magic leap

# Using High Fidelity Drop Simulations of an Augmented Reality (AR) Device to Inform Subassembly Shock Testing

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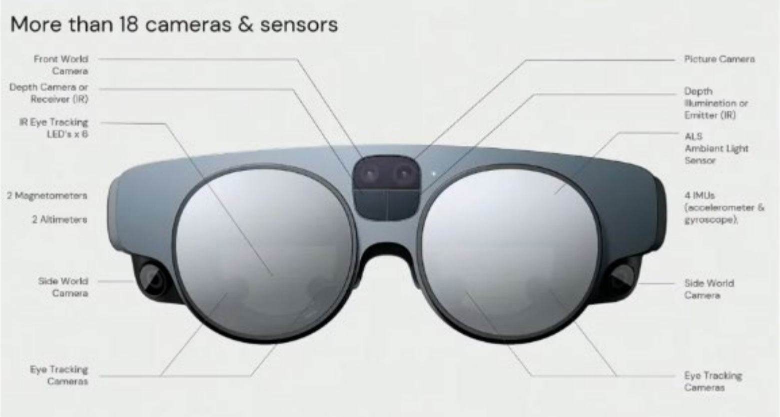
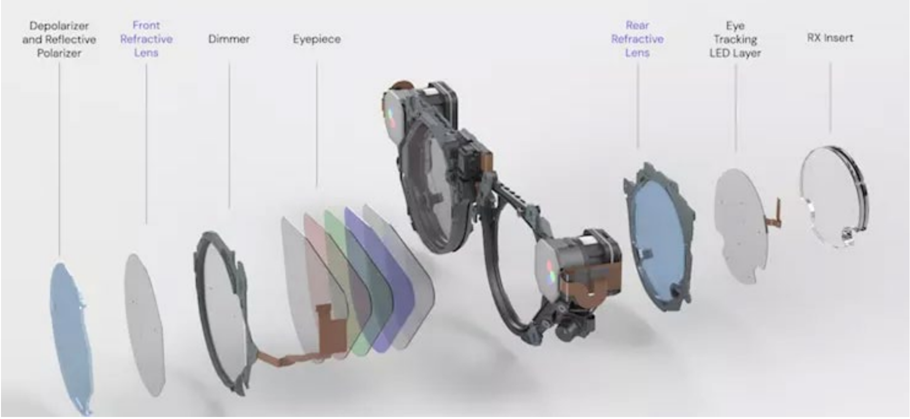
# Product

The examples discussed in this presentation are relevant to the development of ML2.



