

# “ROUGH DIAMOND”

## Two Regulators Review Damage Tolerance

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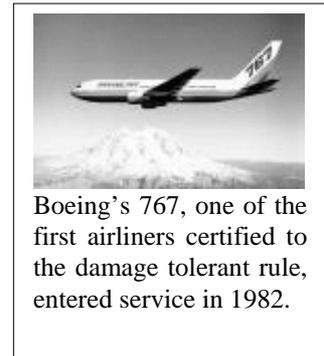
**Key Words:** Damage tolerance, inspection, fatigue, safety, structural integrity, ICAF.

**Abstract.** Two regulators review whether “damage tolerance” is delivering the safety envisioned when it became the preferred fatigue management method for large civil airliners. They laud the method, which they call the “diamond”. It is more valuable and versatile than first thought. It was a breakthrough. However, they find it so cluttered and poorly regulated that many reject it and others misuse it. The diamond is “rough”. They recommend “cutting and polishing”, by simplifying the diamond and its rules.

## 1 INTRODUCTION

In 1978, the FAA adopted “damage tolerance” as the preferred choice for managing fatigue in civil airliners.<sup>1</sup> Many now regard it as the panacea longed for by the investigators of the Comet crashes, which ICAF 2005 remembers.

However, as we do our best to regulate “damage tolerance”, we see problems serious enough to convince ourselves that we must do better. Amid complacency, we wonder how well it really is protecting the safety of our ageing fleets. So, we team up for this review, which we liken to mining and refining a diamond.



## 2 FINDING THE DIAMOND



First, there is confusion about what the rules mean by “damage tolerance”.

### 2.1 Is “damage tolerance” fracture mechanics?

Many equate “damage tolerance” with fracture mechanics, a common method of analysis used for “damage tolerance” evaluations. However, fracture mechanics is not *necessary* for the evaluation: there are other methods. And fracture mechanics is not *sufficient*: it cannot assess the vital element of inspectability, for example. “Damage tolerance” is much more than fracture mechanics.

### 2.2 Is “damage tolerance” a design property?

When the FAA adopted “damage tolerance”, it said it did so “to establish an evaluation requirement rather than an absolute requirement for the strength, detail design and fabrication of the structure”.<sup>1</sup> If the “evaluation” influences the design, as it often does, it does so indirectly, and doesn’t dictate particular properties. The FAA has reaffirmed that “damage tolerance” is not a design property, by requiring it for existing designs.<sup>2</sup>

### 2.3 Is “damage tolerance” a method to develop maintenance?

The rules are clear that the main purpose of the “evaluation” is to develop maintenance, called “Airworthiness Limitations”, to “provide a sound basis for the operator/owner to maintain the airworthiness of the aircraft”.<sup>3</sup> It was a breakthrough: civil aviation’s first logical method for assuring safe inspection intervals. No more risky guesswork. We call it the “diamond”.

### 2.4 The diamond is still rough

The diamond is good in theory, but problematic in practice. Many reject it. For example, few manufacturers of small airliners use it to develop their inspection programs.<sup>4</sup> When they do, few operators follow the programs, and few regulators force them (note the recent CASA and FAA exemptions).<sup>2,5</sup> So, passengers buy tickets on aircraft 20 years (and 20,000 hours) old, their safety resting on inspection programs based on guesswork. Others misuse the diamond. They do not apply it properly. We include examples in section 4. The diamond is still “rough”.

As we talk with manufacturers, operators, and even others in our own authorities, we suspect the main cause of the rejection and misuse is misunderstanding. We recommend simplifying the diamond (in the next section) and its rules (in section 6 and the Annex).

## 3 CUTTING THE DIAMOND

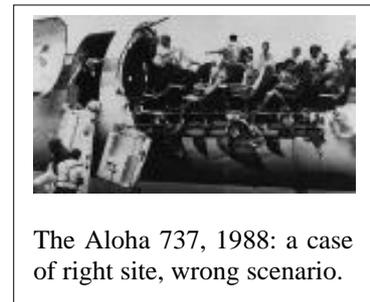
We propose five “facets”: Site, Scenario, Detectable, Dangerous and Duration.

### 3.1 Site

Where could cracks start? We often get this wrong. Test is better than analysis.<sup>6</sup>

### 3.2 Scenario

How will cracks grow? For example, will there be one or many? Will they interact? Will cracks in one part start cracks in another? Wrong answers give a very rough diamond.



