

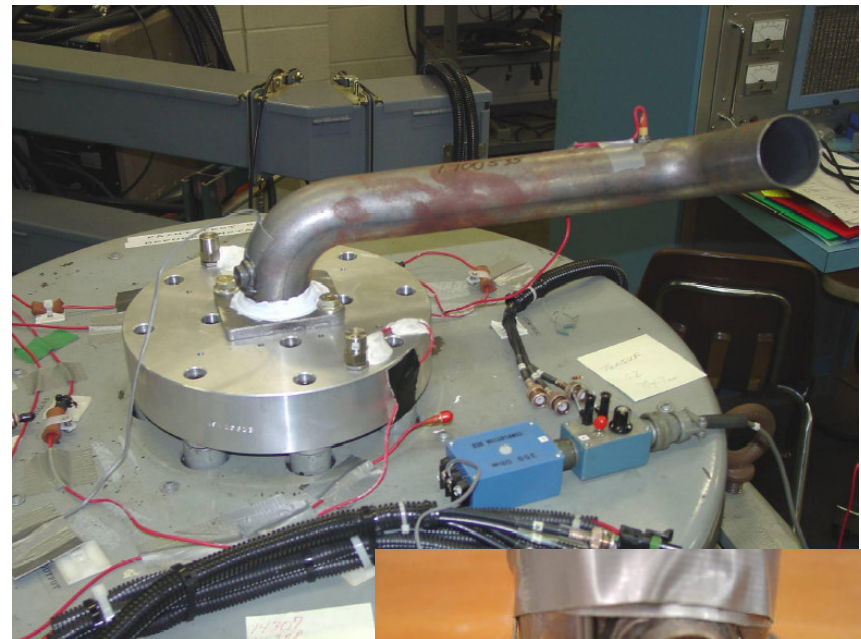


# Accelerated Vibration Testing Based on Fatigue Damage Spectra

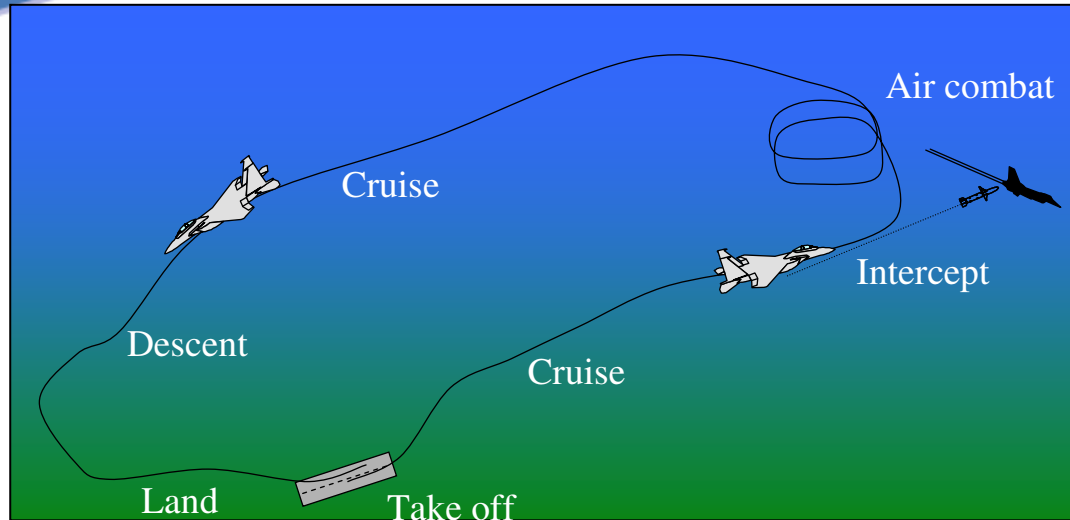
*Dipl.-Ing. Thomas Kemmerich*

# What Do We Want From A Durability Test?

- Durability test that's suitable for the item in question:
  - a component,
  - sub-assembly
  - or whole structure
- Test must replicate the same failure mechanisms as seen in the real world
- Test should be representative of the real loading environment
- Test should be accelerated where possible but not incur unrealistically high loads
- Test specification can be used in FE based virtual test or real physical test

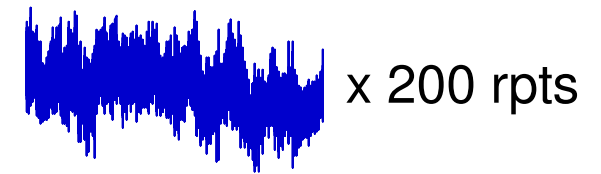


# Mission Profiling

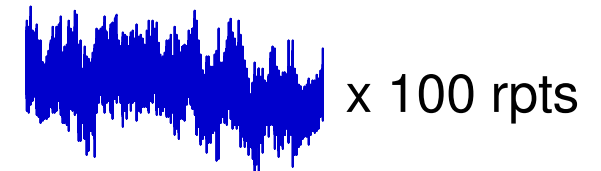


- A **Mission Profile** is a set of loading events that constitute the expected loads seen by a structure over its life.
- Events might be **time series** records of discrete events like curb strikes or potholes, or extra-ordinary emergency cases (**deterministic**)
- or **PSD** records of continuous vibratory loading such as engine induced vibration, etc. (**stochastic**)

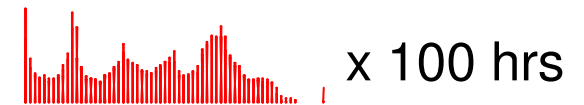
## Mission Profile



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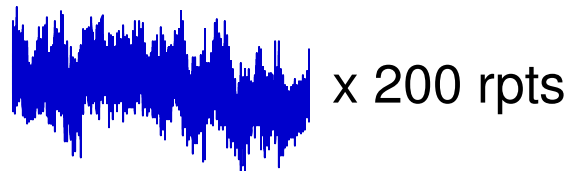
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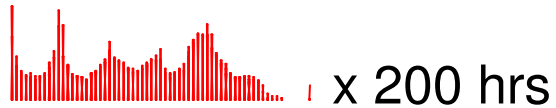
etc...

# Test Synthesis

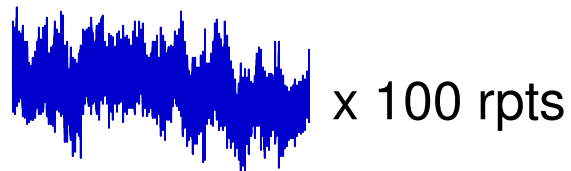
## Mission Profile



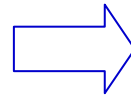
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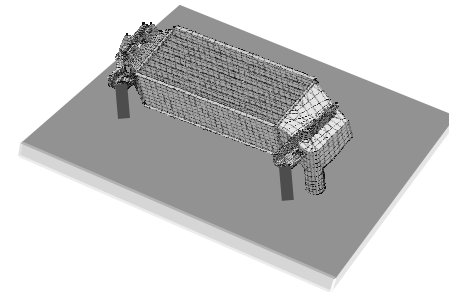
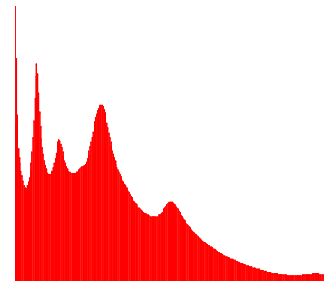


etc...



