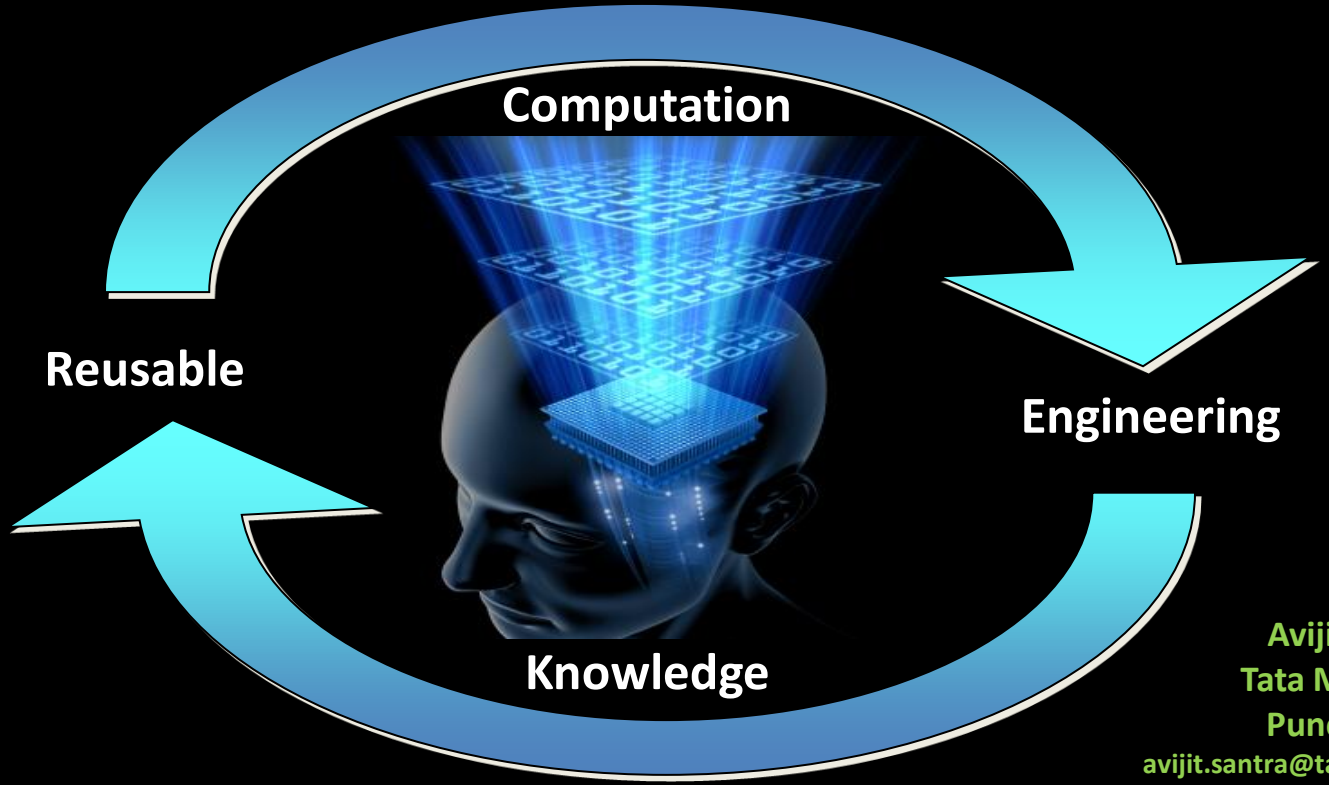
Introducing CUDA in Knowledge Based Engineering Applications for Digital Vehicle Development Programs



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TATA MOTORS

In this Presentation…

- ✓ Brief about Knowledge Based Engineering (KBE)
- ✓ In-house developed KBE solution from Tata Technologies – KNEXT
- ✓ How KBE Kernel has been made GPU Computing enabled
- ✓ KNEXT Framework and Application Case Studies
- ✓ Benefits derived from GPU Computing

Sources of Knowledge in an Organization

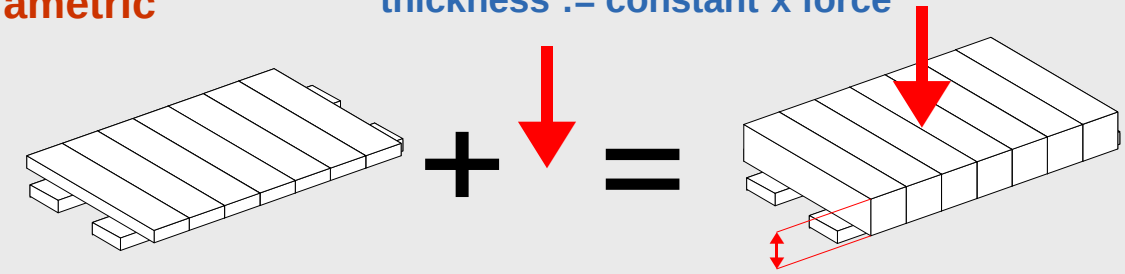
Engineering Knowledge

- Rules & Regulation
- People
- Design Manual
- Processes
- Graphs Benchmark
- Web Intranet
- Product

