# Welcome to the TB-RAM CoE webinar

## Technobothnia Robotic Additive Manufacturing Center of Excellence

**The webinar starts at 13:00**

Agenda

- Team introduction
- Project presentation
- Project results and demonstration
- Future development
- Open discussion

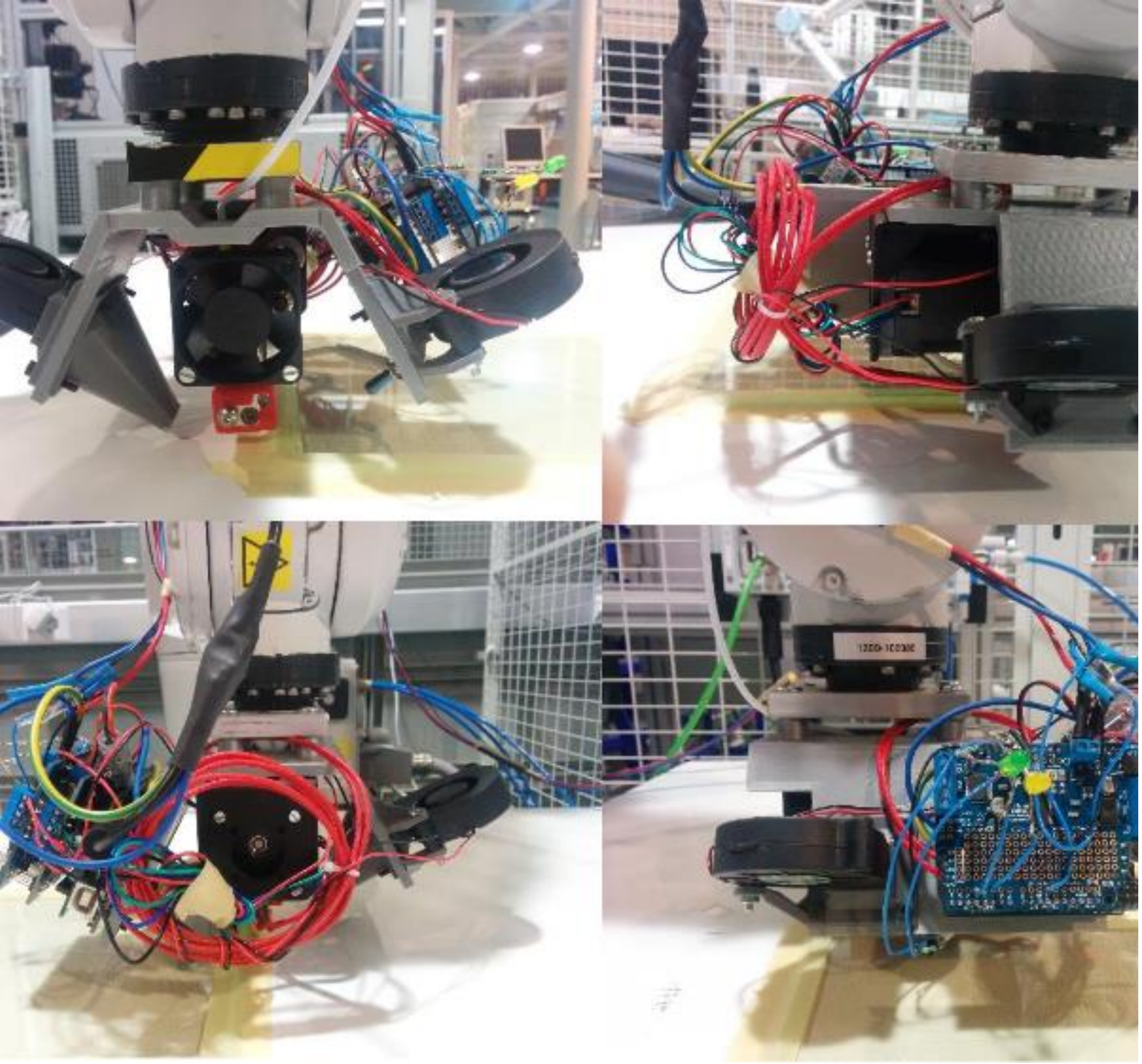
European Union
European Regional Development Fund
Regional Council of Ostrobothnia
Leverage from the EU 2014–2020

# Team introduction

# Project introduction

- The TB-RAM CoE project is centered around creating Robotic Additive Manufacturing (**RAM**) demonstration environment to aid in the development of additive manufacturing competences for companies in Ostrobothnia, as well as for university staff and students.
- The project is financed by the European Regional Development Fund.
- The project is a collaboration between Novia UAS, the University of Vaasa and VAMK.

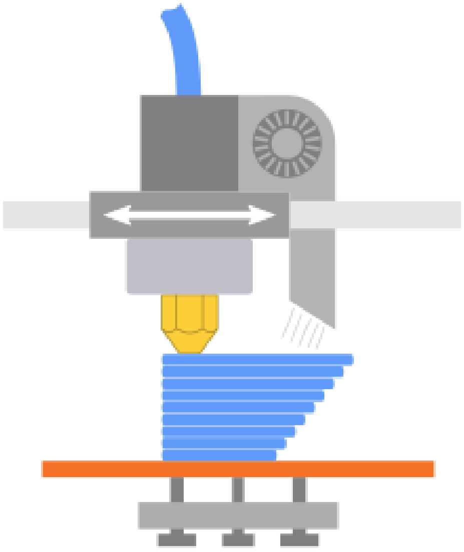
# Project results and demonstration



# The roots

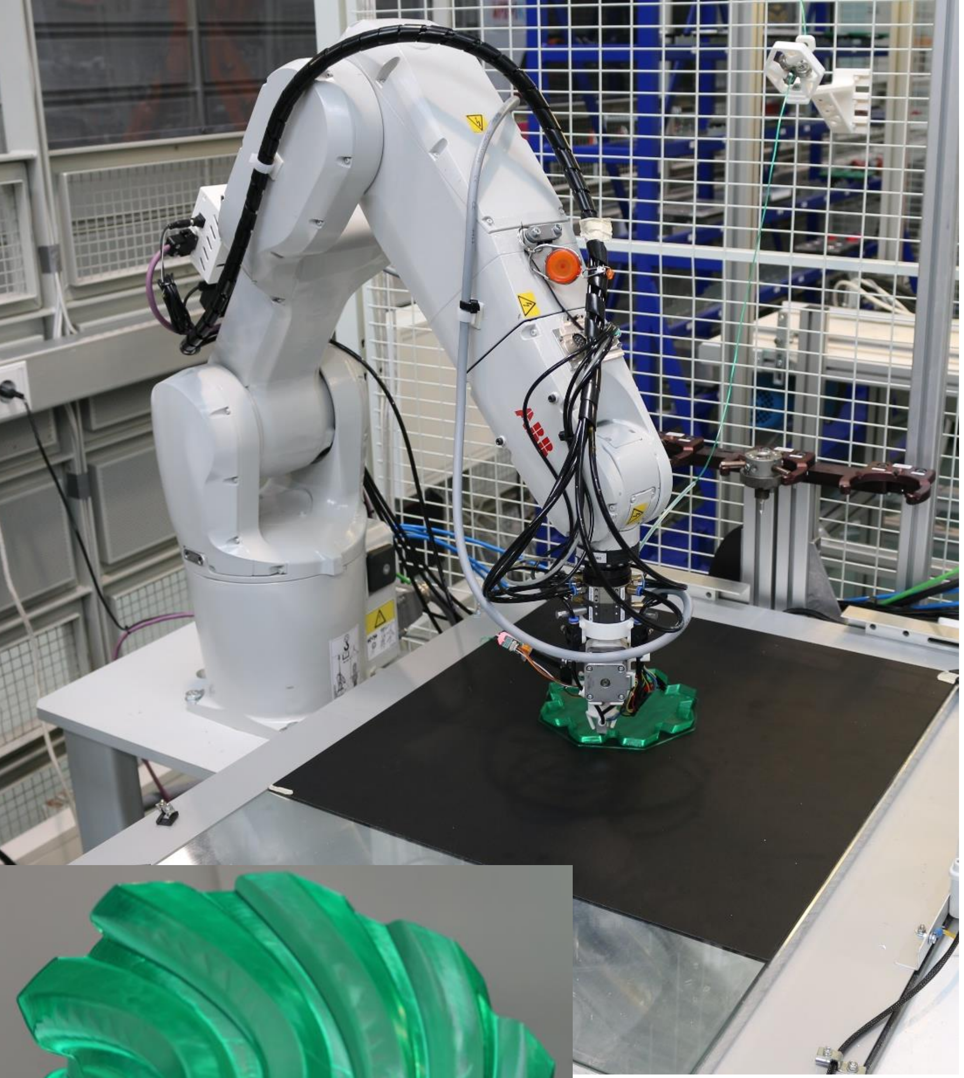
The robotic additive manufacturing platform has its root in the EPS project: *3D printing with Robotic Arm*.

The project produced the original extruder tool and robot control program.



# What is additive manufacturing?

- Additive manufacturing (3D printing) is the process of constructing real objects from digital files.
- Real objects are constructed by depositing thin successive layers of molten plastic or other materials on a build surface. As the material cools it solidifies to form a stable object.
- The most common type of 3D printer is the **Cartesian printer**. These printers are able to position the print head (Nozzle) along three axes.



# Introducing robots to AM: Robotic Additive Manufacturing

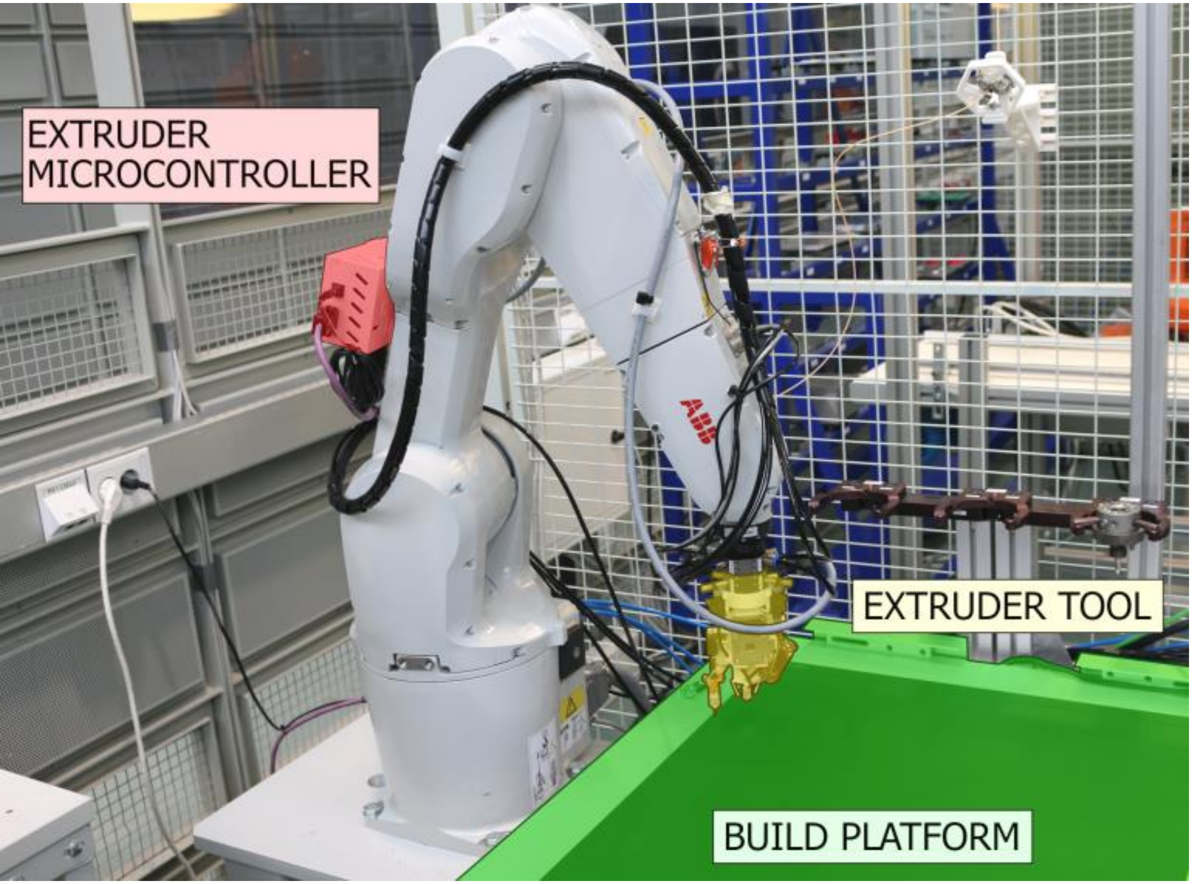
- Robotic AM is an extension of classical Additive Manufacturing in which the print head is attached to a robot arm. RAM leverages the power of robotics to work around the limitations of conventional AM.

- Cartesian 3D printers are incapable of printing larger **NON-PLANAR** objects. Non-planar means that the deposited layers aren't flat/horizontal.
- Cartesian 3D printers are incapable of doing **FREEFORM** printing, in which the print head can rotate freely to deposit material from any angle.
- Cartesian 3D printers usually have a limited print volume due to their need to have their physical axes extend along the entire build volume.

# The TB-RAM platform components

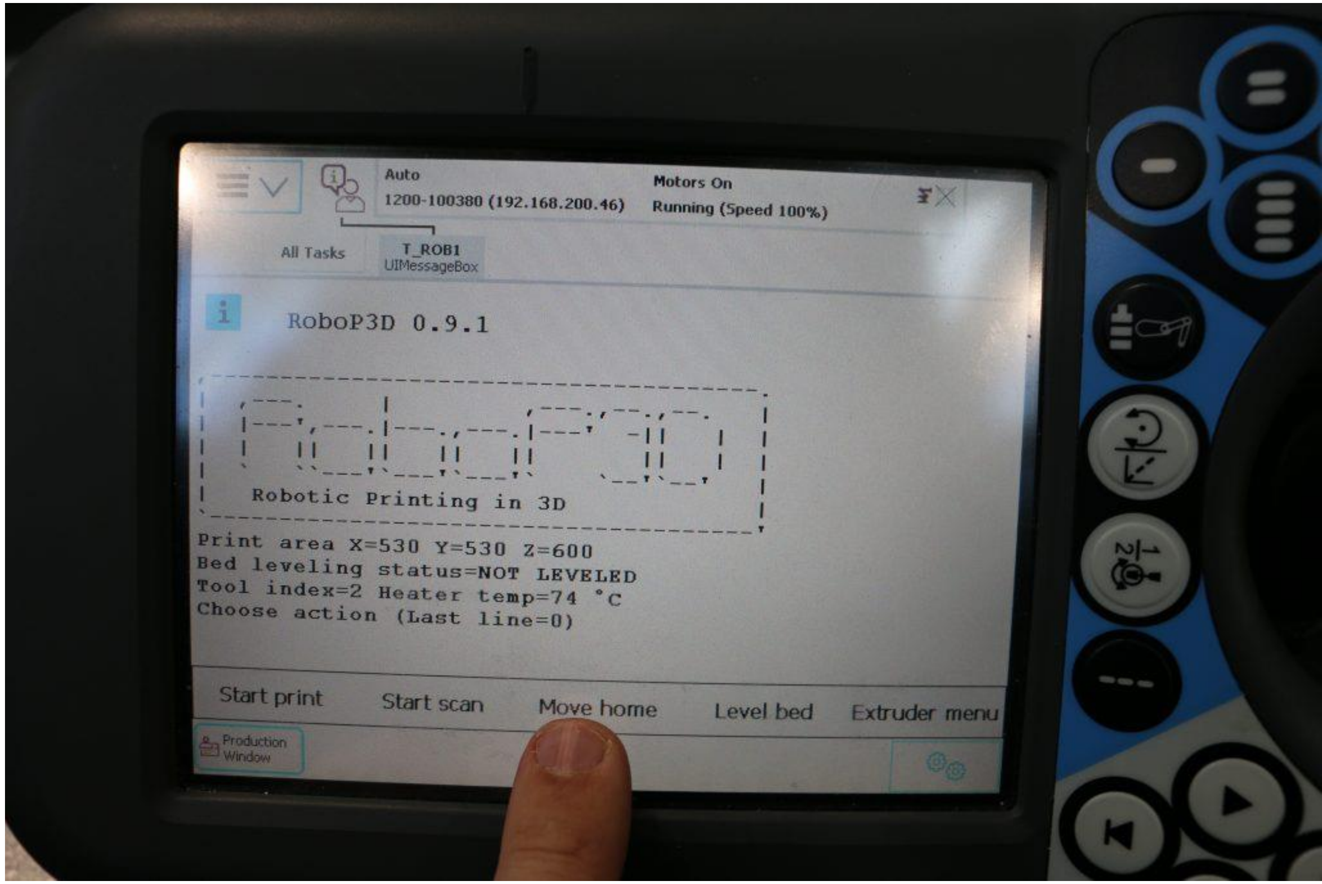
## The hardware

(extruder, microcontroller, build platform and more)

