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Airframe inspection reliability using field inspection data

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Contents

1 Table
10 Figures

(13 pages in total)

AIRFRAME INSPECTION RELIABILITY USING FIELD INSPECTION DATA

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1. SUMMARY
The possibilities within the Royal Netherlands Air Force (RNLAF) maintenance system to establish reliability data relevant for the in-service nondestructive inspection of F-16 airframe structure are described. The principal inspection techniques herewith are manual and automatic eddy current inspection for the detection of fatigue cracking. Use is made of field inspection data registered in the Core Automated Maintenance System (CAMS) for specific airframe inspection points within the F-16 Aircraft Structural Integrity Program (ASIP). The available data include the registration of the number of cracks and the length of the largest crack found during the phased inspections. Further, use is made of crack growth data obtained from the aircraft manufacturer. An evaluation of the field inspection data and the crack growth data allows the estimation of the sensitivity and reliability of inspection for the structural details concerned. The results of this evaluation can be used to revise the current values of the inspection intervals for the ASIP inspection points.

2. INTRODUCTION
Nondestructive inspection (NDI) is an integral part of aircraft maintenance. It is important to select the appropriate NDI techniques and to select the inspection times in terms of initial inspection (inspection threshold) and inspection interval, especially because of their impact on the balance between flight safety and maintenance costs. A too conservative maintenance approach could include unnecessarily frequent inspections resulting in high maintenance costs without an additional increase in flight safety. On the other hand, insufficient maintenance (inspection) could directly lead to an unacceptably low level of flight safety.

The selection of appropriate NDI techniques and the inspection frequency are related to each other because aircraft such as the F-16 have been designed in accordance with the Damage Tolerance (DT) design philosophy (Ref. 1). Damage Tolerance can be defined as "the ability of aircraft structure to sustain anticipated loads (e.g. limit load) in the presence of fatigue, corrosion or accidental damage until such damage is detected through inspections (or malfunctions) and repaired". In the DT design philosophy it is assumed that flaws already exist in the structure as manufactured, and that the structure may be inspectable or non-inspectable in service. Non-inspectable structures must be designed in such a way that the initial damage will not propagate to a critical size (causing failure) during the design service life. For inspectable structures the initial damage must grow slowly and not reach a critical size in some predetermined inspection interval.

The DT approach for inspectable structures is illustrated in figure 1. It is conservatively assumed that all specimens of a specified configuration contain an initial flaw (flaw size a_i) that propagates at a known rate. The assumed initial flaw size is small and generally not detectable with current inspection techniques. After a certain propagation time in service the flaw becomes reliably detectable (flaw size a_d) with a certain NDI technique. Finally, the critical flaw size a_c is assumed to be known from fracture toughness data; a_c is usually defined as the flaw size for which the structure can just sustain limit load.

The initial inspection time (I_1) and inspection interval (ΔI) are subsequently determined:

- I_1 is the flaw propagation period from a_i to a_c (this period is also called the "safety limit" SL) divided by a safety factor. This factor is usually taken as 2 which gives: I_1 = ½ . SL.
- ΔI is the flaw propagation period from a_d to a_c (period $\Delta = I_c - I_d$) divided by a safety factor. This factor is usually taken as 2 which gives: ΔI = ½ . Δ.

The relation between the appropriate NDI technique and the inspection frequency can now be understood. Visual inspection or low level NDI inspection are low cost inspection methods but have a relatively large detectable flaw size a_d and consequently a short inspection interval ΔI. On the other hand, a more advanced NDI technique is more costly in application but will have a smaller a_d and, consequently, will have a larger inspection interval. The aircraft operator has then the choice between frequent inspections with relatively high a_d inspection techniques or less frequent inspections with relatively small a_d inspection techniques, both yielding a same level of cumulative reliability of inspection.

In this paper first some general aspects of NDI reliability will be discussed. Then, the possibilities within the Royal Netherlands Air Force (RNLAF) maintenance system to establish reliability data, especially a_d values, relevant for the in-service nondestructive inspection of F-16 airframe structure will be described. Use will be made of field inspection data registered in the Core Automated Maintenance System (CAMS) for specific airframe inspection points.

3. RELIABILITY OF NONDESTRUCTIVE INSPECTION
The reliability of NDI is generally associated with the ability of an inspector to detect flaws in the parts inspected. The probability of detection (POD) for the flawed parts is then usually taken as measure of the inspection performance. The true POD for a particular flaw size, however, can only be obtained by means of an infinite number of inspections. In practice, a limited number of inspections will only yield an estimated POD. To provide a measure of confidence in the estimated POD, it is usual to incorporate confidence limits (CL) resulting in lower-bound values of the POD. An often quoted value for the reliably detectable flaw size is the 90/95 POD/CL value i.e. the flaw size for which we have 95 % confidence that the true POD is 90 % or more.

In practice, however, the majority of the specimens inspected are without flaws, yielding the possibility of obtaining a spurious indication of a non-existing flaw. Hence, the result of an inspection can be described by means of a quadrinomial distribution, with successful and unsuccessful inspections of both flawed and unflawed specimens (Fig. 2). In analogy with the POD for the flawed specimens a probability of recognition (POR) can be defined for the unflawed specimens. Also for the POR, lower confidence limits can be calculated with statistical methods. Often, the counterpart of POR viz. the false calls probability (FCP) is used as inspection characteristic for the unflawed parts. Both POD and POR (or FCP) are essential inspection characteristics with their relative importance depending on considerations of safety and economy (Ref. 2).
An attractive way to visualize the inspection performance is a diagram in which the POD and POR (or FCP) values are plotted against each other as the detection threshold is varied, yielding a so-called "relative operating characteristic" or ROC curve (Ref. 3). Such a diagram can be useful, for example for the comparison of different inspection techniques and for the performance ranking of individual inspectors.

In this paper we will focus on the POD for flawed parts because this is the most important inspection characteristic from a safety point of view.

