Australian Government
Department of Defence
Defence Science and Technology Organisation

Real-time Risk Management of Aircraft Fleet Based on the Probability of Failure of Aircraft Structures

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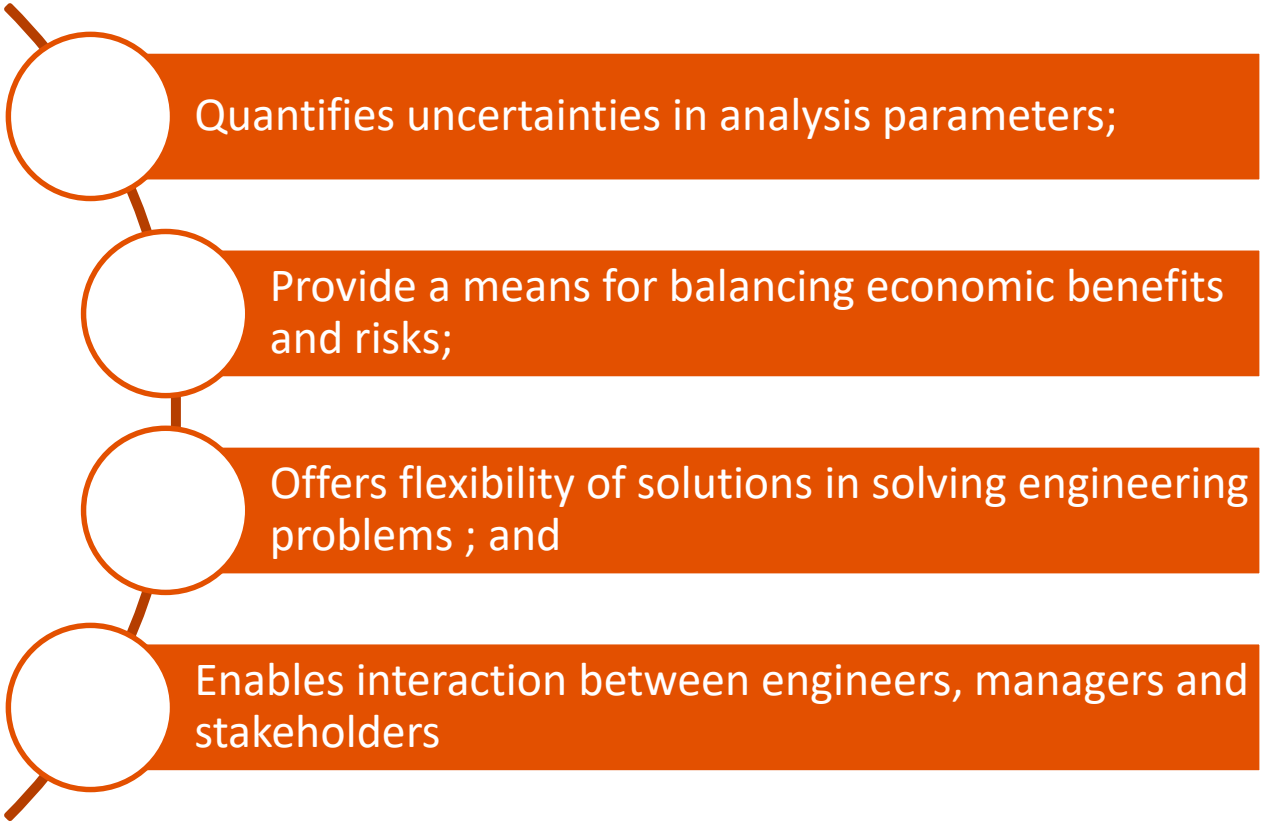
Outline of this presentation

1. Introduction of Probabilistic Risk Analysis (PRA) of Fracture
2. Application of PRA
3. Real-time risk risk analysis
4. Conclusion and future work

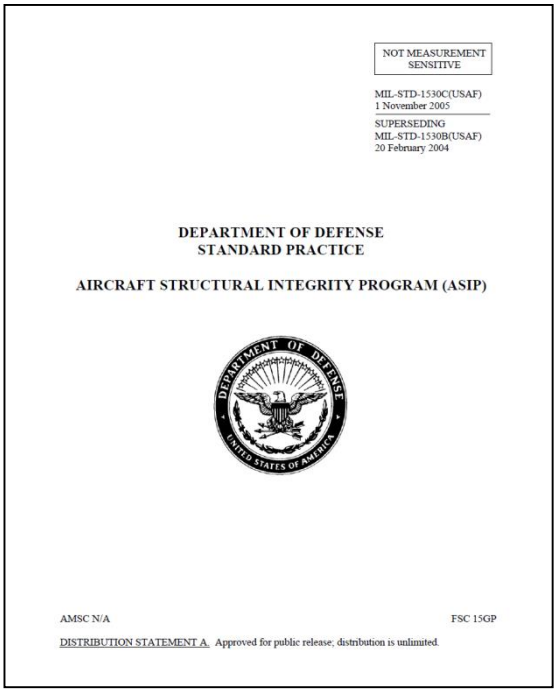
Probabilistic risk analysis (PRA) of fracture



1. MIL-STD 1530C requirement

Aircraft Structural Integrity Program (ASIP)

Role of probabilistic risk analysis in ASIP (MIL-STD- 1530C)



NOT MEASUREMENT SENSITIVE

MIL-STD-1530C(USAF)
1 November 2005

SUPERSEDING
MIL-STD-1530B(USAF)
20 February 2004

DEPARTMENT OF DEFENSE
STANDARD PRACTICE

AIRCRAFT STRUCTURAL INTEGRITY PROGRAM (ASIP)

AMSC N/A FSC 15GP

DISTRIBUTION STATEMENT A. Approved for public release; distribution is unlimited.