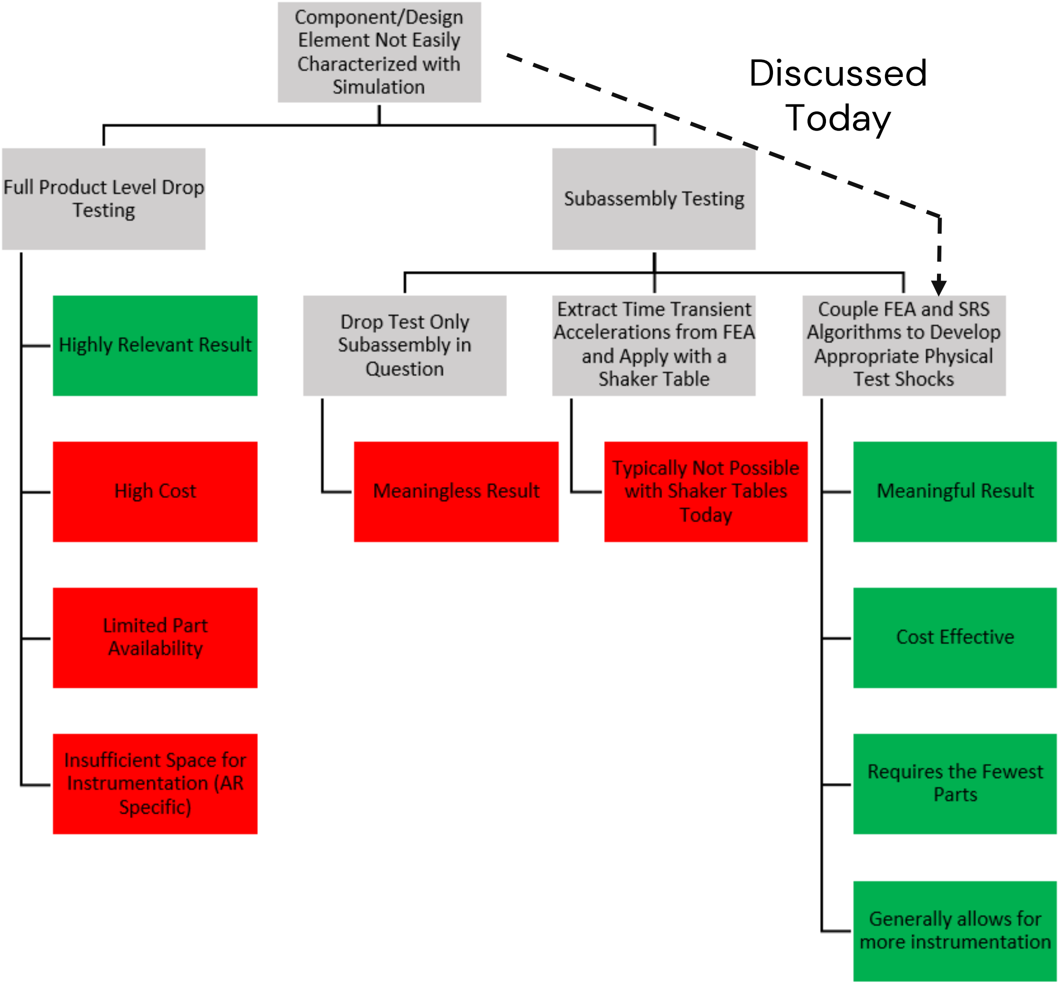



# Outline

1. Problem Overview
   a. Example 1
   b. Example 2
2. Simulation Considerations
3. Shock Response Spectrum Approach

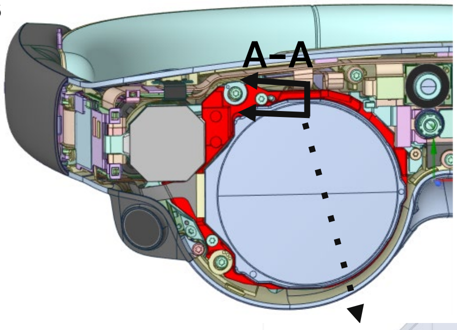
# Problem Statement

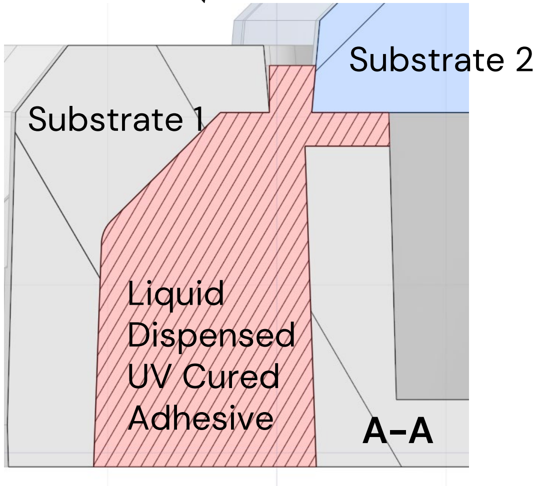
What do you do early in the design cycle when you encounter components or subsystems that cannot be readily characterized by simulation?



# Example 1 – UV Cured Liquid Dispensed Adhesive (LDA) Glue Bond

- Generic characterization of adhesive bond strength is common and valuable – shear, peel, adhesion, cohesion, paired with advanced material models permit exceptional accuracy in modeling adhesive failure mechanisms
- However, the proposed bonding scheme introduced significant variability, the effects of which were most easily captured with in-situ testing. The sources of variability included:
  - Shadowing potentially preventing curing
  - Variability in the amount of adhesive dispensed
  - Variability in the wicking behavior based on exact dispense location
  - Statistical variability in adhesion strength of the LDA to the two different substrates
- Space and manufacturing limitations, and design considerations prevented other bond locations that may have had fewer unknowns



