Commercial Vehicle Modelling and the Influence of Frame Flexibility on Vehicle Response

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Design Systems for "Complete Vehicle" Models

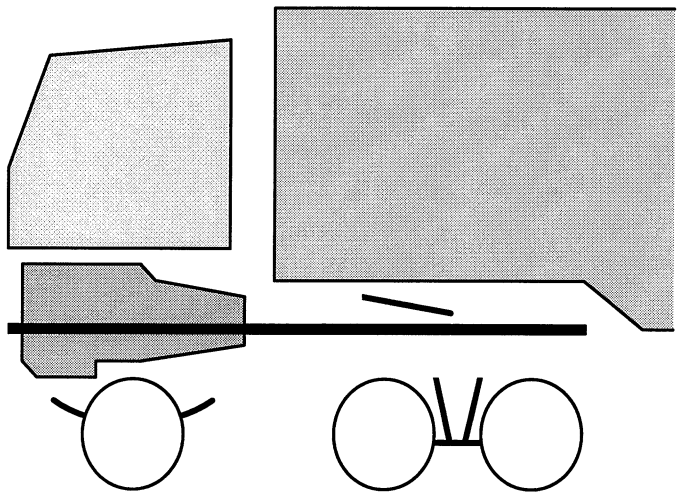
"Complete Vehicle" models are used to optimise characteristics of systems and components in order to fulfil a wide range of demands in areas such as handling, vibration environment, noise, fatigue life, load capacity and packaging.

A "Complete Vehicle" model, does not necessarily imply a very complicated model. It defines a model with "enough" complexity to describe a certain vehicle behaviour.

Limited knowledge about "load spectras" and "dimensioning criterias" can not be compensated by "state-of-the-art CAE-software". All three areas have to be in balance and constantly improved.

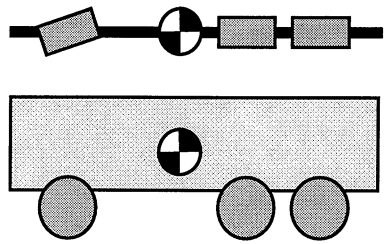
Demands on Design Systems for Complete Vehicle Simulations

- Provide fast parameter studies
  - Efficient data handling and result presentation
  - Tools for sensitivity analysis
  - Low "overhead" in the computer analysis
- Provide flexibility in analysis type
- Reuse of existing (sub)models
  - Frame
  - Cab
  - Engine
  - Axle installations and steering system
  - Superstructure / Trailer



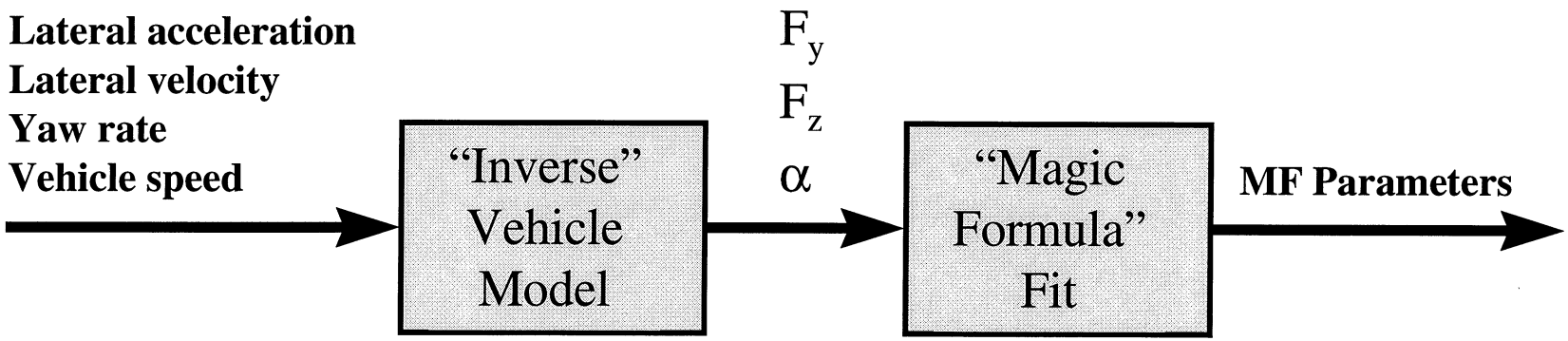
Step-by-step modelling

1. "Bicycle" model
2. Rigid vehicle with "Magic formula" tyres
3. Substructuring
4. Kinematic chassis suspension with discrete springs and dampers
5. Elasto-kinematic chassis suspension
6. Non-linear suspension components
7. Power steering
8. Frame flexibility
9. Final parameterisation



Tyre Model

- "Magic Formula" tyre model (TIRSUB)
- Parameters estimated from
  - Steady state vehicle testing $F_y(\alpha)$
  - Tyre test rig (low speed, flat bed) $F_y(\alpha)$ $M_z(\alpha)$



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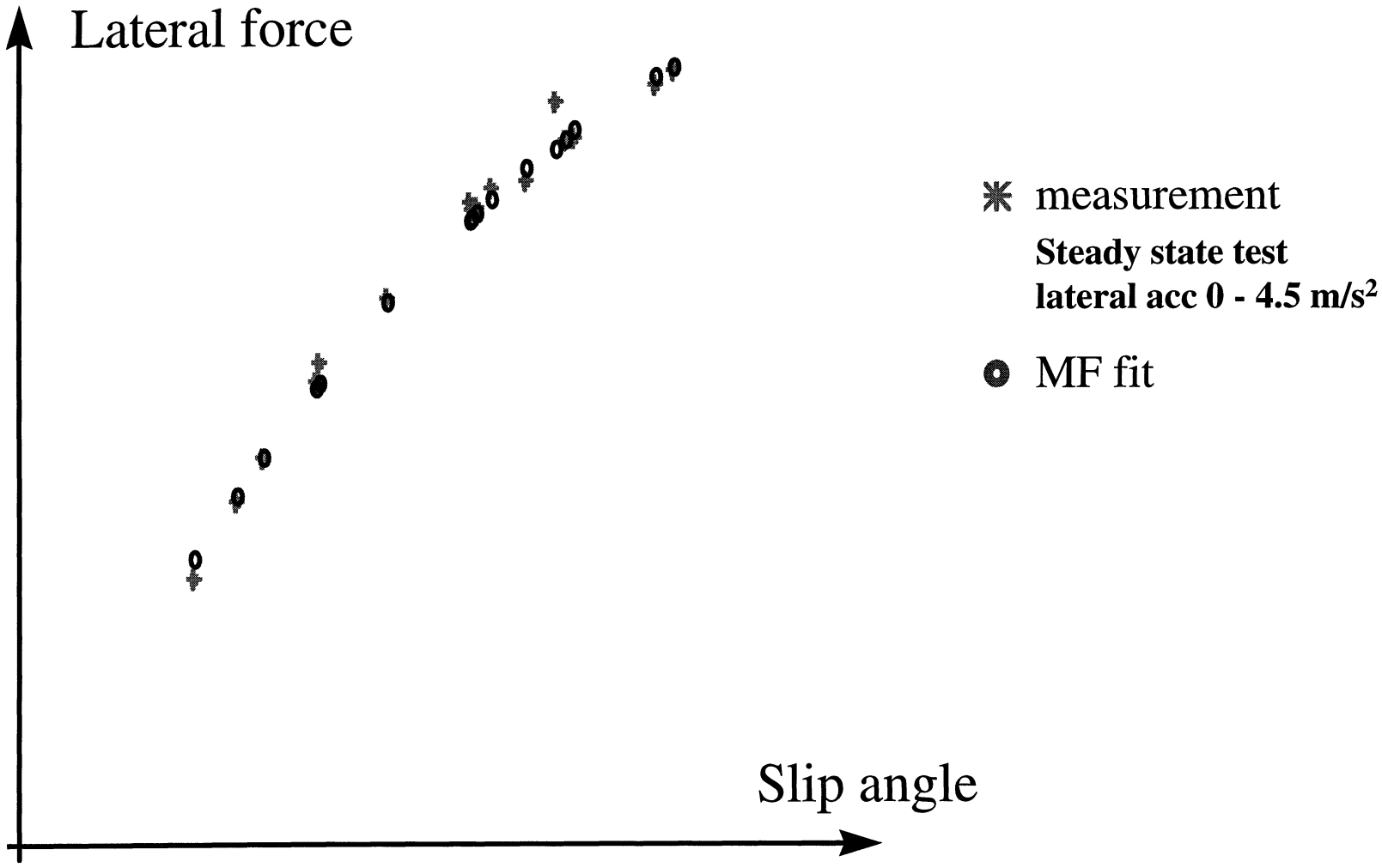
Magic Formula Fit



