rather than 13 hours. However, they would strongly support a limit of no more than 10 hours for late evening and early morning start times.

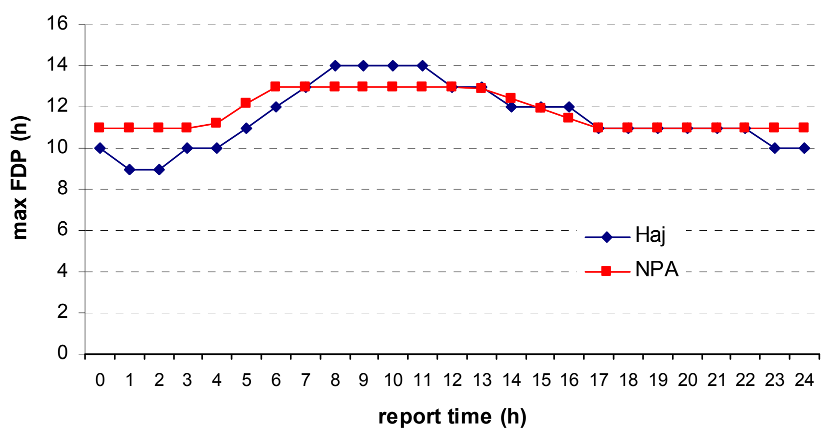

Figure 2:Maximum FDPs based on the Haj results compared with the current proposal

3.2 Mitigating measures for one-hour extensions (AQ1a)

3.2.1 A one-hour extension from 13 to 14 hours for morning departures after 08:00 would be supported by the above discussion, but this would apply irrespective of any mitigating measures. Having established an appropriate maximum limit for FDPs, the regular (up to twice a week) use of extensions would be difficult to justify without further studies. A logical approach would be to allow extensions, together with any mitigating measures, as part of Fatigue Risk Management (FRM). There is further discussion of this issue below (see Section 3.6).

3.3 Commander discretion (AQ1b)

3.3.1 If measures are in place to protect the integrity of schedules and of individual duty patterns, and if reasonable limits are set for maximum FDPs, then the current provisions should be adequate (see Section 5.1). However, there would be a concern if a considerable portion of the 10-hour minimum rest period could not be used for rest, for example because of the location of the hotel at the final destination. One way of protecting against this possibility would be to stipulate that the rest period should provide for at least an eight-hour sleep opportunity.

3.4 Consecutive early starts and consecutive nights (AQ1c).

3.4.1 There are a priori reasons for supposing that both consecutive nights and consecutive early starts would lead to increasing levels of fatigue. These arise from the loss of sleep associated with both types of duty (Section 9.1), and the difficulty of adapting to the unusual working hours. For example, it appears that most shift workers do not adapt to a pattern of night working [Folkard, 2008]. In support of this, there is some evidence from aircrew studies of an increase in fatigue over consecutive early starts [Spencer & Robertson, 2002] (Figure 3) and consecutive nights [Robertson & Spencer, 2003] (Figure 4).

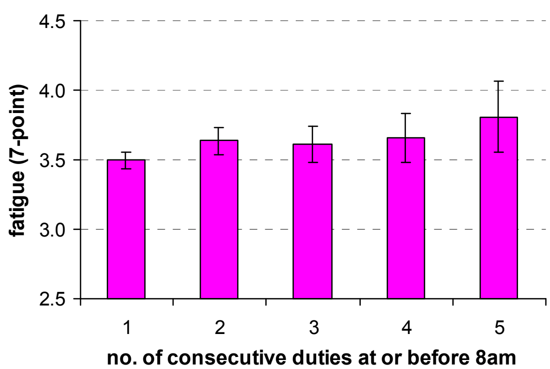

Figure 3: Effect of consecutive early starts

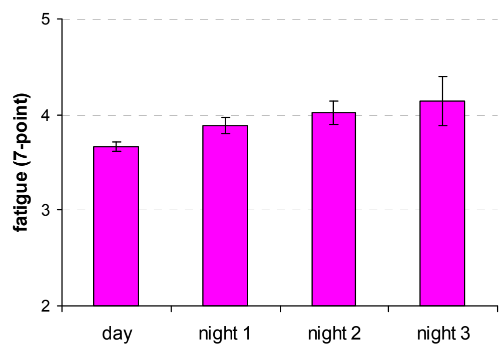

Figure 4: Effect of consecutive nights

3.4.2 However, there are other studies which do not show fatigue increasing on consecutive days. In a recent study of cargo operations, not yet published, fatigue decreased steadily after the first night, and only began to increase again after the fourth night. EasyJet found that pilots could work five consecutive early starts with less fatigue than on a system which was restricted to three consecutive early starts: putting the early starts in a single block was better than combining them in a mixed schedule.

3.4.3 It may be, therefore, that in operations which involve a large percentage of nights or a large percentage of earlies, it is better if they are operated as a block rather than as one or two at a time. This would depend also on the regularity of the pattern of work, and the arrangements for rest. For example, there are advantages for the cargo crews when they are able to spend their rest periods away from home in a hotel within close proximity of the airport. However, problems may arise when the start time, particularly for early starts, varies considerably from one day to the next. For these reasons, it would be sensible to include a restriction, say of three consecutive early starts or night duties, but to allow extensions to this based on FRM.

3.5 Mitigating measures related to the WOCL and number of sectors (AQ1d)

3.5.1 Many of the issues relating to the WOCL encroachment are addressed elsewhere in this report. In particular, the restrictions in the number of sectors for duties encroaching the WOCL would not apply if, as recommended in Section 3.2, extensions are not permitted without FRM.

3.5.2 In studies of the short-haul operations of three separate airlines, it has been possible to determine levels of fatigue associated with multiple sectors, after correcting for time on duty and time of day [Spencer & Robertson, 2000; Spencer & Robertson 2002; Spencer & Robertson, 2003]. The increasing trends in fatigue are shown in Figure 5. In one of the three studies there was no significant difference between one and two sectors. With this exception, they all showed a steady increase, from one sector to the next, equivalent to between 30 and 45 minutes per sector, when compared with the increase in fatigue with length of duty.

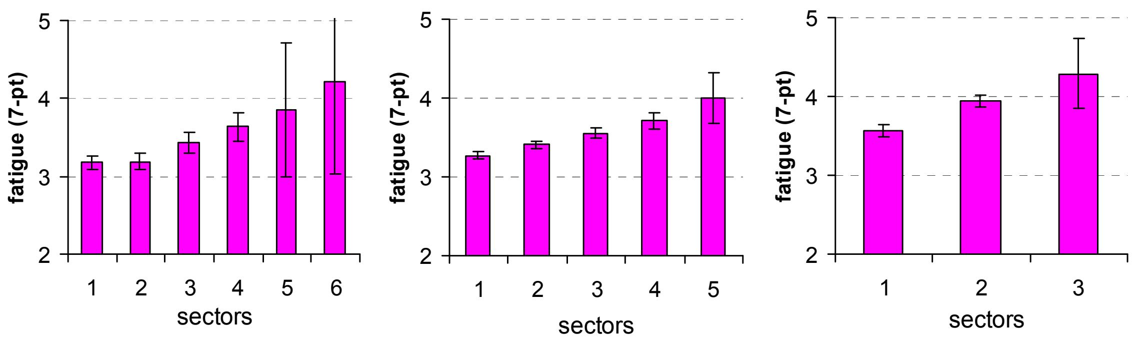

Figure 5: Changes in fatigue with multiple sectors: results from three different airlines

3.5.3 There are several ways in which the maximum FDP might be modified to take this effect into account. For example:

a) no reduction for the first sector, then a reduction of 45 minutes for each subsequent sector;

b) a reduction of 30 minutes for each sector after the first.