### 3.3 Detectable

As a crack grows, this is the smallest size detectable, consistently, considering the inspection method and other factors. So, conservatively, it is the largest crack any single inspection could miss. Beware of optimism. For every lucky find of a small crack, there are many more misses of large ones. “Probability of detection” curves from field trials can help.

### 3.4 Dangerous

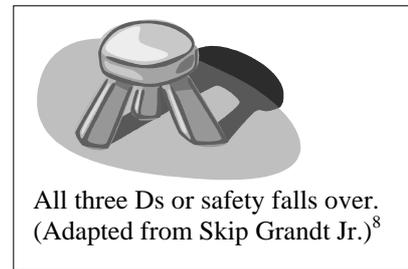
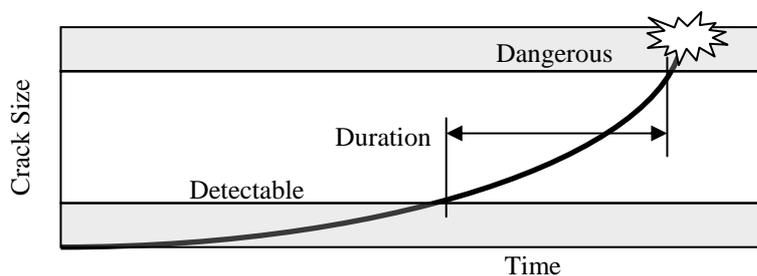
As a crack continues to grow, this is the size that is starting to be “dangerous”, because the structure is about to lose the strength we want to assure.

### 3.5 Duration

This is the time it will take a crack to grow from “detectable” to “dangerous”. It is our “safety window”. The inspection interval must be narrower, and must account for variability – something “damage tolerance” hasn’t done as well as “safe life”. An ASTM Task Group is one group trying to change that.<sup>7</sup>

### 3.6 The three Ds together

Below, left, are the three Ds in the classic graph of crack growth over time.



The three Ds form a three-legged stool (above, right) because we must know all three to assure safety. FAA AC 91-56A, “Continuing Structural Integrity Program for Large Transport Category Airplanes”, has the three Ds, but AC 91-60, “The Continued Airworthiness of Older Airplanes”, does not. That is why Supplemental Inspection Documents (SIDs) better assure safety than Continued Airworthiness Programs (CAPs). The interdependence of “detectable”, “duration” and “dangerous” is important to health and safety in many disciplines.<sup>9</sup>

## 4 USING THE DIAMOND



Some issues deserve special attention.

### 4.1 Uninspectability and the case for retirement

The diamond can identify uninspectable situations, such as where cracks would be dangerous before detectable. Cessna found this when they used the diamond for the 402 wing.<sup>10,11</sup> Piper would find similarly if they used it for the Chieftain wing.<sup>12</sup> Such situations are common. The diamond helps us find them. Then, it prompts us to change the design or the maintenance to lower the “detectable” size, to raise the “dangerous” size, *or to retire instead of inspect*.

*The third is sometimes the only safe and practical choice.* Against the trend, we think retirement needs reinstating as a viable (and sometimes necessary) alternative to inspection. It is more forgiving if we get the crack site wrong, as we often do. For example, in 2005, Cessna learned of a new fatigue-critical site in the wings of US-registered Cessna 402Cs – a site obvious in hindsight, but one missed by two previous thorough analyses.<sup>13,14,15</sup> Australian-registered Cessna 402Cs were serendipitously saved from similar danger, and the urgent inspections that followed, by a life limit that turned out to be right, for the wrong reason.<sup>16</sup> Eastin compared retirement with inspection at ICAF 2003.<sup>17</sup>

Retirement is common for helicopter parts, because crack growth “durations” are often impractically short. We see no reason to change that. However, how would the diamond apply to composites? “Sites” and “scenarios” are complex. The three Ds would often confirm that damage would be uninspectable, if it were to grow, because of its speed or unpredictability. Why, then, do we not “life” more composite structure? Have we returned to endurance limits? The hope seems to be that if strains are low enough, damage will *never* grow (the so-called “no growth approach to the damage tolerance requirements”).<sup>18</sup> In other words, an infinite “duration”. We tried that with metals. But, if it worked in tests, it often didn’t in service. Let’s hope composites do better. Let’s hope that those, like Emerson, who warned us, will not be proven right.<sup>19</sup>

