



# Fundamentals of Tolerance Analysis

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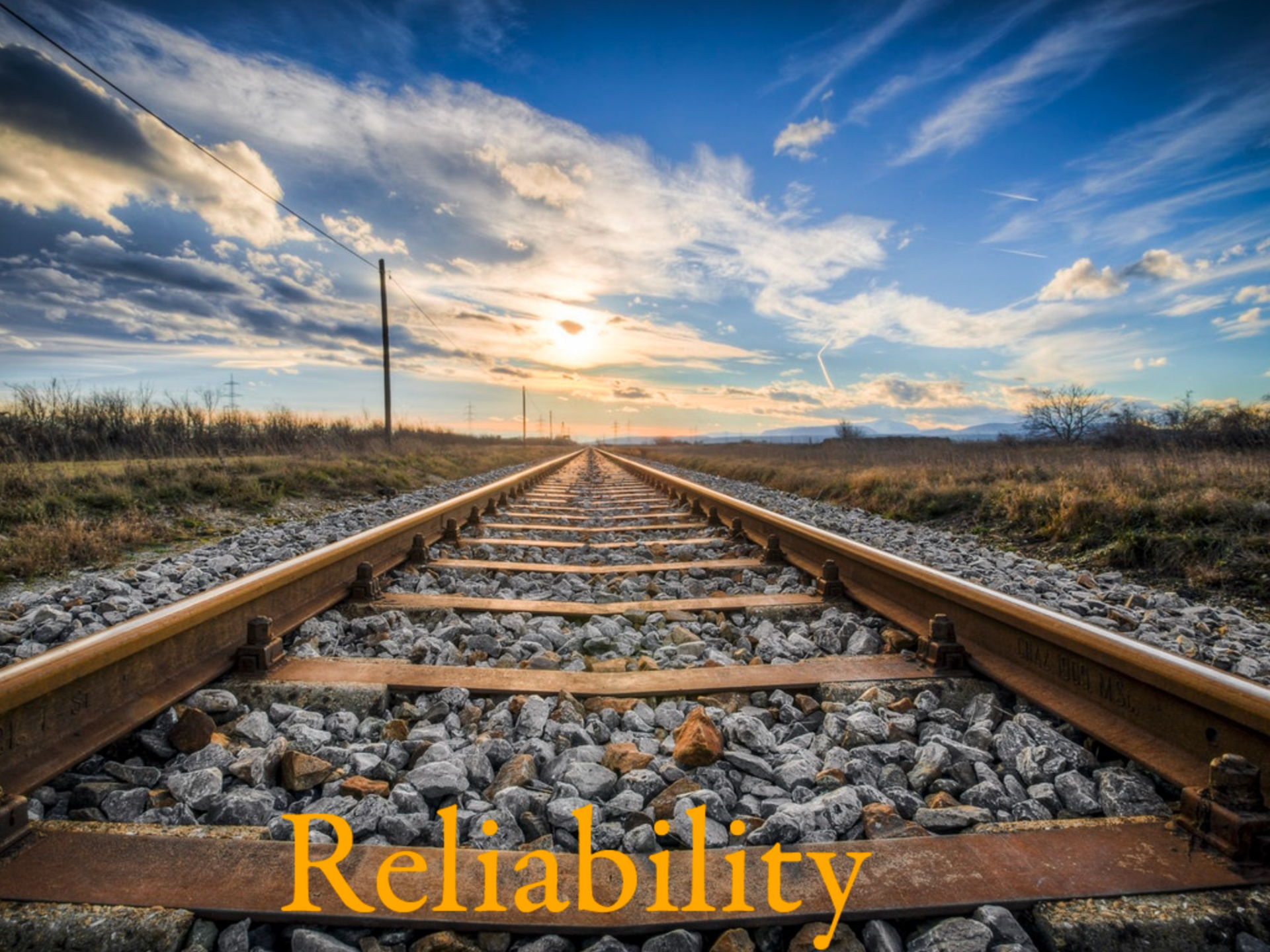
Variation





Design





Reliability



# Tolerance Analysis

What is the role of  
Reliability Engineer?



