VMAP USER FORUM 2025

Gefördert durch:

Bundesministerium für Wirtschaft und Klimaschutz

aufgrund eines Beschlusses des Deutschen Bundestages

VMAP AS A KEY ENABLER FOR THE SUSTAINABILITY & COMPONENT QUALITY ASSESSMENT OF COMPOSITE MANUFACTURING PROCESSES BASED ON SIMULATIVE APPROACHES

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Institute of Lightweight Systems, DLR

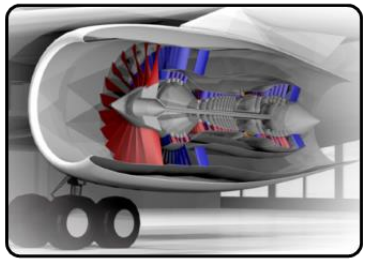
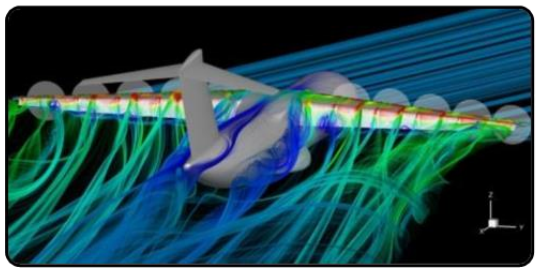
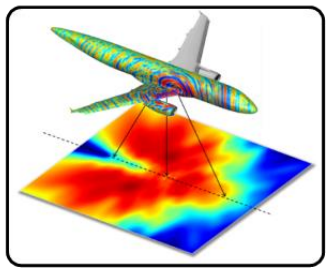
PredictECO

DLR

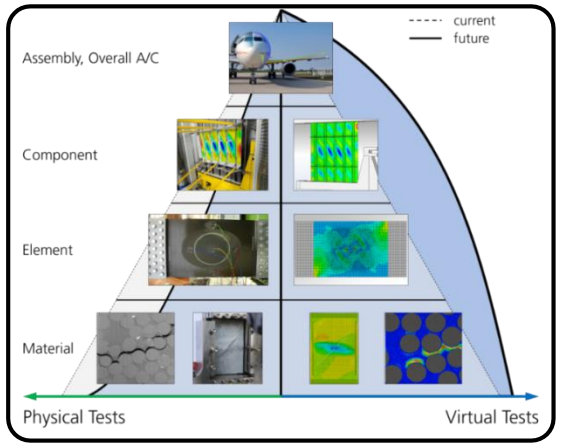
Digitalisation in Aeronautics & Virtual Product

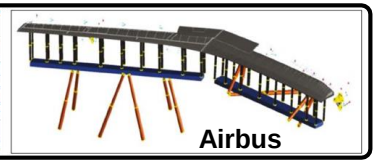
Digital Aircraft



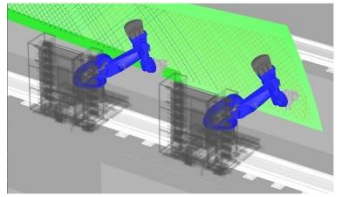
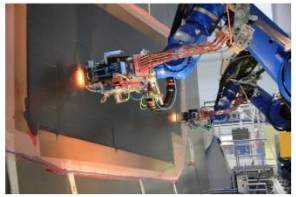





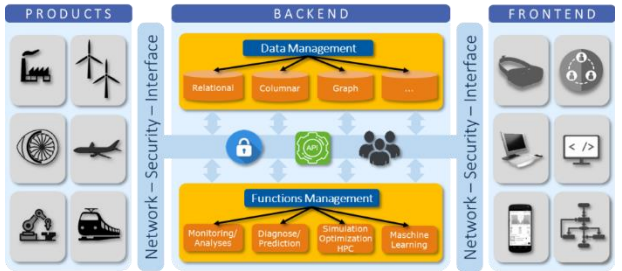
Virtual Certification



Digital Twin

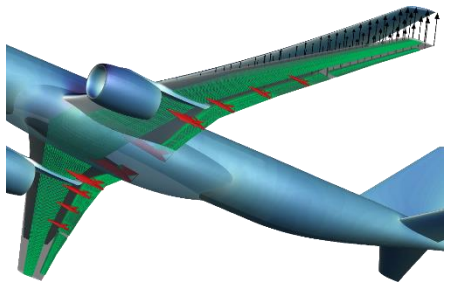



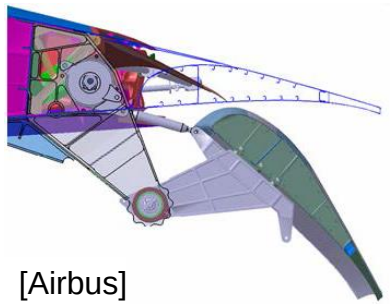


Further information:
www.dlr.de/vph

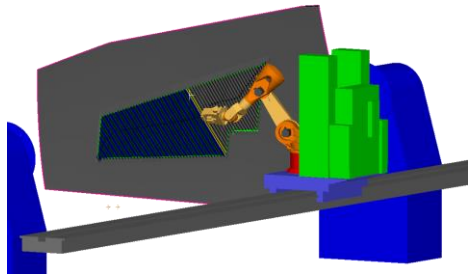
Digital End-to-End-Process

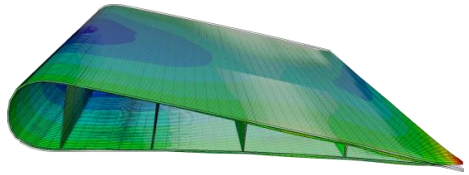
Further information:
www.dlr.de/vph

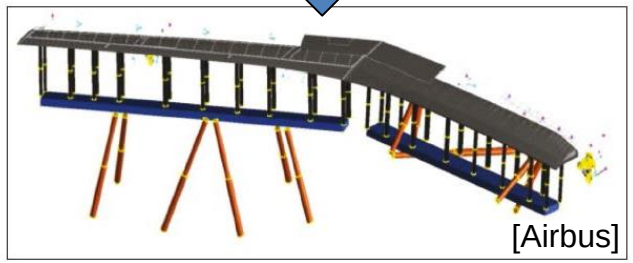




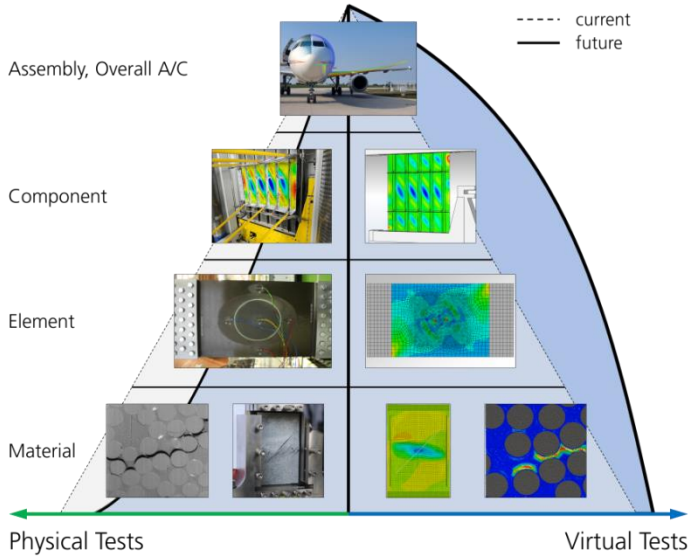
[Airbus]







[Airbus]

