Fatigue scientists resist flight crew schedulers' demand for go/no-go modeling tools as U.S. airlines brace for sweeping new regulations.

BY WAYNE ROSENKRANS

Elusive Bright Line

Airline representatives, fatigue researchers and aviation regulators expect significant near-term progress in reducing the risk of degraded pilot alertness through better application of fatigue theory to flight operations. Some attendees at a recent U.S. symposium, however, criticized government and industry slowness to adopt change. Other specialists expressed confidence that a confluence of cultural changes is now catching up to fatigue science, improving prospects for flexible regulatory oversight and safety enhancement.

The symposium, organized by the MITRE Corp. in cooperation with Flight Safety Foundation and titled "Aviation Fatigue: Building a Bridge Between Research and Operational Needs," was held June 6–8 in McLean, Virginia, U.S., to follow an April 2010 MITRE fatigue summit of 40 aviation leaders. The event comprised discussions of scheduled airline operations, on-demand operations, military operations, shift work such as air traffic control and aviation maintenance, fatigue-prediction tools, and fatigue modeling. This article focuses on issues affecting scheduled airline operations.

A strong undercurrent of the symposium was the U.S. airline industry's anticipation of the Federal Aviation Administration's (FAA's) final rule establishing new flight time limitations and rest requirements (*ASW,* 12/10–1/11, p. 23). Details of the final rule were unknown at press time.

Flights on the backside of the clock present special fatigue challenges.

© Chris Sorensen Photography

Nevertheless, requirements for pilot fatigue education and awareness, and optional fatigue risk management systems (FRMSs) under airline fatigue risk management plans (FRMPs), in the rule will reflect a "societal shift" toward better understanding of fatigue and becoming proactive, said John Allen, director of the FAA Flight Standards Service. Allen said that the final rule will be issued on Aug. 8, 2011. "People expect airplanes to have the same safety as any utility, like water or electricity," he said. "When the FAA does a rule, we must strike a balance between safety and cost to the industry. … We cannot say [the final rule] will save this many accidents; we now say, 'This is the amount of risk we will mitigate.'"

Components of an FRMS include a flight duty time and rest policy, requirements for fatigue and alertness awareness and education, a fatigue reporting system, a system for monitoring flight crew fatigue, evaluation of system performance, and incident reporting (see "Operating Safely During Major Regulatory Transition").

The rule will spell out how to implement an FRMP, the foundation for conducting day-to-day flight operations under an FRMS, said Tom Nesthus, engineering research psychologist at the FAA Civil Aerospace Medical Institute. FRMSs, initially approved by the FAA and reviewed every 24 months, will provide an alternative to compliance with the new prescriptive language.

A theme of several attendees' questions was how FAA oversight under the new rule will differentiate between safe and unsafe operations. "All current operations are within the current regulations but we can't assume they are fatigue-free," Nesthus said. Every carrier has some operations that could be deemed unsafe by fatigue criteria, "but they are flown legally," he added. In

Operating Safely During Major Regulatory Transition

The shift from compliance with decades-old pilot flight time limitations and rest requirements in U.S. Federal Aviation Regulations Part 121.471 to new requirements — set to be announced Aug. 8, 2011 — will be challenging and costly, says Jim Starley, a captain and managing director of flight operations at United Airlines. In a presentation during the MITRE Corp.–sponsored fatigue research symposium in June, Starley cautioned attendees that what actually transpires could differ from his speculation because the airline industry has not seen the U.S. Federal Aviation Administration's (FAA's) final rule.

"Three pages describe the rule we're currently operating under," he said. "It is simple and straightforward to explain to operations [personnel]. … The notice of proposed rulemaking is much more complex than what we currently have. Implementation of the final rule will require significant modification of existing systems and every aspect of our scheduling infrastructure … and will change how the industry operates." He predicted the transition would take "a couple of years … and full fatigue risk management system [FRMS] integration could span well beyond that" before improving safety.

United's existing safety programs include an aviation safety action program; irregularity reporting; individual pilot self-reports of fatigue and potential fatigue reviewed for immediate tactical management of fatigue events; aggregated pilot reports reviewed to identify trends and recommend corrective measures; a flight operational quality assurance program set up to trigger investigations of potential fatigue; fatigue-prediction models to distinguish fatigue factors and windows of circadian low in schedules; an ongoing ultra-long-range versus long-haul operations study involving 70 Boeing 777 pilots; and annual ground school recurrent training of pilots on fatigue causal factors, effects of sleep loss, countermeasures, benefits of napping, results of fatigue studies and research findings.

