DECONSTRUCTING THE MYTH OF MULTI-TASKING

by Loukia D. Loukopoulos

Shortly after pushback from the gate, the captain of a medium-size transport aircraft is getting ready to release the parking brake and start taxiing towards the runway for takeoff. Per procedure, he intends to ask the first officer for flaps to be set to the takeoff position and for taxi clearance. Just then, the company frequency becomes alive, informing the crew that they are blocking the way of another company aircraft that has just arrived and is waiting to pull into the same gate. The first officer contacts the ground frequency to obtain taxi clearance and the captain releases the parking brake, **forgetting** to first ask for the flaps as he intended. During taxi, while conducting the Before Takeoff checklist, the two pilots are again interrupted and inadvertently miss the flaps item on the checklist... The takeoff configuration warning system, designed to alert pilots if the aircraft is not properly configured for takeoff does not function properly that day, and so does not alert the crew that the flaps are not set when the throttles are advanced for takeoff. The aircraft accelerates to normal takeoff speed but crashes at the end of the runway because the wings are not capable of generating enough lift to fly without the flaps extended.

An airport tower controller clears an aircraft "into position and hold" on a runway to be ready to go as soon as she can get another aircraft to cross the far end of the runway. That other aircraft is on the wrong frequency, delaying communication, and the controller must manage several other aircraft during the delay. Visibility is poor because of twilight and smog. **Forgetting** that she has not yet cleared the aircraft holding on the runway to take off, or perhaps confusing it with a similar aircraft still on the taxiway, the controller clears an approaching aircraft to land on the same runway, which it does, destroying both aircraft, and killing several dozen people.

A nurse, preparing to inject a patient, notices that the drug he is drawing into the syringe is not the one he remembered being prescribed. He is about to check the physician's order when he is interrupted by an urgent call from another nurse. After helping the other nurse, he returns to do the injection but **forgets** his intention to check the drug order and injects the drug. The patient suffers a severe adverse reaction.

A driver, late for an appointment, uses her hands-free cell phone to call the person she is meeting to explain the delay. While talking, she becomes **distracted** from driving and she belatedly realizes the car in front of her has suddenly stopped. She slams on her brakes too late to avoid smashing into the stopped car, which bursts into flames.

The father of an infant agrees to drop her off at the day care center on the way to work because the mother, who normally performs this task, is sick today. The infant falls asleep in the rear-seat carrier, and the father, preoccupied with heavy traffic, succumbs to the habit of driving straight to work. In the parking lot, the infant is still asleep in the carrier, the father does not see her,

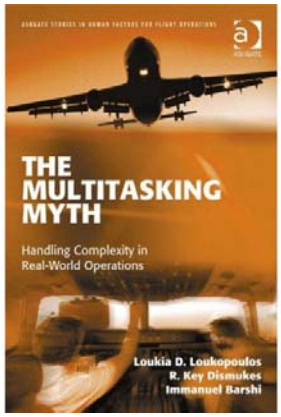
forgets she is there, and goes into his office. Two hours later the infant dies as the car heats up in the summer sun.

Whether engaged in daily life or at work, we are constantly bombarded with **interruptions** and **distractions**, and all kinds of demands that beg for more, and more, faster. So we respond, most often by trying to do many things at once. And we have become so inured to this style and pace of engaging with life and work that we have all come to believe in the myth that we can and must **multitask** - without any repercussions.

Multitasking: what's at stake?

As I hear the door close behind me, busy looking for my cell phone in my bag, I have that sneaky feeling that I forgot to take my keys with me. As I step off the elevator 5 floors below, spontaneously remembering that I need to stop by the post office, I wonder if I watered the plant on my kitchen window sill – I was about to do that earlier when I decided to pack a lunch and proceeded to make me a sandwich instead. A half an hour later, as I step into my office, I remember that I had intended to verify that I didn't lock myself out, after all, and am relieved to fish my keys out of my bag – the search unfortunately also produces an envelope. I realize that I had intended to stop by the post office. (I will water the plant when I return home – I won't forget, promise!).

Like the daily inconveniences of our hurried lives, the tragic mishaps illustrated here speak of individuals performing several tasks **concurrently** and **forgetting** to do an essential task they fully intended to do. The question is: why do even expert, conscientious professionals omit tasks and actions that are not in and of themselves especially difficult? How should we think about pilots, and doctors, and controllers who make such omissions? Are they lacking in competence? Or are these seemingly careless oversights actually manifestations of a natural human vulnerability to committing errors in situations that are subtly more complicated than is readily apparent?



