# The Perils of Multitasking

## Pilots overestimate their abilities, as well as the benefits of doing several things at once.

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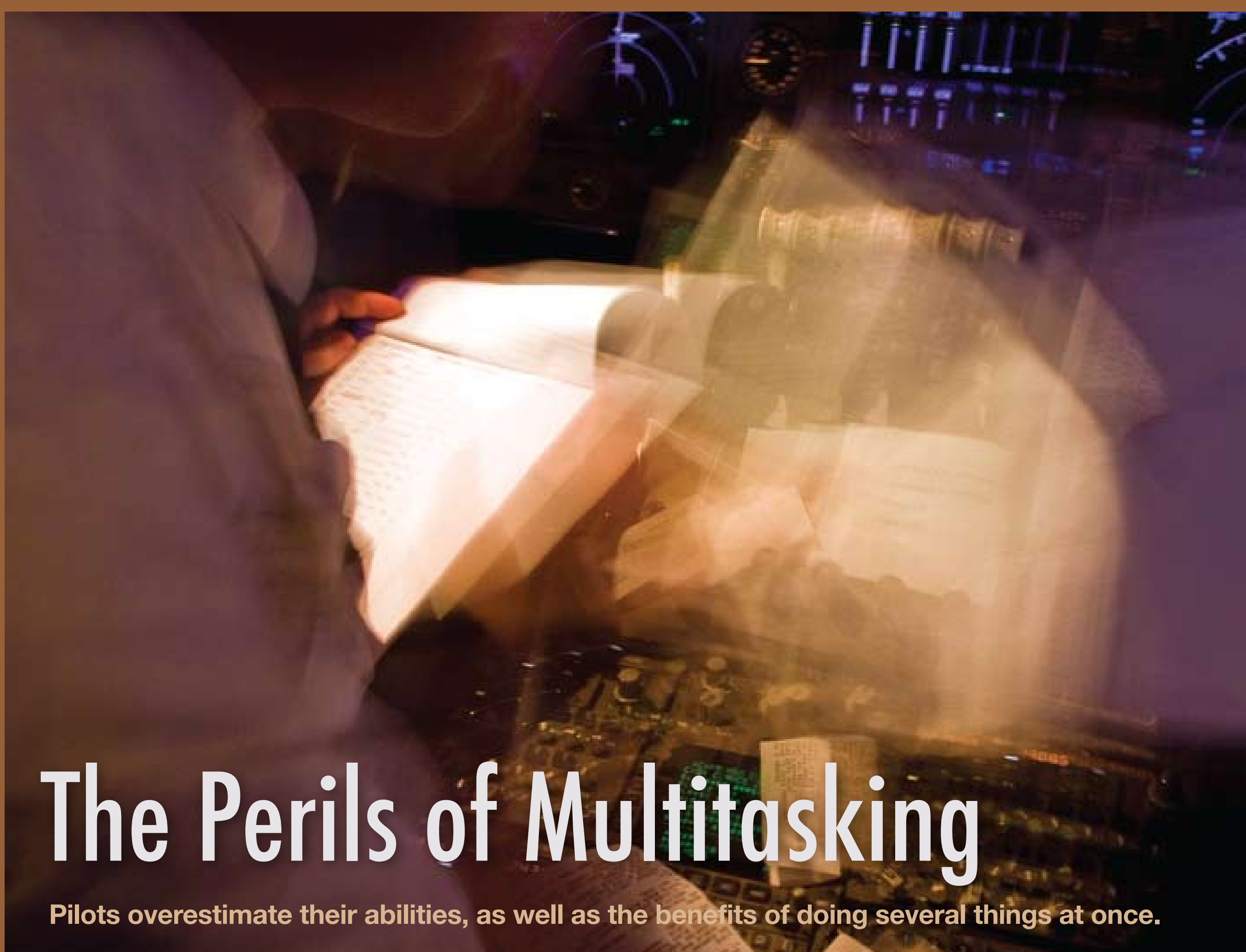
***As we started the taxi, I called for the taxi checklist but became confused about the route and queried the first officer to help me clear up the discrepancy. We discussed the route and continued the taxi. … We were cleared for takeoff from Runway 1, but the flight attendant call chime wasn't working. I had called for the 'Before Takeoff' checklist, but this was interrupted by the communications glitch. After affirming the flight attendants were ready, we verbally confirmed the 'Before Takeoff' checklist. On takeoff, rotation and liftoff were sluggish. At 100–150 ft, as I continued to rotate, we got the stick shaker. The first officer noticed the no-flap condition and placed the flaps to 5. … We wrote up the takeoff configuration warning horn but found the circuit breaker popped at the gate.[1]***

