AI-Driven Innovations for Steel Vehicle Structural Design

Reducing Weight, Enhancing Performance, and Lowering Costs with Advanced AI Solutions

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GREAT DESIGNS IN STEEL™

Topics of the Webinar

- Introduction to Hexagon Design & Engineering Solutions
- What is AI in Structural Design?
- Case Studies
  - Crash and Safety
  - NVH
  - Manufacturing
- Key Takeaways and Summary

Introduction to Hexagon Design & Engineering Solutions

Unlock the World of Engineering Simulation

MSC One

Multiphysics

All physics simulations in one place
Create reliable and accurate digital twins with a complete suite of physics simulation software products including solutions for structural simulation and analysis, fatigue, computational fluid dynamics, acoustic and NVH simulation and multiphysics co-simulation.

- Cradle CFD
- Actran
- CAEfatigue
- Dytran
- MSC Nastran
- Marc
- MSC Apex
- Patran
- MSC CoSim

System Dynamics

Dynamic system simulation must consider complex multibody interactions. Hexagon's system dynamics solutions offer system-level insight into movement, enabling CAE-led development of complex products with reduced prototyping and enhanced collaboration through workflows with other Hexagon and third-party tools.

- Adams
- Adams Modeler
- Easy5
- Romax
- Elements

Virtual Manufacturing

Hexagon solutions simulate entire metal manufacturing process chains, including metal forming, welding and joining and additive manufacturing (AM). Our costing solutions establish target costs early in design to improve material utilization, reduce weight and minimize tooling development times.

- Simufact Forming
- Simufact Welding
- FTI FormingSuite
- Simufact Additive
- MSC Apex Generative Design

Digital Materials

Empowered by synergistic integrated computational material engineering (ICME) and modelling, data management and artificial intelligence capabilities, Hexagon's materials autonomy solutions ensure the ability to meet the evolving needs of new markets and drive sustainable product design.

- Digimat
- MaterialCenter

Simulation Governance

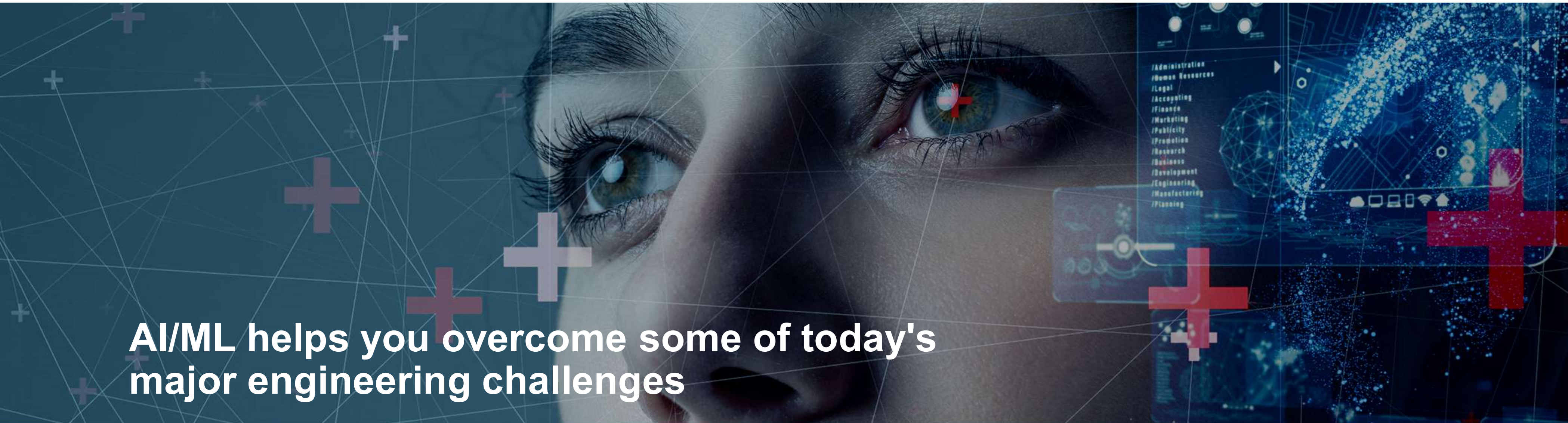
- MaterialCenter
- SimManager

Artificial Intelligence & Machine Learning

- ODYSSEE

What is AI in Structural Design?

GDIS



AI/ML helps you overcome some of today's major engineering challenges

Inefficient Processes

Manual processes that are time-consuming and error-prone, leading to lower efficiency and productivity.

Higher Costs

Expensive manual processes and simulation-based design exploration leading to higher operating costs.

Scalability of Complex Processes

Managing large amounts of data from complex processes, making it difficult to scale operations.

Inaccurate Decision-Making

Lack of decision-support tools, leading to inaccurate or suboptimal outcomes.