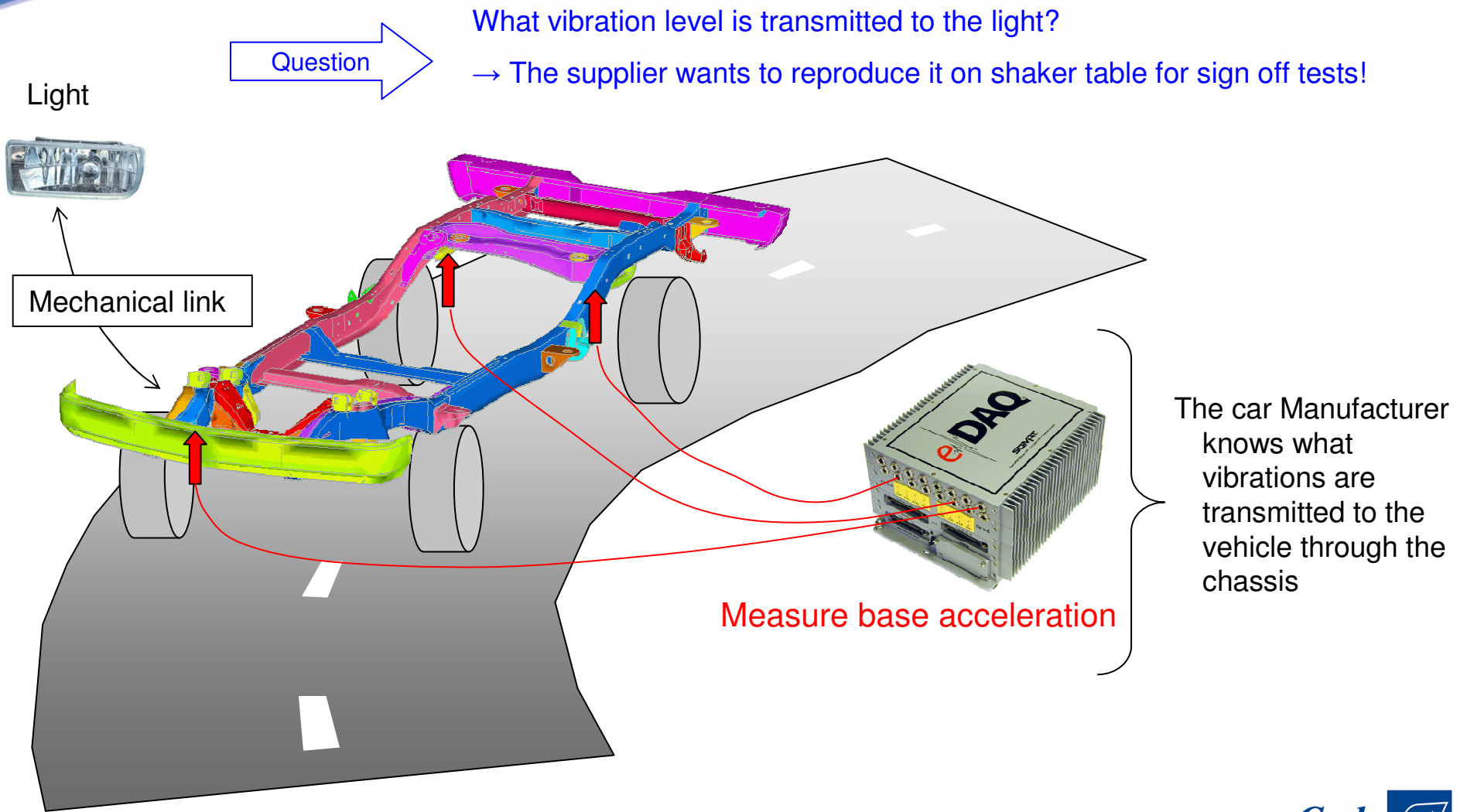
## Test Specification

- Test can be expressed in the form of a **PSD** or **Swept Sine** signal



- Test has **same damage content** as Mission Profile
- Test accounts for **statistical** uncertainties
- Test is **accelerated** to reduce test duration
- Test is **verified** to ensure no unrealistically high loads are induced

# Simple Example



# How to get the Vibrations transmitted to a component?

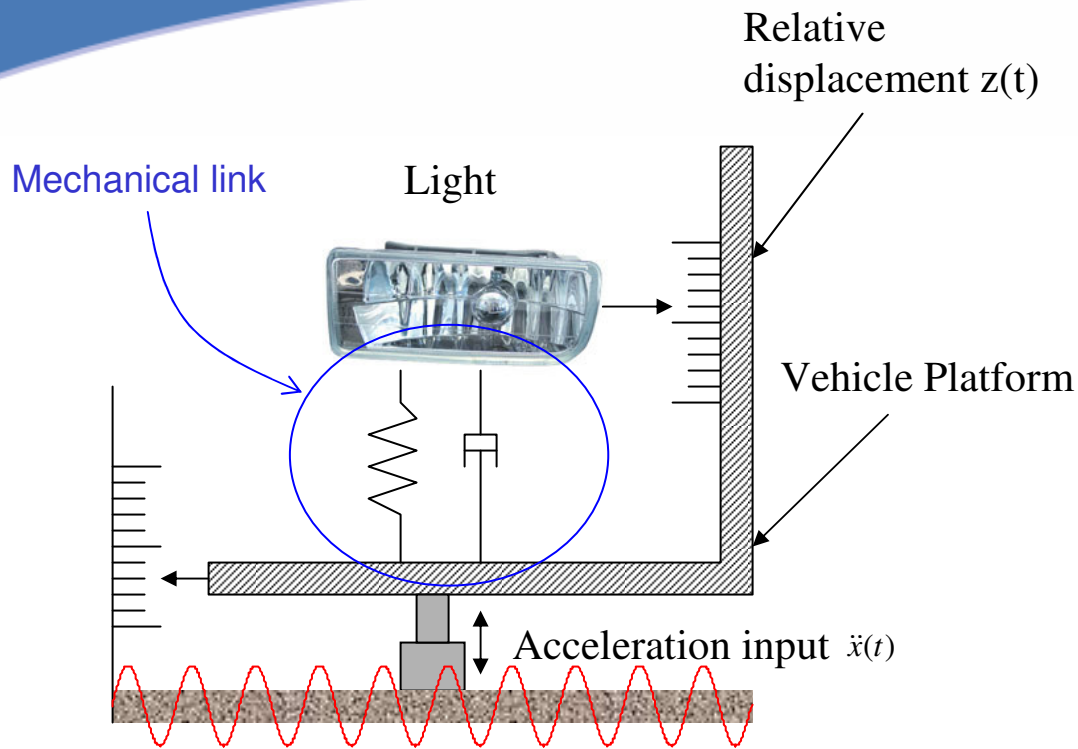
Not realistic!

- Measure it!
  - Difficulties to access the component
  - Lots of components i.e. 100's more channels needed!

To investigate!

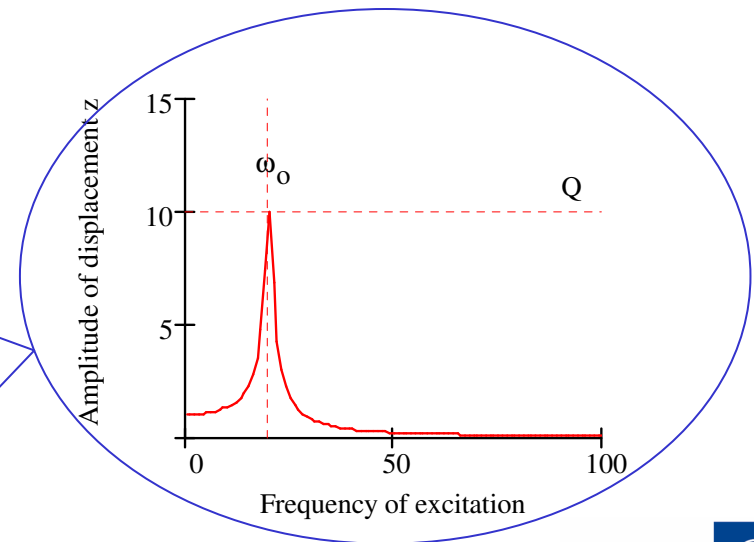
- Use the dynamical properties of the link component / chassis... and get the components response artificially!
  - You may know its frequency response
  - or simply have a rough idea of its 1st natural frequency

