Aviation Human Factors Industry News

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From the sands of Kitty Hawk, the tradition lives on.

Hello all,

To subscribe send an email to: rhughes@humanfactorsedu.com

In this weeks edition of *Aviation Human Factors Industry News* you will read the following stories:

Homegrown Human Factors Training: No FAA Speaker Required

BY DR. BILL JOHNSON

The author has delivered a lot of human factors training in the United States and worldwide. This article is motivated by some of his observations of the industry-developed maintenance human factors training. It is “good-news” story.“We Are Starting/Modifying Our HF Training”

Nearly every week I receive an email that starts with a statement that the writer is developing or modifying their maintenance HF training. Often the request is accompanied by an invitation for me, or a colleague from the FAA, Civil Aerospace Medical Institute or an FAA Airworthiness Inspector to come and speak to your maintenance workforce. Of course, we are flattered by the invitation to visit your organization, to see your maintenance or manufacturing force at work, and then to deliver a portion or all of your training. If only we had the time and other resources we would be delighted to accept such invitations. We are increasingly convinced that we offer a better alternative which is our website (www.humanfactorsinfo.com or www.mxfatigue.com) in combination with your experience, creativity, and personal knowledge of organizational requirements and culture.

Our Invitation Counteroffer

I have been responding to the invitations by directing you to our website, Once I get you to our FAA website I steer you to the training HF materials, the Maintenance Human Factors Training Presentation System, the Fatigue Awareness Training, and the fatigue movie titled “Grounded.”

All of these materials are in usable format and “open source” (code word for free). The Maintenance Human Factors Presentation System is generic legacy HF training. Most users choose to supplement the generic training with discussions about safety culture, voluntary reporting, and other current topics that are organizationally relevant.

When I suggest these sites I often ask for examples of the training that they've developed. In many cases I get to see the products that are derived from those websites and other places. I am usually positively impressed. You have the ability to select the information, graphics, and media that work for you. It is especially excellent when you add pictures from your workplace and use data from your safety management system or recent safety-related events. Just last week I asked a respondent for permission to use some of the ideas and graphics that he added to the FAA and CASA materials. I went from being the trainer to being the student. Thank you for that!

Why You Should Be the HF Training Developer or Trainer

Adult learning is called “Andragogy.” It refers to the training and education practices for adults/mature learners. Most adults, especially aviation maintenance technicians are very practical about what they want to learn and how to learn it most efficiently. Most adult learners seek immediate relevancy. For example, “tell me about good sleep habits and not about sleep theory;” “show me the fuel system and how to troubleshoot a pump failure or how to service a filter rather than how fuel is refined.” Since you know the workplace and organizational challenges you can ensure training that is relevant. You know what is important for your workers.

Because you can zoom on specific issues your training can be efficient and, more likely, effective. Since you know the general background of the students you are able to tailor the information to their knowledge and experience level.

If you, or a colleague, develop and know the human factors training materials it is easier to schedule training, as a formal class or even in short amounts at a shift meeting. You can ensure that recurrent HF training is precisely targeted at your workers.

Train the Trainer

It is important that you or your human factors trainer know some of the fundamentals of being a trainer. Just because you are a great aviation maintenance technician or maintenance supervisor does not qualify you as a human factors trainer. People always ask me “What are the qualifications of good maintenance human factors trainer?” The answer is never straight-forward. At a minimum they must be enthusiastic, have had some formal HF training, and know something about the aviation maintenance environment. That list of this author’s suggestions does not use the words certificate holder or college graduate. While an AMT certificate, maintenance work experience, and college training may be helpful the credential list should not make that a requirement.

A Word about Training Providers

It would be remiss not to mention outside contract training providers. This author confesses a positive bias for external human factors and other training providers, having spent many years in that role prior to FAA. External providers have a broad view of the HF topic and yet they see many specific maintenance training organizations per year. They have many examples of maintenance challenges. External providers have the resources to train their trainers and always provide new materials matched to regulations and local requirements. They get in, get out, and get paid. There is much to be said about the efficiency of a consultant. Each organization must decide what works best for them.