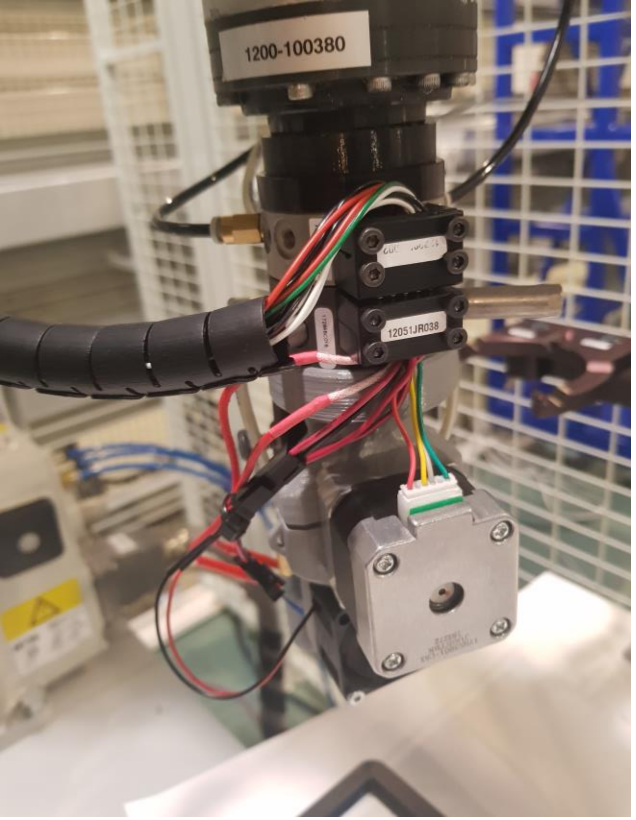


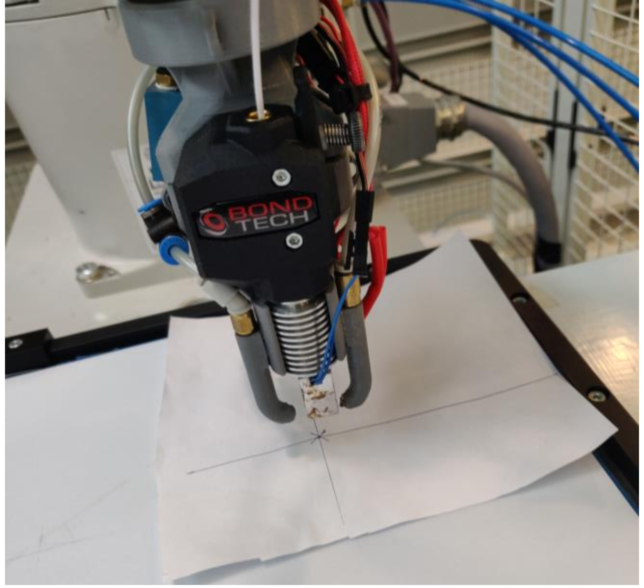

## The software

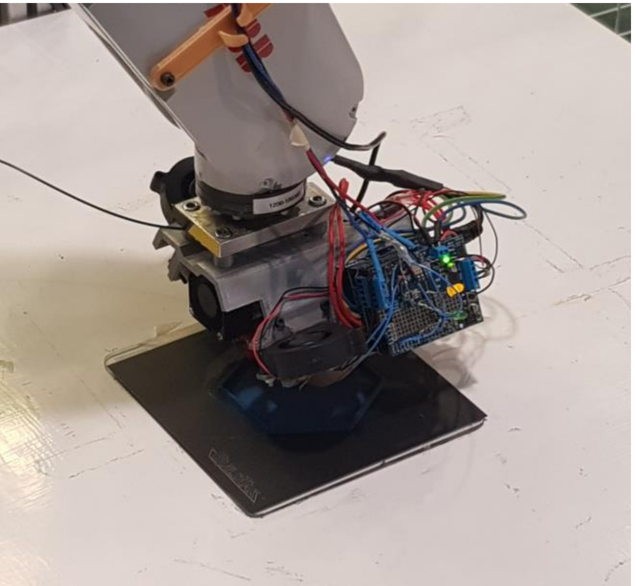
(robot control program, 3D slicers and more)



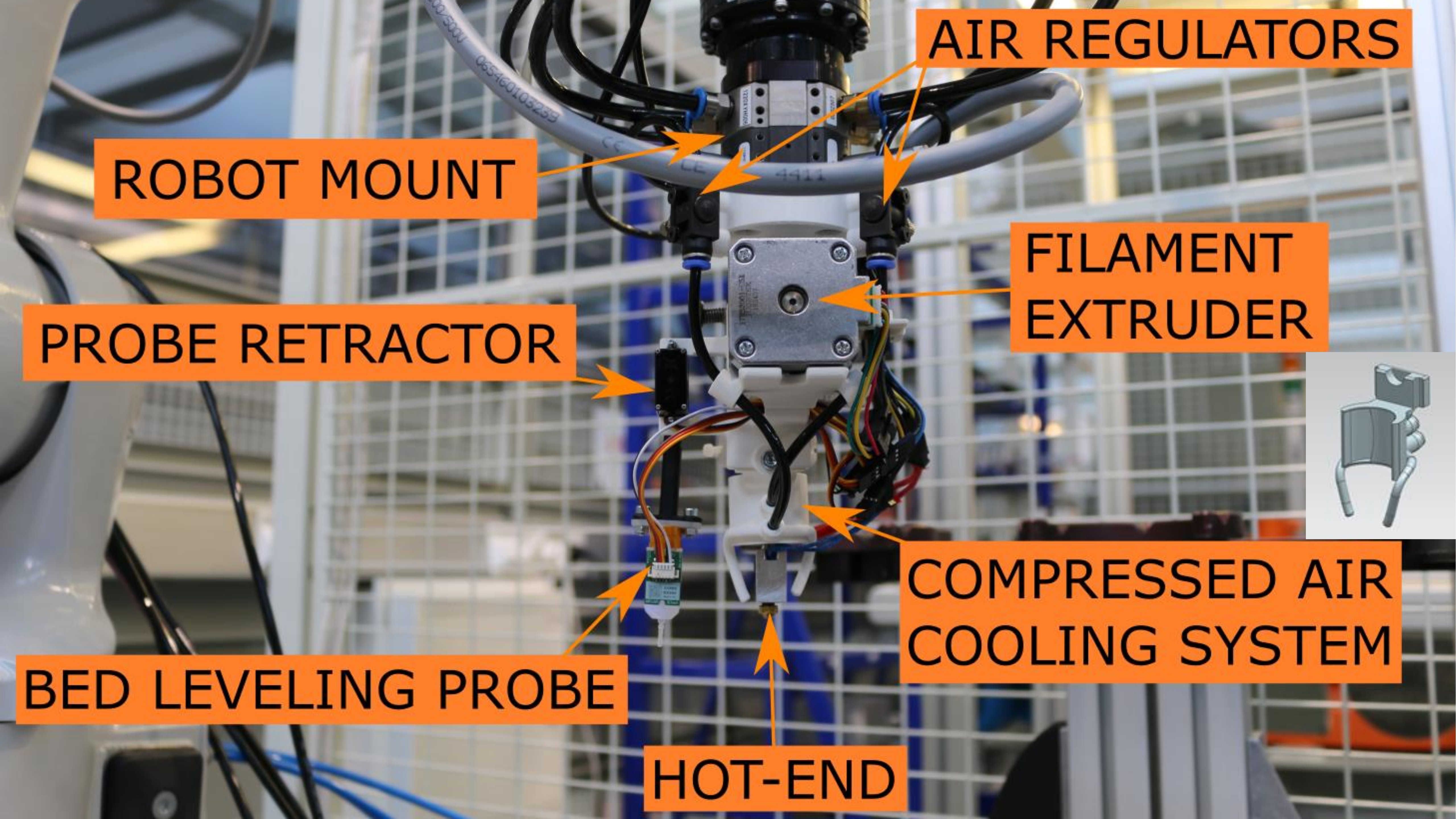
# Developing the extruder tool

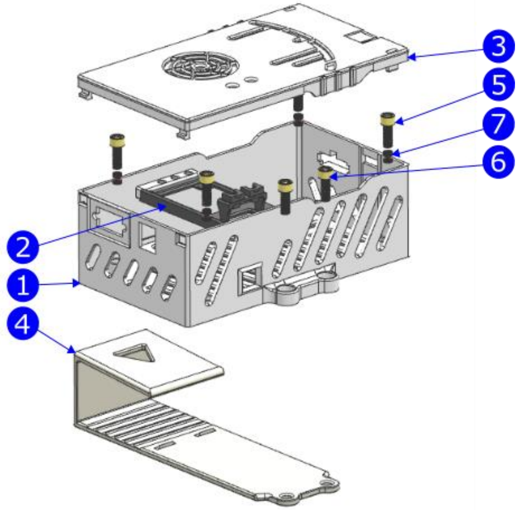


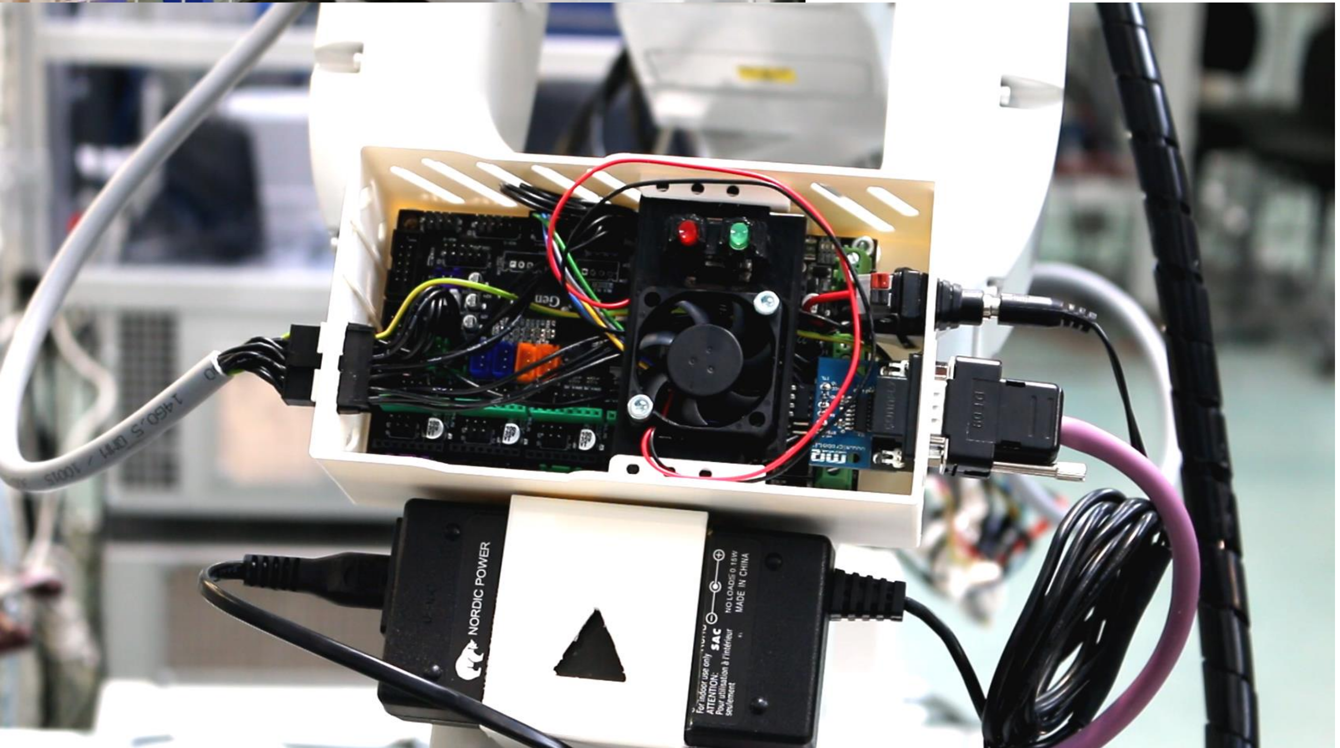




- The extruder tool end-effector serves multiple purposes:
  - It heats and deposits the material through its nozzle.
  - It manages heater temperature.
  - It cools the printed part.
  - It manages bed leveling.
- The extruder tool has gone through several iterations and complete re-designs.
- The pointed design of the final extruder enables freeform and non-planar printing.
- The compressed air-cooling system enables rapid part cooling.


AIR REGULATORS
ROBOT MOUNT
FILAMENT EXTRUDER
PROBE RETRACTOR
COMPRESSED AIR COOLING SYSTEM
BED LEVELING PROBE
HOT-END



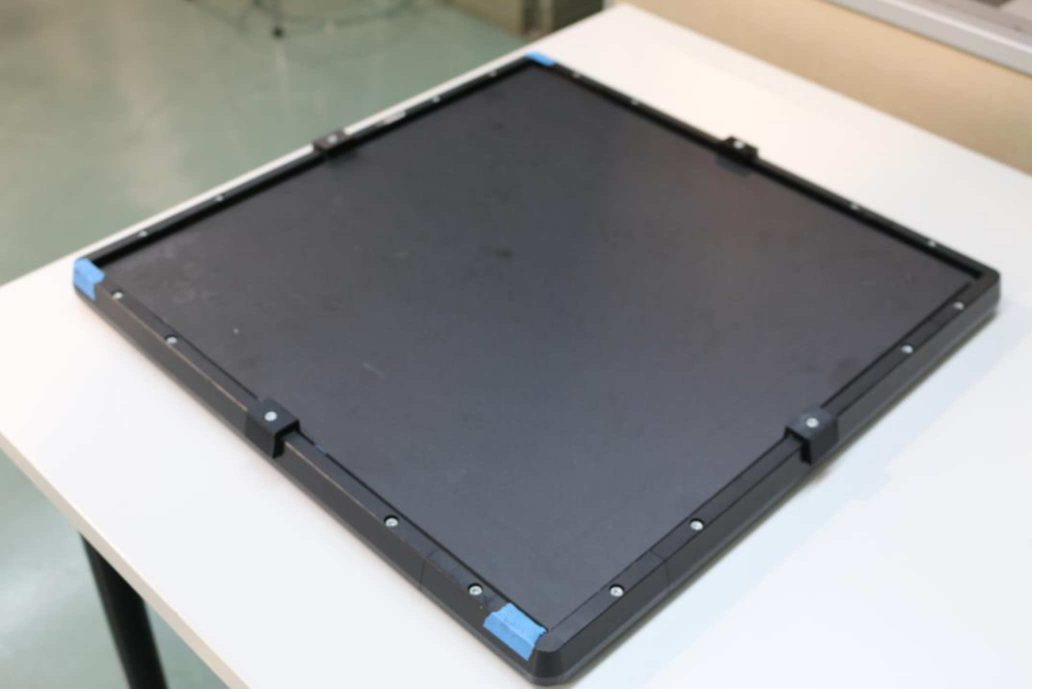

| No. | Component | Qty. |
|---|---|---|
| 1 | Extruder computer box | 1 |
| 2 | Extruder computer fan mount | 1 |
| 3 | Extruder computer lid | 1 |
| 4 | Extruder computer mounting plate | 1 |
| 5 | M4x10 | 4 |
| 6 | M5x14 | 2 |
| 7 | M4x6x6 Brass Instert Embedment Nut | 4 |

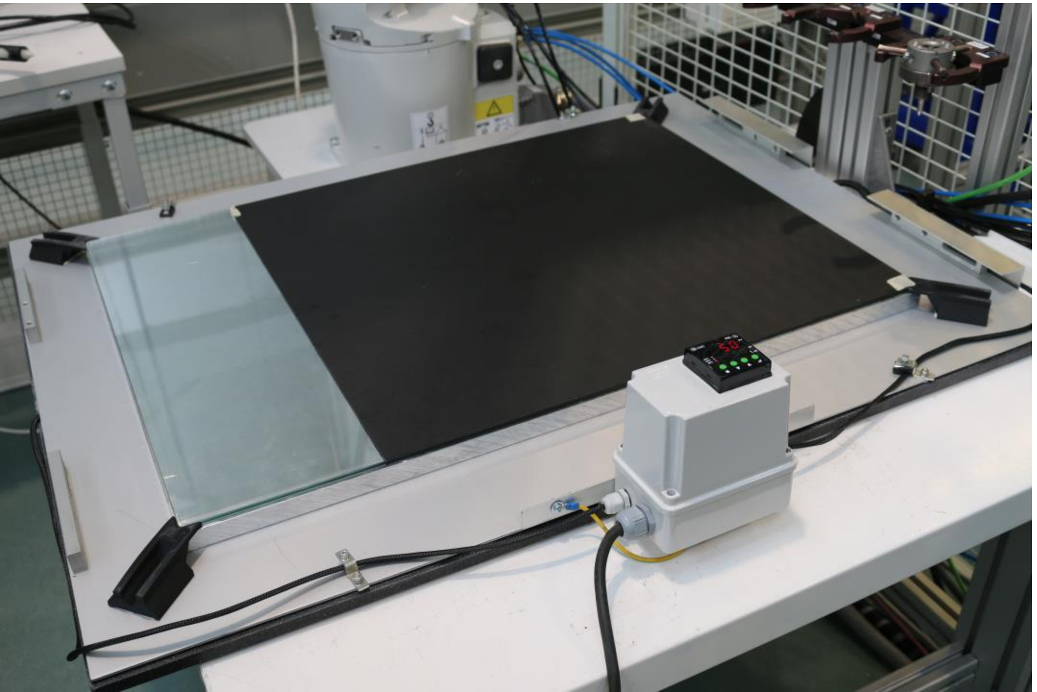



# Extruder microcontroller

- The extruder microcontroller controls the extruder tool.
- The microcontroller firmware is a separate program which communicates with the robot via a serial connection.
- The microcontroller housing was custom built for the RAM platform.