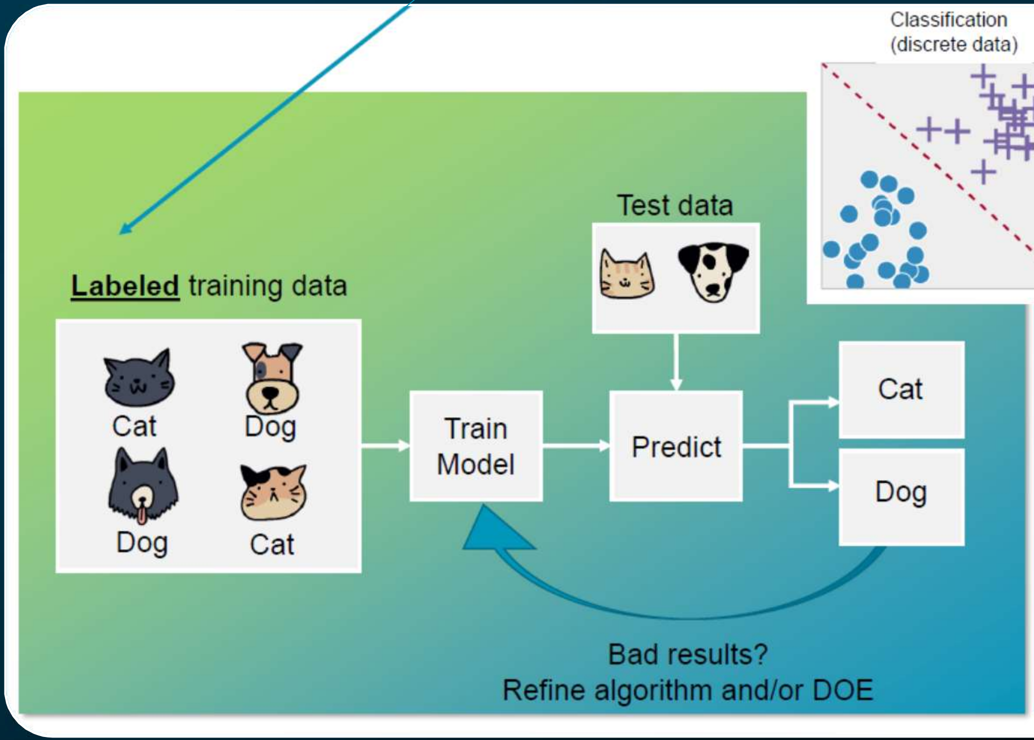
Lower Quality

Identifying key product improvement areas and lacking physics-based optimization tools.

Inability to Extract Full Value of Available Data

Simulations, physical test data, images, CAD datasets produced through the years... not being leveraged within new engineering projects.

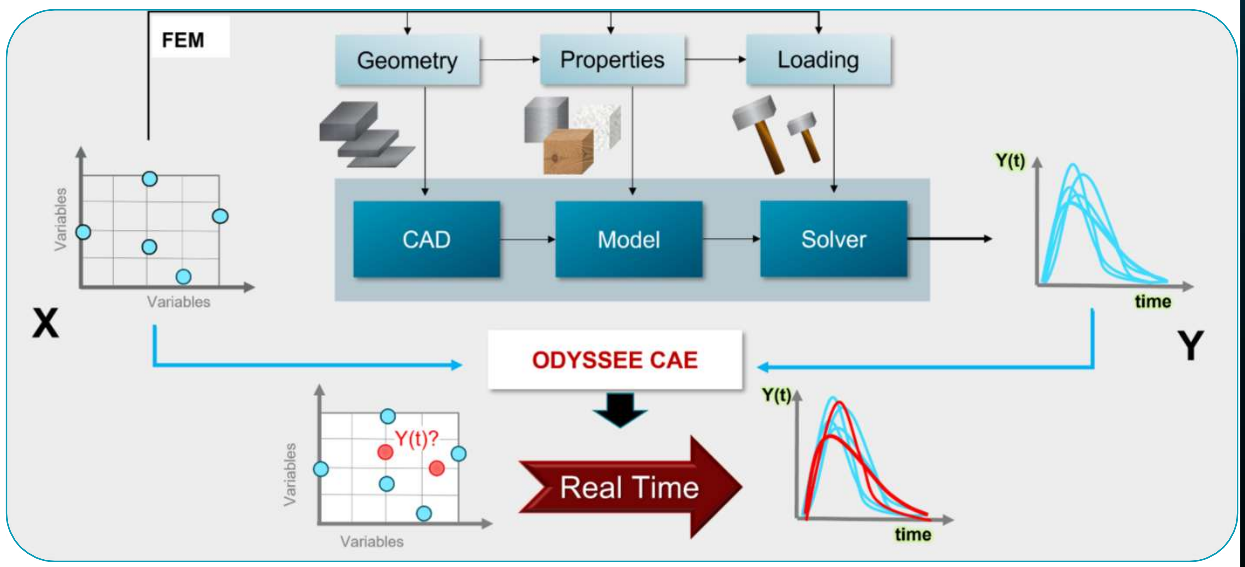
ML Introduction – Supervised Machine Learning



"Machine learning is a branch of artificial intelligence based on the idea that systems can learn from existing data, identify patterns, predict results, and make decisions with minimal human intervention."

ODYSSEE CAE Capabilities

Accelerate design cycles, test more CAE scenarios with real-time FEA results



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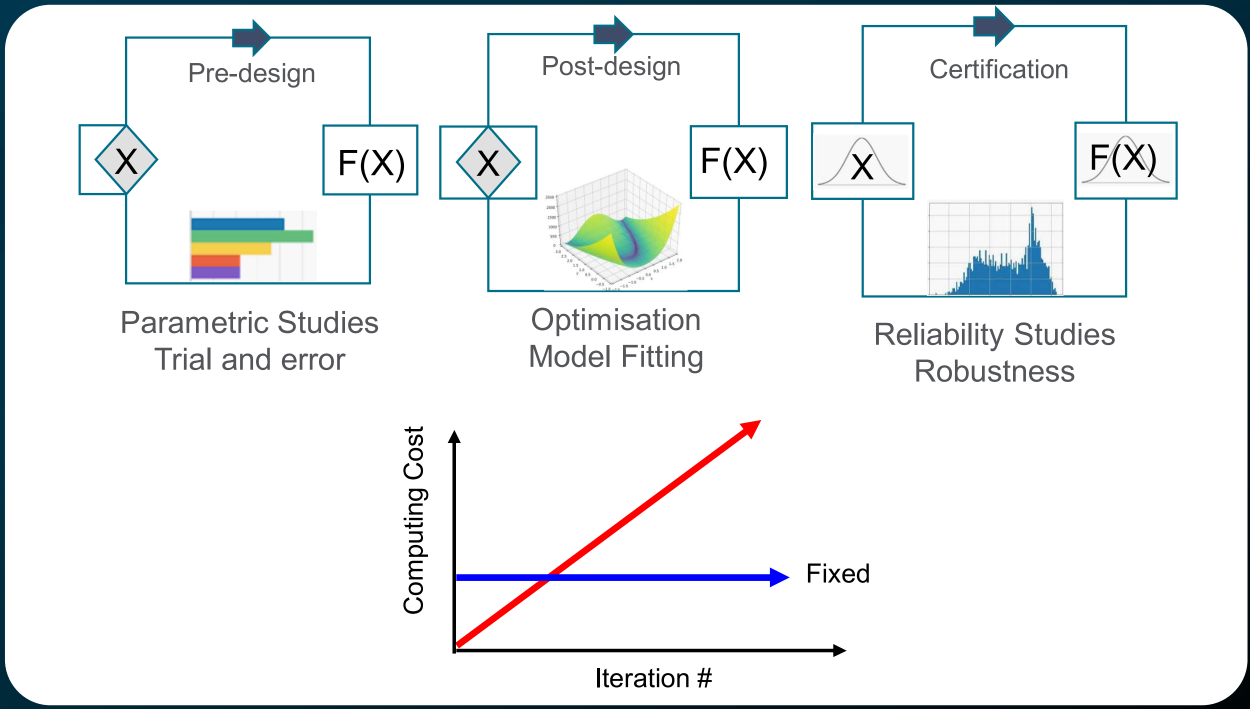
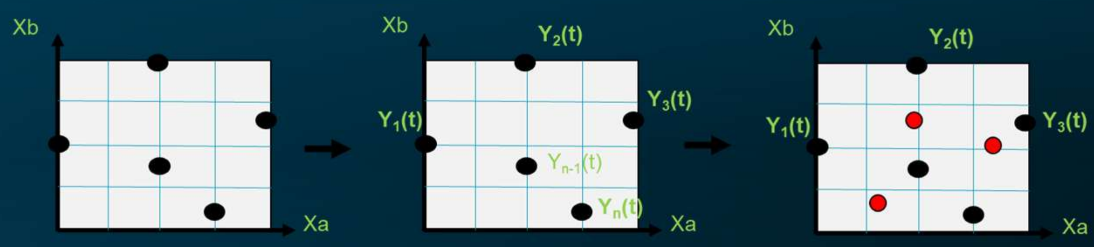
ODYSSEE CAE – Capabilities