Task 1 - Design Information

Task 2 - Design analysis and developmental testing

MIL-STD-1530C 5.2.16
(Initial probabilistic risk analysis)

Task 3 – Full scale testing

Task 4 – Certification & Force Management Development

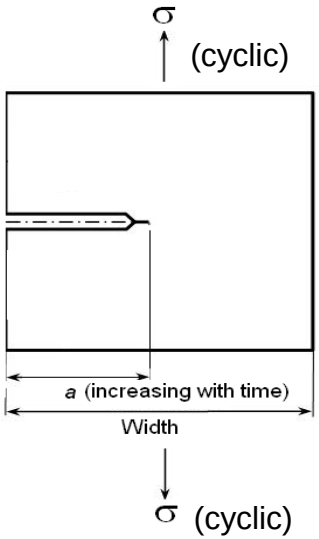
MIL-STD-1530C 5.4.1.1
(Probabilistic risk analysis)

Task 5 – Force Management Execution

MIL-STD-1530C 5.5.6.3
continuing assessment
(Probabilistic risk analysis update)

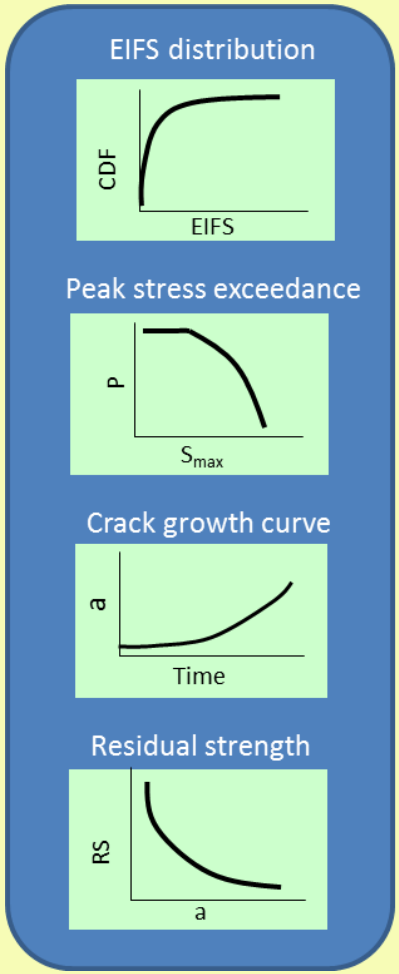
Aircraft Structural Integrity Program (ASIP) Tasks

Probabilistic risk analysis (PRA) of fracture



- Risk - probability of failure or unstable crack growth
- Failure occurs when applied stress exceeds the residual strength

Analysis parameters



Probability of Failure (PoF) calculation:

$$PoF = \int_0^{\infty} f(a)\left(1 - \int_0^{S_{RS}(a_{cr})} f(s)ds\right)$$

Where :