The proposal for no reduction for the second sector and 30 minutes for each additional sector does not adequately reflect the results from these three studies.

3.5.4 Relatively little information has been collected from these studies or elsewhere on the effects of more than four consecutive sectors. From the data that are available it appears that the trend from two to four sectors may extend to five sectors and beyond. Until further studies are carried out it would be reasonable, therefore, to base the duty-hour limitations on this assumption.

3.6 Extensions to FDPs for early evening reporting (Q2)

3.6.1 The issue raised by this question is whether the one-hour extension can be applied to the maximum FDP table irrespective of time of day, or whether extensions for duties starting between 18:00 and 21:59 should be allowed only in conjunction with FRM.

3.6.2 There are several studies that have investigated the development of fatigue in long duty periods starting at different times of day. These were considered in the Moebus report which recommended that 'FDPs for minimum crew should not exceed 10 hours overnight'. Information obtained more recently tends to support this conclusion. For example, fatigue levels reported by pilots at top of descent on Air New Zealand regional operations with start times between 21:00 and 00:00 were shown to be particularly fatiguing [Powell et al., 2008]. In addition, in a study, which has yet to be completed, of crews on freight operations, where almost all duties were overnight, there was evidence of a marked increase in fatigue when the duty period extended beyond 10 hours.

3.6.3 The most extensive investigations of duties starting at different times of day were the three studies of fatigue on the Haj operation, carried out in 1998, 1999 and 2000. On each of the legs between Indonesia and Saudi Arabia, the crews were asked to rate their level of fatigue on the seven-point Samn-Perelli scale, and this was done on six separate occasions during each duty period. The FDPs were generally between 11 and 11.5 hours, and flights departed round the clock. The trend lines in Figure 6 are based on data from the 1998 operation [Spencer & Robertson, 1999], as the other two operations involved many augmented flights. In addition, only the outward flight was used, as the crews were then considered to be fully adapted prior to departure.

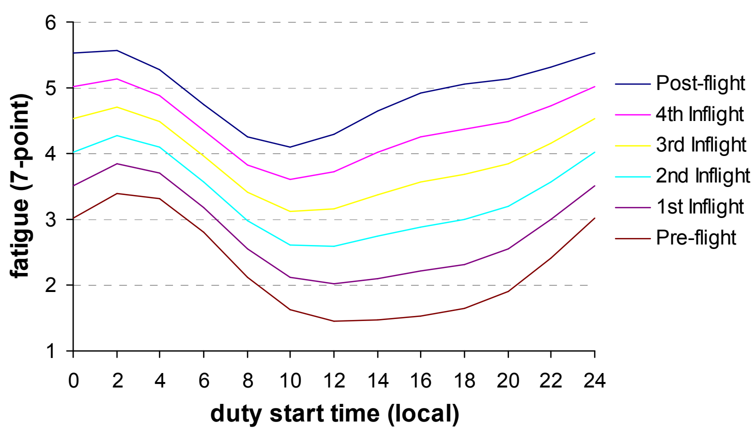

Figure 6: Trends in fatigue based on the Haj 98 operation.

3.6.4 The most fatiguing duties on the Haj operation were those starting in the late evening and early morning. Limits for unaugmented operations based on these results would match very closely with those in the FAA NPRM (e.g. Table A(2)), rather than those in the NPA. In particular, these results, taken together with those from the other studies mentioned above, would strongly suggest that FDPs as long as 12 hours overnight should not be operated with an unaugmented crew.

3.6.5 Therefore an extension of one hour should not be permitted in any circumstances for duties starting between 18:00 and 21:59, or for duties starting between 22:00 and 03:59 which, contrary to the statement in the NPA (paragraph 89), are also at a critical time. This is without prejudice to the recommendation that the use of extensions to the basic FDP table proposed in the NPA should not be permitted outside the period 08:00 to 12:00 (Section 3.2).

4 Augmented Crews

4.1 Economy seats for in-flight rest (Q4)

4.1.1 The TNO report into the value of in-flight relief [Simons & Spencer, 2007] did not recommend any increase in maximum FDP when rest was taken in an economy class seat. In the absence of further studies, there is no reason to change this recommendation.

4.2 The WOCL and in-flight rest (Q5)

4.2.1 This question relates to the proposed extensions of FDP for in-flight rest and, specifically, that they should be independent of time of day.

4.2.2 The logic behind the recommendations of the TNO report was that the extension should be based on a (somewhat conservative) estimate of the typical amount of sleep that crews would obtain, given the time available for rest. This was taken to be 25% of time spent in a bunk (not 75% as stated in the NPA (Section 5.6.2d)), irrespective of the time of day. The decision not to include time of day was made for simplification, also taking into account that different individuals would be sleeping at different times.

4.2.3 In this context, it should be noted that the assumption that a flight encroaching the WOCL would benefit from more recuperative sleep is difficult to justify. The early evening, when many individuals may be attempting to rest prior to a duty in the WOCL, is not a good time to initiate sleep, to the extent that it has even been termed the ‘forbidden zone’ by some sleep researchers.

4.2.4 At the most favourable times of day (i.e. when the maximum FDP is normally 13 hours), the limits proposed in the NPA are generally slightly higher than in the TNO report. For example, the limit is raised to 16 hours, compared with 14:25 hours, for a class 3 rest facility with a double crew. However, as the proposals are independent of time of day, the main differences are at the least favourable times of day, when the maximum unaugmented FDP is 11 hours. At these times, the proposed limits in the NPA are more generous throughout by between two and four hours.

4.2.5 The evidence from studies of aircrew suggests that time of day is still an important factor in augmented operations. On 14-hour flights from London to Singapore with a crew of four, fatigue on the Samn-Perelli 7-point scale immediately after landing averaged 4.8 for the main crew and 5.0 for the relief crew on flights landing in the night, compared with 4.2 for the main crew and 4.6 for the relief crew on afternoon landings [Robertson et al., 2002].

4.2.6 In a study that is currently being prepared for publication, Air New Zealand has used an automated system to collect large amounts of fatigue estimates from aircrew close to top of descent. This has enabled direct comparisons to be made between flights of similar duration at different times of day. In one such comparison, based on returns from over 600 crew members, fatigue levels on a three-crew overnight flight with an FDP of approximately 12½ hours were significantly higher than on a similar flight that was mostly during daylight (4.7 on the Samn-Perelli scale, compared with 3.8).

4.2.7 Based on these results, which are consistent with model predictions, it would be unwise to assume that time-of-day effects are considerably reduced, or even eliminated, when in-flight rest can be taken. A reduction in the maximum FDP limits for duties that extend into the WOCL would therefore be appropriate. FRM provisions should be used to justify overriding such a reduction on the basis of ‘operational experience’.

