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# Application of Flexible Multibody Systems in Modelica for the Simulation of Construction Machinery

15th MODPROD Workshop on Model-Based Cyber-physical Product Development / 04.02.2021

# Agenda

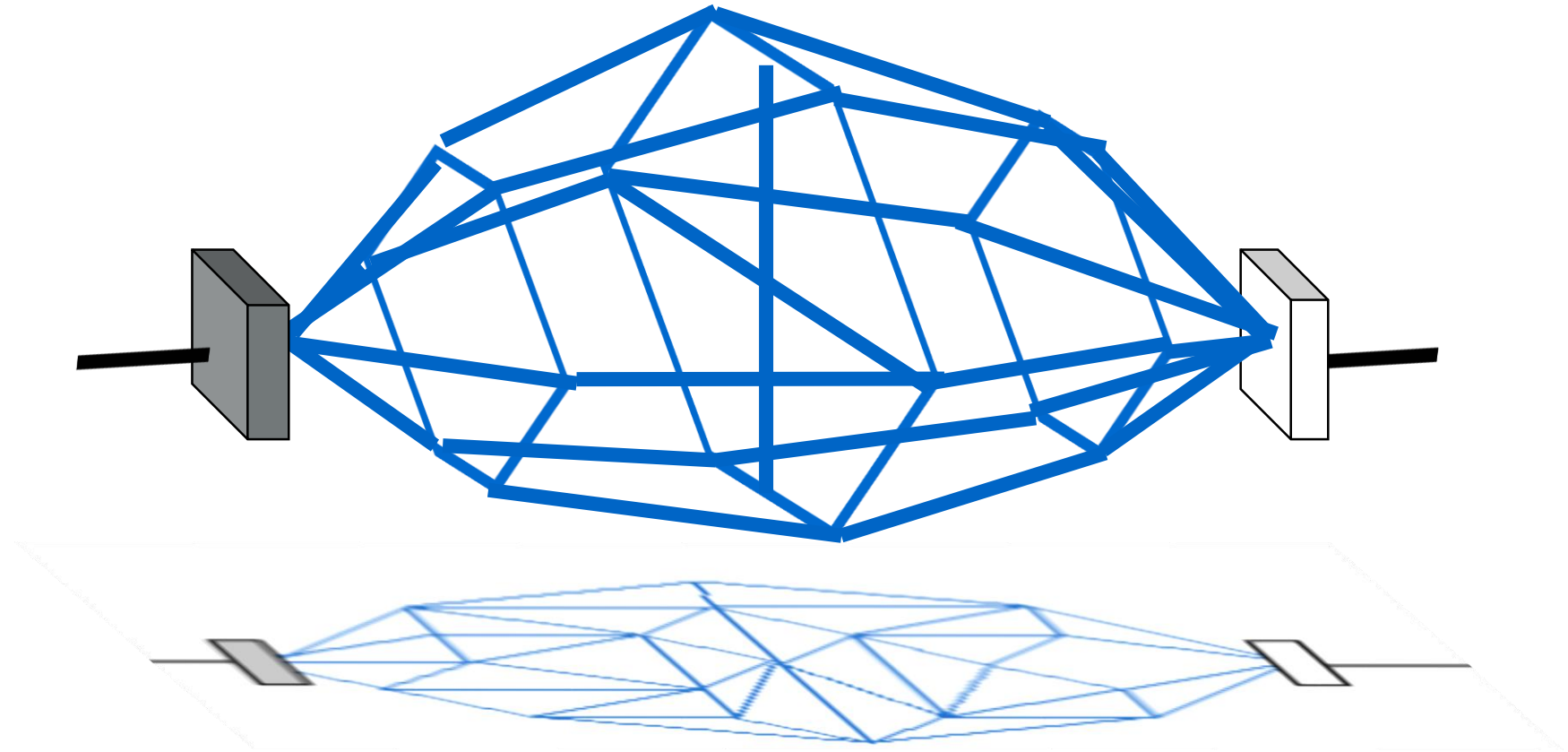
*Introduction*

*Workflow*

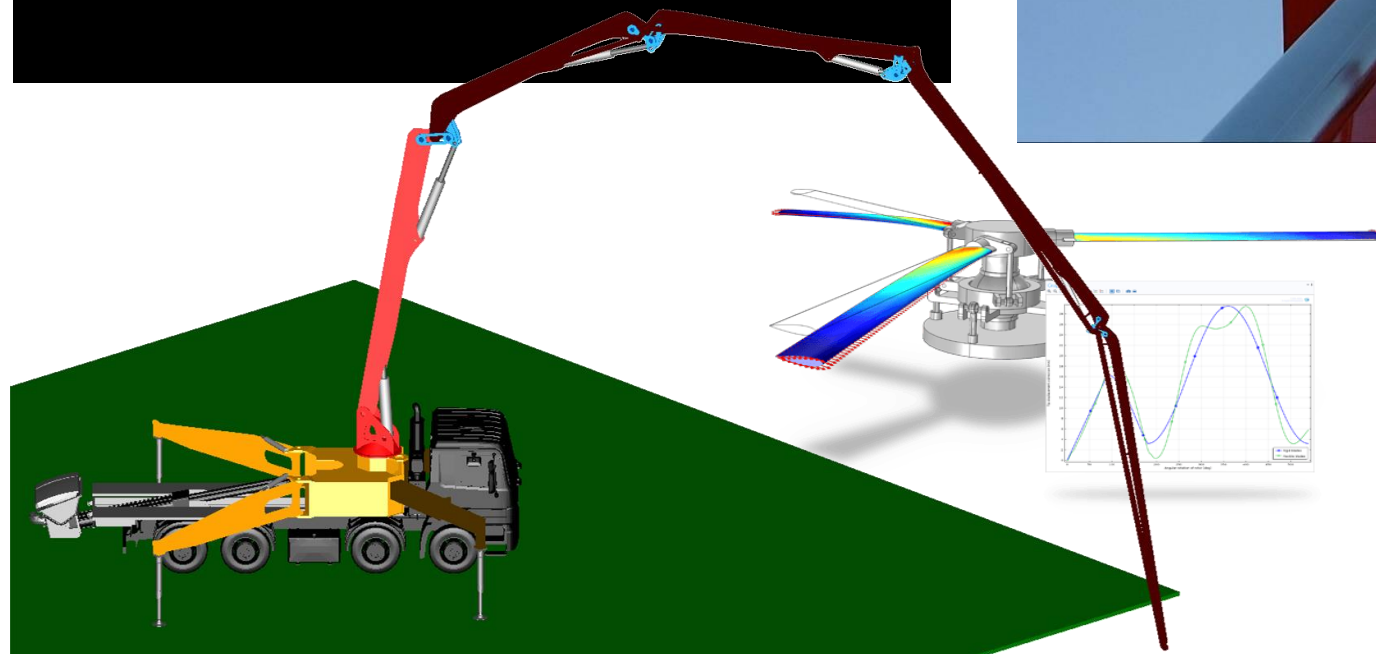
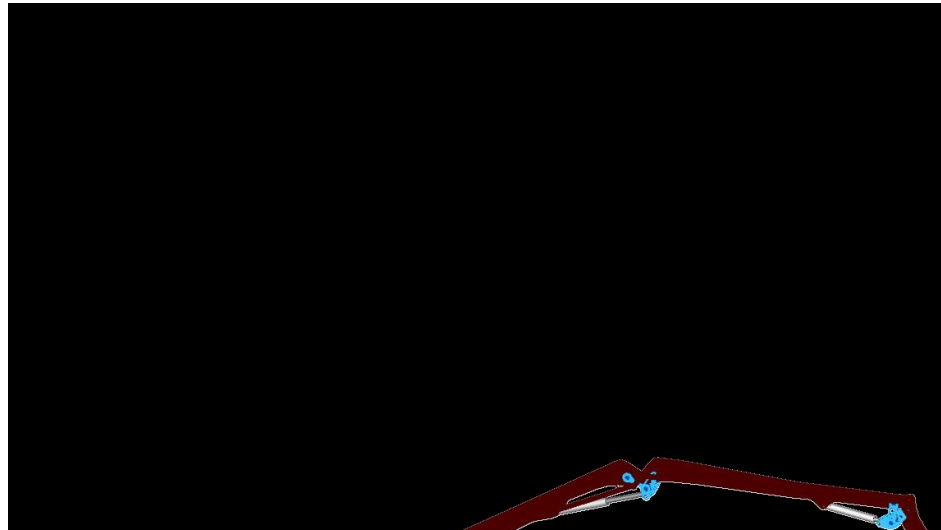
*Library*

