

# SMART|LD Overview



SMART Short Course  
The Aircraft Airworthiness & Sustainment  
Conference  
Grapevine, Texas – March 21, 2016

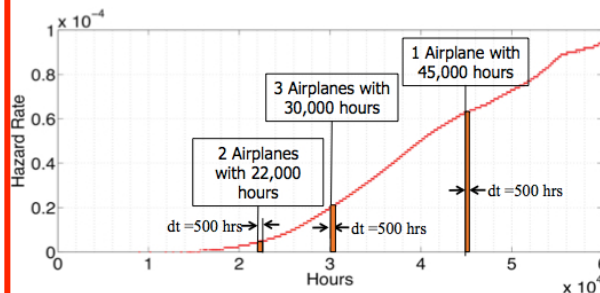
# Program Overview



## Fatigue

### Probabilistic Fatigue Analysis for Small Airplanes (SMART<sub>LD</sub>)

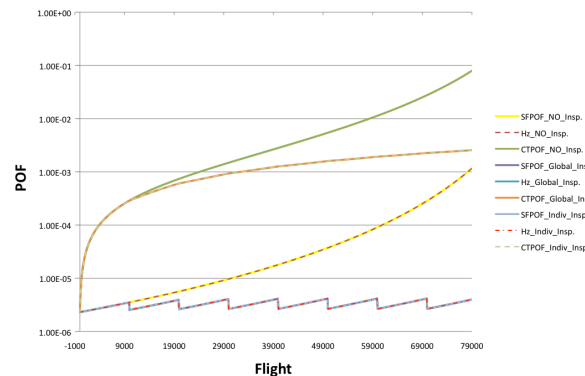
#### Safe-life Approach



- Prob. Life distribution
- Hazard Rate
- Sensitivity Analysis

## Damage Tolerance

### Probabilistic Damage Tolerance Analysis for Small Airplane (SMART<sub>DT</sub>)



- SFPOF, Hz, CTPOF
- Inspection/Repair Effect
- Sensitivity Analysis

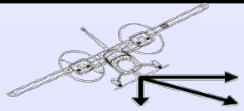
### Probabilistic Fatigue Management Program for General Aviation



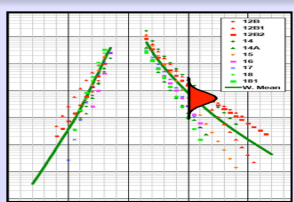
- Develop experience and familiarity with probabilistic approaches within engineering personnel that design, manufacture and maintain general aviation aircraft.
- Verification with in-service findings.
- Develop a Probabilistically-based fatigue management plan (PFMP) for general aviation

## Loading Data

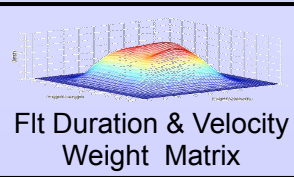
Internally Generated Loading



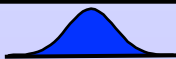
Load Limit Factors



Exceedance Curves

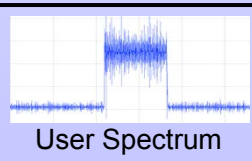


Flt Duration & Velocity Weight Matrix



Sink Rate

User Loading

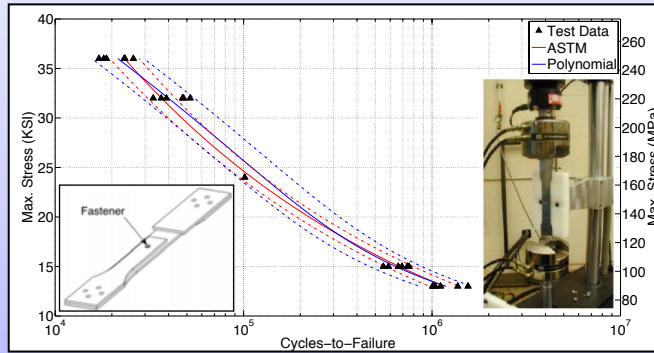


User Spectrum



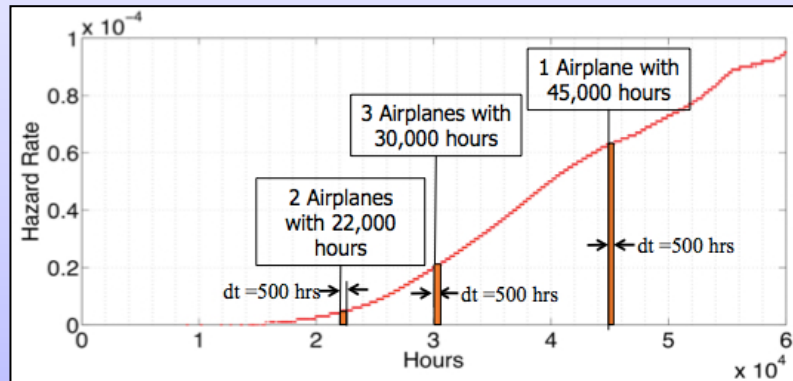
Stress Mult. Factor

## Probabilistic SN Data



- Internal libraries from test results
- FAA AC23-13A
- User Defined

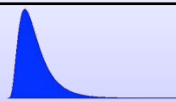
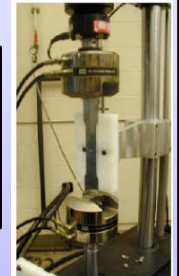
## Monte Carlo Sampling



