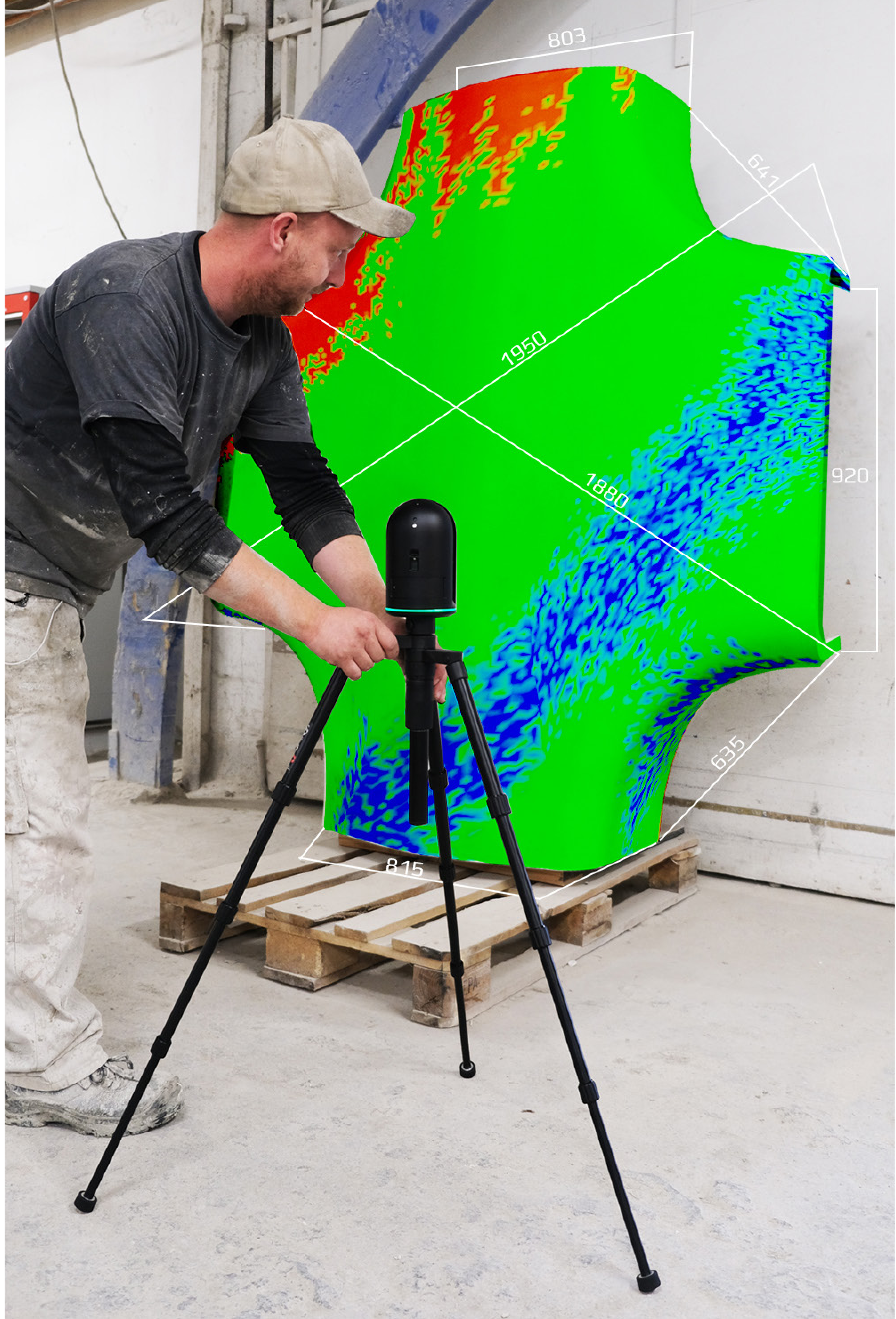
Precision Partner

enhancing GFRC craftsmanship with Industry 4.0 factory-floor feedback



CITA Royal Danish Academy of Fine Arts (KADK)

in collaboration with

InnoBYG Innovationsnetværket for bæredygtigt BYGGERI

About

PrecisionPartner is a Spireprojekt funded by Innovations Netværk for Bæredygtigt Byggeri (InnoByg), and is a collaboration between the following partners

CITA Centre for Information Technology and Architecture
Computation and digital technologies

BB Fiberbeton AS
Fiber reinforced concrete manufacturing

TickCad ApS
3d scanning technologies

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Project Statement

PrecisionPartner explores how skilled hand craft processes can be integrated with and gain value from the digital information chain, via introduction of Build 4.0 technologies to the factory floor.

The project addresses construction sector companies that produce or receive molds to make concrete, glass or fibre composite building elements. While digitalisation increasingly underlies the design and description of molds, their making is disconnected from the digital chain and remains a highly manual process, with skilled craftsman required to fabricate complex geometries up to 6m size at 1mm precision.

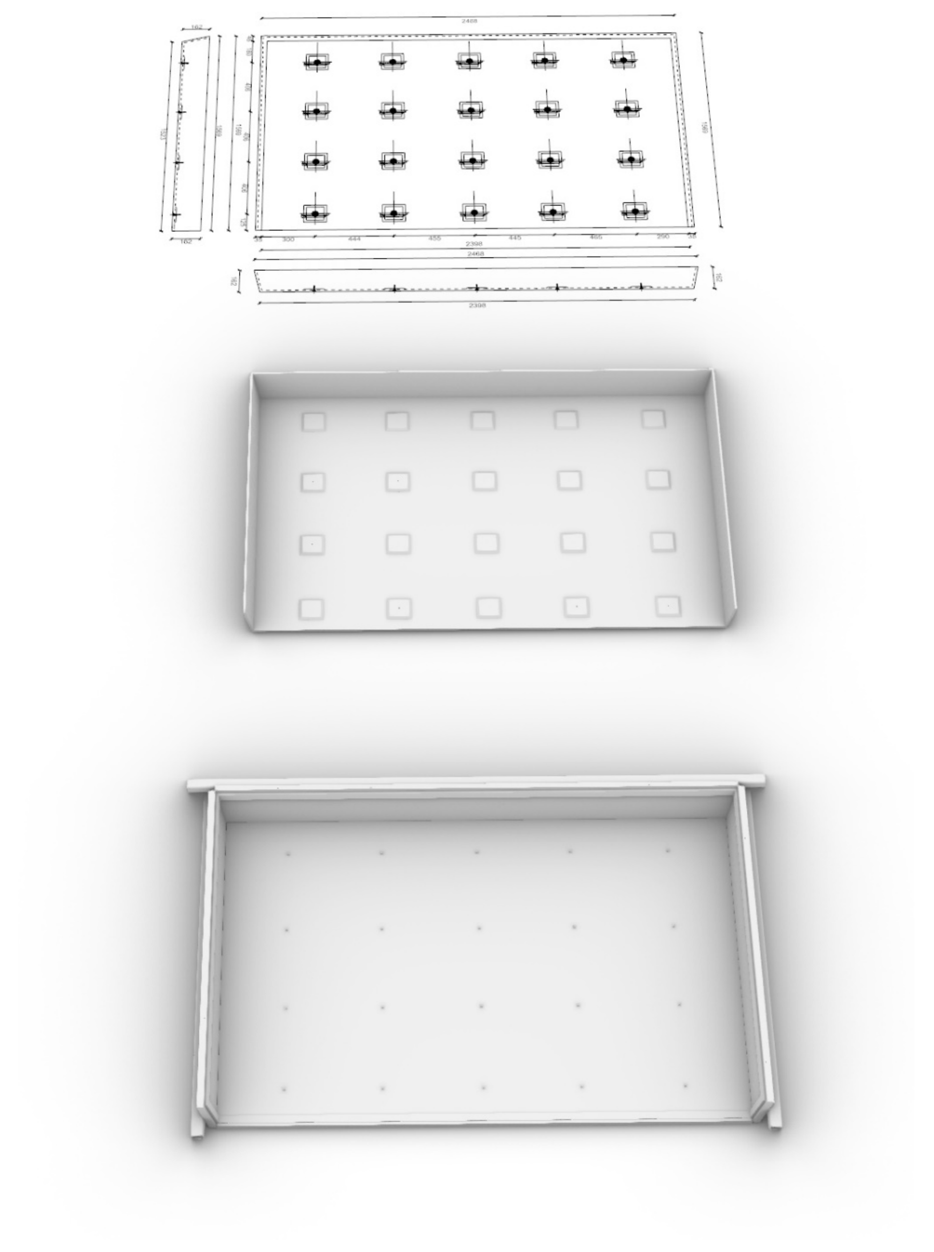
The aim of this project is to digitize the production environment and improve precision and quality control in the mold making process by enabling direct and easy measurement and verification against a digital model, from the factory floor.

Research Question: How do you reconcile skilled craft-based industries such as GRC manufacturing with higher precision digital-chain workflows?

Project Overview

The project develops a digital framework that connects three key components in the process from design data to the making of molds and investigates the potential for digitalisation and automatisation in: modelling, scanning and feedback. A key underlying idea is to digitally enhance existing processes, rather than disrupting or replacing them.

Modelling (WP1)

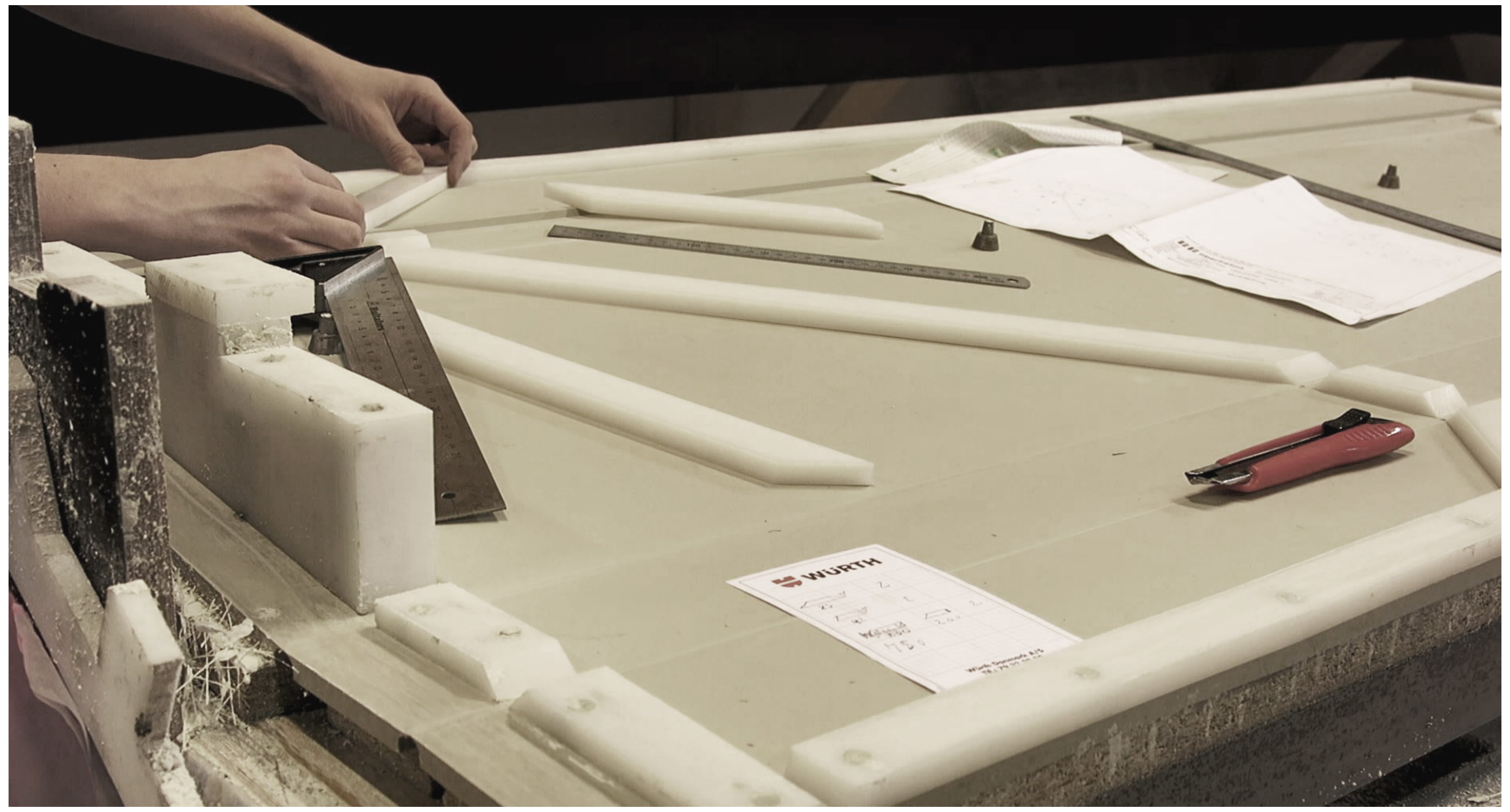


Modelling (WP2)

Modelling (WP3)

Manufacturing Context

BBF produces 70-100 GRC Elements daily (Glass Fiber reinforced concrete).Their manufacturing relies entirely on skilled handcraft. Basing themselves on 2d technical drawings, moldbuilders build the element mold directly from flat sheet materials, combining wood and plastic, cut to shape. They work to architectural tolerances of +-5mm and are hand measured constantly. Concrete is subsequently applied, and after curing the molds are tagged and assembly mounts are fixed.



