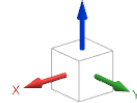
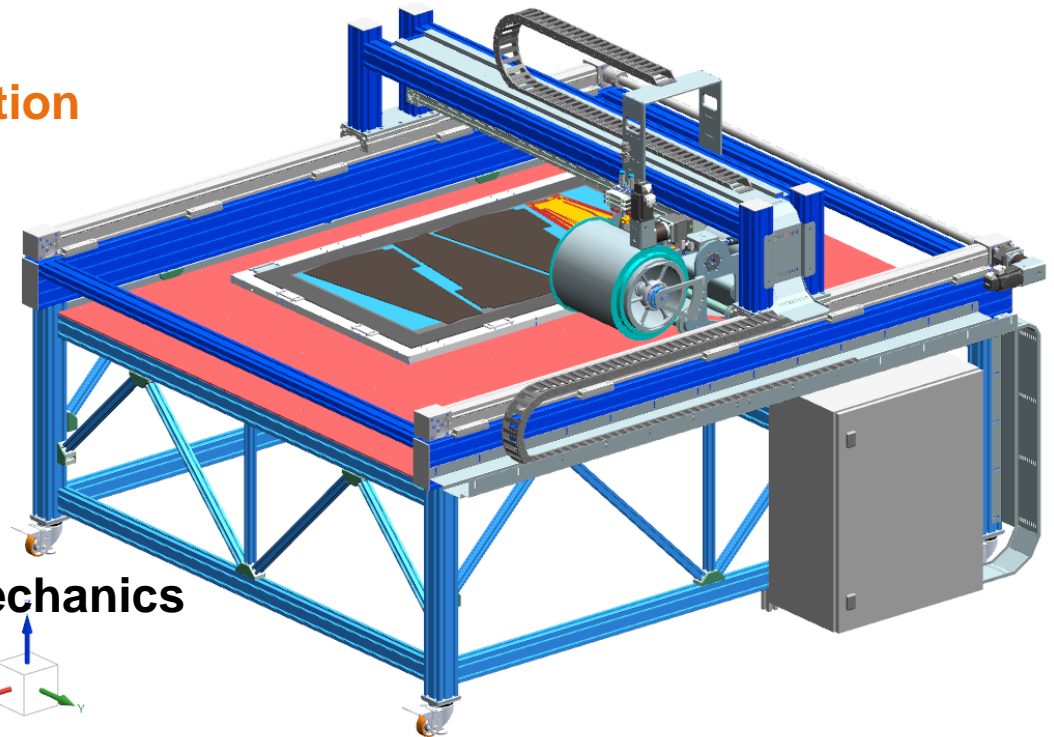


Robotic system for automatic prepreg layup

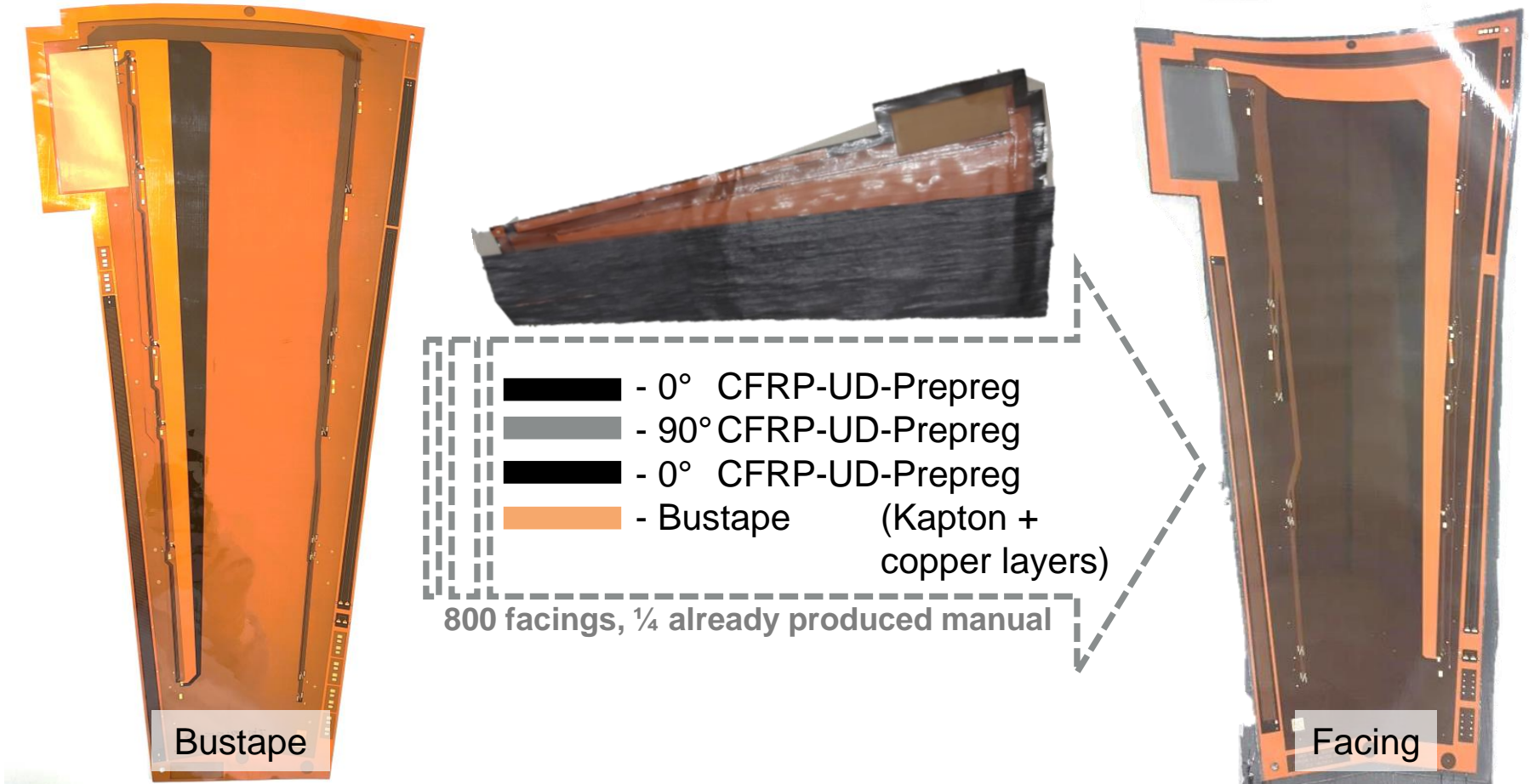
Automation of a prepreg production
using the example
of the ATLAS particle detector

Sören Ahrens
West Lafayette, 30th of May 2024
**Forum on Tracking Detectors Mechanics
at Purdue University**



Motivation

Development of a manual production into an automated production



Wording: **CFRP:** carbon fiber reinforced plastic
Prepreg: pre-impregnated fibers
fibers surrounded by glue, called matrix

UD-tape: unidirectional fibers,
just hold in place by the matrix

Agenda

Chapter 1
Introduction of ATLAS
ITk upgrade

Chapter 2
Industrial layup and
manual DESY
approach

Chapter 3
From conceptual
design to realization

*How to get the manual layup
of prepreg in a tool-supported
manufacturing*

Chapter 4
Construction Design

Apply concepts into a robot

Chapter 5
Building the robot

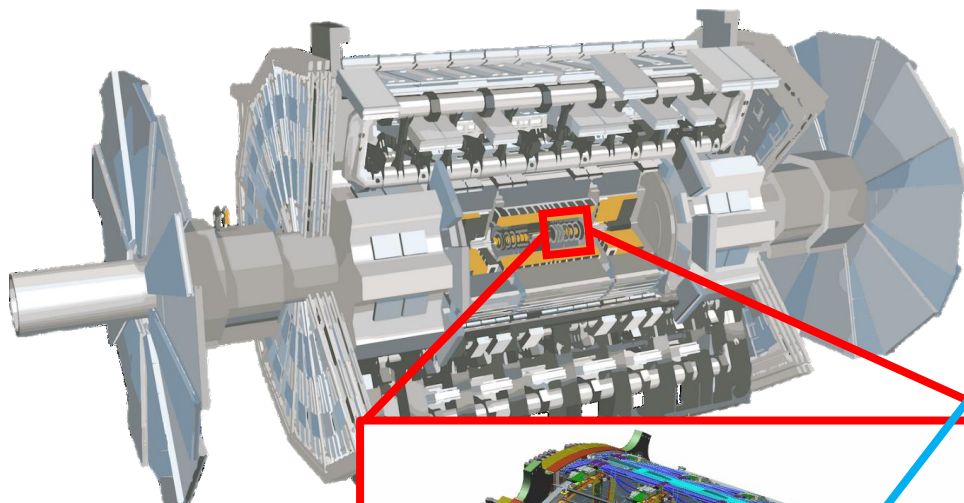
Chapter 6
Summary and outlook

Chapter 1

Introduction of ATLAS

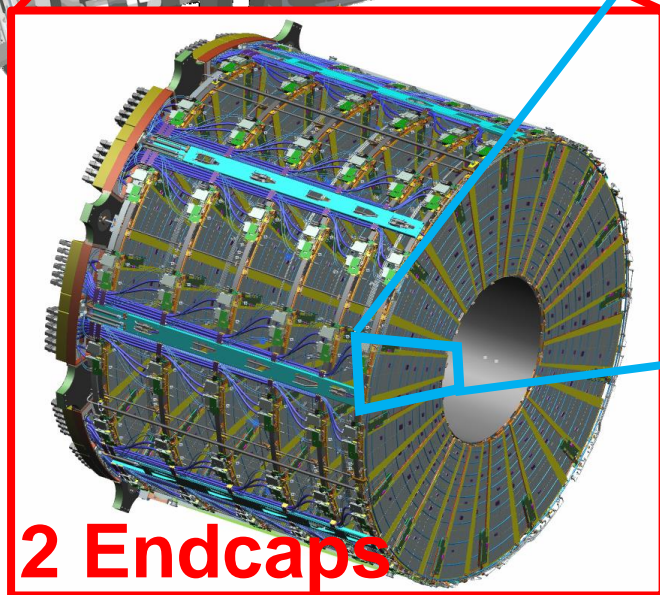
ITk upgrade

ATLAS tracking detector upgrade for High luminosity LHC



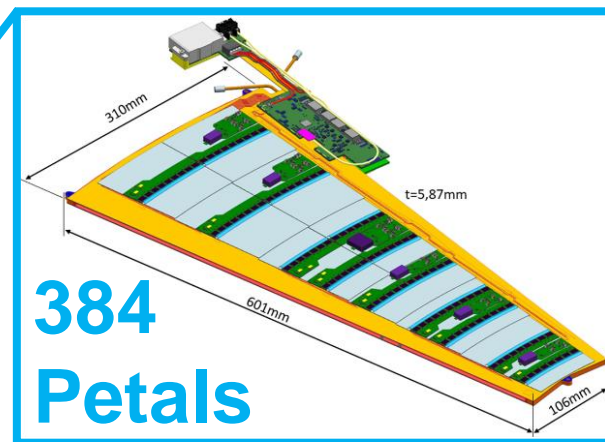
The current ATLAS Inner Detector will be replaced with the Inner Tracker (ITk) to cope with the new High-Luminosity LHC collisions

Source: <https://atlas.cern/Discover/Detector>



2 Endcaps

Source: DESY ATLAS-Group TecTeam

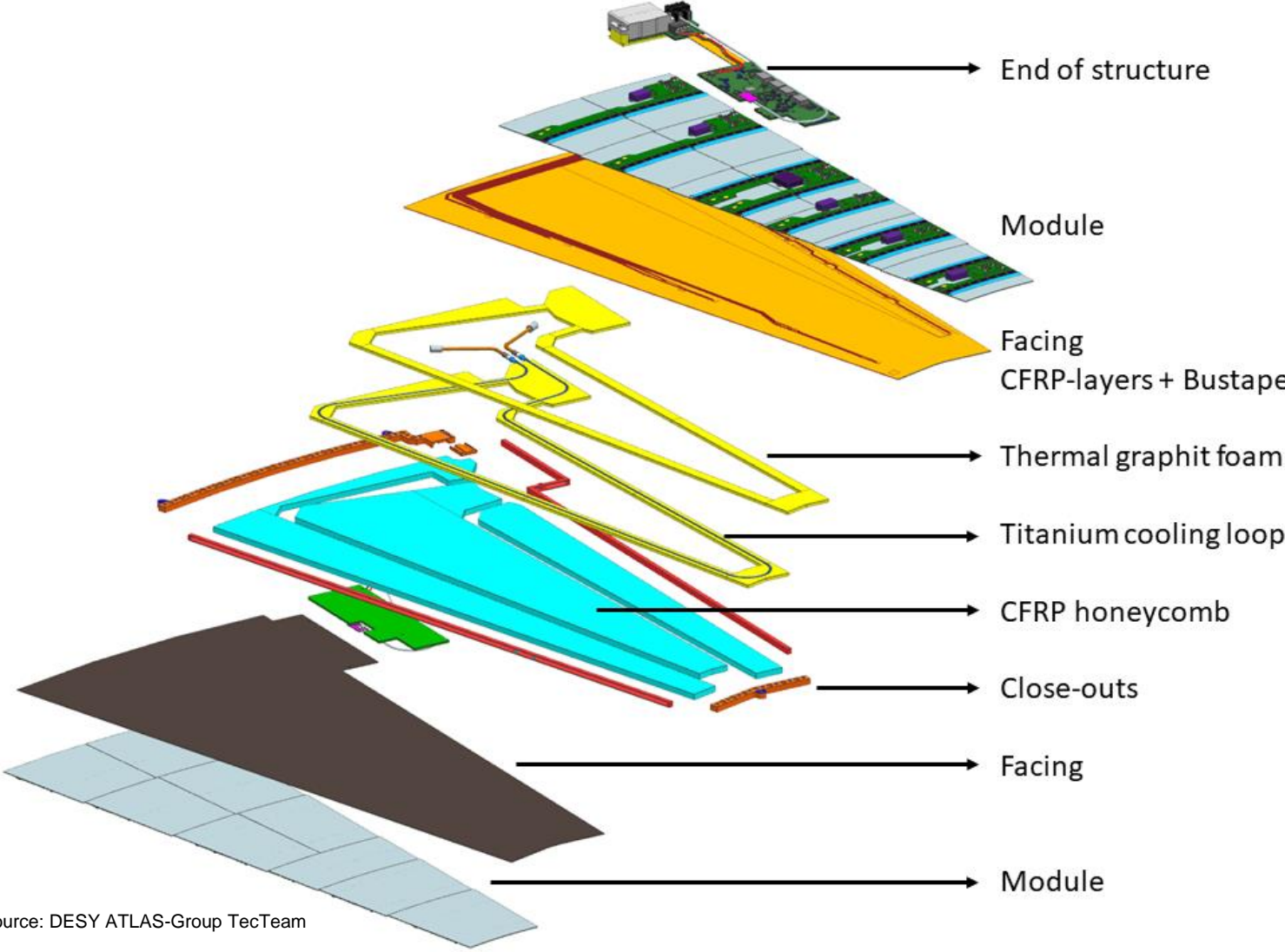


Source: DESY ATLAS-Group TecTeam

DESY-Hamburg is in charge for all **Petal-cores** and its insertion in one **endcap**. The endcaps themselves are built at **Nikhef** in Amsterdam, they will complete the other endcap.