## 4.2 Residual strength ambiguity

The rules generally require “ultimate” strength. The damage tolerance rules only require “limit” strength, two thirds of that. Is there a conflict? If cracking is predicted, but not yet reported in service, we hope there are few, if any, weak aircraft. So, we accept the *possibility* that the strength of a *few* aircraft may fall to *limit*. Once cracking is reported, we try to act to assure *fleet wide ultimate* strength. Emmerson et al said we don’t want “all aircraft in a fleet to become equally unsafe”.<sup>20</sup> What do we do? We redesign either the inspections or the structure to assure ultimate strength. Experience indicates that it is usually more prudent to do the latter, as discussed in an internal FAA policy memorandum from Keith.<sup>21</sup> Whichever, we want quick reporting to responsive designers. We want that for modifications and repairs, not just basic aircraft. Unfortunately, in the United States and Australia, our rules are weak, as Swift discussed.<sup>4</sup>

## 4.3 Flight with known cracks

Regulators have complicated special policies about flying with known cracks. However, the discussion of the previous section helps us. While we may accept the *possibility* an aircraft is weak, we can’t accept a *certainty*. We can’t allow passengers to board an aircraft we *know* is less safe than it should be. So, we want ultimate strength. We want to check the three Ds to assure it until repaired. That was our condition before we approved a Boeing 747 to fly hundreds of flights with metres of unrepaired deep scratches on its fuselage. Flight with known cracks could become less special as new technologies (such as Comparative Vacuum Monitoring<sup>TM</sup>) find smaller cracks and monitor their growth, even in flight.<sup>22</sup>

## 4.4 Cracks and crashes in service

The diamond’s facets can form a convenient check list to compare prediction with practice:

	Prediction	Practice
Site		
Scenario		
Dangerous		
Detectable		
Duration		
	What did the designers assume?	What did the defect or crash investigator find?

The investigation needs access to the design records, which is why it must involve the holder of the type certificate (or supplemental type certificate). If practice does *not* match prediction, the fatigue management program may need correction. Perhaps we should also periodically review the manufacturing inspection records, to look for errors that could possibly escape detection, even if they have not *yet* developed to become safety problems in service.

The above looks simple, but is often poorly understood. We are not getting the most from our expensive reporting systems and databases. For fatigue in safety-critical structure, we must do more than monitor trends. We must investigate every report, using the diamond. Sometimes we only get one warning. Sometimes, the next report comes from the crash site.<sup>23</sup>

#### 4.5 Beyond a life limit

Regulators get requests from independent designers who propose inspections to extend the life of structure past the life set by the manufacturer. While leaving parts in service can never be as safe as replacing them (unless replacement could itself cause damage), that is the risk we accept for all inspection programs. An inspection program must analyse and cover a wide range of sites, not just the most critical site that sets a life limit.

Not knowing everything the manufacturer knows, it is easier for an independent designer to miss a site. For example, the stress analysis of one who tried to extend a wing life for Beech twins missed a site the manufacturer unexpectedly found by test. Once structure exceeds the manufacturer's life, the independent designer must accept responsibility for *all* its continuing airworthiness, not just for fatigue, because no-one else will. That includes supplying maintenance instructions, investigating service findings and developing corrective actions. The FAA is considering publishing guidance on this subject.

#### 4.6 Extending an inspection interval

The three Ds can find faults in the logic that some operators, innocently but unknowingly, try to use to extend inspection intervals: a history of inspections with nil findings. However, the three Ds tell us that what we need is evidence that cracks grow more slowly than predicted. A longer "duration" should allow a longer interval. Operators rarely have the evidence.

The example on the right could have killed all 22 passengers if the blade had gone inboard instead of outboard.



#### 4.7 Ageing aircraft only?

The common definition of an "ageing aircraft" as one 15 or more years old causes two problems. The first is complacency. Safety problems can start earlier, as Airworthiness Directives show. For example, the wings of two types of agricultural aircraft experienced dangerous fatigue cracking after only one year of flying. The second problem is paralysis. Some think managing fatigue in "ageing aircraft" is so mysterious, they don't know where to start. So they don't. More need to know the diamond is simple and versatile enough for all the "ageing" process: from when the aircraft leaves the factory, until it finally leaves the register.

