IAEA Workshop 2010
Machine Development at TMB

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Technology and Management for the Decommissioning of Nuclear Facilties – Prof. Dr.-Ing. Sascha Gentes

Agenda

1. Machine Requirements
2. Preliminary Testing
3. Non-Autonomous Machines
4. Autonomous Machines
5. Outlook

1. Machine Requirements

- On the part of the client (e.g. energy supplier) as well as the TUEV (Technical Inspection Association) various machine requirements for the decontamination of surfaces have to be met.

- In particular the following has to be considered:
  - Compliance with the safety standards according to EU Machinery Directive (declaration of conformity has to be provided)
  - Prevent the danger of crushing / bruise at movable parts
  - Use of closed profiles to allow decontam. and release of machine
  - Small dimension of equipment / machinery (fit through gate)
  - Fall protection of machinery (e.g. safety rope, etc.)
  - Safety and rescue concept in case of:
    - Loss of pressure
    - Loss of adhesion on surfaces which are porose or peeling off

1. Machine Requirements

- Declaration of Conformity (Example)

EG-Konformitätserklärung

Der Hersteller: Muster GmbH,
Musterstraße 65
D-27635 Musterstadt
Tel.: +49(0)48763/57647-0

erklärt hiermit, dass folgendes Produkt:

Produktbezeichnung: Beispielmaschine
Typenbezeichnung: K380
Seriennummer: 830489880
Baujahr: 2010

allen einschlägigen Bestimmungen der Richtlinie **Maschinen (2006/42/EG)** entspricht.
Die Maschine entspricht weiterhin allen Bestimmungen der Richtlinien **Elektrische Betriebsmittel (2006/95/EG)** und **Elektromagnetische Verträglichkeit (2004/108/EG).**

Folgende harmonisierte Normen wurden angewandt:

DIN EN 12100-1	Sicherheit von Maschinen - Grundbegriffe, allgemeine Gestaltungsleitsätze, Teil 1: Grundsätzliche Terminologie, Methodik
DIN EN 12100-2	Sicherheit von Maschinen - Grundbegriffe, allgemeine Gestaltungsleitsätze, Teil 2: Technische Leitsätze und Spezifikationen
DIN EN 60204-1	Sicherheit von Maschinen - Elektrische Ausrüstungen von Maschinen, Teil 1: Allgemeine Anforderungen

Name des Dokumentationsbevollmächtigten: Hans Muster
Adresse des Dokumentationsbevollmächtigten: siehe Adresse des Herstellers

Musterstadt,

Datum	Unterzeichner und Angaben zum Unterzeichner	Unterschrift

1. Machine Requirements

- Furthermore, there are specific requirements subject to the constructural conditions inside of nuclear facilities.

- Specific requirements are, e.g.:
  - Low self-weight
  - Modular design and makeup
  - Adjustability of the system acc. to the geometry / height of the room
  - Adaptability regarding floor conditions (e.g. uneven surfaces)
  - Mobility of the system (handling by trolley or hand)
  - Attachments can be switched on/off seperately on demand
  - Etc.

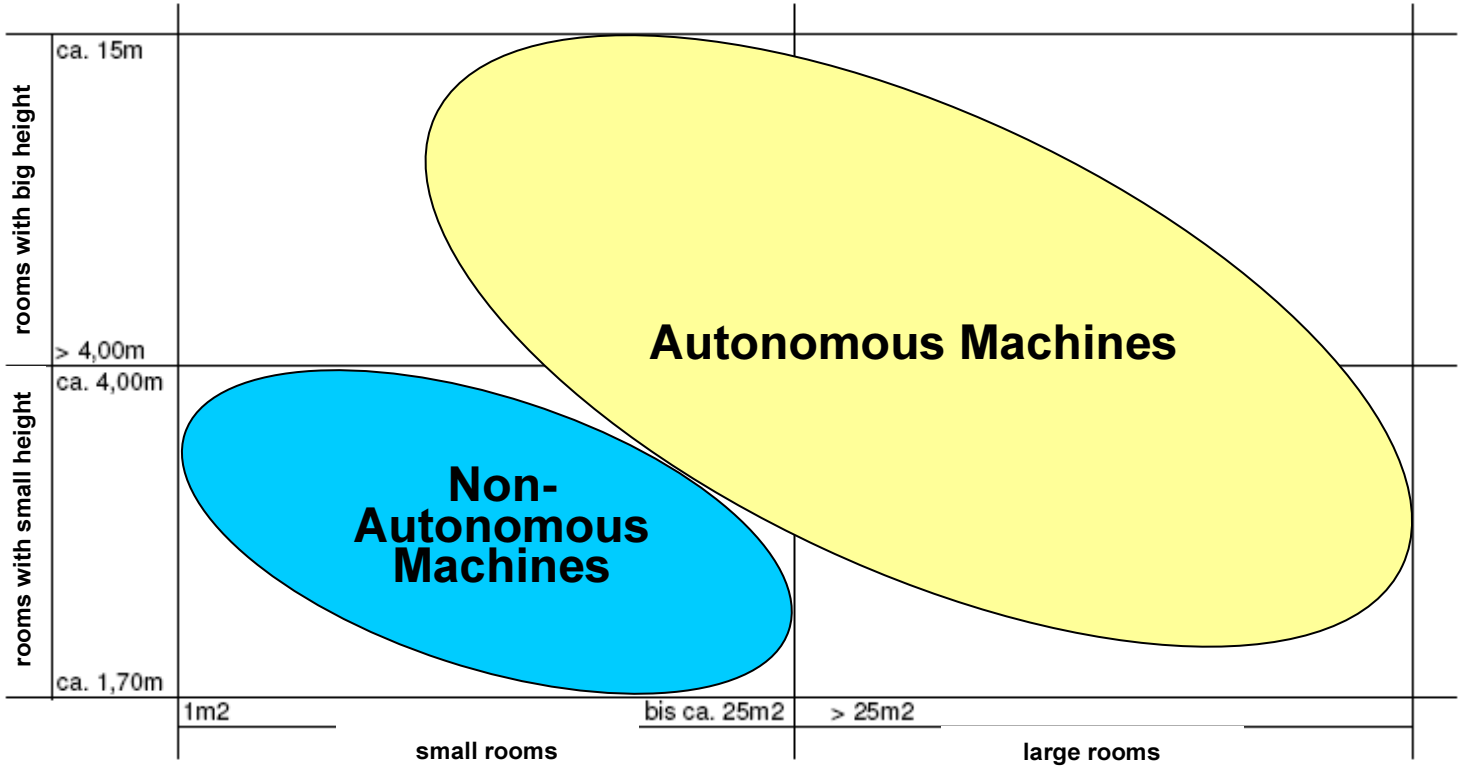
1. Machine Requirements

- The requirements mentioned above determine the most relevant machine characteristics

- Following machine characteristics can be derived:
  - Light
  - Flexible
  - High performance (high rate of removal)
  - Robust
  - 1 operator needed (2 operators at maximum)
  - Preferably autonomous
  - Stable
  - Only short time needed for machine set-up, conversion, disassembly
  - Etc.

