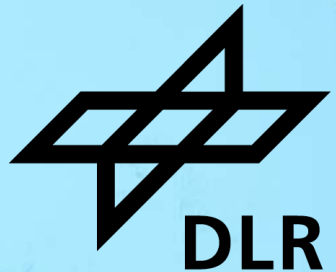


# INTEGRATED DATA MANAGEMENT FOR ADDITIVE MANUFACTURING ENABLING HIGH- FIDELITY MODELING

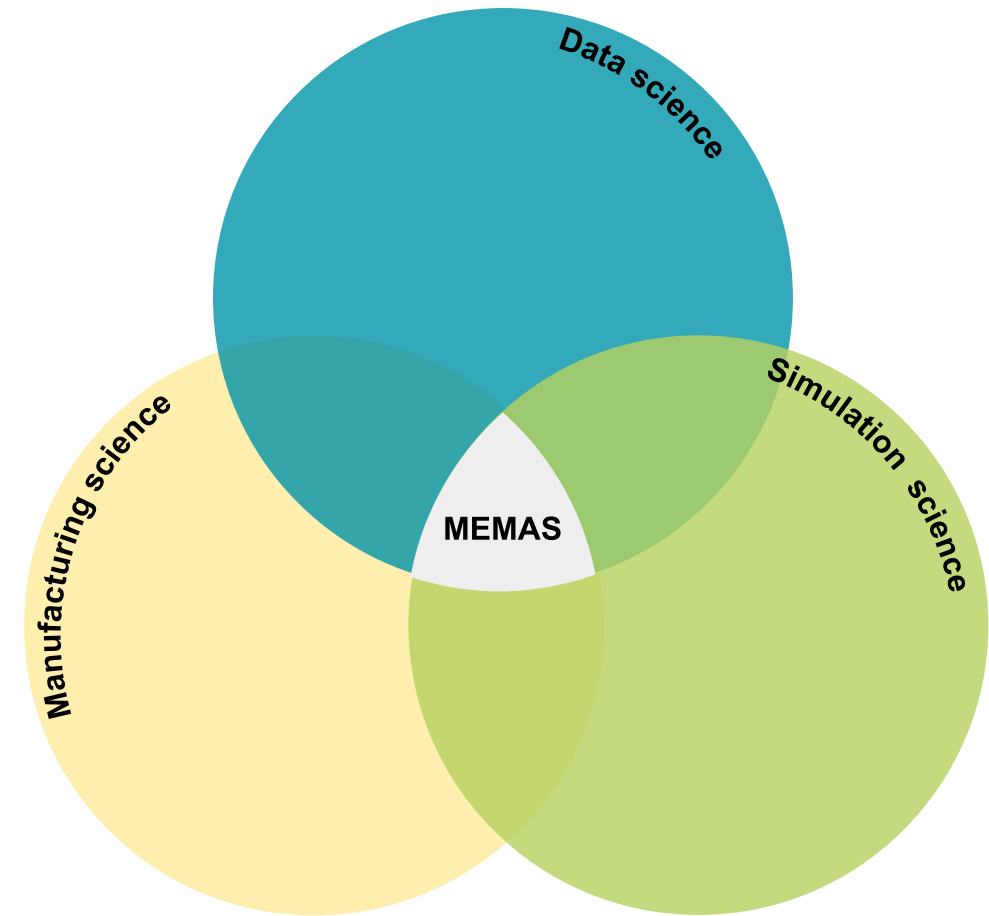
**Project MEMAS** - Metadata Enriched Manufacturing data for Automated Simulation



# Presentation of project partners



- **DLR BT-SIN (aeronautic):**  
Mathieu Vinot – Project Lead
- **DLR BT-AQP (aeronautic):**  
Roland Glück
- **DLR FK-FLK (transport):**  
Nicolas Unger, Pradnil Kamble