Parametric CAD Approach vs KBE

Parametric

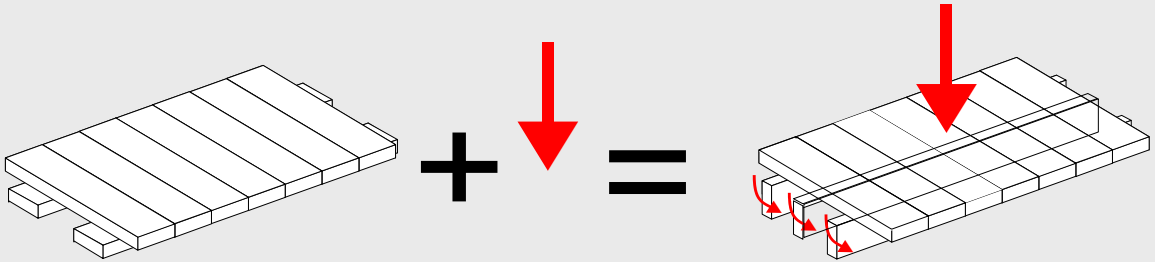
thickness := constant x force



Formula

KBE

'if the load exceeds 90 kg', the beam needs to be rotated & moved to the bottom of the planking with additional support

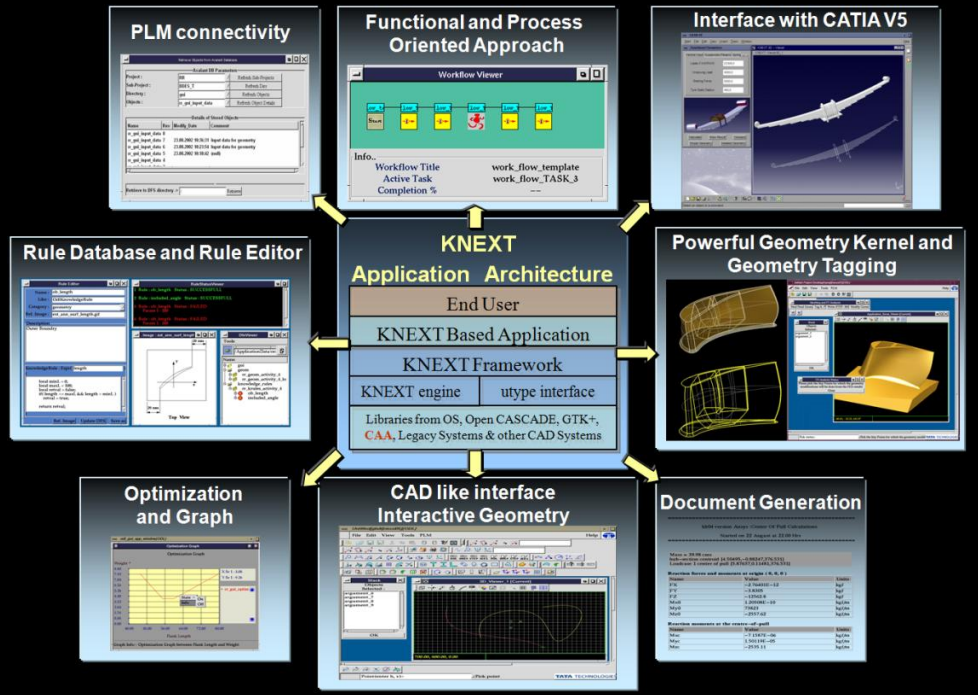


Logic

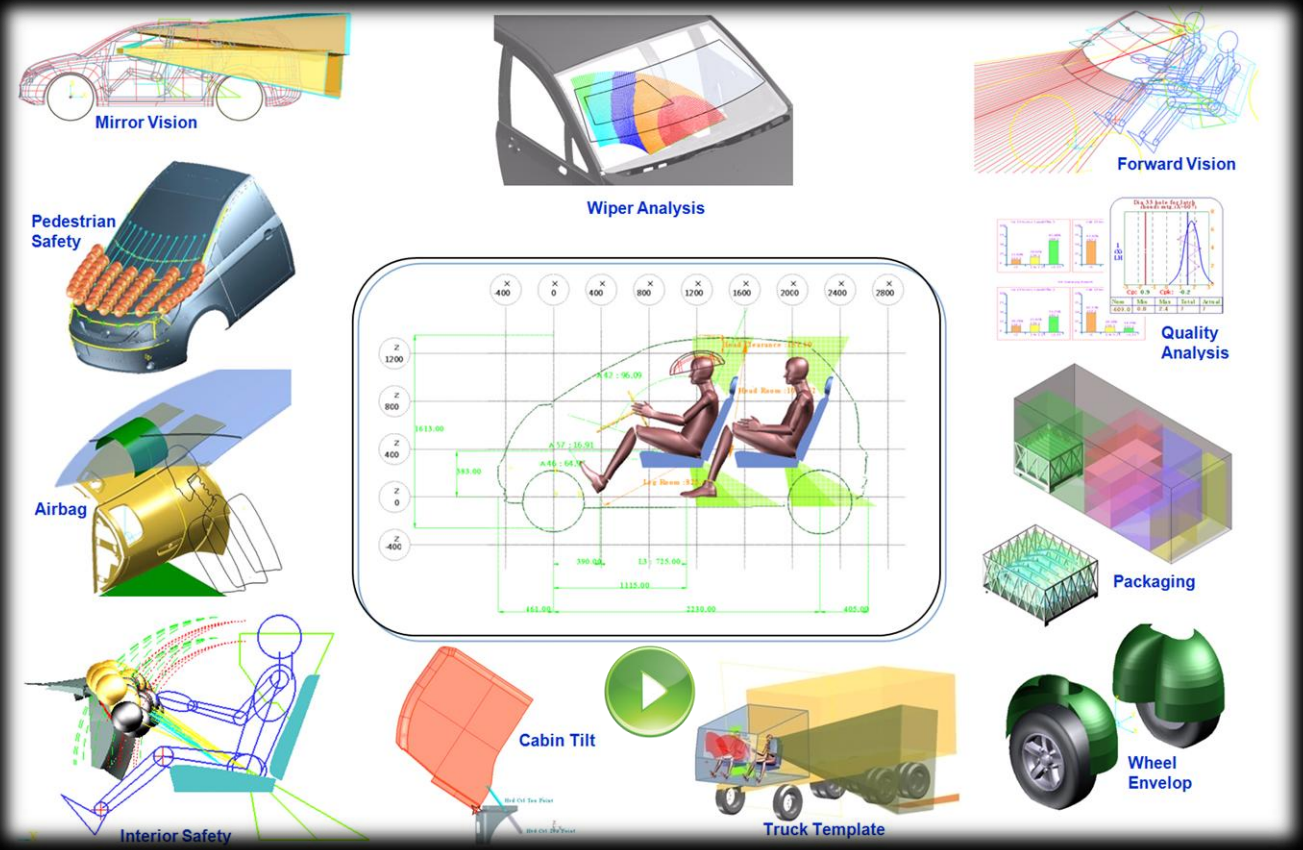
Next Generation KBE Solution – KNEXT

- **In-house developed** KBE Kernel using open standards
  - **Object Definition Language (ODL)** – Simple & Easy to understand

- Domain experts can write their own application
- No compilation, linking; least syntax and run time error
- Memory management completely handled by the kernel
- **Inbuilt Knowledge Modeling** and Rule update process
- Integrate commercially available CAD / CAE tools



