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Airframe Reliability & Risk Assessment: Airframe Prognosis

Paul Hoffman Ph.D., P.E.
Structural Reliability & Risk Assessment Lead
NAVAIR Structures Division
Patuxent River, MD 20670-1906
mailto:Paul.Hoffman@navy.mil

Outline

1. *Current Tracking (Diagnostics) & Why change?*

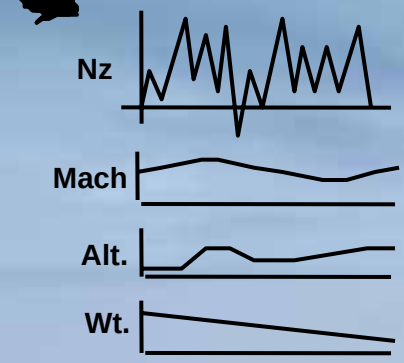
2. *Emerging Airframe Management Method*
   a.k.a. Prognosis, Structural Health Management etc

Fatigue Damage SAFE-Life Methodology

External Loading Sequence*

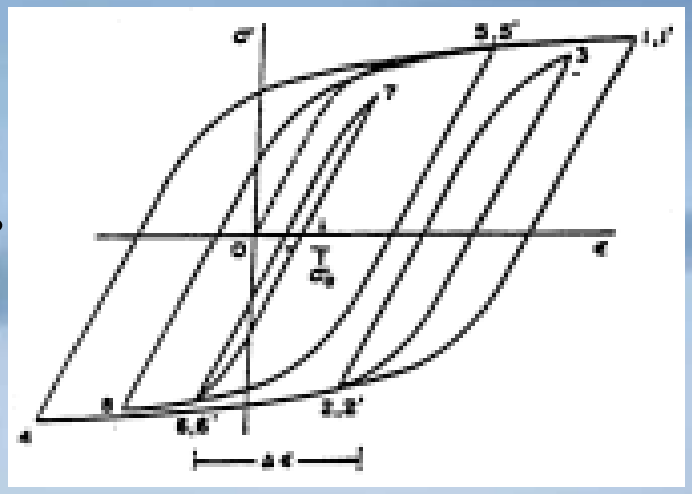
Multi-channel Flight Data Recorder

Electronic Media
[Disks, Tapes, etc.]

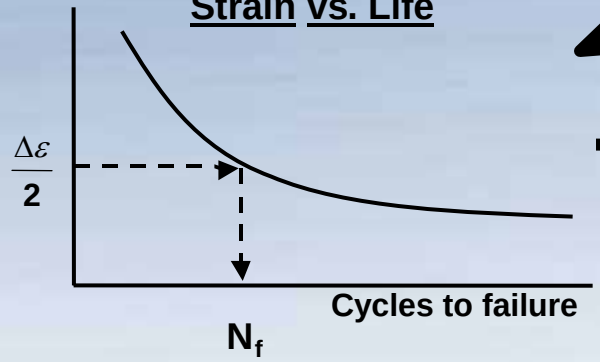


Load to Stress Relationship

Notch Stress-Strain Response*



Strain vs. Life



Damage Computation

$$D_j = \frac{n_1}{N_1} + \frac{n_2}{N_2} + \cdots + \frac{n_k}{N_k} = \sum_{i=1}^{k} \frac{n_i}{N_i}$$