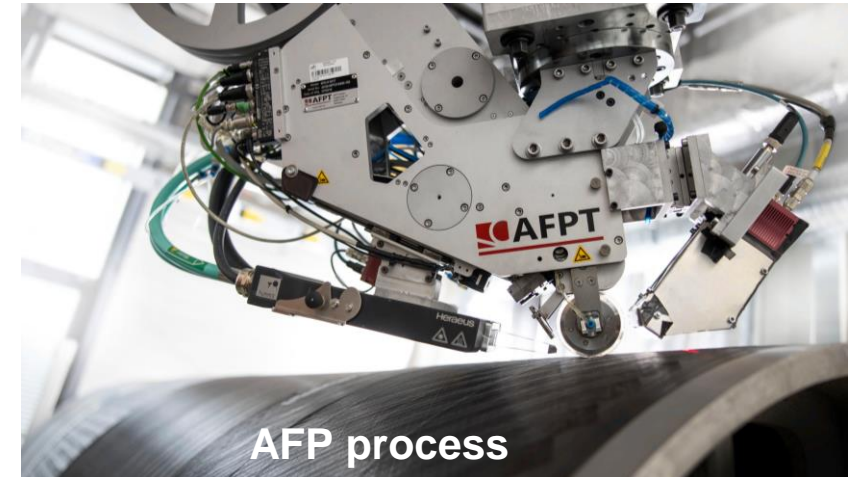
# Project MEMAS – Goals



- Create digital models of each individual manufactured part to increase confidence in simulation and improve manufacturing quality
- Develop a metadata-based simulation framework