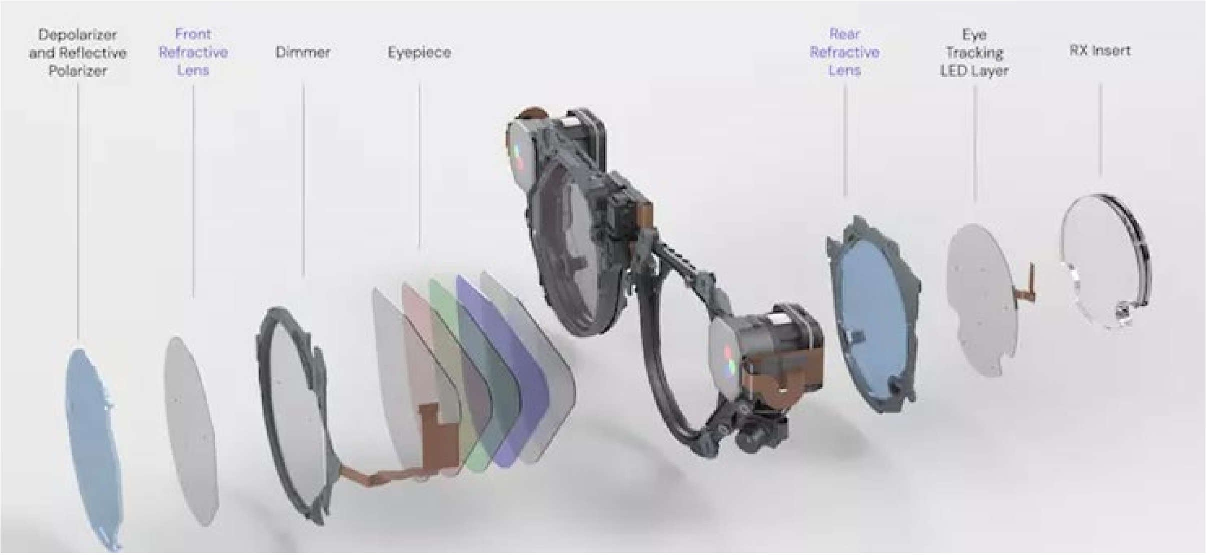
# Example 2 - Camera with MEMs Autofocus

- Our product includes a camera with a MEMs autofocus mechanism that is inherently brittle, particularly at its resonant frequency. As it is a purchased component, we have insufficient detail to accurately simulate MEMs mechanism failure in a drop simulation
- While the vendor had conducted some drop testing, it was in a completely different form factor (cell phone like) and there was no straightforward way to correlate the vendor’s testing to what the module would experience in our product.
- At the time, full product level assemblies were limited in availability, which forced us to subassembly testing.
- Thus, during testing we needed to ensure that the component experienced similar broad-spectrum excitation (ranging from 100Hz to 20kHz) to what our product-level simulations indicated the device would experience in our device.

# Important Simulation Considerations

# Magic Leap Device Drop Simulation Considerations

- Magic Leap's devices are opto-mechanical systems that:
  1. Are sensitive to shock loading on optical elements
  2. Have been space optimized such that gaps between components are very small and require tight control
  3. Have regions with intentional compliance
  4. Have intentionally designed features to pass shock pulses into robust regions of the device.
  5. Need to maintain optical calibration over the duration of their lives (which include an assumed number of drops)
- Due to these sensitivities, every effort is made to ensure simulations match reality as closely as possible.



# Accurate Preload and Appropriate Gaps

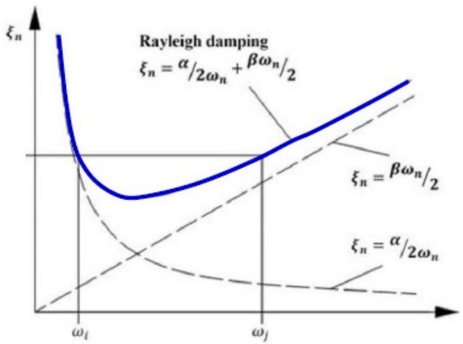
Prior to a drop event, LS-Dyna's Dynamic Relaxation functionality is utilized to get the design as close to the as assembled stress state as possible. Using Dynamic Relaxation (DR), the following is accounted for:

1. **Bolt Pretension** – All fasteners are physically represented and bolt pretension is applied. This ensures:
    - Appropriate assembly gap closure where applicable due to bolt clamping
    - Appropriate component slippage under shock loading
        - Drop loading accelerations on the order of 3000G+ will overcome fastener friction and close gaps locally
2. **Pad Compression and Viscoelasticity** - Pads are explicitly represented with appropriate foam compression curves and viscoelasticity. During DR, pads are compressed, released, and then sufficient additional time is simulated to allow relevant visco-elastic effects to occur.
    - Including visco-elastic effects appropriately dissipates and transfers shocks through any padding as the effective stiffness and energy loss is more accurately captured.
3. **Interferences** – All designed interferences are resolved with either `*CONTACT_*_INTERFERENCE` cards or by moving parts manually into place. This ensures:
    - Appropriate gaps and appropriate component slippage where relevant.

Energy balance is tracked throughout all drop simulations to ensure no erroneous behavior.

# Simulation Damping

- Implementation of damping in non-linear explicit transient dynamic simulations (like drop) is non-trivial
- Three common options exist:
  1. Rely only on algorithmic damping
     - For assemblies, this damping is likely far smaller than the actual damping and, while the simulation may predict the first response to the impulse correctly, the simulation will then “ring” for the remainder of the simulated time.
     - Ringing has significant implications when considering using simulation results in conjunction with SRS algorithms
     - Ringing can also result in non-real peak stresses developing later in the simulation due to amplification effects
  2. Rayleigh Damping
     - Generally a poor tool for drop scenarios as alpha damping aggressively damps rigid body motion while beta damping can negatively impact the time step
  3. Band-Limited Material Damping **(Recommended)**
     (`*DAMPING_FREQUENCY_RANGE_DEFORM` – Robust from R10 Onwards)
     - Applies appropriate damping to a specified frequency range (see documentation for more detail)
     - For our product, extensive testing was done to inform and tune the damping used in our simulation.
- While testing is recommended for all products, some reasonable damping values can be found here (See Irvine, T., Damping Properties of Materials, Rev D, www.vibrationdata.com/damping.htm)




**Rayleigh Damping**

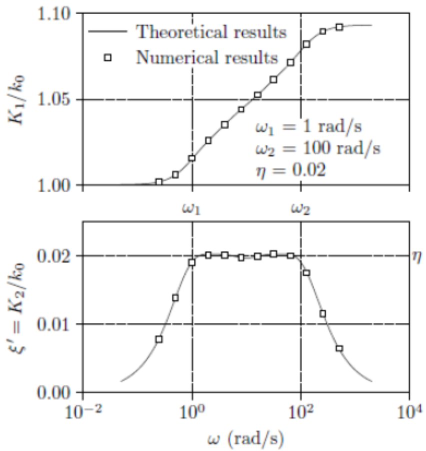
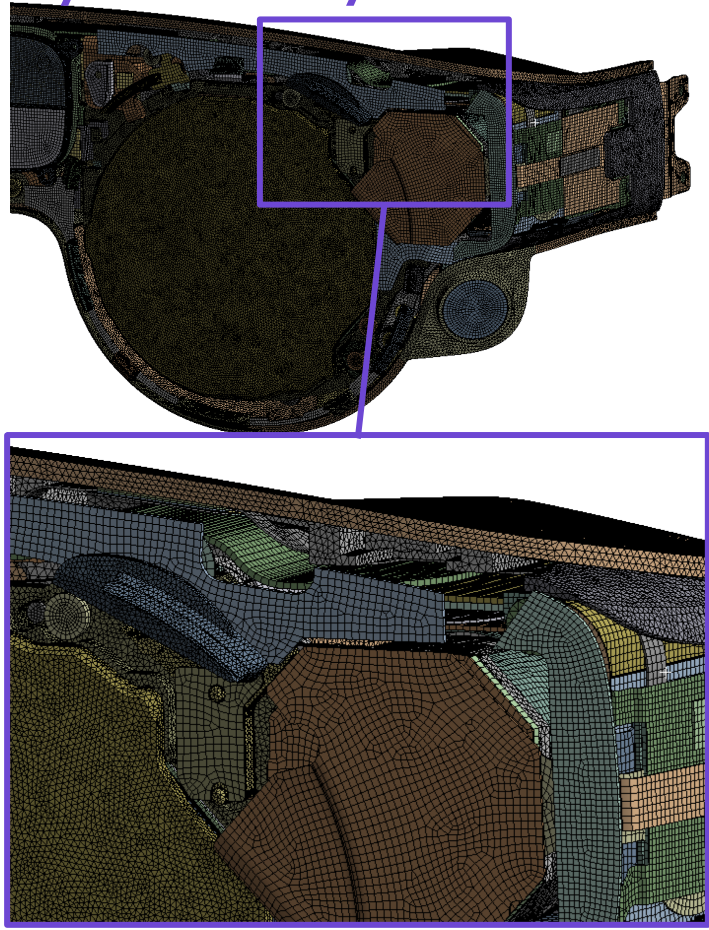



