Comando-Geral de Tecnologia Aeroespacial
Instituto de Aeronáutica e Espaço

Establishing Reliability of Inspection Interval for Structures Subjected to Fatigue Loads

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ASIP Conference 2007

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Establishing Confidence Level of Inspection Interval for Structures Subjected to Fatigue Loads

ASIP Conference 2007

Objective:

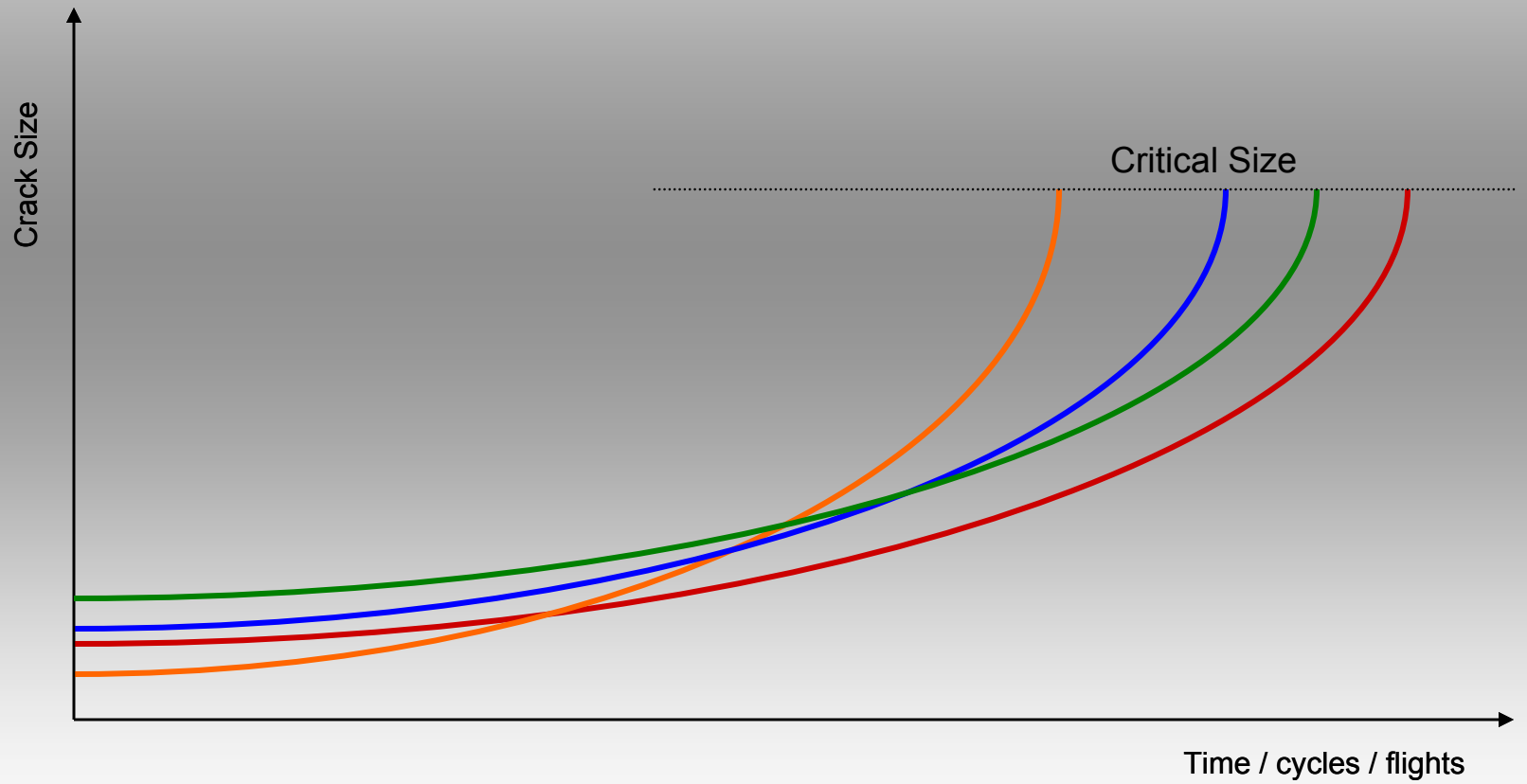
Determination of the Structure Reliability under fatigue loads, given the fracture mechanics analysis and the NDI Method.