# Worst Case Method



Benefits



How to



Example



# Worst Case Benefits



Most common method

Quick

Easy

Simple Math

Only Need Range of Variation (often we use the specified tolerance)

Conservative

No stats or distributions



# How to: Worst Case



Really just making a lot of  
systems virtually

Sum the set of worst dimensions

--

add nominal values

add minimum values

add maximum values



# Worst Case Example



Stack of plates

One plate is 20 mm  $\pm$  1mm

2 plates stack then have possible dimensions of?



When is

Worst Case  
Tolerance Analysis  
Appropriate?

# Root Sum Squared method



Benefits

How to

Example



# RSS Benefits



with just a few assumptions

Uses standard deviations to estimate combined stack up standard deviation

Able to estimate yield or fall out

Assumes a normal distribution (for everything)

Accounts for spread of data

Allows cost/benefit tradeoff analysis

# How to: RSS



touching on basic stats

Sum means

Estimate standard deviation for each element

Sum variances (std dev squared)  
- bonus points - why variances?

Square root of result



# RSS Example



Each plate is nominally 20mm  $\pm$  1mm

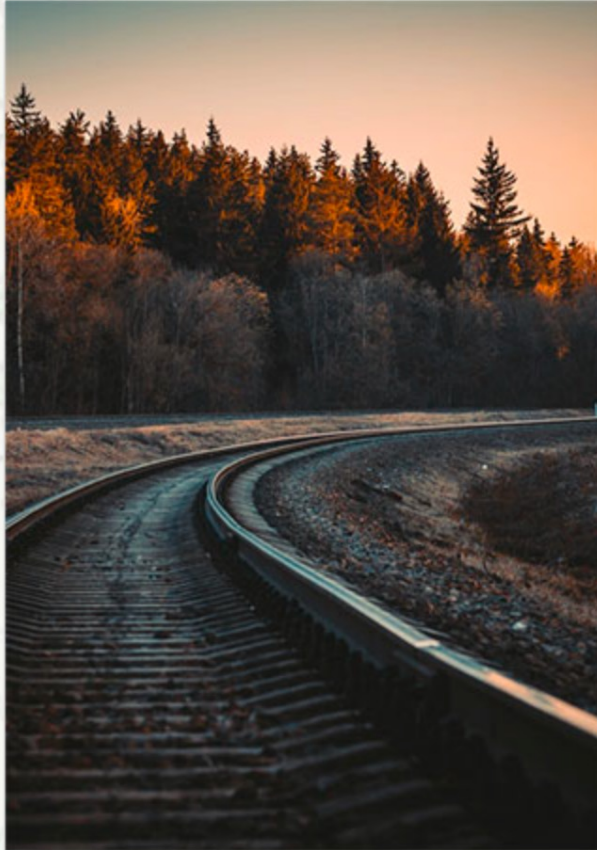
let's assume the plates are normally distributed in thickness...

When is

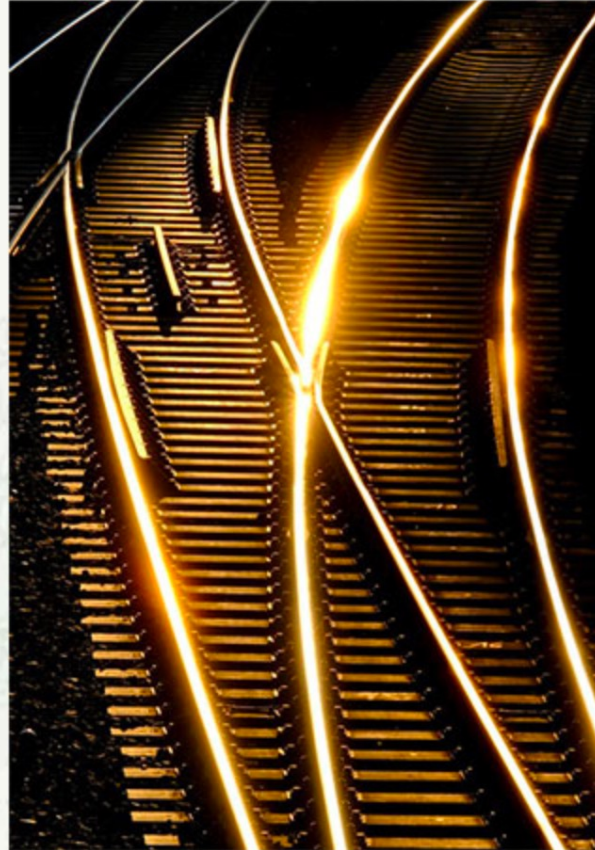
Root Sum Squared  
Tolerance Analysis  
Appropriate?