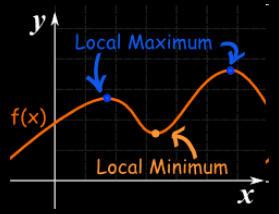
Vehicle Template Application Using KNEXT



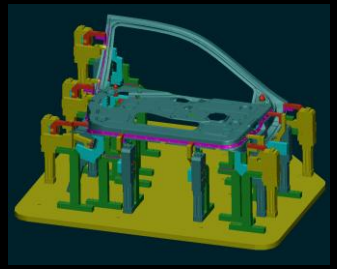
GPU Computing Interface with KNEXT

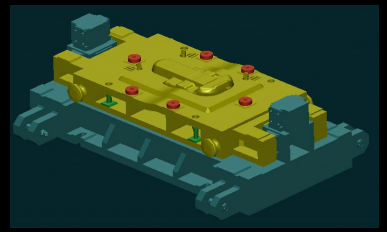
- **KNEXT Language kernel** is GPU computing enabled
  - **matrix and vector** addition, subtraction, multiplication, inverse, transpose, determinant, eigen calculation
  - **Solvers** like simultaneous equation, polynomial, maxima and minima of a function

$$\begin{aligned} a_{11}x_1 + a_{12}x_2 + a_{13}x_3 + \ldots + a_{1n}x_n &= b_1 \\ a_{21}x_1 + a_{22}x_2 + a_{23}x_3 + \ldots + a_{2n}x_n &= b_2 \\ a_{31}x_1 + a_{32}x_2 + a_{33}x_3 + \ldots + a_{3n}x_n &= b_3 \\ \vdots \quad \vdots \quad \vdots \quad \vdots \quad \vdots \\ a_{n1}x_1 + a_{n2}x_2 + a_{n3}x_3 + \ldots + a_{nn}x_n &= b_n \end{aligned}$$