Is this an example of recklessness? Complacency? Absent-mindedness? Complex operating conditions? Complicated operating procedures? Insufficient crew experience? Or something as subtle as multitasking?

During another flight, in February 2009, a crew rejected their takeoff from Birmingham (England) International Airport at 155 kt after finding it impossible to rotate the aircraft. The investigation revealed that "a number of distractions, combined with unusual demands imposed by the poor weather, led to a breakdown of normal procedures and also allowed a missed action [stabilizer trim set for takeoff] to go unchecked."[2]

Are these incidents exceptions to usual practice or symptoms of widerspread vulnerability? What do they say about the progress of an industry that has suffered at least three catastrophic accidents when a takeoff configuration



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warning system failed to alert the crew that they were attempting to take off without having set the flaps?[3,4,5]

In reviewing categories of accidents for 2008 — spurred in part by the fatal Aug. 20 crash of a Spanair McDonnell Douglas MD-82 during an attempted takeoff from Madrid, apparently with improperly set flaps, according to preliminary reports[6] — Flight Safety Foundation decried the "unwelcome return of the no-flaps takeoff" and concluded that "we are not making much progress in reducing the risk of these [types of loss of control] high-fatality accidents" (*ASW*, 02/09, p. 18).

A quick search of the U.S. National Aeronautics and Space Administration (NASA) Aviation Safety Reporting System (ASRS) database reveals more than 50 reports of attempted no-flaps takeoffs in the last decade, as well as reports of incorrectly set trim, airspeed and heading bugs; cockpit windows not latched; and other omissions. In many of these events, the crew was saved by the proverbial bell — a takeoff configuration warning horn. That bell cannot be relied on to always work, however.

What leaves expert, conscientious pilots — and their passengers — hanging by the thread of a last line of defense, such as a warning horn or a checklist?

Articles abound in the daily news about a multitasking society and the dangers inherent in our natural drive to have more than one thing going on at once.[7,8,9,10] Most people know they should not talk on their cell phone while driving, although many do it anyway.[11,12] But what does multitasking have to do with pilots on an airline flight deck?

## Complex Operations

In 2000, we embarked on a research project sponsored by NASA and the U.S. Federal Aviation Administration (FAA) to characterize the nature and demands of routine flight operations. Preliminary findings[13] raised red flags for an industry that, like many others, had unsuspectingly accepted multitasking as a normal state of affairs.

We argued that commercial and public pressures, organizational and social demands, and the increase in air traffic, mixed with a healthy dose of pilots' overestimation of their own abilities, were creating situations that were considered routine, although they concealed appreciable risk.

Our research at the Flight Cognition Laboratory at NASA's Ames Research Center in California is based on a combination of methodologies that through the years have included laboratory experiments, structured interviews and surveys, in-depth analyses of flight manuals, participation and observation of ground and flight training, incident and accident report analyses, and many hours of cockpit jump seat observations during passenger-carrying operations. Taking advantage of these sources of data, we systematically analyzed and contrasted cockpit operations in theory and in reality.[14]

Take any carrier's flight operations manual (FOM) and draw out the flow of activities required of each pilot from moment to moment while the aircraft is taxied from the gate to the runway for takeoff, and you will see the theoretical, "ideal" taxi phase of flight (Figure 1, p. 20).