*Application*

*Outlook*



# Introduction

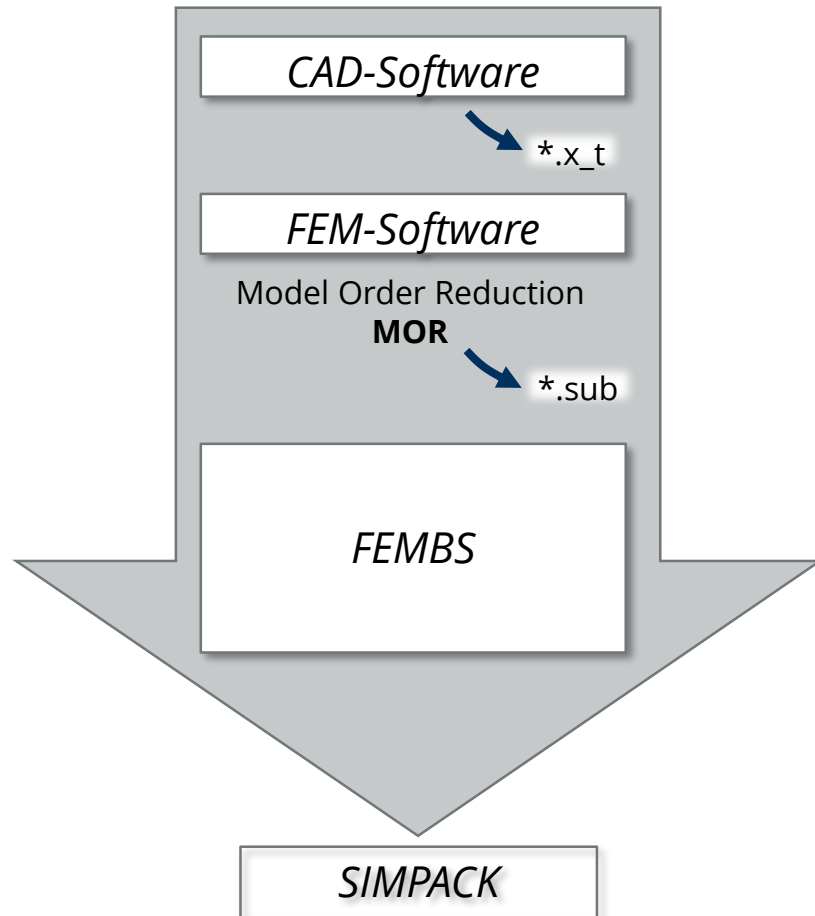


## Effects

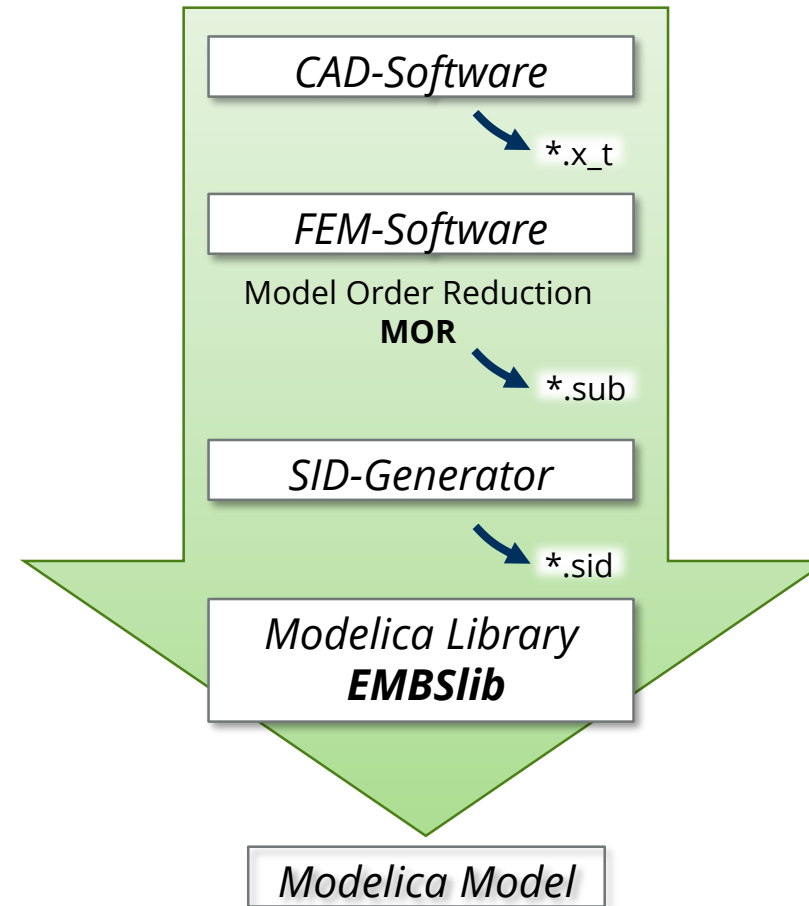
1. Disturbances in forward kinematic sensing
2. Disturbances in calculation for end effector positioning
3. Transfer behaviour of vibration analysis