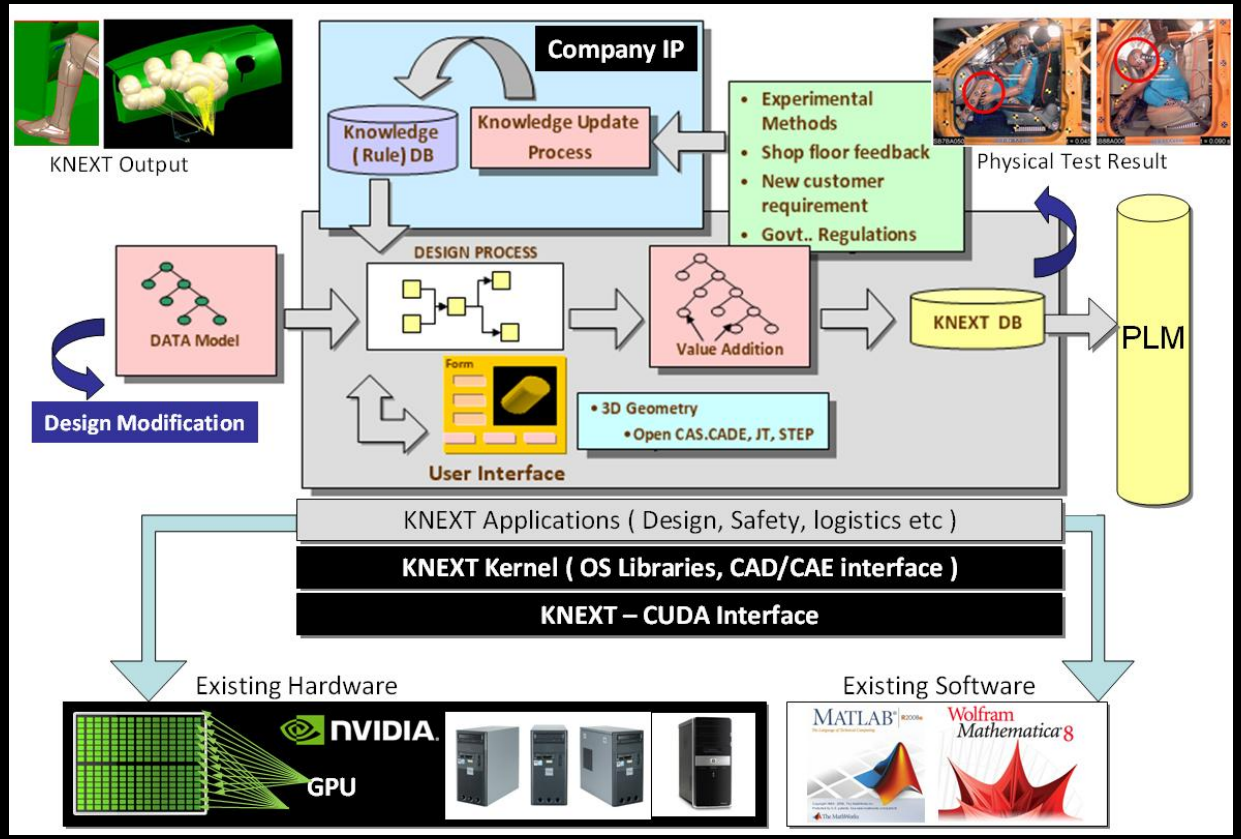


- **KNEXT Geometry kernel** is GPU computing enabled
  - Time consuming topological operation algorithms like **Boolean**, **Extrema** etc of Open Cascade have been converted into parallel computing architecture



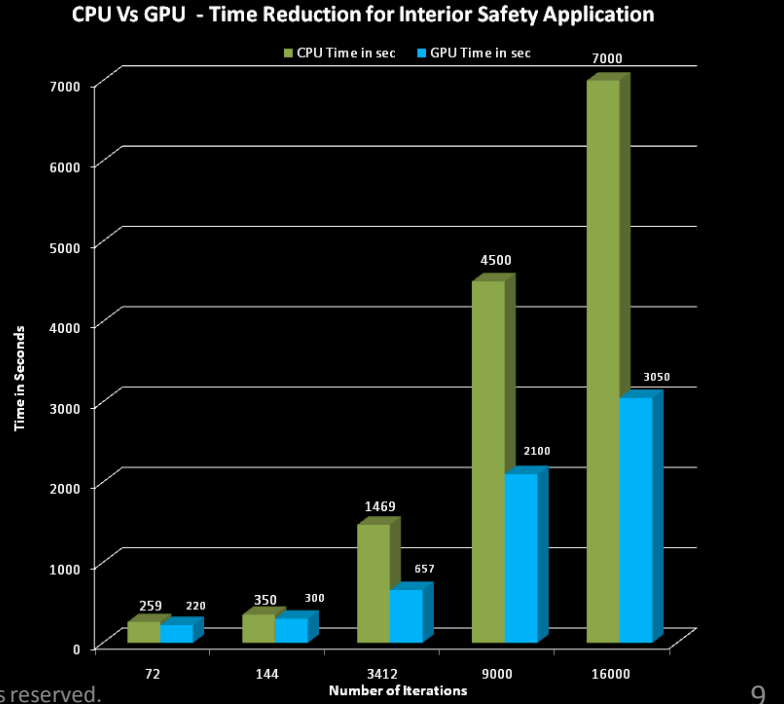


KNEXT KBE Framework



Case 1 – Interior Safety – Head & Knee Impact Zones

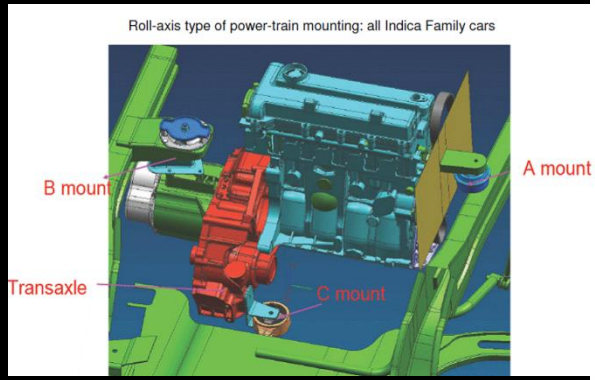
- Determines potential head & knee impact zones with dashboard in a vehicle
  - Digital evaluation at concept stage giving early feedback to Styling
  - Minimizing number of physical crash test of costly vehicle prototypes

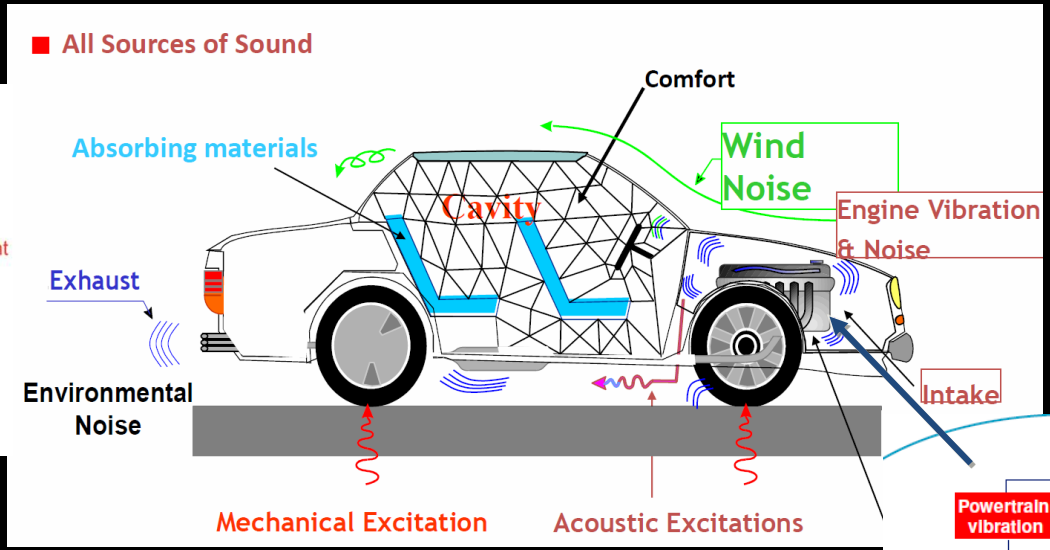


Case 2 – Powertrain Mount Design Optimization (NVH)