Figure 1: Dynamic stiffness of the proposed damping model

**Band-Limited Material Damping**

# Leveraging HPCs to Allow for Higher Fidelity/Accuracy

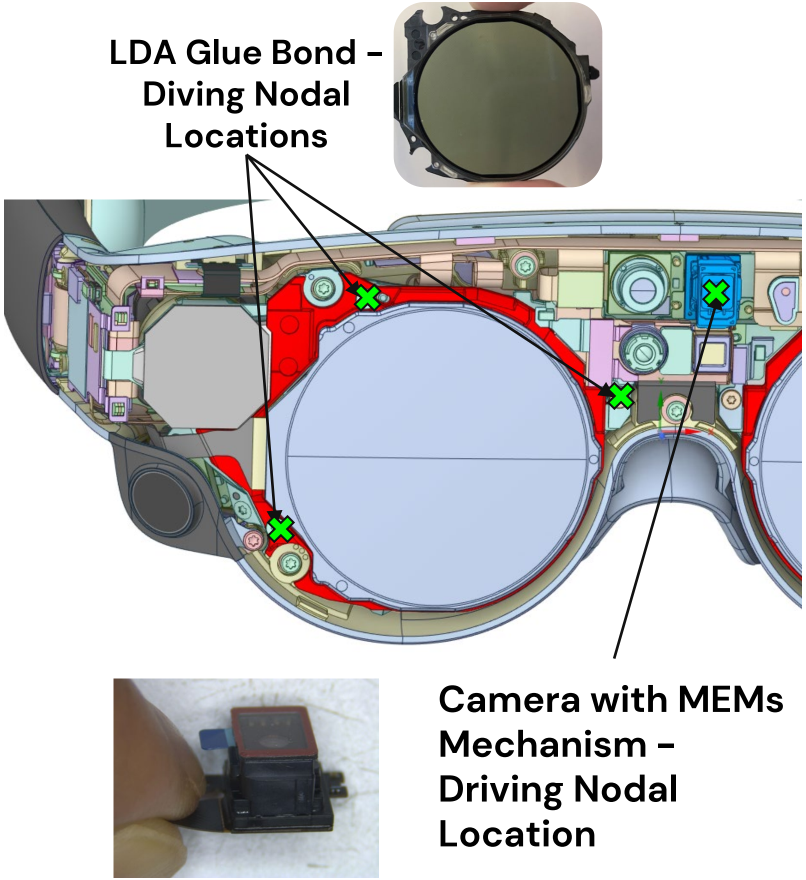
- A significant downside of representing a complex system with a high degree of accuracy in explicit drop simulations is that the total solution time may increase from:
  - Higher mesh density and smaller elements driving more computations per time step and potentially an overall smaller time step
  - DR directly adding the pseudo time to the actual simulation event time
    - Note, if Dynamic Relaxation is used improperly there is a risk of the model "popping" immediately following the end of the Dynamic Relaxation phase. This can create non-real vibrations that can negatively affect the accuracy of the simulation results.
    - When leveraging Dynamic Relaxation, an analyst needs to determine the appropriate settings for their specific problems. Kinetic Energy, Internal Energy, and stress gradients should be examined near time zero to ensure no rapid changes prior to the onset of additional load.
- The simple way around computational time pain points for explicit drop simulations is to leverage additional compute power on the cloud or with your own servers
  - We have witnessed very good scaling (0.75x) with ~20k elements per core.
  - The cost for compute is so affordable that the time savings is an easy decision.