In our new book, **The Multitasking Myth: Handling Complexity in Real-World Operations** (available now through the publisher's website, and online book sellers like Amazon.com), we **deconstruct** the **myth** of **multitasking** in **real-world operations**. We analyze what it means to attempt to juggle multiple demands concurrently, discuss what skills and mental resources are required, and illustrate the weaknesses and limitations that make humans pretty poor multitaskers. But we mainly present the case that no one is impervious to errors when multitasking.

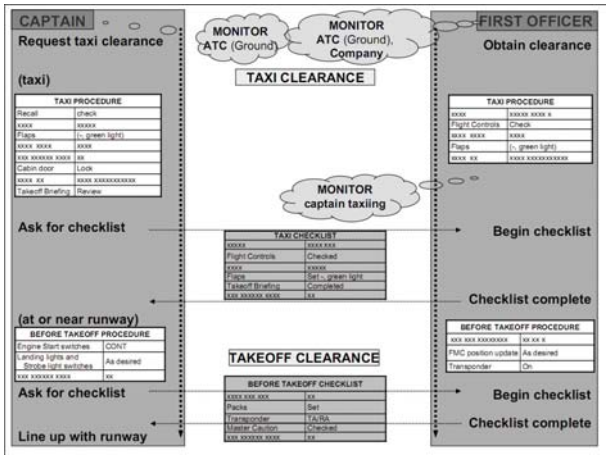
Our research at the Flight Cognition Laboratory focuses largely on the tasks performed by pilots in the course of a flight. We employ a **combination of methodologies** that through the years have included laboratory experiments, structured interviews and surveys, in-depth analyses of flight manuals, participation

and observation of ground and flight training, incident and accident report analyses, and many hours of cockpit jumpseat observations during passenger-flying operations. Other than our own interest (and expertise) in aviation, we find that airline cockpit operations offer a particularly useful setting for studying how individuals handle tasks because such operations are highly **scripted** and **standardized**. It is therefore easier than in most other settings to understand what each individual pilot is expected to be doing at each moment, in what sequence, in coordination with whom, and how, and to observe the factors that perturb the expected sequence, how pilots handle certain situations, what exactly is at risk when that happens and yes, even how these efforts occasionally fail.

Real-World Operations: Ideal vs. Real

When we first embarked on the "fishing expedition" as we called it, we simply had this feeling that pilots face enormous **complexity** in their daily work - complexity that goes severely **under-appreciated** by both pilots and researchers. We strongly felt that no one to that date had ever captured just how complex an otherwise normal flight can be, simply because most of this complexity was considered "normal" and "part of the job." We decided that to best capture the nature of the job, we would have to **immerse** ourselves in the job itself. We spent a considerable amount of time preparing ourselves, by studying Flight Operations Manuals and participating in the training of procedures from those manuals during initial and recurrent training. The outcome of this preparation gave rise to what we have since been referring to as the "**ideal**" representation of activities. This is the way in which activities are laid out on paper (in the manuals), the way in which cockpit tasks are taught in training, and the way in which pilots expect (and are expected) to act in order to do their job.

The following figure, for example, shows the "ideal" taxi phase of flight: the captain's responsibilities and activities are listed on the left hand side – the first officers' on the right hand side. With time running from top to bottom, one can trace the crew's activities from the moment the captain requests that the first officer obtain taxi clearance, all the way to when the aircraft is lined up with the runway, ready for takeoff. There are a number of procedures that pilots conduct individually (shown in white text boxes), two checklists conducted by pilots together, and various pieces of information (e.g., switch to approach frequency, landing clearance) that are requested and/or delivered from external sources –and in an ideal world, all these occur at predictable, given moments in time in the evolution of a normal taxi phase of flight.