The crew's activities can be traced from the moment the captain requests that the first officer obtain taxi clearance until the aircraft is lined up with the runway centerline, ready for takeoff. There are a number of procedures that pilots conduct individually, two checklists conducted by pilots together, monitoring requirements and other pieces of information from external sources. In the ideal world, everything occurs at specific, predictable moments as the taxi phase of flight unfolds.

This is the way activities are laid out in the manuals, the way cockpit tasks are taught in training, and the way pilots are expected to perform, on the line. The activity-tracing exercise can be repeated for every phase of flight, and in each case, the ideal perspective portrays crew activities as linear, or following a prescribed sequence; predictable; and under the moment-to-moment control of the crew.

The real world is not as straightforward. Observation of flight crews, from the vantage point of the cockpit jump seat, helps us understand the full ramifications of that. During our observations, we recorded every event that caused some perturbation — or disruption — of the ideal sequence of activities of the two pilots. It did not take long to realize that the real operational world is more complex and more dynamic than represented in writing and in training.

Let's look at the taxi phase of flight in more detail, as it often unfolds in the real operating environment. The base layer (grayed-out and in the background of Figure 2, p. 21) is the ideal representation depicted in Figure 1. Another layer has been added, formed by some of the many disruptions that were observed from the jump seat during routine flights. Ovals contain some of the possible, additional demands that are not explicitly expressed in the FOMs.

The disruptions listed in each oval carried additional task demands for attention and action. Ice or snow on the ground meant that the captain deferred calling for flaps prior to taxi to avoid contaminating the wing surfaces with slush, continued with other taxi activities, performed the taxi checklist calling for verification of the flaps setting, and remembered to set the flaps right before takeoff. Encountering a busy frequency meant that the first officer had to continue monitoring all radio calls in order to "jump in" when the frequency became available, all while monitoring the captain, maintaining situational awareness and carrying out other pre-taxi preparations.

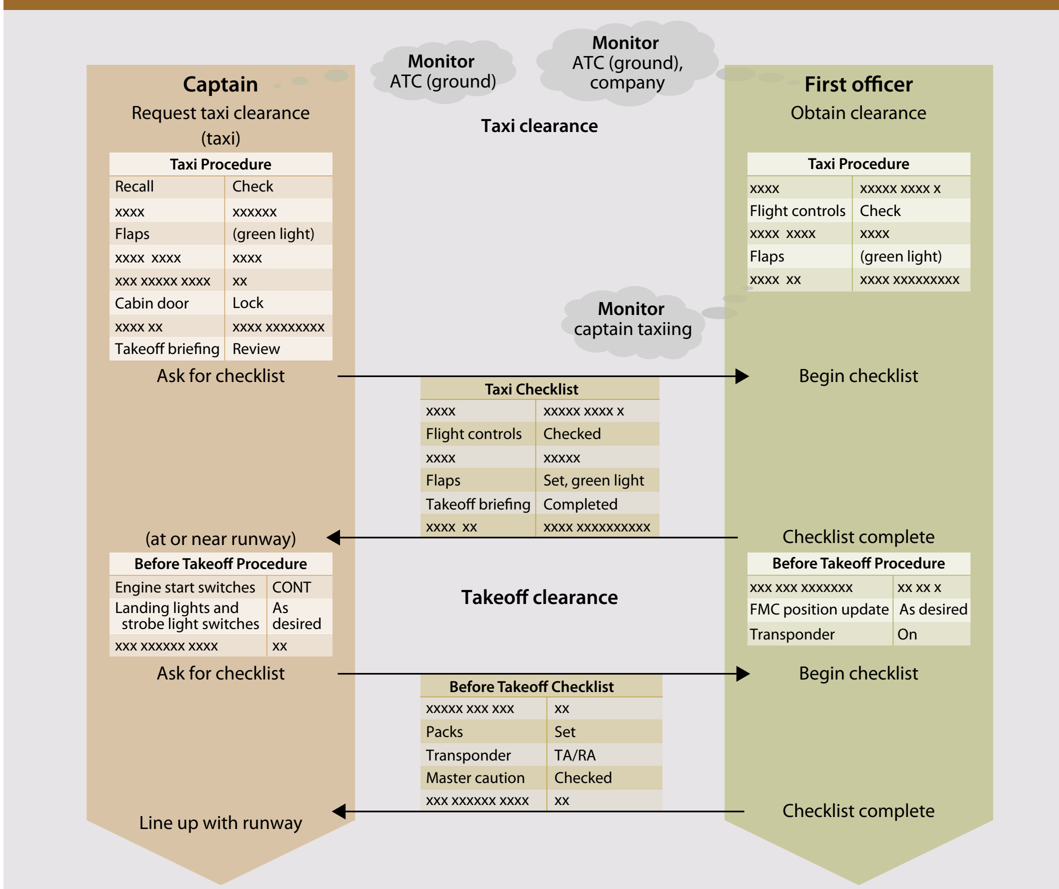
Again, the exercise can be repeated for each phase of flight. The resulting "real" picture reveals activities that are much more fluid, convoluted and variable than in theory: Activities are dynamic and not so linear, are unpredictable, and are not fully under the control of the pilots. Pilots are routinely forced to deviate from their linear, well-practiced and habitual execution of procedures. Neither the nature nor the timing of tasks and events can be anticipated with certainty. Essential information and/or the individuals required to perform some activities are not always available when expected. Tasks often must be initiated earlier or later than planned. Pilots must continually find ways to fit more than the "ideal" activities into the allotted time.