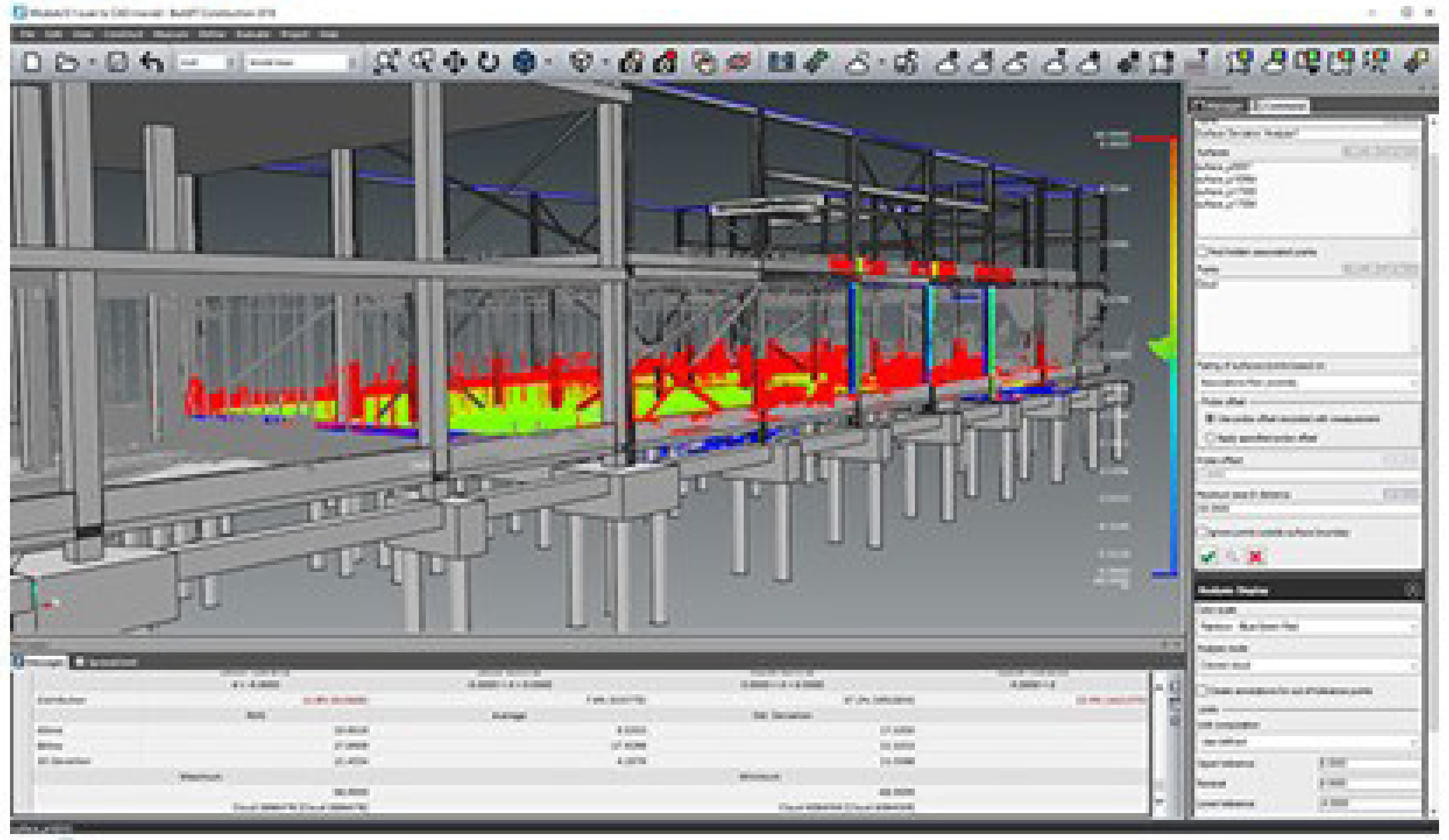
mold building process

concrete spraying and element demoulding

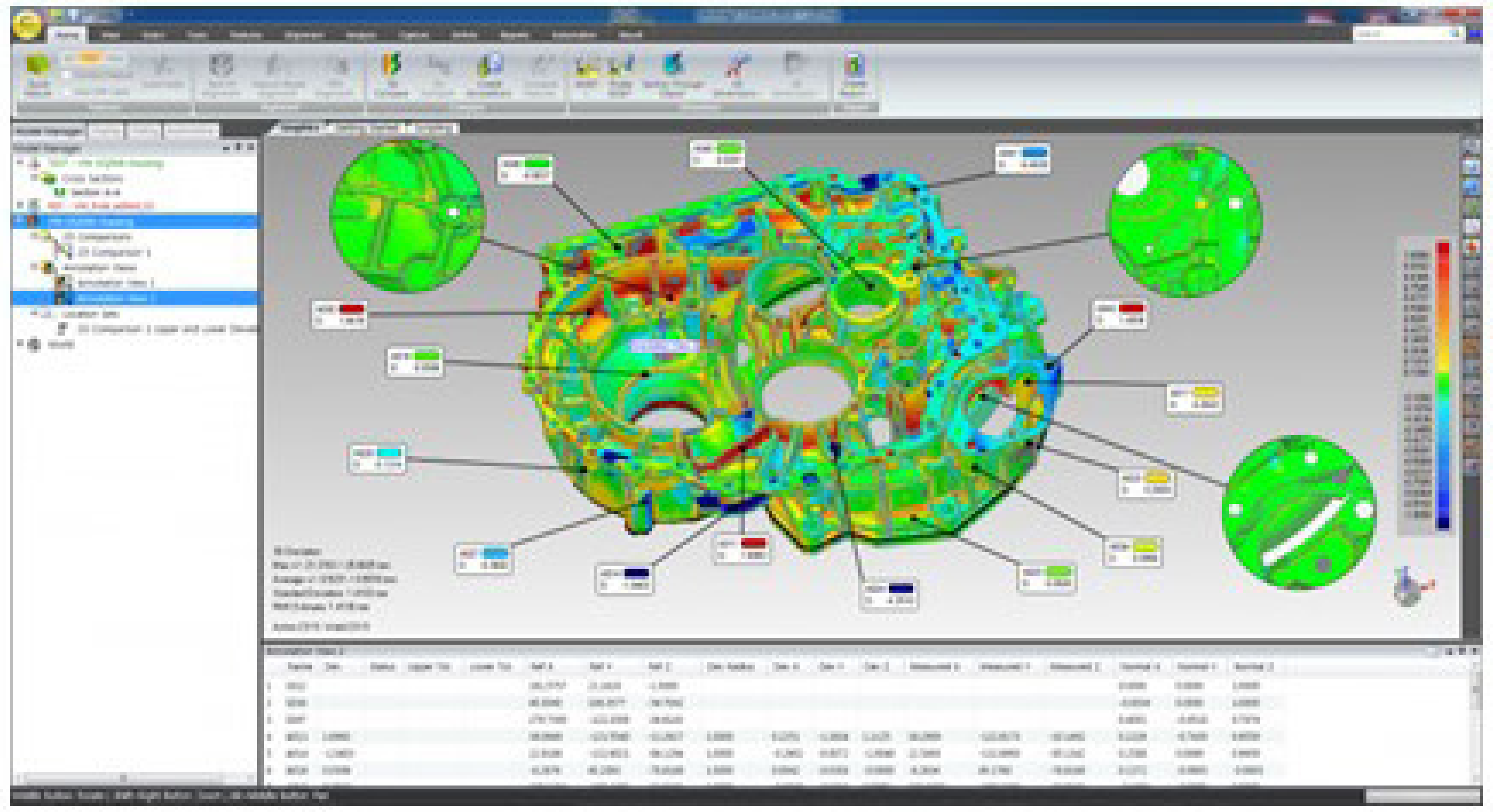
The problem: Existing Metrology takes the perspective of large scale manufacture

Contactless 3d scanning represnts the industry standard for geometrical measurement. However current approaches take the perspective of skilled technicians using advanced cad software, fully controlled environments and highly specific automatisation of measurements. But it is not appropriate for GFRC manufacture, which is based on small batchs, versioning, and quick turnarounds.

