UTED 1968 INTERNATIONAL

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AIRCRAFT MAINTENANCE MAGAZINE

TECHNICIAN 4.0:
THE FUTURE OF AVIATION MAINTENANCE PROFESSIONS IN THE INDUSTRY 4.0 ERA

THREAT AND ERROR MANAGEMENT SYSTEM

PSYCHOLOGICAL SAFETY:
THE BEDROCK OF HIGH-RELIABILITY OPERATIONS IN AIRCRAFT MAINTENANCE

AIRCRAFT MAINTENANCE AND SAFETY:

A TECHNICIAN'S JOURNEY THROUGH TECHNICAL INSPECTION AND REPAIRS IN THE HANGAR

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Dear Readers,

The months of May, June, and July have once again demonstrated the remarkable pace of transformation within the global aviation industry. The record-breaking aircraft orders announced at the Paris Air Show underline not only the recovery and resilience of air travel but also the growing strategic importance of the Maintenance, Repair, and Overhaul (MRO) sector. Boeing's largest order in history, alongside Airbus's impressive sales, signals an era of accelerated fleet expansion—one that will inevitably require stronger maintenance infrastructures and a highly skilled workforce to sustain operational safety and efficiency.

At the center of this evolution lies digital transformation. Artificial intelligence–driven predictive maintenance, digital twin applications, and software-based avionics solutions are redefining both operational practices and business models. For MRO executives, these advancements demand more than technological investment; they require a fundamental rethinking of process management and resource allocation. Maintenance hangars are no longer merely operational facilities—they are becoming technology and data hubs that must integrate seamlessly with global supply chains and digital ecosystems.

Yet, beyond technology, the most decisive factor for the industry's future remains human capital. According to Boeing and CAE, hundreds of thousands of new technicians will be required in the next two decades. This is not just a workforce challenge but a sustainability imperative for MROs worldwide. Industry leaders must therefore focus on long-term workforce strategies: investment in advanced training platforms, international mobility frameworks, and talent management systems that can prepare technicians for a more digital, complex, and data-driven operational environment. Without these, fleet growth risks being undermined by the lack of qualified professionals to support it.

From a national perspective, Türkiye holds significant potential in this global transformation. The increasing visibility of UTED at international events and the strengthening of collaborations with global stakeholders offer unique opportunities to enhance our competitive position in the MRO sector. Aligning global vision with local expertise is not only vital for the professional development of our technicians but also for consolidating Türkiye's strategic role in the aviation ecosystem.

The responsibility for today's leaders is clear: to integrate technological advancement with workforce strategies under a unified, forward-looking vision. At UTED, we are committed to being an active part of this transformation, supporting our technicians, and leading collaborations that will raise our sector to global standards. We believe that the future of aviation safety and sustainability will be built on strategic leadership, targeted investment, and the ever-growing competence of our maintenance professionals.

Ömür CANİNSAN
UTED President

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A New Era in Electric Aviation: The Pipistrel Velis Electro

Electric aircraft are gaining momentum, and the Pipistrel Velis Electro is leading the charge. Recently tested, this fully electric plane promises to change the way we think about aviation. With its advanced technology and eco-friendly design, the Velis Electro could play a key role in the future of aviation. What stands out about the Velis Electro is its electric power system, which reduces operational costs and requires less maintenance than traditional aircraft. Its quiet operation and energy efficiency during test flights have impressed pilots, making it a strong contender for future use in both private and commercial aviation. This aircraft is particularly suited for short flights and pilot training, offering a more sustainable and cost-effective alternative to conventional planes. As the electric aircraft market grows, models like the Velis Electro could become a common sight in urban air transportation. Pipistrel's focus on the Velis Electro marks an exciting step toward greener aviation, and it's clear that electric planes are a big part of the industry's future. As technology advances, we can expect even more electric aircraft to take to the skies, transforming how we travel.

Asia Digital Engineering Accelerates Growth with Key Aviation Accreditations

Asia Digital Engineering (ADE), Capital A's MRO division, earned key certifications from EASA and the FAA, enhancing its global reach and Malaysia's aerospace reputation. The achievement was praised by government and industry leaders as a boost for Malaysia's aviation sector. Since 2020, ADE has completed over 180 maintenance checks and operates across ten countries. The company recently opened Malaysia's largest MRO hangar and plans to launch a new training center to support future growth.

Historic Eurofighter Accord Signed Between Turkey and the UK

An important turning point in Ankara's attempts to upgrade its air force was reached on July 23, 2025, when the United Kingdom and Turkey signed a memorandum of understanding pertaining to the Eurofighter Typhoon. A significant step toward Turkey's intended acquisition of 40 Eurofighter Typhoon aircraft, the agreement was formally signed during a ceremony in Istanbul by Turkish Defense Minister Yaşar Güler and his British counterpart John Healey. Germany reportedly granted Turkey's request that same day, indicating political unity among the consortium members. As both countries confirmed their intention to completing a comprehensive deal, this development has important implications for NATO's collective deterrence in addition to bringing Turkey closer to joining the Eurofighter user group.

TUSAŞ–Airbus: Export Alliance

Turkish Aerospace Industries (TUSAŞ) has signed a strategic cooperation agreement with Airbus in Spain to support the international expansion of HÜRJET, Turkey's first domestically developed supersonic advanced jet trainer. The agreement aims to facilitate HÜRJET's entry into European defense and training markets. HÜRJET, developed entirely with national resources, offers high-speed performance, modern avionics, fly-by-wire systems, and advanced training capabilities, making it suitable for NATO and allied air forces. The partnership with Airbus will help enhance the aircraft's market readiness, compliance with European standards, and logistical integration. This collaboration boosts HÜRJET's credibility and global visibility, strengthens TUSAŞ's role as a key player in the aviation industry, and supports Turkey's goal of achieving strategic independence in high-performance aircraft production.

Indonesia and Turkey Sign Deal for 48 Kaan Fighter Jets at IDEF 2025

Indonesia and Turkey have officially signed a contract for the purchase of 48 Kaan fighter jets at the IDEF 2025 defense exhibition. This agreement marks a major milestone in the growing defense collaboration between the two countries. The Kaan jet, developed by Turkey, is a next-generation fighter designed to enhance Indonesia's military capabilities. The deal comes as part of a broader effort to strengthen defense ties and diversify military resources in the region. The Kaan fighter jet is expected to play a key role in modernizing Indonesia's air force, offering advanced features and combat capabilities. This agreement also demonstrates Turkey's growing influence in the global defense market, as the Kaan jet continues to attract international interest. With its cutting-edge technology and affordable pricing, the Kaan has become a strong contender for other nations looking to upgrade their air forces. The deal signifies the growing importance of defense partnerships between countries and highlights the increasing role of locally developed military technology in global defense markets. As both nations continue to enhance their defense capabilities, this agreement sets the stage for deeper military cooperation in the future.

Pilot Error Confirmed in Jeju Air Crash: Wrong Engine Shut Down After Bird Strike, 179 Dead

An official investigation in South Korea has revealed critical findings pointing to pilot error in the Jeju Air crash that occurred in December, resulting in the deaths of 179 people. Evidence from cockpit voice recordings, flight data, and the physical engine switch recovered from the wreckage indicates that the pilots mistakenly shut down the less damaged left engine after a bird strike. Despite the right engine suffering more severe damage, it continued operating, while shutting down the left engine caused the aircraft to lose control. The investigation suggests that the pilots made a critical error while executing emergency procedures.

Jordan Airmotive Expands Asia-Pacific Presence with Key Engine Delivery

Jordan Airmotive has marked a major step in its global growth by delivering a CFM56-5B engine to BOC Aviation, a leading aircraft leasing company in the Asia-Pacific region. This successful delivery highlights the company's rising influence in the global MRO (Maintenance, Repair, and Overhaul) sector and its ability to provide dependable, high-performance engine services. CEO Mahmoud Bashir emphasized the strategic value of this collaboration, noting it reflects Jordan Airmotive's commitment to quality and customized support. Operating in a competitive and evolving industry, the company continues to stand out by meeting rigorous international standards and offering flexible, cost-effective solutions. With certifications from EASA and the FAA, Jordan Airmotive services a wide range of engines, including modern LEAP and CFM models. It is also investing in technology and workforce development to maintain a leading edge. This achievement not only boosts confidence in its capabilities but also positions the company as a forward-thinking partner for global aviation customers.

Alaska Airlines Resumes Flights After Software Outage

On July 21, 2025, Alaska Airlines resumed flight operations after a software outage grounded its entire fleet earlier that morning. The malfunction, which impacted flight scheduling, caused delays and cancellations for hundreds of flights across the United States. The issue was traced to a critical failure in the airline's flight management system, which led to temporary suspension of services. Passengers experienced significant inconvenience, with some waiting hours to rebook or receive compensation. By mid-afternoon, Alaska Airlines had restored operations, and flights began departing gradually. The airline issued an apology and thanked its staff for managing the situation. Alaska Airlines also pledged to review its systems to prevent future disruptions of this scale. The FAA is monitoring the situation to ensure safety protocols are followed.

Fire in the Sky: F-35 Fighter Jet Crashes Near California Navy Base

An F-35C Lightning II, operated by the U.S. Navy and assigned to Strike Fighter Squadron VFA-125 (Rough Raiders), crashed near NAS Lemoore, California, at approximately 18:30 local time during a routine training sortie. The aircraft was part of the Navy's carrier-based pilot training program.

The pilot executed a successful ejection, with the ejection seat system operating nominally. No injuries were sustained. Emergency response units promptly secured the crash site and contained a post-impact fire.

Initial visual assessments revealed extensive combustion and heavy smoke, consistent with a high-velocity ground impact. No civilian casualties or infrastructure damage were reported.

A formal mishap investigation has been initiated by Naval aviation safety authorities. Analysis of the aircraft's flight data recorder (FDR) and onboard telemetry will be conducted to identify contributing factors and root cause.

Air India Flight 171 Tragedy: Fatal Boeing 787 Crash

Shortly after taking off from Ahmedabad on its way to London Gatwick, Air India Flight 171, a Boeing 787-8 Dreamliner (VT-ANB), crashed on June 12, 2025. In addition to at least 19 individuals on the ground, 241 of the 242 passengers on board perished. The lone survivor was an Indian-born British national. Both engines lost power forty seconds after takeoff when the cockpit fuel control levers were momentarily placed in the "cutoff" position. Voice recordings showed that the pilots were confused with one another. Investigators are concentrating on potential human mistake or systemic breakdown after ruling out mechanical failure. More than 60 people were hurt on the ground when the plane struck a medical college dorm in a crowded area. According to reports, the aircraft was airworthy, and there were no known disciplinary or health problems with the pilots. Since the Boeing 787's launch in 2011, this tragedy is the first fatal accident involving the aircraft.

American Airlines Flight AA3023 Aborts Takeoff Due to Landing Gear Fire at Denver Airport

American Airlines Flight AA3023, a Boeing 737 MAX 8, aborted its takeoff at Denver International Airport on July 26, 2025, due to a landing gear malfunction. At around 2:45 PM, passengers heard a loud bang as the plane accelerated, and the aircraft began veering to the right. The pilots aborted the takeoff immediately. The right main landing gear's tire blew, causing brake friction and a fire. Emergency crews quickly extinguished the flames. All 173 passengers and six crew members evacuated via emergency slides, with one passenger taken to the hospital with minor injuries. The aircraft was grounded for inspection, and a replacement flight was arranged for passengers. American Airlines praised the crew's prompt response and issued an apology The FAA has launched an investigation into the incident. This is the second major incident involving American Airlines at Denver this year.

Powering the Future: TAT Technologies Strengthens Global APU Support with Cargo Giant

TAT Technologies, a provider of innovative solutions for commercial and defense aviation, has signed a five-year maintenance, repair, and overhaul (MRO) agreement with a leading global cargo airline. This deal extends an existing contract for APU (Auxiliary Power Unit) repairs on the airline's U.S.-based Boeing 767 and 757 fleet to cover its entire worldwide fleet. In addition, TAT will now provide APU repair services for the B737 and A300 aircraft platforms. The company has also been awarded a seven-year contract for the B777 fleet's APU maintenance, with the formal signing expected between May and June 2025. The total value of these contracts is estimated between $40 million and $55 million over five years. CEO Igal Zamir highlighted that this agreement strengthens the partnership with an important international customer and reinforces TAT's leadership in the APU MRO market. He also emphasized that the deal reflects the success of the company's customer-focused strategy and its growing service capabilities through its subsidiary, Piedmont Component Services.

CAMO Certification Extension Boosts FL Technics' Market Reach

FL Technics has expanded its CAMO (Continuing Airworthiness Management Organisation) certification to include the Airbus A350 and ATR 42/72 aircraft, increasing its coverage to 13 aircraft types. This strengthens its global position in the MRO (maintenance, repair, and overhaul) market. The certification followed staff training and a regulatory audit, demonstrating a commitment to compliance and quality. The move supports FL Technics' growth strategy, particularly in the Asia-Pacific region, and comes amid rising industry competition and supply chain challenges.

Delta Airbus A330 Makes Emergency Landing in Minneapolis Following Turbulence

A Delta Air Lines flight from Salt Lake City to Amsterdam was forced to make an emergency landing at Minneapolis-St. Paul International Airport on Wednesday after encountering severe turbulence roughly two hours into its nine-hour journey. Flight 56, operated by an Airbus A330-900, departed Salt Lake City at 16:30 local time (23:30 BST) and landed in Minneapolis at around 19:45 local time (01:45 BST). Medical personnel met the plane upon arrival to assess passengers and crew, with 25 individuals transported to nearby hospitals. A total of 275 passengers and 13 crew members were onboard. Delta is coordinating with customers to address immediate needs following the incident. According to data from the U.S. National Transportation Safety Board, turbulence has caused 207 serious injuries requiring hospitalization for more than 48 hours since 2009. Globally, approximately 5,000 severe-or-greater turbulence events occur annually among over 35 million flights. Severe turbulence is defined as vertical air movements producing forces exceeding 1.5g, enough to lift unrestrained passengers from their seats.

Pratt & Whitney Introduces Hot Section Upgrade for GTF Engines

Pratt & Whitney rolled out the Hot Section Plus (HS+) improvement for its PW1000G-JM engines that drive the Airbus A320neo family, with the goal of essentially doubling time on wing. HS+ delivers up to 95% of the GTF Advantage engine technology's durability enhancements. The upgrade affects only 35 part numbers and can be performed on standard maintenance from 2026 onwards. HS+ engines will remain fully interchangeable with current GTF and GTF Advantage engines, and thus operators can handle their fleets without any issues. Certified on the A320neo in the first half of this year, the GTF Advantage features various improvements, such as an enhanced airfoil design, improved high-pressure turbine coatings, and optimized combustor and turbine cooling holes to reduce oxidation. First production deliveries of the GTF Advantage will start by late 2025.

Flames on Takeoff: Delta Boeing 767 Makes Emergency Return to LAX

A Delta Air Lines Boeing 767-400 made an emergency landing at Los Angeles International Airport shortly after takeoff, following a fire in its left engine. The aircraft was en route to Atlanta when flames and smoke were observed coming from the engine moments after departure. The flight crew acted quickly, returning safely to LAX. "The Delta flight returned safely due to a problem with the left engine," a company spokesperson stated. No injuries were reported among passengers or crew. A technical investigation is underway to determine the cause of the malfunction. This incident serves as a strong reminder of the critical role of pilot response and aircraft safety systems in managing in-flight emergencies.