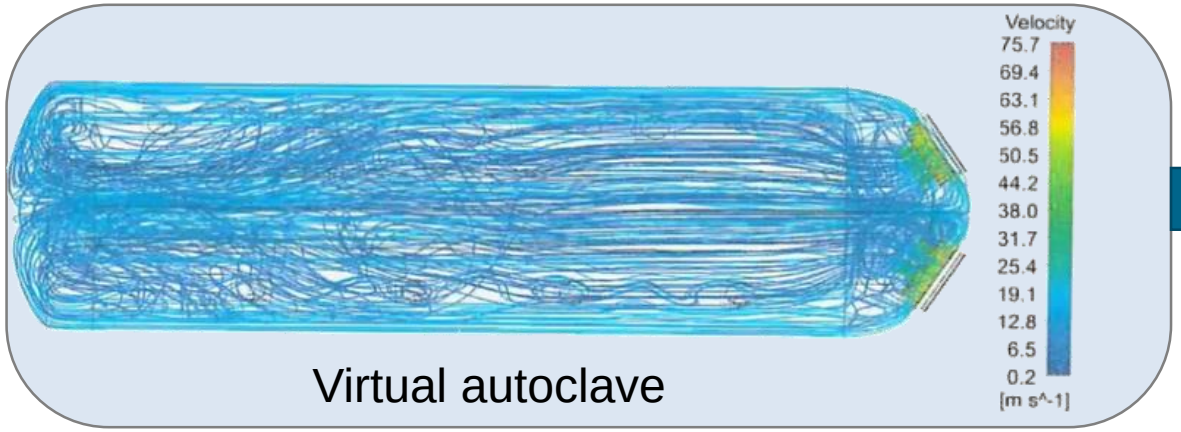


Virtual Design → Virtual Production → Virtual Testing → Virtual Certification

EASA European Aviation Safety Agency

→ Close cooperation w. industry, e.g. @ **Airbus:** FPO, flight physics, structures, systems, testing, DDMS

Manufacturing Simulation
Overview

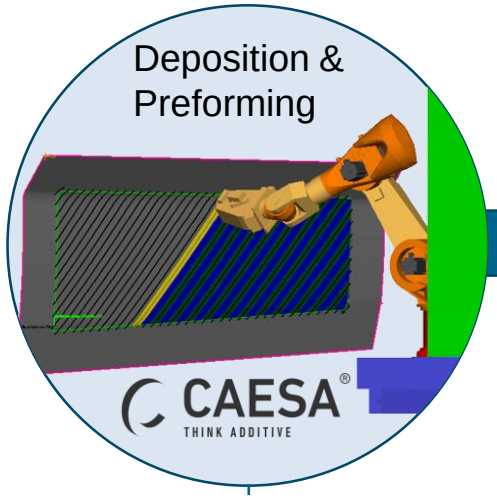


Virtual autoclave

Temperature
Heat transfer

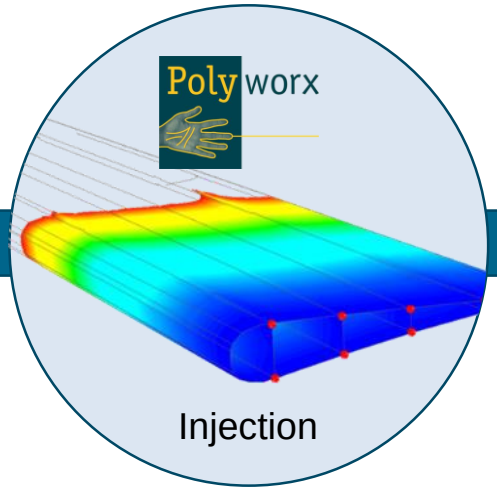
On specimen surface f(time):

Deposition &
Preforming



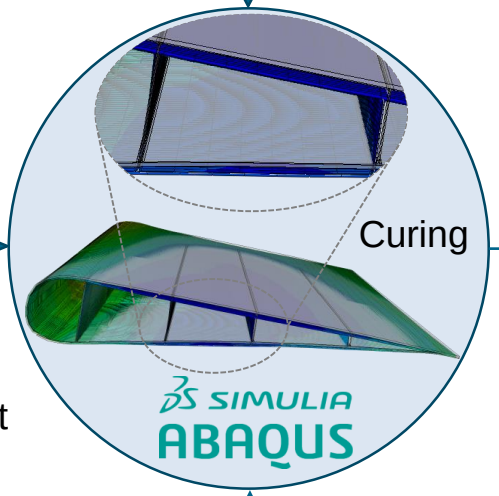
@ final state:

Gaps & overlaps



Injection

@ final state:
Fibre volume content
Degree of cure

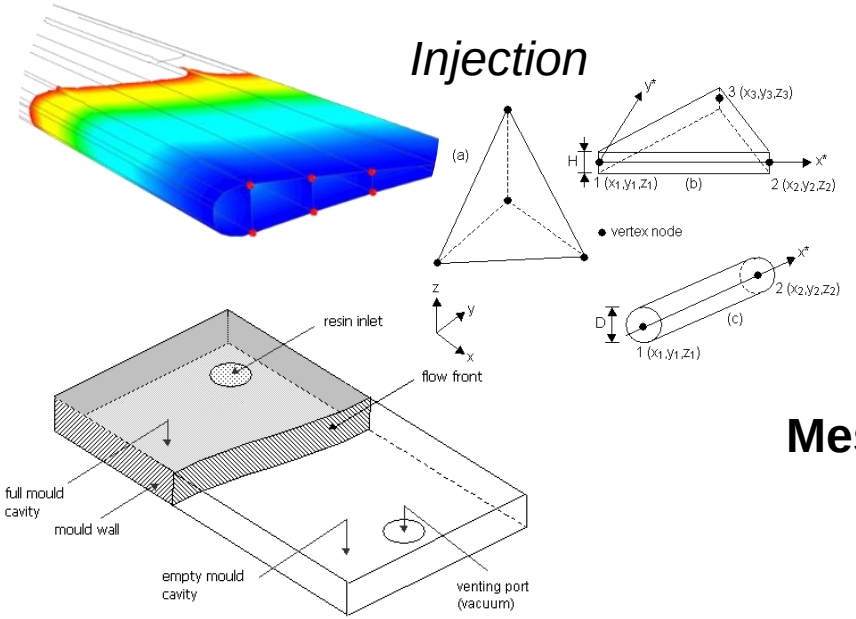


Curing

Requirements

Manufacturing Simulation
Overview

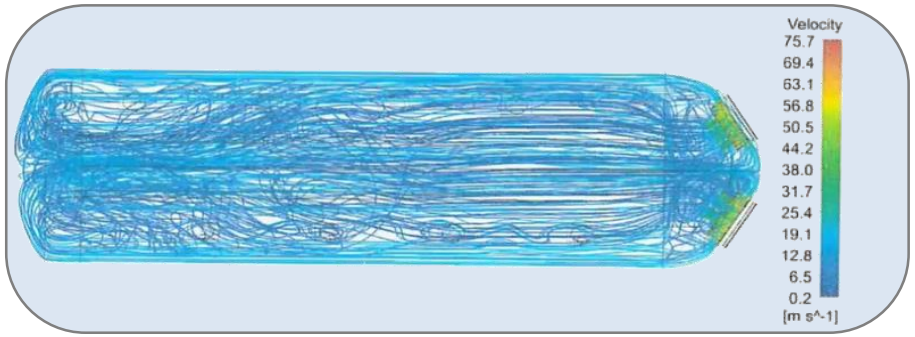
Injection



→ 2.5D based unstructured meshes

Mesh Interpolation

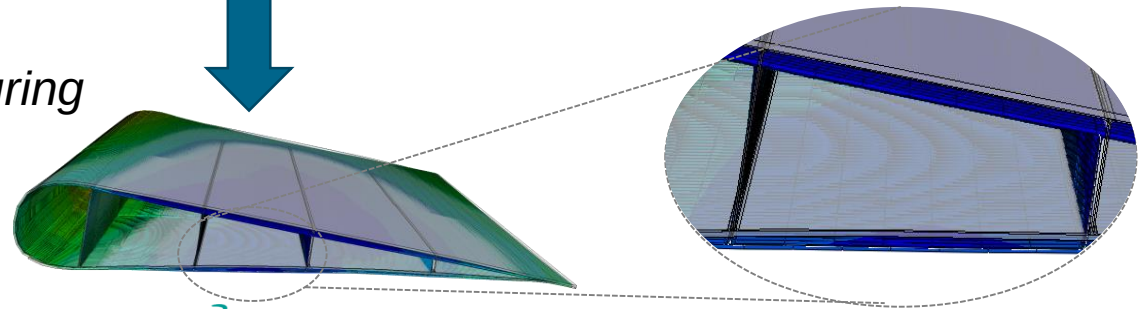
Virtual autoclave



→ point cloud based results

→ *Need for standardized data schemes and tools!*

Curing



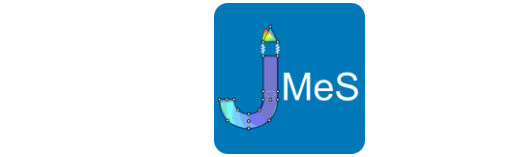
SIMULIA ABAQUS

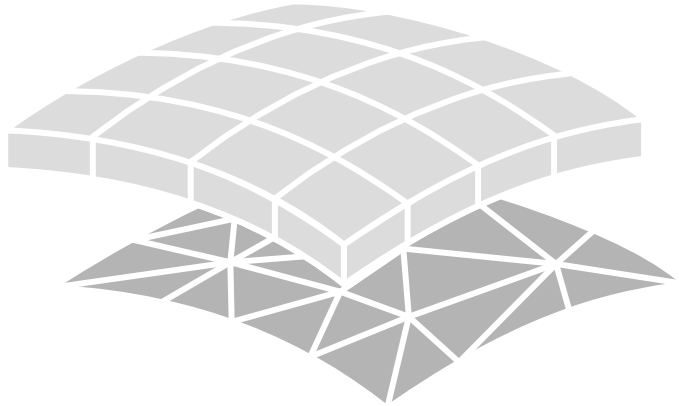
3D FE-Model

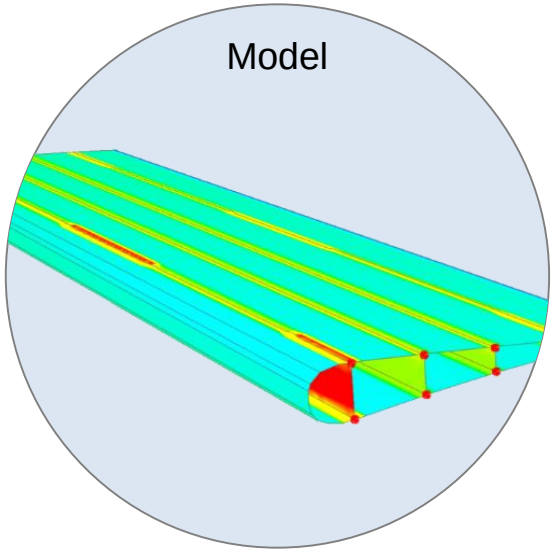
Data
Exchanges

Simulation

vampire

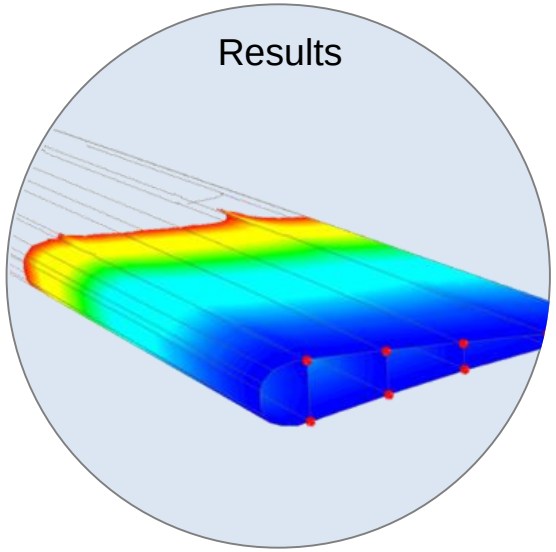




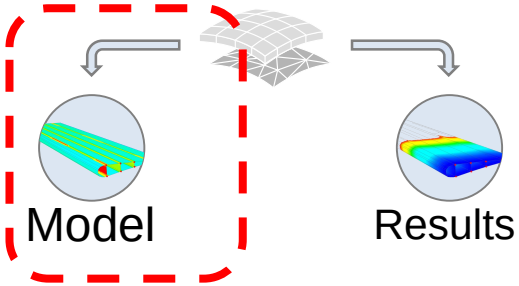


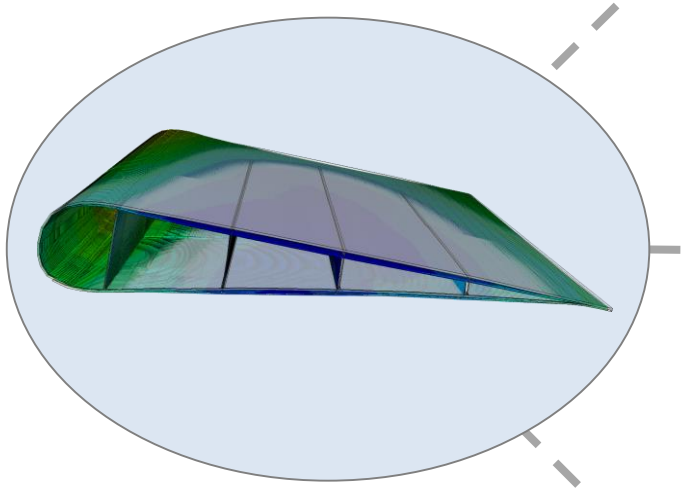
- Physical data
  - Temperature, …
- Mechanical data
  - Constituents, …
- CSM data
  - Discretization, …
  - Loads & BC

- Model data
- Part data
  - Nodes
  - Elements
  - Int.-Points
- Conservation data



