Australian Government
Department of Defence
Defence Science and
Technology Organisation

Preliminary Probabilistic Risk Analysis of a Plate with Multiple Open Holes Considering Multi-Site Damage

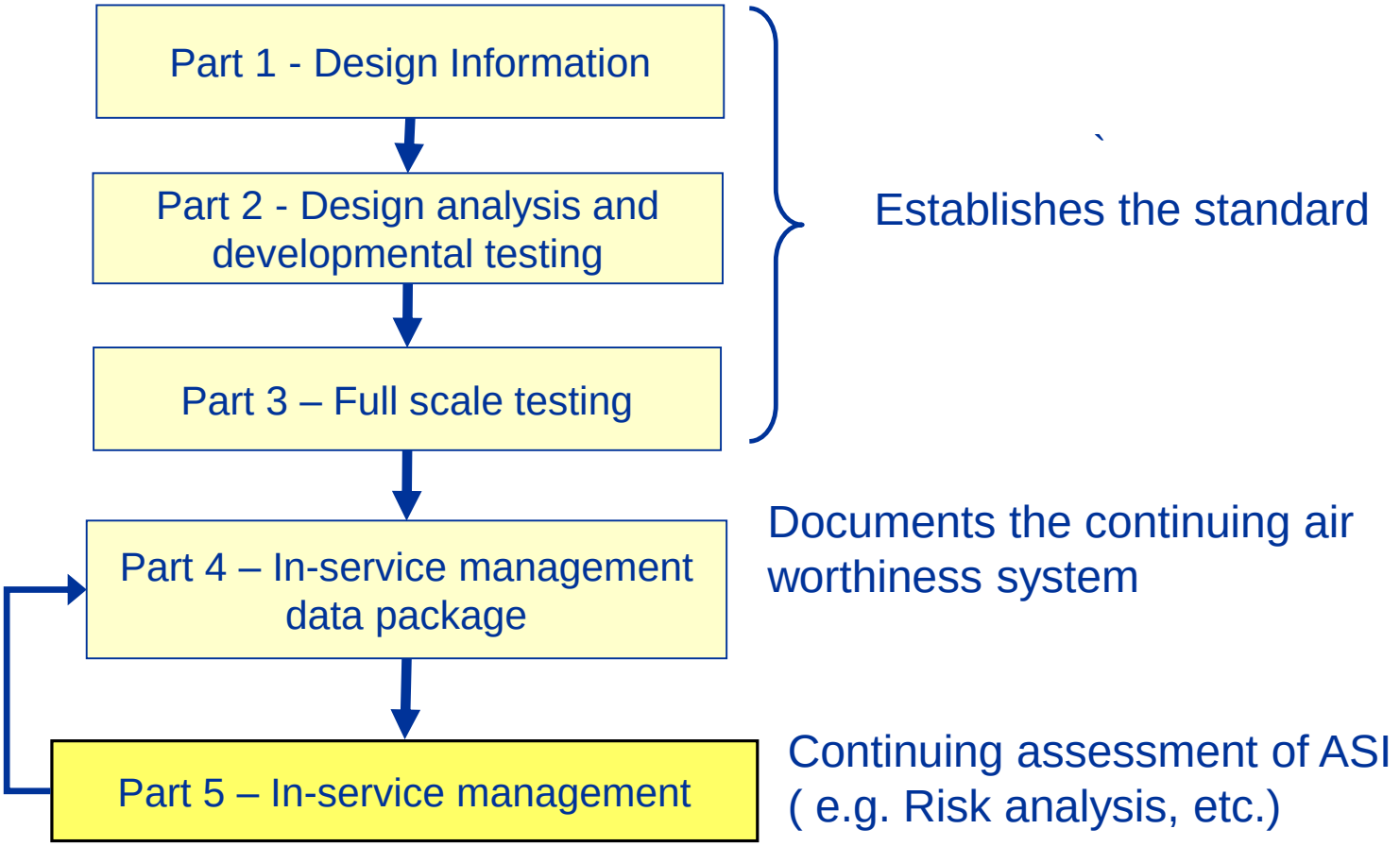
Dr. Ribelito Torregosa and Dr. Weiping Hu
Air Vehicles Division, DSTO, Australia

Presented by Ribelito Torregosa

Outline of the presentation

- Relevance of Probabilistic Risk Analysis (PRA) to aircraft structural integrity assessment and management of military aircraft
- Conventional phase by phase (PBP) risk analysis
- Multi-site damage (MSD) risk analysis
- Comparison of results between different MSD scenarios
- Conclusion

Role of probabilistic risk analysis in ASIP



Aircraft Structural Integrity Program (ASIP) Parts

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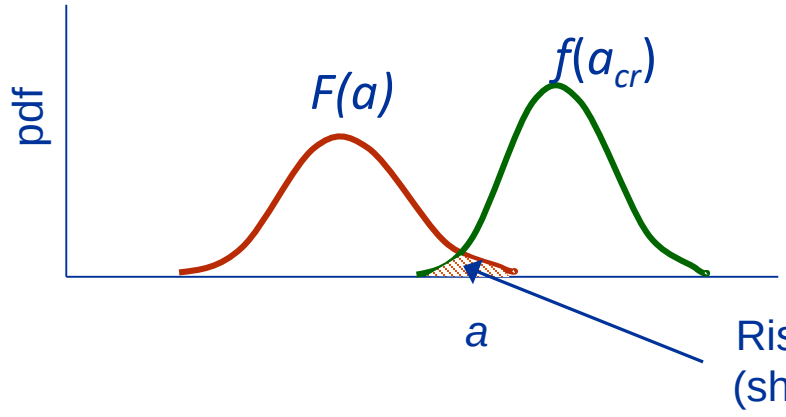
Definition of Risk

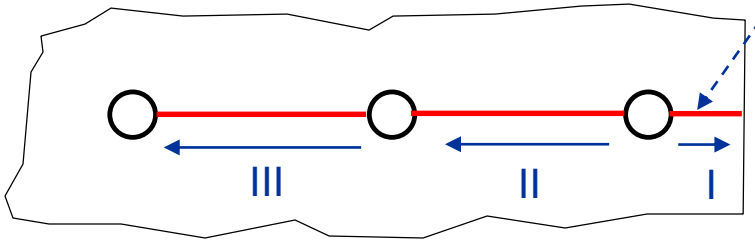
- For a component that contains a crack, the risk is the probability that the component will fail due to sudden fracture during the next flight.
- If the component is a key structure, then its failure also signals the failure of the aircraft
- The probability that a crack size, a exceeds the critical crack size, a_{cr} as described in the figure below.