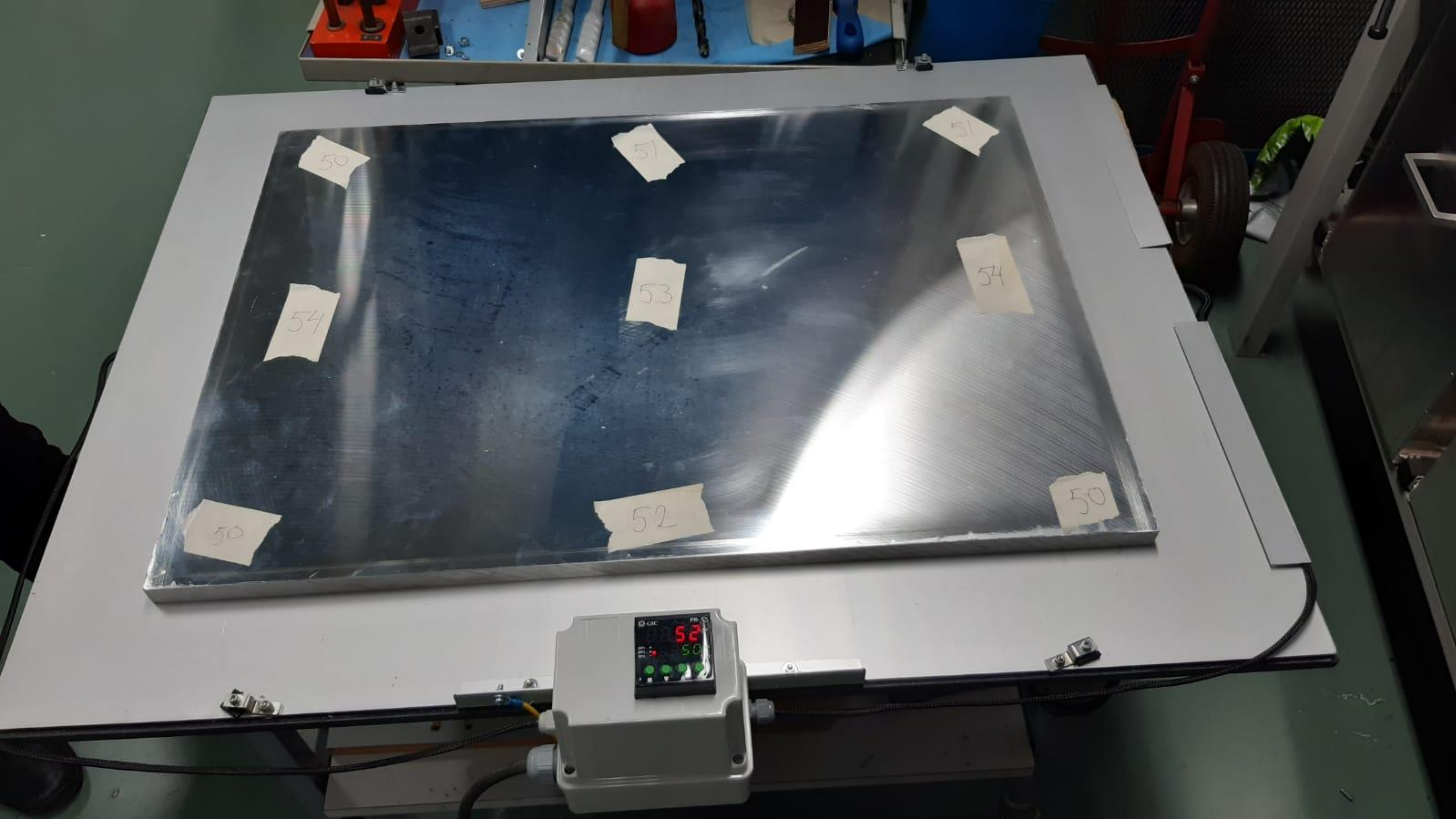
# Filament holder and guide





# The build platform

- The build platform has gone through several iterations.
- Multiple build surface types have been tested
  - Painter's tape
  - Heat-treated glass
  - BuildTak
- The first versions of the build platforms were unheated but caused problems with print adherence.
- The final build platform uses a detachable glass plate, heated by a large metal block. The top surface uses BuildTak.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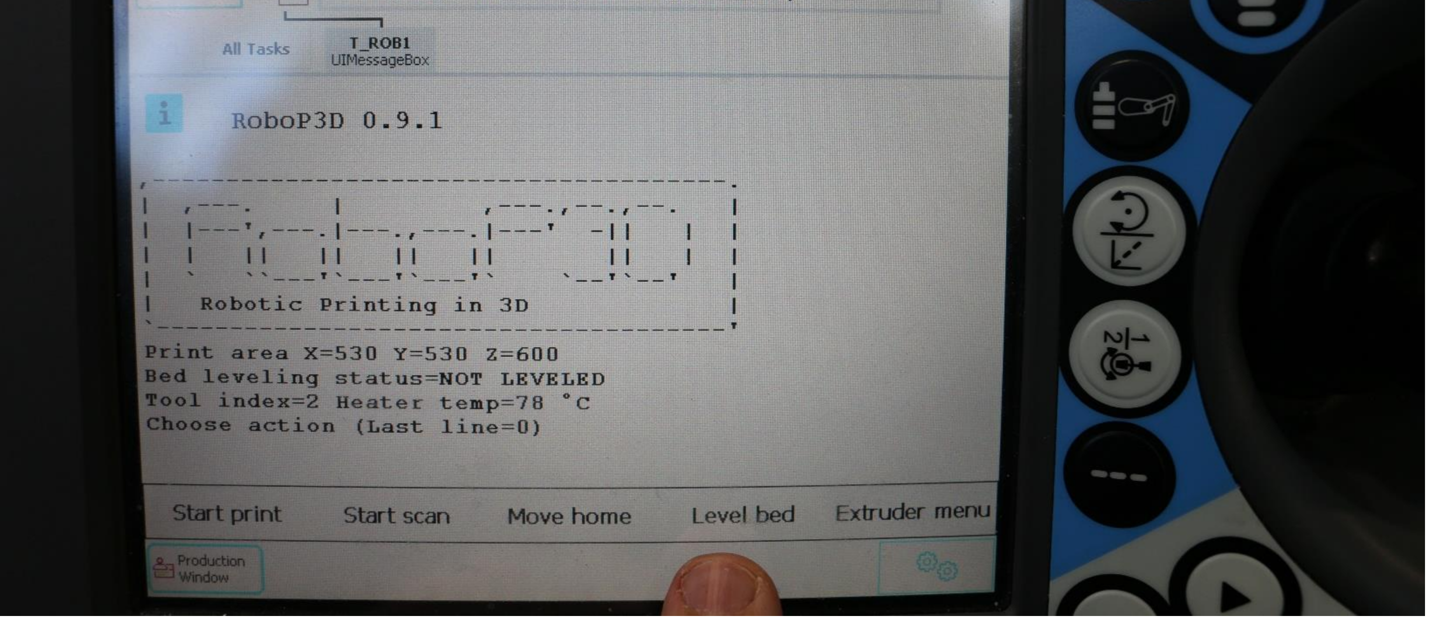
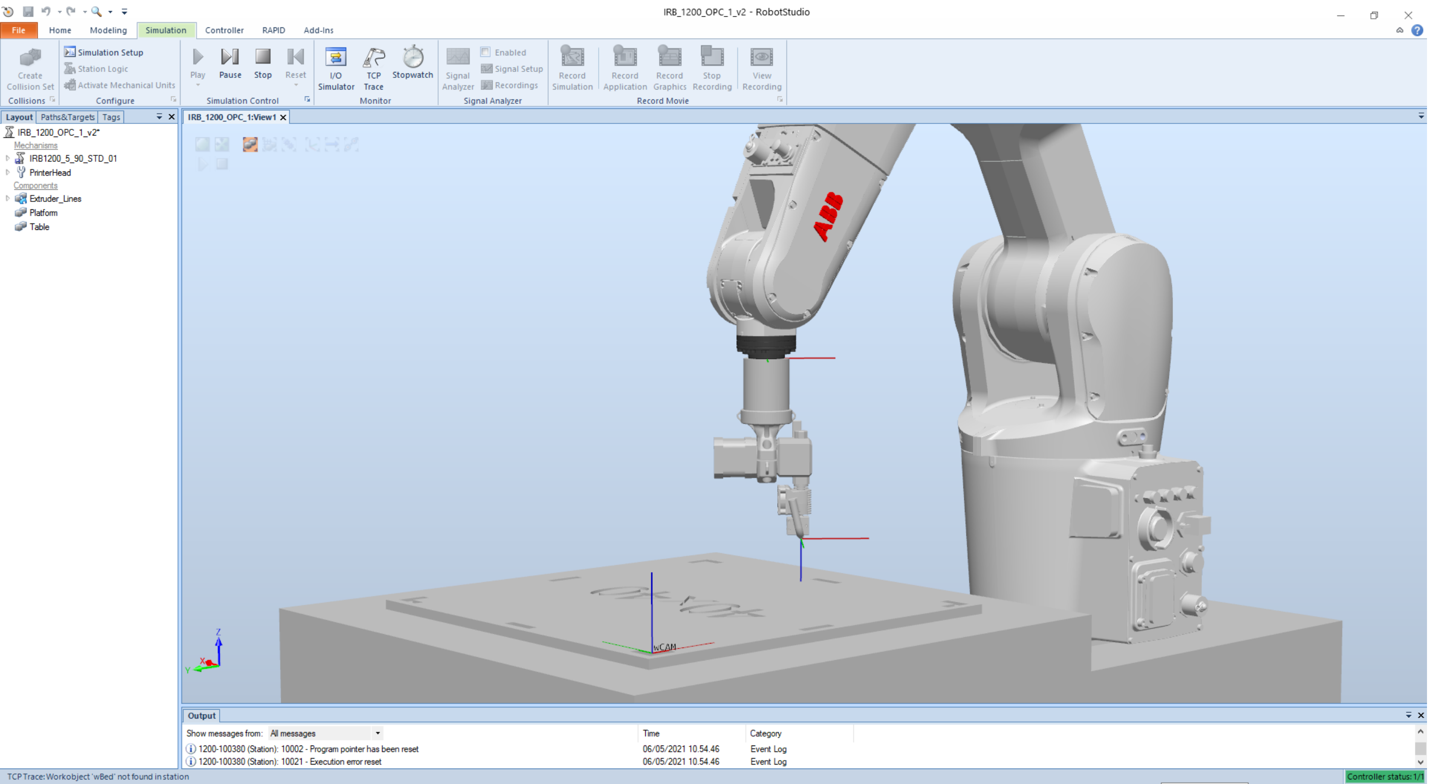
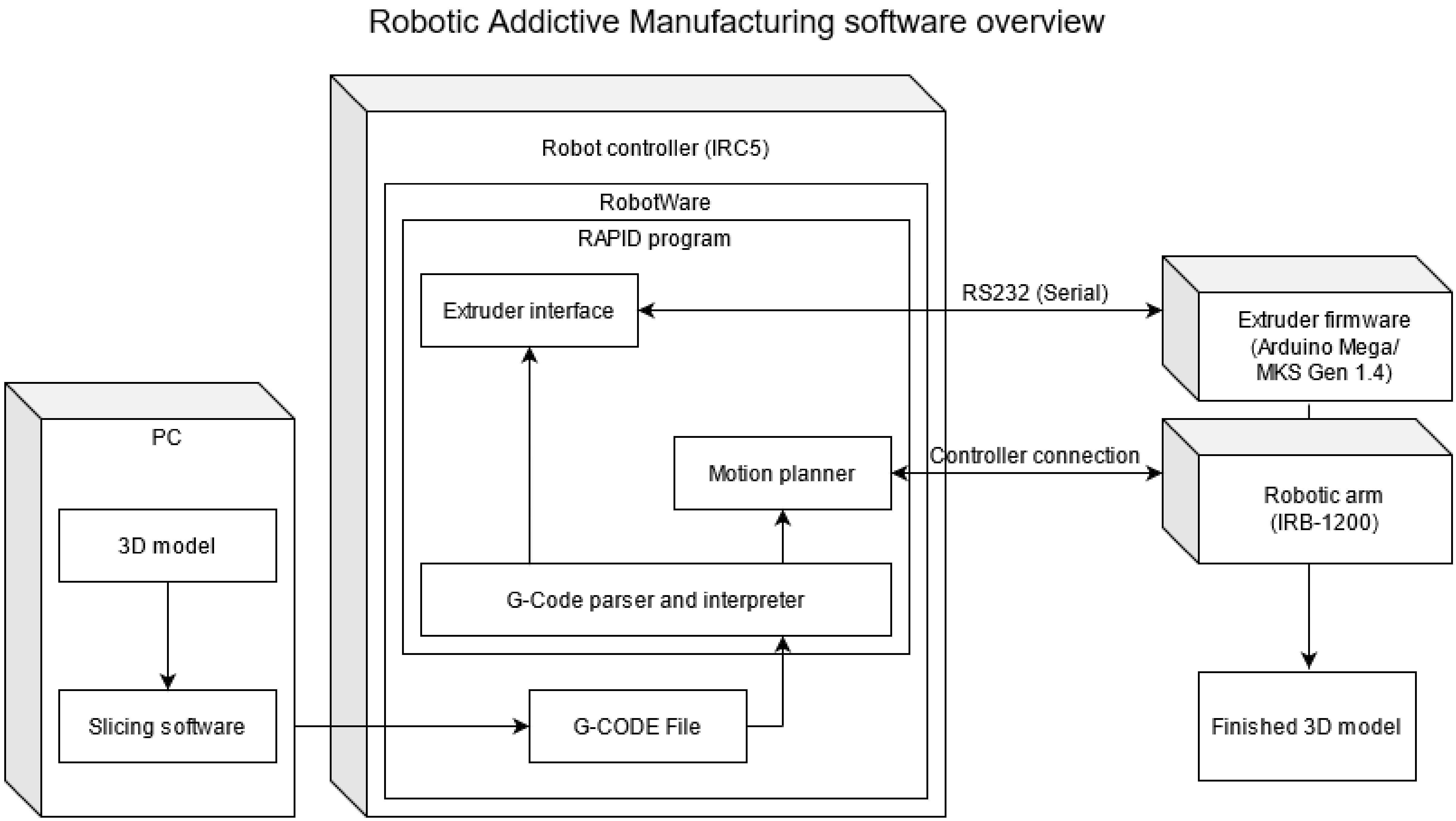


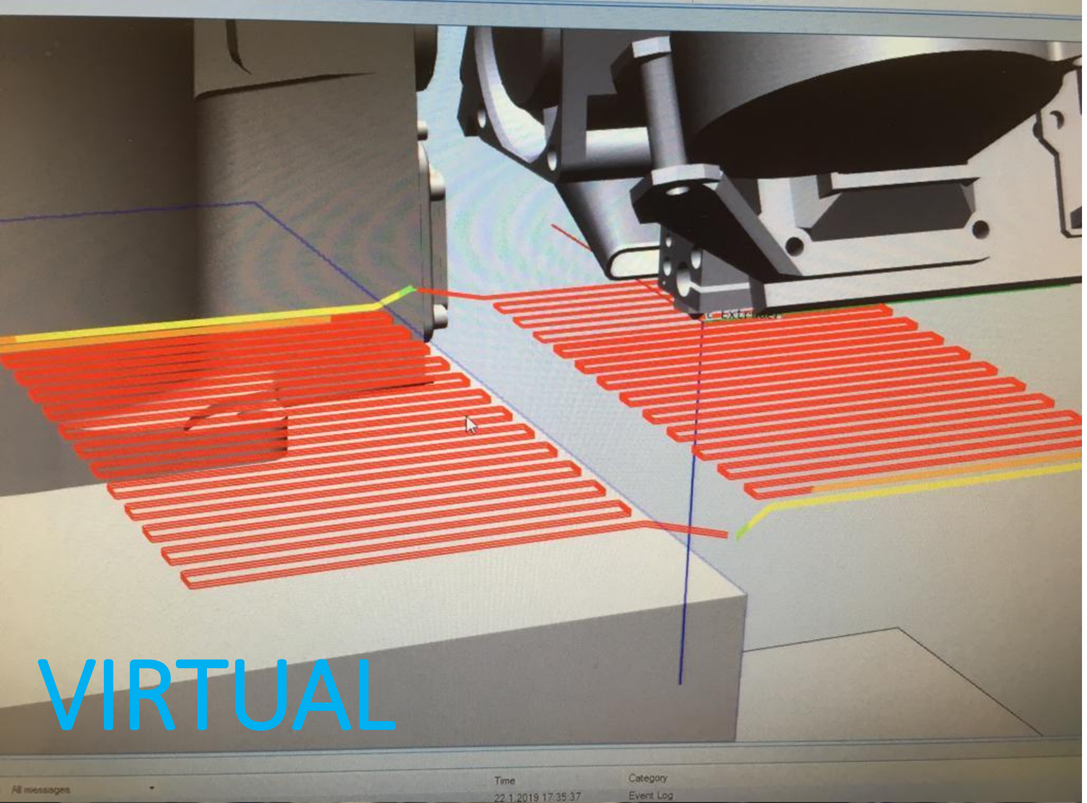



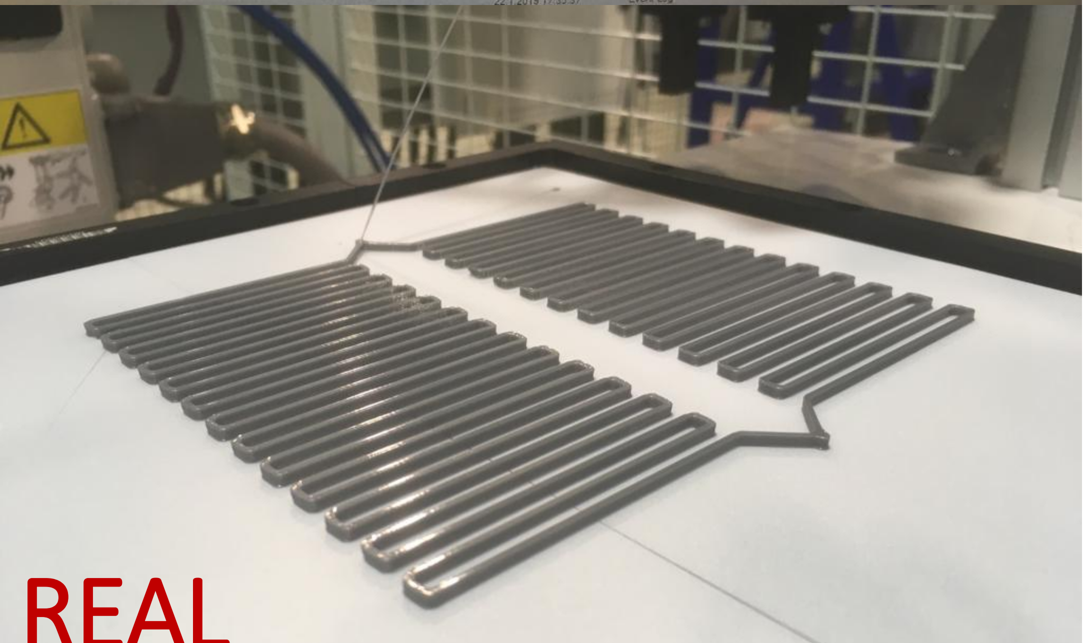

# Software overview

- The RAM platform uses many different software components developed in different computer languages.
- The robot control program was developed in **RAPID** in RobotStudio and handles the translation of G-Code into robot and extruder actions.
- The commercial 3D slicers **PrusaSlicer** and **Ultimaker Cura** were extensively used to produce G-Code from 3D models. In addition, a custom **Parametric Slicer** was developed in Javascript.
- The extruder firmware was written in **C++** in Arduino IDE. The firmware acts as a bridge between the extruder tool and the robot. A **Python** interface was developed for exclusive PC communication.