Data
Standardization – Data types





Numerical implementation data

- Nodes
- Elements
- …

- Results

Connecting data

- Sections
- Loads & BC
- …

- Solution

Math, physics & mech. idealization data

- Materials
- Composites
- Crosssections
- …

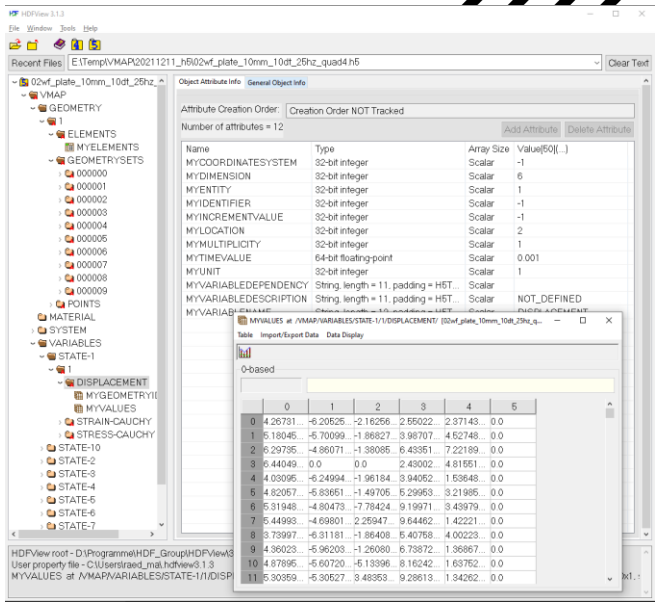
Heavy data

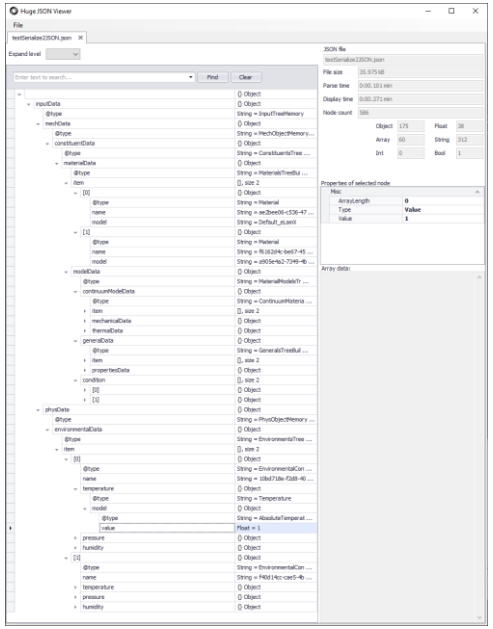
VMAP

References

Light data

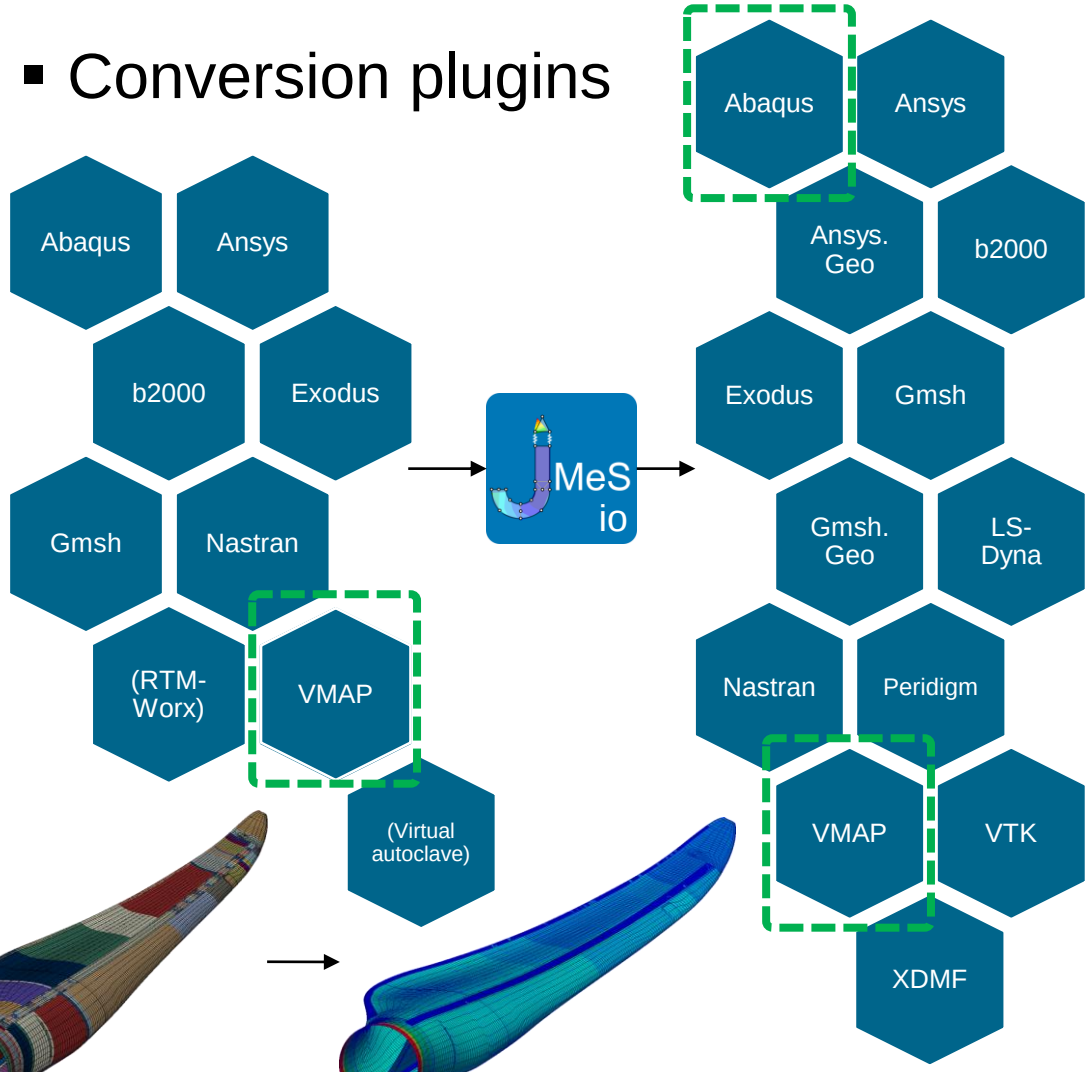
cosmo



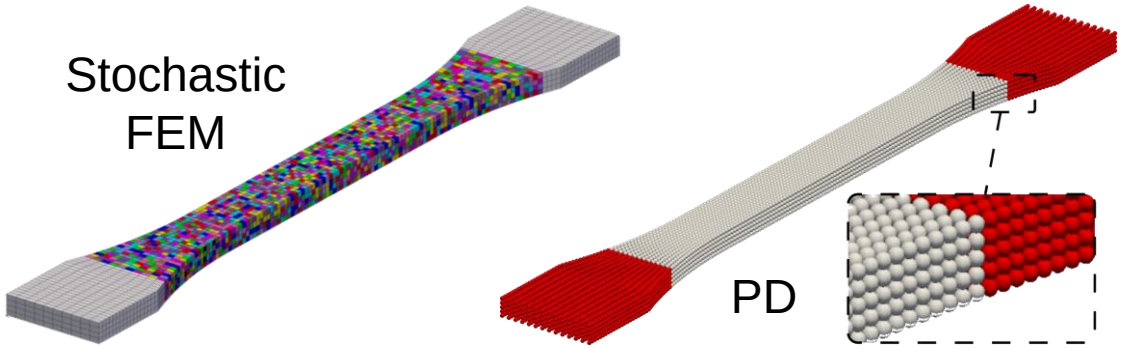


Implementation
Model – Functions

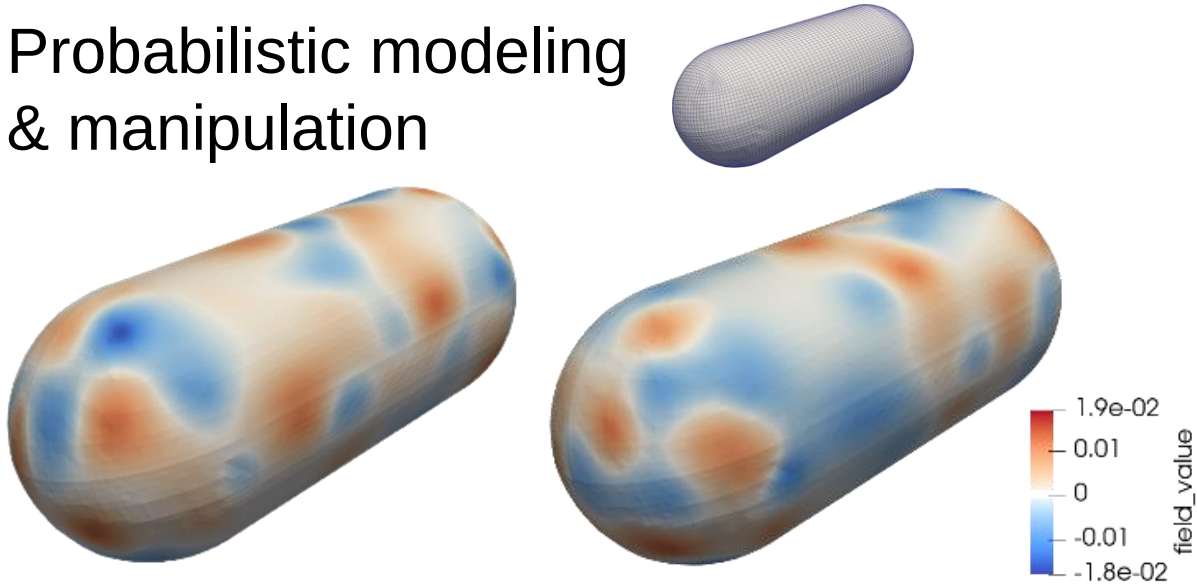
- Conversion plugins



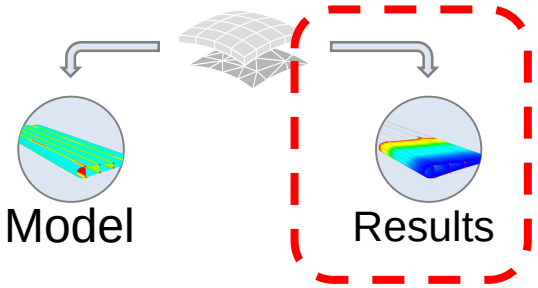
- Idealization & theory-independent model generation