F(a) : distribution of crack sizes

F(a_{cr}) : distribution of critical crack sizes

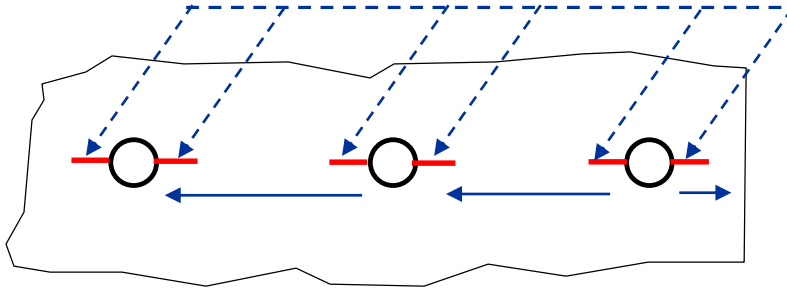
Risk analysis methods



Crack grows in phases

- Simple and easy to analyze
- commonly used method

1) Phase by phase approach



Multiple cracks grow simultaneously

- Complicated procedure
- Realistic

2) Multisite damage (MSD)

Focus of this presentation

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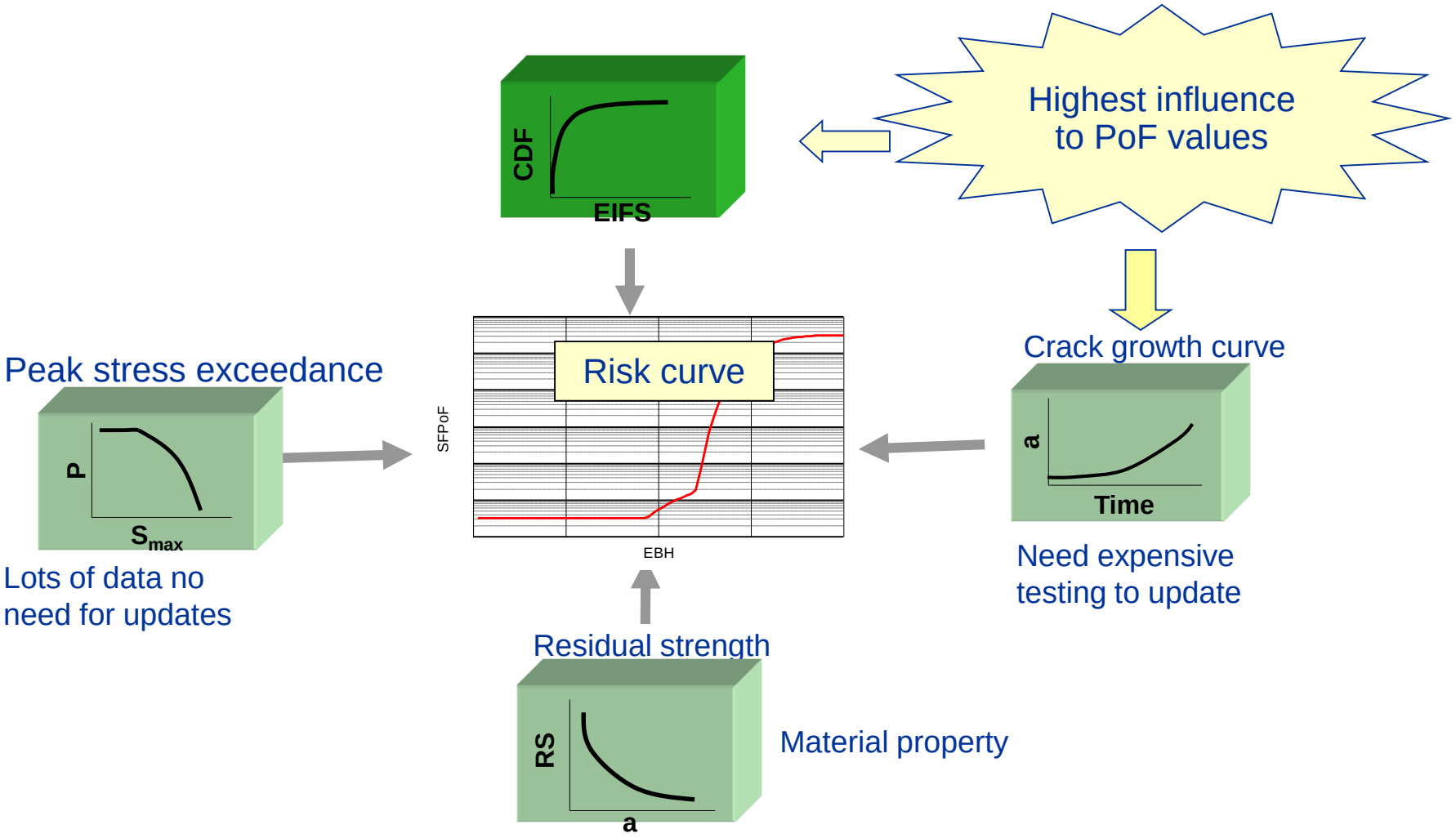
Risk analysis methods (cont.)

- At least four groups of data are required for risk analysis
  - ✓ The distribution of the initial cracks
  - ✓ A crack growth curve from DADTA analysis
  - ✓ The exceedance distribution of the service load
  - ✓ The residual strength distribution of the crack configuration

- From experience, the data of most influence are
  - ✓ The distribution of the initial cracks
  - ✓ The crack growth curve from DADTA analysis

Graphical Representation of the Input Data



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Why MSD analysis is important?

☞ Maintaining structural integrity

"**multiple-site damage** could cause many small cracks in the structure, which grow slowly by themselves, to join one another over time, creating a much larger crack, and significantly reducing the expected time until failure"

☞ Required by standard

"Durability criteria apply to all airframe structural components and shall include criteria that pertain to the onset of **widespread fatigue damage**"