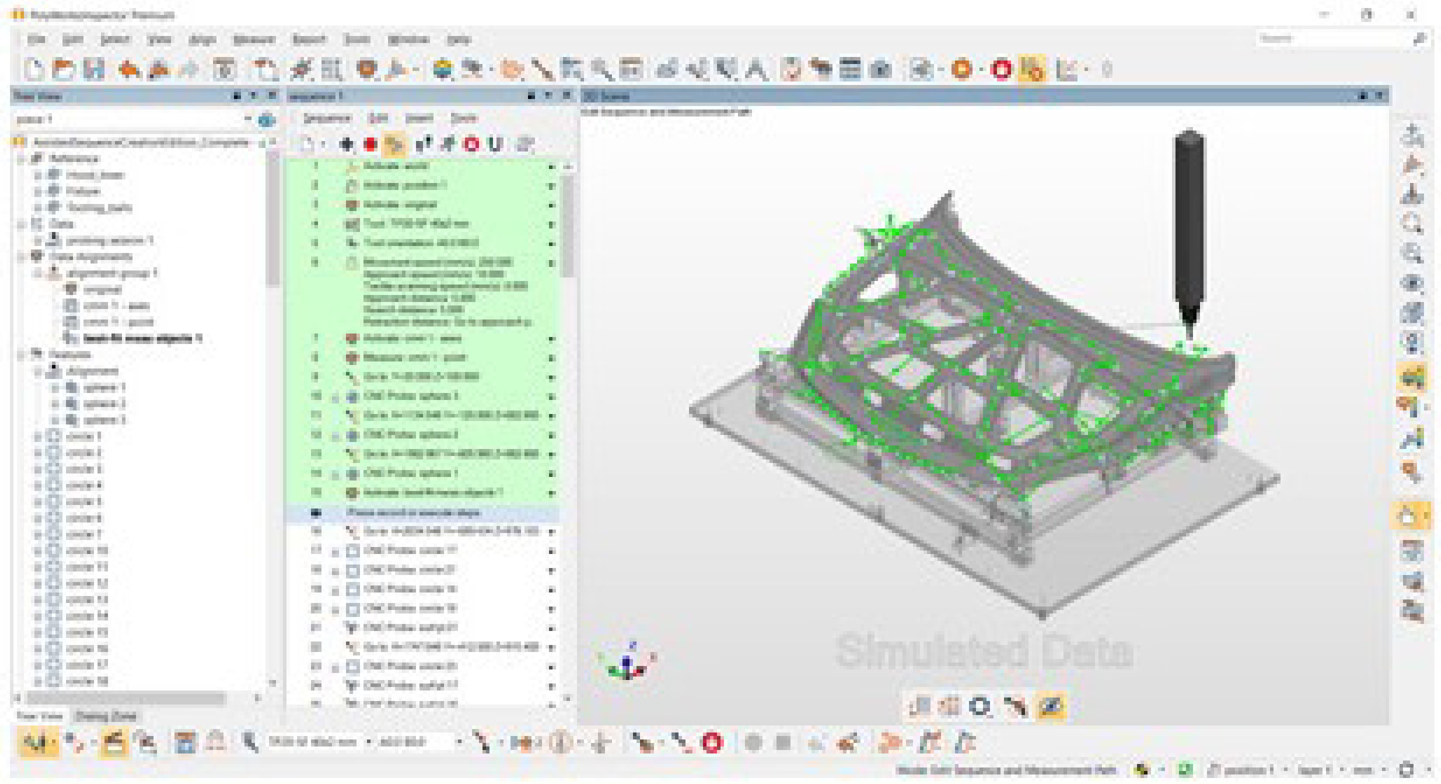
FARO



Geomagic Control X



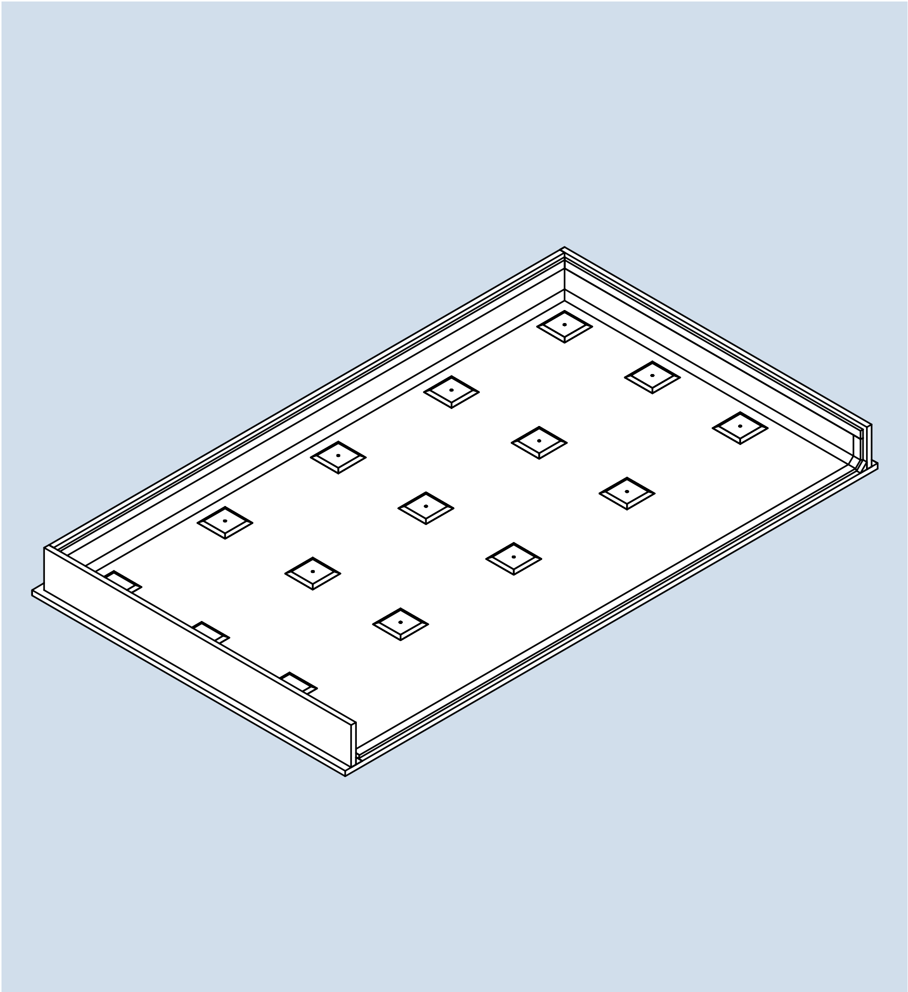
PolyWorks



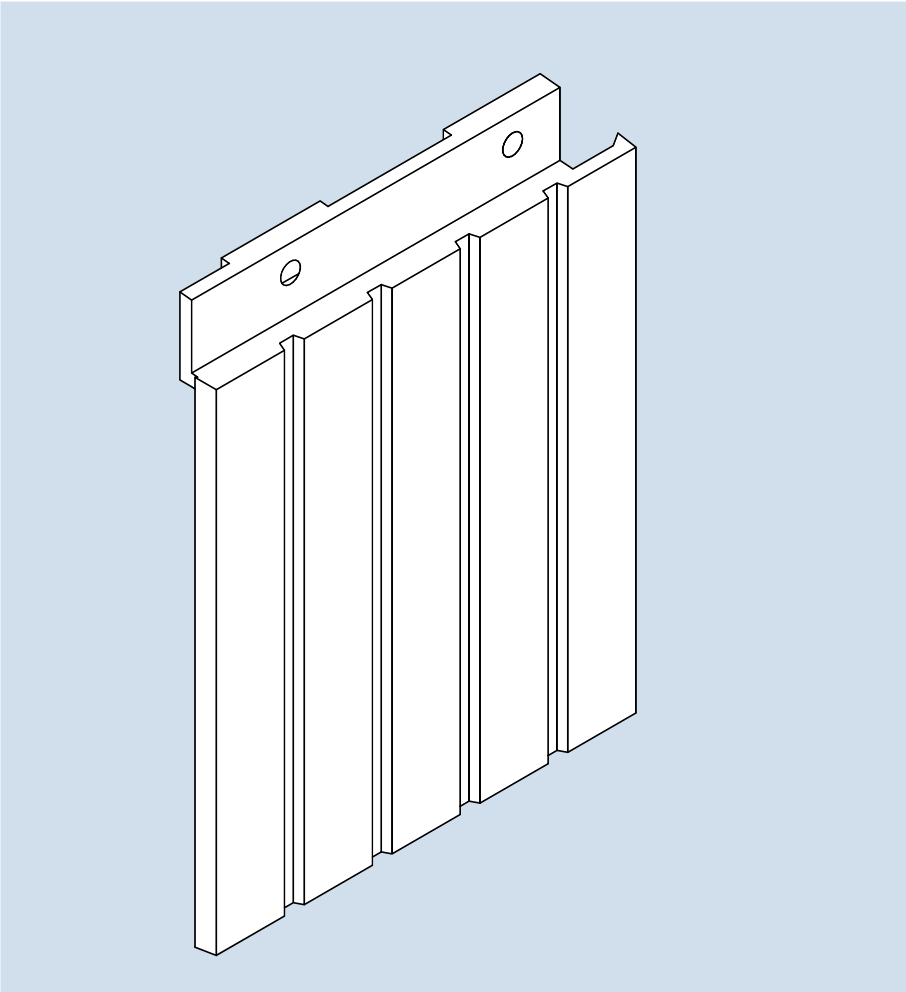
gom

The challenge: High variety, small batch size

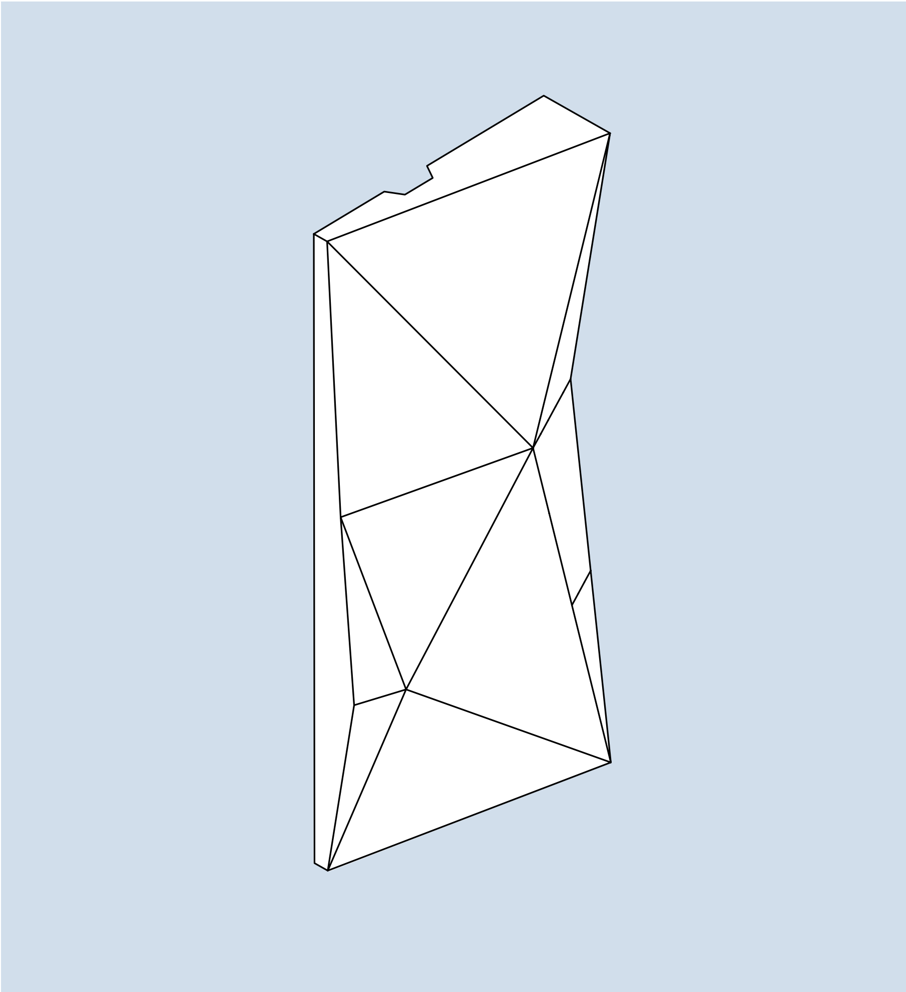
Most elements BBF produces are specific to each project. This high geometric variability makes the manufacturing and assembling of molds very difficult to automate, since, in order to effect overall cost and efficiency, molds are tweaked, and adapted so to be reused many times. The molds produced by BBF can be catergorized in the following families.