Exploded view of the Petal

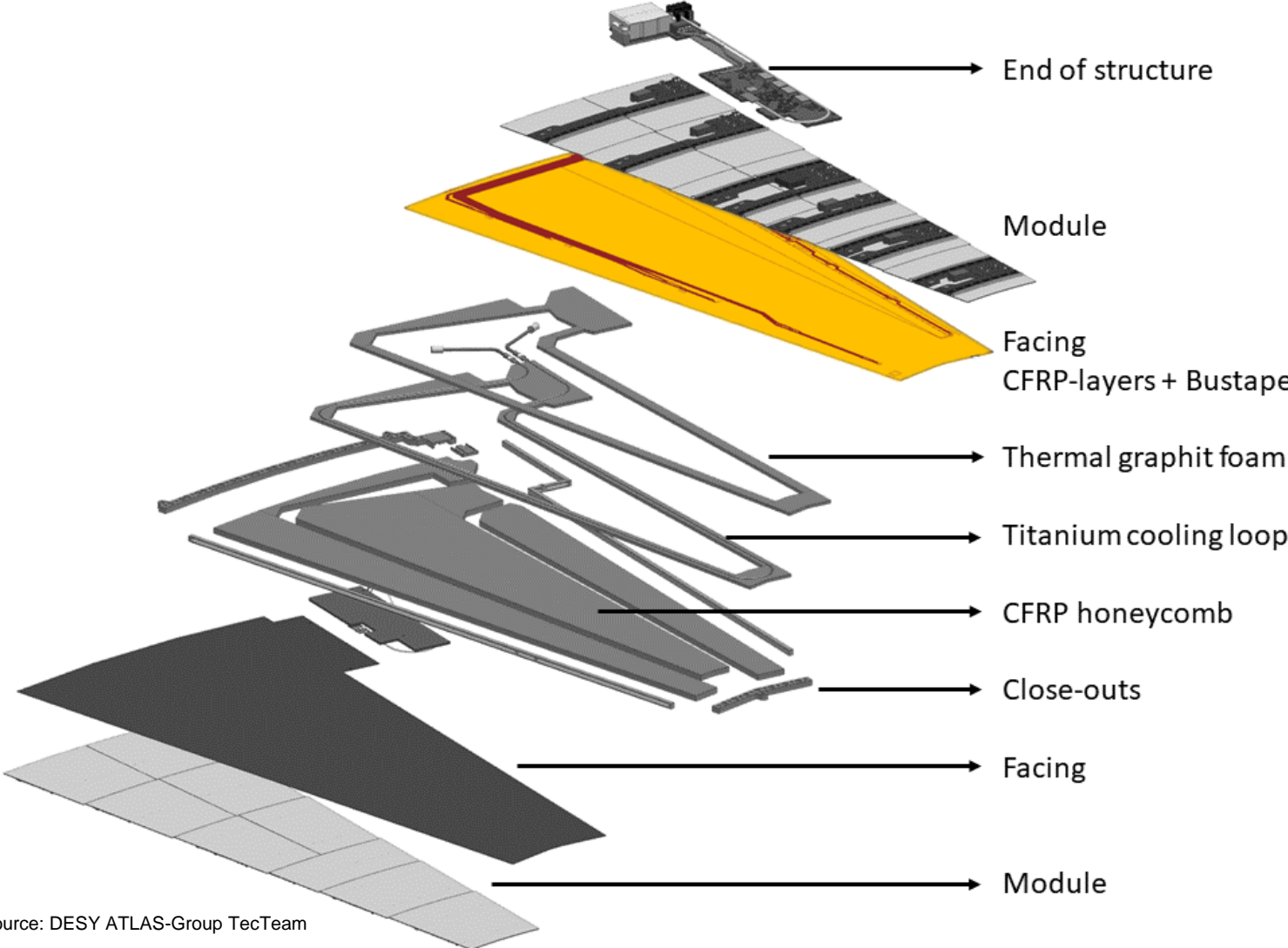
Sandwich structure made out of composites



Source: DESY ATLAS-Group TecTeam

Exploded view of the Petal

Sandwich structure made out of composites



Source: DESY ATLAS-Group TecTeam

Chapter 2

Industrial layup and

manual DESY

approach

State of the art

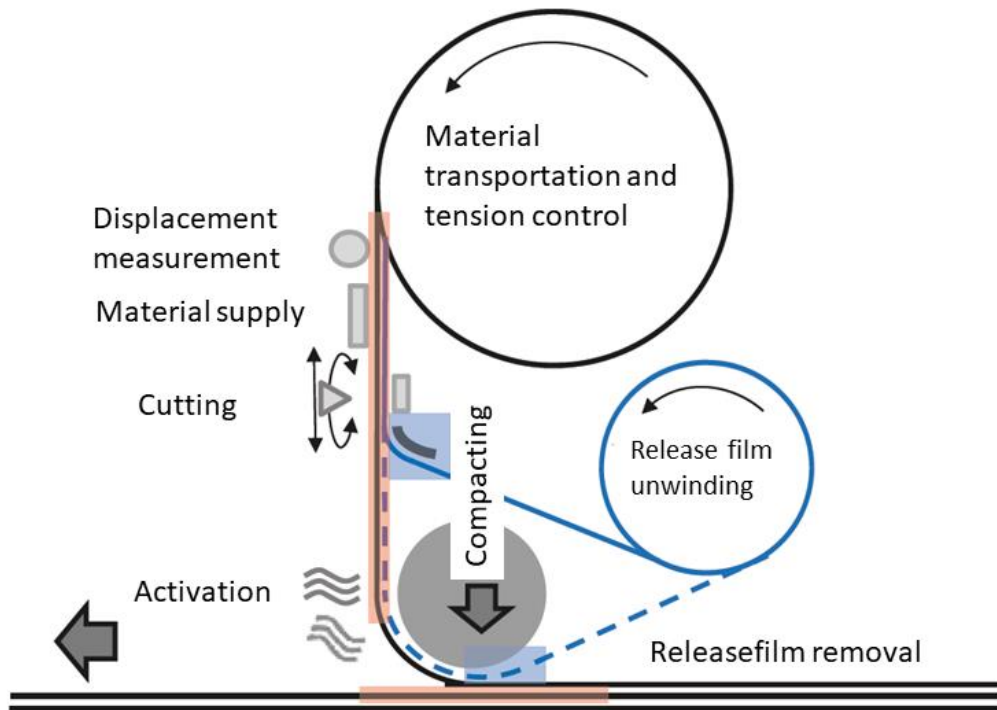
Industrial robot: ATL-procedure (Automated Tape Laying)



Source: <https://mtorres.es/en/equipment/manufacturing-systems/lamination/automatic-wrapping-machine-torreslayup>
Faserverbundwerkstoffe: Prepregs und ihre Verarbeitung – ISBN 978-3-446-43300-7

State of the art

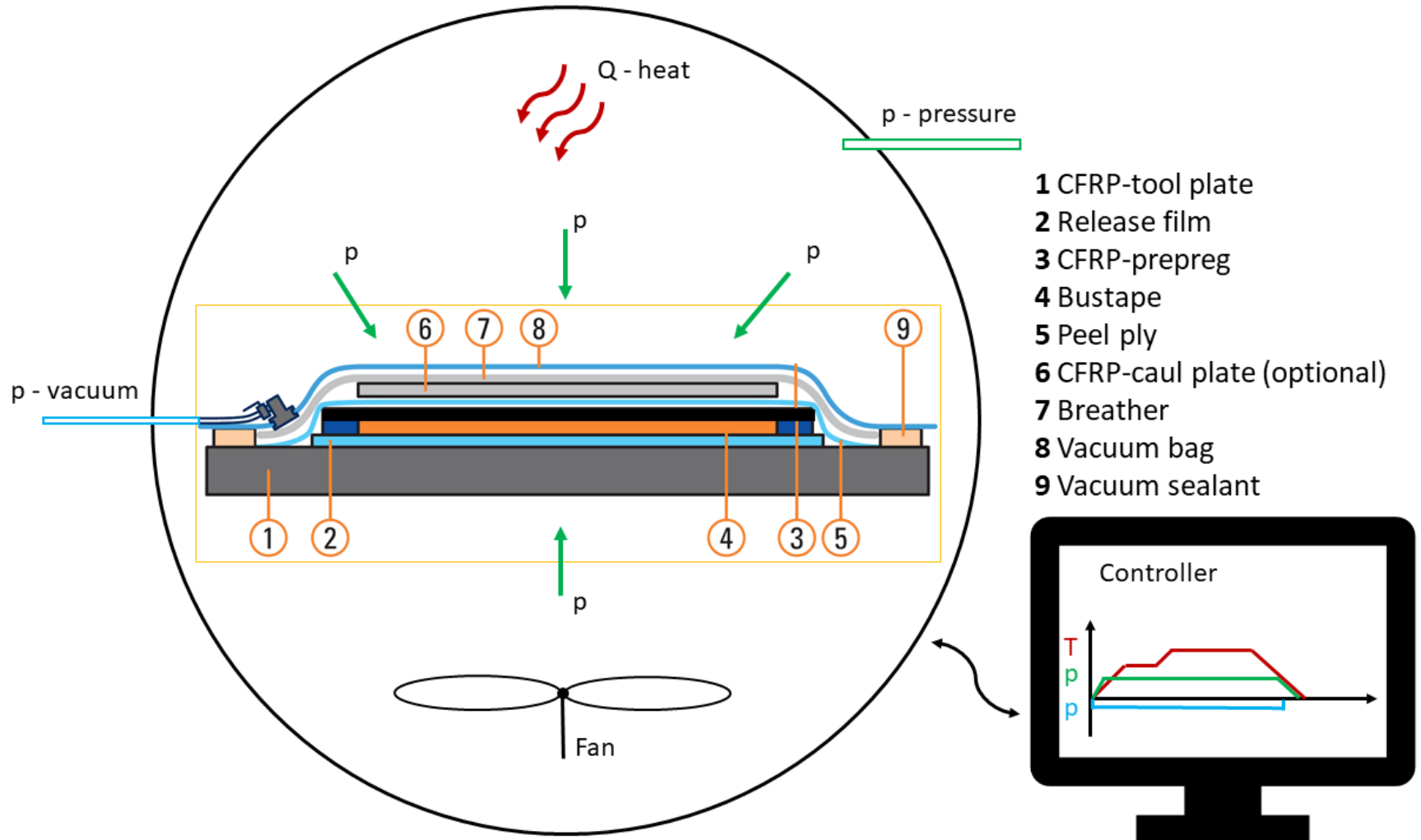
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Autoclave procedure