☞ MIL-STD-1530C (USAF) 5.1.3.4

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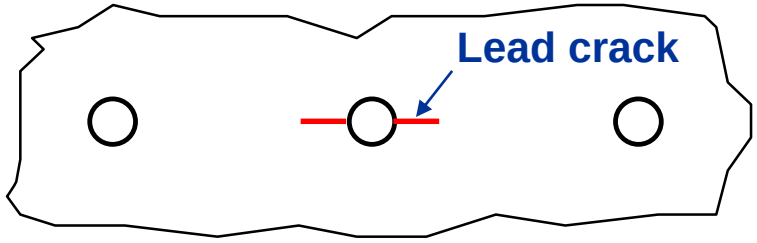
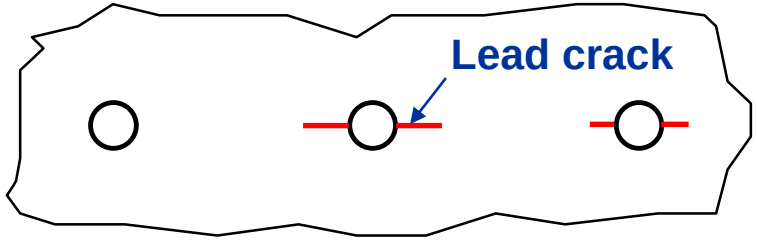
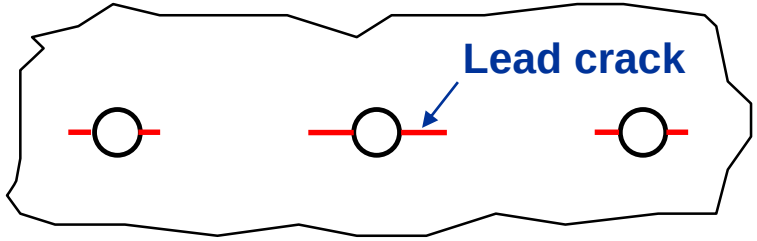
Effect of multiple cracks to the residual strength



