BY RICK DARBY

Ground Effect

Pilot fatigue takes off before the aircraft does.

Flight crew fatigue has become a front-line issue since being implicated as a possible factor in the Colgan Air Flight 3407 accident (*ASW*, 3/10, p. 20). The increasing adoption of fatigue risk management systems and the U.S. Federal Aviation Administration's (FAA's) current notice of proposed rule making for flight and duty time (see "New Proposal, Old Resistance," p. 23) also drive industry interest. Various factors have been cited as contributing to fatigue, including time since awakening, poor-quality sleep, time on duty and circadian disruption. Many studies have focused on the alertness effects of in-flight workload on the flight crew, particularly in takeoff, approach and landing, as well as from extra demands such as bad weather and equipment malfunction.

Dimensions of Workload: Flight Phase vs. Ground Phase

	Flight	Ground	Difference
Mental demand	10.2	13.0	27%
Performance	15.3	14.5	–5%
Physical demand	7.3	7.0	–4%
Effort	8.9	10.9	22%
Temporal demand	10.9	14.9	37%
Frustration level	5.0	7.2	44%

minimum = 0; maximum = 20

Source: Kristjof Tritschler and Steve Bond

Table 1

Although workload is commonly associated with flight time, a recent study suggests that pilot workload on the ground may contribute more to fatigue than workload during flight. In a paper presented at the FSF International Air Safety Seminar in November 2010,[1] Kristjof Tritschler and Steve Bond reported that 82 percent of the study participant pilots "rated the work on the ground to be equally or more exhaustive than the flight phase."

The researchers conducted a field study with 40 pilots of a German low-cost carrier (LCC), using a questionnaire.

The first part compared the flight and ground phases in six dimensions of workload: "mental demand," "physical demand," "temporal demand," "performance," "effort" and "frustration level."

In four of the six dimensions, participants rated workload higher on the ground than in flight, with the greatest difference being in "frustration" (Table 1). The researchers expressed surprise at the findings, saying, "The task of flying a complex aircraft is accepted to be a set of highly demanding tasks. The higher values for 'effort' and 'mental demand' therefore were remarkable, since task demands on the ground are rather low. However, the subjective perception of higher workload on the ground expresses the strong engagement of the pilots between flights during this study."

The second part investigated "factors that occur during a normal working day," which the researchers called "workaday factors." Twenty-one of these were assessed under five classifications: "more work," "effort," "time pressure," "frustration" and "fatigue." Measurement was on a scale from 1 to 5, minimum to maximum.

Turning to ground time workaday factors, the researchers found that the pilots scored factors related to time pressure dominant in five of them: "critical fuel status," "late documentation," "aircraft change," "tight slot" and "tight schedule" (Table 2).

"The shortest resource in this operator's efficient operation was time," said the paper. "According to LCC principles, turnaround times were scheduled to be 25 to 30 minutes. If there are disturbances during the turnaround like late documentation, frustration levels rise. The assumption of limited time available, and no margin for disturbances, seems to intensify the feeling of high workload."

Six workaday factors dominated by higher effort or more work mostly applied to flight time rather than ground time (Table 3). One exception was "no ramp agent," which 70 percent of the pilots agreed results in more work for them, with a mean score of 3.86 on the scale. "Ramp agents are the coordinators for ground services around the aircraft," the paper said. "Today, they frequently have to handle several aircraft at the same time. This leads to the delegation of tasks to the flight crew."

All workaday factors in which "frustration" registered highest were related to pilots' non-flying tasks (Table 4, p. 50). Although frustration is not the same as fatigue, the paper said that "in this mood, frustration … may be experienced as a subjective feeling of fatigue."

"High frustration levels resulted during ground operation, especially with 'sluggish ground operation,'" the paper said. "Examples of sluggish ground handling include late availabilities of servicing equipment — stairs, buses, loading, refueling, pushback — or late arrival of passengers." That factor and "deficient documentation" are frustrating because the pilot is not in control or has limited influence, the paper said.