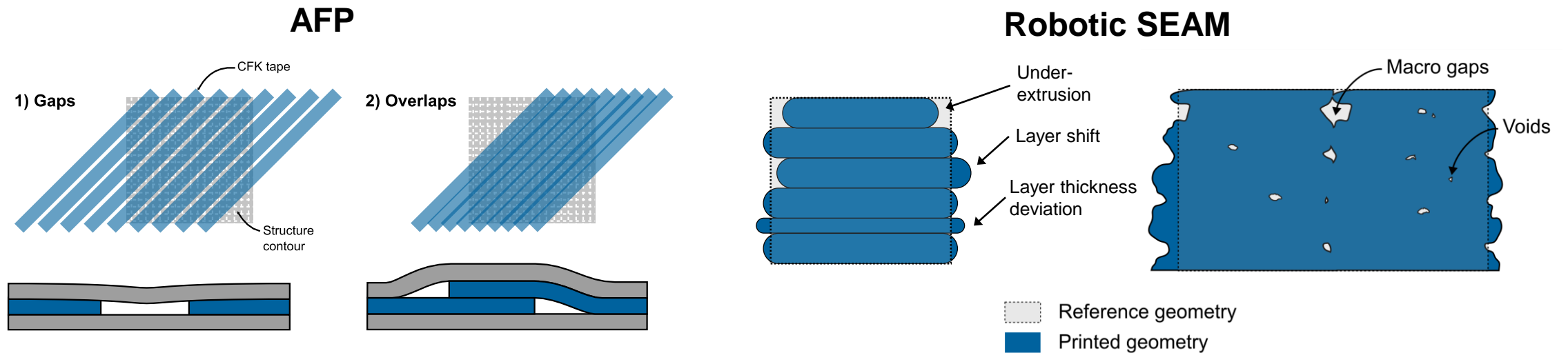
## Complex manufacturing processes

1. Automated Fiber Placement (AFP)
2. Robotic Screw Extrusion Additive Manufacturing (SEAM)



# Why individual models?

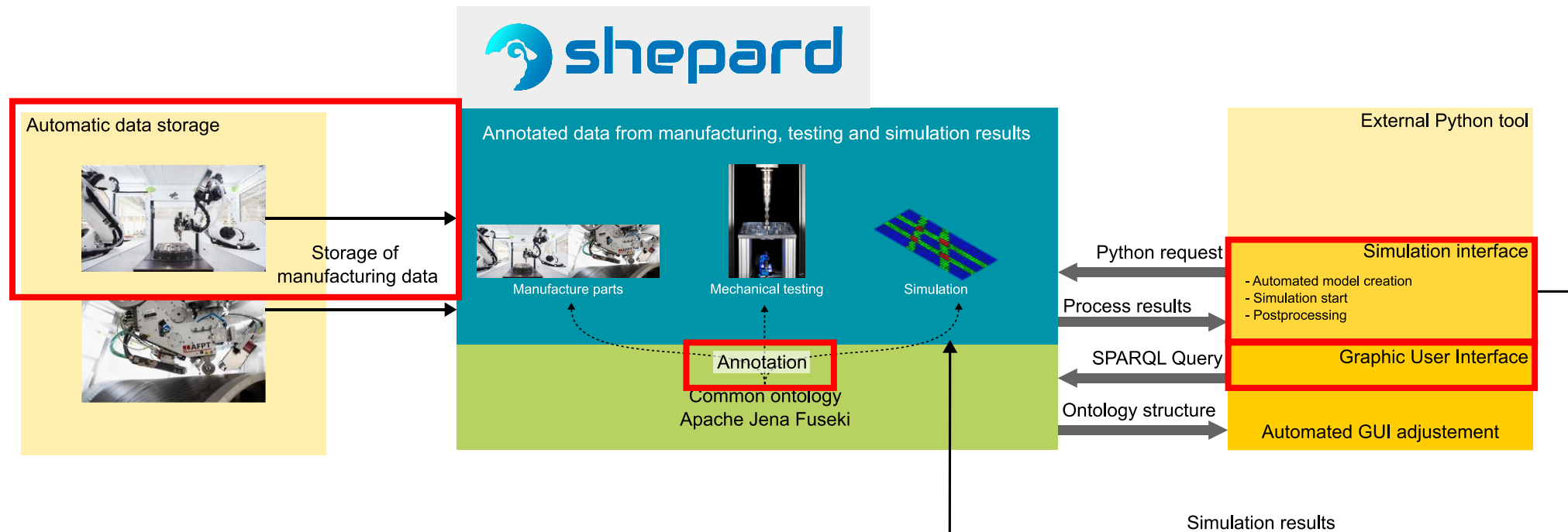
- Large influence of manufacturing parameters on the quality of the end product
- Local defects have global effects on part performance



