

MODELING, SIMULATION,  
PROTOTYPING & VALIDATION

# INTEGRATION OF VEHICLE DYNAMICS WITH FINITE ELEMENT COMPOSITE SIMULATION

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# Introduction

## MODELING, SIMULATION, PROTOTYPING & VALIDATION

- Engineering simulations are becoming increasingly complex and often Multiphysics [1,2,4,10]
- High-fidelity modeling of these systems is increasingly challenging
- Often tools specialize in a specific niche
- Single simulation tools often can't handle the full demands of a system



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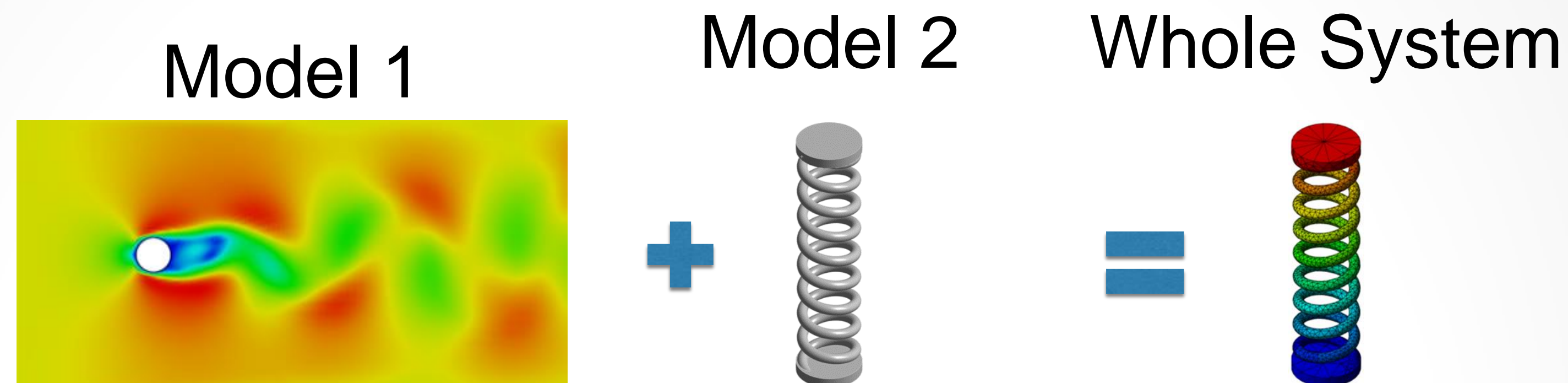




# Motivation

## MODELING, SIMULATION, PROTOTYPING & VALIDATION

- Rather than relying on a single tool, different tools can model various sub-components of an engineering system.
- Allows specialized tools to collectively describe the entire system.
- Called Model Integration or Ensemble Models <sup>[1,2,10]</sup>



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# Case study

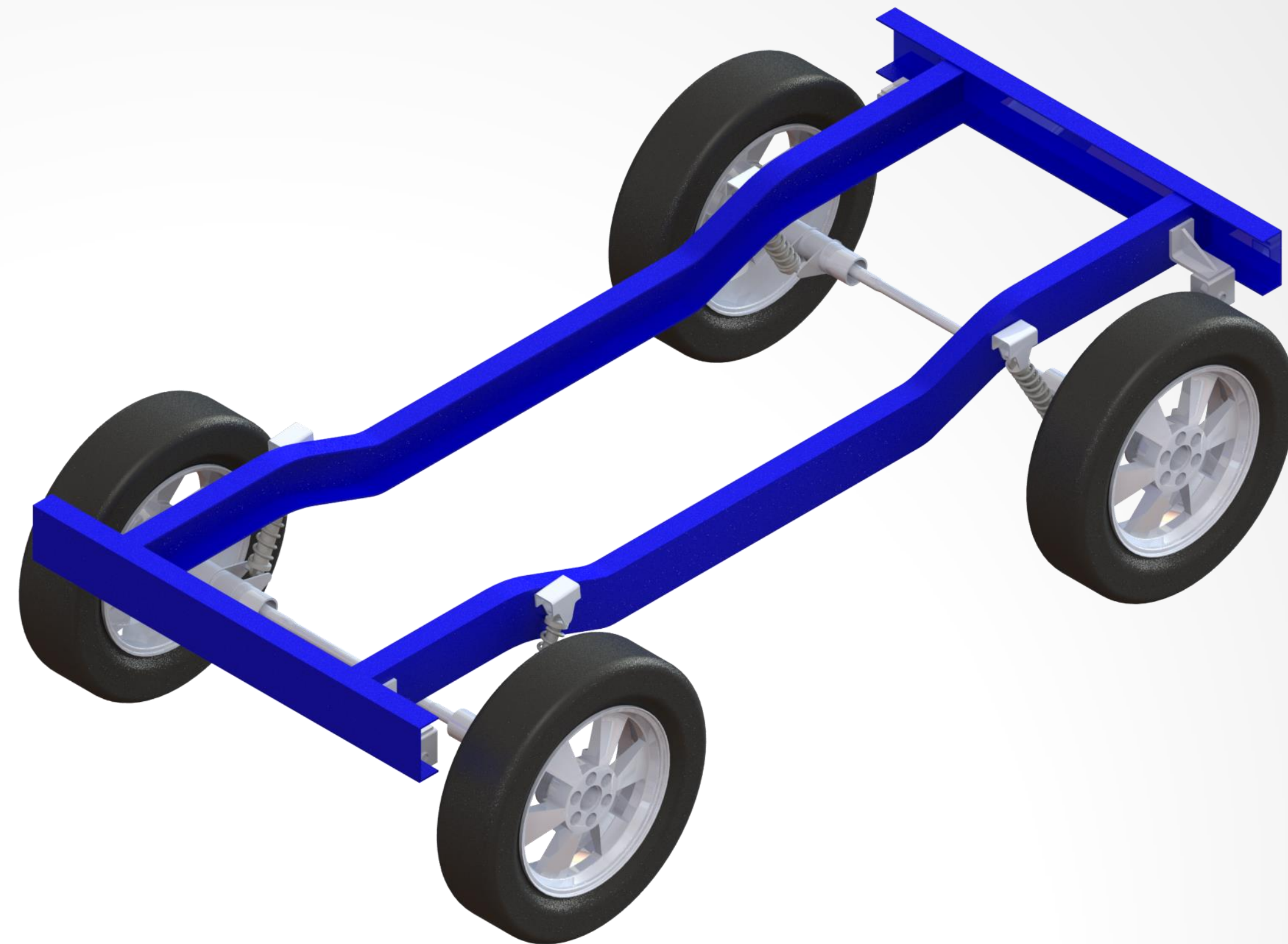
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Consider a vehicle with a composite frame driving over terrain

Multiphysics system:

- A composite frame
- Vehicle Dynamics
- Ground-Wheel interaction

KPIs are maximum stress,  
location of maximum stress,  
and flange deformation



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# Available Tools

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## Project Chrono



Can model vehicle dynamics  
[projectchrono.org](http://projectchrono.org)

## Abaqus



A powerful FEA suite  
[www.simulia.com](http://www.simulia.com)