$$D = \sum_{j=1}^{M} D_j$$

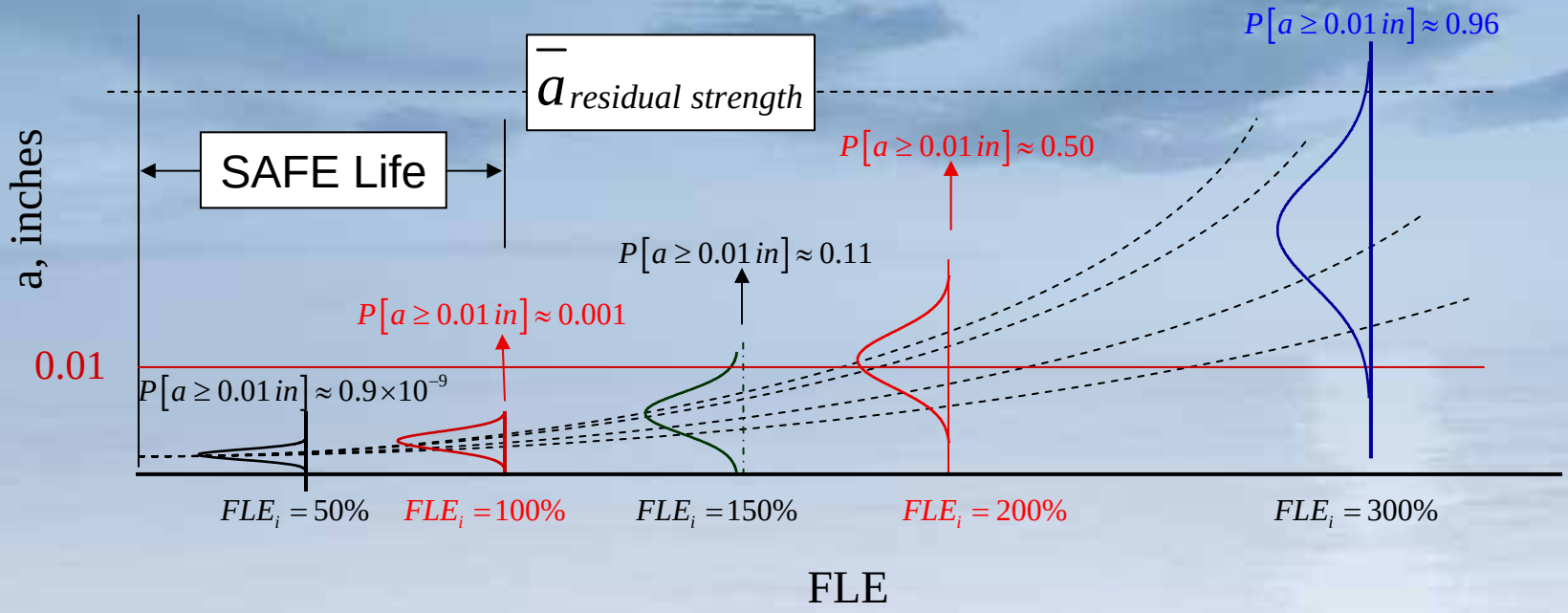
Commonly expressed as fatigue life expended

$$\mathbf{FLE} \equiv \mathbf{D} \cdot 2 \cdot 100\%$$

NOTE: Diagnostics (Data Intense)

Why SAFE-Life preferred?

Interpreting FLE;
Probability of a > 0.01 inches (a.k.a. 10 mils)
Note: 0.01 inches=0.25 mm << $a_{critical}$



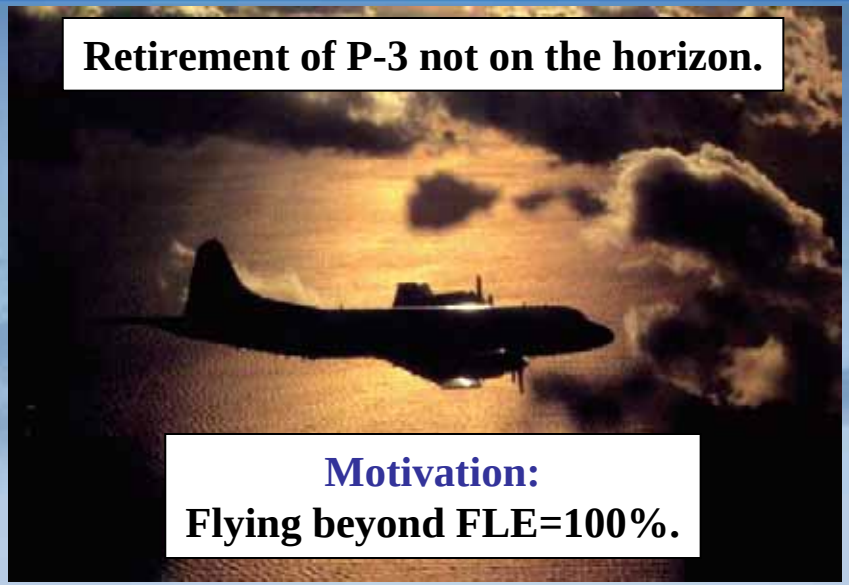
Challenge: After Safe-life then what reliability/risk?