# Investigating Solution 2

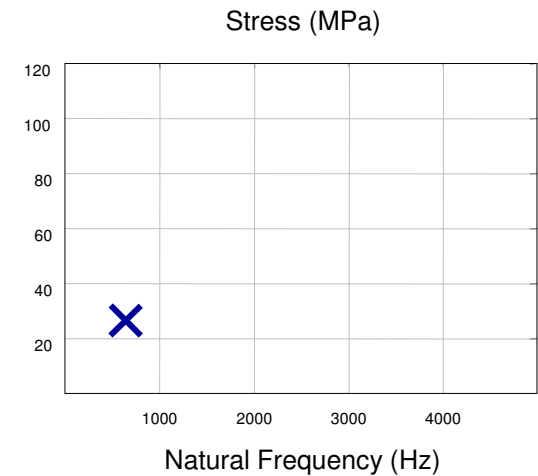
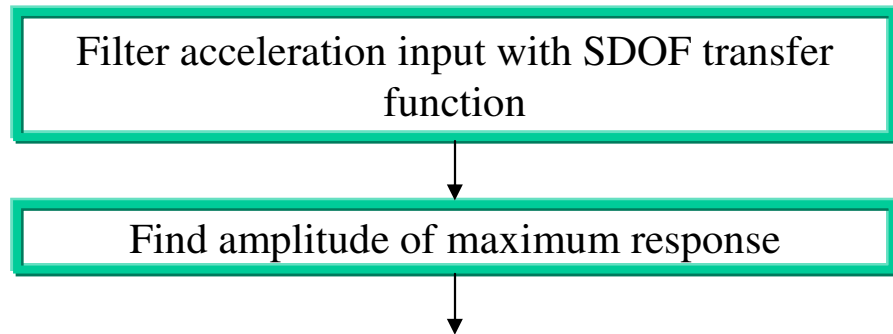
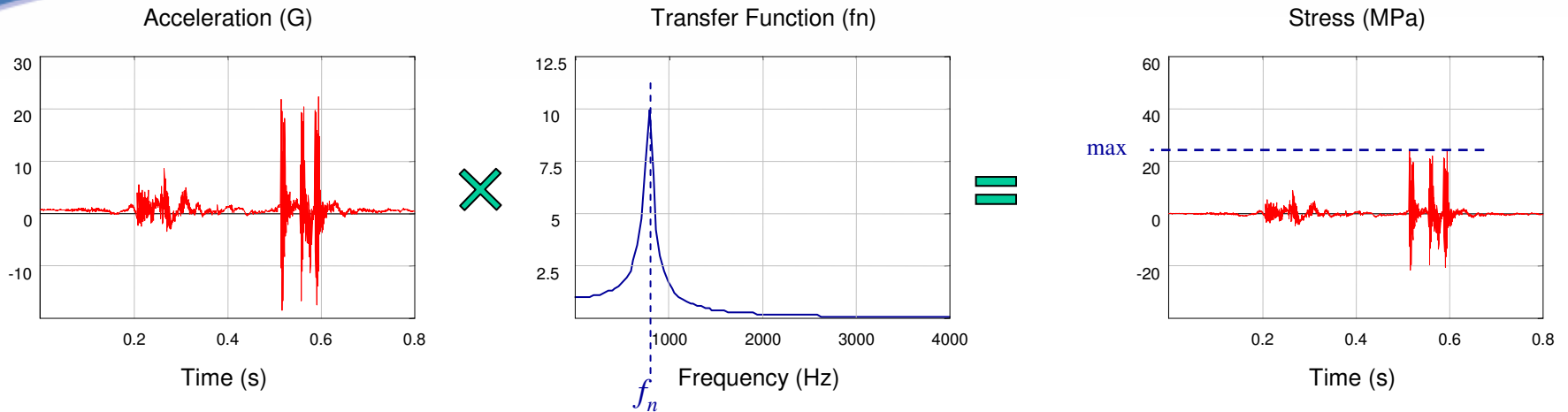


- Consider a simple vibrating component mounted on the vehicle platform
- The component receives the most critical loads when excited at its natural frequency

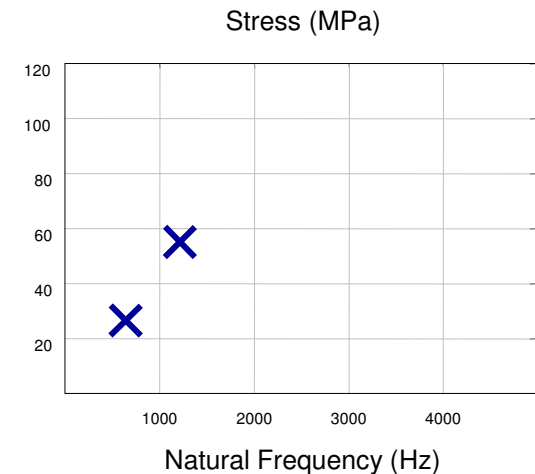
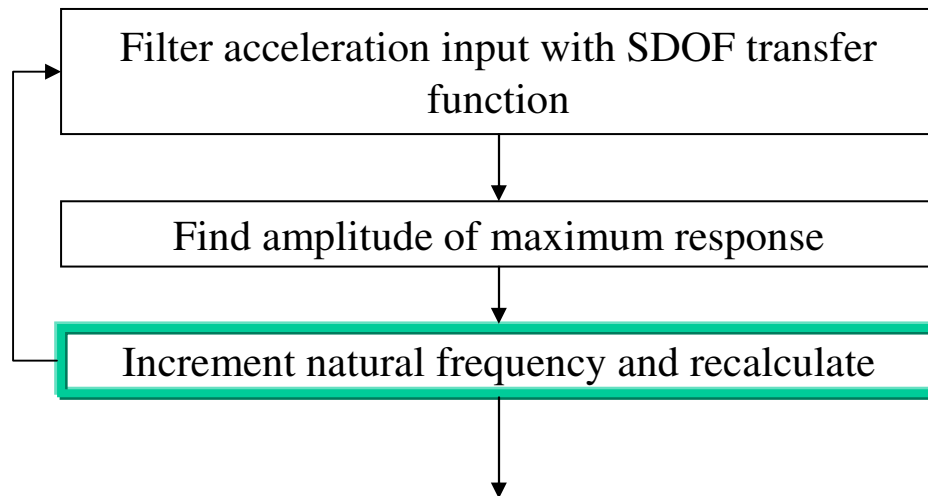
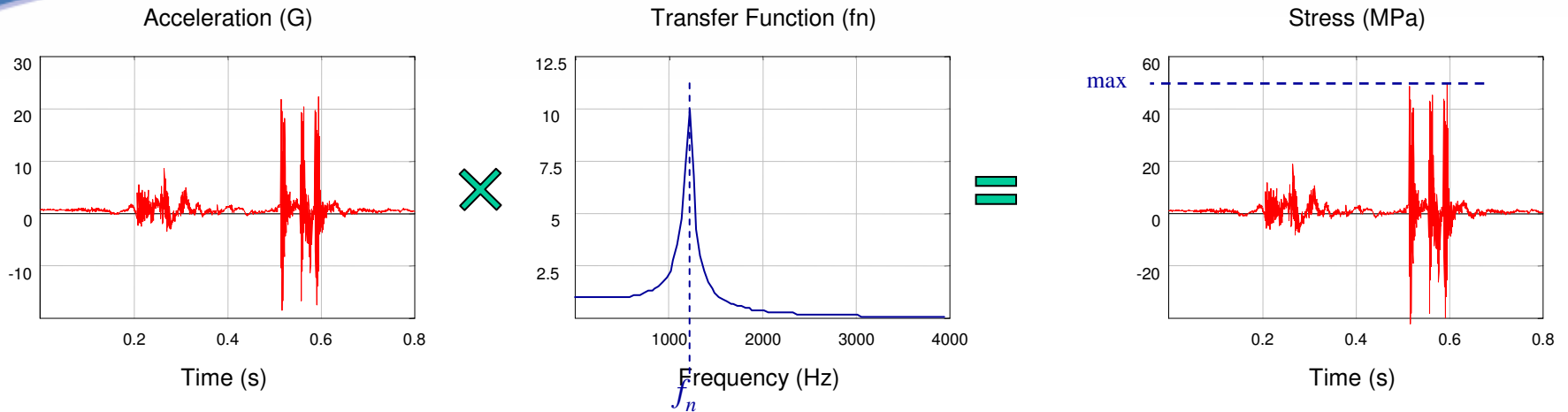
Supposed Frequency Response of the mechanical link!