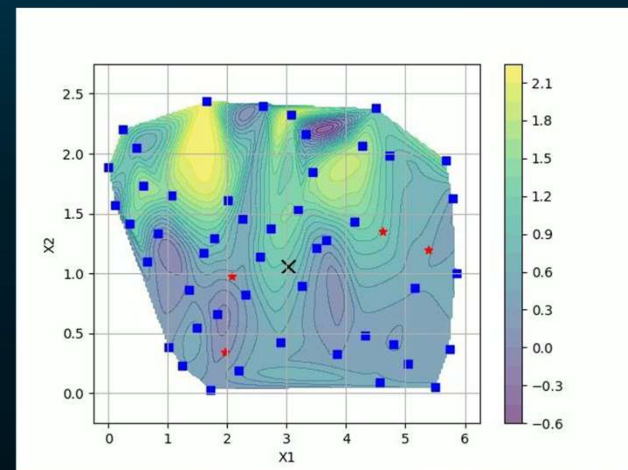
Supporting full range of pre/post design and certification iterations

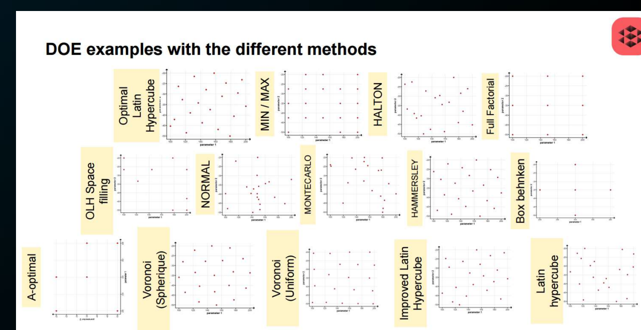


CAE specific needs – Adaptive Design of Experiments

Automated designs, reduction or improvement techniques, adaptive sampling)







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ODYSSEE CAE – Capabilities

Data driven methodology – moving away from differential equations

- **PDE** driven (Du/Dt)
  - PDE Equation => u
  - Given
    - Mü + Ku = F
    - Given M, K, F
  - Find
    - u
  - Needs iterations over time (step by step)
- We call this "integration"

- **Data Driven** (u)
  - u_{old} => u_{new}
  - Given
    - data sets (u_i)
    - Given any u_{old} , M_{new}, K_{new}, F_{new}
  - Find
    - u_{new}
- Needs iterations over data (set by set)c which we call "learning"

Purists deny this! Since Regression distributes the error among all data while ML, attributes it point by point!

Algorithm Selection

METHODS	SOLVER	Type of use
Interpolation methods (direct interpolation)	• Kriging	• Time response • Scalar response
	• RBF • ARBF (adaptive RBF)	• Time response • Scalar response
	• InvD	• Time response • Scalar response
Reduced Order Modelling (ROM) method (decomposition, reduction, reconstruction by interpolation)	• POD Rbf • POD Krigging • POD ARBF (default) • POD InvD	• Animation • Time response • Scalar response
	• Clustering Rbf • Clustering Krigging • Clustering ARBF • Clustering INVD	• Images • Animations • Quick for big data (>1e+6)
	• FFT Rbf • FFT Krigging • FFT ARBF • FFT InvD	• Periodic time response
Clustering Method (classification method)	• SVM	• Time response • Scalar response
Neural Network	• NN	• Big database
Regression	• Linear • Polynomial	

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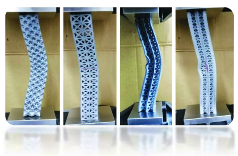
Integration of AI and CAE

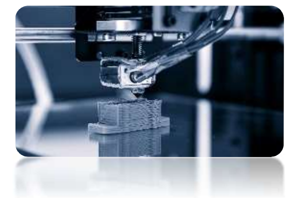
Multi-Body Dynamics

Racing data prediction, chassis frame optimization, ROM generation with sensitivity analysis



