

15th German LS-DYNA Forum

## LS-TaSC 4: Designing for the combination of impact, statics, and NVH

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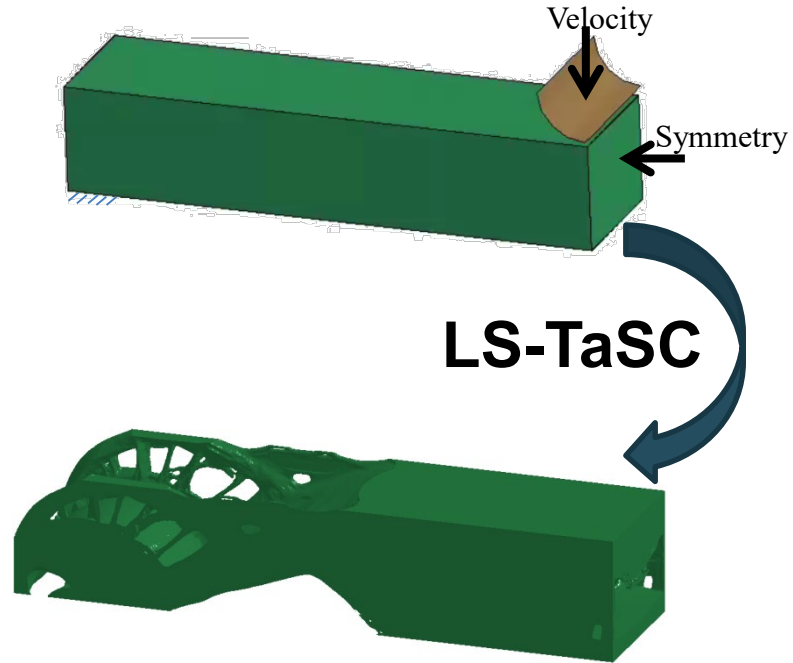
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Bamberg, 16.10.2018

# Outline

LS-TaSC 4 focuses on the design of huge models for a combination of **statics, NVH, and impact**

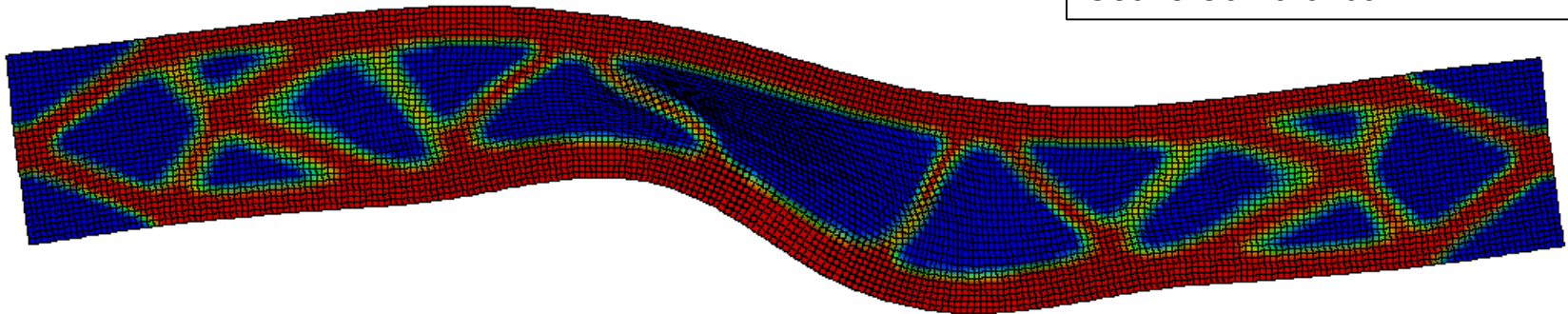
- Multidisciplinary methodology
  - Projected subgradient method
  - Multidisciplinary optimization
  - Workflow improvements
  - Visualization
- Examples
- Conclusions



