Flight Safety
AUSTRALIA

- The trouble with GPS
- Repair of ageing aircraft
- Pilot fade out – hypoxia, fatigue, CO, CO₂

STORM WARNING

NEW AIRWORTHINESS SECTION
We have had a gratifying response to the reader survey and competition in the Winter issue of Flight Safety Australia. Nearly 1500 readers filled out the survey card.

Readers have made very useful suggestions on how to improve the magazine, some of which are reflected in this issue.

We introduce a new airworthiness section to reflect the interests of the many maintenance engineers who receive the magazine. There is also more emphasis on analysing actual incidents to highlight safety issues. Many of your suggestions for stories will be followed up over the next few issues.

There were dozens of entries to our $300 "What Went Wrong" competition. While we have only been able to publish the winning entry this issue, in future issues we will also be publishing the runner-up.

The advertisement opposite gives details of the next competition.

Your stories – and your feedback and suggestions – are vital for the development of Flight Safety Australia.

– Editor

COVER STORY

Storm warning
It's thunderstorm season again  Geoff Smith

FEATURES

What went wrong?
Outback rescue  Competition winner

Fade out
The effects of hypoxia, fatigue, CO and CO₂  Rob Liddell

Trouble with GPS
Watch out for the traps  Allister Polkinghorne

Low flying near power lines
All power lines are potential killers  John Freeman

Damage tolerant repairs
New procedures to prevent "unzipping"  Steve Swift

• The drum on fuel, p. 21 • Maintenance management, p. 24
• Electrical system failure, p. 28 • Regulation p. 30

DEPARTMENTS

Follow up  • 4  Airworthiness  • 24
Briefs  • 4  Sport aviation  • 32
Trendlines  • 8  Airworthiness Directives  • 33
Viewpoint  • 9  Safety Check  • 35

James Kinpton on CASA reviews

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Aloha Airlines Boeing 737, 1988: the skin of the fuselage “unzipped” due to skin joint failure (see inset).

Damage tolerant repairs

In a discussion paper intended for release soon, CASA will be inviting public comment on a proposal to change the rules governing the design and subsequent maintenance of aircraft structural repairs.

Good repair design has never been simple, but it will no longer be good enough to just “stick a patch on it”. New repairs will sprout “fingers”. Old repairs will be put under the microscope of new technology. All this is part of an international move to require structural repairs (and modifications) to be “damage tolerant”.

Fail-safe failed

For the origins of this change, we need to go back to Africa nearly 20 years ago, to 14 May 1977. The crew of Boeing 707 G-BEBP, weary from a long overnight flight from London, lowered flaps for landing. Six seconds later, they heard a loud bang as the tailplane broke off.

There was nothing they could do. Observers at the airfield watched the helpless aircraft pitch down and spear into the ground. All six on board the cargo flight were killed instantly.

Investigators found that a fatigue crack, which had been growing in the top part of the rear spar for hundreds of flights, had finally ruptured the tailplane. But that should not have been dangerous. The Boeing 707 had been designed as “fail-safe”: if one part fails, there is supposed to be a back up.

In fact, the rear spar did have an extra “fail-safe” member. But it didn’t work – the crack went straight through it.

Fail-safe failed. It failed because the crack in the top part was far from obvious and there were no inspections. And it failed because the strength of a cracked tailplane had not been tested: the fail-safe member was not strong enough.

How skin joints can fail

A riveted skin joint showing small fatigue cracks (red) which have started to grow after thousands of fuselage pressurisations. These are hard to detect, even with modern inspection methods.

Once the fatigue cracks grow, it is not long before the shrinking areas of skin between the rivets cannot carry the load, and let go in rapid succession, like a zipper.

Fuselage fatigue has been a problem for jet airliners since the Comet. Repairs can fail unless they are damage tolerant. Steve Swift reports.

“The crew of Boeing 707 G-BEBP, weary from a long overnight flight from London, lowered flaps for landing. Six seconds later, they heard a loud bang as the tailplane broke off.”

So in December 1978, the United States Federal Aviation Administration (FAA) changed the fatigue rules for large aircraft (Amendment 45 to FAR 25). “Fail-safe” was out. “Damage tolerance” was in.