ATS Technic Strengthens MENA Aviation Services with Major Partnership

ATS Technic, an independent aviation maintenance provider certified by EASA, has signed a new line maintenance agreement with Ethiopian Airlines, significantly growing its operations in Jordan and the UAE. This partnership aims to meet increasing regional demand for quality aircraft maintenance while supporting Ethiopian Airlines' modern fleet. Under the deal, ATS Technic will deliver full maintenance services (both scheduled and unscheduled) at major airports such as Amman's Queen Alia and multiple UAE hubs, including Dubai and Abu Dhabi. The company will also assist with fuel management, safety inspections, and coordination with flight crews to improve operational efficiency. ATS Technic's spokesperson, Mahdi Al-Tahaineh, called the agreement a key step in the company's Middle East strategy, emphasizing its role in strengthening aviation standards in the MENA region. The move comes amid growing competition in the maintenance sector, with other companies likely to intensify efforts to win similar contracts. As a result, ATS Technic's ability to meet its service promises will be closely watched. As the UAE's first independent EASA-certified line maintenance firm, ATS Technic provides MRO services through a network of stations across the Middle East and beyond, focusing on safety, quality, and international compliance.

Belarus Drone Found in Lithuania After 5-Day Search

A second Belarusian drone has been discovered in Lithuania following a five-day search. This marks a significant development in the ongoing investigation into potential security threats in the region. The drone was found near the Lithuanian border, raising concerns about the increasing presence of unmanned aerial vehicles (UAVs) in the area. The first drone, discovered earlier in the week, was believed to be a reconnaissance device sent to gather intelligence. Officials are now investigating the purpose of this second drone and its possible connections to recent border tensions. The discovery highlights the growing use of drones for military and surveillance activities, especially in sensitive border regions. Lithuanian authorities have increased surveillance and security measures along the border, as drones pose a new challenge to national security. With tensions rising, both Lithuania and neighboring countries are now looking into ways to prevent similar incidents in the future. As drone technology continues to advance, the potential for their use in military operations and espionage becomes a major concern for nations worldwide. The recent discoveries serve as a reminder of the evolving threats posed by UAVs, requiring countries to adapt their defense strategies accordingly.

Ethiopian Airlines Backs Sustainability and Efficiency with GE Engine Orders

Ethiopian Airlines has finalized two major agreements with GE Aerospace, selecting the GEnx engine to power 11 new Boeing 787 aircraft and reaffirming its previous order of GE9X engines for eight Boeing 777-9s, with options for six more. This brings the airline's GEnx-powered fleet from 19 to 30 aircraft, enhancing its reputation for adopting advanced aviation technologies. Both agreements include long-term service contracts covering maintenance and support for the GEnx and GE9X engines, reflecting Ethiopian's commitment to operational efficiency and sustainability. CEO Mesfin Tasew emphasized that the partnership with GE Aerospace has been vital in maintaining world-class service and modernizing the fleet.GE Aerospace echoed the sentiment, expressing pride in continuing its long-standing relationship with Ethiopian Airlines, which began in 2003. These new deals mark a continued investment in cutting-edge, fuel-efficient engines, such as the GE9X — the most powerful and efficient engine in its class — and the GEnx, which powers two-thirds of all Boeing 787s in operation.Both engine types are compatible with Sustainable Aviation Fuel (SAF), supporting Ethiopian Airlines' environmental goals. Ethiopian Airlines, recognized for its innovation and service excellence, currently serves over 160 destinations globally. With its Vision 2035 strategy, the airline aims to become one of the world's top 20 aviation groups, expanding through multi-hub operations across Africa and continuing to lead in fleet modernization and connectivity.

Werner Aero Expands Global Footprint with Major Warehouse Upgrade

Werner Aero has expanded its global operations by adding 22,000 ft to its warehouse facility, significantly increasing inventory capacity. This strategic move aims to improve service speed, efficiency, and availability of critical aircraft components for airline and MRO partners worldwide. CEO Tony Kondo emphasized the expansion as a step toward supporting growth and enhancing customer satisfaction. Known for its reliable logistics and asset management services, Werner Aero specializes in A320, B737NG, E-Jet, and CRJ aircraft. The company operates globally and maintains high industry standards as an ISO 9001-certified and FAA AC0056B approved supplier.

No Survivors in Angara Airlines An-24 Crash

Russian authorities have confirmed that all 48 people aboard an Angara Airlines Antonov An-24 were killed when the plane crashed in a remote wooded area of the Amur province. The twin-turboprop plane, carrying 42 passengers and six crew, was flying from Blagoveshchensk to Tynda when it went missing while descending to Tynda Airport. A rescue helicopter then located the crashed, alight wreckage some 16km short of the airport. Five children were among the fatalities, officials stated, and three days' mourning were announced by the governor of the region. Rescuers were slowed by rugged terrain and reached the site about an hour after the crash. Early enquiries focus on possible pilot error during difficult weather or technical malfunction. The plane, nearly 50 years old, had just had a technical checkup but was involved in four incidents since 2018. The aircraft crashed after a preliminary first attempt at landing was aborted; radar contact was lost when preparing for a second approach under low cloud cover.

Severe Turbulence on Delta Flight: 25 Injured!

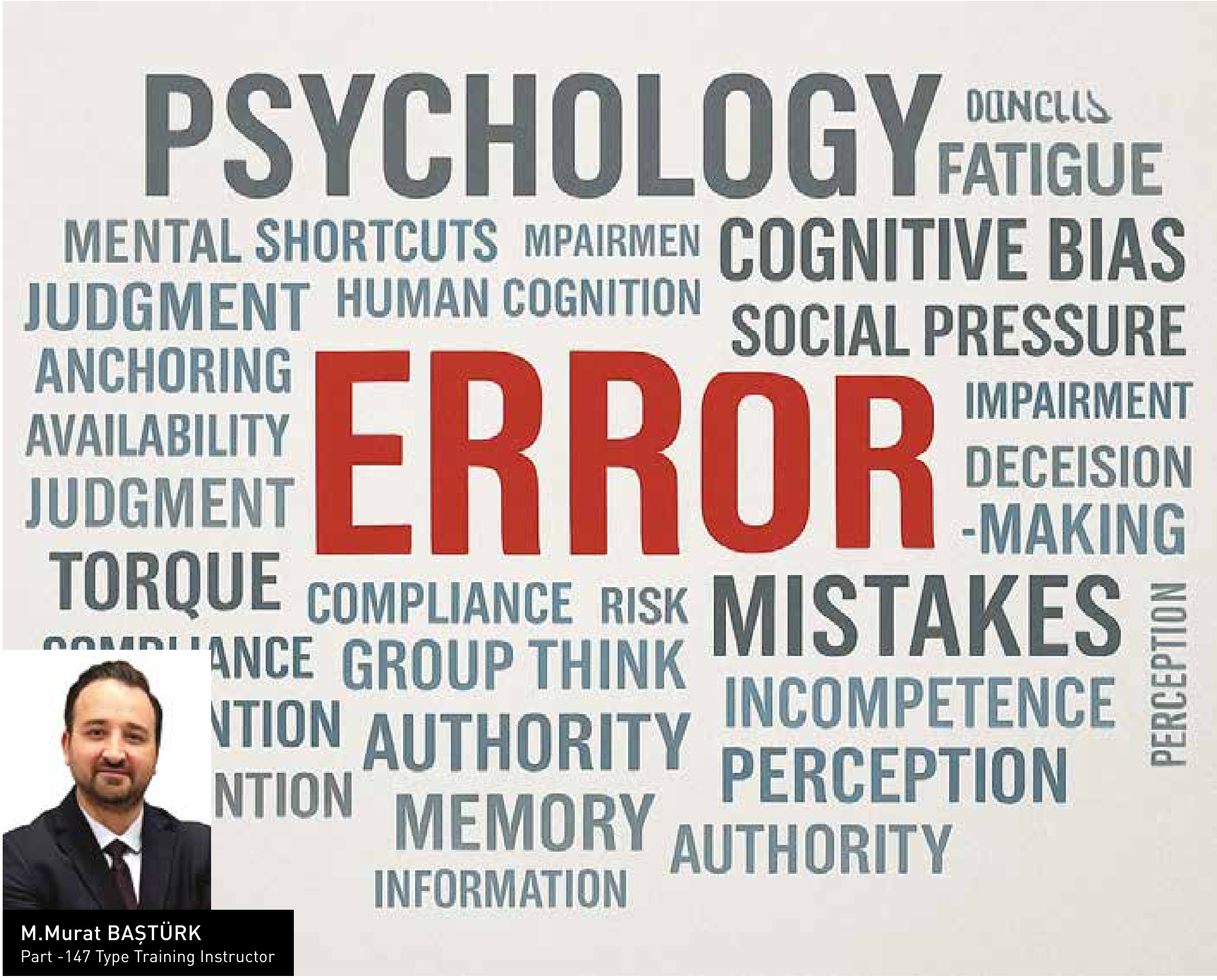
A Delta Airlines aircraft was forced to make an emergency landing due to severe turbulence. According to reports, the Delta Airbus A330, which was operating a scheduled flight from Salt Lake City to Amsterdam, encountered intense turbulence shortly after takeoff. The unexpected and violent shaking caused significant distress onboard, prompting the flight crew to make the critical decision to divert and perform an emergency landing in Minneapolis. Emergency medical teams were on standby upon arrival, and it was confirmed that 25 passengers who sustained injuries during the turbulence were transported to nearby hospitals for treatment.Thankfully, none of the injuries are reported to be life-threatening.

Tragedy at Southend: Four Killed in Beechcraft B200 Crash

A Beechcraft B200 Super King Air operated by Dutch aviation company Zeusch Aviation crashed shortly after takeoff from London Southend Airport on Sunday evening, killing all four people on board. The aircraft burst into flames upon impact, leaving behind a scene of devastation and raising urgent questions about what went wrong. The 23-meter (39-foot) twin-turboprop plane had flown earlier that day from Athens, Greece, to Pula, Croatia, before continuing on to Southend. It was scheduled to return to its home base in Lelystad, the Netherlands, later that evening. Essex Police confirmed that none of the victims were British nationals and that efforts are ongoing to formally identify the deceased. The identities of those on board have not yet been released. Eyewitness John Johnson, 40, from Billericay, Essex, was at the airport with his wife and children, watching planes take off and land, when he saw the accident unfold. "The plane went headfirst into the ground, and there was an enormous fireball," he recounted. "It was absolutely horrifying." Emergency services responded swiftly to the crash site, but there were no survivors. Investigators from the Air Accidents Investigation Branch (AAIB) have launched a full inquiry to determine the cause of the crash.

Powering Global Readiness: GE Aerospace and UAG Join Forces to Expand CT7/T700 Support

GE Aerospace has signed a limited-time agreement with United Aero Group (UAG) to authorize the distribution of CT7/T700 engine parts and spares. This partnership aims to expand GE's aftermarket reach to regions not currently covered by existing agreements. Elissa Lee of GE Aerospace emphasized the importance of ensuring availability of OEM-backed parts to support safety and performance. UAG CEO Jamie Gelder highlighted that the deal strengthens UAG's role in serving the global CT7/T700 operator base with a strong focus on quality and operational readiness.



M.Murat BAŞTÜRK
Part -147 Type Training Instructor

THE PSYCHOLOGY OF ERROR: WHY EVEN THE BEST TECHNICIANS MAKE MISTAKES

Despite the aviation industry's unwavering commitment to the "zero defects" standard, maintenance errors remain a persistent challenge. This article argues that the root cause often lies not in technical incompetence, but in the inherent limitations of human psychology.

By examining the roles of cognitive biases, mental fatigue, and social pressures, we can move beyond a culture of blame and build more robust, human-centric defenses. This paper provides a practical framework for technicians and organizations to understand and mitigate these psychological traps, transforming vulnerability into a cornerstone of safety.

Understanding the Types of Human Error

Before delving into the psychological triggers, it is essential to understand the fundamental categories of human error. Classifying these errors helps in diagnosing their root causes and developing targeted mitigation strategies. Drawing on the work of pioneers like Professor James Reason, we can categorize errors into three primary types:

1. Skill-Based Errors: The "Autopilot" Mistake

These errors occur during highly routine and practiced tasks that require little conscious thought. The technician's skill is solid, but their mind is not fully engaged with the task at hand. Performance becomes automatic, making it vulnerable to lapses in attention and slips in execution.

- **Example:** A technician, having performed countless landing gear inspections, might visually confirm a bolt is safety-wired but fail to notice the wire is loose because their attention was momentarily diverted by a noise in the hangar. Their hands performed the task, but their mind was elsewhere.
- **Common Causes:** Distractions, interruptions, fatigue, and complacency.

2. Rule-Based Errors: The Misapplied Solution

These errors happen when a known procedure or rule is incorrectly applied. The technician correctly identifies the problem but chooses the wrong rule to fix it, often due to a misinterpretation of the situation or reliance on an outdated or imperfect mental model.

- Example: An avionics technician troubleshooting a recurring instrument display fault might apply a troubleshooting rule from an older aircraft model, not realizing the new system has a updated diagnostic procedure. The action was logical but based on an incorrect rule.
- Common Causes: Inadequate or ambiguous procedures, insufficient training on updates, and over-reliance on past experience.

3. Knowledge-Based Errors: The Uncharted Territory

These errors occur in novel or unfamiliar situations where the technician lacks the requisite knowledge or experience. Forced to solve a problem without a pre-existing rule or procedure, they must rely on reasoning and problem-solving, which can lead to mistakes if their mental model is flawed.

- **Example:** A team encountering a complex, intermittent fault never before seen in their fleet might misdiagnose it based on incomplete information, leading to the replacement of a perfectly good component. The error stems from a gap in knowledge, not a lack of skill.
- **Common Causes:** Unprecedented failures, lack of access to technical expertise, time pressure to resolve novel issues.

This typology is not about assigning blame but about understanding the mechanism behind the error. A single maintenance action can involve all three types: a knowledge-based guess on a novel problem, leading to a rule-based decision to apply a certain manual procedure, which then suffers a skill-based slip during its execution. By clearly identifying which type of error we are most vulnerable to in a given situation, we can deploy the most effective defenses, from enhanced checklists to combat slips, to improved documentation to prevent rule-based mistakes, and better knowledge management systems to support decision-making in the face of the unknown.

The Paradox of Perfection

Aircraft maintenance is a discipline built on an uncompromising pursuit of perfection. Every procedure, checklist, and certification is designed to ensure the absolute airworthiness of every aircraft. Yet, within this world of rigorous standards, errors occur. How is it that highly experienced, certified, and conscientious technicians can occasionally overlook a safety wire, misapply a torque value, or miss a critical step in a manual?