4.3 Augmentation in multi-sector (Q6)

4.3.1 The recommendations in the TNO report were based on the assumption of a single-sector FDP. In a two-sector operation, the overall time available for sleep will be reduced by the extra take-off and landing, together with the turnaround time. After allowing for this and, depending on the length of the individual flights and the number of crew, it is likely that the time available for each pilot to rest would be reduced by up to an hour. On this basis, and following the same argument as in the TNO report, the maximum FDP for a class 1 facility should be reduced by approximately 45 minutes, and by 90 minutes for a three-sector operation.

4.3.2 However, two-sector operations can vary, and it is useful to consider three separate cases: (i) two sectors of equal length, (ii) a short sector followed by a long sector and (iii) a long sector followed by a short sector. When both sectors are of approximately the same length, then, providing that the turnaround time is sufficiently short, the cruise phase of both flights taken together should provide sufficient time for all the pilots to rest. In this case, a small reduction in the FDP limit, as suggested above, would be appropriate. A similar reduction might be considered when a short sector is followed by a long sector, providing that the second sector is sufficiently long (and therefore the first sector sufficiently short), to afford sufficient rest for all pilots. The case of a long sector followed by a short sector is likely to be more fatiguing, as crews will generally be able to rest less in the later part of the duty period, when the workload is also higher.

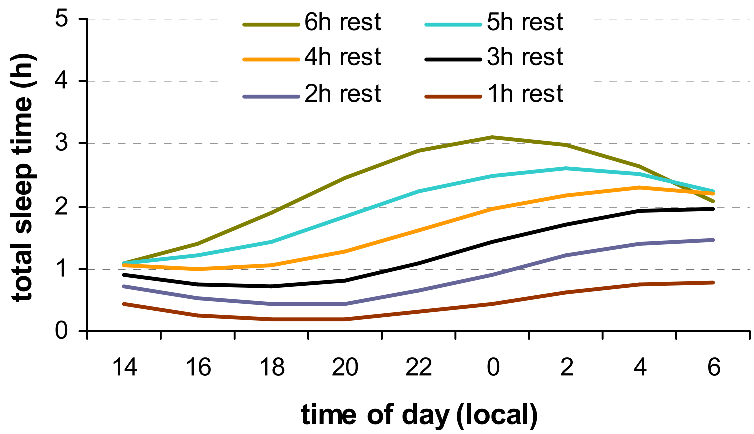

Figure 7: Model of sleep duration as a function of the length of the rest period and the time of day

4.3.3 The question of minimum in-flight rest is not one for which there is a simple answer. The model of in-flight rest for an acclimatized pilot, derived from aircrew studies [Pascoe, Johnson et al., 1994], which was applied in the TNO report (see Figure 7) illustrates the extent to which typical amounts of sleep obtained during a rest period depend on the time of day. Within a one-hour rest period, it is normally possible to obtain at least 45 minutes in the middle of the night, but less than 10 minutes during the early evening. There are times, therefore, when such a rest would be very useful, and others when it would have very little value.

4.3.4 With these considerations in mind, it is not possible to provide clear limits for many multi-sector operations, that will adequately cover every situation. This suggests that an approach based on FRM would be required, and models such as the one illustrated above could be used to provide an initial assessment of any proposed multi-sector FDP.

4.4 In-flight rest for cabin crew (Q7)

4.4.1 As with other aspects of FTL related to cabin crew, the establishment of appropriate requirements for their in-flight rest is complicated by two main issues. The first of these is a lack of clarity concerning the level of alertness which it is necessary for them to maintain. It is generally recognized that take-off and landing are critical phases of the flight for pilots. However, it is unlikely that cabin crew would need to maintain the same level of alertness required by those in control of the aircraft during the landing. This would apply even though they are acknowledged to have important responsibilities for the safety of the aircraft and its passengers.

4.4.2 The second complicating issue is the limited amount of information that is available on the work and rest of cabin crew. In a comprehensive study of their workload and stress levels, Vejvoda et al. [2000] reported that the crews experienced high levels of fatigue towards the end of the flights. This has since been confirmed in several unpublished studies where the fatigue levels of cabin crew have reached levels considerably higher than those of pilots.

4.4.3 In 2005, ECASS (European Committee for Aircrew Scheduling and Safety), carried out a review for the Hong Kong Civil Aviation Department of the requirements for the in-flight rest of cabin crew in future Ultra-Long-Range (ULR) operations. It recommended six hours of horizontal rest in a flight of 19 hours, which could, if certain mitigating measures were in place, be reduced to between four and five hours. The proposals in the NPA for class 1 rest facilities would appear to be broadly consistent with this recommendation. However, the proposed requirements for class 2 and class 3 do not provide for equivalent levels of rest, and, when compared with the class 1 requirements, are not consistent with the conclusions of the TNO report, although these were, of course, based on data from pilots.

4.5 Maximum FDP (AQ2a)

4.5.1 The TNO report is the most comprehensive scientific assessment of the requirement for extending FDPs with augmented crew. Its conclusions are based on the assumption that the additional duty time allowed should be determined by the time available for in-flight rest, as well as by the type of rest facility provided.

4.5.2 The increases proposed in that report are considerably at variance with those implicit in the current proposal. This is particularly so because no distinction is made in the proposal between daytime and overnight flights (see section 4.2). Thus a daytime flight of 13 hours can be increased by four hours to 17 hours with class 1 rest facilities, whereas an overnight flight can be increased by six hours, also to 17 hours.

crew complement	type of rest facility	basic FDP limit (h)		
		13h	12h	11h
2+1	class 3	14	13	12
	class 2	15½	14	13
	class 1	16½	15	14
2+2	class 3	14½	13½	12½
	class 2	17	15½	14
	class 1	18*	17	16

Table 2: Limits for augmented crew based on the TNO report

4.5.3 If there is a preference for specific FDP limits for augmented flights, then it would be possible to derive suitable limits based on approximations to the TNO formulae. These limits would be based on the maximum FDP at specific times of day, plus the calculated extension. Table 2 shows the maximum FDP calculated in this way for daytime (basic maximum 13 hours), intermediate (12 hours) and overnight (11 hours) duties. The values have been rounded to the nearest half-hour. The value of 18 hours, which has been marked with an asterisk, replaces the calculated value of 19 hours, as FDPs over 18 hours are defined as ULR and are subject to separate controls based on FRM.

4.6 Sleep inertia (AQ2b)

4.6.1 Sleep inertia is a transient state of impaired alertness that occurs during the first few minutes after waking. Although its effects are most severe after waking from a period of deep (slow-wave) sleep, it can still occur after a nap [Dinges, 1992]. Indeed, it has been shown that the effects of sleep inertia can persist even after naps shorter than an hour, and that it takes approximately 30 minutes before levels of alertness are recovered and the beneficial effects of the nap start to be felt [Robertson & Stone, 2002]. It is therefore sensible precaution to allow a period of at least 15-20 minutes after waking before a crew member relieves a colleague on the flight deck [Simons et al., 1994].

4.7 Mitigation for non-acclimatization (AQ2c)

4.7.1 Previous studies have shown that in-flight sleep tends to be less restful on a return flight when crews are unacclimatized, than on an outward flight. It was therefore recommended in the TNO report that the extension for unacclimatized crews should be 80% of that applicable to acclimatized crews. However, this requirement may be unnecessary if the basic FDP has already been reduced for unacclimatized crews (see below).

5 Unforeseen circumstances

5.1 Commander's discretion (Q8)

5.1.1 To allow for unexpected events beyond the operator's control, it is reasonable to permit extensions to the maximum FDP as proposed in the NPA. This is provided that the integrity both of the schedule itself and of specific duty patterns (crew pairings) is protected by the regular reporting of the use of such extensions, and by the thorough auditing of the reports by the regulator.