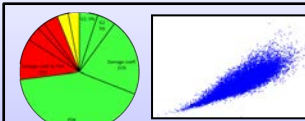
## Random Damage Index



Miner's Coefficient



Life Distribution



Sensitivities

Official  
release 2016

# Smart|LD Capabilities



- Loading Generation
  - Computed from exceedance curves (Internal library and user exceedance option) – Weighted usage available.
  - Flight Duration and Velocity/weight matrices, Design load limit factors, one-g stress, and ground stress as user input.
  - User spectra (Afgrow format)
- Damage accumulated using Miner's rule
  - Safe-Life calculations (in # of flights and # of hours) using Monte Carlo sampling
  - Accumulated damage calculation based on the user number of flight hours.
  - Probability of failure computed using MC sampling
- Multiple random variables
  - Library of exceedance curves (weighted mix ok) – Option for user input exceedance.
  - Flight duration, a/c velocity, one-g stress, and ground stress
  - PSN curve constructed from constant amplitude tests – Option for user input PSN
  - Sink Rate
  - Random damage coefficient.
  - Stress Severity Factor (SSF) option
- Text output files showing Monte Carlo results
- Sensitivities computed using correlation and scatter plots
- Life distribution and hazard rate calculation
- Standard Fortran 95/03, Unix and Windows
- GUI