The answer is rarely a simple lack of skill or knowledge. Instead, it frequently lies in the complex and often invisible workings of the human mind. The very mental processes that make us efficient and expert can also, under the right conditions, lead us astray. Understanding the psychology behind error is not about assigning blame; it is the first and most crucial step in building a smarter, more resilient safety culture. This article explores the cognitive, physiological, and social factors that contribute to maintenance errors and offers a practical action plan for mitigation.

The Unseen Adversary: Cognitive Biases

Our brains are remarkable pattern-recognition machines. To navigate a complex world, they develop mental shortcuts known as heuristics. While generally helpful, these shortcuts can introduce systematic and predictable errors in judgment—especially in high-stakes, technical environments.

- Confirmation Bias: This is the tendency to search for, interpret, and recall information in a way that confirms one's pre-existing beliefs or hypotheses. A technician might quickly latch onto a familiar fault—"It's always the #2 sensor"—and unconsciously prioritize evidence that supports this theory while disregarding clues that point to a different, less obvious component.
- Availability Bias: We tend to overestimate the likelihood of events based on how easily examples come to mind. If a technician spent hours the previous week troubleshooting a specific avionics fault, a similar-but distinct-set of symptoms the following week might be automatically attributed to the same cause, potentially leading to a misdiagnosis.
- Anchoring Bias: The first piece of information we receive (the "anchor") disproportionately influences our subsequent decisions. During a shift handover, a comment like "I think the issue is in the hydraulic pump" can anchor the next technician's investigation, narrowing their focus and causing them to overlook evidence pointing elsewhere.
- Overconfidence Bias: With deep experience and expertise can come a dangerous sense of familiarity. A task performed hundreds of times can feel routine, leading to the temptation to rely on memory rather than the manual, or to skip a step in a checklist. This bias whispers, "I've got this," when the situation demands, "I must verify this."

The Depleted Mind: The Insidious Role of Fatigue

Fatigue is far more than feeling tired; it is a physiological state that impairs cognitive function as significantly as alcohol intoxication. Shift work, long hours, circadian rhythm disruption, and high mental workload all contribute to a depleted mental state.

The effects are multifaceted and dangerous:

- Impaired Attention and Memory: Focus drifts, making it difficult to sustain concentration on complex tasks. Short-term memory suffers, increasing the likelihood of forgetting a step or losing track of a procedure.
- Reduced Situational Awareness: The brain's ability to process multiple streams of information diminishes. Technicians may miss subtle auditory, visual, or tactile cues that are critical for diagnosis and task completion.
- Compromised Decision-Making: Judgment becomes impaired, increasing risk tolerance. The margin for "good enough" may widen under the pressure of fatigue and the desire to get the job done.

- **"Expectation See":** Fatigue narrows perception. Technicians are more likely to see what they expect to see rather than what is actually there, a phenomenon that can cause them to miss a crack, a loose connection, or an installed-but-not-safetyed component.

Mitigating fatigue requires a shared responsibility. Technicians must learn to recognize their own personal warning signs and feel empowered to speak up. Organizations must foster a culture that prioritizes rest, designs humane shift schedules, and views fatigue reports as critical safety data, not complaints.

The Silent Pressure: Social and Operational Dynamics

Human decision-making is not made in a vacuum. It is profoundly influenced by the social and operational environment.

- **Obedience to Authority:** A natural respect for seniority and expertise can sometimes prevent junior technicians from questioning a superior's incorrect assessment. The thought, "They must know better than I do," can override a valid concern.
- **Groupthink:** The desire for harmony or conformity within a team can result in an irrational or dysfunctional decision-making outcome. Individuals may self-censor, withholding dissenting opinions to avoid conflict, leading to a collective oversight.
- **Production Pressure:** The constant tension between the imperative of safety and the pressure to return an aircraft to service on time is a powerful force. This can create an environment where procedural steps are rushed, double-checks are seen as a luxury, and the "get-it-done" mindset overrides the "get-it-right" mindset.

Combating these pressures requires building a culture of psychological safety—an environment where every team member feels safe to speak up, ask questions, and express concerns without fear of reprisal or embarrassment.

Fortifying Our Defenses: A Practical Action Plan

Understanding these psychological traps is only valuable if we translate that knowledge into action. Here is a multi-layered defense strategy:

1. **Embrace Checklists as a Cognitive Shield:** Reframe the checklist from a simple task list to a vital error-capturing tool. It is a backup system for the brain, designed to catch slips and lapses before they become events. Use them rigorously, every time.
2. **Practice the "Stop-Think-Act" Protocol:** When faced with an ambiguity, an interruption, or a feeling of uncertainty, consciously pause. Take a moment to breathe, assess the situation, and mentally rehearse the next steps. This brief pause can break the chain of error.
3. **Normalize Peer Verification:** Formalize the practice of requesting a second set of eyes. This should be standard procedure for critical tasks, not an admission of doubt. A fresh perspective is one of the most effective error-catching tools available.
4. **Champion Transparent Reporting:** A robust Just Culture is essential. Technicians must be able to report errors and near-misses without fear of punitive action, provided their actions were not reckless. These reports are not for blame; they are the lifeblood of organizational learning, providing the data needed to improve processes and prevent future errors.
5. **Promote Self-Awareness and Training:** Integrate human factors training into all levels of maintenance education. When technicians understand why errors happen, they are better equipped to recognize the risks in real-time and take corrective action.

Not Perfect, But Resilient

The goal of aviation maintenance is not to create perfect humans who never error impossible standard. Instead, the goal is to create resilient systems and cultures that understand human fallibility and are designed to catch and mitigate errors before they can compound into incidents.

The best technicians are not those who never make a mistake, but those who possess the humility to understand the limits of their own cognition, the vigilance to guard against those limits, and the courage to speak up for safety. By acknowledging our shared vulnerability to biases, fatigue, and pressure, we stop pretending to be perfect and start building a system that is truly, intelligently, and profoundly safe. In the end, our greatest strength lies in our willingness to admit that we are human.

Deniz GÜNALTAY
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THREAT AND ERROR MANAGEMENT SYSTEM

The Threat and Error Management (TEM) system is a proactive and highly effective safety framework used in aviation to manage human performance and reduce the risk of accidents. It fundamentally shifts the focus from a traditional, reactive approach that often assigns blame to a proactive, systemic one that recognizes threats and errors are an inherent part of complex operations. By understanding the relationship between threats, errors, and undesired states, flight crews can apply countermeasures to maintain a high level of operational safety.

The TEM framework begins with threats. In aviation, threats are external events or conditions that are outside the crew's control but have the potential to increase the operational complexity of a flight. These can be environmental, such as bad weather or a malfunctioning navigation aid, or organizational, like time pressure or a last-minute runway change from air traffic control. The core principle of TEM is that threats are unavoidable and must be anticipated and managed. The goal is not to eliminate them but to prepare for them so they don't lead to a series of errors.

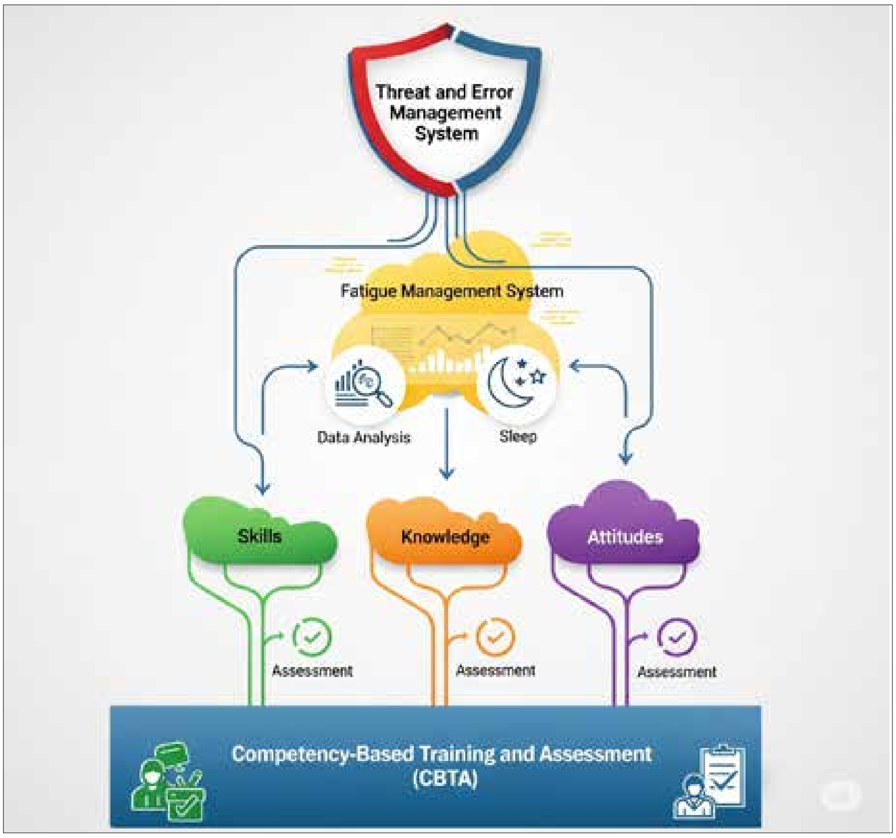
The second component of the TEM model is error. An error is an action or inaction by the flight crew that leads to a deviation from the crew's intentions or expected operational standards. For example, a flight crew might input incorrect data into the flight management system, use a wrong frequency, or miss a step on a checklist. Unlike threats, errors are a direct result of human performance. The TEM framework recognizes that errors are a natural and inevitable part of the human-machine interface. The key is not to view them as a failure of the individual but as an opportunity for the system to detect and correct itself.

When threats and errors are not effectively managed, they can lead to an undesired aircraft state (UAS). A UAS is a deviation from a safe flight path or established operational parameters. Examples include an unstabilized approach, flying at an incorrect altitude, or an aircraft's speed becoming too low. An undesired state significantly increases the risk of an incident or accident. The ultimate objective of TEM is to prevent threats and errors from culminating in a UAS. To achieve this, flight crews continuously employ countermeasures, which are the skills and procedures used to detect and recover from threats and errors. These include communication between crew members, adherence to standard operating procedures, use of checklists, and effective crew resource management (CRM).

Threat and Error Management System (TEM) provides a critical lens for understanding and improving aviation safety. It moves beyond a simplistic view of human fallibility to a more sophisticated model that accounts for the complex interplay between environmental factors, human actions, and system safeguards. By equipping flight crews with the tools to proactively identify and manage threats and errors, TEM has become an essential part of modern aviation, contributing significantly to the industry's remarkable safety record.

THREAT AND ERROR MANAGEMENT FRAMEWORK IN AIRCRAFT MAINTENANCE

The Threat and Error Management (TEM) framework is a crucial safety model in aircraft maintenance, a domain where human factors can directly influence the airworthiness of an aircraft. Unlike the flight deck, where TEM is used to manage in-flight risks, its application in maintenance focuses on ensuring the integrity and safety of the aircraft on the ground. The model helps maintenance crews understand how external threats can lead to internal errors, which, if unmanaged, can result in an undesired state—a condition that could compromise flight safety.



Threats in the Maintenance Environment

In the maintenance context, threats are external conditions or events that can increase operational complexity and raise the likelihood of errors. These threats are often beyond aircraft maintenance technician's immediate control and must be anticipated and managed. Examples include:

- Environmental threats: Poor lighting, extreme temperatures, or excessive noise in the hangar.
- Organizational threats: Time pressure to meet a strict turnaround time, inadequate staffing, or a shortage of specific tools and parts.
- Interpersonal threats: Communication barriers between shifts, or distractions from other teams working on the same aircraft.

A key principle of TEM is that these threats are a normal part of the maintenance environment. The goal is not to eliminate them but to develop a proactive mindset to identify and mitigate them before they lead to an error.

Errors and Their Consequences

An error in aircraft maintenance is a deviation from the intended action or procedure. These are not considered a failure of a technician's skill but rather a natural part of human performance. Common maintenance errors include:

- Procedural errors: Skipping a step in a maintenance manual or performing a task without following the correct checklist.
- Installation errors: Incorrectly connecting a component, mis-torquing a bolt, or installing a part backward.

- Documentation errors: Failing to properly sign off on a completed task or making an incorrect entry in the logbook.

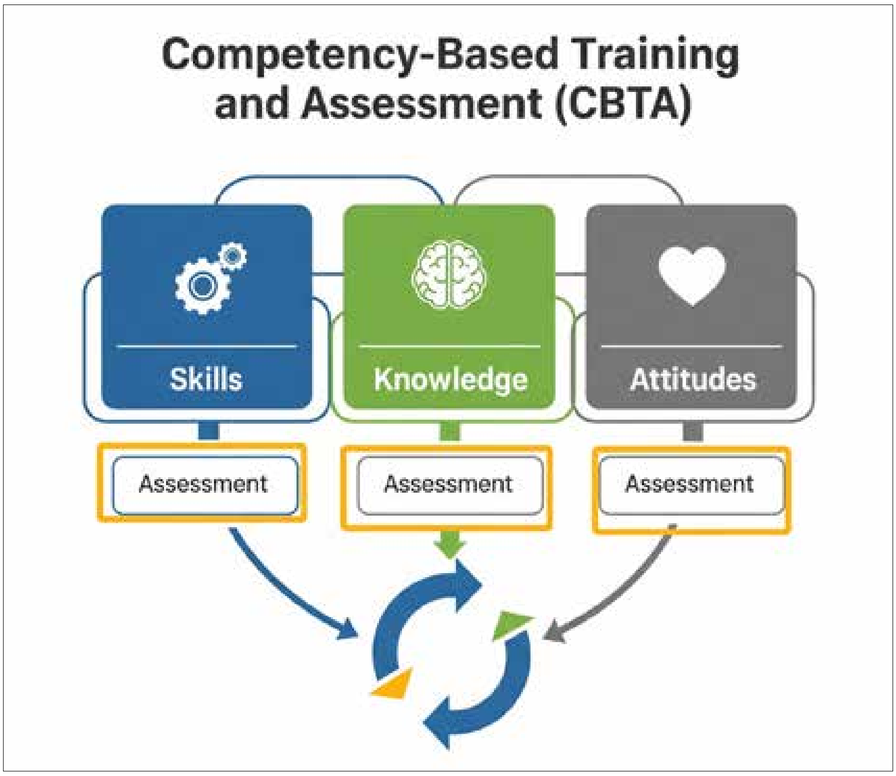
The TEM framework recognizes that errors will occur, and its focus is on creating a system where these errors can be caught and corrected before they lead to an incident.

Preventing Undesired States
An undesired state in aircraft maintenance is the direct result of an unmanaged threat or error. It is a condition where the aircraft is not in an airworthy state when released for flight. Examples include an unfastened component, a tool or Foreign Object Damage (FOD) left in an aircraft compartment, or a critical system that was not reconnected after maintenance. Such states pose a direct threat to flight safety.

The primary objective of TEM for maintenance crews is to prevent the transition from a threat or error to an undesired state. This is achieved through the use of countermeasures—the actions and procedures used to mitigate risk. These include:

- Effective checklists and procedures: Adherence to detailed work cards and quality assurance checks.
- Peer-to-peer verification: Having a second technician inspect and sign off on critical work.
- Human factors training: Awareness of personal limitations such as fatigue and stress.
- Clear communication: Using concise language and read-backs to prevent misunderstandings.
- "Stop-the-job" authority: Empowering any technician to halt work if a safety issue is identified.