# Workflow

## Possibilities

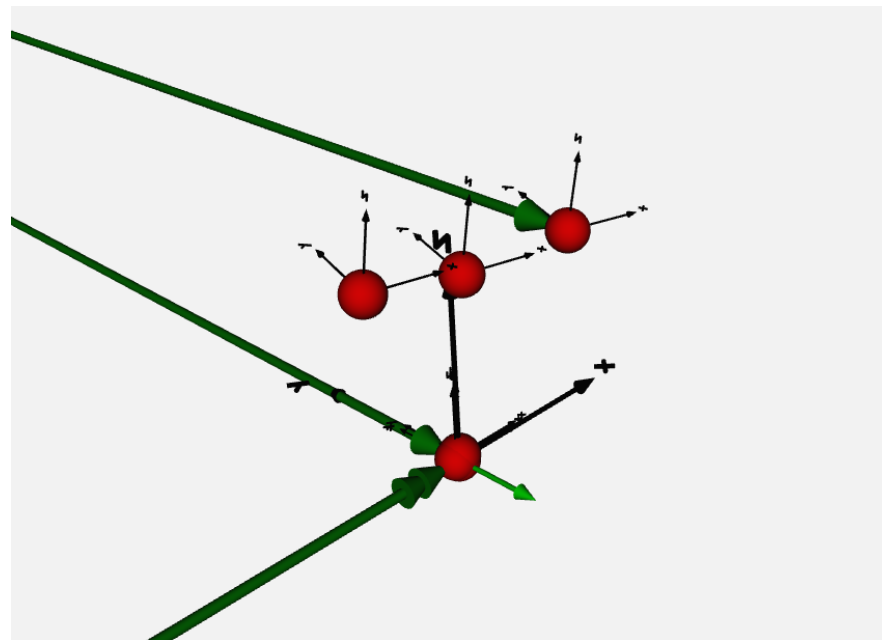
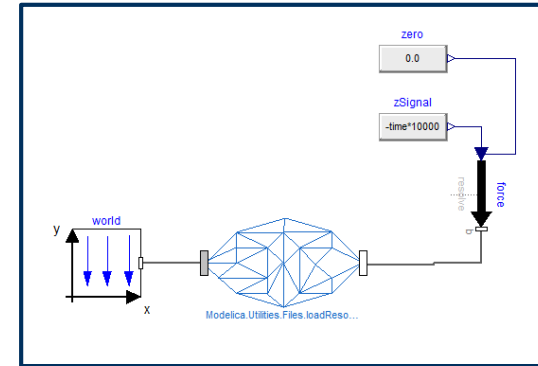


## Our Approach



# EMBSLib- library content

- elastic multibody component: `EMBS_Body`
  - 2 ordinary MultiBody-Connectors
    - `Frame_a` (reference node)
    - `Frame_b [numNodes]`
  - Parameters:
    - `numNodes` (according to SID-file)
    - `numModes` (according to SID-file)
    - path to SID-file
  - 3D-Visualization of:
    - Node-coordinates and spheres
    - Forces and torques in reference node



- EMBSlib
- EMBS\_bodyExample
- Components
  - EMBS\_Body
  - Node
- SID\_File
  - constructor
  - destructor
- ExternalFunctions\_C
  - getMass
  - getM0
  - getM1
  - getM0Node
  - getM1Node
- MatrixFunctions
  - getTaylorFunction
  - getGrMatrix
  - getGeMatrix
  - getTaylorFunctionDerivative

# EMBSLib - SID-file processing

```
EMBS_Body eMBS_Body(numNodes=6,numModes=11,  
SIDfileName="XYZ.SID_FEM");
```

```
parameter EMBSlib.SID_File sid=EMBSlib.SID_File(SIDfileName);
```

```
function getM0  
  input EMBSlib.SID_File sid;  
  input String taylorName;  
  input Integer nr;  
  input Integer nc;  
  output Real[nr,nc] m0;  
  external "C" getM0(sid,taylorName,m0,nr,nc) annotation(  
    Include="#include \"ReadSID_C.h\"");  
end getM0;
```

```
Real mdCM[nr0,1]=EMBSlib.MatrixFunctions.getTaylorFunction(nr0,n  
q,1,mdCM_M0,mdCM_M1,q);
```

```
M_q + k_omega_q + k_q = hd_e;
```