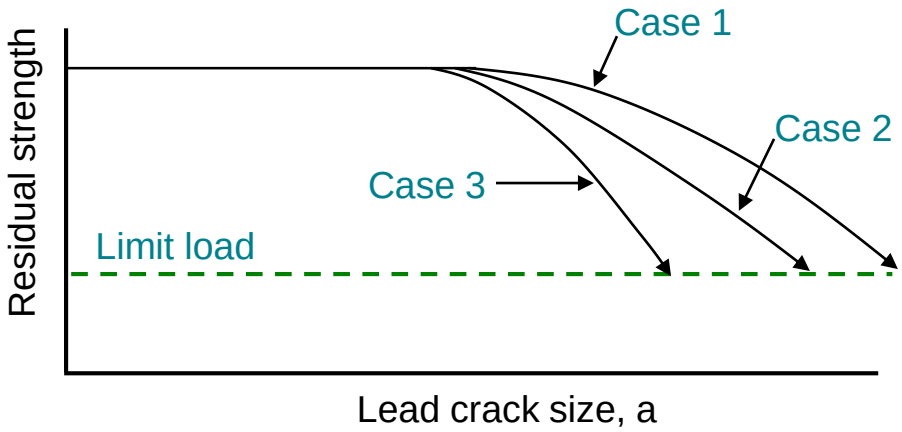
Case 1- Single crack



Case 2- MSD 2 cracks

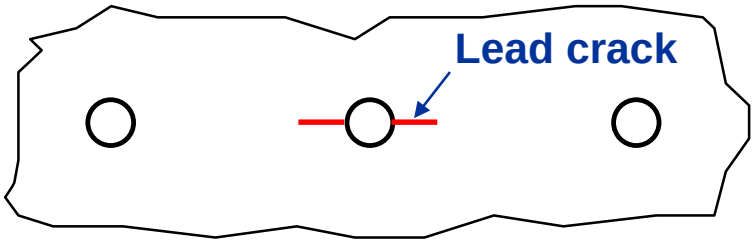


Case 3- MSD 3 cracks

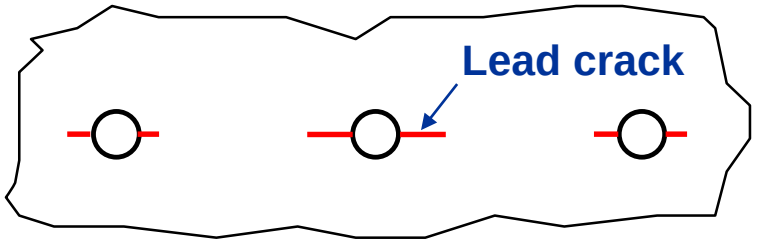


MSD reduces the residual strength

Effect of multiple cracks to the residual strength

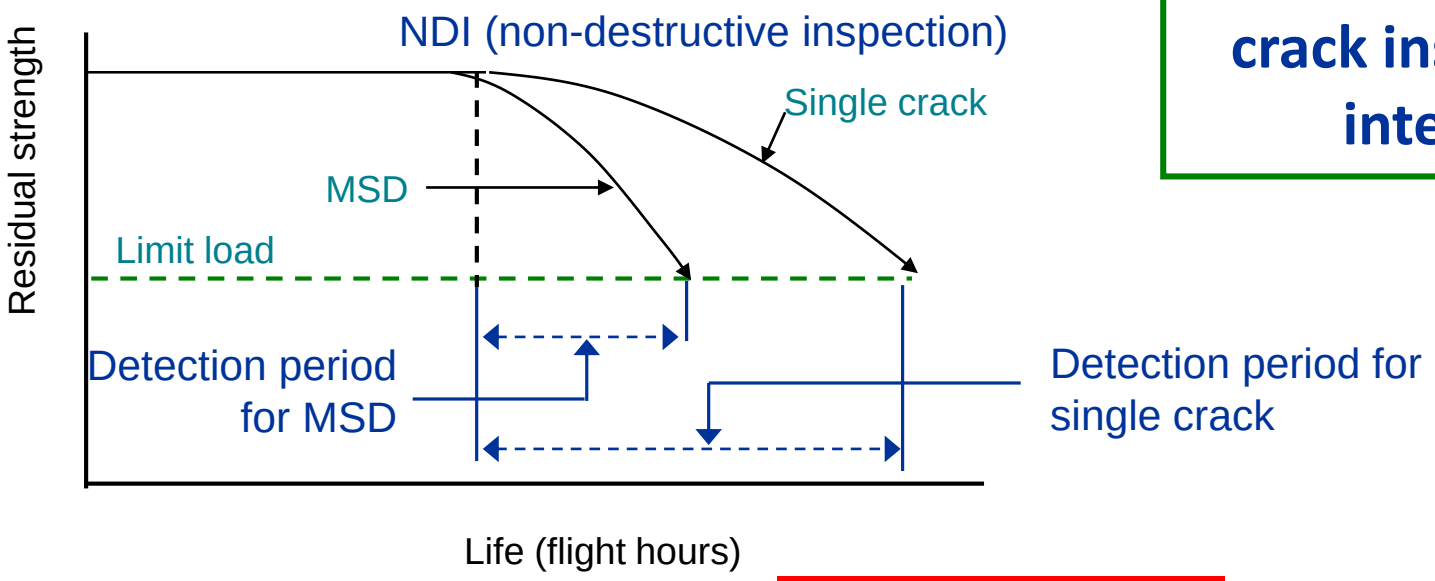


