



Fundamentals of Physics of Failure

Fred Schenkelberg

Failures



Root Cause



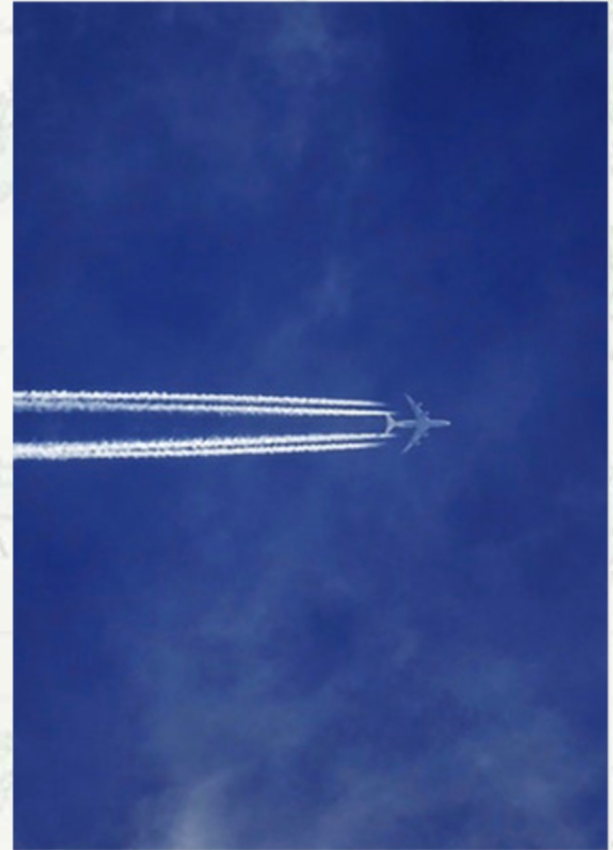
Mathematics



Is there a model for
the applied stress of

85RH/85°C?

Physics of Failure



Models

Mechanisms

Use

PoF Models



A science based approach using modeling and simulation

Based on knowledge of root causes of failure mechanisms

Emperical or Deterministic?

"All models are wrong... but some are useful." George Box

Focus on Mechanisms



Is modeling warranty
returns a PoF model?

Root cause – at fundamental level

Fundamental physical and chemical
behavior of materials to reliability
parameters – Wikipedia

PoF Use



Having a model is nice,
using it is great

Models are not like hammers

Need good information – GIGO

- Decision support / what if analysis
- Avoid or minimize accelerated testing

What else is a good use of PoF?

How do you explain

physics of failure and
reliability?

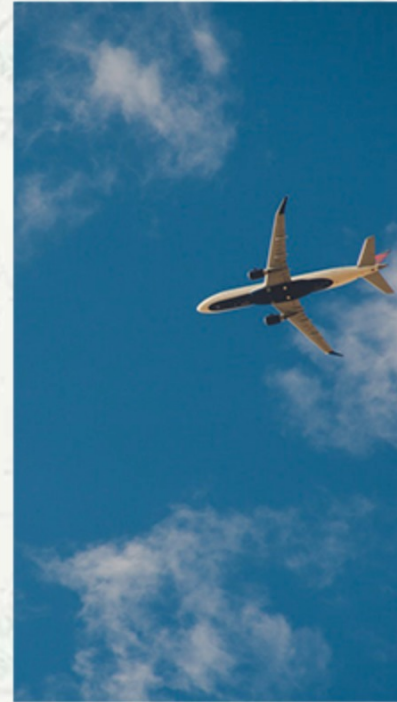
Finding Existing PoF Models



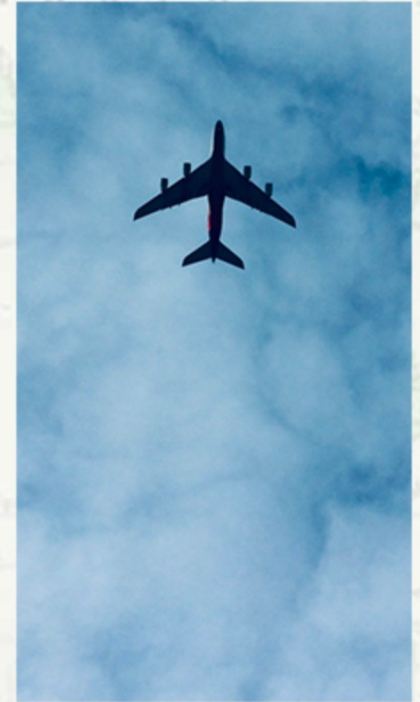
Literature



WARP



CALCE



DFR
Solutions

A historical map of the Pacific Ocean region, showing continents like Asia, Australia, and parts of North and South America. The map is in a light, aged style with various geographical labels. The text "Do a Literature Search" is overlaid in a large, orange, serif font.