One implication of the real picture is that there is considerably more work than the ideal perspective suggests. But it is not just a question of workload quantity. It is also a question of workload management. Responding to the multiple, concurrent demands of flight operations requires interweaving new activities with old ones, deferring or suspending some tasks while performing others, responding to unexpected interruptions and delays and unpredictable demands imposed by external agents — all while monitoring everything that is going on. This is multitasking in a pilot's world.

## Limitations

People often feel they are perfectly capable of performing several tasks simultaneously. There seems to be a popular myth that humans are good multitaskers. In reality, however, human ability to process more than one stream of information at a time and respond accordingly is severely limited. Truly simultaneous performance is possible only when tasks are highly practiced and rehearsed extensively together. Performance in this situation becomes largely automatic, making few demands on the brain's limited capacities for

**'Ideal' Taxi Phase of Flight[1]**




ATC = air traffic control; CONT = continuous; FMC = flight management computer; TA/RA = traffic advisory/resolution advisory

1. The 'ideal' phase represents that described in a flight operations manual.

Source: Loukopoulos, L.D.; Dismukes, R.K.; Barshi, I. *The Multitasking Myth: Handling Complexity in Real-World Operations*. Burlington, Vermont, U.S.: Ashgate Publishing Co. 2009.

**Figure 1**

attention and working memory. But when an individual tries multitasking in a situation that involves novel tasks, complex decision making, monitoring, or overriding habits, it all falls apart.

In principle, pilots, like all people, have limited choices when called to multitask: They can interweave steps of one task with steps of other tasks, or defer one task until the other task is completed, or even purposefully omit one task. The choice and the degree to which any of these proves successful depend on the interaction of the characteristics of the tasks being performed, human information processing attributes, and the experience, skill and goals of the individual — always within the context of prevailing standard operating procedures and operational restrictions. However, the approach people take to multitasking demands is not necessarily deliberate or well thought out.