#### 4.8 Corrosion

With permission, manufacturers of large airliners often ignore the part of the rule about "corrosion". Instead, they use MSG-3, an industry standard which does not mention all the diamond's facets.<sup>24</sup> However, it does say that a Corrosion Prevention and Control Program (CPCP) should control corrosion to "damage that does not require structural reinforcement or replacement". This cost-driven "dangerous" size would generally be conservative for safety. We hope to discuss the regulatory application of the diamond to corrosion in a future paper. Finally, we still seem a long way from analysing fatigue and corrosion together, holistically and interactively, as Hoepfner, Schutz and others rightly keep reminding us.<sup>25,26</sup>

## 5 POLISHING THE DIAMOND

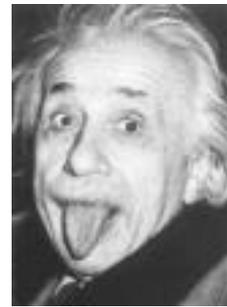


What more can we do to improve our management of fatigue?

### 5.1 Less jargon

Jargon is bad for safety. For example, it contributed to Ansett Australia failing to inspect its Boeing 767s in 2000. Ansett mistook Boeing's reference to "50-series...airworthiness limitations" as meaning a threshold of 50,000 cycles, the 767's Design Service Goal. Ansett's 767s were younger. However, later, Ansett learned that "50-series" was Boeing jargon for damage-tolerance-based inspections, and that some thresholds were 25,000 cycles. Some Ansett 767s were older, had to be grounded, and were cracked when finally inspected.<sup>27</sup>

Even "damage tolerance" is a problem. It confuses, as we said in section 2. And, for some, it suggests structural invulnerability, which can cause complacency and carelessness.



"DADTA", "flaw-tolerant safe life", "no-growth damage tolerance"! The jargon is enough to confuse a genius!

### 5.2 More promotion

We hope our five-faceted diamond will help spread the fatigue management message beyond the clique of specialists: to managers and maintainers, pilots and politicians, repairers and regulators. It is already part of the training course CASA is developing for its staff.<sup>28</sup> Perhaps it could help the guide for airline managers, from the Australian Transport Safety Bureau, and the guide for general aviation airplane owners, from AOPA, AAA, EAA and FAA.<sup>29,30</sup>

## 6 SETTING THE DIAMOND



The best way to ensure people know and follow good practice, like the diamond, is to change the rules. We think they need rewriting, not just revising. For your consideration, in the Annexe, we propose an operating rule that would:

- Use the "Plain English" style President Clinton directed (similar to FARs 11 and 39);<sup>31,32</sup>
- Combine many sets of rules into one;
- Need little advisory material;
- Allow progressive implementation (starting with part 121);
- Regulate continuing airworthiness, not just type certification;
- Hold STC holders to the same standards as TC holders;
- Streamline administration (for example, service bulletins are mandatory unless...);
- Not favour inspections, but equally allow retirement and other maintenance;
- Clearly cover repairs and modifications;
- Clarify residual strength and stiffness requirements;
- Require an "operational limit" for each Fatigue Management Program (FMP);
- Require FMP developers to document the process to be used to disposition service findings and;
- Require periodic reviews of the FMPs.

## 7 CONCLUSION

Damage tolerance is not yet delivering to its full safety potential. It is not used as well as it should. It is not used as often as it could. We hope that simplifying the method (the “diamond”) and its rules (like we propose in the Annexe), will help more to use it, properly, to better manage structural fatigue in the world’s airliners, young or old, large or small. We hope the diamond stimulates debate on outstanding issues, because there is still much to do.

The review will have been worthwhile if, one day, in a travel agency, we overhear:

Client: “I want a hotel with 4 stars, and an airplane with diamond-standard maintenance.”

Agent: “I know just the hotel. And, don’t worry, all airplanes have that safety feature now.”

## 8 ACKNOWLEDGEMENTS

We thank the US FAA and Australian CASA for supporting our review. We thank Wayne Jones for helping us develop the three Ds. We thank Josie and Kathy for loving us while we thought more about this “diamond” than theirs. We thank the companies who operated the planes and buses in which we did most of our thinking and writing.

## 9 DISCLAIMER

The views in this paper are personal, not official views of either FAA or CASA.