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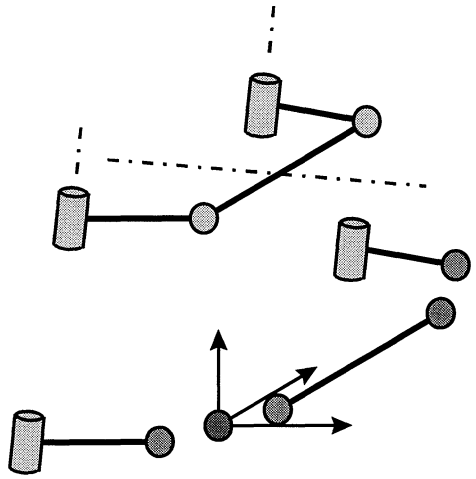
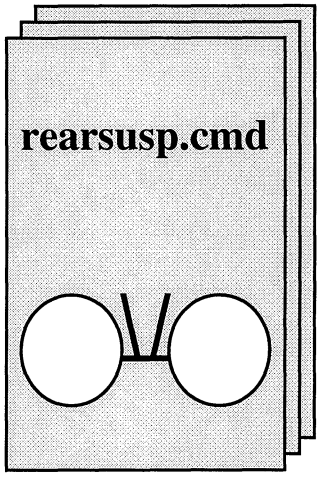
Substructuring

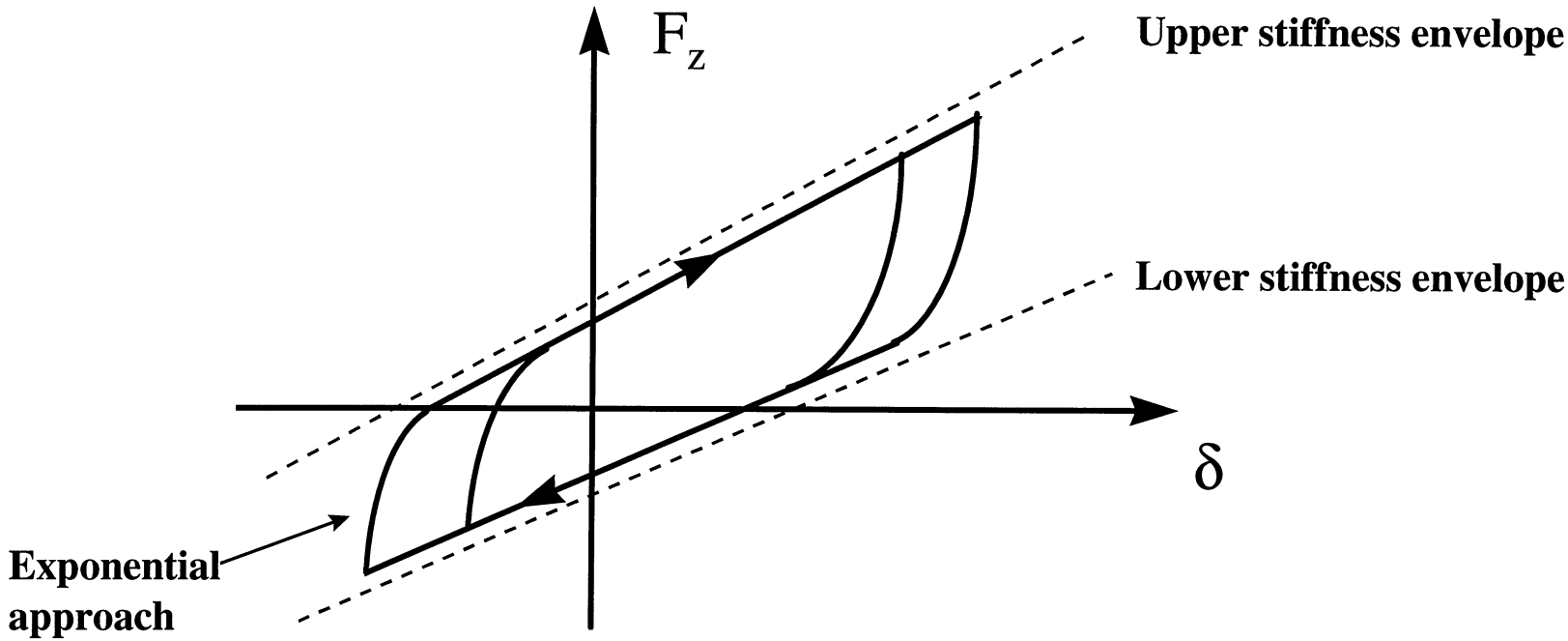
- "Hard-points"
  - Set of reference points to describe topology
  - Use of mirroring for symmetry
  - Local coordinate systems for subsystems
- Submodels
  - CMD-files for main vehicle modules
- Vehicle Parameters
- Final assembly
  - CMD-file to include submodels,
    set vehicle parameters and define analysis
- OUTLINE graphics to verify attachment points





Hysteresis

- "UMTRI" spring hysteresis model
- Analytical solution of first order DE (SFOSUB)