More Advice Wanted?

Loads of new maintenance human factors training development and delivery advice is on its way, with 2017 publication dates. During 2016 FAA accepted many excellent public comments on the proposed replacement for Advisory Circular AC 120-72 formally called Maintenance Resource Management Training. The public input, as always, added high value to the final document. That AC will be replaced with a new focus, mostly a way to direct readers to many sites and sources for HF training materials.

The newly revised Air Transport Association (now A4A) ATA Spec 104 Guide for Maintenance Training Development. Spec 104 is the product of the A4A Maintenance Training Committee and represents the work of many airlines from all of the Americas.

It is an excellent substitute for any textbook on maintenance training development and delivery. It will be available, for sale, from the Airlines for America website (airlines.org) and is a must for all airline training departments.

http://www.humanfactorsinfo.com/

http://www.mxfatigue.com/

http://www.aviationpros.com/article/12315562/airlines.org

CALLBACK

From NASA's Aviation Safety Reporting System

ASRS

"Defined as overconfidence from repeated experience on a specific activity, complacency has been implicated as a contributing factor in numerous aviation accidents and incidents. Like fatigue, complacency reduces the pilot's effectiveness in the flight deck. However, complacency is harder to recognize than fatigue, since everything is perceived to be progressing smoothly."[1]

Complacency plagues more aviation professionals than just pilots. It can occur to anyone while accomplishing the most routine function or the most complex task in any sector of aviation operations. Because immunity from complacency simply does not exist, proactive techniques and procedures are necessary to mitigate its detrimental effects.

Procedural Complacency

This Mechanic erred while performing a procedure on a CRJ-700 engine. Only after extensive damage was done to the engine during run-up testing, did he realize the mistake and distinguish between the apparent and root causes.

From the right seat Mechanic's report:

■ I had performed a Fan Blade Pin change on the Right Engine in accordance with the appropriate work card.… We taxied the aircraft to the testing ramp, and after the required time had elapsed, we began the test by increasing the engine speed to full power. All indications up to this time had been normal.… After several seconds at full power, the vibration began to very quickly increase to 1.1.… Upon arrival [back] at the hangar, it was discovered that extensive damage had occurred within the engine. I very quickly…discovered that a ratchet I had been using to perform the pin change was missing. I then went to the acting Supervisor's office and reported the damage and my missing tool.

Several factors may have contributed to this incident. It was very early in the morning on my first day back to work after three days off. This is a job I have performed often, and overconfidence or complacency may have figured in.

From the left seat Mechanic's report:

■ The procedure was not followed.

Functional Complacency

During the initial takeoff on what seemed to be a routine day, a B767-300 First Officer made a simple, but significant error. Making no excuses, he describes how complacency was the most probable culprit.

■ After becoming airborne on our initial takeoff, the Captain called, "Gear up." Inexplicably, I raised the flap handle instead of the gear handle. Over the next several seconds, the flaps retracted while I confirmed lateral navigation (LNAV) at 400 feet AGL, selected vertical navigation (VNAV) at 1,000 feet AGL, and responded to Tower's call to change to Departure Control. During this time, the flaps were retracting, and the minimum airspeed indicator "hook" increased until the stick shaker activated. When this happened, I looked at the flap indicator, realized my error, and extended the flaps to takeoff position (Flaps 5). Simultaneously, the Captain reduced the climb angle, I raised the gear handle, the aircraft accelerated, and the stick shaker stopped. The rest of the departure was normal.

I screwed up.… No excuses. I have no idea why I reached for the flaps instead of the gear. I have successfully raised the gear—without error—for decades and buckets of hours. Slow down. Don't rush. Fight complacency. Don't think it can't happen to you!

