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AUGUST–SEPTEMBER 2005

Lessons From the Dawn of Ultra-long-range Flight

Flight Safety Foundation is an international membership organization dedicated to the continuous improvement of aviation safety. Nonprofit and independent, the Foundation was launched officially in 1947 in response to the aviation industry's need for a neutral clearinghouse to disseminate objective safety information, and for a credible and knowledgeable body that would identify threats to safety, analyze the problems and recommend practical solutions to them. Since its beginning, the Foundation has acted in the public interest to produce positive influence on aviation safety. Today, the Foundation provides leadership to more than 900 member organizations in more than 150 countries.

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In This Issue

FOURTH WORKSHOP YIELDS INSIGHTS INTO

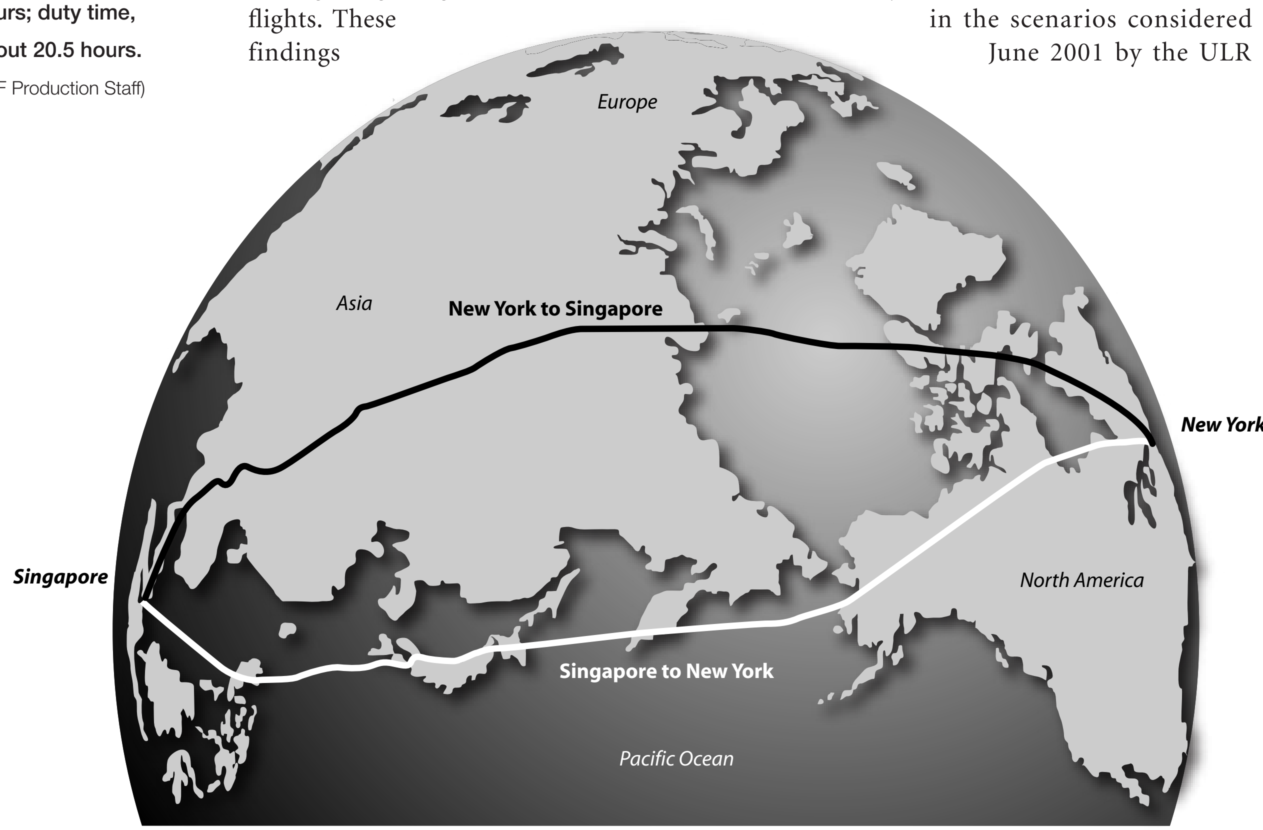
Early Ultra-long-range Flight Experience

Validation studies of nonstop flights between Singapore and the United States show that recommended operational guidelines developed by Flight Safety Foundation can help airlines worldwide to expand their operational envelope while maintaining safety.

— FSF EDITORIAL STAFF

In-flight scientific research for Singapore Airlines and the Civil Aviation Authority of Singapore (CAAS) has found that the typical quality and quantity of sleep obtained by pilots, their alertness levels and their reaction-time performance during ultra-long-range (ULR) flights[1] is not less than those previously measured during long-range flights. These findings have buttressed 2003 consensus recommendations published by Flight Safety Foundation on operational guidelines, regulatory requirements and supporting research requirements for pilots.

ULR flights have planned flight-sector lengths (block times) greater than 16 hours and flight-duty periods from 18 hours to 22 hours in the scenarios considered since June 2001 by the ULR Crew



Daily flights between Singapore and New York were launched by Singapore Airlines in June 2004. Flight time on each leg has averaged about 18.5 hours; duty time, about 20.5 hours.
(FSF Production Staff)

"The airline industry anticipated well in advance the challenges of ULR flights."

Alertness Steering Committee, which conducted four workshops through cosponsorship of Airbus, Boeing Commercial Airplanes and the Foundation. The steering committee provided a global forum to define the operational issues and the technological issues associated with ensuring pilot alertness during ULR flights, and to develop common methods to address these issues. Updated information on the steering committee's recommended guidelines appears in Appendix A (page 7).

Based on recent airplane orders, more airlines are expected to soon begin ULR flights with flight-sector lengths up to about 20 hours. (By comparison, long-range flights have comprised operations with planned flight-sector lengths between 12 hours and 16 hours.)

During the steering committee's follow-up workshop in May 2005 in Los Angeles, California, U.S., about 80 international participants (see Appendix B, page 15) advanced the previous discussions and shared their expertise, said Robert Vandel, FSF executive vice president, and R. Curtis Graeber, Ph.D., chief engineer, human factors, Boeing Commercial Airplanes. Vandel and Graeber have been the steering committee co-chairmen. Additional sponsorship for the Los Angeles workshop was provided by the International Federation of Air Line Pilots' Associations (IFALPA) and the Air Line Pilots Association, International (ALPA).

"The airline industry anticipated well in advance the challenges of ULR flights and succeeded in developing solutions that increased the safety margins before actual flights began," Vandel said. "The Foundation has appreciated the contributions of many international specialists who helped to identify the risk factors and to apply current scientific knowledge to mitigate risks before they became operational problems. Participants in the Los Angeles workshop essentially said that the earlier recommendations of the steering committee were on target and that fatigue risk management systems (FRMS) — thoroughly integrated into current safety management systems — should be a high priority as more plans go forward for ULR flights." (See "Fatigue Risk Management System Helps Ensure Crew Alertness, Performance," page 16.)

Shared Lessons

Among the 16 presentations at the workshop were reports from scientists highlighting current research on aircraft crew fatigue, sleep and alertness as applied to ULR flights (see "Scientists Outline Current Research," page 3); aviation professionals involved in the inauguration of ULR flights by Singapore Airlines (see "The Singapore Experience: Task Force Studies Scientific Data to Assess Flights," page 20, and "Cabin Crews Adapt Readily to Challenges of Ultra-long-range Flight," page 41); and airlines developing plans for ULR flights. Regulators, pilots and airline managers in Singapore conducted a six-year initiative involving extensive international collaboration on ULR-flight issues, and shared what they learned.

"One benefit to other civil aviation authorities is that considerable work already has been done by CAAS," said Dr. Jarnail Singh,[2] chairman of the Civil Aviation Medical Board of CAAS, chairman of the CAAS ULR Task Force,[3] and a ULR Crew Alertness Steering Committee member. "Other civil aviation authorities will have to consider what tools they will require for their circumstances. One of the most critical issues for them would be the validation of any proposed departure window for a ULR flight, which likely would be different than those of Singapore-based flights, considering the unique circadian desynchrony[4] of the pilots.

"Our task force also realized early that there would have to be operational decisions that could be guided only by the amount of science currently available — 'guided' is the key word. The main issue — so long as fatigue issues and alertness issues are properly managed to take care of the pilots and the cabin crewmembers — is not the sector length of ULR flights. Nevertheless, CAAS kept in place the time-proven rules about flight-time limitations [FTL], duty-time limitations and

Continued on page 4

Scientists Outline Current Research

Because aircraft-crew sleep — including adaptation sleep before departure, in-flight sleep and recovery sleep after arrival — is essential for maintaining alertness and managing fatigue on ultra-long-range (ULR) flights,[1] scientists' ongoing study of sleep, fatigue and alertness will influence the safety of such flights well into the future.

During the ULR Crew Alertness Steering Committee's final workshop in May 2005, several scientists presented findings from current research relevant to ULR flights, and several air carriers presented their applications of relevant science in managing fatigue and alertness.

Some scientists said that planners of ULR flights assume that the pilots will be fully rested when reporting for duty, that the pilots will utilize all of the rest opportunities made available to them and that pilots will sleep the majority of the time during these rest opportunities.

"The scientists and the people conducting flight operations are coming together under the umbrella of fatigue risk management systems [FRMS], and there has been good cross-pollination in these workshops," said R. Curtis Graeber, Ph.D., chief engineer, human factors, Boeing Commercial Airplanes and steering committee co-chairman.

For example, Paul Ridley, manager of flight operations, technical and projects for Emirates, said that the United Arab Emirates (UAE) General Civil Aviation Authority applied information and recommendations from the workshops to draft UAE Civil Aviation Advisory Publication (CAAP) 14, *Ultra Long Range Operations: Additional Flight and Duty Time Guidance for Ultra Long Range (ULR) and Other Specific Long Range (SLR) Operations*.

Amendments to UAE civil aviation regulations also are being developed to address current flight time limits in the context of ULR flights and less restrictive "ULR lite" operations that will set the stage for future ULR flights.

Emirates has developed operational plans based on the ULR city-pair methodology and has implemented an FRMS, in which the FRMS committee reviews all proposed crew-operating patterns and conducts risk reviews of routes and airports as recommended by the ULR Crew Alertness Steering Committee.

Following are highlights of the scientists' presentations and discussions:

- David Powell, M.D., chief medical officer for Air New Zealand, said that by integrating the knowledge obtained from pilot fatigue reports, operational studies and focused studies to validate subjective experiences of pilots conducting long-range flights, the airline differentiated effective interventions from ineffective interventions. For example, the airline found that adding a fourth pilot to the crew complement for its Auckland, New Zealand–Los Angeles, California, U.S.–Auckland crew-operating pattern maintained pilot alertness more effectively than providing an extra night of layover rest. This intervention subsequently was implemented for other long-range flights;

- Mick Spencer of QinetiQ said that scientists studying ULR flights by Singapore Airlines found that in-flight turbulence during pilots' scheduled rest periods was the most significant factor affecting their bunk sleep;

- Leigh Signal, Ph.D., of the Sleep/Wake Research Centre of Massey University, Wellington, New Zealand, said that data from Singapore Airlines' ULR flights showed large individual variability in sleep among pilots (the range of in-flight sleep obtained was from more than five hours to less than one hour). In-flight sleep typically was found to be less efficient than at-home sleep, and involved the lighter stages of sleep rather than the deeper stages of sleep;

- Philippa Gander, Ph.D., professor at the Sleep/Wake Research Centre of Massey University, said that, on average in many years of studies, about 30 percent of pilots have declined to volunteer to participate in data collection on sleep, fatigue and alertness. Scientists therefore are developing better data-collection methods and working to understand why some crewmembers experience difficulty in obtaining in-flight sleep and how the quality of in-flight sleep affects subsequent performance;

- Drew Dawson, Ph.D., professor at the Centre for Sleep Research, University of South Australia, said that planners of ULR flights may have to consider the extent to which aircraft crewmembers obtain their sleep within socially appropriate sleep zones (time periods) rather than during biologically appropriate sleep zones. For example, future recommendations may help pilots who conduct ULR flights to plan their recovery time, personal time and preparatory time within their scheduled days/nights free of duty. Scientists will have to develop computer-based models that better predict actual sleep/wake behavior, he said; and,

- Steven Hursh, Ph.D., of Science Applications International Corp. and Johns Hopkins University, said that analysis of ULR flights using one validated fatigue-avoidance scheduling tool shows that pilots' performance varies by the degree to which layover sleep occurs on home-base time or on outstation time.

— FSF Editorial Staff

Note

1. Ultra-long-range (ULR) flights have planned flight-sector lengths (block times) greater than 16 hours and flight-duty periods from 18 hours to 22 hours in scenarios considered during 2001–2005 by the ULR Crew Alertness Steering Committee, which conducted four workshops through cosponsorship of Airbus, Boeing Commercial Airplanes and Flight Safety Foundation.

crew rest requirements, and modified only those that were applicable to ULR flight. Finally, other civil aviation authorities would require validated international norms for measuring alertness and comparing the results among ULR flights, long-range flights and short-range flights. Using any single measurement solely for ULR flights — not being able to compare the results — is pointless. Our position is that multi-center, multi-airline, multi-funded studies should provide normative data as to what is an acceptable level of fatigue for all types of flights."

Having validated methods of addressing alertness and fatigue among Singapore Airlines pilots, CAAS next will examine how to expand ULR flights and to make them more flexible in scenarios such as in-flight diversions and ramp turnbacks (i.e., when the flight crew returns to the gate near the end of their departure window), Singh said.

Validating Crew Alertness

As discussed in "Consensus Emerges From International Focus on Crew Alertness in Ultra-long-range Operations" in the May–June 2003 issue of *Flight Safety Digest,* the main tenets of the steering committee's consensus were that airlines should obtain approval for plans to conduct ULR flights from civil aviation authorities and that the plans should be developed using a scientifically based method that can employ validated mathematical models of crew alertness (computer-based tools that predict alertness levels in the absence of data) to predict how ULR flights can be scheduled to operate safely between specific city pairs. Recommendations also called for plans to incorporate the work/rest scheduling (for pilots and cabin crews), in-flight monitoring of crew rest and crew performance under an independently defined validation plan, and the application of ongoing scientific research.

"The initial scientific validation for CAAS primarily showed how specific operational plans have enabled sufficient pilot alertness for routes between two ULR city pairs," Graeber said. "The airline industry, relatively speaking, is still in its early days of ULR flight. Most of the May 2005 workshop participants said that they believed that our

Crew-rest facilities available for the overhead area of the Boeing 777-200ER and LR have temperature controls and a meal-transfer system. A lavatory, kitchenette and video-entertainment system are options.
(Photo: Boeing)

proposed process for conducting ULR flights works and does not require major changes. Successful ULR flights will depend on the FRMS method, which has been implemented in New Zealand, proposed for implementation in Australia and is being considered for incorporation into standards and recommended practices of the International Civil Aviation Organization."

Another recurrent theme of the workshop was that lessons learned so far in the environment of ULR flight could influence positively other airline operations involving shorter sectors.

"We have seen a very definite 'trickle-down' effect from recommendations specifically for ULR flights to both long-range flights and short-range flights," Vandel said. "For example, the steering committee's basic principles were adapted by one of the low-cost European air carriers to improve pilot-rostering practices within the company. This air carrier demonstrated scientifically that pilots' alertness could be improved measurably, pilot-retention rates could be raised and insurance costs could be reduced."

Case-by-case Approval

The ULR Crew Alertness Steering Committee's recommendations (Appendix A) comprise suggested regulatory language; refinements to scientific research efforts and the corresponding field-validation process; and credible and practical guidance developed by diverse specialists. They are built around the concepts of case-by-case approval of ULR city pairs (which would be treated as variations to the airline's FTL) rather than pursuing broad approval of ULR flights by civil aviation authorities, and of addressing alertness and performance without relying on prescribed duty limits.

The consensus of participating scientists continued to be that in-flight sleep is the best solution to the problem of maintaining crew alertness and performance during ULR flights, Graeber said. Nevertheless, scientific studies have yet to be conducted on cabin crews conducting ULR flights; so far, alertness issues and performance issues for cabin crewmembers have been assumed to parallel those of pilots in most respects, requiring scientifically based provisions for adequate crew complement, in-flight rest and crew-operating patterns.

Many subgroup recommendations that emerged from the May 2005 workshop mirrored earlier discussions. As a result, the steering committee recorded them and referred to them to update the 2003 guidelines without issuing separate subgroup reports. Among the new recommendations made by these participants for further consideration were the following:

In-flight sleep is the best solution to the problem of maintaining crew alertness and performance.

- A subgroup on crewmembers recommended that training modules for ULR flights be tailored to airline schedulers, dispatchers and rostering personnel, medical staff/consultants, mid-level managers, marketing managers and the families of crewmembers. Pilots should be trained on safe use of prescription medications and nonprescription medications (including the applicable regulations and physiological effects of medications on natural sleep rhythms). Special attention should be given to preflight fitness for duty; how an individual crewmember's experience of fatigue may differ from laboratory studies; socially driven rest opportunities versus biological rest opportunities; managing rest during layovers; signs of fatigue and decreased alertness in others; symptoms of sleep disorders; how to dispel misconceptions about fatigue; and countermeasures/healthy methods that assist in obtaining sleep (i.e., sleep whenever sleepy). Rest during ULR flights should be considered mandatory for safety — not optional, linked to personal perceptions or superseded by service demands. Scientists were encouraged to conduct further studies of how to tailor strategies to individual differences and to study the effectiveness of rest periods of different lengths, interaction between in-flight sleep patterns and sleep patterns during layovers, and the effectiveness of a 72-hour layover versus a 48-hour layover;

- A subgroup on methods of regulatory oversight said that civil aviation authorities must require air carriers to have an approved FRMS to conduct ULR flights. Operators also should submit a plan to allow flexibility in the event of rescheduling while ensuring that crews are rested. A captain's discretion to extend the flight-duty period for a ULR flight should be limited to a maximum of three hours;

- A subgroup on future route planning for ULR flights said that the conservative city-pair method (as published by the steering committee) should be the basis of developing new routes. Each flight-planning process for new routes should involve integration of pilot rosters to include existing ULR-flight routes to ensure adequate rest between flight-duty periods. Computer-based modeling should be applied prior to any change in established departure/arrival windows to determine the expected alertness situation of the crew (i.e., to try to avoid pilots experiencing their circadian low — when the human neurophysical process ("body clock") makes the greatest demand for sleep — during takeoff and landing). Allowable delay times should be city-pair dependent and may vary between the home base and outstation. The approved departure window must be designed to cover the approved delay time. Diversion scenarios may result in flight crew reversion to the FTL of non-ULR flights; and initial planning for ULR flights should include risk assessment on possible alternate airports (including air traffic management, seasonal weather and airport-specific risk factors for approach and landing). For operations combining ULR-flight sectors and non-ULR-flight sectors, key issues are that crews obtain sufficient rest before/after each ULR flight and that in-flight rest opportunities be determined by requirements for ULR flights; and,

- A subgroup on operational best practices said that pilots and cabin crewmembers must know at least 36 hours to 48 hours before departure when they will be scheduled for in-flight rest. Educational materials should be developed on how best to manage post-rest handovers on the flight deck and in the cabin, taking into account possible effects of sleep inertia (i.e., time required to transition from sleep to wakefulness). Further research and education should be conducted on appropriate use of controlled napping on the flight deck. Airlines should direct additional attention to the aircraft-handling skills and currency among pilots who conduct only ULR flights, and to pilot transitions between duty on ULR flights and duty on non-ULR flights. Training cabin crewmembers to conduct only ULR flights has been an acceptable practice in early operational experience. The effect of humidification on the ability to sleep in the crew-rest facility should receive more attention, and further research and regulatory oversight should be conducted on minimum performance standards for design and maintenance of crew-rest facilities. Participants also suggested sharing real-world experiences of crewmembers via the Internet to identify, capture and disseminate best practices to future entrants conducting ULR flights. ■

Notes

1. The Ultra-long-range (ULR) Crew Alertness Initiative — cosponsored by Airbus, Boeing Commercial Airplanes and Flight Safety Foundation — defines a ULR flight as "an operation involving any sector between a specific city pair (A-B-A) in which the planned flight time exceeds 16 hours, taking into account mean wind conditions and seasonal changes." Airplanes designed for ULR flights by airlines currently include the Airbus A380 and A340-500, and the Boeing 787-8, 787-9, 777-200ER, 777-200LR and 777-300ER.

2. Singh, Jarnail. Interview by Rosenkrans, Wayne. Los Angeles, California, U.S. May 25, 2005. Flight Safety Foundation, Alexandria, Virginia, U.S.

3. The Civil Aviation Authority of Singapore (CAAS) ULR Task Force comprised CAAS, Singapore Airlines and the Air Line Pilots Association–Singapore.

4. Endogenous circadian rhythm is a scientific term for the neurophysical process ("body clock") that controls the daily cycle of a person's sleep/wake pattern and other physiological variables. Research shows that a person's body clock normally is entrained (synchronized) to the 24-hour day but becomes desynchronized (i.e., out of circadian phase) by time-zone transitions.

Appendix A

Ultra-long-range Crew Alertness Initiative — Recommended Guidelines

The Ultra-long-range (ULR) Crew Alertness Steering Committee's[1] recommended guidelines are based on a fatigue risk management system (FRMS) methodology for addressing crew alertness in planning and conducting commercial flight operations (see "Fatigue Risk Management System Helps Ensure Crew Alertness, Performance," page 16).

Operational Best Practices

Assumption: ULR operations consist of out-and-back flights between an approved city pair using a specific aircraft type with a defined departure window.[2]

Crewing

- Flight crew complement:
  - For initial operations between a city pair, the number of flight crewmembers required would need to be assessed using the best scientific means available at the time and industry operational experience. Following this assessment, if there is a discrepancy between the two recommendations, adopting the higher crew complement would represent best practice.
  - During the initial operations, a validation of the crew complement should be carried out. This validation should consist of a scientific assessment of crew alertness level, confidential crew reporting and any other evidence-based means available (e.g., flight data monitoring [FDM],[3] line operations safety audit [LOSA],[4] etc.).
  - If the validation fails to support the original assessment, a review should be undertaken.
- Flight crew qualifications:
  - Best practice suggests that ULR flight crews should have adequate operational experience, including previous long-range flights.
  - For ULR operations, the flight crew complement will not be less than four pilots, two of whom should hold pilot-in-command qualifications and four of whom should be qualified for the takeoff and landing phases of flight. The hierarchy should be established at the rostering/scheduling stage and should be promulgated by the flight crew. A crewmember qualified as pilot-in-command should be at the controls at all times. Any assigned pilots who are not takeoff-and-landing qualified should be trained to support the command-qualified pilot in conducting landings and emergency procedures, including pilot incapacitation and emergency evacuation.

Education

- Regulatory authorities should require the operator to provide appropriate education to ground staff and flying staff associated with ULR operations. This should include, but not be limited to, management, flight crew, cabin crew, scheduling and rostering staff, dispatchers (as appropriate), operational control staff, and airline medical service providers. Training should be tailored to the job description, using modular content for different audiences, and should be evaluated as ULR experience is gained.
- Curricula should include, but not be limited to, the following topics:
  - Consequences of fatigue on aviation safety;
  - Confidential feedback from incidents;
  - Recognition of signs of fatigue and decreased alertness in self and others;
  - Physiology of sleep;
  - Circadian rhythms;
  - Homeostatic process;
  - Sleep and alertness strategies;
  - Diet and hydration;
  - Prescription and nonprescription medication, plus related regulatory policies;
  - In-flight environment;
  - Work scheduling; and,
  - Crew coordination to address sleep inertia after in-flight rest.