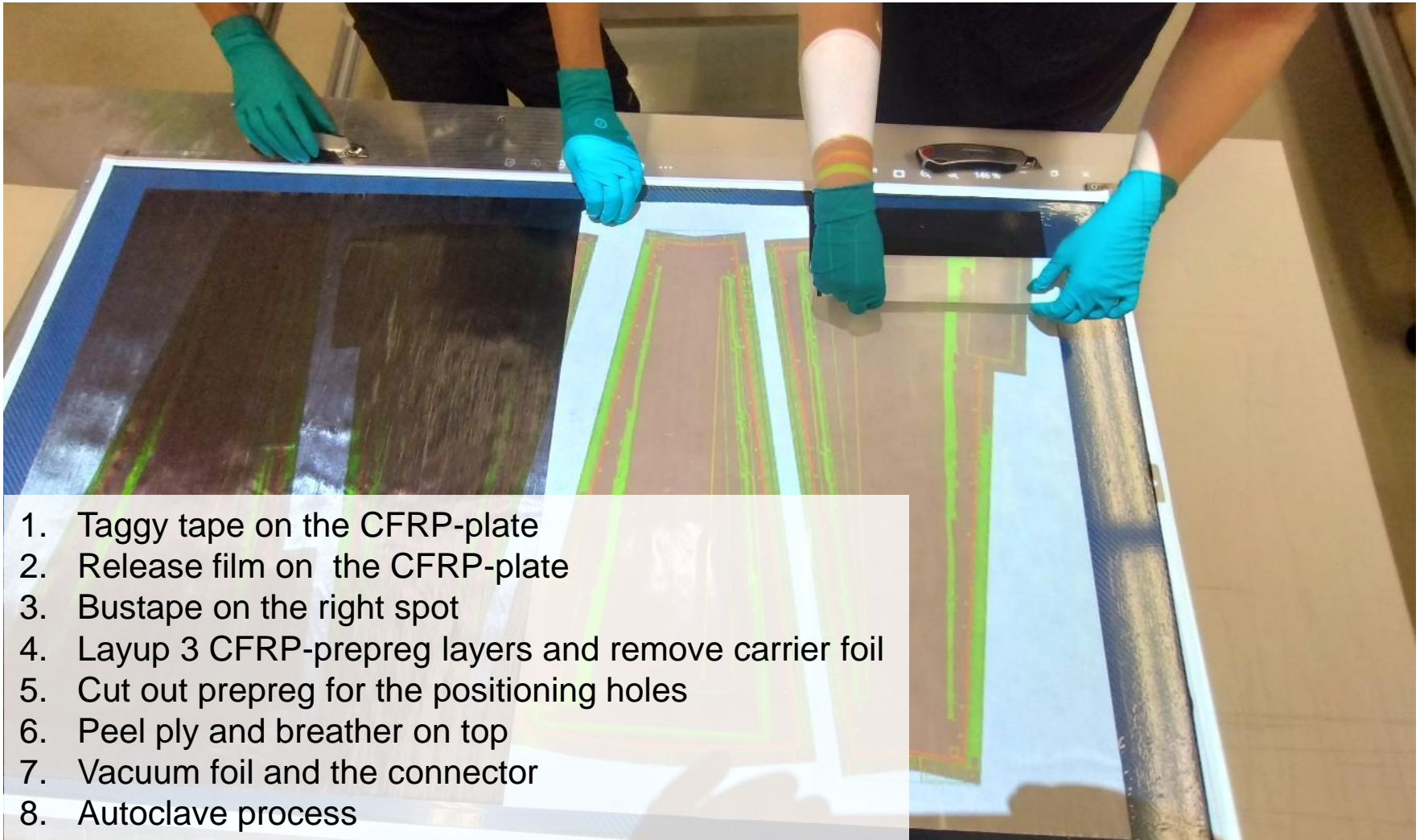
Independent from the layup procedure



Single source layup: Toray datasheet EX-1515

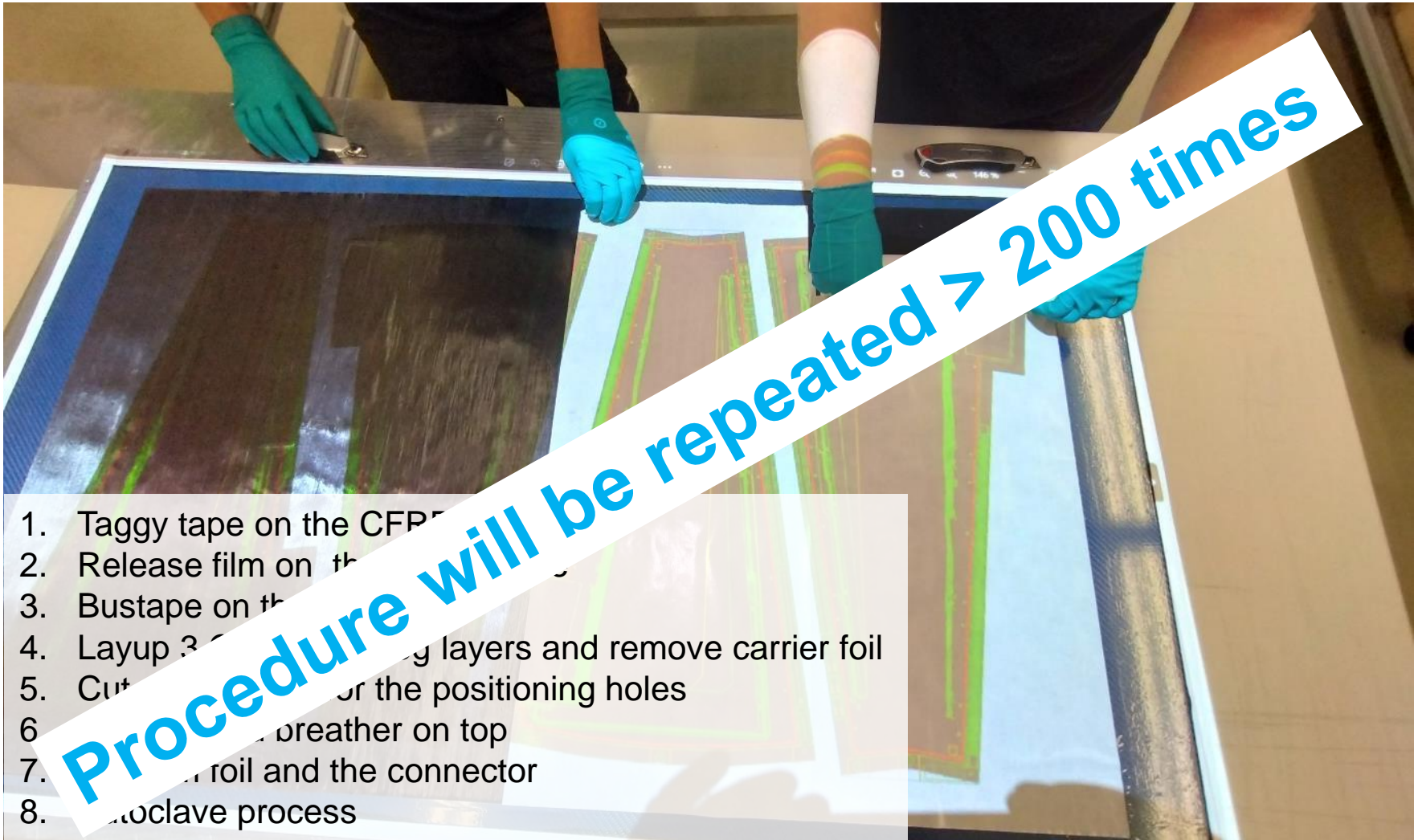
DESY layup

Manual stack-up



DESY layup

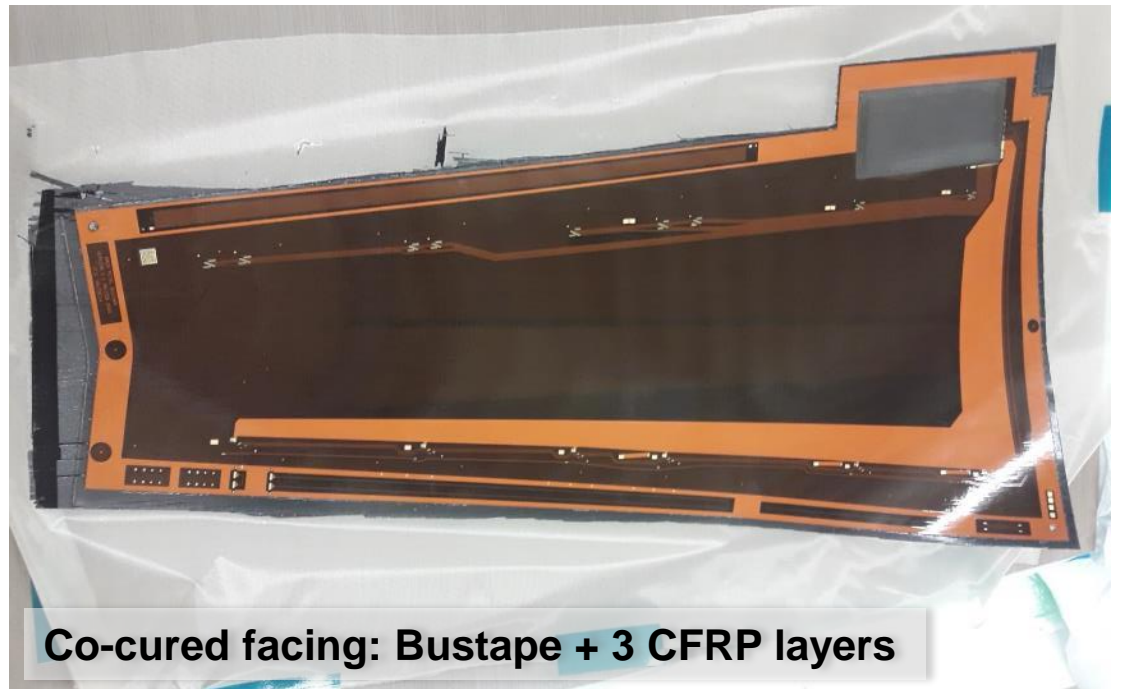
Manual stack-up



1. Taggy tape on the CFRP
2. Release film on the
3. Bustape on the
4. Layup 3 CFRP layers and remove carrier foil
5. Cut for the positioning holes
6. Breather on top
7. Foil and the connector
8. Autoclave process

DESY layup

Manual layup: impression of the production



Chapter 3

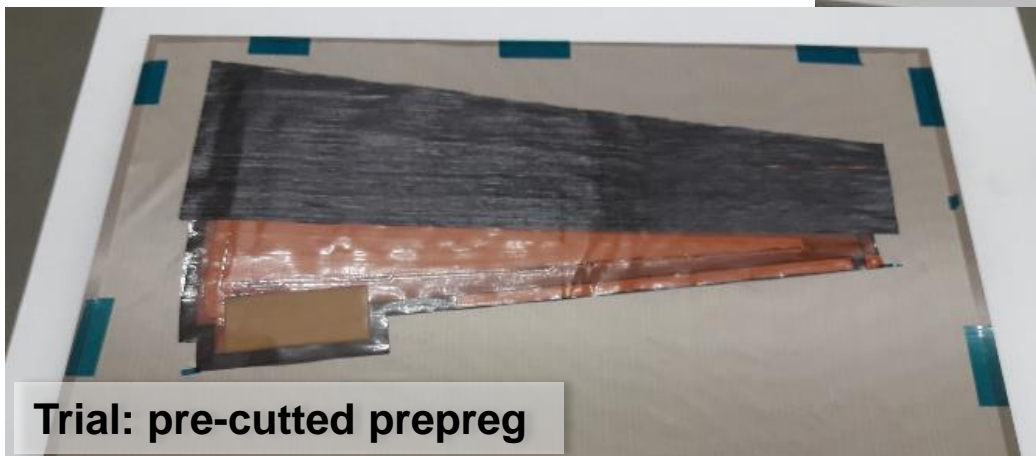
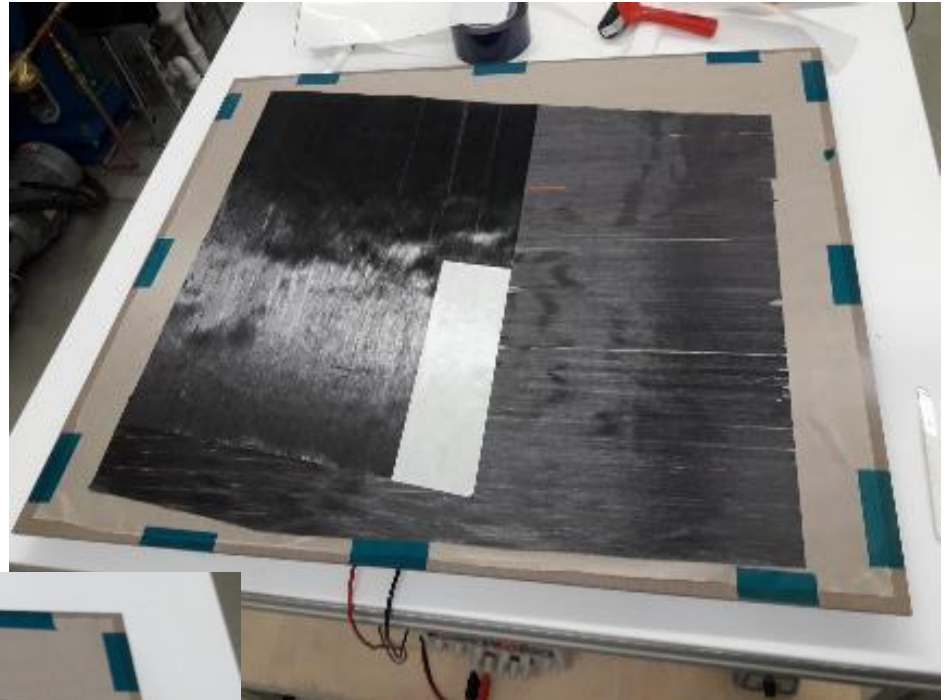
From conceptual design to realization

*How to get the manual layup
of prepreg in a tool-supported
manufacturing*

Conceptual design

Goals to get the manual steps in a tool guided process

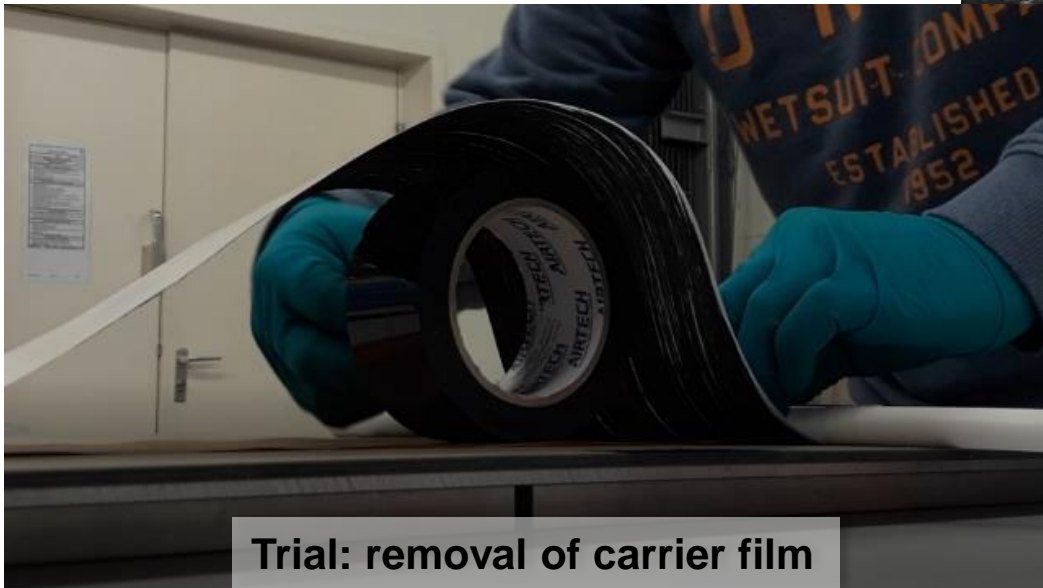
- Lay prepreg on a flat surface
- Release the carrier film
- Cut the prepreg to the right size



Conceptual design

Goals to get the manual steps in a tool guided process

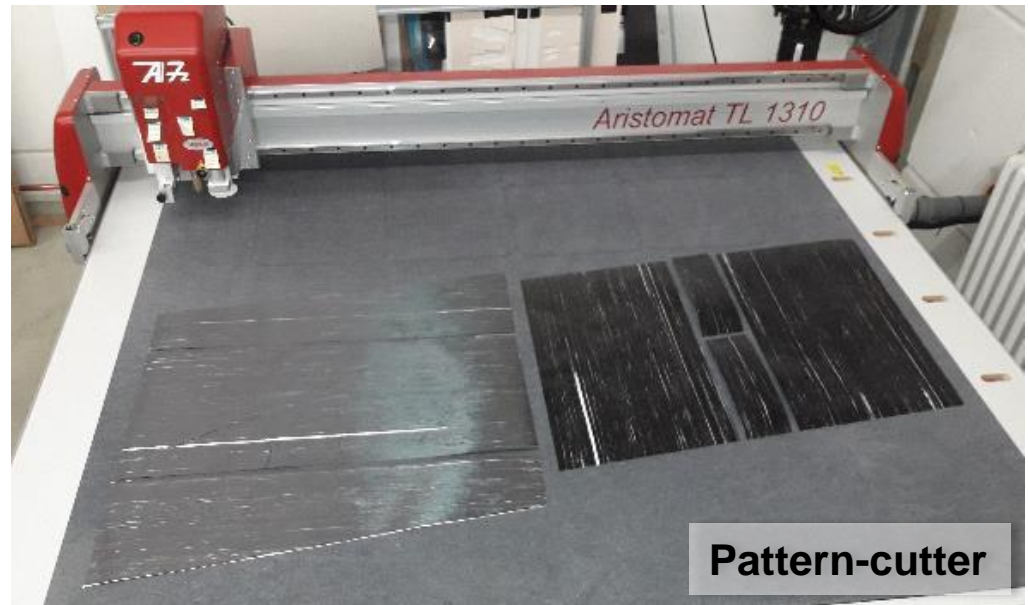
- Lay prepreg on a flat surface
- **Release the carrier film**
- Cut the prepreg to the right size