Robotic Addictive Manufacturing software overview
Robot controller (IRC5)
RobotWare
RAPID program
Extruder interface
Motion planner
G-Code parser and interpreter
G-CODE File
PC
3D model
Slicing software
RS232 (Serial)
Controller connection
Extruder firmware (Arduino Mega/ MKS Gen 1.4)
Robotic arm (IRB-1200)
Finished 3D model



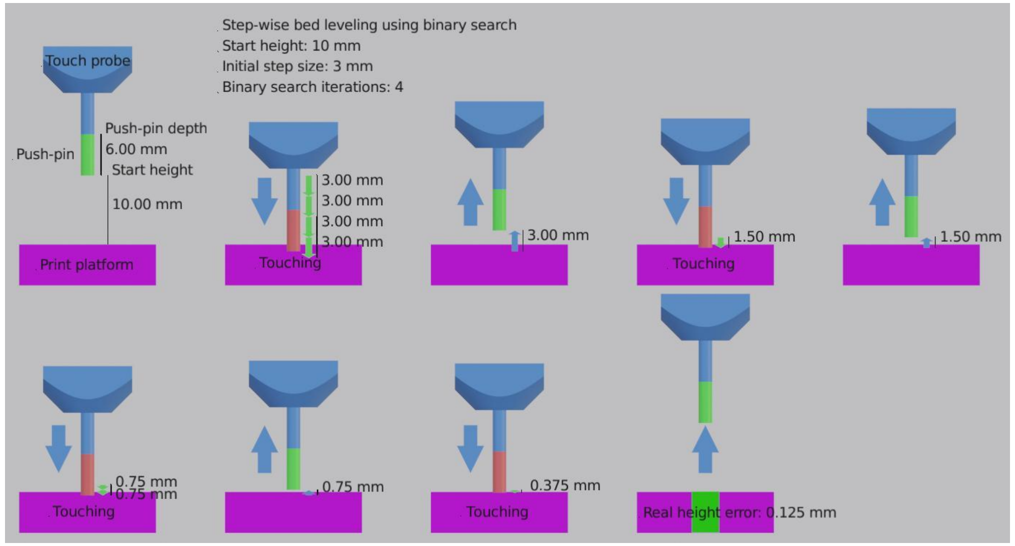




# Simulations in RobotStudio

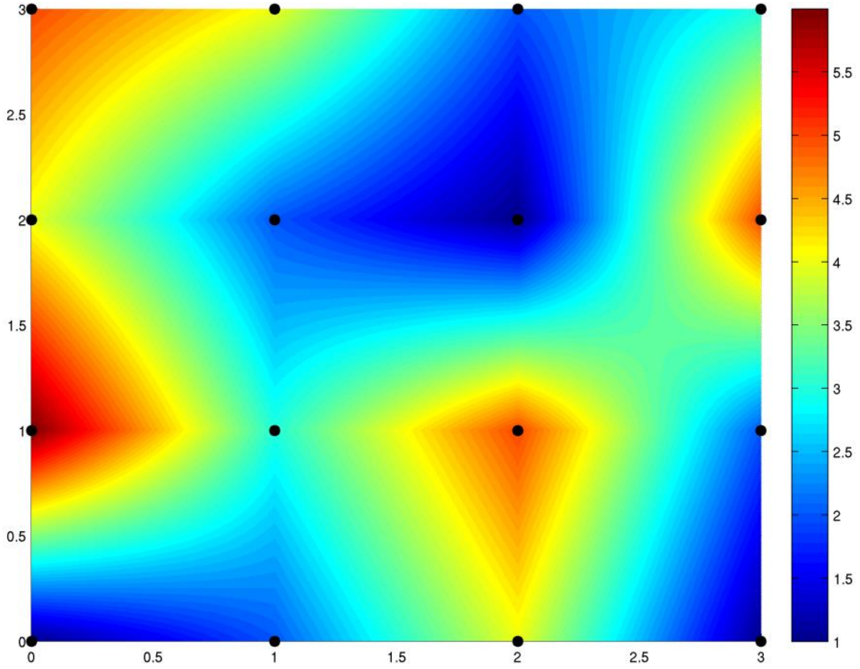
- ABB RobotStudio was used extensively to develop and debug the robot control program.
- A digital twin of the TB-RAM platform has been used to test and debug both regular and freeform printing, as well as extruder synchronization.

# About bed leveling

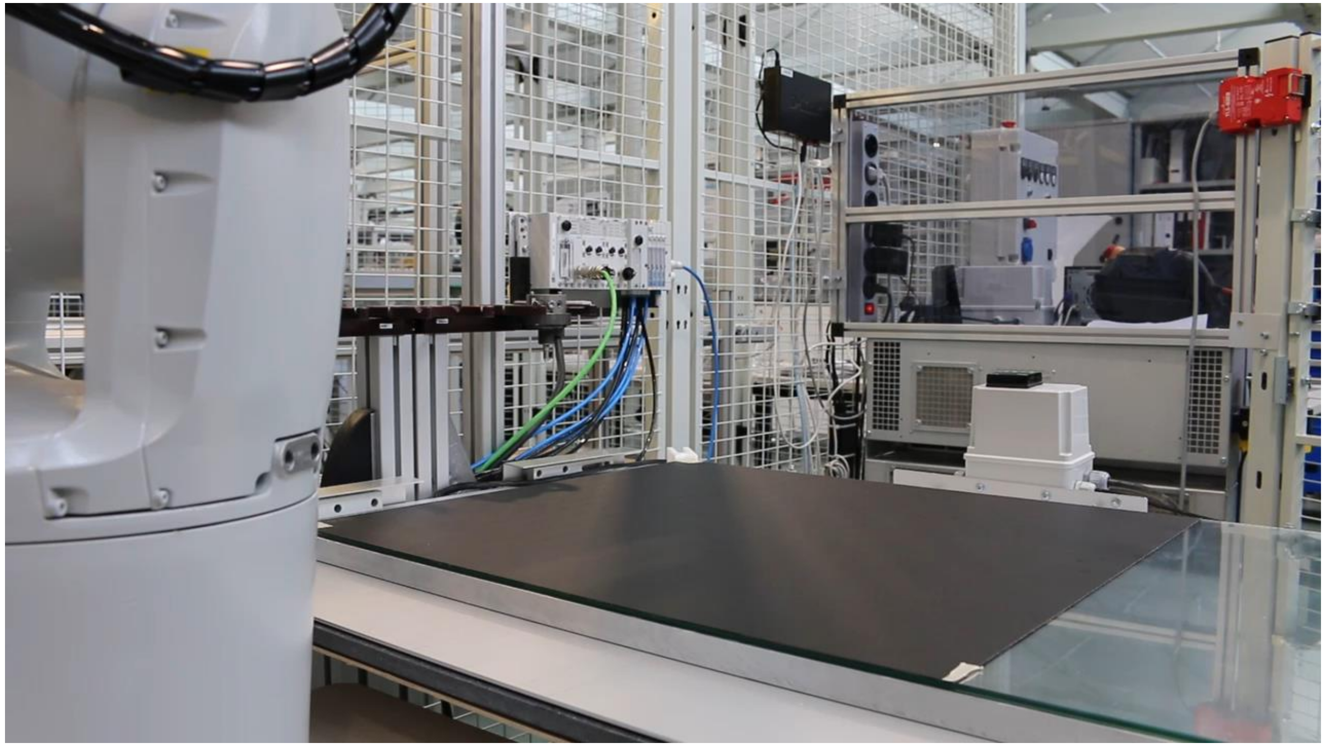
- Additive manufacturing requires an accurately leveled build platform to perform well.
- Bed leveling used to be a manual time-consuming and unreliable procedure.
- By mounting a retractable bed leveling probe on the extruder tool, the bed leveling procedure was almost entirely automated, except for an initial rough estimate of build platform position.