4. NDI RELIABILITY DEMONSTRATION
Independent of the definition of the reliably detectable flaw size a_d, e.g. the 90/50 or 90/95 POD/CL value, one has to determine the POD curve of the relevant NDI techniques for a specific inspection configuration (specimen configuration), see figure 3. For this purpose a so-called NDI reliability demonstration program can be performed.
The design of such a program has been well addressed in an AGARD SMP Lecture Series (Ref. 4). This document describes testing and evaluation procedures for assessing the capability of an NDI system in terms of POD and confidence limits. NDI systems are herewith classified into two categories depending on the outcome of an inspection: NDI systems which produce only qualitative information as to the presence or absence of a flaw ("hit/miss" data) and NDI systems which record a signal response [â] that is correlated with the actual size [a] of the indicated flaw ("â vs. a" data). For both NDI systems, reference 4 gives recommendations for modelling the POD and for calculating lower confidence bounds.
The design of a reliability demonstration program has also been addressed in an FAA supported project at the Aging Aircraft NDI Development and Demonstration Center in Albuquerque (Ref. 5). The three-volume document presents a generic protocol for the conducting of inspection reliability experiments, it further presents a specific protocol for an eddy current inspection reliability experiment, and it gives the results of an actually performed reliability experiment at different airline inspection facilities for the manual high-frequency eddy current inspection of aircraft lap splice joints. Topics addressed include the presentation of POD curves, the treatment of false calls and the presentation of ROC curves.
Further, the NRC Institute for Aerospace Research (IAR) in Canada has performed extensive NDI reliability studies and experiments. For example reference 6 gives the results of an AGARD round-robin NDI demonstration program in which six laboratories in four NATO countries participated. In this program several NDI procedures were evaluated for the inspection of bolt holes of service-expired compressor disks and spacers from the J85-CAN40 engine.
A reference book of available quantitative NDI data has been compiled by the NTIAC in Austin (Ref. 7). This reference book gives guidelines for demonstration of specific NDI process capabilities and it provides more than 400 POD curves for various NDI techniques applied for various inspection configurations.

A well performed NDI reliability demonstration program can yield the necessary reliability data, for example a_d values, for a certain inspection configuration. However, such programs also have their limitations. Besides representativity of inspection configuration and the influence of human factors, the main limitations of performing an NDI reliability demonstration program are the time and costs involved. Especially the number of test specimens necessary for the "reliable" determination of POD and ROC curves is very large. For example, reference 4 recommends that the specimen set should contain at least 60 flawed sites if the NDI system provides only "hit/miss" results and at least 40 flawed sites if the NDI system provides a quantitative response, "â vs. a" data. Furthermore, to enable the estimation of the false call rate, reference 4 recommends that the specimen set should contain at least three times as many unflawed inspection sites as flawed sites.

These limitations are the reason that NDI reliability demonstration programs are infrequently performed and then for applications with only one or with a limited number of inspection configurations. When a large number of different configurations is involved, as for NDI of airframe structure, it is impractical to conduct these extensive programs for each different structural detail. Different approaches can then be distinguished:

- Conduct a limited number of NDI reliability demonstration programs on selected structural details and extrapolate the results of these programs to comparable structural details.
- Make a conservative use of available data from the

literature, for example of relevant POD curves from the NDE capabilities data book (Ref. 7).

- Make use of field inspection data e.g. the NDI results of in-service fleet inspections.

The last approach is an attractive option because of the acquisition of relevant results and because of the relatively low costs involved. Therefore, the "field data use" approach will be further discussed for the in-service NDI of F-16 airframe structure within the Royal Netherlands Air Force.

5. RNLAF IN-SERVICE NDI OF F-16 AIRFRAME STRUCTURE

The general NDI procedures for the in-service inspection of the F-16 airframe structure are described in reference 8. A RNLAF supplement on this reference lists the specific inspection control points within the F-16 Aircraft Structural Integrity Program (ASIP). In this paper the attention will be focused on the ASIP control points because of the crack growth information available (e.g. crack growth curves, critical flaw sizes) and because of the use of a comprehensive registration system for the ASIP field inspection data i.e. the Core Automated Maintenance System (CAMS). When cracks are detected during the inspection of an ASIP point, then the number of cracks and the length of the largest crack found (amongst other general data) are registered in the CAMS system.

The values for initial inspection time (I_1) and inspection interval (ΔI) for each ASIP point are listed in the Fleet Structural Maintenance Plan (FSMP) for RNLAF F-16 aircraft. The I_1 and ΔI values have been derived using the Damage Tolerance approach explained in chapter 3 (I_1 = ½ . SL and ΔI = ½ . Δ), using fatigue crack growth curves relevant for RNLAF usage (determined with a load spectrum based on the actual RNLAF base usage) and using reliably detectable flaw size a_d values based on assumed in-service NDI capability.
The following a_d values are currently used for the primary NDI procedures of ASIP points (all flaw sizes relate to surface crack lengths):

- Manual eddy current inspection: a_d = 0.10, 0.20 or 0.25 inch, depending on the inspection location.
- Automatic eddy current inspection (rotating probe) of bolt holes: a_d = 0.075 inch.
- Magnetic particle inspection: a_d = 0.10 inch.

The majority of the ASIP primary inspections include manual and automatic eddy current inspection. Magnetic particle inspection is only applied for a small number of ASIP points (e.g. the canopy hook support fitting). Penetrant inspection is only used as a back-up NDI procedure. Ultrasonic inspection is applied for a number of inspection points (e.g. the shock strut piston radius of the nose landing gear) but these inspections are RNLAF specific.

Up to now, the a_d values for the ASIP inspection points have been based on assumed in-service NDI capability. These a_d values seem conservative when compared with values from the literature. This means that the inspection intervals for these points may be unnecessarily conservative (large). Therefore, it is worthwhile to evaluate the available field inspection data in CAMS and to assess realistic a_d data for the ASIP inspection points. This information can then possibly be used to revise the current values of the ASIP inspection intervals.

6. POD ASSESSMENT USING FIELD INSPECTION DATA

The CAMS system registers the number of cracks and the length of the largest crack found during the inspection of an ASIP point. The NDI signal responses [â] are not recorded, so the NDI data base is of the "hit" type. Information of the sizes of undetected cracks ("miss"), however, is necessary for the construction of a POD curve (analysis of "hit/miss" data). But, when crack growth data are available, for each crack detected the previously missed crack sizes (during previous inspections) can be estimated (Refs. 9, 10). When crack growth data are not available, the data base will only contain crack detection data. These data can then be used in a limited approach to estimate a_d values by plotting a Cumulative Distribution Function of the crack sizes detected.