# Projected Subgradient Method - Motivation

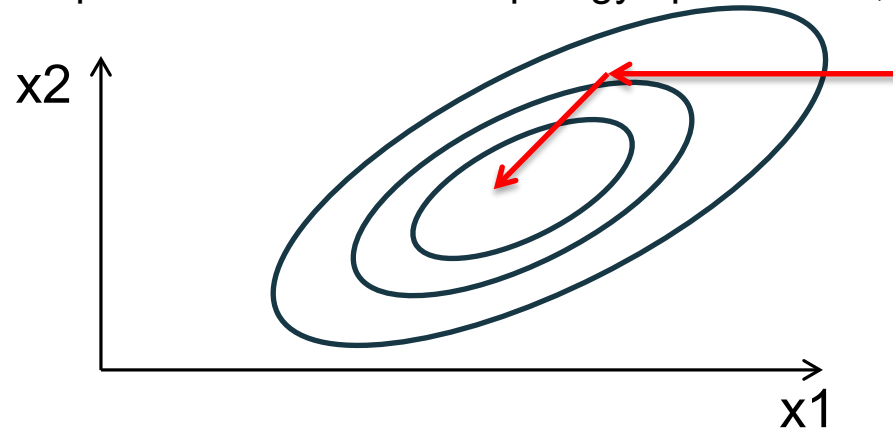
- LS-TaSC 3.2 method: Optimality Criteria for Dynamic Problems
- Objective uniform distribution of Internal Energy Density
  - static and impact load cases
  - not suitable for NVH load cases
  - we need a method that considers frequencies (maximization of fundamental frequency)
  - Projected subgradient method

*Implementation of the Projected Subgradient Method in LS-TaSC™*  
Roux, W., Yi, G., Gandikota, I.  
15<sup>th</sup> International LS-DYNA  
User's Conference



# Projected Subgradient Method

- The projected subgradient method is related to the steepest descent method
  - This family of methods related to steepest descent is popular again in general, because of the *huge data sets*. Our implementation of the projected subgradient is unique to both to us and topology optimization, again because of *the huge data sets*.



$$x^{k+1} = x^k - \alpha_k g^k$$

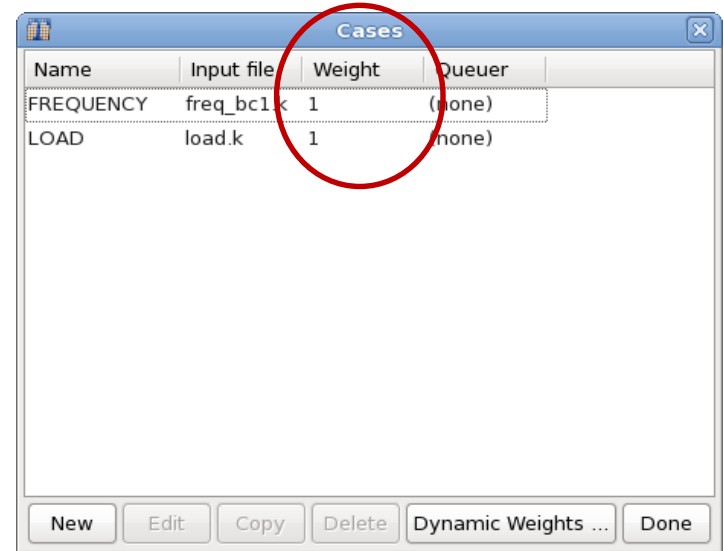
- Topology optimization requires that the mass stay constant over the iterations. The design vector is therefore mapped onto the plane of constant mass.

# Multidisciplinary Optimization

- The descent vector is sourced from the various discipline descent vectors
- Combine normalized vectors using weighting:

$$s = \sum_{lc=1}^m w_{lc} \frac{s_{lc}}{\|s_{lc}\|}$$

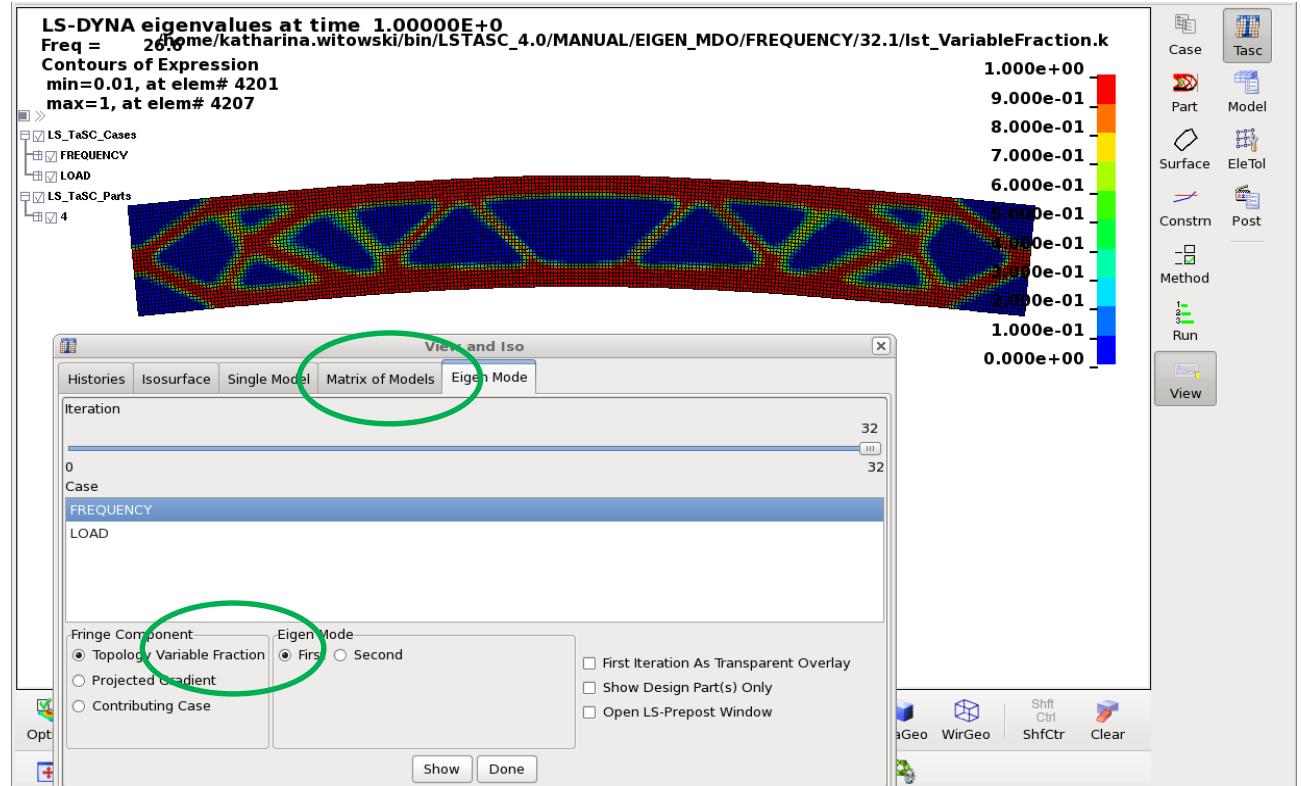
- The weights are provided by the engineer, or computed from information provided by the engineer
  - Solution depends on weights



Name	Input file	Weight	Queuer
FREQUENCY	freq_bc1.k	1	(none)
LOAD	load.k	1	(none)

# New Visualization Features

## ■ NVH load cases: Eigen Modes



# New Visualization Features

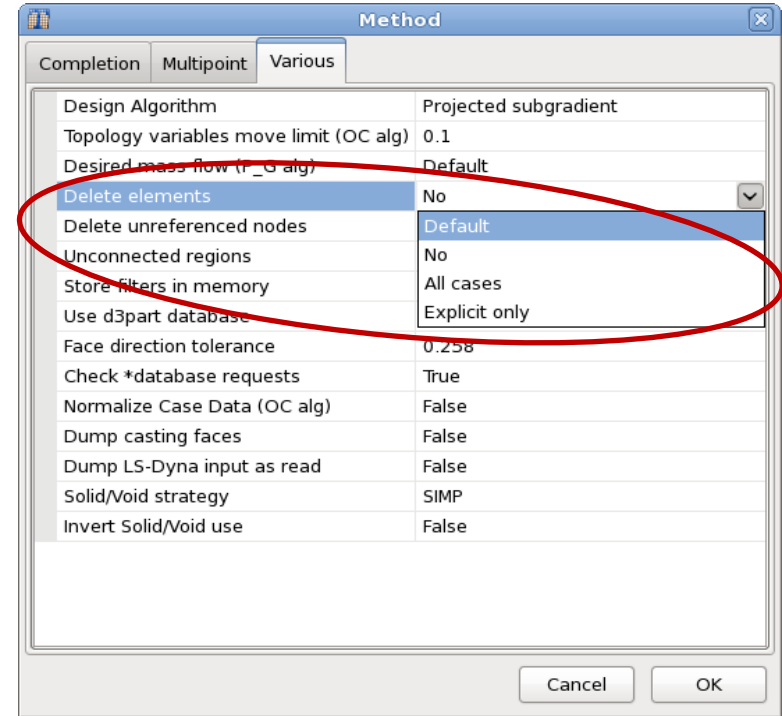
## ■ MDO: Contributing Case

- 0 = none
- 1 = LC 1
- 2 = LC 2
- 3 = LC 1+2
- ...