### Limitations:

No composite modeling

### Limitations:

No vehicle dynamics

Neither tool can cover all aspects of the system

Working together they cover all of the systems demands

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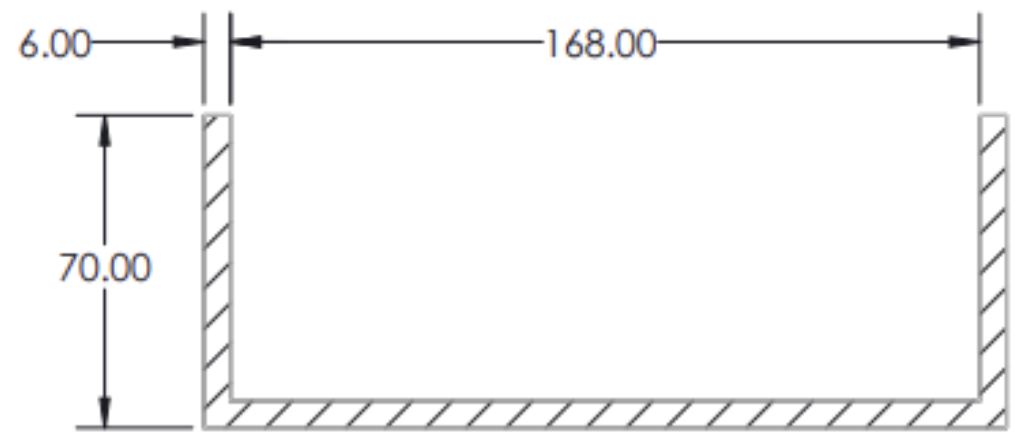
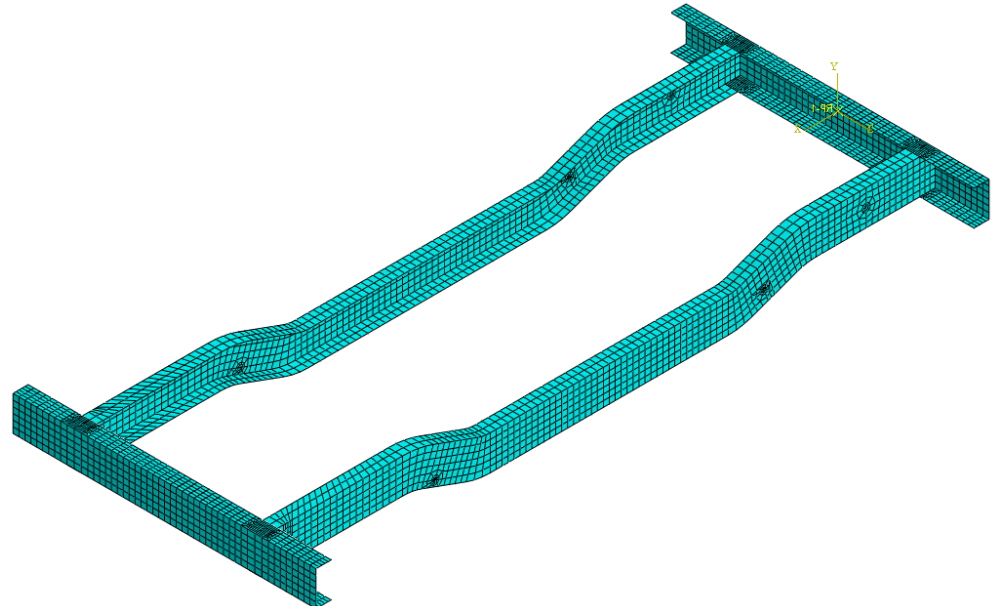
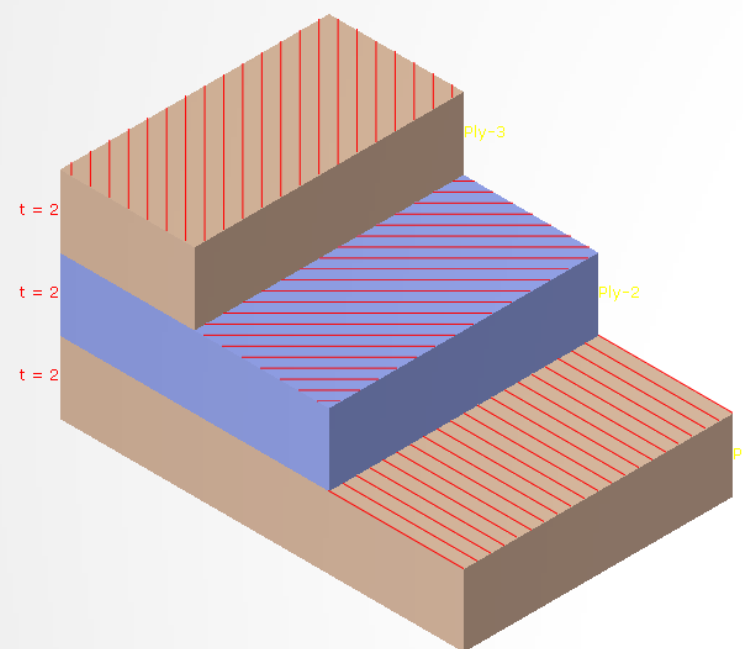




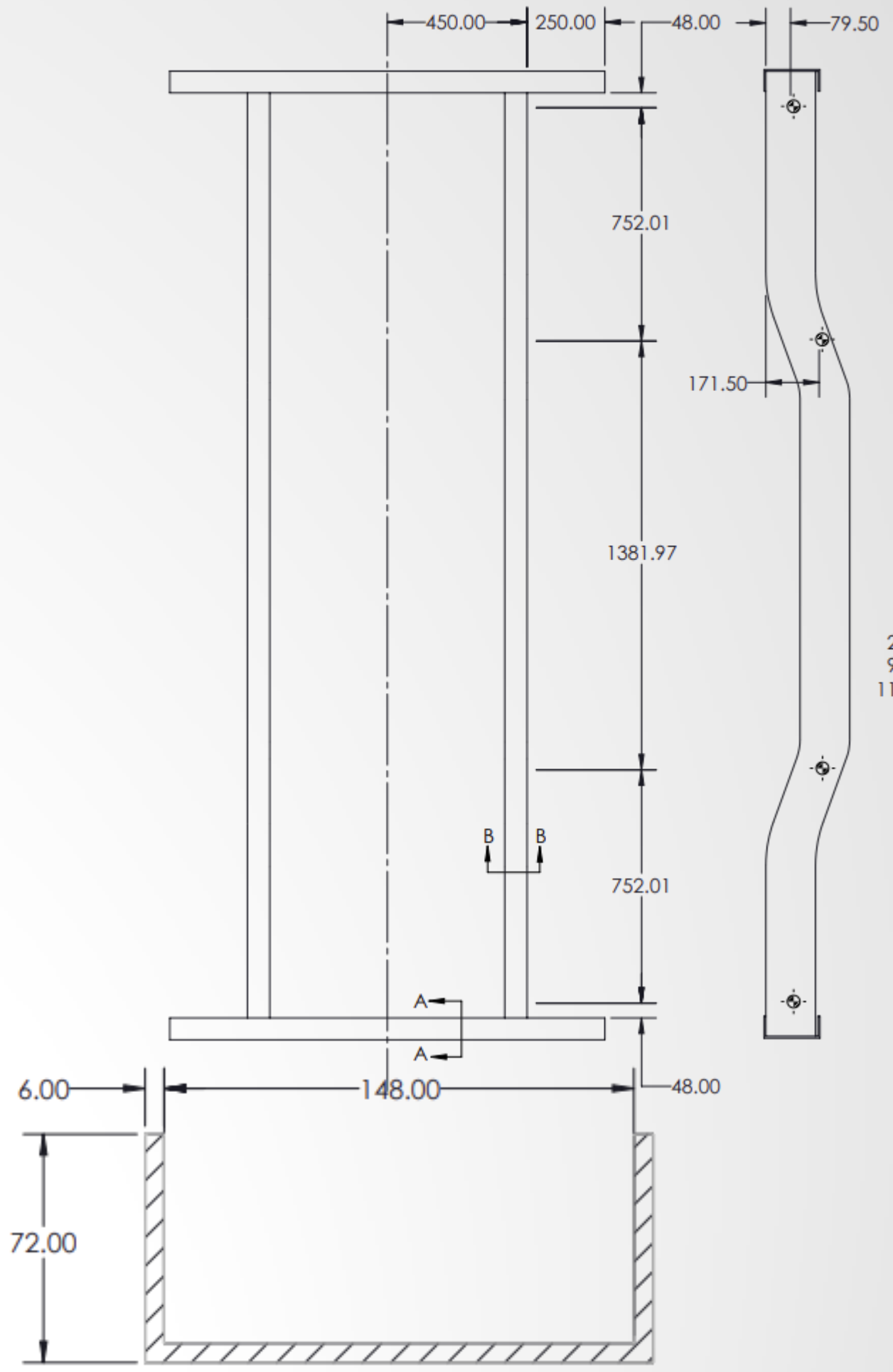
# Abaqus

## MODELING, SIMULATION, PROTOTYPING & VALIDATION

- Models the composite frame
- Layers arrangement [0,45°, -45°]
- Frame is constructed by 4 C beams
- **Needs: Input force**
- **Outputs: Frame Deformation & Stress**