Why change? A New Era!

EA-6B with new wings, reset FLE=100%.

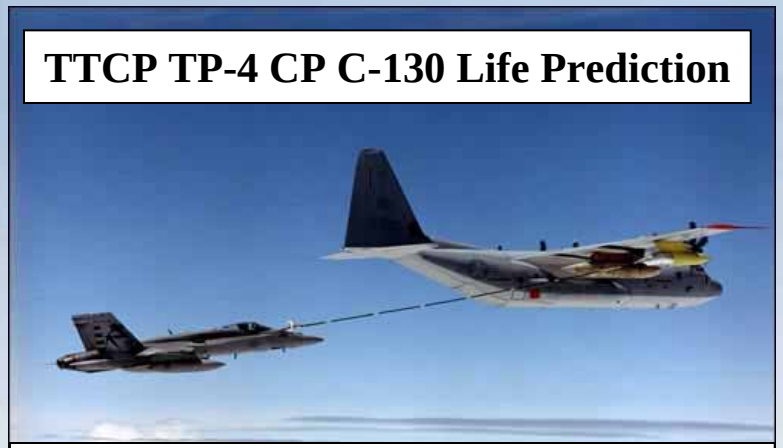
Motivation:
Expect retirement FLE ~170%

Retirement of P-3 not on the horizon.



Motivation:
Flying beyond FLE=100%.