## 10 REFERENCES

1. FAA, FAR Final Rule, Part 25, Amendment 25-45, *Federal Register*, 5 October, 1978.
2. FAA, “Aging Airplane Safety; Final Rule”, *Federal Register*, 2 February 2005. One “exemption” (page 2) was the dropping of aircraft with 10 to 29 seats from the final rule.
3. FAA, FAR Final Rule, Parts 21, 23, 25, 27, 29, 31, 33 and 35, Amendments 21-51, 23-26, 25-54, 27-18, 29-20, 31-4, 33-9 and 35-5, *Federal Register*, 14 October 1980.
4. Swift, S., *Big Challenges for Little Airliners*, 10<sup>th</sup> Australian International Aerospace Congress, Brisbane, Queensland, Australia, July 2003.
5. CASA, Exemptions EX43 and EX44/2004, *Cessna Propeller-Driven Aircraft - Holders of Certificates of Registration and Persons Carrying Out Maintenance - Exemption from Compliance with Supplemental Inspection Documents*, 22 December 2004.
6. Swift, S., *Gnats and Camels*, ICAF 1999, Bellevue, Washington, USA.
7. Tuegel, E., Invitation to take part in ASTM Task Group E08.04.04 Round Robin on Probabilistic Crack Growth Analysis, email, 6 April 2005.
8. Grandt, Alten F. Jr., *Damage tolerant design and nondestructive evaluation*, John Wiley and Sons, New Jersey, USA, 2004.
9. US Multisociety Task Force on Colorectal Cancer, “Colorectal Cancer Screening and Surveillance: Clinical Guidelines and Rationale - Update Based on New Evidence”, *Gastroenterology*, American Gastroenterological Association, 2003, is one example.
10. Swift, S., “Old Commuter Aeroplanes - Consumable Treasure”, *Aviation Bulletin*, CASA, Australia, April 1993.
11. FAA, Notice of Proposed Rulemaking, “Cessna Aircraft Company Models 402C and 414A Airplanes”, *Federal Register*, 15 May 2003.
12. CASA, AD/PA31/124, *Wing Spar Splice Plate (Chieftain)*, 1994, requires retirement of the splice plates because, with the inspections in the maintenance manual, cracks would not be detectable before they were dangerous.
13. FAA, AD 2005-05-51, *Cessna Models 402C and 414A Airplanes*, February 2005.

14. Ensley, R., *Model 402C Wing and Carry-thru Fatigue Analysis*, Cessna Aircraft Company, Wichita, Kansas, USA, 1978.
15. Chan, L., Foster, E., Gamble, G., Townsend, D., *Supplemental Inspection Document Development Program for the Cessna Model 402*, Report No. DOT/FAA/AR-98/66, FAA, Washington DC, USA, 1999.
16. CASA, AD/Cessna 400/40 Amdt 13, *Wing and Airframe*, 1995.
17. Eastin, R. 2003, *A Critical Review of Strategies Used to Deal with Metal Fatigue*, ICAF 2003, Lucerne, Switzerland.
18. FAA, AC 20-107A, *Composite Aircraft Structure*, USA, 1984.
19. Emmerson, A., *New Lamps for Old - Safety Regulation Through Structural Airworthiness Standards*, ICAF 1991, Tokyo, Japan.
20. Emmerson, Torkington and Swift, *Rational Fatigue Life Management*, CASA, 1992.
21. Keith, L., *Guidance Concerning Continued Operational Safety and Airworthiness Directives*, Internal FAA Memorandum, 8 May 1989, Seattle, USA.
22. Structural Monitoring Systems, [www.smsystems.com.au](http://www.smsystems.com.au).
23. Swift, S., *The Aero Commander Chronicle*, ICAF 1995, Melbourne, Australia, has examples of service findings not properly investigated.
24. Air Transport Association, ATA MSG-3, *Operator/Manufacturer Scheduled Maintenance Development*, Washington, DC, USA, 2003.
25. Hoepfner, D., *From Safe Life to Holistic Structural Integrity Design*, NRC IAR Structures Workshop, Ottawa, Canada, 19 July 2002.
26. Schutz, W., *Corrosion Fatigue - The Forgotten Factor in Assessing Durability*, ICAF 1995, Melbourne, Australia.
27. Australian Transport Safety Bureau, *Investigation into Ansett Australia maintenance safety deficiencies and the control of continuing airworthiness of Class A aircraft*, Report BS/20010005, November 2002, pages 52 to 64.
28. Swift, S. and Jones, W., *Structural Integrity Programmes: an Introductory Course*, CASA, Australia, unpublished.
29. ATSB, *Ensuring Aircraft Structural Airworthiness, the Benefits to the Aviation Operator*, Canberra, Australia, not yet published.
30. AOPA, AAA, EAA, FAA, *Best Practices Guide for Maintaining General Aviation Airplanes*, USA, 2003.
31. FAA, *Writing User-Friendly Documents, A Handbook for FAA Drafters*, USA, 2003.
32. Clinton, W., *Presidential Memorandum on Plain Language*, 1998.