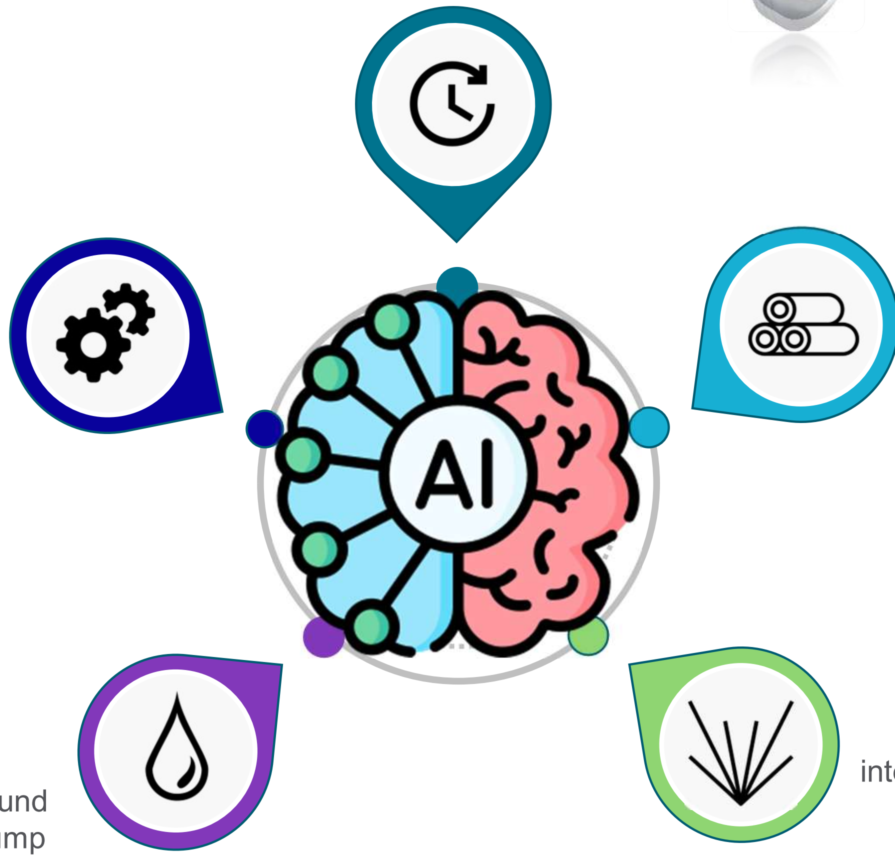
Structural & Thermal Analyses

Buckling modes prediction, fatigue life estimation, thermal behavior of electronic components



Materials & Manufacturing

Material characterization, data enrichment, manuf. process effect prediction, AM part performance



Fluid Dynamics & Acoustics

Steady-state analysis, flow around obstacle, transient analysis, pump membrane optimization

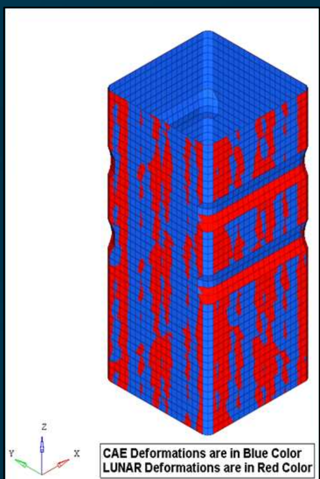
Explicit Analyses

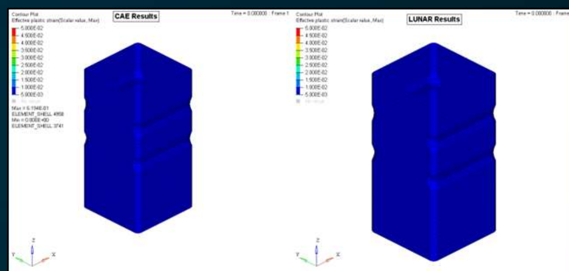
Pedestrian/hood impact prediction, interior/seat design optimization, payload integrity analysis during landing

Case Studies - Crash and Safety

Real-World Application Example: Prediction of Crash Parameters

Challenge: Long time required for predicting effects of materials & thicknesses





CAE AI

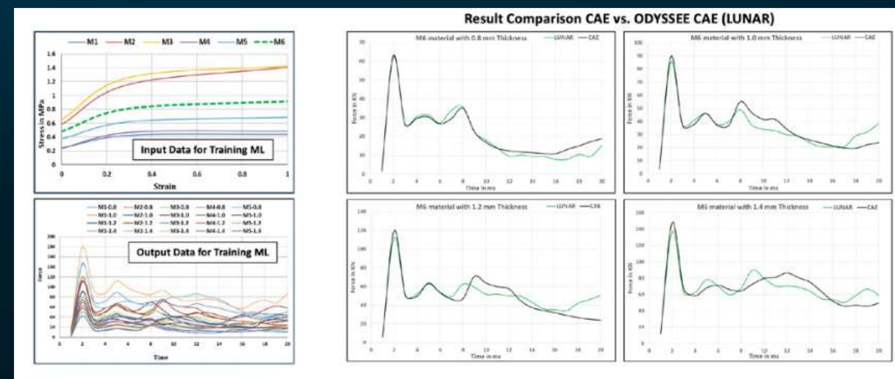
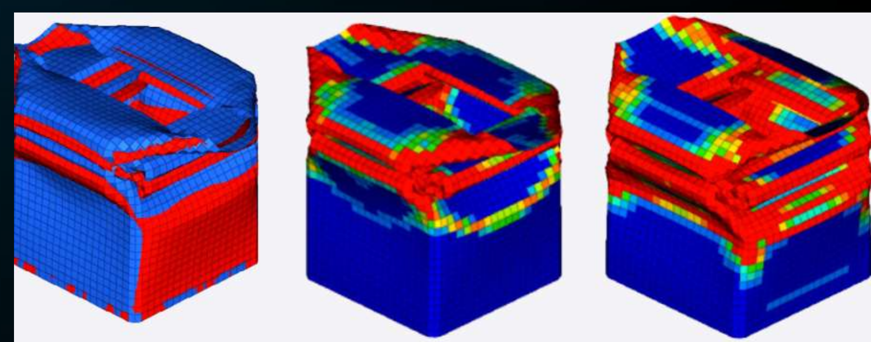


Fig 1: Energy absorption and force prediction for crush can using ODYSSEE CAE



CAE: Blue

AI: Red

(Trained with 20 Runs – 5 materials and 4 thickness – 0.8 mm / 1.0 mm / 1.2 mm / 1.4 mm)