Crack growth data available

For most ASIP inspection points crack growth data are available. These data include realistic crack growth curves and values for the critical crack size a_c. The crack growth curves can be used to estimate the previously missed crack sizes for each crack detected during an inspection. This procedure is illustrated in figure 4. When this procedure is applied for the inspection of an ASIP point for all aircraft in service, this will result in an NDI data base of the "hit/miss" type for that particular ASIP point. When sufficient data are available (see chapter 4) a POD curve can be constructed. In the literature different models of a POD curve for the analysis of "hit/miss" data have been suggested. The most appropriate POD models have been evaluated by the NRC/IAR using the inspection results of actual aircraft engine disks containing service-induced cracks (Ref. 11). It was concluded that the log-normal regression function provides the most realistic POD results. This function was also recommended in an AGARD SMP Lecture Series (Ref. 4).
The log-normal model to relate the POD with crack size [a] can be formulated as follows (after Ref. 4):

$$\mathrm{POD}(a) = 1 - Q(z)\,;\; z = (\ln(a) - \mu)/\sigma \qquad (1)$$

where Q(z) is the standard normal survivor function, z is the standard normal variate, and μ and σ are the location (mean) and scale (standard deviation) parameters.
The two parameters (μ, σ) must be determined with a parameter estimation procedure. Also here, different methods have been mentioned in the literature, such as the Maximum Likelihood Estimators (MLE) method and the Range Interval Method (RIM). These methods have been evaluated in reference 11; it was concluded that the MLE method is the preferred method. For example, the MLE method does not require any information other than the actual "hit/miss" data.
An example of the construction of a POD curve from "hit/miss" data following the aforementioned method (log-normal POD function, MLE parameter estimation procedure)

is given in figure 3 (from Ref. 6). This figure gives the mean POD curve (50 % confidence) and the lower-bound POD curve with a 95 % confidence level. In this example the reliably detectable flaw size a_d has been defined as the 90/95 POD/CL value yielding a 2.6 mm crack length.

Crack growth data not available

For some inspection points crack growth data may not be available. In that case it is not possible anymore to estimate the previously missed crack sizes for each crack detected during an inspection. It is also not possible then to construct a POD curve from the available "hit" data. However, the crack detection data can still be used in a limited approach to obtain information about the detectable crack size by constructing a detection threshold histogram (Ref. 10). For this purpose, the available data are grouped in appropriate intervals of detected crack size, and a histogram is made of the frequency of detection versus crack size. The histogram can yield information such as the sensitivity of inspection (detection threshold) and the mean crack size detected.

A further approach is to assume a Probability Density Function (PDF) for the crack sizes detected and to calculate its integral i.e. the Cumulative Distribution Function (CDF). In analogy with the aforementioned POD(a_i) calculation (with both "hit" and "miss" data available) a log-normal PDF is assumed for the crack sizes detected ("hit" data):

$$\text{PDF:} \quad f(a) = \frac{1}{a\sigma\sqrt{2\pi}} \, e^{-\frac{1}{2}\left(\frac{\ln(a)-\mu}{\sigma}\right)^2} \qquad (2)$$

where μ and σ are the mean and standard deviation of the log crack sizes detected.

Next, a Cumulative Distribution Function (CDF) can be constructed, indicating the probability that the detected crack size has a value less than or equal to [a]:

$$\text{CDF:} \quad F(a) = \int_{x=0}^{x=a} f(x)\,dx \qquad (3)$$

To illustrate the PDF/CDF approach the inspection data of figure 3 (from Ref. 6) have been reviewed. The data comprise 79 "hits", 206 "misses" and only 1 false call. The PDF and CDF for the "hit" data are shown in figure 5. The mean and standard deviation are 2.3 mm and 1.2 mm crack length, respectively. These parameters have been determined with the least squares estimates procedure (in fact, first the μ and σ of ln(a) have been calculated). The goodness-of-fit for the data is shown in figure 6. Figure 5 allows an estimation of the detection threshold (about 0.5 mm) and of the crack length [a] for which there is a 90 % probability that the detected cracks have a length less than or equal to [a] (a = 3.8 mm). The reliably detectable crack length a_d can not be extracted from the CDF.

In figure 7 both the CDF for the "hit" data and the mean POD curve (confidence level 50 %) for the "hit/miss" data from figure 3 have been drawn. A 90 % probability criterion yields the crack lengths 3.8 mm and 2.4 mm for the CDF and POD curve, respectively. These values can not be compared directly: 3.8 mm is the crack length for which there is a 90 % probability that the detected cracks have a length less than or equal to this 3.8 mm, while 2.4 mm is the crack length for which there is a 90 % probability of detection (the 90/95 POD/CL value is a 2.6 mm crack length).

In general, the 90 % probability flaw size calculated from a CDF will be larger than the flaw size with a 90 % probability of detection. It can be concluded that the CDF can not give an exact value of the reliably detectable flaw size a_d, but it can give a conservative estimate of this a_d.

7. RNLAF F-16 FIELD INSPECTION DATA

The CAMS system registers the field inspection data of about 65 ASIP points in F-16 aircraft. At the moment there is an extensive CAMS data base but the amount of crack detection data is still limited because:

- Some ASIP points have large inspection intervals (e.g. exceeding 1000 flight hours) and hence acquire few inspection data.
- For a large number of ASIP points (almost) no cracks are detected.
- For some ASIP points the available crack detection data are the result of a first inspection, so that information of previously missed crack sizes can not be extracted.
- For some ASIP points the CAMS data base has not been kept up with completely (e.g. discipline of data filling-out).

The result is that at the moment for only a few ASIP points a sufficient number of crack detection data is available from which a relevant "hit/miss" data base can be deducted. As an example, ASIP control point 3005 will be taken to show the intrinsic possibilities of further analysis of field inspection data.

ASIP 3005 deals with the inspection of the tab radii in the F-16 16B5120 center fuselage longeron, see figure 8. The longeron is a tee-extrusion machined from 2024-T62 aluminium, and functions to distribute flight loads from the fuselage upper skin to the center fuselage structure. High positive g-loads may cause fatigue cracking in the tab radii of the longeron. NDI involves a manual eddy current inspection technique using a standard eddy current phase-analysis instrument and a 50-200 kHz shielded pencil-probe (Ref. 8). The current value for the reliably detectable crack size a_d has been set at a through-crack (0.090 inch plate thickness) with a length of 0.10 inch.