s = stress

a = crack size

a_{cr}= critical crack size

s_{RS}= residual strength

f(a)= crack size probability density function

f(s)= stress probability density function

1. Analysis of fracture of airframes

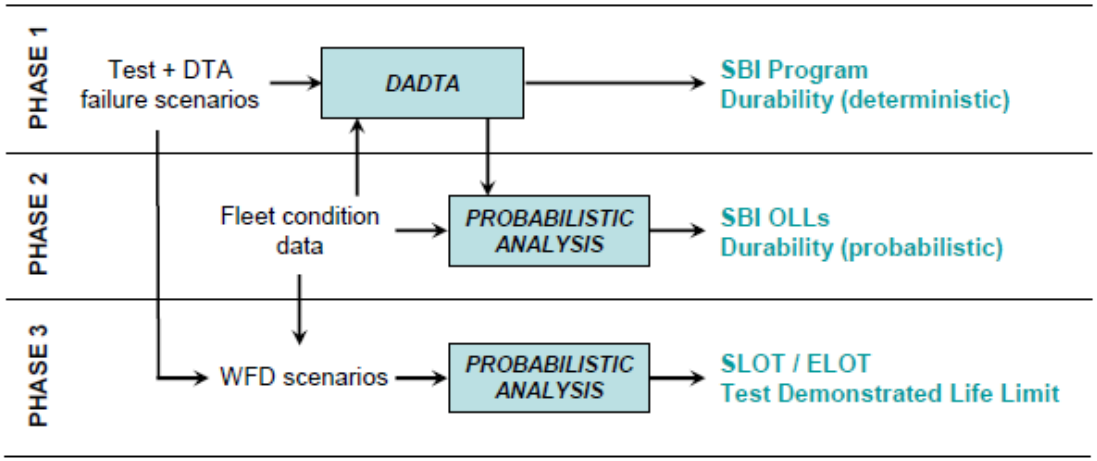
Probabilistic vs. Deterministic

DSTO involvement in C-130J Full Scale Fatigue Test

Order of application

Deterministic — Phase 1

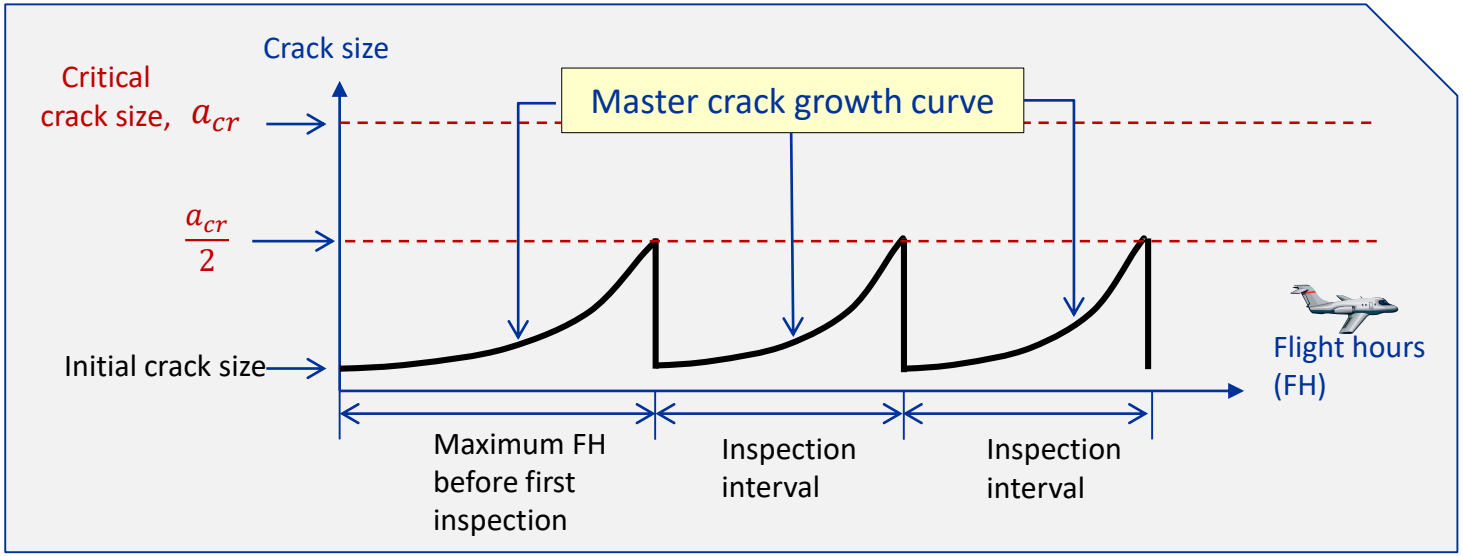
Probabilistic — Phases 2/3



credits to : D. Hartley, R. Ogden and L. Meadows

DSTO

Deterministic approach (Safety by Inspection)



Determine the critical crack size, a_{cr}

Project the crack size using the master crack growth curve

Conduct inspection at flight hours when crack size is projected to be $\frac{a_{cr}}{2}$

Crack size back to initial size

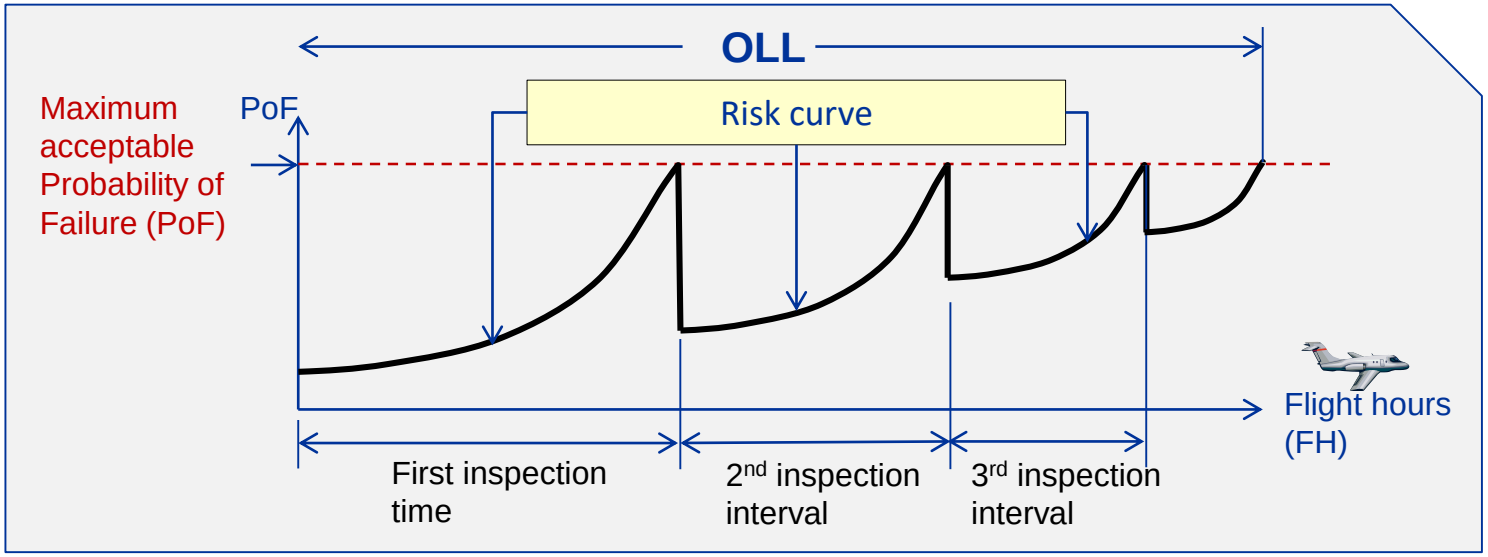
Advantage :

- Conservative

Weakness :