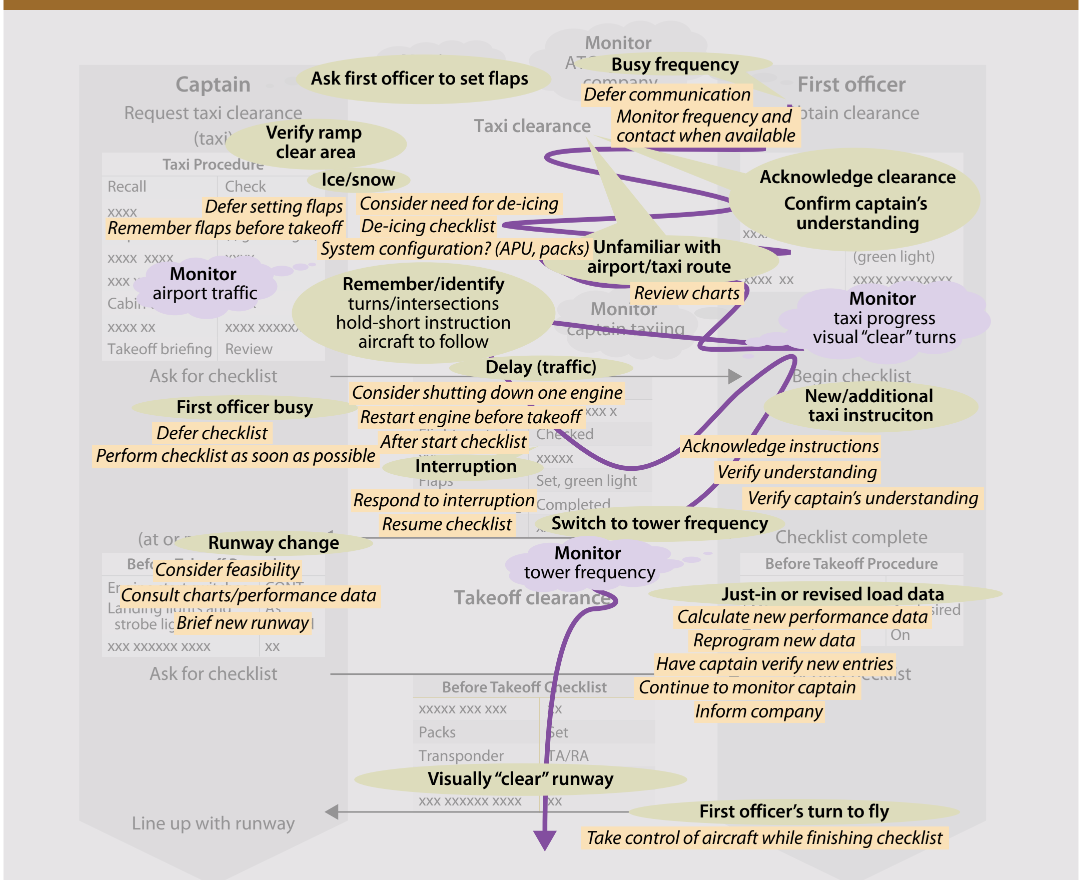
During our observations, we spent many hours watching pilots handle routine multitasking situations, apparently without much effort or many errors — but we became increasingly uneasy with the risks they were unknowingly accepting each time they were called to react in ad hoc, inventive ways. Too many of these seemingly benign situations bore a striking resemblance to stories recounted by pilots in incident reports or that we read about in accident reports.[15]

For example, the crew cited in the first paragraph of this article received a stick shaker warning after rotation and realized they had inadvertently omitted setting the flaps to the takeoff position. This crew had been multitasking, attempting to concurrently address a discrepancy in their route and an inoperative call chime.

The crew in the Birmingham event rejected their takeoff, after finding it impossible to rotate the aircraft, because they had inadvertently omitted setting the stabilizer trim for takeoff. This crew was also multitasking: They had to deice the aircraft, were preoccupied by the weather conditions, were trying to meet a takeoff time constraint, and were focused on remembering (which they did) to set the flaps, which they had deferred earlier because of the slushy conditions.

The Madrid accident apparently resulted from the crew's inadvertent omission of setting the flaps for takeoff, coupled with the failure of the takeoff configuration warning system. Was this crew also multitasking? There

**'Real'[1] Taxi Phase of Flight**




APU = auxiliary power unit

1. The 'real' phase represents the findings of jump seat observers.

Source: Loukopoulos, L.D.; Dismukes, R.K.; Barshi, I. *The Multitasking Myth: Handling Complexity in Real-World Operations*. Burlington, Vermont, U.S.: Ashgate Publishing Co. 2009.