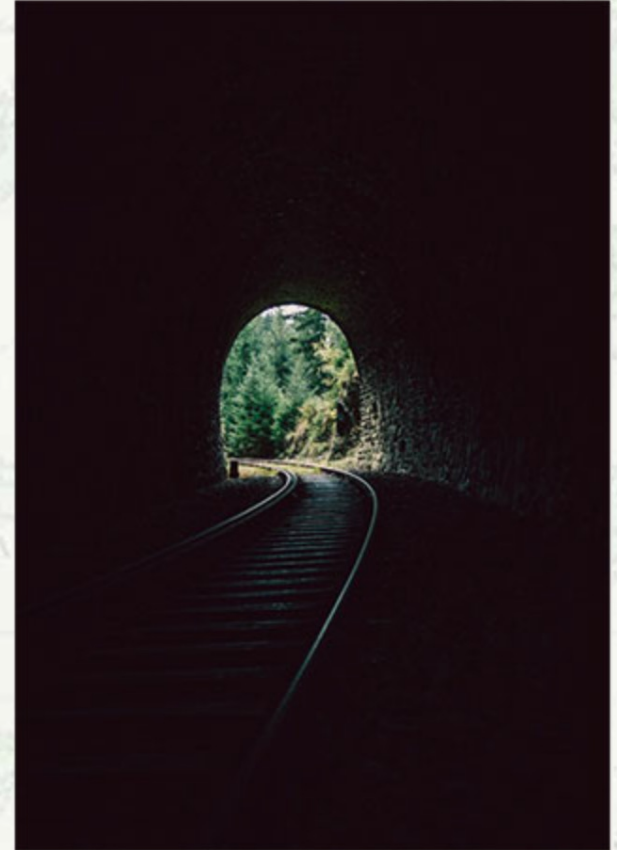
# Monte Carlo method



Benefits

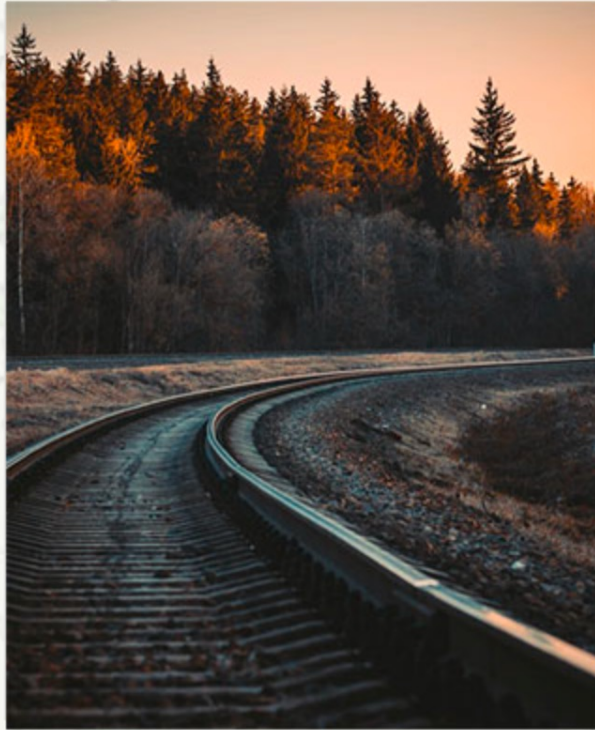


How to



Example

# Monte Carlo Benefits



computer power makes this  
feasible

Accounts for statistical spread of data

Allows estimate of fraction out of  
tolerance

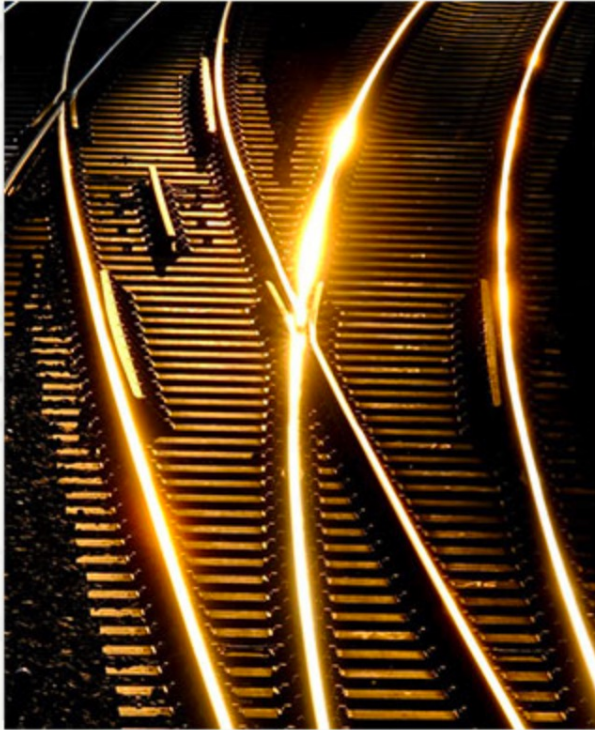
Allows cost/benefit tradeoff analysis

Any set of distributions (not limited to  
normal)