NTSB Cites "Company Culture" In Fatal Crash

Nine people were killed when a de Havilland DHC-3 Otter hit a mountain in Alaska in June 2015, and on Tuesday the NTSB said the pilot had a history of making bad decisions. "Lives depended on the pilot's decision making," said NTSB Acting Chairman Robert Sumwalt. "Pilot decisions are informed, for better or worse, by their company's culture. This company allowed competitive pressure to overwhelm the common-sense needs of passenger safety in its operations. That's the climate in which the accident pilot worked." The pilot, who had been flying air tours for Promech Air in Southeast Alaska for less than two months, chose to continue flying VFR despite IFR weather conditions, the NTSB said.

The pilot had picked up his passengers, who were on a cruise, from a floating dock, and had two choices for a route — a longer route that followed mostly seawater channels, or a shorter route across mountainous terrain. The short route was considered more scenic, but also presented more hazards in the low visibility conditions that prevailed.

The accident pilot and two other Promech pilots chose the short route. Two other more conservative operators cancelled flights that day. In closing the board meeting, Acting Chairman Robert Sumwalt noted that “Safety must be a core value in any aviation operation … not just a priority but a core value … When this board sees an operation in which safety competed with performance and revenue, the reason we see it here at the NTSB is unfortunately because safety lost.”

The NTSB synopsis and recommendations are posted online

Explore the Plane Graveyard Where Crash Investigators Train

It Doesn’t even look like a plane. The Mitsubishi MU-2 is in about a hundred pieces, spread over the floor of a warehouse. Fluorescent lights reflect off the white paint of one dented, jagged, sheet of metal, wearing a thin layer of mud. This is what a dozen washing machines would look like after fighting a wood chipper. It’s actually the wings.The cabin is more complete. A seat hangs out, piles of wiring dangle from the aircraft walls. The detached cockpit lies a few yards away, propped up on a wooden horse. A windscreen wiper sits, limp, on the shattered glass.

Thomas Anthony picks his way through the pieces, holding a flashlight in his gloved hand. “It may give us lessons that could extend far beyond this one individual aircraft,” he says.

But Anthony's not here to figure out what happened to the MU-2. The plane crashed in 2010 in Ohio, killing four people, including the pilot. Five years ago, it settled in at this warehouse, as part of University of Southern California's Aviation Safety and Security Program, which Anthony directs.

The destroyed corporate plane is one of 11 planes, helicopters, and military drones that Anthony and his fellow instructors use to teach 800 trainees every year, giving them hands-on experience with flying wrecks. Students include staff from airlines, manufacturers, insurers, or government and law enforcement—anyone who may need to figure out what caused a crash of an aircraft they are responsible for.

Investigators are detectives, piecing together clues. Without the data-logging black boxes standard on modern, larger aircraft, they must find the subtler signs. If the bulb of a warning light is broken, there's a good chance it was on—when the filament inside gets hot it's more likely to break on impact. Knowing which lights were on reveals more about what was happening as the plane went down.

Anthony will also look at the twisting of the aircraft body to see where energy originated, and where it went. A direct hit to the ground may seem obvious, but holes in cargo bays could point to explosives. Dented engine casings could indicate mechanical failure.

The approach is the same for studying downed airliners, says Gregory Feith, a former investigator with the National Transportation Safety Board. The critical thing is to teach investigators to build up a big picture, rather than zero in on one source of information, even a black box.

"It's up to the investigator to take that data and try to put it into a sequence of events," Feith says. Today's commercial aircraft are so safe, it usually takes an array of interconnected issues to cause a crash. It's not just 'engine failure'. It's engine failure in a thunderstorm, at night, with the pilot was trying to land at an unfamiliar airport, with a short runway, without full training on emergency procedures for that aircraft. "The bottom line is not so much the cause of the accident, although it's important," says Feith. "But how we're going to prevent the accident from happening in the future."

So Anthony will teach his students to look at everything, down to the odd patches of color that could be paint transfer from another aircraft, or even a building. If there's a fire, he'll make them look at whether smoke trails go straight up, meaning it probably started when the plane was stationary, or if they flow in the direction of travel, indicating the flames started mid-air.