# Annexe 1: Proposed Rules

For discussion only. Not an official FAA or CASA rulemaking proposal.

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## **PART 121 - OPERATING REQUIREMENTS: DOMESTIC, FLAG, AND SUPPLEMENTAL OPERATIONS**

### **Subpart L - Maintenance, Preventative Maintenance and Alterations**

#### FATIGUE MANAGEMENT PROGRAMS (FMPs)

##### **1 What is an FMP?**

- (a) An FMP is a document that specifies the maintenance necessary to manage structural fatigue in the airframe after it enters service.
- (b) The FMP specifies:
  - (1) What to do; and
  - (2) When to do it.

##### **2 What rules do these replace?**

- (a) They replace Airworthiness Standards for fatigue and damage tolerance, for airplanes and for rotorcraft.
- (b) Exception: they don't replace parts of §25.571 that maintenance cannot affect, even indirectly, such as damage that happens suddenly in flight (bird strike, rotor burst) and damage that can't or won't be inspected (BVID for composites).

##### **3 How do these rules affect the Maintenance Review Board Procedures (MRB)?**

- (a) You may be familiar with the MRB for large airliners (AC 121-22A).
- (b) These rules only concern structure and do not affect MRB procedures for systems.
- (c) These rules only concern safety and do not affect MRB procedures for economic fatigue inspections.
- (d) These rules only concern fatigue and do not affect the MRB procedures for environmental or accidental damage.

#### FMP RULES FOR OPERATORS

##### **4 Do I need an FMP if I want to operate an aircraft (including a rotorcraft) under this part?**

- (a) Yes. You must have an FAA-approved FMP that covers your aircraft's:
  - (1) Type, by (date);
  - (2) Operation, if unusual, by (date); and
  - (3) Modifications and repairs, by (date).
- (b) Then, you must:

- (1) Do what the FMP says, when it says; and
- (2) Get and follow changes to the FMP.
- (c) If you operate a large transport category airplane, you should check §121.370 (a). It may ask you to assess your aircraft's repairs before paragraph (a) of this rule does.

##### **5 What if the standard FMP does not apply to my aircraft or its operation?**

- (a) You must get either:
  - (1) A FMP that does; or
  - (2) Supplements that, with the FMP, do.
- (b) These rules for FMPs apply to supplements.

##### **6 What do I do with service bulletins?**

- (a) If you get service bulletins that recommend maintenance for the airframe, you must assess them and, for each one, decide whether it is "maintenance necessary to manage structural fatigue in the airframe" (§1) of your aircraft:
  - (1) If you think it is, you must do what the service bulletin says; and
  - (2) If you think it is not, you must record your reasons in the aircraft's maintenance records.
- (b) If you are not sure, you could start by asking the issuer of the service bulletin.
- (c) If the issuer of the service bulletin is also the producer of your FMP (as they will be mostly), expect a revision to the FMP - see §14.
- (d) If you get a revision to the FMP, you must do what it says, when it says - see §4.

##### **7 What if I can't follow the FMP exactly?**

- (a) Tell us as soon as you see a problem.
- (b) We will let you operate (or continue to operate) your aircraft under this part if you can convince us, by written argument, that your alternative proposal will still manage structural fatigue.

#### FMP RULES FOR TC HOLDERS

##### **8 What must I do if I hold a type certificate?**

- (a) There is nothing you *must* do under these rules.
- (b) However, if you want operators to be able to use your type of aircraft under this part:
  - (1) You must produce an FMP; and
  - (2) You must get us to approve it.
- (c) For (b), see §4 for the dates by which operators must have an FMP. If you don't produce an FMP by then, and if no-one else does (see §30), we will not allow your type of aircraft to operate under this part.

##### **9 How do I get FAA to approve my FMP?**

- (a) You must send us your FMP.
- (b) You must send us a report that tells us how:

- (1) The FMP complies with the rules in the next section, "RULES FOR FMP CONTENT";
- (2) You will investigate service findings for their possible effect on the FMP; and
- (3) You will supply the FMP and its amendments to operators (same as §21.50).