PROBE BINARY SEARCH PROCEDURE

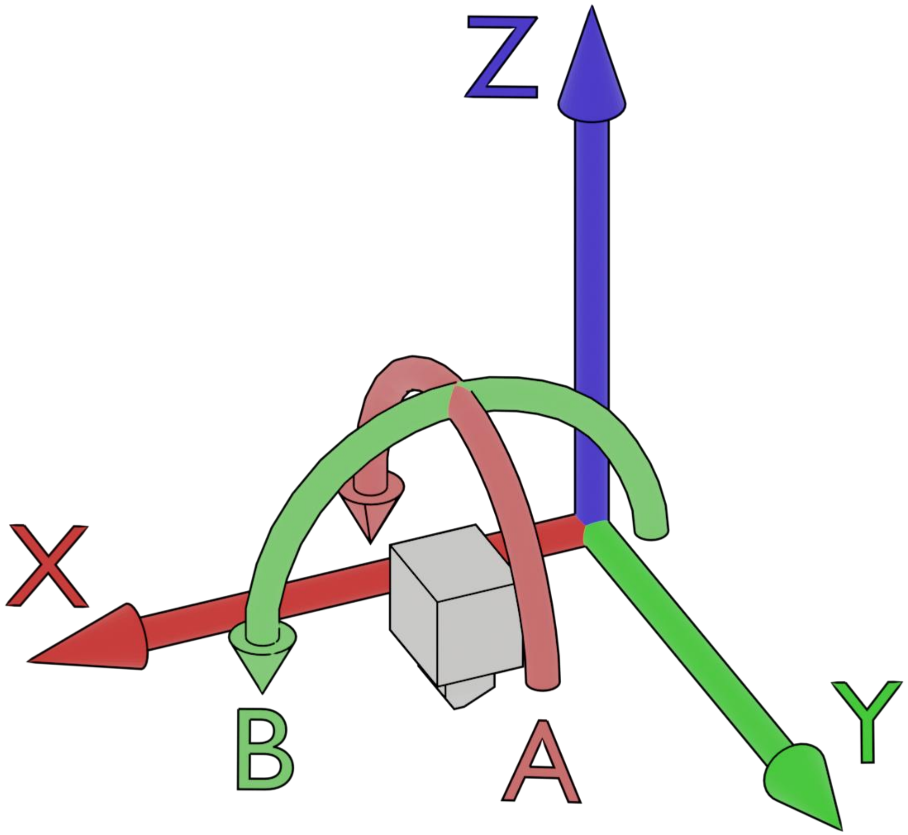



ACTUAL BED HEIGHT GRAPH

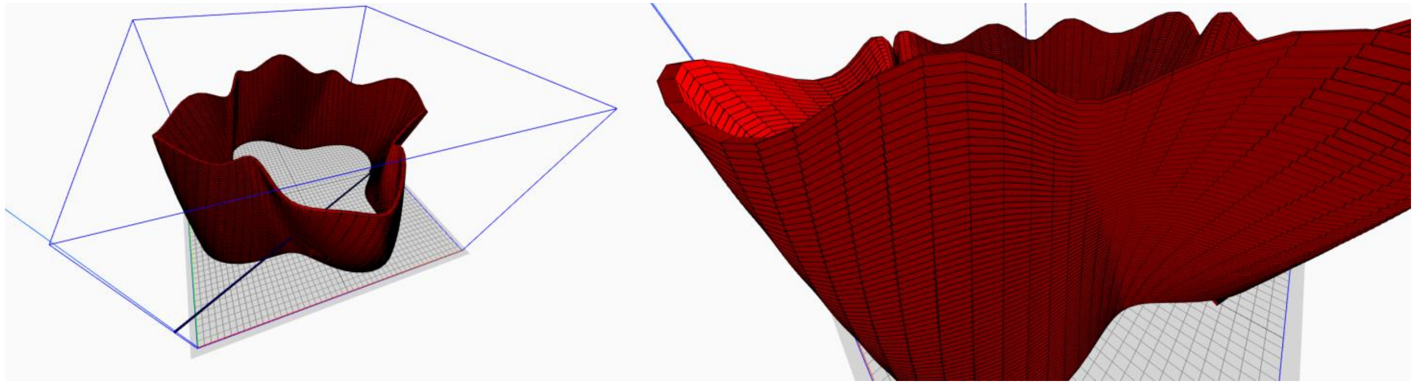


# Freeform and non-planar printing

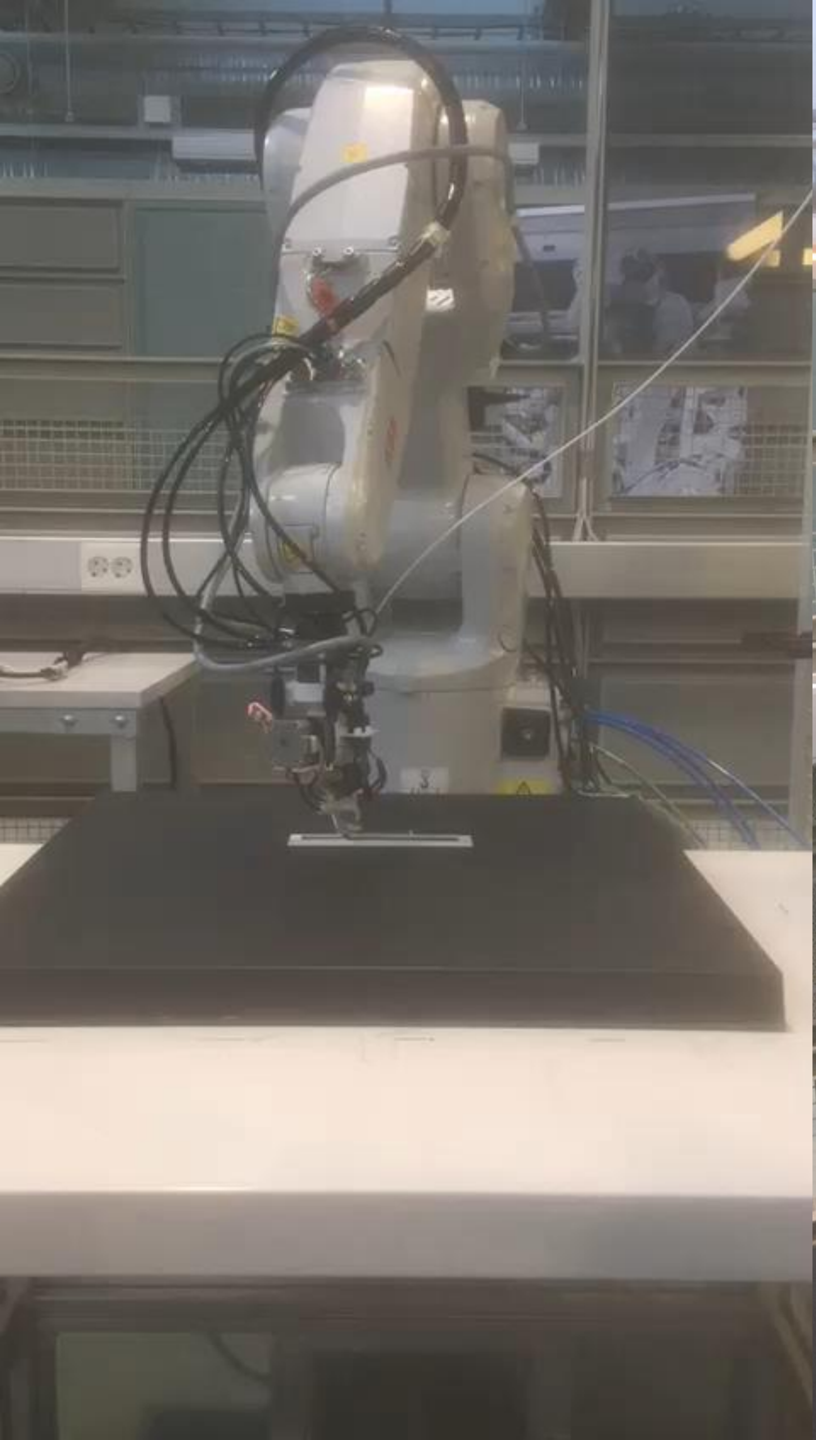
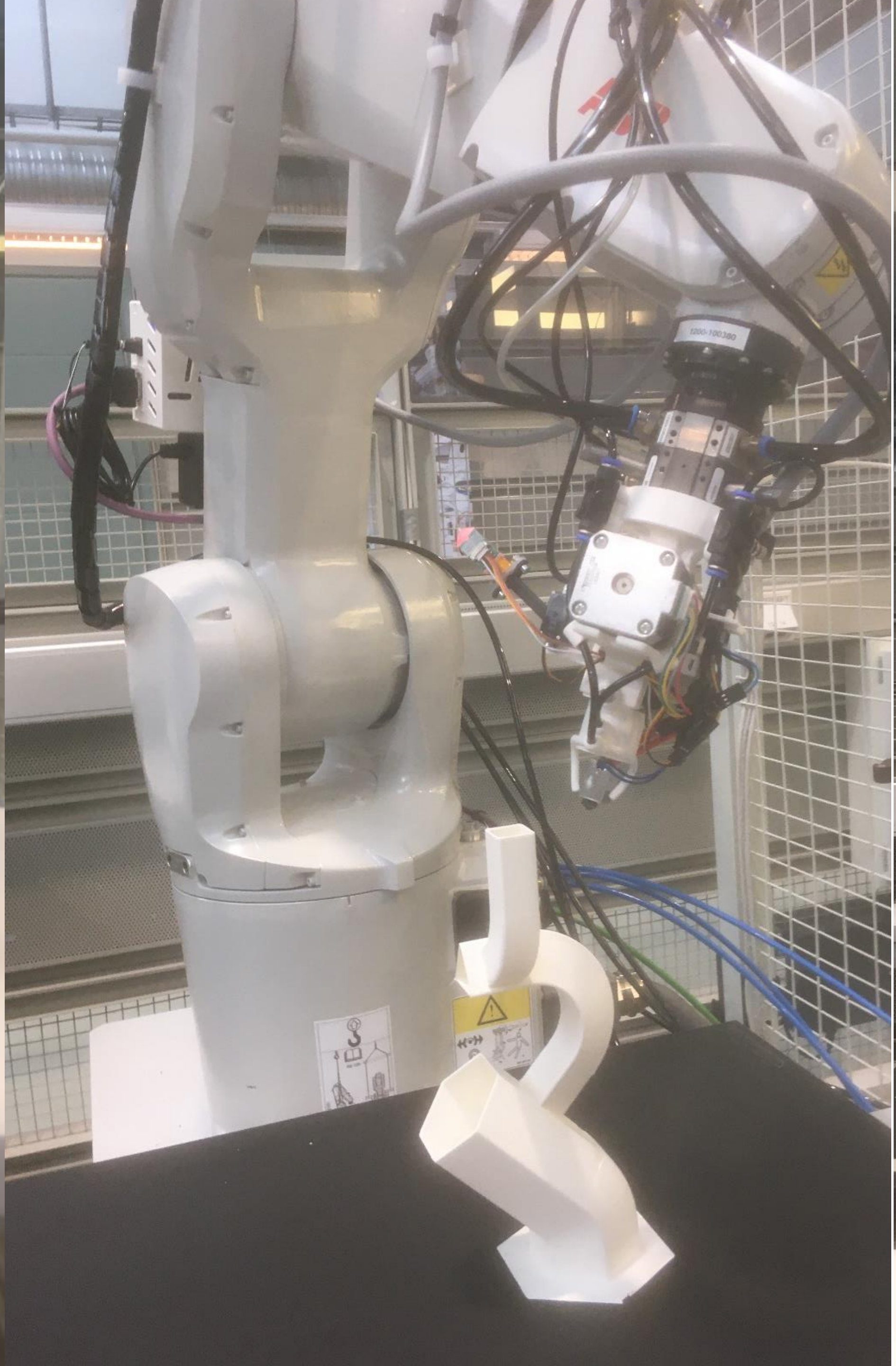
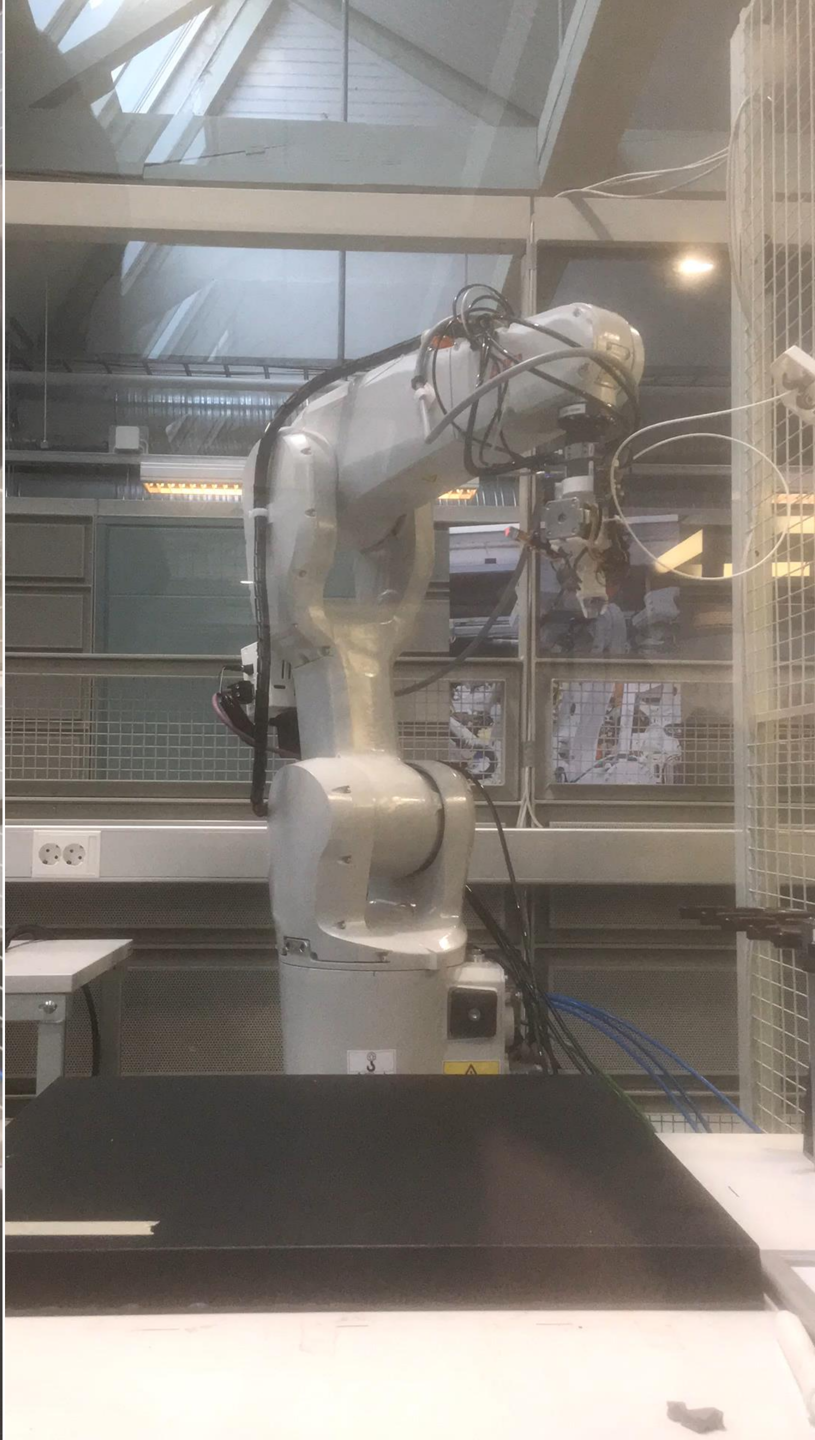
- Print head rotation was added to the robot control program by extending the typical G-code commands available to 3D printers.
- Freeform movement allows for the creation of both **NON-PLANAR** and **FREEFORM** objects.
- Freeform movements require special care to avoid unexpected robot collisions.




PRINT HEAD ROTATION USING THE *A, B* PARAMETERS



PARAMETRIC FREEFORM SLICER

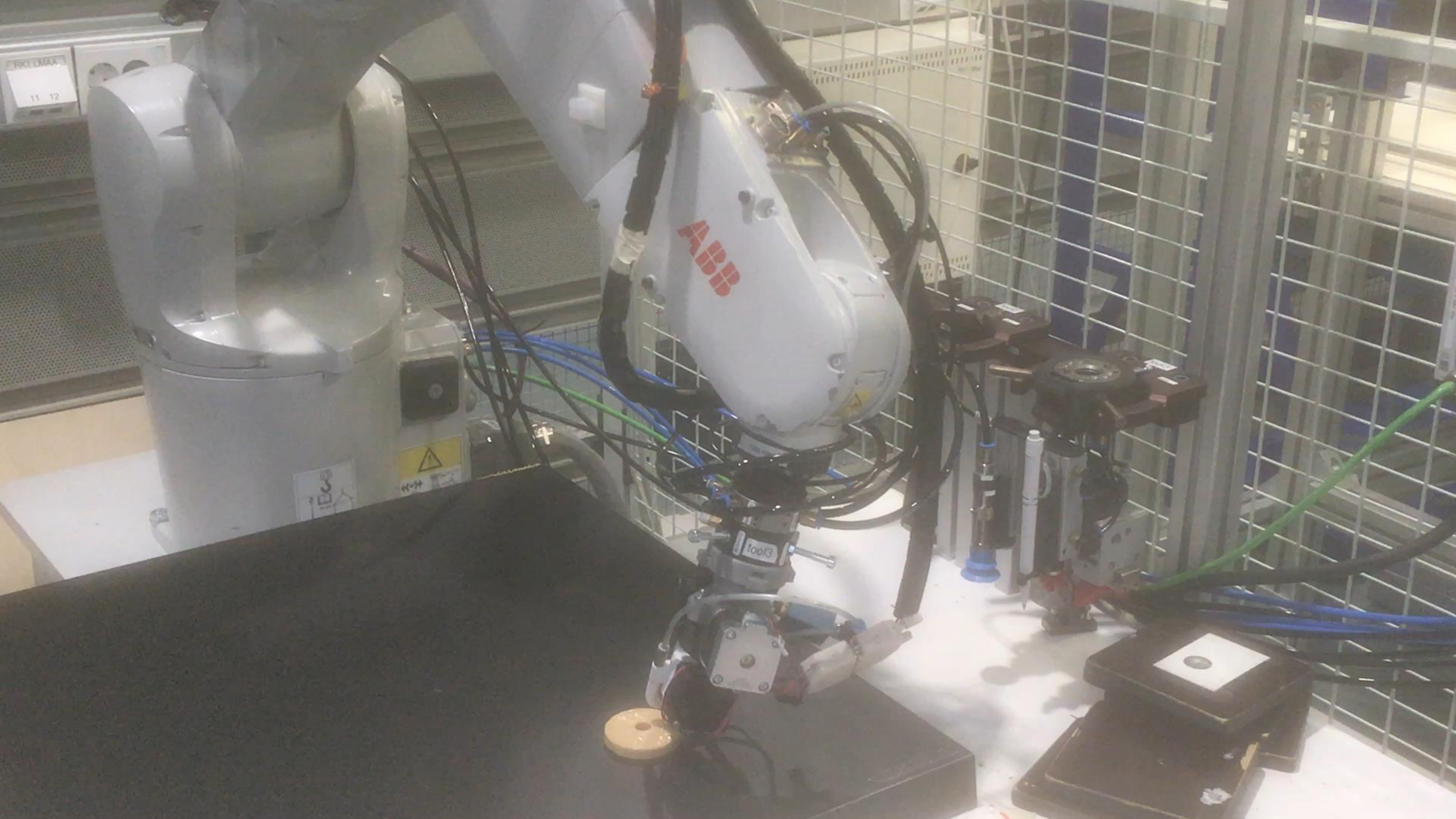
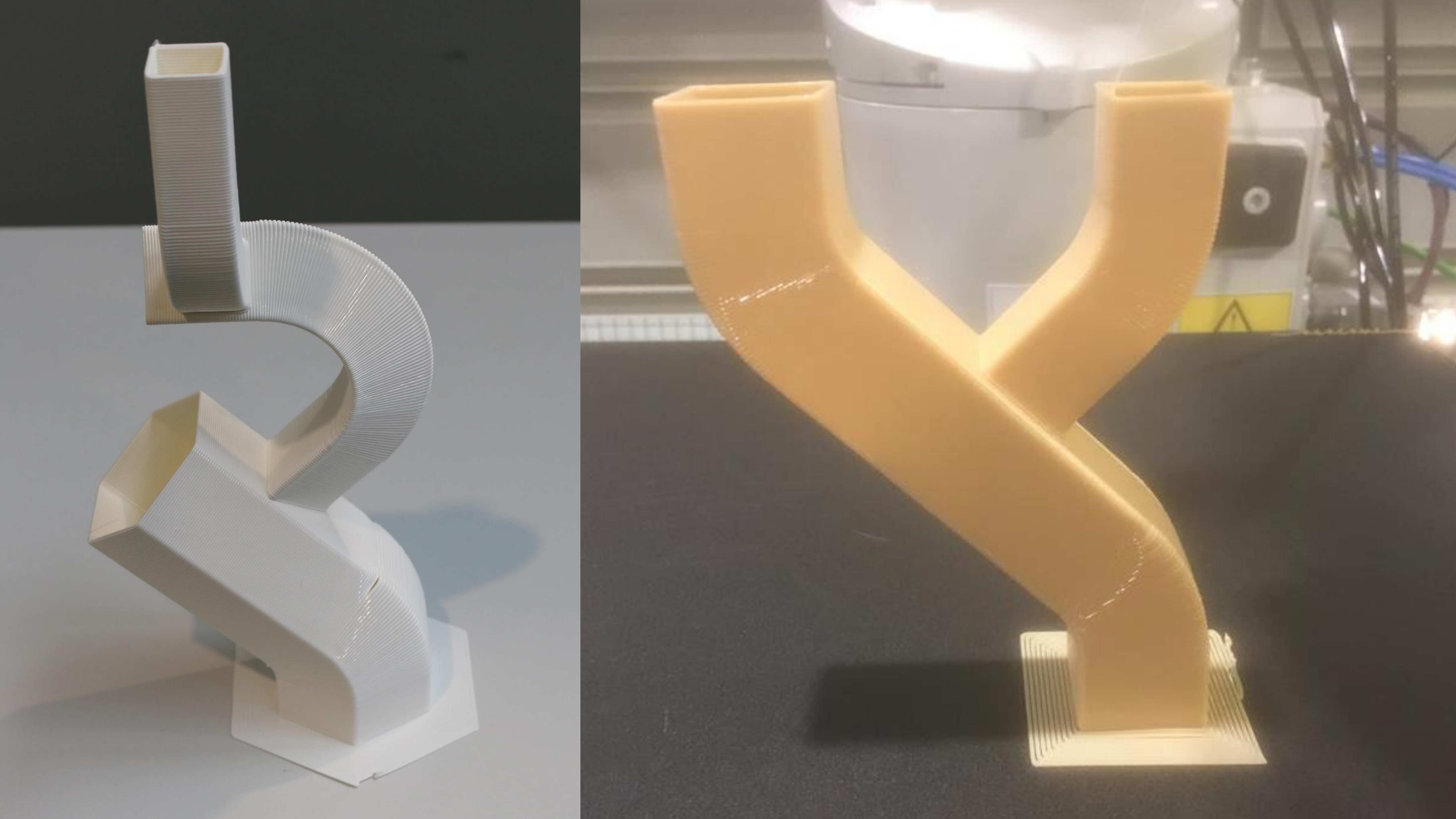
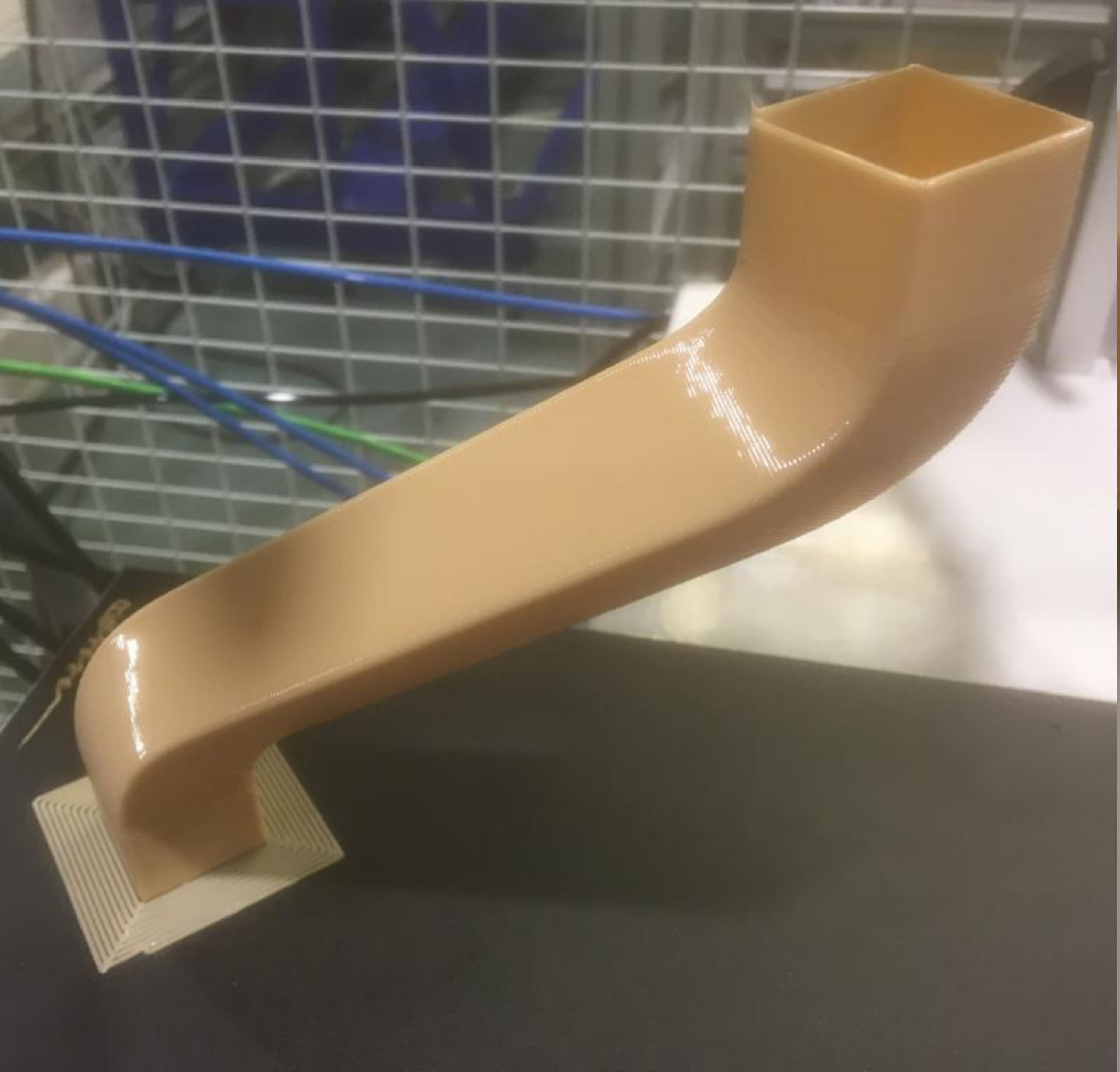