SECTION A-A  
SCALE 1 : 2



SECTION B-B  
SCALE 1 : 2

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# Project Chrono

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- Models the vehicle dynamics and wheel-ground interactions
- The terrain is split into **rigid** and **soft** terrain
- Vehicle Drives on and off this terrain in a meandering path
- **Needs: Frame Deformation**
- **Outputs: Path, Force**



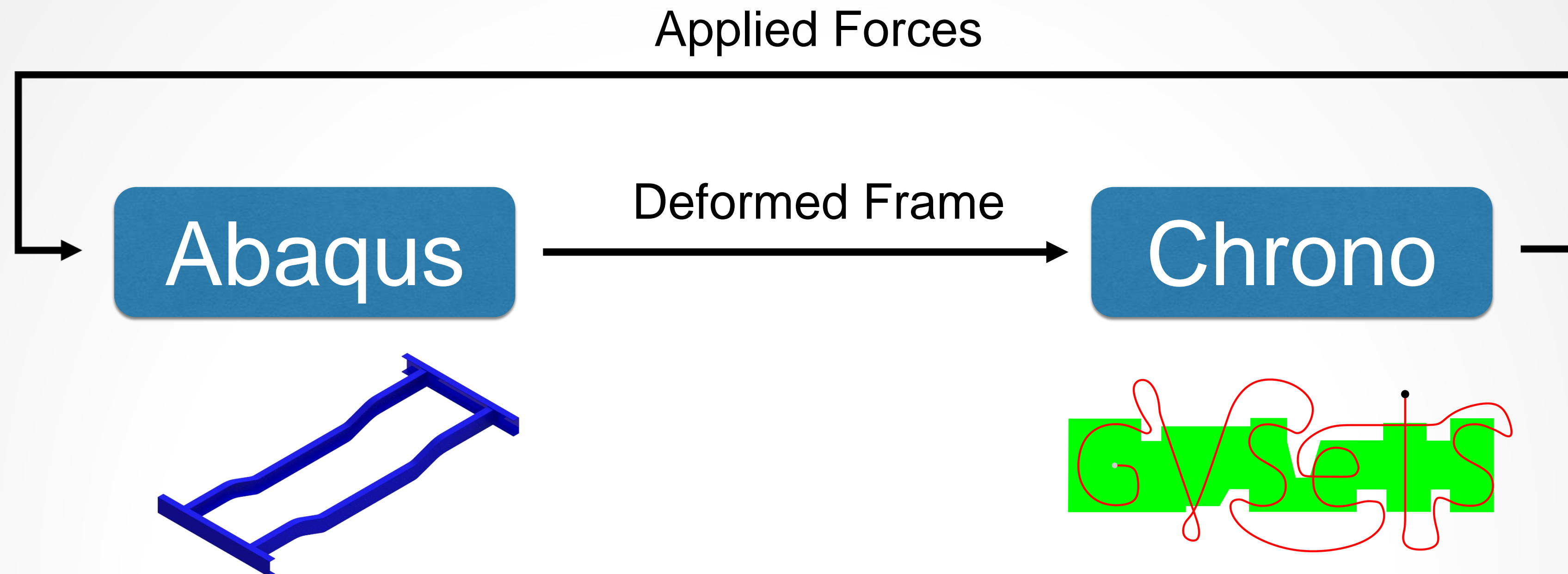
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# Overview

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- Each tool needs information from the other
- The necessary data is exchanged throughout the simulation



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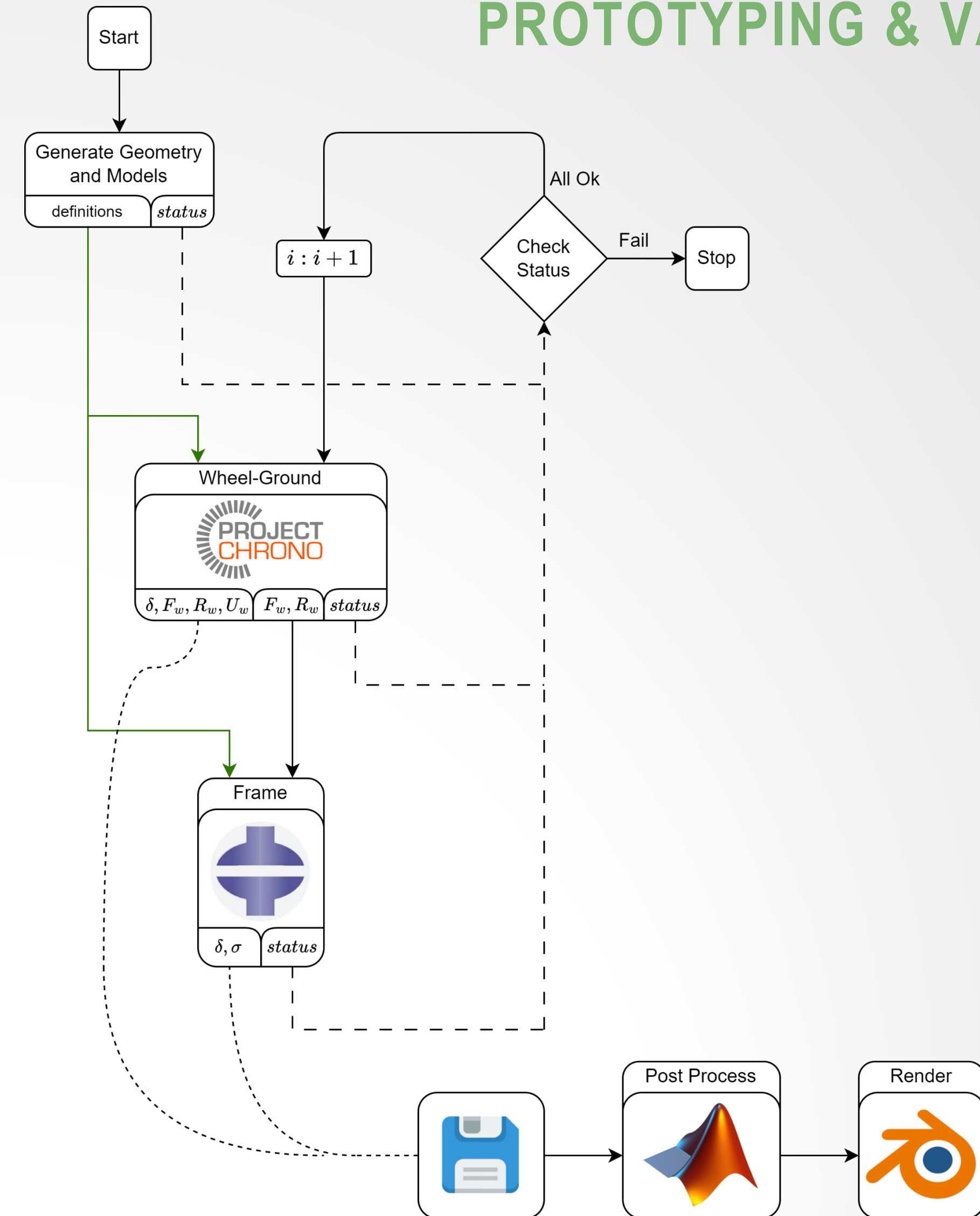