The crack growth curve for the ASIP 3005 control point is shown in figure 9. It is in fact a durability crack growth curve with an initial flaw size of 0.007 x 0.007 inch and a functional impairment crack size of 0.187 inch. Durability is not a safety life concept but an economic life concept; the durability life represents the life for which flaws will not grow to an extent that requires extensive repair before one design service life. ASIP 3005 is treated as a durability item (and not as a damage tolerance item) because the 16B5120 longeron is believed not

to be a safety of flight structure; the predicted durability life is 4320 flight hours (Ref. 12).
The current inspection interval is 200 flight hours; it is in fact not based on the crack growth data of figure 9 but on a former durability analysis of the aircraft manufacturer using a different crack growth curve. That analysis resulted in a relatively short interval (less than 100 flight hours) which was rounded up to a phase inspection interval of 200 flight hours, however, because of the longeron not being a safety of flight structure.

The available CAMS field inspection data of ASIP 3005 are given in table 1. This table lists for 27 aircraft the actual crack lengths detected and an estimation of the crack lengths missed during the previous inspections (between brackets). For this crack length estimation the crack growth curve in figure 9 was used. It is possible that in practice some cracks have been missed and which are hence not included in table 1. This will however only influence the size of the NDI data base and not significantly the shape of the POD curve (and a_d assessment). In total, the inspection results yield 28 "hit" data points and 36 "miss" data points (in total 64 "hit/miss" data points). These data points have been used to draw a CDF and a mean POD curve, see figure 10. The two curves correlate remarkably well and show that the sensitivity of inspection (detection threshold) is about 0.02 inch (0.5 mm). Further, a 90 % probability criterion yields the crack lengths of 0.093 inch (2.4 mm) and 0.108 inch (2.7 mm) for the POD and CDF curve, respectively. Without defining a specific confidence level on the POD to determine the reliably detectable crack size a_d, the POD curve in figure 10 indicates that the a_d value lies in the range of 0.10 inch. This value is equal to the currently used value of a_d for ASIP 3005 and for other comparable ASIP points inspected with the manual eddy current technique. Finally, it is emphasized again that the CDF can not give an exact value but only a conservative estimate of a_d.

8. CONCLUDING REMARKS

In this paper the possibilities within the RNLAF maintenance system to establish reliability data relevant for the in-service nondestructive inspection of F-16 airframe structure have been described. It has been shown that an evaluation of the CAMS field inspection data and crack growth data allows an estimation of the sensitivity and reliability of inspection for the structural details concerned. The results of such an evaluation can be used to revise the current values of the ASIP inspection intervals.
For the ASIP 3005 inspection point it has been shown that the reliably detectable flaw size lies in the same range as the currently used value of a_d (0.10 inch). So, in this particular case no revision of the currently used inspection interval is proposed. It is nevertheless a remarkable outcome because it has often been suggested that the value of 0.10 inch is on the very conservative side for this inspection configuration. A quick survey of the field inspection data in table 1 does also suggest this. The lesson learned is thus that realistic values for a_d are often larger than generally assumed.

The ASIP 3005 evaluation has demonstrated that the CAMS field inspection data can, in principle, be used to determine more realistic a_d values and hence more realistic values of the ASIP inspection intervals. For most ASIP points, however, the a_d and ΔI evaluation can not yet be performed because of the limited amount of crack detection data in the CAMS data base, see chapter 7. Some possibilities to overcome this limitation are:

- Stringent maintenance of the CAMS data base.
- Combination of crack detection data for ASIP points with comparable inspection configuration such as location and inspection technique (for example for the carry-through bulkhead ASIP points).
- Combination of RNLAF crack detection data with comparable crack detection data of other Air Forces. Estimation of previously missed crack sizes can then be done using crack growth curves incorporating a Crack Severity Index (CSI) for differences in base usage (load spectrum).

For the last item it is recommended to perform this activity within the framework of a NATO RTO Working Group to be established.

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Table 1 Available CAMS field inspection data of ASIP 3005; inspection of the tab radii in the F-16 16B5120 center fuselage longeron.
Listing of actual crack length [inch] detected and estimation of crack lengths missed during previous phased inspections (between brackets).

Aircraft CAMS Code	Phased Inspection Times (Flight Hours)								
	1200	1400	1600	1800	2000	2200	2400	2600	2800
A1869 RH	-	-	-	-	-	0.049			
A1870 LH	-	-	-	-	-	0.03			
A1870 RH	-	-	-	-	-	0.11			
A1871 RH	0.05								
A1873 RH	-	-	0.049						
A1874 RH	-	-	-	-	-	(0.029)	(0.035)	0.047	
A1875 RH	-	-	-	(0.025)	0.03				
A1876 RH	-	-	-	-	-	(0.038)	0.05		
A3199 RH	-	(0.019)	(0.021)	(0.025)	0.03				
A3202 RH	-	-	-	(0.025)	0.03				
A3203 RH	-	-	(0.021)	(0.025)	0.03				
A3204 RH	-	-	(0.019)	(0.021)	(0.025)	0.03			
A3208 RH	-	-	-	(0.025)	0.03				
A3209 RH	-	-	(0.021)	(0.025)	0.03				
A3616 RH	-	-	-	-	-	(0.030)	0.039		
A3620 RH	-	-	-	-	-	(0.026)	(0.031)	0.04	
A3623 RH	-	-	-	-	-	(0.019)	(0.021)	(0.025)	0.03
A3624 RH	-	-	-	-	(0.031)	0.04			
A3643 RH	-	-	-	(0.025)	0.03				
A3657 RH	-	-	-	-	-	(0.064)	0.15		
A4360 RH	-	-	(0.038)	0.05					
A4361 RH	-	-	(0.025)	0.03					
A4362 RH	-	-	(0.025)	0.03					
A5136 RH	-	(0.021)	(0.025)	0.03					
A5137 LH	-	-	(0.021)	(0.025)	0.03				
A8213 LH	-	-	(0.065)	0.157					
A8255 LH	-	-	-	-	(0.017)	0.019			
A8267 LH	-	-	-	-	-	-	(0.053)	(0.080)	0.236