Motivation

ASIP Conference 2004

One speaker showed concern about DTA philosophy

Understandable considering how uncertainties can affect predicted life

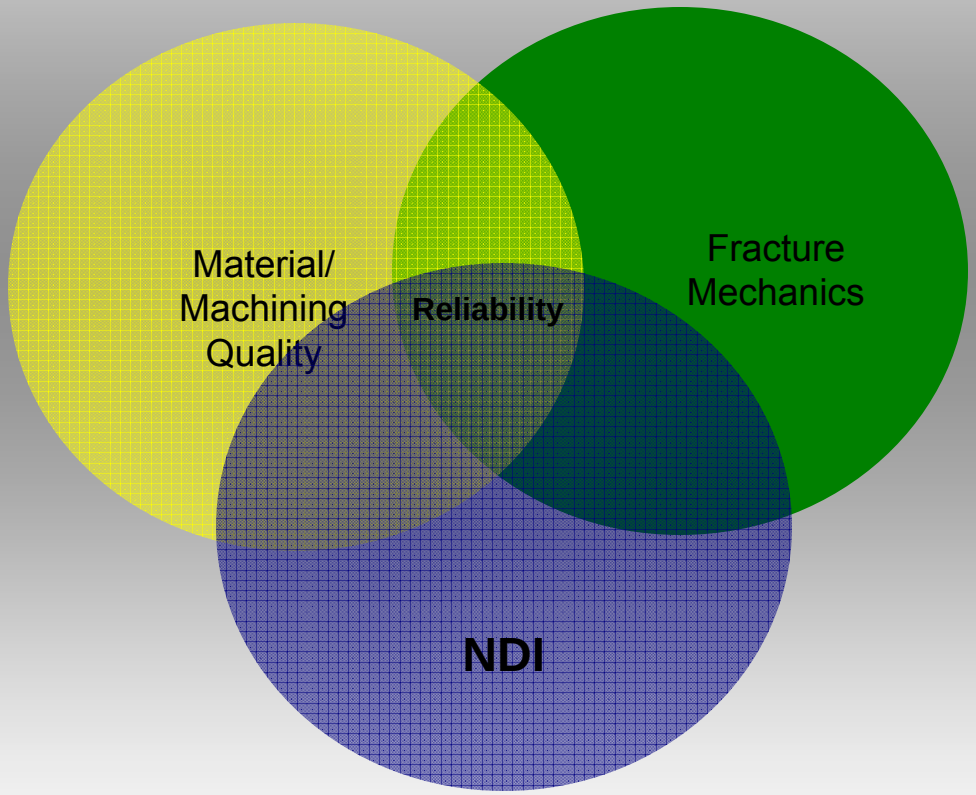

Crack Size
Critical Size
Time / cycles / flights

Outline

- Uncertainties
- Methodology
- Results
- Summary

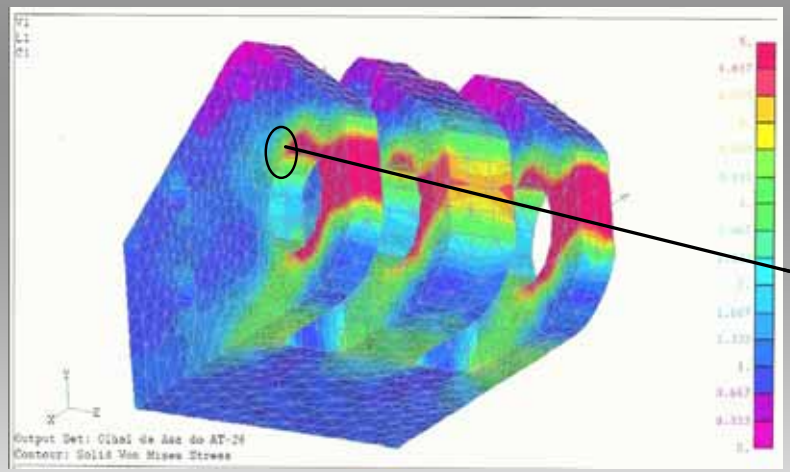
- Uncertainties

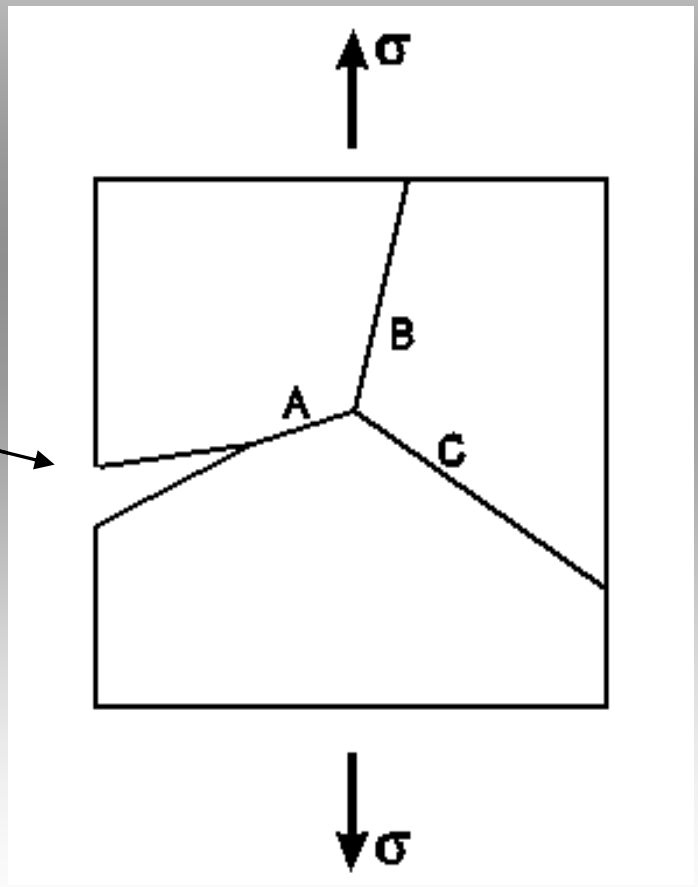
- Uncertainties