The screenshot displays the LS-PrePost interface. At the top, the title bar reads "LS-DYNA keyword deck by LS-PrePost" and the file path is "/hgme/katharina.witowski/bin/LSTASC\_4.0/MANUAL/EIGEN\_MDO/FREQUENCY/32.1/1st\_ContributingCase.k". The main window shows a contour plot of a structure with a color scale on the right ranging from 0.000e+00 (blue) to 3.000e+00 (red). The plot shows high values (red/yellow) in the central and end regions. A tree view on the left shows the model hierarchy: LS-TaSC\_Cases, FREQUENCY, LOAD, LS-TaSC\_Parts, and 4. Below the plot, the "View and Iso" dialog box is open, showing the "Single Model" tab. The "Iteration" list shows iteration 0 and 32. The "Case" list shows "FREQUENCY" and "LOAD". The "Fringe Component" section has "Contributing Case" selected and circled in green. Other options include "Topology Variable Fraction", "Solid Density", "Shell IED", "Von-Mises Stress", "Topology Material Utilization", "Solid IED", "Projected Gradient", "First Iteration As Transparent Overlay", "Show Design Part(s) Only", and "Open LS-Prepost Window". The "Show" and "Done" buttons are at the bottom of the dialog.

# Workflow improvements

- Different element deletion for implicit vs explicit cases
  - Option of deletion for explicit but not implicit
  - Automatic deletion of loose regions/elements
- Different materials between cases
  - Allow different materials for each case, such that the one case is linear, the other nonlinear, or heat transfer. This allows for example one case to be at a different temperature than the other.





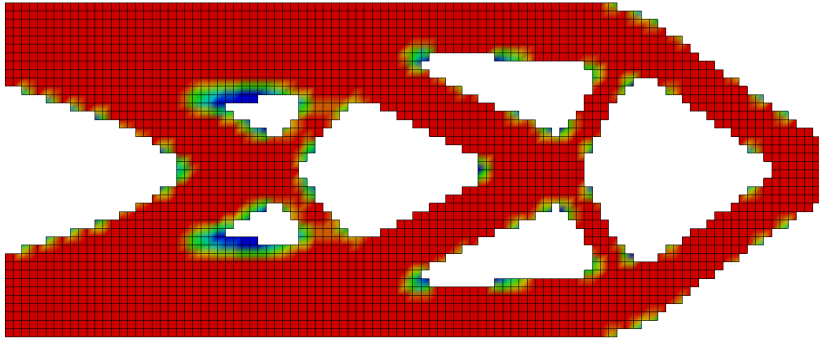
# Examples

The benchmark problems demonstrate the new multidisciplinary solver:

- Huge models
- NVH benchmark problems
- Multi-disciplinary design optimization considering NVH and static
- Impact, static, and NVH

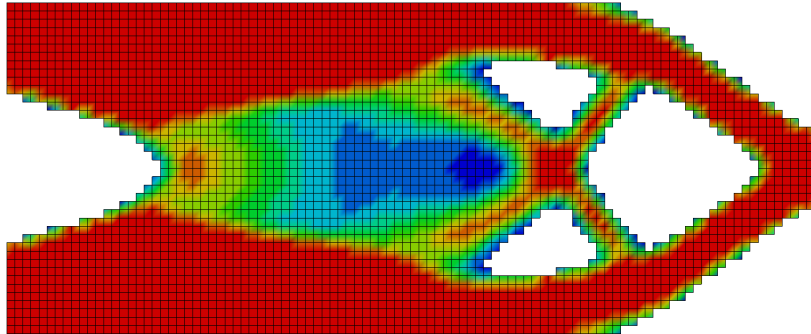
# Performance relative to previous method

- Mathematical programming techniques allow many power-ups



Projected subgradient (new):