**10 Might my current maintenance manual be approvable "as is"?**

- (a) Yes. The maintenance it specifies might already be enough "to manage structural fatigue in the airframe after it enters service" (see §1). You just need to convince us.
- (b) You will not need to rejustify the fatigue aspects of your manual if we have already approved it to one of the standards we list in §2. However, you still need to tell us everything else we ask for in §9.

**11 How do I keep my FMP approved?**

- (a) Every 2 years you must send us:
  - (1) Your latest FMP; and
  - (2) A report that tells us how, over the last two years, you have done §9(b)(2) and 9(b)(3).
- (b) We may also audit you and your FMP at other times.

**12 Can the FAA cancel my FMP's approval?**

- (a) Yes, but we will first:
  - (1) Write to tell you why we don't think it meets the rules for FMPs in this part; and
  - (2) Publish a notice in the *Federal Register* to alert those that cancellation could affect.
- (b) We will reapprove your FMP if you fix the problems we tell you about.

**13 Must I ask FAA to approve changes to my FMP?**

- (a) No, but we still want to know what safety issues are developing, and how you are handling them. So, you must still send us a copy of every change.
- (b) The change and its reason must be clear.
- (c) Of course, if we don't think the change meets the rules for FMPs in this part, we will write to tell you why, and what you must do.

**14 May I issue a service bulletin instead of changing the FMP?**

- (a) Yes, you may - subject to (b).
- (b) If you do issue a service bulletin, within a year, you must eventually put its content into the FMP. We want the FMP to stay the complete program of "the maintenance necessary to manage structural fatigue", as we define in §1.

**15 Do I include the FMP in the Instructions for Continued Airworthiness (ICA)?**

- (a) Yes, if your type is new enough to have an ICA. If so, the FMP must replace the Airworthiness Limitations.

- (b) No, if your type does not have an ICA. If so, the FMP must be part of the maintenance manual and must be prominent.

**RULES FOR FMP CONTENT**

**16 What aircraft and operations should the FMP cover?**

- (a) It is up to you. But remember that operators under this part will only want your FMP if it covers their aircraft and its operation (see §4).
- (b) In (a), "cover" means the FMP's maintenance must be effective for the aircraft and its operation.
- (c) The FMP must clearly state the *aircraft* it covers, including:
  - (1) Types;
  - (2) Models; and
  - (3) Modifications.
- (d) The FMP must clearly state the *operations* it covers, including, if they make a difference:
  - (1) Weight;
  - (2) Flight time; and
  - (3) Temperature.
  - (4) The FMP must clearly state its "operational limit" - the oldest aircraft it will cover (which is therefore the oldest aircraft we will let operate under this part). See §25.

**17 What loads must the FMP consider for fatigue?**

- (a) Flight loads;
- (b) Ground loads; and
- (c) Sonic excitation.

**18 How do I work out the fatigue loads?**

- (a) For the external flight and ground loads on the aircraft:
  - (1) You may use published data, if available for similar aircraft and operations; but, if not
  - (2) You must measure the external loads (widely enough to take account of geographic differences and long enough to take account of seasonal differences).
- (b) For the internal structural loads the external loads produce in the airframe:
  - (1) You may use analysis, if you have previously used the method of analysis on similar structure and measured its accuracy; but, if not
  - (2) You must measure the internal loads.

**19 What causes of fatigue must the FMP cover?**

- (a) Now, the FMP need only cover fatigue caused by the loads of §17 acting on normal quality, as-manufactured structure.
- (b) In the future, we may expand this to include manufacturing, operational or maintenance damage (or error) that is likely to:
  - (1) Happen; and
  - (2) Not be detected before the next flight.

**20 What structure must the FMP cover?**

- (a) Everything that affects safety, including:
  - (1) Modifications; and
  - (2) Repairs.

**21 What maintenance may the FMP specify?**

- (a) The FMP may specify to:
  - (1) Inspect structure; or
  - (2) Replace structure; or
  - (3) Modify structure.
- (b) If (a)(3), the FMP must specify the maintenance for the modified structure. And, if the modification is to prevent or repair fatigue cracking in service, we will let you call it a “terminating modification” if you can convince us it won’t need special maintenance until the FMP’s operational limit.
- (c) Please note that this rule uses simple maintenance terms, not technical jargon such as damage tolerance, safe life, fail safe and others.