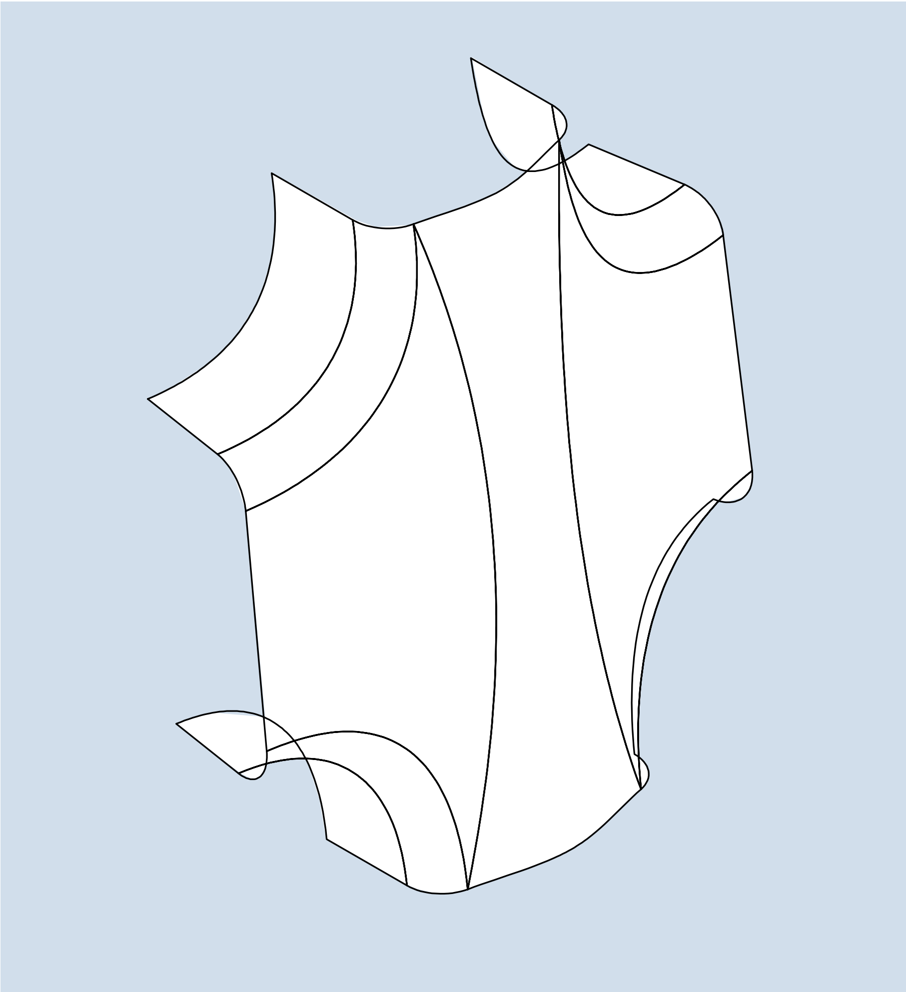
balcony panel



facade panel



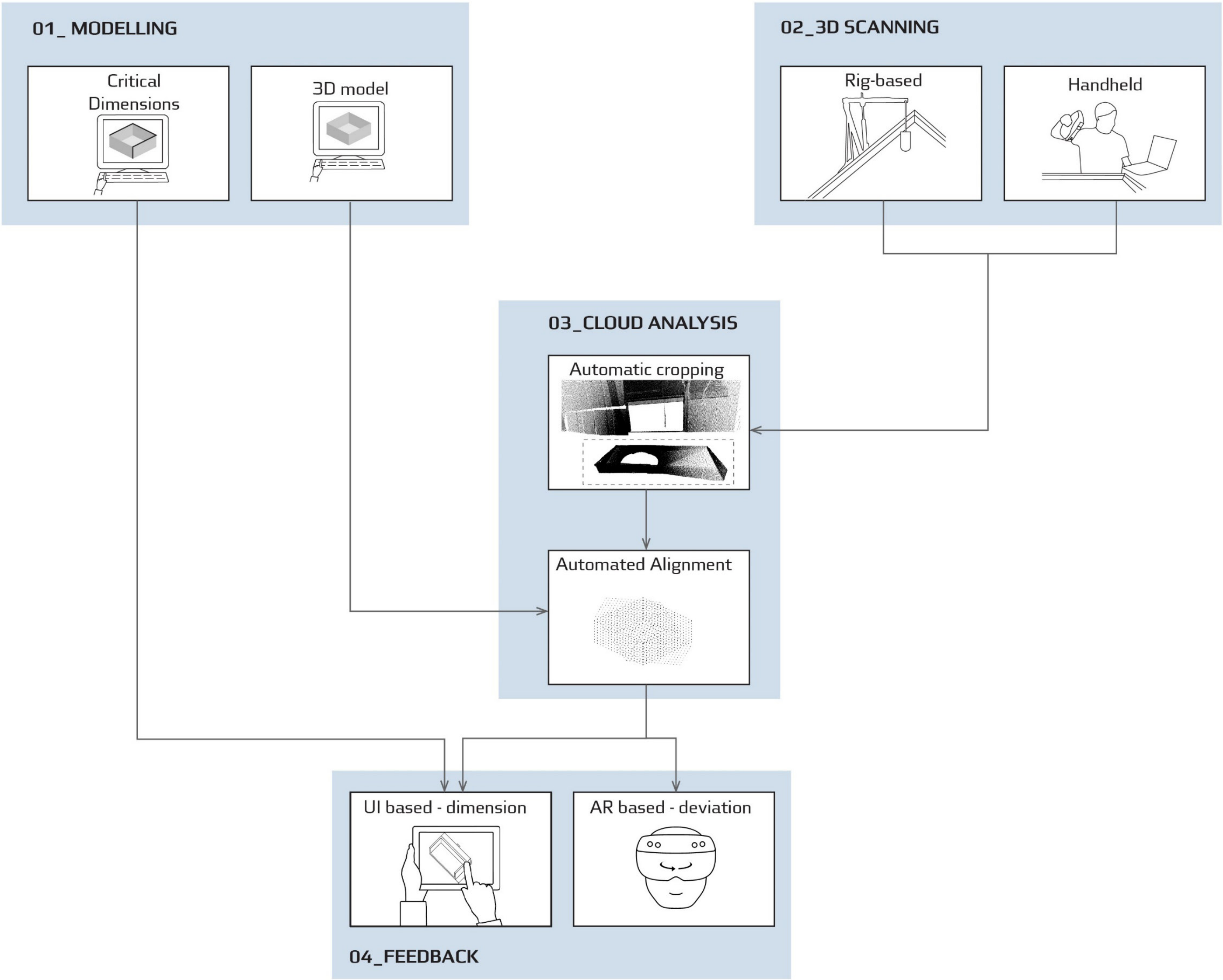
faceted panel



freeform panel

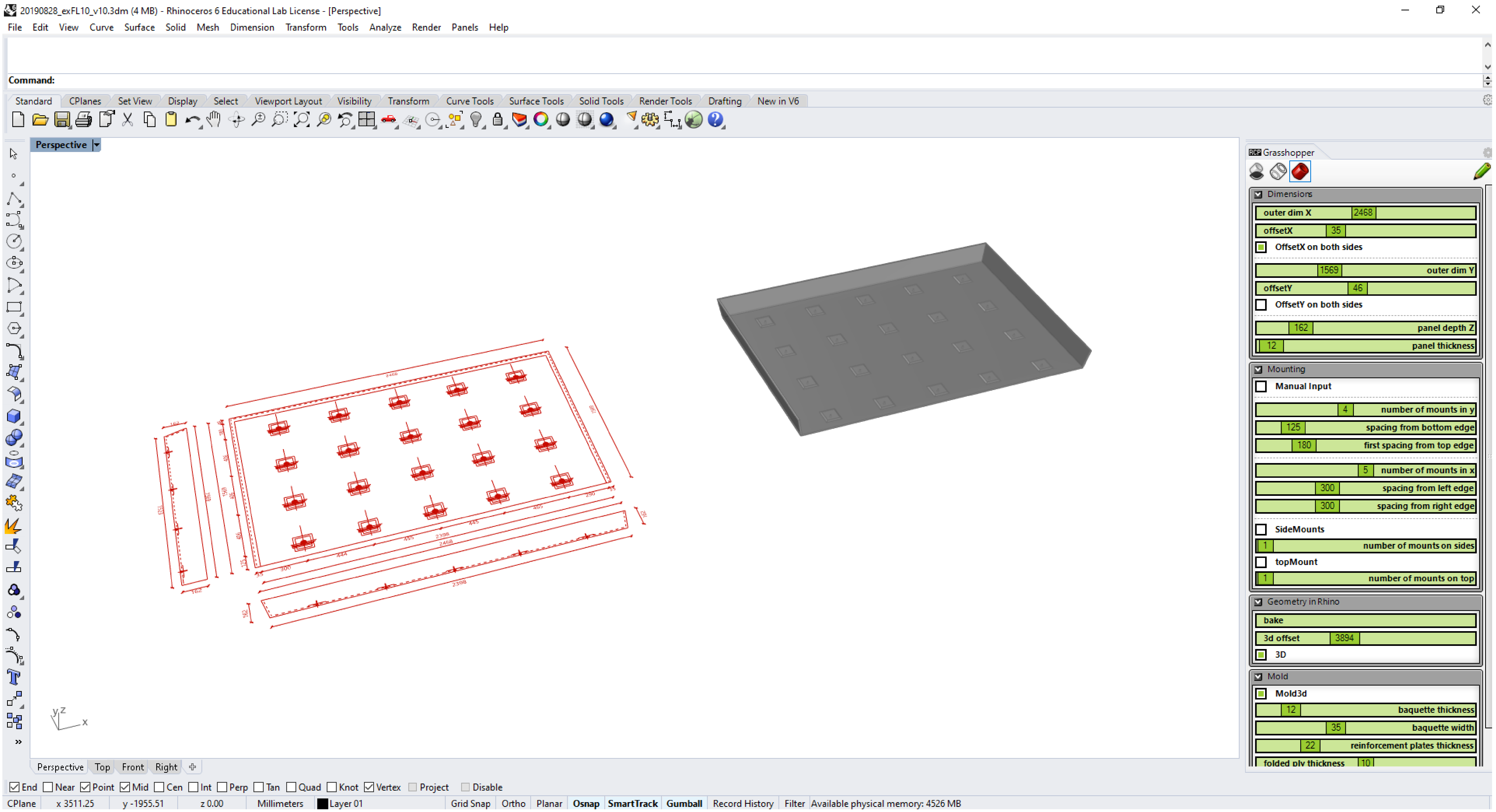
Method Overview

Precision Partner workflow establishes an automated connection between craft mold-making practice and precise, digital information, thruogh shop-floor feedback. The Framework is open ended and easily integrates with existing prodcution pipelines. It is also accessible to workforce without specialized computer skills.



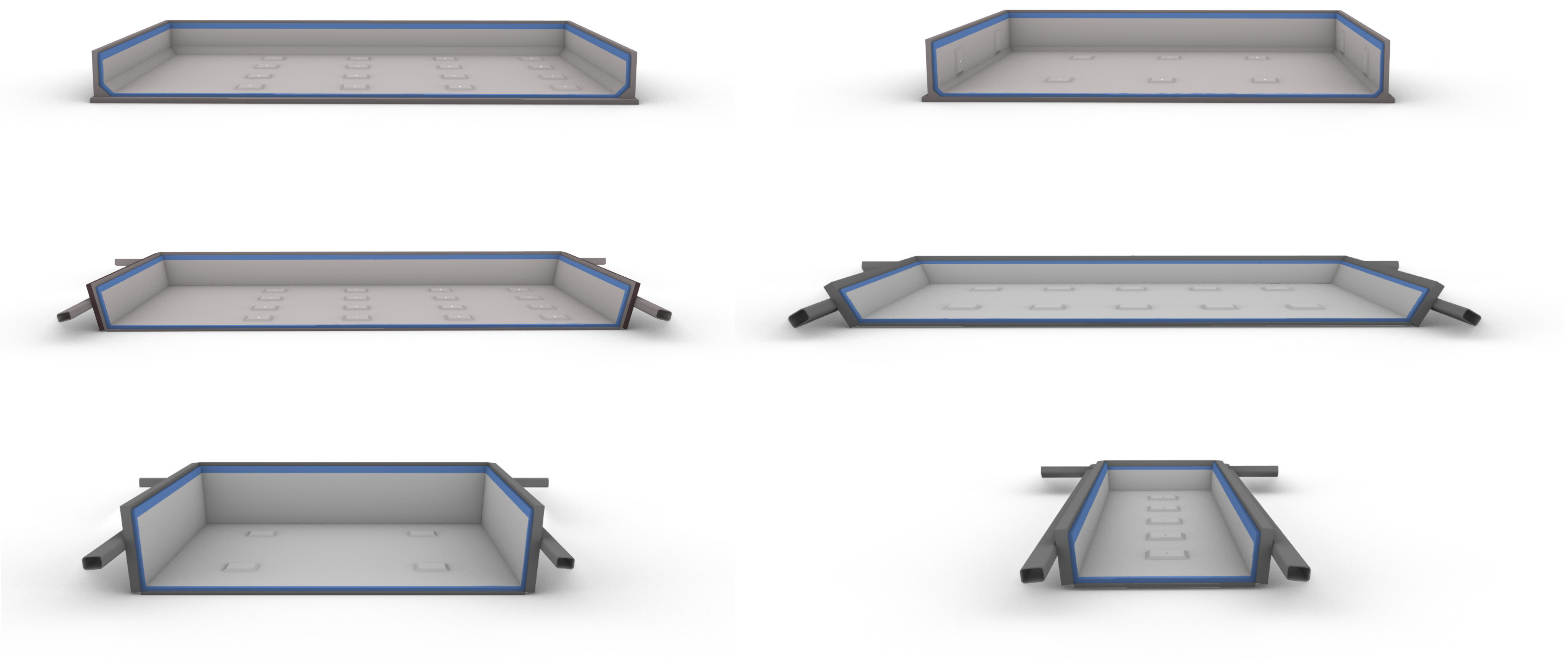
Mold configurator

Digital representation is at the core of production feedback. We create a parametric mold configurator which is able to model both the element and the mold of Balcony type elements.



Model Output

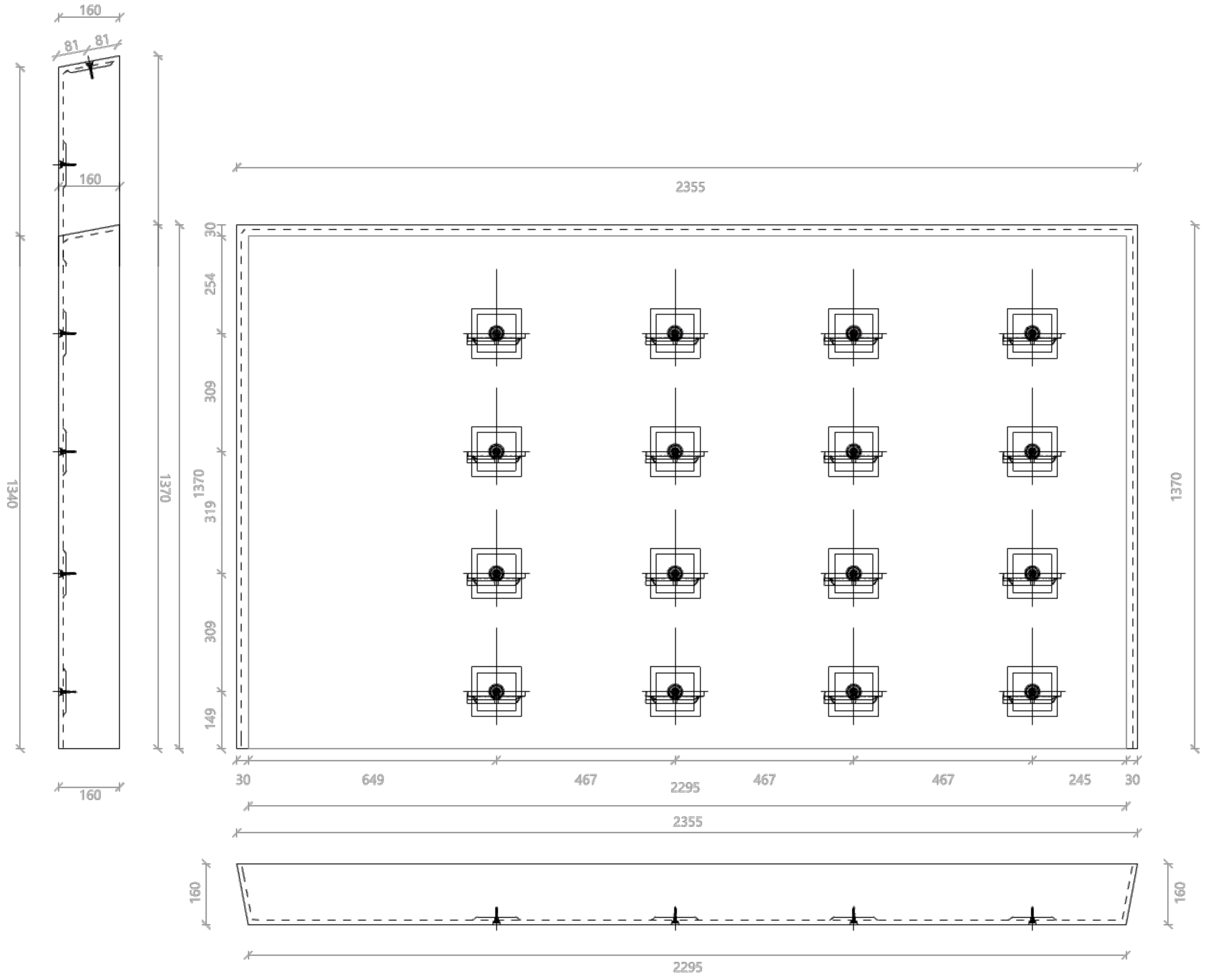
The configurator outputs digital information for the next steps of the computational process, these include the 3d model of the element, the 3d model of the mold, as well as a list of critical dimensions of the element.