- 30 FEA calls
- 0.1 step size

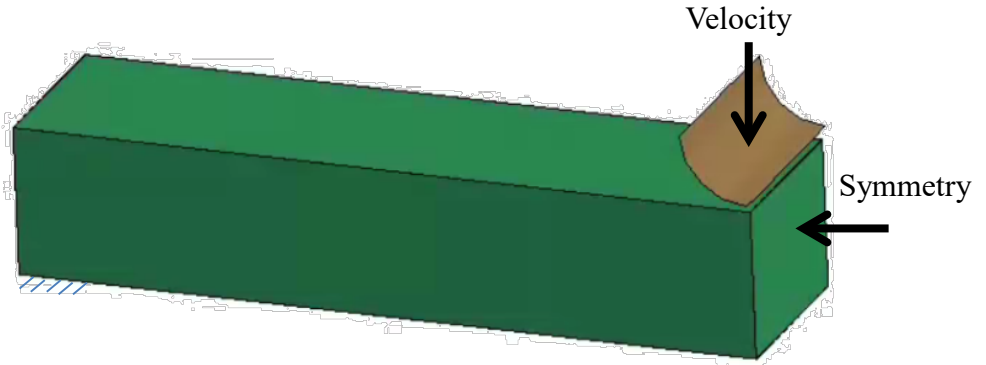


Optimality Criteria (old):

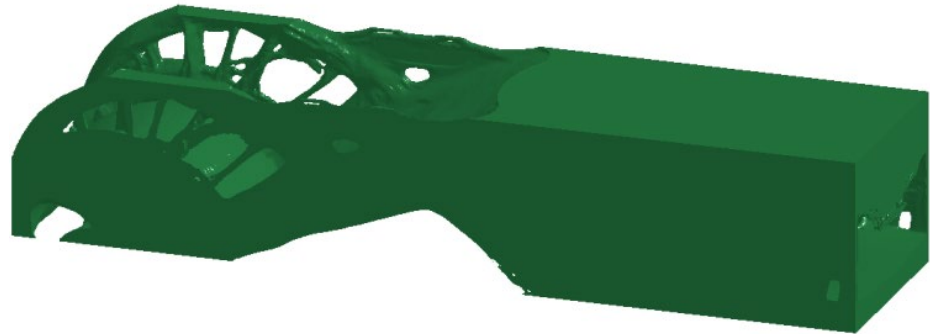
- 30 FEA calls
- 0.1 step size
- Needs about 50 iterations to match the new algorithm

# Huge model performance

- Impact load case
  - 13.1 million elements
- Mass fraction: 0.25
- Projected subgradient method
  - 30 Iterations