TTCP TP-4 CP C-130 Life Prediction



Motivation:
All 5 nations well past initial service life

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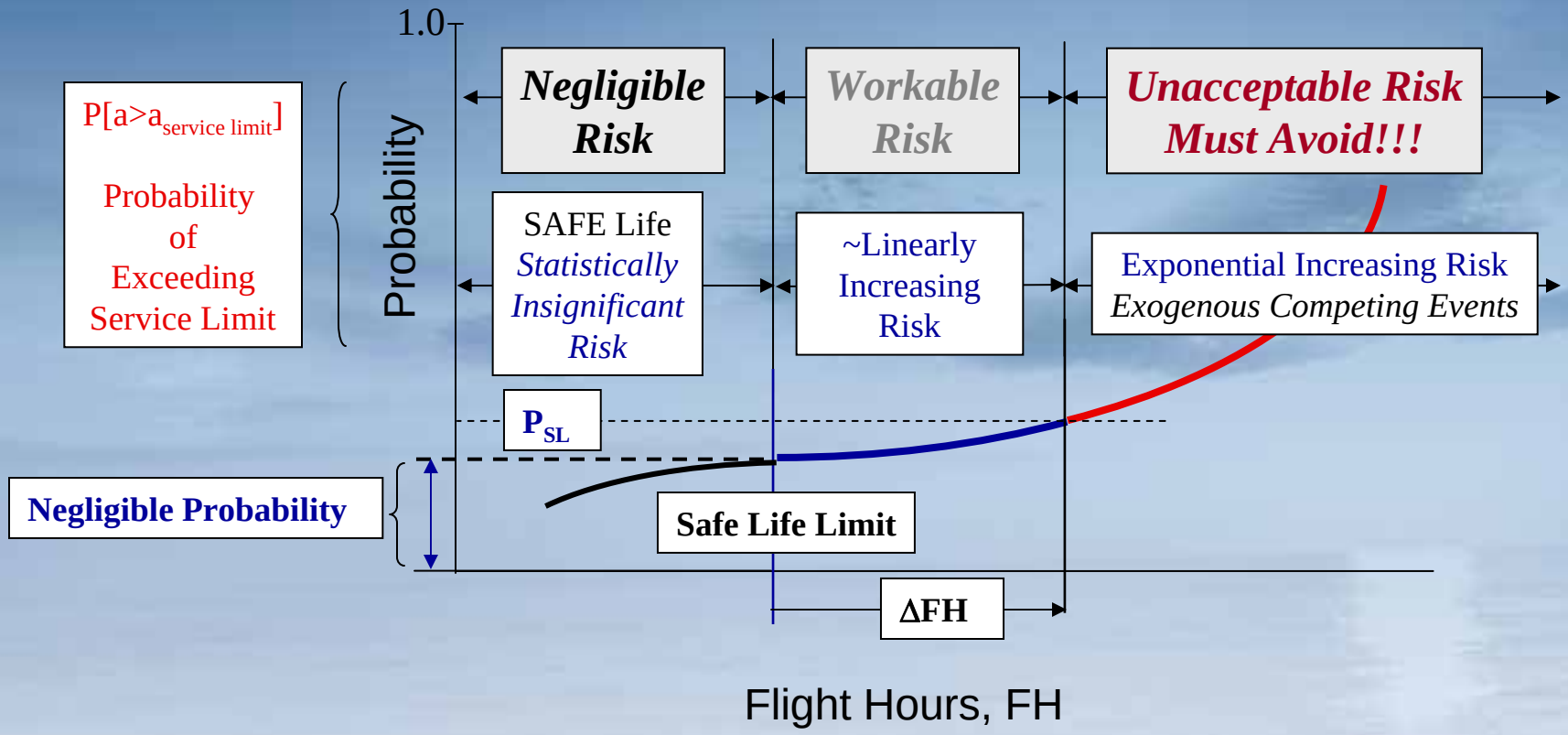
Structures Division's Perspective
An Emerging Airframe Life Management Methodology

Airframe Prognostics/Prognosis

At the core a Quantitative Probability-Based

- **Assessment of Current Airframe Integrity**
  - ***What's the probability distribution of damage?***
- **Prediction of Future Airframe Integrity**
  - ***What's the probability < residual strength?***