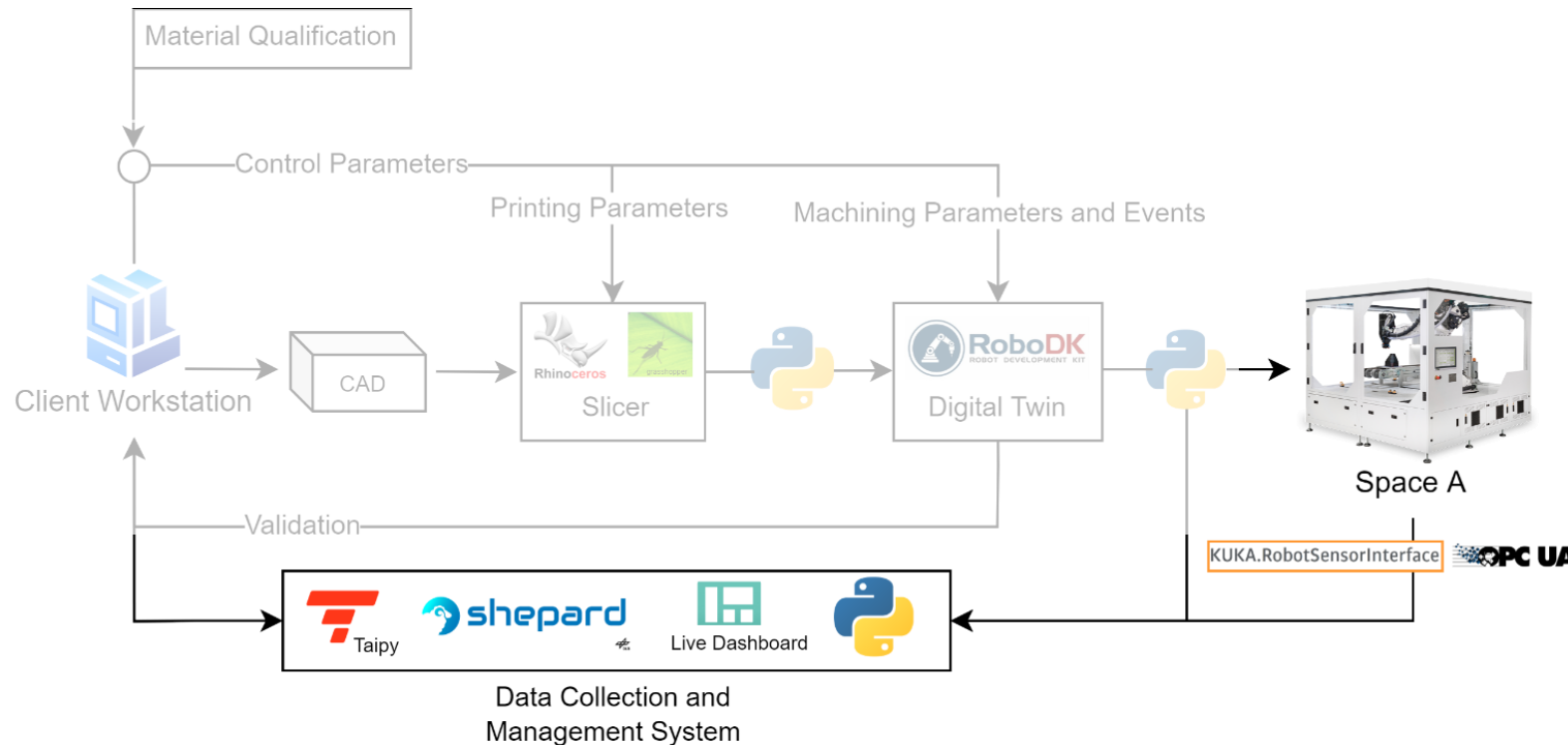
- Estimation of defects from data:
  - direct measurement (e.g. robot data)
  - derivation through analytics and process models (e.g. extrusion data)

# The MEMAS approach

- Develop a common platform for manufacturing, test and simulation data
- Use of metadata and a common ontology to bridge the different fields
- Automated acquisition and annotation of heterogeneous data
- FAIR data storage and individual tools & interfaces



# Data Acquisition – Technical Details



## KUKA.RobotSensorInterface

- Real-time monitoring and control
- High temporal data resolution
- Absolute velocities and accelerations
- Actuator and motor currents reflecting the operational status

## OPC UA

- Open, cross-platform standard
- Secure and reliable data exchange
- Actual and target temperatures across different zones
- Motor RPMs and operational statuses
- Cooling degrees and sensor outputs



- Python open-source library designed for easy development of data-driven web applications
- Covers both front-end and back-end
- Can handle for large data-sets



- multi-database storage system for highly heterogenous research data and related metadata
- Developed at DLR BT
- Open-source

# Data Acquisition GUI



## **Control data acquisition and systematically store data to database adhering to FAIR principles**

- Create projects, parts, materials etc.
- Add metadata & additional heterogeneous data (e.g. CAD)
- Configure manufacturing data collection
- Toggle data recording
- Perform analytics

# Data Acquisition GUI – New Build Studio



Overview New Build Studio Data Control Centre Real Time Record Analytics

Menu Overview New Build Studio Data Control Center Record Real Time Analytics

## Add new Project, Part, Material, Applicator, or Extruder.

PROJECT PART MATERIAL APPLICATOR EXTRUDER

### Create Project

Enter Project name \* :

Enter description \* :

CREATE NEW PROJECT

### Add Material

Enter material name \* :

Enter manufacturer \* :

Enter matrix \* :