Do a Literature Search





A historical map of Asia and Oceania, showing various regions like 'SOUTH ASIATIC', 'RUSSIA', 'MONGOLIA', 'INDIAN OCEAN', and 'NEW HOLLAND'. The map is in a light, aged style with green landmasses and blue water.

U of Maryland CALCE



A historical map of the Pacific Ocean region, showing continents like Asia, Australia (labeled 'NEW HOLLAND'), and parts of North and South America. The map is in a vintage style with various geographical labels and a color palette of greens, browns, and blues.

DFR Solutions Sherlock



What mechanisms

would you like to
model?

Creating a PoF Model



Concept



Research
Project



Degree

Conceptually



It's a model, just because
you can make it more
complex, should you?

Objective – estimate time to failure

Approach – stress(es) influence on TTF

Relationships – experimental work

Modeling – mathematics, simulation

Check step – how accurate is the model

Refine – improve with better data

Do a Research Project



If the value of model is high, this makes sense

Deep dive on specific mechanism

Which mechanisms to model?

Earn an Advanced Degree



You will finally have a
doctor in the family

This is going back to school.

- + Lab equipment
- + Guidance and Reviews
- Rigor
- Published

Is it worth having

and using a PoF
model?

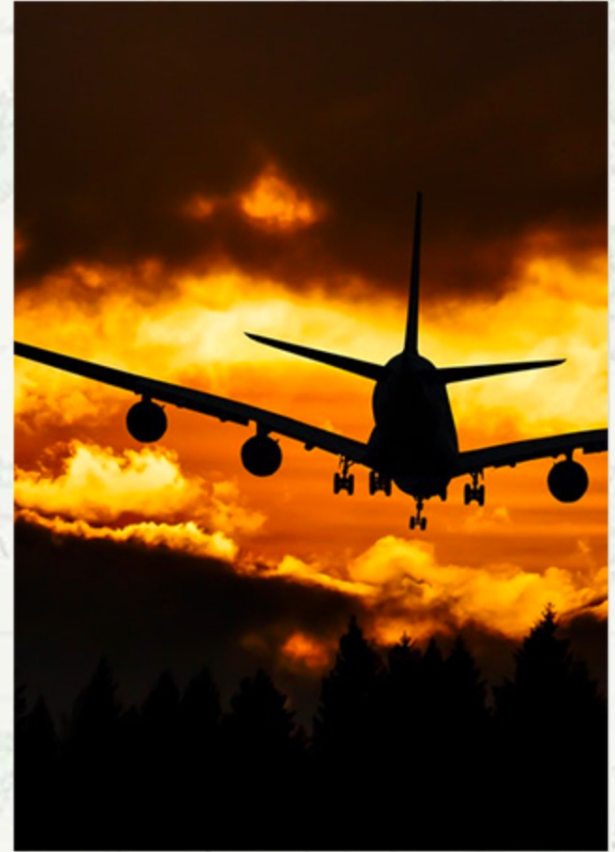
Example PoF Models



Electromigration



Wire Bonds



Solder Joints

Electromigration



Black's Equation

$$TTF = A(J^{-n})e^{\frac{Ea}{kT}}$$

A is a constant based on cross-sectional area
J is the current density
Ea is the activation energy
k is Boltzmann constant
T is temperature
n is a scaling factor

Temperature & Humidity on Wire bond attach



Pecks equation for wire
bond/ bond pad
connections

$$TTF = A_0 (RH^{-2.7}) f(V) \exp\left(\frac{E_a}{kT}\right)$$

A is a constant,
RH is the relative humidity,
f(V) is a voltage function (often cited as
voltage squared),
E_a is the activation energy,
k is Boltzmann's constant,
and T is temperature in Kelvin