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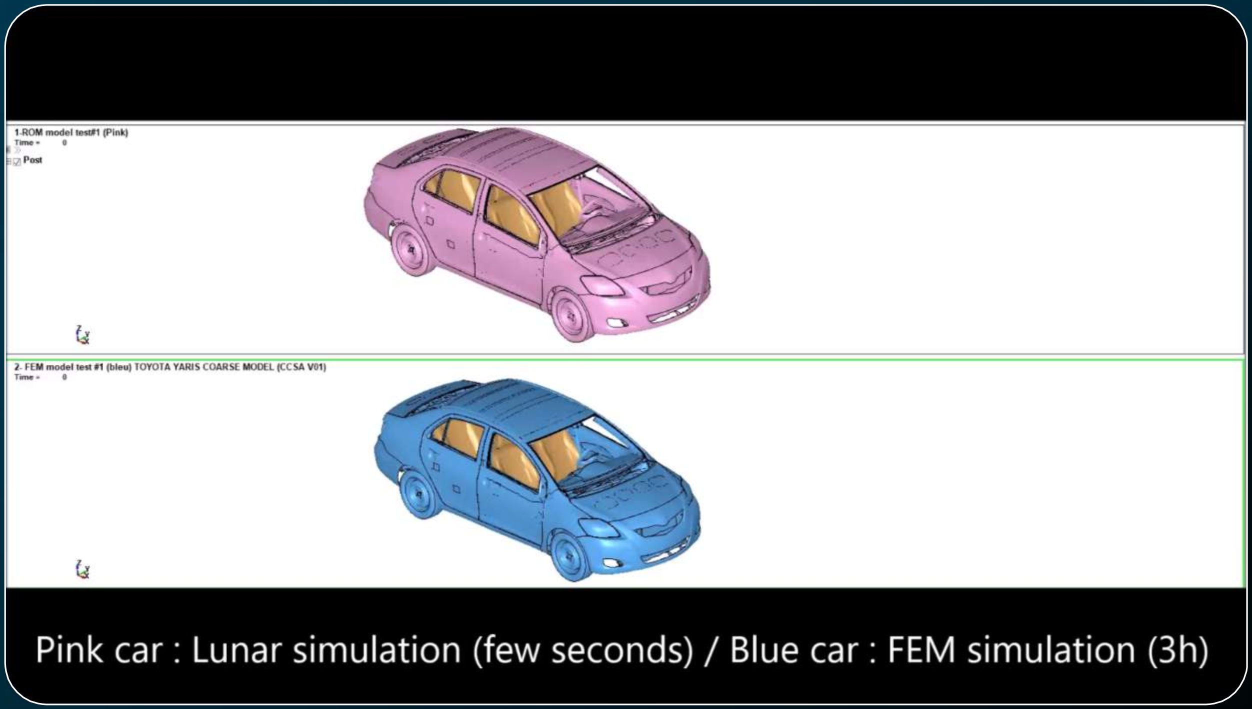
Real-World Application Example: Front Crash in Real Time

Challenge: Optimizing the design requires multiple time-consuming simulations



Solutions

- By first identifying the most sensitive variables, AI enables design optimisation using very few evaluations of the model. Ultimately, AI can be used to find the best design.
- Design exploration studies can be performed in minutes.

Benefits

- Using AI allows engineers to determine the most sensitive parameters first and then evaluate different scenarios (in a few seconds instead of hours) with historical curves and animations with elemental info (stress, strain…)
- Finally, AI can perform optimisation (multi constraint), multi objective) and generate optimal responses (curves and field data) in a few seconds.

Real-World Application Example: Injury Prediction Considering Driving Posture

Challenge: Long CPU hours for two-phase simulations

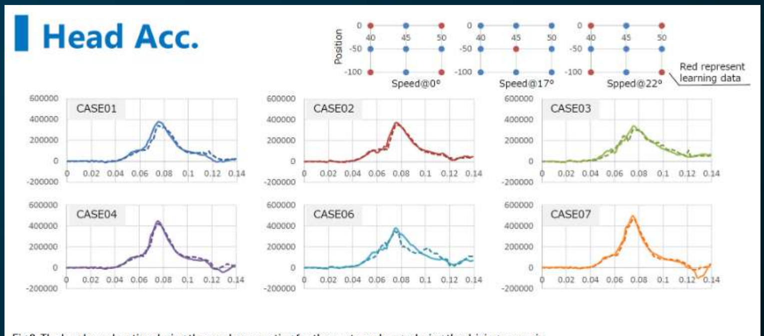
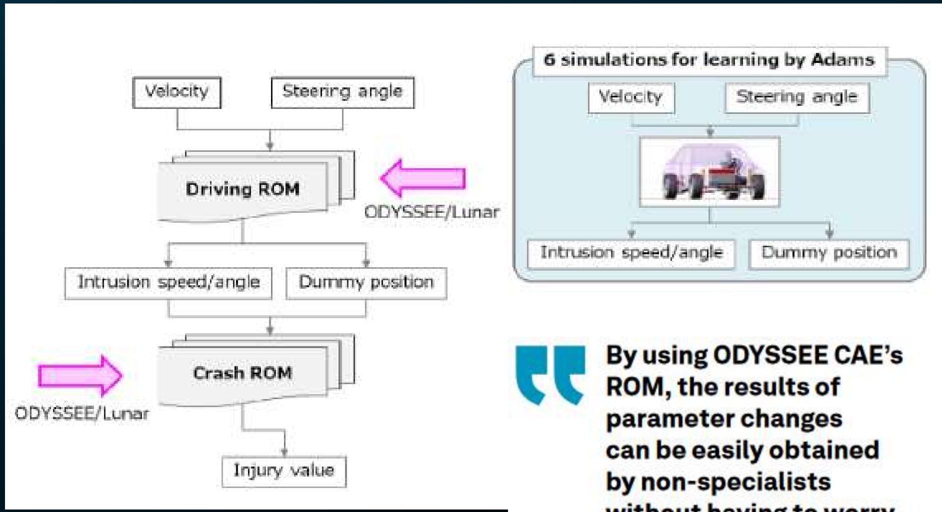


Fig 2: The head acceleration during the crash accounting for the posture change during the driving scenario.
ODYSSEE CAE prediction is the solid line, LS-DYNA simulation is the dashed line.