model parameterization

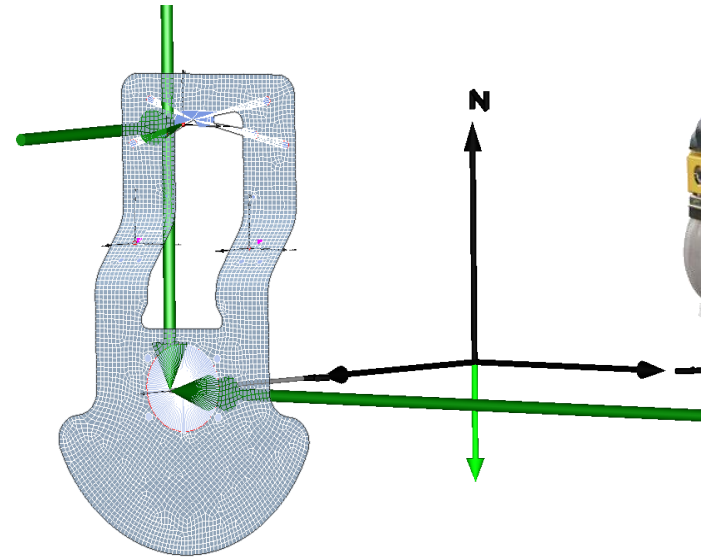
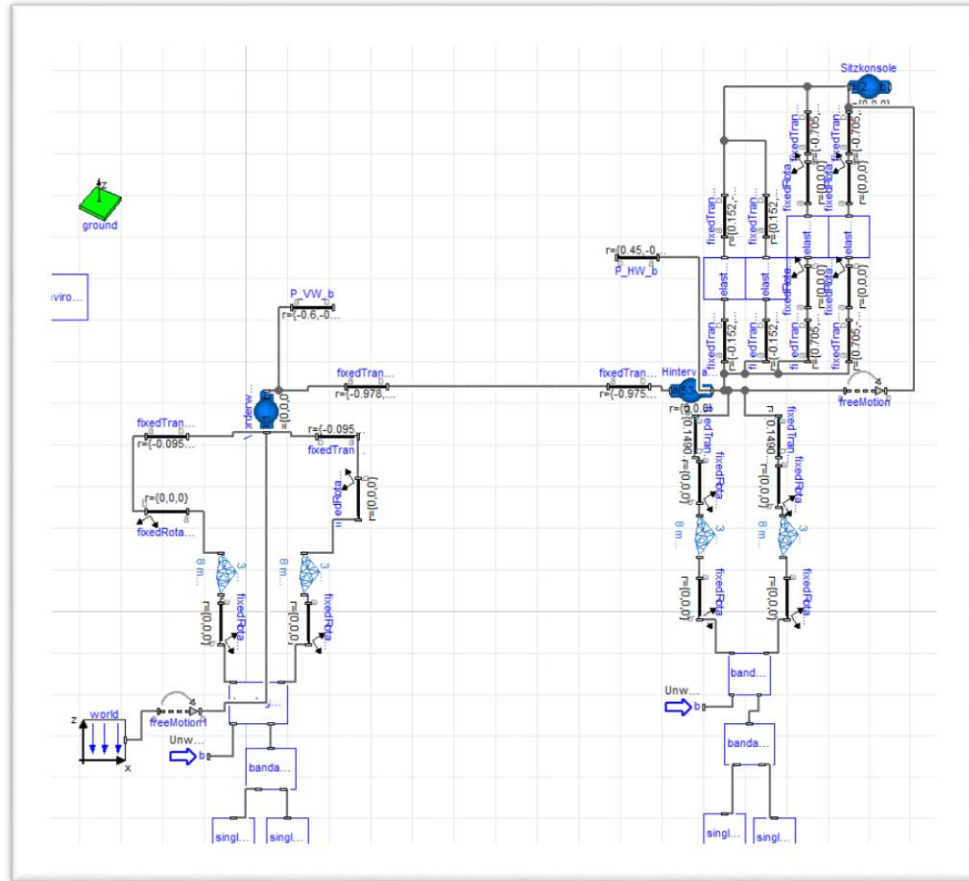
ExternalObject creation  
(SID-Parser)

Retrieve several parameters  
from SID-object once before  
initialization  
(header-only code)

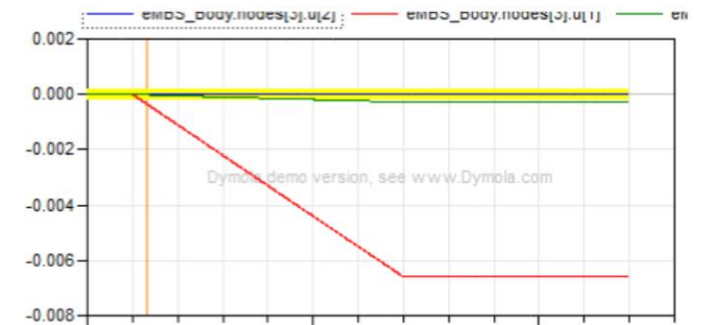
Calculate variables depending on  
modal coordinates and SID-  
parameters during simulation