5.1.2 The question as to whether an FDP of 16 hours for flight crew or one of 17 hours for cabin crew is too high is one that should be asked about the basic maximum FDP, rather than about the use of commander's discretion. If the basic limits are reasonable and adequate safeguards are in place to protect its abuse, then the occasional application of commander's discretion can be tolerated.

5.1.3 Subsequent to the Review Meeting, guidance material on commander's discretion, produced by ECA has been forwarded to me by EASA, with an invitation to comment. It contains a proposal that each operator should develop a policy for commander's discretion based on a number of requirements designed to ensure that an operator takes full responsibility for the safe application of commander's discretion.

5.1.4 From a purely scientific viewpoint, it might be considered that the application of any form of discretionary powers in contravention of the basic regulations is undesirable, on the grounds of an increased fatigue risk. However, such a rigid stance is unacceptable in practice. There are then two overriding requirements: firstly, that discretion should only be used in response, if not to an emergency, then at least to an event that could not reasonably have been anticipated; and secondly, that the commander should have sufficient understanding of fatigue and the risks associated with fatigue to make the correct decision.

5.1.5 To address the first point: there is a risk that operators might rely too heavily on commanders using their discretion, and even put undue pressure on commanders. This must be prevented as it would pose a severe strain on the integrity of the basic regulations and on the safety of the operations themselves. A strong system for controlling and monitoring the use of discretion is required. The proposed 33% limit on the number of flights exceeding the maximum is very high. However, the precise limit is not a matter for scientific discussion. It should be based on an assessment by the industry of what it is reasonable to allow, considering the normal uncertainties implicit in passenger flights. To assist such an assessment, it may be necessary to collect more information from current operations. The aim should be to ensure that sufficient margins are included in schedule design so that commanders are not expected to operate discretion as a matter of routine.

5.1.6 The second point raises the issue of training. Commanders cannot be expected to exercise discretion without an understanding of all the issues. Other members of the crew also need to be trained to recognize the symptoms of fatigue, and to evaluate the risks associated with their own mental and physical state. Training would ideally be included as part of an FRM system, and such a system would also provide the best framework for developing the operator's requirements, such as those outlined in the ECA document.

5.2 Short-term re-planning (Q9)

5.2.1 Short-term re-planning may be required in a variety of different circumstances, for example in response to severe weather conditions or other emergency situations. The most common requirement, as mentioned during the Review Meeting, tends to be to cater for flight delays associated with aircraft becoming unserviceable.

5.2.2 The consequences of such delays for the aircrew involved will depend on the notification they can be given and on whether they have already left their place of rest. Although such events should occur infrequently (and records should be kept and checked to ensure that this is the case), some restrictions are required to ensure that the risks arising from aircrew fatigue in these situations are limited.

5.2.3 In the absence of scientific evidence, it is only possible to provide advice based on general considerations and on operational experience. For example, under CAP371, there is provision for 'delayed reporting' when a crew member is informed of the change before leaving the place of rest. However, the current proposal relates to the introduction of split duty and reduced rest shortly before or after reporting. It is difficult too envisage how short-term changes of this nature can be accommodated satisfactorily into a general FTL scheme, rather than as part of FRM.

6 Cumulative fatigue (AQ3)

6.1 Introduction

6.1.1 There is very little scientific evidence to support specific limits for cumulative duty hours. The main issue is that sufficient time for recovery sleep or sleeps should be provided at regular intervals to overcome the effect of schedules that disrupt the normal pattern of sleep. The limits of 60 hours in seven days and 190 in 28 days are very high when crews are subject to continual disruption of the sleep and circadian rhythms. However, it is recognized that the long-haul limit over 28 days is effectively restricted by the 28-day limit on flying hours.

6.2 A 14 day limit and recovery rest (AQ3a)

6.2.1 The present proposal would allow 120 hours' duty in 14 days. I have seen no data from civil aviation on work rates of this level of intensity, although I am aware of problems that have arisen in military transport operations at these very high rates of working. It would seem wise to apply a lower level of say 100 hours in 14 days, to provide some extra protection. If rates higher than this are achieved on a regular basis, it would be extremely valuable to study their effects.

6.3 Rolling 12-monthly limits (AQ3b)

6.3.1 Again, it is difficult to comment on this from a scientific viewpoint. The rolling limit was recommended in the Moebus report to prevent the possibility of 1800 hours being flown in 18 consecutive months, against the presumed intention of the yearly limit

6.3.2 However, if the intention of this rule is to limit the accumulation of fatigue over long periods, this could be better achieved in other ways. One possibility would be to stipulate a continuous period of time off at regular intervals (for example at least seven consecutive days off every three months).

7 Split duty (Q10)

7.1 The provisions for split duty closely follow those of CAP 371. Therefore, although there is very little direct scientific evidence to justify them, they have the advantage of being supported by operational experience.

7.2 It could be argued that the scientific justification can be derived by analogy with the extensions provided for augmented flights by in-flight relief. In that case, the proposed changes to maximum FDP could be justified provided that the 'suitable accommodation' was at least equivalent to a class 1 rest facility, and that the accommodation available in other cases was at least equivalent to a class 2 rest facility. It would also be necessary to ensure that the accommodation is not in a remote location. If it is, the duration of the break used in the calculation should be reduced by the additional travelling time.

7.3 However, there are differences between in-flight relief and a break within a split duty that have implications for the alertness of the crews. In an augmented flight, the crews are able to arrange the timing of their rest periods, and different individuals are able to rest at different times. The same does not apply to split duty, where the break may occur at an unfavourable time for both members of the crew (it is assumed that the split duty rules will only apply to unaugmented FDPs, although that is not stated explicitly).

7.4 If the break occurs during the evening, and the remainder of the FDP extends into, or through, the WOCL, there is a risk that crews will not rest well enough prior to the time when they would be naturally most tired (see Paragraph 4.2.3). Similarly, if the first part of the FDP overlaps the WOCL and the subsequent break covers the later morning period, a time which is less conducive to sleep, they may not be well-prepared for duty later in the day. It was for these reasons that the Moebus report suggested that split duty be limited to between 06:00 and 22:00. However, if the time is unrestricted, it is recommended that the requirement to provide suitable accommodation be extended to cover all split duties where any part of the duty encroaches into the WOCL.

7.5 It is important that, if the overall FDP is extended, the alertness of the crews during the final landing phase is not compromised. For that reason, and to ensure that the break is not too far removed from the end of the FDP, it would be sensible to ensure that the break is not positioned too soon within the duty period (e.g. within the first 33%). This would be analogous to the timing of the first rest period in a single-sector three-crew operation.

8 Standby

8.1 Airport standby (AQ4)

8.1.1 No direct scientific evidence is currently available on this issue. However, if a comfortable, quiet environment is not available for rest, or if a crew member is on immediate readiness, it is unlikely that much benefit would be derived from the standby period. In this case, it is reasonable that the FDP should count in full from the start of standby.