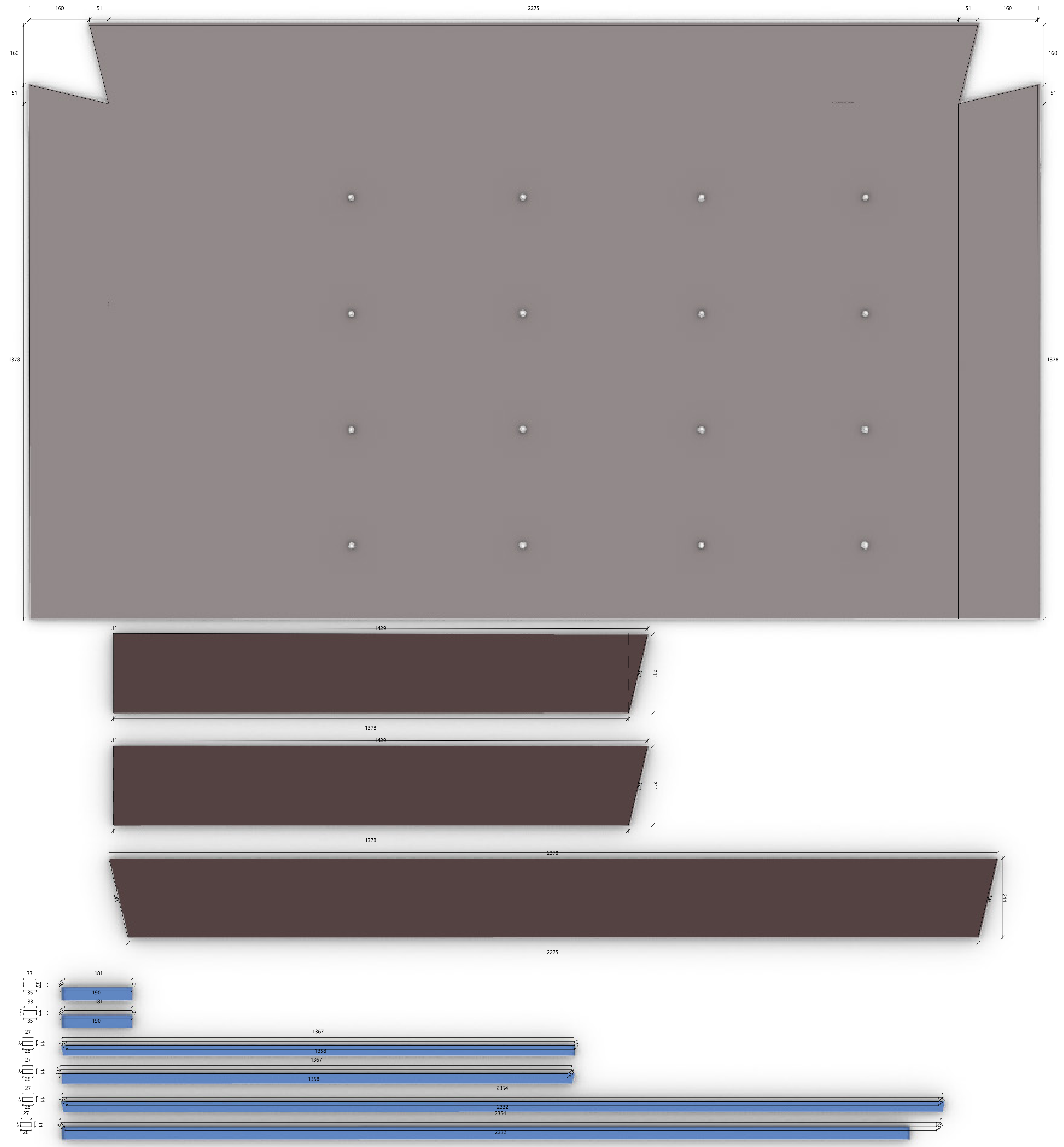
3d model of element and corresponding mold

Production output

The configurator outputs manufacturing information for the mold builders: A set of 2d drawings as well as a cutting list for the mold itself.



Technical drawing set

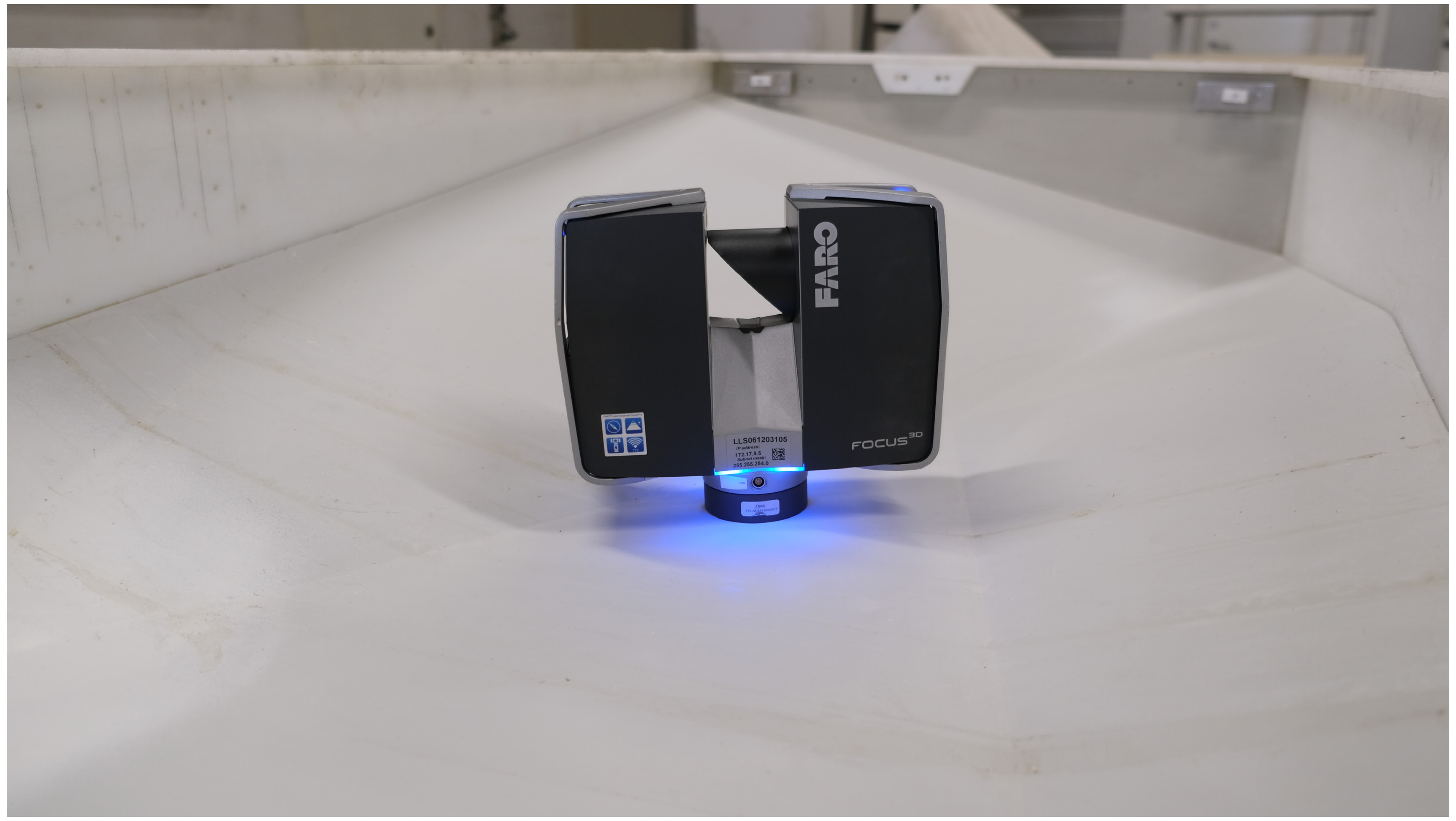


mold cutting list

Scanning FAROFocus

We test sevrall scanners to determine the best balance between quality of the scan, scanning duration and scanner dimensions in relation to the scanned element is best suited to the project.

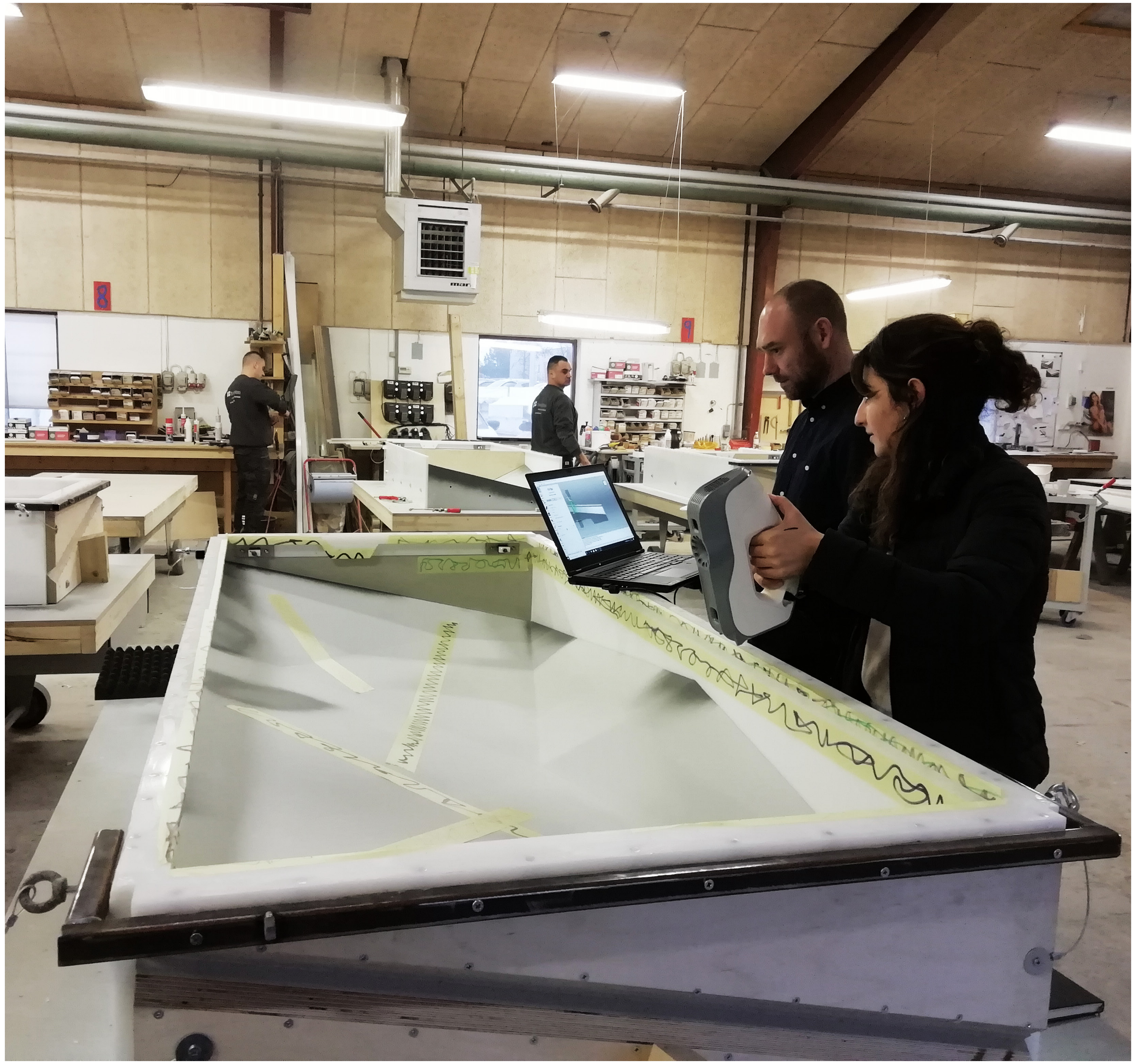
The FARO Focus 150s is Lidar-based and delivers high quality scans but the scanner is bulky and scanning time at high resolution is considerably lengthy and requires registration and post proessing.

scanning with the FARO Focus both on tripod and in element, and resulting point clouds

Scanning
ArtecEva - handheld

The Artec Eva3d is a handheld scanner which relies on photogrammetry stictching to reconstruct geometry. It is small sized and lightweight, and provides the pootential to be used for both full element scans as well as partial scans with trackers. The main limitation of the scanner was the need to add marking tape to the element mold, since the elements are without texture, which makes the scanner lose it’s calibration during the scanning.