Solve kinematic equations in  
modal domain

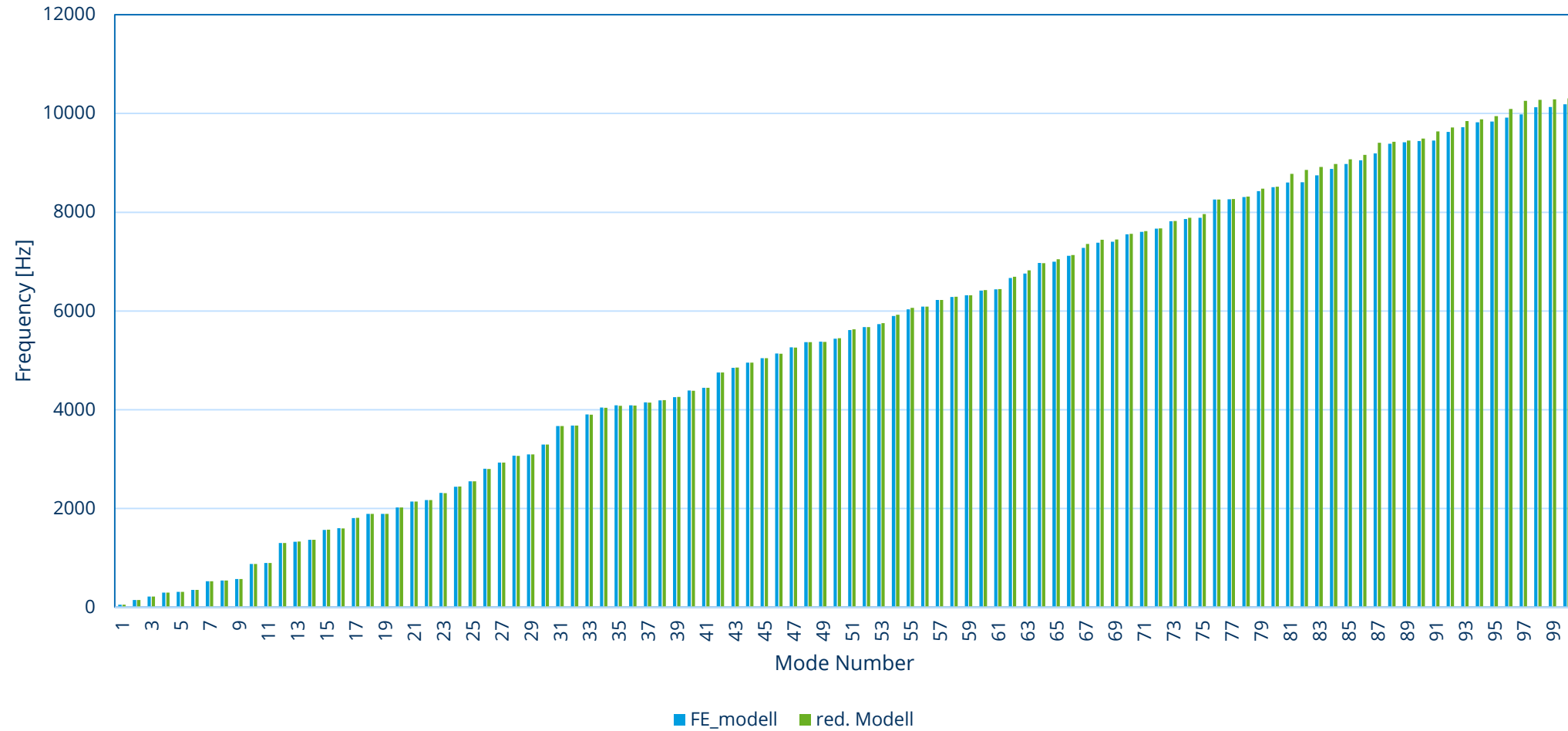
# Tandem Roller



Mode	Eigenfrequenz
1	48,773 Hz
2	145,28 Hz
3	213,67 Hz
4	296,51 Hz
5	308,23 Hz
6	352,26 Hz
7	523,54 Hz
8	541,7 Hz
9	569,89 Hz
10	873,05 Hz
11	893,36 Hz



# Eigenfrequency





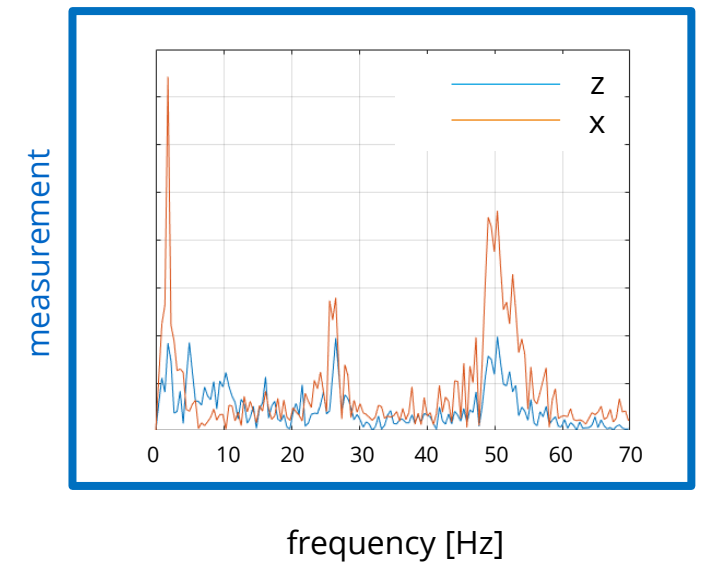
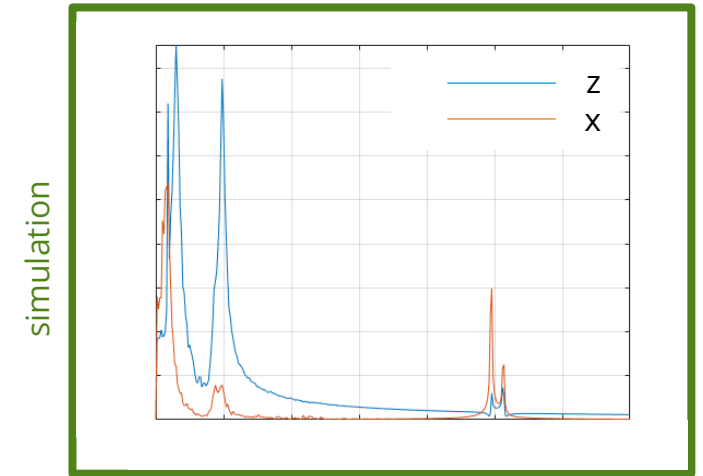
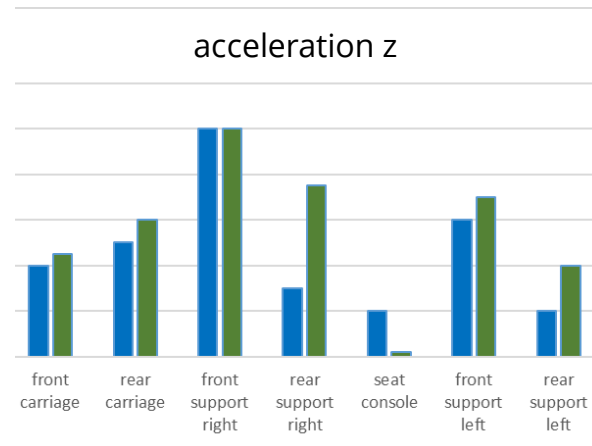
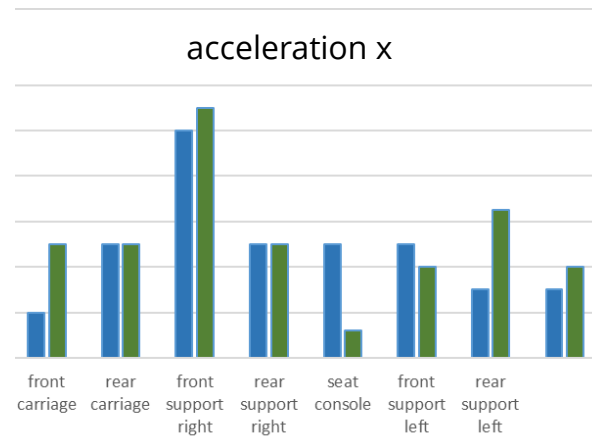
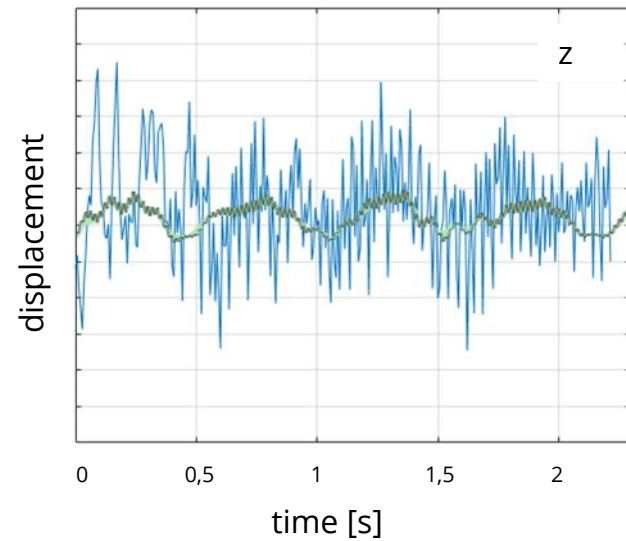
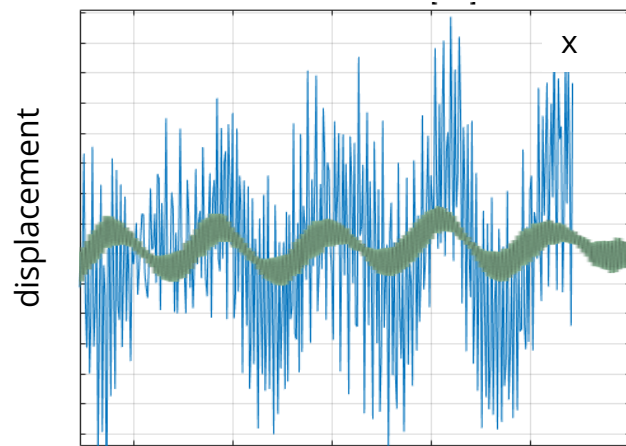
# Photogrammetric Survey