Conceptual design

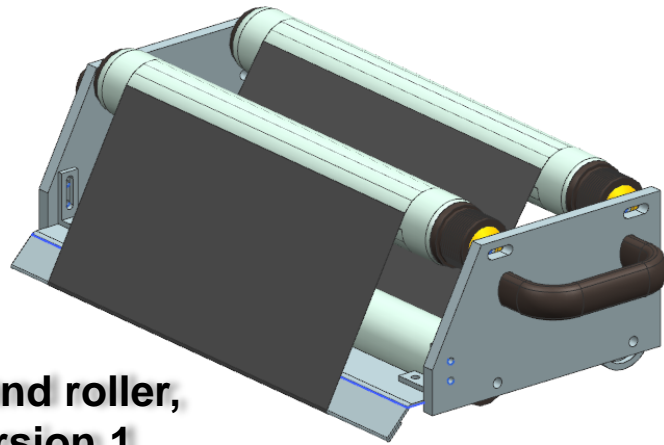
Goals to get the manual steps in a tool guided process

- Lay prepreg on a flat surface
- Release the carrier film
- **Cut the prepreg to the right size**

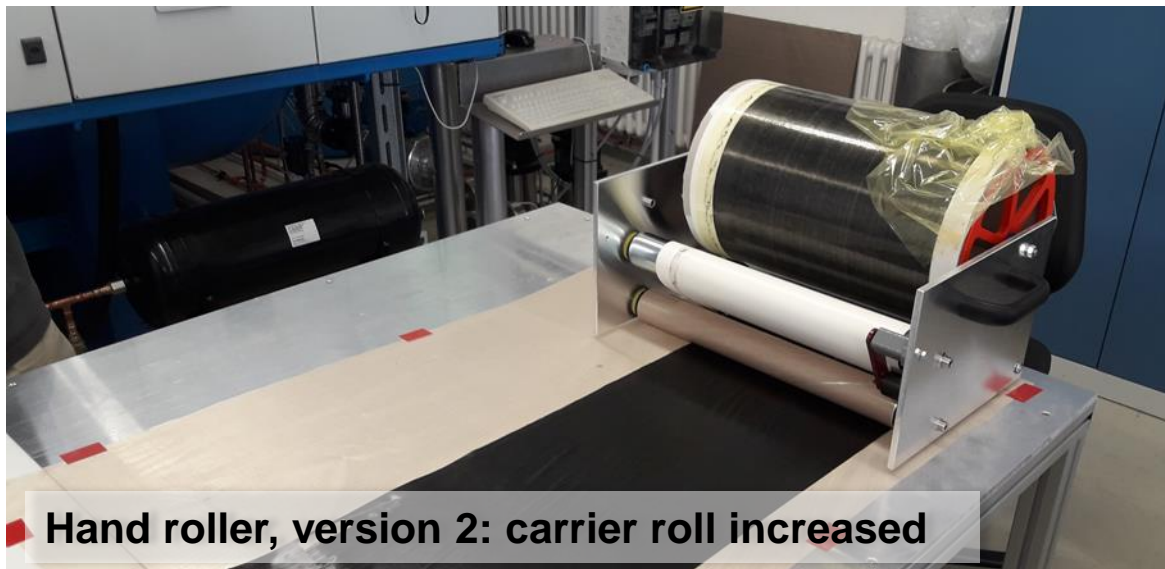
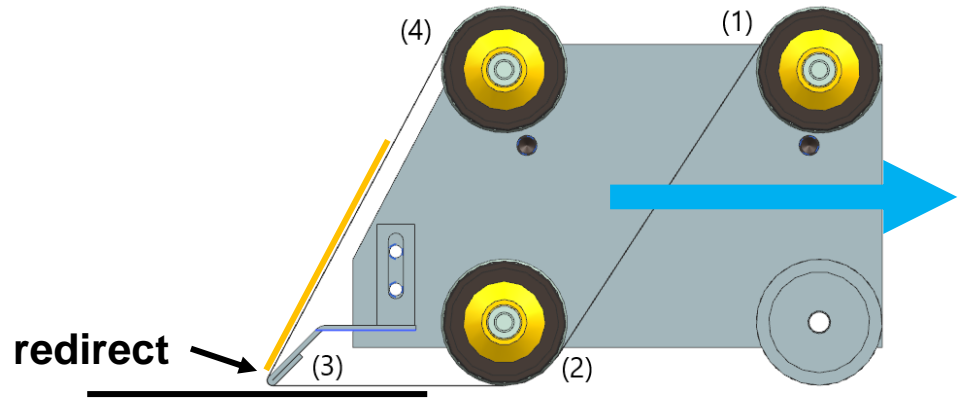