Concerns include possible future accountability for accommodating circadian rhythms of individual flight crewmembers; routinely submitting new reports for different types of FAA oversight; mandatory FRMS for operations longer than 16 hours; uncertainty in differentiating domestic and international operations; one duty rest period irrespective of type of operation; accounting for time zone transitions and their effects on flight and duty time; a new type of reserve program; changes to consecutive nighttime operations and transportation of "deadheading" pilots; differences to operate in unsafe geographic areas; and modifying software to handle reports to the FAA and FAA audits of scheduling practices.

"Other elements we will have to contend with [are] rebuilding how we describe fatigue policies and regulations [to operations personnel] and establishing new flight and duty time baselines from which labor agreements are negotiated," Starley said.

— WR

contrast, the application of FRMSs, notably in ultra-long-range (ULR) flights — nonstop segments longer than 16 hours — has provided a level of fatigue risk that has been consistently acceptable.

"The last two decades of scientific research have produced excellent insights, but translating science into effective operational uses remains a challenge," said Hasan Shahidi, director of aviation safety at MITRE. "Complexity, uncertainty and diversity have yet to be addressed."

Mark Rosekind, a member of the U.S. National Transportation Safety Board, said that an operator's accident-free history does not mean that fatigue risk has been mitigated. The board cited fatigue as a causal factor in six air transport accidents in 1997–2009 and issued more than 190 fatigue-related recommendations for all modes of transportation. "We will need multiple solutions," he said. "We will need to learn from other industries [such as long-haul trucking], to share data and not just results, to expand and apply knowledge even within companies, and to capitalize on emerging knowledge and technology."

The value to airlines of taking the FRMS route is inherent incorporation of current fatigue science. Scientists consider fatigue to be a phenomenon primarily associated with time elapsed since awakening but also involving biological sleep need and sleep opportunity in relation to the exact timing of a person's circadian clock (rhythm) and rate of adaptation to circadian disruptions, said Melissa Mallis, chief scientist, operational and fatigue research, Institutes for Behavior Resources. She estimated that 35 U.S. air carriers have at least partially adopted an FRMS.

An FRMS also is flexible and adaptable as airline operations change over time. "It mitigates the effects of fatigue for a specific operation using a data-driven and evidence-based process," Mallis said. "An FRMS addresses physiological and operational factors, offers an interactive way to safely schedule and conduct flight operations on a case-by-case basis, and continuously monitors and manages safety risks associated with fatigue-related error."

Researchers hope to better accommodate different individual responses to sleep loss and circadian disruption, but FRMSs already are "sufficiently robust for implementation in operations — such as in an FAA-approved ULR operations specification [ops spec] — that can't otherwise be accommodated under prescriptive rules," she said.

Some symposium presenters cited innate differences among pilots — called *genetically instantiated trait-like features* that affect their ability to remain alert and to perform at the required cognitive level — as a significant frontier for aviation fatigue modeling and prediction.

"We know that half to two-thirds of [behavioral alertness is] attributable to this trait of the person's biology," said Daniel Mollicone, president of Pulsar Informatics. "Some people are unbelievably robust in the face of fatigue stressors. So I see this [differential susceptibility to fatigue stressors] as an opportunity in the future to be more exact in models by capturing that trait. … This will involve an appeal to professionalism [with each of us] needing know who we are [as to] our susceptibility to chronic sleep restriction or to profound deficits during night work."

Symposium attendees drew attention to aviation professionals being expected to report fit for duty, and to the apparent contradiction with scientists' statements that individual pilots have limited ability to assess their own alertness when fatigued. "People are not able to predict when they will have a microsleep or a lapse," Mallis said. "We can be trained to know fatigue signs and to evaluate others, and this addresses our inability to self-monitor."