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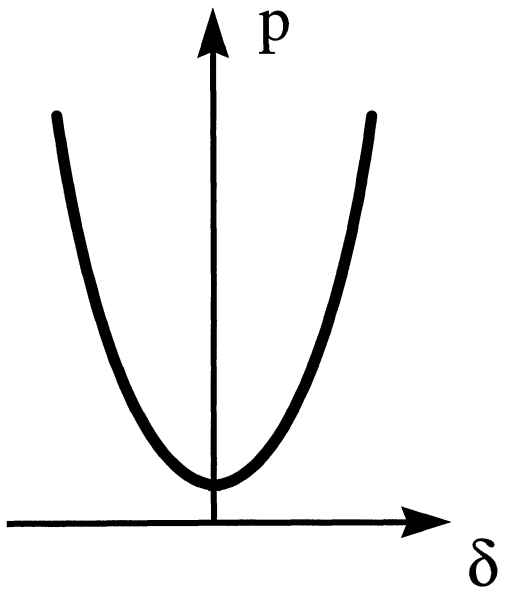
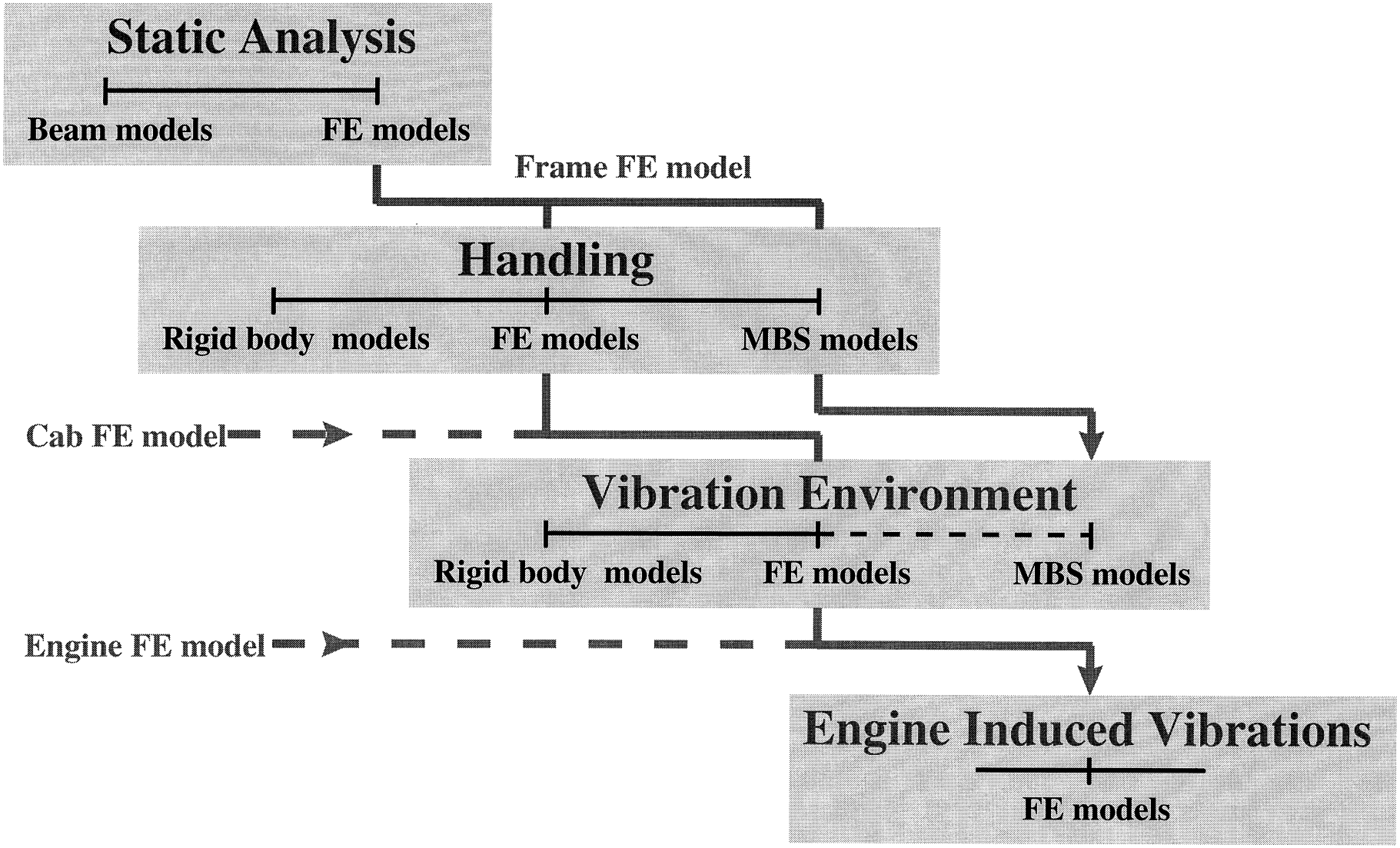
Steering Servo Model

- Quasistatic with respect to hydraulics
- Piston and steering column friction
- Polynomial description of pressure vs valve opening



Complete Vehicle Analysis



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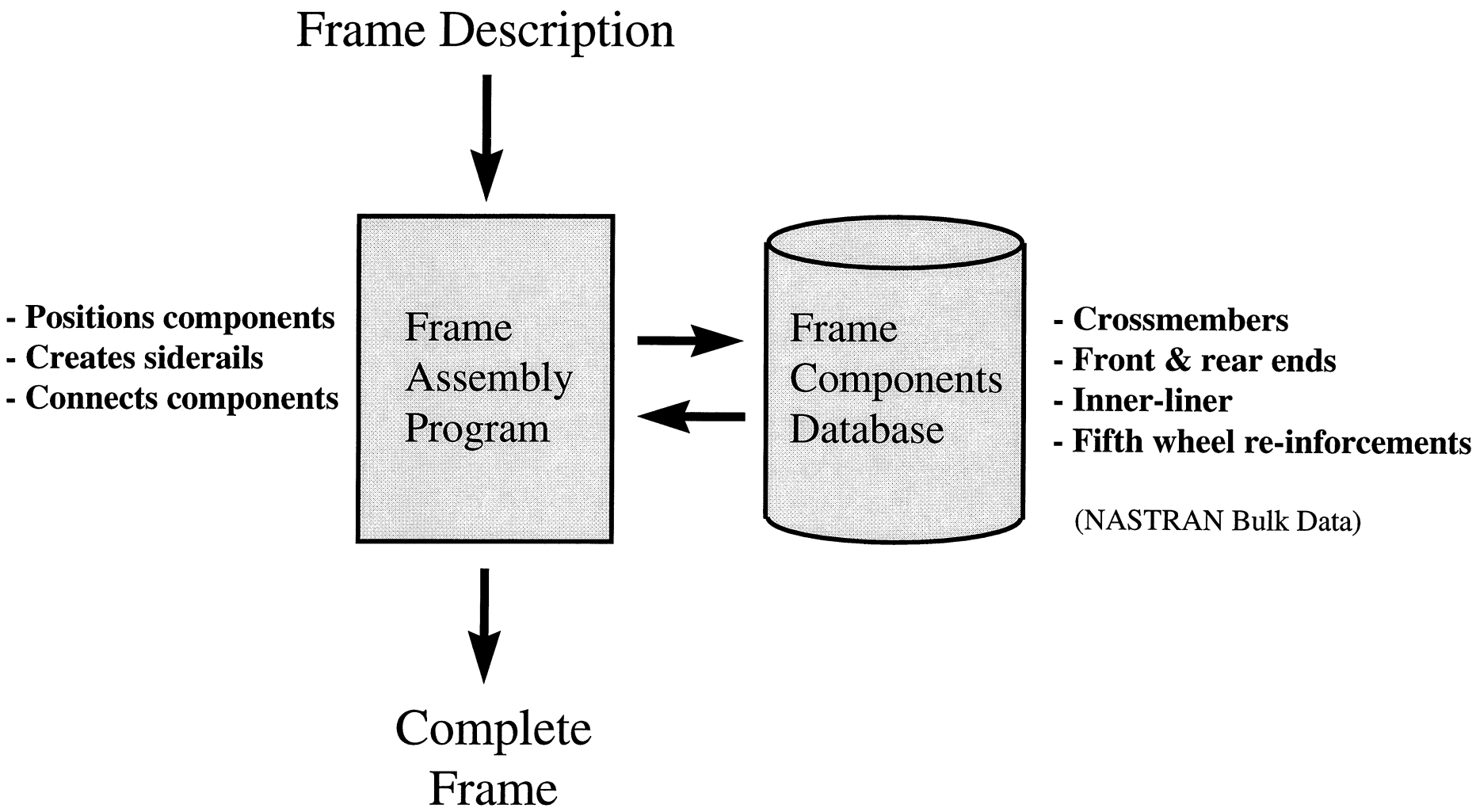
Frame Assembly