- Uncertainties

Initial and detectable size Quality Control

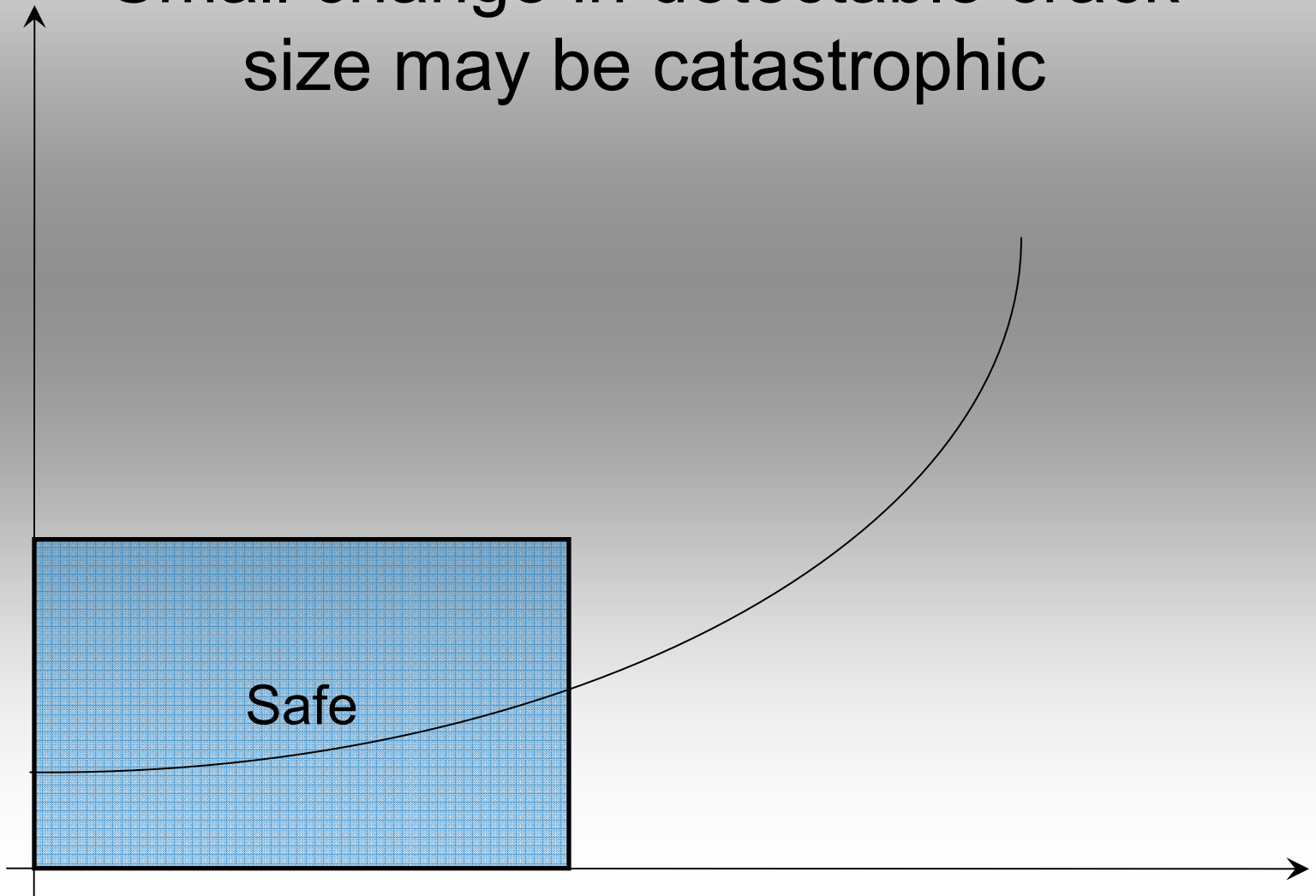




Crack is always there
Most NDI Method has resolution of 0.05 inch or worse

- Uncertainties

Small change in detectable crack size may be catastrophic



- Uncertainties

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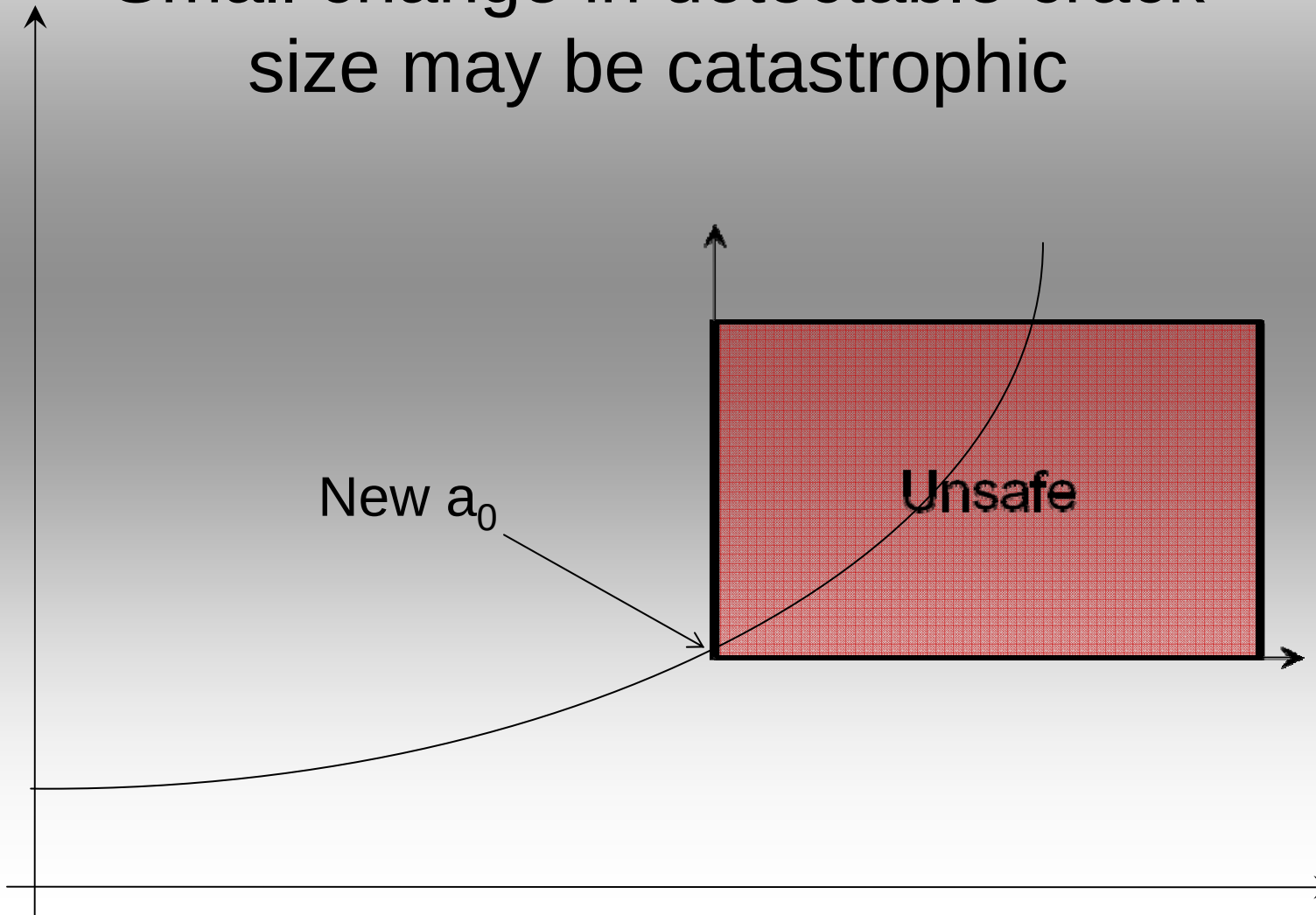
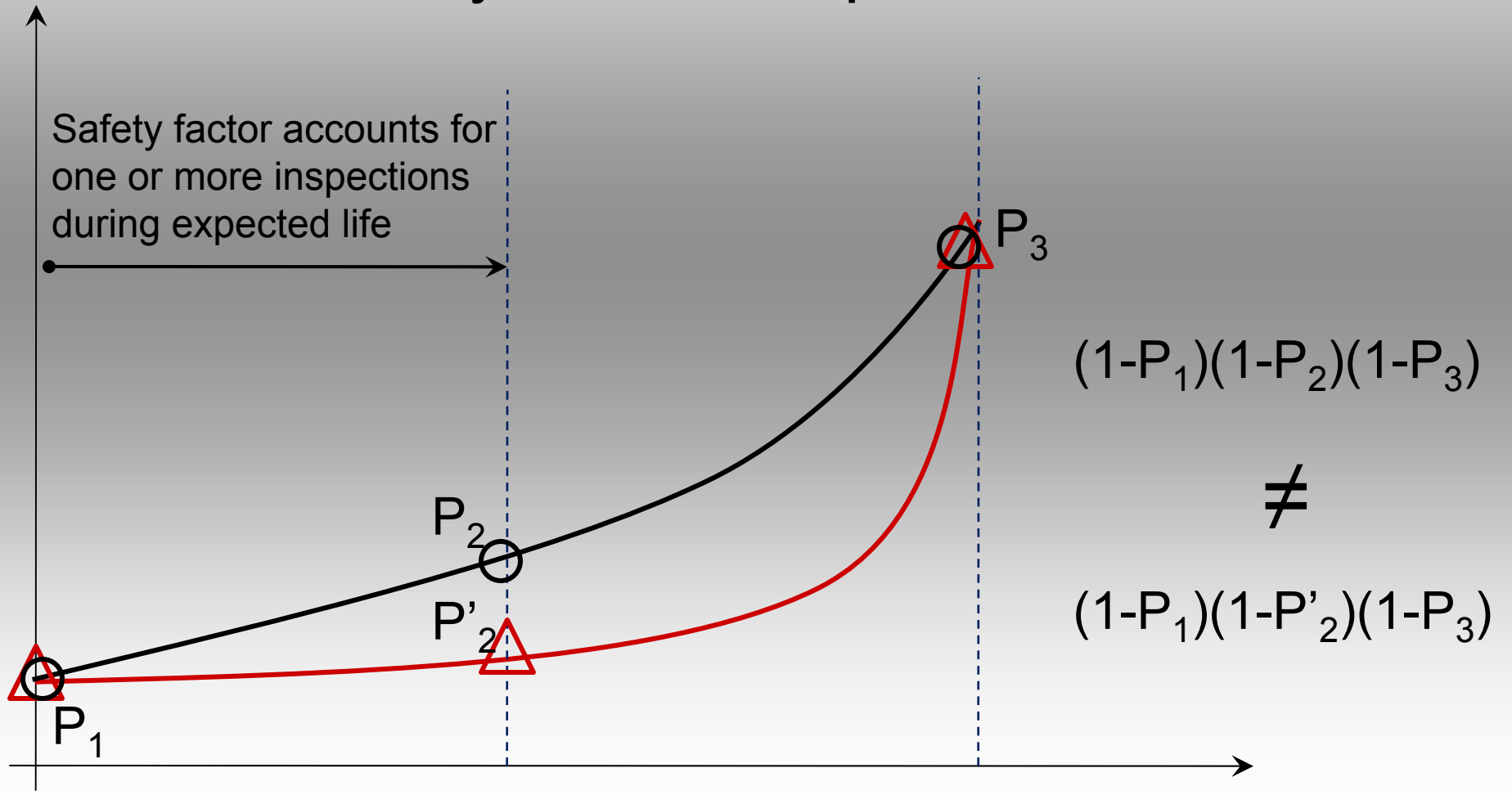