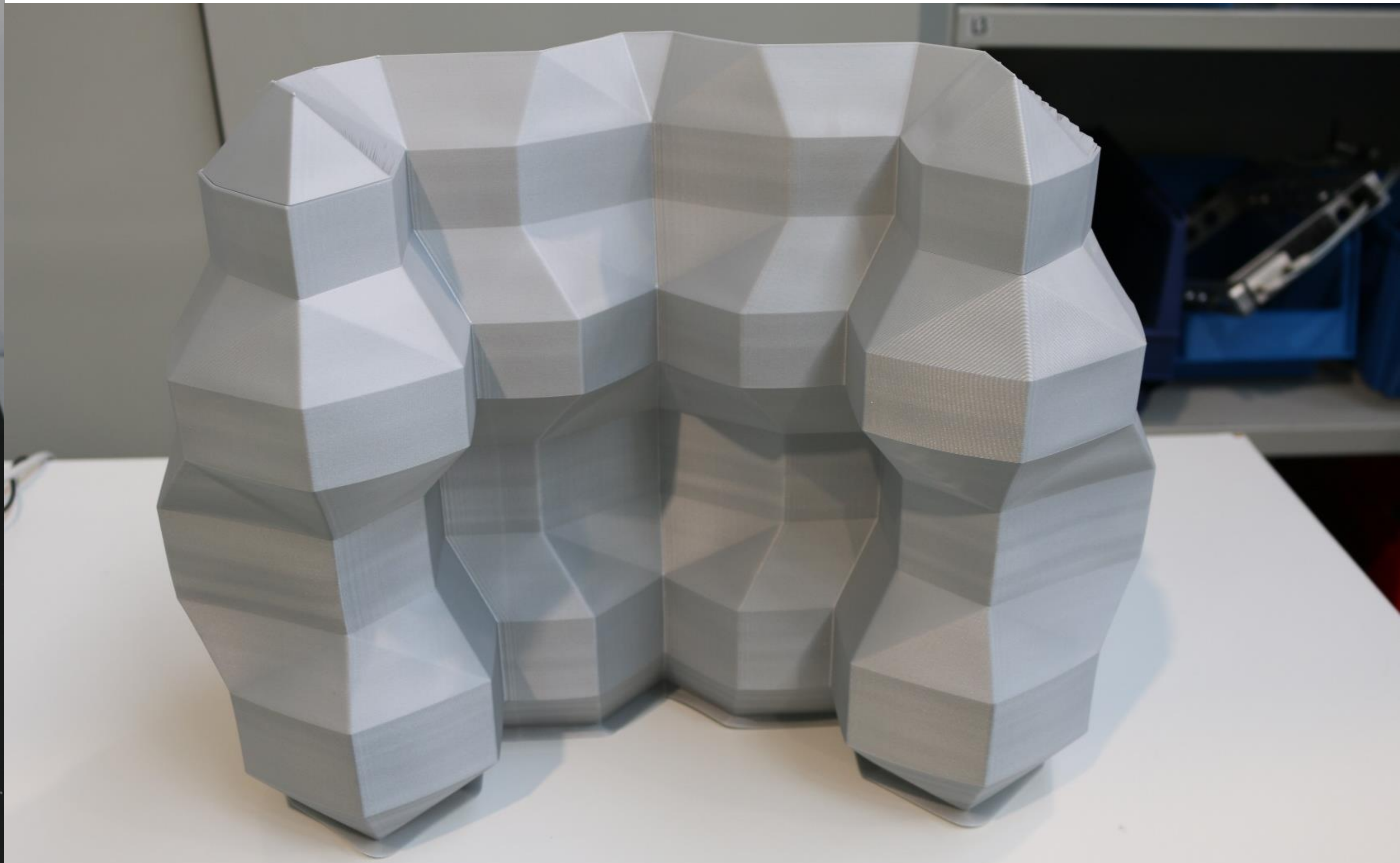
ABB
tool3

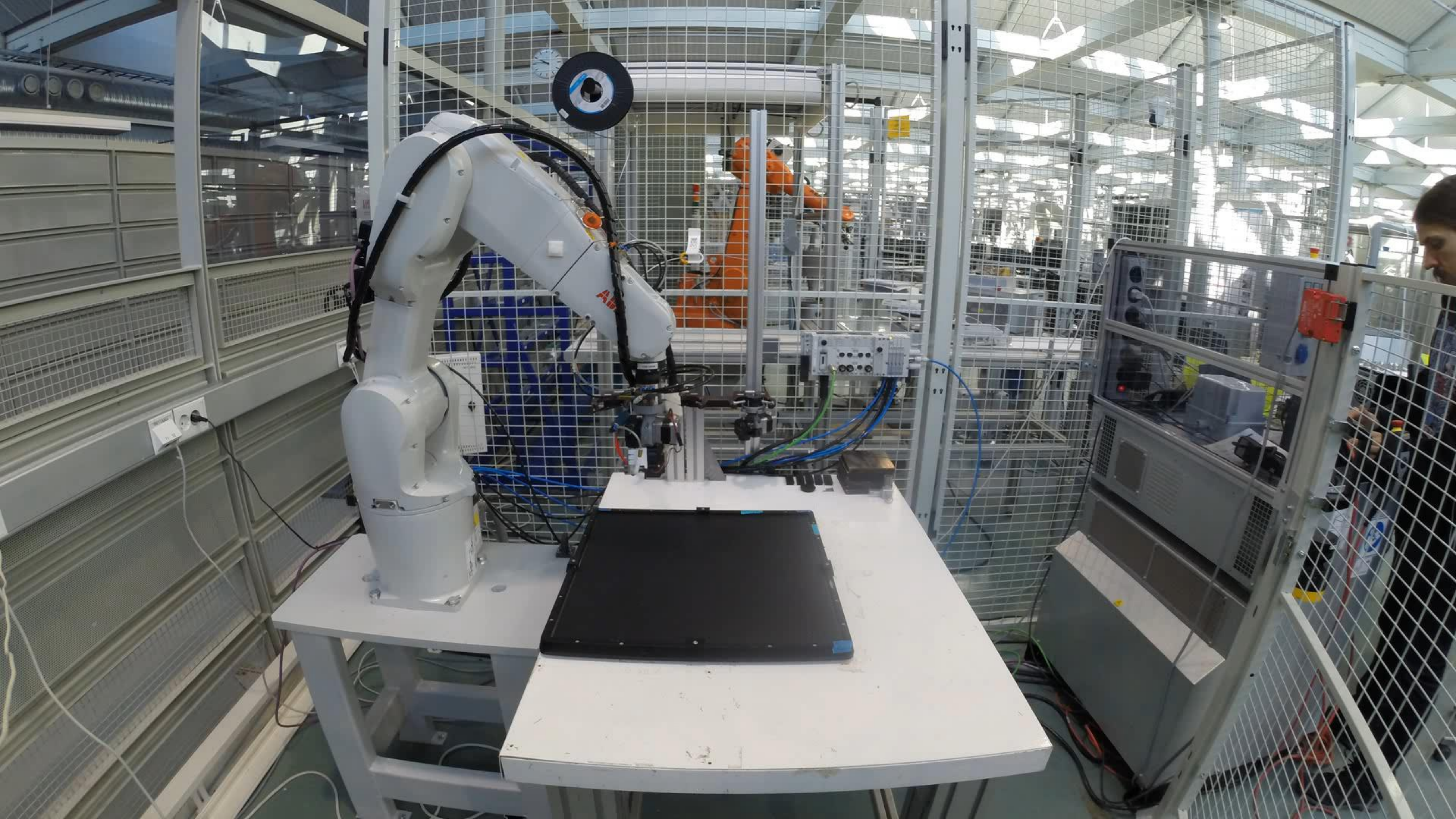




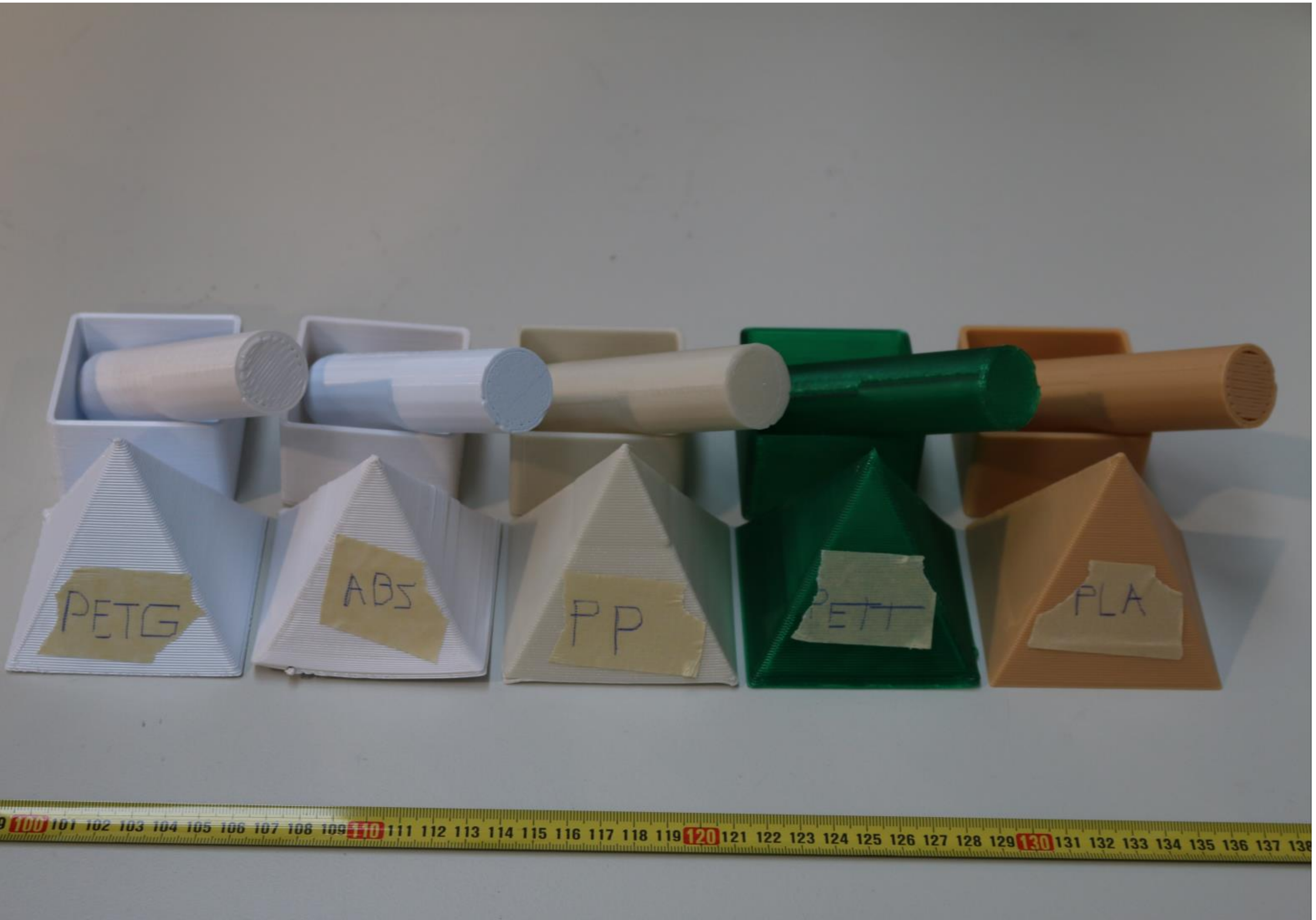
# Large-scale printing

The robot arm has an extensive reach compared to cartesian 3D printers. This allows for extra large objects to be manufactured.





# Material testing



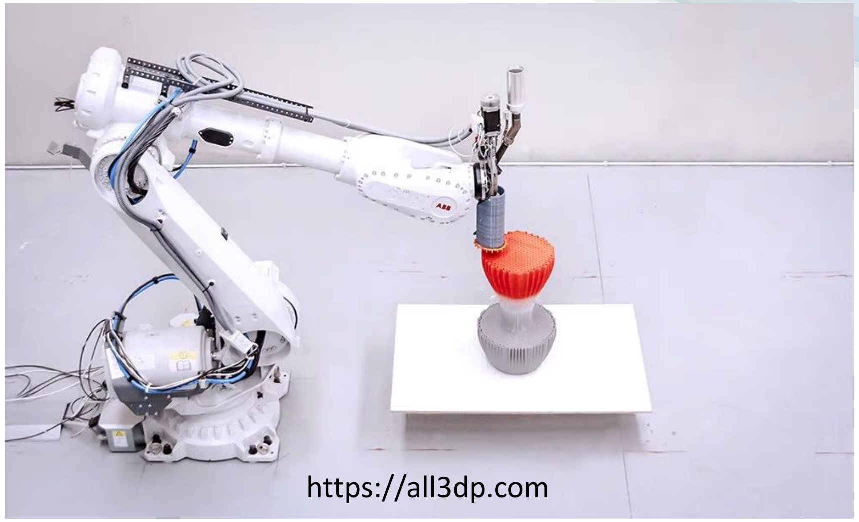

- A large number of materials have been tested with the RAM platform:
  - Polyethylene terephthalate glycol (**PETG**)
  - Acrylonitrile butadiene styrene (**ABS**)
  - Polypropylene (**PP**)
  - Polyethylene coTrimethylene Terephthalate (**PETT**)
  - Polylactic acid (**PLA**)
  - **Filaflex** (Thermoplastic elastomers, **TPE**)
- Due to the relatively open interior of the extruder design the **FilaFlex** filament would not flow through it.
- Special print surfaces had to be used for certain materials, such as box tape for Polypropylene.

# TB-RAM CoE, ABB Robotstudio Add-In

**The project also includes testing with commercial products:**

- **Robotic 3D printing with a granular extruder**
  - there is an add-in for the ABB robot in the RobotStudio environment. This allows a commercial extruder to be connected to the robot as a printhead.

- **Using the YuMi Collaboration Robot with a 3D-Printing pen**
  - manual 3D printer pen was attached to the YuMi Collaboration Robot and tested for printing functionality



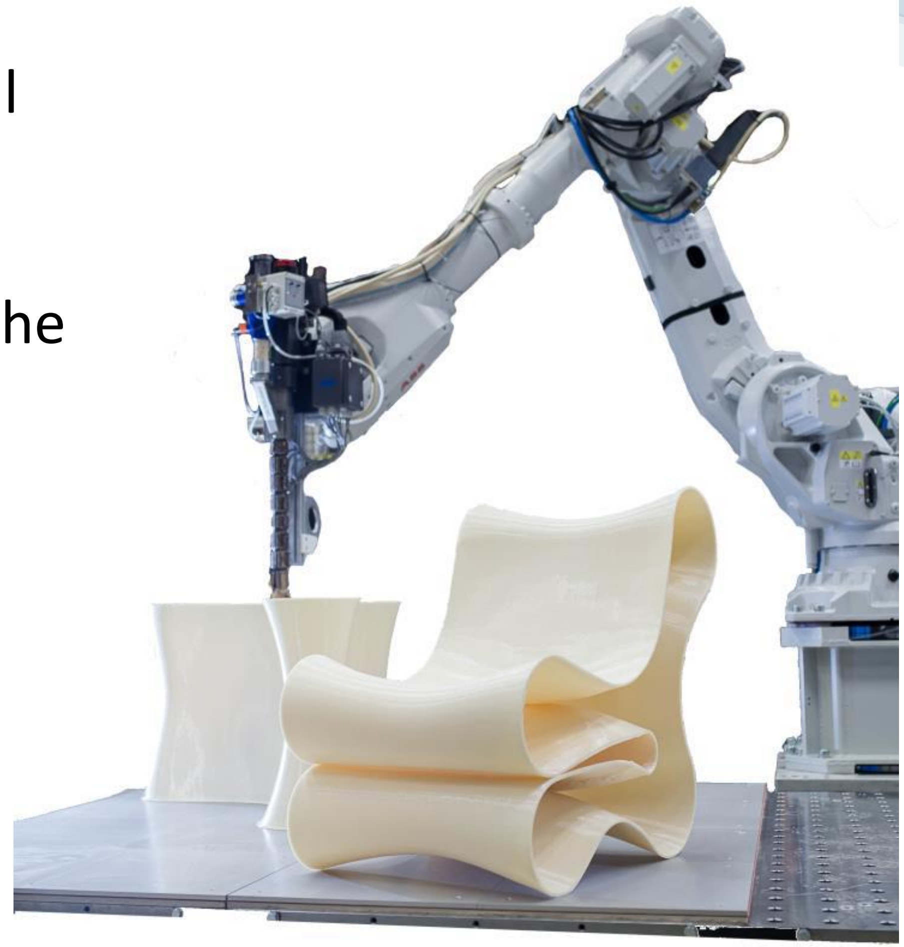

# TB-RAM CoE, ABB Robotstudio Add-In

Generates RAPID code from G-code (used for traditional small 3D printers).