Enter fiber type \* :

Enter fibre volume fraction \* :

Reinforced \* : ?  
▼

ADD NEW MATERIAL



# Data Acquisition GUI – New Build Studio



The screenshot shows the 'New Build Studio' interface. At the top, there are navigation buttons: Overview, New Build Studio (active), Data Control Centre, Real Time Record, and Analytics. A sidebar on the left contains a menu with options: Menu, Overview, New Build Studio (active), Data Control Center, Record Real Time, and Analytics. The main content area is titled 'Add new Project, Part, Material, Applicator, or Extruder.' Below this title are tabs for PROJECT, PART, MATERIAL (active), APPLICATOR, and EXTRUDER. The 'Create Project' section has input fields for 'Enter Project name \*' and 'Enter description \*', with a 'CREATE NEW PROJECT' button. The 'Add Material' section has input fields for 'Enter material name \*', 'Enter manufacturer \*', 'Enter matrix \*', 'Enter fiber type \*', and 'Enter fibre volume fraction \*', along with a 'Reinforced \*?' dropdown and an 'ADD NEW MATERIAL' button.

This screenshot shows the 'Materials' collection page. The breadcrumb is 'Collections / Collection'. The title is 'Materials' with a back arrow. Below the title are icons for adding, deleting, editing, and viewing. The collection ID is 1216, and it was created on Tue Dec 05 2023 by Remanan Kumary Asha, Aravind, and updated on Fri Dec 08 2023 by Remanan Kumary Asha, Aravind. The Shepard logo is visible. Under 'Attributes', there is a table with 'Object type' as 'is\_materials'. Under 'Data Objects', there is a pagination control showing '1' of 25 items, sorted by 'Created At' in ascending order. A specific data object is highlighted: 'Akromid B3 ICF 30 AM' with ID 1358, created on Fri Dec 08 2023 by Unger, Nicolas, and having 11 references.

This screenshot shows the details for the 'Akromid B3 ICF 30 AM' Data Object. The breadcrumb is 'Collections / Collection / DataObject'. The title is 'Akromid B3 ICF 30 AM' with a back arrow. Below the title are icons for adding, deleting, editing, and viewing. The Data Object ID is 1358, created on Fri Dec 08 2023 by Unger, Nicolas, and updated on Mon Dec 11 2023 by Remanan Kumary Asha, Aravind. The Shepard logo is visible. Summary statistics show 0 Parents, 0 Children, 0 Predecessors, 0 Successors, and 2 References. Under 'Attributes', there is a table with the following data:

Key	Value
is_reinforced	True
fibre_volume_fraction	30
Object type	is_material
matrix	Polyamide 6
manufacturer	Akroplastic
fibre_type	Carbon

# Data Acquisition GUI – Real Time Record



INSTANCE RECORD VISUALIZE

### Create Instance

Select Project:

Select Part:

Enter instance name \*:

Enter description \*:

Select Machine:

Select Applicator:

Slicing Operator \*:

Completed?:

Select Material:

Select Cell:

Slicing Tool \*:

Confidential?:

Filter by Material distributor:

Filter nozzle by diameter:

Intended use:

Filter by Material Matrix:

Select Extruder:

Filter nozzle by length:

Notes:

CREATE INSTANCE

**Tips:**

- Fields marked with \* are mandatory
- Use filter dropdowns if necessary
  - for Material (Distributor or Matrix).
  - for Applicator (Shape, Diameter or Length).