Conceptually~Risk-Based Tracking



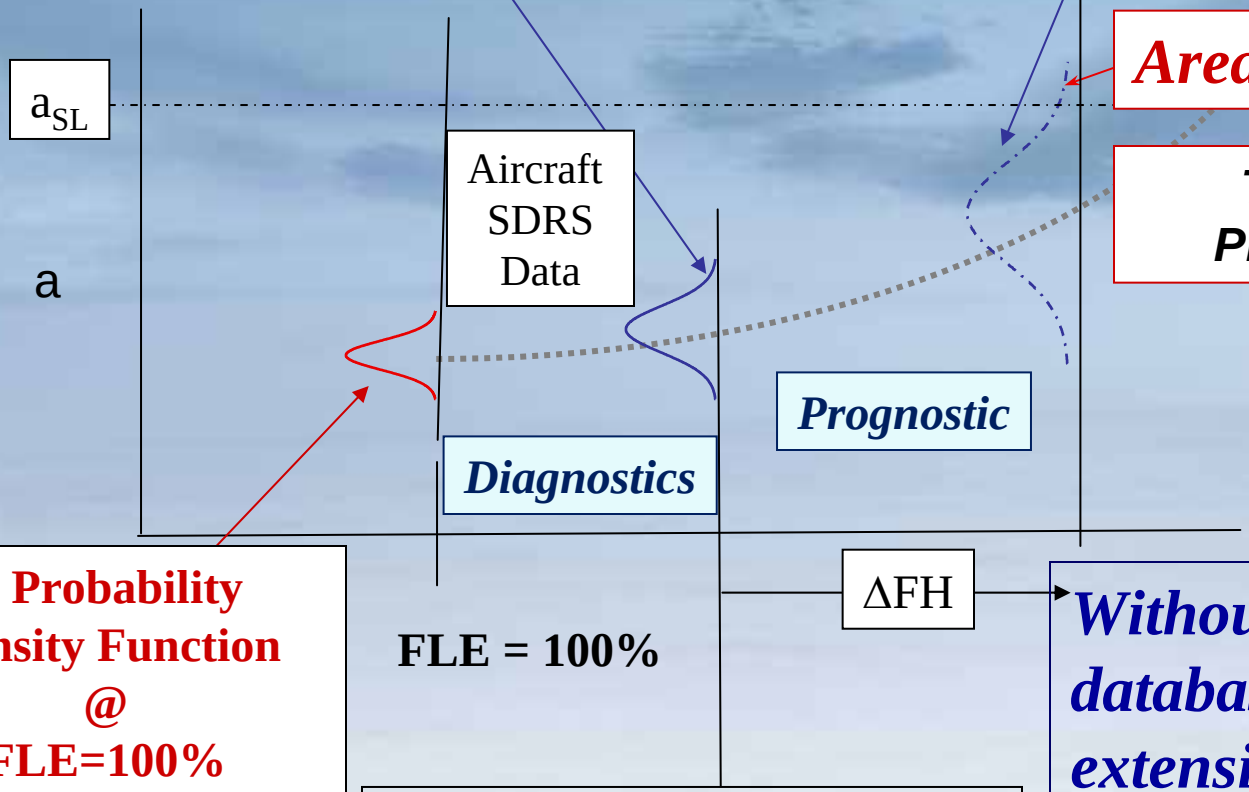
$a_{service\ limit}$ is the maximum manageable crack size
P_{SL} is the maximum acceptable probability of exceeding $a_{service\ limit}$
Both are defined & justified by engineering within the organization