Ultra-Long-Range Impact

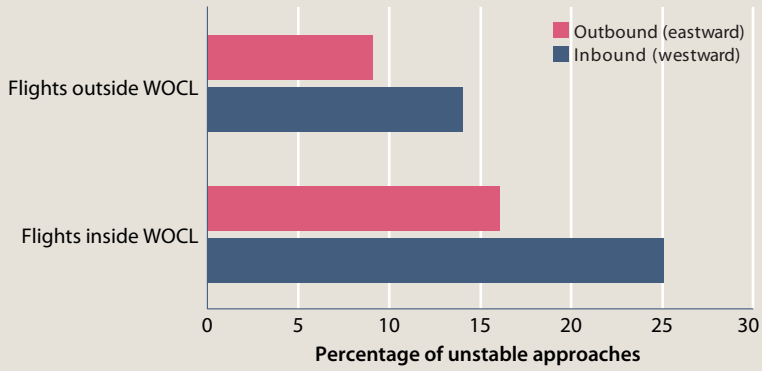
As predicted in 2003 when an earlier work group addressed flight crew alertness during ULR operations by Singapore Airlines (*Flight Safety Digest,* 8/05-9/05, p. 1), operators of long-range and short-range flights can benefit from the same principles, data and experience, presenters said.

The FAA's Nesthus described how the agency collaborated on research protocols and then approved the New York–Mumbai, India, ULR city pair for Delta Air Lines. A November 2008 FAA proposal to standardize ULR ops specs was withdrawn in response to industry comments, and instead, American, Continental and Delta agreed to participate in new airline-funded, parallel ULR research projects. The FAA has worked with these airlines on this research focusing on 70 pilots per carrier, all operating Boeing 777s under FRMSs.

Each airline has been following a common protocol — based on actigraphy (using a wrist-worn device to record all time awake and asleep for three weeks), psychomotor vigilance tests (PVTs) on smartphones, personal activity logs, and self-described levels of fatigue, alertness and sleep quality. Each airline added customized elements to the common protocol.

Presenting one year of ULR research, Greg Belenky, research professor and director of the Sleep and Performance Research Center at Washington State University Spokane, said that cognitive performance by the same group of Continental pilots was measured on a sequence of ULR

Possible Links Between Fatigue Risk and Unstable Approaches



FOQA = flight operational quality assurance; ULR = ultra long range; WOCL = window of circadian low (0300-0500)

Notes: Transatlantic flights between the same ULR city pairs were operated by 70 captains and first officers on Boeing 777s in research for American Airlines. The company analyzed FOQA data for predefined parameters deemed to indicate unstable approaches, and compared pilot alertness at the corresponding time.

Source: Martin Moore-Ede, Circadian

Figure 1

and long-range flights on 777s. "The point of the study was to see if ULR operations were as safe as the long-range operations [for the same pilots]," he said.

This research was unique in collecting flight operational quality assurance (FOQA) data "in the hope of seeing relationships between FOQA and PVTs, etc.," Belenky added.

Martin Moore-Ede, a physician and chairman and CEO of Circadian, summarized American's ULR research project. The reason for replicating research done for Singapore Airlines was to employ the common protocol and database design being used by Delta and Continental, he said. "We now have data that can be compared for 210 pilots, with a few exceptions because of differences in the nature of fatigue," Moore-Ede said.

American's research beyond the common protocol focused on validating the company's FRMS and fatigue modeling, and testing a new metric called "descent unstable landing" — extrapolated from selected flight parameters in FOQA data to discover relationships between alertness and stable approaches. Researchers decided that pilots would find it "more interesting [than PVT results] to have the model predict an unstable approach," Moore-Ede said.

"We find that the low-risk crew pairings have higher rates of stable landings and lower rates of unstable landings [compared with high-risk crew pairings]," he said (Figure 1). High-risk pairings include flight during the body clock's 0300–0500 window of circadian low.

"We have looked at other variables, such as the difficulty of the approach, but it looks as though fatigue is the strongest driver," Moore-Ede said. "This may become an operationally relevant crew standard, a very interesting tool for FRMS with [an expert scoring system that] would cost the airline no more to track [the daily] percentage of final approach instability events."

Douglas Rohn, director of the Aviation Safety Program Office of the U.S. National Aeronautics and Space Administration (NASA), said that NASA also is looking at the relationship between alertness measurements, FOQA exceedances, and errors and events revealed by other data sources. "NASA and easyJet are specifically studying pilot fatigue in short-haul work schedules … predictive tools and mitigation design," Rohn said.

However, Belenky noted that some fatigue scientists are less enthusiastic about prospects of correlating unstable approaches with alertness data, given the complexity of variables such as 20–30 minutes of sleep inertia immediately after a ULR crew rest period, and close to the time of the approach.