Objective : " To achieve world class Noise Vibration Harshness (NVH) Quality for Passenger Cars and Commercial Vehicles "

- Optimizes **Natural frequencies & Kinetic Energy** Fraction in power train mount design from a given set of design variables **(mount-location, orientation and stiffness)**

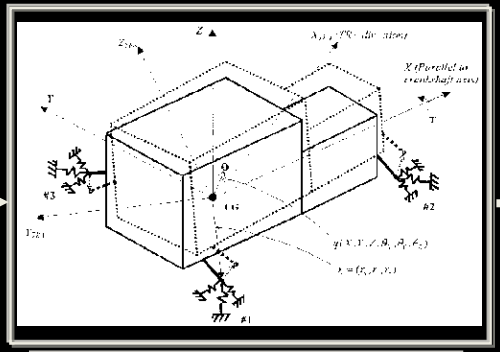




Case 2 – Mathematical Model with KBE

Input Parameters

- Number of Mounts
- Number of Cylinders
- Engine torque
- Idle RPM
- Engine Orientation
- Type of Vehicle
- Mount Stiffness
- Location, orientation
- Vehicle CG



Create Mathematical Model

$$[M] = \begin{bmatrix} m_c & 0 & 0 & 0 & 0 & 0 \\ 0 & m_c & 0 & 0 & 0 & 0 \\ 0 & 0 & m_c & 0 & 0 & 0 \\ 0 & 0 & 0 & I_x & -I_{xy} & -I_{xz} \\ 0 & 0 & 0 & -I_{xy} & I_y & -I_{yz} \\ 0 & 0 & 0 & -I_{xz} & -I_{yz} & I_z \end{bmatrix}$$

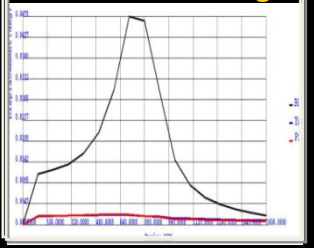
Formation of no. of sets of input data

Formation of [Mass] & [Stiffness Matrix]

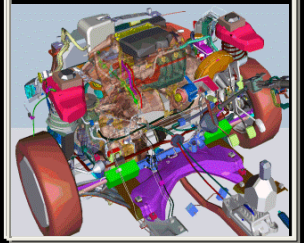
$$[K] = \begin{bmatrix} K_{11} & & & & & \\ 0 & K_{22} & \text{Symmetric} & & & \\ 0 & 0 & K_{33} & & & \\ 0 & K_{42} & K_{43} & K_{44} & & \\ K_{51} & 0 & K_{53} & K_{54} & K_{55} & \\ K_{61} & K_{62} & 0 & K_{64} & K_{65} & K_{66} \end{bmatrix}$$

GPU Computing

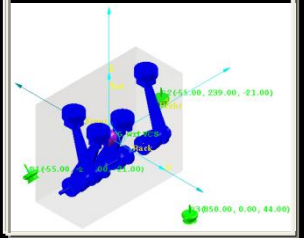
Powertrain Displacement with Transient Loading



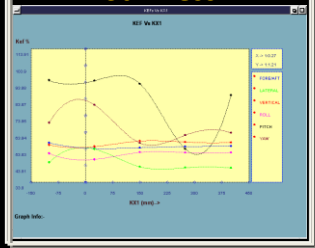
Powertrain Displacement and Envelope



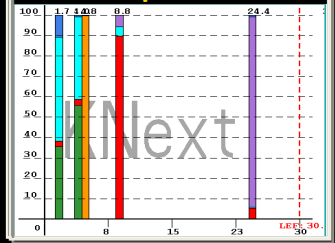
Optimized Mount Position and Orientation



Kinetic Energy Fraction and Mount Stiffness



Kinetic Energy Fraction and Natural Frequencies



Driver Comfort (Full Vehicle Model)

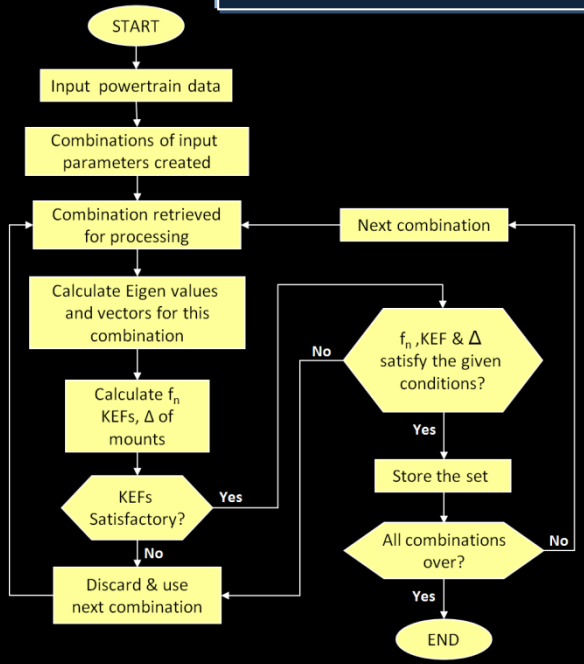
Case 2 – Time Reduction Using GPU Computing