- Uncertainties

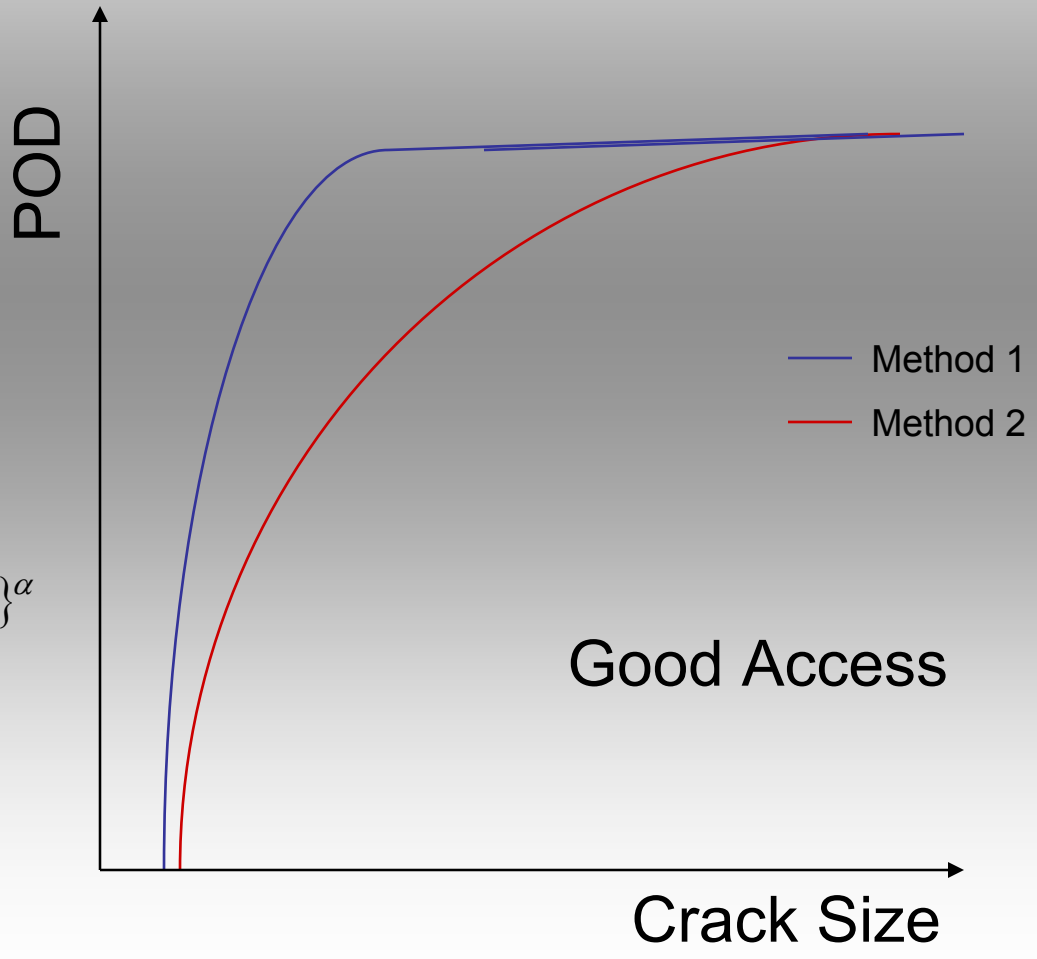
Usually, curve shape not a factor



- Uncertainties

NDI

$$p_{od} = 1 - e^{-\{(a-a_0)/(\lambda-a_0)\}^{\alpha}}$$



- Uncertainties

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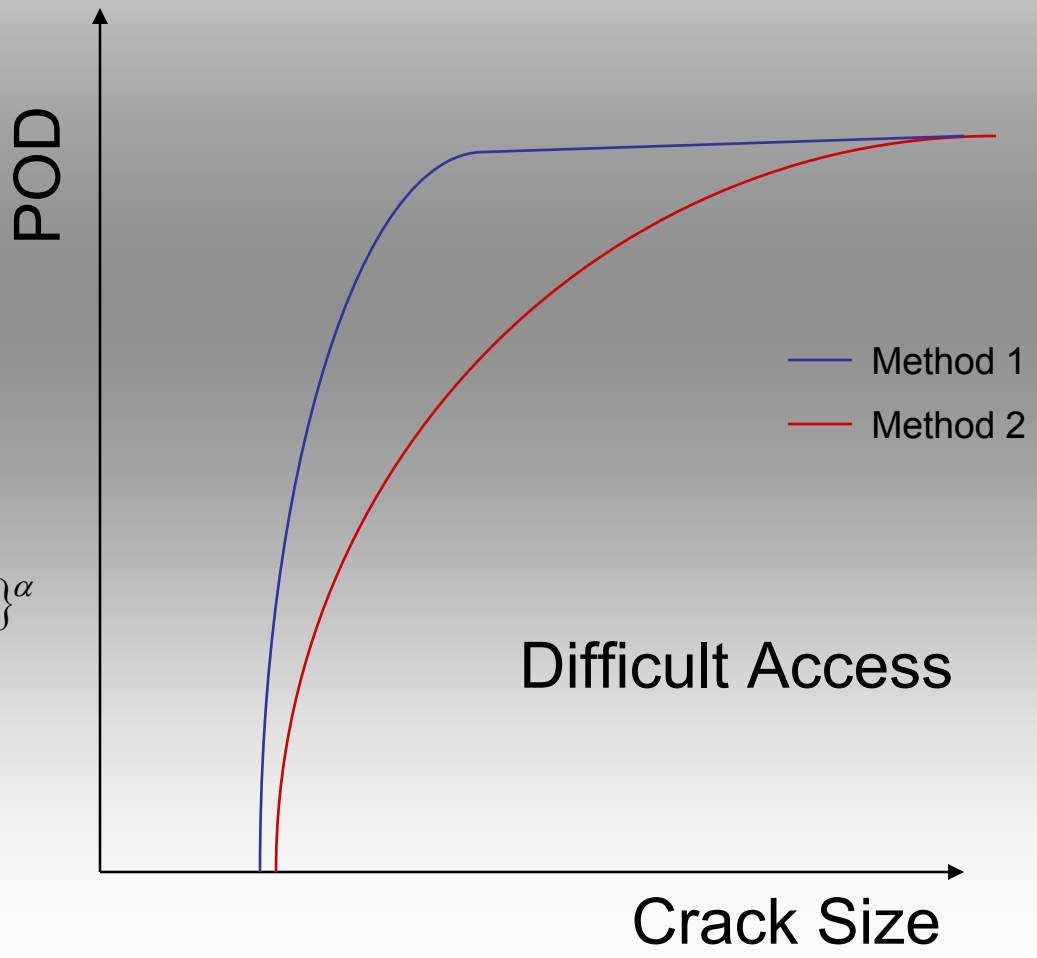
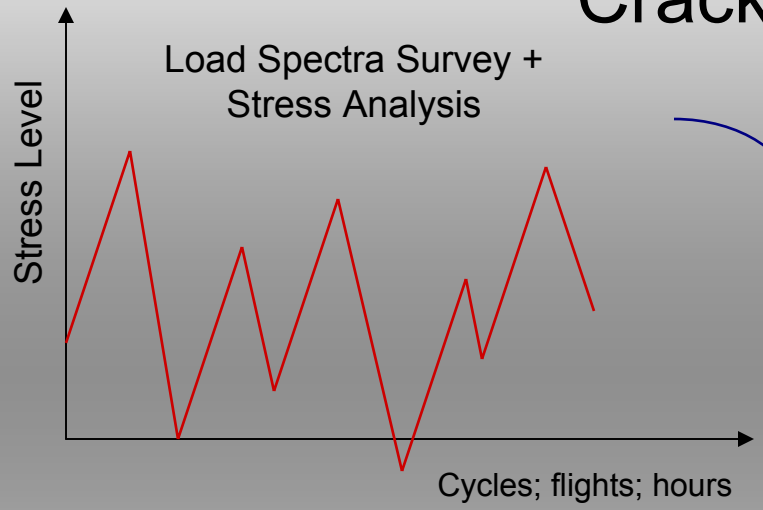
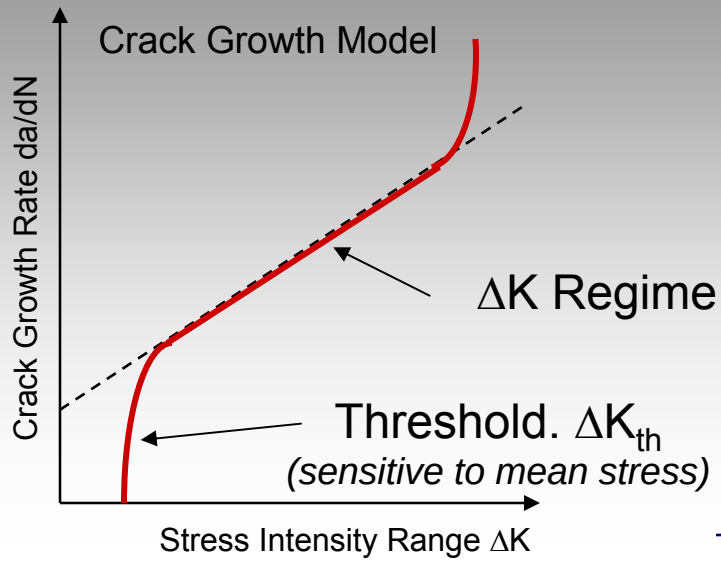