Based on our graphical representations of all phases of flight in

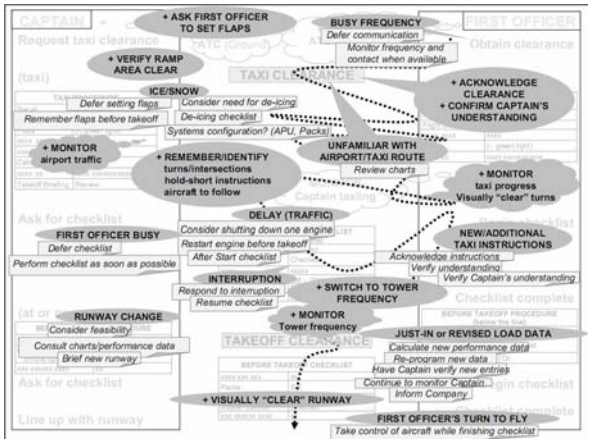
this manner, we ended up characterizing the "ideal" world as:

- **linear**: tasks always follow a prescribed order in a fixed sequence
- **predictable**: tasks and events can all be exactly anticipated, both in nature and timing
- **controllable**: execution of tasks is under the moment-to-moment control of the crew

(Chapter 3 of the book)

Naturally, we did not really expect the real world to be as straight-forward as it appears in written form in a manual. To qualify that, however, we accepted the generous hospitality of a number of U.S. airlines who allowed us entry to their cockpits. We flew mainly on short-haul flights and, from the vantage point of the cockpit jumpseat, observed flight crews perform the "ideal" activities took note of every single event that came to cause even the slightest perturbation to the "ideal" sequence of activities of the two pilots in the cockpit. We quickly realized that the real operational world is inundated with perturbations – and marveled at how swiftly and deftly pilots handled them all. The subjects of our observation, the pilots, often expressed disappointment for not having been able to "provide us with any useful data." Little did they know that, in fact, every single flight was replete with interruptions, distractions, and unexpected task demands, and therefore, without exception, provided ample data to fill a notebook. We were well on our way towards capturing the essence of complexity of real-world operations.

We first expressed this complexity by way of a graph – one that we would be able to immediately contrast with the "ideal" graph. The following figure shows the "**real**" taxi phase of flight. The base layer (washed-out and in the background) is the "ideal" figure from before. Laid on top is another layer, formed by some of the many perturbations that we observed from the jumpseat occur during routine taxi phases of flight. Ovals contain some of the possible, additional demands that are not explicitly expressed in the FOMs (e.g., the crew may have to deal with ice or snow on the ground, or unexpected (but normal and actually quite frequent) events that crews have to work around (e.g., the first officer may encounter a busy frequency when s/he attempts to make contact in order to request the taxi clearance).



Each event in an oval implies a set of activities in response (e.g., the crew may have to consider shutting down an engine to save on fuel if delays are encountered during taxi, and will have to remember to restart the engine and conduct the appropriate checklist prior to attempting to take off). In other words, to respond to such perturbations crews basically have to accept a (considerable, in many cases) additional amount of extra workload.

What's more important, however, is that time continues to unfold, meaning that pilots have to do more than the

"ideal" in the same amount of time – something they do by effectively interleaving new with old activities, deferring or suspending some tasks while performing others, responding to unexpected interruptions and delays and unpredictable demands imposed by external agents, and keeping track of the status of all tasks during these events. In other words, they have to engage in the **concurrent management** of **multiple tasks,** i.e., to **multitask**.

As this type of graphical representation draws out quite nicely, in contrast to the linear, predictable, controllable activities of the "ideal" world, the "real" world is much more fluid, convoluted, and variable. Specifically, activities are:

- **dynamic** (non-linear): because tasks do not always follow a prescribed order. Pilots often deviate from the linear flow of actions, for legitimate operational reasons or because of new, additional tasks that have to be inserting within the flow of activities.
- **semi-predictable**: because tasks and events can not all be exactly anticipated (neither their nature nor their timing). Many of the observed perturbations are partially or completely unpredictable and must therefore be handled on the spot. Compounding this uncertainty, neither the information necessary to perform specific crew tasks nor the persons required to interact with in order to perform other tasks are always available when they are necessary and expected.
- **semi-controllable**: because the initiation of tasks is not entirely under pilot control. It is often the case that tasks must be initiated earlier or later than planned, because of particular operational circumstances.

(Chapter 4 of the book)

Handling the complexity

So how do pilots handle the complexity of "real" operations? The subjective experience of is one of being perfectly capable of performing several tasks simultaneously. In reality, however, the human ability to process more than one stream of information at a time and respond accordingly is severely **limited**. Truly simultaneous performance is only possible 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 attention and working memory. Try this in a situation with multiple tasks that involve novelty, planning, or overriding habits and it all quickly falls part.