By actively applying these countermeasures, maintenance crews can interrupt the chain of events that could lead to a serious incident.



In conclusion, the Threat and Error Management system offers a powerful, proactive approach to safety in aviation maintenance. It provides a framework for technicians to not only recognize the human element in their work but also to develop a resilient system of checks and balances that anticipates and manages threats and errors, ultimately ensuring the airworthiness and safety of the aircraft.

TEM AND CBTA RELATIONSHIP
Threat and Error Management (TEM) system is closely related to Competency-Based Training and Assessment (CBTA). They are not the same thing, but they are a perfect example of a symbiotic relationship in aviation safety.

- TEM is a conceptual framework. It defines what skills and behaviors are necessary for safe operations. TEM outlines that air crews and aircraft maintenance technicians must be competent in identifying and managing threats, mitigating errors, and preventing undesired states.
- CBTA is a training methodology. It defines how those necessary skills and behaviors are developed and evaluated. CBTA structures training around observable competencies, ensuring that personnel are not just taught information, but can also demonstrate the practical application of their knowledge in real-world scenarios.

Essentially, CBTA uses the TEM framework as a foundational element of its curriculum. A CBTA program for pilots, for example, would have a specific competency area dedicated to "Threat and Error Management." The training would then focus on developing and assessing the pilot's ability to apply TEM principles in a variety of situations, such as handling an unexpected equipment malfunction or communicating under pressure.

Therefore, while TEM provides the safety model for effective human performance, CBTA provides the educational and assessment system to ensure that personnel are fully proficient in that model. The two work together to shift aviation training from a focus on simply checking boxes to a focus on demonstrable, on-the-job competency.

TEM AND FRMS RELATIONSHIP

There is a very direct and important connection between the two systems. A Fatigue Risk Management System (FRMS) is a specialized and highly focused component of the broader Threat and Error Management (TEM) framework.

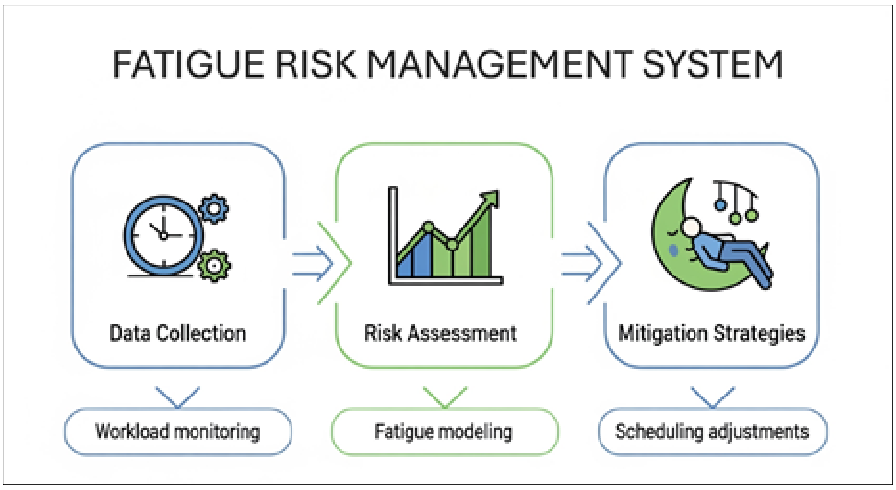
The relationship can be understood as follows:

- **Fatigue as a Threat:** Within the TEM model, fatigue is considered a significant internal threat. A fatigued individual, whether a pilot, an aircraft maintenance technician, or an air traffic controller, is at a higher risk of making errors due to reduced alertness, impaired judgment, and slower reaction times. This is a condition that must be actively managed to prevent it from leading to an incident.
- **FRMS as a Countermeasure:** The FRMS itself is the primary countermeasure designed to manage the specific threat of fatigue. It's a comprehensive, data-driven system with policies, procedures, and training all aimed at mitigating the risks associated with fatigue. It helps identify when fatigue is a factor and provides the tools and strategies to manage it, such as flexible scheduling, monitoring of duty times, and encouraging proper rest.

In short, while TEM provides the overall safety umbrella by managing all types of threats and errors, FRMS is a specific, robust tool that handles one of the most critical and common human-factors threats: fatigue.

Here is a more detailed breakdown of the connection between the Threat and Error Management (TEM) system and a Fatigue Risk Management System (FRMS).

The most important concept to understand is that FRMS is a specialized, detailed layer of the broader TEM framework.



TEM provides the overall safety philosophy, while FRMS provides the specific tools to manage one of the most critical human-factors threats: fatigue.

Here is a step-by-step breakdown of how they are connected:

1. Fatigue as a Threat in the TEM Framework

In the TEM model, a threat is an external or internal condition that increases operational risk. Fatigue is an excellent example of an internal threat. It is a physiological state that, when unmanaged, significantly increases the likelihood of a human error.

- How Fatigue Works as a Threat: Fatigue doesn't just make a person tired; it impairs cognitive function. A fatigued crew member or aircraft maintenance technician is more susceptible to:
  - Reduced Situational Awareness: The ability to perceive and comprehend what is happening is degraded. A fatigued pilot might not notice a change in the weather forecast or an incorrect instrument reading.
  - Slowed Reaction Time: A fatigued technician may take longer to recognize a tool left in a compartment or to respond to an urgent issue.
  - Poor Decision-Making: Fatigue can lead to "go/no-go" decisions based on flawed judgment, such as deciding to push a schedule despite feeling unwell.
  - Memory Lapses: It becomes easier to forget a critical step in a checklist or a key piece of information from a briefing.

Because fatigue so directly affects the human element, it is recognized as a profound threat that, if left unchecked, will inevitably lead to an error.

2. The FRMS as a Proactive Countermeasure

This is where the FRMS comes into play. It is the sophisticated countermeasure specifically designed to manage the threat of fatigue. Instead of simply reacting to a tired crew member, an FRMS uses a proactive, scientific approach to prevent fatigue from becoming a threat in the first place.

An effective FRMS includes a variety of countermeasures, such as:

- Predictive Scheduling: Instead of just setting legal duty limits, an FRMS uses bio-mathematical models to predict crew member alertness based on factors like flight schedules, time zones, and known sleep cycles. This allows airlines to design rosters that minimize the risk of cumulative fatigue.
- Education and Training: All personnel receive detailed training on the causes of fatigue,

its symptoms, and effective personal strategies for managing it (e.g., proper sleep hygiene, nutrition).

- Safety Reporting System: An FRMS creates a non-punitive culture where crew members can report feeling fatigued or can report a fatigue-related event without fear of reprisal. This data is critical for identifying high-risk schedules or operations.
- Voluntary Reporting: The system encourages a "go/no-go" decision, where a crew member can declare themselves unfit for duty due to fatigue. This is the ultimate TEM countermeasure, as it prevents the fatigued individual from engaging in operations.

3. The Consequence: Preventing Undesired States

The ultimate goal of both TEM and FRMS is to prevent an undesired state, which is a condition that directly compromises safety.

- Unmanaged Fatigue (Threat) Leads to a Procedural Error (e.g., missing a checklist item) Results in an Undesired State (e.g., flying with a system in an incorrect configuration) Which can lead to an Incident or Accident.
- FRMS (Countermeasure) Manages the Threat of fatigue Prevents the Error from occurring in the first place Maintains a Safe and Desired State of operation.

In summary, the FRMS is a core pillar of a robust TEM system. It takes one of the most common and dangerous threats—human fatigue—and provides a data-driven, systematic set of countermeasures to manage it, thereby directly supporting the overall goal of keeping operations safe.

CBTA provides the educational framework to train and assess the necessary skills.

FRMS provides a specific, data-driven system to manage the threat of fatigue.

TEM is the overarching operational philosophy that allows the crew to recognize and manage the specific fatigue threat and any resulting errors in real-time.

Together, they form a cohesive and highly effective safety ecosystem.

Of course. Here is a detailed example tailored to an aircraft maintenance technician, showing how CBTA, FRMS, and TEM work together in their day-to-day operations:

An AOG (Aircraft on Ground) Maintenance Scenario

Imagine an aircraft maintenance technician (AMT) who is part of a night shift team. A critical flight is scheduled for early the next morning, but the aircraft has an unexpected mechanical issue, putting it in an Aircraft on Ground (AOG) status. The pressure is on to fix it.

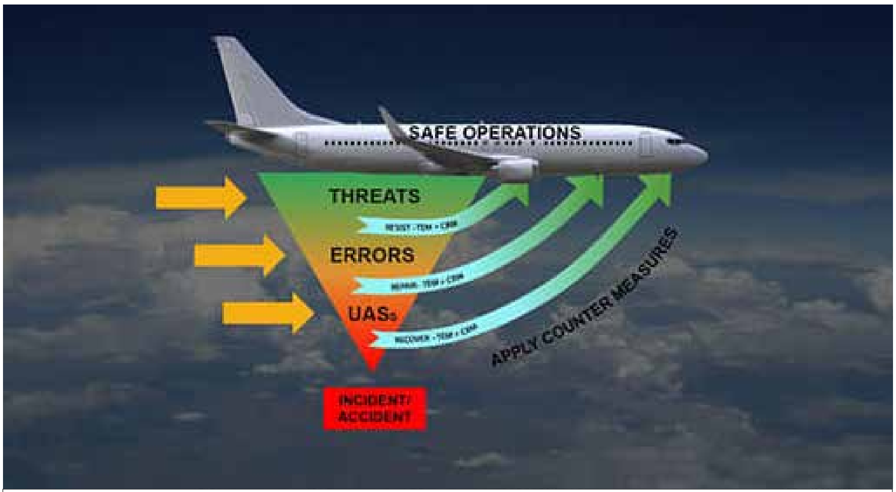
1. The Role of CBTA: Building the Foundation

AMT's initial training and ongoing professional development are structured around a Competency-Based Training and Assessment (CBTA) program. This training goes beyond just teaching him how to install an engine; it focuses on developing key competencies. A significant part of his CBTA curriculum is dedicated to human factors, specifically TEM and FRMS.

- FRMS Competency: AMT was trained to understand the physiological effects of working at night, recognize the signs of fatigue (a threat), and use personal countermeasures like strategic breaks and proper nutrition.
- TEM Competency: AMT was also trained on other TEM skills critical for maintenance, such as meticulous use of checklists, tool control, and the importance of a peer-to-peer verification check on critical tasks.

2. The Role of FRMS and TEM: Managing the Real-World Threat
On this particular night, AMT is feeling the pressure from the AOG status. The late hour and the urgency create a dual threat: fatigue and time pressure.

- FRMS in Action (Proactive): The maintenance facility's FRMS has already implemented safeguards. It's not a culture of "work until the job is done," but one of smart scheduling. The system ensures mandatory rest periods and discourages excessive overtime to prevent technicians from becoming dangerously fatigued.
- **TEM in Action (Dynamic):** Despite the FRMS, AMT feels its concentration wavering as he or she works on the complex repair. AMT recognizes this as a sign of fatigue—a threat to his or her work quality.
- **Applying Countermeasures:** Instead of pushing through, AMT applies a key TEM countermeasure AMT learned in training: AMT takes a brief, self-declared break to get a drink and reset focus.
- **Managing Errors:** Later, as AMT is re-installing a critical component, AMT's fatigue causes a momentary lapse. AMT almost forgets to apply the correct torque to a bolt. However, due to TEM training, the maintenance team has a protocol in place: a required peer-to-peer verification. A colleague cross-checks AMT's work and spots the untightened bolt. The error is caught and corrected immediately.



3. The Result: Avoiding an Undesired State
Because the threat of fatigue was actively managed by AMT's personal use of FRMS principles and the subsequent error was caught by the TEM countermeasure of a peer-check, a potentially catastrophic undesired state (an aircraft being released with a critical mechanical defect) is avoided.

The aircraft is ready for its morning flight, safe and airworthy, proving that CBTA builds the competence, FRMS manages a specific threat, and TEM provides the overarching framework to ensure that human factors are managed effectively in the maintenance environment.

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TECHNICIAN 4.0:

THE FUTURE OF AVIATION MAINTENANCE PROFESSIONS IN THE INDUSTRY 4.0 ERA

In aviation, maintenance technicians are evolving beyond the traditional screwdriver, transforming into digitally skilled "Technician 4.0" profiles. This transformation spans from augmented reality to big data, from remote support systems to cybersecurity, representing not just a technological shift but also a human-centered mindset change. Digitized maintenance processes are building a new aviation culture by placing the human factor at the core.

FROM CLASSIC TOOLBOX TO DIGITAL GLASSES

The routines of a technician starting the morning shift in the hangar are rapidly evolving. Equipped with a digital tablet, augmented reality (AR) glasses, and a device enabling real-time data connection, the technician of today no longer relies solely on listening to engine sounds for fault detection. Instead, the "Technician 4.0" analyzes engine data to make informed decisions. Industry 4.0 represents the integration of physical systems with digital technologies such as IoT, artificial intelligence (AI), big data, AR, and cloud computing into aviation maintenance processes. Passenger aircraft generate terabytes of data on every flight, placing aviation at the core of this transformation.

THE TRANSFORMATION OF A PROFESSION: AIRCRAFT MAINTENANCE TECHNICIANS

Aircraft maintenance has evolved from a profession rooted in mechanical knowledge and hands-on experience to a hybrid role requiring digital literacy, data analysis skills, the use of remote maintenance systems, and the application of AR-supported instructions. The traditional screwdriver has been supplemented—if not replaced—by software-based diagnostic tools, mobile maintenance applications, and digital maintenance logs. Today's technicians must be proficient with digital interfaces, capable of interpreting big data, adept at receiving remote support, and aware of cybersecurity risks.

THE DIGITAL REVOLUTION IN THE HANGAR

Modern hangars have embraced e-logbook systems, AR glasses, sensor-supported predictive maintenance, drone inspections for external airframe surveys, and mobile data collection systems. These technologies accelerate maintenance workflows while simultaneously elevating the technician's role to one demanding more complex and cognitive competencies.

A REAL-LIFE EXAMPLE: DATA-DRIVEN FAULT DETECTION ON THE A320 NEO

An Airbus A320 NEO departing from Istanbul experienced a slight vibration in the left engine. Sensors detected the anomaly and issued a "T+40 hours preventive maintenance" recommendation. The aircraft continued its scheduled operations, and during planned maintenance, a microscopic crack was found on a fan blade. The success behind this outcome was a "Technician 4.0" skilled in interpreting and analyzing data.

NEW GENERATION SKILLS: WHAT SHOULD A TECHNICIAN KNOW?

Digital Literacy: Access to maintenance systems, data entry, and proficiency in tablets and mobile devices are mandatory.

Basic Programming and Code Reading: Understanding software-related faults and debugging simple code structures are essential.

Big Data and Analytical Reading: Recognizing anomalies in data and playing an active role in predictive maintenance.

Cybersecurity Awareness: Knowledge of software security, password protection, and unauthorized access risks.

Working with Remote Support Systems: Ability to receive remote engineering assistance via AR and live video streaming.