Vibration & Solder Joints



Steinberg - has many models describing vibration effect on structures

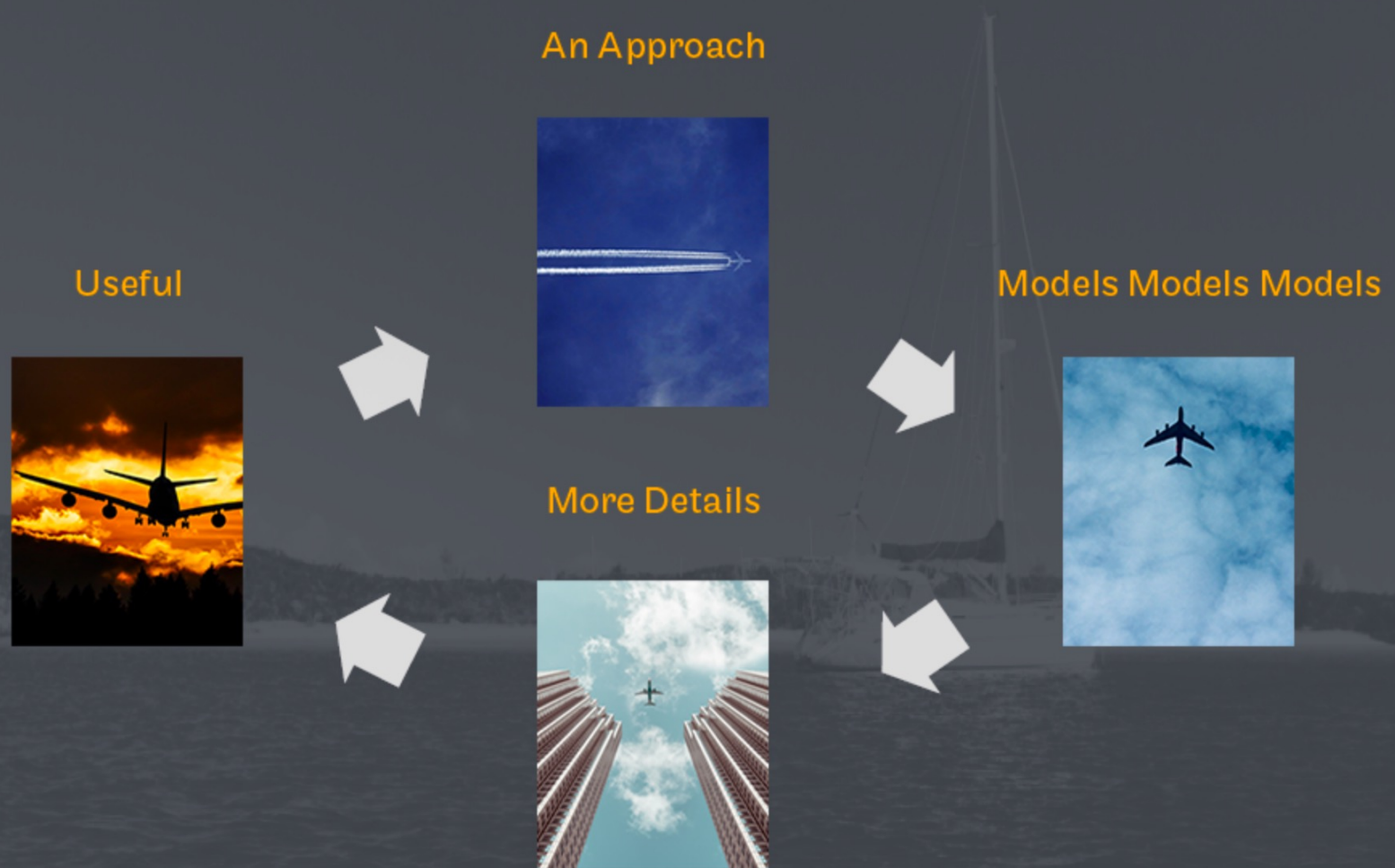
$$Z_0 = \frac{9.8 \times 3 \sqrt{\pi / 2 \times PSD \times f_n \times Q}}{f_n^2}$$

$$Z_c = \frac{0.00022B}{chr\sqrt{L}}$$

Z is maximum displacement,
PSD is the power spectral density (g^2/Hz),
 f_n is the natural frequency of the CCA,
Q is transmissibility (assumed to be square root of natural frequency),
 Z_c is the critical displacement (20 million cycles to failure),
B is the length of PCB edge parallel to component located at the center of the board,
c is a component packaging constant,
h is PCB thickness,
r is a relative position factor,
and L is component length.

How have you made
made use of models?

In Summary



More Information

Visit [AccendoReliability.com](https://www.AccendoReliability.com)

Let me know if you have any questions.

Check out the reliability engineering podcast network at [Reliability.FM](https://www.Reliability.FM)

Let's only use useful reliability standards.