In principle, individuals have a limited number of **choices** in attempting to perform multiple tasks competing for attention: **interleave** steps of one task with steps of other tasks, **defer** one task entirely until another task is performed, or **omit** one task altogether. Their choice and the degree to which they succeed depend on the interaction of the characteristics of the tasks performed, human information processing characteristics, and the experience, skill, and goals of the individual. Ultimately, however, the chosen approach is not even necessarily deliberate, much less well thought out; rather, individuals may simply initiate tasks as the thought occurs to them or **react** to task demands

as they occur, an approach that increases vulnerability to error.

We proceeded to organize our observations of pilots managing the concurrent task demands in their operational environment into 4 **prototypical** situations. The challenges these situations present to pilots are illustrated here with examples from actual observations from the line (i.e., from real flights).

1. Interruptions and Distractions: these occur whenever some event diverts attention from an ongoing task, causing it to be suspended, at least momentarily. **Interruptions** vary greatly in their urgency and in the demands they impose. Being handed a fuel slip by the Gate Agent while the first officer is occupied in running the preflight checks may intrude on his attention for only a few seconds and may not immediately require full attention (i.e., if the first officer has not yet started programming the FMC, he can temporarily set the fuel slip aside), whereas being instructed to change radio frequencies during the approach may require the monitoring pilot to immediately interrupt other duties (i.e., monitoring the approach) to devote full attention to entering the new frequency and establishing contact with the next controller.

Ongoing tasks also vary greatly in the degree to which they can be interrupted without disruption. Taxiing the aircraft in full visibility at a familiar airport along an uncomplicated route makes few demands on cognitive resources and generally allows the crew to accommodate the interruption of a radio call without difficulty. But programming a complicated route into the FMC, a task that makes substantial demands on cognitive resources, may be seriously disrupted by an interruption.

Interrupting events also vary greatly in their nature and timing, as well as in how predictable they are. Some interruptions, such as the issuance of a revised departure clearance as the crew is approaching the runway for departure and in the process of receiving takeoff clearance, are unexpected, both in content and in timing. Other interruptions, like the transmission of a landing clearance during the execution of an approach, are expected by the crew because they are required for proper execution of the flight. The exact timing and nature of even the expected interruptions, however, is generally **unknown** and **unpredictable**. The crew cannot be certain when the landing clearance will be delivered or if it will be delivered at all for that matter – another aircraft on the runway may lead the controller to have to issue a go-around instruction instead of a landing clearance. Nor can the crew predict what tasks they will be performing at the moment the controller's message arrives over the radio. Not knowing exactly when each interruption will occur, or what its nature will be, prevents planning other tasks to accommodate even anticipated interruptions.

2. Tasks cannot be executed in their normal, practiced sequence: Often, the operational situation may not permit a task to be performed in its normal sequence. For example, a crew may be forced to **defer** setting flaps to the take-off position, normally done before taxiing to the takeoff runway, because company policy required that taxiing in these conditions be done with the flaps retracted to prevent slush from the taxiways being thrown up on the flaps.

In other situations, a task cannot be executed because information or a person expected to supply this information or with whom a task must be coordinated is not available when needed. For example, a first officer may be forced to suspend entering data into the FMC during preflight because the final passenger count has not yet been delivered to the cockpit by the lead flight attendant--the passenger count is a required data point – or a captain may be forced to defer executing a checklist because the first officer is busy with another task at that moment.

3. Unanticipated new task demands arise: Additional task demands often arise while the crew is executing procedures in the FOM-prescribed manner and sequence. In some situations, the additional task is to be performed at a later time. For example, while the aircraft is descending from 15,000 feet, the air traffic controller may instruct a crew to report passing through 8,000 feet. In this situation the unanticipated task must be **added** to the **existing** task requirements, and the crew must hold the controller's instruction in memory for several minutes while busy with landing preparations, and remember to retrieve the instruction from memory when the aircraft passes through 8,000 feet. In other situations the new task must be performed immediately. The first officer, for example, may be unexpectedly given instructions for a change to the original routing at the beginning of the taxi phase of flight, as she is about to begin monitoring the captain who will be bringing the aircraft to the departure runway. Responding to an instruction of this nature must be immediate – the information conveyed redirects what the crew will do next - so the first officer has no choice but to respond to the communication and attempt to integrate the new task it generates with her existing activities.