Isosurface plot  
of optimal design



# Huge model performance

- Computational cost for huge problem

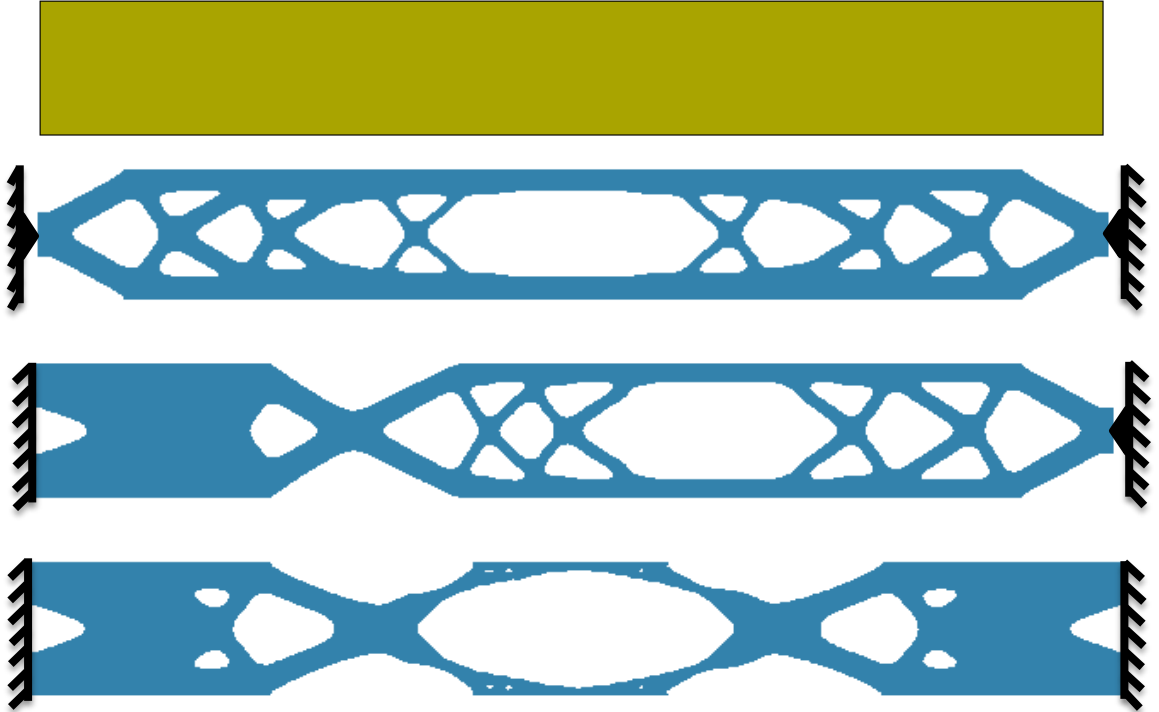
## HUGE MODEL PERFORMANCE

Model size	<b>13.1 million elements</b>
Physics	Explicit impact analysis
LS-DYNA analysis time for one iteration	600 CPU hours (5 hours using 120 CPUs on a remote cluster)
Part design time – first iteration	25 CPU minutes (1 CPU)
Part design time – all other iterations	2 CPU minutes (1 CPU)
Peak memory use by LS-TaSC	15 GB

# NVH Benchmarks

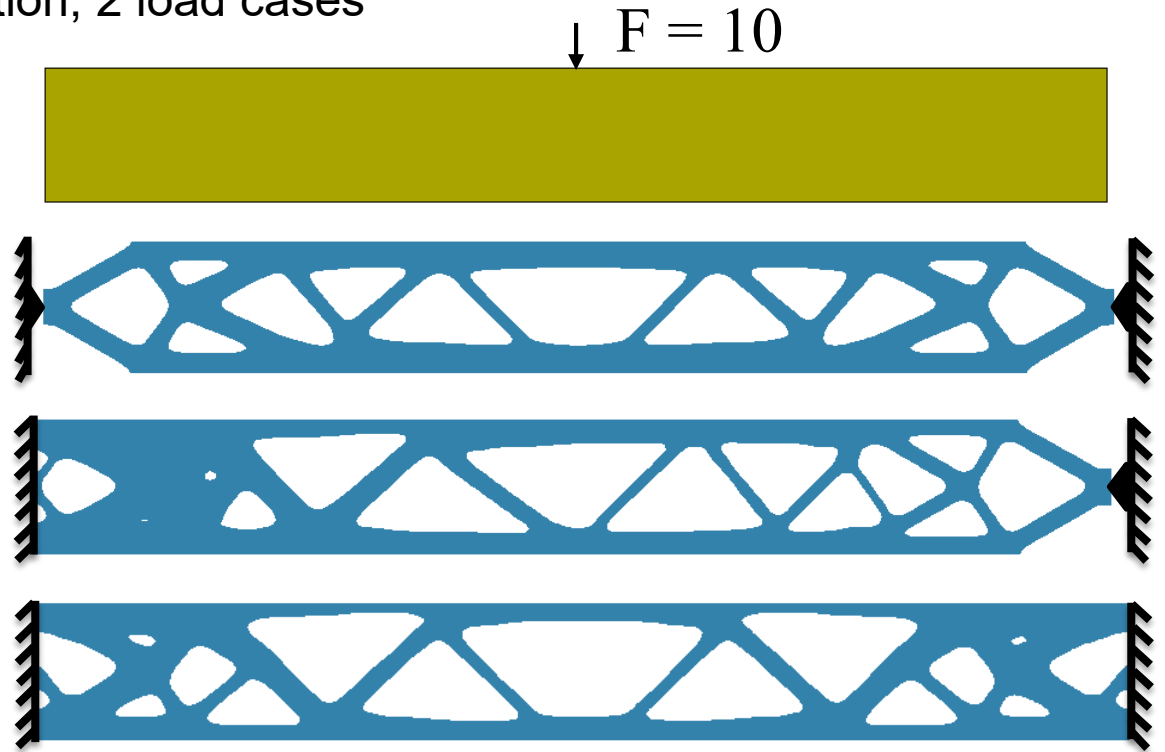
- Maximization of Fundamental Frequency
- Mass fraction: 0.5
- 3 different boundary conditions