# Flow Chart

## MODELING, SIMULATION, PROTOTYPING & VALIDATION

- A custom python tool was created to handle data extraction
- Status codes are used to determine the state of each tool
- All data is saved for later post processing

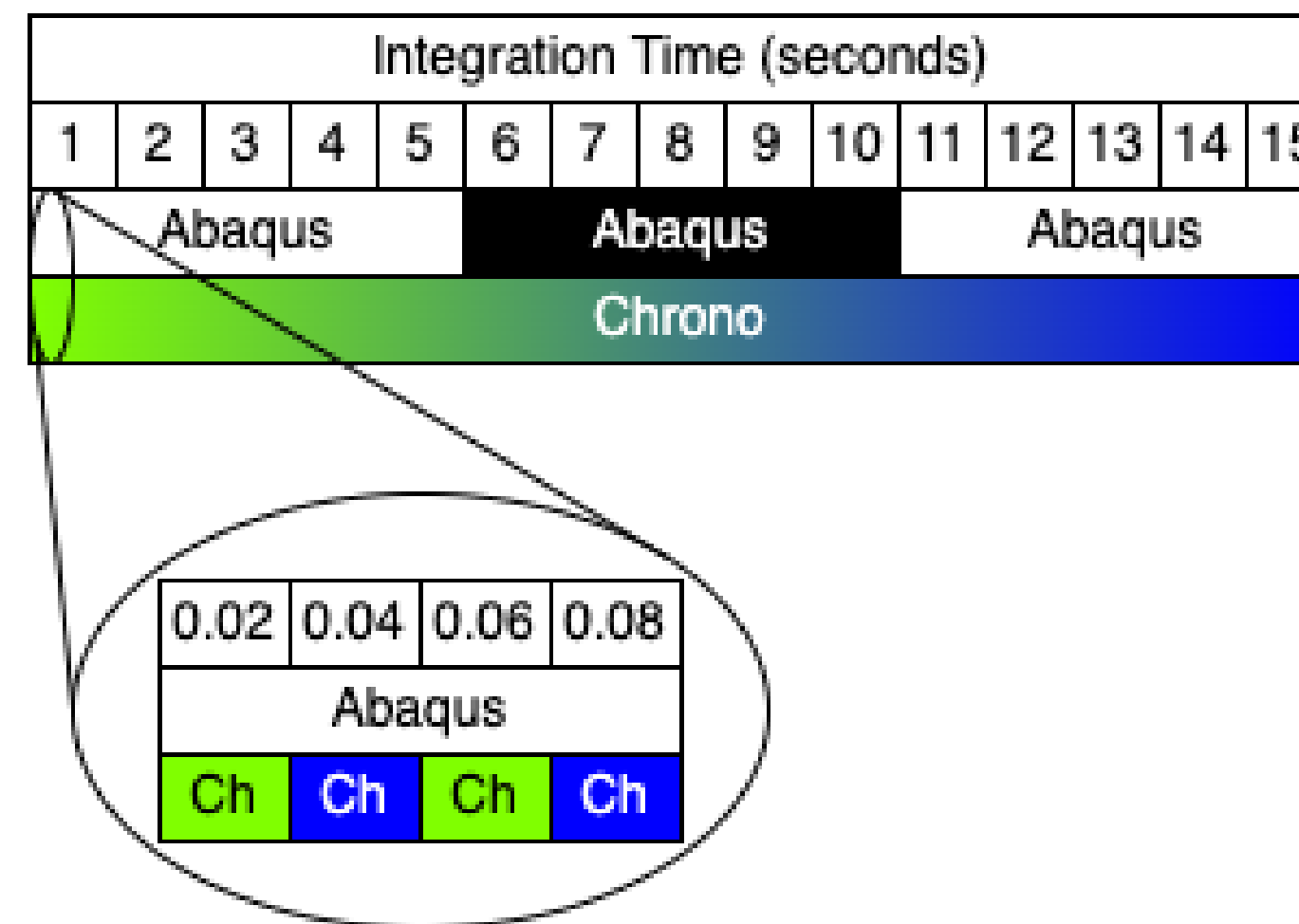


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# Integration Time

- Abaqus and Chrono should exchange data at each time step.
- High computational cost of Abaqus makes this approach impractical.
- As such, Abaqus is run intermittently, with Chrono using the most recent deformed frame from Abaqus.



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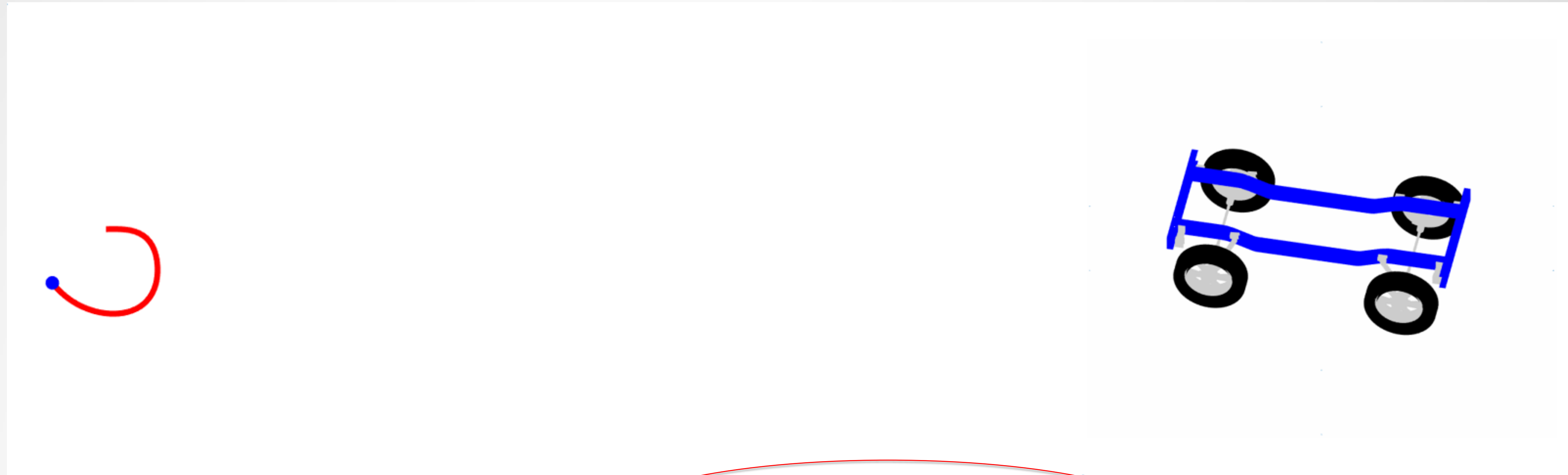


# Result Layout

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↓ *Path of the vehicle* ↓

↓ ↓ *Vehicle  
Render*  
(Does flash)