The crash shunted the MU-2's entire instrument panel and flight controls hard to the left. Anthony highlights the flap lever with his flashlight. It's bent almost 90 degrees. "Because that's been jammed in place, that's probably where it was set at the time," he says.

Adding in weather reports from the night of the crash and intel from nearby pilots, Anthony concludes the wings iced up. The plane stalled, and hit the ground nose first. It's a lesson that could save lives in the future—and teach others to save even more.

https://www.wired.com/video/2017/04/inside-the-plane-graveyard-training-future-air-crash-investigators/

https://www.wired.com/2017/03/boeings-test-protocol-new-planes-beat-oblivion/

FAA Cautions Pilots About Third-Party Checklists

SAFO Recommends Comparing Any Such Checklist Against Manufacturer's PublicationThe FAA has published a Safety Alert For Operators (SAFO) informing pilots and operators of the potential risks of purchasing a commercially available checklist, obtaining a free download,

or developing their own aircraft checklist in lieu of using the checklist contained in the manufacturer's Pilot Operating Handbook (POH)/Airplane Flight Manual (AFM).

Recently, a pilot was unable to lower the aircraft's landing gear and referred to a COTS checklist for the specific type of aircraft. The aircraft landed with the landing gear partially extended. On contact with the runway, the landing gear collapsed, and the aircraft sustained substantial damage.

The post-accident investigation compared the POH/AFM and the COTS checklist used. The investigation found that the COTS checklist did not match the manufacturer's checklist relating to the landing gear failure and manual gear extension. The omission of steps within the COTS checklist significantly contributed to the pilot's inability to fully extend the aircraft's landing gear. Further, the CAUTION statement in the POH/AFM was not present on the COTS checklist. The CAUTION states: "Do not re-engage landing gear operating motor in flight. To reduce landing gear side loads to a minimum, avoid crosswind landing and high speed turns while taxiing."

The FAA recommends that pilots and operators, other than those operating an aircraft under 14 CFR Part 121 or 135 that choose to use COTS or personally developed checklists should meticulously compare them to the manufacturer's checklist and placards contained in the POH/AFM to confirm they are consistent. This action will ensure the pilot has all pertinent manufacturer's information during aircraft flight operations.

Training to "Startle"

The "Startle" response, common to all mammals, reptiles, fish, and humans – including pilots of any and every skill or experience level, is an innate and involuntary reaction to sudden or threatening stimuli. Triggered by disturbing and unexpected events, our reaction is reflexive, the result of a defense mechanism that is deeply imprinted in the DNA of all vertebrates.

Nowhere in the aviation experience is this more prevalent than Loss of Control In-Flight (LOC-I) or during aircraft upset events. Pilots often instantly react in one of three ways: fight, flight, or freeze. More often than not, this results in applying insufficient or incorrect recovery techniques with all too often catastrophic results. LOC-I is unchallenged as the leading cause of aviation fatalities, and subsequent mishap investigations frequently acknowledge Startle as a causal factor. Fortunately, it doesn't have to be this way. When a pilot is properly trained, the Startle reflex can be minimized and its effects significantly mitigated.

It is critical that pilots understand the basic physiological processes that occur in their brains and bodies when experiencing Startle. On-aircraft UPRT directly addresses Startle to effectively enhance a pilot's ability to safely and effectively counter its effect. The ultimate goal of this training is to reduce a pilot's level of impairment, and duration of impairment, following an aircraft upset or LOC-I situation.

UPRT should not be focused solely on aerobatics and spins. UPRT should not be about "pulling Gs" or channeling your inner Red Bull racer. UPRT that concentrates only on "stick and rudder" training is, quite simply, insufficient and incomplete. Rather, effective UPRT is focused on understanding energy relationships and what is referred to as "brain training." This brain training emphasizes controlled, physiological exposure to increasing levels of stimuli (e.g. unusual attitudes) to gradually reduce Startle magnitude and impairment time.