Symmetric boundary conditions  
→ Symmetric results



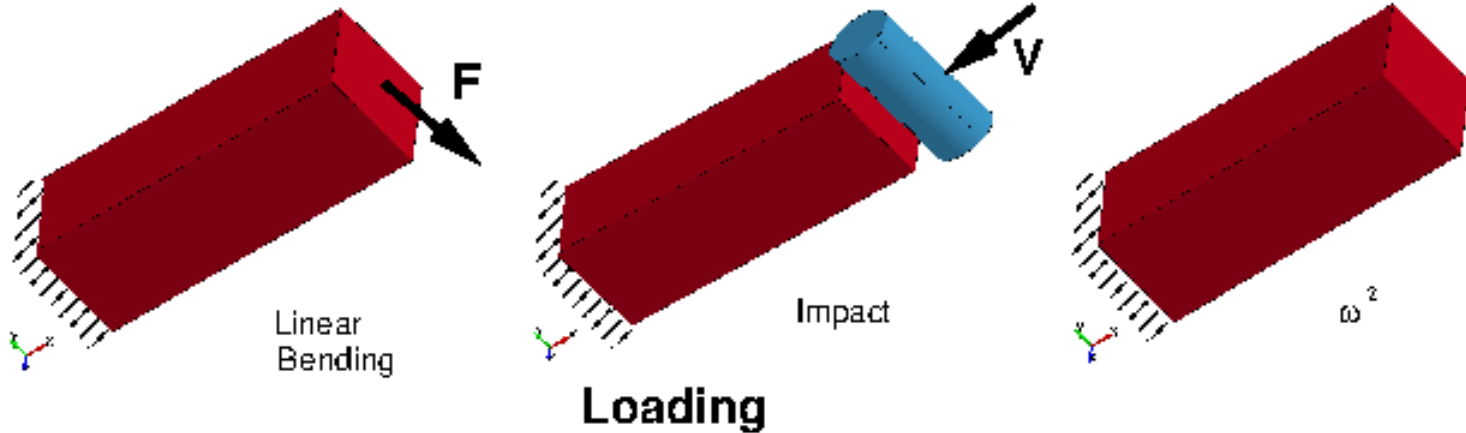
# NVH Benchmarks

- Multi-disciplinary optimization, 2 load cases
  - fundamental frequency
  - linear static load
- Mass fraction: 0.5
- 3 different boundary conditions



# Impact, statics, and NVH

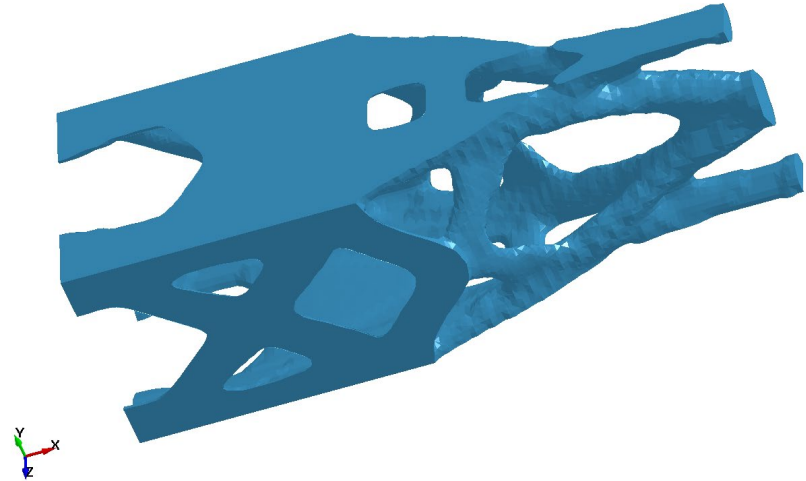
- Multi-disciplinary optimization, 3 load cases
  - Equal weights
- Mass fraction: 0.1