By using ODYSSEE CAE's ROM, the results of parameter changes can be easily obtained by non-specialists without having to worry about complicated setting changes or errors."

Masahiro Takeda,
CAE Engineer

JSOL, Japan

9 Simulations

Prediction accuracy: 98.6%
Two phase simulation time: 19 hours
Odyssee CAE time: <1s

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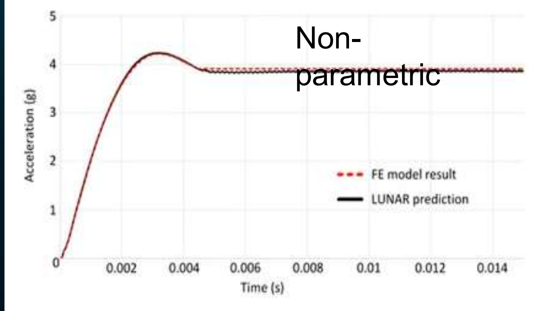
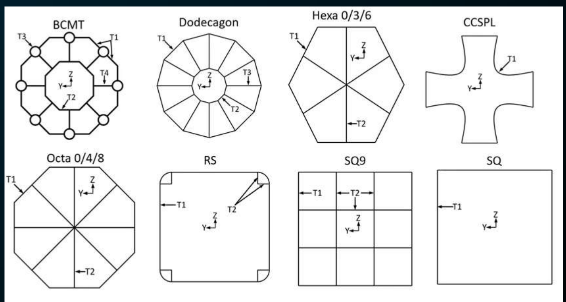
Real-World Application Example – Crash Structure Optimization

Challenge: Identifying optimal designs for occupant safety by controlling structural deformation, acceleration, and impact forces

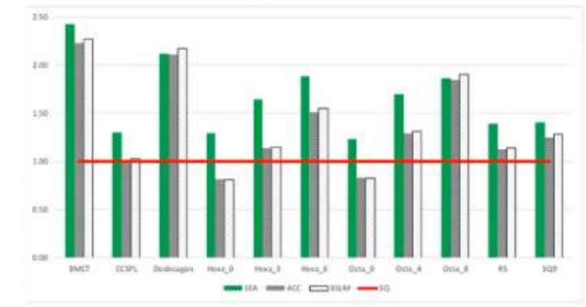
- AI Solution:
  - Developed Reduced-Order Models (ROM) to analyze 12 complex structural geometries.
  - Automated optimization evaluated thousands of design scenarios, requiring only 1,500 simulations instead of the typical 15,000 for full FEM optimizations.
  - Enabled accurate predictions of critical performance metrics like maximum structural loading and acceleration with less than 5% average error.
- Benefits:
  - Quickly pinpointed optimal crash structure designs, significantly reducing analysis time and cost.
  - Demonstrated clear performance advantages of innovative hexagonal crash can designs.



AI Predicted and FEA calculated acceleration curves



Cross section designs



Comparison of structural designs to the standard squared design (red line)

Case Studies - NVH

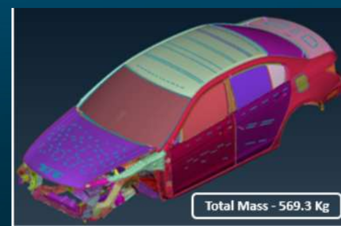
Real-World Application Example: Front Lateral Bending Mode Optimization

Objective

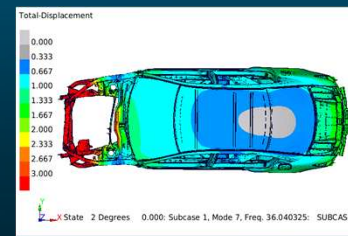
Optimization of front lateral bending mode

- **10 DOE runs to train the model**
- **Identification of sensitivity: 2s**
- **Time required for new response prediction → 5 sec**
- **AI accuracy: 96%**

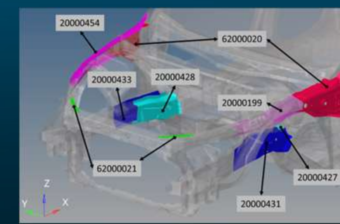
- Optimization target: 7th mode >= 40Hz
- Regular CAE run for optimization: 72 hrs
- AI: 1 min