- Vehicle Location
- Deformed Path
- Vehicle Path

Fast-forwarded through rigid regions  
Target Speed of 10mph

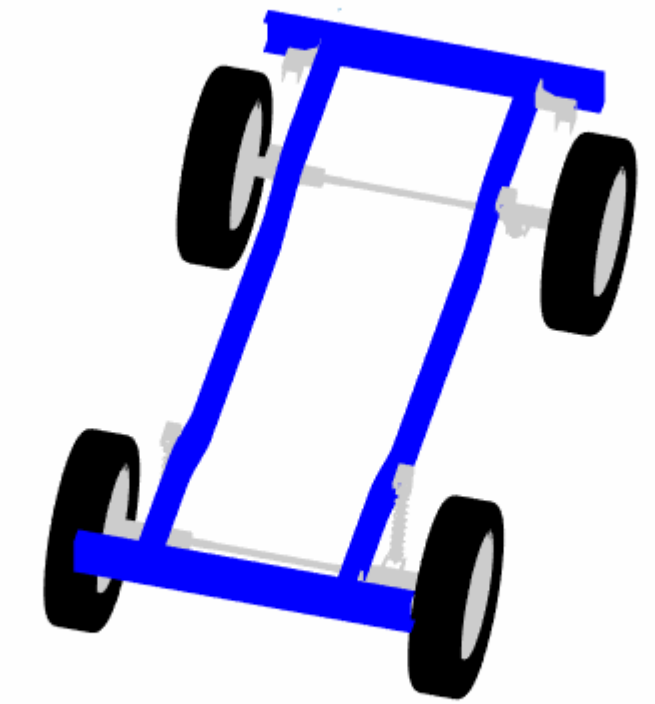
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# Flow Chart

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- Vehicle Location