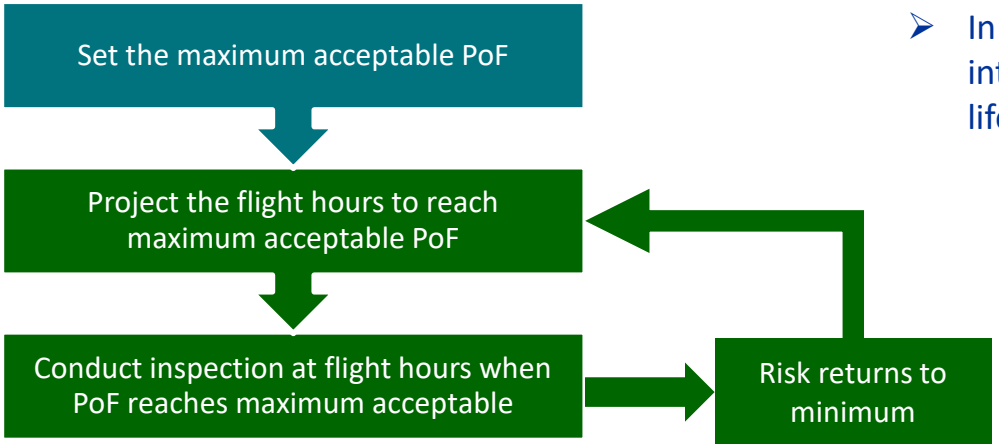
- Implies that safety of an airframe can be maintained indefinitely through inspection

Probabilistic approach - Operational life limit (OLL)



Advantage:

- In addition to safe inspection intervals, identifies the operation life limit (OLL)



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2. Improving the accuracy of probabilistic risk analysis

Real-time risk assessment

Real-time risk analysis (RTRA)

- continuous analysis to evaluate information at any given point of time

Companies

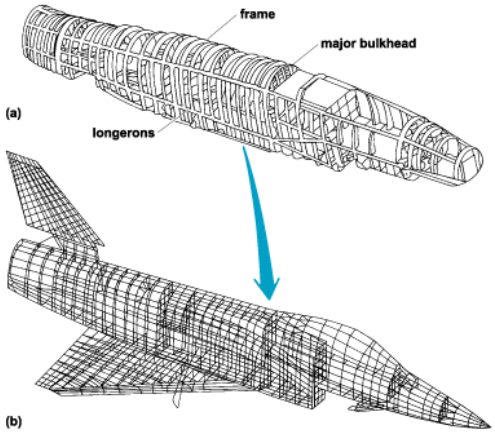
At risk $100m's ??

Individual investors

Personal incomes

☞ RTRA is commonly conducted for various assets at risk

What about aircraft structures?

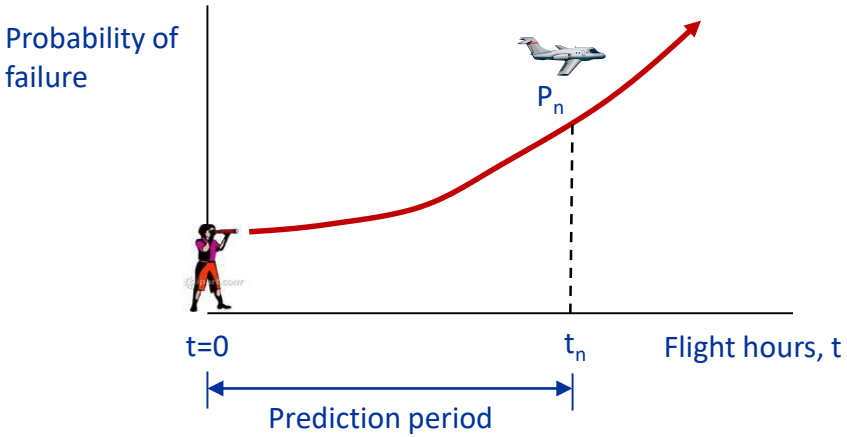


Risk analysis ? - Yes

Real-time risk analysis ? - No

At risk $$$ millions ??

Understanding risk analysis of aircraft structure



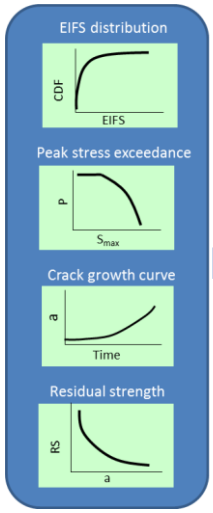
Interpreting Probability:

✗ P_n = probability that an aircraft will fail at time, t_n

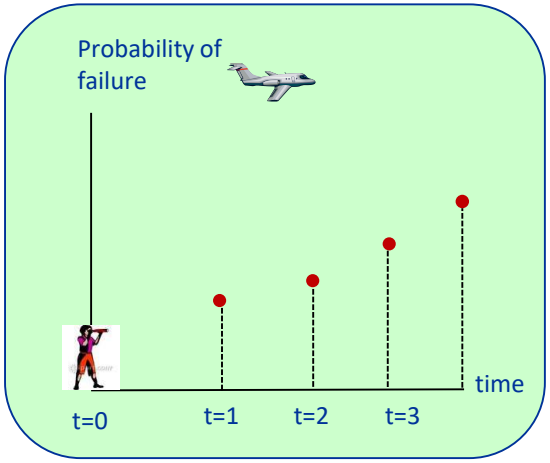
✓ P_n = probability that an aircraft will fail between t=0 and t_n