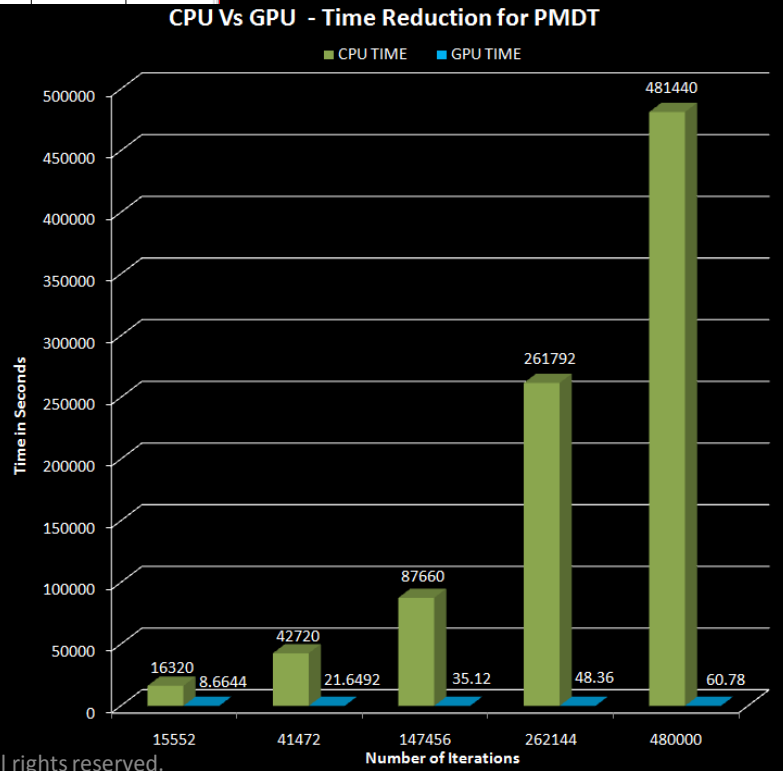
The following output came in less than 1 second !!!

RESULTS

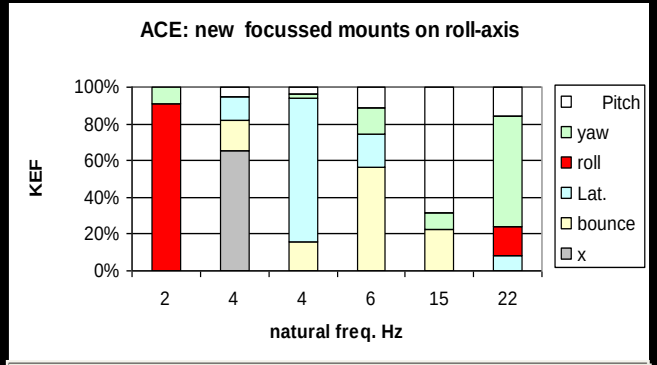
mount1(x)	mount1(y)	mount1(z)	mount2(x)	mount2(y)	mount2(z)	mount3(x)	mount3(y)	mount3(z)	mt1(degV)	mt1(degC)	mt1(degZX)	mt2(degV)
-258.00	-260.00	36.00	-261.00	263.00	37.00	505.00	0.00	-118.00	0.00	0.00	-30.00	0.00
-258.00	-260.00	36.00	-261.00	263.00	37.00	505.00	0.00	-118.00	0.00	0.00	-30.00	0.00

2 data satisfied out of 233280 data

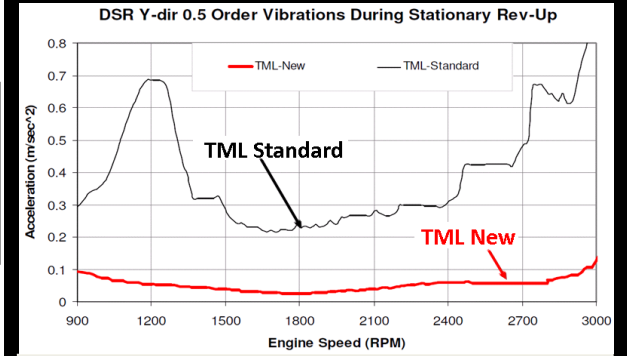




Case 2 – Implementation in TATA ACE



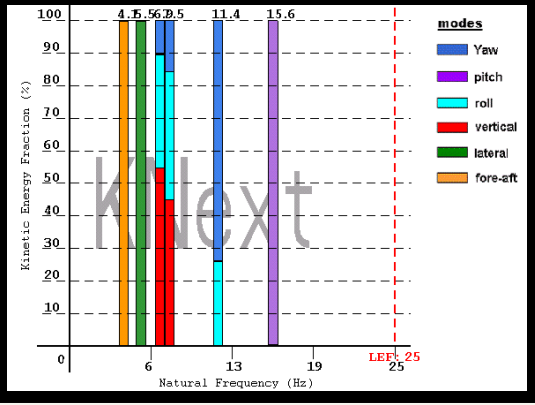
Modal Decoupling



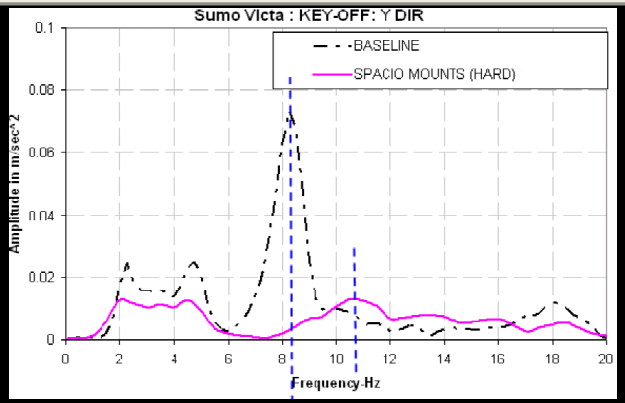
Vibration Control for ACE-0.75T

- Standard Powertrain mounting had a resonance of Roll at 10 Hz [= 0.5 order at 1200 RPM]; this was reduced to 2 Hz with focused mounting on PT-roll-axis; thus giving **lower vibrations at Driver's Seat and other tactile points.**