- Create instance of a part
- Add relevant metadata, such as Material, Nozzle, Robot Base
- Configure and start data acquisition

Collections / Collection / Parent / DataObject

### Block\_1

Data Object ID: 2797  
created at Mon May 20 2024 by [redacted]

1 Parents 0 Children 0 Predecessors 0 Successors 73 References

#### Description

First trial

#### Attributes

Key	Value
Description	First trial
Completed	True
Slicing Tool	Rhino
Object type	is_instance
Slicing Operator	Aravind
Created by	[redacted]
Confidential	False
Intended Use	NA
Name	Block_1
Created at	2024-05-20 19:29:54

#### Parent

**Small Block Print** ID: 2792  
created at Mon May 20 2024 by Remanan Kumary Asha, Aravind

#### Related Objects

Children Predecessors Successors

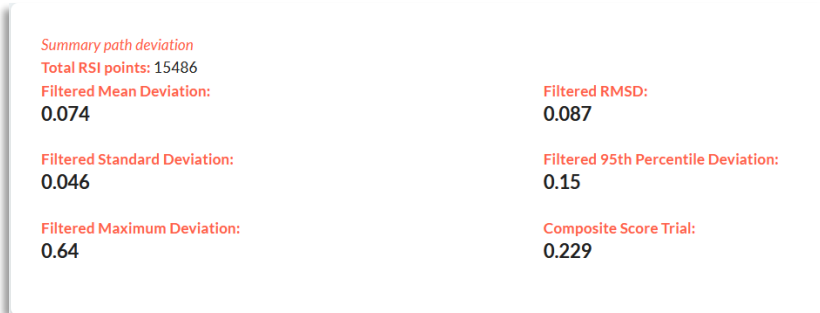
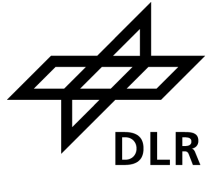
#### References

Timeseries 67 Structured Data 2 File 1 URI 0 Collection 0 Data Object 3

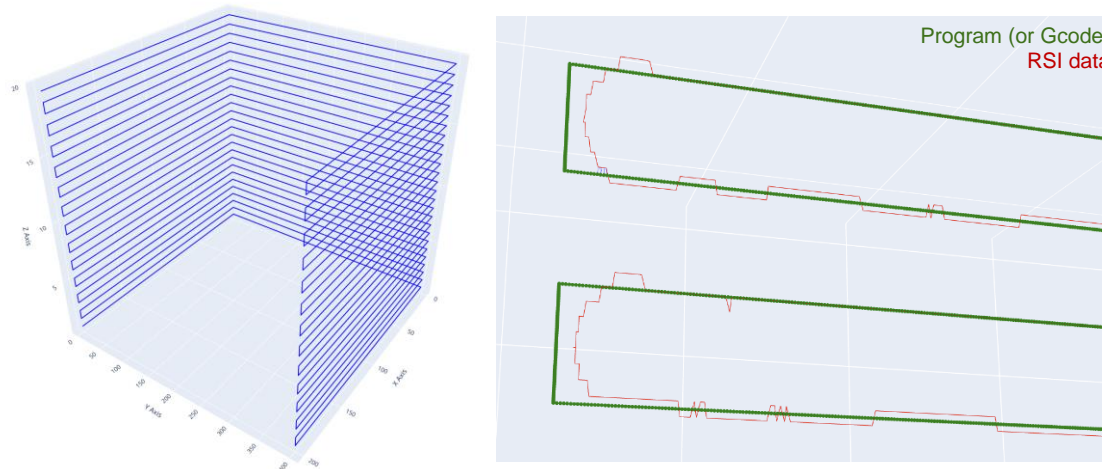
Create new Reference

- geometric\_complexity.json** | ID: 2907 | Container: 2904  
created at Mon May 20 2024 by Remanan Kumary Asha, Aravind
- pathdeviation.json** | ID: 2898 | Container: 2895  
created at Mon May 20 2024 by Remanan Kumary Asha, Aravind