- Long term prediction high uncertainty
- Update prediction with passage of time
- **Real-time risk analysis** minimises uncertainty

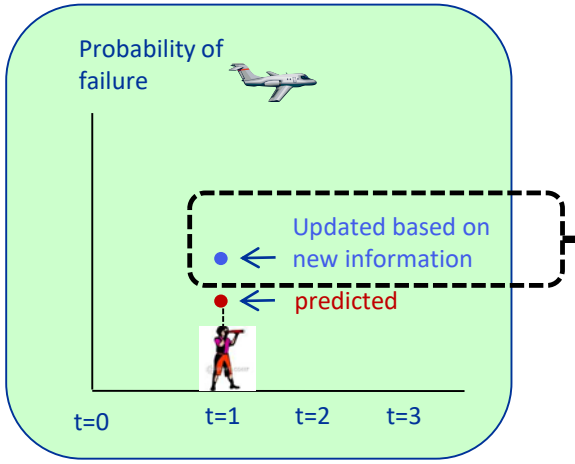
Updating the risk analysis of fracture



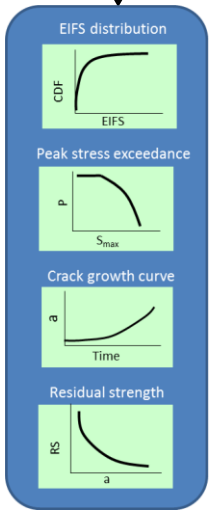
Analysis parameters



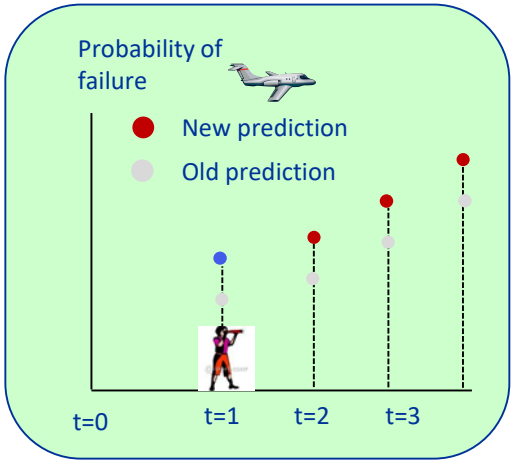
Prediction : observer at t=0



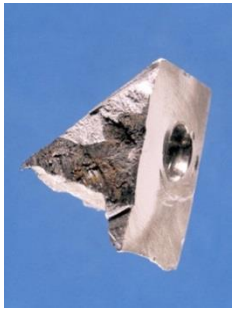
Observer at t=1



Updated analysis parameters



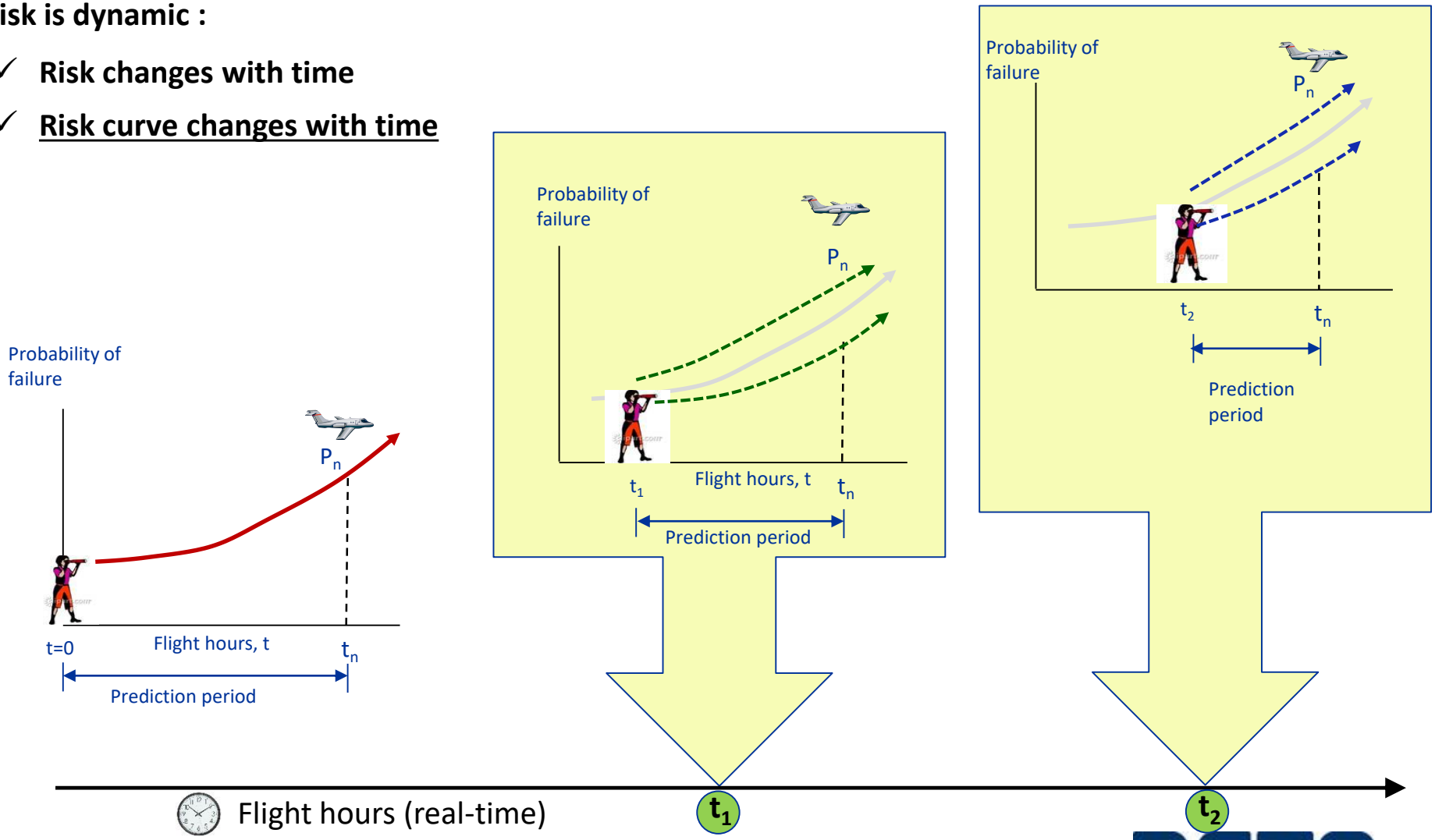
New prediction : observer at t=1