1. Machine Requirements

- According to their characteristics machines are suited for different application areas within a nuclear facility:



1. Machine Requirements

- Based on the different requirements machines can be grouped into two categories:
  - Non-autonomous machines
  - Autonomous machines

- According to these two groups the following machines were developed / are under development at the KIT:
  - Non-autonomous machines: AMANDA II und AMANDA III
  - Autonomous machines: AMANDA I und MANOLA

2. Preliminary Tests

- Prior to the construction of the different machines several preliminary tests were conducted:
  - Tests regarding surface abrasion (mill, milling discs, etc.)
  - Tests concerning suction plates (force vs. surface quality)
  - Analysis of motion sequences

2. Preliminary Tests

- Surface Abrasion and Tools
  - Milling Disc (n) ⇒ Roughness
  - Feed (v) ⇒ Precision
  - Downforce (F) ⇒ Manipulator
  - Milling Power (P) ⇒ Operating Efficiency

2. Preliminary Tests

- Parameters of the 20 Testing Series

Milling Depth	Feeding Speed	Milling Discs
1 mm 3 mm	1 m / min 2 m / min	Disc 1 Disc 2 Disc 3 Disc 4 Disc 5



2. Preliminary Tests

- Surface Textures (Roughness of the Surface R_a)

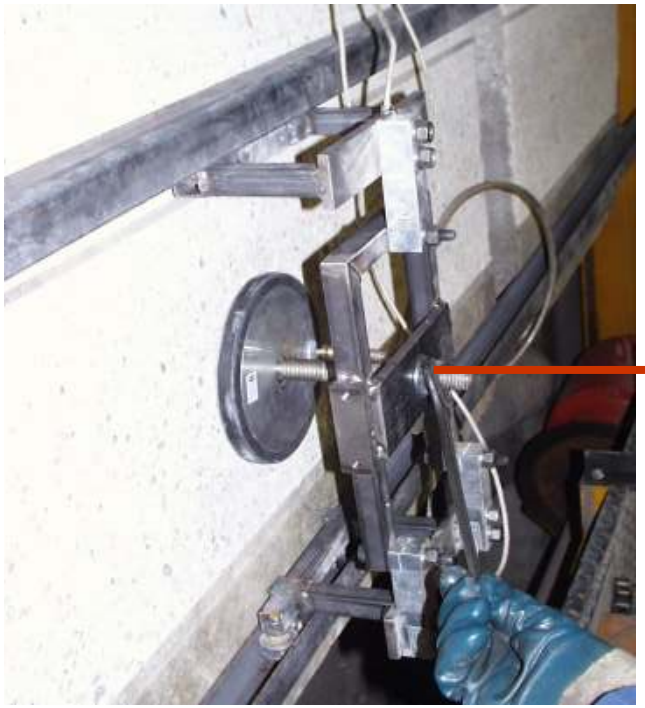
Disc 1 | Disc 2 | Disc 3






2. Preliminary Tests

- Vacuum Suction Plates Experiments



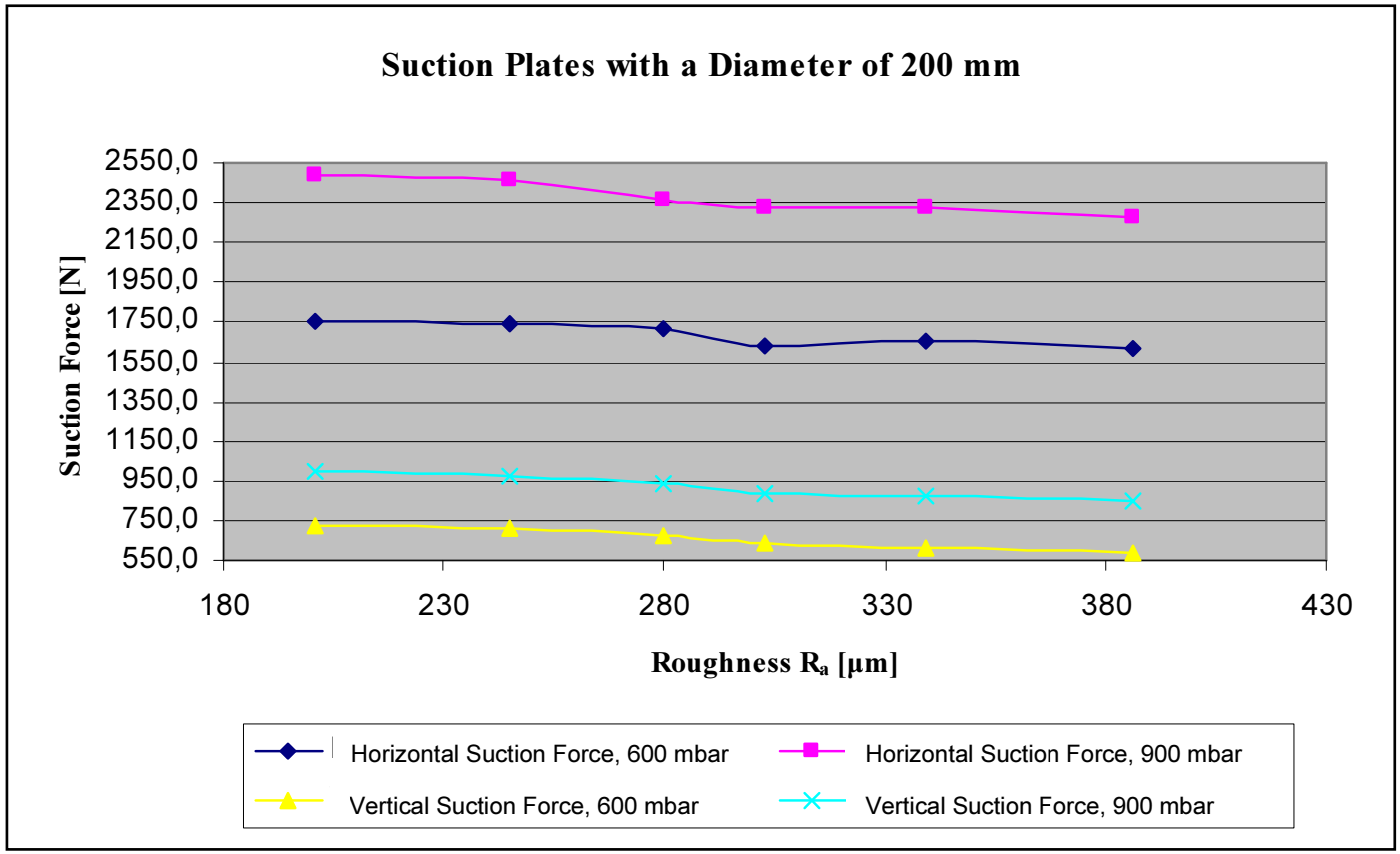
$F_{horizontal, max}$

$F_{vertical, max}$

$F_{h,max}$ and $F_{v,max}$ = f (disc, milling depth, roughness R_a)

2. Preliminary Tests

- Interdependence of the maximum Suction Force and the Roughness of the Surface R_a



2. Preliminary Tests

- Motion Sequence (motion scheme, figure)

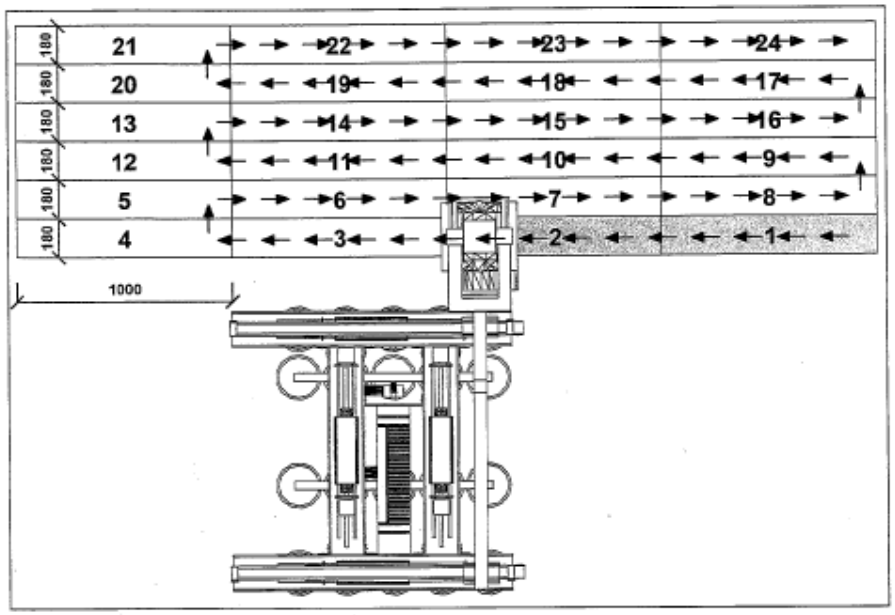


Abbildung 3.24: Laufschema 1

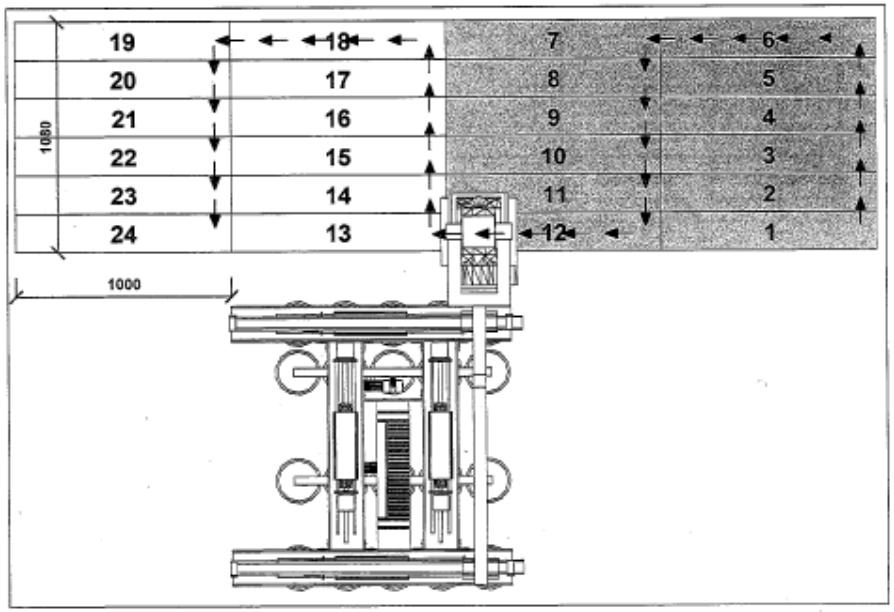


Abbildung 3.25: Laufschema 2

Source: Diplom Thesis of Mrs. Andrea Rothe, FS 06/07

3. Non-autonomous Machines

- AMANDA II
  - ‚Suction rod'
  - 2 mills with extraction
  - Fixed length (approx. 2,85m)
  - Footing with rollers
  - Weight approx. 200 kg
  - Automatic milling process
  - 2 operators required