Conceptual design

Manual tools: laydown of the prepreg and carrier film removal



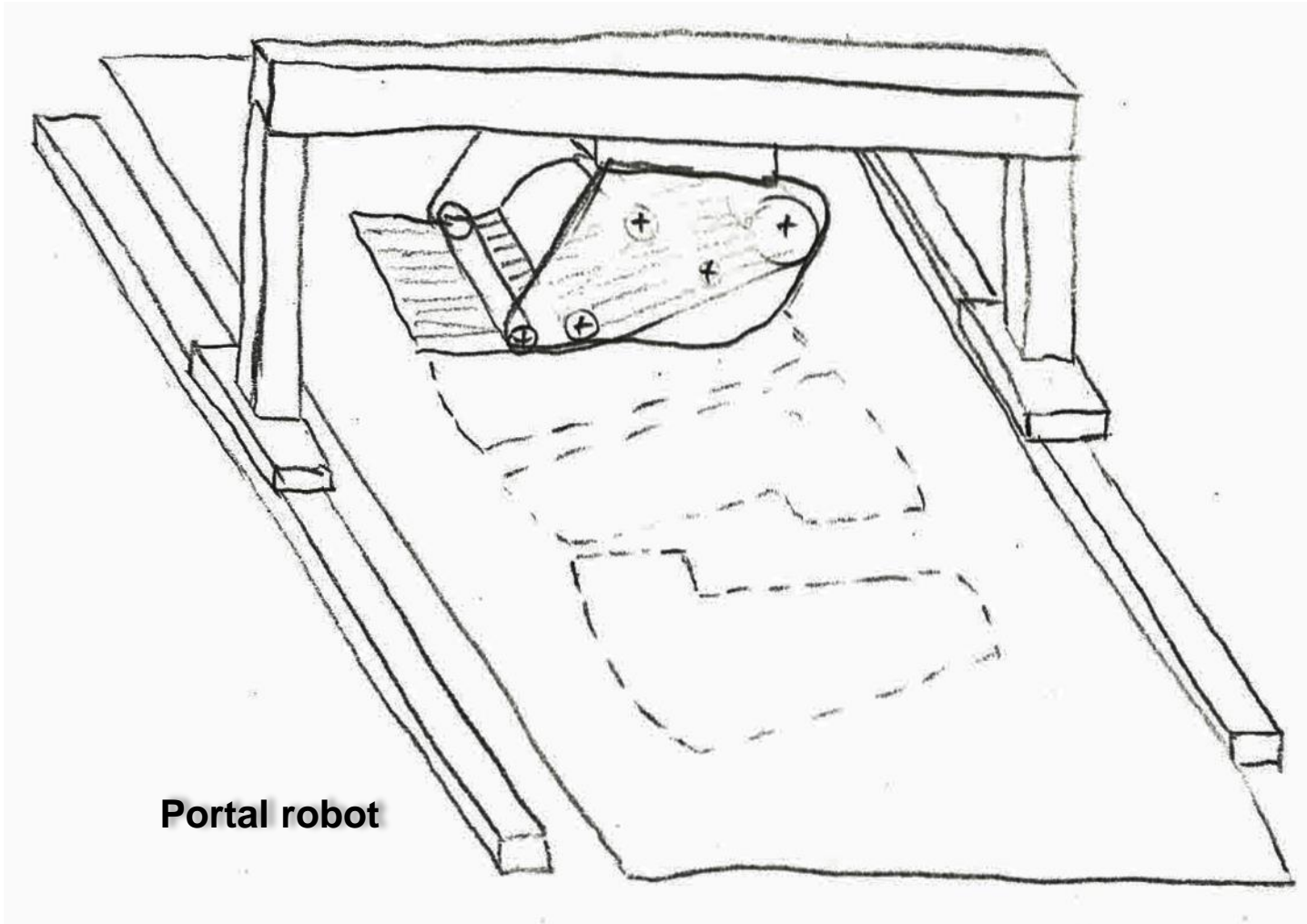
Hand roller,
version 1



Hand roller, version 2: carrier roll increased

Conceptual design

Three concepts



Portal robot

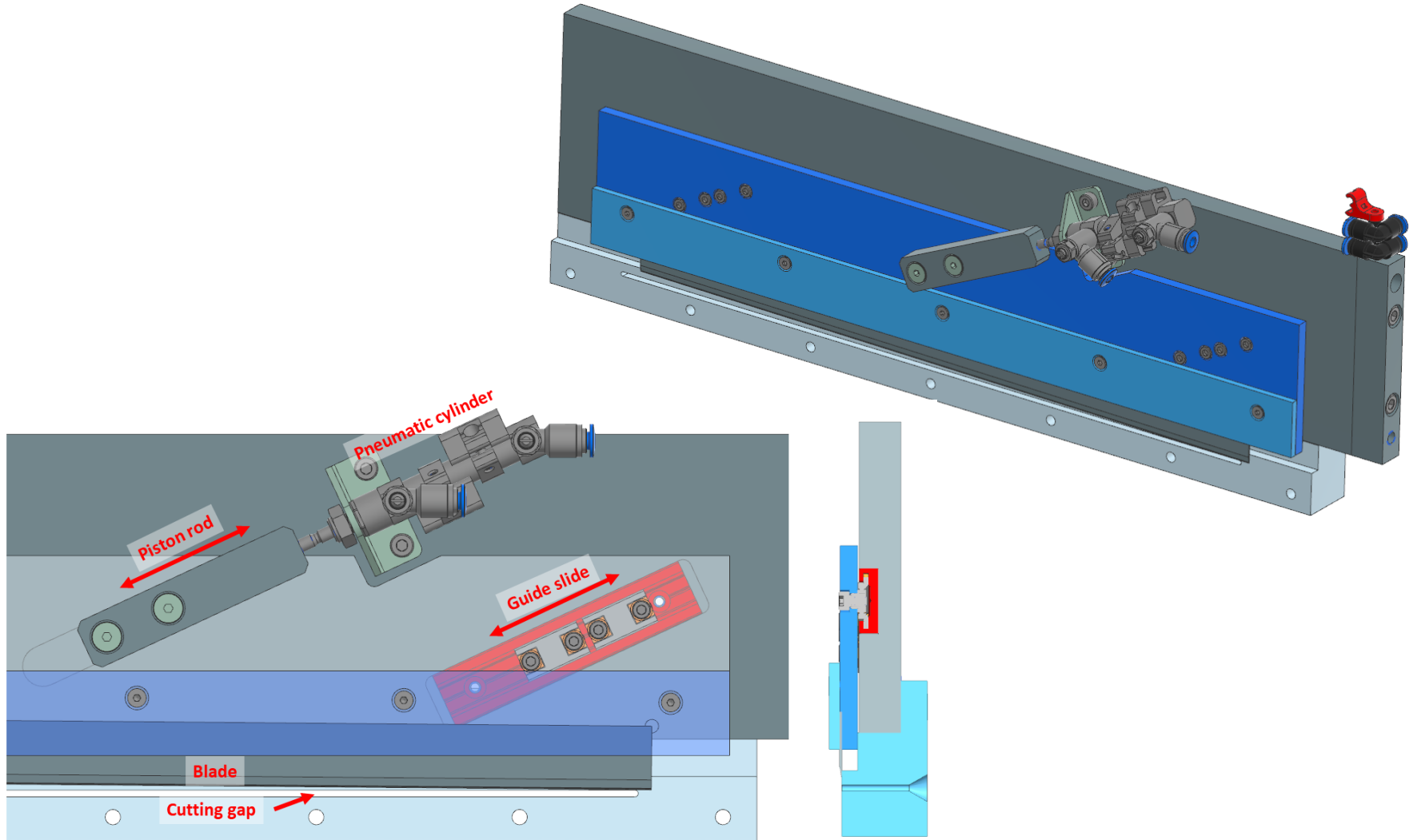
Chapter 4

Construction Design

Apply concepts into a robot

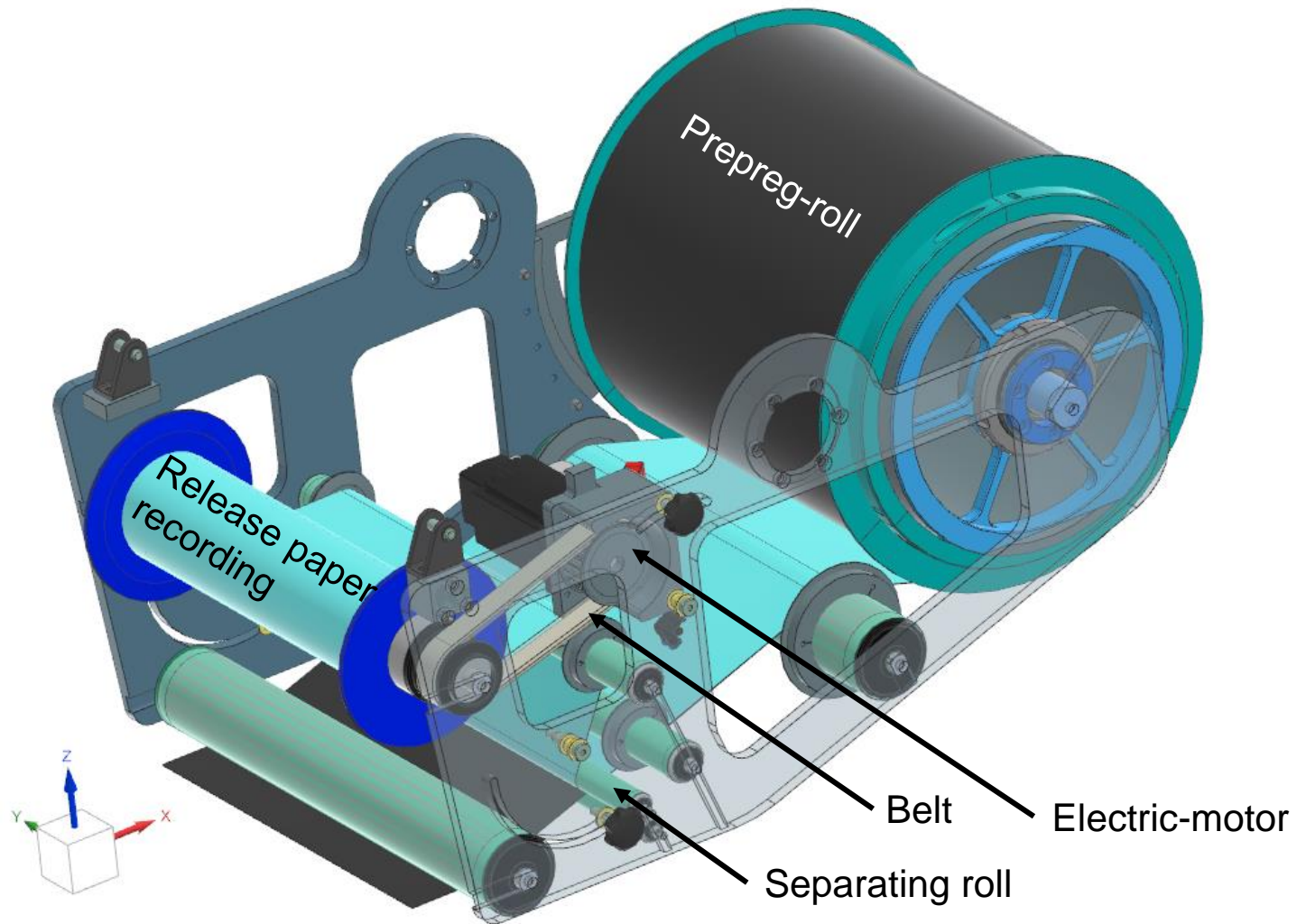
Construction design

Prepreg cutting unit



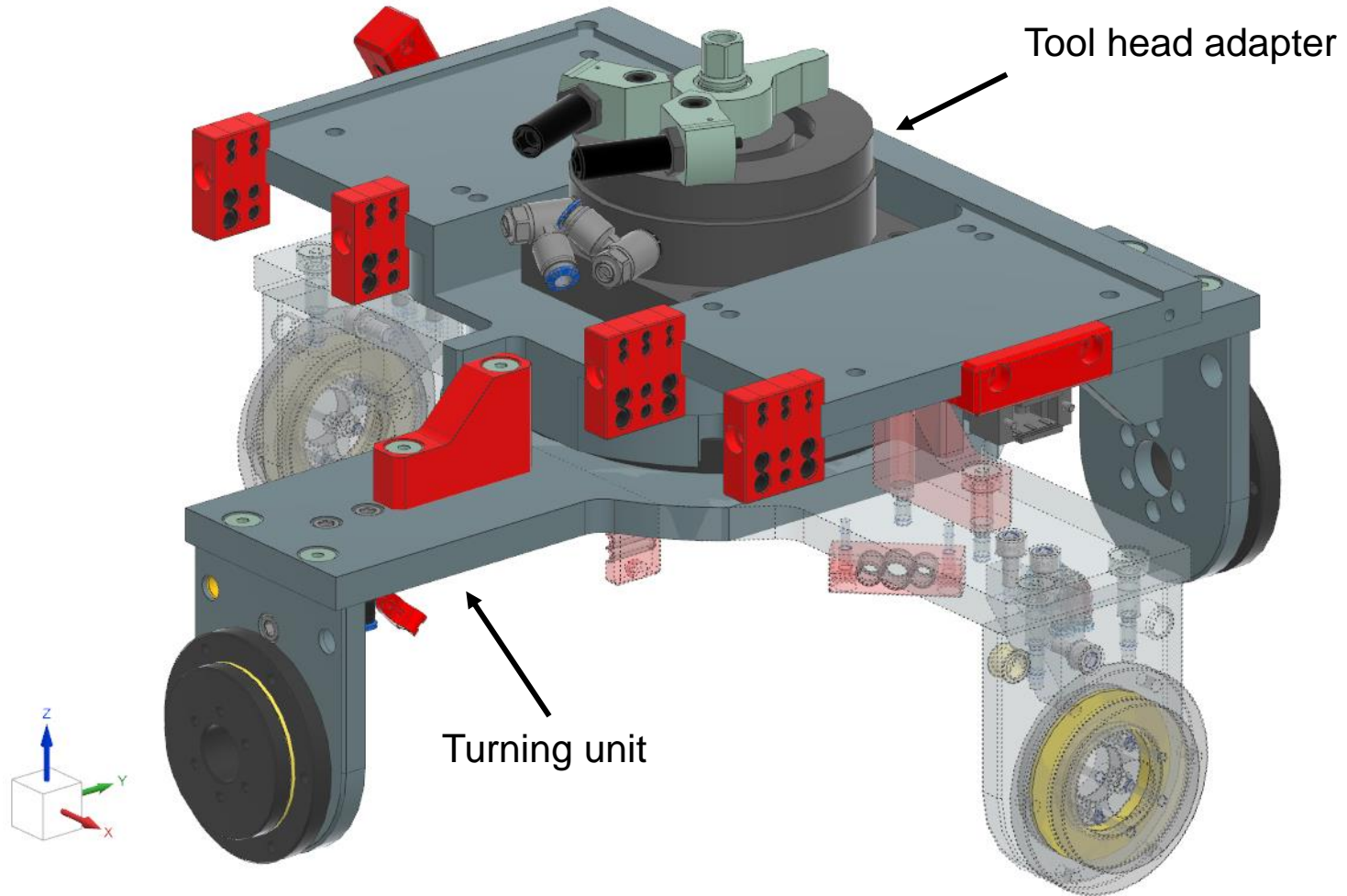
Construction design

Release of carrier film and transportation of the prepreg



Construction design

Realization of the layup (0/90/0): turning- and tilting unit



Construction Design

Tool head

Pneumatic cylinder

- Tilting and lowering

Turning- and tilting unit

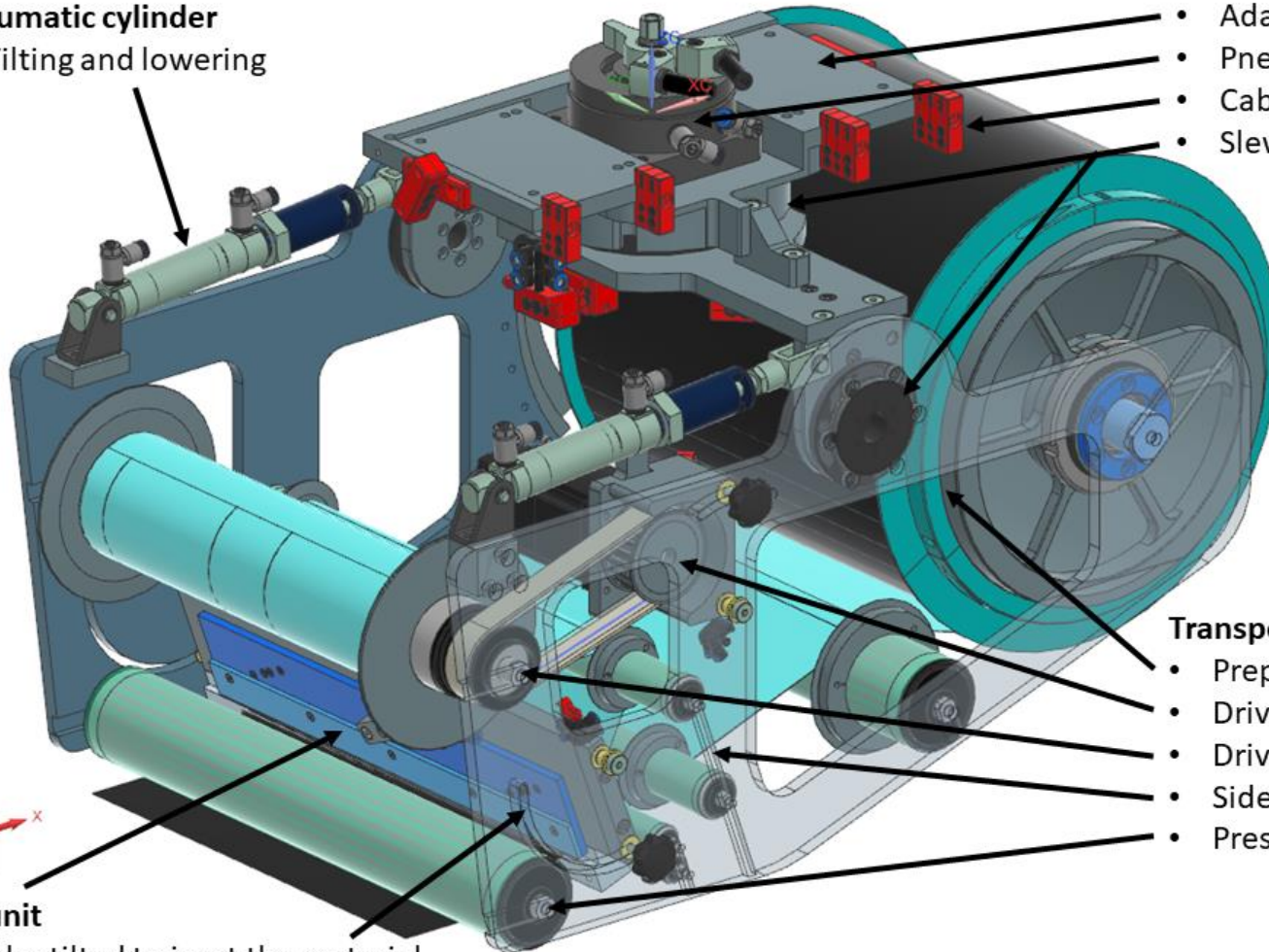
- Adapter plate for portal mounting
- Pneumatic rotating cylinder
- Cable guides
- Slewing ring bearing

Transport unit

- Prepreg roll
- Drive motor
- Drive roll
- Side plate with guide slots
- Pressing roll