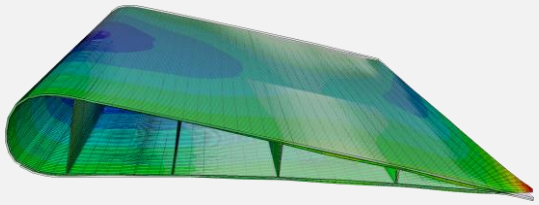
- Probabilistic modeling & manipulation



Implementation
Result I/O



Input data

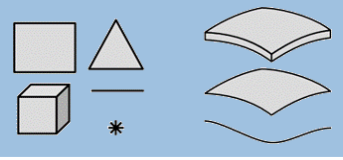


In memory

Preprocessing → *vampire* → Postprocessing

FE-Resultdata handling

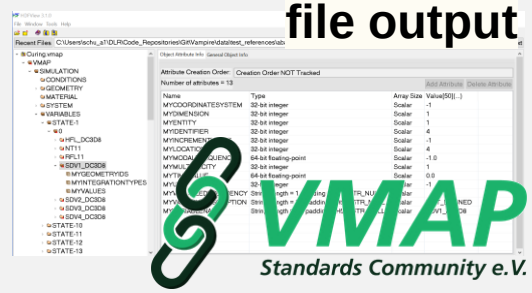
Mesh discretization storage

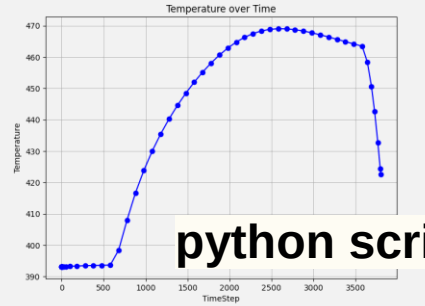


file data access

API	*simples*	*medcoupling*	*pynastran,h5py*	*?*

file output



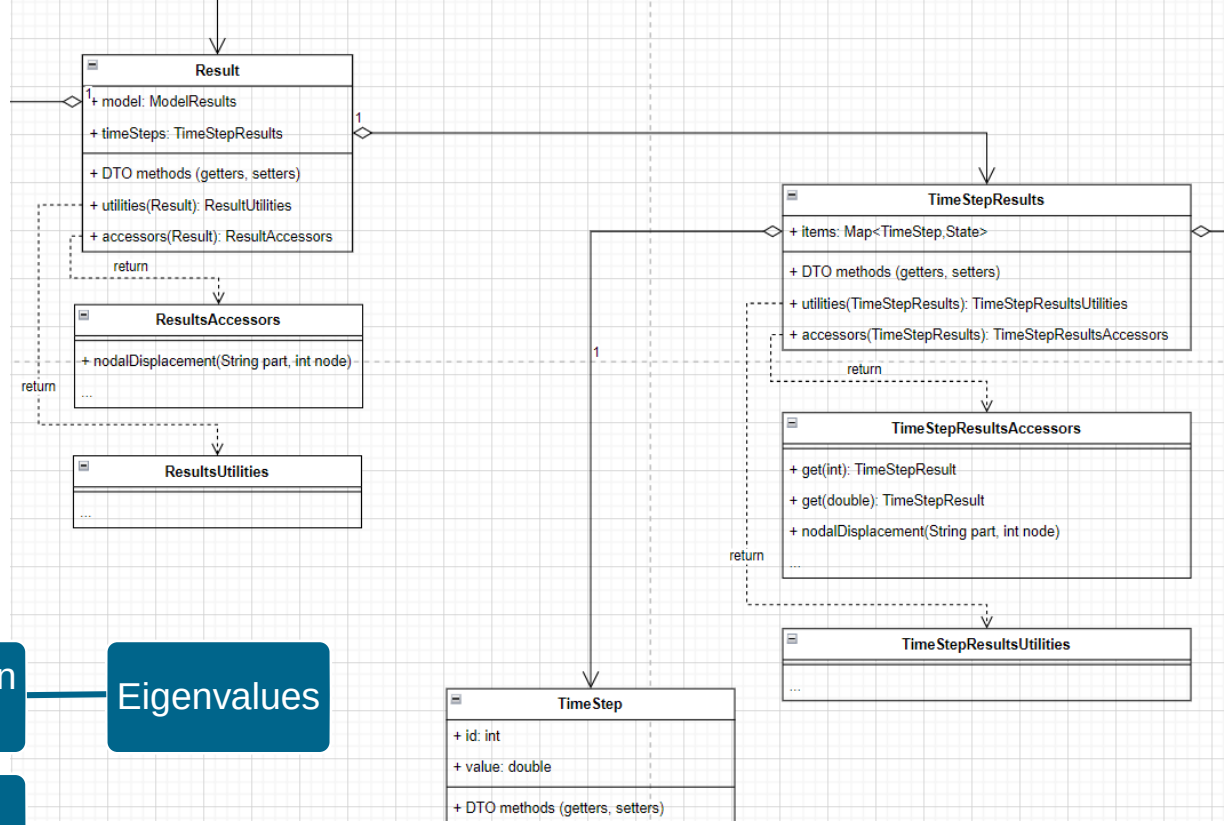


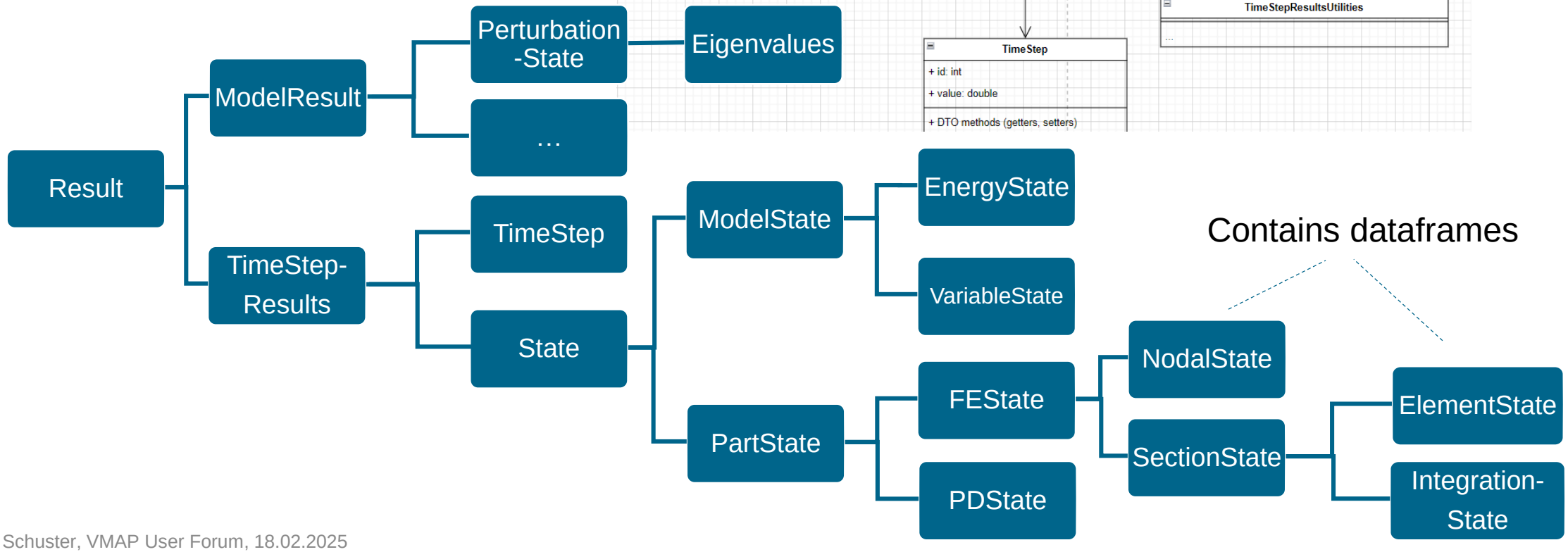
python scripting

SIMULIA ABAQUS · b2000 pro++ · code_aster · MSC Nastran™ · • • •

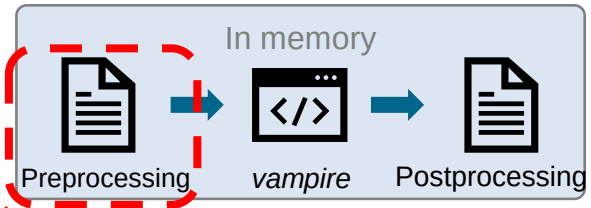
Implementation
Results – Data structure

- Simplified from UML
- Based on user stories
- Expandable





Implementation
Results – Access Abaqus data



- Investigated open source libraries:
  - PyAbaqus
  - AbaPy
  - pylife-odbclient
  - In-house tools
- Implementation features
  - Data acquisition by means of Abaqus python API
  - Read all available result types (curr. elemental, nodal) @ timesteps
  - Subselection possible
- Data storage: simple datatypes (list,dict)
- Serialization → pickle protocol in python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                                   [ 1.00000000e+00,  2.00000000e+00,  1.00000000e+00,
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                                   [ 1.00000000e+00,  3.00000000e+00,  1.00000000e+00,
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                                   [ 1.00000000e+00,  4.00000000e+00,  1.00000000e+00,
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                    'type': ''}}
```

element type and elemental result name

Raw data

column description

Code Example

```python
from vampire.datamodel.simulation import Simulation