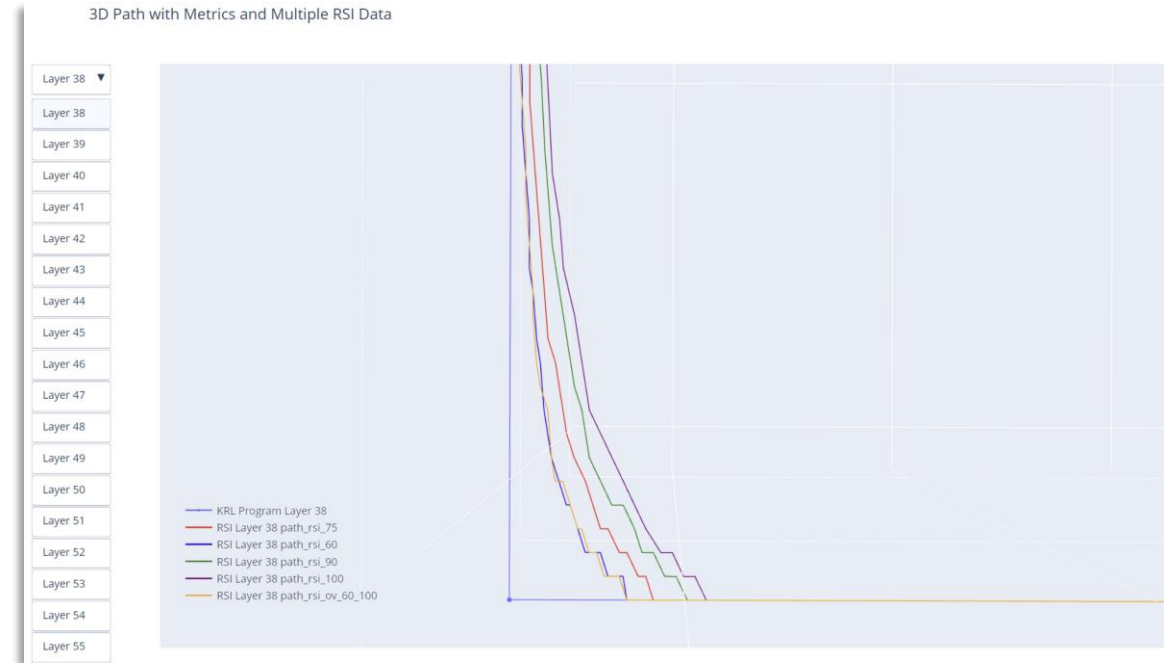
# Data Acquisition GUI – Analytics



Path deviation summary as per customized metrics



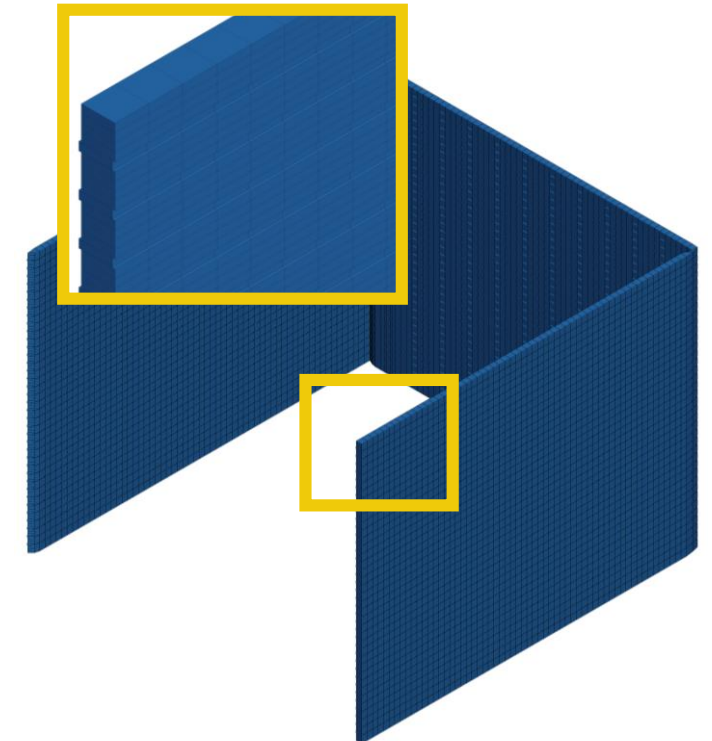
Path deviation comparison of nominal paths that is the SRC code to actual positioning captured within RSI data