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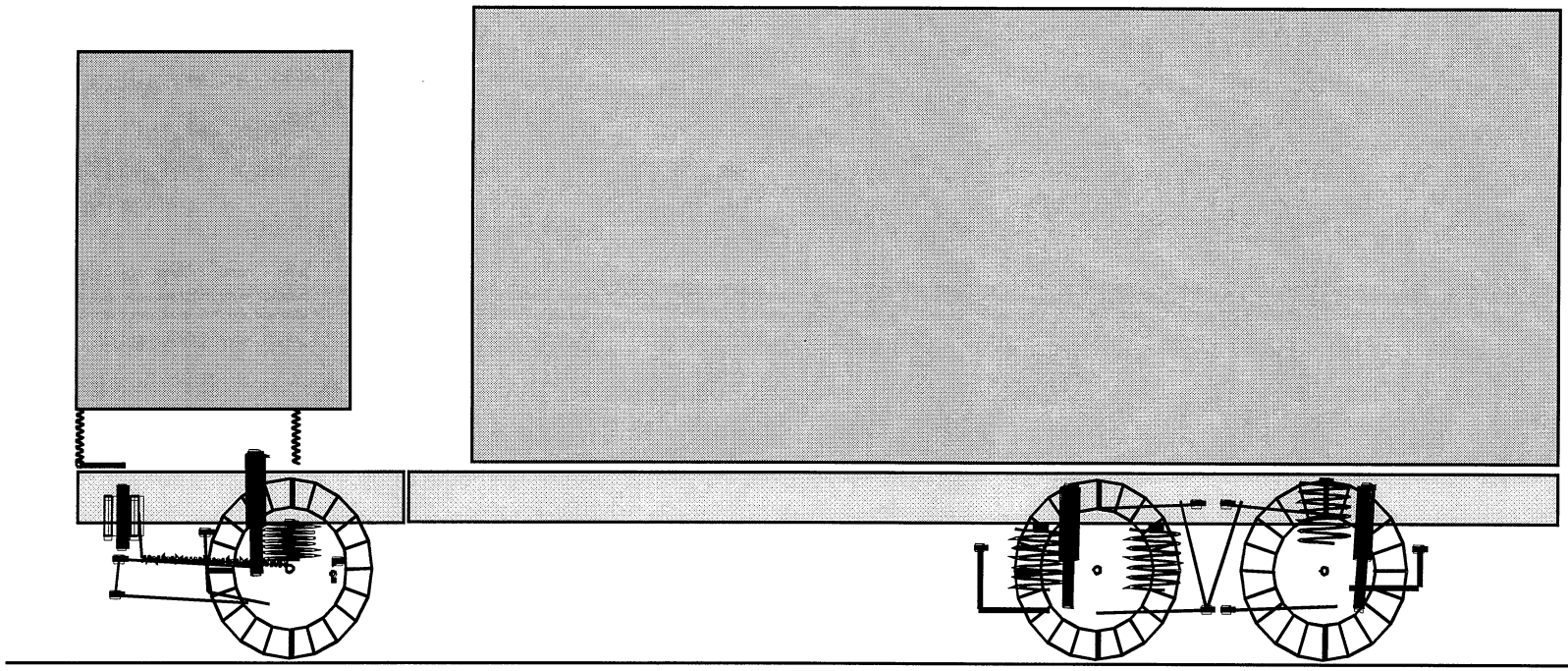
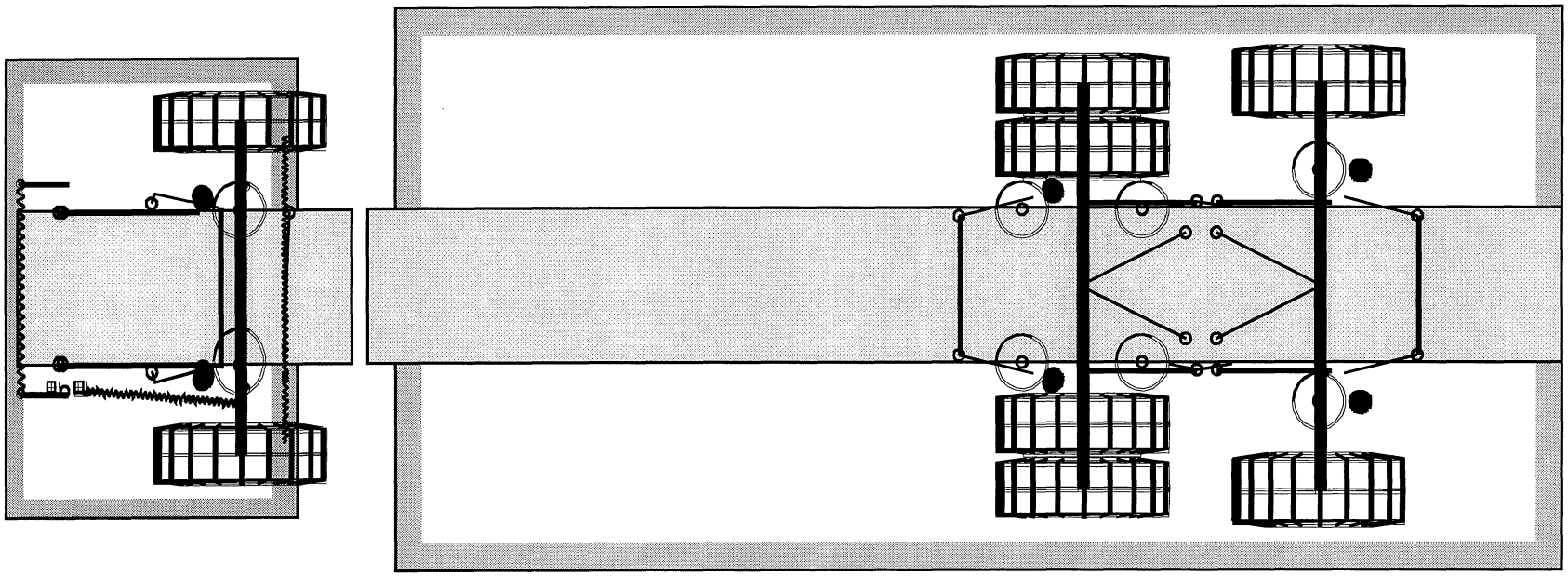
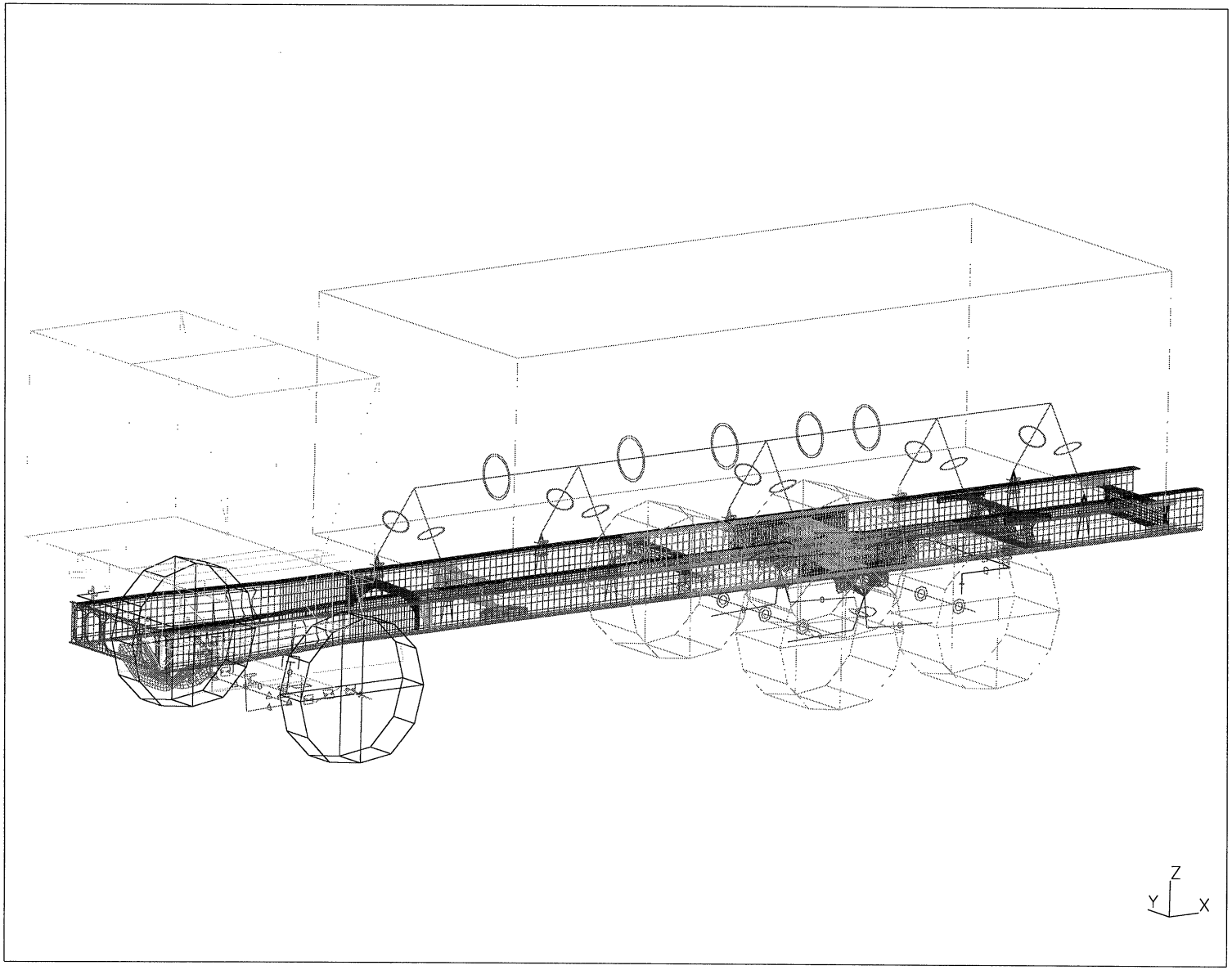
Final Model (1)