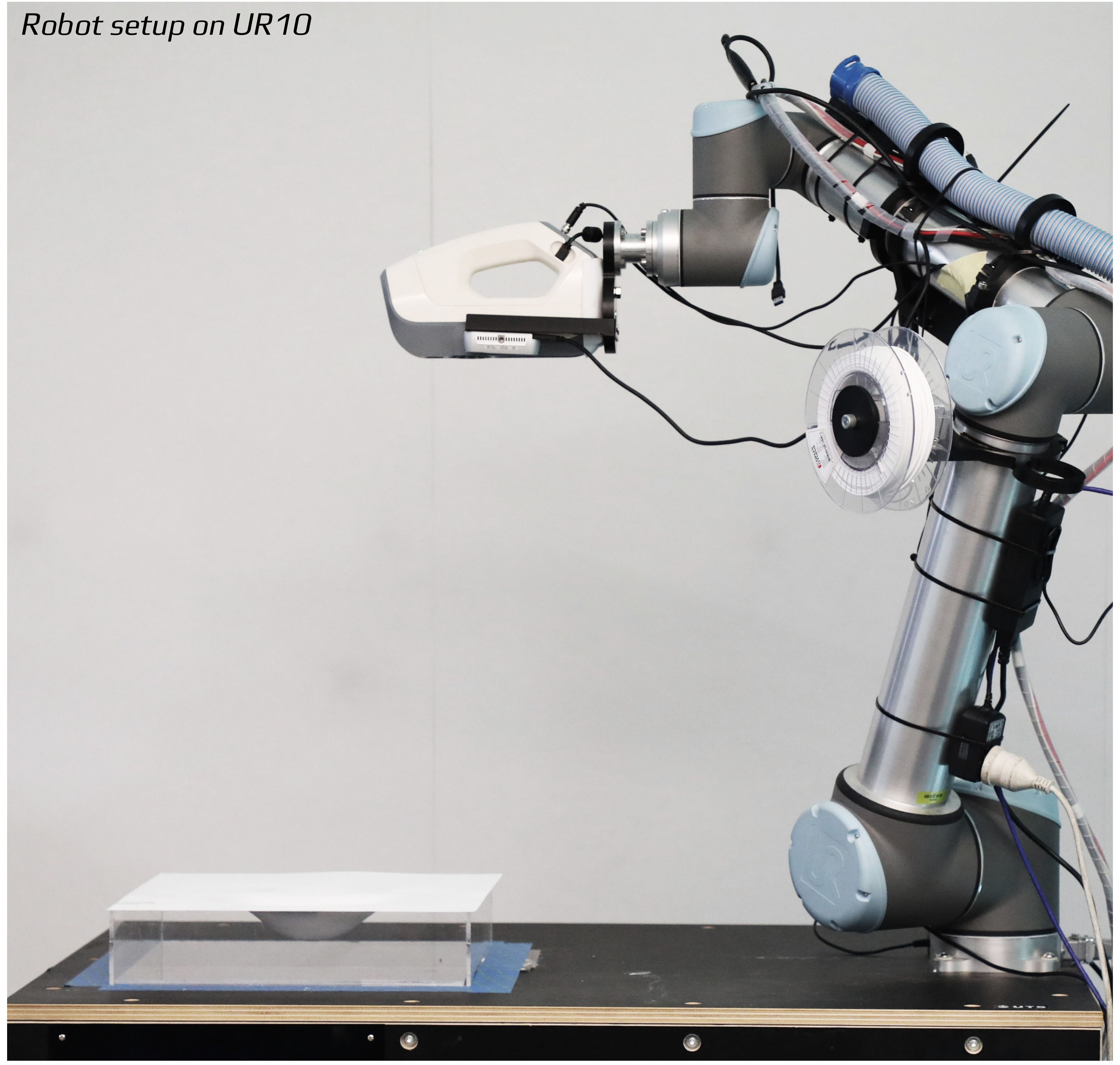


using the Artec hand held scanner

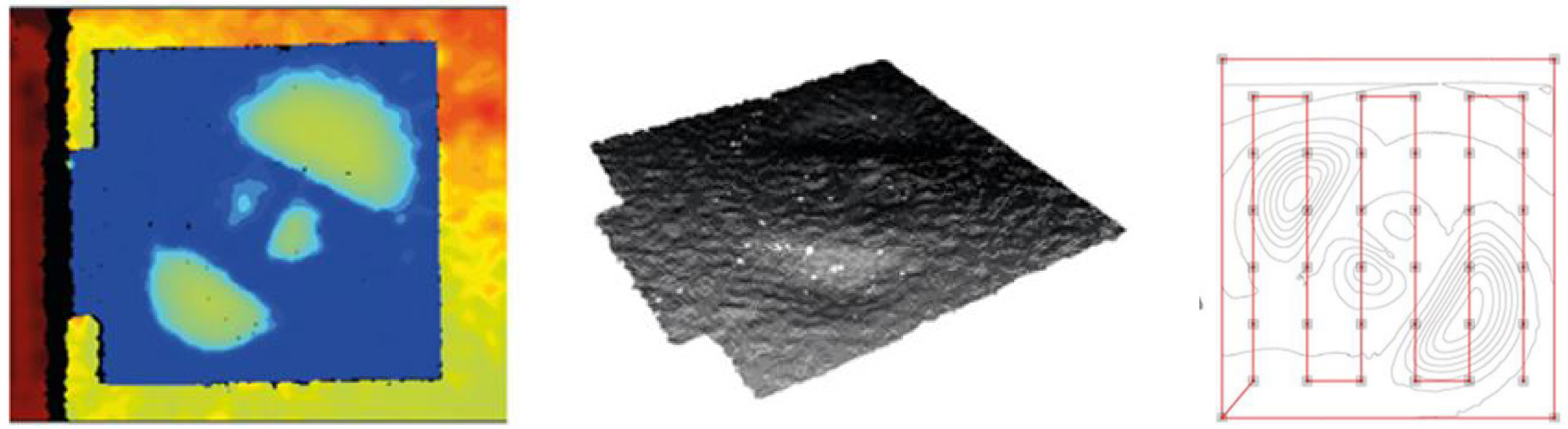
complete and partial scans of balcony element

Scanning
ArtecEva - on robot

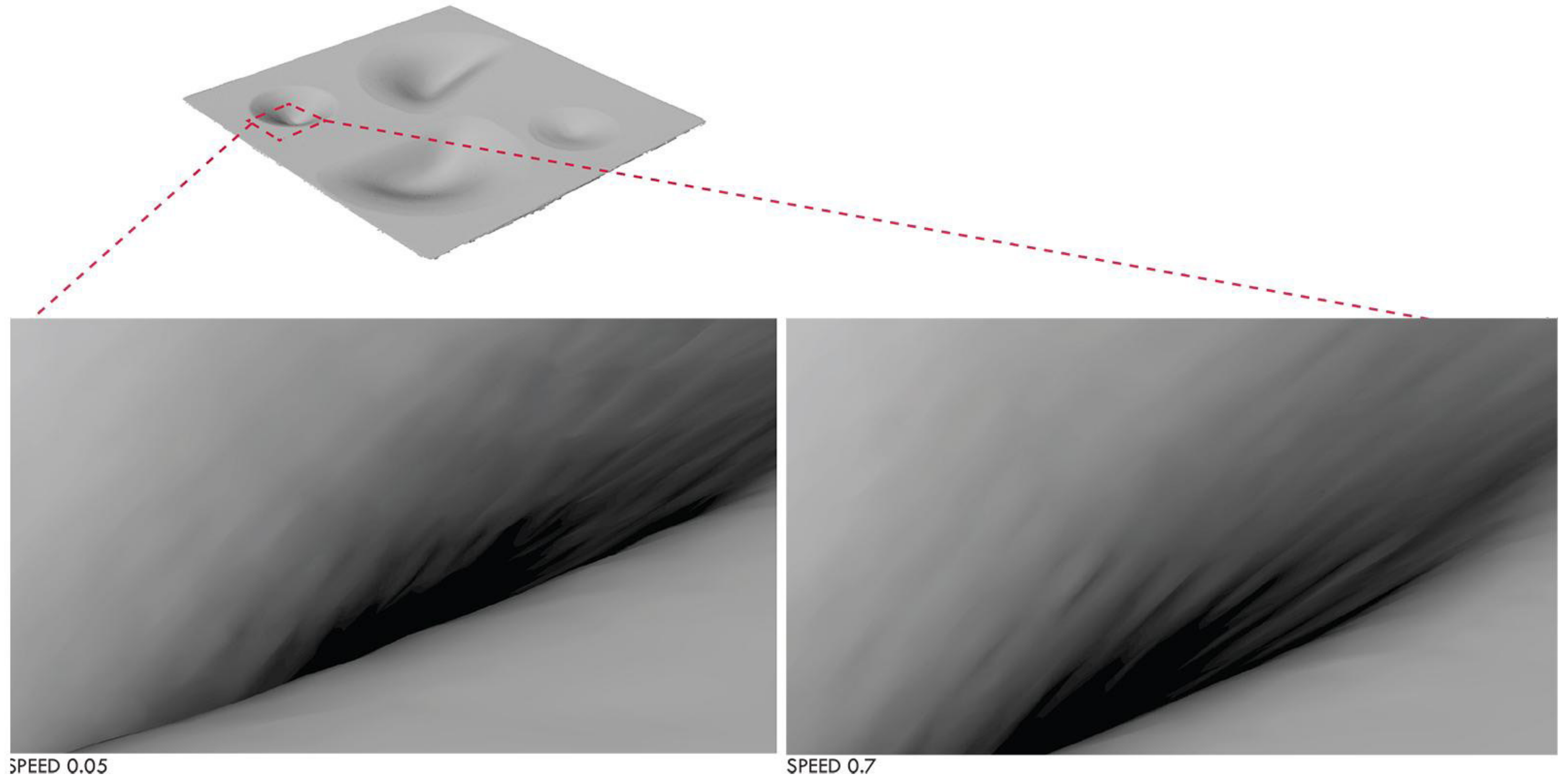
By attahing the ArtecEva to a UR10 robotic arm, we are able to obtain a very high quality scan without problems of calibration loss at a very fast scanning speed. The workflow uses an Intel Real Sense camera to capture the bounds of the unknown element, then a scripts automatically generates the toolpath for robotic scanning.



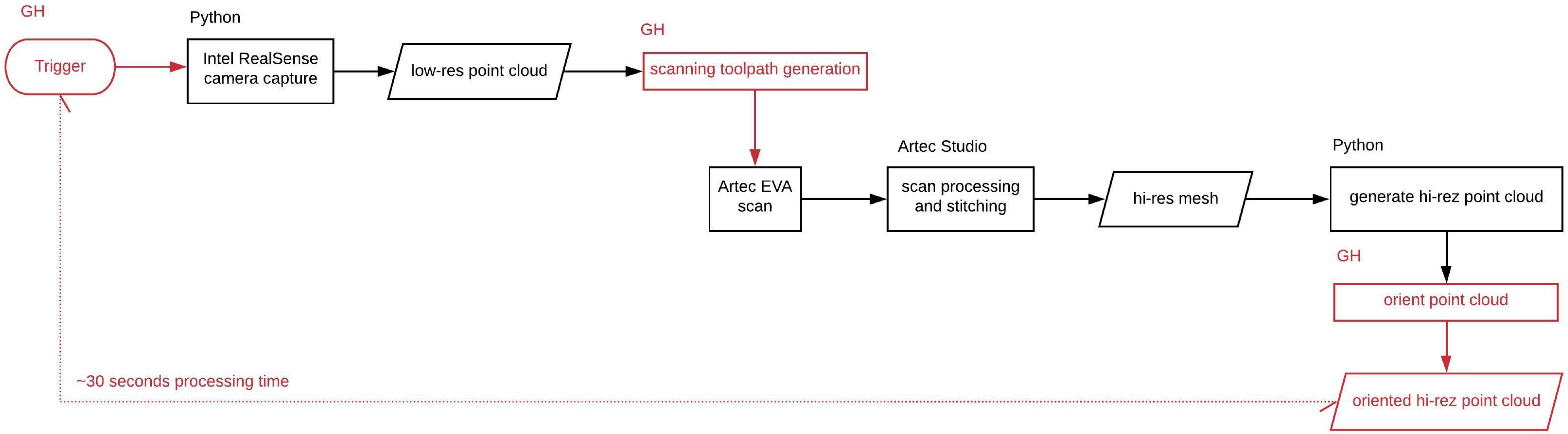
Robot setup on UR10



mesh reconstruction and toolpath generation from RealSense infrared depth image



obained mesh quality at different speeds



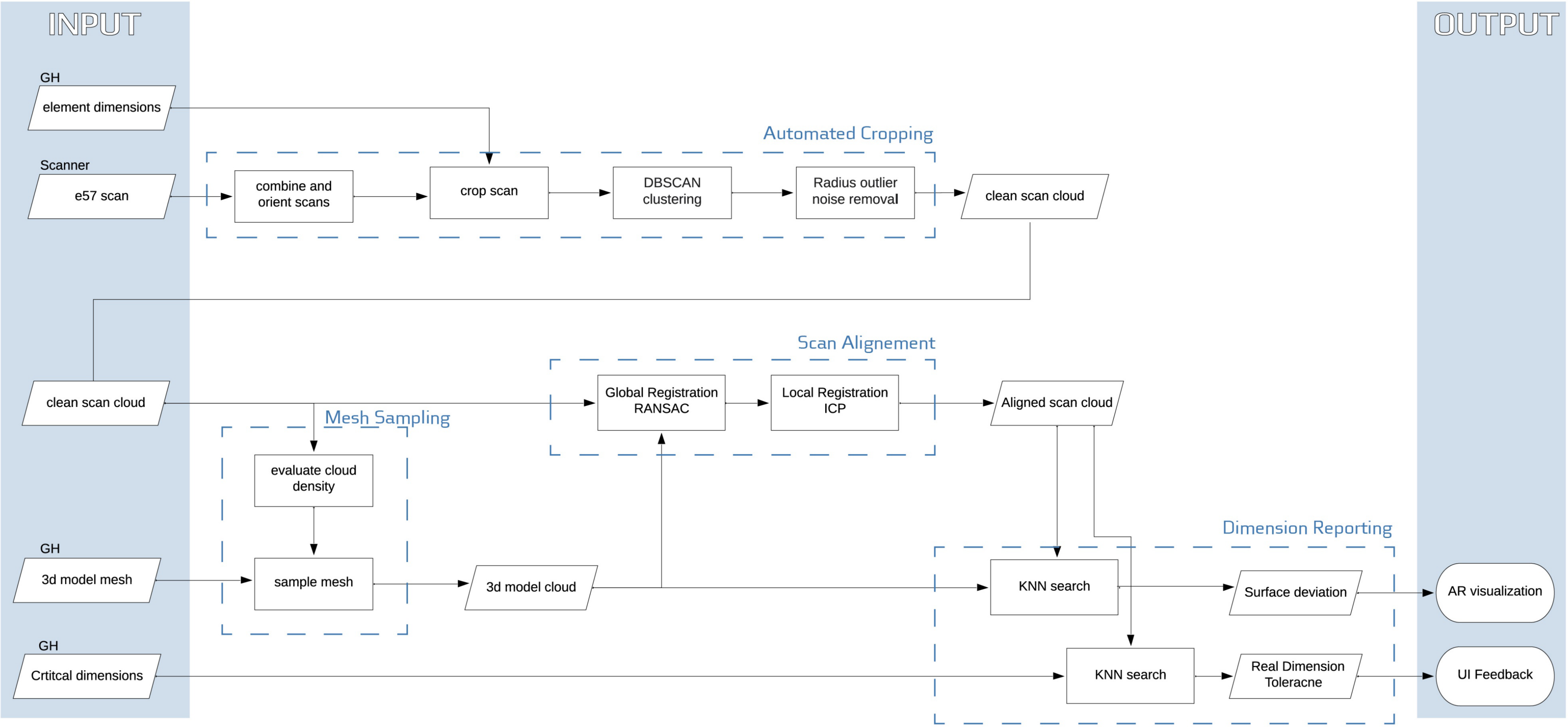
Scanning
Leica BLK360

The Leica BLK 360 is an attractive scanner choice because of its size and weight and as it uses Lidar technology. We attach it to a movable rig which allows to scan multiple units on the shop floor.