Single crack



MSD

MSD reduces the crack inspection interval



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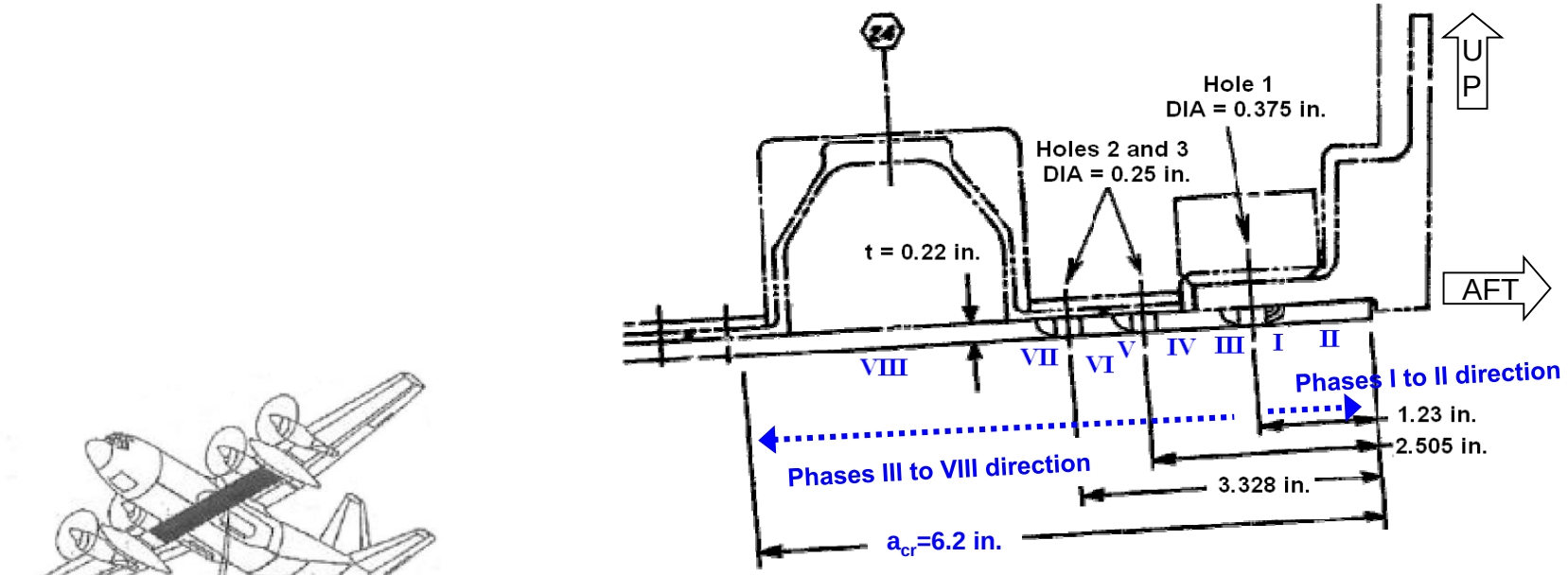
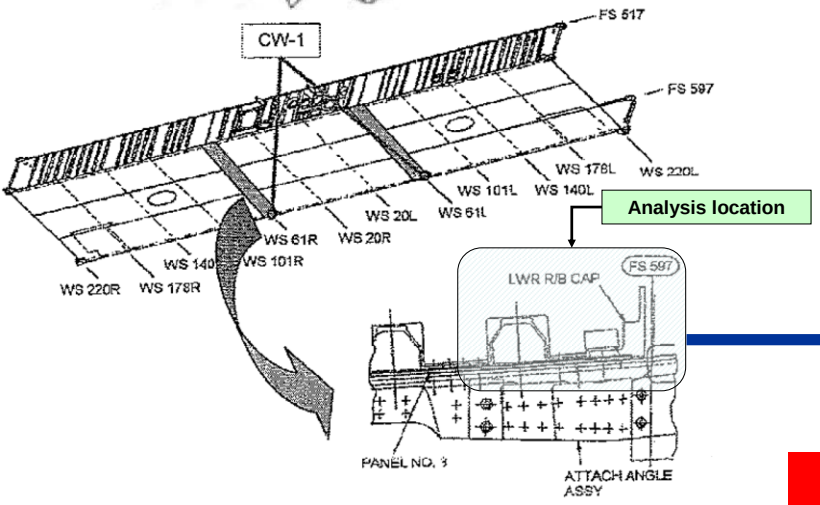
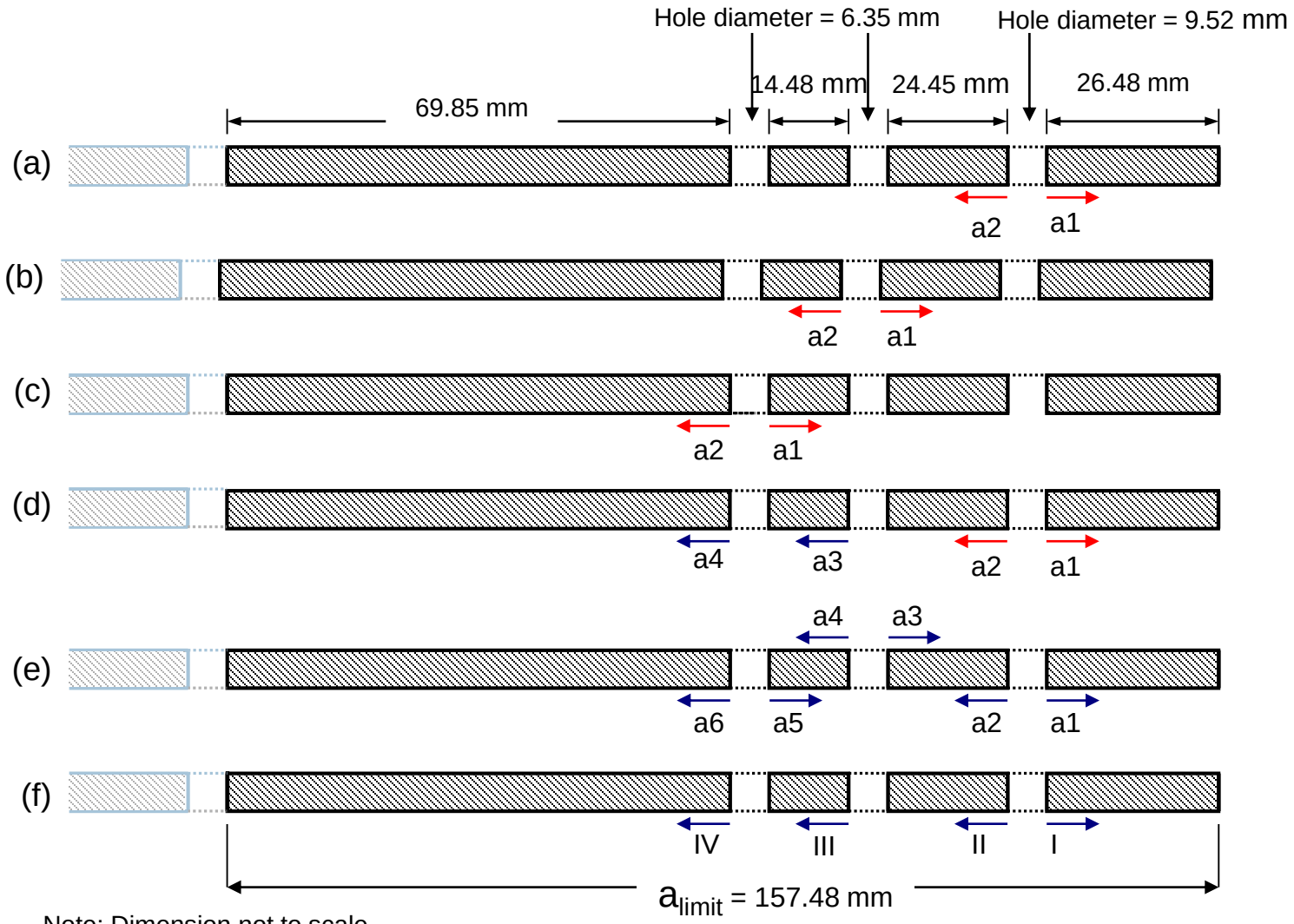
Probabilistic Risk Analysis of C130-H CW-1 Location