  - (-) Only for fixed heights
  - (-) High self-weight
  - (-) Not stable

3. Non-autonomous Machines

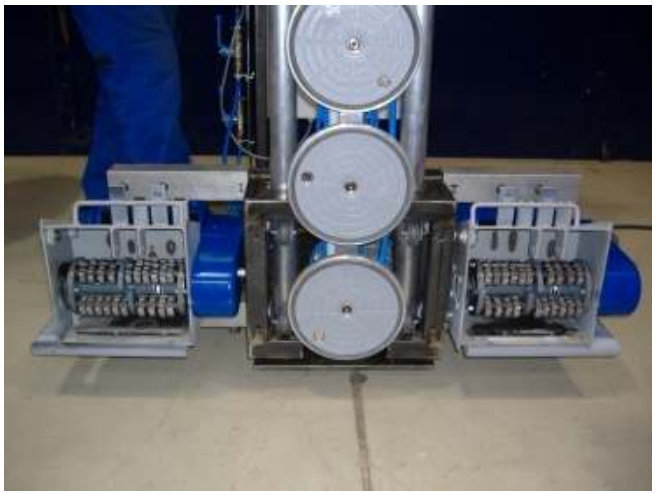
- AMANDA II

3. Non-autonomous Machines

- AMANDA III
  - ‚Suction rod‘
  - 2 mills with extraction
  - Modular system (max. height 4 m)
  - With trolley
  - Weight approx. 180 kg
  - Automatic milling process
  - 1 operator required
  - Output approx. 10 m^2 / hour
  - (+) Variable operating height
  - (+) Movable due to trolley
  - (+) Stable

3. Non-autonomous Machines

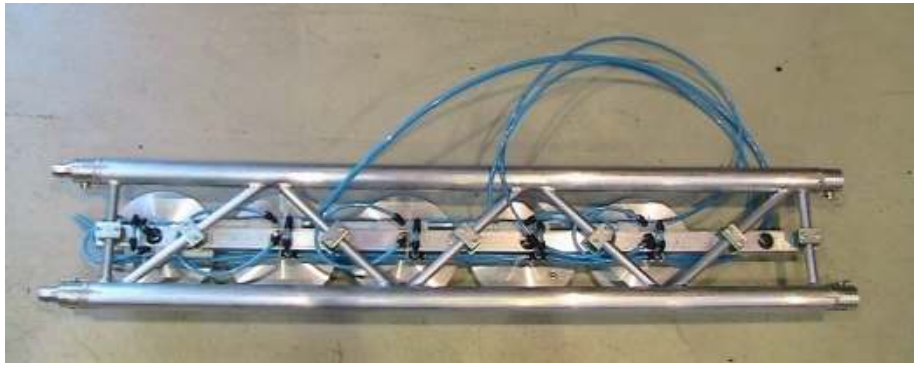
- AMANDA III



3. Non-autonomous Machines

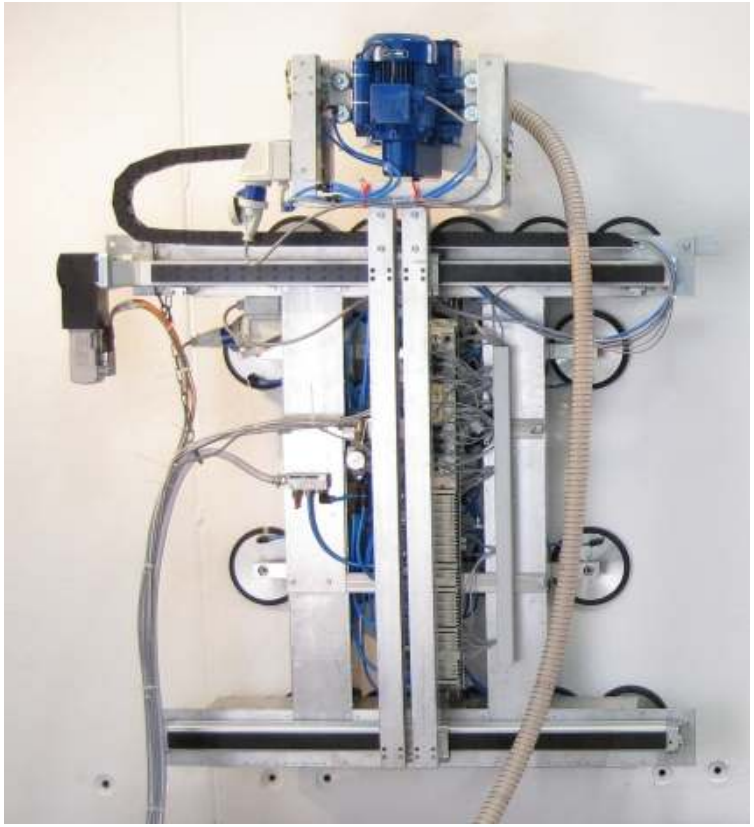
AMANDA III

Module AMANDA III		Weight (in kg)	
Modul	Lenght of module (in m)	Without suction plates	With suction plates
1	0,20	1,15	spacer without suction plates
2	0,25	1,25	spacer without suction plates
3	0,50	1,75	spacer without suction plates
4	1,00	2,80	11,45
5	1,50	3,75	17,10