UPRT should, however, be a focused evolution with specific exposure and learning objectives for each flight. This training should occur with an FAA-approved UPRT provider, and it must be in an aircraft capable of withstanding the forces generated as a result of an individual pilot's unpredictability. It's important to realize that while flight characteristics vary from platform to platform, the laws of physics and aerodynamics are absolute.

Remember, no pilot is immune to Startle. According to Human Factors psychologist Jo-Anne Hamilton, two systems in the brain—the reflexive fast system and the slow system—play different roles in our reaction to perceived danger. The reflexive fast system acts immediately—in one twelfth of a second—by sending information directly to the sense organs through the thalamus, and on to the amygdala.

The body automatically responds with increased activity such as:

- Circulation increasing blood supply to brain, muscles and to limbs (more O_2)
- Brain activity changes: we think less and react more instinctively
- Heart beats quicker and harder, coronary arteries dilate
- Blood pressure rises
- Lungs take in more oxygen and release more CO_2
- Liver releases extra sugar for energy
- Muscles tense for action
- Sweating increases to speed heat loss
- Adrenal glands release adrenalin to fuel response

The slow system sends sensory information to the hippocampus and cortex for further evaluation. It's slower because it requires conscious processing. Australia's Griffith University conducted research focused on individual, crew and organizational strategies for managing Startle. Their research revealed that a pilot's conscious processing during a Startle event can be impaired for up to 30 seconds, with corresponding psychomotor impairment for up to ten seconds.

These facts are further reinforced from a study conducted by Steve Casner, a research psychologist at NASA's Ames Research Center, along with airline pilot collaborators, Richard Geven and Kent Williams. The research trio presented 18 active Boeing 747 pilots with in-flight emergencies that matched emergencies practiced during training. The test revealed that all 18 pilots "performed impeccably, providing the correct response for each emergency." However, when the researchers incorporated situations that *differed from those typically used in training, and presented the emergencies in ways that pilots had not yet encountered*, they frequently "struggled or made critical errors." The goal of effective on-aircraft UPRT is to provide *atypical* training to enhance the "slow system" referenced by Hamilton, through repetition and exposure, to ultimately decrease peak impairment levels and impairment time.

On-aircraft, specific and recurrent UPRT is critical to countering a pilot's peak impairment level and duration of impairment associated with an aircraft upset. Even with enhanced visuals and limited motion, a simulator cannot replicate the forces and psychological/physiological exposure experienced during on-aircraft UPRT. If properly briefed, executed, and debriefed, this training could provide the necessary skills to save lives should the unexpected occur, and might just be the most rewarding and enjoyable aviation training available.

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FAA Issues Study on UAS Human Collision Hazards

What might happen if a drone hits a person on the ground? What's the risk of serious injury?

Although the Federal Aviation Administration (FAA) can't yet definitively answer those questions, studies by a consortium of leading universities have made a start toward better understanding the risks of allowing small unmanned aircraft – or drones – to fly over people.

The consortium that conducted the research includes the University of Alabama-Huntsville; Embry-Riddle Aeronautical University; Mississippi State University; and the University of Kansas, through the Alliance for System Safety of UAS through Research Excellence (ASSURE). ASSURE represents 23 of the world's leading research institutions and 100 leading industry and government partners. It began the research in September 2015.

The research team reviewed techniques used to assess blunt force trauma, penetration injuries and lacerations – the most significant threats to people on the ground. The team classified collision severity by identifying hazardous drone features, such as unprotected rotors.

The group also reviewed more than 300 publications from the automotive industry and consumer battery market, as well as toy standards and the Association for Unmanned Vehicle Systems International (AUVSI) database. Finally, the team conducted crash tests, dynamic modeling, and analyses related to kinetic energy, energy transfer, and crash dynamics.

When the studies were complete, personnel from NASA, the Department of Defense, FAA chief scientists, and other subject matter experts conducted a strenuous peer review of the findings.