Proposed Fleet Risk Assessment

Aircraft by Aircraft

II. Present Damage State Estimation. Based on SDRS recorded data (+ more?) for projection from FLE=100% baseline

III. Future Model Assessment. Based on estimated/random loads



Area above a_{SL} = POF

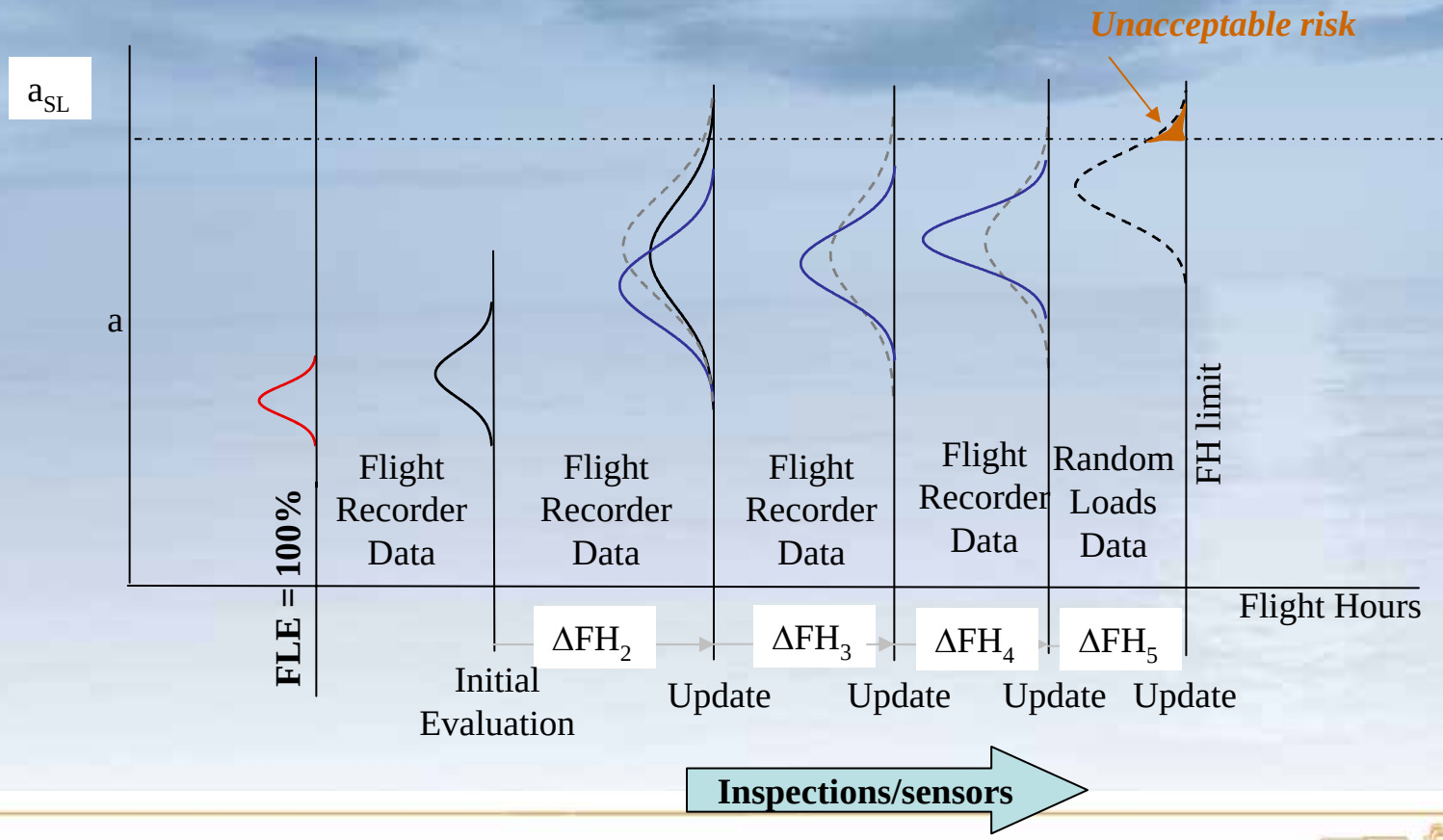
Tracking "Risk"
Prob[a>a_{SL}] < limit

I. Probability Density Function @ FLE=100% Based on Fleet findings + test data

Without a feedback database , a one time extension!