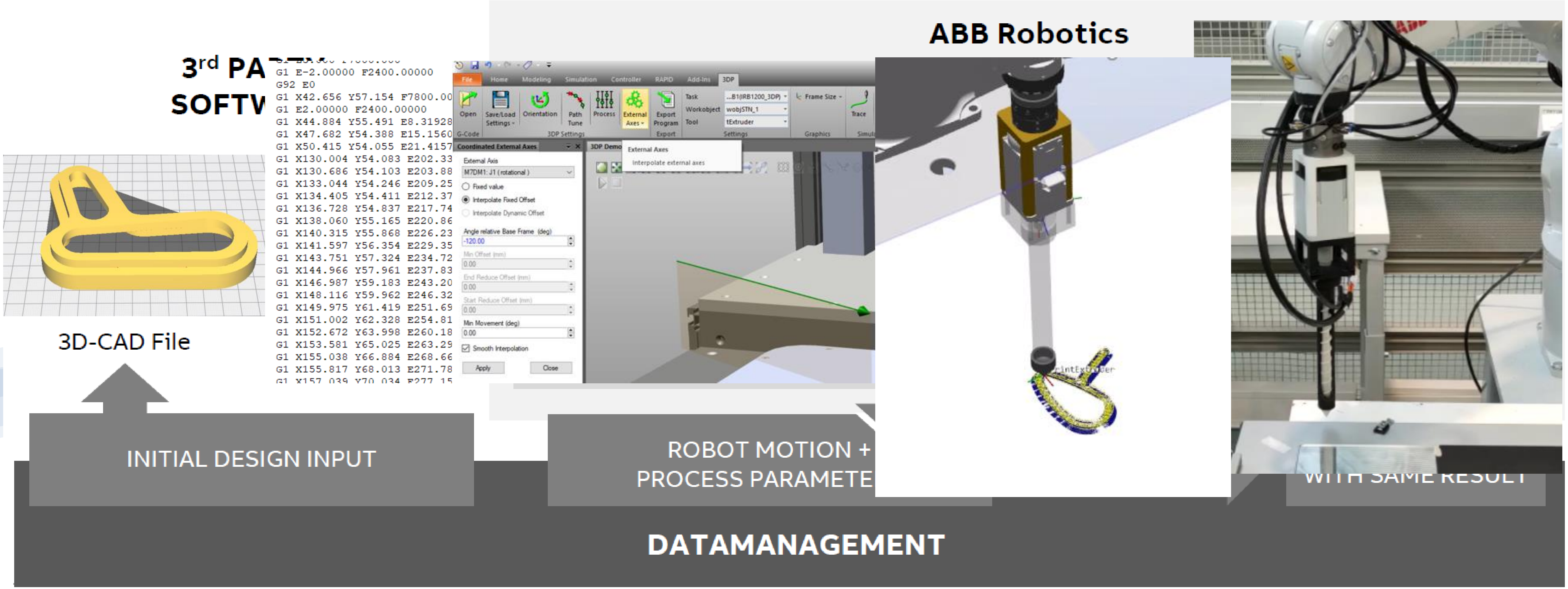
No limit for number of coordinate points = no limit for the product size .

Support for coordinated external axes (linear and/or rotational).

Granules extruder controlled as an IRC5 axis or with DispenseWare.

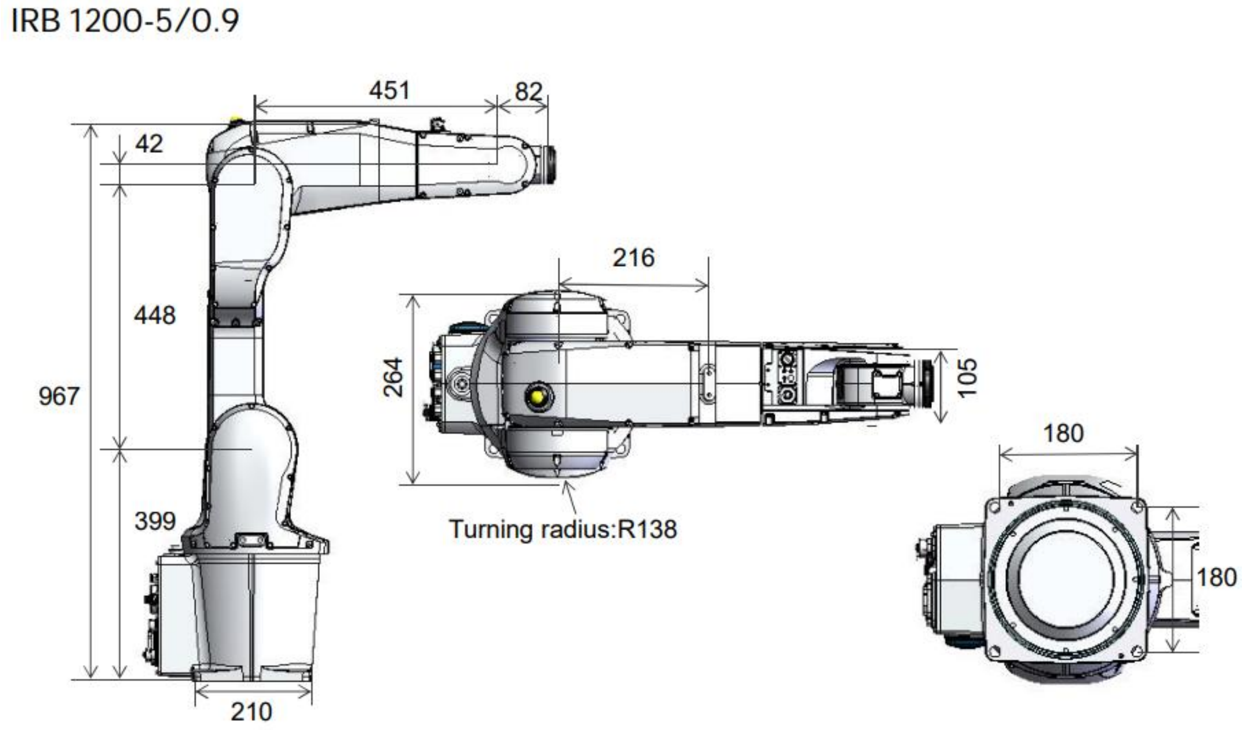


# TB-RAM CoE, ABB Robotstudio Add-In



# TB-RAM CoE, ABB Robotstudio Add-In


## ABB – IRB – 1200 ROBOT



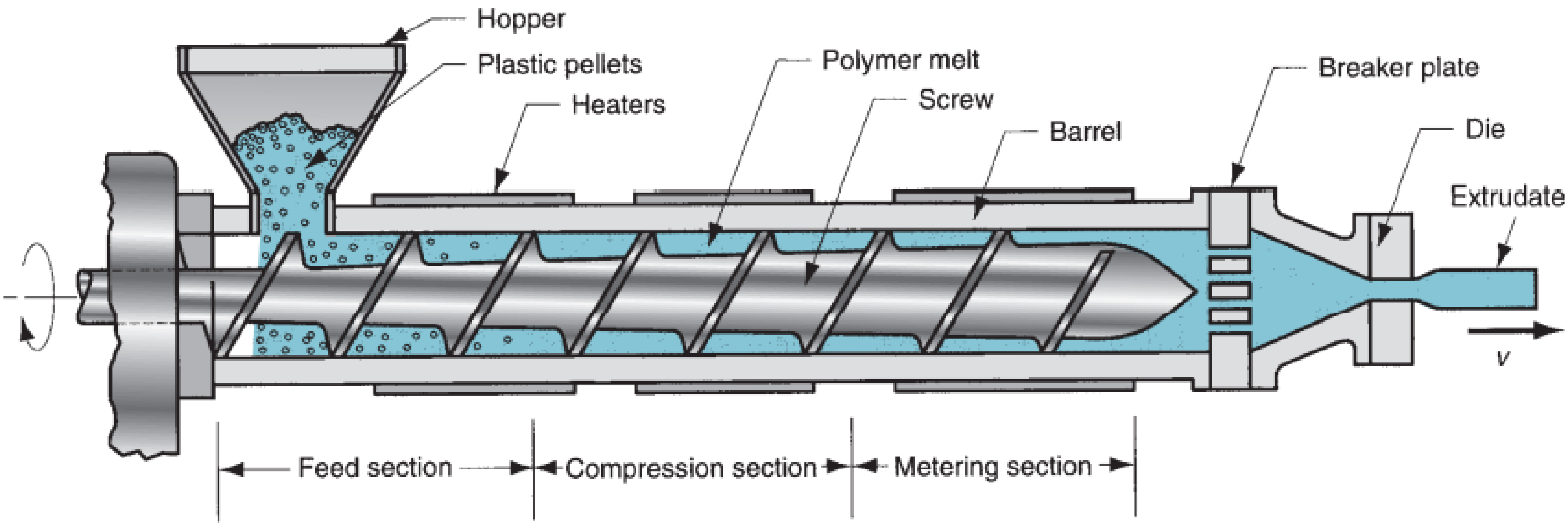
# TB-RAM CoE, ABB Robotstudio Add-In

## MOTOR UNIT 80

- Standardized motor unit package
- Smallest ABB motor unit

| | |
|---|---|
| Weight | 1,4 kg |
| Rated speed | 6000 rpm |
| Max. Dynamic Torque | 2,5 Nm |

# TB-RAM CoE, ABB Robotstudio Add-In




https://mechanicalbase.com/all-aspects-of-plastic-extrusion-process-equipments-dies-design-calculations/

# TB-RAM CoE, ABB Robotstudio Add-In

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service for solution
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your money in safe
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**JAIHO GROUP**
**NINGBO JAI HO MACHINERY CO.,LTD**

ADD.:No.26,Dinghai Industry, Zhoushan,Zhejiang
contact:Thomas Ji Email:thomas@jaihogroup.com.cn,
TEL:86-574-89086758 FAX:86-574-87359334 www.jaiho-screw.com, www.jaihogroup.com.cn

**Customer: Mathieu GONZALEZ** Date:5TH MAR 2021

Adds.:Wolffintie 33, 65200 Vaasa, Finland. PI No.:JG1926701-181X

ORIGINAL

## PROFORMA INVOICE

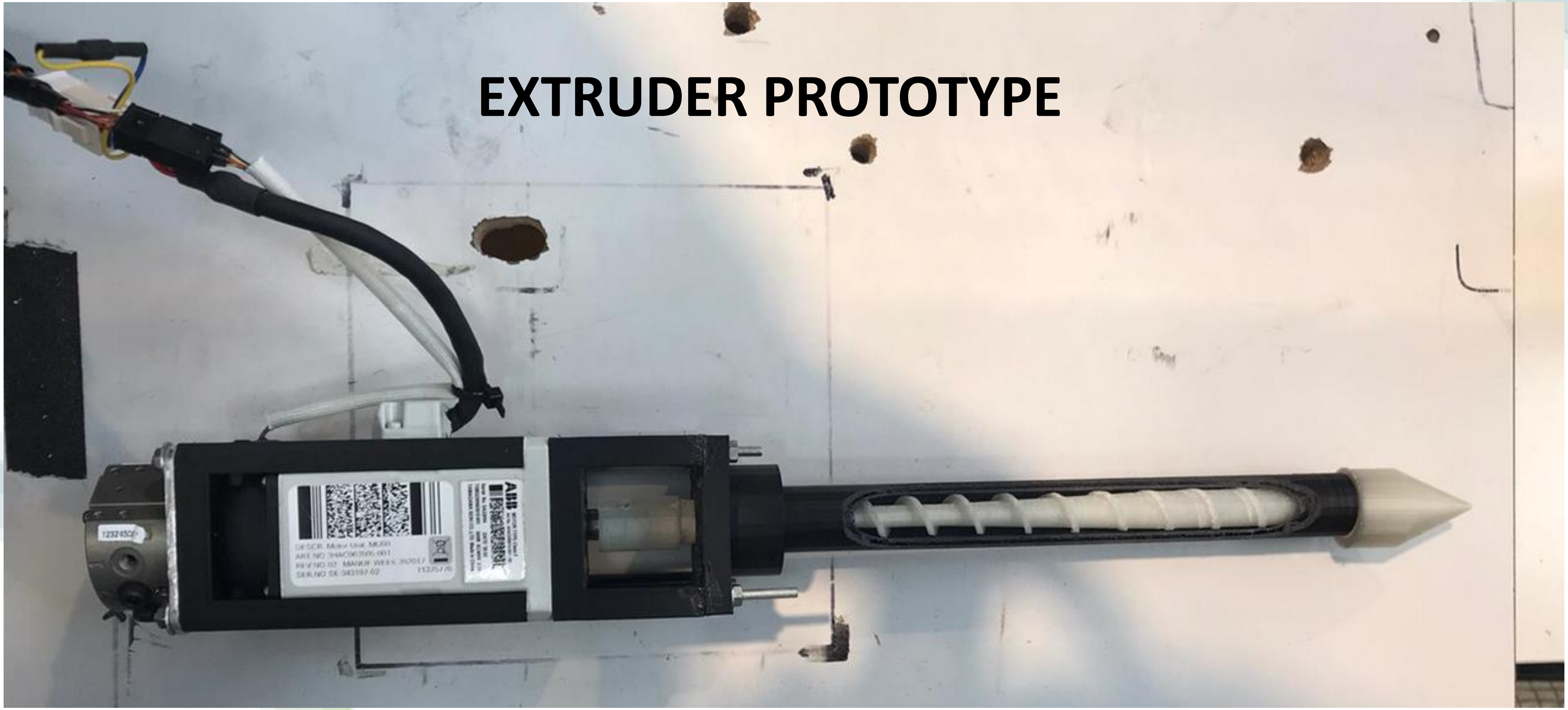
| Item | Name | Drawing | Qty | Treatment | Delivery time | Unit price/set |
|---|---|---|---|---|---|---|
| 1 | D16 screw barrel for extruder | From supplier | 1 Set | 38CrMoAlA material / chrome plating | Within 30 days | $400.00 |
| 2 | Temperature controller | Standard | 1 set(3pcs/set) | Standard | | $60.00 |
| 3 | 1.75mm and 3.0mm nozzle | | 2 pc | | | $60.00 |
| 4 | Breaker | | 1 pc | | | $30.00 |
| 5 | Thermocouple | | 1 set(3pcs/set) | | | $60.00 |
| 6 | Hopper | | 1 pc | | | $50.00 |
| 7 | Heater | | 1 set(3pcs/set) | | | $60.00 |
| Freight cost by air | | | | | | $150.00 |
| Total price | | | | | | $870.00 |

**Technical Parameter :**
1.Hardness after hardening and tempering: HB280-320;
2.Surface roughness: Ra0.4μm

**Terms and Conditions :**
Trade Terms : Express
Production Time: Within 30 days after received deposit.
Packing: Slushing oil coated& film wrapped in plywood case.
Mode of Transport: Express
Payment Terms: Through Alibaba
Other: All delivered products are brand new at shipment
Quotation validity: 2 month