DIGITAL INTERACTION BETWEEN PILOT AND TECHNICIAN

Historically, fault reporting began with verbal communication from the pilot to the maintenance team. Today, integrated digital systems instantly relay error codes, timestamps, and contextual data directly to the technician. This advancement reduces time loss, improves fault diagnosis accuracy, and expedites spare parts procurement.

Technician 4.0: Aircraft maintenance is no longer just about mechanical skills; it now requires digital literacy and data analysis. Screwdrivers have been replaced by tablets, AR glasses, and digital maintenance systems. With Industry 4.0, technicians have evolved into a hybrid role, combining physical and digital skills as they work with IoT, artificial intelligence, big data, and cloud-based processes.

THE RISK FOR THOSE UNABLE TO ADAPT

While digitalization offers clear benefits, it also presents challenges:

Technicians unable to adapt to new technologies risk job insecurity.

Educational infrastructure largely remains traditional, lacking sufficient digital skill training.

Younger technicians tend to be more digitally fluent, while senior staff may struggle to keep pace.

Hence, up-to-date and comprehensive training programs must be developed collaboratively by educational institutions, industry associations, and regulatory bodies.

RETHINKING EDUCATION AND CERTIFICATION

Digital training enriched with AR and VR simulations should be expanded.

AI-supported maintenance scenarios should be incorporated.

Regulatory authorities such as EASA and FAA need to integrate digital competencies into certification standards.

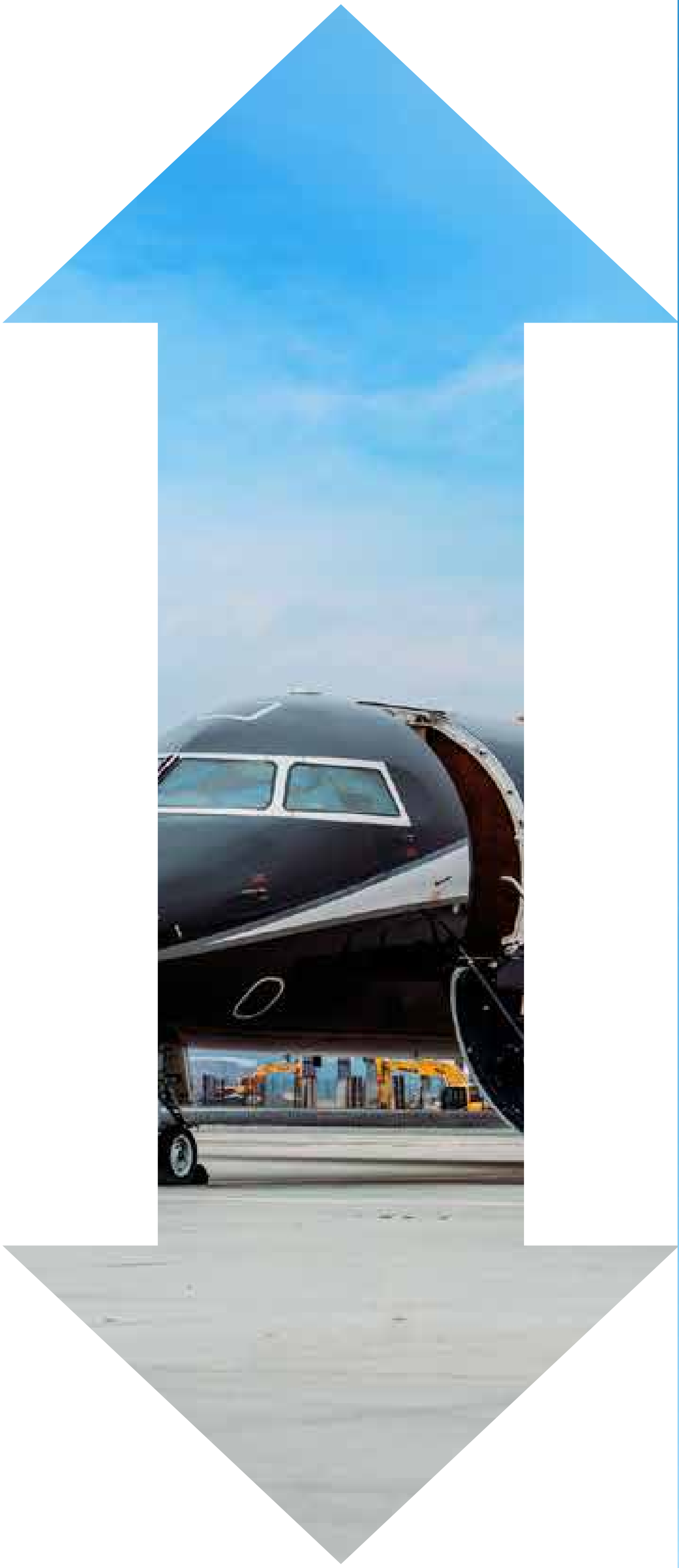
Organizations like UTED should offer continuous professional and digital development programs.

A DIGITAL FUTURE CENTERED ON THE HUMAN FACTOR

As aviation technology becomes increasingly complex, the safe operation of aircraft remains fundamentally reliant on human expertise. Machines can collect data and issue early warnings, but effective intervention and decision-making depend on skilled human technicians. The "Technician 4.0" concept embodies a new maintenance culture that integrates technology with human intellect and experience. This culture not only uses technology but understands it and places the human element at the center of operations. Digitalization transforms the technician's role from a passive data entry operator to an active decision-maker.

Although aircraft and systems evolve, the essential role of the human factor in maintenance endures. Therefore, alongside technological advancements, continuous investment in workforce training, motivation, and psychological resilience is critical. Educational institutions, professional associations, and regulatory bodies must develop modern training models that maintain technicians' technical and digital competencies without neglecting human-centered approaches.

In conclusion, the future of aviation maintenance is shaped by technology, yet sustainable safety is unattainable without knowledgeable and experienced human technicians. The "Technician 4.0" vision opens new horizons for aviation maintenance by harmonizing technology and human expertise.



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BETWEEN THE CONTROLLER'S LIPS, A CATASTROPHE WAITING TO HAPPEN

The expression ramak kala ('by a hair's breadth') is frequently used by safety investigators when examining incidents and accidents. The word ramak, borrowed from Arabic root rm , originally means 'the final sign of life before death, a glance.

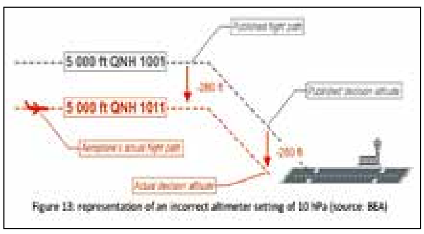
In Turkish, the well-known proverb "The grasshopper jumps once, twice…" points to the fact that if preventive action is not taken after escaping from serious accidents by a hair's breadth, eventually a catastrophic accident will occur. Near miss events are investigated, root causes identified, and corrective actions implemented to prevent recurrence.

The expression "weakest link" became famous when it was used as the title of a quiz show. The strength of a chain is equal only to the strength of its weakest link. This is indeed a very accurate description. When pulling or carrying a heavy load with a chain, it will always break at its weakest link.

One example of such a weak link can be found in the procedure "RNP Approach with Baro VNAV – down to LNAV/VNAV minima", which is one of the applications of Performance-Based Navigation (PBN). This is a very sophisticated system that enables passenger and cargo aircraft to conduct non-precision approaches at airports where the ILS system is unavailable, using GPS technology. Its lateral accuracy is ±0.3 NM — in other words, the aircraft can follow its intended course with a lateral error of only 0.3 NM.

While GPS technology allows for precise lateral tracking, another crucial safety issue is the accurate determination of the aircraft's vertical position. GPS-derived altitude can often be inaccurate. Instead, the aircraft's altimeter measures external atmospheric pressure to calculate altitude. During an RNP APCH approach, the airport control tower provides the QNH — the current local atmospheric pressure in millibars. The pilot manually enters this QNH into the aircraft's system. The aircraft then compares its altimeter reading with the QNH to calculate its precise height above ground level.

Unfortunately, the weak link in this system is that the QNH information is transmitted verbally by the controller and then manually entered into the aircraft system. A mere 10 millibar under-read by the controller would cause the aircraft to believe it was 280 feet higher than it actually was.



Representation of a 10 hPa Altimeter Setting Error

On 23 May 2022 at 13:40, an Airbus A320 aircraft, registration 9H-EMU, operated by Airhub Airlines of Malta, was approaching Paris Charles de Gaulle Airport (CDG). As the ILS system for the intended runway was unavailable, the crew elected to perform an "RNP Approach with Baro VNAV – down to LNAV/VNAV minima." The aircraft, arriving from Stockholm, carried 172 passengers, 2 pilots, and 4 cabin crew.

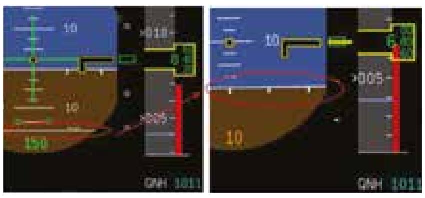
The French female ATC controller, when providing the QNH in English, gave an incorrect value of 1011 mbar instead of the correct 1001 mbar. The Malta pilots entered the erroneous value into the system. As a result, the aircraft believed itself to be 280 feet higher than it truly was.

The striking detail is that the same controller, around the same time, provided the correct value (1001 mbar) to two French aircraft in French, while only the Malta aircraft received the erroneous QNH in English.

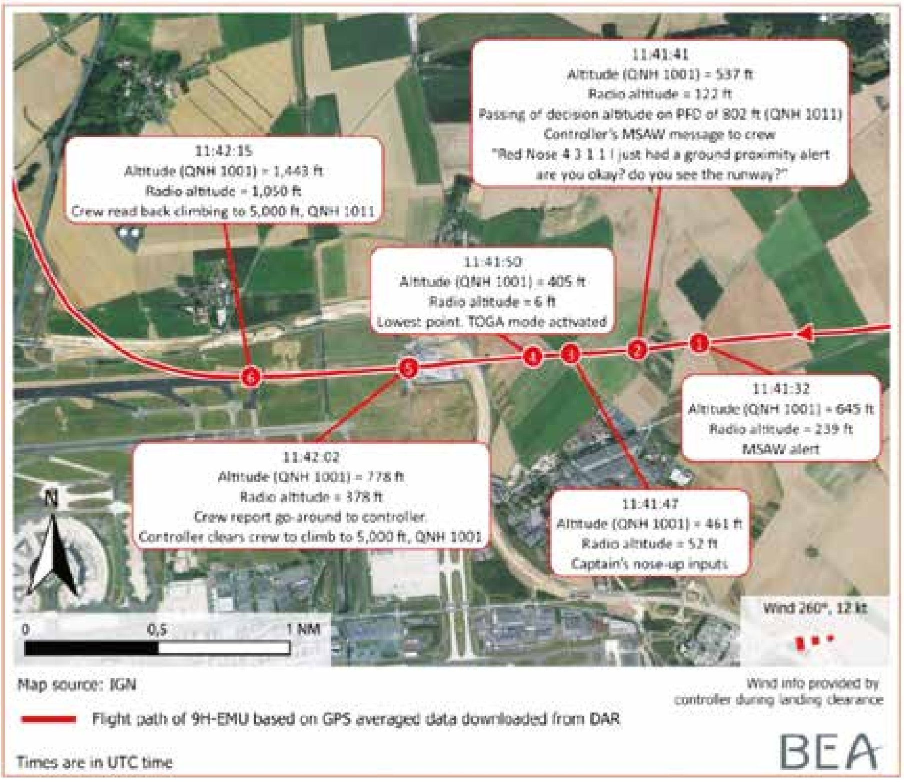
As the Malta A320 approached dangerously close to the ground, the pilots initiated a TOGA go-around 1.5 NM from the runway threshold, as they had no visual contact with the runway. The radio altimeter showed that the aircraft had been just 6 feet (less than 2 meters) above the ground at that moment.

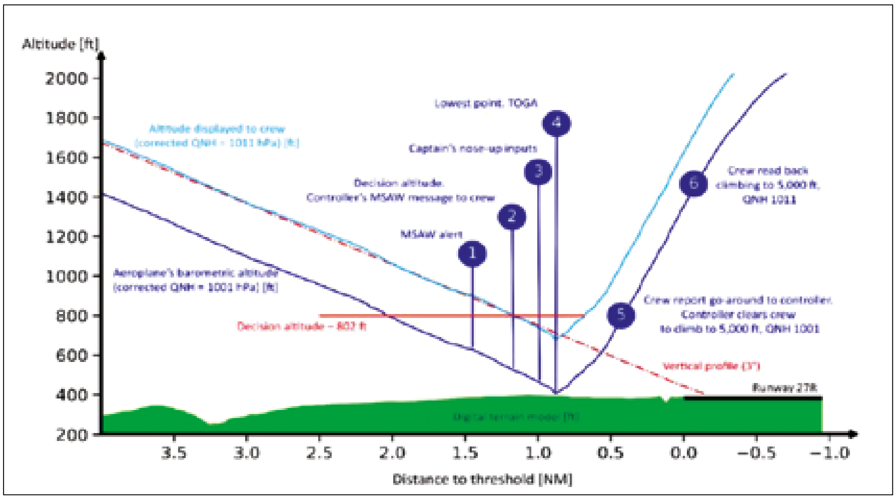
This incident narrowly avoided becoming a CFIT (Controlled Flight Into Terrain) accident — an accident in which an aircraft, under the control of the flight crew, is flown unintentionally into terrain. Such accidents often occur not due to technical failures, but because the pilot is unaware of the true position of the aircraft.

A well-known example of CFIT is the crash of World Focus Airlines' MD-88



Radio Altimeter Height Indication of 9H-EMU (Source: Airbus)





(registration TC-AKM), operating for Atlasjet on 30 November 2007, which struck a mountain near Keçiborlu, 18 kilometers from Isparta, Turkey.

Another significant point in the Malta A320 incident is that the Honeywell EGPWS (Enhanced Ground Proximity Warning System) on board did not issue the "TERRAIN AHEAD – PULL UP" warning. The French investigation authority BEA determined that this was not due to malfunction, but because the older-generation model installed on the aircraft was not designed to provide a warning in that specific situation. Later versions of Honeywell's EGPWS corrected this deficiency.

Tests using the ACSS T2CAS system's TAWS module under identical conditions successfully triggered the "TERRAIN AHEAD – PULL UP" alert. Unfortunately, it is estimated that around 1,600 Airbus and Boeing aircraft worldwide are still equipped with older-generation EGPWS units that will not issue such warnings under similar circumstances.

Replacing these units with newer models is not mandated, as the upgrade would be prohibitively expensive.

Source: BEA Investigation Report on Serious Incident – 9H-EMU, Malta Airbus A320 at Paris CDG, 23 May 2022

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Trainer -Anahtar Training

PSYCHOLOGICAL SAFETY: THE BEDROCK OF HIGH-RELIABILITY OPERATIONS IN AIRCRAFT MAINTENANCE

Psychological safety is not a luxury but a necessity in aircraft maintenance units operating as High-Reliability Organizations (HROs). It empowers Aircraft Maintenance Technicians (AMTs) to report errors, share concerns, and contribute their expertise without fear of blame. Core HRO principles—such as preoccupation with failure and deference to expertise—rely on a culture of open communication. Without psychological safety, organizations risk silence, hidden errors, and systemic failures. By embracing a Just Culture that balances accountability with trust, aviation maintenance units can foster continuous learning, operational excellence, and true airworthiness.