import seaborn as sns
inputFile = os.path.join(
    os.path.dirname(__file__),"Test_CureModel_HT.odb"
)
sim = Simulation()
sim.readModel(inputFile)
sim.readResults(inputFile)

data = sim.results.getTimeSeriesNodalData(
    loadCaseName="Curing",
    partName="PART-1-1",
    dataSetName="NT11",
    identifiers=[1.0, 2.0],
    timeStepMin=0,
    timeStepMax=-1,
)

sns.lineplot(
    data,
    x="timeStep",y="COL1",
    hue="identifier",palette="viridis"
)

sim.export(os.path.dirname(__file__),filetype="vmap")
```

- Simulation object definition
- Define input files with mesh and result data
- Required result parser inferred from file extension (explicit solver name possible)

Code Example

```python
from vampire.datamodel.simulation import Simulation
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sns.lineplot(
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    x="timeStep",y="COL1",
    hue="identifier",palette="viridis"
)

sim.export(os.path.dirname(__file__),filetype="vmap")
```

- Use of generic access routines
- Selected results as ordinary *pandas* DataFrames

	identifier	timeStep	COL1
0	1.0	0.000000	393.149994
1	2.0	0.000000	393.149994
2	1.0	0.100000	393.150146
3	2.0	0.100000	393.150146
4	1.0	0.200000	393.150299
..	...	...	...
103	2.0	3765.070312	439.321869
104	1.0	3793.669922	424.503540
105	2.0	3793.669922	431.945251
106	1.0	3800.000000	422.618774
107	2.0	3800.000000	430.264496

[108 rows x 3 columns]

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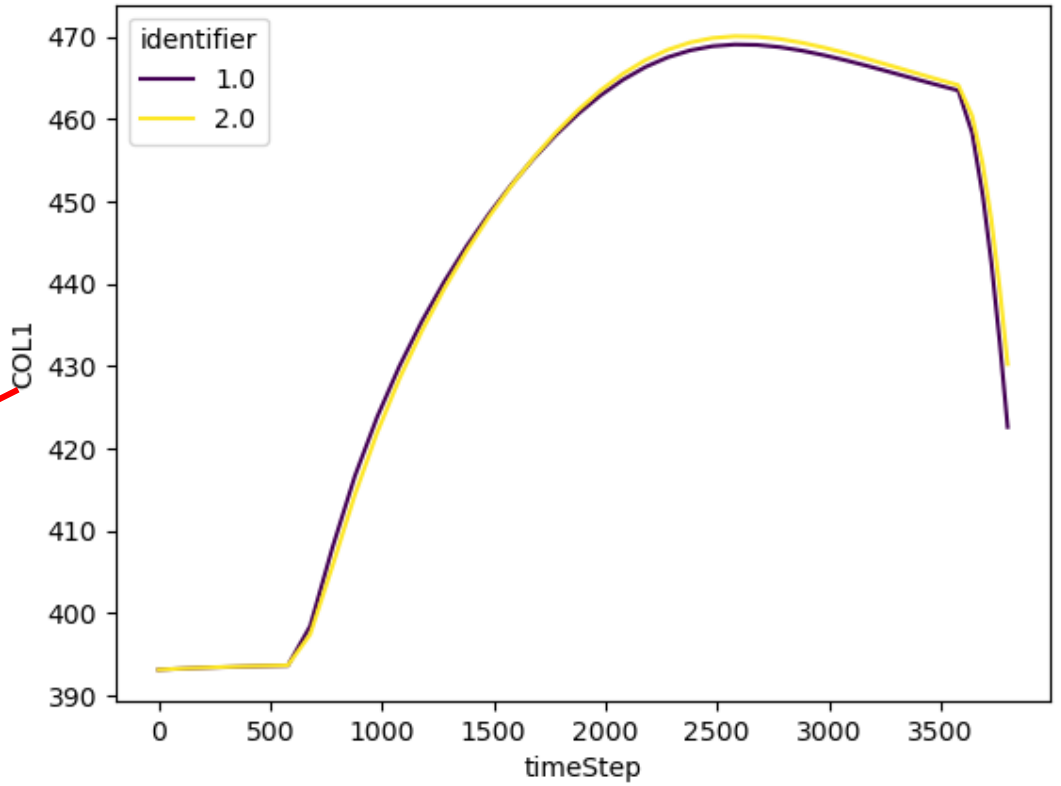
    dataSetName="NT11",
    identifiers=[1.0, 2.0],
    timeStepMin=0,
    timeStepMax=-1,
)

sns.lineplot(
    data,
    x="timeStep",y="COL1",
    hue="identifier",palette="viridis"
)

sim.export(os.path.dirname(__file__),filetype="vmap")
```