Pilots also face challenges when they must remember to **substitute** an atypical action for one step of a **habitual** task – or when they have to remember to *not* perform a normal step of a habitual task. For example, while flying a single engine approach in a particular twin-engine jet (i.e., when one of the engines has malfunctioned or has been shut down for precautionary reasons), the crew may forget to *not* extend the flaps all the way to the normal final landing configuration, rather than only part of the way, as required by the single-engine non-normal procedure.

4. Multiple tasks must be interleaved: In many situations pilots cannot defer one task long enough to complete another task and must attempt to interleave the two (or more) tasks. A routine approach may, for example, quickly become complex with multiple tasks requiring attention concurrently to the main task of flying the approach with all the component tasks involved: an instruction by air traffic control may challenge the crew to also to maintain best forward airspeed, who may also have to be on the look out for conflicting air traffic reported in the vicinity, and watch out for the aircraft in front, which they are closing on. Each task makes substantial cognitive demands, so it is not possible to perform them simultaneously. Rather, pilots must **switch attention** back and forth among concurrent tasks, trying to avoid becoming preoccupied with one task to the neglect of the others.

Vulnerability to Omissions (and other errors)

Every one of the four prototypical situations is most certainly very familiar to pilots who routinely address these and similar operational demands on the line. (With some imagination, we are all intimately familiar with each of these situations in our own lives and work). The pressure they create on crews, however, pushes them from a role that is ideally proactive toward a more problematic, reactive mode of operating. During our observations, we spent countless hours watching pilots handle routine situations without considerable effort and without errors –but contemplated on the **risks** they may have been unknowingly accepting each time they did so.

Generally speaking, though each of the situations highlights different aspects of the operational environment, the four situations share a common element in that they increase **vulnerability** to **error**. We looked closely at our observations and complemented them with incident and accident reports describing similar situations – and realized that pilots typically respond to the concurrent task demands arising from the various operational perturbations in one of two fundamental ways: either by **deferring** one or more tasks, or by **interleaving** multiple tasks. Our research in the Flight Cognition Laboratory has been focusing on key aspects of human cognition that lie at the heart of multitasking, namely memory for future events (prospective memory), automatic processing, and switching attention.

Deferring tasks: Suspending or deferring a task with the intention to return to it later, or forming an intention to add a new task at a later time, requires **prospective memory** (see reviews in McDaniel & Einstein, 2007 and Kliegel, Martin, & McDaniel, 2004). When a crew, for example, has to defer setting the flaps and completing the Taxi checklist for operational reasons, prospective memory is engaged. Typically, the pilots will announce their intention to set the flaps later and to complete the checklist by explicitly state their intention to complete these tasks when they reach the runway hold-short line, and **encode** an **explicit intention** in memory, so that when they observe the hold-short line it will act as a cue that will help trigger retrieval of the intention from memory - but must then focus attention on various other tasks during the taxi while maintaining in memory the intention to set the flaps and to complete the checklist as intended. In general, the tasks that are performed while waiting to execute a deferred task make sufficient demand on humans' limited attentional capacity that the deferred task cannot be maintained continuously in focal awareness and working memory; thus, the intention to return to the deferred task must be **retrieved** from long-term memory at the appropriate moment.

The cognitive mechanisms of retrieval of deferred intentions are clearly rather fragile, as personal experience so frequently (and painfully) suggests. Retrieval of intentions from memory requires that the individual notice one or more **cues** associated with the intention and that the association in memory between the cue and the intention be strong enough to help prompt retrieval of intentions from memory (Nowinski & Dismukes, 2005). However, not all cues are equally

effective. The hold-short line, for example, is a mediocre cue in this case because it is always present at the runway and is associated in memory with all previous flights, and it is especially associated with the tasks that are normally performed as the aircraft turns onto the runway – it is therefore likely to trigger retrieval of goals and tasks normally performed when taking the runway, rather than with the goal (i.e., the deferred intention) of setting the flaps and completing the Taxi checklist. Of course, even normally effective cues may fail, if an individual's attention is heavily occupied by demanding ongoing tasks (Stone, Dismukes, and Remington, 2001).