Real-time risk analysis of an aircraft

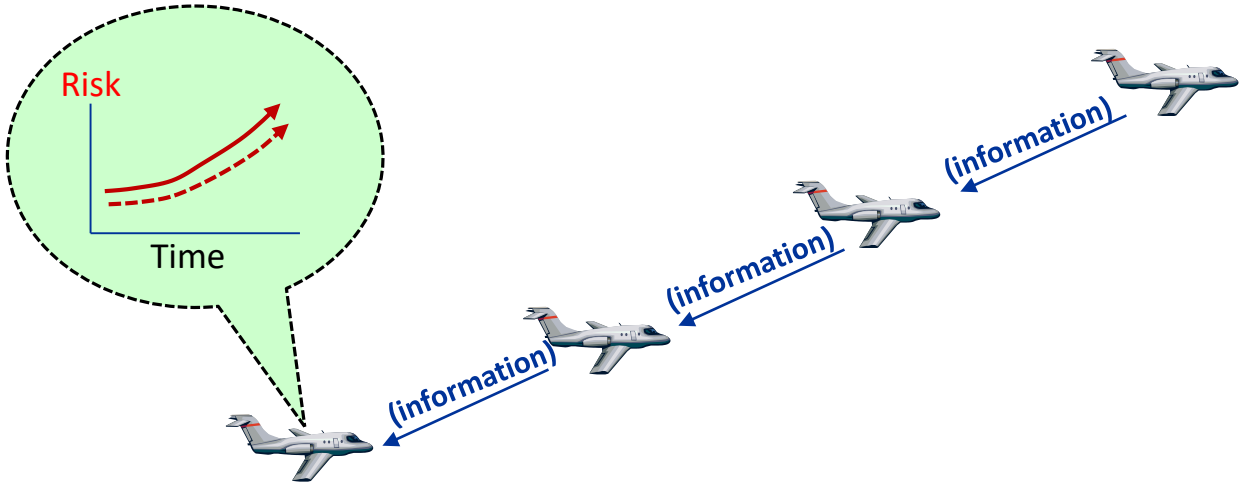
Risk is dynamic :

- ✓ **Risk changes with time**
- ✓ **Risk curve changes with time**



Real-time risk analysis of aircraft fleet

- Makes full use of fleet information
- Most beneficial to low flight hour fleet members



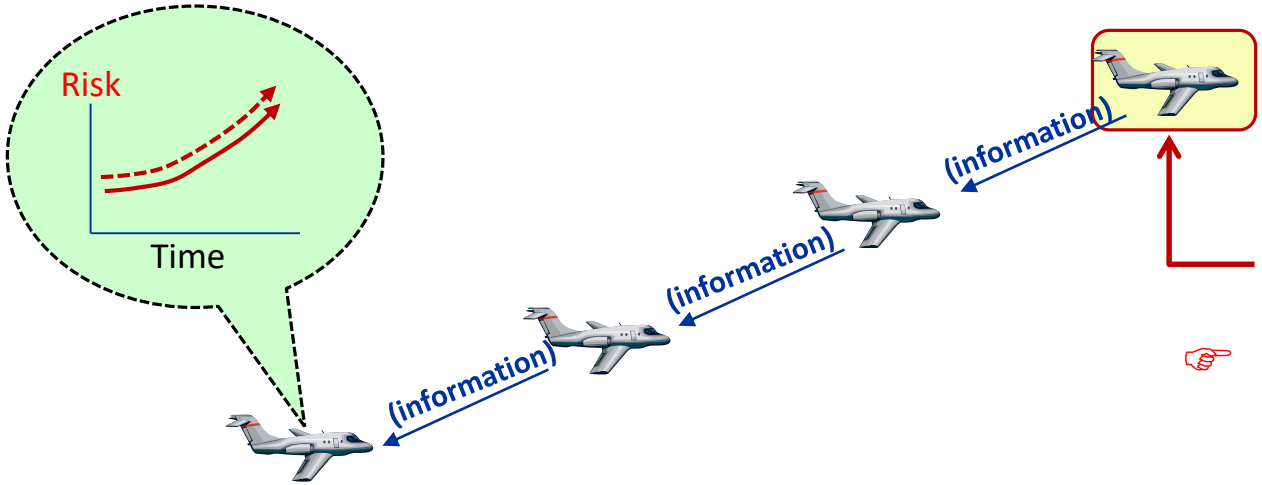
Case 1:
All fleet members are safe

☞ Risk level reduction

Bayesian updating

Real-time risk analysis of aircraft fleet

- Makes full use of fleet information
- Most beneficial to low flight hour fleet members