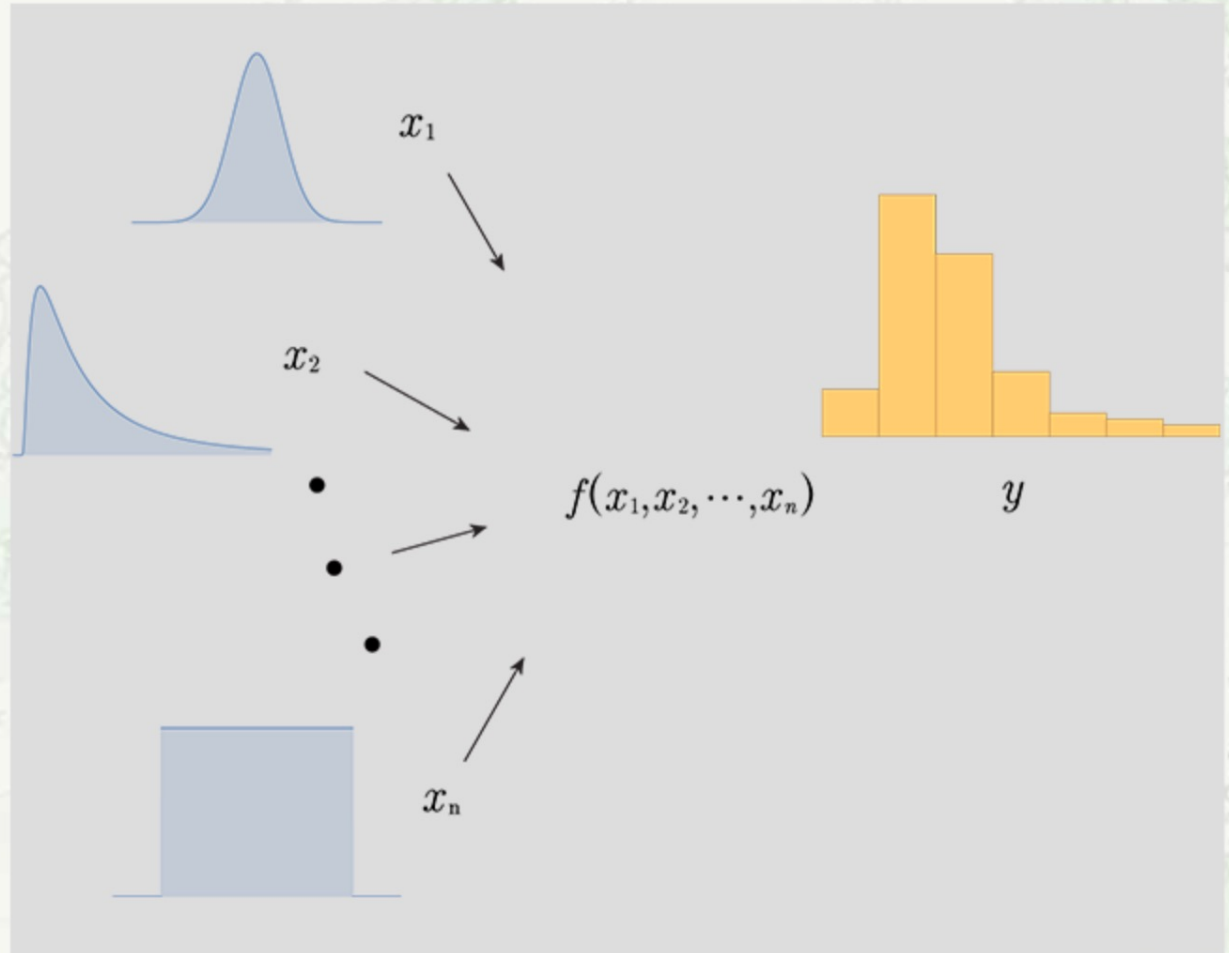
With good data, most accurate



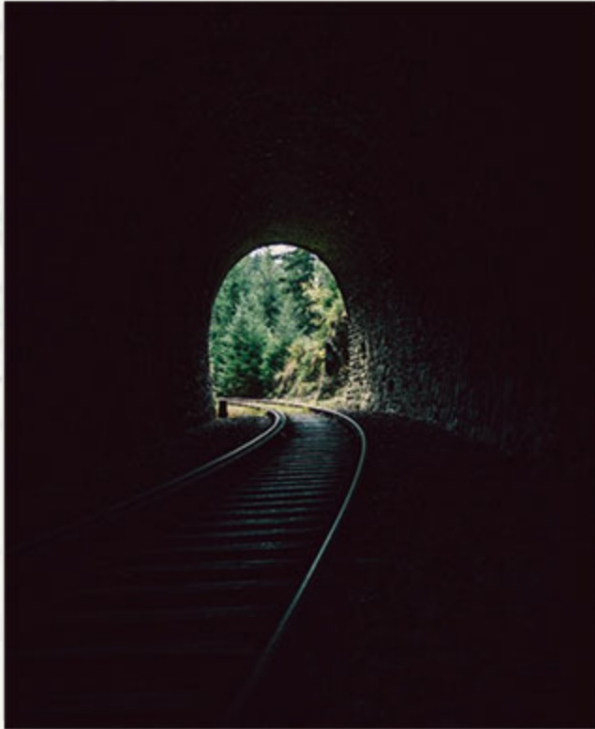
# How to: Monte Carlo



Really just making a lot of  
systems virtually



# Monte Carlo Example



It's fun, too

The transfer function is the sum of the thicknesses in this case.

(see last webinar for more on the method)



When is

Monte Carlo  
Tolerance Analysis  
Appropriate?

# Reliability Engineering Role



Data



DFR



Variation



# Data



data for data driven decision  
making

Means are just not sufficient

Specifications are not data, they are hope

For the important stuff,  
get the data

Remember to run a Gauge R&R as well

# Design for Reliability



Design for variability is part  
of design for reliability  
(quality, mfg'ility, etc)

Design to work is a good practice

Design to work with the existing  
(potential) variability is better

Or, understand what variability to reduce  
or closely monitor



# Variation



Variation happens

Many sources of variation

Some are expected and common cause

Some are special causes

All leads to shorten product longevity

What are some  
hurdles?



# In Summary

Conduct Analysis



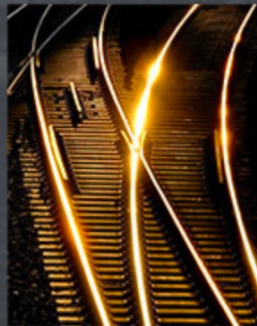
Variability



ID Critical Systems



Collect Data



# More Information

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

Let me know if you have any questions.

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