



Engineering Out the Error in Aircraft Maintenance

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July 2026

On 10 June 1990, British Airways Flight 5390 was on a routine flight from Birmingham, England, to Málaga, Spain, carrying 81 passengers and four crew. Thirteen minutes after take-off, as the aircraft climbed through 17,000 feet, a loud bang was heard from the cockpit and the cabin violently decompressed. The left cockpit windscreen blew out with explosive force, and the captain, who was not secured, was forced headfirst out of his seat into the open window. Although his upper torso was outside the aircraft, his knees caught on the flight controls and prevented him from being thrown out entirely (Air Accidents Investigation Branch [AAIB], 1992).

The copilot, fighting hypoxia and shock, clung onto the captain's ankles while cabin crew restrained his body as the aircraft descended for an emergency landing. The aircraft landed safely and the captain survived, despite sustaining hypothermia-related injuries.

The cause of the incident was not weather, structural fatigue or system failure. It was incorrectly selected windscreen bolts (AAIB, 1992).

The windscreen was replaced the night before the flight and required a total of 90 bolts to secure it. Investigations discovered that 84 of the 90 bolts were smaller in diameter than required, while the remaining six were of the correct diameter but shorter in length.

The windscreen was replaced overnight during a night shift, when fatigue and circadian effects may have increased susceptibility to error. The engineer selected the replacement bolts by visual comparison with the removed bolts and did not refer to the Illustrated Parts Catalogue to confirm the correct part number (AAIB, 1992).

Visually, the bolts were a near match. Mechanically, they were not.

This breakdown in verification was shaped by human limitations: fatigue, circadian effects and cognitive shortcuts had eroded the safeguards built into the task.

A similar lesson had emerged two years earlier. In 1988, Aloha Airlines Flight 243 suffered catastrophic fuselage failure when fatigue cracks that had gone undetected during inspection propagated silently until the structure gave way in-flight. The failure did not stem from the Non-Destructive Testing equipment itself, but from the limits of the "human in the loop". The aircraft was a high-cycle, short-haul airframe operating in a harsh coastal environment where heat, humidity and salt exposure accelerated corrosion and structural degradation. Inspectors had to sustain detailed visual and NDT inspections across large areas of structure and thousands of fastener locations, under conditions of intense repetition where attention naturally degrades over time and inspection fatigue becomes a risk (National Transportation Safety Board [NTSB], 1989).

Together, these incidents point to a fundamental safety lesson: procedures, checklists and inspections are essential, but they still depend on humans detecting small deviations reliably, often under adverse conditions.

The next advance in maintenance safety will therefore come not from asking people to be more vigilant, but from redesigning work so that predictable human limits are no longer the last line of defence.

Why Maintenance is Vulnerable to Human Limits

This vulnerability is most acute in high-volume, low-variability maintenance tasks involving hundreds or thousands of small, similar looking parts. The work is repetitive, the differences are subtle and the consequences of a lapse may only surface much later.

From a safety systems perspective, this environment resembles Reason's organisational accident model, often illustrated as the "Swiss cheese" model (Reason, 1990, 2000). Each barrier — experience, inspection and procedures — contains inherent vulnerabilities, including fatigue, time pressure and complacency, which can create latent conditions that weaken the system. When these vulnerabilities align, a discrepancy measured in fractions of a millimetre can result in catastrophic failure.

When More Checks are Not Enough

Some maintenance tasks push beyond what humans can reliably deliver, not because people are careless, but because the work demands a level of continuous attention that cannot be sustained indefinitely.

In a typical engine strip, technicians must sort, inspect, pack and order hundreds of bolts, nuts, washers and screws removed from the engine. Many components appear nearly identical, with differences in thread pitch, shank length or diameter measured in tenths of a millimetre. Correctness depends not on whether a part looks acceptable, but on whether it is precisely correct. This process alone consumes numerous man-hours per engine, creating conditions where monotony and boredom can quietly erode attention.



Figure 1. Manual Sorting and Inspection of Hardware.

Adding more inspections does not always resolve this. It may simply redistribute the same burden across more people, work steps and handovers, creating additional interfaces where error can re-enter the system.

Procedural controls are effective at ensuring known steps are not missed, but they are less effective at distinguishing what is almost correct from what is precisely correct — particularly where differences are visually subtle and consequences are latent.