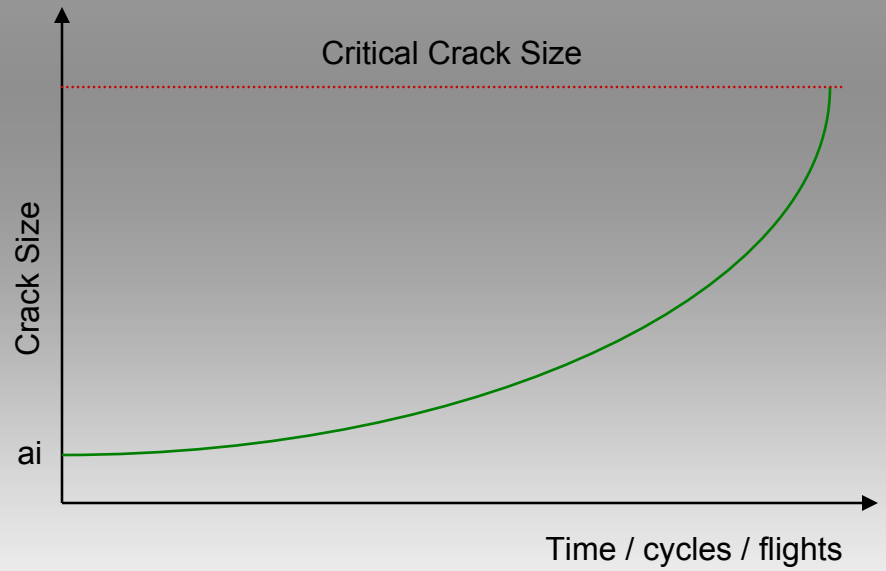
- Uncertainties

Crack Growth Curve

Past use to predict future



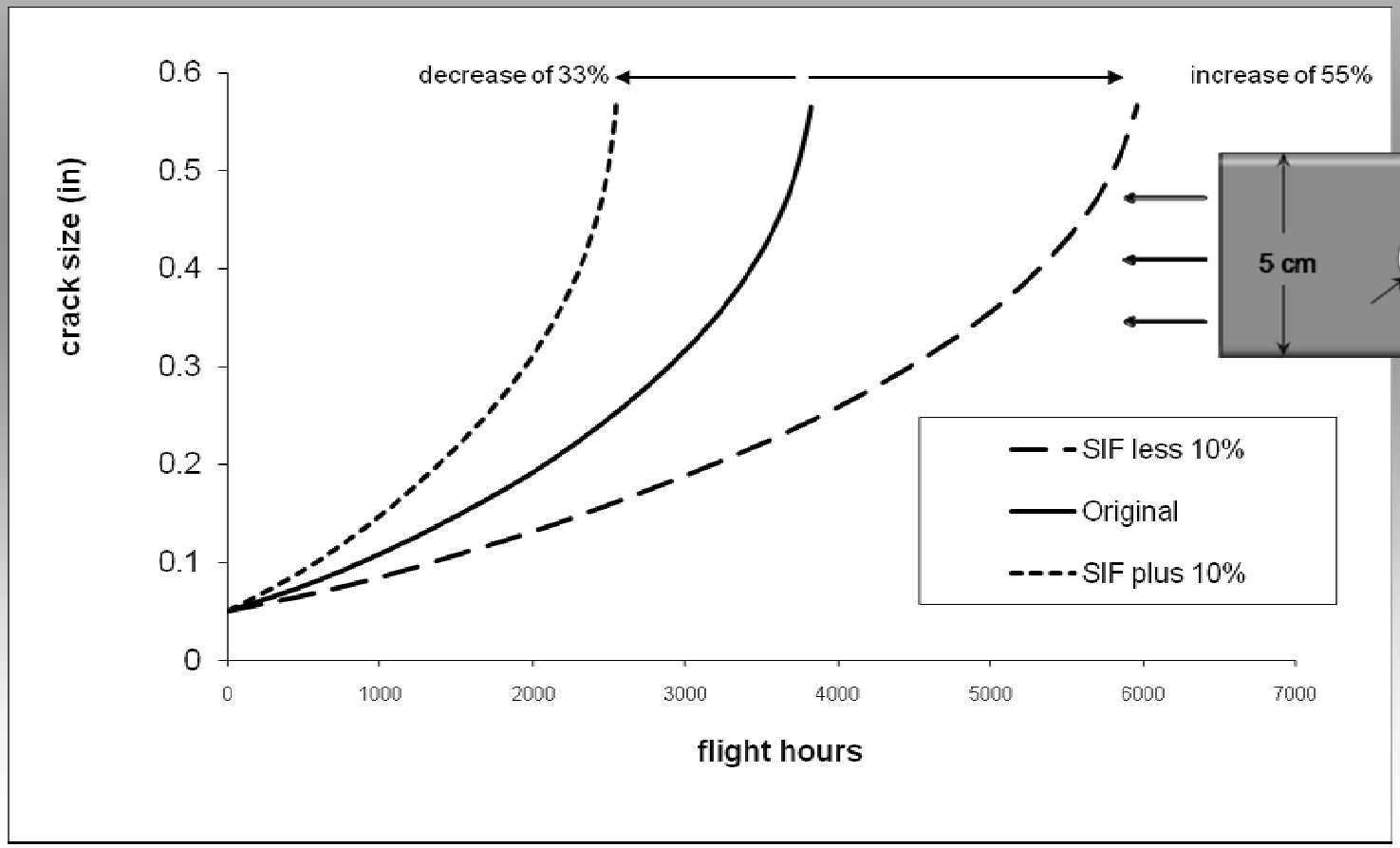




- Uncertainties

Uncertainties in the CGC

One simple example



- Methodology

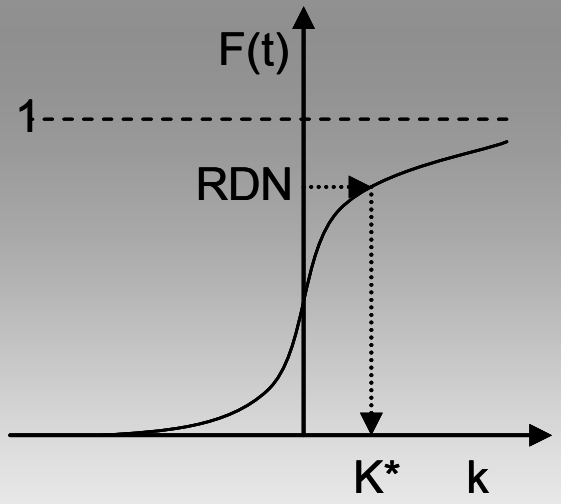
• Methodology

- Use of Monte Carlo Simulation – With option for Latin Hypercube

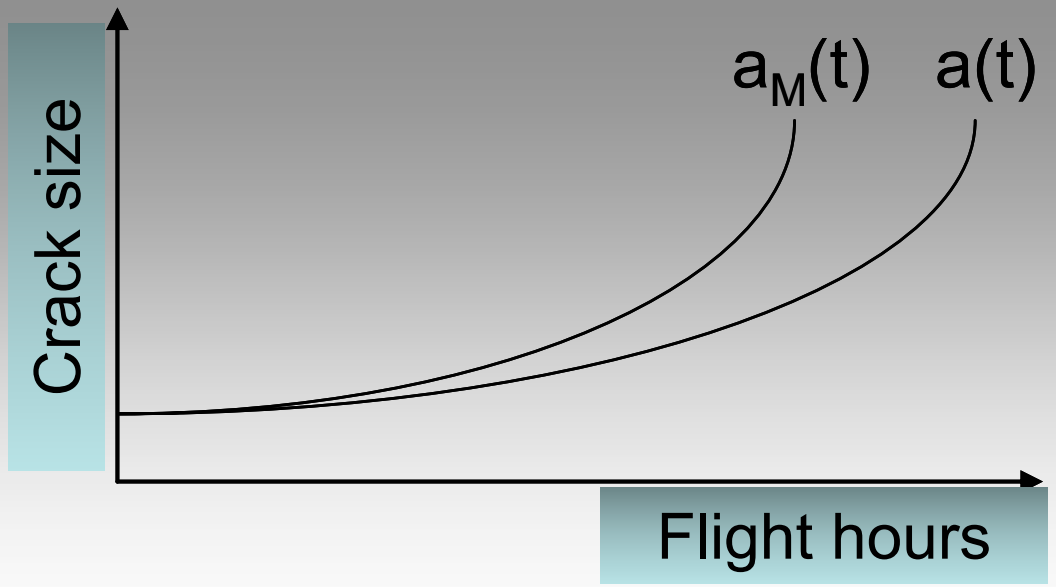
1. Initial crack is distributed between the intrinsic flaw defect and the minimum detectable size;
2. All parameters have uncertainties represented by their distribution. Crack growth curve may be pre-analyzed and growth rate summarized with just one (normal) distribution;
3. Probability of detection considered cumulative.