The studies identified three dominant injury types applicable to small drones:
- Blunt force trauma – the most significant contributor to fatalities
- Lacerations – blade guards required for flight over people
- Penetration injuries – difficult to apply consistently as a standard

The research showed multi-rotor drones fall more slowly than the same mass of metal due to higher drag on the drone. Unlike most drones, wood and metal debris do not deform and transfer most of their energy to whatever they hit. Also, the lithium batteries that power many small drones need a unique standard to ensure safety.

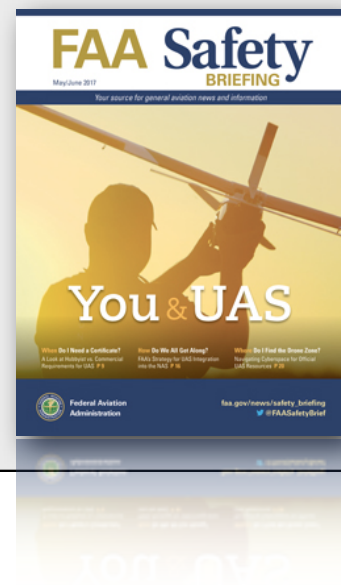
The team recommended continued research to refine the metrics developed. The team members suggested developing a simplified test method to characterize potential injury, and validating a proposed standard and models using potential injury severity test data.

The second phase of ASSURE's research is set to begin in June 2017, and will examine the risks of collisions with aircraft.

The report on the ASSURE research and two video files are available here: http://pr.cirlot.com/faa-and-assure-announce-results-of-ground-collision-study/

You and UAS

The May/June 2017 issue of FAA Safety Briefing focuses on the exciting and ever-expanding world of Unmanned Aircraft Systems (UAS). Feature articles answer the Who, What, Where, When, Why, and How of UAS operations, including the regulatory and technical challenges they present.



To see the FAA's strategy for UAS integration into the NAS, check out the article "How Do We All Get Along?" at https://adobe.ly/2qou51j.

http://www.faa.gov/news/safety_briefing/

FlightSafety Tailors New Program for Mx Managers

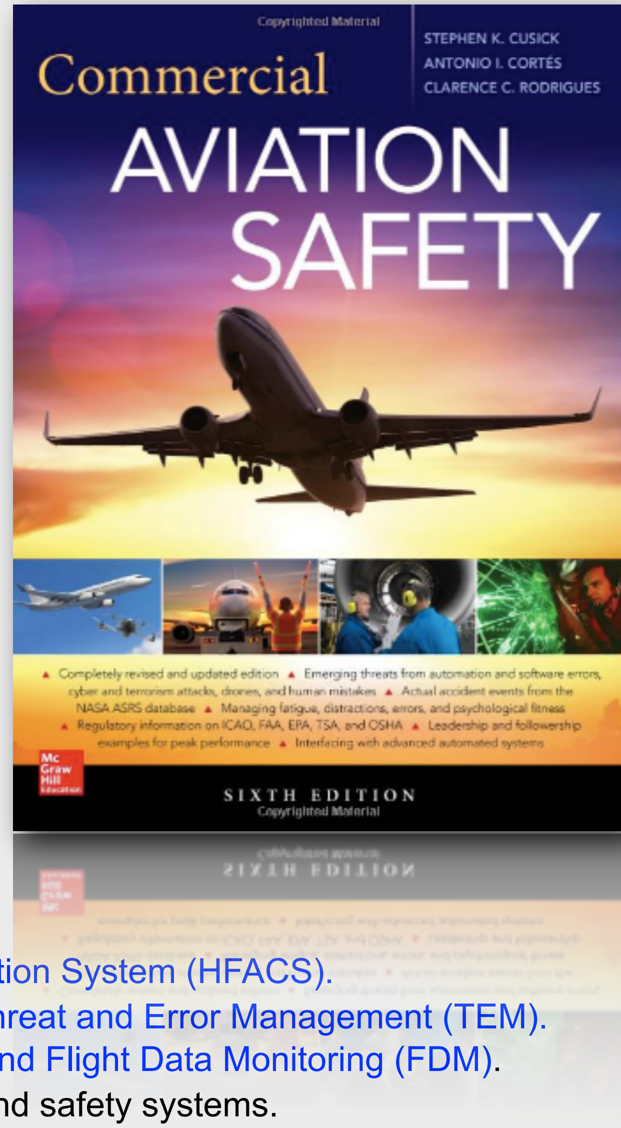
FlightSafety International has developed a new aviation maintenance management program tailored for current and future maintenance department managers. The program is designed to enhance skills, as well as address challenges and trends that are identified by maintenance department leaders, instructors and other experts, FlightSafety said. Offered at FlightSafety's Training Center in Dallas, the three-day program includes modules on leadership qualities, foundations of management, service culture, communications, accountability and delegation, finance and team building, among others.