# Methodology



**SMART**<sub>LD</sub>

**Small Aircraft Risk Technology – Linear Damage Analysis**

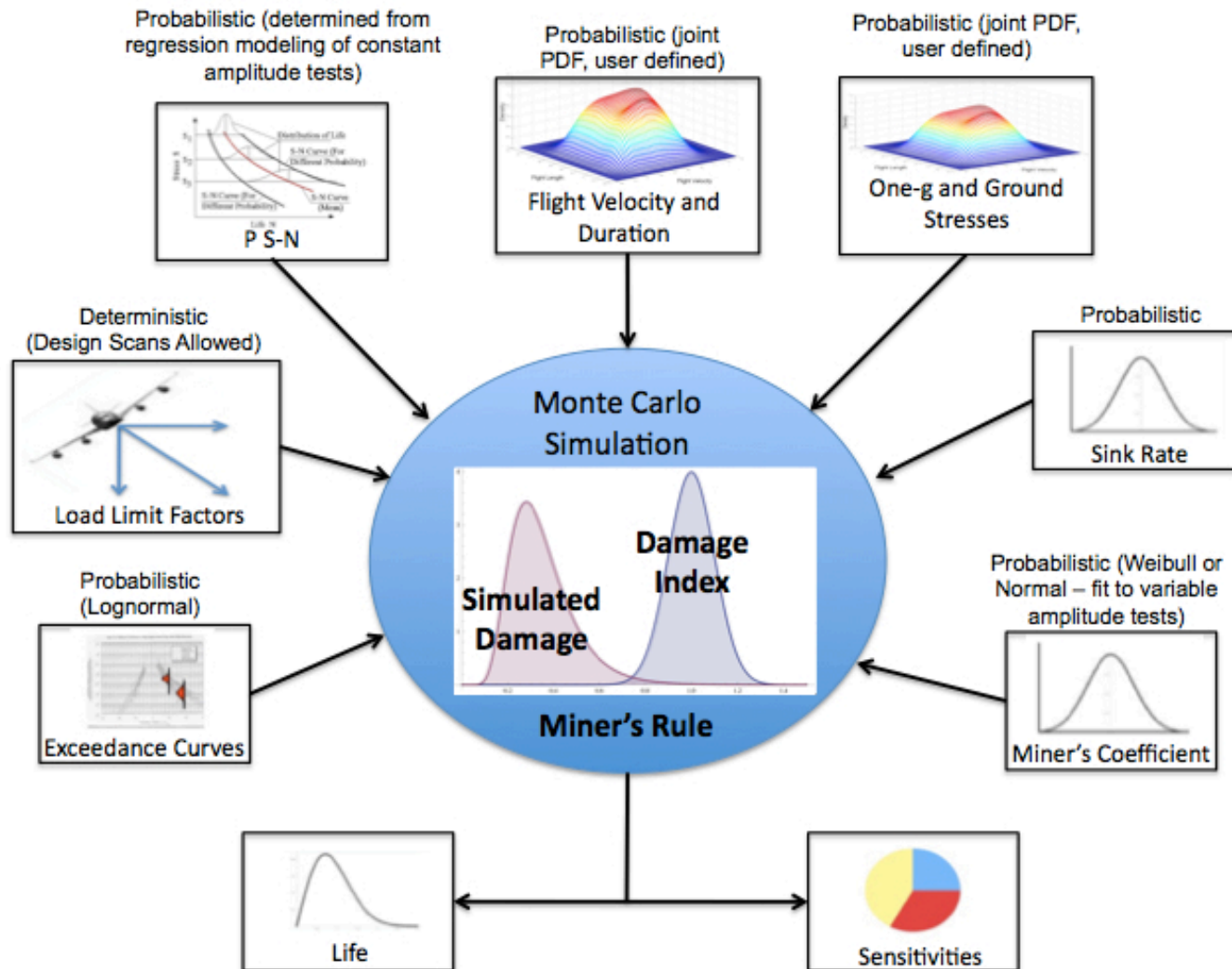


NuSS  
Sustainment  
Solutions

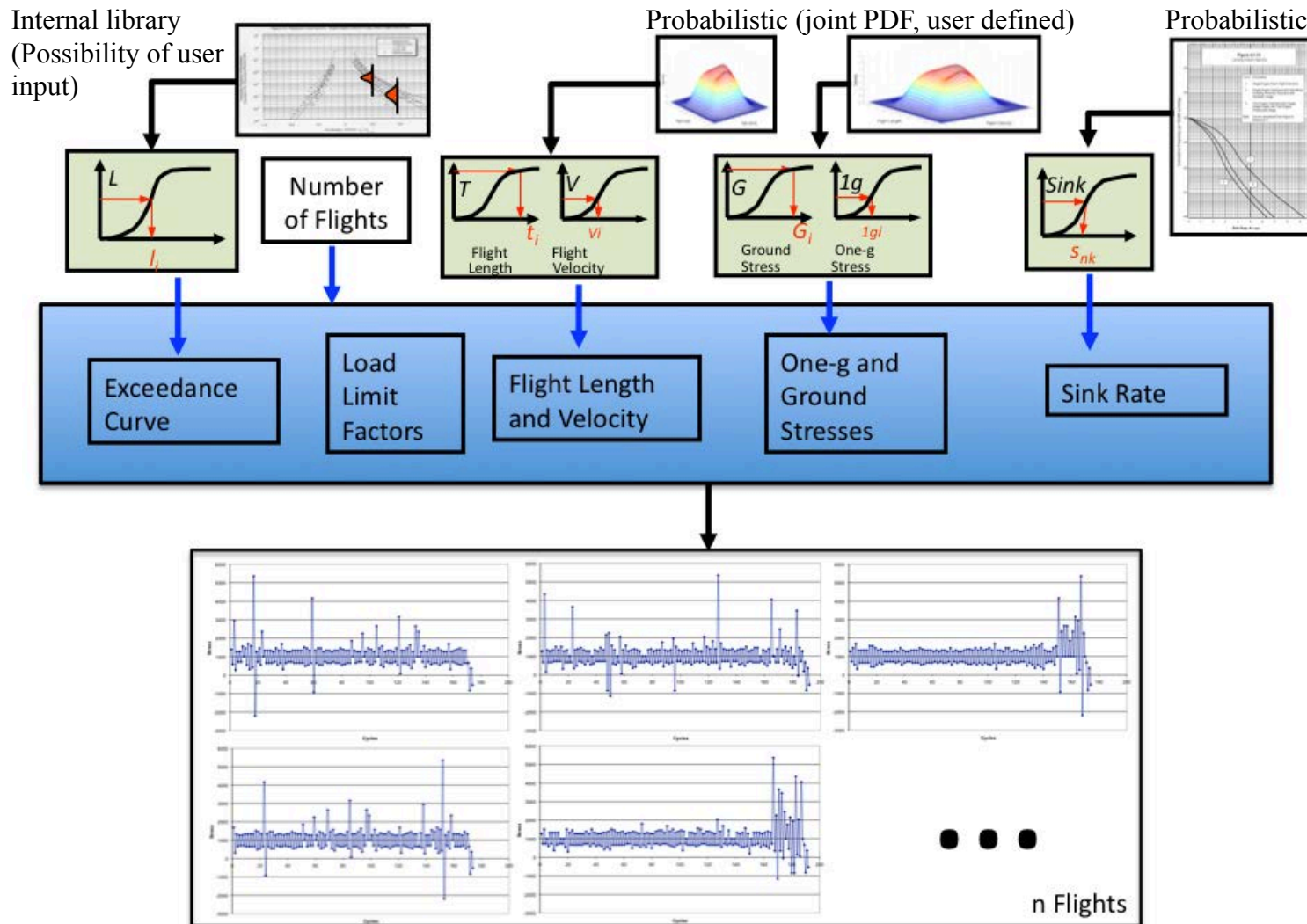
TEXTRON AVIATION

# Risk Methodology

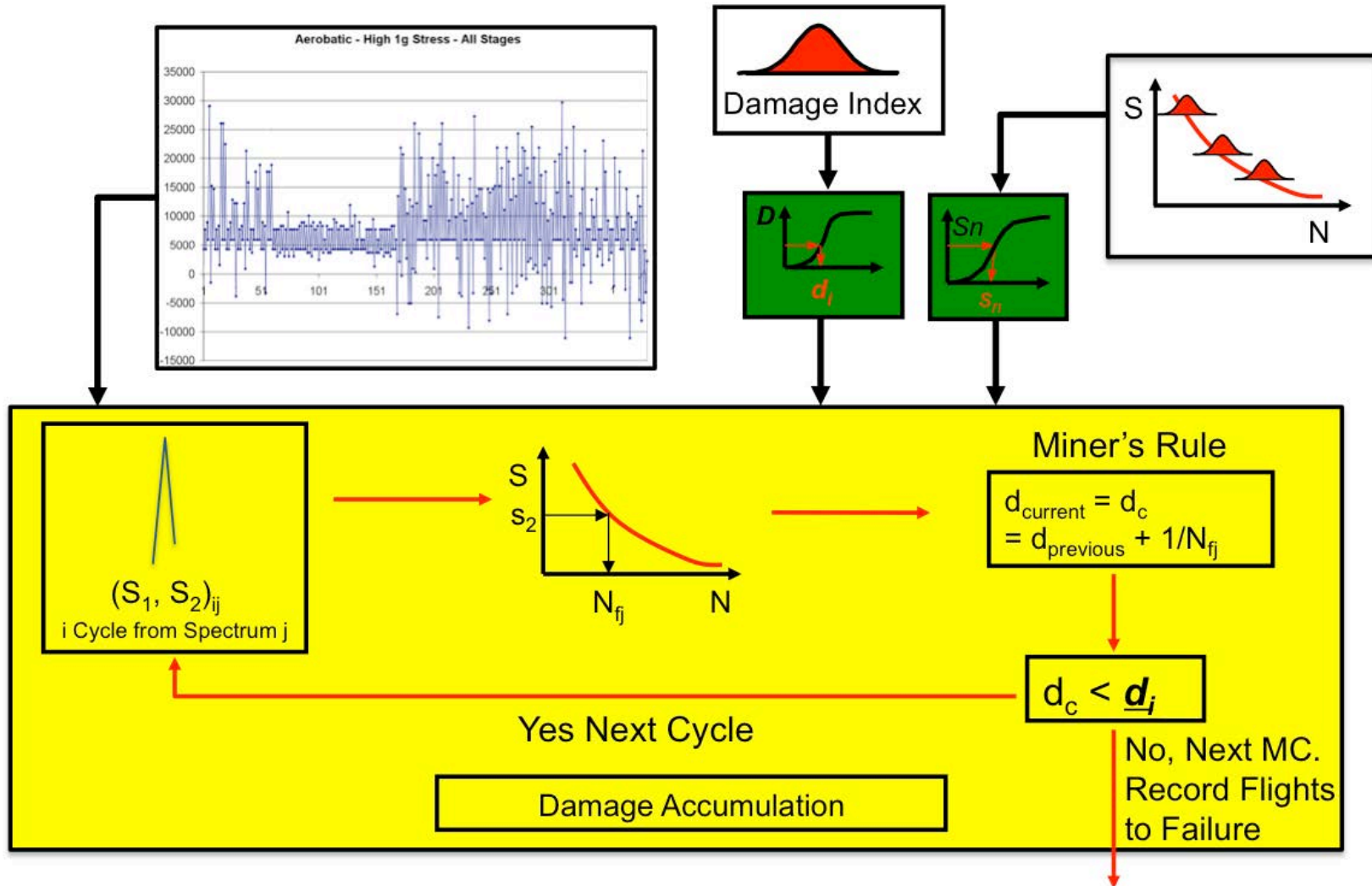
## Methodology Summary



# Loading Generation

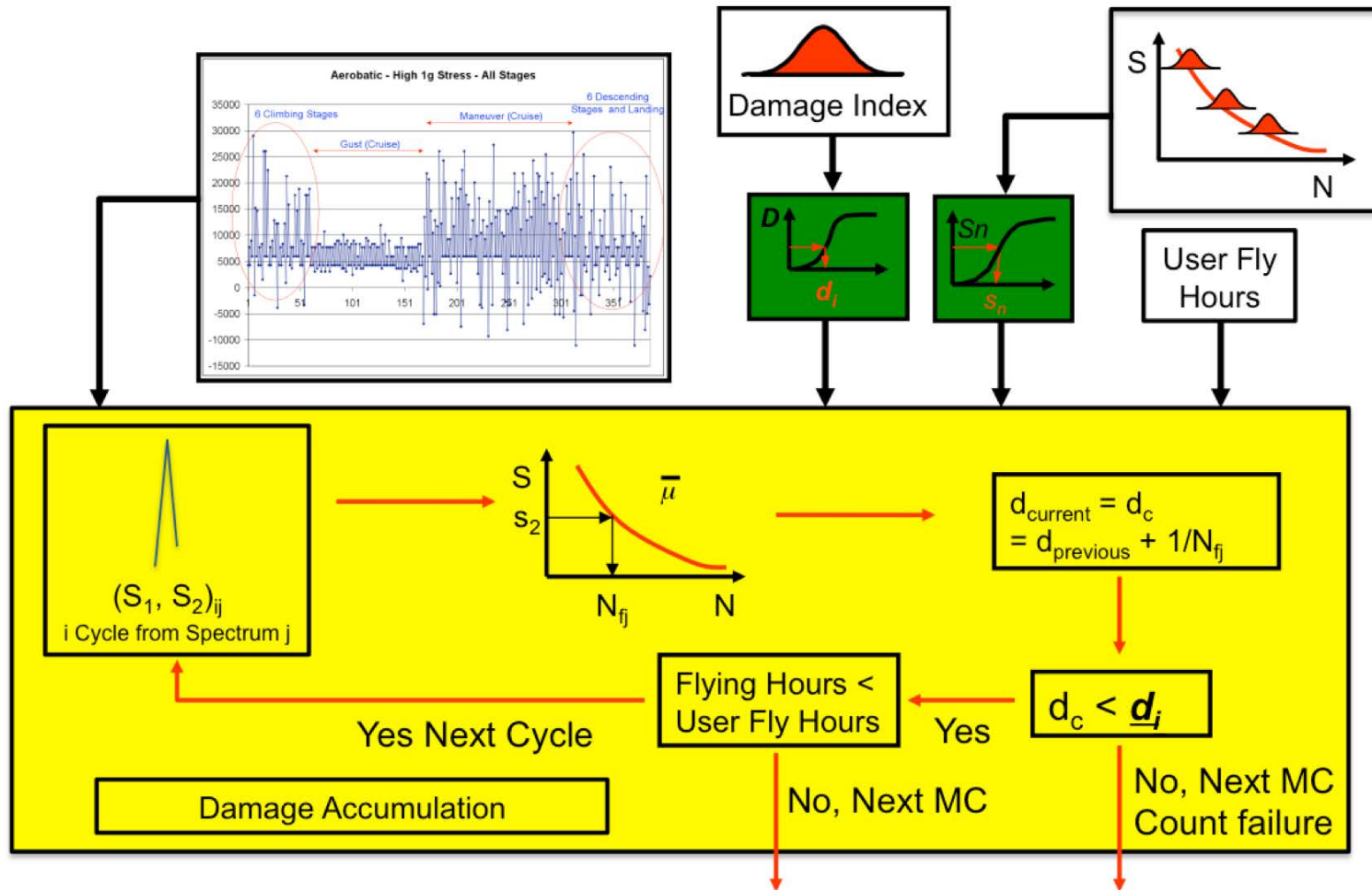


# Damage Methodology (Safe Life)





# Hours Methodology (Current-Future Risk)



# Variables Classification



Variable	Type