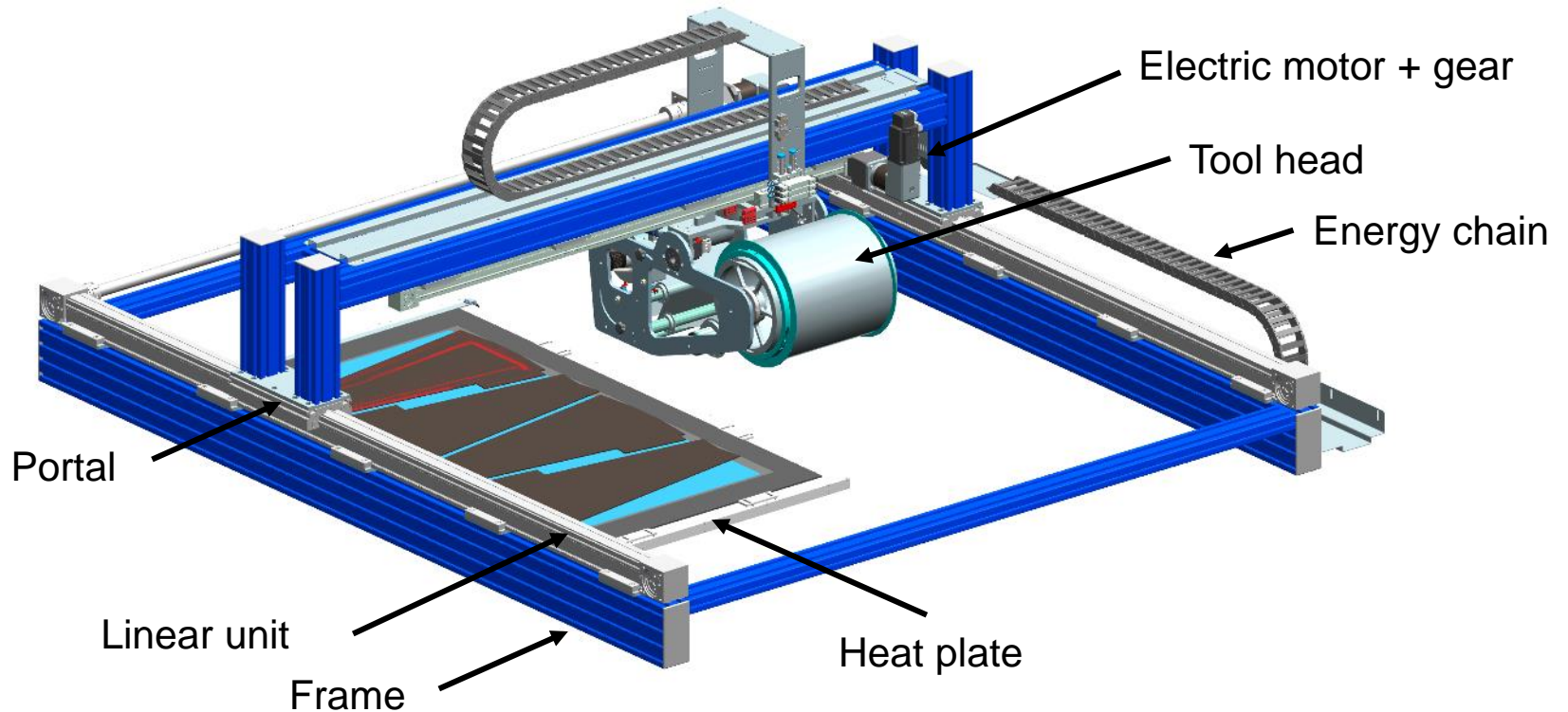
Cutting unit

- Could be tilted to inert the material



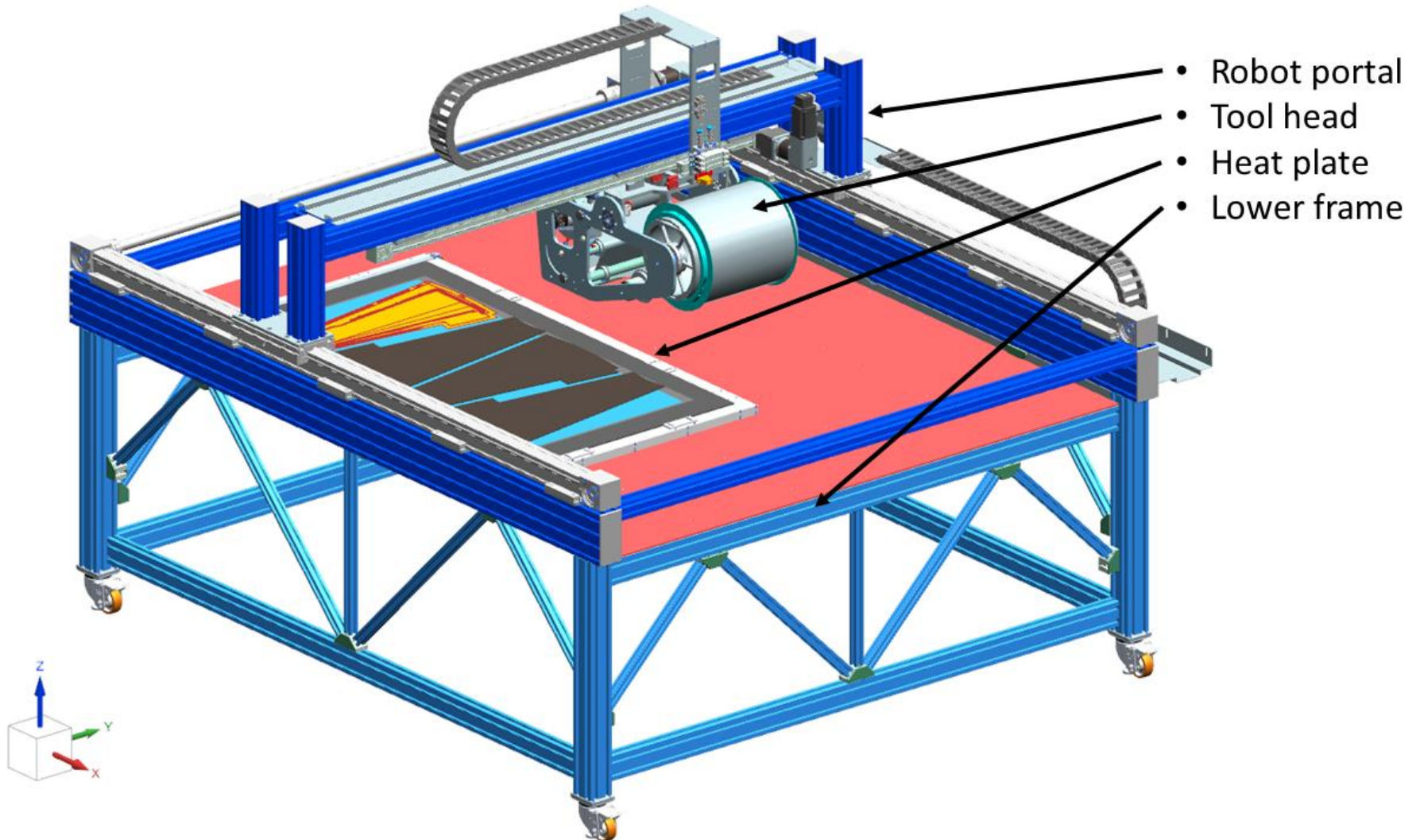
Construction design

Portal + tool head + heat plate



Construction design

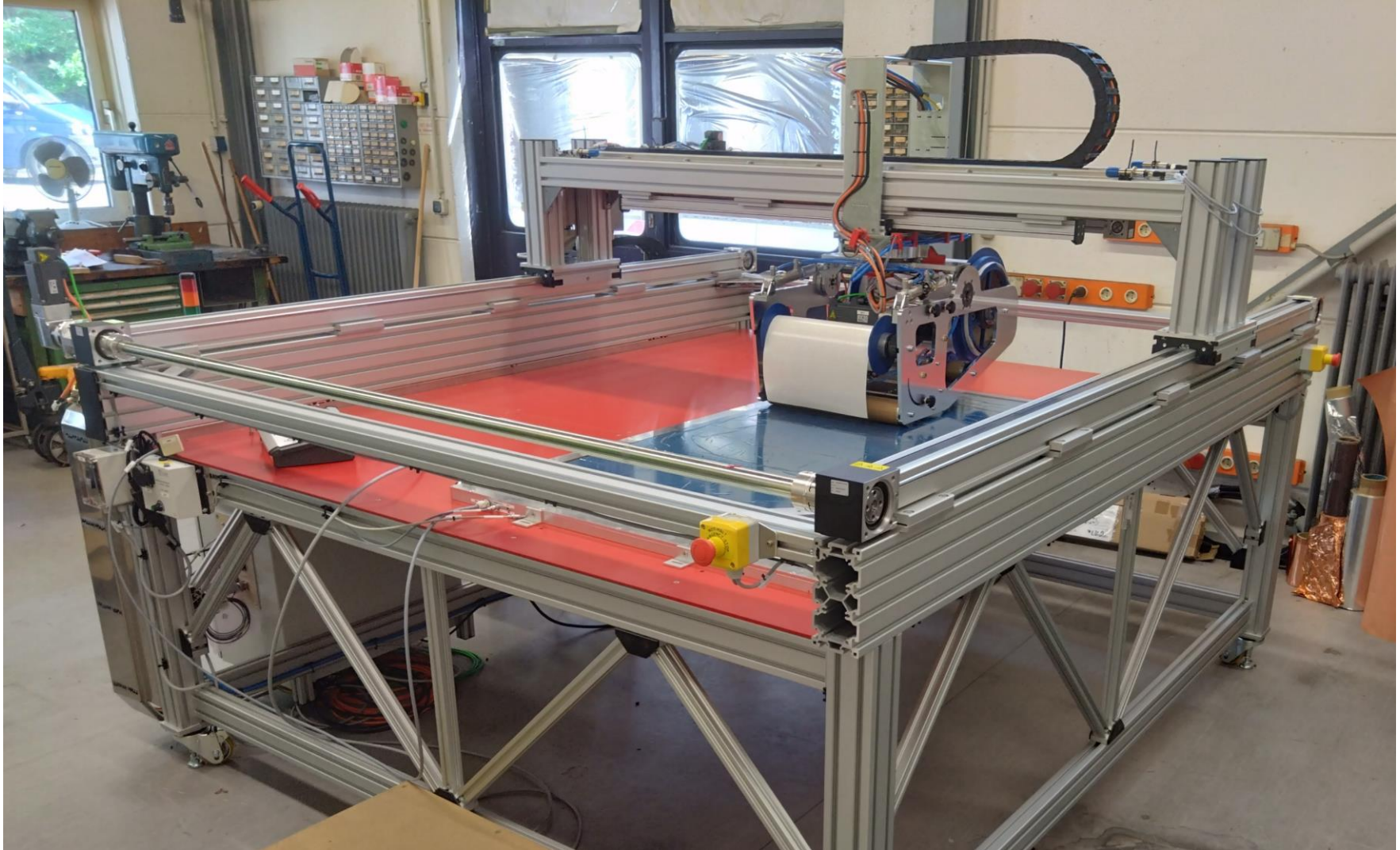
Main assembly



Chapter 5

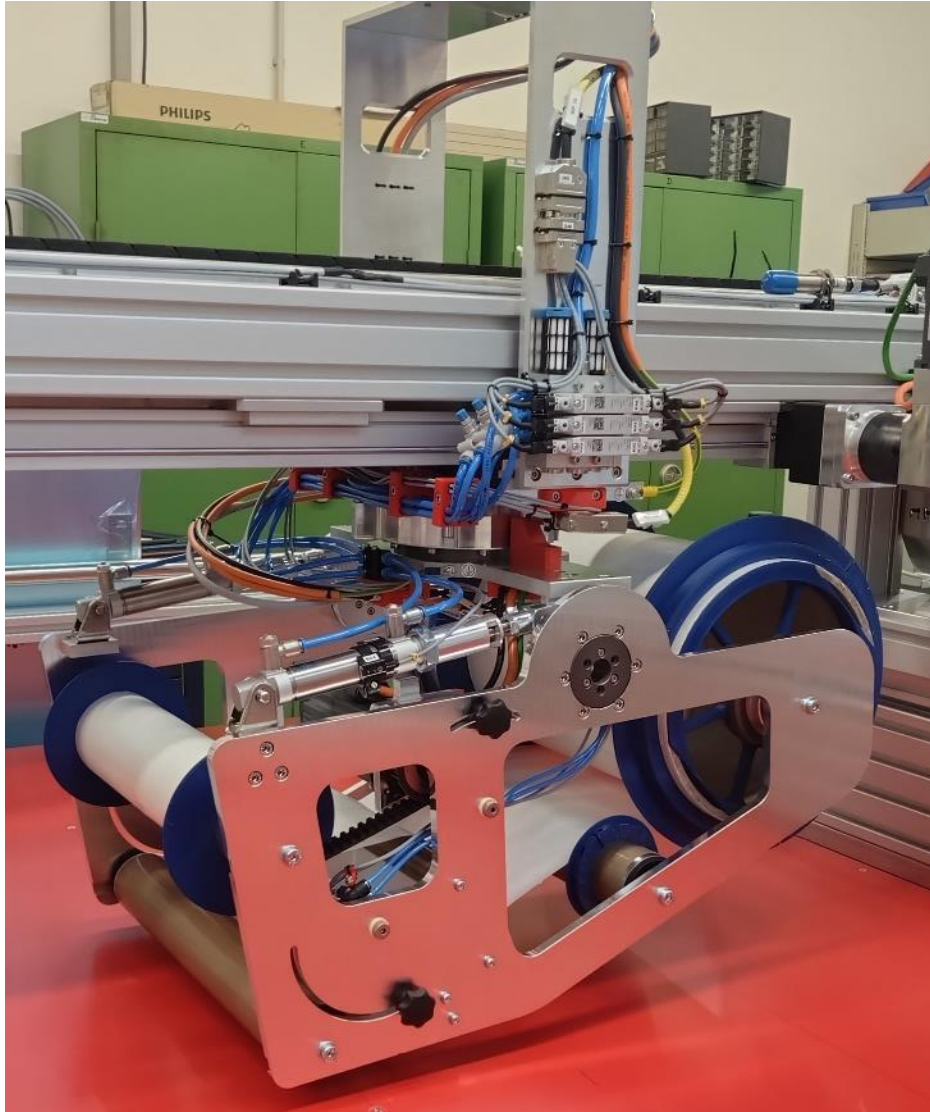
Building the robot

Picture of the fully assembled robot



Implementation

Tool head in detail



Chapter 6

Summary and outlook

Challenges

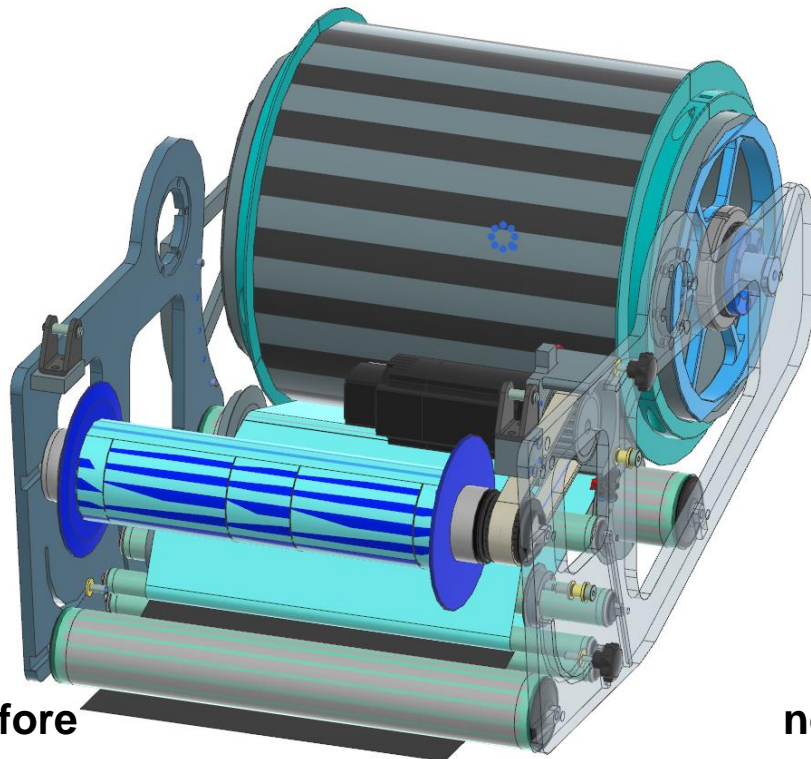
- Finding out a working procedure
- Reduce the design to a simple solution
- Power transfer to the tool head
- Align the assembled frame
- Programming and tuning of the motor controller
- **Calibrating and tuning the winding motor to the stage movement: still in progress**

Lesson learned

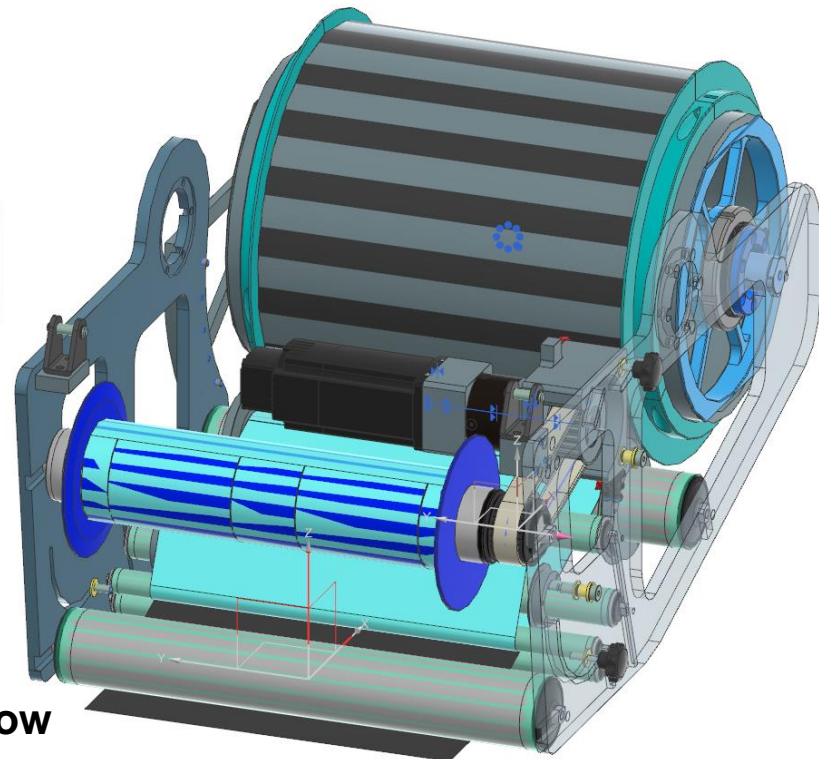
- Complex industrial solutions can be applied and simplified for our purpose