Deficient documentation, such as erroneous weight and balance data or mistaken aircraft-performance calculations, is frustrating because it can affect safety and because it may not be obvious, so that pilots must be extra alert to catch any anomalies, the researchers said.

"Pilots in general have a low tolerance for failure, probably founded by the nature of risks inherent in their work of flying," the paper said. "This is reflected in rather high frustration ratings for 'deficient documentation.'"

It seems logical that inadequate paperwork would increase workload as well as frustration, and indeed, while 90 percent of pilots agreed that "frustration" was a workaday factor compared with 88 percent who agreed that "more work" was a factor, the mean values assigned were nearly identical, 3.64 and 3.63, respectively.

Time Pressure in Workaday Factors

	Agree	Mean	Std. Dev.
Critical fuel status			
More work	98%	3.41	0.97
Higher effort	98%	3.67	0.98
Time pressure	98%	4.36	0.90
Frustration	95%	2.55	1.22
Contributes to fatigue	98%	3.31	1.17
Late documentation			
More work	80%	2.63	1.34
Higher effort	83%	2.91	1.07
Time pressure	83%	4.15	0.71
Frustration	80%	3.13	1.01
Contributes to fatigue	83%	2.64	0.99
Aircraft change			
More work	90%	3.97	0.74
Higher effort	90%	3.53	1.06
Time pressure	90%	4.14	0.83
Frustration	93%	2.62	1.21
Contributes to fatigue	90%	3.33	1.07
Tight slot			
More work	83%	2.27	1.10
Higher effort	85%	3.24	0.85
Time pressure	85%	4.12	0.81
Frustration	83%	2.39	1.03
Contributes to fatigue	83%	3.06	1.00
Tight schedule			
More work	85%	2.41	1.10
Higher effort	85%	3.59	0.96
Time pressure	85%	3.94	0.95
Frustration	88%	2.91	1.17
Contributes to fatigue	88%	3.66	1.03

minimum = 1; maximum = 5

Source: Kristjof Tritschler and Steve Bond

Table 2

The researchers said, "Fifteen additional comments were given by the pilots in this questionnaire to the issue of a duty change. These showed strong emotional expressions. Most of these

Higher Effort, More Work in Workaday Factors

	Agree	Mean	Std. Dev.
High density airspace			
More work	88%	3.26	1.20
Higher effort	88%	4.06	0.54
Time pressure	85%	1.71	0.87
Frustration	85%	2.26	1.19
Contributes to fatigue	88%	3.66	1.06
Special airport			
More work	88%	3.31	1.16
Higher effort	88%	3.94	0.91
Time pressure	85%	1.79	1.04
Frustration	85%	1.38	0.82
Contributes to fatigue	85%	3.18	1.14
Bad weather			
More work	100%	3.53	1.01
Higher effort	100%	3.78	0.83
Time pressure	98%	2.33	1.03
Frustration	98%	1.69	0.86
Contributes to fatigue	100%	3.68	1.10
Major airport			
More work	93%	3.38	0.79
Higher effort	93%	3.62	0.83
Time pressure	90%	2.19	1.12
Frustration	90%	1.67	0.86
Contributes to fatigue	93%	3.27	0.96
Supplementary procedures			
More work	80%	3.84	0.85
Higher effort	80%	3.53	1.05
Time pressure	80%	2.94	1.08
Frustration	80%	1.84	0.88
Contributes to fatigue	80%	3.19	1.18
No ramp agent			
More work	70%	3.86	0.89
Higher effort	70%	3.46	1.07
Time pressure	70%	3.22	1.25
Frustration	70%	2.93	1.33
Contributes to fatigue	70%	3.14	1.24

minimum=1; maximum=5

Source: Kristjof Tritschler and Steve Bond

Table 3

comments emphasized difficulties and frustration due to disturbance of their private life after a change of duty. Fifty-eight percent of the pilots agreed that 'no break' was a relevant factor."