Gust/Maneuver Load Exceedances	Probabilistic: (Lognormal)
Aircraft Velocity and Flight Duration	Probabilistic: (Joint PDF with Correlated Variables)
Maneuver Load Limit Factors	Deterministic
Gust Load Limit Factors	Deterministic
Ground/One-g Stress and Flight Duration	Probabilistic: (Joint PDF with Correlated Variables)
Sink Rate	Probabilistic
P-S-N	Probabilistic (Determined from regression modeling of constant amplitude tests)
SSF	PSN Curves (Probabilistic) User Input/ Direct Input (Deterministic)
Miner's Damage Index	Probabilistic (Weibull or Normal Distribution– fit to variable amplitude tests)



NuSS  
Sustainment  
Solutions

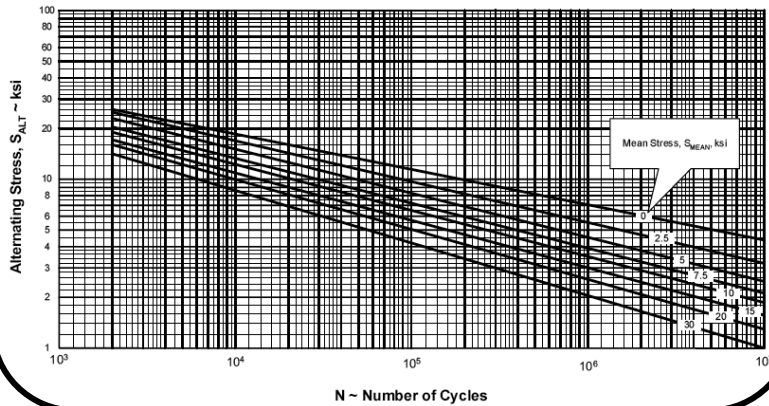
TEXTRON AVIATION

# Stress Life Curves

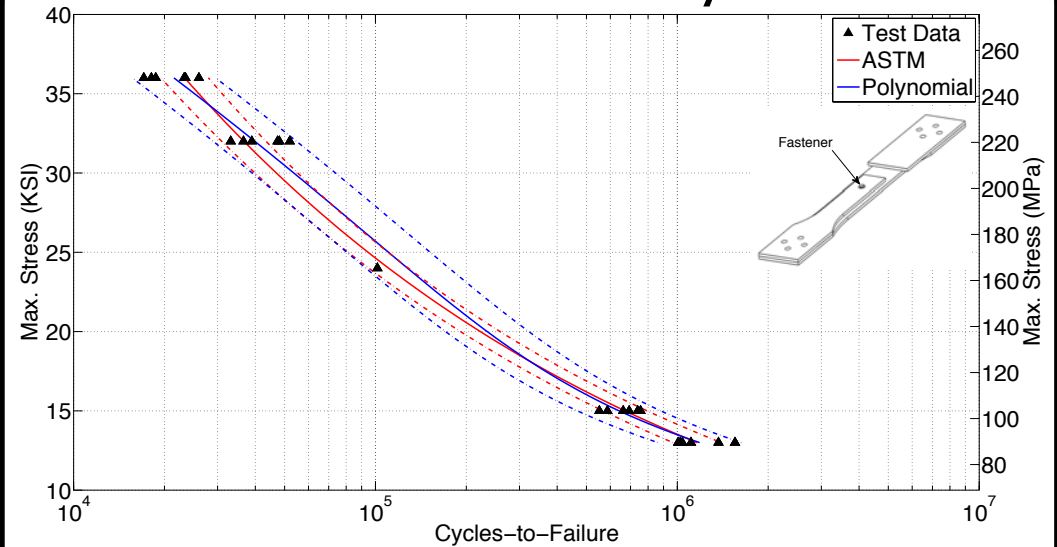
Risk Methodology



## FAA AC-23-13A



## ASTM E739-91 & Polynomial



```

AI6061-T6.sn
! LOG(N) = A + B * LOG (Seq + C) + Z*Stdev
! Seq = Smax*(1-R)^D
! E = Endurance limit
! Z ~ N(0,1)

*** SN PARAMETERS ***
A = 11.3196
B = -5.4083
C = 0.0
D = 0.0
E = 0.0
Stdev = 0.5
  