- Methodology

Basic process

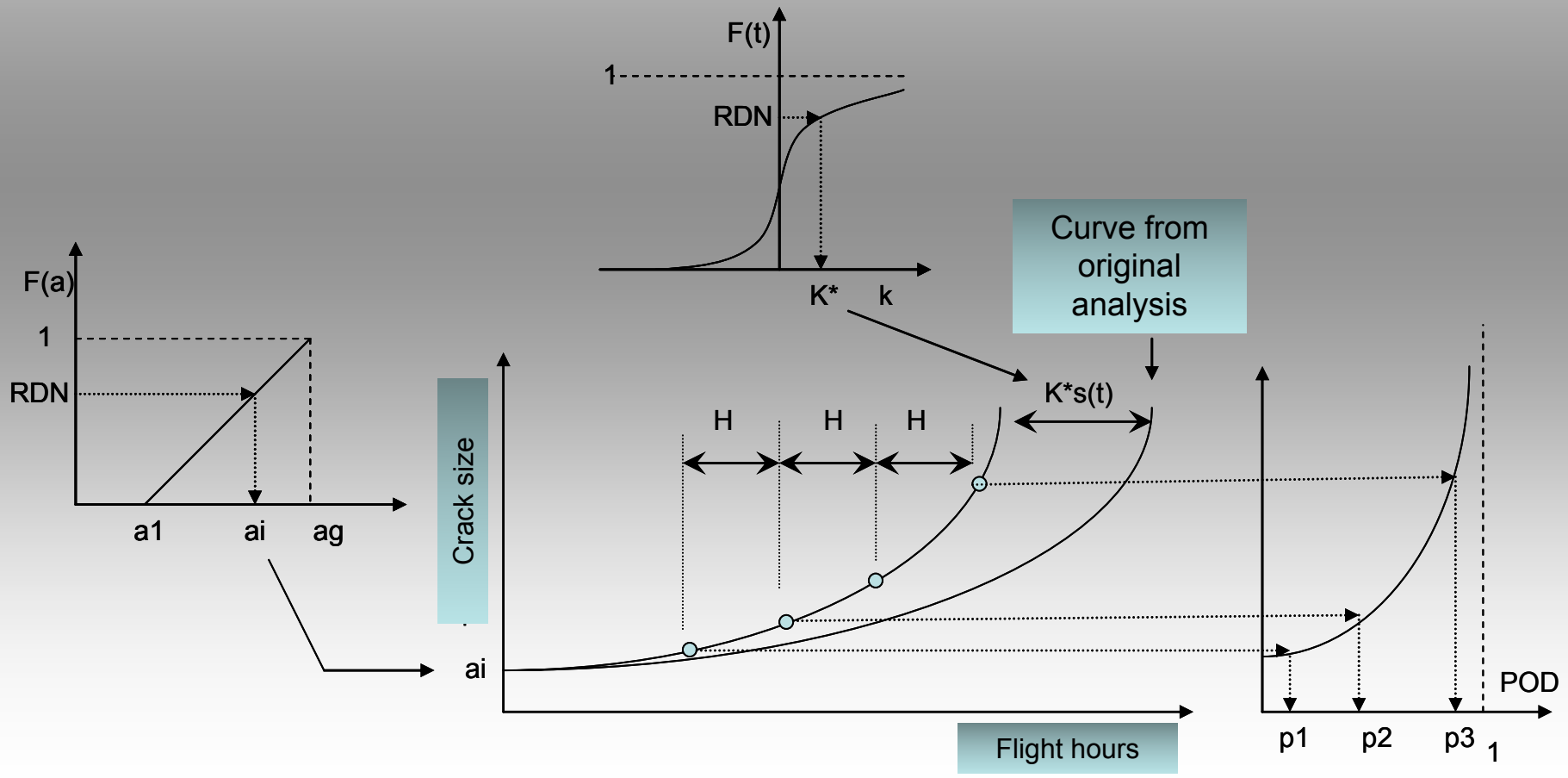


$$a_M(t) = a(t) + k^*s(t)$$



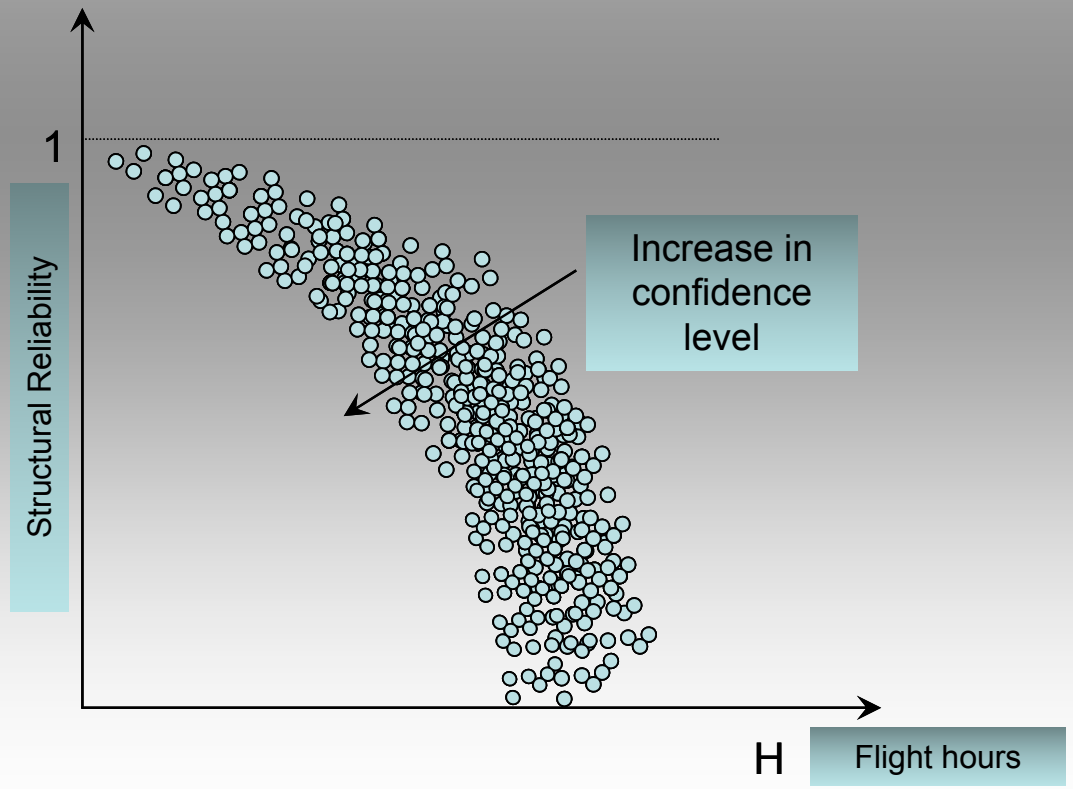
- Methodology

Overall Process



- Methodology

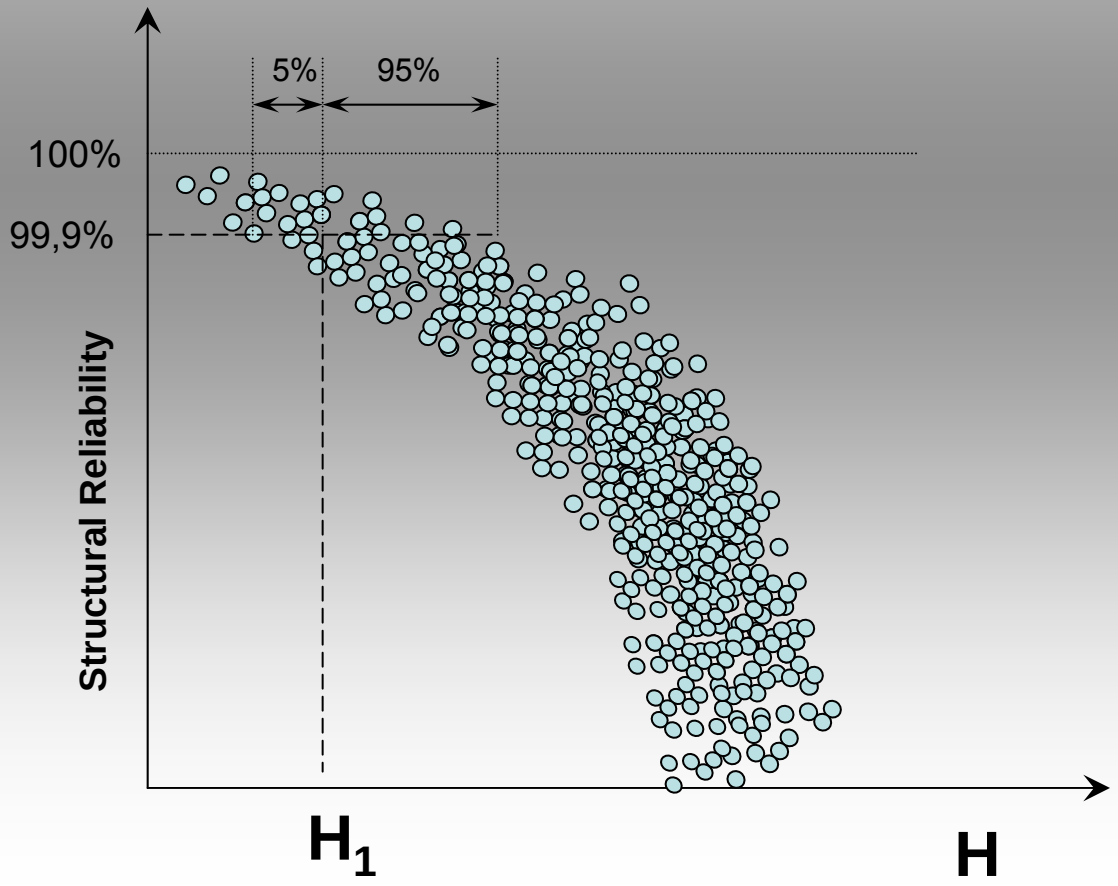
Expected Distribution in the *H vs Reliability chart – "cascade"*



- Methodology

Example of NDE interval characterization

for 99.9% During H_1 with 95% CL



For this case:

Risk during H_1 period = 0.001

Risk per flight hour defined as:

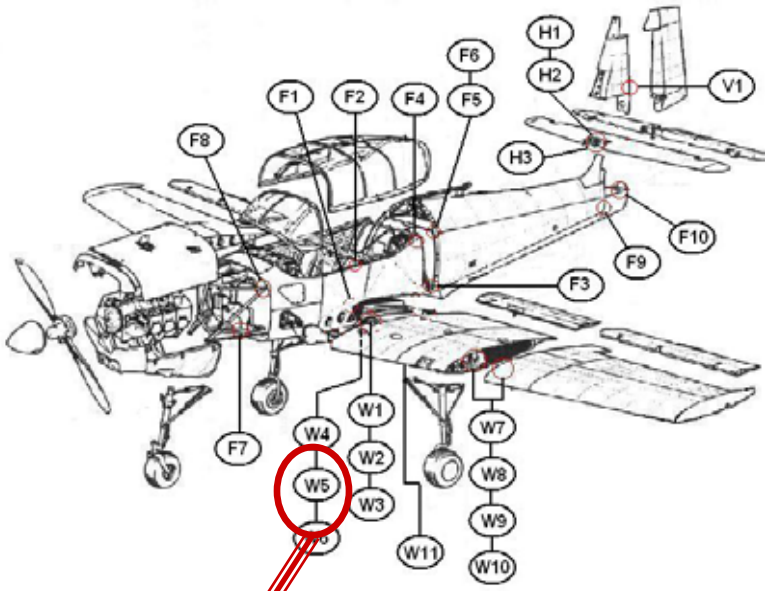
$R = 0.001/H_1$

- Results

- Results

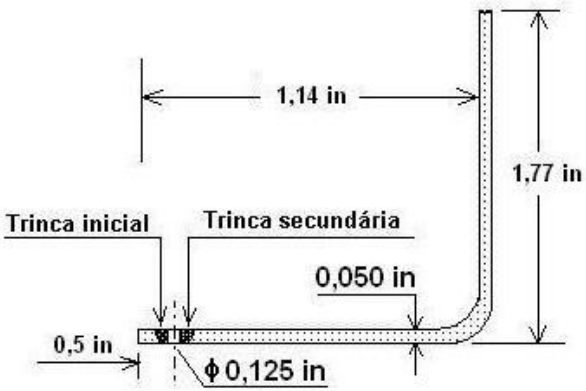
T-25 Universal – Basic Trainer

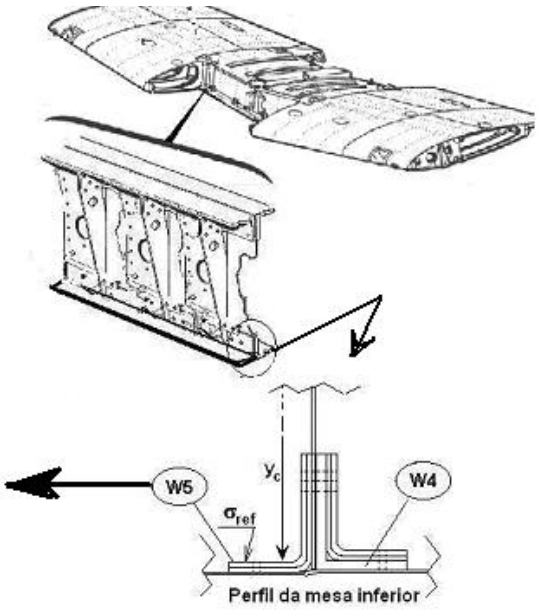
Wing Main Spar



W5 – Spar lower cap

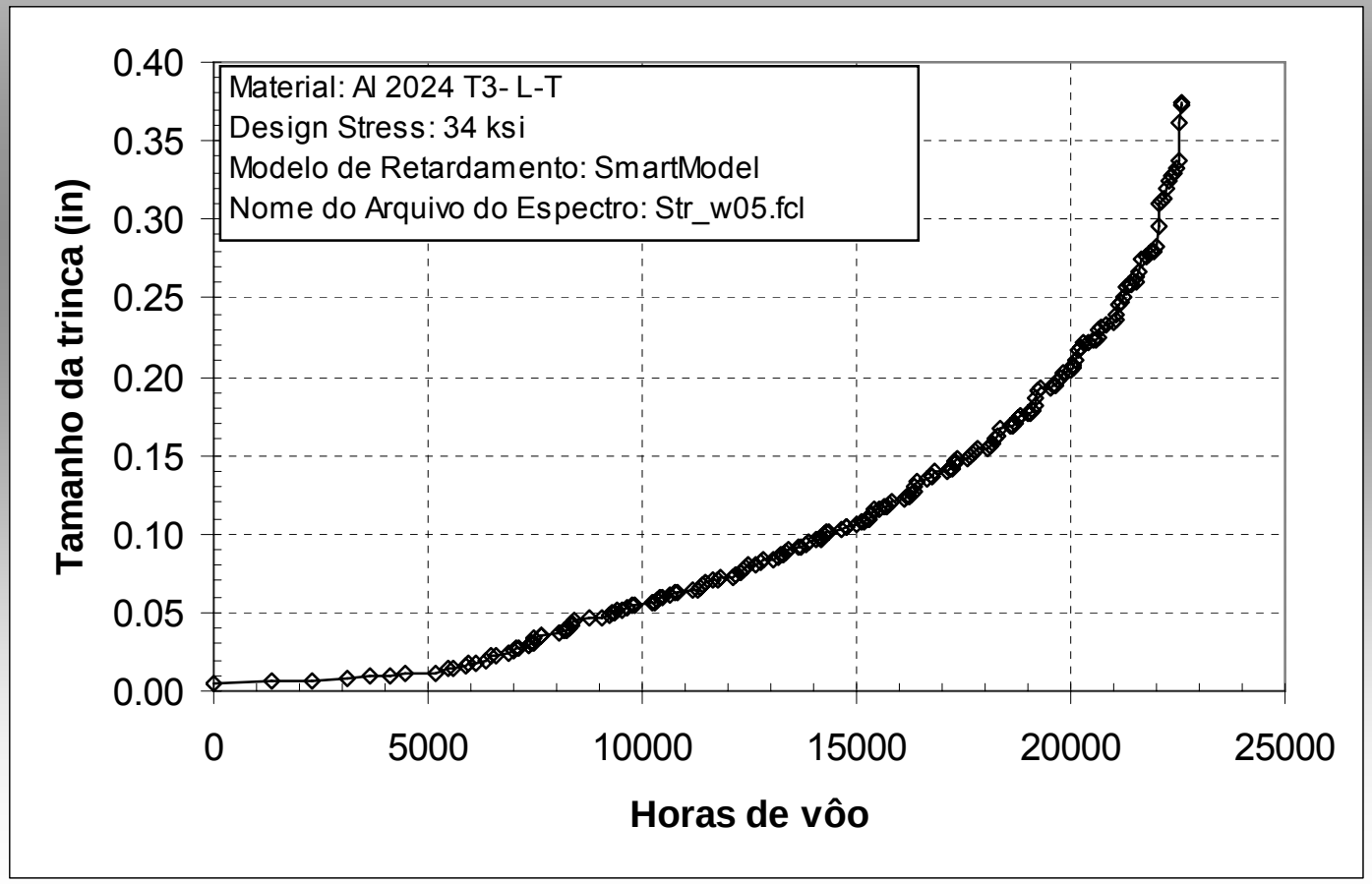
(PN 621-510-40)





- Results

Best available data gives:



NDI: Dye Penetrant

90/95% initial detectable size:

$a_{90/95}$ = 0.1 in

SF = 2 ➔

H = 4,175 FH

- Results

Parameter	Unit in mm	Units in inches
a_0	0,762	0,030
λ	1,65	0,065
α	0,50	0,50

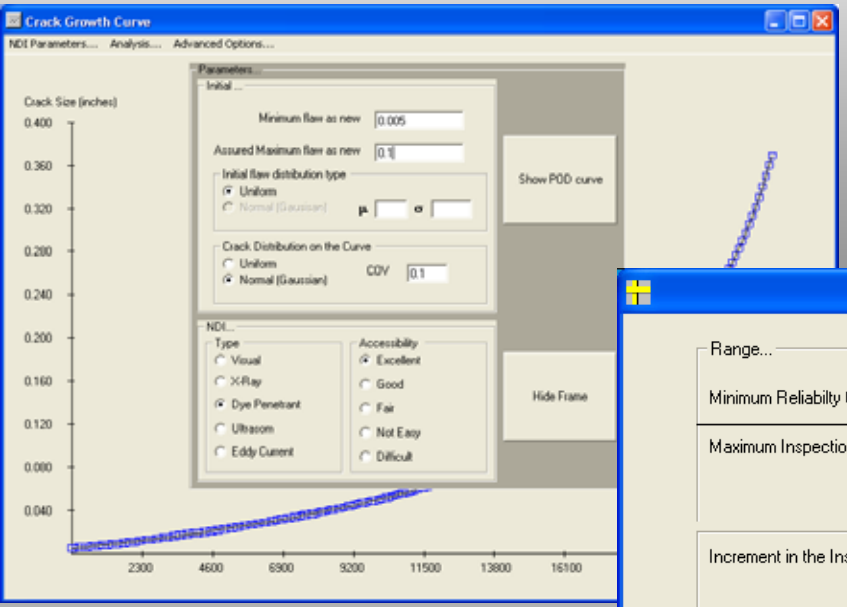
$$p = 1 - e^{-\left\{(a-a_0)/(\lambda-a_0)\right\}^{\alpha}}$$

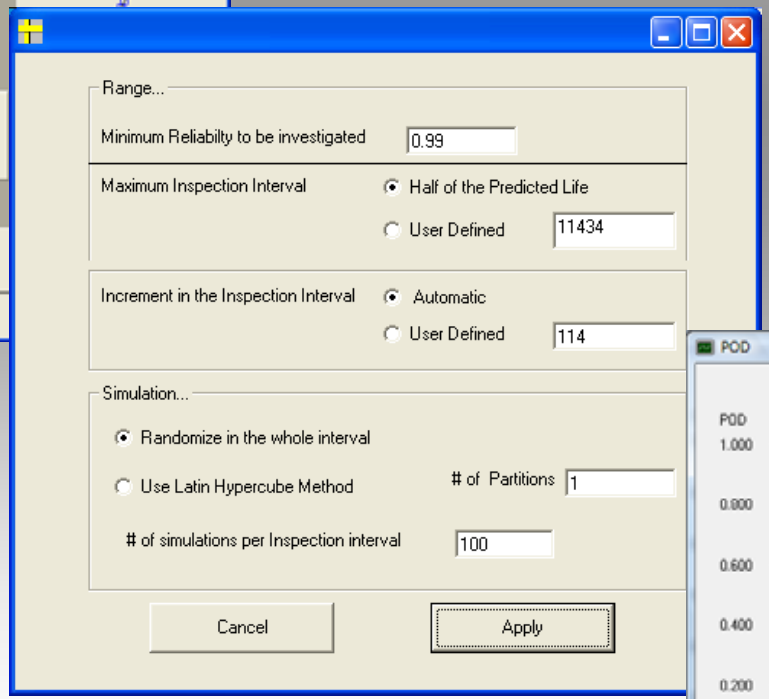
FAA AC AMJ 25-1309

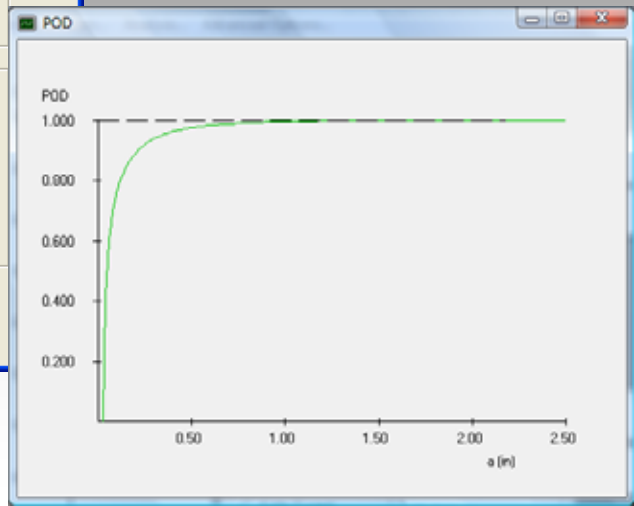
Qualitative probability	Risk probability by flight hour
Extremelly improbable	10^{-9}
Extremelly remote	10^{-7}
Remote	10^{-5}
Probable	10^{-3}