C130-H CW-1 MSD crack scenarios analysed

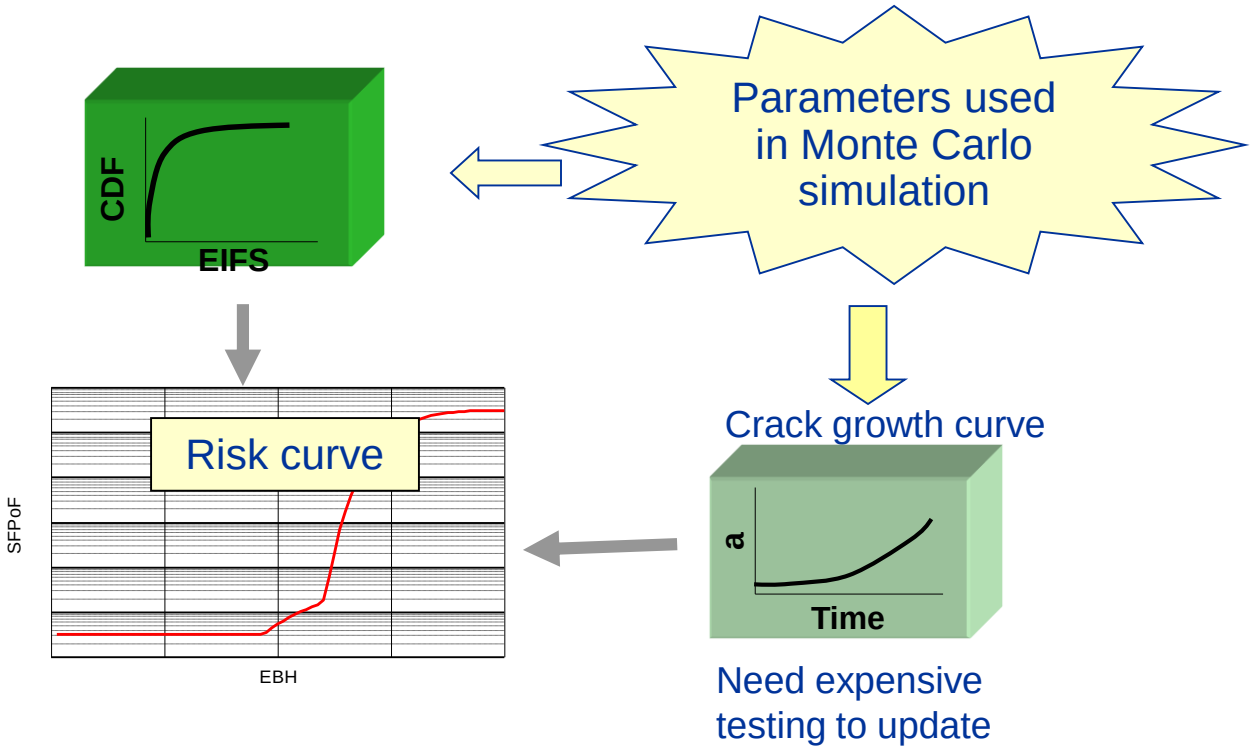


Note: Dimension not to scale

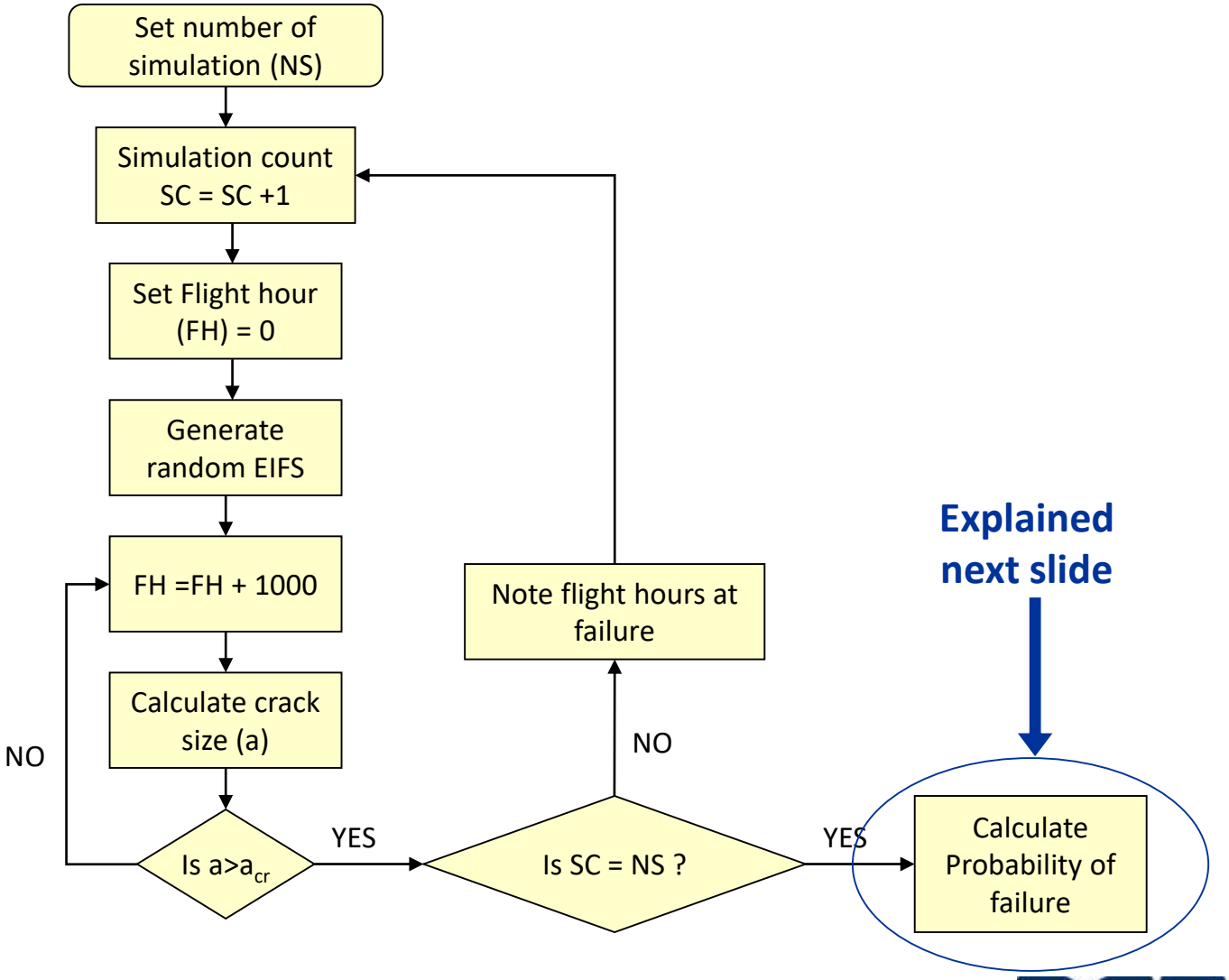
Legend:

Lead crack

2 – Parameter Monte Carlo simulation of MSD Risks

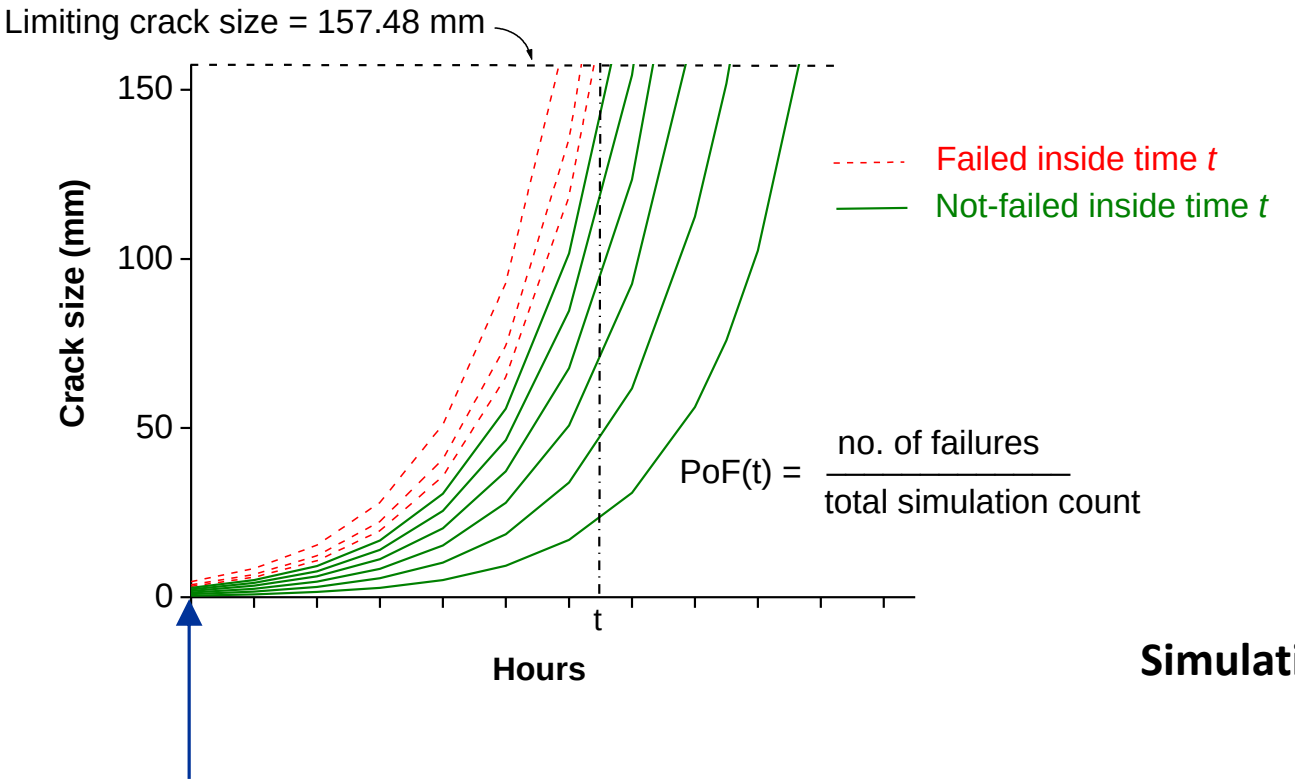


MSD Probabilistic Risk Analysis Methodology



Monte Carlo Simulation of the Probability of Failure

Calculation of the Probability of Failure



Simulation runs = 1,000,000

Randomly generated crack size at time zero (EIFS)

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Probabilistic risk analysis of failure tool - FracRisk