- Deformed Path
- Vehicle Path

Fast-forwarded through rigid regions  
Target Speed of 10mph

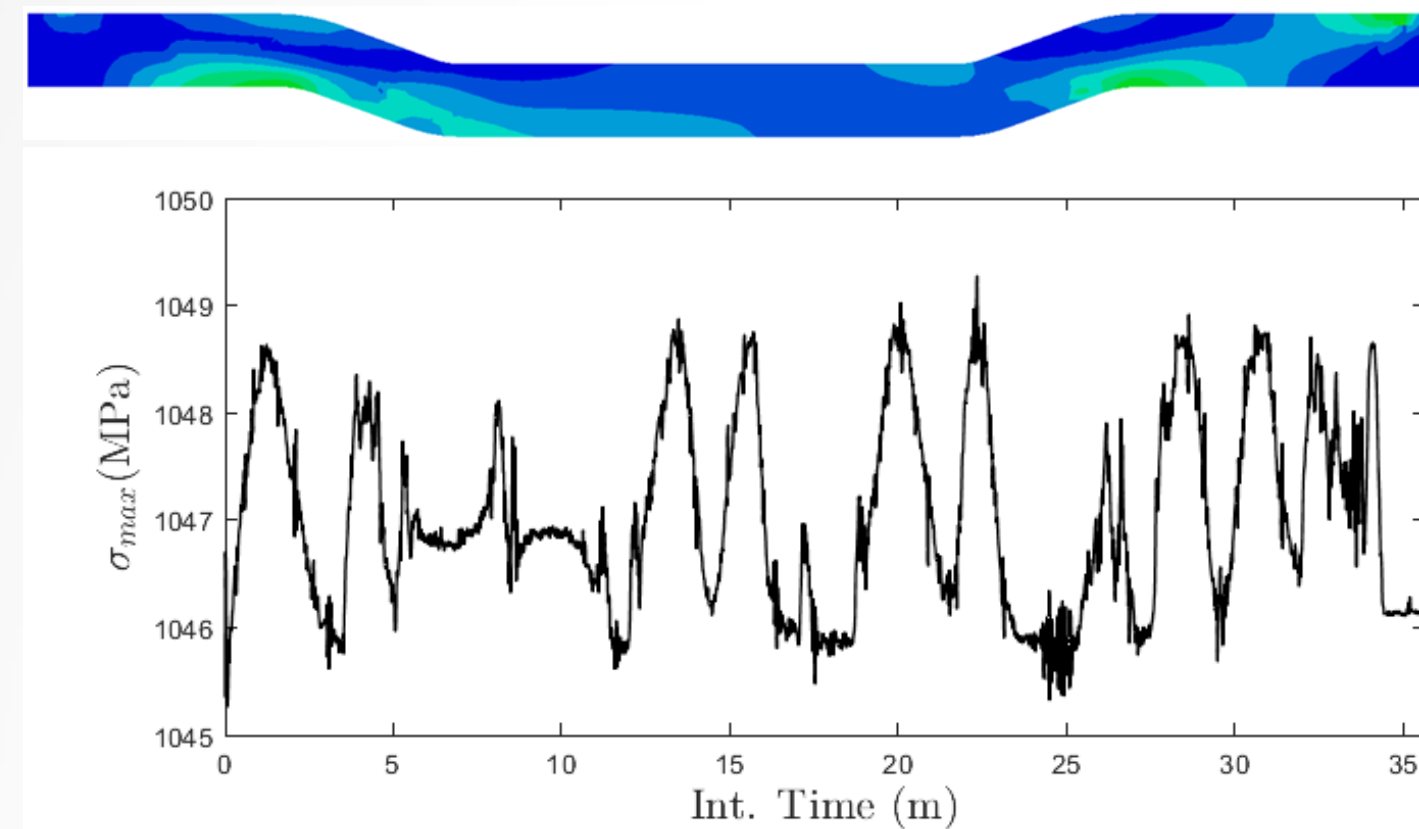
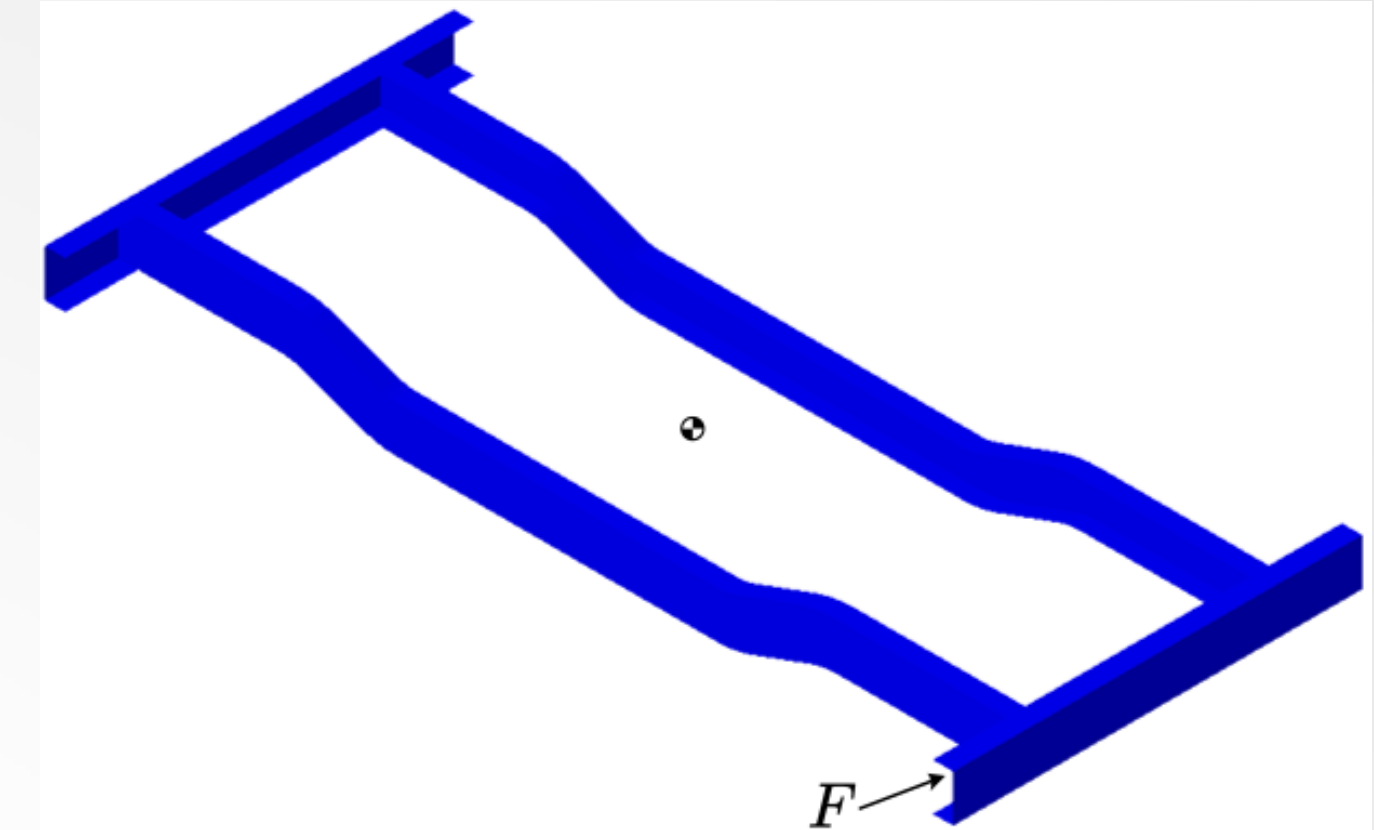
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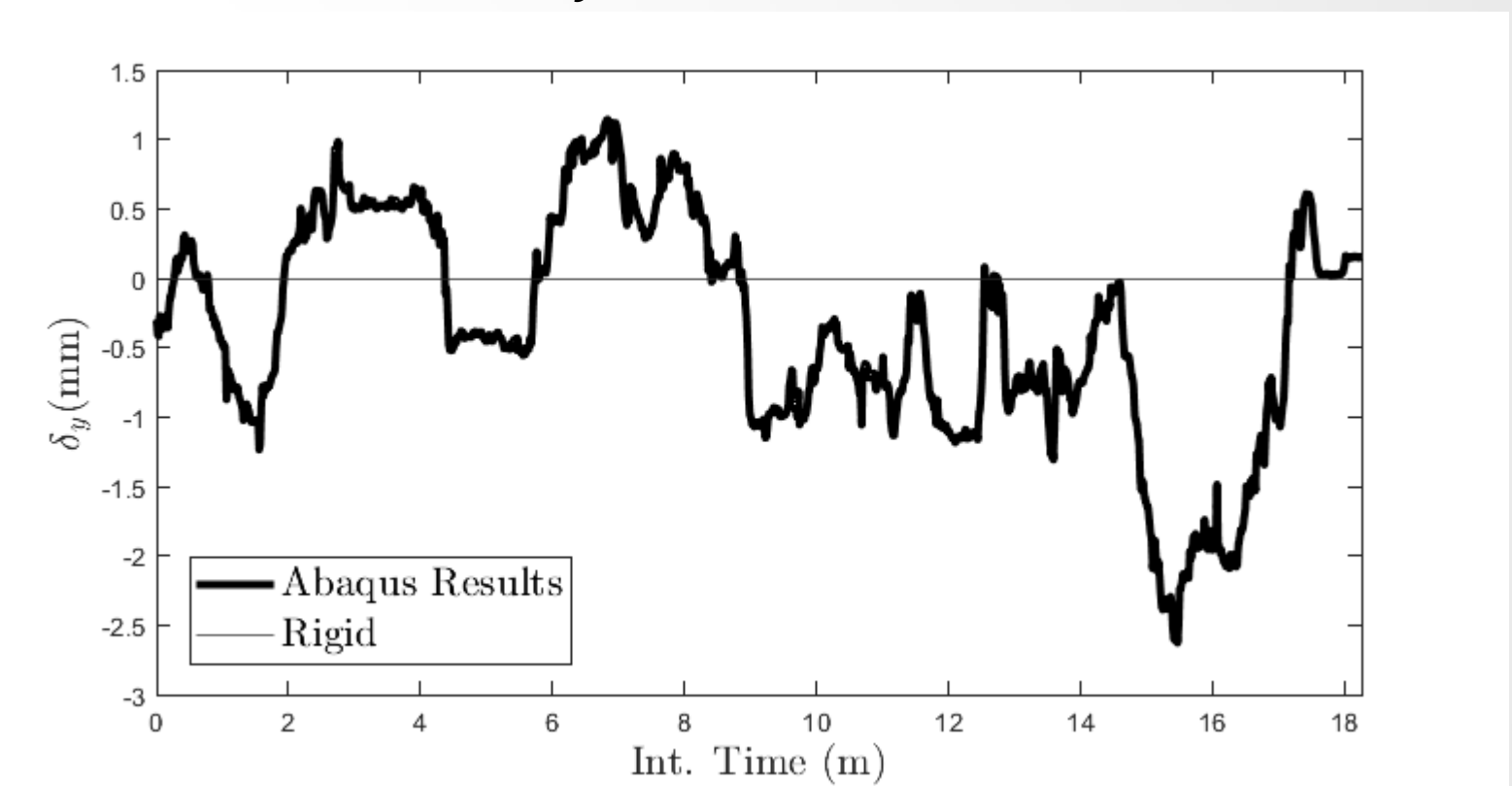
# Frame Stress