8.2 Limits for standby duty (Q11)

8.2.1 There are very few studies that address this issue, apart from those mentioned in the RIA of the NPA (section 5.11.2). There is operational experience of the 12-hour limit for standby not at the airport, both from both the UK (CAP 371) and overseas, which appears to be favourable. However, the effect on sleep and the alertness levels of the crews will depend on factors other than its duration, such as how and when standby is scheduled, the probability of being called out from standby, etc. These are aspects of an operation that are difficult to regulate, but which can be addressed within the framework of FRM.

8.3 Standby and cumulative limits (Q12)

8.3.1 The proposed contribution of standby to duty limits would appear reasonable based on general considerations. However, as stated in the Moebus report, there is no scientific evidence available that addresses this question.

8.4 Home standby (AQ5)

8.4.1 There is some evidence that individuals who are on call may suffer a degree of sleep disturbance [Torsvall & Åkerstedt, 1988]. The proposed small reductions in maximum FDP allow for the difficulty in obtaining sufficient rest prior to duty, particularly when the standby period is at a time when sleep is not normally taken. However, there is no direct evidence from aircrew studies either in favour or against such a provision. This is an issue that would be suitable for future investigation.

9 Disruptive schedules

9.1 Disruptive schedules and the definition of earlies/lates (Q13)

9.1.1 Although several large studies have been carried out of short-haul operations involving both early starts and late finishes, little information has been obtained on the effect of a rapid transition from lates to earlies. However, the disruption of sleep associated with both types of duty has been extensively researched, and this provides indirect evidence of the extent of the disruption that might arise.

9.1.2 Figure 8 shows the sleep loss associated with duties ending late in the day (redrawn from Robertson & Spencer, 2003), and that associated with duties starting in the early morning (redrawn from Spencer & Robertson, 2002). Both trends are broadly consistent with results obtained from shift workers more generally.

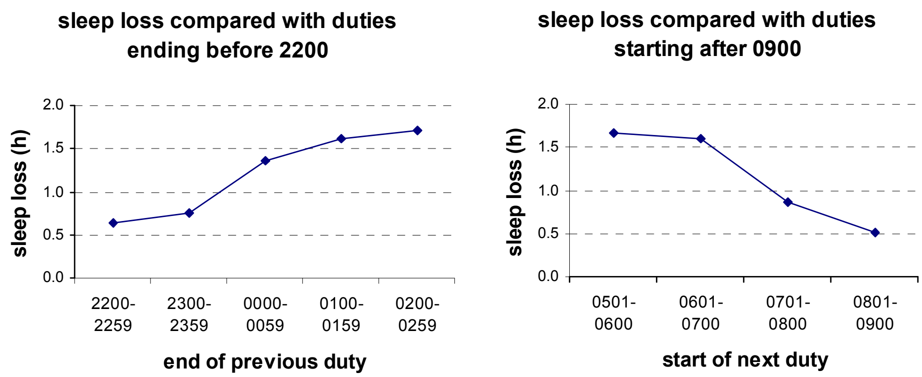

Figure 8: Length of sleep after late finishes and before early starts

9.1.3 The duration of sleep following a late finish gradually reduces with progressively later duty-end times. After waking, individuals tend to remain in bed for around 20 minutes, possibly in an attempt to obtain more sleep, before finally getting up. The end of sleep generally occurs in the late morning, when the circadian rhythm of body temperature is on an upward trend, and when sleep is more difficult to sustain. Prior to an early start, the amount of sleep obtained reduces with progressively earlier start times. Individuals advance their bedtime, but normally take over a half an hour to fall asleep, because the early to mid-evening is a particularly difficult time at which to initiate sleep (see Paragraph 4.2.3).

9.1.4 A transition from a late finish to an early start without an intervening night's sleep will inevitably involve some sleep disruption and, without direct information, it is difficult to speculate on how aircrew would adjust their sleep pattern. However, these results from individual late finishes and early starts provide a strong argument for a redefinition of both, in order to limit the overall loss of sleep. The critical times appear to be around midnight for a late finish and 07:00 for an early start. Compared with the current definitions, this would entail an advance of an hour for a late finish and a delay of an hour for an early start. Thereby the combined sleep loss from consecutive duties, based on Figure 8, would be limited to approximately three hours.

9.1.5 These results have been obtained from studies of aircrew based in the United Kingdom. It is possible that, because of cultural differences related to time of day, some adjustment to the definitions would be required in other European states.

9.1.6 There was some discussion during the Review Meeting of other disruptive schedules, particularly ones in which an early start is followed, after a minimum rest period, by a night duty. Such a pattern of duty would be permitted under the current proposal, although the loss of sleep is likely to be even greater than for the late–early combination. It is therefore recommended that additional provision be included to restrict such disruptive scheduling. A simple way of achieving this would be to prevent an early start from being followed by a duty that overlaps the WOCL without an intervening night off. This would have the additional advantage of limiting the disruption caused by advancing schedules, by preventing an early start from being followed by a 'super-early' (i.e. a duty starting within the WOCL).

9.2 Acclimatization (Q3)

9.2.1 This question concerns the adequacy of the proposed definition of acclimatization, which is based on 72 hours or 36 consecutive hours free of duty in an area of three hours time difference. It is acknowledged in the NPA that this is an attempt to keep the regulations simple, as more accurate definitions would introduce what is perceived to be too much complexity.

9.2.2 When considering the issue of acclimatization, it is useful, at the outset, to distinguish between the resynchronization of the circadian rhythm, and the recovery of sleep. These two processes, though they are interrelated, are not the same. The proposed definition would seem to be related to the recovery of sleep, because it allows for a longer period of time when there are duties which might interfere with the timing of sleep. If the view is taken that 'acclimatization' should be considered as 'recovery', then this definition has some merit.

9.2.3 However, the definition of acclimatization is used to determine the maximum FDP based on start time. It is necessary, therefore, to consider the resynchronization process also, as this determines the phase of the circadian rhythm, including the timing of the WOCL.

9.2.4 Trends in resynchronization rates based on estimates of core body temperature rhythms suggest that about three days may be required to adjust to a five-hour westbound transition, and a day or two longer for a similar eastward transition [Pascoe, Spencer et al., 1994]. However, after large time-zone transitions, particularly in an eastward direction, the recovery times are considerably less predictable. Figure 9 shows the pattern of recovery for 10 individuals (not pilots) after a 10-hour eastward transition from London to Sydney [Spencer et al., 1995).

9.2.5 Similar trends were observed in pilots (Figure 10) after a nine-hour eastward transition [Spencer et al., 1991]. Some individuals adapted by a phase advance, and some by a phase delay, as if the body clock were responding to a westward shift. There was also considerable variation in the rates of adaptation. However, even where the adaptation was relatively quick, this appeared to be achieved by a reduction in the amplitude of the rhythm lasting for several days. During this period, it was very difficult to determine the phase of the rhythm, and hence to identify the presence of a WOCL.