Layer by layer comparison of multiple instances (with varying velocity) for path deviation to nominal – visualization of velocity effect over path deviation at higher reorientation

# Simulation Creation GUI

- Selection of part to be simulated and automatic recognition of process type based on semantic used
- User input about degree of detail in simulation model and actual/ideal geometry



# Simulation Creation GUI



- Storage of simulation model back into shepard with semantic annotations
- Use of software neutral data formats for finite-element mesh data

Collections / Project MEMAS - SEAM / Part SEAM MEMAS

## Part SEAM MEMAS

Data Object ID: 699547  
created at Thu Jun 13 2024 by Vinot, Mathieu  
updated at Mon Jun 24 2024 by Vinot, Mathieu

1 Parents 0 Children 0 Pr

is instance of Part is manufactured by Screw extrusion additive manu

### Structured Data Reference

#### Parent

Part ID: 699545  
created at Thu Jun 13 2024 by Vinot, Mathieu

#### Related Objects

Children Predecessors Successors

#### References

Timeseries 2 Structured Data 1 File 0

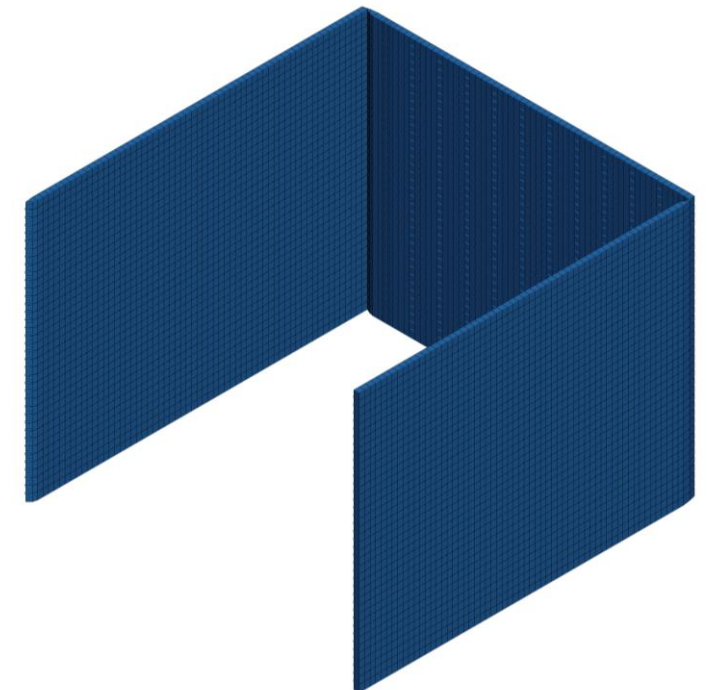
Create new Reference

finite\_element\_data | ID: 699940 | Container: 6999  
created at Fri Sep 20 2024 by Vinot, Mathieu

```
Tree
Select a node...
object {4}
  _id {1}
  fe.node [1160]
  fe.elem.solid.hex8 [288]
  _meta {2}
```

### Structured Data Reference

```
Tree
object fe.elem.solid.hex8 0
  object {4}
    _id {1}
    fe.node [1160]
    fe.elem.solid.hex8 [288]
      {10}
        EID : 1
        G1 : 1
        G2 : 2
        G3 : 147
        G4 : 146
        PID : 1
        G5 : 291
        G6 : 292
        G7 : 437
```



created at: 20/09/2024, 12:13:41

# Conclusion and Outlook



- Implemented a FAIR data storage for heterogeneous data in shepard IDMS
- Created an application-oriented ontology for the manufacturing, testing and simulation of composite structures
- Developed a data acquisition & metadata annotation pipeline for Robotic SEAM
- Developed GUIs for pipeline configuration, data analytics and simulation model creation
  
- Manufacturing of a hybrid structure with AFP and Robotic SEAM for concept validation
- Expansion of the framework, analytics & simulation tools