宁波佳义和机械有限公司
NINGBO JAI HO MACHINERY CO., LTD

# TB-RAM CoE, ABB Robotstudio Add-In



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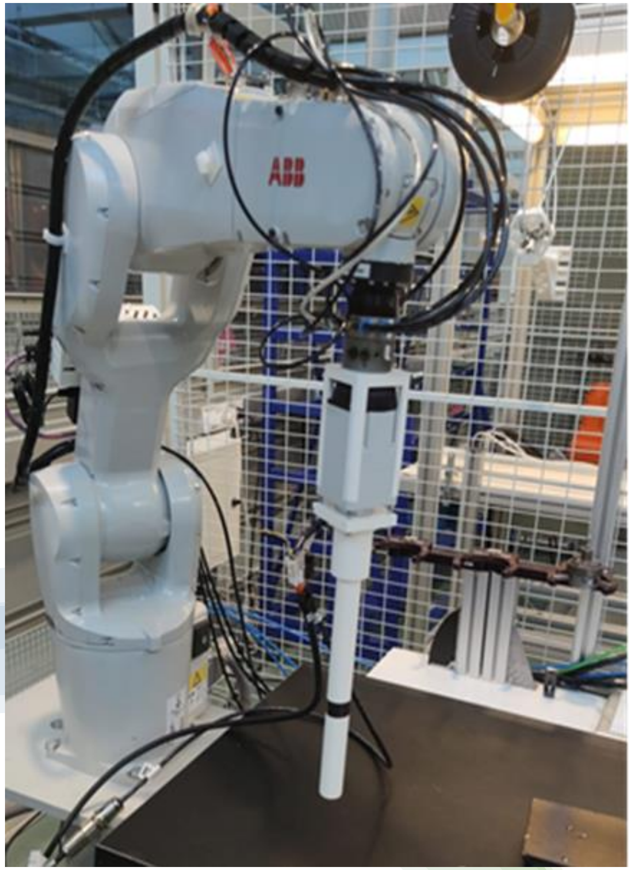
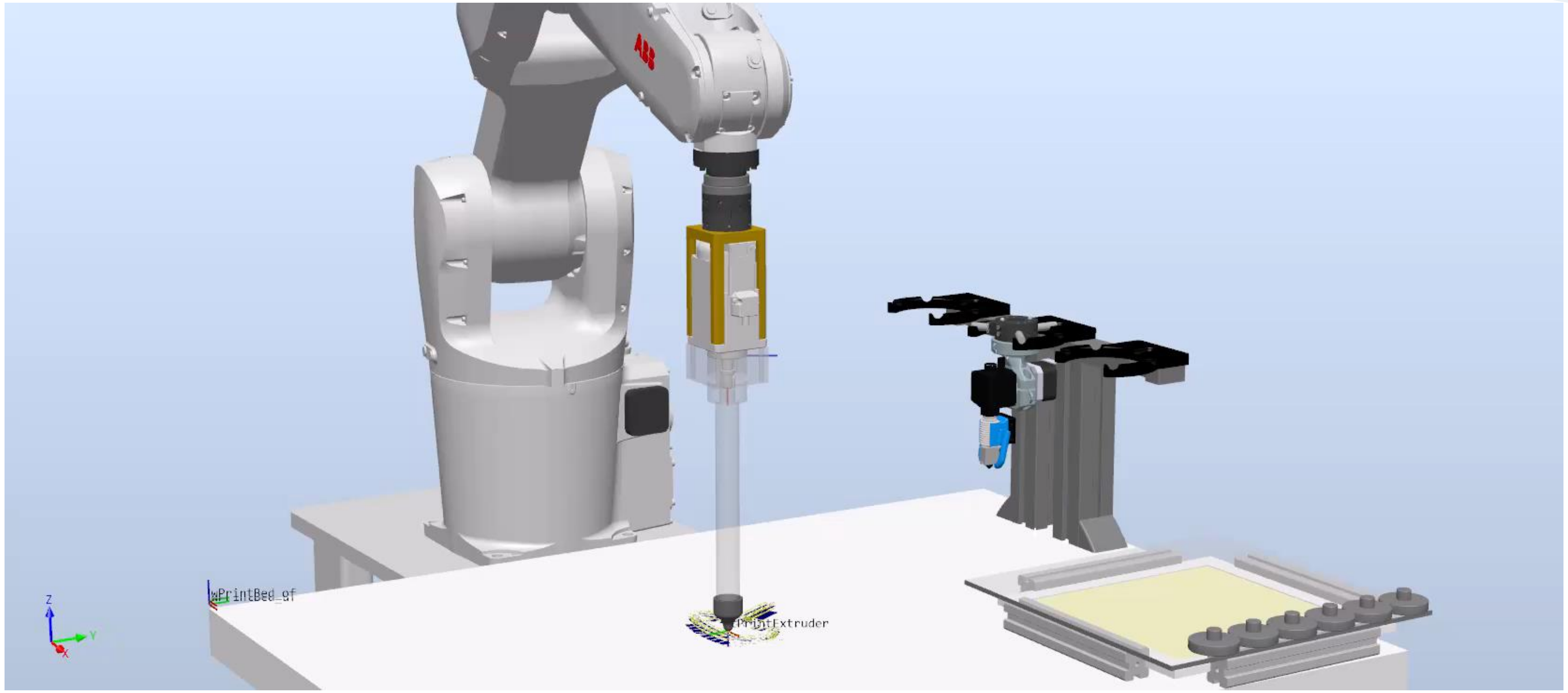
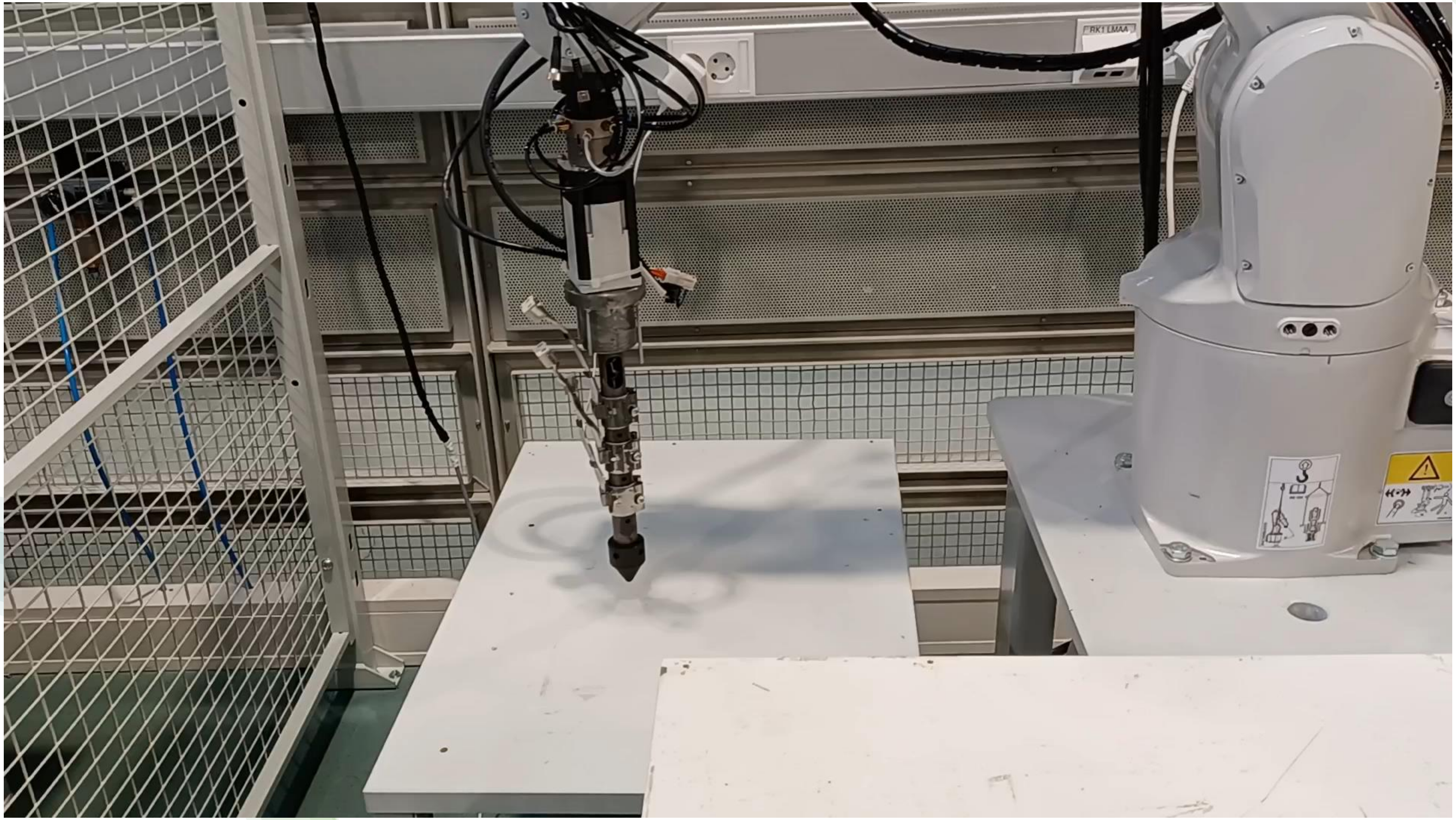


# TB-RAM CoE, ABB Robotstudio Add-In

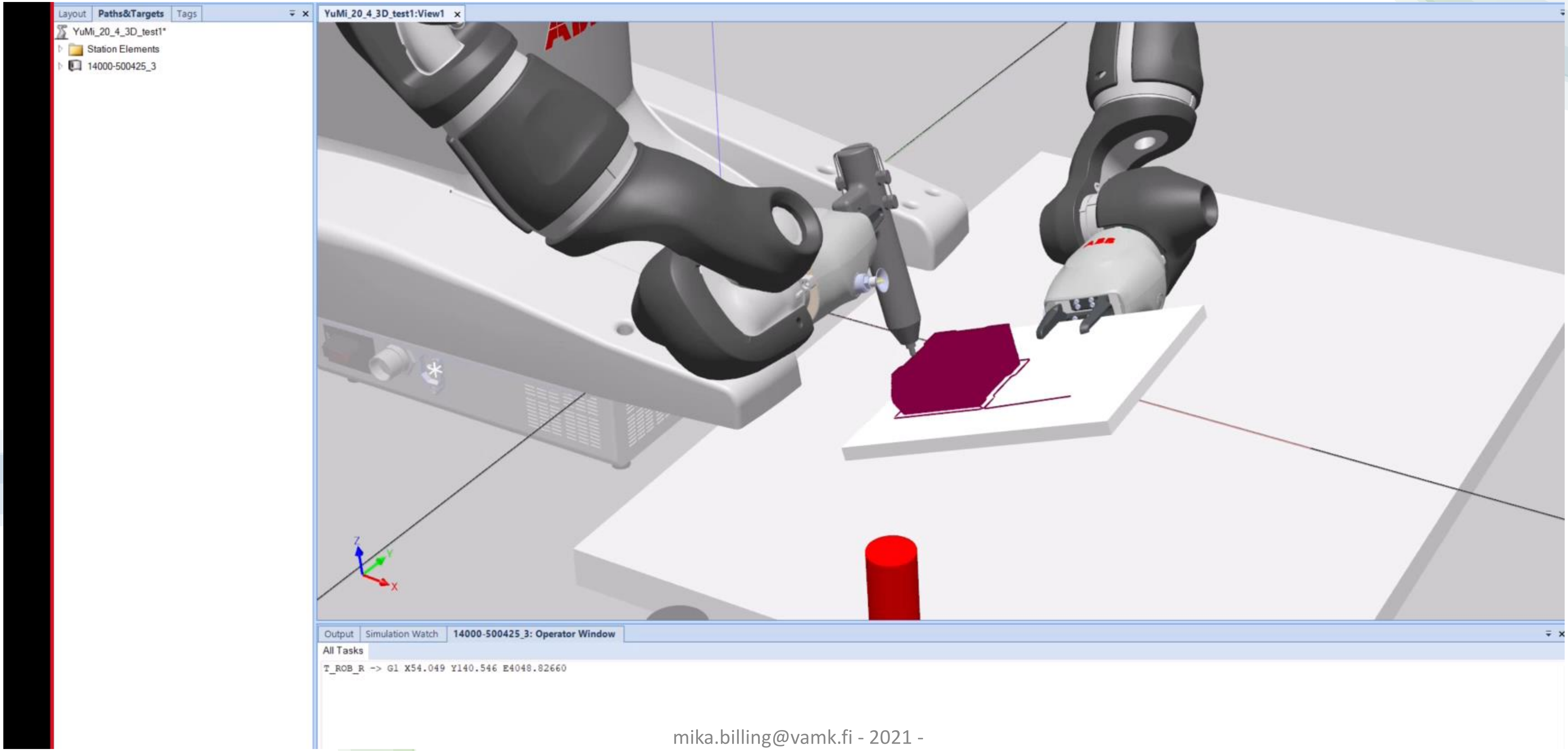
# TB-RAM CoE, ABB Robotstudio Add-In



# 3D-Print with ABB YuMi-Cobot

- Basic 3D-printer pen attached to YuMi robot

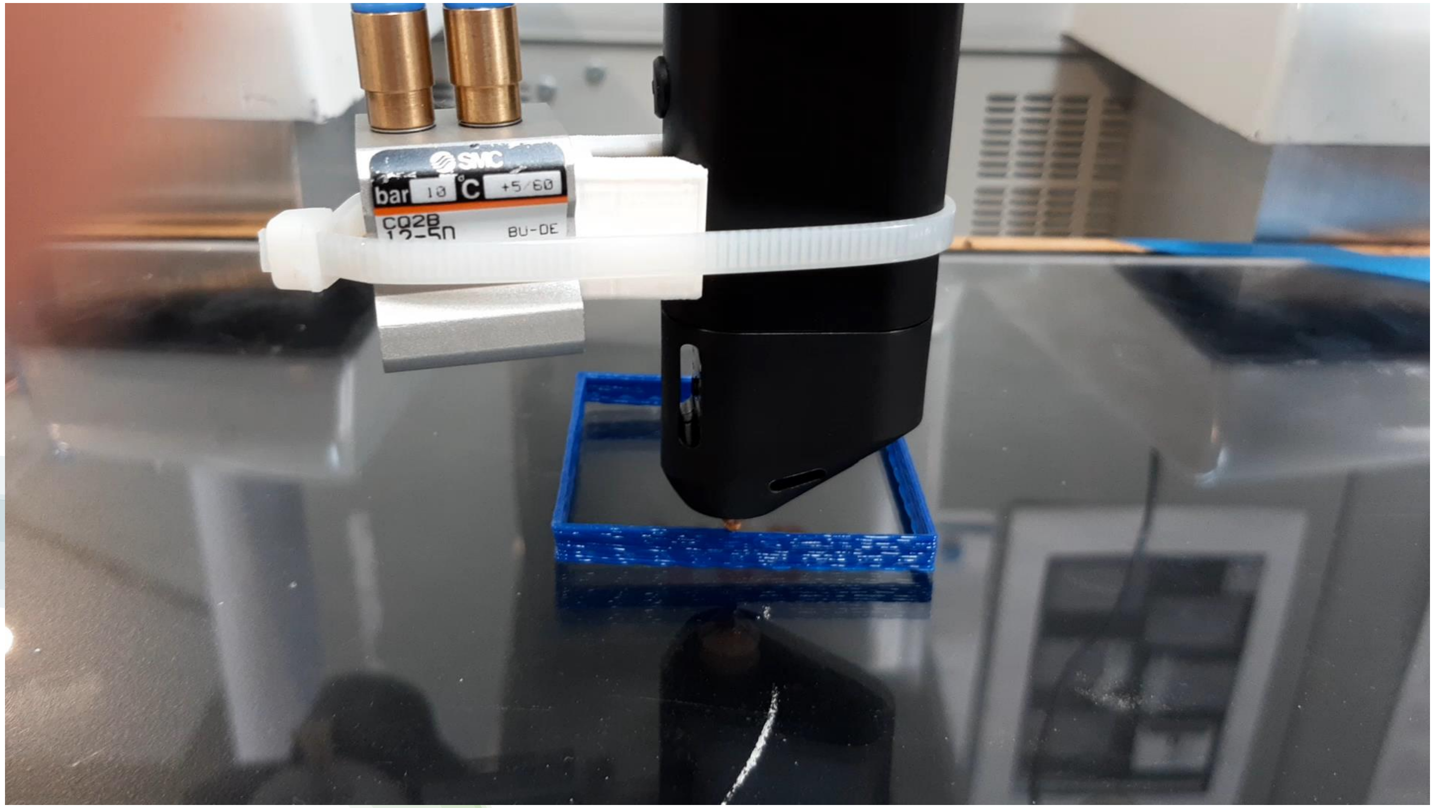

# 3D-Print with ABB YuMi-Cobot

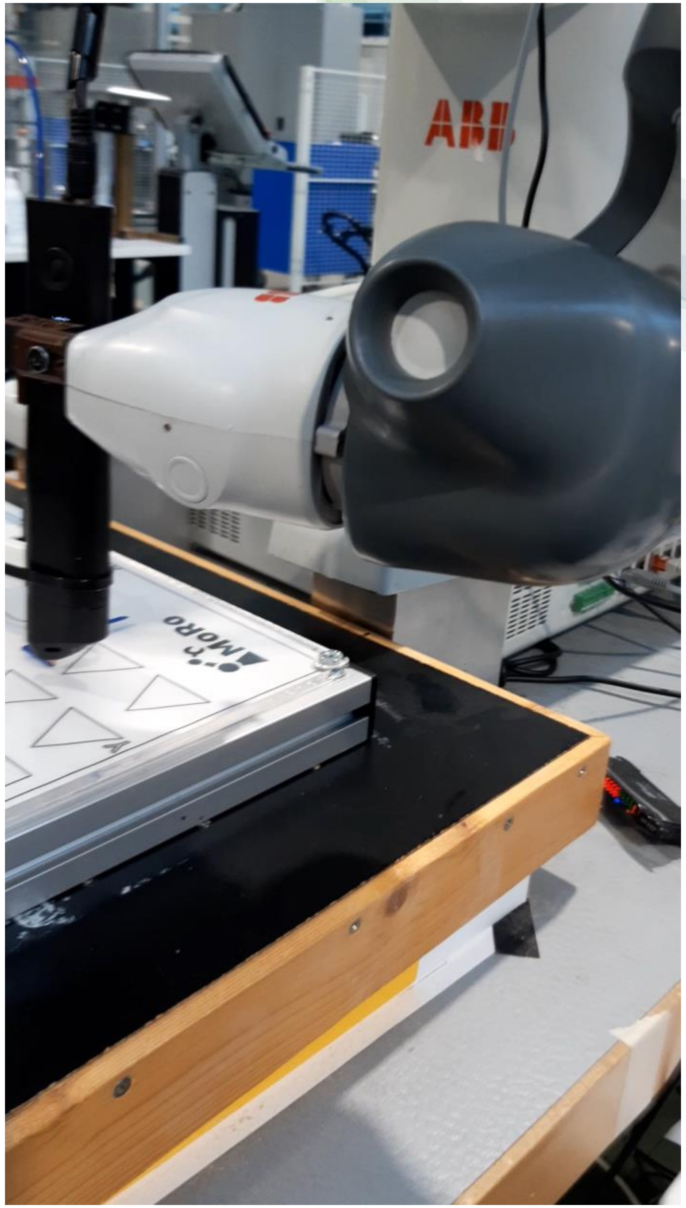


# 3D-Print with ABB YuMi-Cobot

- Modifying gripper fingers to hold printing pen

# 3D-Print with ABB YuMi-Cobot



# Future development

# Technobothnia Robotic Additive Manufacturing Center of Excellence

For more information about the TB-RAM CoE project, for resources related to RAM and for contact information for demonstrations and usage of the TB-RAM platform, please visit:

http://www.tbram.fi

# Open discussion

VAMK
VAASAN AMMATTIKORKEAKOULU
UNIVERSITY OF APPLIED SCIENCES

YRKESHÖGSKOLAN
NOVIA

Vaasan yliopisto
UNIVERSITY OF VAASA

**TB-RAM CoE 1.3.2019 - 31.12.2021**

Österbottens förbund
Pohjanmaan liitto

European Union
European Regional Development Fund

Leverage from
the EU
2014–2020