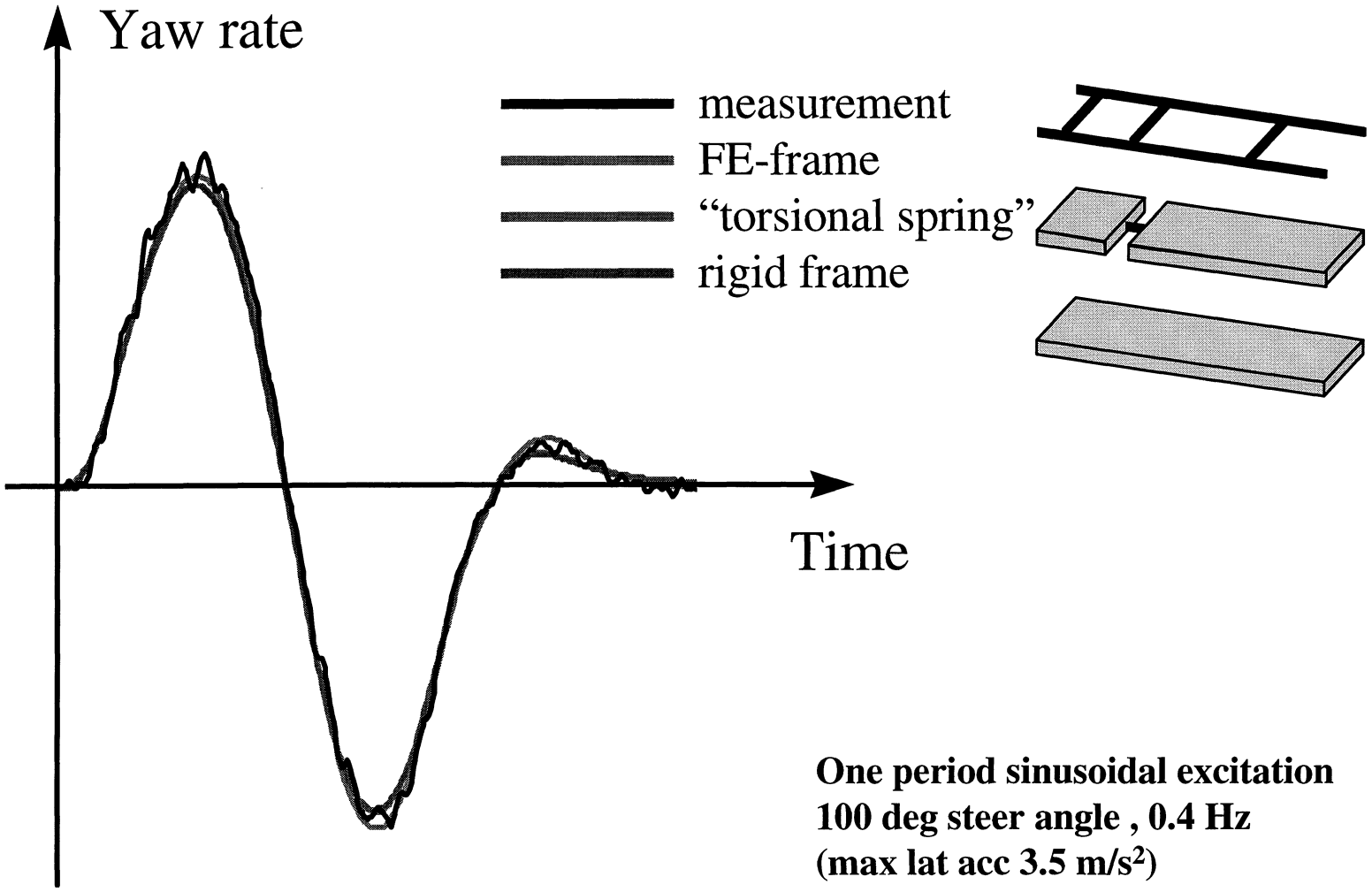
(104 "hard-points" controls 410 markers)

Final Model (2)




Z
Y
X

Results: Handling (1)



One period sinusoidal excitation
100 deg steer angle , 0.4 Hz
(max lat acc 3.5 m/s^2)