Delays and Disruptions

- The approval for ULR operations should include a maximum departure delay after scheduled time of departure as a limit. The allowable delay time is ULR city-pair-dependent and may be different for the home base and the outstation, and for different city pairs. The proposed departure-time window should be designed to cover the approved delay time and to allow for flexibility in the event of rescheduling while ensuring that a crew is rested. Caution is required to avoid the "creeping-delay" effect.

- As part of the ULR city-pair approval, regulatory authorities should require operators to demonstrate plans to cope with delays and disruptions, including diversions.

- A diversion may result in reversion from the flight and duty time limitations of ULR flight to those of long-range flight. The operator should conduct risk assessment on possible alternate airports during initial ULR planning, to include seasonal weather (e.g., snow), air traffic management, local area issues (e.g., terrain, local wind effects, wind shear) and specific training for some diversion airports. Pilots, schedulers, operational managers and non-operational managers should receive risk-assessment training for ULR flights to include unusual situations, diversions, change of flight operations (e.g., ULR flight to long-range flight) after an en route technical stop — including support/assistance/advice to pilots from the home base.

- The pilot-in-command has the final authority for any variation from the ULR scheduled duty. After consulting with all operating crewmembers, the pilot-in-command should assess crew fatigue levels to determine whether the flight can be conducted safely.

Standby

- Regulatory authorities should require the operator to demonstrate that its standby activation system will ensure that a crewmember assigned to ULR duty from standby status will have fulfilled the pre-ULR rest requirements.

- ULR operations may require a dedicated standby system with crewmembers aware of the potential ULR assignment.

- Early notification of in-flight rest allocation is desirable.

In-flight Environment

- Rest:

  – Regulatory authorities should require the operator to demonstrate that the crew-rest facilities are sufficient to provide adequate rest opportunity in order to ensure that pilot alertness is maintained at an acceptable level. Preferably, these should include both an acceptable sleeping surface and the provision of a comfortable reclining seat for non-sleeping rest. Ideally, each resting pilot should have an individual sleeping compartment with facilities available to enable him or her to have a choice of a comfortable reclining seat or sleeping surface at all times. These facilities should be separated from the flight deck and not be positioned in the passenger cabin.

  – Comment: It is assumed that the design requirements for the crew-rest facilities will be covered under a separate document (e.g., advisory circular). The following factors should be considered, as well as other sleep/rest-related requirements:

    - Noise levels;

    - Space for changing into and out of uniform/sleep suit;

    - Reading lights;

    - Ventilation, temperature and humidity controls;

    - Alert systems and a communication system to the flight deck and passenger cabin; and,

    - In-flight entertainment and other passenger-cabin provisions.

- Lavatories:

  – There should be a lavatory dedicated for flight crew use within a secure area and accessible from the flight deck.

- Flight deck environment:

  – Due consideration should be given by operators to encourage manufacturers to continue improving flight deck ergonomic design aspects to assist in reducing stress and fatigue levels. Examples could include comfortable seating, suitable lighting, adequate provision of sunshades on all windows (to limit sunlight and heat), noise management, humidification and appropriate alert systems.

Rostering Practices

- ULR operating pattern (including flights and layovers) — The build of a ULR pattern should:

  – Provide adequate preflight sleep opportunities (preferably, a period of rest that affords two major sleep opportunities) so that it is possible for crewmembers to be fully rested prior to departure;

  – Ensure that the layover provides an adequate sleep opportunity (preferably, two sleep opportunities) so the crewmembers are adequately rested for the return flight;

  – Provide adequate recovery time after the pattern to allow for physiological recovery from the trip;

– Provide reasonable additional time off for normal social interaction; and,

– The recovery time should not be used as pre-ULR rest requirements.

- In-flight rest:

  – Regulators should ensure that operators have a responsible scheme for in-flight rest planning.

  – Operators should provide guidance to crew for in-flight rest planning.

  – This information should be tailored for the specific flight pattern.

  – Crews should be given adequate prior notification of their allocated in-flight rest period.

  – Although preprogrammed rest periods are highly desirable, the crew should have the flexibility to alter the plan, if needed, once aboard the airplane.

  – Guidance should be provided on how to manage crew change/handover procedures following a rest period. The implications of sleep inertia should be emphasized.

  – Cockpit napping (or controlled rest on the flight deck) can provide effective short-term recuperation but should be used cautiously and not as a replacement for planned rest in a bunk or to extend approved duty times.

- Scheduling of ULR trips:

  – Positioning is considered duty and may not be part of a pre-ULR rest period.

  – A ULR flight duty period may not be combined with other duties in a single duty period (e.g., simulator sessions, recovery days, office work or other flights).

Go/No-go

- Operators should provide the crew with suitable go/no-go guidance material affecting crew performance with regard to crew alertness and/or rest facilities on:

  – Minimum equipment list (MEL) provisions;

  – Delays;

  – Disruptions;

  – Diversions; and,

  – Any other areas that may affect crew alertness.

Operational Validation Programs

Overview of the Validation Process

- Before initiation of ULR operations, a steering committee composed of representatives from the operator, pilots' group and regulators must be established and define the validation plan (Figure 1, page 10). The assistance of a subject matter expert (SME) may be required. The steering committee will select an "independent" scientific organization to assist in the data collection, analysis and recommendations. The SME should be from a different organization than the scientific group conducting the validation.

- Validation is required from the commencement of ULR flights and should be conducted in two phases: initial validation and ongoing monitoring. The initial validation should be sufficiently rigorous to ensure operational safety equivalent to, or better than, that in current long-range operations.

- As a result of initial validation, the operational model may then be adjusted as required, and ongoing monitoring will continue to take place.

What Should Be Validated?

- Validate the ULR operational model to include validation of the agreed assumptions upon which the ULR approval is based. For example, this includes variables such as the city pairs, aircraft types, departure windows, routing, pre-ULR rest, post-ULR rest, crew complement, in-flight rest strategy, rest rostering in flight, etc.

- The objective is to determine whether the level of flight crew performance/alertness and safety is equivalent to or better than that existing in current long-range operations.

When Validation Should Take Place

- Initially, at launch of operations;

- Continuous monitoring is required;

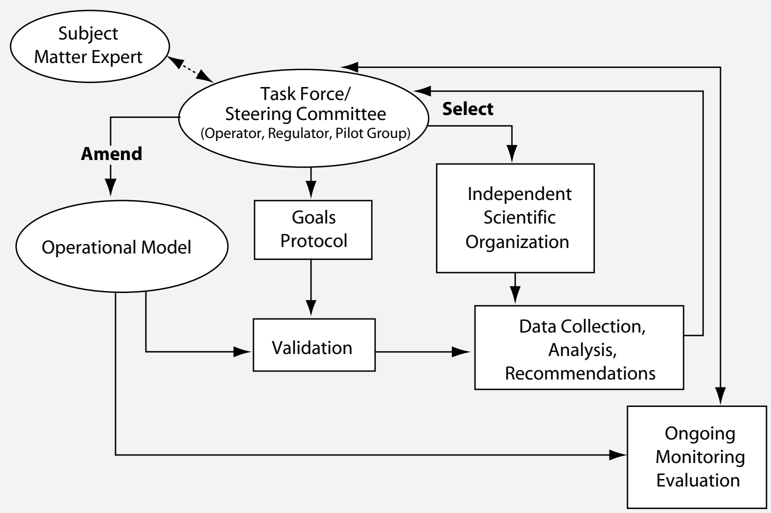
- Specific validation may be required; and,

- Any change to the ULR operational model.

  The recommendation is that the steering committee will, in each case, assess any change to the ULR

Figure 1

Validation Process of the Operational Model



Source: Ultra-long-range Crew Alertness Steering Committee

operational model and decide whether some type of validation is needed for that particular change.

Triggers for Reassessment

- The primary triggers requiring reassessment by the steering committee are changes to city pair, departure-time window, time zone or aircraft type.
- These secondary triggers also should be considered:
  - Crew demographic change (e.g., age distribution, gender distribution, etc.);
  - Crew base change; and,
  - Same city pairs, but route change.

Validation Metrics

- Initial validation must include both subjective measures and objective measures, using a combination of the following methods:
  - Sleep: sleep diaries (subjective), Actiwatches[5] with diaries (objective), polysomnography[6] (objective);
  - Alertness: subjective rating scales, electroencephalography (EEG)/electrooculography (EOG) (objective); and,
  - Performance: subjective rating scale, reaction time tests (objective), other cognitive tasks (objective).
- Ongoing monitoring may include some of the methods listed above in addition to normal processes as adopted by the operators (e.g., FDM, LOSA, crew reports, air safety reports, etc.), regulatory feedback and/or confidential reporting.

Global Regulatory Approach

Regulatory Requirements:

To be granted approval to conduct ULR operations, an operator must comply with the following minimum requirements:

- Submit to the applicable civil aviation authority an operational plan that has been developed using a scientifically based approach, or equivalent, to achieve an acceptable level of safety, taking into account at least the following:
  - Departure-time windows;
  - Rostering arrangements for operating flight crew and cabin crew, and standby crewmembers;
  - Proposed rest requirements:
    - Preflight;
    - In-flight; and,
    - Postflight;
  - Crew complement: A minimum of four appropriately qualified flight crewmembers to include a minimum of two pilots who must be pilot-in-command qualified, plus augmented cabin crew to enable adequate rest on board;
  - Standby activation;
  - Exceptional circumstances/commander's discretion: The commander's discretion should be limited to a maximum extension of three hours to the flight duty period; and,
  - Proposed validation program.

Note: It is not the intent of this document to preclude future flight schedules comprising more than two sectors, one of which is a ULR sector. The key issue is sufficient rest before/after each ULR sector with rest times still predicated by ULR requirements. Common license/

mixed-fleet operations allow crews to mix ULR sectors and other sectors. However, any changes to the originally approved and validated city pair operation will require a revised operational plan. The ability of the industry to address such changes will be improved in the light of actual ULR experience. The ULR planning process for new routes should be conservative and should include integration of pilot rosters to include existing routes that ensure adequate rest between duties.

- Propose a validation program that covers at least the following:
  - Establishment of an operational steering committee comprising representatives of the company, the regulator and the pilots' association to define the validation plan and provide oversight;
  - Standardized methodology for initial validation:
    - Sample size;
    - Sampling intervals;
    - Objective measures — operational and/or individual; and,
    - Subjective measures;
  - Ongoing monitoring — all aspects (i.e., sleep achieved, performance, etc.):
    - Sample size;
    - Sampling intervals;
    - Objective measures — operational and/or individual; and,
    - Subjective measures;
  - Occasions when revalidation is required; and,
  - Feedback reporting system.
- Develop rest requirements that take into account both preparatory and recuperative rest (including sleep) that meets the modeled assumptions, or equivalent, covering:
  - Preflight;
  - In-flight; and,
  - Postflight;

  Note: It is intended that before a crew undertakes a ULR operation, both flight and cabin crewmembers will be acclimatized to the initial point of departure both before a ULR operation and, following return from a ULR operation, before undertaking any other flight duty. Cabin crew scheduling may require special attention because of the ability of cabin crewmembers to crew multiple aircraft types.
- Provide adequate rest facilities that enable horizontal rest for crewmembers resting in flight (e.g., Australian and International Pilots Association facility standard AIPARS 001-1998, toilet requirements, environment, etc.);
- Develop material to provide appropriate training and education for all staff involved in the operation; and,
- Develop material for the operations manual that addresses all of the above.

  Note: Regulators may need to review/revise existing regulatory material in the light of ULR operations (e.g., where existing "hard" limits may be exceeded by ULR — 18 hours maximum flight duty period) and "grandfather rights."

Approval Process

The approval process will require at least the following:

- Initial approval:
  - Submission of the proposed operational plan;
  - Consideration of the proposed operational plan by the civil aviation authority. This should be an iterative process between the civil aviation authority and the operator;
  - Submission of operations manual amendments reflecting the proposed operational plan; and,
  - Initial approval by the civil aviation authority (e.g., operations specifications/variations/approval/interim approval).
- Final approval and ongoing safety oversight by the civil aviation authority, which, based on the validation program, may require modification of the regulatory basis.
- City pairing — Once a city pair has been approved, additional destinations in the same "cluster" may be considered, taking into account the following to achieve an equivalent level of safety:
  - Time zone;
  - Departure-time windows;
  - Acceptable increase in flight time;
  - Operational variables; and,
  - Risk levels.

Recommendations

- The International Civil Aviation Organization (ICAO) should establish an SME group to develop standards and recommended practices (SARPs) for fatigue risk management to be incorporated in *Annex 6 to the Convention on International Civil Aviation: Operation of Aircraft* that will encompass ULR operations. An FRMS is an integral part of a safety management system that provides a means of ensuring that employees' alertness and performance are not degraded to an unacceptable level as a result of fatigue. The purpose of an FRMS is to reduce the errors, incidents and accidents in which fatigue is a contributory factor. An FRMS is expected to lead to improved safety, efficiency, productivity and operational flexibility while satisfying the operator's duty of care to its employees and to the public.

- Because on-board crew sleep is a critical factor in ULR operations, the quality of the crew-rest facility is of paramount importance. Regulatory guidance material should be developed to ensure that crew-rest facilities are adequate for proposed ULR operations.

- The ULR Crew Alertness Steering Committee recognizes that ensuring flight crew proficiency is a critical issue for assuring the safety of ULR operations; however, it was deemed outside the prescribed scope of crew alertness which governed this initiative. Another, more qualified, group should consider flight crew proficiency for ULR operations and define the regulatory requirements necessary to achieve them.

Research and Development

The goal of the ULR Crew Alertness Steering Committee's proposed research and development is to better understand and predict the impact of flight and duty schedules and rosters on crew performance and flight safety. There are some key research questions and issues that need to be addressed.

Research That Needs to Be Done

- What are the relationships between objective and subjective measures of sleep quality/quantity? Use polysomnography, which is the current standard among objective measures and involves analysis of data showing brain-wave activity (electroencephalography), eye movement (electrooculography) and muscle tone (electromyography) to validate other methods that could be equally effective or more effective but cost less to implement than polysomnography.
  - Wherever possible, multiple measures should be used until these relationships are clearly established. This will enable advice to the operational community on which measures to use in which circumstances (could enable a tool kit to be created for validation of ULR operations and possibly other operations, and continuous improvement within an organization).

- Establish the linkages between physiological alertness (electroencephalography), vigilance (psychomotor vigilance task) and flight crew performance (FDM and LOSA).
  - Wherever possible, multiple measures should be used until these relationships are clearly established. This will enable advice to the operational community on which measures to use in which circumstances (could enable a tool kit to be created for validation of ULR operations and possibly other operations, and continuous improvement within an organization).

- Continue the search for practical methods for monitoring circadian phase in field settings. The current standard markers for circadian phase are the evening rise of melatonin and body temperature low point. Melatonin cannot be sampled during sleep and is suppressed by light. Temperature is influenced by levels of physical activity, and monitoring is intrusive. There are several reasons why it would be useful to be able to predict circadian phase:
  - To know where the circadian low point is occurring (if in flight);
  - To optimize personal sleep strategies; and,
  - To determine the rate of readaptation and recovery at the conclusion of a flight pattern.

- Research on the effects of aging on sleep (on-board, during layovers and between trips) and its impact on operational performance.

- Research on the impact of ULR (and other) schedules on family and social life of crew. There are growing indications in shift-work research that life outside of work is an important intervening variable in an individual's ability to cope with work demands. This information can be valuable, for example, in education and training, and work force morale and retention.

- Research on long-term health implications for crew of ULR and other schedules.

  Multivariate analyses are recommended to take account of factors such as age, order in the bunk, crew rank, gender and individual variability.

Mathematical Model Application Issues

Mathematical modeling is a tool that is based on known situations and may be used to predict outcomes in the absence of data.

- No mathematical model captures all aspects of a situation.

- The data set used to develop the mathematical model should be relevant to the situation being predicted (e.g., the characteristics of the population, the environment in which the data were collected, etc.).

- Different mathematical models use different inputs and provide different outputs. The inputs need to be able to be measured practically in the work environment (e.g., prior work history is easy, light exposure is more difficult). The outputs have to be tailored to the problem being addressed (e.g., to what degree mathematical model predictions are indicative of overall flight crew performance).

- Mathematical models should not be used in isolation. They are one tool that can be used to develop and assess ULR operations and are a support, but they are not a substitute for operational knowledge and standard regulatory processes.

Improving Mathematical Models

Mathematical modeling is an iterative process of data collection and model refinement. The following are suggestions for improving the process:

- Every effort should be made to share existing data for mathematical model validation. This could be facilitated by a central research advisory panel.

- Create and improve dialog between the operational community and mathematical modelers (integrate operational personnel into mathematical-modeling teams).

- Encourage mathematical modelers to communicate and publish their efforts.

Mathematical models need to be strengthened in the following areas:

- Progressively address individual variability.

- Predictive mathematical models should be expanded to include measures of reliability/variability/confidence.

Application of Research and Mathematical Modeling to Operational Validation Programs

- Develop an integrated approach to research, mathematical modeling and operational validation for continuous improvement of ULR operations (the iterative process).

- Build tools for the regulators and operators by standardizing:

  – Questionnaires and diaries/logs;

  – Data-collection protocols (e.g., duration of preflight and postflight recording periods); and,

  – Actigraphy methodology (e.g., epoch length, sensitivity settings and event markers).

- Address the comparability of different performance and vigilance testing devices.

- Provide feedback to the research community of data collected for operational validation, as part of the continuous improvement process.

General Principles

- Funding:

  – Availability of funds — who should fund?

  – Those that will benefit should fund — the stakeholders (e.g., manufacturers, operators, regulators, crew associations).

- Conditions of funding:

  – Minimize proprietary information and maximize public availability.

  – Define incentives:

    - Worldwide improvement in safety;

    - More efficient and accurate tools for ULR route planning and validation;

    - Reduce duplication of effort; and,

    - Recognition that the public interest could benefit the company (customer loyalty).

  – Address disincentives to making information available:

    - Shareholder interests/profits; and,

    - Perceived loss of competitive advantage.

- Visibility and accessibility of data and results: All research projects should include a full report to all stakeholders, peer-reviewed publications and feedback to the research advisory panel (for quality assurance).

- Standardized methodology should be employed as much as possible because it allows for comparability/

sharing of data for research and operational validation purposes (e.g., subjective and objective measures of sleep and alertness).

Recommendations

A research advisory panel should be created under the auspices of Flight Safety Foundation, ICAO, etc. The aim is to provide a focal point for research in ULR operations.

Membership of this body should include specialists from the following types of organizations:

- Manufacturers;
- Operators;
- Regulators;
- Scientific researchers; and,
- Crew associations.

The objectives of this body are to:

- Provide a source of information/advice on ULR operations;
- Develop a register for past, present and proposed research projects, including data collection for operational validation;
- Develop a register of qualified and competent research teams; and,
- Develop standard data collection and analysis methods for operational validation.

The registration of research teams and projects, although voluntary, would be strongly encouraged. The research advisory panel will develop information templates for submitting details about mathematical model specification and use, research teams and projects.

- An example of a template for model specification appears on pages 18 and 19 of the May–June 2003 edition of *Flight Safety Digest*.

With regard to the research projects, the intention is that the research advisory panel will provide high-level descriptions of objectives, methods, datasets available and personnel to contact. Any more detailed exchange of information would be negotiated directly between the parties. ■

Notes

1. Beginning in late 2000, the Ultra-long-range (ULR) Crew Alertness Steering Committee has conducted four workshops through cosponsorship of Airbus, Boeing Commercial Airplanes and Flight Safety Foundation. The Air Line Pilots Association, International and the International Association of Air Line Pilots' Associations participated in cosponsoring the fourth workshop in May 2005.
2. The ULR Crew Alertness Steering Committee defines a ULR flight as "an operation involving any sector between a specific city pair (A-B-A) in which the planned flight time exceeds 16 hours, taking into account mean wind conditions and seasonal changes."
3. The U.K. Civil Aviation Authority, in Civil Aviation Publication 739, *Flight Data Monitoring,* first issued Aug. 29, 2003, defines *flight data monitoring* (FDM) as "the systematic, proactive and nonpunitive use of digital flight data from routine operations to improve aviation safety." Another term for FDM is *flight operational quality assurance* (FOQA).
4. A line operations safety audit (LOSA) involves the collection of data by trained observers during routine flights to determine how flight crews detect, manage and mismanage threats and errors. The International Civil Aviation Organization (ICAO) has endorsed LOSA as a tool for monitoring normal flight operations and developing countermeasures against human error. ICAO Document 9803, Line Operations Safety Audit (LOSA), contains detailed information on planning and conducting a LOSA, including guidelines for airlines on using LOSA data to gauge operational strengths and weaknesses. LOSA also enables airlines to compare data among de-identified data gathered by other airlines.
5. The Actiwatch — a small, lightweight device approximately the size of a wristwatch — measures and records motions of the body; this research method is called actigraphy. Actigraphy devices have proven to be highly sensitive to sleep, and they are a useful means of objectively monitoring sleep over extended periods of time.
6. Polysomnography, a method of recording in-flight sleep data, involves recording brain activity (by electroencephalography), eye movement and muscle tone using small electrodes that are attached to the head and the face of the pilot.