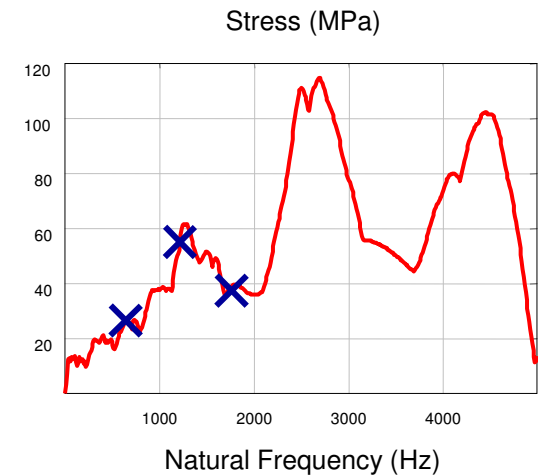
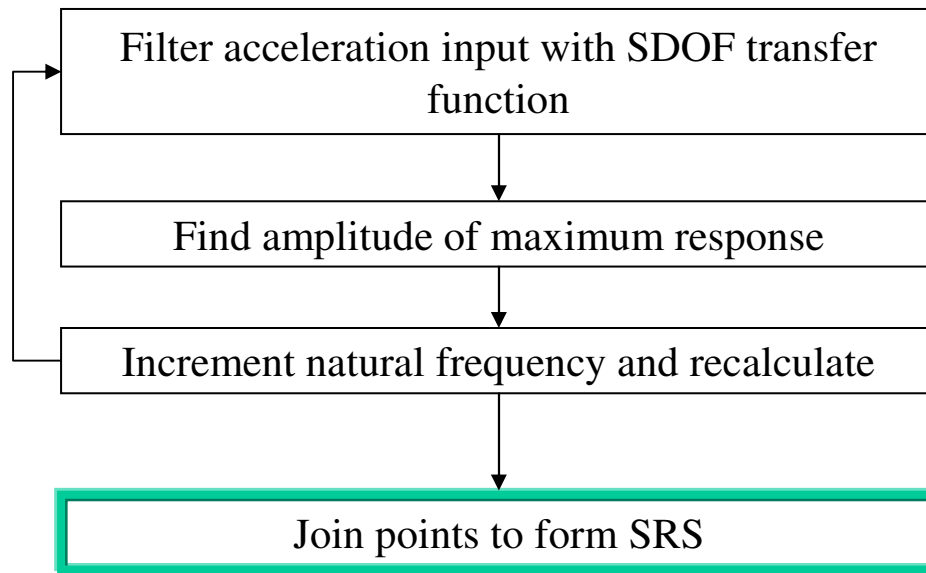
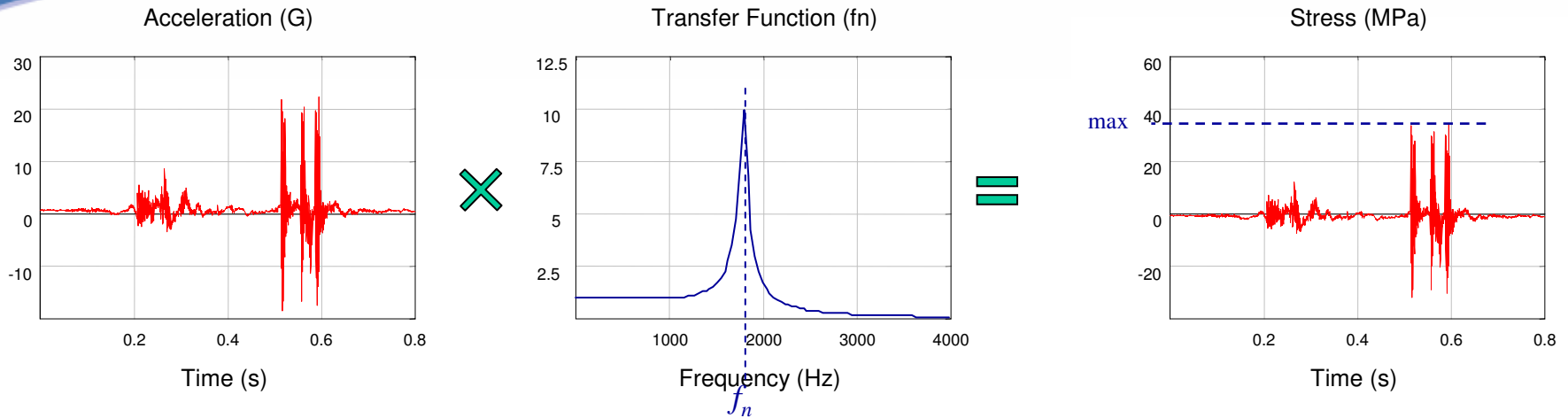
# Shock Response Spectrum (SRS)