Case 2 – Implementation in Sumo-VICTA



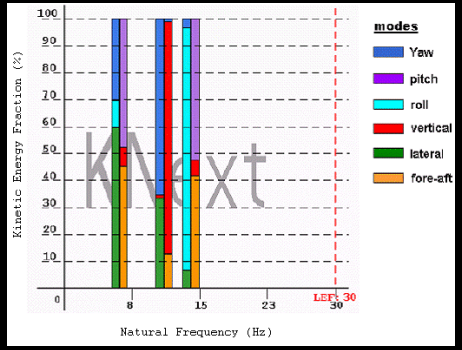
Reduction in Body-jerk during Key-on-key-off



Modal Decoupling

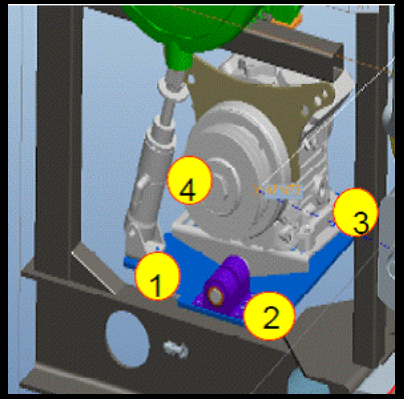
- ✓ Driver's Seat-rail acceleration during the transient event of torque fluctuations [like Key-on-key-off of vehicle] was found sensitive to stopper design &/or stiffness of the rubber-mounts.
- ✓ **Application recommended a new set of mounts for minimum body-jerk**

Case 2 – Implementation in Hi-deck Bus LPO 1628

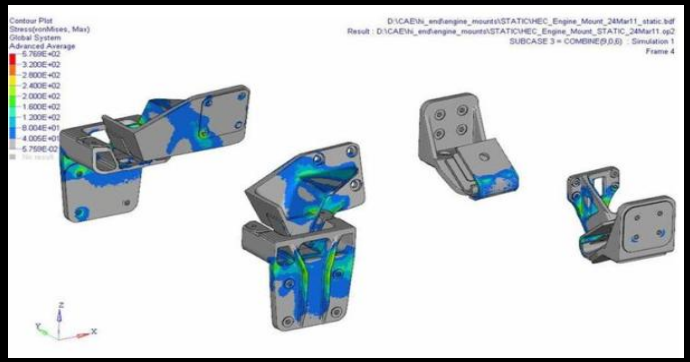


Vibration Isolation and Modal Decoupling by fine-tuning 6 Power-train mounts

Analysis of A/c Compressor Mounting dynamics



Stress-Analysis in mount brackets



- ✓ **This gives less vibration to Driver & Passengers.**
- ✓ **This will assure good key-on-key-off jerk to Body of the Bus.**

Benefits

Reducing Design Cycle Time:

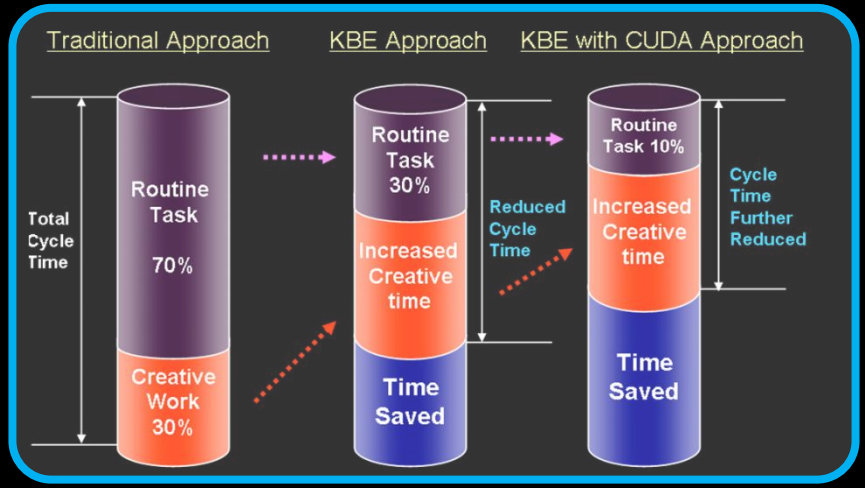
The KBE applications powered by GPU computing help designers to iterate on engineering parameters and arrive at an optimized solution very quickly.

Improving Quality of Final Product:

The applications have inbuilt knowledge rules and regulations which ensures design validation against manufacturing and operating environment.