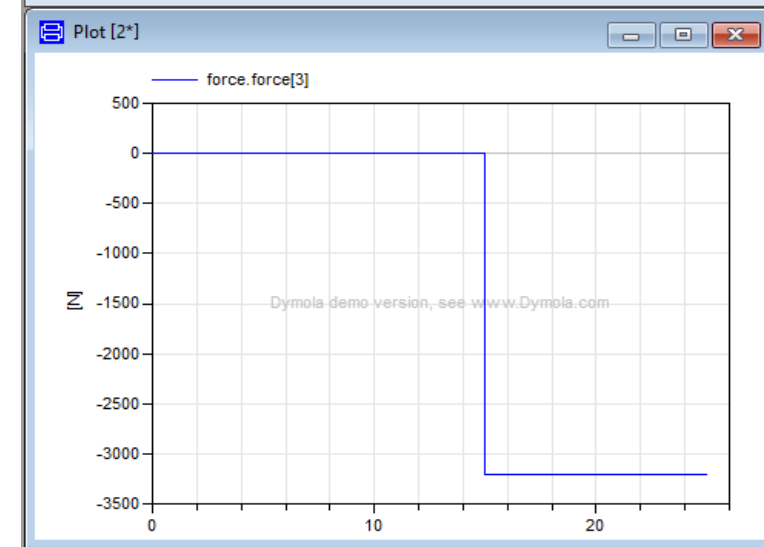
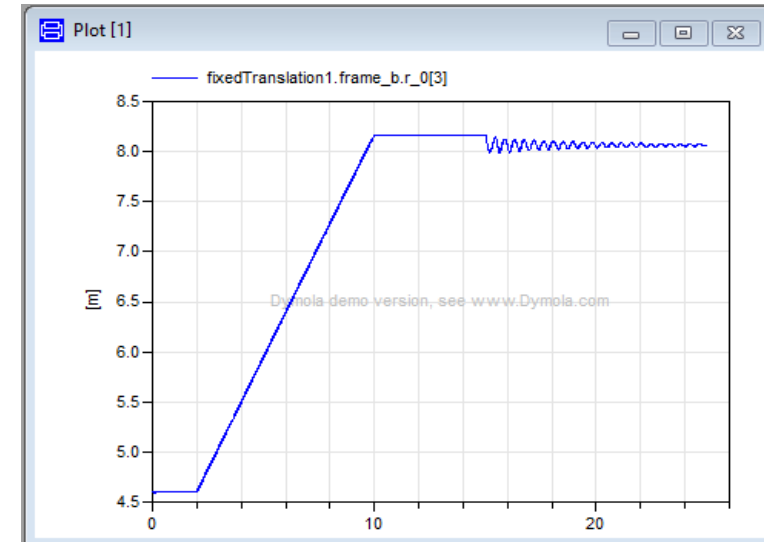
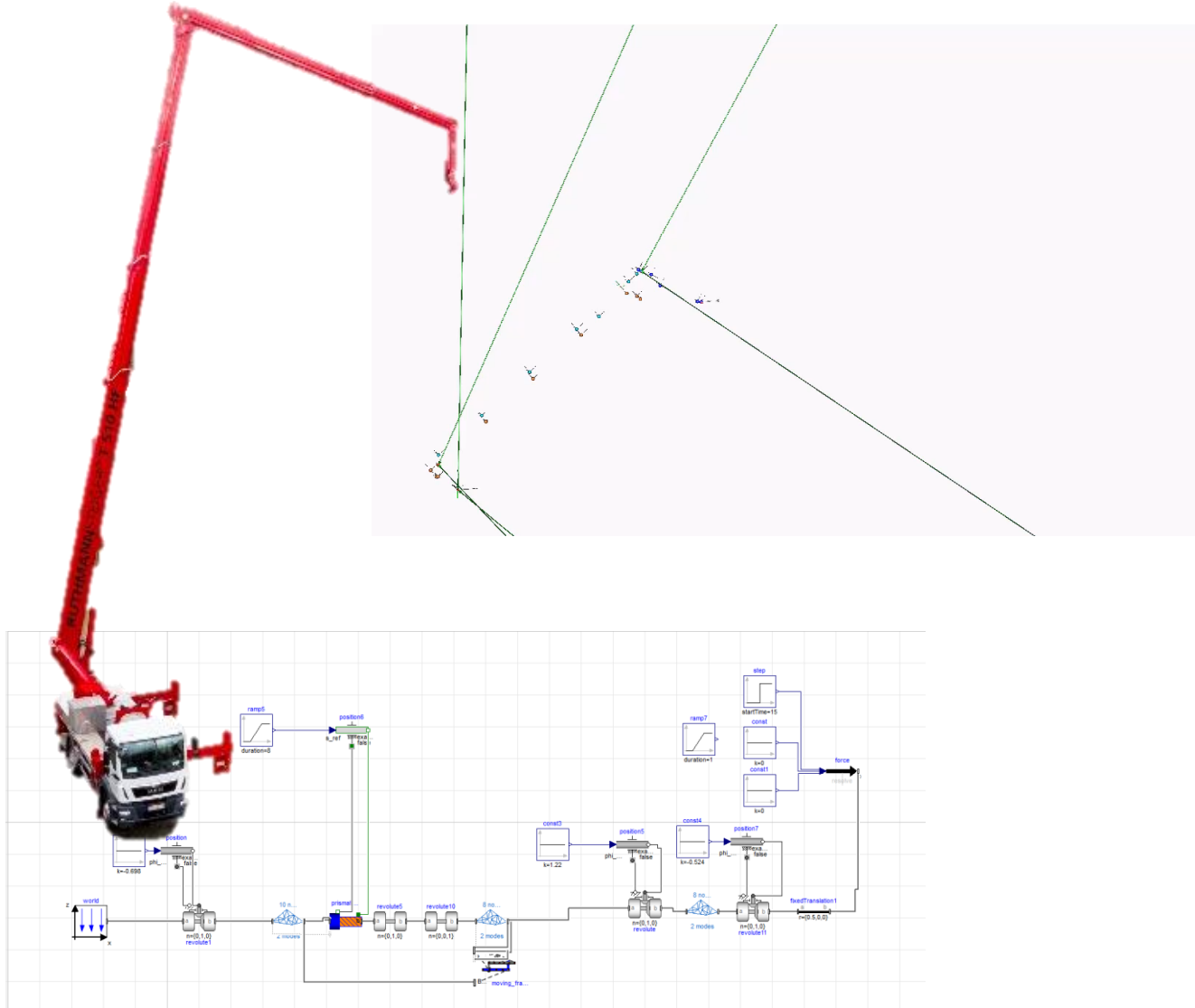
- 2 high-speed cameras 4MP
- Principle digital image correlation
- Adhesive marker for recording the deflections
- 1000 fps