Dash (-) means: no inspection data available

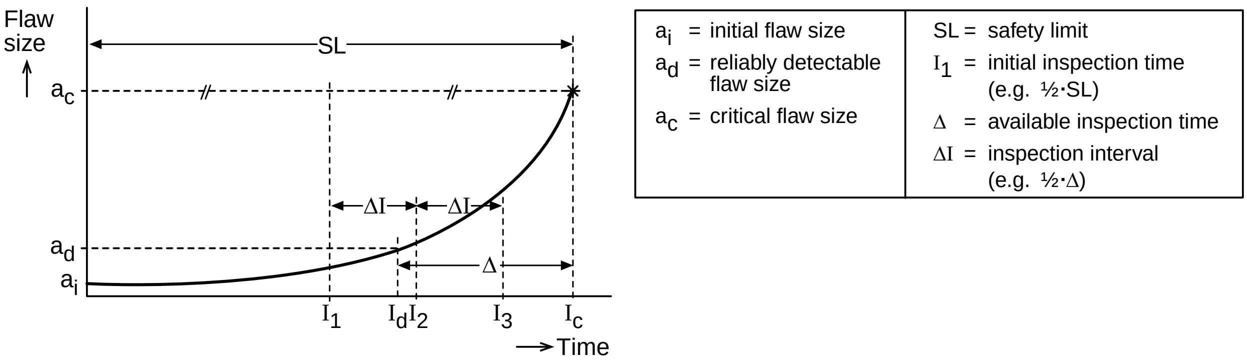

Fig. 1 Damage tolerance approach for inspectable structures.
Determination of the initial inspection time I_1 and the inspection interval ΔI

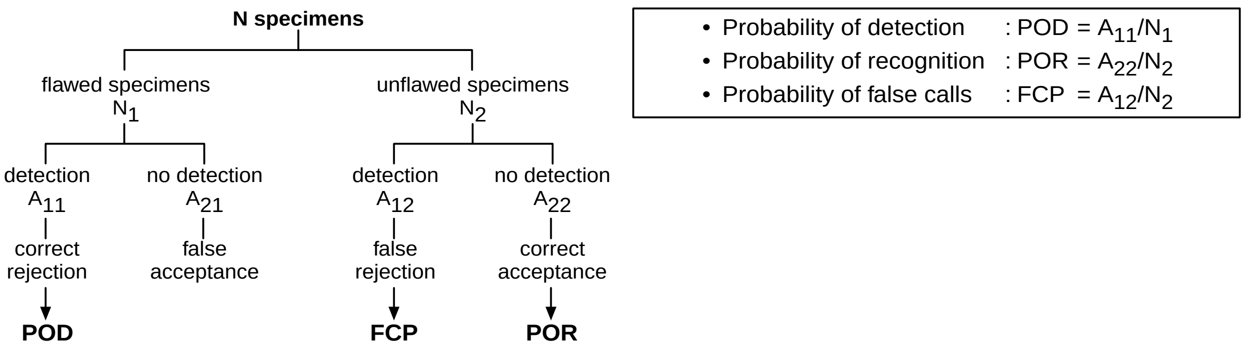

Fig. 2 The four possible outcomes of an inspection

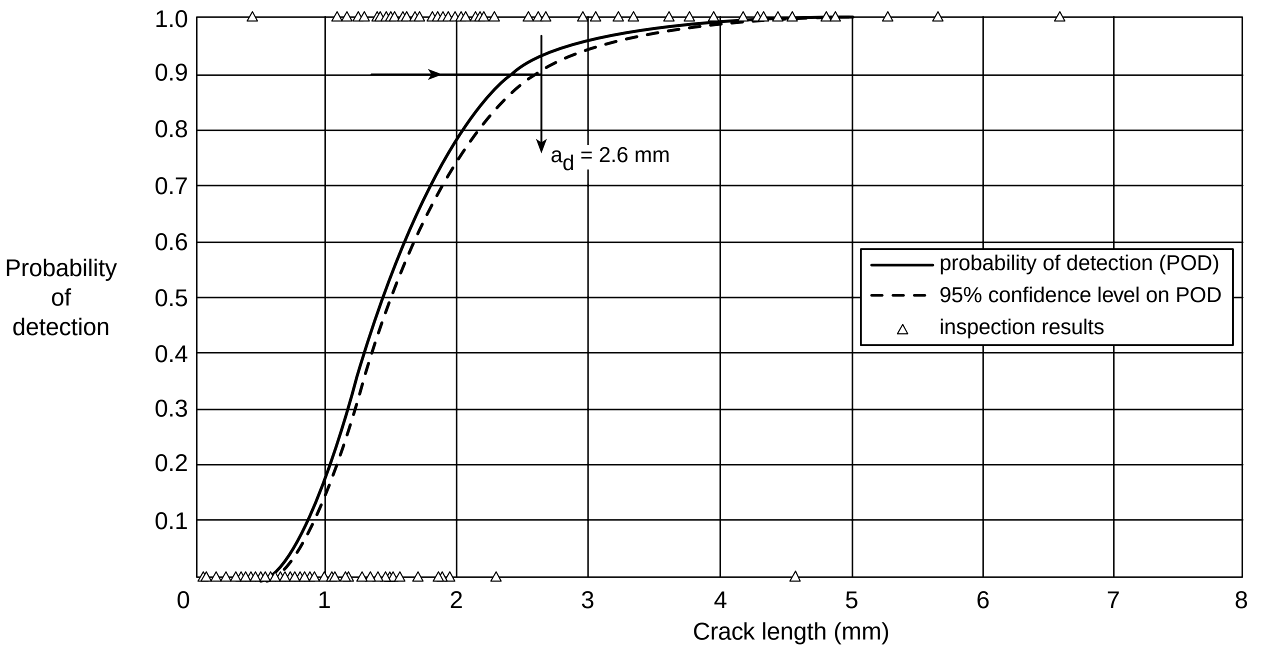

Fig. 3 Construction of a probability of detection (POD) curve, with its lower 95% confidence bound, from “hit/miss” data [Fig. 16 from Ref. 6].
Log-normal POD model with MLE parameter estimation procedure.
Reliably detectable flaw size a_d is 2.6 mm (here defined as the 90/95% POD/CL flaw size)