Capabilities

PROF method

FracRisk

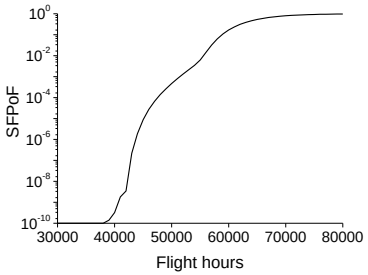
Bayesian risk updating

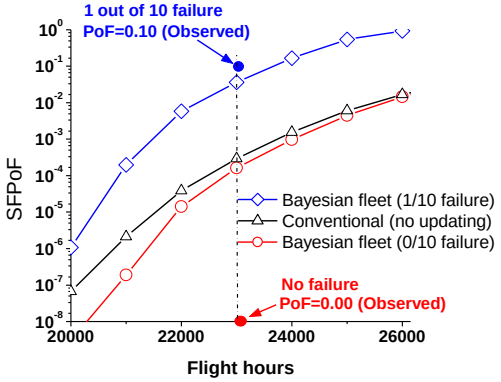
Multi-site damage (MSD) risk analysis

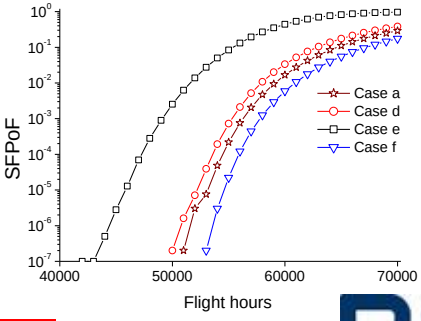
This module used in the analysis

DSTO developed risk analysis tool

Risk Curves

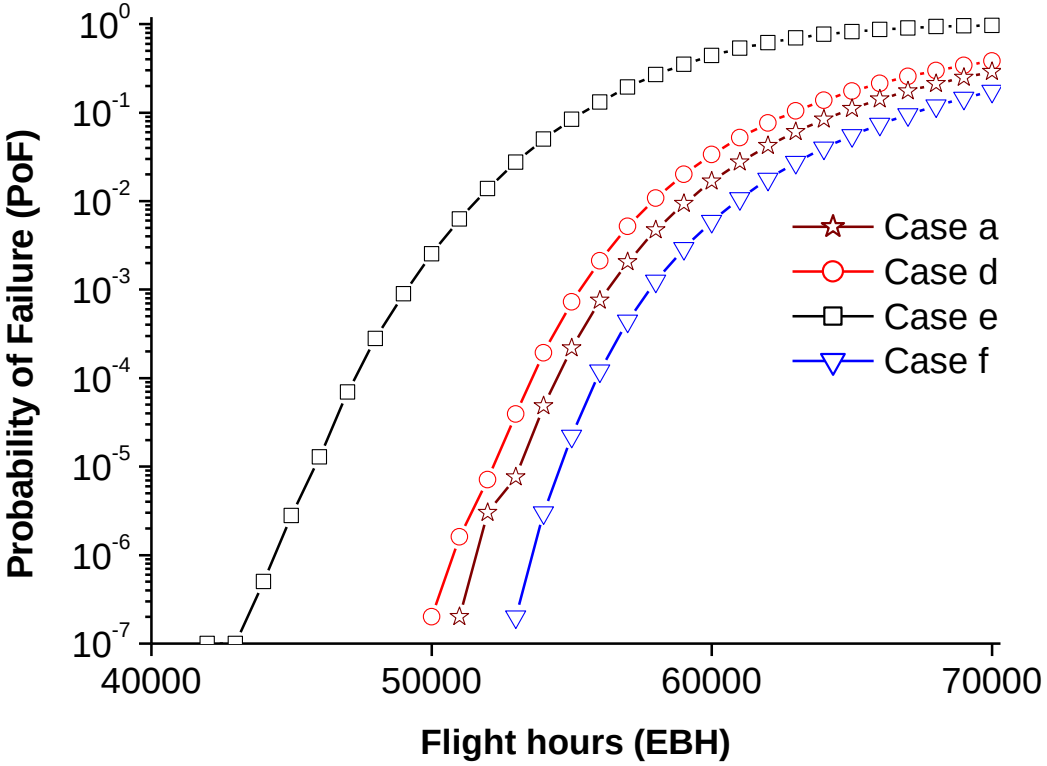


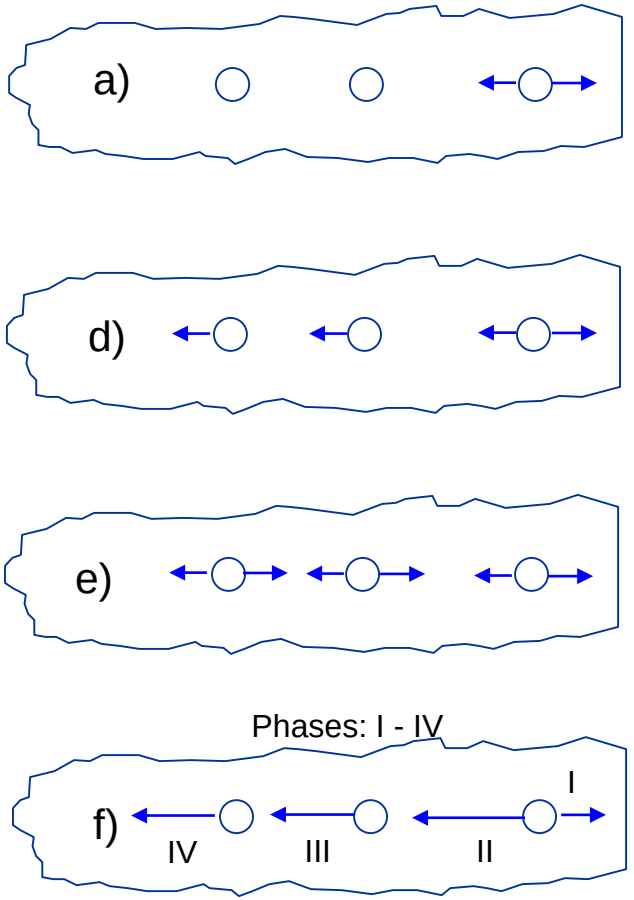




Probability of Failure (PoF) with increasing cracks numbers

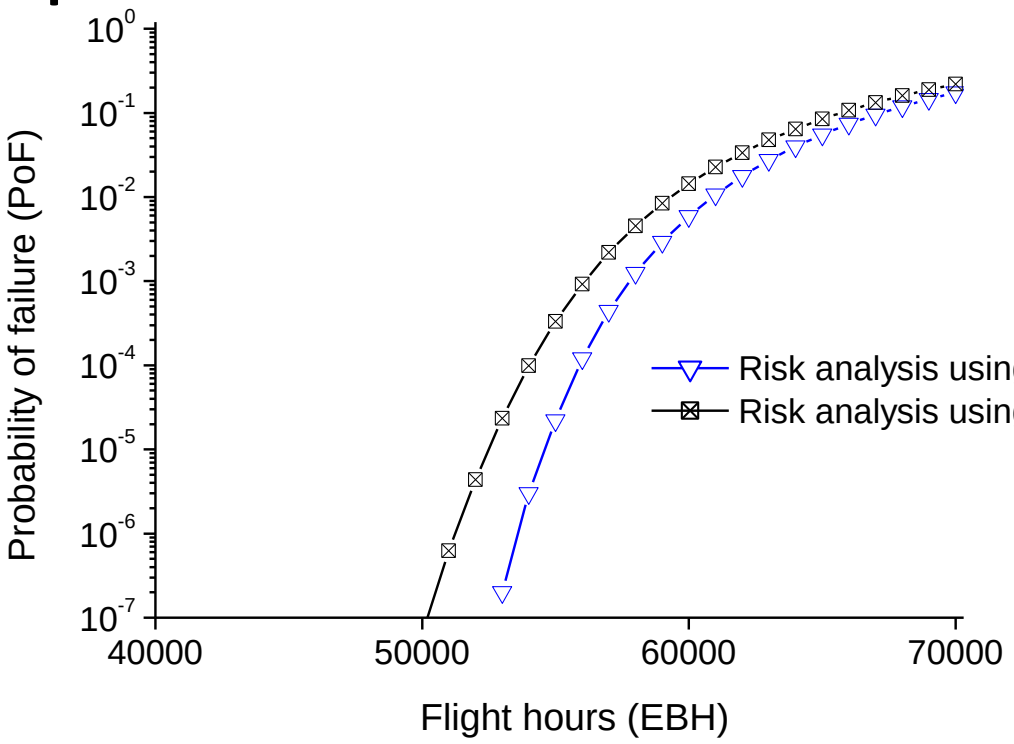
☞ **Probability of failure increases with the increase of the number of cracks**





Probability of Failure (PoF) as a function of risk parameters

☞ **Probability of failure increases with the increase of unknown parameters**

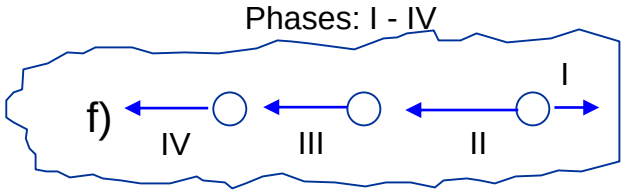


☞ **2 parameter risk analysis**

1. Crack growth curve
2. Equivalent initial flaw size

☞ **4 parameter risk analysis**

1. Crack growth curve
2. Equivalent initial flaw size