```

User-defined PSN

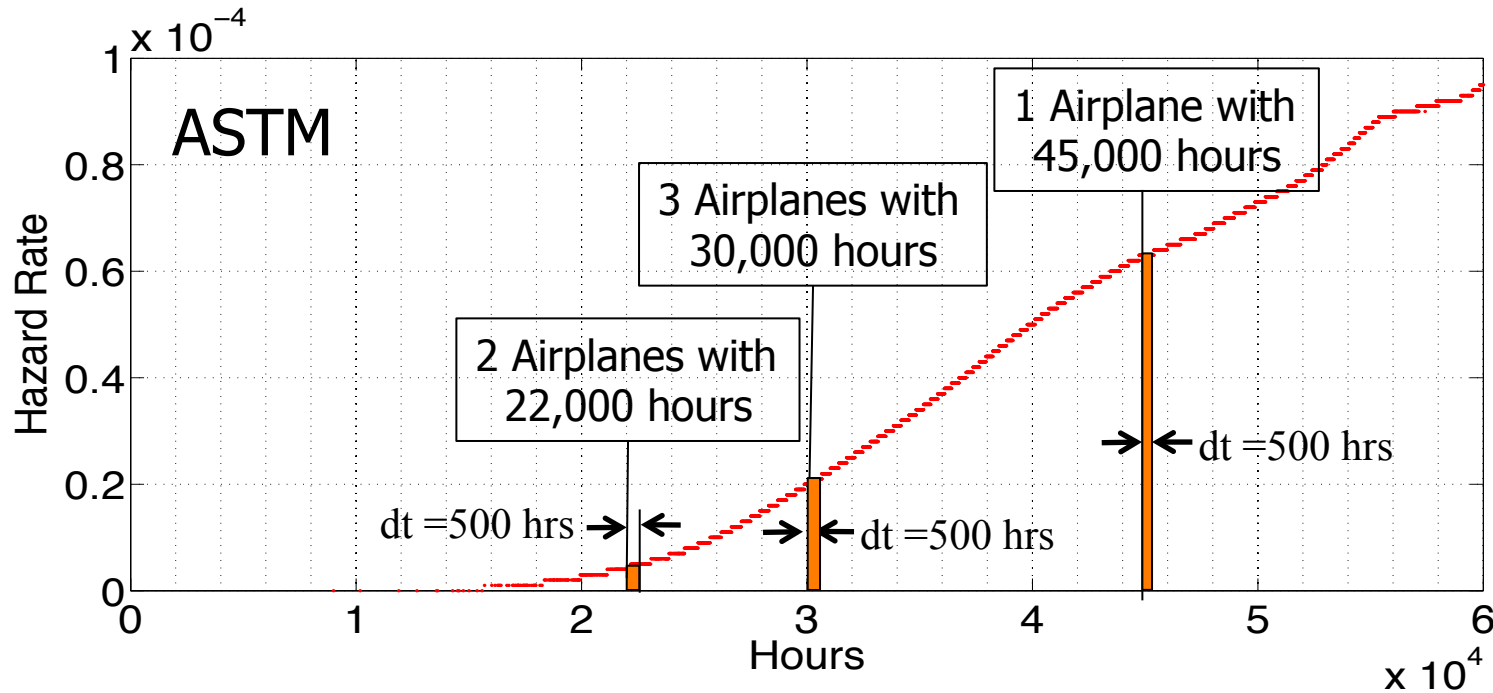


Testing  
Data



- Different Configurations
- ✓ Open Hole
  - ✓ Filled Hole
  - ✓ Load Transfer

# Hazard Function Example Application



- Fleet of 6 Airplanes.
- Calculate Hazard Next 500 hrs.

No A/C	Hours	H <sub>z</sub> (t)*dt	H(t)
2	22,000	0.002	0.004
3	30,000	0.01	0.03
1	45,000	0.0315	0.0315
Fleet Total Hazard			0.0655