Case 2:
Lead member failed

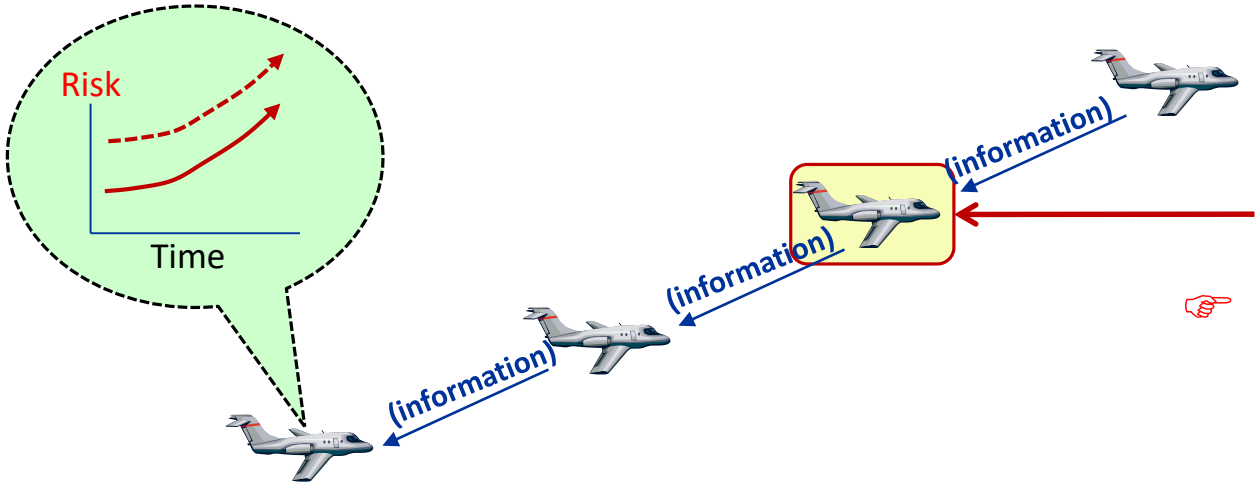
Risk level increase

Flight hours

Bayesian updating

Real-time risk analysis of aircraft fleet

- Makes full use of fleet information
- Most beneficial to low flight hour fleet members



Case 3:
Non-lead member failed

☞ Higher risk level increase

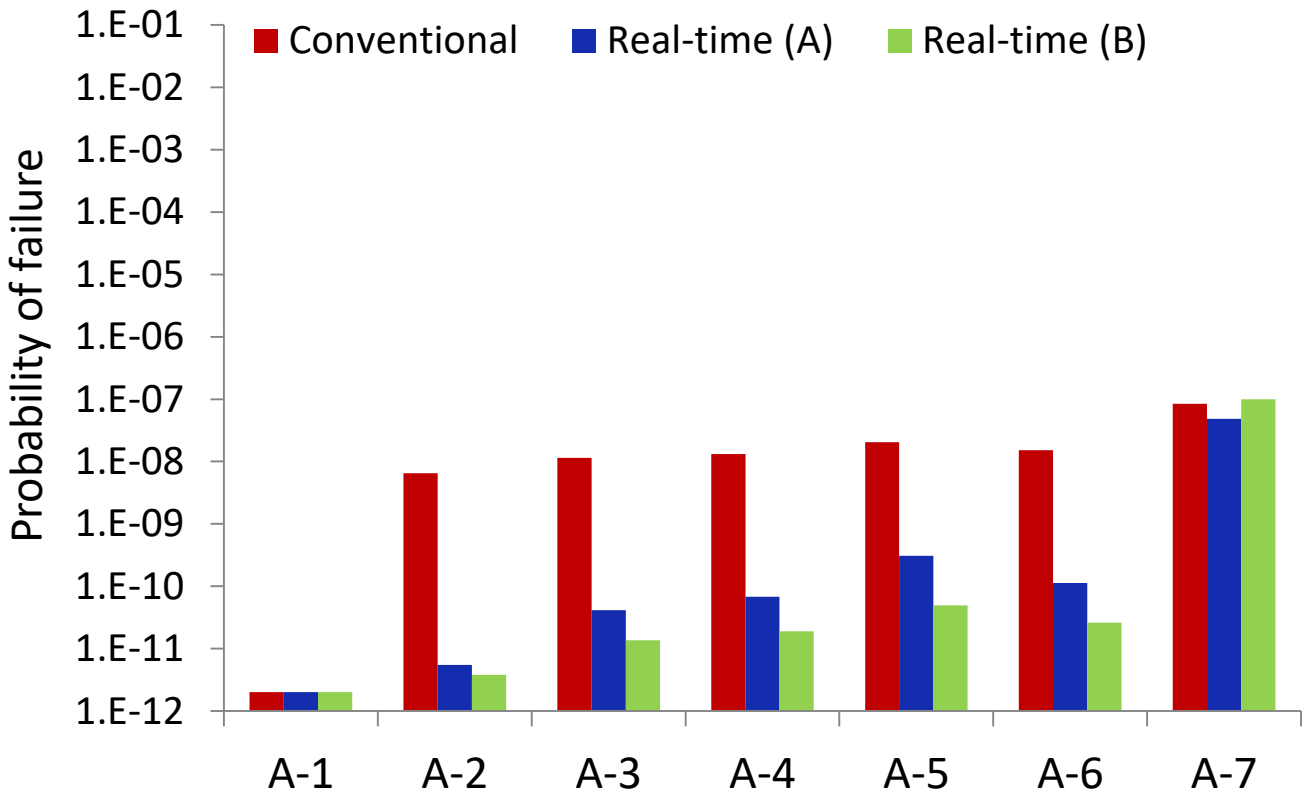
Flight hours

Bayesian updating

3. Real-time risk analysis sample problem

Real-time risk assessment (no failure)