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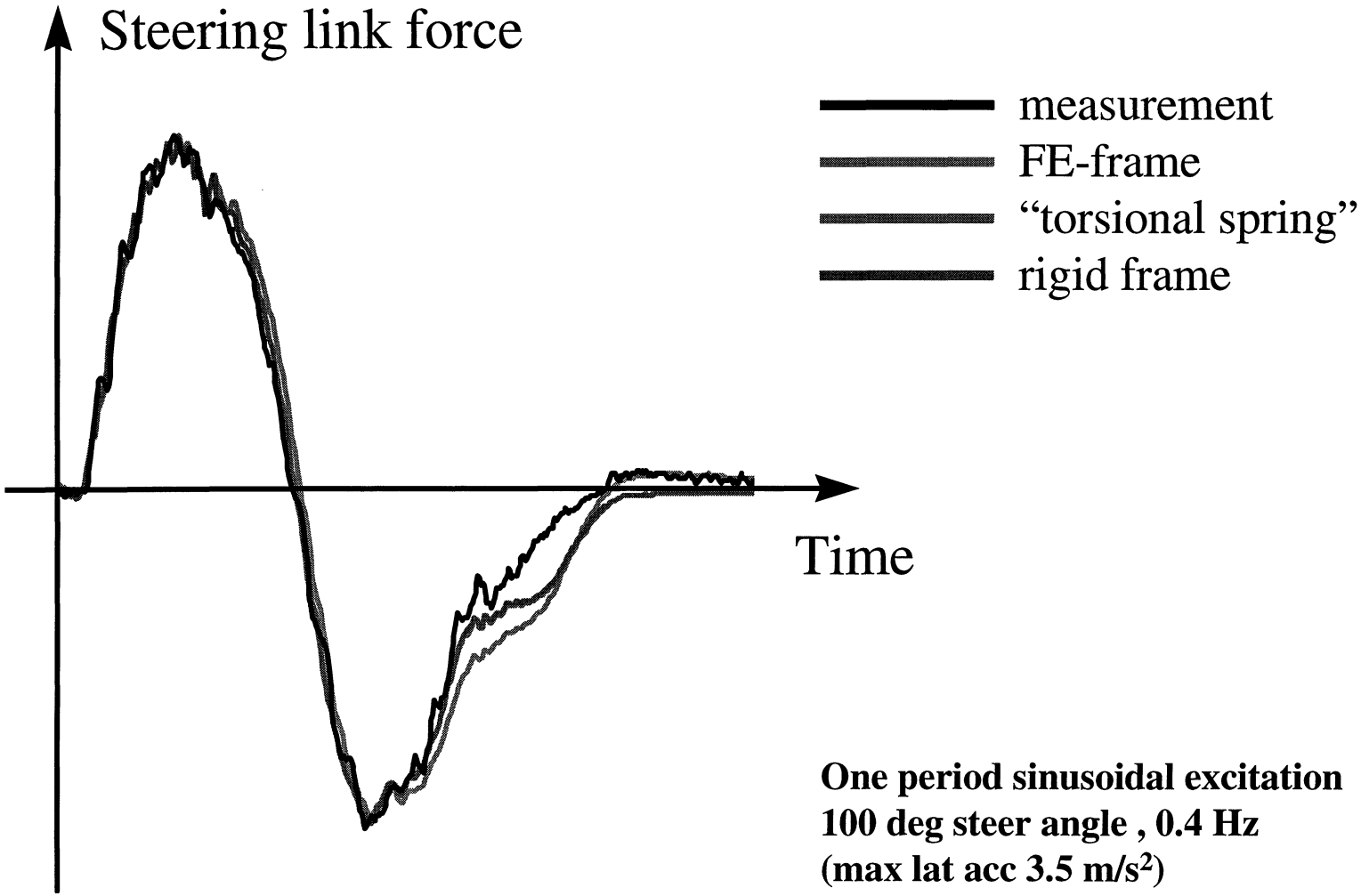
Results: Handling (2)



One period sinusoidal excitation
100 deg steer angle , 0.4 Hz
(max lat acc 3.5 m/s^2)

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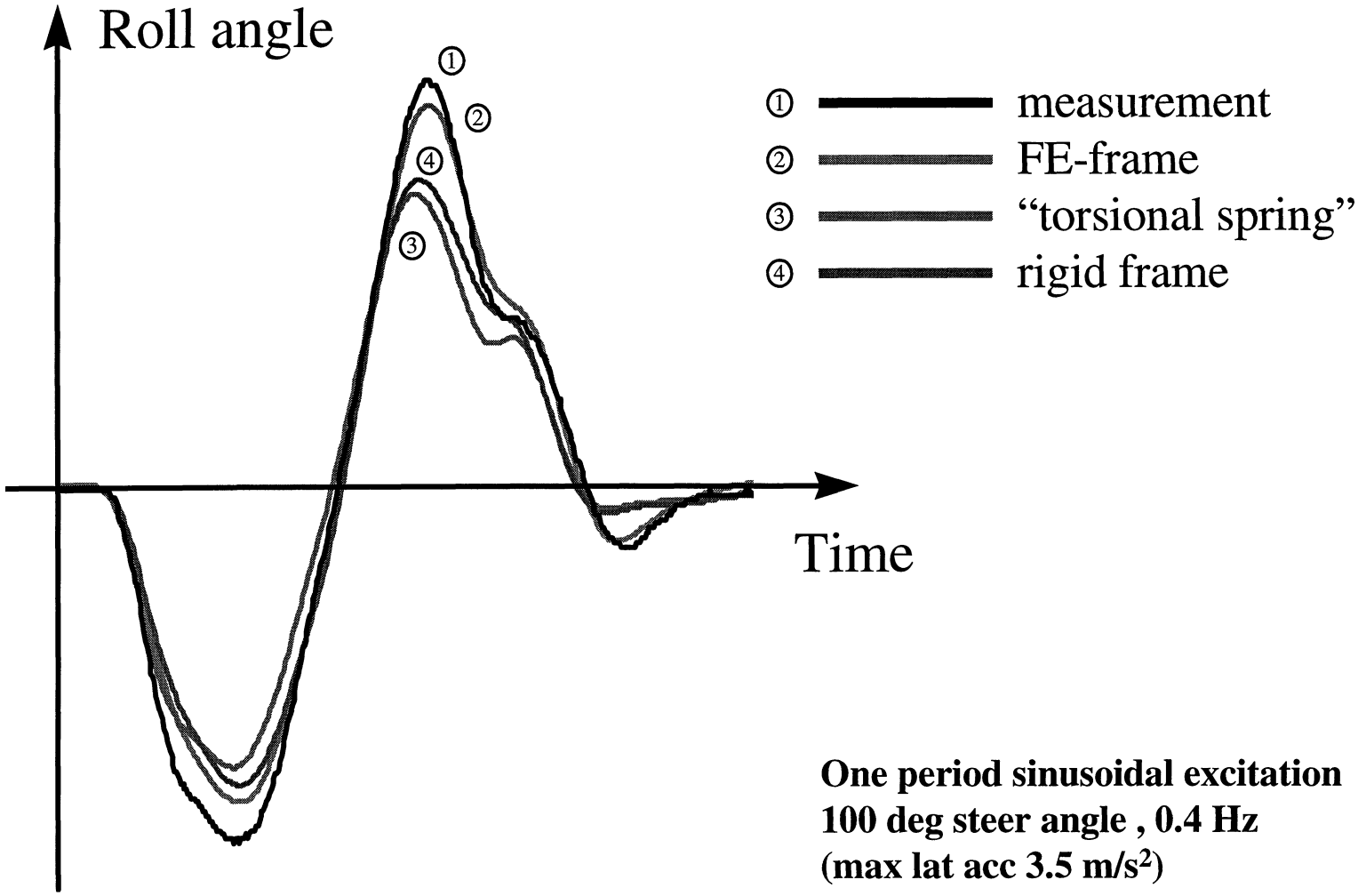
Results: Handling (3)