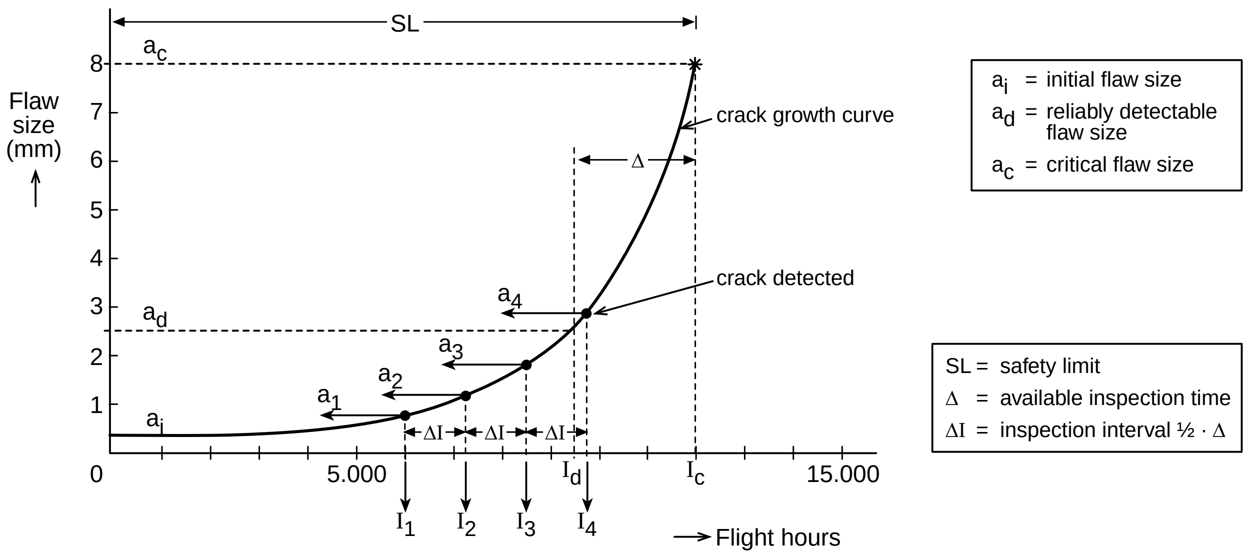

Fig. 4 Crack growth curve for a fictive ASIP control point, with the crack detected at the 4th inspection. Estimation of the crack sizes missed during the previous inspections I_1 (initial inspection), I_2 and I_3

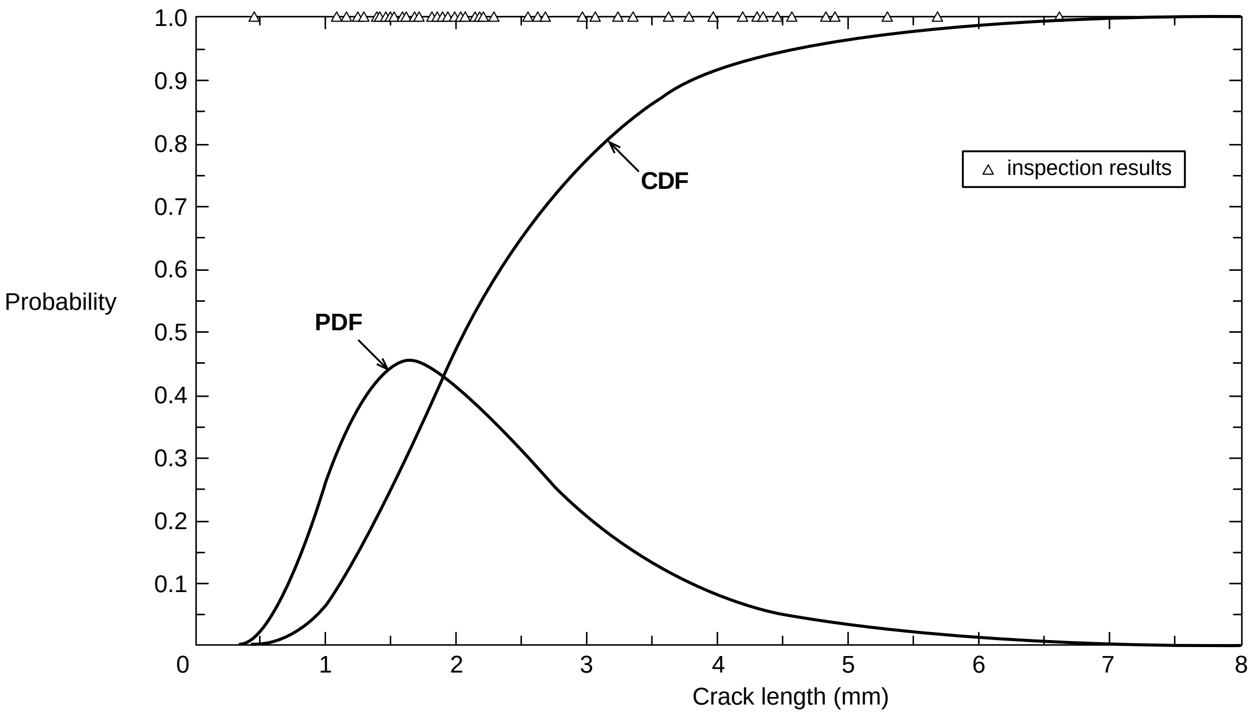

Fig. 5 Probability Density Function (PDF) and Cumulative Distribution Function (CDF) for the “hit” data (79 cracks detected) from figure 3