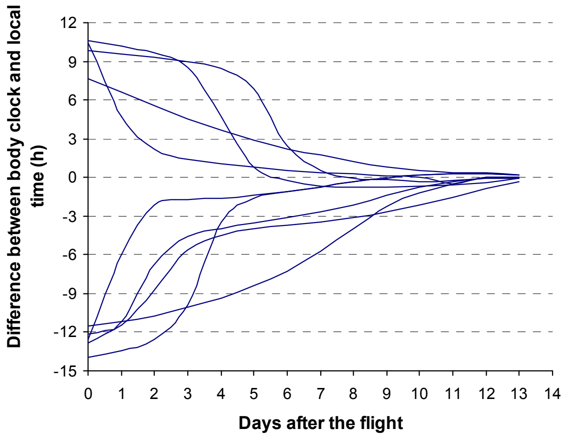

Figure 9: Adaptation to a 10h eastward transition

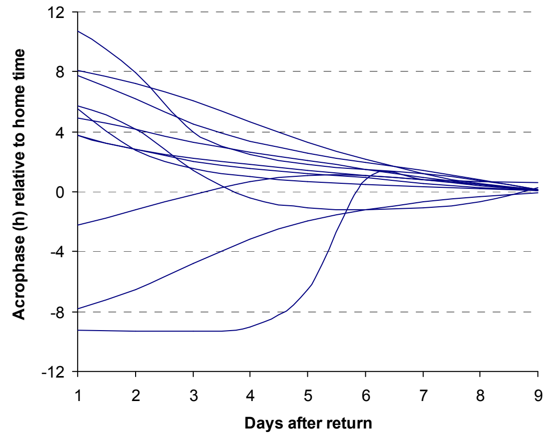

Figure 10: Adaptation of pilots to a 9h eastward transition

9.2.5 Therefore, although the proposed definition of acclimatization may possibly offer an acceptable practical solution for short transitions, it does not adequately address the issues associated with longer transitions, i.e. those over five or six hours. For example, at least on the third and fourth days after a long time-zone transition, the position of the WOCL, even if present, would be indeterminate. If a table for maximum FDP based on start time were used, errors of up to 12 hours would be possible in the timing of the WOCL.

9.2.6 It is for this reason that it is necessary to introduce the concept of the unacclimatized crew member. This would apply for a period of one, two or three days, two days after a long time-zone change (e.g. five or more eastward, six or more westward), when a single maximum FDP, irrespective of start time, would be appropriate. The maximum value would need to be set conservatively to allow for the unknown timing of the WOCL. After this period, crews would then be assumed to be acclimatized to local time. This approach is discussed in more detail below in the following section.

9.3 TZC non-acclimatized FDP table (AQ6a)

9.3.1 Table 3 illustrates how the FDP limits might be adjusted to accommodate different time-zone transitions and different layover periods. It is based on typical rates of acclimatization, though it is acknowledged that rates can vary considerably between individuals. It takes into account that the process of acclimatization depends on the duration of the period of adjustment as well as on the number of time zones crossed.

9.3.2 After any significant time-zone shift there will be a period of about two days (indicated by B) when the crew member might be considered to be 'partially acclimatized' to home time. During this period, the application of the FDP limits based on home time might be justified on the grounds of simplicity, although it would be preferable to use partially acclimatized tables. These are discussed more extensively in the Appendix.

9.3.3 After this initial period, and depending on the size and direction of the transition, there would be a period of one, two or three days (indicated by X) when both the amplitude and phase of the circadian rhythm would be difficult to predict. This is the time when the crew member would be considered to be unacclimatized. During this time, a cautious approach would be to set a limit consistent with the most unfavourable time of day. Finally, there would be a period of about a day (indicated by L) when it might be reasonable to assume that the crew member would be partially acclimatized to the new local time.

9.3.4 At the Review Meeting, the complex question of acclimatization following multiple time zone transitions was raised, and I promised to address this in my final report. A possible approach is outlined in the Appendix.

time-zone transitions		duration of layover (h)						
eastward	westward	24	48	72	96	120	144	168+
3-4	5-6	B	B	L				
5-6	7-8	B	B	X	L			
7-8	9-11	B	B	X	X	L		
9-12	12	B	B	X	X	X	L	

Table 3: Scheme for non-acclimatised FDPs (see text for details)

9.3.5 The other issue that needs to be addressed is that of minimum rest. After a transition of four hours or more, the desychronization of the body clock with the local environment may make it more difficult to obtain adequate sleep. It would therefore be sensible, in these circumstances, to impose a minimum rest of 14 hours, irrespective of the time of day, as is currently proposed.

9.4 TZC - continual circadian disruption (east-west / west-east transitions) (AQ6b)

9.4.1 Problems associated with continual circadian disruption can often arise with alternating east-west schedules. However, they may also be associated with long time-zone transitions more generally, including repeated ‘back-of-the-clock’ operations, such as those between Europe and Australasia. The origin of these problems is often the requirement to undertake a long-haul tour of duty when sleep and circadian rhythms have not recovered from the effects of the preceding duties. It would seem inconsistent for regulations to cover one specific type of schedule and not others in which similar issues arise.

9.4.2 To address this issue, simulations have been carried out, using the model for circadian adaptation included within the SAFE program, to determine the recovery period that would be required for aircrew to readapt to within an hour of home time. The original table based on the results of those simulations was somewhat complicated, and the authors of the Moebus report decided to recommend a simplified and shortened form, which is shown here as Table 4.

9.4.3 The numbers in the table are the recovery nights expressed as a function of the maximum time difference from home base during the time away, and the total time away (layover duration). They represent the approximate average recovery time that would be necessary to ensure that crews have re-adjusted close to home time before undertaking another duty schedule.

Layover (h)	Maximum time difference (h)		
	<5	**5-7**	**8-12**
<36	1	2	2
36-60	2	3	3
60-84	3	3	3
84-132	3	4	5
>132	3	5	6

Table 4: Recovery nights following return to base

9.4.3 The authors of the Moebus report recommended that the above table should be amended in the event that any part of the FDP for the return flight overlapped the WOCL (on home base time). In this case, to ensure sufficient time for the recovery of sleep, it was recommended that at least two local nights free of duty should be provided.

10 Reduced rest

10.1 Reduced rest (Q14)

10.1.1 The requirements for minimum rest are designed to provide crew members with the opportunity to report for duty in a fully rested state. This is not possible if the rest period is reduced to 7½ hours when, as shown in the STARE report, the impact on sleep is more severe than that associated with early morning start times.

10.1.2 The only information on the impact of reduced rest on aircrew alertness has recently been made available through the STARE report, for which the executive summary has been included within the NPA documentation. In this report there are some interesting general observations on the relationship between fatigue and aircrew performance, including information from Flight Data Management (FDM). Of the results that relate specifically to reduced rest, the most worthy of note are the following:

i. approximately 5% of morning duties following reduced rest exceeded a critical value on the Fatigue Risk Index (FRI). It is claimed that this was due to the pattern of duty preceding the reduced rest;

ii. the frequency of air safety reports from all three airlines studied was greater after reduced rest than after a normal night, during a period from three to five hours of flight duty. This trend was reversed in one airline after more than five hours;

iii. reduced rest was associated with a large sleep debt (see above);

iv. assessments of sleepiness were obtained from aircrew on three duty schedules with reduced rest overnight: three flights + rest + three flights (n=57); five flights + rest + three flights (n=45); and flight + split duty break + two flights + rest + one flight (n=10). On all the flights following the reduced rest, sleepiness remained at an acceptable level and was broadly consistent with model predictions.

10.1.3 These results represent an interesting first step in the investigation of the impact of reduced rest, but they cannot, as they stand, justify the full extent of the current proposal, as they do not explore the provisions of the proposal to the limit. If, as claimed, the pattern of previous duty may be crucial, then this would need to be investigated in more detail, and further limitations added as appropriate. In particular, the combination of split duty and reduced rest raises serious concerns, which the limited data so far collected do not fully address.