3. Residual strength
4. Stress exceedance



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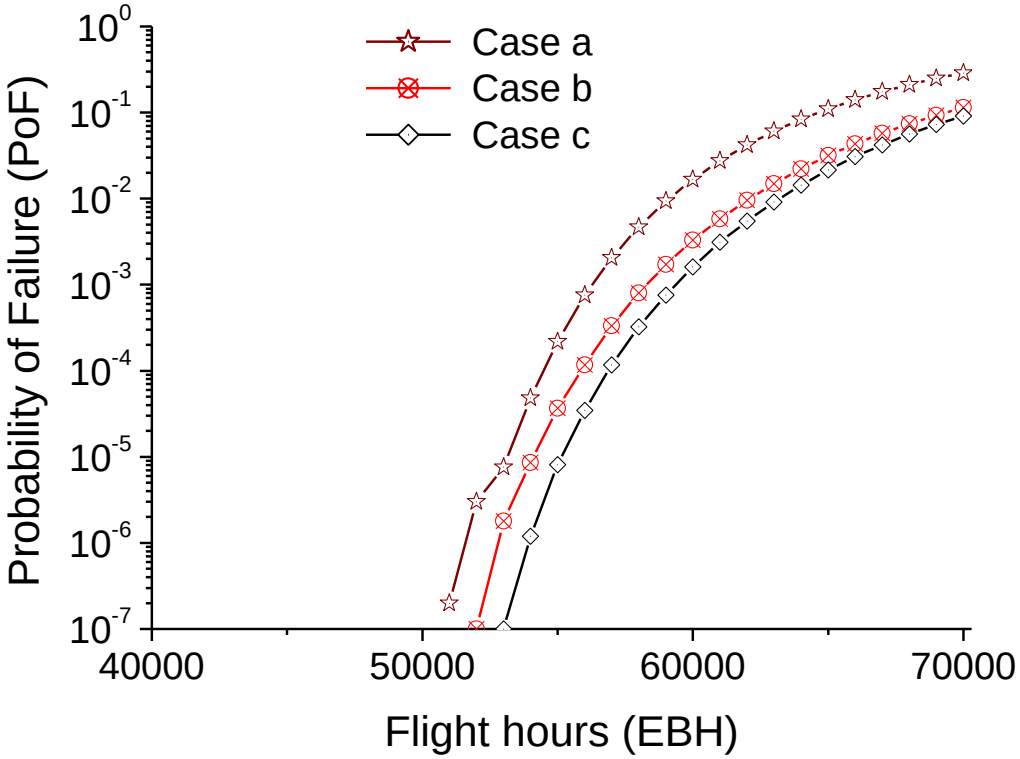
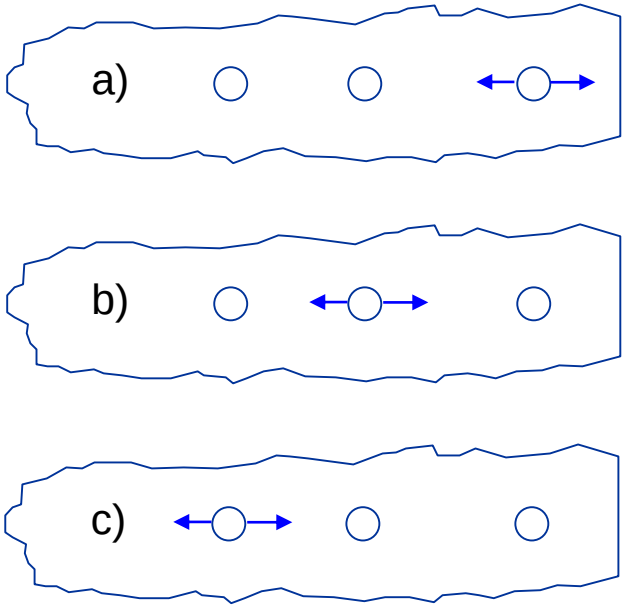
Probability of Failure (PoF) by varying hole location

☞ **Probability of failure increases when the lead crack is closer to the edge**





Conclusions

- The presence of multi-site damage significantly increases the risk of failure for a structural component Updating risk analysis results can be done by utilising flight hours information
- The simplistic approach using only two sets of parameters to conduct risk analysis is shown to give lower risk values compared to the analysis using four parameters
- An increase in the number of cracks resulted to a corresponding increase in the risk of fracture
- Cracks closer to the edge of a component will result in a higher risk of failure due to its higher likelihood of becoming an edge crack

Questions ?