New FAA Study: 'Laser Strikes'

In a separate report, the FAA Civil Aerospace Medical Institute recently analyzed a total of 2,492 incidents of laser illumination of aircraft in flight that occurred in the United States between 2004 and 2008.[2]

"The principal concern is the effect laser illumination may have on flight crew personnel during landing and departure maneuvers when procedural requirements are critical," the report said. "Federal Aviation Regulations require a 'sterile cockpit' (i.e., only operationally relevant communication) below 10,000 ft to minimize distractions and reduce the potential for procedural errors. Laser illumination during these critical operations can create unsafe conditions by distracting or visually impairing flight crewmembers, thus disrupting cockpit procedures and crew coordination."

Exposure to laser illumination in the airspace around airports can include annoyance, distraction and transient visual effects. These effects may involve:

- Glare — momentary loss of view of an object in a person's field of vision because of a bright light, as motorists can experience at night if headlight beams from an oncoming car have not been lowered.
- Flash blindness — a temporary visual interference effect that persists after the source of illumination ceases.
- Afterimage — A color-reversed image left in the visual field after exposure to bright light, which can persist for several minutes.

The study on which the report is based stratified laser illumination events into 1,000-ft increments, divided into zones "equivalent in altitude" to flight hazard zones around airports.[3] "Additionally, data from the laser illumination reports were used to evaluate the adverse visual and operational effects experienced by pilots within the range of altitude[s] corresponding to the flight hazard zones," the report said.

Of the 2,492 laser events, the cockpit was illuminated in 1,676, or 67 percent. "From 2004 to 2008, the [annual] number of aircraft illuminations increased from 46 to 988, which included an increase from 27 to 767 in cockpit illuminations," the report said.

Altitude information was available for 1,361 of the 1,676 events in which the cockpit was illuminated. For the five-year period, 325 cockpit illuminations occurred within the laser-free flight zone, up to 2,000 ft altitude.[4] The majority of the events, 848, occurred within the critical flight zone, from 2,001 ft to 10,000 ft. The rest, 188, occurred above 10,000 ft.

Information about the phase of flight was provided for 1,218 — 73 percent — of the cockpit illumination events. Of those events, 69 percent happened during the approach (Figure 1). Departure events were about 8 percent of this total. The large proportion of

Frustration in Workaday Factors

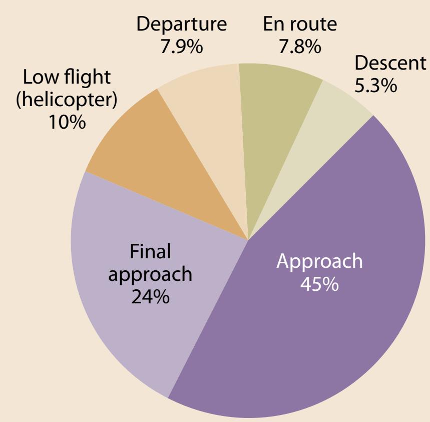
	Agree	Mean	Std. Dev.
Sluggish ground handling			
More work	83%	2.70	1.19
Higher effort	83%	2.88	1.22
Time pressure	85%	3.71	1.14
Frustration	85%	3.94	0.85
Contributes to fatigue	85%	3.06	1.01
Change of duty			
More work	83%	2.30	1.29
Higher effort	83%	2.15	1.28
Time pressure	80%	2.31	1.26
Frustration	93%	3.89	1.15
Contributes to fatigue	85%	2.82	1.36
Deficient documentation			
More work	88%	3.63	0.81
Higher effort	90%	3.39	0.80
Time pressure	88%	3.29	1.07
Frustration	90%	3.64	1.10
Contributes to fatigue	90%	2.67	1.07

minimum =1; maximum = 5

Source: Kristjof Tritschler and Steve Bond

Table 4

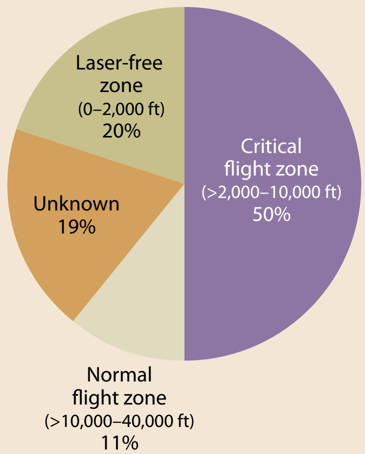
Percentage of Cockpit Illuminations, by Phase of Flight, 2004–2008