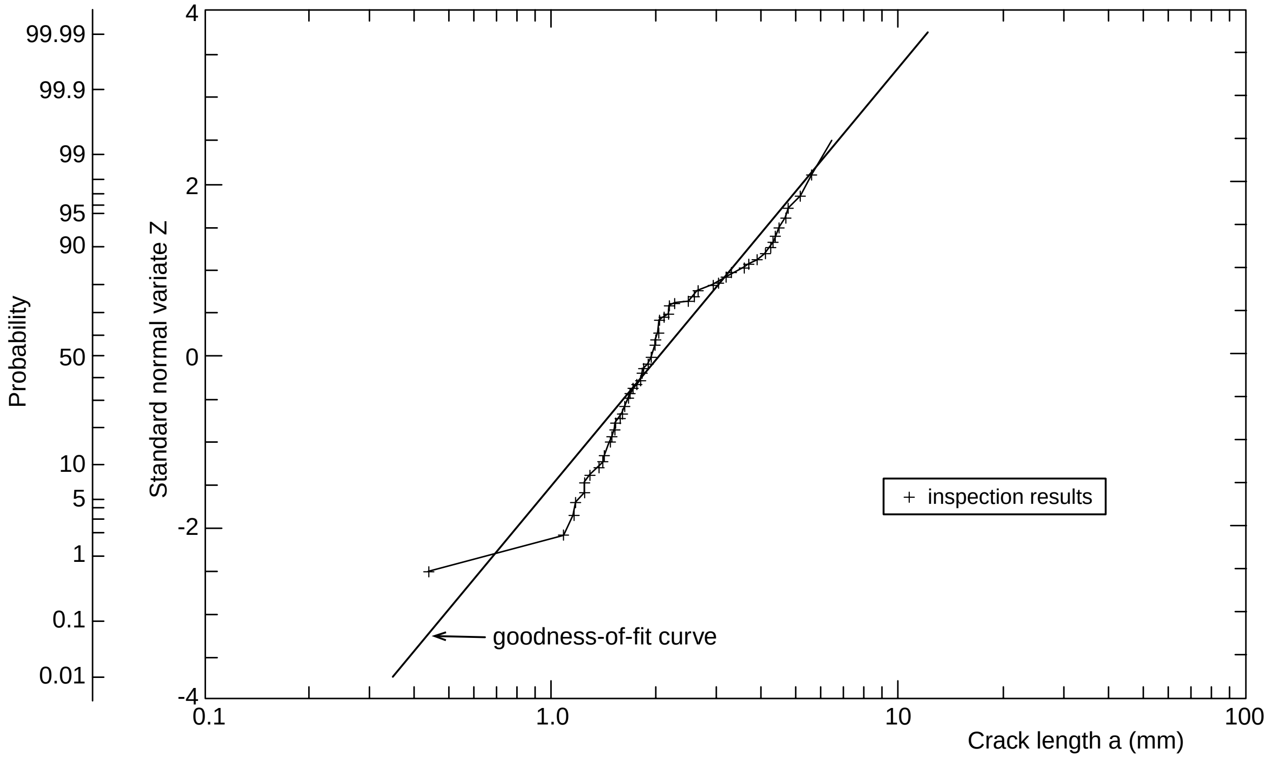

Fig. 6 Goodness-of-fit for the log-normal PDF estimation for the “hit” data from figure 3.
Standard normal variate z = (ln(a)–μ) / σ and its corresponding cumulative probability versus the crack length detected, plotted on log-normal probability paper

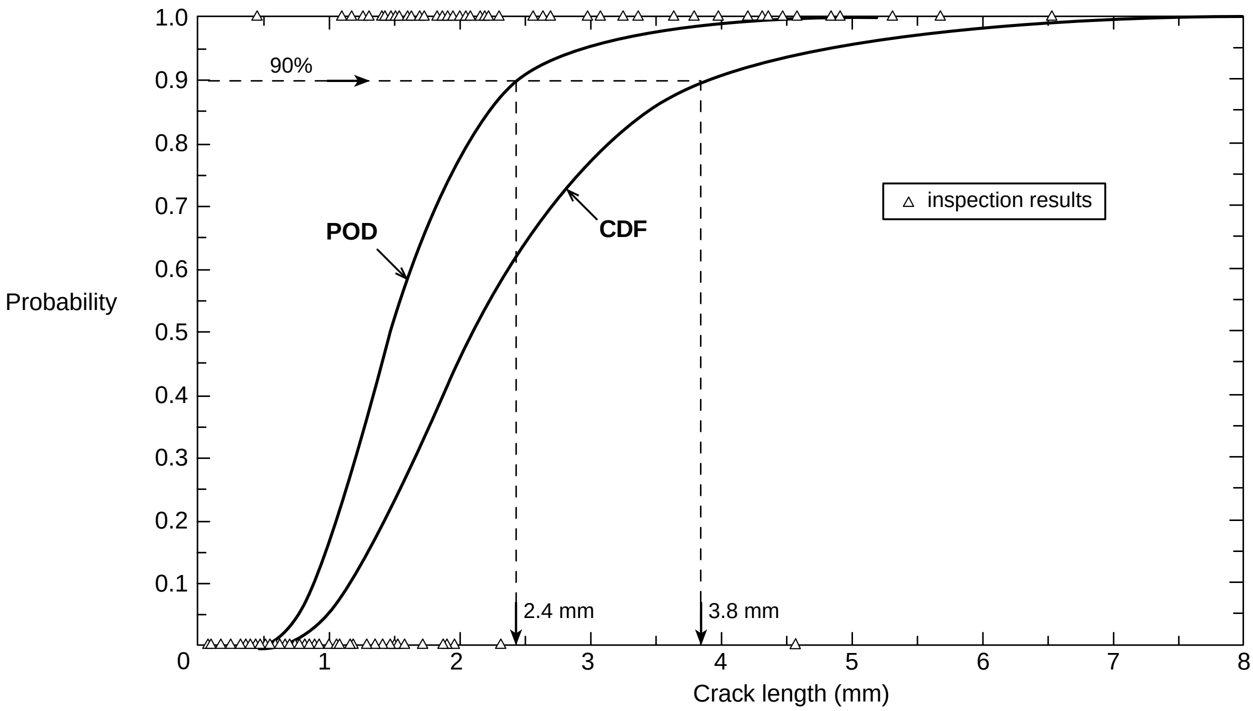

Fig. 7 Cumulative Distribution Function (CDF) for the “hit” data and Probability of Detection curve (POD, 50% confidence level) for the “hit/miss” data from figure 3