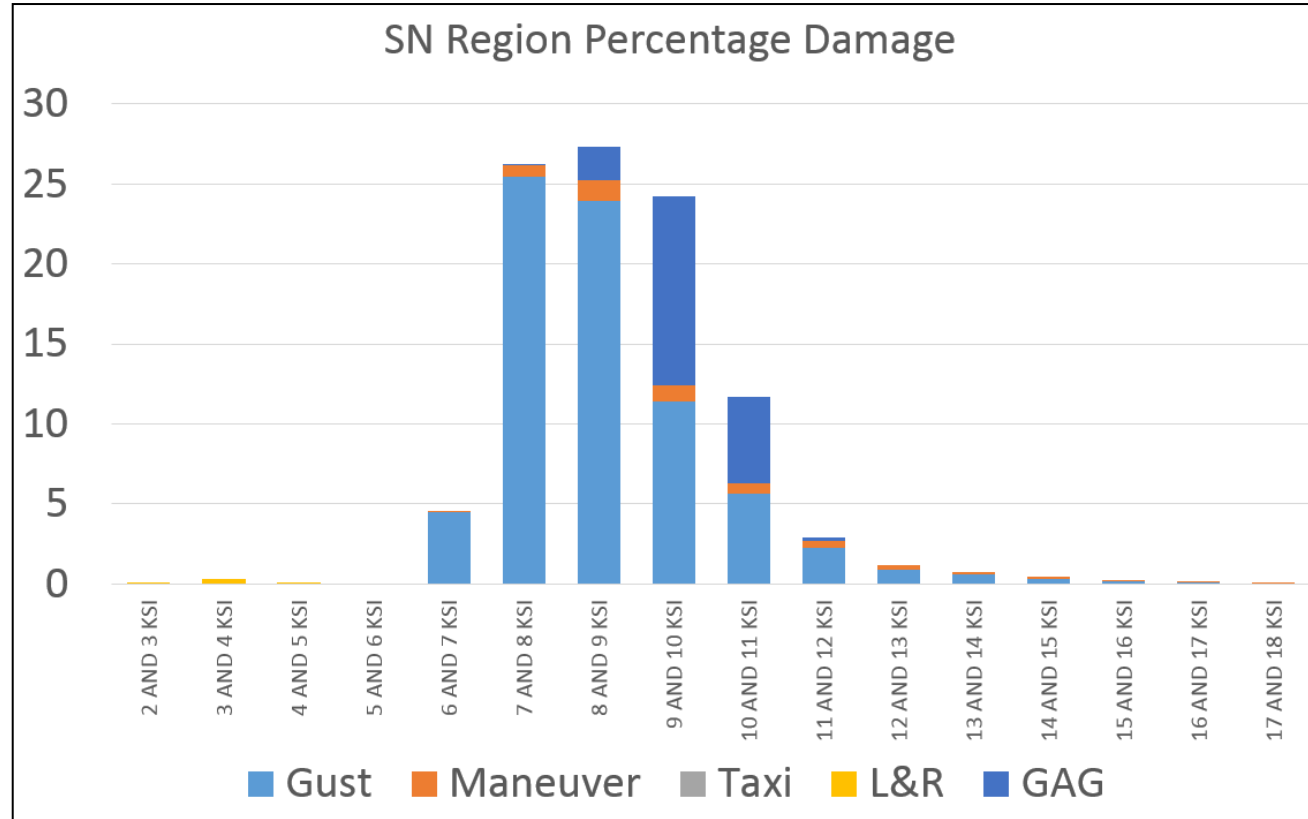


TEXTRON AVIATION

# PSN Region Accumulated Damage

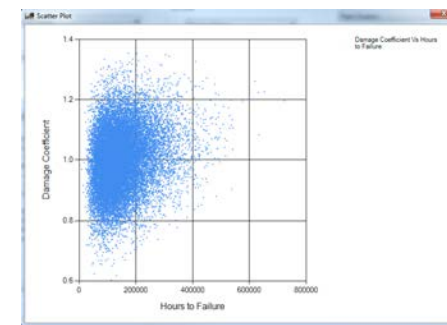
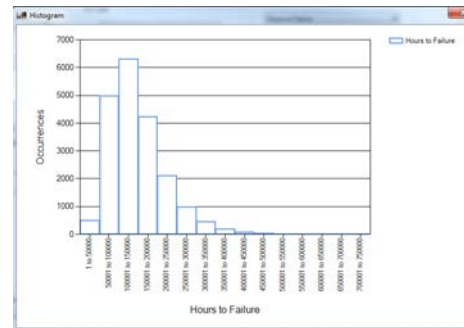
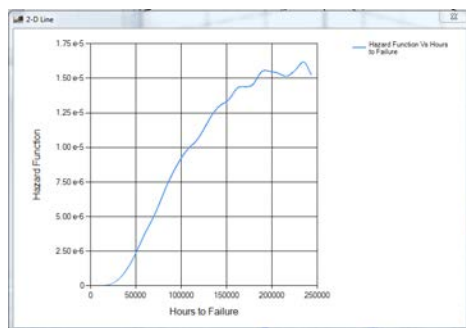
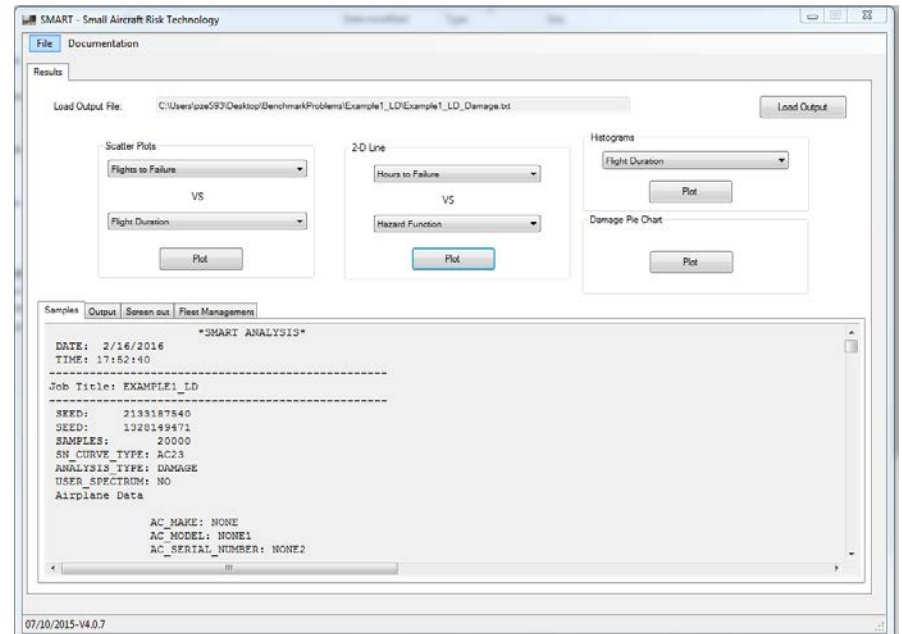
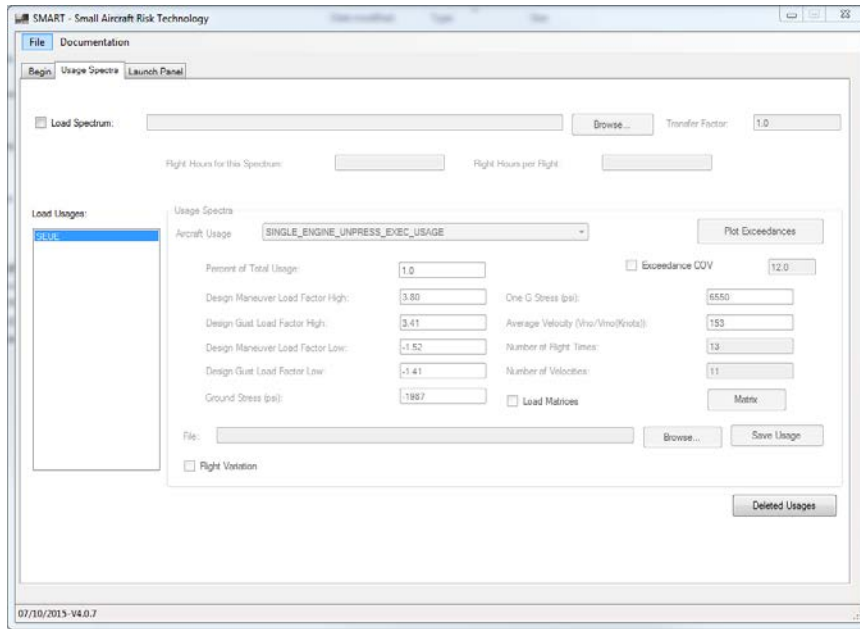