**Figure 2**

are indications that the crew was distracted by an overheating probe, and had to return to the gate for maintenance, receive additional fuel, and start the engines anew.

Our research has focused on key aspects of human cognition that lie at the heart of multitasking, namely remembering to perform tasks that must be deferred (prospective memory), automatic processing and switching attention between tasks. There is considerable scientific evidence that pilots, like all people, are highly vulnerable to inadvertent but potentially deadly omissions when a situation leads them to defer a task that normally is performed at a particular time and place. Deferring a task breaks up the normal sequence of habitual actions and removes environmental cues that help pilots remember what to do next.

Interruptions create especially dangerous prospective memory situations — by requiring pilots to remember to resume the deferred, interrupted task — but are so commonplace that pilots may not recognize the threat. Interruptions typically disrupt the chain of procedure execution so abruptly that pilots turn immediately to the source of interruption without noting the point where the procedure was suspended, without forming an explicit intention to resume the suspended procedure, or without creating salient cues to remind themselves to resume the interrupted task. Certain phases of flight such as taxi-out and approach are often so busy that it is extremely difficult for pilots to pause long enough to review whether they have completed deferred or interrupted tasks.

A crane lifts the wreckage of a Spanair McDonnell Douglas MD-82 that crashed in August 2008 during takeoff from Madrid.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Pilots also are highly vulnerable to errors of omission when they must attempt to interweave two or more tasks — performing a few steps of a task such as flight management system (FMS) data entry, switching attention to another task such as monitoring taxi progress, back and forth. Much of the time pilots can interweave tasks without problems, but if one task becomes demanding— the FMS does not accept the input, for example — their attention is absorbed by these demands, and they forget to switch attention to other tasks. Monitoring, a crucial defense against threats and errors, often falls by the wayside when pilots must interweave it with demanding tasks. In fact, monitoring is far more difficult to maintain consistently than most pilots realize, as evidenced by studies of automation monitoring.[16,17]

## Dispelling the Myth

There is no single best technique to manage the challenges posed by multitasking in flight operations, but we have suggested various things that pilots and organizations can do.[18] First, we must dispel the myth that multitasking comes easily to humans, especially to pilots with "the right stuff." We must help pilots recognize typical multitasking situations that create vulnerability to error even in the most routine aspects of operations. Organizations must take a close look at the difference between the ideal perspective and the real nature of actual flight operations and adjust procedures, training and expectations accordingly.

Fortunately, both individual pilots and organizations can reduce the peril of multitasking. Pilots can treat interruptions, suspending tasks, deferring tasks or performing tasks out of normal sequence as red flags. When interrupted, they can reduce vulnerability by pausing momentarily to mentally note the point at which the procedure is interrupted and by reminding themselves to return to that place later, before addressing the interruption. When suspending or deferring tasks, they can identify when and where they intend to perform the task; create salient reminder cues, such as putting an empty coffee cup over the throttles when they have deferred setting the flaps to their takeoff position; and ask the other pilot to help remember. When forced to interweave tasks, such as monitoring and data entry, pilots can bolster their implicit intention to not stay head-down too long by explicitly noting to themselves the need to perform only a few steps of the one task before checking the status of the other task.

At the organizational level, we were greatly encouraged when one of the air carriers participating in our research, inspired by our preliminary findings, undertook a comprehensive review of all normal cockpit procedures. After months of analysis, that carrier's review committee devised procedural modifications to reduce multitasking demands in daily operations and to help crew performance become resilient in the face of inevitable disruptions of the ideal flow of procedure execution. The revised procedures demonstrated substantial decrease in error rates.

Although the risks of multitasking have been widely underestimated by both individual pilots and flight organizations, we are confident that by taking decisive action, the industry can make substantial progress in protecting pilots from these risks and reducing the types of accidents that have been associated with them.

*For more information and to download relevant presentations and publications, visit <human-factors.arc.nasa.gov/flightcognition>.*

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*Their book,* The Multitasking Myth*, was reviewed in* ASW *in April 2009, on p. 53.*

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