**22 What must the FMP say about each maintenance item?**

- (a) What to do, including, if inspection:
  - (1) Where to inspect;
  - (2) How to get access;
  - (3) What inspection method to use; and
  - (4) What to look for.
- (b) If part replacement, how to replace the part.
- (c) When to do it.
- (d) For inspections, what to do if you find something, including:
  - (1) Reporting instructions;
  - (2) Instructions about continued flight before permanent repair (if that is safely possible - see §23); and
  - (3) Repair instructions (or how to get them).

**23 How much strength and stiffness must the FMP's maintenance assure?**

- (a) It depends on the certainty of cracking in the individual aircraft:

Certainty of cracking	Strength Requirement	Stiffness Requirement
Predicted	Limit strength (the limit loads in the type's airworthiness standard may permanently deform the cracked structure, but must not cause failure - see §2X.305 in the airworthiness standard)	Full aeroelastic stability (see §2X.629 in the airworthiness standard).
Found, but in other aircraft	Ultimate strength (within a year of the first fleet finding)	Full aeroelastic stability (also within a year)
Found in this aircraft	Ultimate strength (before further flight and until repair)	Full aeroelastic stability (before further flight and until repair)

- (1) The FMP’s maintenance must assure the strength and stiffness (a) requires.

**24 When must the FMP schedule maintenance?**

- (a) The FMP must schedule maintenance in time to stop cracks weakening the structure below the strength and stiffness of §23.

*Note: We hope to develop this rule in a future paper, after more consideration of the diamond’s applicability to inspection thresholds and life limits.*

**25 What methods can I use to prove my FMP's maintenance will be effective?**

- (a) Broadly, there are three methods:
  - (1) Analysis;
  - (2) Test; and
  - (3) The service experience of similar designs.
- (b) You must test when:
  - (1) Service experience, if available, is not relevant enough or long enough; or
  - (2) Analysis would have uncertainty that would be hard to quantify and address (often true for what the experts call “widespread fatigue damage”, “multisite damage” and “multi-element damage”).
- (c) The same applies for modifications and repairs.
- (d) If your proof relies on test or service experience, your FMP's operational limit must not be longer than the test or service experience justifies so far.

**26 How do I allow for uncertainty in my proof?**

- (a) You must consider uncertainty by:
  - (1) Rational statistical methods; or
  - (2) Conservative judgement.

**27 How do I allow for variability between the way aircraft are operated?**

- (a) You must consider either:
  - (1) The worst case within the FMP's stated applicability (see §16); or
  - (2) Different maintenance for different operations.

**28 What must I do if my FMP (or a change to my FMP) would schedule a time for maintenance that some aircraft may have already exceeded?**

- (a) You must specify a special time for them.
- (b) The time must balance cost and safety.
  - (1) If the risk is high and immediate, the time may be short or even "before further flight".

## FMP RULES FOR STC HOLDERS

### **29 What must I do if I hold a supplemental type certificate for aircraft that operate under this part?**

- (a) There is nothing you *must* do under these rules.
- (b) However, if you want operators to be able to use aircraft with your supplemental type certificate under this part:
  - (1) You must produce an FMP supplement;
  - (2) You must get us to approve it; and
  - (3) You must follow the rules for type certificate holders in the section "FMP RULES FOR TC HOLDERS".
- (c) You must follow this rule even if your FMP supplement simply says to follow the basic FMP without change.
- (d) For (b), see §4 for the dates by which operators must have an FMP supplement that covers modifications, such as your STC. If you don't produce an FMP supplement for them by then, and if no-one else does (see §30), they won't be able to operate aircraft with your STC under this part.

## FMP RULES FOR OTHERS

### **30 May I produce an FMP or a supplement if I do not hold a type certificate for an aircraft or a supplemental type certificate for a modification?**

- (a) Yes, you may produce an FMP or a supplement, and we will approve it, and let that approval continue, if you follow the rules in the section "FMP RULES FOR TC HOLDERS".
- (b) This rule, and others in this section, are an opportunity for an individual or group (such as a "type club") if the holder of the type certificate or supplemental type certificate cannot or will not produce an FMP.

### **31 Would I need an STC?**

- (a) You need an STC if you want the maintenance in your FMP or supplement to override maintenance in the aircraft's type certificate.
- (b) You do not need an STC, but you may need some other FAA approval, if you want to override Airworthiness Limitations that are not referenced on the type certificate.