10.1.4 Reduced rest is an issue, rather like ultra-long-range operations, which does not seem to fit very easily within an FTL scheme. Much depends on the types of schedule within which it is included, and how frequently it is used. It is therefore proposed that, similarly to ultra-long-range, those operators who wish to use it have to demonstrate its acceptability within tightly controlled limits using an FRM approach. The data so far collected are inadequate to justify more general guidelines at present but, as more information becomes available from different operators operating different schedules, it may be possible to develop an acceptable regulatory scheme at a later date.

10.2 Reduced rest with split duty (AQ7)

10.2.1 The STARE report presents one set of results for reduced rest following split duty, where the levels of sleepiness during the flight after the period of reduced rest were within acceptable limits. These results are interesting, but cannot be used in general to support the combination of split duty and reduce rest, for a number of reasons:

i. the results are based on only 10 responses;

ii. there is no indication in the report of the duration of the reduced rest period, in particular whether it corresponded to the minimum value of 7.5 hours;

iii. there is no indication in the report of the duration of the split duty or of the duration and timing of the duty period, except whether they were in the morning or the afternoon;

iv. as predicted sleepiness after the reduced rest was relatively low, the schedule studied cannot be representative of the most demanding schedules with reduced rest, such as those highlighted earlier in the report (STARE report, figure 1-3);

v. there are general grounds to be concerned about reduced rest, arising both from the drastic reduction in sleep duration (STARE report, figure 8) and the increase in air safety reports during the first five hours of flight duty (STARE report, figure 4).

10.2.2 While it is recognized that reduced rest followed by split duty may be acceptable *in some circumstances*, there are no grounds for its inclusion in a general FTL scheme.

11 Other issues

11.1 Rest on the flight deck

11.1.1 There is evidence to support the view that controlled rest on the flight deck is being widely used, particularly as a way of managing fatigue on long overnight duties. This was discussed as an additional topic towards the end of the Review Meeting, where the opinion was expressed that the generous FDP limits for overnight flights in the current provisions could not be sustained by a minimum crew without extensive use of in-flight rest.

11.1.2 It is necessary to distinguish between two uses of controlled rest on the flight deck. It may be used as a preventative measure in anticipation of high levels of sleepiness later in the flight, or as an emergency measure when levels of sleepiness have already reached a high level. Purely from the scientific viewpoint, its use as a preventative measure is to be encouraged. Indeed, sleepiness would be minimised if crews alternated periods of rest throughout the cruise phase, allowing only sufficient time to recover from sleep inertia (Section 4.6). Whether it is operationally acceptable for a two-crew aircraft to be operated for long periods with only one pilot awake is a question for the regulator, not the scientist.

11.1.3 A concern associated with the use of controlled rest, which I have heard expressed by airline safety managers, is that crews often use it as a substitute for obtaining adequate rest prior to a flight. The situation might arise, as with some shift-workers, where aircrew come to regard long periods of continuous duty as an opportunity to catch up on sleep they have chosen not to take during their previous off-duty period.

11.1.4 Its use as an emergency measure is somewhat different. Even with sympathetic rostering, and even when the limits on overnight duties are reasonably set, there will be times when a crew member needs to rest briefly to overcome the sudden pressure for sleep. For this reason, several operators employ controlled rest as an emergency measure in the form of the 'NASA nap' [Rosekind et al., 1994], a 60-minute sleep opportunity, including a final 20-minute period to overcome the effects of sleep inertia.

11.1.5 Given the widespread current use of napping on the flight deck, there are strong grounds for the regulator to provide general guidance, whether as part of the FTL scheme itself or elsewhere. This is particularly the case when long duty periods overnight, which are known to be extremely demanding, are permitted. The possible risks need to be addressed, and these will include ensuring that adequate measures are in place to ensure the alertness of the one pilot who remains awake.

11.2 FTL and Fatigue Risk Management

11.2.1 The role of an FTL scheme in relation to Fatigue Risk Management was discussed during the Review Meeting. The problem now arising with FTL schemes is that they are more likely to be exploited to the limit. In the past, schedules have been protected either by industrial agreements or by operators working in a less competitive environment and not under pressure to push their schedules to the limits of what is permitted.

11.2.2 A standalone FTL scheme will be seen as defining the limits of what is safe, as any operation will be permitted that lies within the confines of that scheme. I am concerned that this may be one of the risks arising from the current approach. The opportunity will arise for any ambiguities and loopholes in the regulations to be exploited. Indeed, it is impossible to envisage a simple scheme that could address adequately the detailed and complex nature of the relationship between roster design and aircrew fatigue. This is in addition to the problems of regulating for the unexpected events that are an inevitable feature of actual operations.

11.2.3 With FRM, the airlines themselves can take a greater share of the responsibility for the safety of their own operations, instead of simply relying on the rules to protect their crews from undue levels of fatigue. It can also provide a more flexible framework for handling emergency events and other unusual situations. However, I would not advocate the use of FRM alone, but would rather see the role of an FTL scheme as providing the overall framework or envelope, by defining the general limits for a safe operation.

12 Summary of key points

12.1 The following is a list of the most important issues, from my perspective, which have arisen from the discussions in Cologne, and from the review of the proposal in general:

i. The proposed limits for maximum FDPs are too generous for many overnight duties.

ii. The one-hour extensions should not be permitted, except possibly for duties starting between 08:00 and 12:00.

iii. The provisions for augmented crews should follow more closely the recommendations of the TNO report, particularly with respect to overnight flights.

iv. The definition of acclimatization does not allow adequately for the effect of time-zone changes. This applies both to the FDP limits on layover at a remote destination, and to the recovery time on return to home base.

v. More protection is required for disruptive schedules, particularly those involving late finishes followed by early starts and early starts followed by night duties. The definition of earlies and lates should be extended.

vi. The definition of a home base should be qualified to ensure that it is not used to evade the requirement for positioning flights to count as duty;

vii. Provisions for reduced rest should not be included.

viii. The safety concerns arising from the extensive use of in-flight rest on the flight deck should be addressed.

ix. The use of commander's discretion should be regulated and monitored to ensure that it is not used on a routine basis.

x. It is not possible for an FTL scheme to cover every eventuality. Fatigue Risk Management can provide a more flexible approach in many situations.

12.2 In conclusion, it is my opinion that the current provisions, viewed in their entirety, do not provide sufficient protection against the risks of fatigue, particularly in an environment where competitive pressures may become increasingly powerful. Therefore, I strongly recommend that careful consideration be given to the various issues addressed here, and that further changes are made to ensure that the proposed scheme is a more accurate reflection of current scientific knowledge.

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Appendix: Time-Zone Changes and Acclimatization

A1 Introduction

A1.1 The definition of acclimatization and the incorporation of provisions to cover unacclimatized aircrew present particular difficulties. This is due both to the complexity of the acclimatization process and its impact on sleep and fatigue, and also to the wide variation between different individuals and, indeed, between the same individual on different occasions.

A1.2 An approach to this problem was discussed in Section 9, which included definitions for the FDP limits for unacclimatized crews (Table 3) and for the duration of the recovery period after return to base (Table 4). Although these definitions might be considered to be fairly complicated, they already involve some degree of simplification. They have been proposed as a compromise that avoids some of the extra complexity that would be required to represent the acclimatization process more fully.