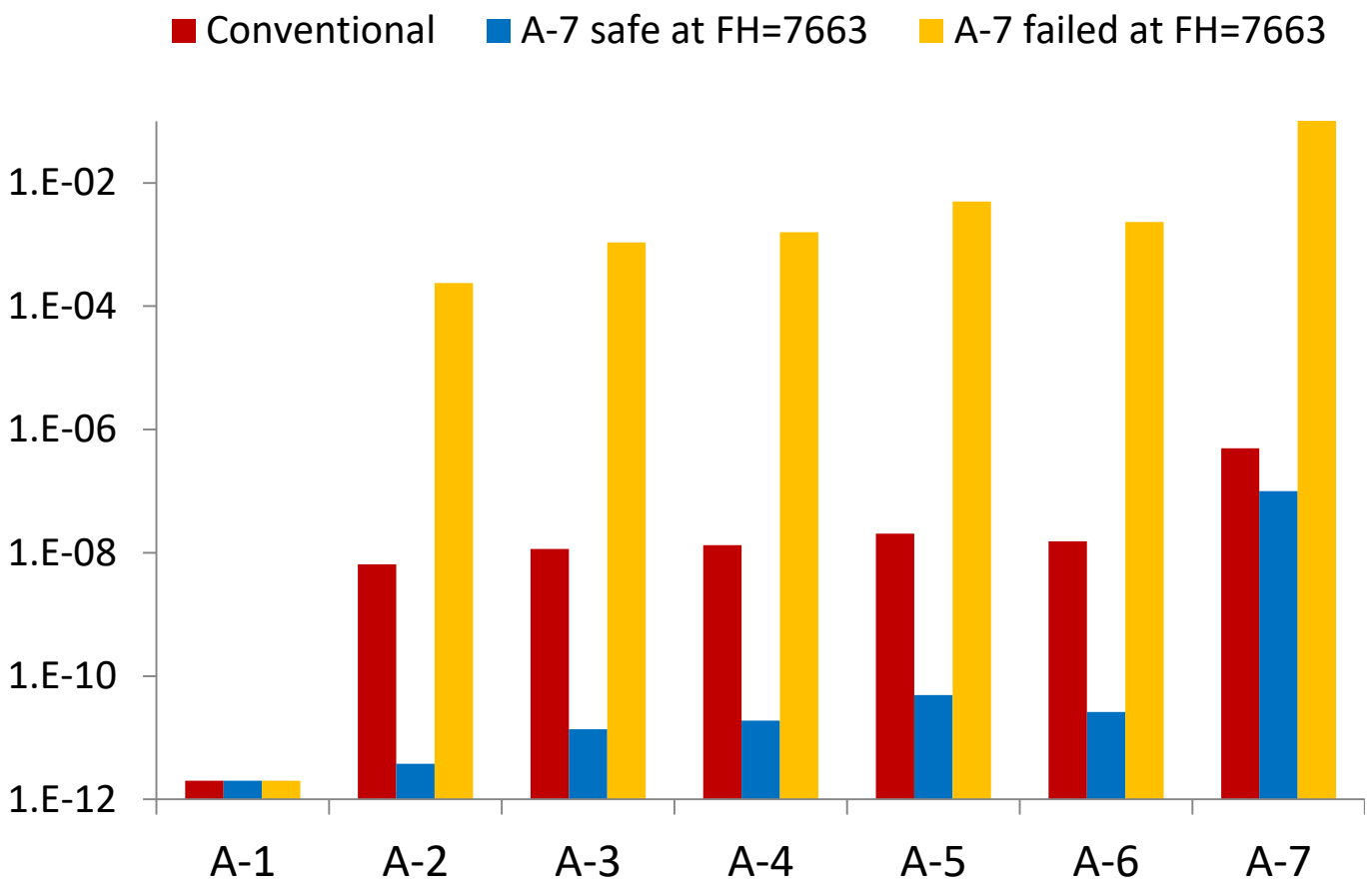
Hypothetical aircraft	Flight hours (A)	Flight hours (B)
A-1	3000	3000
A-2	6100	6100
A-3	6300	6300
A-4	6350	6350
A-5	6500	6500
A-6	6400	6400
A-7	**7000**	**7663**



Analysis using DSTO developed FracRisk program

Real-time risk assessment (failure observed)

Aircraft	Flight hours (B)
A-1	3000
A-2	6100
A-3	6300
A-4	6350
A-5	6500
A-6	6400
A-7	**7663**



Analysis using DSTO developed FracRisk program

Conclusion

1. Real-time risk analysis can improve the reliability of the risk prediction by progressively reducing the high uncertainties in the initial prediction;
2. Real-time risk analysis can be used to optimize the fleet utilization; and
3. Real-time risk analysis presents a framework of identifying which fleet member's risk of failure is acceptable when one fleet member fails.

Future work

Apply the method to a real fleet to supplement the existing management strategy.

Questions?