This is where automation becomes more than a productivity tool. It becomes a way to redesign the task so that precision and verification are built into the process, allowing humans to focus on oversight.

Automation as a Safety Strategy

Automation is not about replacing people or improving productivity alone. Its safety value lies in removing variability at its source. Machines do not experience fatigue, and sensors do not rely on human memory, approximation, or sustained vigilance. By taking on repetitive, error-prone work, automation narrows the gap between what a task requires and what humans can reliably deliver. This shifts the human role towards oversight, interpretation and intervention when anomalies arise.

Research supports this approach: AI-assisted visual inspection can reduce errors that tend to emerge when inspection work becomes repetitive or rushed (Doğru et al., 2020).

At an organisational level, this reflects a different way of creating safety value: not by doing the same work faster with fewer people, but by redesigning work so that critical outcomes are no longer dependent on human performance alone.

Human Accountability Remains Central

This raises an important question: as automation and artificial intelligence become increasingly embedded in maintenance processes, who remains accountable?

Across airworthiness authorities, artificial intelligence is currently neither recognised nor accepted as an authority for inspection, conformity determination or maintenance release. Accountability remains with a qualified human (European Union Aviation Safety Agency [EASA], 2025; Federal Aviation Administration [FAA], 2024).

This is not resistance to automation. It reflects something more fundamental: aviation safety is not only about detection accuracy, but also about responsibility, traceability and governance. Certification decisions carry legal and safety accountability that cannot be delegated to a machine or algorithm.

This, however, does not limit the role of automation. AI is increasingly used to constrain error, verify correctness and reduce human exposure to known failure modes. AI does not replace the inspector but reshapes the system so that fewer errors reach the point where human judgement is required (EASA, 2025; FAA, 2024).

The critical distinction is this: humans remain responsible for acceptance, but they are no longer asked to compensate for biological limits in environments or tasks known to degrade performance. Automation absorbs the burden of precision, repetition and discrimination, preserving human oversight where it is strongest: interpretation, exception handling and accountability.

This approach also mirrors applied inspection research in Singapore, where automated visual inspection systems are designed to support rather than replace human intervention and engineering judgement (Rice et al., 2018).

AI PASS: Applying the Principle in Practice

In the maintenance, repair and overhaul (MRO) world, AI PASS illustrates this shift from relying on vigilance to engineering precision into the workflow. Automation is often difficult to implement in MRO because aircraft and components come in many forms, conditions and configurations; maintenance findings are seldom identical; and technicians must continuously adapt to what they see in front of them.

In such a variable environment, errors can enter quietly when safety-critical verification depends on manual, repetitive judgement. This is where ST Engineering saw an opportunity to apply AI and automation to take on the most repetitive and error-prone elements of the workflow, enforcing precision while keeping human authority and oversight.

One example of such a system is the AI Automated Picking & Screening Sorter (AI PASS), which is now being deployed to engineer safety into maintenance processes.

“We have designed the AI PASS to deliberately engineer safety and consistency into the task to remove repetitive and visually strenuous inspection work. The system reduces exposure to fatigue and human errors and provides a first-cut filter to remove unserviceable hardware, while the inspector retains full authority and accountability.”

– David Goh, Vice President Operations, ST Engineering

AI PASS does not replace human authority. It performs the exhaustive inspection and verification work, while a qualified technician retains responsibility for the final acceptance decision.

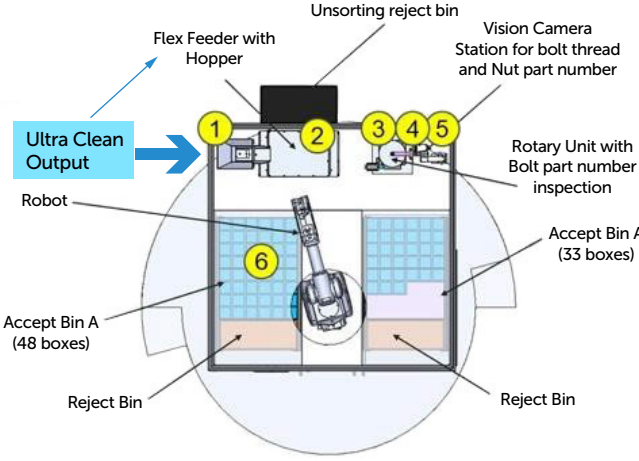


Figure 2. AI PASS system layout / process overview. (ST Engineering, 2025)