Improvement

Optimization of the drive unit by implementing a gear



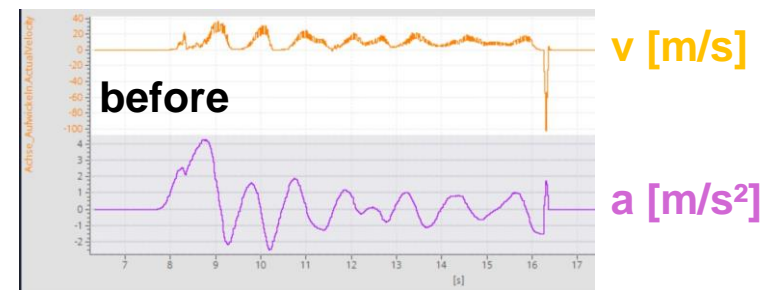
before



now

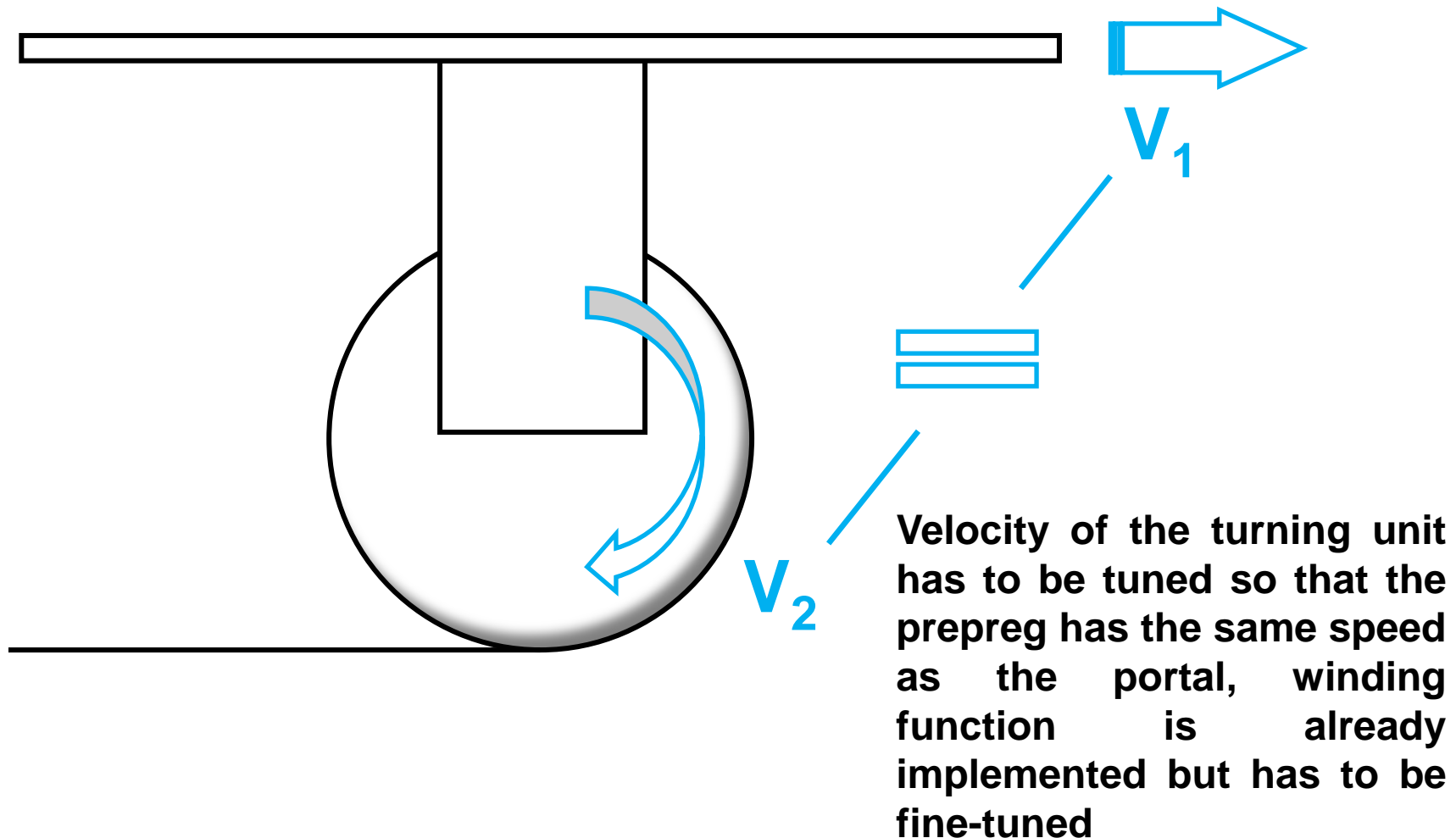
Before: force and rotation mass (mass moment of inertia) were too low so that the controller was overloaded by the speed of adaptation → system was speeding up and down all the time

Now: movement is smooth and constant

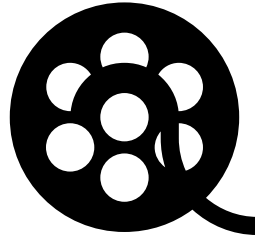


Outlook

Optimization of the drive unit + production of X bus tapes



Thank you



Contact

Deutsches Elektronen-
Synchrotron DESY

www.desy.de

Sören Ahrens

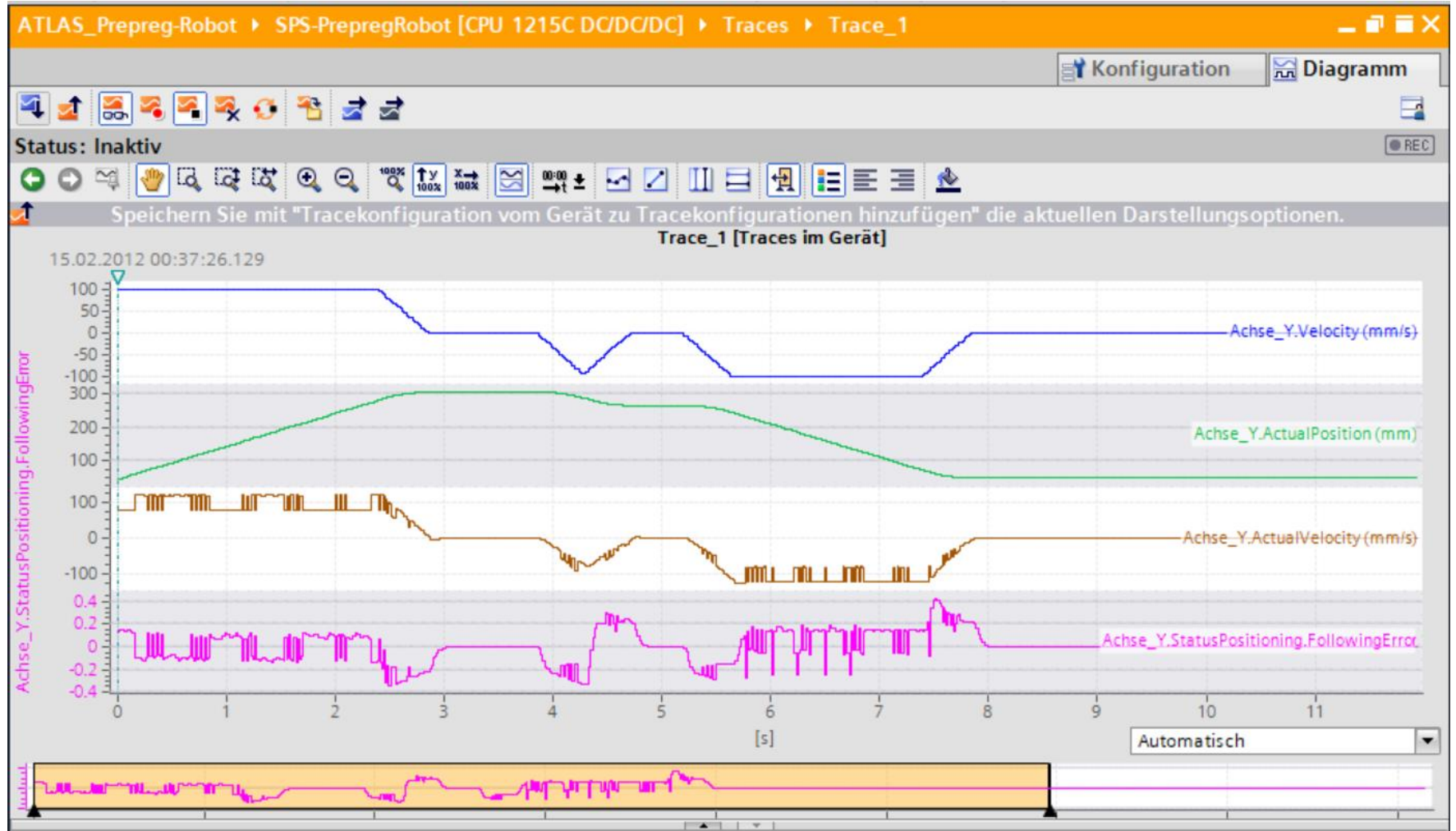
ATLAS

soeren.ahrens@desy.de

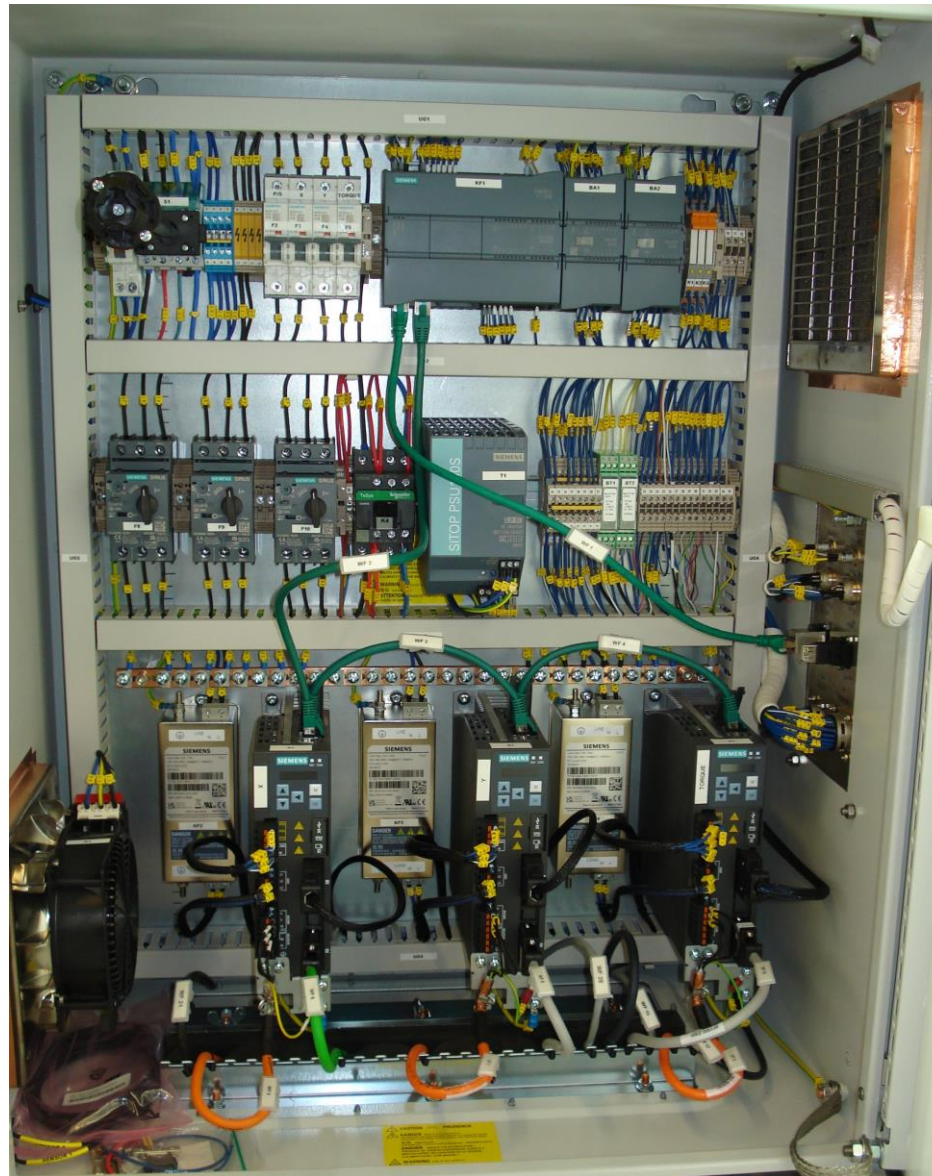
+49-40-8998-3879

Implementation

Adaptation of the motor control unit



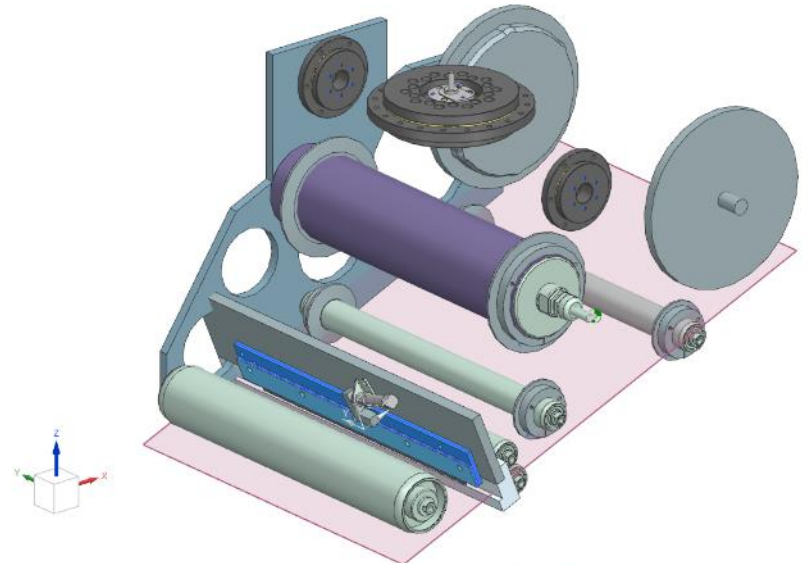
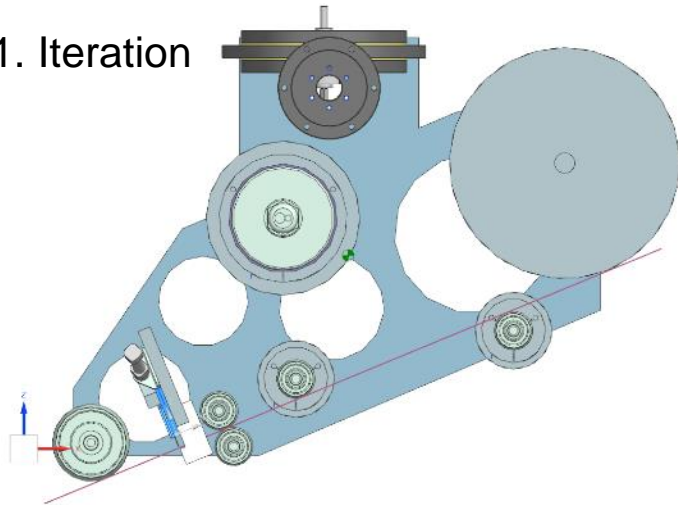
Controller cabinet