Appendix B

Ultra-long-range Crew Alertness Initiative Steering Committee Members and Other Participants

Ultra-long-range Crew Alertness Steering Committee (2005)

Capt. Greg Fallow, New Zealand Air Line Pilots Association, International Federation of Air Line Pilots' Associations (IFALPA) and Air New Zealand

Philippa Gander, Ph.D., Sleep/Wake Research Centre, Massey University

R. Curtis Graeber, Ph.D., Boeing Commercial Airplanes (co-chairman)

Dr. Jarnail Singh, Civil Aviation Authority of Singapore

Barbara Stone, Ph.D., QinetiQ

Capt. Robert Ting, Singapore Airlines (Association of Asia Pacific Airlines)

Régine Vadrot, Airbus

Robert Vandel, Flight Safety Foundation (co-chairman)

Capt. Bryan S. Wyness, Air New Zealand

Richard Yates, Aviation Consultant

Larry Youngblut, U.S. Federal Aviation Administration

Other Participants in Ultra-long-range Crew Alertness Workshop (2005)

Capt. Masayuki Ando, IFALPA

Phil Armitage, Qantas Airways

Dr. Greg Belenky, Sleep and Performance Laboratory, Washington State University

Derek Brown, U.K. Civil Aviation Authority

Capt. Jean F. Certain, Air France

Patrick Seow Thiam Chye, Singapore Airlines

Capt. M. Davis, Hong Kong Civil Aviation Department

Drew Dawson, Ph.D., Centre for Sleep Research, University of South Australia

Capt. Don Dillman, American Airlines

Foo Juat Fang, Singapore Airlines

Georg Fongern, IFALPA

Capt. Carl Hager, Pilot Association, South African Airways

Capt. Paul Ho K.C., Singapore Airlines

Capt. Gary Hogan, Northwest Airlines

Dr. Ian Hosegood, Emirates

Dr. Don Hudson, Aeromedical Associates

Steven R. Hursh, Ph.D., Science Applications International Corp. and Johns Hopkins University

Jim Johnson, Air Line Pilots Association, International (ALPA)

Capt. Edward Jokinen, Air Canada

Kathryn Jones, British Air Line Pilots Association (BALPA)

Capt. Ng Kok Seong, Air Line Pilots Association–Singapore (ALPA–S)

Candace Kolander, U.S. Association of Flight Attendants

Senior First Officer Shane Landsberger, ALPA–S

Capt. Chris Lawrence, Hong Kong Air Line Pilots Association (Cathay Pacific)

Capt. Wan-Lee Lee, Civil Aeronautics Administration, Taiwan, China

Capt. Dave Lynch, Air Canada

Capt. Jim Mangie, Delta Airlines (Air Transport Association)

Dominique Marchant, Direction Générale de l'Aviation Civile (DGAC), France

Capt. Bob Markert, United Airlines

Genevieve Molinier, DGAC

Lam Seet Mui, Singapore Airlines

Capt. Rapintara Nitayavardhana, Thai Pilots Associations (THAIPA)

Dr. Rose Ong, Cathay Pacific Airways

Gayle Otsuka, Boeing Commercial Airplanes

Dr. David Powell, Air New Zealand

Capt. Stan Prout, Australian and International Pilots Association (Qantas Airways)

Senior First Officer Visu Ramasamy, ALPA–S

Capt. Selva Rasiah, ALPA–S

Jeff Rees, Civil Aviation Authority of New Zealand

Capt. Carsten Reuter, German Air Line Pilots Association

Capt. Paul Ridley, Emirates

Greg Roach, Ph.D., Centre for Sleep Research, University of South Australia

Wayne Rosenkrans, Flight Safety Foundation

Capt. Mohd. Al Sam, General Civil Aviation Authority, United Arab Emirates

Alex Samel, Ph.D., Institute of Aerospace Medicine, German Aerospace Center (DLR)

Leigh Signal, Ph.D., Sleep/Wake Research Centre, Massey University

Dr. Ries Simons, Netherlands Aeromedical Institute

Capt. Worapote Siriwunsakul, THAIPA (Thai Airways)

Mick Spencer, QinetiQ

Jean-Jacques Speyer, Airbus

Capt. Jim Starley, Continental Airlines

Capt. Glenn Sycamore, Cathay Pacific Airways

Allan Tang, Civil Aviation Authority of Singapore

Senior First Officer William Teng, ALPA–S

Matthew Thomas, Ph.D., Sleep Research Centre, University of South Australia

Senior First Officer Nick Trowsdale, BALPA (British Airways)

First Officer Douglas Tweedlie, Air Canada Pilots Association (Air Canada)

Shoichiro Umeda, Japan Airlines

Pierre Valk, Ph.D. Netherlands Aeromedical Institute

Capt. Klaus Walendy, Airbus

Capt. Phillip Walker, Cathay Pacific Airways

Capt. Dave Wells, ALPA (Federal Express)

Capt. Frank Williamson, ALPA (United Airlines)

Capt. Kent Wilson, Air Canada Pilots Association

Diana Woo, Singapore Airlines

Capt. Johnny Woods, South African Airways

Fatigue Risk Management System Helps Ensure Crew Alertness, Performance

An essential element for ultra-long-range flight operations, an FRMS goes beyond traditional flight and duty time regulations.

— ULR CREW ALERTNESS STEERING COMMITTEE

Adequate crew-rest facilities aboard aircraft conducting ultra-long-range flights are vital in helping to combat fatigue.

(Photo: Boeing)

Flight and duty time limitations, and rest requirements traditionally have provided the regulatory basis for managing fatigue. A fatigue risk management system (FRMS) provides an alternative, scientifically based means of managing the risks associated with fatigue and can enable companies to safely conduct flight operations beyond existing prescriptive regulatory limits.

An FRMS is an integral part of a safety management system that provides a means of ensuring that employees' alertness and performance are not reduced to an unacceptable level as a result of fatigue. The purpose of an FRMS is to prevent errors, incidents and accidents in which fatigue is a contributory factor. An FRMS is expected to improve safety, efficiency, productivity and operational flexibility while satisfying the company's duty of care to its employees and to the public.

An FRMS should include the following elements:

- A fatigue risk management policy;

- Education and awareness training programs;
- A crew fatigue-reporting mechanism with associated feedback;
- Procedures and measures for assessing and monitoring fatigue levels;
- Procedures for reporting, investigating and recording incidents that are attributable wholly or partially to fatigue; and,
- Processes for evaluating information on fatigue levels and fatigue-related incidents, implementing interventions and evaluating their effects.

Figure 1 summarizes the proposed overall structure of an FRMS. The detailed structure of an FRMS might vary for different work groups within a company and among different-size companies.

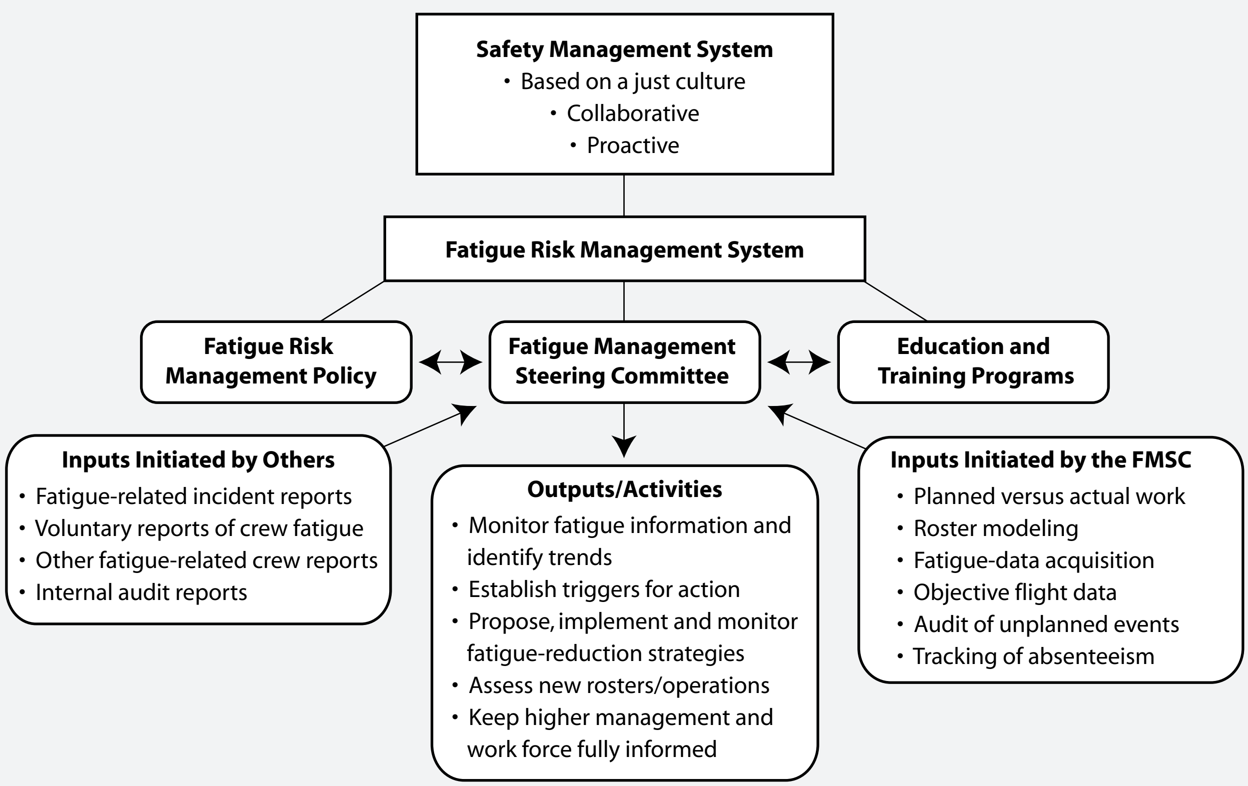
Fatigue Risk Management Policy

The company's fatigue risk management policy must be an integral part of its safety policy. The fatigue risk management policy should be open and transparent (i.e., clearly written and readily available to all crewmembers), and should include the following elements:

- Commitment by the highest levels of company management to fatigue risk management;
- A specified line of accountability in the company for fatigue risk management;

Figure 1

Fatigue Risk Management System Structure



FMSC = Fatigue management steering committee

Source: Ultra-long-range Crew Alertness Steering Committee

- Definition of the responsibilities of the company management and the employees;
- Identification of the work groups covered by the FRMS;
- Terms of reference for a fatigue management steering committee (FMSC), including frequency of meetings;
- Identification of fatigue-reporting mechanisms;
- Policies for identifying and managing employees who are fatigued to an extent that represents a safety risk, including provisions for employees to opt out of assignments;
- Commitment to provide training and resources in support of the fatigue risk management policy; and,
- Commitment to act on recommendations regarding fatigue risk management that arise from an internal audit.

Functions of the FMSC

The FMSC is the focal point for coordinating all fatigue risk management activities within the company. The FMSC's functions include the following:

- Monitoring fatigue-information sources;
- Investigating fatigue-related issues;
- Requesting an internal audit of specific issues;
- Proposing solutions to fatigue-related issues;
- Making recommendations on priorities for targeting fatigue-management resources;
- Providing timely feedback to the work force;
- Providing transparent and timely feedback to the highest levels of company management;
- Cooperating with internal audits and regulatory audits; and,
- Overseeing the quality assurance of fatigue risk management training (initial and recurrent) across the company.

Representation on the FMSC

The FMSC should include balanced representation from the company and employees, with scientific/specialist advice available as needed. Company and employee representatives may be drawn from the following groups:

- Cabin crewmembers;
- Flight crewmembers;
- Medical staff;
- Manpower planners/rosterers;
- Commercial/marketing staff;
- Training staff;
- Technical staff;
- Safety staff; and,
- Operations staff.

Information Sources

Sources of information for the FMSC include the following:

- Information initiated by others:
  - Voluntary fatigue reports (confidentiality optional);
  - Other fatigue-related reports from crew (e.g., captain's special reports, cabin crew voyage reports);
  - Monitoring of calls reporting that a crewmember is "too fatigued" to take duty;
  - Fatigue-related incident reports;
  - Internal and external audit reports; and,

  – Periodic external scientific/specialist review of the FRMS.

- Information initiated by the FMSC:

  – Planned work versus actual work (e.g., rostered/scheduled duty versus actual duty, trip swapping, use of reserve and standby);

  – Roster modeling;

  – Fatigue-data acquisition (e.g., questionnaires, diaries, actigraphy,[1] performance testing);

  – Objective flight data (e.g., from flight data monitoring [FDM],[2] line operations safety audits [LOSA][3]);

  – Audit of unplanned events (e.g., delays, diversions, captain's discretion, etc.); and,

  – Tracking of absenteeism.

Activities and Outputs

The FMSC's activities and outputs include the following:

- Monitoring fatigue information and identifying trends;
- Establishing triggers for action;
- Proposing, implementing and monitoring fatigue-reduction strategies (e.g., roster changes, layover hotels, crew rest);
- Assessing new rosters/operations; and,
- Keeping higher levels of management and the work force fully informed of the activities, findings and recommendations of the FMSC.

Recommendations

The Ultra-long-range (ULR) Crew Alertness Steering Committee[4] recommends that:

- An FRMS, with appropriate regulatory oversight, should be considered as an acceptable alternative to prescriptive flight and duty time limitations and rest requirements. For operators that choose this alternative means of regulatory compliance, the FRMS should become a required component of the safety management system;
- An FRMS should be an essential element of ULR flights; and,
- Some components of an FRMS — in particular, fatigue-management education and awareness training programs — should be required as part of any prescriptive regime.■

Notes

1. Actigraphy is a research method that objectively detects and monitors sleep over extended periods of time through the use of devices, such as the Actiwatch (a small, lightweight device approximately the size of a wristwatch), to measure and record motions of the body.
2. The U.K. Civil Aviation Authority, in Civil Aviation Publication 739, *Flight Data Monitoring,* first issued Aug. 29, 2003, defines *flight data monitoring* (FDM) as "the systematic, proactive and nonpunitive use of digital flight data from routine operations to improve aviation safety." Another term for FDM is *flight operational quality assurance* (FOQA).
3. A line operations safety audit (LOSA) involves the collection of data by trained observers during routine flights to determine how flight crews detect, manage and mismanage threats and errors. The International Civil Aviation Organization (ICAO) has endorsed LOSA as a tool for monitoring normal flight operations and developing countermeasures against human error. ICAO Document 9803, *Line Operations Safety Audit (LOSA)*, contains detailed information on planning and conducting a LOSA, including guidelines for airlines on using LOSA data to gauge operational strengths and weaknesses. LOSA also enables airlines to compare data among de-identified data gathered by other airlines.
4. Beginning in late 2000, the Ultra-long-range (ULR) Crew Alertness Steering Committee has conducted four workshops through cosponsorship of Airbus, Boeing Commercial Airplanes and Flight Safety Foundation. The Air Line Pilots Association, International and the International Association of Air Line Pilots' Associations participated in cosponsoring the fourth workshop in May 2005.

The Singapore Experience

Task Force Studies Scientific Data to Assess Flights

Culminating a process begun in 1998, ultra-long-range flights by Singapore Airlines provided scientific validation of operational plans while integrating current perspectives of the civil aviation authority, the airline, the pilot association and consulting scientists specializing in pilot sleep, fatigue and alertness.

— CAPT. PAUL HO K.C., SENIOR FIRST OFFICER SHANE LANDSBERGER,
LEIGH SIGNAL, PH.D., DR. JARNAIL SINGH; AND BARBARA STONE, PH.D.

Alertness levels on the flight deck were monitored by scientists during initial ultra-long-range flights conducted by Singapore Airlines in the Airbus A340-500.
(Photo: Copyright Airbus)

Singapore Airlines launched daily ultra-long-range (ULR)[1] flights in February 2004 with Singapore–Los Angeles, California, U.S., as its first ULR city pair.[2] Daily flights between a second ULR city pair — Singapore–New York, New York, U.S. — commenced in June 2004. The following overview of the issues involved in the rule-making process, including several years of activities leading to these flights and their subsequent scientific validation, integrates the perspectives of the Civil Aviation Authority of Singapore (CAAS), Singapore Airlines, the Air Line Pilots Association Singapore (ALPA–S) and consulting scientists specializing in crew sleep, fatigue and alertness.

Following the 1998 application by Singapore Airlines to operate nonstop flights to Los Angeles using Airbus A340-500 aircraft, CAAS established the CAAS ULR Task Force in 1999 to examine the feasibility of such flights, given that the proposed flight sectors would involve flight-time limitations (FTLs) in excess of the 16 hours permitted by CAAS regulations.

The CAAS ULR Task Force comprised members from CAAS, Singapore Airlines and ALPA–S. Their objective was to develop recommendations accommodating the proposed ULR flights. Where required, the recommendations could be unique to the environment of ULR flights and would not impinge upon other types of current operations. The recommendations later culminated in CAAS issuing a set of rules for ULR flights.

In recognition that the ULR flights would be treading on new regulatory territory, the CAAS ULR Task Force agreed that conservatism would be built into the rules. Members also agreed that the rules for ULR flights would have to be validated by scientific studies of flight crews after the flights were launched.

The CAAS ULR Task Force began by studying the current FTLs and how they had been developed, including the reasons for mandatory breaks after a number of consecutive flight-duty periods (FDPs), and the monthly FTLs and yearly FTLs for prevention of cumulative fatigue.

The association of the number and composition of pilots with the duration of a flight was studied, as were factors for the avoidance of fatigue. The task force also studied regulations governing flight times adopted by other regulatory authorities worldwide and the scientific literature available on the topic. The focus was on how, over the years, FTLs had changed and on the factors that had enabled these changes to be made.

During early deliberations of the CAAS ULR Task Force, members recognized the futility of trying to develop "generic" recommendations that could cover all possible scenarios in ULR flights (i.e., recommendations applicable irrespective of time of departure/landing, destination, time-zone change and flight duration). Thus, deliberations focused on the Singapore–Los Angeles ULR city pair with defined departure/landing windows for Singapore and Los Angeles.

In a parallel initiative begun in late 2000, the issues associated with ULR flights were discussed comprehensively in a series of four industry workshops cosponsored by Airbus, Boeing Commercial Airplanes and Flight Safety Foundation. Participants in the first workshop in Washington, D.C., U.S., in June 2001 defined a ULR flight and the basic method of formulating acceptable limits for crew alertness on ULR flights. They agreed that the alertness levels should be no less than those typical of current long-range flights.

Participants in the second workshop in Paris, France, in March 2002 underscored the need to look at the issues of ULR flight in a focused manner (i.e., considering a defined city pair, defined departure windows and a defined aircraft type). This was, in essence, the method that had been advocated by the CAAS ULR Task Force.

Participants in the third workshop in Kuala Lumpur, Malaysia, in March 2003 provided the framework for a method of rule making with guidance on the key issues of ULR flight.

The fourth workshop in Los Angeles in May 2005 included presentations of the following findings from the Singapore experience and related subjects.

Singapore Task Force Links to European Studies

To gauge the possible levels of fatigue and alertness on the proposed ULR flights for the Singapore–Los Angeles ULR city pair, the CAAS ULR Task Force envisaged a requirement to use the available data on current long-haul operations. Members also identified a requirement for focused research.

At about this juncture in the CAAS ULR Task Force deliberations, Airbus applied to the European Joint Aviation Authorities (JAA) for certification of the A340-500 aircraft, including its ULR flight capability.

JAA commissioned the European Committee for Aircrew Scheduling and Safety (ECASS) to conduct a study to predict the levels of alertness on ULR flights operating with four pilots. ECASS includes scientists from QinetiQ (United Kingdom), Karolinska Institute (Sweden), Rene Descartes University (France), German Aerospace

Center and Netherlands Organization for Applied Scientific Research. The Singapore–Los Angeles ULR city pair was used as the case study by ECASS because these routes were considered the "launch pad" for initial ULR flights with the A340-500. JAA invited CAAS representatives as observers for the JAA–ECASS study.

Other assumptions in this study were:

- Defined departure windows from Singapore and from Los Angeles;
- A Singapore to Los Angeles FDP of 18 hours, 10 minutes;
- A Los Angeles to Singapore FDP of 20 hours, 25 minutes;
- Time difference between Singapore and Los Angeles of nine hours;
- A layover of 48 hours or 72 hours; and,
- Division of the cruise phase of the flight to give each pilot two in-flight rest periods.

ECASS conducted computer-based modeling to predict the levels of alertness of the flight crew during the proposed ULR flight. The results of the modeling indicated that it should be possible for a four-person crew to operate the route without experiencing greater problems with fatigue than they are exposed to in several current long-range operations. The model also predicted that crew alertness would be better if each pilot took two in-flight rest periods instead of one.

Volunteer pilots were asked to maintain a diary that recorded sleep and duty.

The ECASS scientists also said that ULR flights would require careful monitoring and that the in-flight crew-rest facilities would have to be of a high standard providing an environment conducive to sleep.

Following the JAA–ECASS study, the CAAS ULR Task Force members decided to validate the European findings based on information from current Singapore Airlines schedules. With this objective in mind, the task force launched a Phase II study designed to gather data from Singapore Airlines pilots (the initial modeling involved data from European pilots only) on routes that, among others, would closely resemble the proposed Singapore–Los Angeles ULR city pair (i.e., current multi-segment flights between Singapore and cities on the West Coast of the United States).

During a 10-week period, Singapore Airlines volunteer pilots were asked to maintain a diary that recorded sleep and duty beginning 48 hours before departure from Singapore and ending 48 hours after return to Singapore. The pilots recorded the duration and quality of all sleep periods at home, in flight and during the layover. The diaries also garnered information on levels of alertness during the following periods: preflight, immediately before and after each in-flight rest period, at the top of descent, and postflight.

Objective estimates of the duration of sleep were recorded by having the volunteer pilots on the U.S. West Coast routes wear an activity monitor (Actiwatch)[3] on their wrists.

The Phase II study validated the findings of the JAA–ECASS modeling. With four pilots, having two in-flight rest periods each, the levels of alertness for the Singapore–Los Angeles ULR city pair were projected to remain as high as those seen in the current Singapore Airlines routes studied.

Based on the recommendations derived from the findings of the JAA–ECASS modeling and the subsequent validation, CAAS issued provisional rules to allow Singapore Airlines to operate ULR flights between Singapore and Los Angeles at the defined departure windows with a four-pilot crew (two of whom must be pilot-in-command qualified).

The rules require independent in-flight crew-rest facilities with an environment conducive to sleep and a scheme that allows two periods of in-flight rest per pilot.

Singapore Airlines also was required to implement a training program and to issue guidelines on sleep physiology, coping strategies for ULR flights, in-flight rest and sleep management, fatigue countermeasures, and alertness management to all crewmembers (flight crew and cabin crew) embarking on ULR flights.

The rules further said that the initial operating period after service introduction of the A340-500 for ULR flights would be monitored to ensure that alertness levels on the flight deck were as predicted and that the crewmembers were appropriately rested.

The CAAS provisional rules for ULR flights were sent to three civil aviation authorities (JAA, U.S. Federal Aviation Administration [FAA] and U.K. Civil Aviation Authority [CAA]) and to the International Civil Aviation Organization (ICAO) for their appraisal and suggestions. All suggestions were discussed by the CAAS ULR Task Force members, and a final set of provisional rules were issued to Singapore Airlines, enabling the company to commence ULR flights.

Singapore Airlines Begins ULR Flights

Training for ULR flights comprises several courses at Singapore Airlines. All crewmembers complete a one-day course called "Fatigue and Alertness Management." This course is designed to provide the crewmembers with strategies to manage their rest prior to a ULR flight, during the layovers and after the ULR flight. The course provides in-flight rest strategies to help the pilots maintain alertness on the flight deck.

The pilots are required to complete a training module called "Route Clearance." This module provides them with the information and procedures required to operate within the North Atlantic Region.

The airline also conducts a classroom briefing called "Trans-polar Operations," which covers operating procedures and guidelines when operating in the North Polar Region.

Prior to conducting a ULR flight, the flight crew is scheduled for a rest period of not less than 48 hours, which includes two local nights free from flying duties. Each pilot is scheduled for a minimum of four local nights of rest after completion of a rostered duty assignment.[4] A dedicated standby crew is scheduled for each of the ULR flights. The standby crew comprises two captains and two first officers.

The following are the current schedules in local time:

- Singapore–Los Angeles–Singapore sectors:
  - Depart Singapore 1610; arrive Los Angeles 1630;
  - Depart Los Angeles 2020; arrive Singapore 0540.
- Singapore–New York–Singapore sectors:
  - Depart Singapore 1205; arrive New York 1730;
  - Depart New York 2300; arrive Singapore 0535.

These flights must be conducted within the constraints of the following departure windows (current scheduled departure times are in parentheses and all times shown are local time):

- For the Singapore–Los Angeles ULR city pair:
  - Departing Singapore 0800 to 1200 or 1600 to 2000 (1610);
  - Departing Los Angeles 1200 to 1600 or 2000 to 0300 (2020).
- For the Singapore–New York ULR city pair:
  - Departing Singapore 1010 to 1410 (1205) or 2200 to 0200;
  - Departing New York 0930 to 1330 or 2300 to 0300 (2300).