A1.3 This Appendix provides an example of how the subject of acclimatization might be addressed in more detail. In particular, it covers the extension of the definition to cover periods away from home base involving multiple duties and layovers at different locations. This is in response to a request made at the Review Meeting.

A1.4 The following section (A2) introduces the issue of partial acclimatization, with an indication of how a table for maximum FDP might be constructed for partially acclimatized aircrew. This table is one of the components used in the calculation of maximum FDP on layover, which is the subject of Section A3. Section A4 covers the detailed calculations that are necessary to cater for multiple layovers.

A2 Partial acclimatization

A2.1 During a relatively short layover (i.e. one of no more than 60 hours), it is likely that the phase of the body clock will remain close to base time. This would be the case particularly if the crews are mindful of the quick return and do not try to adapt to the local environment. In Section 9, it was suggested that the basic FDP table could be applied with some adjustment, to account both for some sleep disruption and for some small change in the circadian rhythm.

report time	23-1	1-3	3-5	5-6	6-7	7-8	8-12	12-14	14-17	17-23
acclimatized	10	9	10	11	12	13	14	13	12	11
partially acclimatized	9	9	9	10	11	12	13	12	11	10

Table A1: Limits (h) for acclimatized and partially acclimatized crews

A2.2 A simple way of implementing this would be to allow a reduction of say an hour in the limits for acclimatized crews, subject to the same overall minimum value. In Table A1, the limits in hours, calculated in this way, are shown alongside those of Section 3 (Table 1), based on the results of the Haj study. Tables involving a similar one-hour adjustment could be derived in the same way from any other acclimatized table.

A3 Maximum FDP on layover

A3.1 When the duration of the layover is longer than 60 hours it is unreasonable to assume that little adaptation has occurred, even if the crews then return immediately to base. After large time-zone transitions, there is likely to be a period during which the rhythm is changing rapidly, when its phase is uncertain and when, in some instances, its amplitude is significantly reduced. The greatest uncertainty arises after long eastward flights, when the sleep patterns of aircrew tend to be considerably disrupted.

A3.2 In these circumstances, it would be reasonable to limit the maximum FDP to its minimum value (based on the Table 1, this would be nine hours for a single-sector duty) for a number of days, until such time as the partially acclimatized table could be applied, based on local time. The exact number of days would depend on the number of time zones crossed and the direction of travel.

A3.4 Table A2 shows a scheme for calculating maximum FDP using this approach. It is essentially a more comprehensive version of Table 3 in Section 9. The various abbreviations are as follows:

AL acclimatized limits based on local time;
PB partially acclimatized limits based on base time
PL partially acclimatized limits based on local time
X minimum limit (e.g. nine hours).

time-zone transitions		duration of layover (h)							
eastward	westward	12-36	36-60 (returning to base)	36-60 (not returning to base)	60-84	84-108	108-132	132-156	156+
2	3-4	PB	PB	PL	AL	AL	AL	AL	AL
3-4	5-6	PB	PB	X	PL	AL	AL	AL	AL
5-6	7-8	PB	PB	X	X	PL	AL	AL	AL
7-8	9-11	PB	PB	X	X	X	PL	AL	AL
9-12	12	PB	PB	X	X	X	X	PL	AL

Table A2: Scheme for calculating maximum FDP (see text for details)

A3.5 A natural definition of acclimatization follows immediately from Table A2. A crew member can be considered to be 'acclimatized' when the table indicates that the acclimatized limits based on local time can be applied (i.e. where AL appears in the table). It should not be assumed that all aircrew will have adapted completely within that time, and indeed some will adapt more rapidly. However, this definition and these limits should provide reasonable protection against the worst effects of circadian desynchronization.

A4 Layovers at multiple locations

A4.1 Table A2 is only directly applicable to a single location on layover. However, aircrew may undertake a sequence of duties involving time-zone transitions before finally returning to home base. If they become acclimatized to local time while on layover, then that location can be treated at their new 'base' for the purpose of calculating maximum FDP. However, some provision is required to cover for consecutive layovers in which a crew member has not become acclimatized at any point. A possible way of addressing this problem is outlined in the remainder of this section.

A4.2 If a crew member becomes partially acclimatized at any location before undertaking the next FDP, then it would be reasonable to base the calculations during the following layover on the assumption that they had been fully, not partially, acclimatized. However, if they are still unacclimatized when they start the next flight, then the basis for the calculation of maximum FDP during the subsequent layover period needs to be determined.

A4.3 With the proviso that any set of rules is likely to give rise to anomalies and inaccuracies, I would propose the following:

a) If the time-zone change on the second flight is less than two hours in either direction, then the additional effect of the second flight may be ignored: the duration of the second layover should be added to the first, and the maximum FDP should be based on the combined layover time, based on the first flight alone.

b) Otherwise, there will be a period of time during the second layover period when the minimum limit will need to be applied. This time should be based on two quantities: (i) the amount of time remaining during the first layover period before partial acclimatization would have been assumed, and (ii) the duration of the period of minimum FDP for the second flight based on Table A2, as if it were the only flight.

c) The values in (i) and (ii) should be added together when the second flight is in the same direction as the first, and subtracted if the flights are in opposite directions. This will determine the duration of the period of minimum FDP, and it would be followed, as in Table A2, by a 24-hour period during which crews would be assumed to be partially acclimatized to local time.

A4.4 To illustrate the method of calculation, consider a sequence of flights between London and Auckland via Hong Kong, where London is on UTC time, Hong Kong is UTC+8 and Auckland UTC+13, and the layover times in Hong Kong, Auckland and Hong

Kong are three, two and three days respectively.

a) First layover in Hong Kong. This follows an eastward flight across eight time zones. After a layover of three days (72 hours) there would, according to Table A2, be a further 36 hours (108 less 72) before partial acclimatization would be assumed. The crews are therefore still unacclimatized and the residual period of 36 hours is carried forward to the next layover.

b) Layover in Auckland. This follows a five-hour transition in the same direction as the previous flight. From Table A2, a five-hour eastward transition has a 48-hour period with the minimum FDP. This is added to the value carried over (36 hours) to give a total of 84 hours. This is the period after landing in Auckland when the minimum FDP would be applied to the following flight. It would be followed by a period of 24 hours of partial acclimatization. However the duration of the layover in this example is two days, or 48 hours. The crews are therefore still unacclimatized, and the residual period of 36 hours (84 less 48) is carried forward to the next layover.

c) Second layover in Hong Kong. This follows a five-hour transition in the opposite direction to the previous flight. A five-hour westward transition has a 24-hour period where the minimum FDP applies. The difference between 24 and the carried-forward value of 36 hours is 12 hours, which is the length of time when the minimum FDP would be applied to the second layover in Hong Kong. For a layover between 12 and 36 hours the partial acclimatization rule would apply. However, the return flight occurs after three days, or 72 hours. At that stage the crews would be assumed to be fully acclimatized to Hong Kong time. Therefore the normal fully-acclimatized table would be applicable to the final flight.

A4.5 This discussion has highlighted the difficulty of incorporating scientific knowledge of the process of acclimatization into the regulations. However, as long as there is a requirement to operate disruptive schedules involving multiple layovers, it will be necessary to ensure that adequate protection is in place. An alternative to complex regulations, as in many other areas covered in this report, would be an approach based on FRM. The fatigue issues arising in schedules such as the one in the above example, could then be addressed by the equivalent of the city-pair methodology for ULR operations.