mobile scanning rig on the factory floor

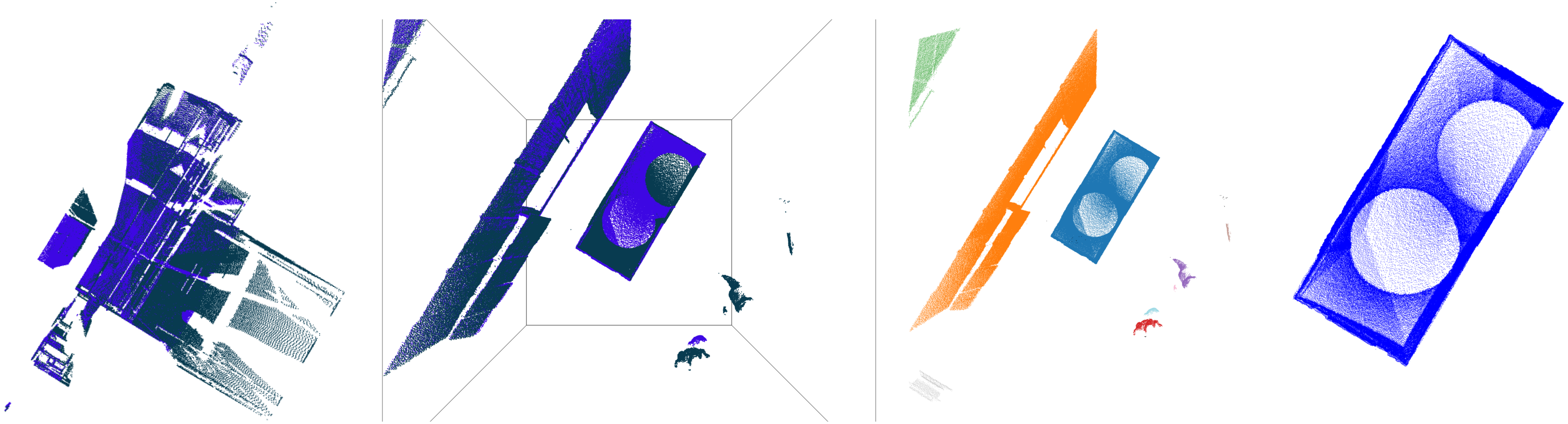
Point Cloud data analysis

This workflow connects a series of established point cloud processing algorithms to geometric information exported from Rhino/ Grasshopper at the modelling stage, in order to generate the feedback information to be visualized on the web interface as well as the Hololens



Automated
Scan Processing

The first part of this workflow combine and orients the multiple scans present in the e57 file, we crop it and then run a "Density-based spatial clustering of applications with noise" segmentation. We then extract the element and remove possible noisy points



1 Combine + orient scans

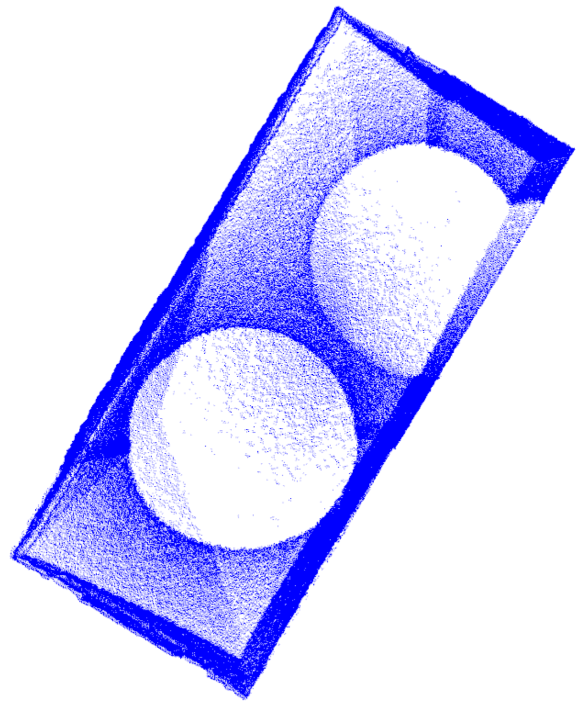
2 Crop Scan

3 DBSCAN Clustering

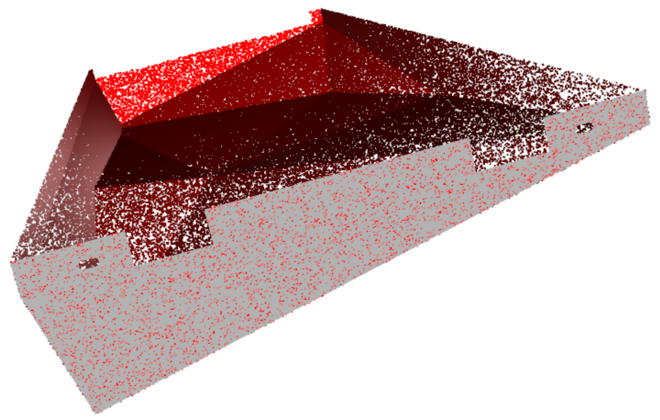
4 Radius Outlier Noise Removal

Automated
Scan Comparison

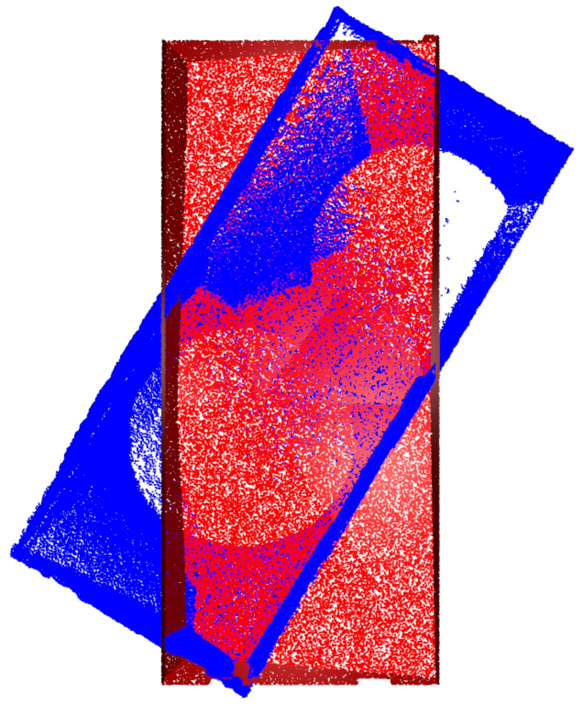
The second part creates a model point cloud sampled at the same density as the scan piont cloud. We then match the cloud centers and and run a global registration using Random Sample Consensus algorithm. This is then further refined by a local registration using Iterative Closest Point algorithm. Finally, we can run a K-Nearest Neighbour search to determine the critical dimensions pre-defined in the modelling stage on the scan.