## MODELING, SIMULATION, PROTOTYPING & VALIDATION

- Abaqus calculates the stress within the frame
- Slows down at turns, then speeds up
- Inertia causes the applied load to change



$\delta_y$  measured at  $F$



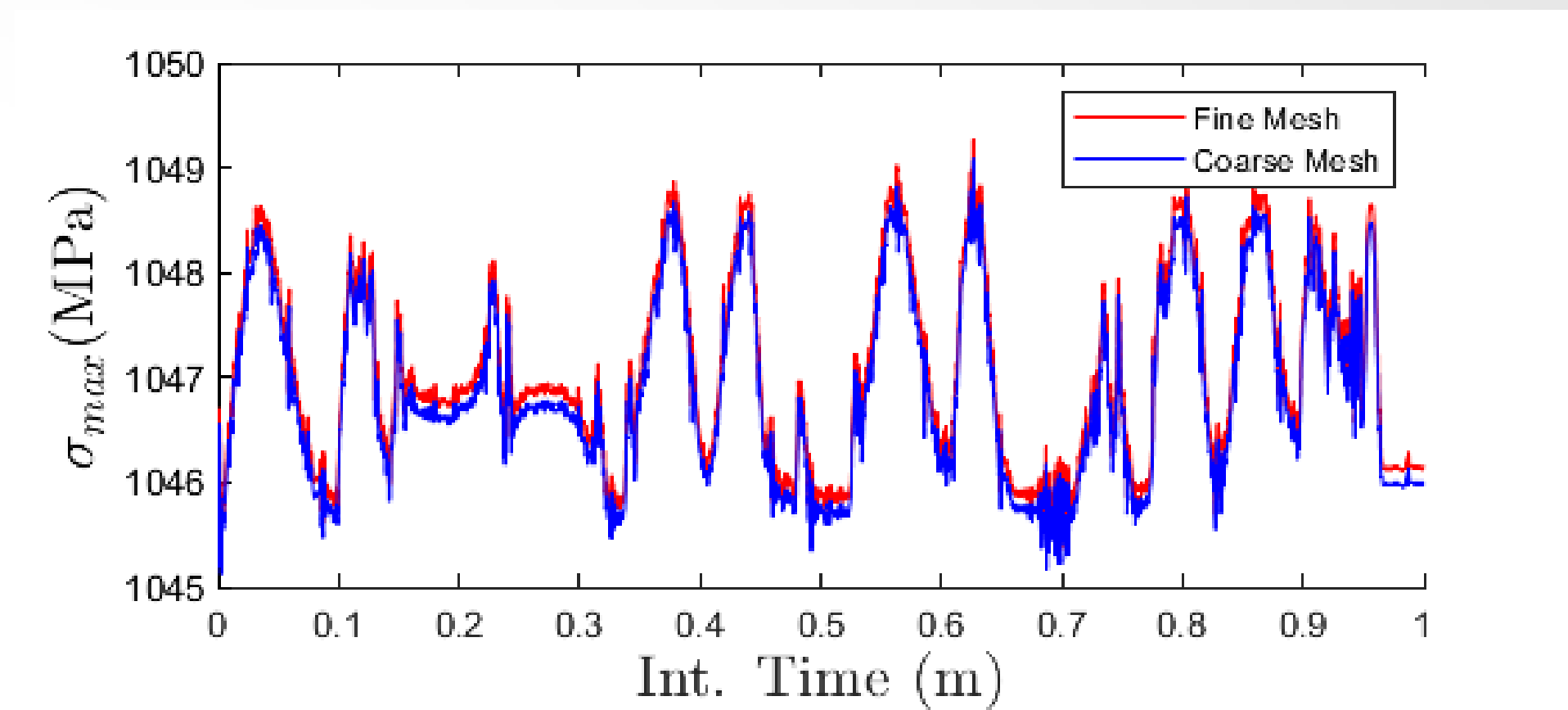
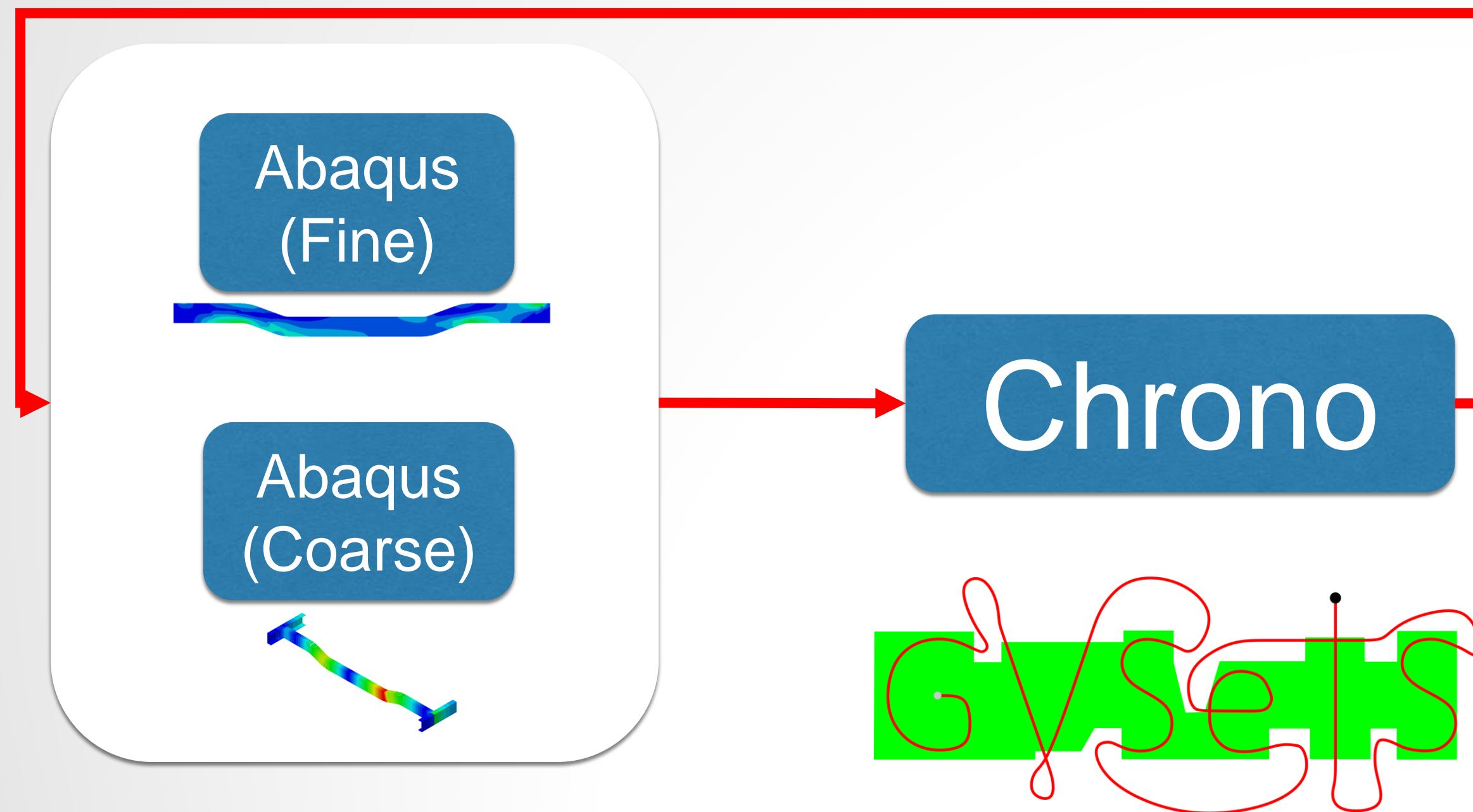
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# Component Substitution

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- Different frame models can easily be interchanged with one another
- For example, the fine mesh used for the frame can be replaced with a coarse one



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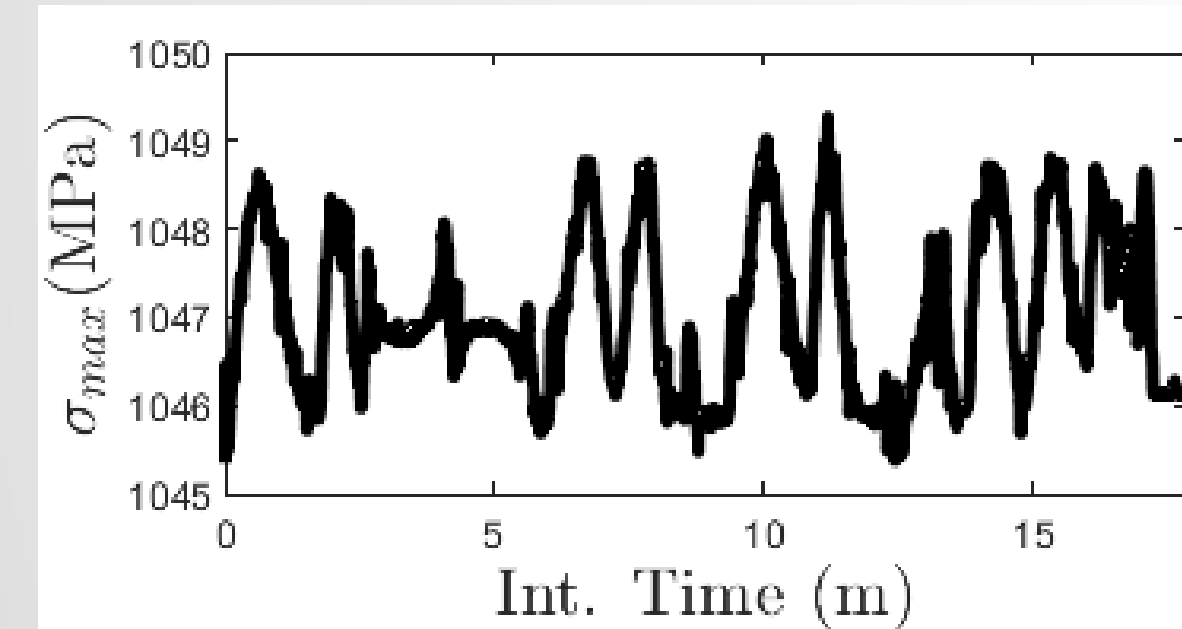