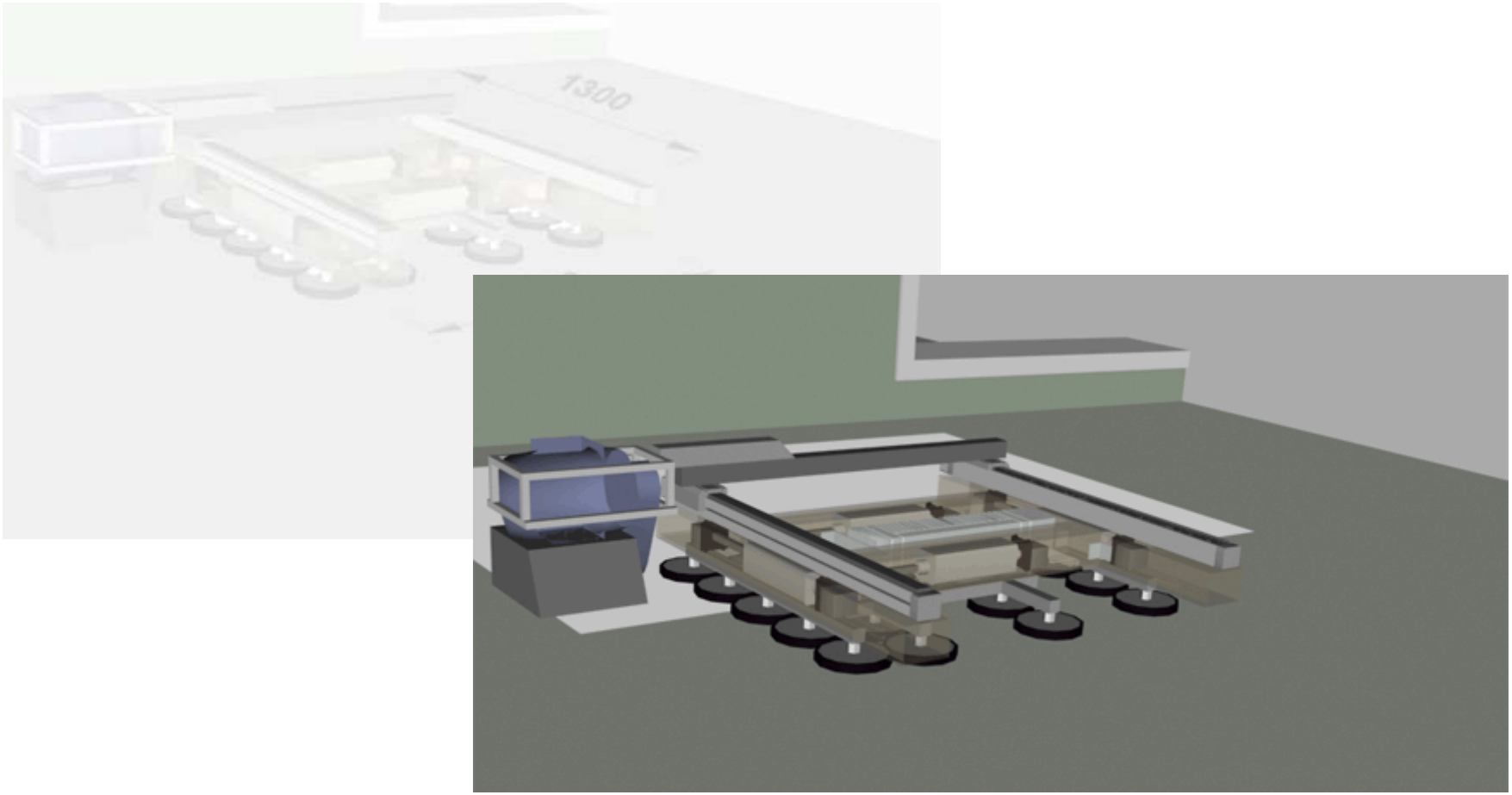
4. Autonomous Machines

- AMANDA I
  - Autonomous Manipulator for Decontamination Assignments
  - One mill with extraction
  - Equipped with vacuum technology
  - Weight approx. 300 kg
  - Automatic milling process
  - 1 operator required
  - Output approx. 6-8 m^2 / hour
  - (+) Suitable for high rooms
  - (+) Remote controlled
  - (-) High self-weight