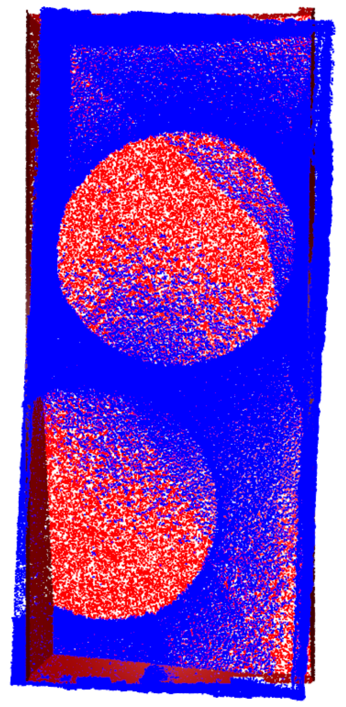
5 calucalte scan density



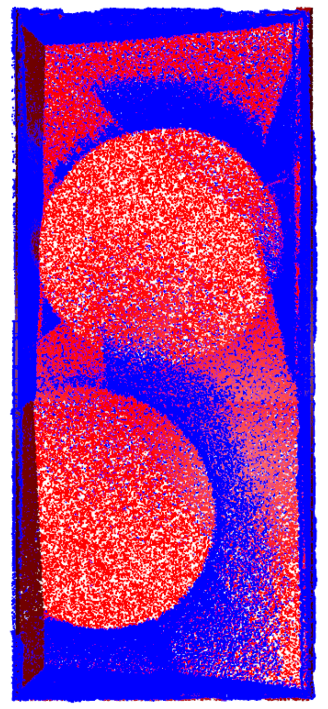
6 sample model mesh



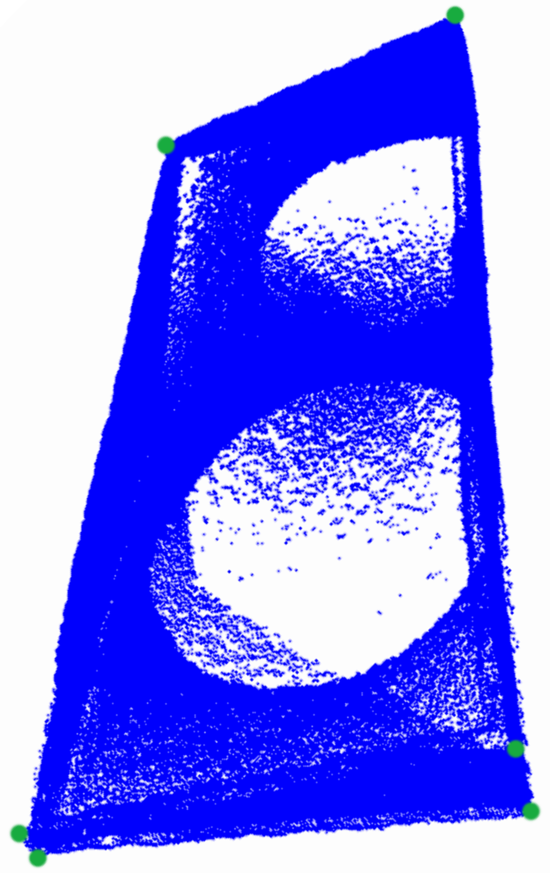
7 Match point cloud centers



8 Global registration RANSAC

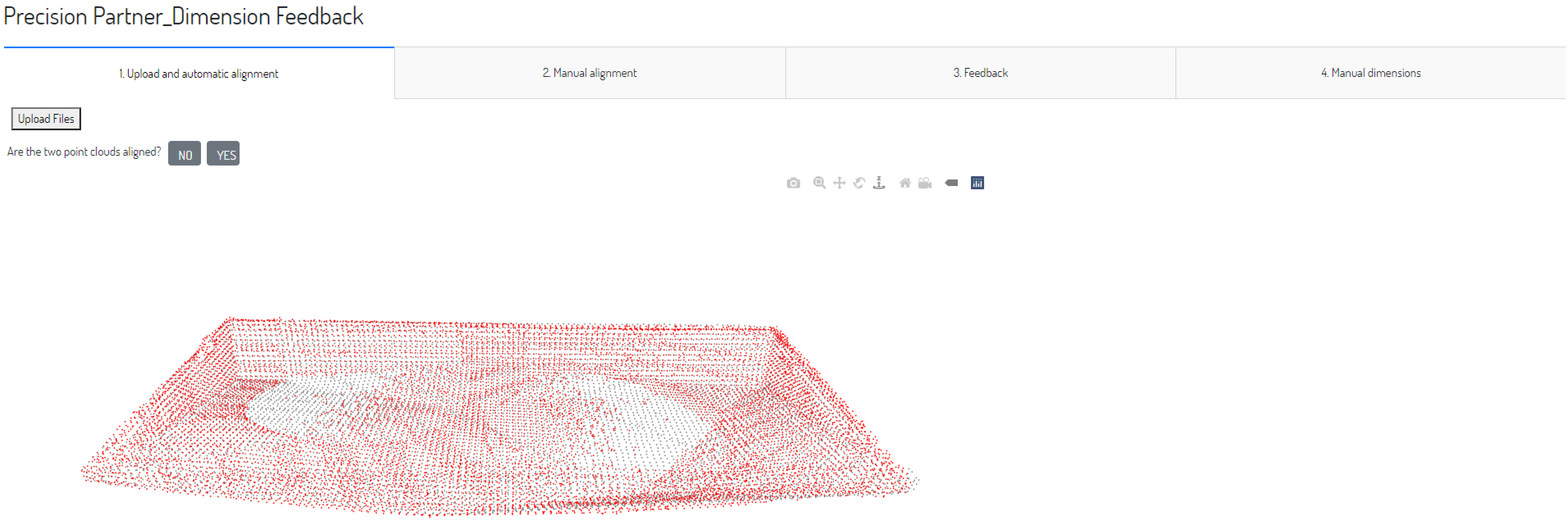


9 Local registration ICP



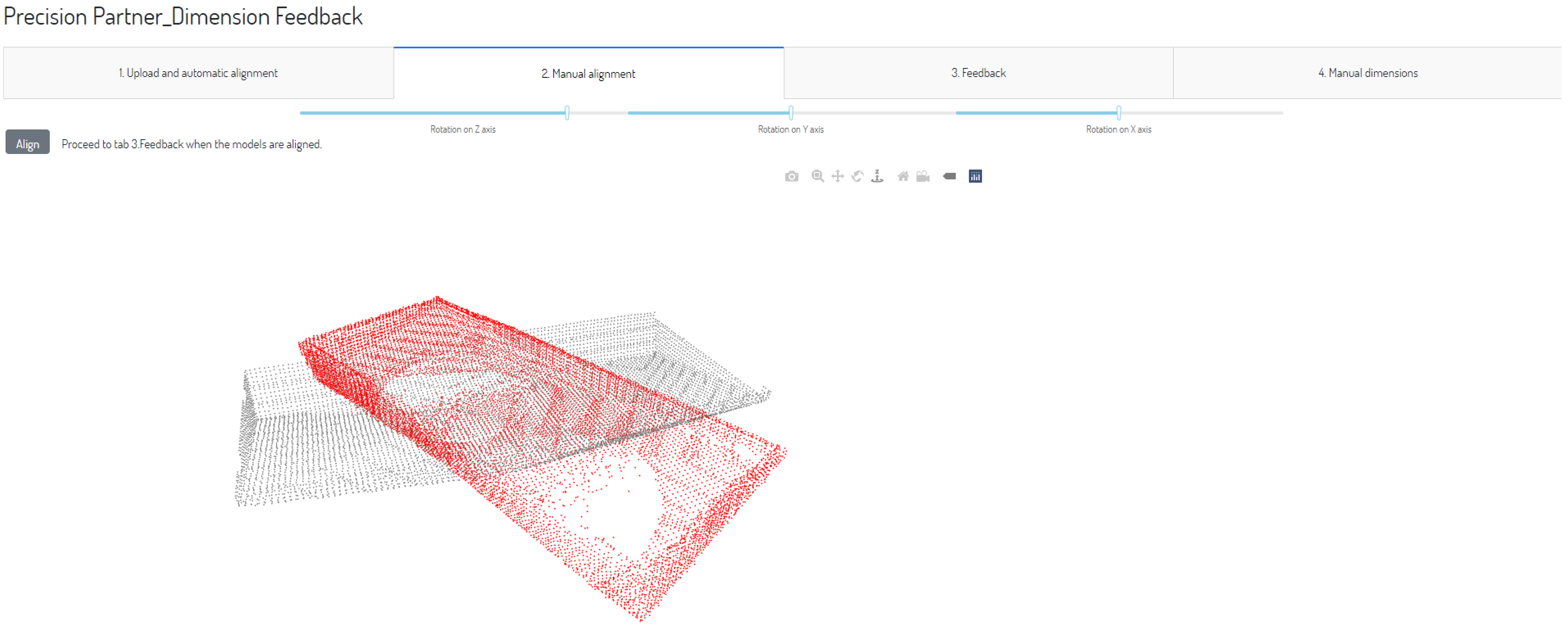
10 K-Nearest Neghbour Cloud search

Feedback
User Interface



In Tab1, the user points to the element root folder. The scan cloud is analyzed and is aligned to the model cloud using RANSAC global registrationand ICP local registration.

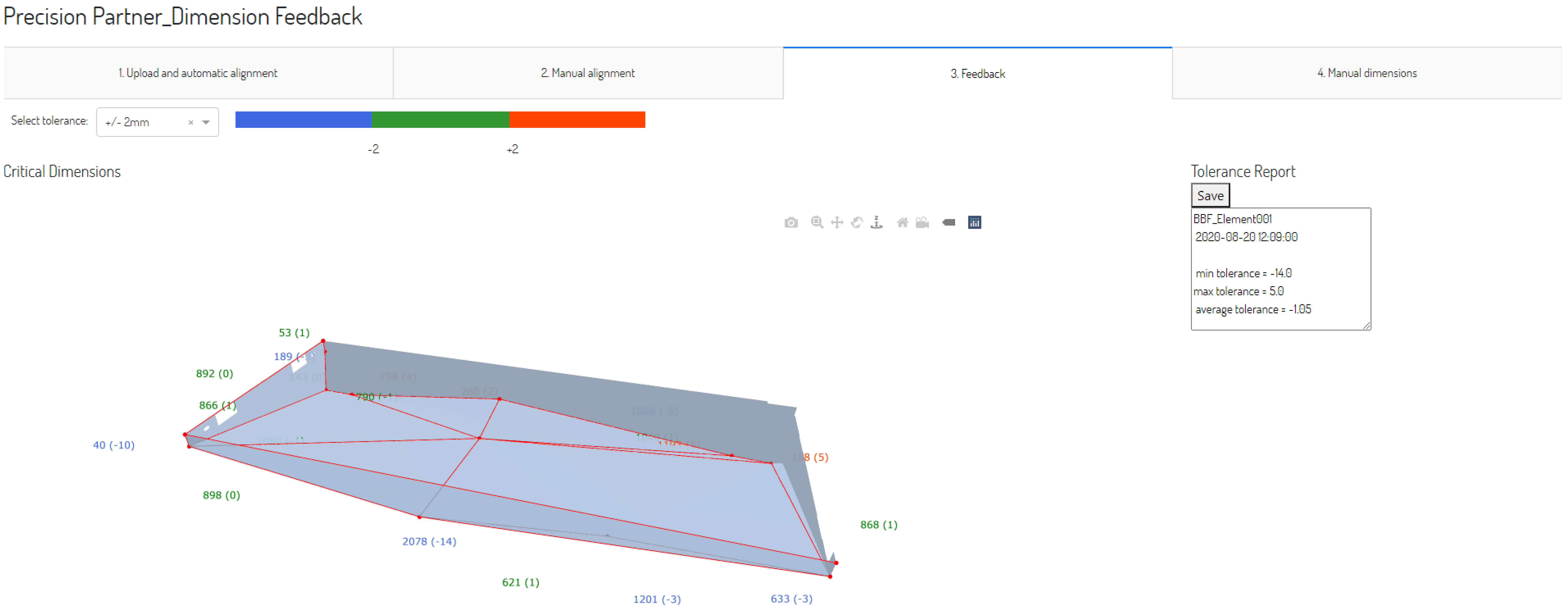
Feedback
User Interface



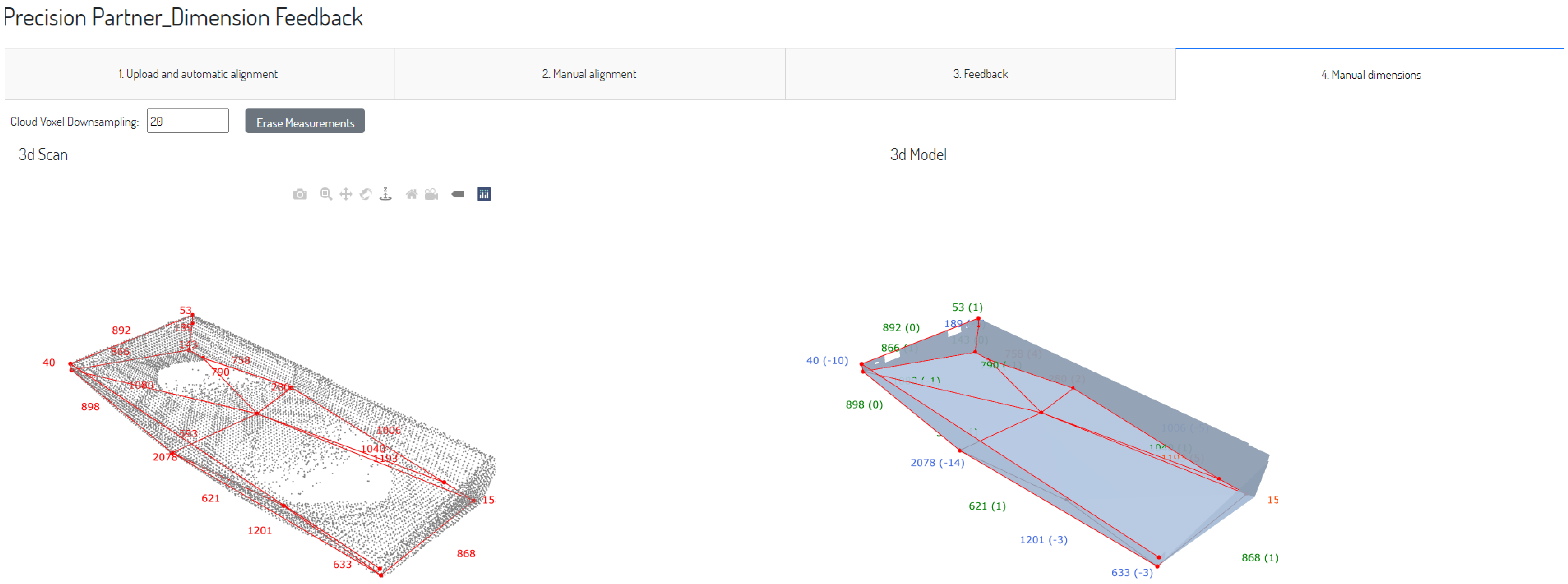
Tab 2 is a manual alignment fallback should the automated alignment fail.

Feedback
User Interface

In Tab3 the tolerance of the critical dimensions is displayed on the 3d model. The user can toggle the tolerance gradient scale.



Feedback User Interface

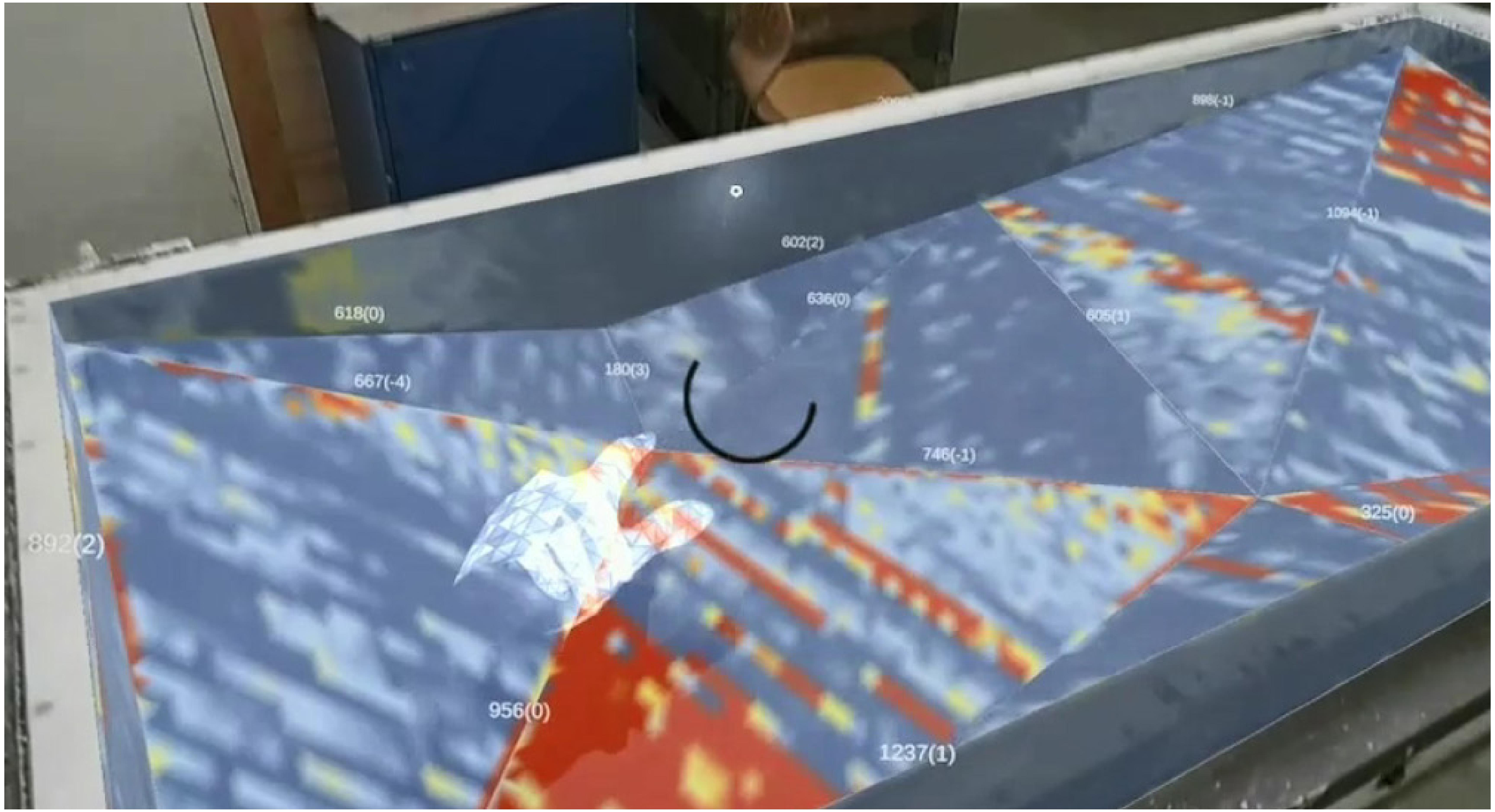


In Tab4 the user can visualize the cloud and the 3d model side to side, and can addadditional dimension queries to the point cloud.

Feedback
Augmented Reality

QR code alignment of the Hologram to the Factory Floor

Using a microsoft Hololens, the operator can visualize an Augmented Reality representation of surface deviation directly on the element, as well as the critical dimension tolerance.



Outlook

Industry 4.0 in architecture is about assisting skilled work not replacing it. It is about making the wealth of digital data and technology accessible on a dirty and "non-digital" work environment.

Hardware wise, While there are good 3d scanning solutions for scanning large buildings with sufficient precision, the same doesn't yet exist for large building elements

Software wise, open source point cloud tools and feedback tools are in place.

- There is a need to develop modelling frameworks for feedback. These extend the typical geometric representation by including additional specific data that enables later correspondence between the ideal and the actual, and to communicate it back easily on the shop floor.

Our future ambition to investigate partial progressive feedback, that traces the life of the mold.