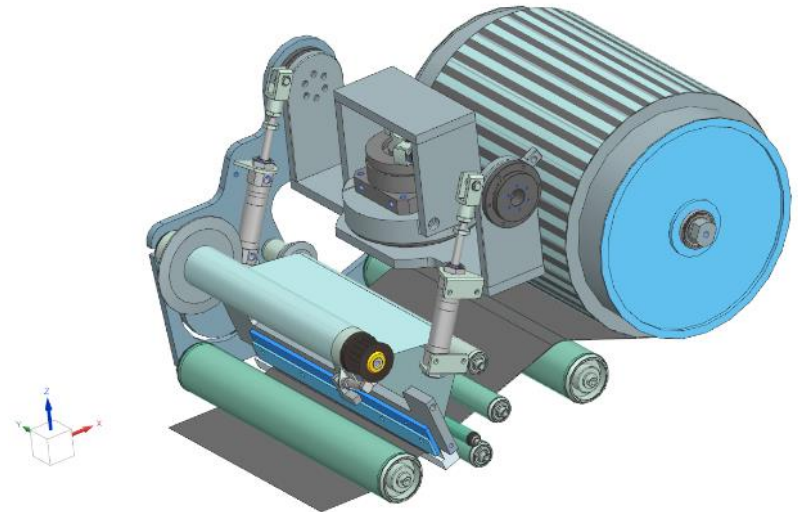
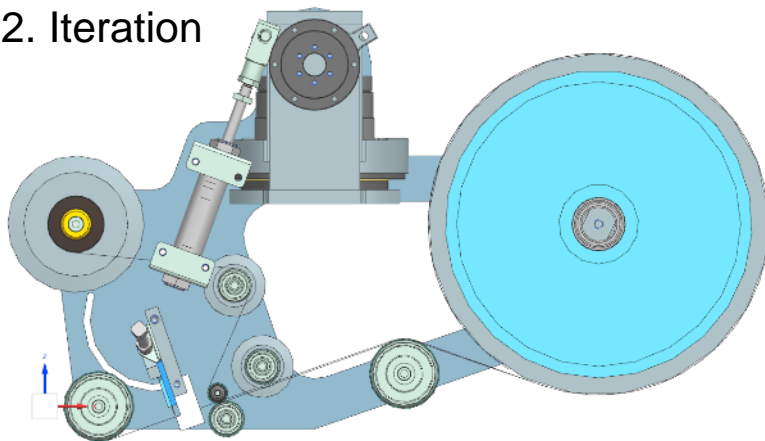
Conceptual design

Development tool head

1. Iteration

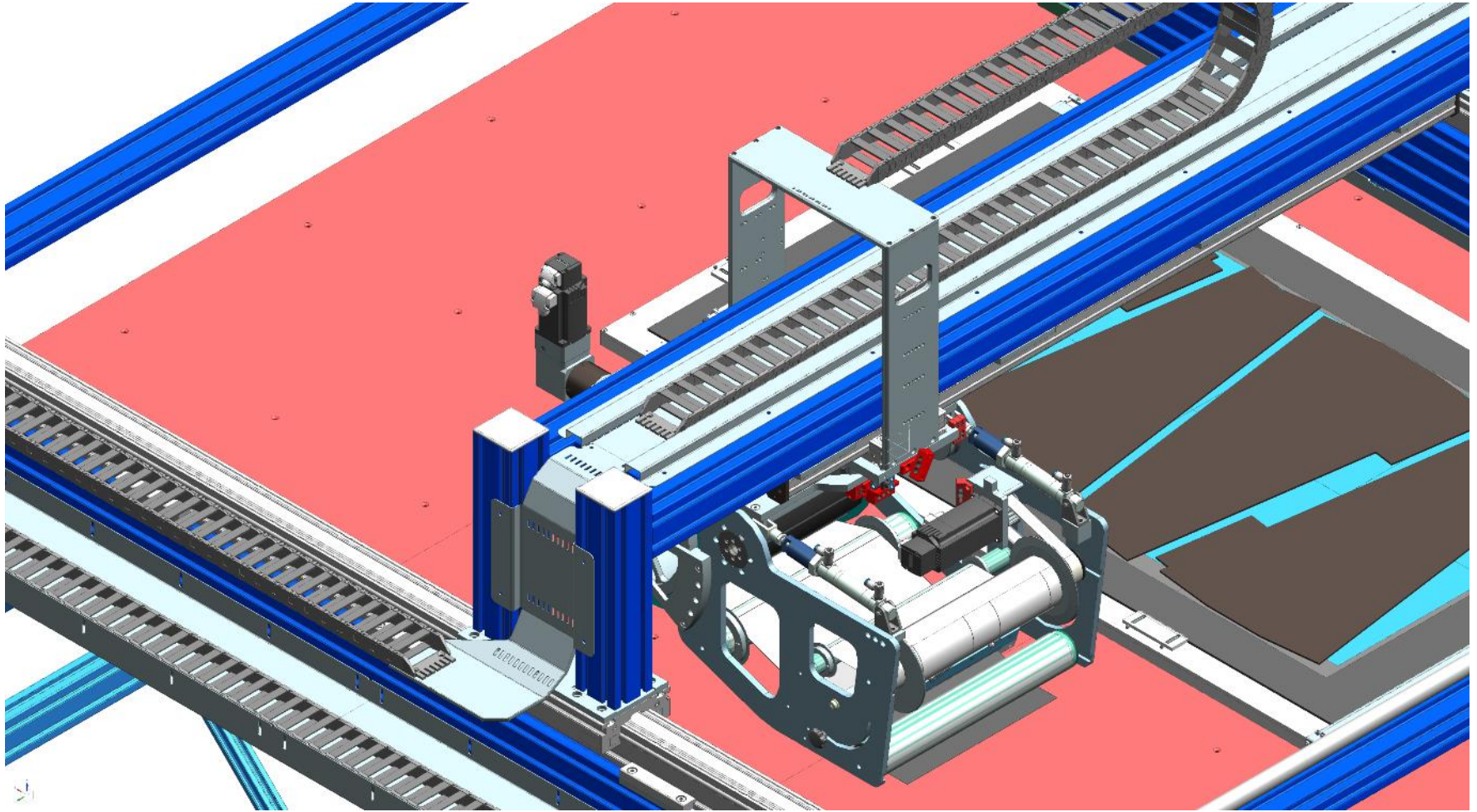


2. Iteration



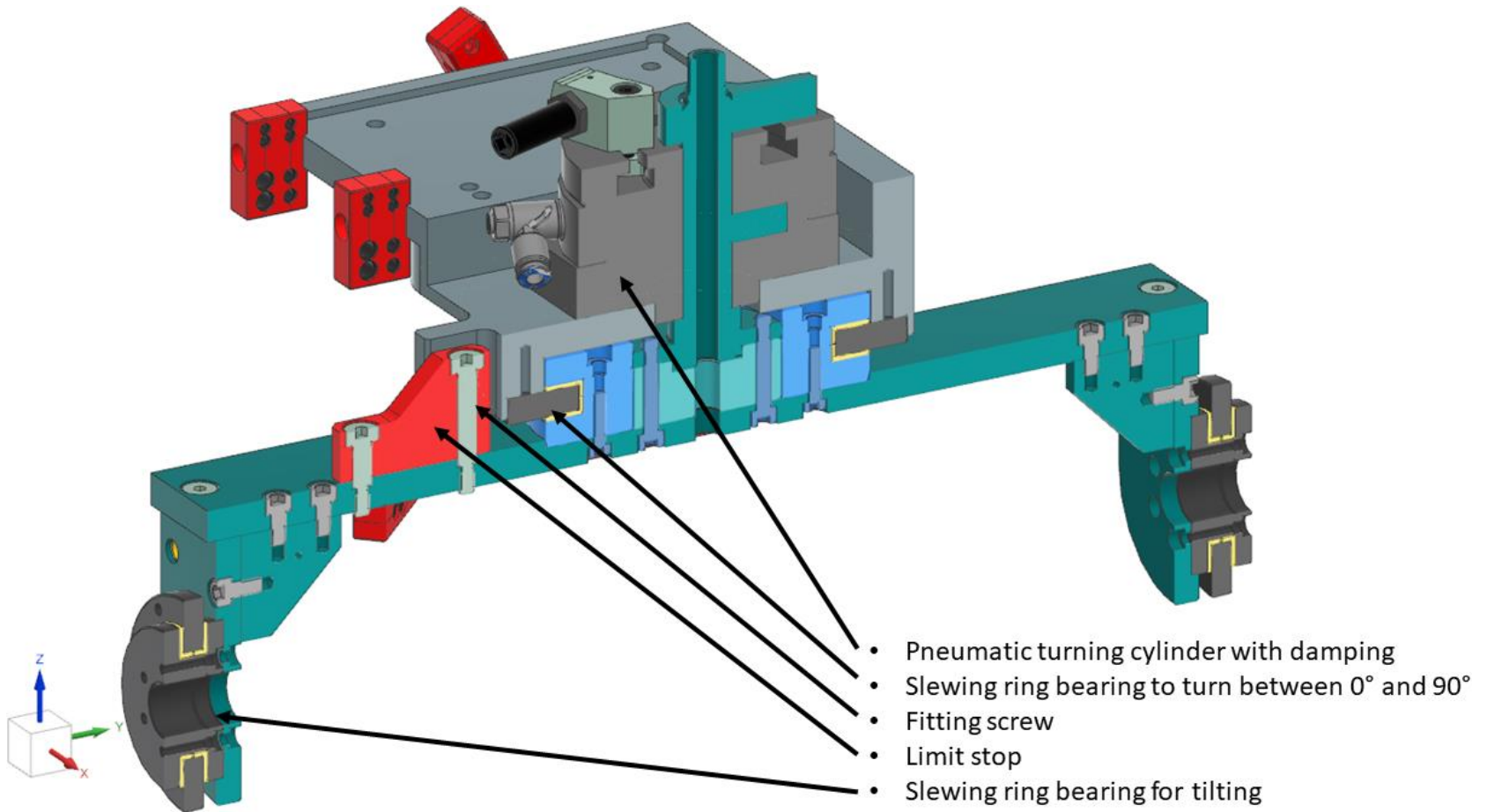
Construction design

In detail

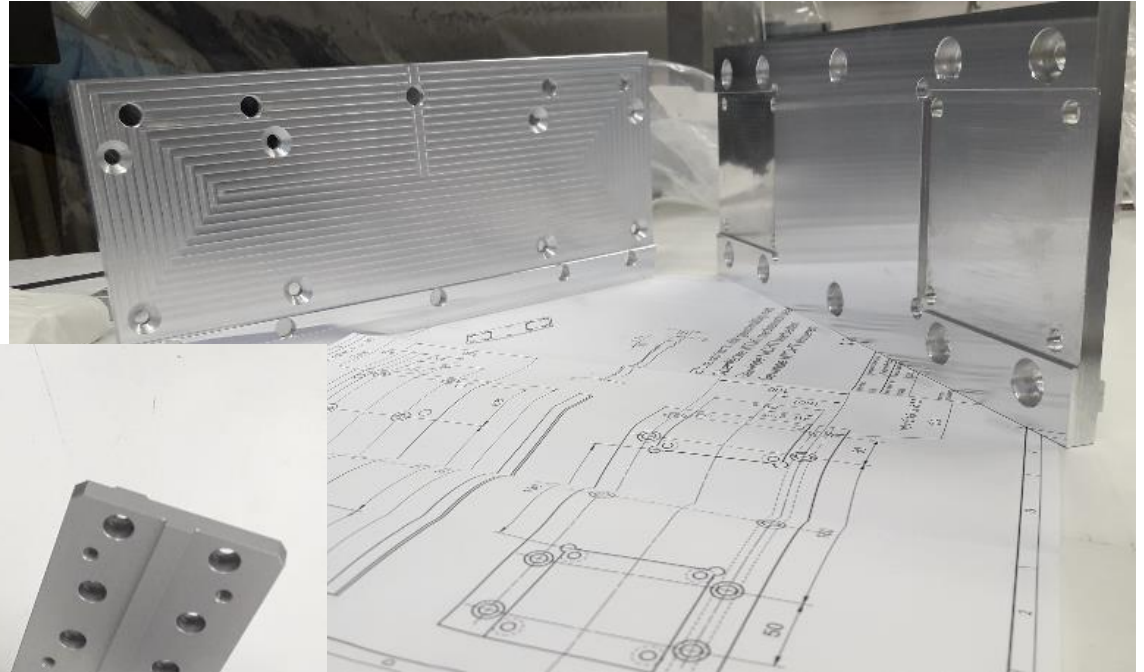


Construction design

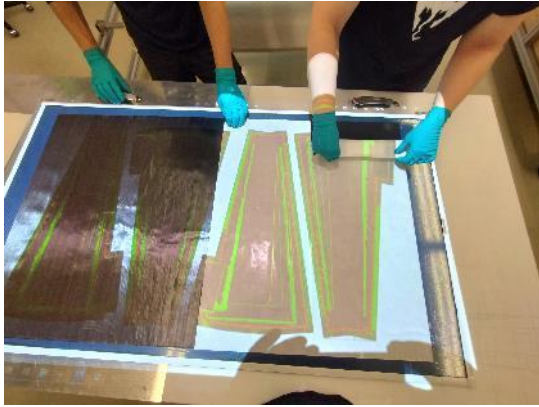
Tool head: turning and tilting unit in section view



Milled parts



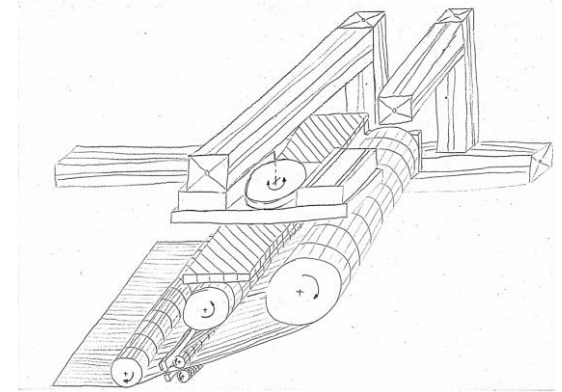
Summary



Manual production



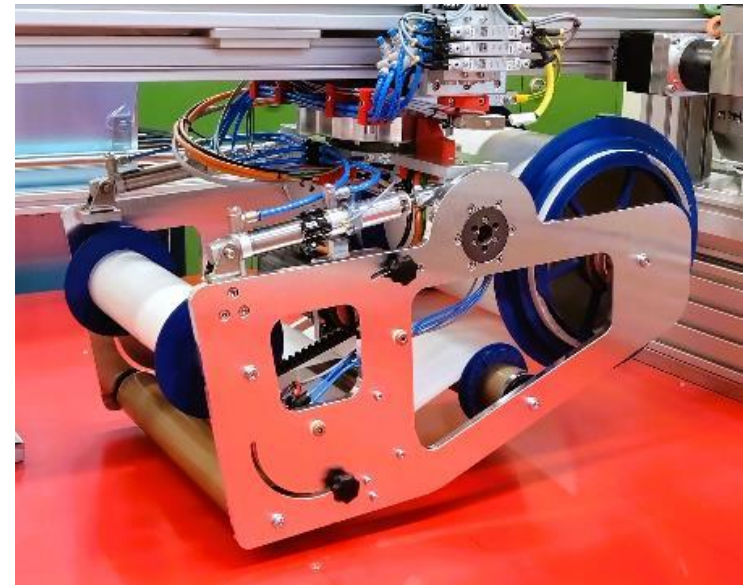
Trials



Conceptual design



Sheet metal parts



Construction