Regional Airline Research

Prescriptive requirements in the FAA's final rule "level the playing field for smaller operators that can't afford an FRMS," said Scott Foose, senior vice president, operations and safety, Regional Airline Association (RAA; *ASW,* 5/11, p. 34). "Depending on the final rule, we expect 80 percent of RAA members to have an FRMS while 20 percent, the smaller carriers, will be absolutely fine and safe operating under the prescriptive rules, " he said.

Almost no fatigue research has been conducted on multi-segment, short-haul operations

— typically five takeoffs and landings per day, Foose said. In the context of FAA rulemaking, the RAA contracted with the Sleep and Performance Research Center.

Foose and Hans Van Dongen, a research professor at the center, announced a few of the preliminary results of the first phase, based entirely on laboratory modeling. Van Dongen said that the objective was "to predict the performance consequences of additional workload associated with five-segment duty days as compared to one-segment long-range duty days of the same duration."

The regional airline pilot who begins his or her workday early in the morning can maintain "a net stable level of alertness through the first 12 to 16 hours of the day," he said. "Time on task augments fatigue but this is overcome by [overnight sleep after duty]."

ICAO Perspectives

The International Civil Aviation Organization (ICAO) expects to complete FRMS standards and guidance soon, said Michelle Millar, FRMS project officer at ICAO. Recently, the organization has been forging a global agreement on FRMS that regulators will follow to provide oversight of operators in their jurisdictions. ICAO's timetable calls for FRMS standards and guidance to be effective in October 2011 and implemented on Dec. 15, 2011, she said.

These amendments to ICAO annexes will say that "states must have limitations [on flight and duty time] and also may allow FRMSs based on scientific principles," Millar said. New materials will recommend best practices to states.

Any organization planning to monitor or compare the FRMSs of different entities will benefit from ready access to shared data, said Emma Romig, principal investigator, flight deck research and development, Boeing Commercial Airplanes. Such access will become a critical aspect of judging FRMS effectiveness and performing quality control.

Romig has been converting legacy data sets, including those from the early ULR work for Singapore Airlines and Delta, to Boeing's proposed data-interchange specifications, called the *alertness data standard format* and the *common alertness prediction interface.* Boeing is willing to share these specifications with the research community for common benefit.

Pilot Sleep Disorders

Flights selected for study should reflect the range of typical airline pilots and their health conditions, not have only pilots matching narrow health criteria, Circadian's Moore-Ede said in response to audience questions about how to account for pilot sleep disorders.

Jim Mangie, a captain and pilot fatigue program director for Delta, said he sees no need for mandatory screening of pilots for sleep disorders because "a significant percentage of [U.S.] pilots have been diagnosed and treated [for sleep disorders] and are back flying." This has been a desired result of ongoing FAA and airline initiatives to update the education of aviation medical examiners, pilots and air traffic controllers, Mangie and other presenters said.

Other attendees wanted fatigue-prediction software features that generate a so-called "bright line" — that is, giving the user an unambiguous, automated decision about safe or unsafe fatigue risk. Some suggested that a minimum prediction of, say, 77.5 percent of the flight crew's baseline/optimum alertness as determined by a PVT would serve that purpose. The scientists present disagreed with this premise.

"We always want the tools to estimate [only] the range of fatigue risk … not set an arbitrary number with a risk of people relaxing [operational vigilance] at that point. … Tools are not a way of ranking every single trip and individual," Moore-Ede said.

Airlines understandably want new tools with built-in "threshold tie breakers" and "decision makers," agreed David Neri, deputy director, Warfighter Performance Science and Technology Department, U.S. Office of Naval Research. A *threshold* is an informational caution and interventional warning from a software tool to the operator.

"There has been a big call from operators for a measure of when someone is 'good to go,'" Neri said. "They say they need a way to resolve ties [among alternatives presented rather than] using model output as a caution. … Models are seductive when people want a bright line, but the people who make decisions should consider many factors."

A non-U.S. researcher was optimistic about the pace of implementing fatigue science within the global airline industry. "I'm astonished by how far things have moved forward. [Aviation professionals now] are really wrestling with operational implementation issues," said Philippa Gander, professor and director of the Sleep/Wake Research Centre at the Massey University campus in Wellington, New Zealand.

The industry should look at FOQA exceedances as one of many possible sources of operational data that could be relevant to FRMSs but have not been used that way, Gander added. "Models possibly have been oversold and accepted at face value," she said. "One clear message from regulators is that no operational decision should ever be made solely based on a fatigue model threshold."