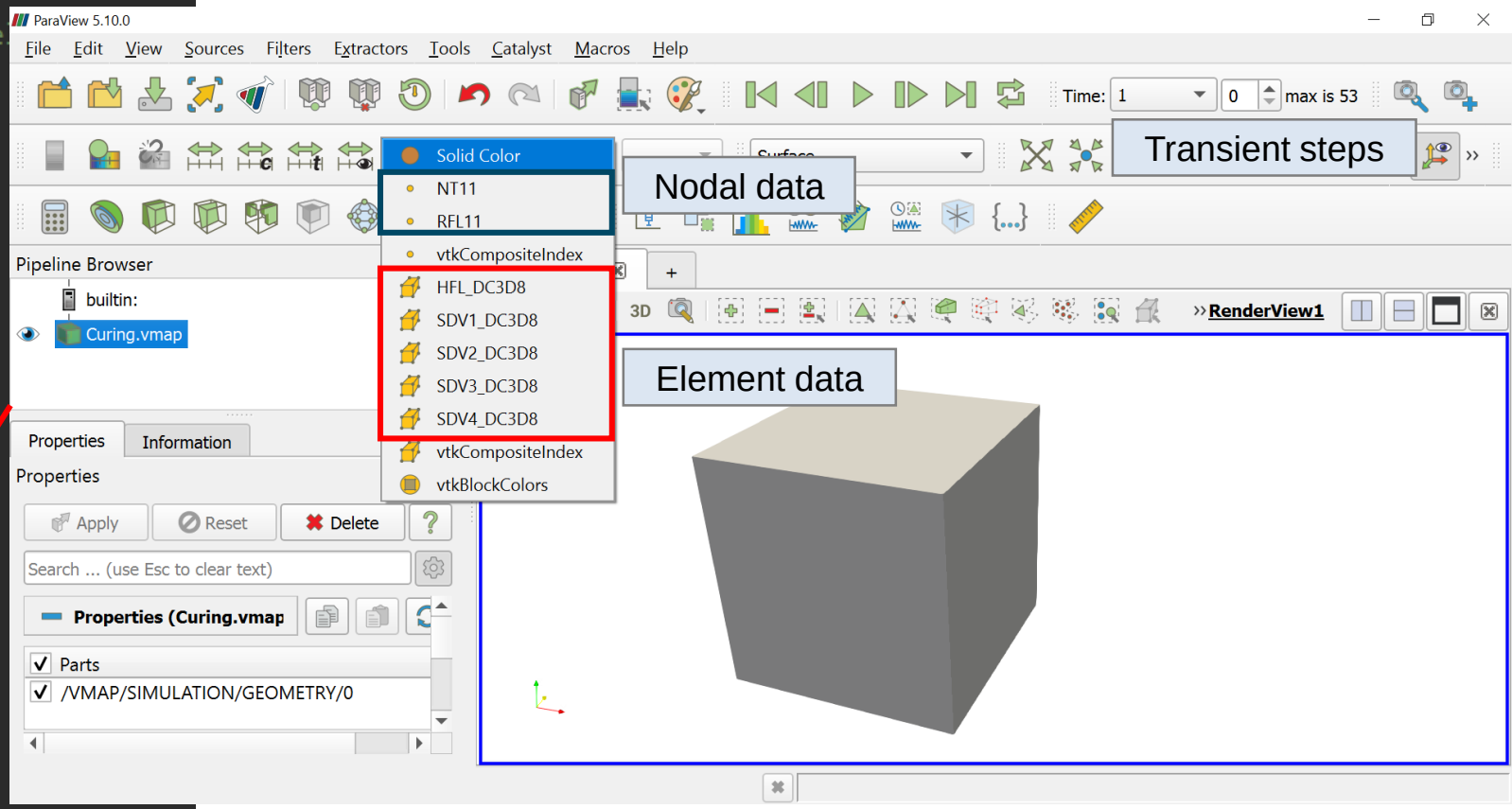
Easy use of common functions to plot data



Code Example

```python
from vampire.datamodel.simulation import Simulation
import seaborn as sns
inputFile = os.path.join(
    os.path.dirname(__file__),"Test_CureMode
)
sim = Simulation()
sim.readModel(inputFile)
sim.readResults(inputFile)

data = sim.results.getTimeSeriesNodalData(
    loadCaseName="Curing",
    partName="PART-1-1",
    dataSetName="NT11",
    identifiers=[1.0, 2.0],
    timeStepMin=0,
    timeStepMax=-1,
)

sns.lineplot(
    data,
    x="timeStep",y="COL1",
    hue="identifier",palette="viridis"
)

sim.export(os.path.dirname(__file__),filetype="vmap")
```