The program expands upon FlightSafety's suite of professional development programs aimed at maintenance professionals and technicians. FlightSafety also offers professional development courses through its Master Technician program that are designed to provide aircraft maintenance personnel with the skills needed to interact effectively with customers, managers and coworkers. The Master Technician program further helps prepare technicians for additional responsibilities or management roles. More than 3,000 people have become FlightSafety Master Technicians.

New Edition of Commercial Aviation Safety book just released.

Up-To-Date Coverage of Every Aspect of Commercial Aviation Safety. Completely revised edition to fully align with current U.S. and international regulations, this hands-on resource clearly explains the principles and practices of commercial aviation safety- from accident investigations to Safety Management Systems.

Commercial Aviation Safety, Sixth Edition, delivers authoritative information on today's risk management on the ground and in the air. The book offers the latest procedures, flight technologies, and accident statistics. You will learn about new and evolving challenges, such as lasers, drones (unmanned aerial vehicles), cyberattacks, aircraft icing, and software bugs. Chapter outlines, review questions, and real-world incident examples are featured throughout.

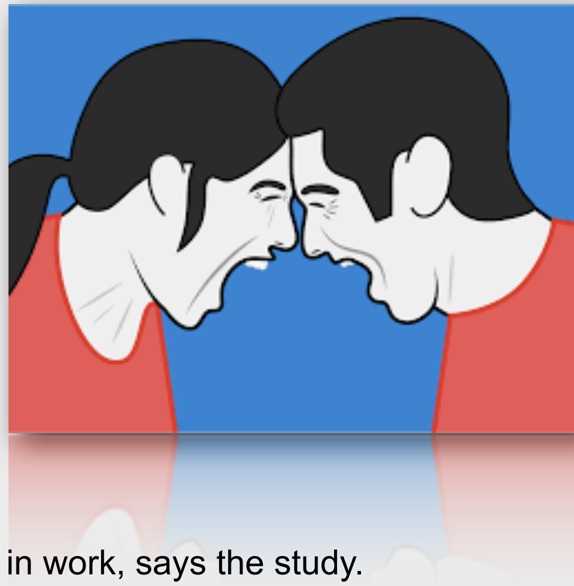


Coverage includes:

* ICAO, FAA, EPA, TSA, and OSHA regulations.
* NTSB and ICAO accident investigation processes.
* Recording and reporting of safety data.
* U.S. and international aviation accident statistics.
* Accident causation models.
* The Human Factors Analysis and Classification System (HFACS).
* Crew Resource Management (CRM) and Threat and Error Management (TEM).
* Aviation Safety Reporting System (ASRS) and Flight Data Monitoring (FDM).
* Aircraft and air traffic control technologies and safety systems.
* Airport safety, including runway incursions.
* Aviation security, including the threats of intentional harm and terrorism.
* International and U.S. Aviation Safety Management Systems.