4. Autonomous Machines

- AMANDA I – Simulation Studies



4. Autonomous Machines

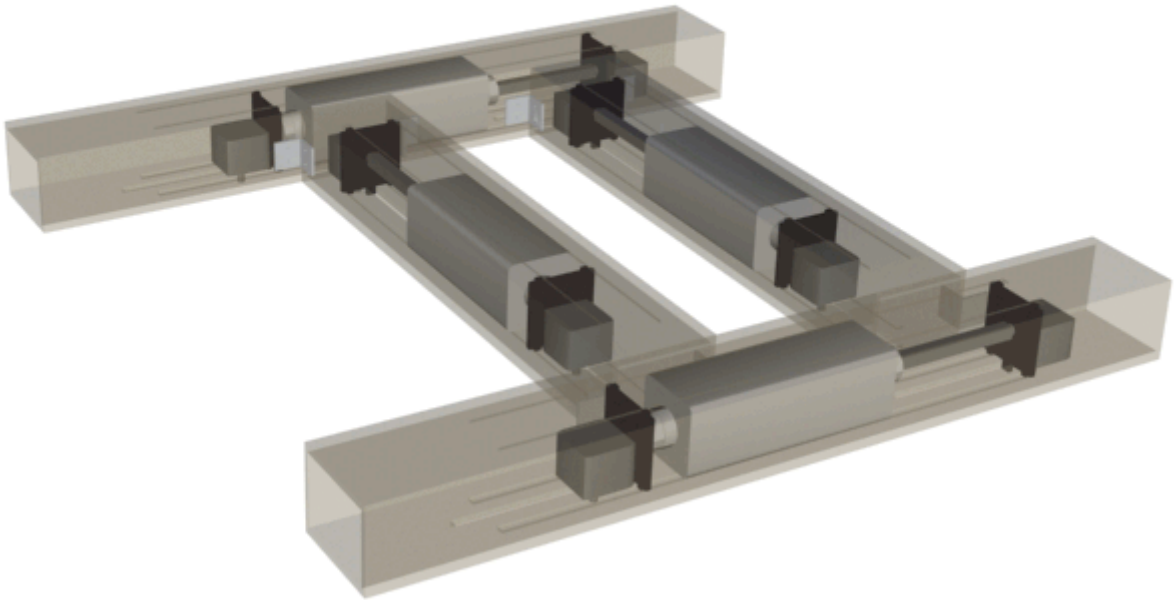
- AMANDA I – Easy and Flexible Assembly

0 kg

4. Autonomous Machines

- AMANDA I – Easy and Flexible Assembly

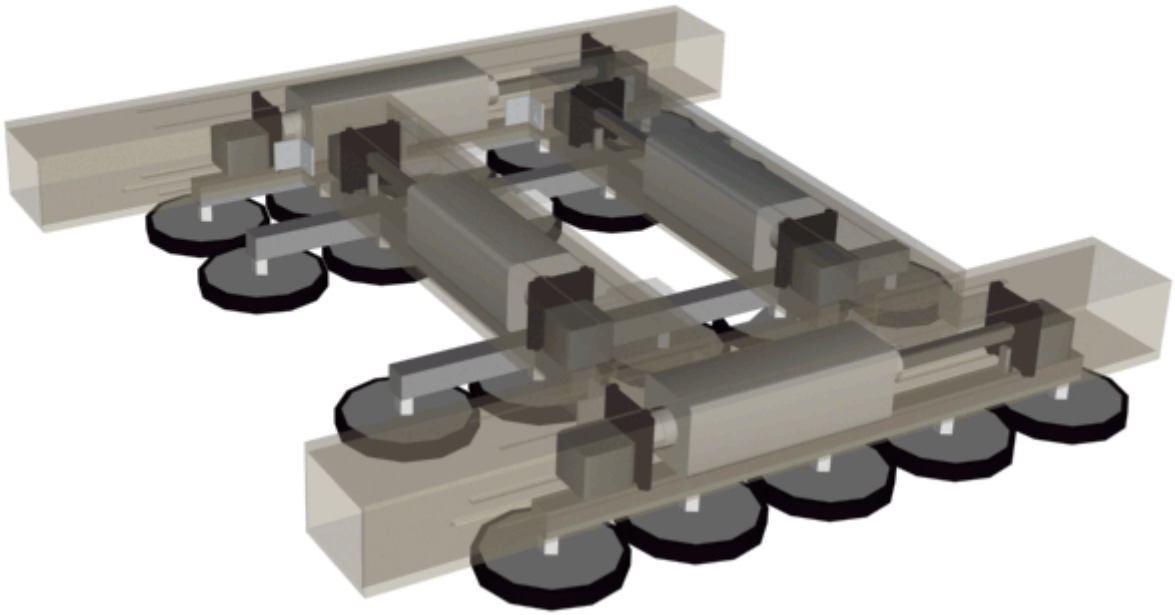
96 kg



4. Autonomous Machines

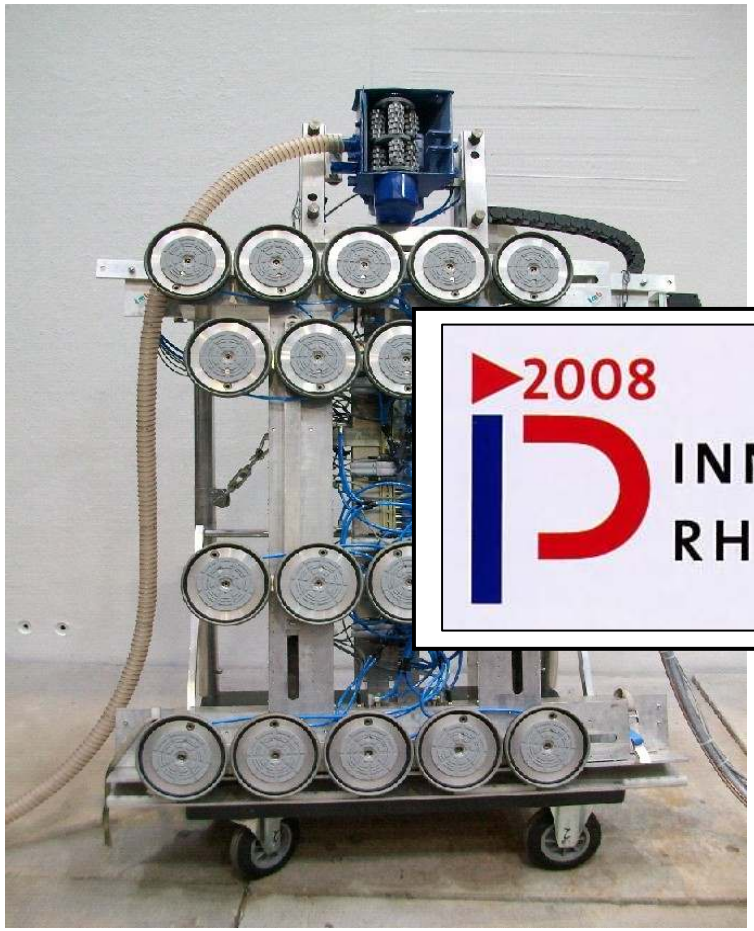
- AMANDA I – Easy and Flexible Assembly

159 kg