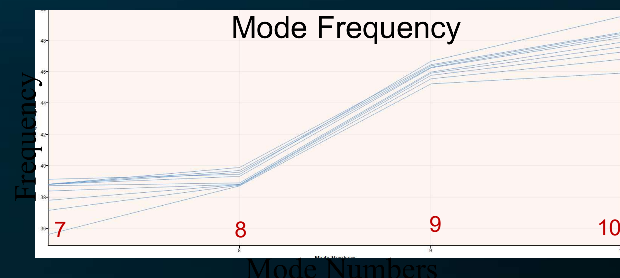
Honda Accord



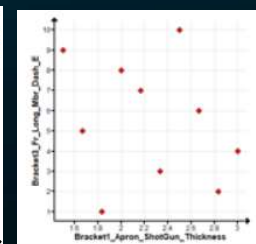
Bending Mode



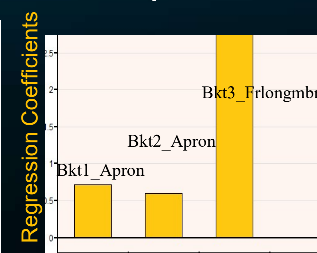
Sensitive parts



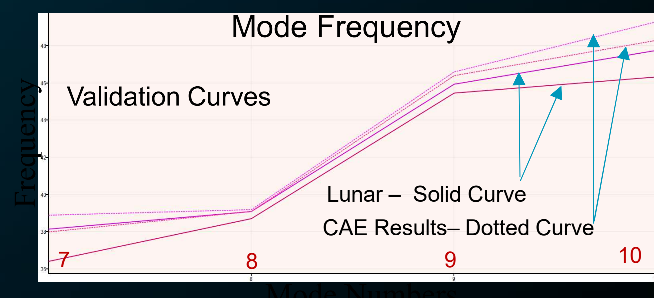
Base results to ML model



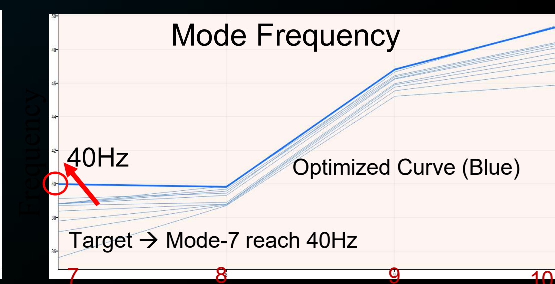
DOE Plot



Sensitivity of Parts



Correlation of AI predicted & CAE results



Optimized results

Satven
Satyam-Venture Engineering Services Pvt Ltd

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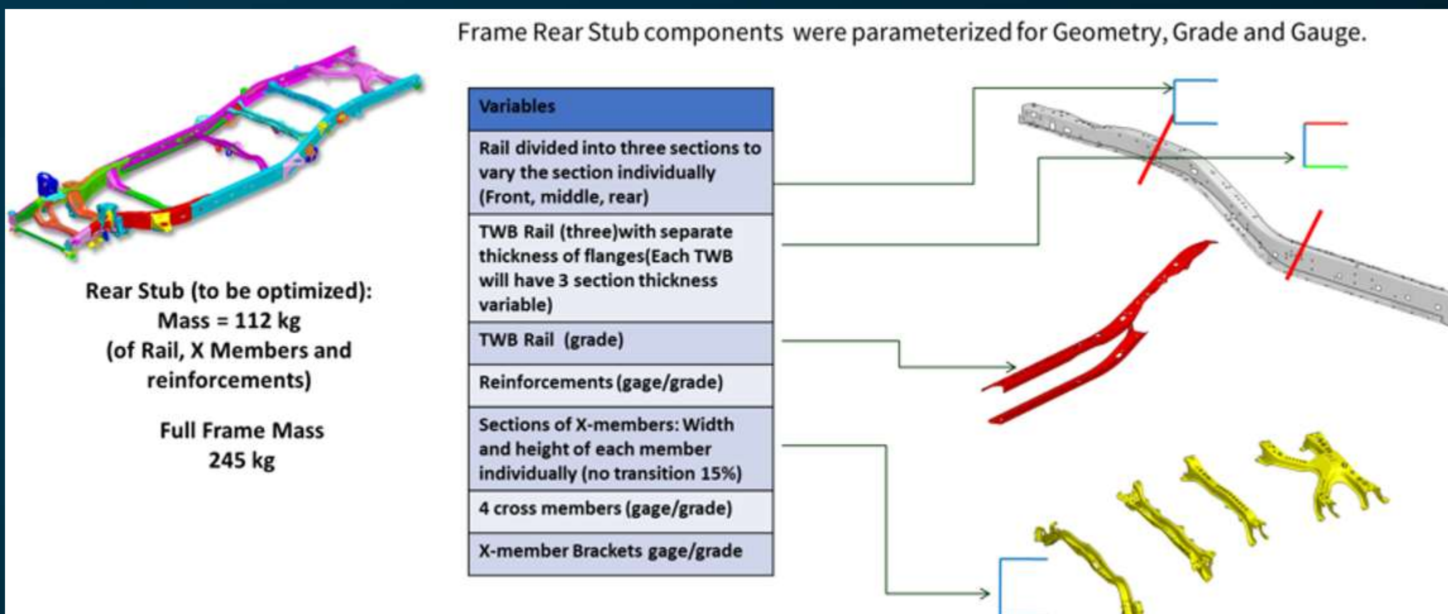
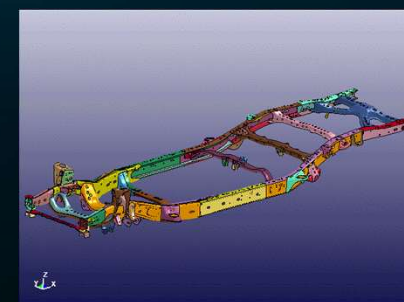
Real-World Application Example: Chassis Frame Optimization for Natural Frequency

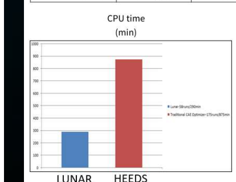
Challenge: Lightweight design with tailor welded blanks



Variables
Rail divided into three sections to vary the section individually (Front, middle, rear)
TWB Rail (three)with separate thickness of flanges(Each TWB will have 3 section thickness variable)
TWB Rail (grade)
Reinforcements (gage/grade)
Sections of X-members: Width and height of each member individually (no transition 15%)
4 cross members (gage/grade)
X-member Brackets gage/grade



Design	First Natural Frequency	Total mass	Rear Stub Mass	Mass Saving (%)
Baseline	11Hz	245	112	
Lunar Optimization	10Hz	224.4	91.4	18.4%
CAE Validation	10.3Hz	223.3	90.3	19.3%



Courtesy of ETA

AI achieved the optimization target with only 1/3 of the CPU time by the conventional optimization method

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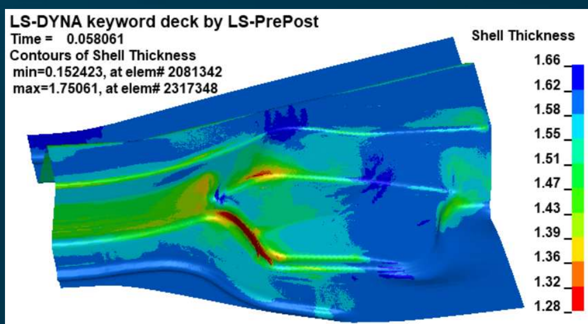
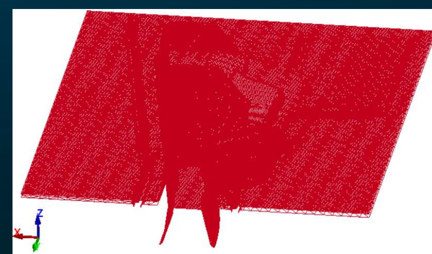
Case Studies - Manufacturing