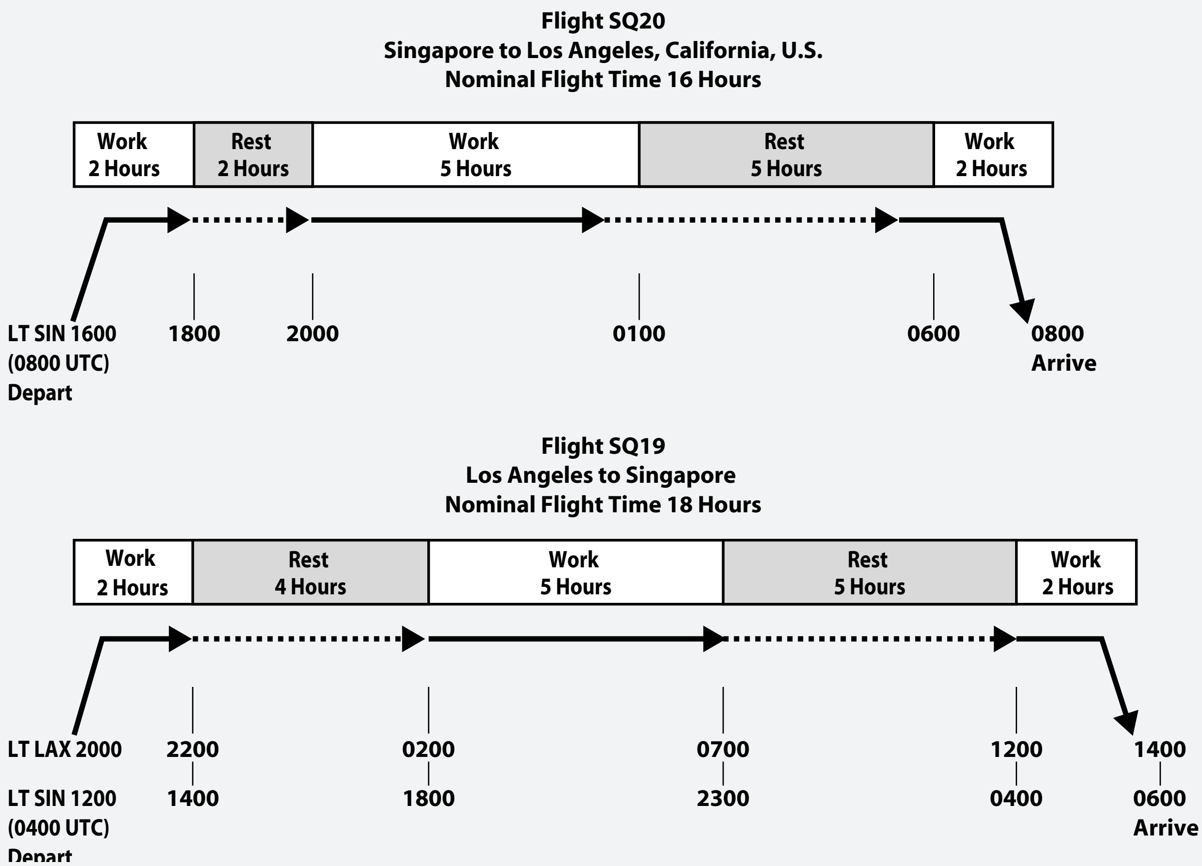
The rest/work schedules adopted for the main flight crews are shown in Figure 1 (page 24) and in Figure 2 (page 25).

Precoordinated Rest Periods Require Notice of Changes

The flight crews are instructed to ensure that any request to change the preassigned in-flight rest periods is made at least one day prior

Figure 1

Main Flight Crew In-flight Rest/Work Schedules, Singapore Airlines ULR Flights, 2005[1]



LAX = Los Angeles (California, U.S.) International Airport LT = Local time SIN = Singapore Changi Airport
UTC = Coordinated universal time

Note:

1. ULR flights have planned flight-sector lengths (block times) greater than 16 hours and flight-duty periods from 18 hours to 22 hours in scenarios defined by the ULR Crew Alertness Steering Committee, an initiative cosponsored by Airbus, Boeing Commercial Airplanes and Flight Safety Foundation.

Source: Capt. Paul Ho K.C.; Senior First Officer Shane Landsberger; Leigh Signal, Ph.D.; Dr. Jarnail Singh; and Barbara Stone, Ph.D.

to the day of departure. If a standby crewmember is called up, the standby crewmember takes the rest periods of the crewmember being replaced.

During their scheduled rest opportunities, all aircraft crewmembers have access to bunks in separate types of crew-rest facilities: a forward compartment configured for pilots and an aft compartment configured for cabin crewmembers. The crew-rest facilities have the following features:

- A lie-flat bunk;
- Temperature control;
- Humidifier; and,
- In-flight entertainment system.

The crew-rest facilities for pilots provide a reclining seat when the bunk is stowed. In the cabin, passenger seats also are provided for resting pilots and cabin crewmembers.

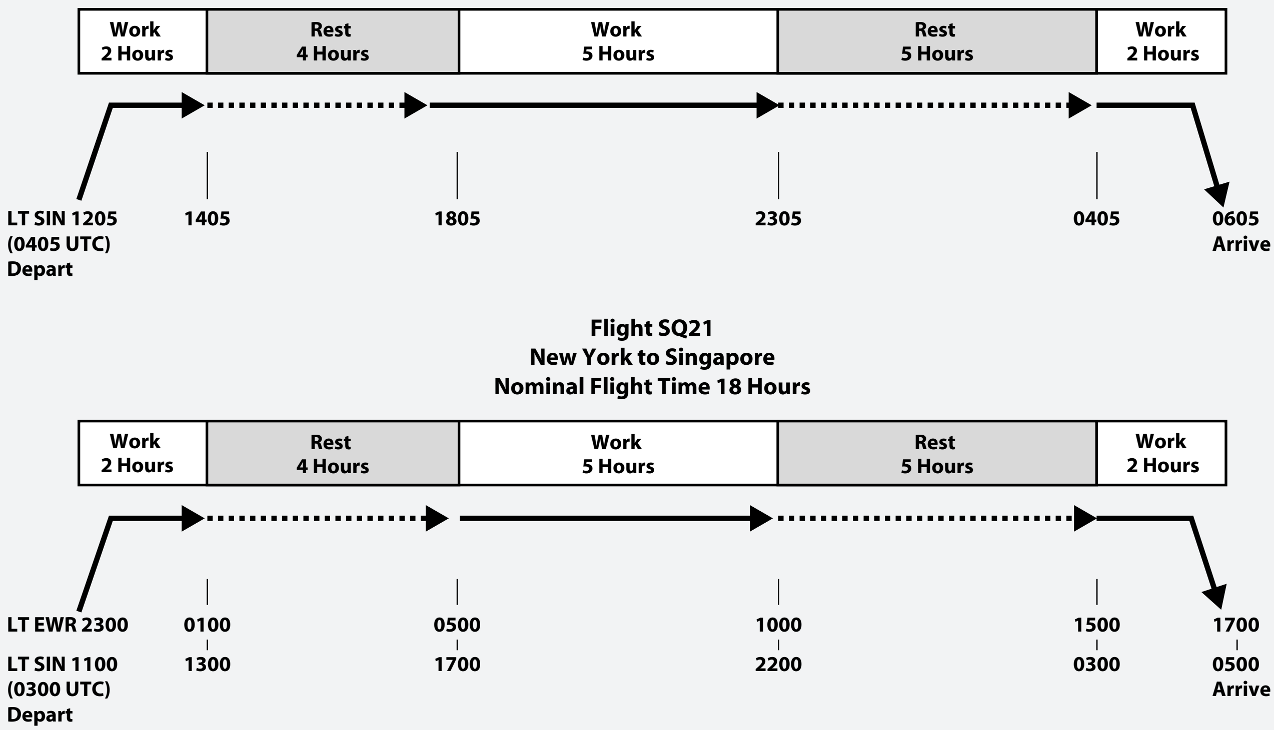
The following are some of the precautions taken whenever the polar routes are used by Singapore

Figure 2

Main Flight Crew In-flight Rest/Work Schedules, Singapore Airlines ULR Flights, 2005[1]

Flight SQ22
Singapore to New York, New York, U.S.
Nominal Flight Time 18 Hours

Flight SQ21
New York to Singapore
Nominal Flight Time 18 Hours



EWR = Newark (New Jersey, U.S.) Liberty International Airport LT = Local time SIN = Singapore Changi Airport
UTC = Coordinated universal time

Notes:

1. ULR flights have planned flight-sector lengths (block times) greater than 16 hours and flight-duty periods from 18 hours to 22 hours in scenarios defined by the ULR Crew Alertness Steering Committee, an initiative cosponsored by Airbus, Boeing Commercial Airplanes and Flight Safety Foundation.

Source: Capt. Paul Ho K.C.; Senior First Officer Shane Landsberger; Leigh Signal, Ph.D.; Dr. Jarnail Singh; and Barbara Stone, Ph.D.

Airlines flight crews during operations for the Singapore–New York ULR city pair:

- Solar radiation forecasts are obtained from the U.S. National Oceanic and Atmospheric Administration. Activity level 4 (severe) or higher[5] precludes the use of the polar route;
- Available en route alternate airports must be within 180 minutes of the polar route; and,
- Fuel-temperature prediction and fuel-freeze analysis are conducted for each flight.

From February 2004 to March 2005, there were 19 ULR flights with departure delays that ranged from one hour to five hours, 45 minutes. In addition, during this period, there were three ULR flights with delays of between five hours, 45 minutes and 15 hours, 17 minutes. A flight that does not depart within the established departure window is cancelled.

From this experience, Singapore Airlines made the following observations:

- The crew complement of four pilots has been optimal;

- The precoordinated in-flight rest periods have been effective;

- The constricted departure windows for ULR flights unduly have protracted some flight delays;

- The requirement to provide 48 hours of rest after a ramp turnback (i.e., flight crew returned to the gate after beginning to taxi for departure) has resulted in significant disruptions to crew duty assignments; and,

- The constraints of the 180-minute rule have restricted the use of the polar routes because of the absence of suitable en route alternate airports.

As a result, the current CAAS FTLs for managing en route diversions and destination diversions during ULR flights will be examined, and the possibility of introducing additional windows of departure will be explored to obviate the long delays that otherwise may be encountered.

Researchers Study Actual ULR Flights During 2004

After Singapore Airlines ULR flights to Los Angeles began on Feb. 3, 2004, ECASS and the Sleep/Wake Research Centre of Massey University, New Zealand, were contracted to conduct a study of the sleep, alertness and performance of the flight crews. This study, from February 2004 through July 2004, had the following main components:

- A self-administered, diary-based study; and,

- A polysomnography[6] study in which a researcher accompanied pilots during flight operations.

The timing of the component studies is shown in Table 1 (page 27).

During the diary-based study, diary data were collected during February, March and July 2004. During this period, 232 diaries were returned from 110 pilots (with an average age of 43.7 years). Measures included the following:

- Subjective evaluation of sleep for two days prior to departure, during the trip and for four days after returning to Singapore;

- Subjective ratings of sleepiness (Karolinska Sleepiness Scale)[7] and fatigue (Samn-Perelli fatigue scale)[8] for two days prior to departure, during the trip and for four days after returning to Singapore;

- Objective performance testing during each flight, using the VigTrack[9] task provided by the Netherlands Organization for Applied Scientific Research; and,

- Monitoring of sleep patterns throughout the rostered duty assignment using wrist actigraphy.

In April and June 2004, data were collected in flight by researchers from Massey University with a particular focus on objective sleep monitoring and performance testing in flight. This part of the validation exercise — the polysomnography study — monitored 41 pilots (also, coincidentally, with an average age of 43.7 years) across eight rostered duty assignments. Measures included the following:

- Measurement of sleep during the Singapore–Los Angeles flights and the Los Angeles–Singapore flights, using polysomnography;

- Monitoring of sleep patterns for four days prior to departure, throughout the flight, and for four days after return to Singapore, using wrist actigraphy and sleep diaries;

- Measurement of sleep during a night scheduled for sleep adaptation prior to departure, using polysomnography; and,

- Objective performance testing during each flight, using the psychomotor vigilance task (PVT);[10] subjective ratings of sleepiness (Karolinska Sleepiness Scale) and fatigue (Samn-Perelli fatigue scale). In April 2004, Massey University scientists and ECASS scientists presented an interim report based on data collected during the first two months of ULR flights. These data indicated that the levels of alertness throughout the Singapore–Los Angeles–Singapore flights were no lower than

Table 1

Timing of Data Collection Singapore Airlines ULR Flights, 2004[1]

	February	March	April	May	June	July
Diary-based Study[2]	X	X				X
Polysomnography Study[3]			X		X	

ULR = Ultra-long range

Notes:

1. Flight sectors were Singapore to Los Angeles, California, U.S., and Los Angeles to Singapore. ULR flights have planned flight-sector lengths (block times) greater than 16 hours and flight-duty periods from 18 hours to 22 hours in scenarios defined by the ULR Crew Alertness Steering Committee, an initiative cosponsored by Airbus, Boeing Commercial Airplanes and Flight Safety Foundation.
2. The diary-based study included self-administered questionnaires for pilots to subjectively evaluate fatigue, sleepiness and sleep.
3. Polysomnography, one method of measuring alertness, involves recording brain activity, eye movement and muscle tone using small electrodes that are attached to the head and face of the pilot.

Source: Capt. Paul Ho K.C.; Senior First Officer Shane Landsberger; Leigh Signal, Ph.D.; Dr. Jarnail Singh; and Barbara Stone, Ph.D.

those experienced by the Singapore Airlines flight crews conducting long-haul flights. Alertness was sustained on the ULR flights as a result of the additional time available for rest and the ability of the crews to take two rest periods in flight.

The CAAS ULR Task Force was reassured by these preliminary results, which indicated that initial ULR flights were proceeding as expected and that there were no major problems associated with flight crew alertness.

In November 2003, Singapore Airlines asked CAAS to consider its request to initiate ULR flights to New York. Approval of these flights would be contingent on the initial study results from the Singapore–Los Angeles flights. QinetiQ was contracted to conduct a study of flight crews during this second phase of ULR flights. A similar method was adopted for this ULR city pair as for the Singapore–Los Angeles ULR city pair but without on-board researchers or in-flight recordings of brain activity to measure sleep.

A modeling study was conducted in December 2003. The model was validated with the preliminary ULR data from the Singapore–Los Angeles flights. CAAS approval for the Singapore–New York flights was granted in May 2004 after the QinetiQ scientists indicated that the modeling and validation results showed that these flights would meet the preliminary CAAS standards on fatigue and alertness.

The Singapore–New York ULR flights began June 28, 2004. Immediately following the launch, these flights were monitored by the QinetiQ scientists. The New York ULR study continued until November 2004.

Scientists Present Detailed Results of In-flight Research

The detailed results of research for the Singapore–Los Angeles ULR city pair were presented on Dec. 15, 2004, and the interim results for the Singapore–New York ULR city pair were presented on Dec. 16, 2004. These presentations were made in London, England, by the respective scientific organizations. The participants included the CAAS ULR Task Force members, as well as invited representatives from Airbus, the International Federation of Air Line Pilots' Associations, JAA and U.K. CAA.

Across the eight rostered duty assignments included in the polysomnography study, the Singapore–Los Angeles flights had an average duration of 15.5 hours and departed Singapore about 0800 coordinated universal time (UTC; 1600 local time). The Los Angeles–Singapore flights had an average duration of 17 hours and departed

Los Angeles about 0400 UTC (2100 local time). Because of the different times of year in which data were collected, the flight duration in the diary-based study was slightly different. During the initial months, the flight from Singapore was about 15 hours and the return flight to Singapore was about 18 hours. During the final month of the study (summer in the Northern Hemisphere), both flights had a duration between 16 hours and 17 hours.

During each sector, one captain (the pilot-in-command of the flight) and one first officer comprise the main crew. Another captain and another first officer, comprising the relief crew, alternate with the main crew in flight deck duty and in obtaining sleep during the precoordinated in-flight rest periods.

In general, pilots who had been the main crew during the flight from Singapore were assigned to the three-day layover, and pilots who had been the relief crew spent two days in Los Angeles. Pilots who were the main crew during the flight from Singapore were relief pilots during the return flight; and, similarly, pilots who were the relief crew during the flight from Singapore were the main crew during the return flight to Singapore. The mean duration of the two-day layover was 50.8 hours, and the mean duration of the three-day layover was 74.9 hours.

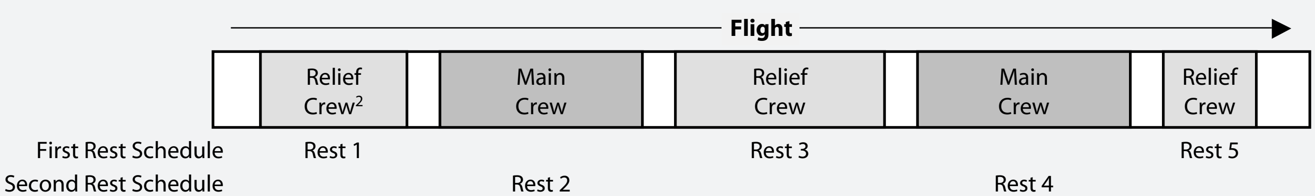
Based on the results of previous studies, flight crews were advised to obtain sleep during two scheduled rest periods during each flight. This meant that over the course of the flight, it was anticipated that four rest periods would be scheduled. In practice, the main crew took the second rest period and the fourth rest period (known as the second rest schedule), and the relief crew took the first rest period and the third rest period (known as the first rest schedule). During the polysomnography study of flight operations for the Singapore–Los Angeles ULR city pair, it became apparent that an additional rest period (i.e., fifth rest period) frequently was allocated (on 13 of 16 flights) for the relief crew toward the end of the flight, although only seven pilots used this period for sleep (Figure 3). The fifth rest period was taken at a time when the relief crewmembers were no longer required to be on the flight deck.

The diaries were designed on the assumption that individual pilots would have two opportunities to rest. Therefore, some of the details of the third rest period may not always have been collected. (Approximately 20 percent of the relief pilots recorded sleeping at this time.)

There was a general tendency for ratings of fatigue and sleepiness to increase throughout the flights. Figure 4 (page 29) shows the

Figure 3

Singapore Airlines Schedule of Rest Periods During a ULR Flight[1]



ULR = Ultra-long range

Notes:

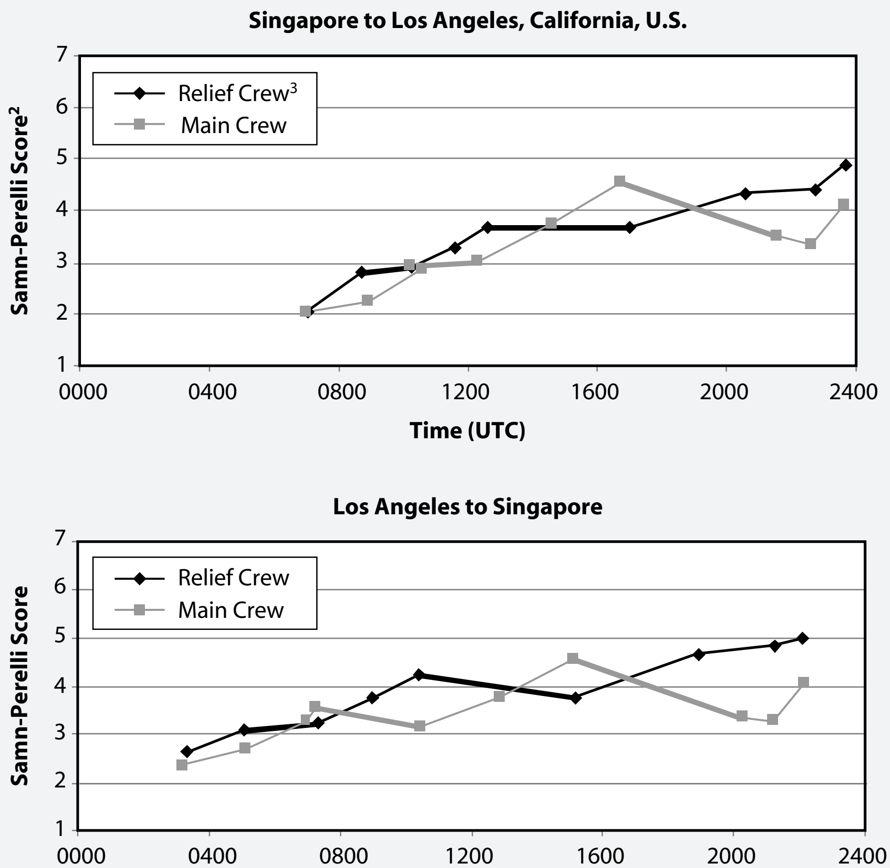
1. ULR flights have planned flight-sector lengths (block times) greater than 16 hours and flight-duty periods from 18 hours to 22 hours in scenarios defined by the ULR Crew Alertness Steering Committee, an initiative cosponsored by Airbus, Boeing Commercial Airplanes and Flight Safety Foundation.
2. During each sector, one captain (the pilot-in-command of the flight) and one first officer comprise the main crew. Another captain and another first officer, comprising the relief crew, alternate with the main crew in flight deck duty and in obtaining sleep during the precoordinated in-flight rest periods.

Source: Capt. Paul Ho K.C.; Senior First Officer Shane Landsberger; Leigh Signal, Ph.D.; Dr. Jarnail Singh; and Barbara Stone, Ph.D.

subjective ratings of fatigue collected during the diary-based study. The thicker lines indicate the rest periods. In both studies, the main crews recorded their highest ratings — during their flights from the Singapore base and their return flights — prior to the second rest period. In contrast, the relief crews were most fatigued during the final stages of the flight. The large increase in fatigue among the relief crew at the end of the flight, compared with the beginning of the flight, was accompanied by reduced performance on the VigTrack task.

Figure 4

Average Levels of Fatigue Reported by Singapore Airlines Pilots During ULR Flights, 2004[1]



ULR = Ultra-long range UTC = Coordinated universal time

Notes:

1. ULR flights have planned flight-sector lengths (block times) greater than 16 hours and flight-duty periods from 18 hours to 22 hours in scenarios defined by the ULR Crew Alertness Steering Committee, an initiative cosponsored by Airbus, Boeing Commercial Airplanes and Flight Safety Foundation.
2. Using the Samn-Perelli fatigue scale, study participants rate themselves as 1 (fully alert, wide awake); 2 (very lively, responsive, but not at peak); 3 (OK, somewhat fresh); 4 (a little tired, less than fresh); 5 (moderately tired, let down); 6 (extremely tired, very difficult to concentrate); or 7 (completely exhausted, unable to function effectively).
3. During each sector, one captain (the pilot-in-command of the flight) and one first officer comprise the main crew. Another captain and another first officer, comprising the relief crew, alternate with the main crew in flight deck duty and in obtaining sleep during the precoordinated in-flight rest periods.

Source: Capt. Paul Ho K.C.; Senior First Officer Shane Landsberger; Leigh Signal, Ph.D.; Dr. Jarnail Singh; and Barbara Stone, Ph.D.

Because most of the crews on the two-day layover were the main crews on the return flight, the Massey University scientists had difficulty separating the effects of crew position (main/relief) and layover duration when considering the levels of alertness during the return flights. Nevertheless, based on information from the diary-based study, there were indications of slightly higher levels of fatigue (Samn-Perelli fatigue scale) and sleepiness (Karolinska Sleepiness Scale) associated with the longer layover period.

There was a general trend for an increase in response time on the PVT during both the flights from Singapore and the return flights. Nevertheless, the magnitude of the changes was not as great as for the subjective measures. There was a great deal of variability in psychomotor performance among crewmembers, and a relatively low number of crewmembers were studied, which may have limited the scientists' ability to detect statistically significant differences in these comparisons.

The following results summarize the polysomnography study, unless otherwise stated. The time allocated for flight crew rest averaged about seven hours on the flight from Singapore and eight hours on the return flight, irrespective of the rest schedule. All pilots used at least one in-flight rest opportunity for sleep. On both sectors, 50 percent of the main crews used their first rest opportunity for sleep, and all of the main crews used their second rest opportunity for sleep. (Nevertheless, in the diary-based study, only 26 percent of pilots said that they tried to sleep during the first rest period on the flights from Singapore, compared with a little more than 50 percent of pilots on the return flights.) In comparison, the majority of relief crews used only their second (i.e., longest) rest opportunity for sleep. On average, the main crews spent more of their available rest time (about 60 percent) trying to sleep, compared with the relief crews (about 50 percent). In-flight sleep was obtained in a bunk on 80 percent of occasions and in a cabin seat on 7 percent of occasions, and in-flight sleep was taken in an unreported location on the remaining occasions.