# Shock Response Spectrum (SRS) Approach

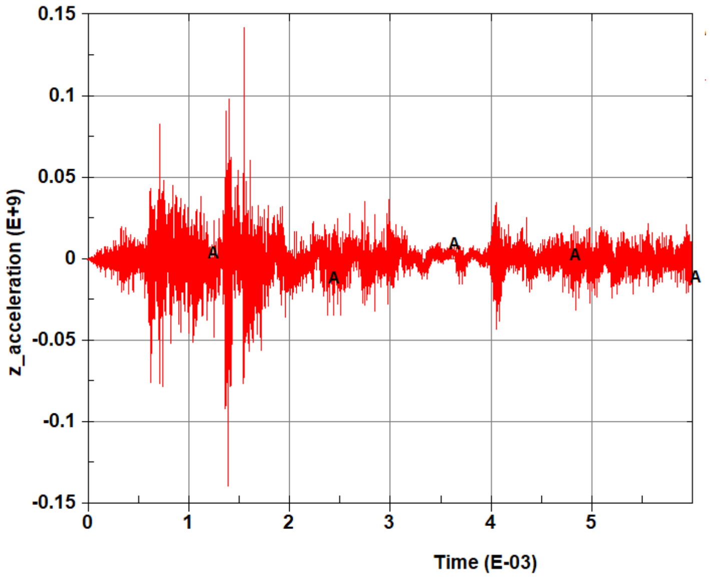
# Identify Driving Nodal Locations to Drive Physical Tests

- The first step in extracting meaningful data to inform subassembly testing is to identify the portions of the assembly that will be included in the sub assembly testing.
  - **LDA Glue Bond** – subassembly testing is only relevant if the assembly attached to the glue bond is represented in full
    - Therefore, nodal accelerations are extracted at the mount points
  - **Camera with MEMs Mechanism** – the desired information can be achieved with camera only testing
- For the relevant locations, nodal data can be extracted using the `*DATABASE_HISTORY_NODE_SET` card in LS-Dyna
- Drop simulations should be conducted at all relevant orientations and x, y, z accelerations extracted for each
- **Note**, all subassembly test fixtures should be designed such that the fixture natural frequencies are significantly above the frequencies of interest