Real-World Application Example: AHSS Stamping Simulation

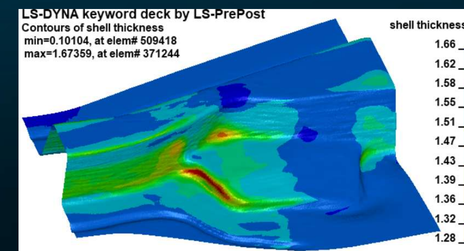
Challenge: To predict thickness and strain distributions on deformed stamping panels

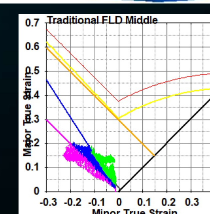


Training Data: 49 DOE with 10 states each

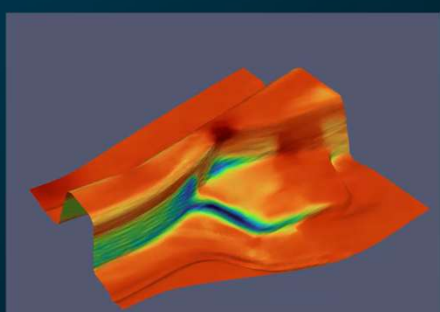


Input for Prediction: initial blank, new tools in initial position.

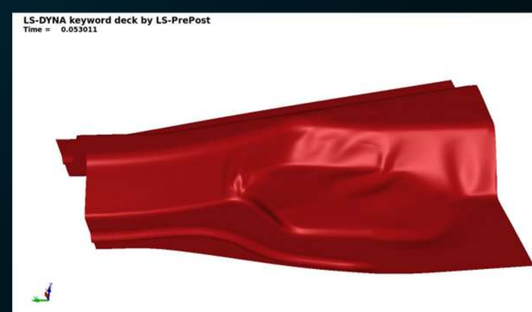




Prediction Output: deformed drawn panel and thickness.



SimAI

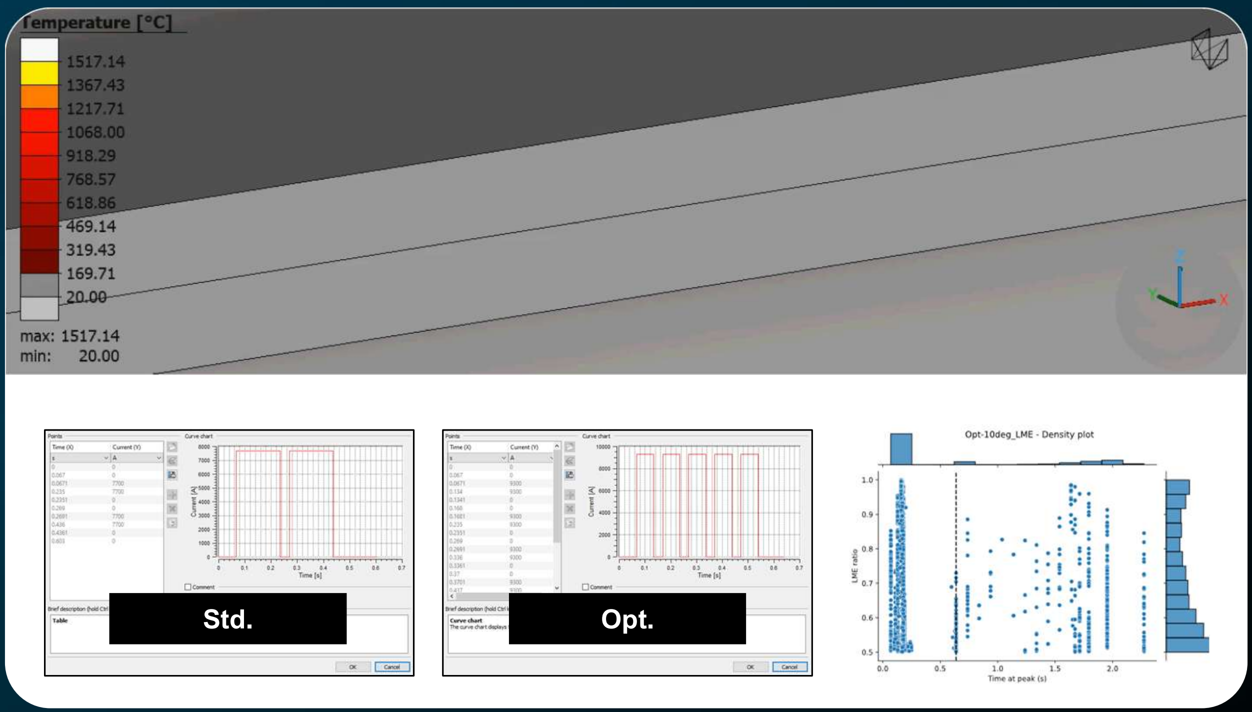


LS-Dyna

Courtesy of Li Zhang, Ansys

Real-World Application Example: Resistance Spot Welding Optimization

Challenge: Extensive manual testing for RSW schedules (material compatibility, weld quality)



AI Solution:

Predictive simulations to create optimal welding schedules

Reduced physical testing, automated optimization of welding parameters

Outcome:

Improved weld reliability and substantial reduction in testing costs and time.

Key Takeaways and Summary

Embracing AI in Steel Vehicle Design

- **AI Transforms Structural Design:** AI accelerates design, reduces costs, and improves quality by automating tasks, enabling faster, more reliable results.
- **Improved Efficiency:** AI speeds up iterations and optimizations, shortening development cycles and cutting costs—essential in the fast-moving automotive industry.
- **Data-Driven Decisions:** Real-time data and design learnings ensure higher accuracy and better decision-making throughout the design process.
- **Cross-domain integration:** Seamlessly optimize across structures, materials, dynamics, and acoustics.
- **The Future of Engineering:** AI is reshaping structural engineering, turning engineers into AI application specialists, and pushing performance and sustainability.
- **Stay Competitive with AI:** Adopting AI isn't just about keeping up—it's about leading the way in innovation, competitiveness, and sustainability.

Act Now: Embrace AI-driven solutions to revolutionize your vehicle structural designs

Thank You!

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