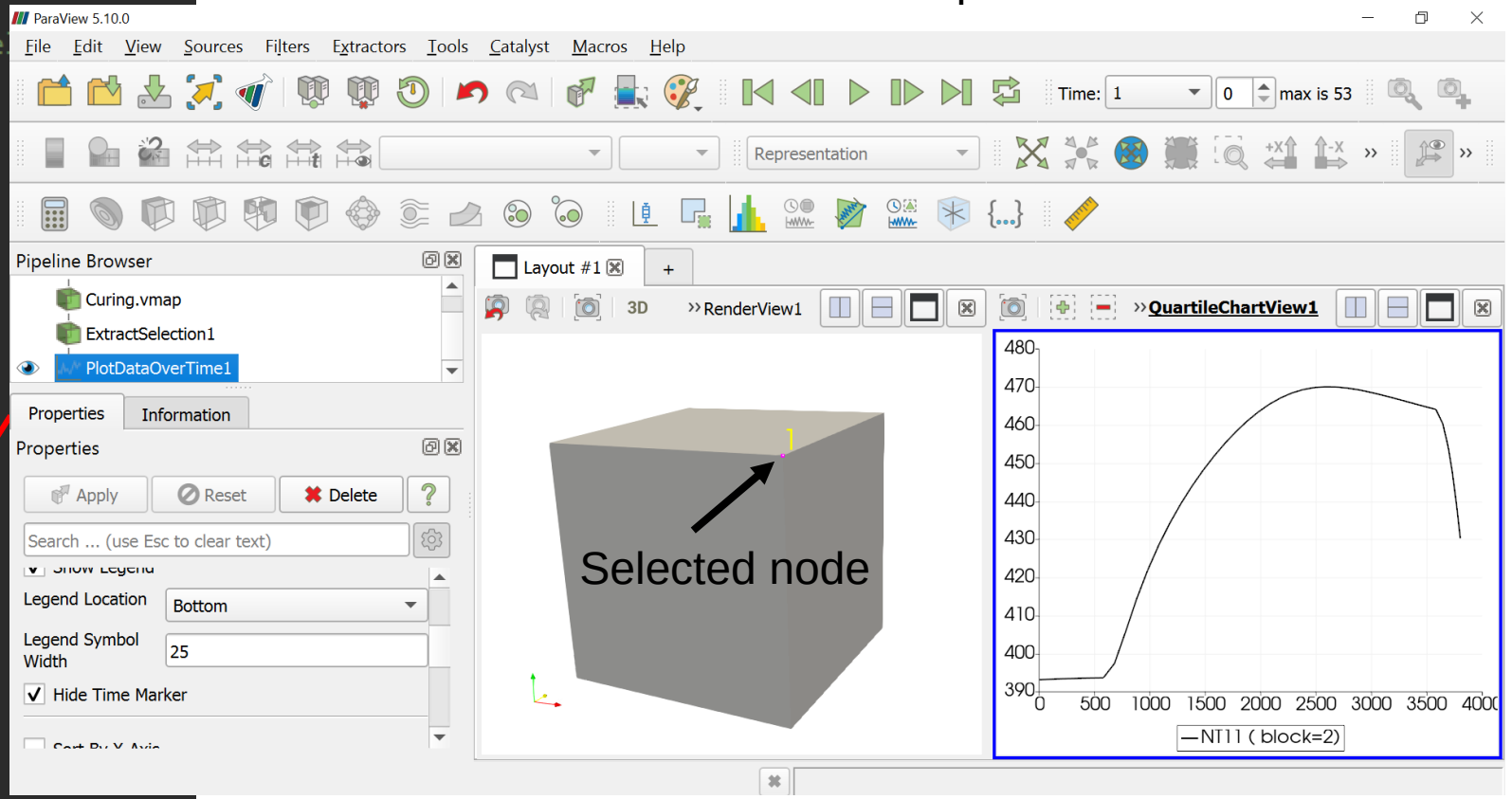
VMAP File Export



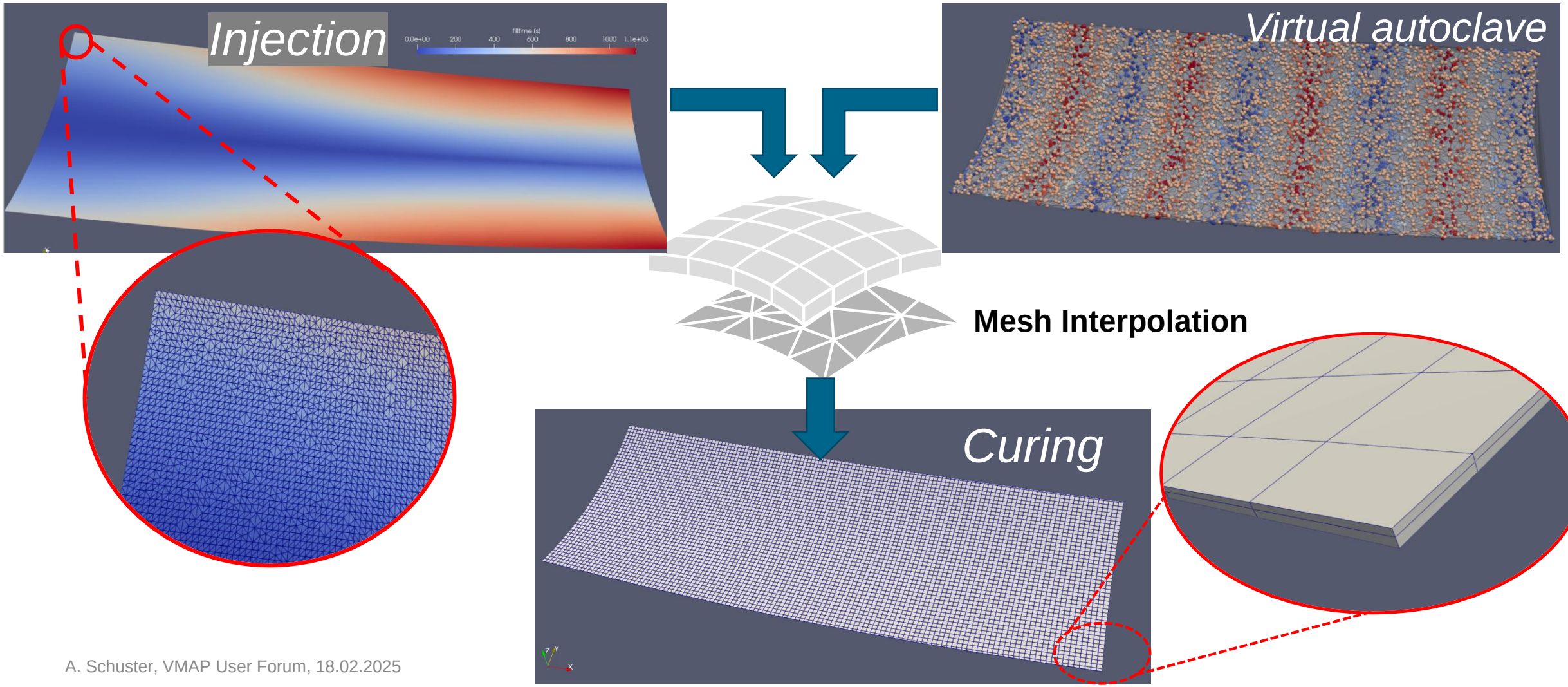
Code Example

```python
from vampire.datamodel.simulation import Simulation
import seaborn as sns
inputFile = os.path.join(
    os.path.dirname(__file__),"Test_CureMode
)
sim = Simulation()
sim.readModel(inputFile)
sim.readResults(inputFile)

data = sim.results.getTimeSeriesNodalData(
    loadCaseName="Curing",
    partName="PART-1-1",
    dataSetName="NT11",
    identifiers=[1.0, 2.0],
    timeStepMin=0,
    timeStepMax=-1,
)

sns.lineplot(
    data,
    x="timeStep",y="COL1",
    hue="identifier",palette="viridis"
)

sim.export(os.path.dirname(__file__),filetype="vmap")
```

VMAP File Export



Manufacturing Simulation
Results



Summary

- Tools and processes for simulation-based assessment of composite structure manufacturing processes developed at DLR
- Extensible storage approach for discretization based FE model and result data
- Pre- and post-processing interfaces to various tools and solvers available
- seamless integration of VMAP standard into tool-chain of selected project usecase
- Next steps: interpolation of data from injection and autoclave simulation to target CFRP structure required for curing simulation

THANK YOU FOR YOUR ATTENTION

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