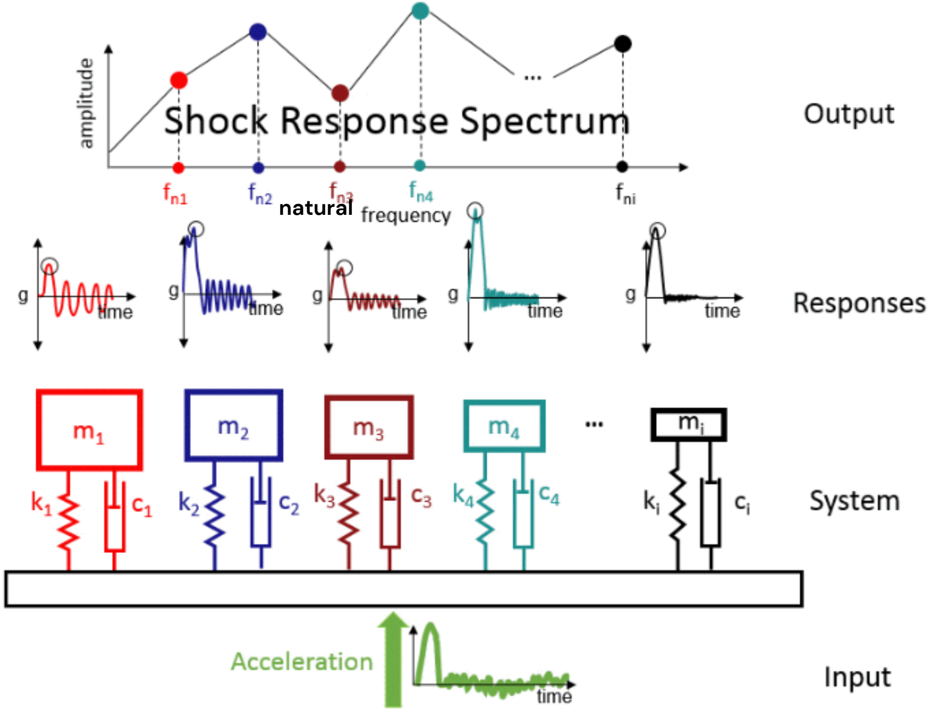
# Aliasing Considerations

- Avoiding aliasing when extracting nodal acceleration data is highly non-trivial.
- The biggest risk with acceleration data output is that the analyst unknowingly extracts data at a frequency that is too low to adequately capture all the important information.
  - Note, often analysts cannot know what frequencies matter.
- To avoid this risk, two different approaches can be considered:
  - Acceleration data at the driving locations should be output at every time step. This ensures all frequency information is captured, but can result in larger files and may require additional DSP.
  - If every time step is not an option, a quick check to confirm a sufficient sampling frequency is to double integrate the output acceleration data to displacement and compare against LS-Dyna's calculated displacement. If the two don't match, aliasing has occurred and a higher output frequency is recommended.
- While these are good rules of thumb, it is recommended that every analyst be trained in aliasing and Digital Signal Processing (DSP) techniques.



# SRS Process – Example

- Once nodal accelerations are extracted from a high fidelity simulation with appropriate damping and a sufficiently high sampling rate, then one can pass the time transient data through standard Shock Response Spectrum (SRS) algorithms.
  - These algorithms are readily available in the public domain.
- As mentioned earlier, it is this process that is particularly susceptible to ringing in a model.
  - If ringing occurs due to insufficient damping then the SRS single degree of freedom systems at or near the ringing frequency will experience amplification. This could result in an extreme amplitude on the final spectrum.




**SRS Process**
(https://community.sw.siemens.com/s/article/shock-response-spectrum-srs)

# Creating a Pulse to Match SRS Simulation Output

- As the final step in this process, an analysts and/or experimentalist needs to:
  1. Choose the pulse type to apply (judgement call by the analyst and experimentalist)
  2. Process the time transient pulse signal through the same SRS algorithms while varying the shock pulse duration and amplitude until good correlation is achieved
  3. Evaluate the calculated equivalent test shock against available shock tower specifications
     - If you cannot create the shock indicated by the SRS process with your available equipment then you may need a resonant fixture and/or may need to consider hiring a test house with greater capabilities.
- To confirm the appropriate shock is applied, it is recommended that during testing both the shock input and sub-assembly specific accelerations are measured.
  - Note, mass of accelerometers need to be accounted for. As always aliasing is a concern.

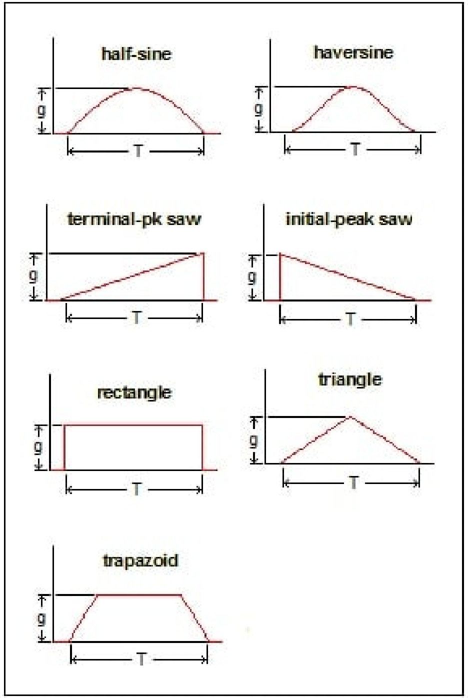



Figure 16: The Classic Shock pulse shapes.

(https://www.sentekdynamics.com/page-7-how-to-select-a-vibration-testing-system) magic leap



# Thank you