In our previous article, we explored the foundational concept of psychological safety among Aircraft Maintenance Technicians (AMTs), defining it as a team's shared belief in interpersonal risk-taking without negative consequences. We highlighted how this belief enables transparent reporting of errors and fosters collaboration, crucial elements in the safety-critical world of aviation maintenance. Building on that understanding, this piece delves into why psychological safety is not just beneficial, but an absolute necessity for organizations operating in the challenging framework of High-Reliability Organizations (HROs).

Aircraft Maintenance Units as High-Reliability Organizations (HROs)

Aircraft maintenance units, whether in-house airline operations or independent Maintenance, Repair, and Overhaul (MRO) companies, function within the demanding environment of High-Reliability Organizations. HROs are entities that consistently achieve near error-free performance despite operating in hazardous conditions where the consequences of mistakes could be catastrophic. In aviation maintenance, where precision and collaboration are paramount for systemic reliability, the stakes are undeniably high. Human error, unfortunately, remains a significant contributing factor to aviation accidents, underscoring the critical need for robust safety mechanisms.

At the heart of the HRO philosophy are core principles designed to prevent catastrophic failures. Two prominent principles are "pre-occupation with failure" and "deference to expertise".

Pre-occupation with failure means maintaining a constant "unease" and a continuous questioning of the status quo. Even minor indicators, anomalies, or near-misses are not dismissed but are actively used as opportunities to assess the system's strength and condition. This encourages technicians to report potential issues without fear of reprisal, enabling swift corrective actions before they escalate into disasters.

Deference to expertise signifies that in safety-critical situations, the practical, tacit knowledge of frontline personnel is valued more highly than the theoretical expertise of those not directly involved in the operational process. This means that an AMT on the hangar floor, who possesses intimate knowledge of a specific aircraft system, should feel empowered to speak up, and their input should be prioritized and acted upon.

The Indispensable Role of Psychological Safety in HROs

Psychological safety is indispensable for HROs to genuinely achieve their safety objectives. It is the catalyst that cultivates an "informed culture" where open communication and information sharing between managers and employees are the norm. This openness allows organizations to identify risks promptly and proactively prevent accidents, a concept referred to as "organizational mindfulness".

The inherent "unease" and "pre-occupation with failure" that characterize HROs make psychological safety an absolute necessity. Consider the perilous paradox: the very drive for perfection and a "zero accident" vision can inadvertently lead to the suppression of vital error reporting if psychological safety is absent. If employees fear negative

consequences, such as blame, humiliation, or career damage, for highlighting potential problems or admitting errors, this fundamental HRO principle is directly undermined. This fear creates an "epidemic of silence," where crucial information about systemic vulnerabilities or individual mistakes is withheld, preventing the organization from learning and adapting. Such concealment is far more dangerous than acknowledging and learning from incidents, as it allows latent errors to compound into catastrophic failures. Therefore, psychological safety serves as the critical link between the intent of HRO principles and their effective implementation, ensuring that the aspiration for perfection genuinely enhances safety rather than inadvertently fostering a dangerous suppression of safety-critical intelligence.

The "Just Culture" Connection

The concept of a "Just Culture" is closely intertwined with psychological safety in HROs. A Just Culture strives to balance psychological safety with accountability. It encourages employees to report safety-related information without fear of retribution for honest mistakes, while still addressing deliberate disregard for established procedures or reckless behavior. This distinction is vital: it promotes transparent reporting and continuous learning from unintentional errors, which are seen as opportunities for organizational improvement, while maintaining discipline and trust by holding individuals accountable for intentional violations. For AMTs, this means feeling safe to admit a missed inspection step or question an ambiguous protocol, knowing the focus will be on improving the system, not on assigning blame.

In conclusion, for aircraft maintenance units navigating increasing traffic volumes and technological complexity, psychological safety is not a "soft" ideal but a practical, strategic imperative. It transforms human fallibility into a proactive safety net, ensuring technicians prioritize airworthiness over silence. By fostering an environment where AMTs feel secure in speaking up, asking questions, and even admitting mistakes, organizations can truly achieve the continuous learning and nearly error-free performance demanded of High-Reliability Operations.

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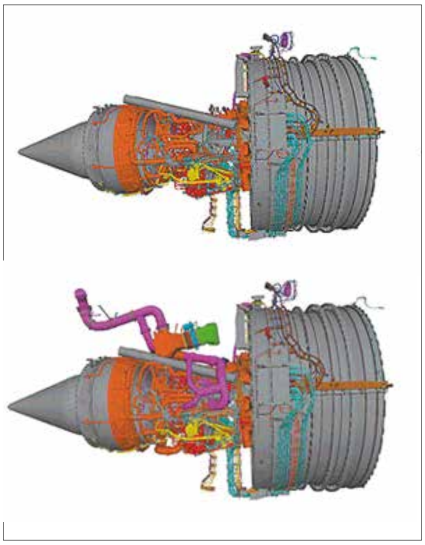
POWERING EFFICIENCY:

THE NO-BLEED SYSTEM ARCHITECTURE OF THE BOEING 787



The Boeing 787 Dreamliner features an architecture that largely replaces the pneumatic systems found in most conventional commercial aircraft with electrical systems. This innovative "no-bleed" system architecture reduces fuel consumption while increasing operational efficiency. The fundamental difference in the system's architecture is the emphasis placed on electrical systems, which brings numerous advantages.

The Boeing 787 Dreamliner represents one of the most significant advancements in modern commercial aviation, introducing a revolutionary "more-electric" architecture that replaces many of the traditional pneumatic systems with electrical ones. Unlike conventional aircraft where bleed air taken from the engines powers systems such as cabin pressurization, air conditioning, or de-icing, the 787 eliminates the bleed manifold entirely and distributes electrical energy instead. This design change reduces the load on the engines, improves efficiency, and provides airlines with substantial benefits in terms of fuel savings, operational performance, and reliability.

Thanks to this innovative system, functions like air conditioning and wing ice protection are now powered electrically rather than pneumatically. The result is an increase in operational efficiency, with fuel consumption reduced by approximately three percent during flight. Since pneumatic systems require a portion of the high-pressure air generated by the engine, overall thrust efficiency is reduced, but in the electrical system this energy loss is eliminated. The engine can devote its full power to propulsion, which not only lowers fuel burn but also increases the aircraft's range. The reduced number of moving parts and mechanical connections translates into lower maintenance requirements and higher system reliability, both of which contribute directly to reduced operating costs for airlines.

The no-bleed system architecture provides an additional one to two percent improvement in fuel consumption, especially noticeable during cruise, where power demands are highest. Instead of wasting excess compressed air as in conventional systems, electrical energy is distributed efficiently to where it is needed. This optimization of power use represents a fundamental step toward making long-haul operations more economical and sustainable.

Hydraulic systems also benefit from the more-electric design. Rather than relying on large, air turbine-driven hydraulic pumps, the 787 employs pumps powered by electric motors. This approach increases efficiency throughout the flight while simultaneously achieving weight savings. By designing the hydraulic system to operate at higher pressures, smaller components could be used, reducing overall system weight and freeing valuable space within the aircraft. The result is an optimized balance between performance, efficiency, and structural design. Environmental control has likewise been redesigned around electrical power. Cabin pressurization and climate management are handled by variable-speed compressors driven by electric motors, which deliver only the precise level of pressure and airflow required at any given moment. This ensures efficiency while minimizing unnecessary energy consumption. The wing ice protection system has also undergone a dramatic transformation. Instead of using hot bleed air, the 787 employs electro-thermal heating blankets, which consume around fifty percent less energy compared to traditional systems. Beyond reducing energy demand, this system improves aerodynamic performance during flight by lowering drag, which further

contributes to the overall efficiency gains of the aircraft.

At the heart of the Dreamliner's innovation is a hybrid electrical network capable of operating at multiple voltage levels. Power generated by both the engines and the Auxiliary Power Unit is supplied as variable-frequency electricity and distributed across the aircraft. The modular architecture of this system makes power monitoring and distribution easier and more reliable, ensuring that essential functions

are maintained under varying flight conditions. Importantly, the 787's generators are designed to operate without constant-speed drives, which reduces system complexity, minimizes maintenance needs, and enhances reliability.

Together, these innovations establish the Boeing 787 as a landmark in the transition toward more-electric aircraft. The elimination of bleed systems in favor of electrical power offers a wide range of advantages, from reducing fuel consumption and extending flight range to lowering maintenance costs and increasing operational reliability. More importantly, this architecture supports the global drive for sustainability by cutting energy waste and lowering emissions, thereby benefiting not only airlines but also the environment. The Dreamliner's no-bleed design is therefore more than just a technological innovation—it is a decisive step toward the future of commercial aviation, where efficiency, reliability, and environmental responsibility converge in one aircraft.

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DOES WORK PASSION AFFECT SAFE BEHAVIOR IN AVIATION?

In the high-stakes world of aviation, safety is more than a checklist—it's a mindset. But what if we told you that the secret to safer behavior in aviation doesn't start with rules or procedures, but with something deeply personal: passion for the job?

Recent research we conducted with over 500 professionals in Turkey's civil aviation sector reveals a compelling truth: employees who are passionate about their work—specifically, those with "harmonious passion"—are more likely to behave safely on the job. In other words, when employees love their work in a balanced and autonomous way, they naturally act with greater awareness and responsibility, especially in safety-critical environments like aviation.

Let's pause and unpack this idea of "work passion." Psychologists distinguish between two types:

Harmonious passion, where individuals engage in work they love, but in a way that stays in balance with the rest of their lives.

Obsessive passion, where the job becomes an uncontrollable need—dominating one's thoughts and behaviors, often at the expense of well-being.

Recent research in Turkey's civil aviation sector shows that employees with harmonious passion—those who love their work in a balanced and autonomous way—are more likely to engage in safe behavior. In contrast, obsessive passion offers no significant safety benefits and may even increase burnout or risk-taking. An internal locus of control, or the belief that one can influence outcomes, further strengthens this effect, fully mediating the relationship between passion and safety. For airlines and aviation leaders, fostering autonomy, supporting work-life balance, recruiting for attitude and responsibility, and training employees to strengthen their belief in personal impact are key strategies. Ultimately, combining passion with personal responsibility can elevate aviation safety from mere compliance to true excellence.

Our findings show that harmonious passion has a clear, positive impact on safety behavior, both in following procedures and in voluntarily promoting a safer workplace. Obsessive passion, on the other hand, showed no significant benefit—and in some other studies, it's even linked to burnout and risky behavior.

But the story doesn't end there. We also explored a psychological trait called the "locus of control"—whether individuals believe they can influence what happens to them, or if they think outcomes are shaped by luck, fate, or other external forces. Unsurprisingly, employees with an internal locus of control (those who believe their actions make a difference) were also more likely to engage in safe behavior. In fact, this belief fully mediated the relationship between passion and safety. Harmonious or even obsessive passion had the strongest positive effect when paired with a strong internal belief in personal responsibility.

So what does this mean for airlines, airports, and aviation leaders?

It means that if we want safer behavior—not just compliance, but true safety culture—we need to do more than enforce rules. We need to fuel harmonious passion and cultivate a mindset of responsibility. That starts with the way we recruit, train, recognize, and support aviation personnel.

Some practical takeaways:
Foster autonomy: Let employees feel ownership of their roles. Avoid micro-management and allow room for initiative.

Promote work-life balance:
Harmonious passion thrives when people can integrate work with a healthy personal life. Shift planning and task design matter.

Recruit for attitude: Prioritize candidates who demonstrate emotional intelligence, responsibility, and decision-making maturity.

Train for mindset, not just skills:
Develop programs that strengthen employees' belief in their impact on safety outcomes.

The aviation sector has long understood the role of technical skills and regulatory compliance in preventing accidents. But human psychology—how people feel about their work, and how much control they believe they have—can be the invisible lever that moves us from "safe enough" to "safety excellence." And that, in the end, might be our most valuable pre-flight check of all.

PRELIMINARY REPORT ON AIR INDIA FLIGHT 171:

A CATASTROPHIC FAILURE WITH UNANSWERED QUESTIONS

A preliminary investigation into the deadliest aviation accident of the decade involving Air India Flight 171 reveals manual fuel cutoff of both engines seconds after liftoff, leading to total engine failure and crash. The Boeing 787-8, operating with experienced pilots and valid certifications, crashed just 32 seconds after takeoff, resulting in 260 fatalities and 68 injuries. The report highlights unresolved questions regarding pilot actions and references a 2018 non-mandatory service bulletin addressing fuel control switch issues. The investigation faces criticism from pilot associations and regulatory bodies for its limited transparency and implications of pilot error.

A preliminary investigation report has been released concerning the deadliest aviation accident in the past decade, which resulted in the deaths of 260 people and injuries to 68 others. While the report provides partial insight into the causes of the crash, it raises far more questions than it answers.

On June 12, 2025, Air India Flight 171 was scheduled to operate from Ahmedabad, India, to London, United Kingdom. The aircraft, a Boeing 787-8 Dreamliner, had been delivered to Air India in 2013, making the airline one of the earliest operators of this model. At the time of the crash, the aircraft had accumulated 41,868 flight hours. It held a valid airworthiness certificate, had undergone regular maintenance, and was considered to be in good operational condition on paper.

The flight was commanded by a 56-year-old captain with over 15,000 total flight hours, including more than 8,500 hours on the Boeing 787. The first officer was 32 years old and had logged 3,403 total flight hours, with 1,128 hours on the same aircraft type.

At 07:43 UTC, the crew requested clearance for pushback and engine start-up. Twelve minutes later, they confirmed readiness for taxi with all pre-flight checks completed.

Eight minutes after that, they received clearance to enter the runway. Takeoff clearance followed four minutes later. The aircraft carried 230 passengers and 12 crew members.

At 08:08:39 UTC, flight data recorded liftoff. Three seconds later, the aircraft reached a peak airspeed of 180 knots. However, at the fourth second after liftoff, the fuel control switch for one engine was moved from RUN to CUTOFF. One second later, the fuel control switch for the second engine was also set to CUTOFF. The aircraft lost all engine thrust at this critical moment.

Three seconds after fuel cutoff, the Ram Air Turbine (RAT) deployed, indicating complete engine power loss. Eight seconds after the second engine was shut down, the fuel control switches were reactivated—first one switch, followed four seconds later by the other. At the 26th second, the flight crew issued a MAYDAY call. The aircraft crashed into the ground six seconds later, remaining airborne for a total of just 32 seconds.

Video footage shared shortly after the crash speculated that both engines had failed, given the RAT deployment. The preliminary report confirmed that engine shutdown was not due to mechanical failure but rather manual fuel cutoff. The report emphasized that these switches are specifically designed to prevent accidental activation, both in placement and mechanism.