On the flights from Singapore, the main crews averaged 3.21 hours of sleep, with a median sleep efficiency (i.e., hours of sleep obtained divided by hours of sleep attempted times 100) of 76 percent, while the relief crews averaged 2.28 hours of less efficient sleep (with a median sleep efficiency of 69 percent). On the return flight, the main crews averaged 3.55 hours of sleep, and the relief crews averaged 2.52 hours. Sleep efficiencies were comparable to the flights from Singapore. There was substantial variability in sleep quantity and sleep efficiency among individual crewmembers.

The main crewmembers who slept only once in flight tended to obtain less sleep than main crewmembers who slept during more than one rest opportunity. Moreover, crewmembers who slept during an early in-flight rest opportunity obtained a similar amount of sleep during their later in-flight rest opportunity, compared with crewmembers who slept only during the later rest opportunity. This indicates that sleeping early in the flight does not restrict the amount of sleep obtained during later in-flight rest opportunities.

A comparison of sleep efficiency during a crewmember's longest in-flight sleep with the sleep efficiency recorded during one night in Singapore indicated that sleep in flight was of lesser quality (73 percent sleep efficiency and 77 percent sleep efficiency on flights from Singapore and return flights, respectively, compared with 86 percent sleep efficiency in Singapore).

Data from the polysomnography study — for individual rest periods during the flights from Singapore and the return flights — are shown in Figure 5 (page 31).

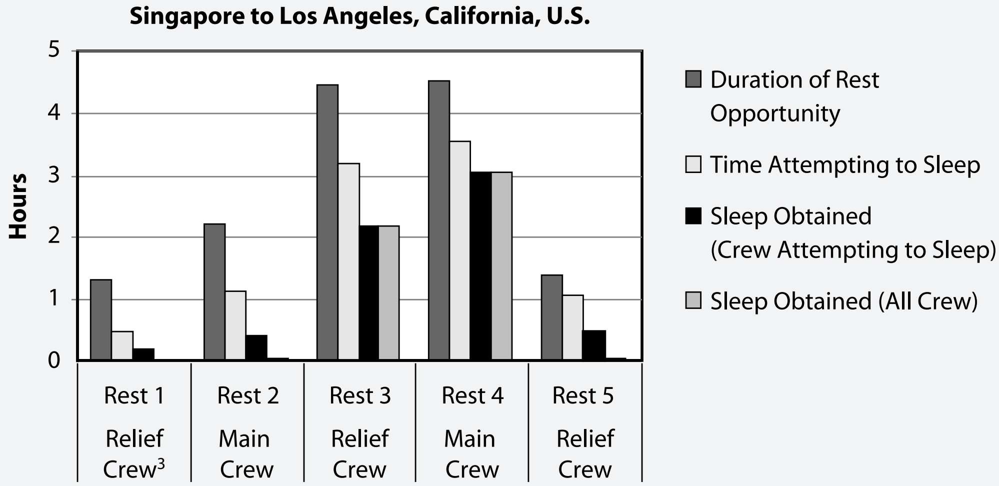
During the diary-based study, flight crews were asked to comment on the bunk environment. Compared with the Phase II study, there were fewer reports of disturbance by aircraft noise or by random noise. Nevertheless, the rear bunk environment was reported to be noisier than the front bunk environment. Turbulence was the most commonly cited factor disturbing sleep, and turbulence was cited in reports on one-third of all rest periods.

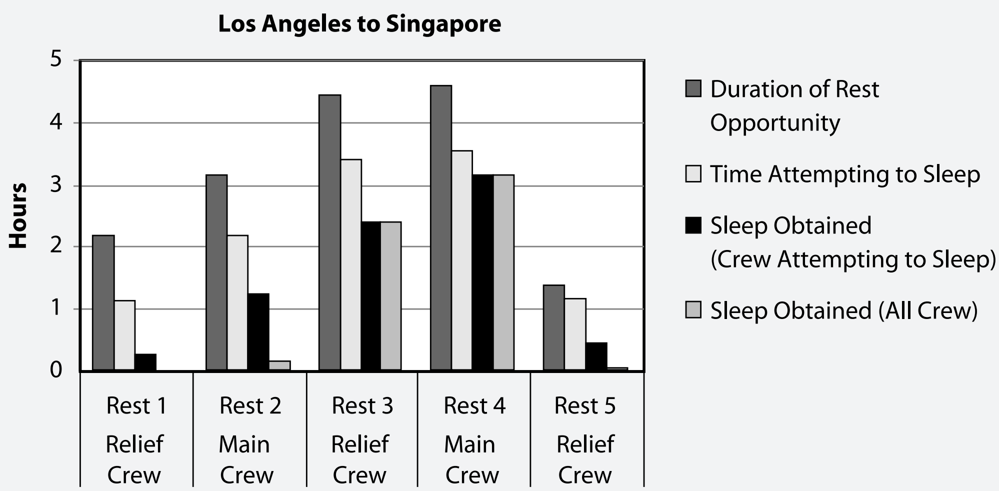
Sleep obtained prior to the flight from Singapore averaged more than 7.3 hours according to the diaries, but only 6.5 hours according to the actigraphy data. Approximately 20 percent of pilots obtained less than six hours of sleep in the 24 hours prior to departure according to the actigraphy data, however.

Continued on page 32

Figure 5

Polysomnography Data[1] for Rest Periods of Pilots During Singapore Airlines ULR Flights,[2] April 2004 and June 2004





ULR = Ultra-long range

Notes:

1. Polysomnography, one method of measuring alertness, involves recording brain activity, eye movement and muscle tone using small electrodes that are attached to the head and face of the pilot.
2. ULR flights have planned flight-sector lengths (block times) greater than 16 hours and flight-duty periods from 18 hours to 22 hours in scenarios defined by the ULR Crew Alertness Steering Committee, an initiative cosponsored by Airbus, Boeing Commercial Airplanes and Flight Safety Foundation.
3. During each sector, one captain (the pilot-in-command of the flight) and one first officer comprise the main crew. Another captain and another first officer, comprising the relief crew, alternate with the main crew in flight deck duty and in obtaining sleep during the precoordinated in-flight rest periods.

Source: Capt. Paul Ho K.C.; Senior First Officer Shane Landsberger; Leigh Signal, Ph.D.; Dr. Jarnail Singh; and Barbara Stone, Ph.D.

The pattern of sleep on layover was fragmented. According to the diary data, flight crews averaged 8.2 hours of sleep per 24 hours on the two-day layover and 7.4 hours of sleep per 24 hours on the three-day layover. Compared with the results from the diaries, the actigraphy data indicated that slightly lower amounts of sleep were obtained in each 24-hour period during the layover and that the amount of sleep obtained per 24 hours did not differ among crewmembers on the two-day layover versus the three-day layover. The total additional sleep reported during the extra day of layover in Los Angeles averaged 5.9 hours (actigraphy data indicated 6.5 hours). Nevertheless, 38 percent of flight crews obtained less than six hours of sleep (based on actigraphy data) in the 24 hours prior to their return flight.

The fragmented pattern of sleep was similar for both layover durations. Flight crews tended to split their sleep into two briefer periods, one during the nighttime in Los Angeles and the other at a time corresponding to nighttime in Singapore.

After their return to Singapore, most individuals reported obtaining a recovery sleep of approximately 3.5 hours, after which they slept in a pattern influenced by local time. From the diary data, the timing and subjective quality of sleep appeared to be back to normal after three nights. There were no polysomnography data to confirm this observation, however. The actigraphy data from the polysomnography study showed that, during the first 24 hours after their return to Singapore, flight crews tended to split their sleep into two periods, consisting of a brief daytime sleep followed by an overnight sleep. Based on the actigraphy data, there was no difference in the quantity of sleep obtained in four post-trip 24-hour periods, compared with pre-trip data on quantity of sleep obtained.

In-flight sleep had a beneficial effect on subjective ratings of alertness.

Pilots' Alertness on ULR Flights Compared to Long-range Flights

The consensus of the Massey University scientists and QinetiQ scientists was that levels of subjective alertness of the Singapore Airlines flight crews — on both their flights from Singapore and their return flights — were no lower than the levels reported on many other long-haul flights, including those studied in Phase II. This may be a result of the additional time available for rest during the ULR flights. In addition, the division of the cruise phase into two rest periods per crew helped to alleviate the reduction in alertness associated with long continuous periods on the flight deck.

Although pilots had the opportunity to sleep during multiple rest periods, most of them chose to sleep only once. There was also a large degree of variability among crewmembers in the quantity and quality of in-flight sleep obtained.

The data demonstrated that in-flight sleep had a beneficial effect on subjective ratings of alertness. This effect was not observed in the PVT data from the polysomnography study, however, possibly because of the high degree of individual variability among pilots.

There were no statistically significant differences in the amount of sleep obtained per 24 hours by pilots on two-day layovers versus three-day layovers, but there was a trend for those on three-day layovers to obtain less sleep in the first 24 hours after arriving in Los Angeles. Comparing the second night of the layover with the third night of the layover, the pattern of sleep was very similar with many pilots attempting at least some sleep close to normal Singapore time.

In the polysomnography study, there was no detectable difference in performance or subjective alertness at the beginning of the return flight for crew after a two-day layover versus a three-day layover. The main crews, whose schedules of in-flight rest opportunities were most conducive to obtaining sleep, were the least fatigued pilots on the return flight. In the diary-based study, where it was possible to separate the effects of layover duration and crew position (main/relief), there was some indication that lower levels of alertness were associated with the longer layover.

For the flights from Singapore to New York, the average flight time was 18.48 hours and the average duty time was 20.68 hours. For the return flights, the average flight time was 18.46 hours and the average duty time was 20.40 hours.

During the QinetiQ study of ULR flights between Singapore and New York in July, August and November 2004, local time in New York changed from daylight-saving time to standard time, and local times relative to UTC were an hour longer. Therefore, for the first two months of the study, the time-zone change was plus 12 hours between Singapore and New York, and for November, this time-zone change was plus 11 hours. During November, the departures from New York occurred around 0300 UTC (versus 0200 UTC for July and August). This, together with differences in the weather conditions between summer and winter, resulted in an average layover duration of 76.3 hours for November, compared with 74.3 hours during July and August. The local time change did not result in any major differences between the two data sets.

In contrast to the study of the Singapore–Los Angeles ULR city pair, during the Singapore–New York study, all flight crews spent three days on layover. The average duration of the layover was 74.9 hours.

The pilots' organization of rest periods during flights on the Singapore–New York routes was similar to that adopted on the Singapore–Los Angeles routes. The diaries showed that an almost equal number of pilots (197) followed the first in-flight rest schedule compared with the number (195) that followed the second rest schedule. Those who followed the second in-flight rest schedule all reported taking two rest periods. Of those following the first rest schedule, 67 pilots reported taking three rest periods, 129 reported taking two rest periods (119 pilots taking the first and third rest periods, 10 taking the third and fifth rest periods), while one pilot reported taking only one rest period (position three of the five possible rest periods).

On the majority of flights for the Singapore–New York ULR city pair, the rest periods were organized by mutual agreement (52 percent of the flights) or the rest periods were planned in advance (41 percent of the flights). Seven percent of the flight crews said that the captain determined the organization of the in-flight rest periods.

There was a general trend for fatigue and sleepiness to increase throughout the flights, except during a rest period, when there typically was a reduction. The highest levels of fatigue were at the end of the flight for those on the first rest schedule, although these levels were no higher than those in previous operations.

The average levels of fatigue (measured on the Samn-Perelli fatigue scale) and sleepiness (measured on the Karolinska Sleepiness Scale) during the flights from Singapore to New York are shown in Figure 6 (page 34). The numbers shown in boxes indicate the average amounts of sleep, both bunk sleep and nonbunk sleep, reported by the crews during the corresponding rest periods. The thicker lines indicate the timing of the rest periods.

The pilots on the second rest schedule (main crew), who normally would have been at the controls on landing, reached their highest level of fatigue (4.53 on the Samn-Perelli fatigue scale) and sleepiness (5.72 on the Karolinska Sleepiness Scale) just before their second rest period. These levels were somewhat lower than those at the equivalent point on the Singapore–Los Angeles route. Due to the difference in the timing of the flights, however, their second rest period began just before midnight Singapore time, at a more favorable time with respect to alertness than on the Singapore–Los Angeles route, where the flights began in the early hours of the morning. Alertness at top of descent and during postflight activities was also slightly higher for this crew than on the Singapore–Los Angeles route.

The lowest levels of alertness for the flight crews on the first rest schedule (relief crew) were at the end of the flight. These levels (4.57 on the Samn-Perelli fatigue scale and 5.70 on the Karolinska Sleepiness Scale at the top of descent) were lower than those for the crews on the same schedule on the Singapore–Los Angeles route (although no lower than those on the return flight from Los Angeles). The explanation for this appears to be the relatively small amount of sleep that the flight crews on the Singapore–New York route managed to obtain in their second rest period. Although this rest period was more than five hours, they reported having obtained 2.07 hours sleep, with sleep efficiency of just 38.7 percent. On the Singapore–Los Angeles route, the equivalent rest period, though briefer, was obtained later in the night whereas, on the flight to New York, the rest period ended close to midnight Singapore time.

The highest levels of fatigue were at the end of the flight.

The average levels of fatigue and sleepiness during the return flight from New York are shown in Figure 7 (page 35). The trends throughout the flight were similar to those on the flight from Singapore, although the initial levels of alertness were slightly lower and the difference between the two flight crews at the end of the flight was slightly less marked. Given the similar timing of these two flights with respect to Singapore local time, this would suggest that the circadian phase[11] of the crews was still aligned reasonably closely with home time at the point of departure.

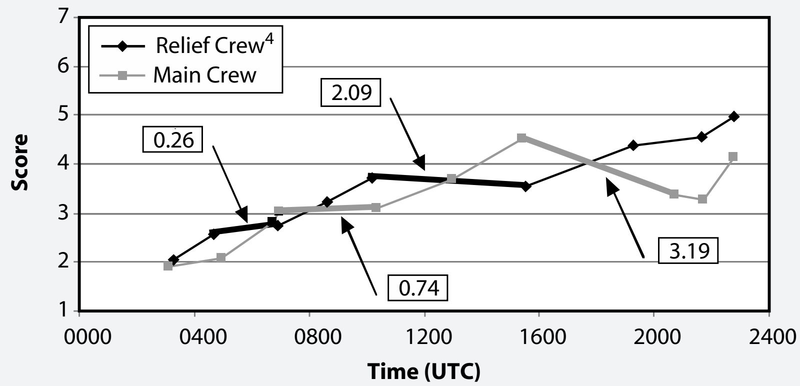
Pilots on the first rest schedule (the relief crew) were more fatigued and more sleepy at top of descent than pilots on the second schedule (the main crew). Levels of fatigue and sleepiness were also greater on the return flight to Singapore, compared with the flight from Singapore. There was a strong effect associated with the amount of in-flight sleep obtained on both the Samn-Perelli fatigue scale and the Karolinska Sleepiness Scale (Figure 8, page 36). For every hour of additional sleep, there was an average reduction of 0.13 on the Samn-Perelli fatigue scale and 0.19 on the Karolinska Sleepiness Scale.

Continued on page 36

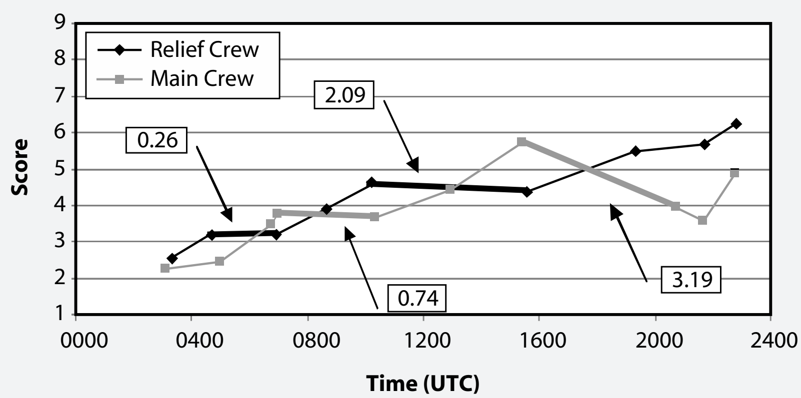
Figure 6

Average Levels of Pilot Fatigue and Sleepiness on Singapore Airlines ULR Flights,[1] Singapore to New York, New York, U.S.[2] 2004

Samn-Perelli Fatigue Scale[3]



Karolinska Sleepiness Scale[5]



ULR = Ultra-long range UTC = Coordinated universal time

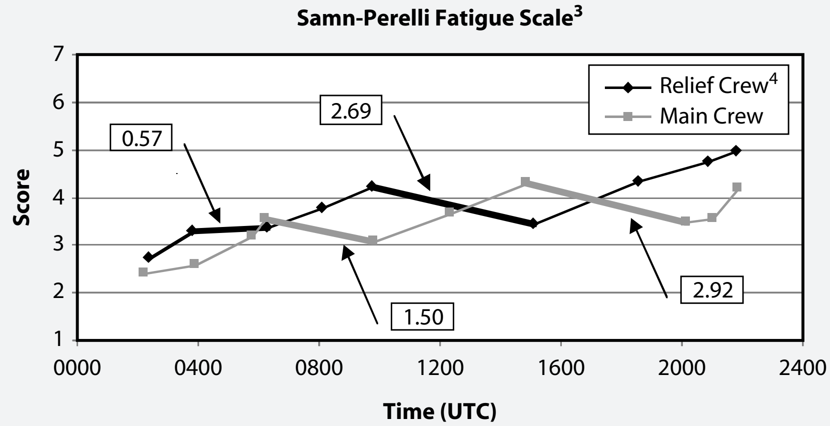
Notes:

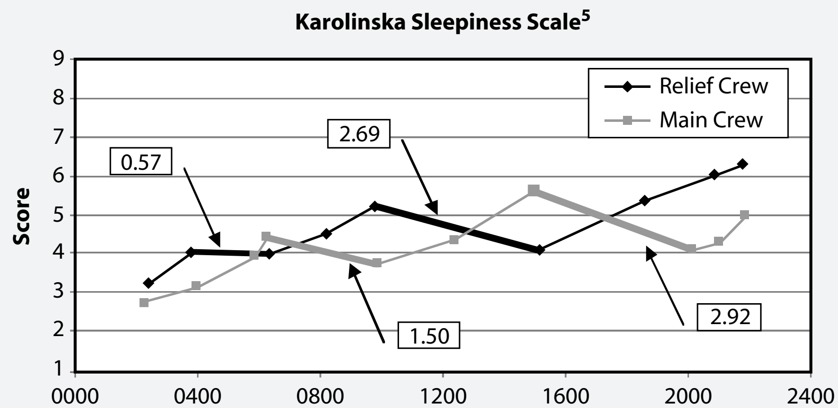
1. ULR flights have planned flight-sector lengths (block times) greater than 16 hours and flight-duty periods from 18 hours to 22 hours in scenarios defined by the ULR Crew Alertness Steering Committee, an initiative cosponsored by Airbus, Boeing Commercial Airplanes and Flight Safety Foundation.
2. Flights to the New York area arrive at Newark (New Jersey) Liberty International Airport. Changi Airport is the home base of Singapore Airlines.
3. Using the Samn-Perelli fatigue scale, study participants rate themselves as 1 (fully alert, wide awake); 2 (very lively, responsive, but not at peak); 3 (OK, somewhat fresh); 4 (a little tired, less than fresh); 5 (moderately tired, let down); 6 (extremely tired, very difficult to concentrate); or 7 (completely exhausted, unable to function effectively).
4. During each sector, one captain (the pilot-in-command of the flight) and one first officer comprise the main crew. Another captain and another first officer, comprising the relief crew, alternate with the main crew in flight deck duty and in obtaining sleep during the precoordinated in-flight rest periods.
5. Based on subjective responses to a questionnaire, the Karolinska Sleepiness Scale rates each study participant from 1 (very alert) to 9 (extremely sleepy); this standardized tool is used by sleep researchers worldwide and can be correlated with objective measures of sleepiness.

Source: Capt. Paul Ho K.C.; Senior First Officer Shane Landsberger; Leigh Signal, Ph.D.; Dr. Jarnail Singh; and Barbara Stone, Ph.D.

Figure 7

Average Levels of Pilot Fatigue and Sleepiness on Singapore Airlines ULR Flights,[1] New York, New York, U.S., to Singapore[2] 2004





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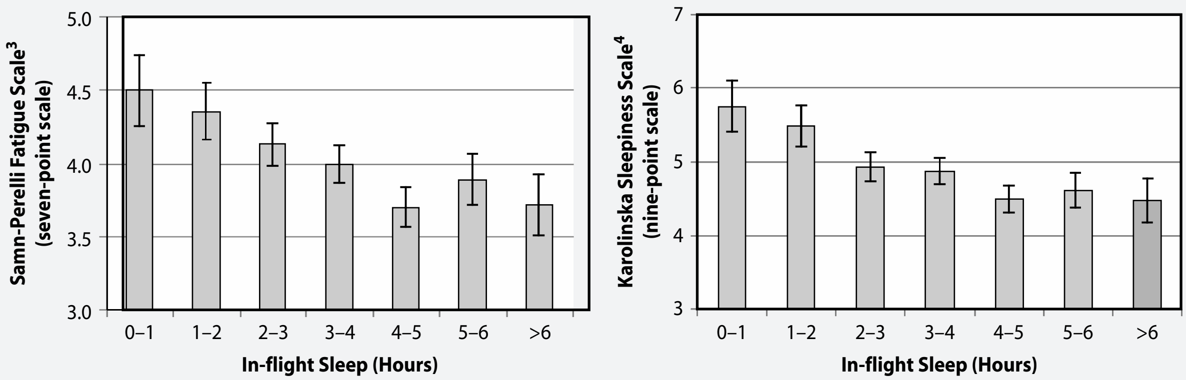
2. Flights from the New York area depart from Newark (New Jersey) Liberty International Airport. Changi Airport is the home base of Singapore Airlines.
3. Using the Samn-Perelli fatigue scale, study participants rate themselves as 1 (fully alert, wide awake); 2 (very lively, responsive, but not at peak); 3 (OK, somewhat fresh); 4 (a little tired, less than fresh); 5 (moderately tired, let down); 6 (extremely tired, very difficult to concentrate); or 7 (completely exhausted, unable to function effectively).
4. During each sector, one captain (the pilot-in-command of the flight) and one first officer comprise the main crew. Another captain and another first officer, comprising the relief crew, alternate with the main crew in flight deck duty and in obtaining sleep during the precoordinated in-flight rest periods.
5. Based on subjective responses to a questionnaire, the Karolinska Sleepiness Scale rates each study participant from 1 (very alert) to 9 (extremely sleepy); this standardized tool is used by sleep researchers worldwide and can be correlated with objective measures of sleepiness.

Source: Capt. Paul Ho K.C.; Senior First Officer Shane Landsberger; Leigh Signal, Ph.D.; Dr. Jarnail Singh; and Barbara Stone, Ph.D.

Figure 8

Comparison of Pilot Fatigue and Sleepiness at Top of Descent With Amount of In-flight Sleep, Singapore Airlines ULR Flights,[1] New York, New York, U.S., to Singapore[2] 2004



ULR = Ultra-long range

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1. ULR flights have planned flight-sector lengths (block times) greater than 16 hours and flight-duty periods from 18 hours to 22 hours in scenarios defined by the ULR Crew Alertness Steering Committee, an initiative cosponsored by Airbus, Boeing Commercial Airplanes and Flight Safety Foundation.
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Source: Capt. Paul Ho K.C.; Senior First Officer Shane Landsberger; Leigh Signal, Ph.D.; Dr. Jarnail Singh; and Barbara Stone, Ph.D.