Saving IT Resource:

Using GPU computation saves need of high capacity CPU configuration



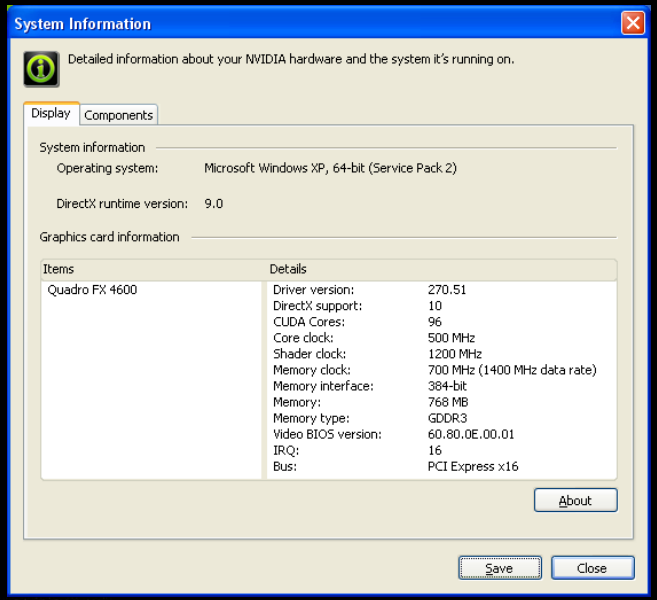
Total no of CAD workstation in Tata Motors = 954

Make & Model	Quantity	NVIDIA Graphic Card
IBM Z - Pro	317	Quadro FX 4600
HP XW8400	100	Quadro FX 4600
Fujitsu Celsius	351	Quadro FX 4800
HP Z800	186	Quadro FX 4800

System Information

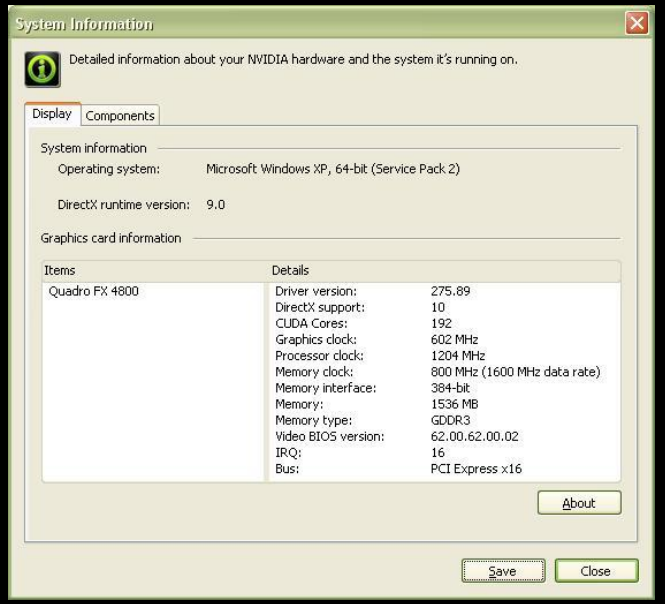
IBM Z-Pro

- Intel Xenon 3.00 GHz Processor
- 4 GB RAM
- Windows XP 64 bit SP2
- Quadro FX 4600



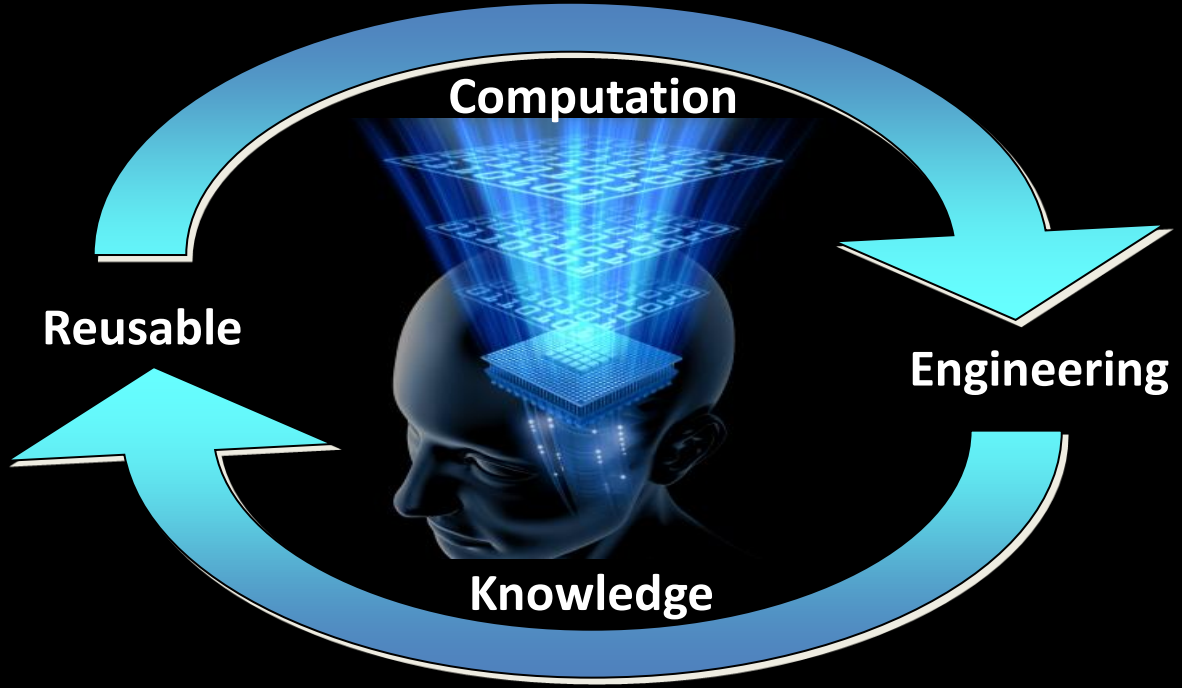
HP XW 8400

- Intel Xenon 3.00 GHz Processor
- 4 GB RAM
- Windows XP 64 bit SP2
- Quadro FX 4800



Thank You

Abhay Tarnekar | Yogesh Deo | Avijit Santra



Acknowledgement

Mr. T N Umamaheshwaran, CTO, Tata Motors Ltd