SN REGION	TOTAL
BELOW 1 KSI:	0.00
BETWEEN 1 AND 2 KSI:	0.00
BETWEEN 2 AND 3 KSI:	0.03
BETWEEN 3 AND 4 KSI:	0.30
BETWEEN 4 AND 5 KSI:	0.07
BETWEEN 5 AND 6 KSI:	0.00
BETWEEN 6 AND 7 KSI:	4.52
BETWEEN 7 AND 8 KSI:	26.19
BETWEEN 8 AND 9 KSI:	27.33
BETWEEN 9 AND 10 KSI:	24.26
BETWEEN 10 AND 11 KSI:	11.67
BETWEEN 11 AND 12 KSI:	2.88
BETWEEN 12 AND 13 KSI:	1.18
BETWEEN 13 AND 14 KSI:	0.76
BETWEEN 14 AND 15 KSI:	0.42
BETWEEN 15 AND 16 KSI:	0.19
BETWEEN 16 AND 17 KSI:	0.10
BETWEEN 17 AND 18 KSI:	0.05
BETWEEN 18 AND 19 KSI:	0.03
BETWEEN 19 AND 20 KSI:	0.01
BETWEEN 20 AND 21 KSI:	0.01
...	...
BETWEEN 39 AND 40 KSI:	0.00
ABOVE 40 KSI:	0.00



TOTAL STAGE PERCENTAGE 100.00 75.15 4.90 0.00 0.40 19.55

# GUI

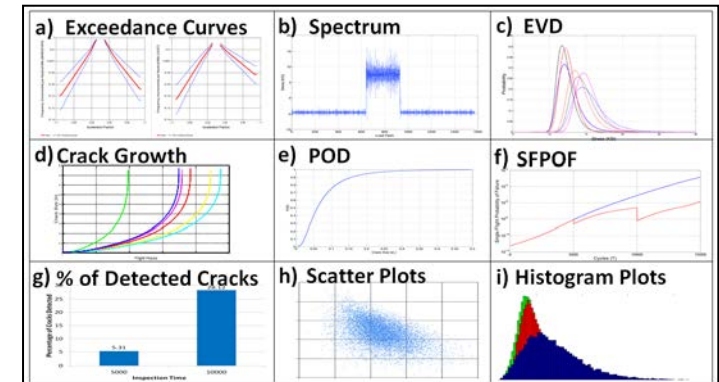


# Upcoming plans



## ➤ Rollout plan

- Smart|LD – 2016 official release
- Smart|DT – multi-phase rollout
  - Phase I: Spring 2016:
    - Master curve implementation, WBI with multiple repair, multi-threaded, Nasgro/Afgrow/Fastran interfaces.
  - Phase II: Late 2016, Early 2017
    - Multiple random variables (dadN, geometry), numerical integration, Kriging surrogate modeling, sensitivities, importance sampling
  - Phase III: Future plans
    - Cloud capabilities, optimized inspection schedule, probabilistic database, etc.
- Training
  - AA&S 2016
    - Monday morning: LD
    - Monday afternoon: DT
    - Presentation on Efficient Methods for POF Calculations



## Web site upcoming



## ➤ Contacts for more information

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# Questions