Two aspects of the report are especially noteworthy. First, a 2018 service bulletin addressed potential faults in the locking mechanism of fuel control switches, based on incidents involving Boeing 737s. Although the issue also applied to 787s, the FAA did not classify it as a safety hazard and issued only a non-mandatory recommendation.

Second, cockpit voice recordings revealed a puzzling exchange between the pilots. One asked, "Why did you cut off the fuel supply?", to which the other responded, "I didn't." The report states that it was not possible to determine which pilot made which statement due to unresolved voice identification.

This preliminary report has been met with significant criticism, especially from the Indian Airline Pilots Association, which condemned its implication of pilot error. The Indian aviation authority has also been criticized for failing to deliver a more comprehensive and transparent investigation.

THE DEMING CYCLE AS A FRAMEWORK FOR CONTINUOUS IMPROVEMENT IN AVIATION QUALITY MANAGEMENT

Quality management is vital in high-reliability industries like aviation, where safety and precision are critical. The PDCA (Plan-Do-Check-Act) cycle, popularized by W. Edwards Deming, serves as a proven framework for continuous improvement. By emphasizing iterative learning and evidence-based process optimization, PDCA helps aviation maintenance organizations enhance safety, operational efficiency, and regulatory compliance. Integrating the Deming Cycle into organizational culture fosters a proactive approach to risk management, ensuring sustainable operational excellence and reinforcing passenger safety.

Quality management has become a cornerstone of modern organizations, particularly in high-reliability industries such as aviation, where safety, efficiency, and precision are paramount. One of the most influential thinkers in this field, W. Edwards Deming, famously asserted that "if you cannot describe what you are doing as a process, you do not know what you are doing." This statement underscores the importance of structured processes in achieving organizational goals and ensuring consistent outcomes. Within this framework, one of the most enduring tools for continuous improvement is the PDCA cycle—also known as the Deming Cycle or Deming Wheel. The PDCA methodology was popularized by Deming in the 1950s during his work with Japanese industries, where it became a central driver of post-war industrial transformation and global competitiveness. The approach reflects a scientific method applied to management, emphasizing observation, experimentation, and iterative learning. Its lasting relevance lies in its adaptability, as it can be applied across a wide range of contexts, including manufacturing, healthcare, aviation maintenance, and service industries.

The PDCA model is a four-stage iterative process that enables organizations to introduce improvements in a systematic, evidence-based manner. It begins with the planning stage, where organizations identify what needs to be improved and set clear,

measurable objectives. This requires a comprehensive understanding of current processes as well as the recognition of deficiencies, inefficiencies, or risks that must be addressed. In aviation, for example, planning may involve analyzing maintenance procedures to identify safety vulnerabilities. The next stage is implementation, where changes are introduced on a controlled, small scale. This trial approach allows organizations to test proposed improvements without exposing the entire system to potential disruptions. At the same time, employees must be adequately trained and provided with the necessary resources to ensure reliable execution. Once changes are implemented, their effectiveness is assessed through the evaluation stage, where outcomes are measured and compared against the objectives defined earlier. Data collection, monitoring, and analysis determine whether the improvements achieved the intended results. In industries such as aviation, this stage is particularly critical because compliance with international safety standards is mandatory. The final stage of the cycle is action. If the changes prove successful, they are standardized and integrated into routine operations. If the expected results are not achieved, corrective measures are introduced, and the process is redesigned. This reinforces the iterative nature of the cycle and ensures that improvement remains continuous rather than a one-time effort.

The Deming Cycle is not merely a theoretical model but also a practical tool with significant implications for sectors that demand precision and reliability. In aviation, continuous improvement is inseparable from the culture of safety. Aircraft maintenance organizations employ PDCA as a systematic framework to minimize human error, enhance process efficiency, and strengthen compliance with regulatory standards. Each iteration of the cycle helps cultivate a culture of learning and adaptability—an indispensable quality in environments where even minor mistakes may have critical consequences. The application of PDCA supports not only operational effectiveness but also proactive risk management, enabling organizations to anticipate and address potential failures before they escalate into threats to safety.

Ultimately, the PDCA cycle provides organizations with a structured methodology for achieving continuous improvement. Its iterative nature ensures that improvements are tested, validated, and standardized, thereby creating a sustainable framework for operational excellence. In aviation maintenance, applying the Deming Cycle not only enhances efficiency and reliability but also directly contributes to passenger safety and public trust. Embedding PDCA into organizational culture transforms improvement into an ongoing pursuit rather than an incidental effort, aligning with Deming's philosophy that true quality management is a continuous journey of learning, adaptation, and accountability.

ALUMINUM ALLOYS USED IN AVIATION

Although the use of composite materials in aircraft has increased in recent years, aluminum is still used at a rate of 50–60%. Aluminum is extensively employed in the fuselage, general structural components, and in compartments where high strength and corrosion resistance are required.

Aluminum, a ductile metal, is located in group 3A of the periodic table and has an atomic number of 13. Aluminum, an element with a +3 valence and an atomic weight of 26.89, has a density of 2.7 g/cm at 20 °C, a melting point of 659.8 °C, a boiling point of 2450 °C, a specific heat of 0.224 Cal/g (at 100 °C), a heat of fusion of 400 Cal/g, electrical conductivity at 20 °C of 65% that of copper, thermal conductivity 0.5, and light reflectivity of 90%, and these properties can be greatly changed by adding alloying elements. It is usually found in nature as bauxite ore (Al O) and has superior resistance to oxidation. With the development of technology and due to its technical properties, aluminum, which falls into the category of light metals and is one of the youngest members of the global metal world, is widely used in many fields of industry. The strength-to-weight ratio (specific strength) of aluminum is very high, it is soft, and it weighs one-third of steel. As a result of alloying it with alloying elements and increasing its mechanical properties to be comparable to steel, aluminum alloys have expanded their areas of use. Due to their low density and high mechanical properties, their use is rapidly increasing in many important production areas such as medicine, construction, food, automotive, aviation, aerospace, and defense industry.

Aluminum alloys are numbered using a 4-digit system. The first digit symbolizes

the main alloying element. The second digit gives information about the modification number of the alloy. If the second digit is 0, this means there is no modification. The last two digits indicate the alloy designer. In industrial applications, the mechanical properties of aluminum alloys are also increased by heat treatment processes, and their areas of use are expanded. Heat treatment generally covers heating and cooling processes applied to metallic materials to change their mechanical properties. For this purpose, heat treatments such as annealing, solution treatment, and aging are applied to aluminum alloys.

The 1XXX, 3XXX, 4XXX, and 5XXX series of wrought aluminum alloys are non-heat-treatable alloys. These alloys can only be hardened through shaping. The 2XXX, 6XXX, 7XXX, and 8XXX series alloys, on the other hand, can be hardened by heat treatment. Alloys created by combining aluminum with different materials are used in a wide range in the main structure of aircraft and many of its parts. There are many reasons why aluminum is preferred in aircraft structural parts. The most important reasons for the preference are aluminum's lightness, corrosion resistance in the atmosphere, thermal and electrical conductivity, and ease of production. Since aluminum is physically soft in its pure form, it does not have sufficient strength for aircraft construction. Commercially obtained aluminum gains some hardness and strength through mechanical processing via the remaining foreign substances. These simple alloys are suitable for the production of secondary aircraft elements, but for the production of primary elements, which carry loads and whose fracture could endanger the aircraft, aluminum alloys with higher strength are used.

Aluminum alloys have led to an expansion of application areas. Due to their low density and high mechanical properties, their use is rapidly increasing in many important industries such as medicine, construction, food, automotive, aviation, space, and defense.

Below are the designation criteria of the Aluminum Association (AA) for wrought alloys.

Alloy	Code Main Alloying Element
1XXX	Commercially pure aluminum (↗99% Al)
2XXX	Copper
3XXX	Manganese
4XXX	Silicon
5XXX	Magnesium
6XXX	Magnesium + Silicon
7XXX	Zinc
8XXX	Other elements
9XXX	Unused series

Use of Aluminum in Aviation

Since the 1915s, aluminum has started to be used instead of heavier steel in the aviation sector. During this period, copper-alloyed 2XXX series aluminum was used as a structural material in wings and fuselages. Aluminum use became widespread during and after the Second World War. During these dates, the 2014–2017–2024 alloys were used, while the need for high tensile strength paved the way for the use of 7000 series aluminum. Currently, 2XXX, 5XXX, 6XXX, and 7XXX series aluminum are used. In addition, 3XXX and 4XXX series aluminum are also used in a limited manner. Lithium-containing 8XXX series aluminum, which provides advantages in terms of lightness and elasticity, is currently used only in military aircraft/helicopters and spacecraft due to its very high price, and cannot be used in civilian passenger/cargo aircraft. Aluminum standards used in the aviation sector are recognized by AMS (Aerospace Materials Specifications).

Although the use of composite materials in aircraft has increased in recent years, aluminum is still used at a rate of 50–60%. Aluminum is heavily used in the aircraft fuselage, general structural elements, and compartments where durability and high corrosion resistance are required. In military aircraft, the aluminum usage rate rises to 75–80%. Aluminum is used in aircraft wings, flaps, landing gears, main fuselage frames and stringers, hydraulic systems, fuselage, connecting rivets, and engine exhaust sections.

Aluminum Alloys Used in Aircraft Wings

Wings are evaluated in two separate structures. Since the upper wing is subjected to load, 7075-T6 / T651 alloy is used. In some aircraft, 7050-T7451, produced in aluminum sheet form, is also used. The lower wing is subjected to bending and tensile loads, and is made from 2024-T3 / T351 material, which has high fatigue strength and high damage tolerance due to its flexibility. However, recently, 2324-T39 (Boeing) and 2124-T3/T351 (Airbus) alloys, which provide more advantage in fatigue and damage tolerance, have started to be used.

Aluminum Alloys Used in Aircraft Fuselage

Main fuselage structure frames and stringers: 7050-T7451 and 7050-T7651 (AMS 4201)

Fuselage attachment stringers: 7075-T6 / T651

Fuselage skin: 2024-T3 / T351 Alclad (clad on both sides)

Load-bearing areas: 7075-T6 / T651 plates and sheets

Aluminum Alloys Used in Wheels

In this section, to withstand the strength and flexibility encountered during landing in the main load-bearing part of the aircraft landing gear, 7075-T6 / T651, 7050-T7451, and 2024-T3 / T351 are used, while alloys with higher strength and durability such as 2014-T4 / T351 and 2017-T4 are used as connecting elements.

Aluminum Alloys Used in Other Areas

5052-H32 / H34 Plate: Used in applications where high fatigue and corrosion resistance and good formability are required. Most intensively used in fuel tanks.

5052-T0 Drawn Seamless Pipe and Rod: Used in fuel and oil pipes and their connecting parts.

6061-T4 / T6 Plate/Sheet: Used in regions and systems requiring high strength, good machinability, weldability, and corrosion resistance. Most commonly used in aircraft ladders, service systems, electronic device boxes.

6061-T0 / T4 / T4511 / T6 / T6511 Extrusion: Used in various connecting parts as different extrusions (profiles). Used in fuselage panels, edge coverings of emergency exit locations in wings, and engine cowlings. Recently, 6013-T6 and 6063-T6 materials are also used instead of 6061 due to better formability and higher corrosion resistance.

The lithium-alloyed 8XXX series aluminum, which provides advantages in terms of lightness and elasticity, is currently used only in military aircraft/ helicopters and spacecraft due to its very high cost, and cannot be used in civilian passenger or cargo aircraft

Use of Aluminum in Joining Aircraft Parts

If permanent and airtight connection against air is desired, welding should be used. In this process, 4XXX series aluminum is used. In other joining methods, mechanical joining (rivets, pins, threaded fasteners, collar components, special connecting elements) is used. The materials used in mechanical joining are manufactured from 5056-H34 / H32, 2017-T3/T351, 2117-T3/T351, 2024-T351 / T3.

AIRBLUE FLIGHT 202 TOXIC COCKPIT ENVIRONMENT AND TRAGEDY

On July 28, 2010, at 09:41 local time, an Air Blue airline A321 jet-powered passenger aircraft with tail number AP-BJB, arriving from Karachi, crashed into a mountain while approaching Islamabad, the capital of Pakistan. All onboard — two pilots, four cabin crew members, and 146 passengers — lost their lives. There was no technical fault found on the aircraft in this accident.

The root cause of this accident, which claimed the lives of 152 people, included not only rule violations and disregard for the aircraft's protective systems but also noncompliance with CRM rules and the negative behavior of subordinates being suppressed and rendered passive by their superior. The aircraft's captain, Pervez Ikbal Chodhari, was an experienced pilot with 25,497 flight hours, including 1,060 hours on the A321 type. The first officer had a total of 1,837 flight hours, with 286 hours on the A321 type. Although CRM rules are intended to ensure cooperation and communication between the two pilots in the cockpit during events and decision-making, there was no evidence of CRM compliance in the cockpit of Air Blue flight ABQ-202 from Karachi to Islamabad. In this accident, which claimed 152 lives, there was no technical fault in the aircraft, the flight crew's licenses were valid, and neither pilot had health issues.

Although the accident report received much criticism, it was not prepared by an independent board but by the Accident Investigation Board formed by the Pakistan Civil Aviation Authority (PCAA) for this accident. There are drawbacks to having accident investigations conducted by the Civil Aviation Authority after aircraft accidents. It should be noted that after an aircraft accident, potential parties responsible for errors or negligence may include the aircraft operator, the maintenance provider, the flight crew, the control tower, the airport administration, and the country's Civil Aviation Authority. Having the Civil Aviation Authority conduct the investigation is equivalent to asking the authority to investigate itself. Nobody admits fault easily. Therefore, even if the Civil Aviation Authority's supervision deficiencies or incorrect actions contributed to the accident, they are not investigated. In Turkey, this problematic situation was prevented in 2013 with the establishment of an Accident Investigation and Inquiry Board (KAİK) under the Ministry of Transport and Infrastructure of the Republic of Turkey to investigate transportation accidents. In 2019, this institution was renamed the Transportation Safety Investigation Center (UEİM), responsible for examining serious accidents

and incidents in transportation, including road, rail, maritime, and aviation sectors, preparing reports, delivering them to relevant national or international institutions when necessary, and publishing annual statistics on accidents and incidents.

Following the crash of Air Blue airline's A321 passenger aircraft that killed 152 passengers, the members of the Accident Investigation Board established by the Pakistan Civil Aviation Authority (PCAA) were: Board Chairman (PCAA), Flight Operations Representative (PCAA), Technical Representative (PCAA), Air Traffic Representative (PCAA), Medical - Flight Medicine Representative (PCAA), Airworthiness - Maintenance Representative (PCAA), Pakistan Air Force Representative, and Air Blue Airline Representative. Additionally, representatives from foreign organizations supported the Accident Investigation Board in its work. The crash of the A321 aircraft involved the interest of many foreign organizations. Examining the representatives sent to support the board shows this very strikingly. The representative of the accident investigation authority BEA of France, the country of Airbus, the Type Design Owner and Manufacturer of the aircraft, served as a technical advisor. The representative of IAE, the Type Design Owner of the aircraft's V2500 jet engines, was from the NTSB, the accident investigation authority of the USA. The technical advisor for the NTSB was a representative appointed by Rolls Royce through IAE. The FAA, the United States Civil Aviation Authority, was also represented. (IAE is a partnership between the U.S.-based Pratt & Whitney and UK-based Rolls Royce, headquartered in the USA.) Many advisory representatives from different organizations were included in the board. The European Union Aviation Safety Agency (EASA) was not represented by a consultant.