Source: U.S. Federal Aviation Administration

Figure 1

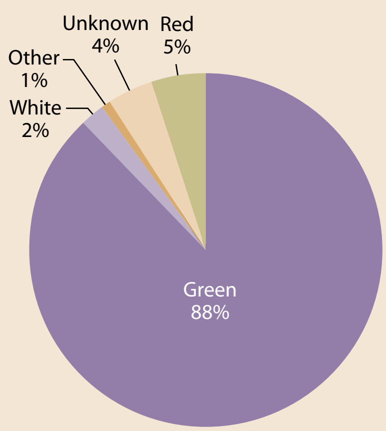
Percentage of Cockpit Illuminations, by Flight Zone, 2004–2008



Source: U.S. Federal Aviation Administration

Figure 2

Percentage of Cockpit Illuminations, by Color, 2004–2008



Source: U.S. Federal Aviation Administration

Figure 3

cockpit illuminations occurring during approach versus departures is a concern, the report said, because "distraction and/or disruption occur when the flight crew is busy performing critical flight operations at low altitude, and [the aircraft] is most vulnerable."

About 70 percent of the cockpit illumination events were reported to be at or below the 10,000-ft altitude limit of the critical flight zone, and about 20 percent within the laser-free zone (Figure 2). In the laser-free zone, the percentage of cockpit illuminations doubled during the study period, from 13 percent to 27 percent.

Laser illuminations can be particularly hazardous for helicopter pilots, the report said: "The flight crews in these aircraft are susceptible to visual impairment … due to their low-altitude flight profile and the large, wrap-around bubble canopies on helicopters that can allow more light to enter and scatter throughout the cockpit. Furthermore, these aircraft frequently have a single pilot, which adds to the danger of sudden incapacitation from a laser strike."

Although red and red-orange lasers have been in use among the public for more than a decade, green lasers have grown in popularity as their technology has become more affordable. Green lasers were used in the great majority of illuminations during the study period (Figure 3).

"Another reason for the increased number of reports is that a green laser beam may appear as much as 28 times brighter than an equivalently powered red laser beam," the report said.

The report offered recommendations to minimize the effects of laser illumination, based on reports from flight crewmembers and international civil aviation authorities. Among the recommendations were:

- "Engage the autopilot, check the aircraft's configuration, and re-establish a normal flight profile, if necessary."
- "Use the body of the aircraft to block the light by climbing or turning 90 degrees to the beam, if practical."
- "If one crewmember has avoided exposure, consider handing over control to the unexposed crewmember."

Air traffic control should be notified of the incident, including the location and direction of the beam and the aircraft's position.

Notes

1. Tritschler, Kristjof; Bond, Steve. "The Influence of Workload Factors on Flight Crew Fatigue." *Proceedings of the FSF 63rd annual International Air Safety Seminar, Milan, Italy*. Alexandria, Virginia, U.S. 2010.
2. FAA Civil Aerospace Medical Institute. *The Illumination of Aircraft at Altitude by Laser Beams: A 5-Year Study Period (2004–2008)*. DOT/FAA/AM-10/21, December 2010. <www.faa.gov/library/reports/medical/oamtechreports/2010s/2010/201021>.
3. Flight hazard zones consist of specified protected airspace around airports. In a two-runway airport, the zone extends 2 nm (4 km) in all directions from the runway centerline, plus an additional 3-nm (6-km) extension beyond the 2 nm along the extended centerline.
4. In 1995, FAA Order 7400.2, *Procedures for Handling Airspace Matters*, established protected zones around airports including the laser-free flight zone and the critical flight zone.