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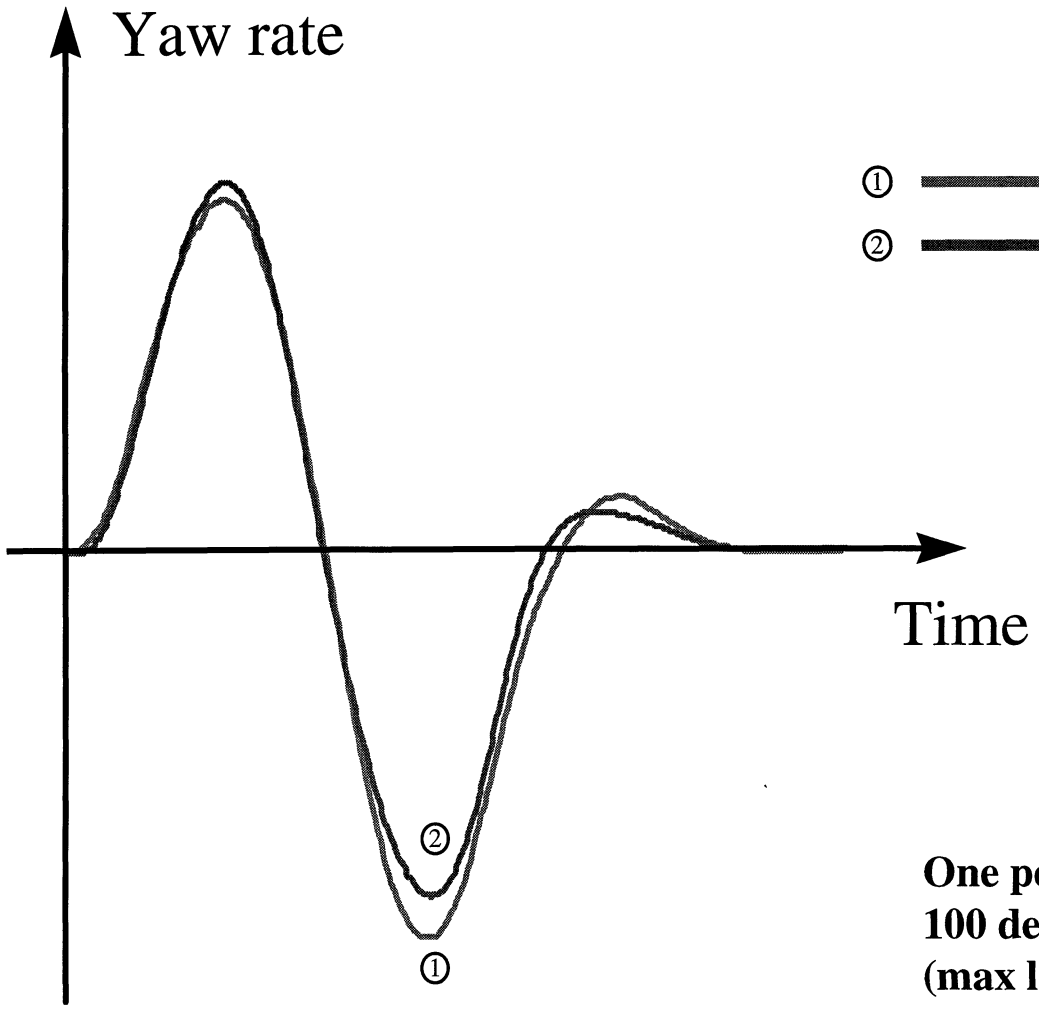
Model complexity



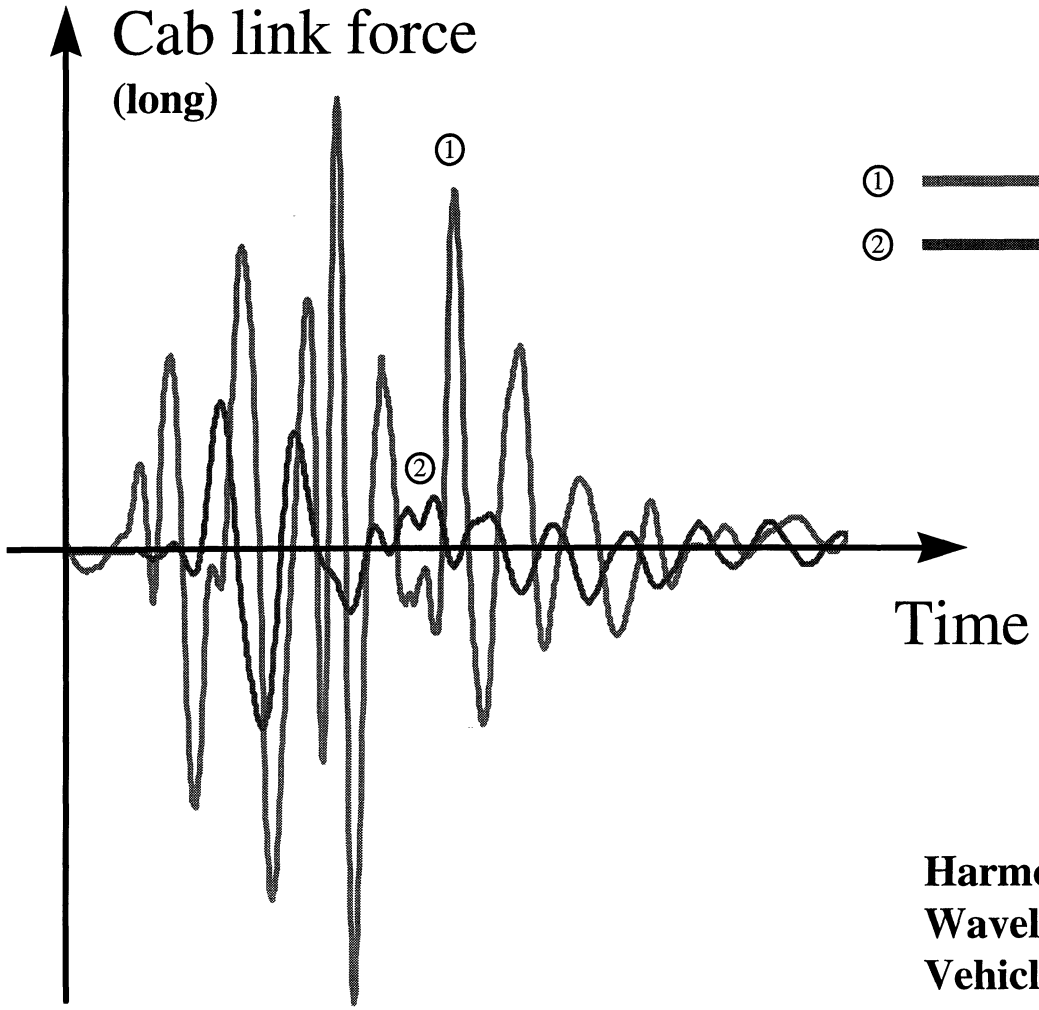
① FE-frame

② SIMULINK model

3-dof (lat, yaw, roll)

One period sinusoidal excitation
100 deg steer angle , 0.4 Hz
(max lat acc 3.5 m/s^2)

Results: Bump (1)