# Impact, statics, and NVH

## ■ Results (80 Iterations)

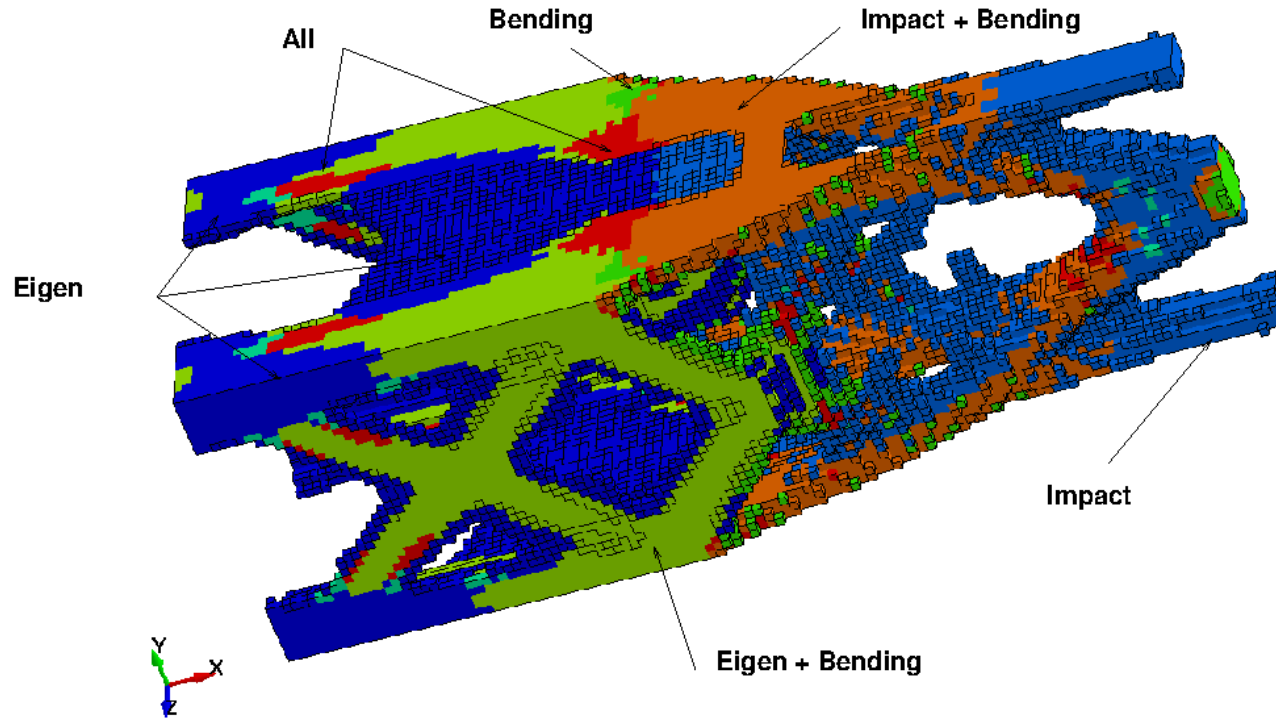
■ Optimal geometry





# Impact, statics, and NVH

- New plot type shows which load case contributes the material used in the part.

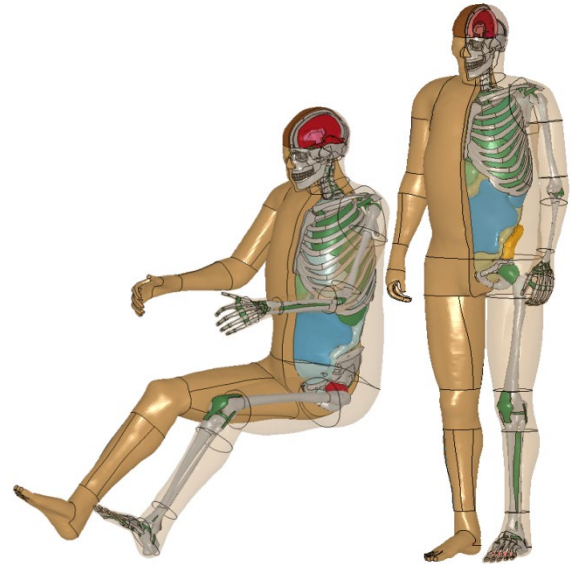


# Conclusions

- The Projected subgradient method provides option to run MDO
  - combines the disparate crash and NVH design disciplines
- It ran 10 000 000+ solid element crash models out of the gate
- The Beta version of LS-TaSC version 4 is available

# More Information on the LSTC Product Suite

- Livermore Software Technology Corp. (LSTC)  
[www.lstc.com](http://www.lstc.com)
- LS-DYNA
  - Support / Tutorials / Examples / FAQ  
[www.dynasupport.com](http://www.dynasupport.com)
  - More Examples  
[www.dynaexamples.com](http://www.dynaexamples.com)
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  - Support / Tutorials / Examples  
[www.lsoptsupport.com](http://www.lsoptsupport.com)



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