Data Show Pilots' Total Bunk Sleep

The average total amounts of the bunk sleep obtained on the flights from Singapore to New York were 2.28 hours for pilots who took the first rest schedule and 3.51 hours for those who took the second rest schedule. On the return flights, these totals were 3.08 hours and 4.05 hours, respectively. Total bunk sleep combined over both schedules and both flights is shown in Figure 9 (page 37). The data represent sleep periods from 392 flights, including 25 flights (6.4 percent) for which no bunk sleep was reported. The majority of these reports of no bunk sleep (17) were on the flight from Singapore. At the other extreme, on 39 percent of the flights, pilots obtained more than four hours of sleep during the flight, and there were seven reports of more than seven hours of sleep.

With the exception of the brief fifth rest period (when taken), most sleep typically was obtained toward the end of the flights. Particularly on the flights from Singapore, many pilots chose not to sleep in the bunk during the briefer first rest period.

The proportion of pilots asleep at any given time during the 2.5 days prior to a flight from Singapore was calculated from the diary data. The pattern of sleep was fairly consistent across the two days. Nevertheless, on the second full day before the flight from Singapore, approximately 20 percent of pilots napped, compared with fewer than 6 percent on the following day. There was also an advance in wake-up times and get-up times on the night before the flight.

The pattern of pilot sleep on layover was extremely fragmented, with the majority of crewmembers taking four, five or six separate rest periods during the 74.9-hour layover period. The average duration of an individual sleep was 4.58 hours, and the crews obtained an average total of 23.2 hours of sleep, equivalent to 7.5 hours in each 24-hour period. A possible advantage of the timing of the return flight from New York is that there is the opportunity to obtain sleep close to the normal home time (Singapore local time) prior to departure. As a result, more than 80 percent of pilots reported sleeping between midday and 2000 local time (i.e., within nine hours of reporting for duty).

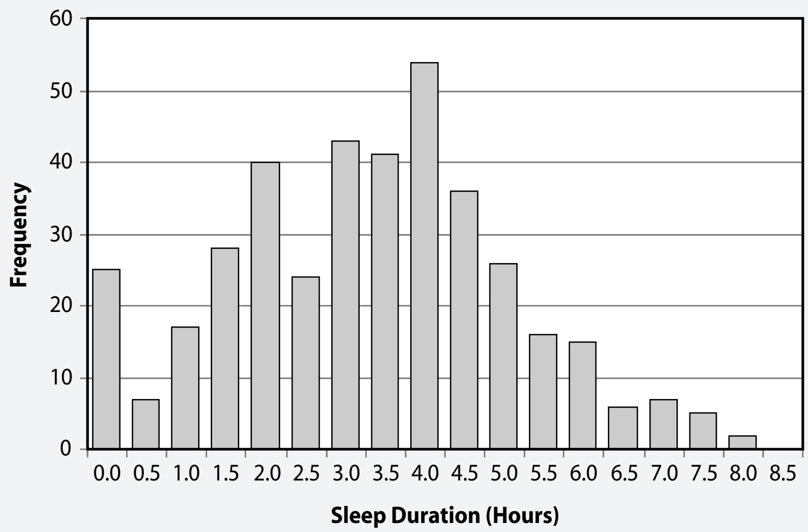
On their return flights to Singapore, the majority of flight crews napped for an average duration of 3.97 hours on arrival, which was followed by an overnight sleep period. Over the subsequent nights, sleep followed a normal pattern, with few pilots napping during the day.

Sleep onset was earlier on the first night after returning from New York than on the second night and third night. In addition, the requirement for more sleep was greater after the first night than after the second night, third night and fourth night.

The conclusion of the QinetiQ scientists was that the alertness levels of the flight crews for the Singapore–New York route were similar to those on the Singapore–Los Angeles route. In

Figure 9

Total In-flight Bunk Sleep of Pilots During All Singapore Airlines ULR Flights Studied in 2004[1] Histogram[2]



ULR = Ultra-long range

Notes:

1. ULR flights have planned flight-sector lengths (block times) greater than 16 hours and flight-duty periods from 18 hours to 22 hours in scenarios defined by the ULR Crew Alertness Steering Committee, an initiative cosponsored by Airbus, Boeing Commercial Airplanes and Flight Safety Foundation. During 2004, the Singapore Airlines ULR flights were conducted between two city pairs: Singapore–Los Angeles, California, U.S., and Singapore–New York, New York, U.S. Changi Airport is the home base of Singapore Airlines. The U.S. airports are Los Angeles International Airport and Newark (New Jersey) Liberty International Airport.
2. In this histogram, groups of numbers (values representing sleep duration) are graphed based on how often they appear in the data (frequency).

Source: Capt. Paul Ho K.C.; Senior First Officer Shane Landsberger; Leigh Signal, Ph.D.; Dr. Jarnail Singh; and Barbara Stone, Ph.D.

The flight crew-rest facility in the Airbus A340-500 provides reclining seats when the bunks are stowed.

(Photo: Copyright Airbus)

particular, the alertness levels were no lower than those experienced by flight crews on other long-haul flights — for example, those between Singapore and London — that have been studied previously.

Depending on the timing and duration of the individual rest periods, the pilots reported being able to sleep between 30 percent and more than 60 percent of the available time. The sleep that they obtained appeared to be beneficial in terms of the improvement in both subjective alertness and performance at the end of the rest period.

Near the end of the flights, the alertness of the pilots who took the first rest schedule was considerably lower than the alertness of those who took the second rest schedule, and who normally would be on the flight deck for landing. This difference was particularly large on the flights from Singapore and can be explained by the timing of the rest periods for the two crews.

The pilots appeared to have coped well with the difficult 11-hour or 12-hour time-zone transition. Many slept frequently on layover, with some of the sleep periods coinciding with the Singapore night. There is a possibility that this practice has limited the circadian phase adjustment that normally would have been anticipated. As a result, these crewmembers managed to sleep during the day prior to departure and to maintain their alertness at a high level during the early stages of their flights.

ALPA–S Pilots Engaged in Planning ULR Flights

The objective of ALPA-S, in partnership with the other stakeholders in the CAAS ULR Task Force, was to provide feedback and input to the planning process from the pilots' perspective. This proactive participation obviated the need at a later time to elicit cooperation from the line pilot community and assisted in their education and in addressing their concerns during the modeling and validation processes for ULR flights. Meetings with the JAA Joint Operational Evaluation Board and ECASS, and inspections and visits of mock crew-rest facilities in France and Germany — including participation in numerous crew-alertness workshops — were integral to this participation.

The perspective of ALPA–S has reflected the feedback received from line pilots' experience gathered during the initial period of 16 months of daily flights for the Singapore–Los Angeles city pair and 12 months of daily flights for the Singapore–New York city pair.

ALPA–S has compared the current guidance material on in-flight rest to pilots' actual line practices on these flights. The CAAS Air Operators Certificate Requirements (AOCR) for ULR flights by Singapore Airlines says that guidance to aircraft crewmembers is to be provided on expected preflight preparation and in-flight rest. AOCR also says that an in-flight rest plan must provide at least two rest periods, one of which shall be not less than four hours. This guidance material is provided to aircraft crewmembers in tabular descriptive form.

In line with the objectives set out while the CAAS ULR Task Force was developing the provisional rules for ULR flights, the intent was that such guidance material on in-flight rest not be too prescriptive for the line crews. Line pilots appeared to prefer two brief rest periods of approximately 2.5 hours duration (depending on actual flight time) followed by two long breaks of approximately five hours duration (depending on flight time) alternating between main crew and relief crew on a given ULR flight sector.

The line pilots flying the ULR flight sectors have reported that not only is this method of taking rest practical, it also fulfills the requirements stipulated in the AOCR. Pilots said that such practice affords the main crew and the relief crew a practical opportunity to obtain recuperative rest during at least one of the two rest periods. The polysomnography and objective performance measurements employed in the scientific studies also appeared to have validated this method of taking rest for these routes and departure times.

Feedback and anecdotal evidence received by ALPA–S from line pilots operating ULR flights have indicated that flight crews experience sleep patterns similar to sleep patterns in their in-flight rest not only during layover but also during post-ULR-flight rest at their base (Singapore). Pilots told ALPA–S that such sleep patterns were disruptive to post-ULR-flight rest at layover hotels and also to recuperative rest at their base. This could be the result of a change from the single-rest-period practice (as done on current long-range flights) to the two-rest-period practice adopted on ULR flights. ALPA-S believes that this phenomenon may warrant further study with a view to develop ways to mitigate or alleviate the effects on flight crews.

The CAAS ULR Task Force ensured that pilot crew-rest facilities designed for ULR flights would meet or exceed the current standard of those in long-range commercial passenger jets.

During initial ULR flights, numerous heater failures occurred in the crew-rest facilities. Some heater failures rendered unserviceable the respective crew-rest facilities for pilots or cabin crewmembers. Pilots who attempted to obtain rest in a business-class seat during heater failures said that the situation was not conducive to recuperative rest and had an adverse effect on in-flight alertness. The manufacturer has issued procedures that minimize the probability of failure of heaters in crew-rest facilities.

Humidification is provided in the crew-rest facilities for cabin crewmembers and in the crew-rest facilities for pilots. Based on feedback from line pilots, humidification improves physiological performance and alertness during ULR flights and enables these pilots to obtain better recuperative rest. During early operational experience, the humidifiers often failed in flight. Recent operational experience showed that the failure rate has improved markedly. The manufacturer currently is modifying these units to further improve dispatch reliability.

The crew-rest facility for cabin crewmembers has two emergency exits (hatches). Initial safety training was conducted in these aircraft, and the repeated use of the hatches in training loosened the securing mechanisms. As a result, the emergency hatches often detach during flight, disrupting the rest of pilots and cabin crewmembers.

ULR flights are designed so that flight crews will obtain adequate recuperative sleep on layover and during the scheduled postflight period. The quality of crew layover hotels has been good and has been subject to close scrutiny by Singapore Airlines and ALPA–S. Nevertheless, providing an environment that is conducive for pilots to obtain such rest merits closer attention.

Feedback to ALPA–S from flight crews indicated that noise generated by hotel air-conditioning

Numerous heater failures occurred in the crew-rest facilities.

systems disrupted sleep. Failure of hotel cleaning staff to observe "DO NOT DISTURB" signs also was disruptive. Measures have been taken to resolve the problems.

CAAS, Singapore Airlines and ALPA-S will be guided by long-term operational experience and appropriate scientific data to amend the requirements and conditions for ULR flights to further improve flight crew alertness.■

About the Authors

Capt. Paul Ho K.C. is an Airbus A340-500 pilot for Singapore Airlines. Senior First Officer Shane Landsberger is International Federation of Air Line Pilots' Associations director for the Air Line Pilots Association–Singapore and an A340-500 pilot for Singapore Airlines. Leigh Signal, Ph.D., is associate director of the Sleep/Wake Research Centre of Massey University, Wellington, New Zealand. Dr. Jarnail Singh is chairman of the Civil Aviation Medical Board, Civil Aviation Authority of Singapore (CAAS) and chairman of the CAAS ULR Task Force. Barbara Stone, Ph.D., is head, Sleep Research, QinetiQ Centre for Human Sciences, Farnborough, England.

Notes

1. Ultra-long-range (ULR) flights have planned flight-sector lengths (block times) greater than 16 hours and flight-duty periods from 18 hours to 22 hours in scenarios defined by the ULR Crew Alertness Steering Committee, an initiative cosponsored by Airbus, Boeing Commercial Airplanes and Flight Safety Foundation. Changi Airport in Singapore is the home base of Singapore Airlines. The airline's ULR flights from Singapore to Los Angeles, California, U.S., use Los Angeles International Airport. The airline's ULR flights from Singapore to the New York, New York, U.S., area use Newark (New Jersey) Liberty International Airport.

2. Principal tenets adopted by the ULR Crew Alertness Steering Committee include the requirements that airlines obtain approval for operational plans for ULR flights from civil aviation authorities and that operational plans be developed using a scientifically based method. This method can employ validated mathematical models of crew alertness (tools that predict outcomes in situations in the absence of data) to show how ULR flights can be conducted between specific city pairs. The focus on requirements for specific city pairs — rather than generic rules — enables regulators and scientists to take account of all relevant factors, such as the effects of crossing time zones and the circadian rhythm (body clock) of aircraft crewmembers.

3. The Actiwatch — a small, lightweight device approximately the size of a wristwatch — measures and records motions of the body; this research method is called actigraphy. Actigraphy devices have proven to be highly sensitive to sleep, and they are a useful means of objectively monitoring sleep over extended periods of time.

4. The term "rostered duty assignment," as used by Singapore Airlines, means a scheduled period specifically for pilots conducting ULR flights. This period includes the scheduled flight duty for the sector from Singapore and the return sector, and all associated days/nights free of duty that precede and follow these sectors (including the layover).

5. Fisher, Genene M. "Integrating Space Weather and Meteorological Products for Aviation." *Bulletin of the American Meteorological Society.* November 2003. "Typically, airline dispatchers review the U.S. National Oceanic and Atmospheric Administration (NOAA) Space Environment Center's 'Space Weather Now' Web site <www.sec.noaaa.gov/swn> and will not plan a polar flight if a level-S4 (severe) solar radiation storm is active or expected," Fisher said. "A severe solar-radiation storm elevates the radiation exposure to passengers and crew at high latitudes and most likely will result in a blackout of high-frequency radio communications through the polar regions with an increased likelihood of navigation errors." <www.sec.noaa.gov/alerts/description.html> The NOAA scale for solar radiation storms comprises S5 (extreme), S4 (severe), S3 (strong), S2 (moderate) and S1 (minor).

6. Polysomnography, a method of recording in-flight sleep data, involves recording brain activity (by electroencephalography), eye movement and muscle tone using small electrodes that are attached to the head and the face of the pilot.

7. Based on subjective responses to a questionnaire, the Karolinska Sleepiness Scale rates each study participant from 1 (very alert) to 9 (extremely sleepy); this standardized tool is used by sleep researchers worldwide and can be correlated with objective measures of sleepiness.

8. Using the Samn-Perelli fatigue scale, study participants rate themselves as 1 (fully alert, wide awake); 2 (very lively, responsive, but not at peak); 3 (OK, somewhat fresh); 4 (a little tired, less than fresh); 5 (moderately tired, let down); 6 (extremely tired, very difficult to concentrate); or 7 (completely exhausted, unable to function effectively).

9. VigTrack software for hand-held computing devices presents the study participant with a set of vigilance and tracking tasks that enable scientists to objectively assess alertness.

10. Psychomotor vigilance tasks require the study participant to respond as quickly as possible to the presentation of stimuli, enabling scientists to objectively assess alertness.

11. Endogenous circadian rhythm is a scientific term for the neurophysical process ("body clock") that controls the daily cycle of a person's sleep/wake pattern and other physiological variables. Research shows that a person's body clock normally is entrained (synchronized) to the 24-hour day but becomes desynchronized (i.e., out of circadian phase) by time-zone transitions.

Cabin Crews Adapt Readily to Challenges of Ultra-long-range Flight

Methods of managing fatigue and maintaining alertness have included prescheduled relaxation/sleep in a crew-rest facility, rest breaks in crew seats and controlled napping.

— FSF EDITORIAL STAFF

Crew-rest facility for Boeing 777-200LR cabin crewmembers.

(Photo: Boeing)

During 2003, about 1,500 cabin crewmembers received training for ultra-long-range (ULR) flights[1] in preparation for Singapore Airlines' February 2004 introduction of daily nonstop flights between Singapore and Los Angeles, California, U.S., with the Airbus A340-500. Except for methods of obtaining sleep before, during and after ULR flights — part of a training module, unique to ULR, called the crew alertness management program — most training was familiar to those already accustomed to long-range operations, said Lam Seet Mui, senior manager, cabin crew training, and Patrick Seow Thiam Chye, in-flight supervisor, both of the Cabin Crew Division of Singapore Airlines.[2]

"Training methodology has been the same for topics such as evacuation, but specific content of the module on safety emergency procedures is geared toward the A340-500 because these cabin crews need to know the exact equipment

Crew-rest facility for Airbus A340-500 cabin crewmembers.
(Photo: Copyright Airbus)

and safety features on that aircraft type," Lam said. "In long-range operations, each cabin crewmember takes three hours of rest according to the regulatory requirements, so we had significant experience conducting emergency procedures that might occur while some of the cabin crew is at rest."

In a process similar to that used by flight crewmembers conducting ULR flights, cabin crewmembers take rest using a combination of prescheduled relaxation/sleep in a cabin crew rest facility, rest breaks in crew seats and controlled napping (i.e., five-minute "power naps") if required. Several cabin crew work/rest patterns have evolved — all designed to provide adequate rest opportunities (including time to sleep), to reduce fatigue and to maintain the alertness required during all phases of flight. Unlike the flight crew's designation of a "main crew" and a "relief crew," however, the cabin crewmembers operate as one crew with their number reduced temporarily during the designated rest opportunities in the cruise phase.

Civil Aviation Authority of Singapore (CAAS) regulations applicable to cabin crew in-flight rest on ULR flights are similar in concept to those applicable to flight crew, Lam said. CAAS requires cabin crews to have the opportunity for four hours of in-flight rest during a flight-duty period (FDP) of less than 19 hours and five hours of in-flight rest during an FDP of 19 hours or more.

"Cabin crewmembers rostered for a ULR flight must have three local nights free of duty at the Singapore home base before departure, and the day before the flight from Singapore must be free of duty," she said. "After the flight from Singapore, while each cabin crewmember must have at least two nights without duty at the layover station [i.e., Los Angeles or New York, New York, U.S. (service to Newark Liberty International Airport, New Jersey, which began in June 2004)], the company has arranged for cabin crews to have an additional layover night for standby duties. After the return flight to the Singapore home base, cabin crewmembers must have at least 48 hours of rest including three local nights."

Rest Schedules

Although the physiology of sleep is the same for cabin crew and flight crew, CAAS regulations reflect the current consensus among aviation safety specialists about differences in stress levels, work environments and required levels of alertness between the cabin crew and flight crew, Lam said.

"A cabin crew typically is divided into group A and group B, each with a designated crewmember-in-charge [CIC] so that whenever the primary CIC is resting, the standby CIC is on duty," she said. "The patterns are planned so that, at all times, we have at least one group on duty, and during the peak times of major meal services — as well as during takeoff and landing — both groups are on duty. In our single-rest pattern, group A goes on rest for four hours or five hours, depending on the flight sector, as group B goes on duty; then with a 15-minute overlap and information handover, group A goes back on duty as group B goes on rest. Alternatives for some flights include a split-rest pattern and a mixed-rest pattern."

In a 3-2-2-3 split-rest pattern applicable to Singapore–New York flights, group A takes rest for three hours while replaced by group B, then group B takes rest for two hours while replaced by group A, then group A takes rest for two hours while replaced by group B, and finally group B takes rest for three hours while replaced by group A. In the alternative 3-5-2 mixed-rest pattern, group A takes rest for three hours while replaced by group B, then group B takes rest for five hours while replaced by group A, and finally group A takes rest for two hours while replaced by group B. At other times, both groups are on duty.

Feedback Prompts Changes

ULR flights began using only the single-pattern shift — basically, one four-hour/five-hour rest opportunity — for group A and then for group B, supplemented by flexible opportunities for controlled napping by cabin crewmembers if required.

"Our initial feedback about the single-rest pattern from cabin crews [that conducted Singapore–Los Angeles ULR flights] was that they preferred this work/rest pattern," Lam said. "When we later launched the Singapore–New York ULR flights, we got further feedback, and some crews said that they would prefer a split-rest pattern with two rest opportunities of two hours or three hours, so we added that option. Later, feedback from other crewmembers said that they preferred to take one opportunity for five hours of rest, so we added the third option of the mixed-rest pattern. We have continued to listen to our cabin crews to adjust these work/rest patterns as we gain experience, and we have confirmed through electronic surveys and focus groups that practical effects are as expected."

Although individual preferences may vary, the predominant factor that drives which cabin crew work/rest pattern is used on a given flight is the local time of the departure window.

"For example, we know that most cabin crewmembers will not be able to rest for five full hours at a stretch if their only rest opportunity begins at 1400 local time," Seow said. "Therefore, the 3–2–2–3 split-rest pattern was developed to meet the needs of everyone. In this pattern, if individuals cannot rest well at the first rest opportunity, they can look forward to the next rest opportunity of two hours. Nevertheless, given the departure windows for the flights from Los Angeles to Singapore, the single-rest pattern has proven to be most valid because these crewmembers ought to obtain a full four/five hours of sleep at their first rest opportunity. There is a lot of flexibility in our work/rest patterns. The desired outcome is not to follow any specific pattern, but to ensure that each cabin crew can be rested to their personal maximum level."

In another example — ULR flights from New York to Singapore — the 3–5–2 mixed-rest pattern has been the most conducive to sleep and to maintaining alertness at other times.

The cabin crews train for various scenarios, and protocols are in place for waking the group A cabin crewmembers or the group B cabin crewmembers as required to handle specific types of in-flight emergencies. The protocols take into account the number of cabin crewmembers required, which depends on the type of emergency, flight phase and circumstances.

"Our protocols call for waking and alerting the group at rest at the discretion of the CIC on duty," Seow said. "If the emergency is serious enough, the group on duty will wake the CIC who is at rest and/or activate the entire resting crew if required. But if the nature of the situation is a minor medical emergency, for example, the alternate CIC on duty is trained and capable of handling the situation with only the group on duty."

"There is a lot of flexibility in our work/rest patterns."

Although cabin crewmembers may have opportunities for as much as five hours to relax, sleep, socialize, read/study, exercise or participate in recreational activities, standard operating procedures have been implemented for maintaining situational awareness and personal safety.

"Seat belts are provided at every bunk, and in-flight procedures require crewmembers to wear the seat belt whenever occupying a bunk, just like when they are in a crew seat," Seow said. "Sufficient crew seats are located in the main cabin, independent of the rest areas, so crew bunks are out of bounds for occupancy during takeoff and landing."

Exercise Encouraged

Passenger safety briefings and in-flight health guidance for ULR flights are similar to that of other flights. Crewmember instructions and in-flight media provide the same advice to passengers as on other types of Singapore Airlines flights. The advice includes periodically performing leg/foot exercises and moving about the cabin to prevent deep-vein thrombosis (formation of blood clots while sedentary).

"Our A340-500s have 181 seats configured for passenger comfort during ULR flights; even in the executive economy class, passengers have a lot more distance between seats and room to move around, compared with our other fleets," Seow said. "At every seat, we provide an advice card that encourages passengers to obtain regular exercise during the flight. Before showing each movie, we also prompt passengers about the health measures that they should be using for the duration of flight. This includes visiting a passenger corner where they can stand up, move around, stretch their muscles, have a drink and have a snack."

No Change in Behavior

During four workshops conducted in 2001 through 2005 by the ULR Crew Alertness Steering Committee — cosponsored by Airbus, Boeing Commercial Airplanes and Flight Safety Foundation — some safety specialists suggested that a greater-than-normal incidence of inappropriate/abusive passenger behavior might occur in the cabin environment (see "The Singapore Experience: Task Force Studies Scientific Data to Assess Flights," page 20). Lam and Seow said that no greater incidence of such behavior was reported during the first 15 months of ULR operations on the Singapore–Los Angeles routes or during the first 12 months on the Singapore–New York routes.