Available now through Amazon: https://www.amazon.com/Commercial-Aviation-Safety-Stephen-Cusick/dp/1259641821

Sleep loss 'starts arguments at work'



Erratic and disruptive behavior at work can be caused by even a single night's loss of sleep, say researchers.

Lack of sleep does not only mean tired workers, says the study, but can also cause "unwanted" activity, which it links to lower levels of self-control.The study, published by the Rotterdam School of Management, says that such sleep-related disruption can cost billions in lost productivity.

Sleeplessness can cause a "destructive cycle" in work, says the study.

"Unwanted behavior in the workplace often stems from selfish impulses that are not kept in check by self-control," says researcher Laura Giurge of the Rotterdam School of Management, Erasmus University in the Netherlands.

This could be anything from being rude to someone else in the office or increasing the likelihood of workplace theft.

But the study suggests that lack of sleep, even for a single night, can be a powerful influence over people who would otherwise not behave that way.

"This study shows that the display of unwanted behavior is not a fixed character trait," says Ms Giurge.

"It can vary from day to day, even within the same person."

The study argues that lack of sleep can reduce people's sense of self-control and their ability to "regulate their impulses" - so that they behave in a way that they would not do normally.

"This can lead into a possibly destructive cycle," says the study and could contribute to unethical behavior.

Such lack of sleep can also make it more difficult for people at work to overcome feelings of failure, says the study, with workplace problems seeming to become overwhelming.

There have been previous studies which have examined how sleep deprivation can disrupt "moral judgement" and alter the quality of decision-making.

This has been studied in areas such as whether lack of sleep changes the behavior of judges and how sleep deprivation might change how soldiers behave under pressure.

Suit Up and Fly High in NASA’s Science Spy Plane

Suit up with a NASA high altitude ER-2 pilot as he prepares for a scientific research mission flying as high as 70,000 feet in the agency’s modified U-2 spy plane.

blob:https://www.wired.com/d4833575-1fe3-4d3d-83f4-f6c74c5d6e31

Mechanics contaminated Air Force One planes, causing $4 million in damage and threat of fire

Airline mechanics assigned to perform critical maintenance on the fleet of Air Force One planes used to fly President Donald Trump and previous presidents were caught using contaminated tools on the craft, causing more than $4 million in damage that could have caused a fire to break out on the plane, according to a federal investigation.Three mechanics working for Boeing, which has a contract to perform critical maintenance on the Air Force One fleet, "failed to observe explicit warnings" while attempting to clean the plane at a Boeing-owned plant in San Antonio, Texas.

The dangerous cleaning methods employed by the Boeing employees could have caused a fire to break out on board the plane, according to an investigation, which refers to the three employees in question as "Mishap Mechanics," or "MM."

The shoddy work took place during routine maintenance checks performed from April 1 to 10 last year.

Three mechanics involved in the incident all were "assigned to the Presidential Airlift Squadron, Andrews Air Force Base, Maryland," according to the investigation. "The three Boeing mechanics were supporting the heavy maintenance contract between the United States Air Force and Boeing."

Investigators found that "three factors substantially contributed to the mishap."

"First, MM2 failed to observe explicit warnings concerning cleanliness while performing tasks on the [plane's] oxygen system," according to the investigation. "Second, Boeing failed to exercise adequate oversight over the timeliness and quality of maintenance being performed on the [aircraft]. Lastly, MM1, MM2, and MM3 failed to absorb or retain oxygen system training and failed to apply cleanliness procedures while performing oxygen system maintenance."

As of Thursday, "the cost to remediate the known contamination of the oxygen system is over $4 million, which was paid for by Boeing," according to the investigation. "There were no injuries as a result of the mishap."

A Boeing spokesman would not say whether the mechanics in question had been disciplined or fired, according to Defense One.

"We did complete some investigations alongside our Air Force partners," Davis told the publication. "Collectively, we did some corrective action reports so that we can ensure we have exemplary performance in the future."

https://media.defense.gov/2017/May/09/2001744177/-1/-1/1/AFD-170509-335-001.PDF