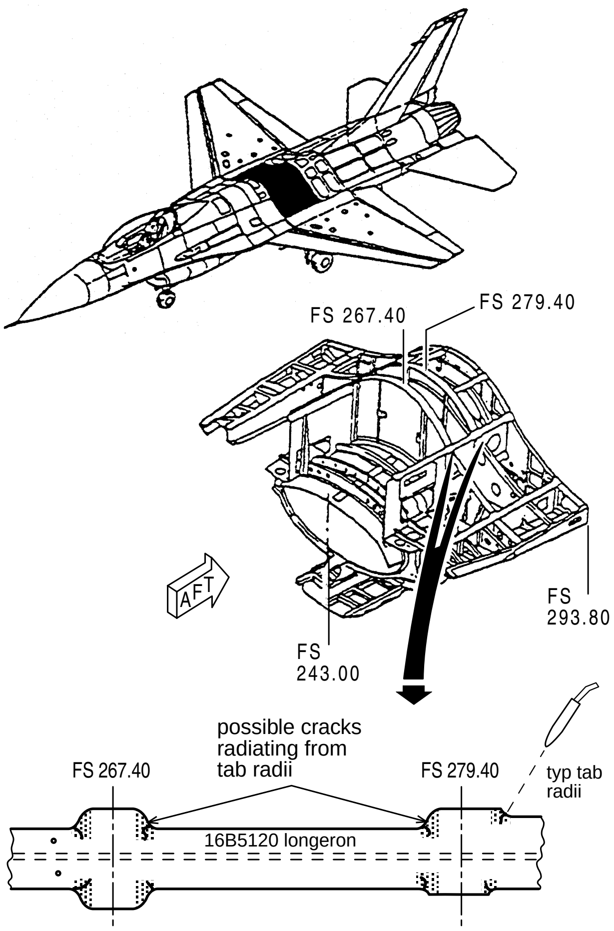

Fig. 8 F-16 ASIP 3005 inspection point. Manual eddy current inspection of the tab radii in the center fuselage longeron [Fig. 6-12 from Ref. 8]

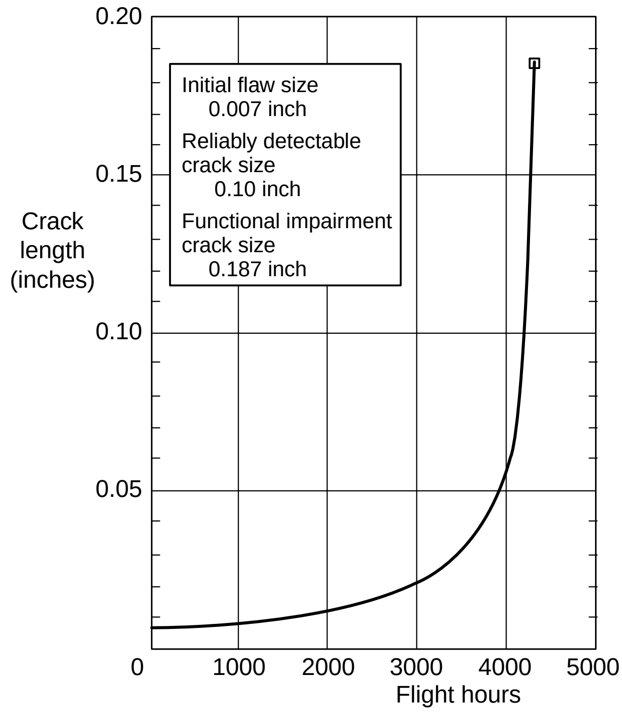

Fig. 9 Crack growth curve for the F-16 ASIP 3005 control point [Fig. 8.2.2-2 from Ref. 12]

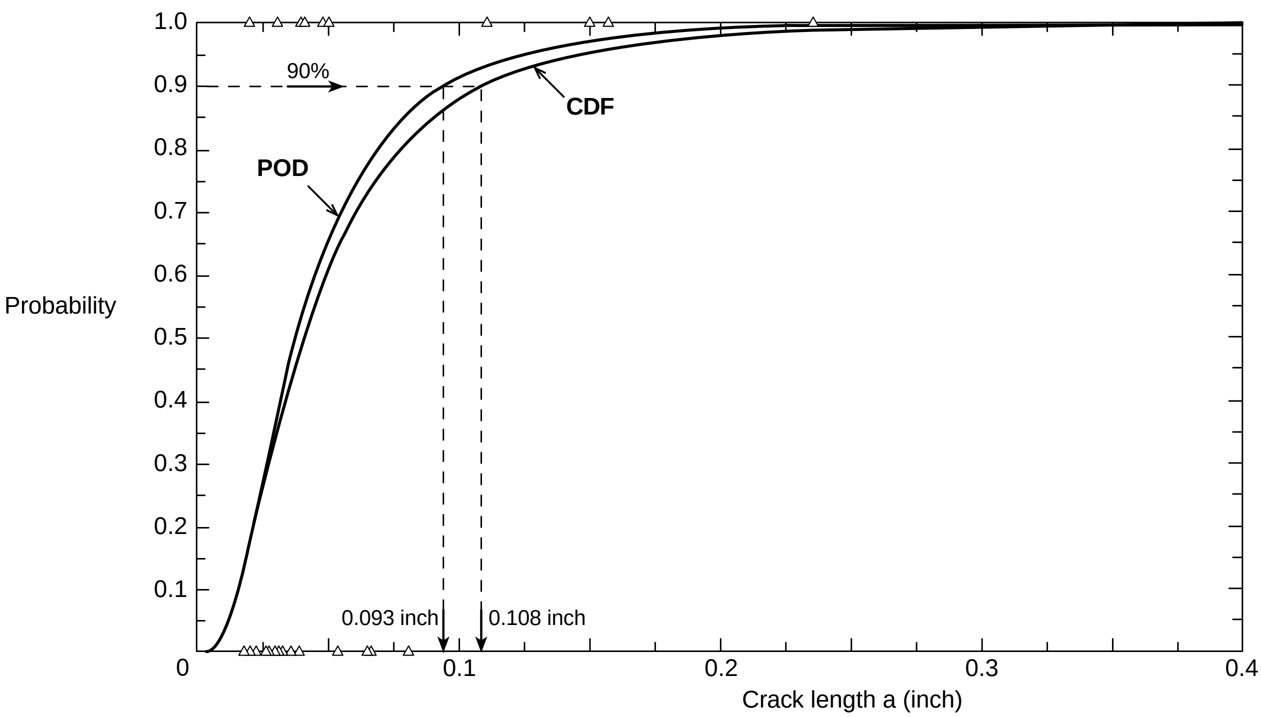

Fig. 10 CDF of 28 “hit” data points and mean POD curve of 64 “hit/miss” data points for the inspection of ASIP 3005, tab radii in the F-16 center fuselage longeron