"So far, we have not noticed any difference in terms of passenger-behavior incidents, compared with our other types of operations," Lam said. "Our A340-500 cabin crews have been trained especially to be sensitive to passenger reactions, behavior and nonverbal cues, and how to take care of irate passengers."

Furthermore, the airline's system for monitoring minor cabin safety/security occurrences has recorded rates during ULR flights that generally are comparable to other types of flights.

"So far, nothing of concern has occurred," Lam said.

Focus on Fatigue

Among the most important lessons learned by the first cabin crews conducting ULR flights has been the requirement for recognition and open discussion of fatigue and alertness, she said.

"Our training program creates an awareness of their own level of fatigue as well as the fatigue levels of the passengers," Lam said. "The main difference between training for ULR flights on the A340-500 and other types of flights or aircraft is how crewmembers recognize this."

Also significant is that cabin crewmembers learn to consider fatigue and diminished alertness a serious matter, Seow said.

"This degree of emphasis on fatigue and alertness was something new," he said. "I personally find our crew alertness management program to be extremely useful in practice; the module goes a long way toward making us better prepared to obtain required rest before flight, in flight and postflight. This knowledge is how cabin crew colleagues and I have been able to maintain constant awareness of alertness and to take care of ourselves."

The broader context of cabin crew selection and training for ULR flights has been important not only from a commercial standpoint — inaugurating a new service — but in establishing international precedents for safety, Lam and Seow said.

"Among experienced cabin crewmembers who already managed well their fatigue levels during long-range operations, ULR flights have reaffirmed their confidence," Lam said. "Some of them initially told me, 'Hey, this is nothing very new.' But their training reinforced the importance of managing alertness and fatigue and why they must follow the recommendations on taking rest."

Advance Notice Helps

Pride in being the first cabin crews to conduct ULR flights has been very strong, but not every cabin crewmember has been able to adapt as expected, Seow said.

"Before we launched the Singapore–Los Angeles service, we hypothesized about what would be the significant issues of fatigue and alertness for cabin crews [based on computer-based modeling and validation studies of pilots]," Lam said. "After we launched ULR flights, we wanted to know whether our hypotheses were correct and if cabin crewmembers actually were using additional coping strategies that we had not incorporated into the training."

Focus-group comments so far have generated questions for further studies

— especially the preliminary finding that some individuals may have significant difficulty obtaining sleep aboard the aircraft regardless of the rest opportunities provided, Lam said.

As with research on sleep efficiency — that is, hours of sleep obtained divided by hours of sleep attempted times 100 — among pilots during ULR flights, cabin crewmembers have said that advance knowledge of their planned rest opportunities at layover stations helps them to obtain in-flight sleep.

"Before arriving at the outstation [i.e., Los Angeles or New York], we encourage the CIC to inform all cabin crewmembers about the rest opportunities to be provided on their return flight," Seow said. "Advance notice helps them to ensure that they have enough sleep during layover. For example, if individuals know that their in-flight rest opportunity will be provided on the second position of a single-rest pattern, they know that they will need to plan to obtain enough sleep before the flight begins to remain alert. We even encourage them to sleep a little bit more than usual before reporting for duty to be sure that they have adequate sleep, and we have heard that this method works well."

Preventing microsleeps[3] during landing also has been an objective of the methods of ensuring adequate cabin crew rest and alertness. Microsleeps per se might not affect the crewmember's performance during an emergency, but might reflect inadequate preflight rest or in-flight rest, Lam said. Moreover, observant passengers who see cabin crewmembers experiencing microsleeps may have a negative perception of safety.

"We are all fully aware of how microsleeps might affect us, and we have used controlled napping as a supplemental countermeasure to manage microsleeps," Seow said. "We encourage openness in the leadership style of CICs, who tell cabin crewmembers that if they need a controlled nap, they should just tell the CIC. Open communication about individual feelings of fatigue has contributed toward improving the overall level of alertness in the landing phase of ULR flights. Social interaction — among pilots, cabin crewmembers and passengers — also helps to maintain the overall level of alertness."

Win-win Solution

The initial selection of cabin crewmembers for A340-500 ULR flights was conducted by deploying cabin crew teams with previous experience on the Airbus A340-300. Lam said that, overall, fewer than the original 1,500 cabin crewmembers currently fly on the ULR flights for two primary reasons: promotions leading to subsequent reassignment of crewmembers to other fleets; and instances in which a small group of cabin crewmembers were unable to sleep easily during ULR flights.

"Company management has proposed a one-time opportunity for such crewmembers to opt out and transfer to another fleet," Lam said. "After these cabin crewmembers have chosen to opt out, we will invite cabin crewmembers from other fleets to opt in for the A340-500 training and assignment, so this would be a win–win solution."

Although some of the cabin crewmembers from other fleets have no prior experience on the A340-500, they want to be part of ULR flights because they consider the assignment to be prestigious, Seow said.

Changes Suggested

As among pilots, cabin crewmembers have asked for a few changes to make their crew rest facilities more conducive to restful sleep based on their initial experience.

"I certainly did not expect any bunk to match the comfort of my king-size bed at home, but the cabin crew rest facility does provide an environment for the cabin crew to obtain adequate rest," Seow said.

Aids to obtaining sleep — such as eyeshades and ear plugs — vary in effectiveness according to individual preferences, he said.

The most-suggested improvements for cabin crew rest facilities involved the brightness of lights on illuminated signs (which was adjusted promptly) and adding the option of using duvets (flat cloth bags filled with feathers, down or similar lightweight insulating material) as an alternative to heavier blankets on bunks, Lam said. Other suggestions involved bunk shape and height, thickness of mattresses, curtains, range of temperature control and noise from movements of other cabin crewmembers. ■

Notes

1. Ultra-long-range (ULR) flights have planned flight-sector lengths (block times) greater than 16 hours and flight-duty periods from 18 hours to 22 hours in scenarios defined by the ULR Crew Alertness Steering Committee, an initiative co-sponsored by Airbus, Boeing Commercial Airplanes and Flight Safety Foundation.

2. Lam, Seet Mui; Seow, Thiam Chye Patrick. Interview by Rosenkrans, Wayne. Los Angeles, California, U.S. May 26, 2005. Flight Safety Foundation, Alexandria, Virginia, U.S.

3. Microsleeps — brief episodes of sleep intrusions into wakefulness with loss of attention, typically between two seconds and 30 seconds — are important signs of decrements in neurocognitive functioning that have been known to cause lapses in pilot performance during any phase of ULR flights. Signs of microsleeps include a blank stare, head snapping, momentary "dozing" or prolonged eye closure that occur when a person is fatigued but tries to remain awake to perform a monotonous task. During microsleeps, the person will not be aware of warning lights and other events.

South Africa Reports Decline in Commercial Aircraft Accidents

Accidents involving small transport aircraft decreased from 55 in 2003 to 43 in 2004. One large transport aircraft accident, with no fatalities, occurred in 2004.

– FSF EDITORIAL STAFF

South African Civil Aviation Authority (CAA) data[1] show decreases in accident numbers from 2003 to 2004, both among large commercial air transport aircraft weighing 12,500 pounds/5,700 kilograms or greater and among small commercial air transport aircraft (Table 1, page 47).

In the large commercial air transport category, the number of accidents decreased from two in 2002 and in 2003 to one in 2004. During the 1993–2004 period, the number of accidents in the category was highest in 1998, when there were six accidents. The one accident in 2004 compared with an annual average of 2.6 accidents in the preceding 11 years.

CAA also reported the numbers of accidents in the smaller commercial aviation category (an amalgamation of aircraft weighing a maximum of 12,500 pounds/5,700 kilograms or having a maximum approved passenger-seating configuration of nine seats, as well as aircraft used in commercial helicopter air transport, helicopter external-load operations, emergency medical services and aviation training).

The 43 accidents in the smaller commercial aviation category in 2004 represented a 22 percent reduction from the 55 accidents in 2003 and a 20 percent reduction from the 54 accidents in 2002. The 43 accidents in 2004 were 72 percent higher than the annual average of 25 during the 1993–2003 period.

There were no fatalities in the large commercial air transport category in either 2003 or 2004 (Table 2, page 47). During the 1993–2003 period, there were fatalities in this category in only two years: one fatality in 1998 and three fatalities in 2002.

In the smaller commercial aviation category, the 10 fatalities in 2004 represented a 65 percent decrease from the 29 fatalities in 2003. The 10 fatalities in 2004 compared with an annual average of 8.3 fatalities in the 1993–2003 period.

CAA ranked the main causal factors in accidents involving all aircraft categories (Table 3, page 47). "Pilot/flight crew" was the leading causal factor in every year from 1999 to 2004.

Continued on page 48

Table 1
Civil Aircraft Accidents, by Type of Operation, South Africa, 1993 Through June 2005

Type of Operation	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	Through June 2005
Large commercial air transport (Part 121)	1	2	2	3	3	6	4	3	1	2	2	1	0
Small commercial transport/ charter/Part 127, 133, 135, 138, 141	9	18	8	16	14	16	10	37	35	54	55	43	21
Total	**10**	**20**	**10**	**19**	**17**	**22**	**14**	**40**	**36**	**56**	**57**	**44**	**21**

Note: Part 121 applies to large-aircraft air transport operations involving aircraft weighing more than 12,500 pounds/5,700 kilograms or a maximum approved passenger seating configuration of more than nine seats. Part 127 applies to operations with helicopters engaged in commercial air transport operations. Part 133 applies to helicopter external-load operations. Part 135 applies to small-aircraft air transport operations involving aircraft weighing a maximum of 12, 500 pounds/5,700 kilograms or a maximum approved passenger seating configuration of nine seats. Part 138 applies to emergency medical services operations. Part 141 applies to aviation training organizations.

Source: South African Civil Aviation Authority

Table 2
Civil Aircraft Accident Fatalities, by Type of Operation, South Africa, 1993 Through June 2005

Type of Operation	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	Through June 2005
Large commercial air transport (Part 121)	0	0	0	0	0	1	0	0	0	3	0	0	0
Small commercial transport/ charter/Part 127, 133, 135, 138, 141	1	2	3	8	3	8	16	7	7	9	29	10	1
Total	**1**	**2**	**3**	**8**	**3**	**9**	**16**	**7**	**7**	**12**	**29**	**10**	**1**

Note: Part 121 applies to large-aircraft air transport operations involving aircraft weighing more than 12,500 pounds/5,700 kilograms or a maximum approved passenger seating configuration of more than nine seats. Part 127 applies to operations with helicopters engaged in commercial air transport operations. Part 133 applies to helicopter external-load operations. Part 135 applies to small-aircraft air transport operations involving aircraft weighing a maximum of 12, 500 pounds/5,700 kilograms or a maximum approved passenger seating configuration of nine seats. Part 138 applies to emergency medical services operations. Part 141 applies to aviation training organizations.

Source: South African Civil Aviation Authority

Table 3
Main Causal Factors in Aircraft Accidents, All Aircraft Categories, South Africa, 1999–June 2005

Broad Causal Factors	1999	2000	2001	2002	2003	2004	Through June 2005
Mechanical/engine/powerplant	11	24	26	29	30	44	27
Aircraft operational	4	10	7	3	1	7	1
Pilot/flight crew	145	92	78	119	122	93	39
Maintenance/servicing	23	12	9	4	4	5	2
Weather-related	3	12	3	6	6	3	4
Collision-related	12	2	7	10	5	6	8
Total	**198**	**152**	**130**	**171**	**168**	**158**	**81**

Note: Data are derived from final accident investigation reports.

Source: South African Civil Aviation Authority

Table 4
Reported Aircraft Accidents Compared With Aircraft Registrations, South Africa, 1992–June 2005

Year	Registered Aircraft	Aircraft Accidents	Accidents as Percentage of Registered Aircraft	Fatal Accidents	Fatalities
1992	5,549	179	3.23%	19	37
1993	5,661	190	3.36%	14	30
1994	5,915	171	2.89%	17	33
1995	6,182	169	2.73%	11	30
1996	6,421	187	2.91%	20	42
1997	6,625	156	2.35%	22	38
1998	6,977	177	2.54%	26	63
1999	7,222	150	2.08%	27	57
2000	7,484	153	2.04%	26	41
2001	7,717	146	1.89%	22	35
2002	7,927	169	2.13%	19	32
2003	8,403	139	1.65%	17	48
2004	8,822	149	1.69%	17	34
Through June 2005	9,063	80	0.88%	6	12

Source: South African Civil Aviation Authority

"Mechanical/engine/powerplant" was the second-most-cited causal factor in every year except 1999 during the period.

Comparisons of annual numbers of accidents and fatalities must take into account the increased exposure time during the period, as a result of a larger volume of air traffic. Although the number of registered aircraft categorized as commercial aviation was not reported, the total number of registered aircraft in South Africa increased by 59 percent, from 5,549 in 1992 to 8,822 in 2004 (Table 4). During the 1992–2004 period, accidents as a percentage of total registered aircraft decreased from 3.23 percent in 1992, and a high of 3.36 percent in 1993, to 1.69 percent in 2004.

Note

1. The data are available on the Internet at <www.caa.co.za>.

STATS

Improving Human-machine 'Cooperation' on the Flight Deck

Authors emphasize ways that flight deck design can be adapted to the pilots' cognitive resources.

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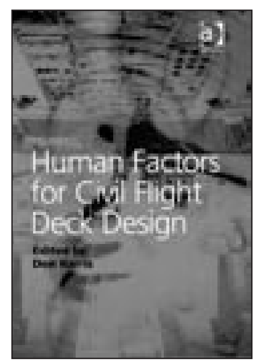
Books

Human Factors for Civil Flight Deck Design. Harris, Don (ed.). Aldershot, England: Ashgate Publishing, 2004. 327 pp. Figures, tables, references, index.



"Technological advances and changes in the operational context for civil aircraft have resulted in the constant evolution of flight decks," say Florence Reuzeau and René Nibbelke in their chapter discussing the flight deck design process. "Designs have had to change to adapt to the new technologies, operational requirements and the more restrictive requirements (safety, availability, maintainability, etc.)."

But traditional human factors methods — based on disciplines such as measuring how well pilots can see instruments or reach controls — that were adequate for earlier, relatively low-tech flight decks are no longer sufficient for designing advanced flight decks.

"Today, the commercial task (passengers and freight management) is quite demanding in terms of cognitive resources," the chapter authors say. Improved technology, helpful on one level, can increase cognitive strain on another level.

For example, they cite research suggesting that the "distance" between the systems and the human is increasing. Useful technical tools that are designed to help the human operator can add secondary or "parasitic" tasks, related to the handling of the tool, to the primary task of flying the aircraft.

"The operator has to have a clear vision of the final objective of the work but also of the intermediary objectives relating to the tool," the chapter authors say. "The problem for the designer is to provide timely, context-sensitive information. Obviously, the information needed to use a landing gear … is not the same as the information needed to manage an automatic system that could have its own internal logic."

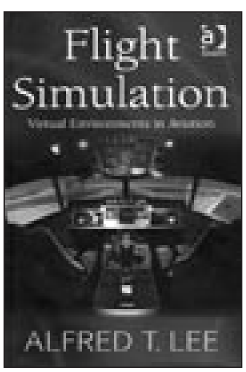
In his chapter about which flight deck tasks should be automated — and how the automation should interact with the pilot — Sidney Dekker says that "automation has taken over many of the more tedious tasks, from holding a heading for long stretches of time, to doing onerous fuel and weight calculations in real time. Automation, however, has redistributed workload rather than just reducing it. The benefits of automation are most noticeable when they are of least value: during low-tempo [low-workload] operations when the human operator already had little to do."

The key issue, Dekker says, is not how much automation there should be or "function allocation" (trying to determine what computers do better and what people do better).

"The central flaw of function allocation lies in the false idea of fixed strengths and weaknesses," he says. "Capitalizing on some strength of computers does not replace a human weakness. It creates new human strengths and weaknesses — often in unanticipated ways."

The key to a successful automation future "lies in how [automated systems] support cooperation with their human operators — not only in foreseeable standard situations, but also during novel, unexpected situations," he says.

Other chapters discuss head-up displays, warning system design, handling qualities and various aspects of flight deck evaluation.



Flight Simulation: Virtual Environments in Aviation. Lee, Alfred T. Aldershot, England: Ashgate Publishing, 2005. 149 pp. Figures, table, bibliography, index.

As flight simulation has matured technologically, it has become apparent that simulator design requires more than engineering, says the author. Understanding of piloting tasks and the complex human experience of flight has led to focusing on human-centered design and evaluation of piloted flight simulators.

"This book has several objectives," says the author. "The first is to describe the key component technologies of flight simulators and how they support the pilot's experience of flight and the pilot's performance of specific tasks. An additional objective is to provide some understanding of the capacity and limitations of the pilot in areas that are directly relevant to the design of flight simulation devices. How flight simulation technology is applied in the world of aviation is also described, as are studies that have examined the effectiveness of this technology in pilot training and evaluation."

The author acknowledges that simulating the actual handling characteristics of a particular aircraft is still a challenge. But the technology continues to improve.

"Simple control-loading systems which provide resistance forces to control input have … evolved into very complex and sophisticated systems capable of continually monitoring and feeding back control loads to pilot inputs," he says. "Such systems can also provide other flight cues such as low-amplitude, high-frequency vibrations associated with a variety of aircraft and environmental conditions. Newer, less costly force-feedback systems using microprocessor and electronic torque motors will eventually bring high-fidelity handling characteristics even to the most inexpensive flight training devices."

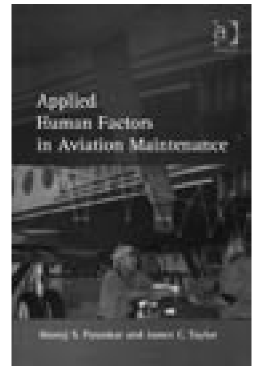
One chapter addresses what the author believes are inherent limitations of simulator technology. "To apply the necessary accelerations to ground-based flight simulators in an attempt to reproduce all of the forces a given aircraft is likely to encounter in operational flight is essentially impractical and, for training devices at least, cost-prohibitive," he says.

Another limitation is that, however realistic the flight simulation, it can never fully replicate the psychological conditions of actual flight — the pilot knows that there is no physical risk.

The author foresees continuing advances in visual-scene simulation, including greater use of satellite imagery and terrain modeling, and improvements in the realism of aircraft-handling characteristics, especially for lower-cost flight training devices.

Applied Human Factors in Aviation Maintenance. Patankar, Manoj S.; Taylor, James C. Aldershot, England: Ashgate Publishing, 2004. 170 pp. Figures, tables, references, index.

The authors discuss human factors issues in maintenance that have been revealed by reports submitted to the U.S. National Aeronautics and



Space Administration (NASA) Aviation Safety Reporting System (ASRS).

"Considering the global awareness of human performance issues affecting maintenance personnel, there is enough evidence in the ASRS reports to establish that systemic problems such as impractical maintenance procedures, inadequate training and safety-versus-profit challenge continue to contribute toward latent failures," the authors say. "Although a handful of error-mitigation techniques have been used to minimize such latent failures, the sustained use of such error-mitigation techniques have been marred by factors including, but not limited to, the following: low mechanics' trust in their management, inconsistent professionalism among the mechanics and limited regulatory and corporate resources allocated to safety issues."

The authors say that human factors knowledge must be applied to quality-control issues that arise in maintenance. Examples of such issues described in the book are incomplete and confusing instructions; assuming that already installed parts are correct; assuming that the previous repair was correct; and one supervisor who curtailed further inspection of an airliner near where corrosion had been found because the maintenance was behind schedule and the supervisor could not afford any more "write-ups."

Reports

Solar Radiation Alert System. U.S. Federal Aviation Administration (FAA) Office of Aerospace Medicine. DOT/FAA/AM-05/14. Final report. July 2005. Copeland, Kyle; Sauer, Herbert H.; Friedberg, Wallace. 12 pp. Figures, tables, references. Available through the U.S. National Technical Information Service.*

Occupants of aircraft in flight are exposed to ionizing radiation at higher-than-normal dose rates. Although galactic solar radiation is the principal type of ionizing radiation, at times a disturbance in the sun such as a solar flare also increases ionizing radiation in the form of a large flux of solar protons, which can expose aircraft occupants at high altitudes.

A solar radiation alert (SRA) system has been developed to continuously evaluate proton-flux measurements made by instruments on geosynchronous operational environmental satellites (GOES). If the GOES measurements indicate a likelihood of substantially elevated dose rates at high altitudes, FAA's Civil Aerospace Medical Institute issues an SRA via the U.S. National Oceanic and Atmospheric Administration's Weather Wire Service. The alert includes estimated dose rates, measured in microsieverts per hour, based on five-minute averages, at various altitudes between 30,000 feet and 70,000 feet.

The report describes the methodology for estimating effective dose rates for the SRA system. An example is given using effective dose rates from solar protons in the atmosphere during a solar-proton event in January 2005.

"The SRA system provides timely, quantitative information for the aviation community on … hazardous solar radiation levels at aircraft flight altitudes in high-latitude regions," says the report. "This information enables users to decide whether or not reducing aircraft flight altitudes is appropriate."

La Révolution des Drones/The UAV Revolution. Toulouse, France: Académie Nationale de L'Air et de L'Espace (ANAE; French National Air and Space Academy), 2004. Dossier 25. 88 pp. Tables, figures, references, photographs. Available from ANAE.**

"As a result of recent advances in key areas such as information technology, robotics, optronics, radar imaging and data transmission, UAVs (unmanned aerial vehicles) are rightly playing a greater and greater role in aeronautics and defense activities," says the report. "For the moment, they are mainly used for military missions … . However, numerous applications linked to domestic security or civilian missions could emerge in the future as soon as problems linked to the operating costs of UAVs and their integration into general air traffic control have been settled."

Among possible civil applications of UAVs, the report cites study of the atmosphere and oceans; border surveillance; crop spraying; maritime surveillance of shipping routes to spot drug smuggling, illegal immigration and pollution; freight transport; surveillance of oil and gas pipelines, overhead cables and high-tension lines; and surveillance of road traffic.

Although operational uses of UAVs are still rare, the report says that UAVs were used in security preparations for G8 (Group of Eight, involving leading world economic powers) meetings and for the 60th anniversary celebration of the Allied landing in Normandy, France, during World War II.

"The academy came to the conclusion that the UAV 'revolution' is not a passing fad, but rather an inescapable evolution in technology and methodology in terms of the deployment of modern resources in the third dimension," says the report. "The UAV must not be treated simply as an aircraft without a pilot, but must be seen as one element in a pioneering system which opens up new possibilities in the tactical, operational and even strategic domains, and promising prospects for dual utilization, in particular in the vast area of civil safety. Firstly, however, the technical and psychological obstacles to integration of UAVs into airspace must be overcome."

The report is bilingual, with English and French text on facing pages. Color photographs show five operational or planned UAV systems.

Regulatory Materials

Thermal/Acoustic Insulation Flame Propagation Test Method Details. U.S. Federal Aviation Administration (FAA) Advisory Circular (AC) 25.856-1. June 24, 2005. 13 pp. Figures. Available from the U.S. Department of Transportation.***

This AC provides guidance about the test method to determine the flammability and flame-propagation characteristics of thermal/acoustic insulation materials for airplanes required to comply with U.S. Federal Aviation Regulations (FARs) Part 25.856.

Amendment 25-111 (July 31, 2003) introduced updated fire protection requirements for thermal/acoustic insulation materials. The amendment added test requirements for resistance to flame propagation and to burn-through penetration.