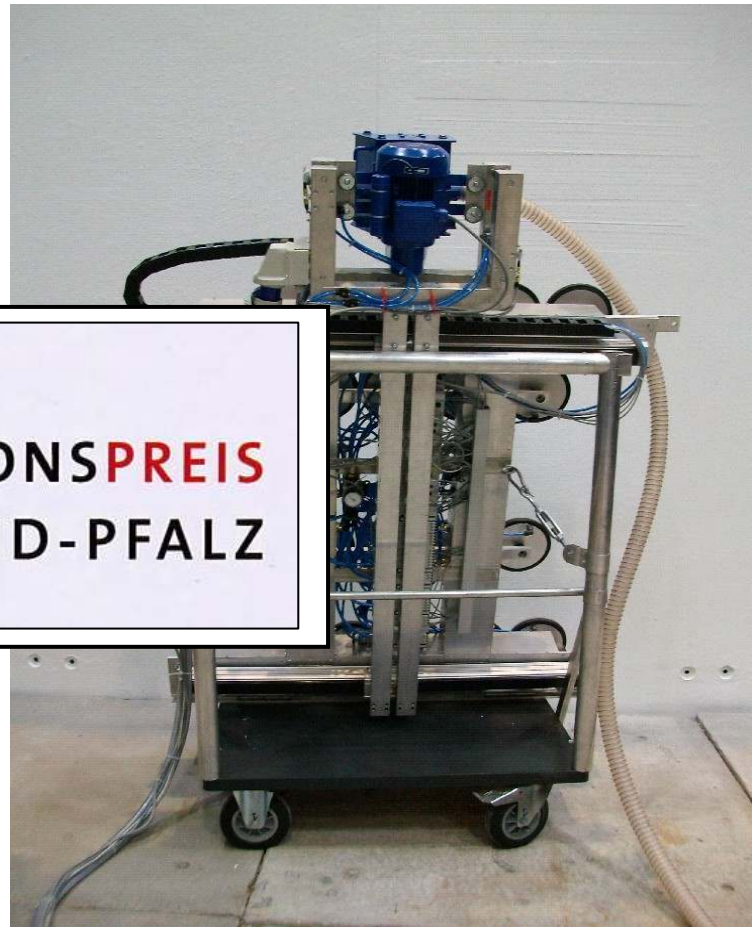


4. Autonomous Machines

- AMANDA I – Innovation Prize Winner



2008 INNOVATIONSPREIS RHEINLAND-PFALZ

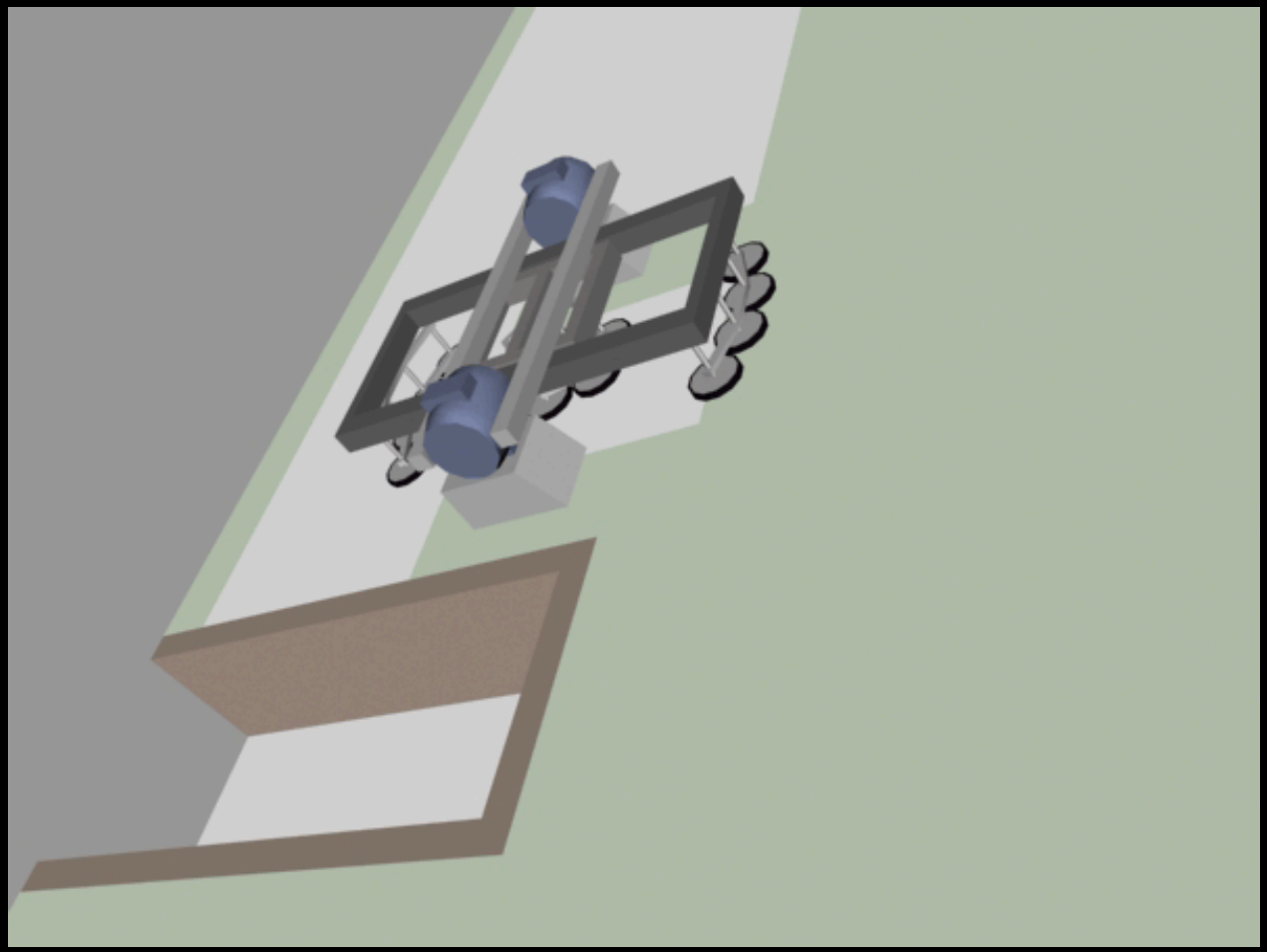


4. Autonomous Machines

- MANOLA – Manipulator Operated Laser Ablation
  - 4.1 Simulation Study
  - 4.2 Support System
  - 4.3 Trolley
  - 4.4 Positioning System
  - 4.5 Control System
  - 4.6 Programming
  - 4.7 Operator Interface