- Results

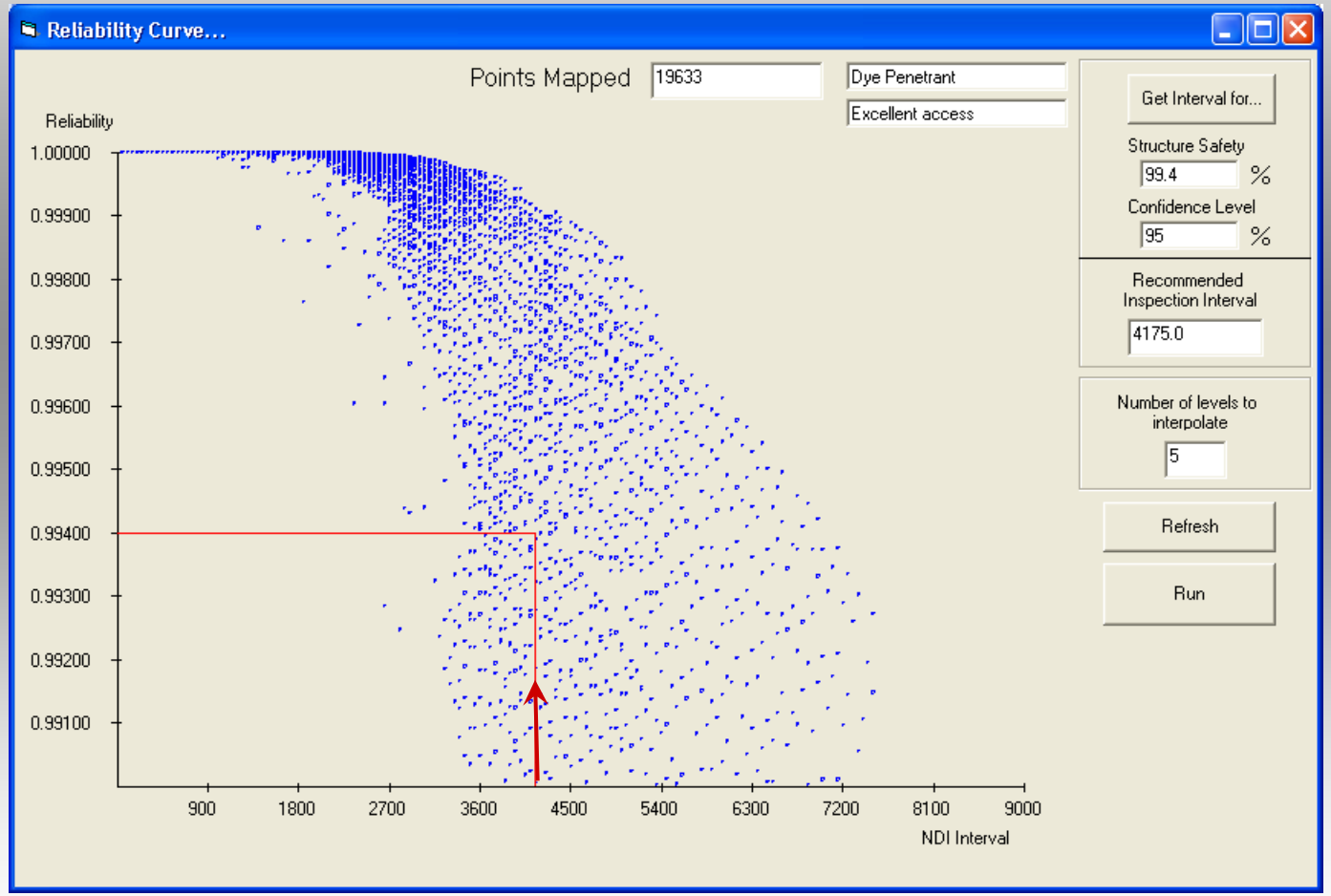
Some setup screens







- Results



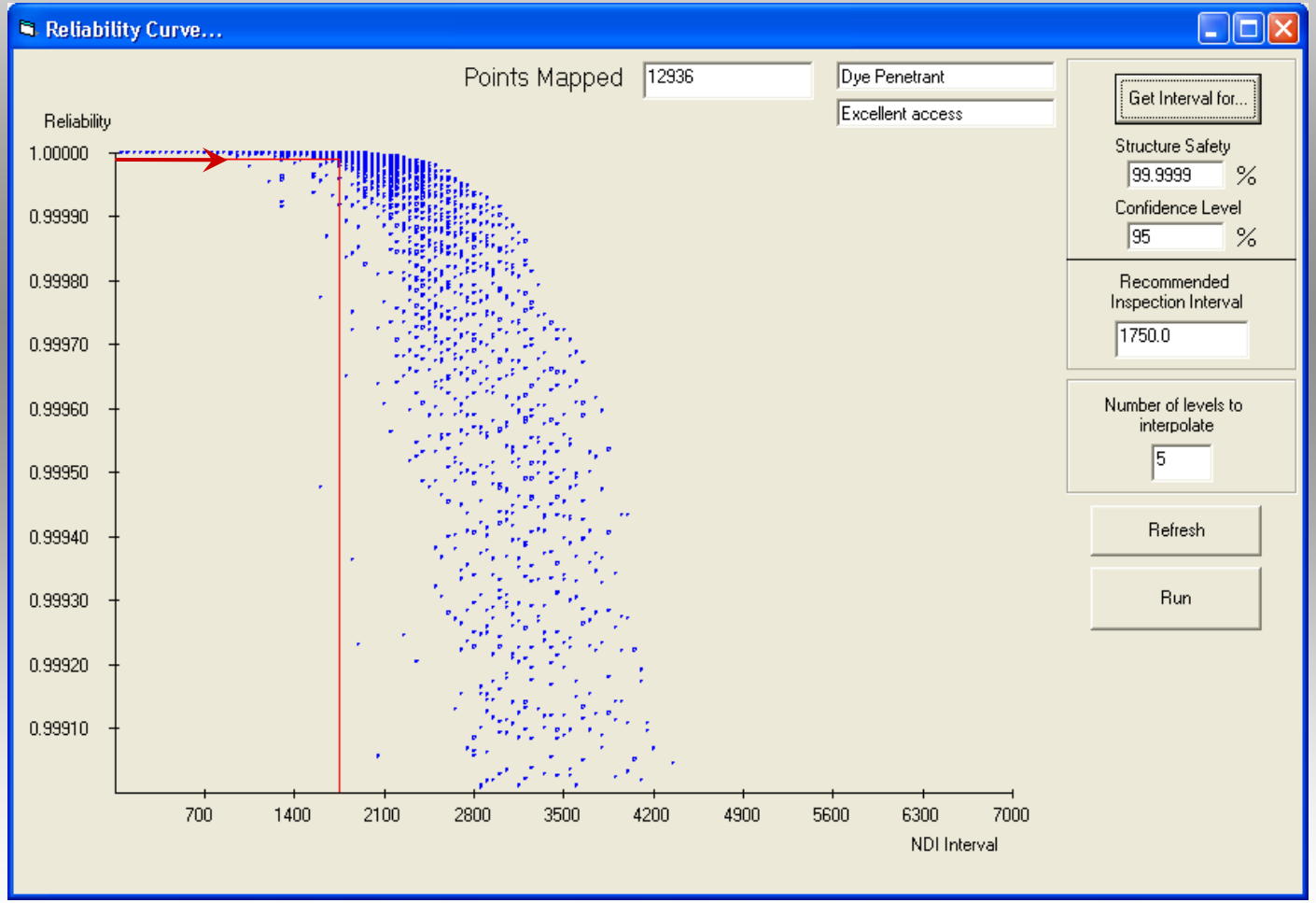
Risk from original DTA NDI interval:

$0{,}006/4175 \sim 10^{-6}$ per flight hour

➔ 1 in 1 million

➔ Remote risk

- Results



Define interval for a risk of: 1 in 1 billion

0,000001/1750 ~ 6 10^{-10} /flight hour

➔ ~ 1 in 1 billion

Suggested interval is 1.750 fh for this case

- Summary

- Summary

  - Initial crack size and crack growth curve considered to have scatter
  - POD was considered be a function of the NDI method, accessibility and crack size
  - Monte Carlo simulation is used to obtain the inspection Interval, given a desired safety and confidence level
  - It is necessary to run the program several times and refine the search according to the aimed reliability

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