"Experience has shown that the Bunsen burner test that was required prior to the adoption of Amendment 25-111 did not provide a sufficient measure of thermal/acoustic insulation's resistance to flame propagation," the AC says. "In addition, since most thermal/acoustic insulation is installed in parts of the airplane that are not accessible for fire fighting, it is critical that the material combinations themselves will not propagate a fire if ignited."

The AC describes an acceptable test method for demonstrating compliance; a method of configuring samples for testing; test-conduct considerations; and materials to which the regulation is not applicable. ■

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***U.S. Department of Transportation
Subsequent Distribution Office, M-30
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Internet: <www.airweb.faa.gov>

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Tail Strikes Runway During Takeoff in Gusty Crosswind

A report by the Australian Transport Safety Bureau said that the flight crew initiated the rotation five knots below rotation speed as the airplane encountered a crosswind gust.

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The following information provides an awareness of problems through which such occurrences may be prevented in the future. Accident/incident briefs are based on preliminary information from government agencies, aviation organizations, press information and other sources. This information may not be entirely accurate.

AIR CARRIER

Rotation Continued Beyond Targeted Pitch Attitude

Boeing 737. Minor damage. No injuries.

During takeoff from an airport in Australia, the cabin crewmembers seated at the rear of the airplane felt and heard the airplane scrape the runway; during climb, they told the flight crew about the possible tail strike. The captain took control from the first officer, who had been flying the airplane; flew the airplane in a holding pattern to reduce fuel quantity; and landed the airplane at the departure airport.

An inspection confirmed that there had been a tail strike, with slight ground contact, the accident report said.

The investigation found that automatic terminal information service (ATIS) information for the departure airport at the time of the occurrence said that Runway 03 was wet, wind was from 320 degrees at 20 knots with an 18-knot crosswind and there was wind shear near the airport.

Data for weather at the time of takeoff indicated that there was a gusty crosswind varying between 319 degrees and 331 degrees at 18 knots to 21 knots, the average direction was 325 degrees, and the average velocity was 19 knots.

An analysis of data from the flight data recorder showed that the first officer had initiated rotation at V_1 (defined by the report as takeoff decision speed; 142 knots), five knots slower than V_R (rotation speed).

"The lack of change in airspeed at V_1 was indicative that the aircraft had encountered a wind gust, which was consistent with the crosswind conditions," the report said. "However, the rotation was not delayed when the gust was encountered, as recommended in the FCTM [flight crew training manual]. Rotation continued beyond the target 8.2-degrees nose-up pitch liftoff attitude, and the aircraft was at a nose-up pitch of 13.2 degrees at liftoff. Despite the early rotation, it was conducted at a pitch rate of about three degrees per second, which was consistent with the information in the FCTM."

Left control wheel application was about 23 degrees throughout the takeoff roll until rotation and then was increased to as much as 48.8 degrees. This resulted in deployment of spoiler panel 3 and spoiler panel 4, reducing the lift coefficient and tail clearance as the airplane became airborne, the report said.

Airplanes Collide on Ramp

McDonnell Douglas DC-9. Substantial damage. One serious injury, two minor injuries.

Airbus A319. Substantial damage. One minor injury.

Daytime visual meteorological conditions prevailed as the airplanes were being taxied in a ramp area at an airport in the United States. The DC-9 was being taxied to the ramp after a flight during which the flight crew had reported a decrease in right hydraulic system fluid quantity. The crew conducted a normal landing and taxied the airplane under its own power to the ramp, where they stopped to await a tow to the gate while the A319 was being pushed back. The DC-9 moved forward and struck the A319's right wing.

In addition to the four injuries involving people in the airplanes, a ramp agent was injured. Both airplanes were evacuated after the accident.

A preliminary report said that the fluid quantity in the right hydraulic system in the DC-9 was below "EMPTY," and the left hydraulic reservoir fluid quantity was above "FULL."

'Breakdown in Crew Effectiveness' Cited in Practice Approach

Boeing 747. No damage. No injuries.

Daytime instrument meteorological conditions prevailed during the instrument landing system (ILS) approach to an airport in England after a cargo flight from the United States. The three members of the crew were the only people in the airplane.

The airplane's departure had been delayed more than three hours because of loading problems. The technical log contained minor unserviceable items, but the crew believed that the airplane was in compliance with serviceability requirements during the flight.

About 1600 local time, the captain (the pilot flying) briefed other crewmembers for a practice Category II approach and automatic landing on Runway 05, established the airplane on a heading of 050 degrees and began a descent to 6,000 feet.

At 1605, after instructions from air traffic control (ATC), the descent was continued to 3,000 feet on a heading of 180 degrees. At 1607, ATC told the crew to turn the airplane left to 020 degrees and to report when the airplane was established on the ILS. During the turn, the crew received clearance to descend "to 2,000 feet and further with the ILS." At 1609, the crew said that the airplane was established on the localizer, and they received clearance to descend on the ILS and contact the airport air traffic control tower. At 1610, a controller cleared the crew to land.

The report said, "Within the aircraft, the commander had configured with flap 20 and with the gear still retracted for the descent from 3,000 [feet above mean sea level (MSL)] to 2,000 feet [MSL]. By this time, both autopilots had been selected. During the descent, the copilot noted flags on his instruments indicating that the localizer and glideslope were not being received. The commander had indications from his instruments that they were established on the localizer, and all three crewmembers then discussed the problem and attempted to identify the cause. Shortly afterwards, the aircraft [entered visual meteorological conditions] at approximately 900 feet [MSL]. With the ground and PAPIs [precision approach path indicators] in visual contact, the commander immediately disconnected the autopilots and leveled the aircraft."

The commander flew the airplane on the localizer, intercepted the glideslope from below and conducted a normal landing.

Airport officials were unaware of the incident until they received noise complaints and examined the radar recording. The airport authority notified the U.K. Air Accidents Investigation Branch (AAIB).

The report said that during the descent to 2,000 feet, the standard procedure would have been "for the handling pilot to select the cleared altitude and then 'ALT SEL' on the MCP [mode control panel]."

The commander said that he had "controlled the descent using vertical speed at 500 feet per minute," the report said. "However … the rate of descent was fairly constant at 1,570 feet per minute. Furthermore, there was no indication of any change in rate of descent as the aircraft approached its cleared altitude of 2,000 feet. This meant that the cleared altitude had either not been selected or had [been] deselected early in the descent, possibly due to a technical unserviceability or at an apparent glideslope capture."

After the incident, maintenance personnel found no problems with ground systems or aircraft systems.

The report said that while the crewmembers were troubleshooting the flags on the copilot's instruments, "no one was actively controlling or monitoring the aircraft. This was a clear breakdown in crew effectiveness."

Ramp Worker Struck by Propeller

Saab 340B. No damage. One serious injury.

Nighttime visual meteorological conditions prevailed as the captain taxied the airplane to the gate at an airport in the United States. He shut down the left engine while taxiing and feathered the propeller on the right engine after wheel chocks were inserted by ramp personnel at the gate.

The captain said that as the cabin door was opened, he felt "three or four quick thumps" and received a signal from a ramp worker to shut down the engine. After shutting down the engine, the captain exited the airplane and saw a ramp-service agent lying beneath the airplane. The crew radioed the airport control tower that medical assistance was required. Medical-service personnel arrived soon thereafter.

The ramp worker who signaled the captain to shut down the engine had placed chocks around the left main gear. He was placing a safety cone near the left wing tip when he heard a loud thump and saw the other ramp worker on the ground.

A witness near the airplane's left wing tip observed the other ramp worker place chocks around the nosewheel and then walk toward the right wing. She said that she heard the "sound of something hit the propeller" and saw the ramp worker "flip and land on the ground."

The preliminary accident report said that the Saab 340 was the only propeller-driven aircraft serviced by the airline which provided ramp services for the operator of the Saab 340.

Landing Gear Actuator Rod Penetrates Pressure Bulkhead

McDonnell Douglas MD-88. Substantial damage. No injuries.

Daytime visual meteorological conditions prevailed for the domestic flight in the United States. Soon after takeoff, the flight crew heard a loud bang, the cabin depressurized, and the crew was unable to retract the landing gear. The crew returned the airplane to the departure airport and conducted a normal landing.

A preliminary inspection of the airplane revealed that the nose landing gear actuator rod had penetrated the pressure bulkhead. Worn threads were found on the nose landing gear actuator piston rod and a sheared key-locking washer in the gear assembly.

The actuator was believed to have been original equipment on the 15-year-old airplane.

Report Calls Braking Anomaly 'Pilot-induced'

Gulfstream G159 Gulfstream 1. Minor damage. No injuries.

Three flight crewmembers were conducting a maintenance flight to test the airplane's wheel brakes and were flying the airplane to their company's maintenance base at an airport in South Africa. The crewmembers conducted a landing at an en route airport, and during the landing roll, the pilot had "no brake authority with full brake application and no nosewheel steering," the accident report said; as the airplane slowed to 40 knots, braking and nosewheel steering became available.

Maintenance was performed, and additional test flights were conducted, with "exactly the same effects," the report said. Further maintenance was performed, and crewmembers conducted another test flight.

"On landing, without any input from the crew, the brakes would bind and release in half-second intervals," the report said. "The result was that all four main wheels locked up, resulting in a blowout of all four main wheel tires."

The chief maintenance engineer was unable to identify any technical problem that could have been responsible for the anomaly, and the report said that the event was "pilot-induced," with "excessive braking after touchdown to be able to vacate the runway at Taxiway A."

Faulty Installation Causes Reverse Operation of Pitch-trim Switch

Fairchild SA227-DC Metro 23. No damage. No injuries.

During departure from an airport in Australia, the captain observed that excessive forward force on the control column was required to trim the airplane in a nose-down position. The captain transferred control to the first officer, who trimmed the airplane, and the flight continued to the destination airport.

After landing, the crewmembers examined the system and found that the captain's control-yoke pitch-trim system was operating in reverse.

After discussions among the crewmembers, the operator's chief maintenance technician and chief pilot, a decision was taken to use the airplane for two more scheduled flights. A suitable maintenance facility was located at the second destination airport. At the maintenance facility, maintenance personnel found that the pitch-trim switch had been installed upside down; the switch was removed, reinstalled and checked for correct operation, and the airplane was returned to service.

Before the occurrence, the airplane had undergone scheduled maintenance at a contract maintenance facility; the maintenance included replacement of the control-column pivot bearings, which required removal of the control yoke and the pitch-trim switch. Maintenance personnel "indicated that they had completed the work and that the duplicate functional check was conducted with no apparent discrepancies," the incident report said.

"The aircraft departed on the occurrence flight after the crew had conducted preflight checks, including a check of the pitch-trim system cockpit indication for correct operation."

Investigations by the operator and the maintenance contractor determined that "the only plausible scenario … was that the [maintenance personnel] responsible for the pitch-trim-switch installation had installed the switch incorrectly," the report said.

The report said that the airplane's minimum equipment list "provides no relief for flight with one pitch-trim system inoperative, and so the decision to continue the scheduled flights in this condition was contrary to the requirements of the operator's flight operations manual."

Airplane Collides With Tug During Takeoff

Mitsubishi MU-2B-60. Substantial damage. No injuries.

Nighttime visual meteorological conditions prevailed when the MU-2 pilot was cleared for takeoff from an airport in the United States. Several seconds after issuing the takeoff clearance, however, the tower controller canceled the clearance because he observed airborne traffic off the departure end of the runway.

The pilot told the tower controller that he had the traffic in sight. The controller told the pilot to maintain visual separation with the traffic and cleared him for takeoff.

The pilot said that airspeed was 80 knots when he checked his engine instruments and reconfirmed visual separation with the traffic beyond the end of the runway. When he looked back down the runway, he saw a tug on the centerline moving from right to left. The pilot applied maximum wheel braking and reverse thrust to reject the takeoff, while maneuvering the airplane toward the left side of the runway. The MU-2's right wing tip fuel tank separated when it struck the cab of the tug. The operator of the tug was not injured.

The operator of the tug, which was towing a McDonnell Douglas MD-80, had been cleared by the ground controller to cross the runway. The preliminary report said that recorded landline transmissions indicated that the ground controller and tower controller had not coordinated the tug's runway crossing.

Deteriorating Weather Forces Ditching of Sightseeing Airplane

Cessna 172N. Destroyed. One fatality, two serious injuries.

Daytime visual meteorological conditions prevailed for the departure from an airport in New Zealand for a 45-minute commercial sightseeing flight. The pilot flew the airplane to 1,400 feet — the usual altitude for the route — but visibility and ceiling decreased quickly in low clouds and mist.

The pilot reversed course and then decided that weather conditions would preclude visual flying to the alternate airport and that his only option was to ditch the airplane in the bay. After the ditching, the airplane broke into several sections, and one passenger was trapped in the fuselage and drowned. Local residents helped the pilot and the other passenger to shore.

The accident report said that meteorological information received by the operator and pilot showed that flight conditions were suitable but that the operator "did not make full use of all the meteorological information that was available to him." The pilot probably could have safely flown the airplane to the alternate airport or returned to the departure airport, if he had made an earlier decision to turn back, the report said. His ability to make a timely decision "could have been enhanced if he had been forewarned that a sudden weather deterioration was possible," the report said.

Airplane Overruns Runway After Tail Wind Landing

Cessna 525A CJ2. Substantial damage. One minor injury.

Daytime visual meteorological conditions prevailed for the business flight in the United States. The pilot said that he flew the airplane in "one circle" around the airport to observe the wind sock and then conducted a landing on a 2,948-foot (899-meter) runway. He said that the wheel brakes failed during the landing roll with about one-third of the runway length remaining and that the airplane continued off the departure end of the runway and struck water.

A witness said that he observed the airplane as it was flown in a "low pass down Runway 29" and then was landed on Runway 11, touching down about halfway down the runway; he said that the airplane slowed "as it impacted the water."

A preliminary inspection revealed no problems with the brake system; the emergency brake system had not been used. The anti-skid system was not tested because of saltwater damage. The report said that the airplane's flap selector was in the "GROUND" position but the flap indicator was in the 15-degree position, the left throttle lever was in the idle cutoff position, and the right throttle lever was bent to the right at the idle stop.

Tread marks began about two-thirds of the way down the runway and continued in the grass and dirt between the runway and the water.

Winds six minutes after the accident at an airport nine nautical miles (17 kilometers) northwest of the accident site were from 280 degrees at nine knots.

A notation in the U.S. Federal Aviation Administration *Airport/Facility Directory* said that the airport was "CLOSED to jet traffic."

The report said that, according to the Cessna 525A Landing Distance Chart, an airplane with a landing weight of 11,000 pounds (4,990 kilograms) "requires 2,930 feet [894 meters] of landing distance in a no-wind situation. With a 10-knot tail wind, the airplane requires 3,500 feet [1,068 meters] of landing distance."

Unrelated Hydraulic Problems Cited in Landing Gear Collapse

Dassault Falcon 900EX. Minor damage. No injuries.

Nighttime visual meteorological conditions prevailed for the landing at an airport in England after a flight from Tanzania. The flight crew used normal systems and emergency systems in their attempts to extend the landing gear, but they observed no indications that the landing gear were extended.

The crewmembers told air traffic control about the problem and flew the airplane to another airport that they considered more suitable for landing. They conducted a full-flap landing, and the airplane initially touched down on all three landing gear; during the landing roll, the right main landing gear partially retracted, and the airplane veered right onto grass.

Four days earlier, during their flight from England to Tanzania in the same airplane, the "HYDR #1 PUMP3" caution light had illuminated intermittently during final approach. The crewmembers knew that the airplane had a hydraulic system problem when they began the return flight to England, but they believed, incorrectly, that the minimum equipment list (MEL) allowed them to operate the airplane with the problem. The accident report said that because maintenance facilities were limited in Tanzania, the crew decided to fly the airplane back to England, as planned. During the flight, the "HYDR #1 PUMP3" caution light again illuminated — at first intermittently, but later continuously.

The airplane had two independent main hydraulic systems. The no. 1 system — which provided hydraulic power to the landing gear, landing gear doors, normal brakes, primary flight controls and leading-edge slats — was pressurized by either the no. 1 pump driven by the no. 1 engine or the no. 3 pump driven by the no. 3 engine. The no. 2 system — which provided hydraulic power to the flaps, air brakes, emergency brakes, primary flight controls and outboard slats (when emergency slat extension was selected) — was pressurized by the no. 2 engine-driven pump or by an electric pump.

An investigation found that a leak from the no. 1 hydraulic pump drain had caused loss of fluid in the no. 1 system; a damaged seal or a problem with an associated spring washer was believed to be the cause of the leak. The aircraft manufacturer said that the no. 3 hydraulic pump "might have had either a sticking of its internal mechanism or a slight offset of its regulation, resulting in reduced delivery pressure."

Failure of the no. 3 hydraulic pump probably would have had minimal effect on airplane operations if not for the leak in the no. 1 pump, the report said.

The report said that the crew had "misinterpreted their MEL," which "allows dispatch with two of the three caution lights serviceable, and not two of the three hydraulic pumps, as the crew believed." The crew also used a checklist that was marked "FOR TRAINING PURPOSES ONLY" with procedures that were "for USA-registered aircraft only." (The checklist also said, "For non-USA-registered aircraft, consult AFM [airplane flight manual] for alternate procedures.") They said that the training checklist was easier to use than the AFM, which was in the airplane.

As a result of the investigation, the U.K. Air Accidents Investigation Branch recommended that the manufacturer review the phrasing of the master MEL and the checklist for hydraulic system failure, that the training organization review the accuracy of its documents, and that the manufacturer and the training organization ensure that simulators "represent with acceptable realism the pilot input, as defined in the operations manual, to successfully lock down the landing gear during emergency gear extension."

Airplane Strikes Terrain After Long Takeoff Roll

Piper PA-60-601P Aerostar. Destroyed. Six fatalities.

Several witnesses observed the airplane being refueled and a substantial amount of luggage being loaded before it departed in daytime visual meteorological conditions from an airport in the

United States. The preliminary accident report said that density altitude was about 3,000 feet when the commercial pilot began the takeoff on Runway 16. The winds were from 160 degrees at three knots.

The witnesses said that the takeoff roll appeared to be much longer than normal and that the airplane lifted off near the end of the 3,930-foot (1,199-meter) runway. One witness said that the airplane "clipped the trees" beyond the departure end of the runway and "had trouble gaining altitude."

Another witness, a former flight instructor, observed the airplane, with the landing gear retracted, rolling left and right in level flight about 500 feet above ground level before it rolled left to an inverted attitude and descended out of view behind trees. He said that the engines had sounded as if they were at full power but had "shut off" when the airplane rolled inverted.

A fire began after the airplane struck a five-foot (two-meter) retaining wall supporting the patio of a private residence about 1.1 nautical miles (2.0 kilometers) from the airport.

OTHER GENERAL AVIATION

Failed Bolt Cited in Landing Accident

De Havilland DH82A Tiger Moth. Minor damage. No injuries.

The airplane was being flown from a private airstrip in England so that a flight instructor could revalidate the pilot's private pilot certificate. The pilot conducted a wheel landing and planned to allow the airplane's tail skid to settle on the runway before he applied power for another takeoff and landing.

The report said, "Before the tail skid touched, the right undercarriage collapsed and the aircraft tipped onto its nose and right wing tip before settling back in an upright attitude."

The instructor said that the touchdown was normal and that the damage included detachment of the right undercarriage drag strut from the fitting that secured it to the fuselage; the damage resulted from failure of the swivel bolt. The instructor, a retired metallurgist, said that he observed a fatigue crack; the accident report said that the fatigue crack apparently had occurred during a brief period and that the bolt through the strut-fork fitting and the swivel bolt "appeared to have been excessively tightened at some point."

The airplane's maintenance technician said that he would begin inspecting swivel bolts during annual inspections of Tiger Moths.

Airplane Strikes Terrain During Runway 'Familiarization' Approach

Bushmaster 2000. Substantial damage. No injuries.

The pilot of the experimental airplane conducted a takeoff from a new 1,400-foot (427-meter) private airstrip in Canada, intending to fly the airplane to a nearby airport but altering his plans to conduct an approach to the new airstrip "for familiarization," a preliminary report said.

The pilot applied carburetor heat before closing the throttle for descent to traffic-pattern altitude; he opened the throttle after he had flown the airplane along about two-thirds of the airstrip at low altitude. When the throttle was opened, the engine popped and sputtered, and the pilot landed the airplane on a nearby road. After touchdown, the airplane departed the road and nosed over into soft ground.

Weather conditions were described as conducive to carburetor icing.

Wind Shear Likely Caused Glider Tow Plane Stall

Pierre Robin DR400/180R. Substantial damage. One minor injury.

The airplane was being flown in a glider-towing operation in England, and the pilot had completed his second tow flight of the day and was preparing to land the airplane. After he turned the airplane onto final approach between 150 feet and 250 above ground level, the airplane rolled right "in what initially appeared to be a controlled manner," the accident report said. "However, the roll to the right continued, and the aircraft departed from controlled flight, impacting the ground in a steeply banked attitude, having turned through about 120 degrees from the direction of landing."

The pilot had about 4,000 flight hours in gliders and was a glider instructor; he had 469 flight hours in airplanes, primarily in towing gliders and flying motor gliders.

Wind at the time of the accident was from the northwest at 20 knots to 25 knots, across "a line of substantial trees, thereby creating turbulence on the approach down to about 50 feet," the report said.

The pilot flew the airplane at an approach airspeed that would have been appropriate in calm conditions but was less than recommended for the wind at the time. The report said that during the approach, the pilot probably encountered wind shear that caused the airplane's right wing to stall.

"The roll and the pilot's application of full left aileron would have served to exacerbate the situation, causing the aircraft to enter an autorotative maneuver from which there was insufficient height to recover," the report said.

ROTORCRAFT

Faulty Trim System Cited in Emergency-landing Accident

Hughes 369D. Substantial damage. Three minor injuries.

Daytime visual meteorological conditions prevailed for the departure from an airport in Sweden. About 30 seconds after takeoff, the pilot believed that the amount of required control force was increasing to prevent the helicopter from rolling. Application of trim did not alleviate the problem.

The accident report said, "After a minute or so, the force to the left had become so great that the pilot was obliged to support [the control] with his left hand and left knee to keep the helicopter in normal flying attitude, and he determined to land at the first possible site."

He rejected the first landing attempt because of difficulty in maneuvering the helicopter. On the second attempt, the helicopter struck the ground and rolled over.

The report said that the accident was caused by "a technical fault in the helicopter's lateral-trim system that resulted in its becoming uncontrollable, successively working to its left stop position."

Helicopter Strikes Power Line During Locust Survey

Bell 206B JetRanger. Substantial damage. One minor injury.

The helicopter was being flown in locust-control operations in Australia. During the flight, a lands-protection ranger asked the pilot to land in a paddock to allow examination of a band of locusts.

The pilot conducted two orbits of the proposed landing area during which he asked the three other people in the helicopter to watch for power cables and other potential hazards in the landing area.

"The pilot and senior ranger saw a north-to-south-running power cable located on the western boundary of the paddock," the accident report said. "They also noted a westerly spur line emanating from a power pole located abeam the intended landing point. That power pole was also supporting the north-to-south power cable. No one aboard the helicopter identified a second spur line emanating from that same power pole and tracking to the east and overhead the intended touchdown point."

During final approach, as the pilot flew the helicopter through 25 feet above ground level, the previously unobserved power cable caught between the helicopter's skids and fuselage. The helicopter pitched nose-down and struck the ground.

After the accident, the operator's chief pilot changed company procedures to require pilots to limit to two the number of helicopter passengers during locust-survey operations. The action was intended to increase the helicopter power margin and to "decrease the incidence of pilots being constrained to the conduct of heavy, shallow arrivals and departures to/from landing areas," the report said. ■

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