Responding to interruptions is a special case of prospective memory (Dismukes & Nowinski, 2006; Dodhia & Dismukes, 2008). Interrupting a task implicitly creates a need to remember to resume the interrupted task later. Interruptions are often so **salient** and **abrupt** (and frequent and common-place) that individuals may not have time to encode an intention to resume, or even think to do so, much less to create conspicuous cues to serve as reminders (Dismukes, 2007; Dodhia and Dismukes, 2008). Some phases of flight, furthermore (Taxi, Approach), present such a continuous flow of task demands that any pause for a moment to review whether all tasks have been completed is virtually impossible. With little or no encoding of the intention and without identifying or creating specific reminder cues, **forgetting** to resume interrupted tasks in a timely manner is common.

Checklists are major safeguards for just these types of situations. But they are often not sufficient: deferring one task often forces related tasks to also be deferred. For example, deferring setting the flaps for takeoff necessitates deferring running the Taxi checklist, which includes the flaps as an item to check. This **compounds** the risk of forgetting to set the flaps because crews may forget to run the checklist for the same reasons they are vulnerable to forgetting to set the deferred flaps before attempting to take off. (The cues that normally prompt execution of the checklist have been **removed**, and preparations for starting the takeoff occupy the pilots' attention).

Interleaving tasks: pilots do not normally have the luxury of deferring one task until another is completed; they must often interleave two or more tasks, which they accomplish by performing a few steps of one task, **switching attention** to the other task to perform a few steps, and back and forth in this fashion. When two tasks can be practiced together consistently and frequently, the steps of the two tasks become interrelated, and the two tasks merge into a single integrated task. The story is quite different when tasks that have not been practiced together consistently, if ever, must be interleaved.

When the officer, for example, discovers a numerical error on the load sheet she must re-program the FMC during taxi. Entering and verifying numerical data makes substantial demands on conscious processing, which is why the FOM prescribes that it is ideally accomplished during preflight, when the first officer can devote full attention to it. Interleaving the FMC activity with the taxi duties means that the first officer must shift attention back and forth between the head-down FMC activity and the head-up activity of monitoring the progress of the taxi to help the captain catch any threats or

errors, requiring her to **self-interrupt** each task periodically. This is effectively another special case of prospective memory (Dismukes, 2007) – therefore prone to the errors described earlier. In the absence of an established schedule for how long it is acceptable to attend to one task before attention must be switched to the other task, pilots are vulnerable to becoming **absorbed** in one task and forgetting to switch attention to check the status of the other task and perform steps of that task if needed (Dismukes et al., 1998).

Switching attention generally makes high demands on limited cognitive resources. Once the task switch has been accomplished, additional attention is required to acquire information and update situational awareness, which is why individuals report that having to switch among tasks increases the subjective experience of workload.

Monitoring is another major safeguard against inadvertent omissions. However, it is at the same time the task perhaps most often interleaved with other tasks, because of a misconception that it is automatic and easy to perform. The very fact that it is relatively automatic also makes monitoring, vulnerable to errors of omission in the same ways as other task-switching situations.

Protection from Omissions (and other errors)

In **The Myth of Multitasking** we devote a significant portion of our writing characterizing the complexity of real-world flight operations. We provide the basis for understanding the nature of the risks that are the outcome of this complexity, and the mechanisms by which they render pilots vulnerable to specific patterns of error. We argue that the need for concurrent task management has not been adequately understood or sufficiently appreciated, either at the personal or the organizational level. In fact, we show that existing procedures sometimes **exacerbate** the concurrent task demands of operations and argue that existing training does not adequately prepare pilots to manage those demands. But we don't leave you hanging. The last chapter of our book describes **techniques** that pilots and operators in other high-risk environments can use, as well as ways organizations can reduce concurrent task demands and vulnerability to error. We also talk about a recent experience, assisting one U.S. air carrier **redesign** their normal procedures. And although we use cockpit operations for our examples and analysis, the lessons learned apply equally well to any arena in which individuals must juggle multiple tasks or must defer an intended action, that is, practically any professional setting.

Multitasking permeates almost every aspect of modern personal and professional life. Although our examples focus on aviation, this book is as much about doctors operating on patients, technicians running a control room at a power plant, cashiers tending to a line of shoppers, or parents picking up and dropping off their children at afternoon activities as it is about airline pilots.

Visit the Presentations and Publications section of this website to downlod the presentation we gave at the European Aviation Safety Symposium in March 2009.

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