Let us return to the flight in which the accident occurred. After takeoff, at 07:52 local time, the cabin crew served tea and croissants to the flight crew. During the initial climb, the captain tested the first officer's knowledge by asking questions and,

contrary to company procedures/ norms, used insulting words and a mocking tone. The captain's question-and-answer sessions, advice, and instructions continued intermittently for approximately one hour after takeoff. Following these intermittent demeaning sessions, the first officer generally remained silent, lost confidence, became submissive (suppressed), and later did not intervene when the captain made errors or violations.

The captain was aware of the weather conditions at the destination airport, Islamabad, which were cloudy, rainy, and overcast. He received this information from both the control tower and the METAR report from the ATIS (Automatic Terminal Information Service) system. Under these conditions, the tower instructed incoming aircraft to circle above the clouds and only descend for landing once visual contact with the runway was confirmed. The procedure also defined the approach path to the runway, and no other approaches were permitted outside this procedure. Understanding that due to bad weather the aircraft might not be able to land and could be diverted to another airport, the captain instructed the first officer to input four different waypoints into the Flight Management Computer (FMC) that were not in the flight plan and not compliant with procedure.

As they approached Islamabad airport, heavy clouds and rain were present. The tower instructed the aircraft to circle above the clouds until visual contact with the ground was established. The captain then activated his plan, engaging the four waypoints that were not allowed by procedure. In the last 70 seconds of the flight, the system called EGPWS ("Enhanced Ground Proximity Warning System") issued 21 "Too Close to Terrain – Pull Up" audible warnings, but the captain did not respond. Throughout this process, the first officer made no intervention apart from stating "We are too close to the ground" and "We need to climb." When the tower asked the first officer if they had visual contact with the ground because of doubts about the aircraft's behavior, he consulted the captain, saying, "What should I answer?" Following the captain's instructions, he responded, "Yes. We have visual contact."

The twenty-first EGPWS warning ended abruptly when the aircraft struck the Margalla Hills. The resulting fire, fueled by the crash and wreckage, was extinguished after some time due to heavy rain. Rescue teams, who had to carve paths through the densely forested mountainous area to reach the crash site, found that there was nothing they could do for the 152 people aboard the aircraft.

HOW FAR CAN A BOEING 777 FLY WITHOUT REFUELING?

A Boeing 777 aircraft, when fully loaded with passengers and cargo, has a maximum flight range of approximately 9,395 nautical miles (17,395 kilometers). However, factors such as wind conditions, cruising altitude, and payload can affect the actual distance it can fly without refueling. This aircraft type is also equipped with a fuel-saving feature called "Eco Throttle," which can help extend the range by up to 10%.

For example, wind conditions play an important role during the flight. The direction and speed of the wind can affect the aircraft's ground speed and, consequently, its fuel consumption. Adverse wind conditions can shorten the aircraft's range, while favorable winds allow the aircraft to cover longer distances using less fuel. At the same time, flight altitude is also an influential factor on range. At higher altitudes, air density decreases, which helps engines operate more efficiently and reduces fuel consumption. Additionally, the aircraft's payload condition is important; with more cargo or passengers, the aircraft's weight increases, which in turn increases fuel consumption and reduces range. The high range capability of the Boeing 777 makes it an extremely attractive option for international air transport, while it should be remembered that the flight can be affected by various external factors. Despite these dynamic conditions, the aircraft provides airlines with flexibility and efficiency, facilitating global transportation.

Factors Affecting the Aircraft's Range

Payload Factor

The number of passengers, cargo, and fuel on board affects the aircraft's range. As the load increases, the available fuel for the flight decreases, and the aircraft's range diminishes.

Fuel Capacity

The Boeing 777 has models with different fuel capacities. The most common model, the Boeing 777-300ER, has a maximum fuel capacity of approximately 47,890 gallons (181,280 liters). Other models, such as the Boeing 777-200LR, have even larger fuel capacities.

Flight Conditions
Factors such as wind direction, speed, and altitude can affect the aircraft's fuel consumption and thus its range. Tailwinds can increase the aircraft's ground speed and improve fuel efficiency, allowing it to fly longer distances. Headwinds, on the other hand, can reduce ground speed and increase fuel consumption, decreasing the range.

Flight Profile
The flight profile, including climb, cruise, and descent phases, affects fuel consumption. Climbing to higher altitudes initially requires more fuel, but once cruising altitude is reached, the aircraft experiences lower drag and better fuel efficiency. Descent consumes less fuel.

ETOPS Certification
The Boeing 777 is certified for ETOPS (Extended-range Twin-engine Operational Performance Standards), allowing it to operate on long transoceanic routes. This certification ensures that in the event of an engine failure, the aircraft can safely reach an alternate airport within a specified time. ETOPS regulations can impose limits on the maximum distance the aircraft can fly to the nearest suitable diversion airport.

Additional Factors
Other considerations, such as air traffic control restrictions, flight planning, and operational requirements, can also affect the aircraft's range.

In general, the Boeing 777 is a long-range aircraft capable of flying nonstop on intercontinental routes. It can typically cover approximately 9,395 nautical miles (17,395 kilometers) without refueling. For example, the route from Istanbul New Airport to Auckland International Airport in New Zealand is 17,173 km. However, the specific range may vary depending on the factors mentioned above.

Turkish Airlines and the Boeing 777
Our national flag carrier, Turkish Airlines, operates 54 Boeing 777 aircraft for passenger and cargo transport. These aircraft are used for both international and domestic flights, enabling Turkish Airlines to maintain a significant position among global airlines. The Boeing 777 provides passengers with a comfortable travel experience due to its spacious cabin design and high comfort levels. In addition, its powerful engines allow for long-range flights. These features, combined with Turkish Airlines' extensive flight network and competitive service approach, provide a significant advantage in meeting the needs of both passengers and cargo transport.

By using these aircraft, Turkish Airlines serves numerous destinations worldwide while continuously prioritizing customer satisfaction. This allows the airline to offer high-standard services to both individual passengers and commercial cargo clients, maintaining its leading position in the aviation sector.

COSMIC RADIATION AT HIGH ALTITUDES

Air travel is transporting an increasing number of passengers. In 2023, 4.2 billion passengers were carried by airplanes worldwide. Cosmic radiation, composed of high-energy particles, loses energy gradually as it travels from space toward the Earth, colliding with particles in the atmospheric layers, which reduces its intensity (or flux). The Earth's magnetic field deflects cosmic radiation in the Equatorial Region, significantly reducing its effect, especially between latitudes 0° and 30°. As one moves toward the poles, the magnetic field weakens, so cosmic radiation is less deflected and its impact increases in those areas.

Since the intensity of cosmic radiation is higher at the altitudes where we fly in airplanes, it is expected that its effects on our bodies will also be greater. Figure 1 shows that the cosmic ray dose (or cosmic radiation dose) increases with altitude. The 'effective dose rate' in microsieverts per hour (μSv) is only 0.03 at sea level, whereas at the 10–12 km altitude where we fly with airplanes, this value rises to approximately 8 μSv, or 260 times that at sea level.

Cosmic Rays

Physicists first noticed cosmic rays during laboratory studies while investigating why electrically charged objects gradually lost their electric charges. Initially, they thought the effect originated from naturally radioactive materials in the Earth's crust. Eventually, Austrian physicist Victor Hess, in 1912, rode a balloon and observed his electroscope's indicator, noting that as he ascended, the electrical charge gradually decreased. He concluded that something hidden was coming from the sky, from space, ionizing the air, and thus the charges on the electroscope gradually decreased. This hidden agent was called 'cosmic rays' (Hess later received the Nobel Prize in 1936 for his research and this discovery).

In the 1950s, physicists determined that cosmic rays were not composed of light particles (photons) or electromagnetic waves, but rather a continuous 'ion flux' consisting mostly of protons at very high speeds and a smaller number of heavier particles. Nevertheless, the term 'cosmic rays,' though historically inaccurate, remained. These 'very fast' and therefore 'very high-energy' protons and ions coming constantly to Earth from the depths of space beyond our solar system are slowed by the dense atmospheric layers they must pass through, generating mesons and many other secondary particles in large numbers from the atoms they collide with, affecting us in the atmosphere and on Earth, including muons that can penetrate deep underground.

Cosmic rays are fundamentally the same type of ionizing radiation as natural radiation from the Earth's crust and radiation from nuclear power plants, capable of causing changes and damage in cells, molecules, and atoms in the human body. At low doses, the likelihood of cancer is small, though very rarely DNA breaks may occur.

Dose Received on Airplanes

The magnitude of the dose received from cosmic radiation on airplanes depends on flight altitude, flight duration, solar activity (effectiveness), and the geographic (geomagnetic) latitude of the flight path. Due to business trips, many people spend approximately 240 hours per year on airplanes. During this time, the total dose a person might receive, although dependent on the flight route from one part of the world to another, can roughly be estimated as 0.008 x 240 = 1.92 mSv.

The cosmic radiation dose received varies depending on the departure and arrival locations. For example, Table 1 below shows the variation range of cosmic doses for flights from Frankfurt to various cities (similar dose ranges could apply for Istanbul or Ankara instead of Frankfurt).

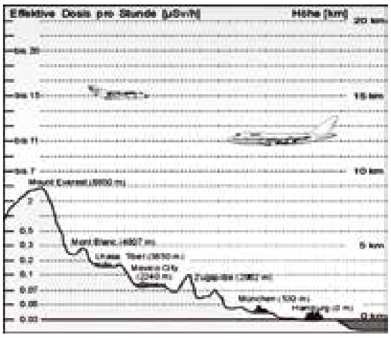
Dose Received by Aircrew

Assuming that pilots and flight attendants generally work 80 hours per month and 10 months per year, their estimated dose can be roughly calculated as: 800 hours x 0.008 = 6.4 mSv. This dose can be considered a maximum dose. (In Germany, the average value measured with radiation dosimeters for male personnel is 2.9 mSv per year).

Situation for Aircrew in the EU and Germany

According to European Union (EU) regulations, for aircrew whose annual dose may exceed 1 mSv, body doses must be determined with 'dosimeters,' evaluated, and preventive measures taken if necessary. Aircrew, like nuclear reactor personnel or doctors working with X-ray devices, are classified as 'radiation workers,' trained on the effects of radiation on the body, and therefore the annual dose limit of 20 mSv applies to them as well. In EU countries, aircrew doses must be measured according to relevant regulations, calculated and evaluated with appropriate computer programs, and reported to the competent authorities.

Since 2003, in Germany, the cosmic radiation doses received by all aircrew on registered aircraft (scheduled, charter, cargo, and military) have been calculated and recorded monthly using radiation dosimeters installed on airplanes and relevant dose calculation programs. Between 2004 and 2009 in Germany, the number of aircrew increased by 23% to 36,600 people.



The cosmic radiation dose received during air travel is equivalent to the dose from X-rays in a computed tomography (CT) scan and carries an extremely low probability of causing any damage to the body.

Departure	Arrival	Dose Range* (μSv/h)
Frankfurt	Rome	3 - 6
Frankfurt	Gran Canaria	10 - 18
Frankfurt	Rio de Janeiro	17 - 30
Frankfurt	Johannesburg	18 - 30
Frankfurt	Singapore	28 - 50
Frankfurt	New York	32 - 80
Frankfurt	San Francisco	45 - 110

In EU countries, it is mandatory to measure the dose received by airline personnel according to relevant regulations, calculate and evaluate it using appropriate computer programs, and report it to the competent authorities.

During this period, the collective radiation dose received by personnel also increased by 48%, reaching 86 person-Sv. The average annual dose was 2.35 mSv in 2009, with male aircrew receiving the highest average dose of 2.9 mSv. Due to low solar activity in 2009, cosmic rays penetrated the atmosphere more, resulting in higher doses for aircrew.

In Germany, aircrew receive the highest doses among all personnel exposed to ionizing radiation, including those working in nuclear power plants. Although the highest average dose in 2009 was 2.9 mSv, this value remains well below the 20 mSv annual upper limit for radiation workers. On the other hand, this dose received solely from cosmic rays, when combined with natural terrestrial radiation at sea level with an annual average of 2.4 mSv, means that aircrew remain within the 1–10 mSv range of doses from natural radiation.

Furthermore, calculations made at the GSF Institute in Munich, Germany, using the specially developed EPCARD computer program, show that for intra-European flights at 11 km altitude, the dose per flight is below 0.010 mSv, less than 0.040 mSv for South Africa and South America, and between 0.050 and 0.080 mSv for Europe–USA flights.

As a result, the dose received from cosmic rays during air travel and the potential risk should be considered within the same framework as the 'natural radiation dose' we constantly receive, along with other radiation doses from technological life (such as X-ray or MRI exposure), relevant regulations should be applied, and excessive or unreasonable precautions should not be taken.

In Turkey, there are no publications regarding the measurement or personal records of doses received by aircrew, so the situation is unknown.

Does the Cosmic Radiation Dose on Airplanes Affect Our Health?

In fact, we all live with natural radiation, including cosmic radiation, from the beginning.

Radiation doses we constantly receive from nature:

Natural Radiation Source	Effective Dose (mSv/year) World Averages	Range of Variation (mSv/year)
EXTERNAL EXPOSURE		
Cosmic Rays	0.4	0.3 - 1.0
Terrestrial Gamma Rays	0.5	0.3 - 0.6
INTERNAL EXPOSURE		
Inhalation / (Mostly Radon)	0.3 - 1.0	0.2 - 10
Ingestion	0.3 - 0.6	0.2 - 0.8
TOTAL	2.4	1 - 10

As seen in Table 2, the annual average radiation dose of 2.4 mSv varies greatly between 1 and 10 mSv, and half of the average dose comes from radon gas, a decay product of radioactive materials (uranium and thorium) in the Earth's crust. Cosmic rays also contribute more to the radiation dose for people living at high altitudes and during air travel, as can be seen from Figure 1 and the table above.

The cosmic radiation dose received during air travel is generally equivalent to the dose from a single X-ray examination. This dose, however, is comparable to that received from X-rays in a medical CT scan and carries a very low probability (risk) of causing damage to the body. As a protective measure, aircrew reaching certain limit values are not allowed to fly for a period of time.

However, the risk may be significant for embryos developing in the womb, potentially increasing the chance of congenital defects. Therefore, pregnant aircrew are not assigned to flights, and pregnant women are advised against long air travel for work or travel purposes.

Practical shielding or protection against highly penetrating cosmic radiation on airplanes is not possible. Although the risk is very low, with over 4 billion annual travel flights, particularly domestic flights, reducing flight frequency as a protective measure, and opting for sea or land travel, is left to individual choice. Reducing flights also contributes to protecting the atmosphere from greenhouse gases (CO2).

Note: This text is quoted from the article titled "Cosmic Radiation Dose We Receive on Airplanes and Our Health?" by Radiation Physicist Dr. Yüksel Atakan on the website www.herkesebilimteknoloji.com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