# Validation

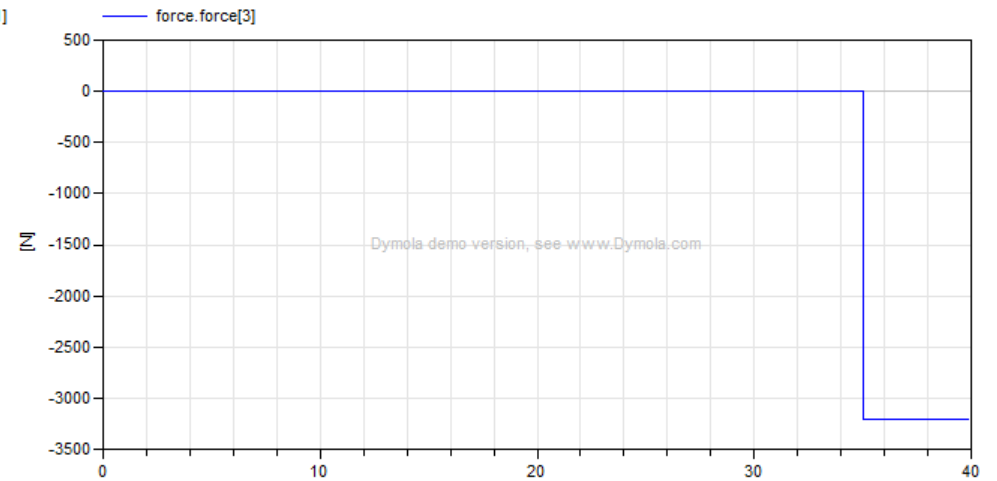
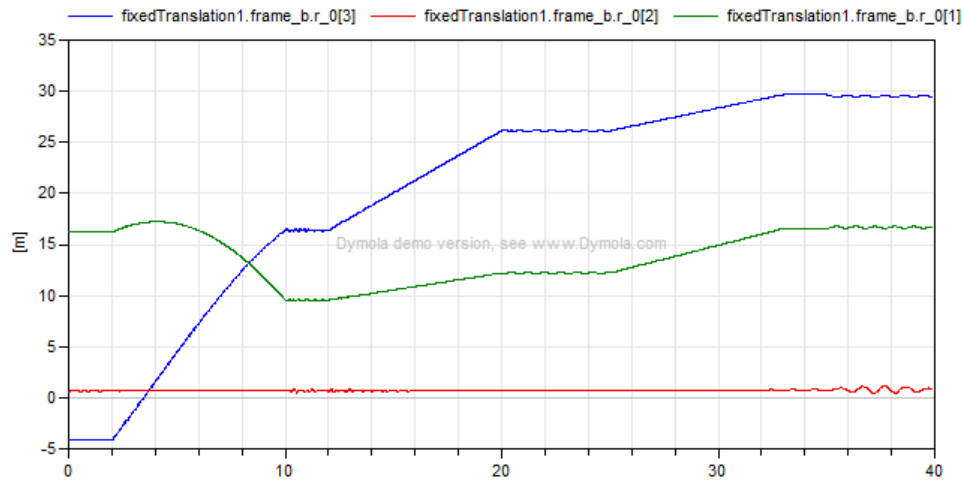
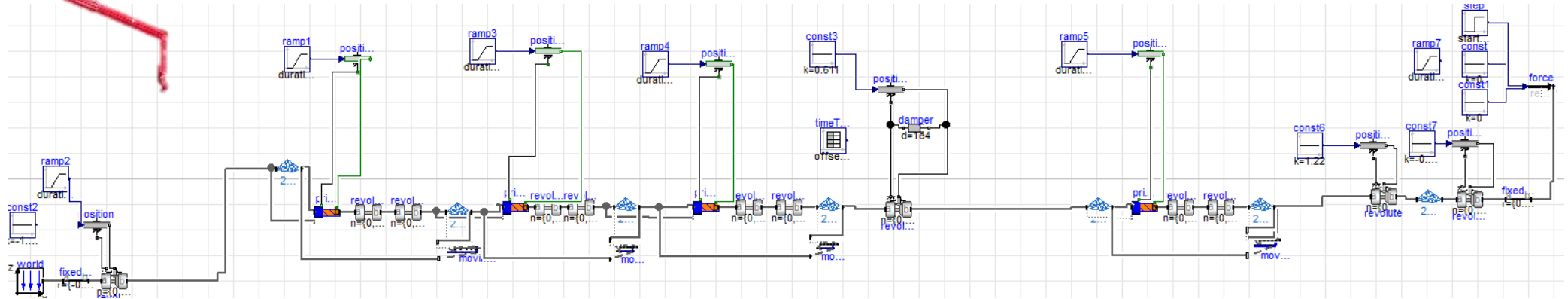
seat console – measurement  
 seat console – simulation