It integrates mechanical, optical, and robotic subsystems to remove visual approximation and manual repetition from the process entirely:

- Mechanical hoppers perform initial segregation
- 3D cameras capture geometry for AI comparison against standard profiles (including threads) to verify form and fit
- Machine vision systems screen features and read part markings using AI-based recognition (OCR); items with unreadable markings are rejected for manual review
- Robotic arms handle components without manual contact
- Automated binning separates accepted and rejected parts
- Auto logging generates digital traceability and an end of run AI PASS report summarising results and exceptions

Before automation, manual hardware sorting consumed significant man-hours per engine, frequently exceeding production schedules and

exposing technicians to eye strain, repetitive strain injuries and the constant risk of misidentification. The implementation of AI PASS has reduced sorting and inspection time, freeing significant man-hour capacity while removing one of the most error-prone manual tasks from the process. AI PASS also directly removes multiple hazards: cuts and abrasions from sharp hardware, musculoskeletal strain, prolonged eye strain under magnification, pinch-point exposure and cognitive overload from repetitive decision-making.

The Way Forward

British Airways Flight 5390 and Aloha Airlines Flight 243 share a common thread: catastrophic outcomes began with small deviations that slipped through systems reliant on sustained human attention. Neither was a failure of competence or intent. Both exposed the limits of systems that demanded perfect precision under real-world conditions. Procedure-driven safety remains essential, but it can plateau in repetitive,

high-volume tasks where small differences must be detected consistently, every time.

AI and automation offer the next safety gain when they are used to redesign processes so that precision is verified, variability is contained and errors are eliminated before they reach the aircraft. This does not mean automation is free from risk. Automated inspection systems must themselves be validated, calibrated, maintained and monitored.

AI may assist, screen and enforce consistency, but final acceptance, judgement and accountability must continue to reside with qualified humans.

The future of maintenance safety is not human versus machine. It is human-centred automation: systems designed so that humans remain responsible for judgement and accountability, while technology absorbs the burden of repetitive precision work and reduces exposure to predictable human limits.

CAAS, Flight Safety Foundation and Japan Civil Aviation Bureau are jointly organising the fourth Asia Pacific Summit for Aviation Safety (AP-SAS) in Osaka, Japan from 4-6 August. Join us as we bring together over 400 aviation leaders and experts to address emerging aviation safety priorities and strengthen collaboration in the Asia Pacific region.

Themed “Achieving Safety Excellence: Collaborate, Reinforce, Transform”, some key highlights of this annual summit include:

- Keynote address by Mr Onuma Toshiyuki, President of the International Civil Aviation Organization Council;
- Expert discussions on operational resilience, safety culture, and human capital development;
- Insights on leveraging artificial intelligence and emerging technologies to enhance aviation safety.

Registration is now open. For programme details and to secure your spot: flightsafety.swoogo.com/ap-sas-2026.

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3-7 Aug 2026	Safety Management System Implementation
11-14 Aug 2026	ICAO Training Package: Safety Management System Assessment and Monitoring
24-28 Aug 2026	ICAO Training Package: Personnel Licensing (PEL) System ICAO Annex 14 Requirements and Application
24-28 Aug 2026	Safety Oversight Inspectors (Aerodrome)
24 Aug-3 Sep 2026	Safety Oversight Inspectors (Airworthiness)

September

28 Sep - 1 Oct 2026	Aviation Security Management Programme
21-25 Sep 2026	ICAO Training Package: Obstacle Limitation Surfaces (OLS) <i>[New]</i>
21-23 Sep 2026	SMS Evaluation – The Enhanced PSOE Approach <i>[New]</i>

October

13 - 15 Oct 2026	Safety Leadership Programme <i>[New]</i>
19 - 23 Oct 2026	Safety Case Development and Evaluation
26 - 30 Oct 2026	Aviation Incident Investigation Analysis and Report Writing

November

2-6 Nov 2026	Safety Management System Implementation
2-6 Nov 2026	Human Factors in Aviation Workshop
11-13 Nov 2026	Continuous Safety Monitoring for Regulators: Implementation and Best Practices
30 Nov-4 Dec 2026	ICAO Training Package: Personnel Licensing (PEL) System

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