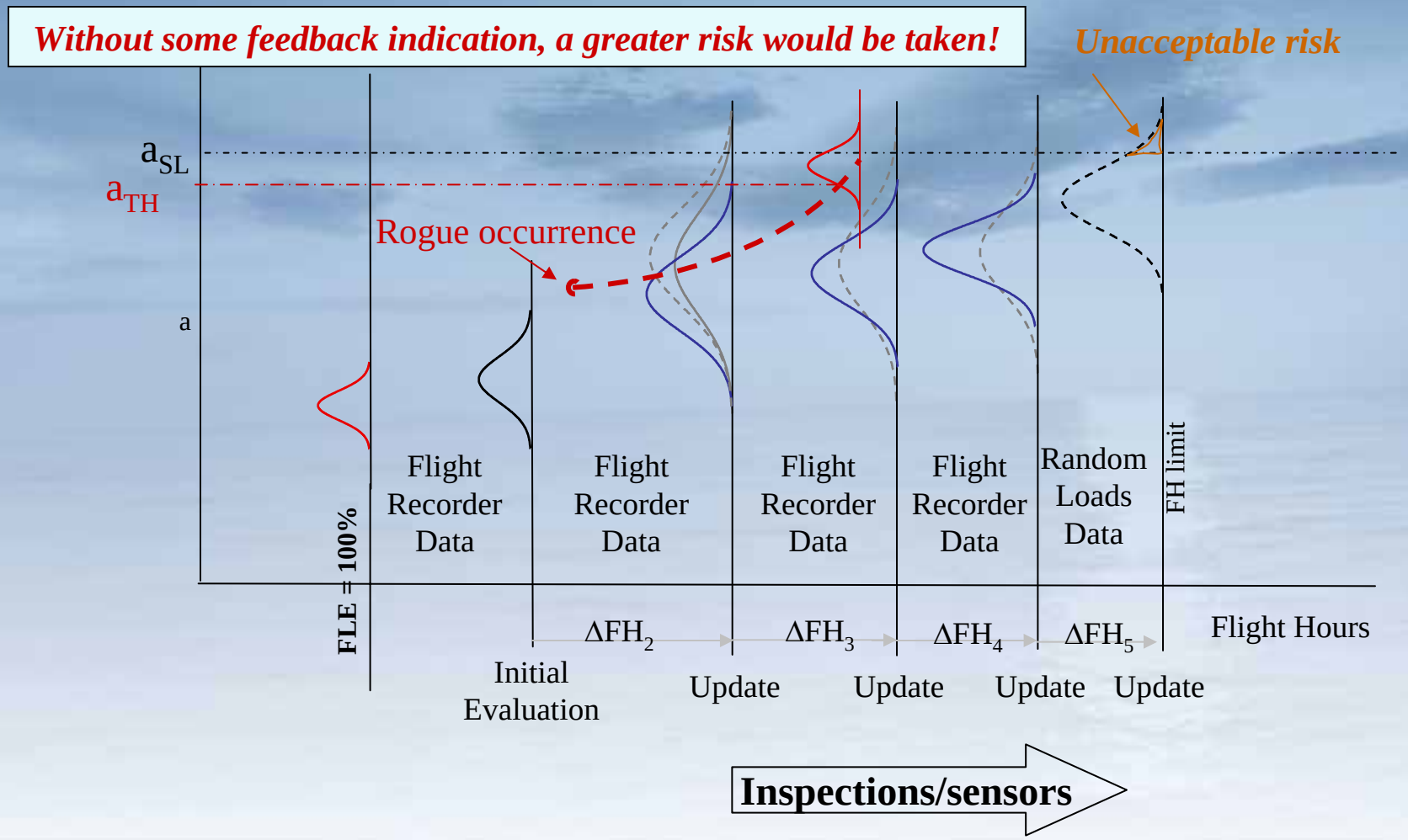
PROGNOSIS: Load-Cycle Induced Fatigue

1. Estimate initial (solid black) PDF with SDRS data from 100% FLE (red PDF)
2. Project future crack distribution (dashed gray curve) based on random load
3. Update after ΔFH_2 with known/tracked loads (solid black curve.)
4. With inspection and/or sensor indicating no cracking, update current crack PDF(solid blue curve.) Repeat for next interval ΔFH_3 and so forth



PROGNOSIS: Loads only model versus rogue!

Can a sensor suite and an inspection schedule provide the feedback? Ideally detect some minimum threshold value with a virtual POD of 100%. Also the threshold must be less than the maximum risk taking crack a_{SL}.



SIPS-Structural Integrity Prognosis System

- DARPA=Sponsor, NGC=Prime & NAVAIR=potential transition.
- The prognosis system/vision is founded on collaboration between sensor systems, advanced reasoning methods for data fusion and signal interpretation, and probabilistic physics-based models for fatigue
- Prototype Prognosis Process Validation/Demonstration:
  - EA-6B Outer Wing Panel (Laboratory) on-going
  - Next, conditionally, a P-3 (Commencing 3QFY08)
- OBJECTIVE: Fly an aircraft to its maximum usable life


questions?