Since damage from fatigue and corrosion is inevitable in old aircraft, there is a need for a genuine ability to fly safely with damage until it is detected and repaired. Damage tolerance is what fail-safe tried to be.

While still valuing structural redundancy, damage tolerance emphasises testing:

- Fatigue testing so we know where, when and how to look for cracks.
- Residual strength testing to confirm that the cracked structure is strong enough.

There must be specific, directed inspections. It is no longer good enough to hope that damage will be obvious. Damage tolerance also calls for consideration that the back up structure might itself be cracked.

But in 1978 the new rules only applied to new aircraft — the ones with the least urgent need. So in May 1981, the US FAA took the bold step of requiring a damage tolerance assessment of old...
Aircraft (Advisory Circular 91-56). Such retrospectivity is unusual. Normally the lower safety level of superseded rules is constant and tolerable. But fatigue is different. With inadequate rules the risk just keeps rising until it eventually becomes intolerable.

A damage tolerance assessment of a fail-safe aircraft almost always results in extra inspections: the now familiar Supplemental Structural Inspection Document (SSID). SSIDs have been developed for most large jet airliners.

But during the flurry of activity which followed the Aloha Airlines Boeing 737 accident in 1988, it was recognised that something had been overlooked: SSIDs cover the standard aircraft, but aircraft do not stay that way for long. They need improvements, so they get modified; they get damaged, so they get repaired. These alterations must also be damage tolerant to ensure a consistent level of safety throughout the airframe. The safety chain is only as strong as its weakest link.

The diagram on page 27 shows a typical old-style repair. The problem is that cracks start in the underlying skin and stay hidden under the doubler. Such a repair caused a Fokker F28 to make an emergency descent in Papua New Guinea after a hole blew in its rear pressure bulkhead. Similarly, a Lockheed L-188 Electra on an Australian domestic flight barely made it to its destination after a repaired wing plank ruptured, spewing fuel over the countryside. The tanks were empty by the time the aircraft landed.

A damage tolerance assessment would have shown that such repairs can only be kept safe by looking regularly from the inside, or using clever inspection methods to look through the doubler. Two such methods are X-ray and low frequency eddy current.

The diagram on page 27 also shows two ideas on how repairs can be made more damage tolerant in future.

A damage tolerance assessment involves asking:
- Where will it crack?
- When will it crack?
- How fast will cracks grow?
- How well can we find the cracks?
- When will things become unsafe?

For repairs, the process is set out in the table below. The result, like the SSID for the standard airframe, will be extra inspections. Uninspectable repairs will have to be upgraded.

If adopted, implementation would be progressive, starting with the pressurised fuselages of the oldest jet airliners. To help with the assessment, aircraft manufacturers will be producing simplified manuals. Specialist engineers will probably be able to do it just as easily from first principles – if they can get enough design information.

Designers of new repairs will have to

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**Step one - Collect data**
Identify all structural repairs and modifications to primary structure:
- check aircraft records thoroughly
- undertake physical airframe survey

**Step two - Categorise repairs**
Categorise all repairs into the following classes:

- **Class A**: Damage tolerant - any further damage should be picked up with the existing structural inspection program.
- **Class B**: Damage tolerant - but special or supplementary inspections will be needed to check for any further damage.
- **Class C**: Not damage tolerant - but recently installed and structurally sound. Must be upgraded to Class B or better within a specified time limit.
- **Class D**: Not damage tolerant, not recently installed or exhibits signs of structural degradation. Must be upgraded to Class C or better before further flight.

**Step three - Determine structural maintenance requirements**
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Continue with existing structural inspection program.

Identify additional inspections required and incorporate them into the aircraft's structural inspection program.

Upgrade to Class B or better within a short specified time limit. Identify and incorporate additional inspections as required.
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consider not just strength, but stiffness and inspectability. We now know, for example, that "you can go wrong if it's big and strong", contrary to what engineers were once taught.

And so we keep on learning. If there is one thing we can be sure about in the ageing aircraft business, it is that we are not finished yet.

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