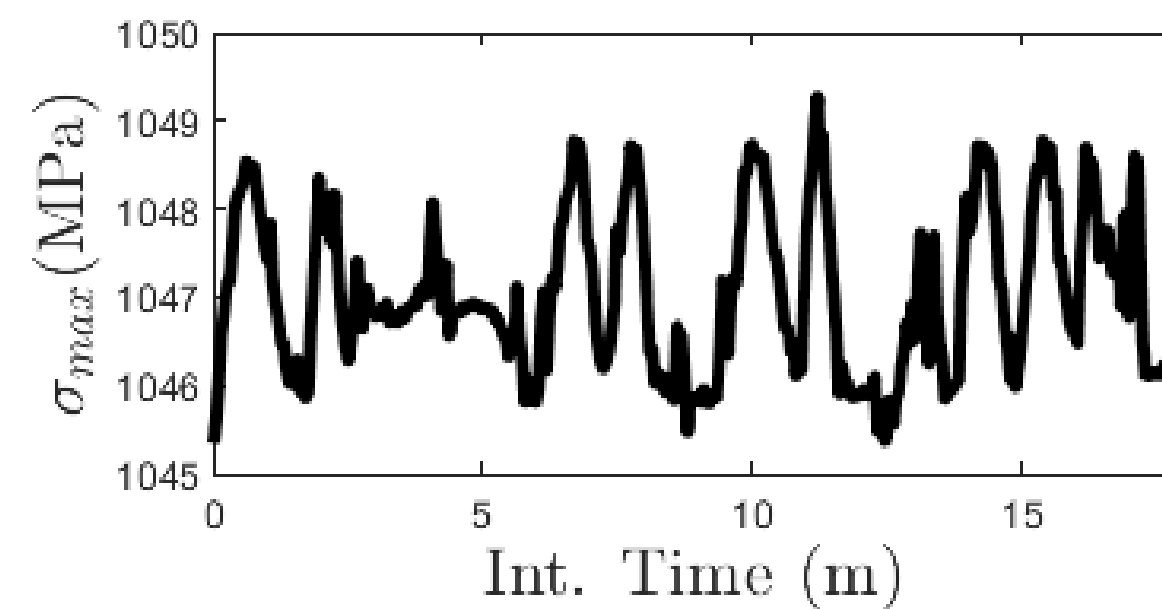
# Integration Time

- Data is exchanged at periodic intervals.
- Decreasing the exchange time from Abaqus has a negligible effect.
- Increasing Chrono's exchange time causes the simulation to diverge.

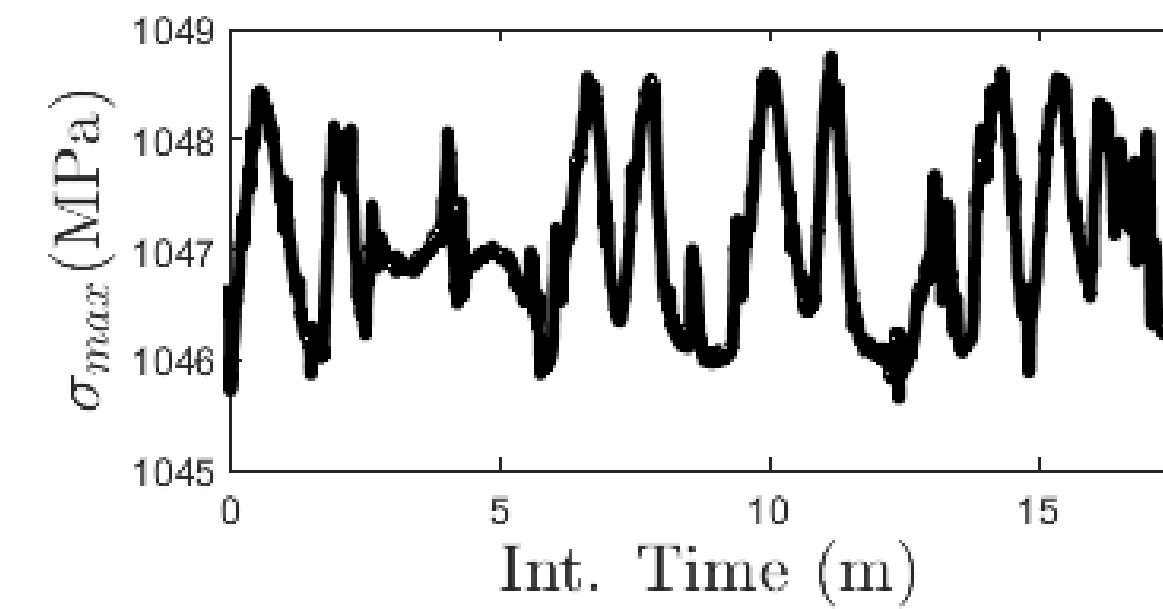
	Case 1	Case 2	Case 3	Case 4	Case 5
<b>Ch.(s)</b>	0.002	0.002	0.002	0.004	0.010
<b>Aba.(s)</b>	5	10	30	2.5	5
<b><math>\sigma</math>(MPa)</b>	1049.27	1049.27	1047.27	1048.75	1301.45



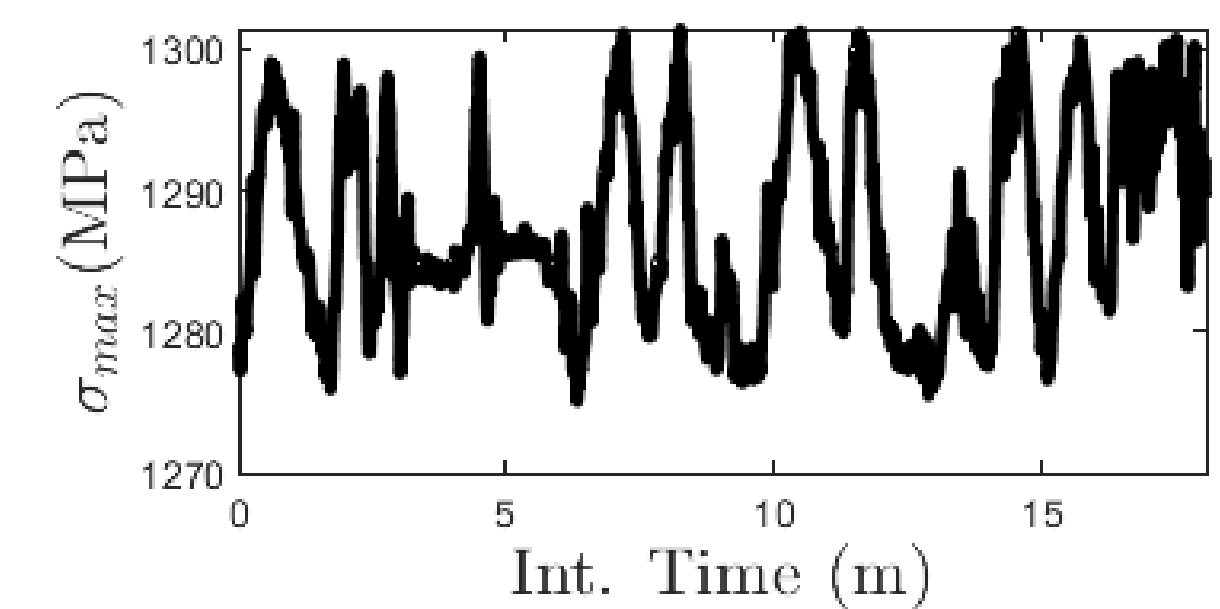
Ch.:0.002, Aba.: 10s



Ch.:0.02, Aba.: 30



Ch.:0.004, Aba.: 2.5s



Ch.:0.01, Aba.: 5

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# Conclusions

## MODELING, SIMULATION, PROTOTYPING & VALIDATION

- Multiphysics engineering systems often lack a single tool capable of modeling each component.
- Case study: a composite vehicle traversing a path
  - Abaqus analyzes the vehicle's composite frame.
  - Chrono models vehicle-terrain dynamics.
- Integrating these tools produces a high-fidelity description that was previously unattainable.

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