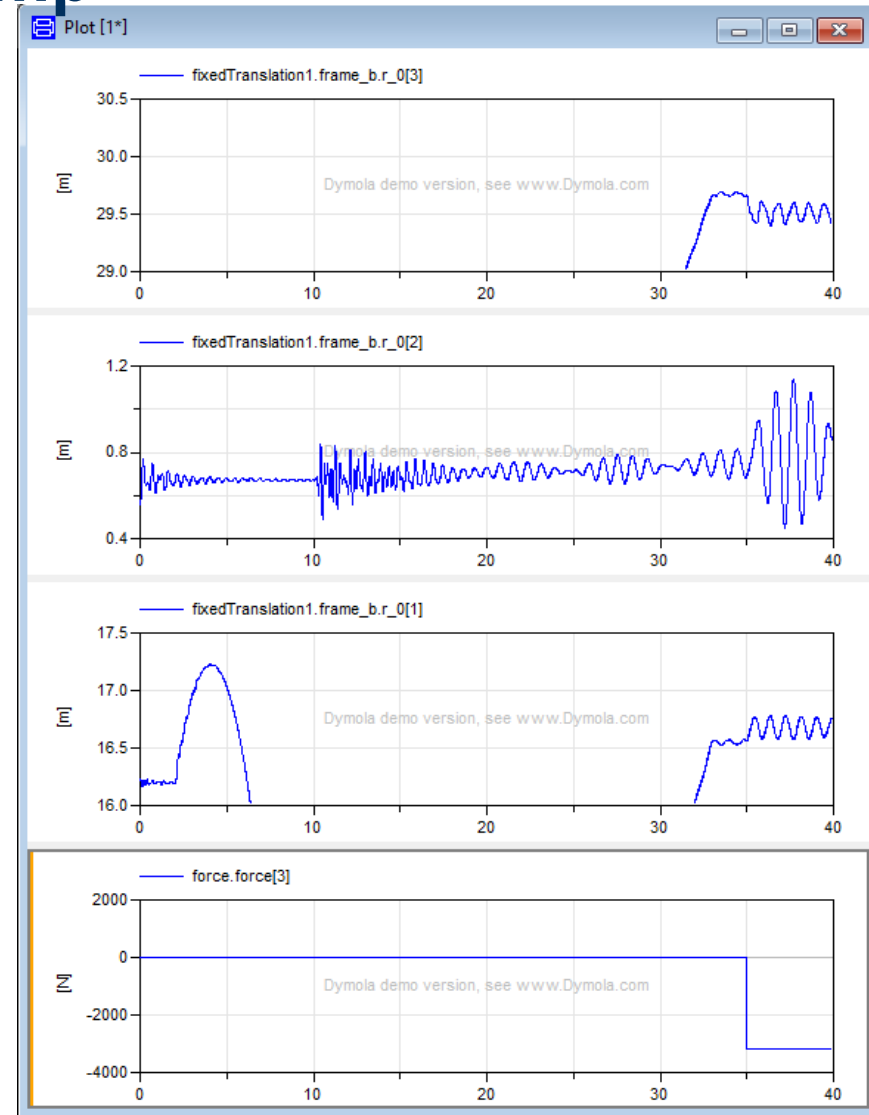
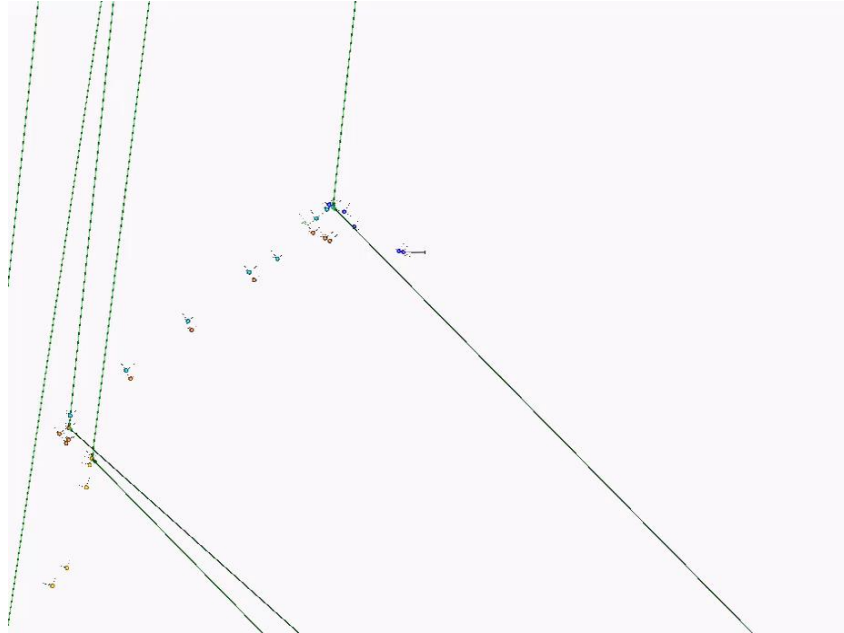
# Boom Lift - Upper Arm - Bungee Jump



# Boom Lift - Total Boom



# Boom Lift - Total Boom - Bungee Jump



# Last Slide

## Conclusion

- Implementation of flexible bodies with a noncommercial library in Modelica
- Application of high frequency excitation with the vibration transfer behaviour
- Application of low frequency excitation without validation

## Next Steps

- Validation of the boom lift model
- Boom lift model improvement
- Investigation of the tandem roller model deviation
  - Elastomer modeling
  - Flexible body behavior



## Thank You!

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Federal Ministry  
for Economic Affairs  
and Energy

on the basis of a decision  
by the German Bundestag

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