① ——— FE-frame
② ——— rigid frame

Harmonic bump left wheel
Wavelength 0.9 m , height 0.05 m
Vehicle speed 20 m/s

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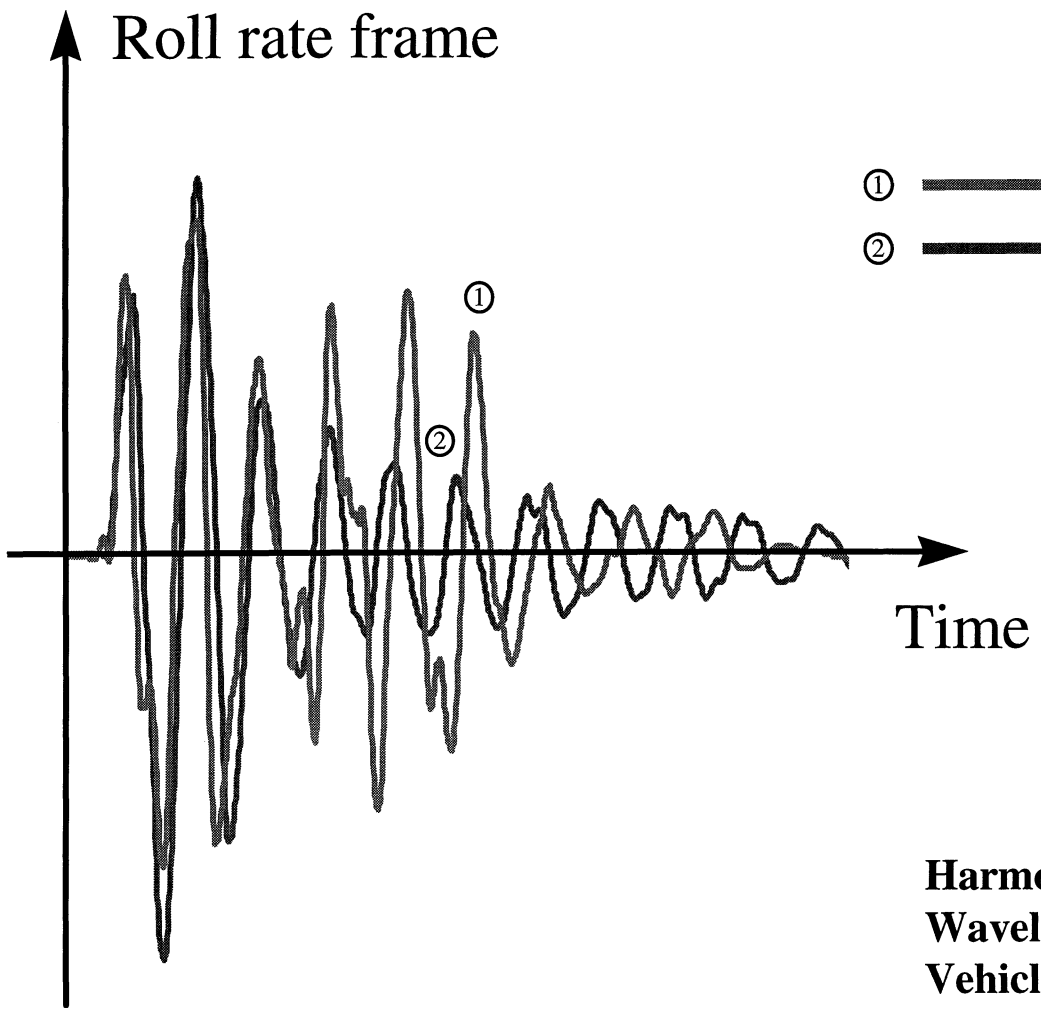
Results: Bump (2)



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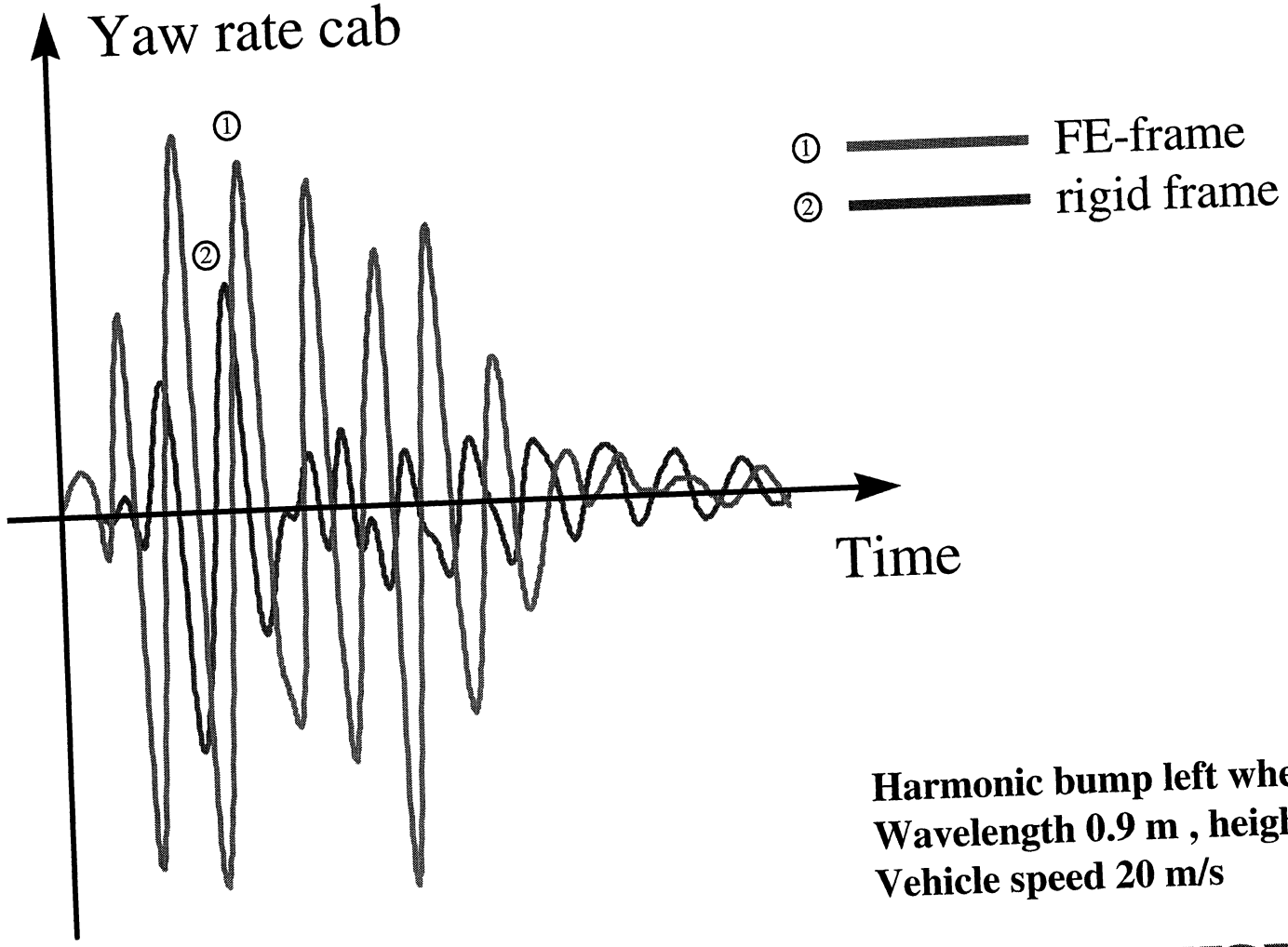
Results: Bump (3)



Harmonic bump left wheel
Wavelength 0.9 m , height 0.05 m
Vehicle speed 20 m/s

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Model size

	# dof	# equ	cpu (s)	cpu (normalized)
"Bicycle" model	3	54	4	10
"Torsional spring"	63	1758	263	700
FE-frame	450	3857	2743	7000
SIMULINK	3	6	0.4	1

Original NASTRAN model, 90000 dof, reduced to 50 exterior grid points (300 dof).

Harmonic steer input
4 s simulation
Sun Sparc 20

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Conclusion

- Substructuring and parametrisation is a necessity in complete vehicle simulations of heavy trucks.
- Finite Element models together with MBS provides an unmatched flexibility in analysis compared to other methods, (same model useful for both handling and vibration environment studies).
- Can not yet compete with dedicated models with respect to efficiency, (especially linear studies in frequency domain).

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Simplicity

…perfection is finally attained not when there is no longer anything to add, but when there is no longer anything to take away…

Antoine De Saint Exupéry, Wind, Sand and Stars. 1968