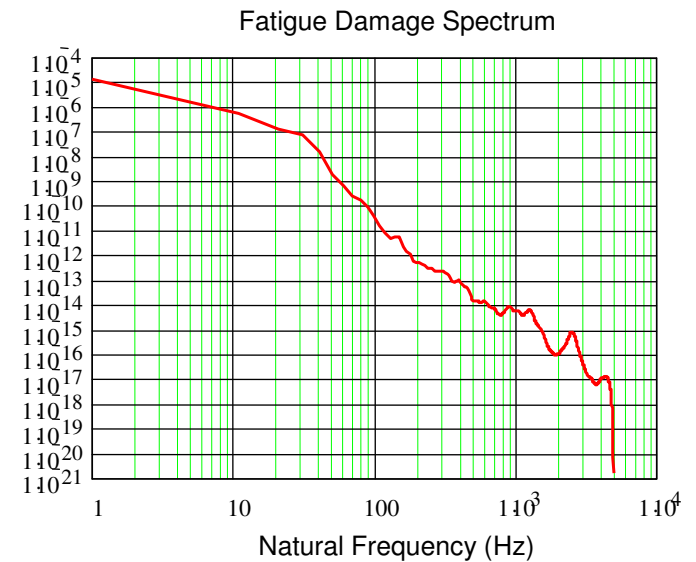
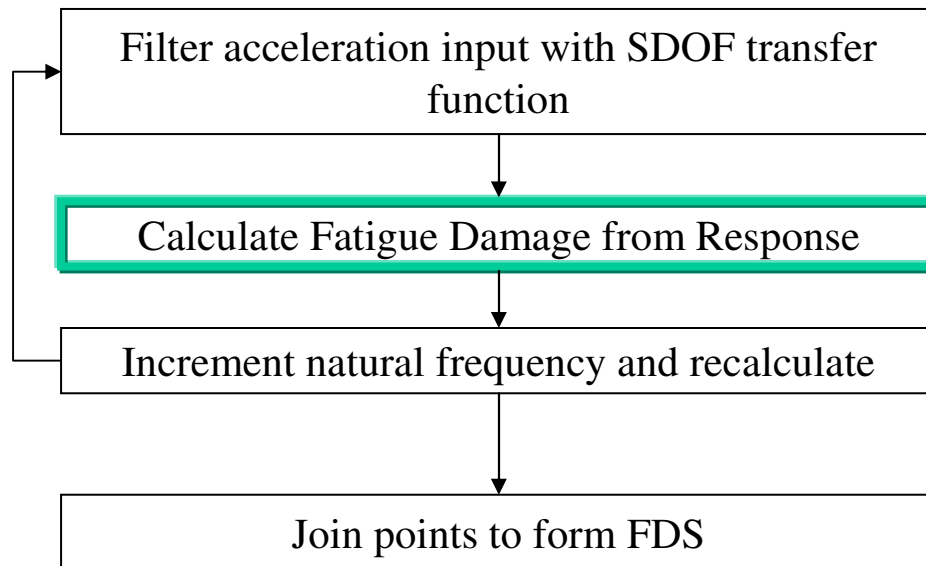
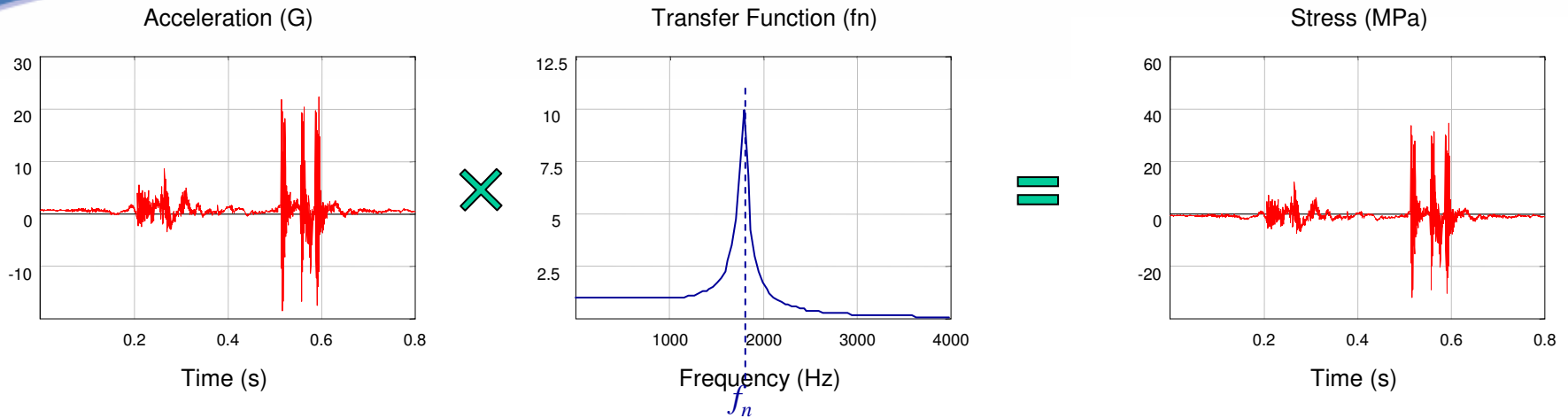
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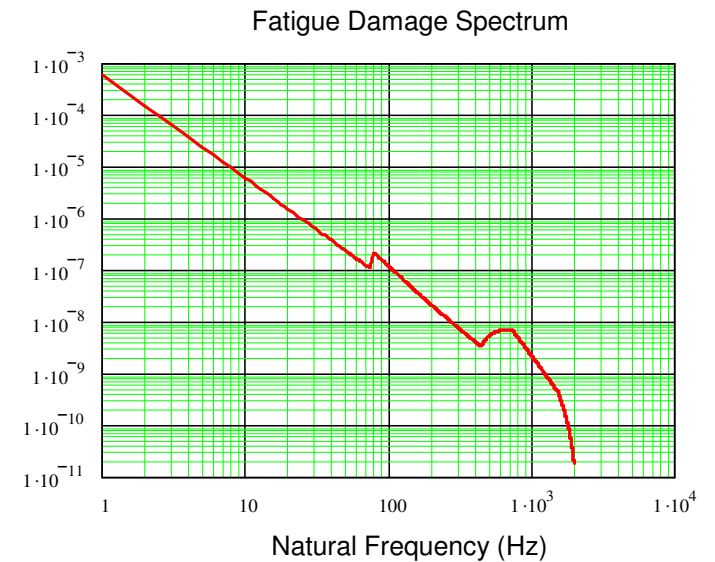
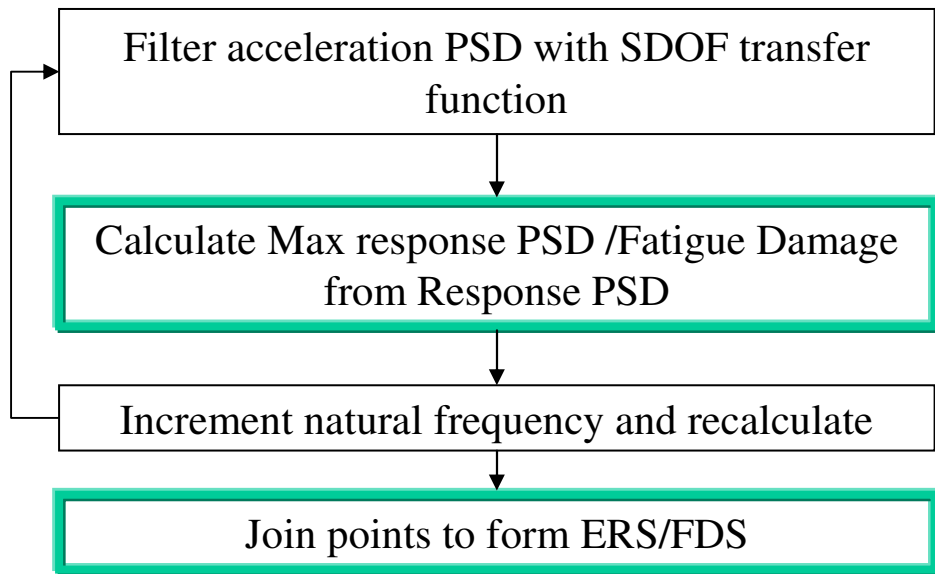
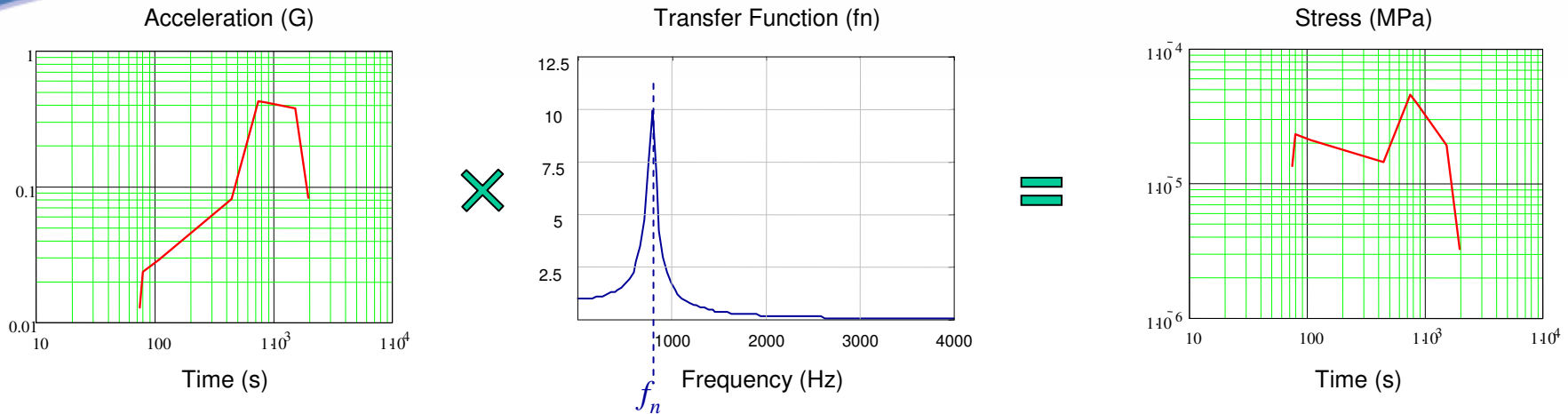
# Shock Response Spectrum (SRS)



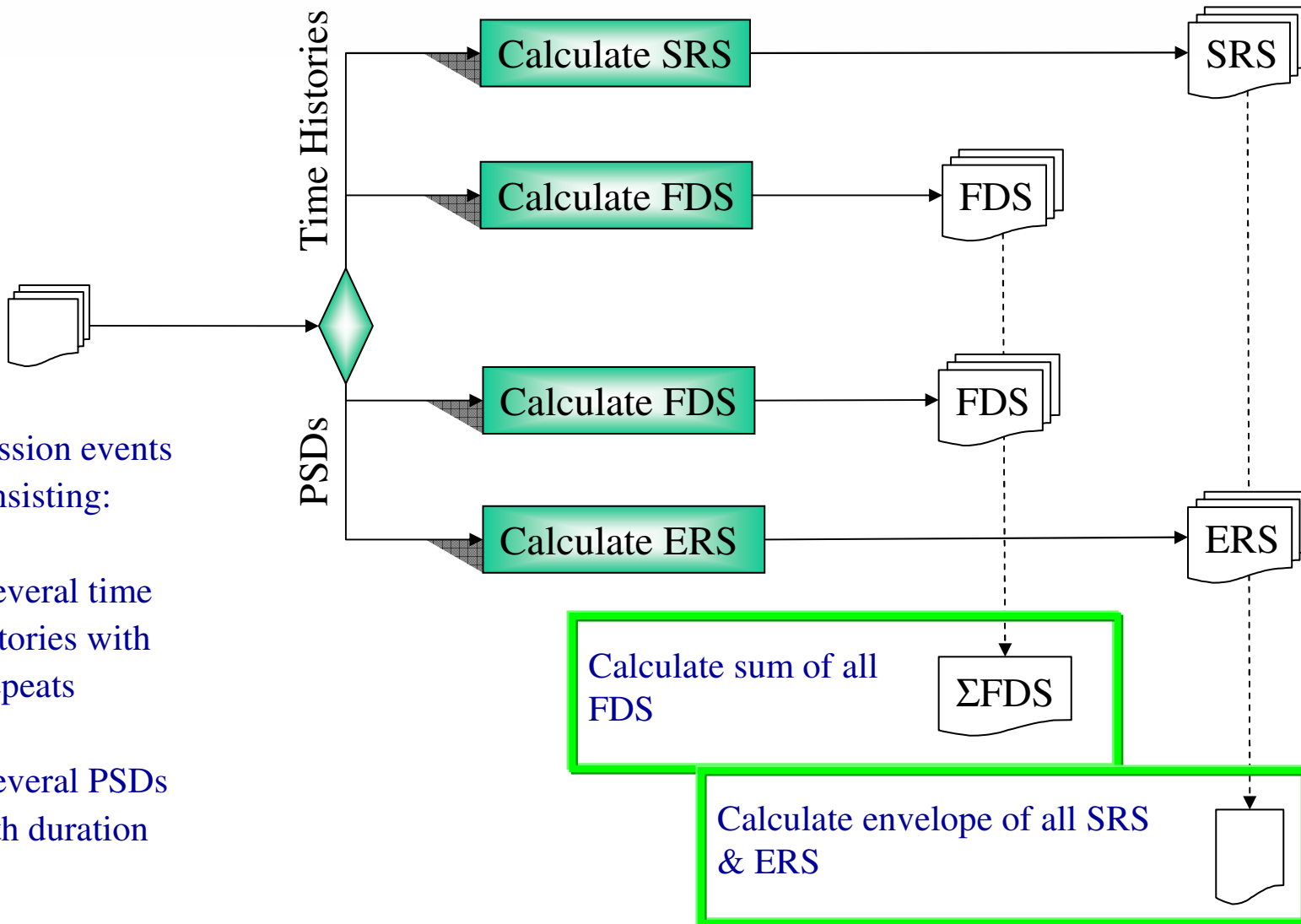
# Lalanne's Fatigue Damage Spectrum (FDS)



# PSD Input



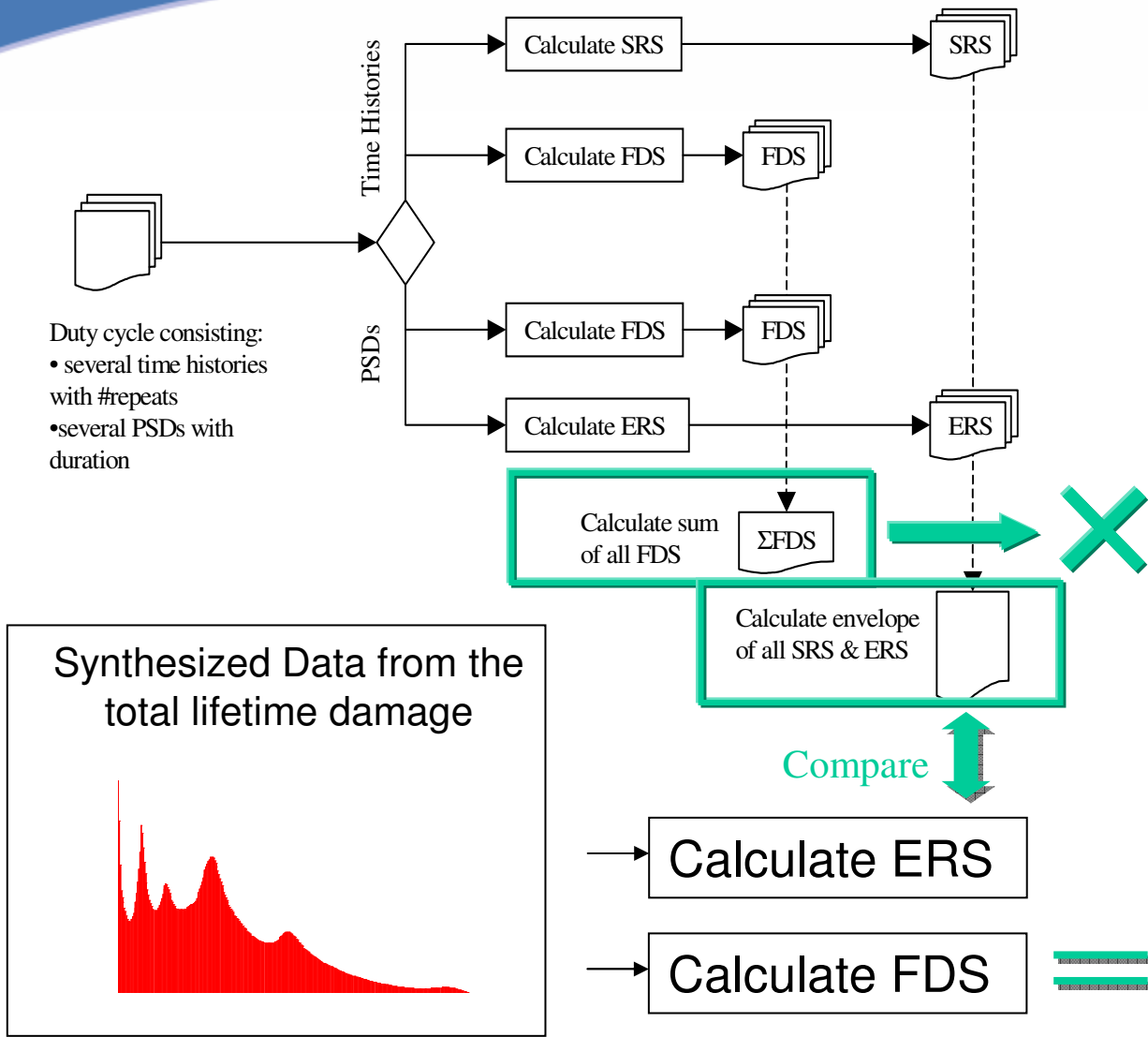
# Mission Profiling



Mission events consisting:

- several time histories with #repeats
- several PSDs with duration

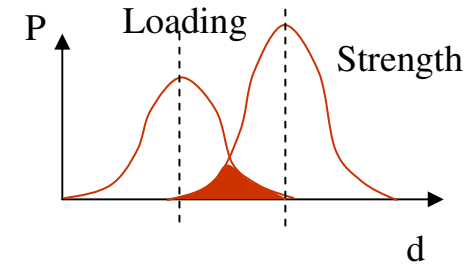
# Test Synthesis



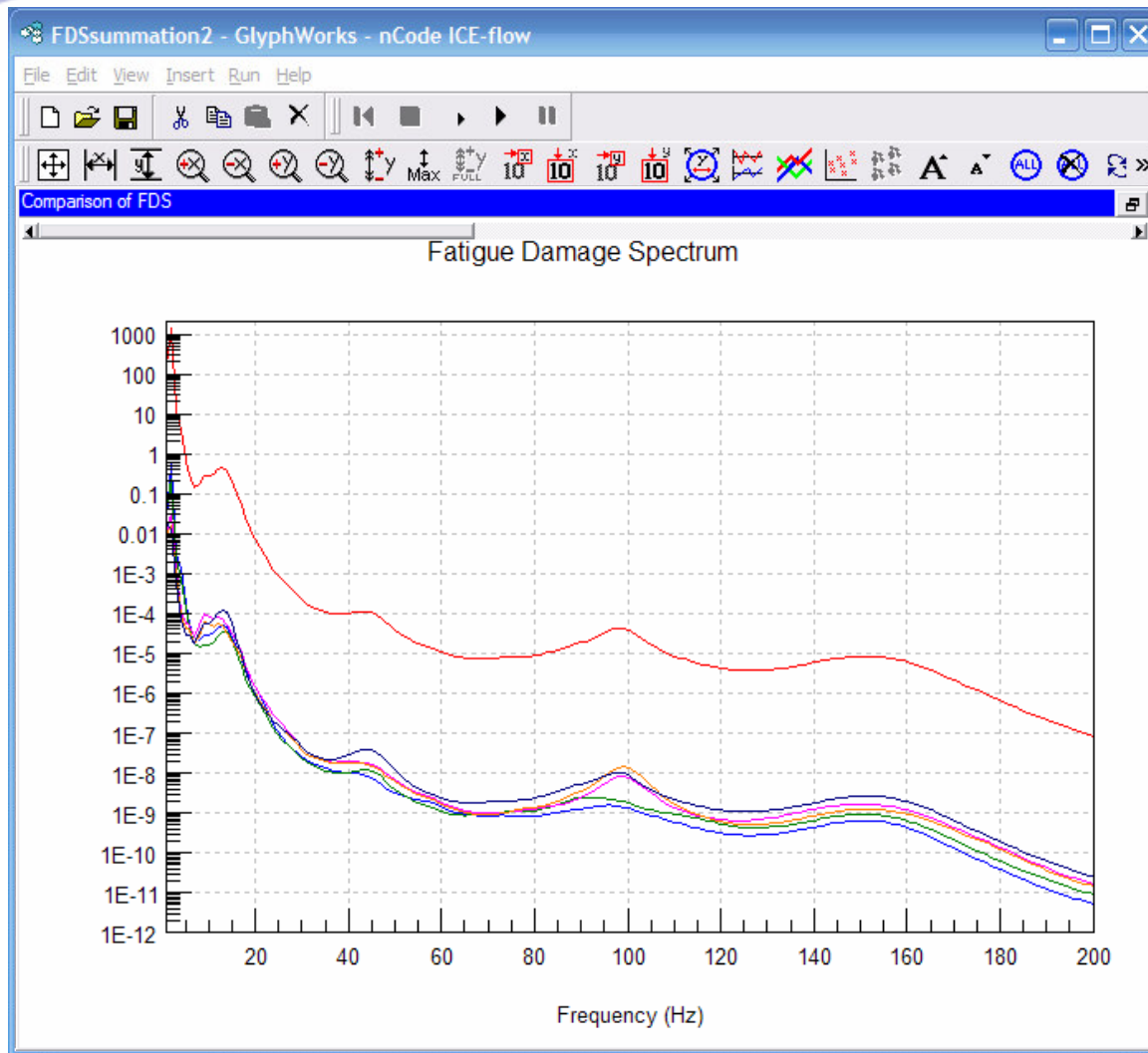
Guarantee Coefficients:

\* k safety

\* k test

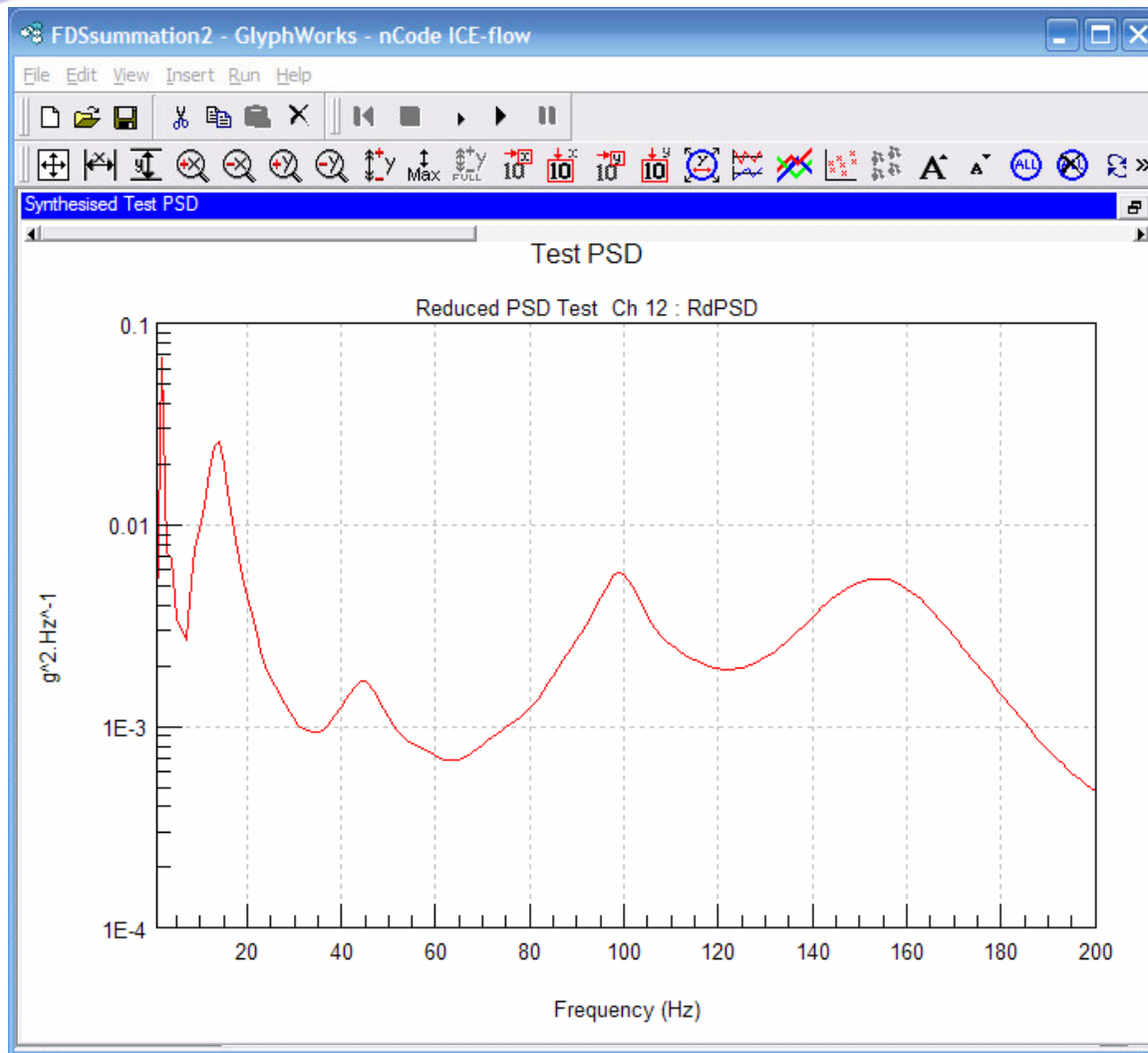


# Calculate the Test PSD



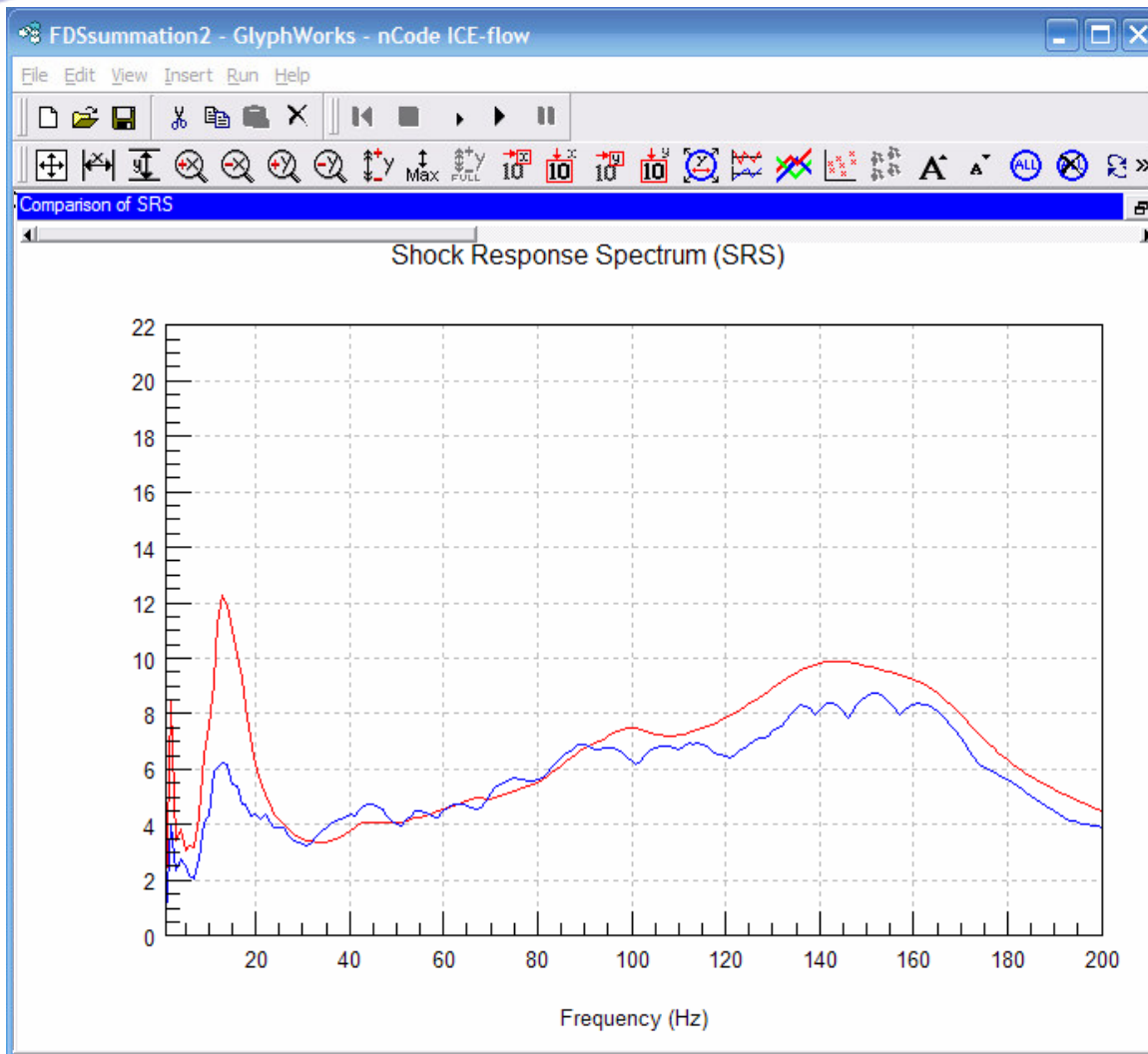
- Cumulative FDS for target design mission
- FDS of each mission event

# Calculate the Test PSD



- Test PSD contains the same damage as the target design mission over an accelerated period
- Test time = 53 hours
- Target mission = 1000 hours


# Calculate the Test PSD




- ERS of accelerated test is comparable with SRS of target Mission
- Test time = 53 hours
- target mission 1000 hours

# Summary

- Shown how to represent a real environment by a **Fatigue Damage Spectrum (FDS)** and **Shock Response Spectrum (SRS)**
- FDS and SRS imply the dynamics of the component having to know the real vibration environment
- Shown how we can calculate an equivalent test signal having the same damage as the real vibration environment **used to drive the vibration test**



**nCode**   
Managing Durability

Aerospace Testing Expo2006 Europe, Hamburg, Germany

## ACCELERATED VIBRATION TESTING BASED ON FATIGUE DAMAGE SPECTRA

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**ABSTRACT**

Failure of an aerospace component can arise through the long term exposure to fatigue damaging events such as large numbers of low amplitude random events and/or relatively fewer high amplitude events. Mission profiling and test synthesis is a process for deriving a simple laboratory test that has at least the same damage potential as the real environment but in a fraction of the real time. In this paper we introduce the technical concepts and present a case study showing how new technology has dramatically reduced the time it takes to prepare and reduce the original test data.

**KEYWORDS**

Fatigue Damage Spectrum, Mission Profiling, Test Synthesis, Shock Response Spectrum, Extreme Response Spectrum, Accelerated Vibration Test

**INTRODUCTION**

A successful durability rig test should satisfy the following criteria:-

1. The test must be suitable for the item in question, be that a single component, sub-assembly or airframe.
2. The test must replicate the same failure mechanisms observed in the real loading environment.
3. The test should be representative of the real loading environment within known statistical margins.
4. The test should be accelerated where possible to improve development schedules and reduce cost; however, it should not incur unrealistically high loads that might alter the failure mechanism.
5. The test specification should be suitable for laboratory based testing and Finite Element (FE) based analysis.

In this paper we are interested in vibration testing employing electrodynamic shaker or hydraulic shaker rigs. The method derives a test signal in the form of acceleration PSD that can be used as input to the test rig or a suitable FE based analysis. To understand the approach we must first review the Shock Response Spectrum (SRS), Extreme Response Spectrum (ERS), and Fatigue Damage Spectrum (FDS). These are discussed in the following sections. We can then see how each representation is used to describe the lifetime fatigue damage and shock response during the Mission (or Duty) Profiling stage and how a synthesised test PSD is derived. The paper concludes with a short case study demonstrating the design appraisal of an underslung

used to ensure  
representative of the  
component  
loads or  
SRS can be  
(Health and  
n)

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