4.1 Simulation Study

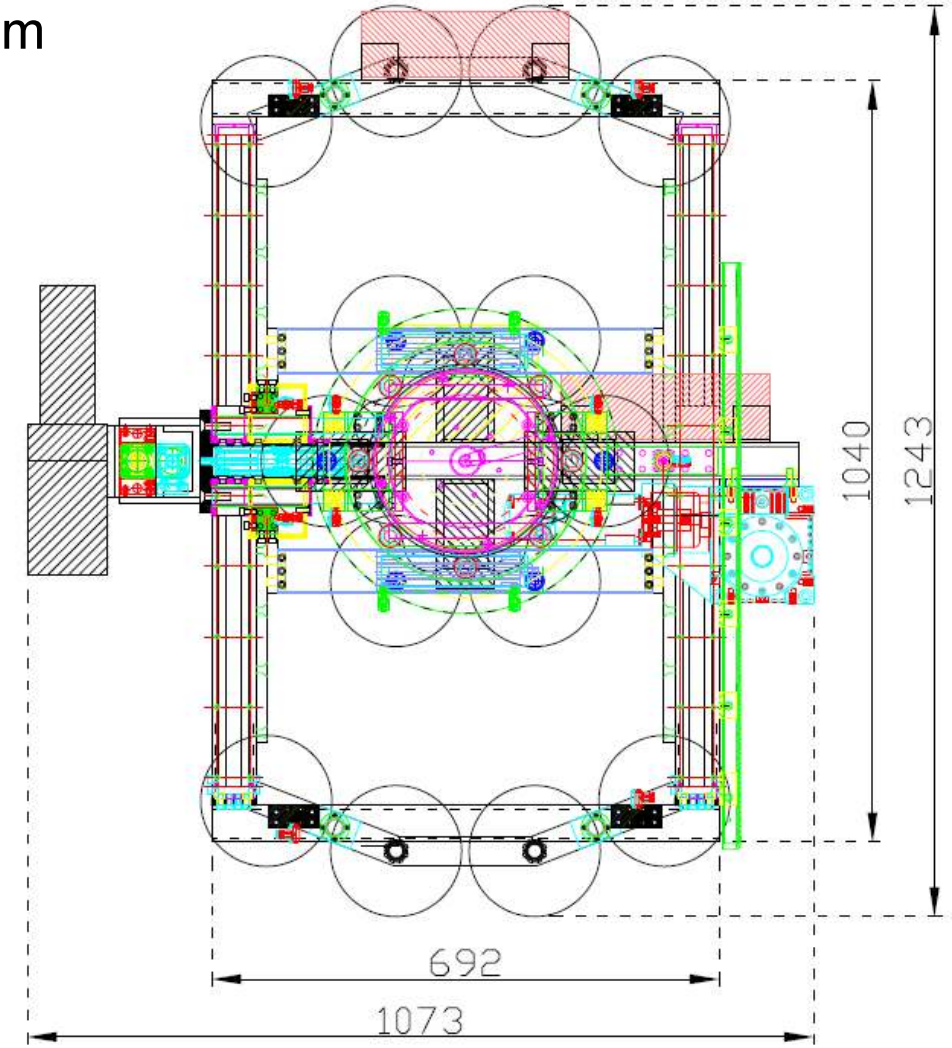
- Motion Sequence



4.2 Support System

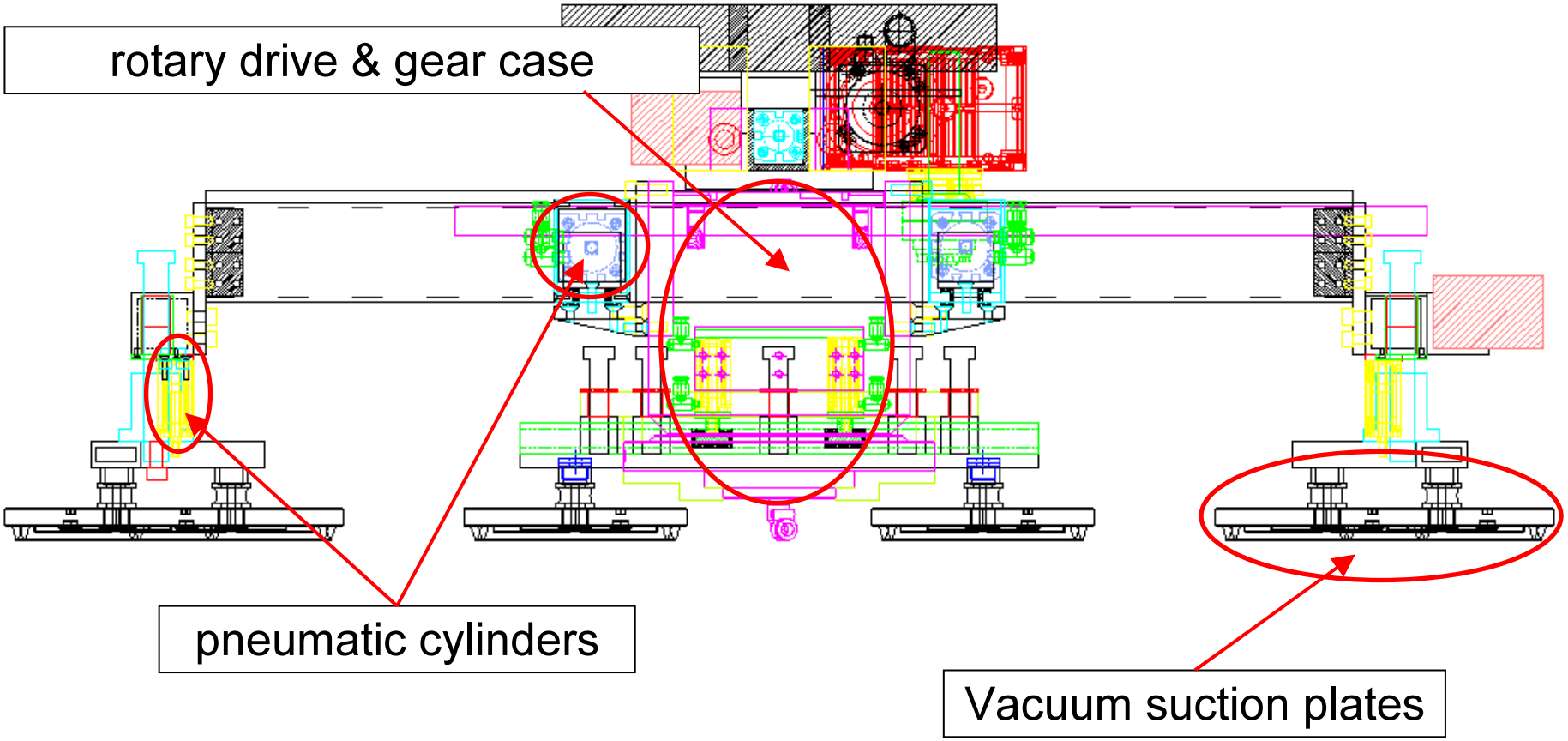
- Components of the support system
  - Main frame (43 kg)
  - Sub frame (44 kg)
  - Traverse (33 kg)
  - Attachment (20 kg)
  - Equipment (30 kg)

Total weight: approx. **170 kg**



4.2 Support System

- Longitudinal section

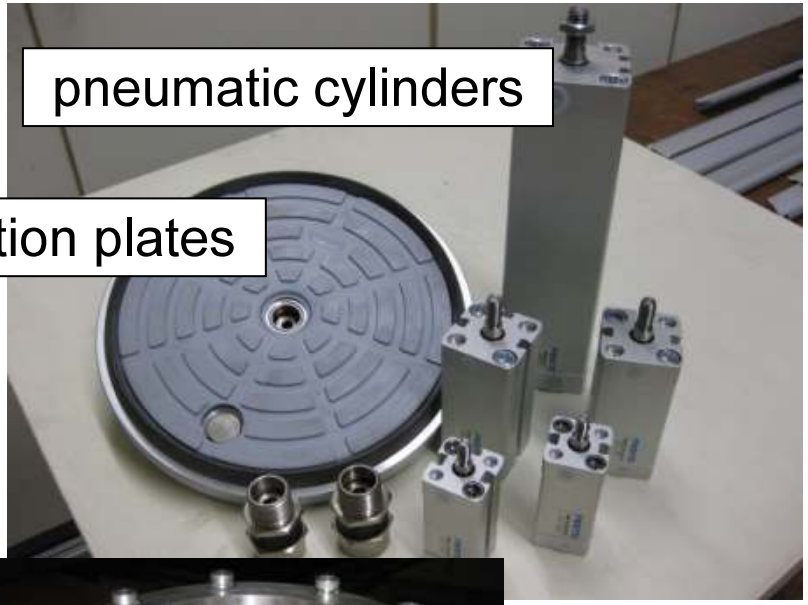


4.2 Support System

- Components

gear case

rotary drive



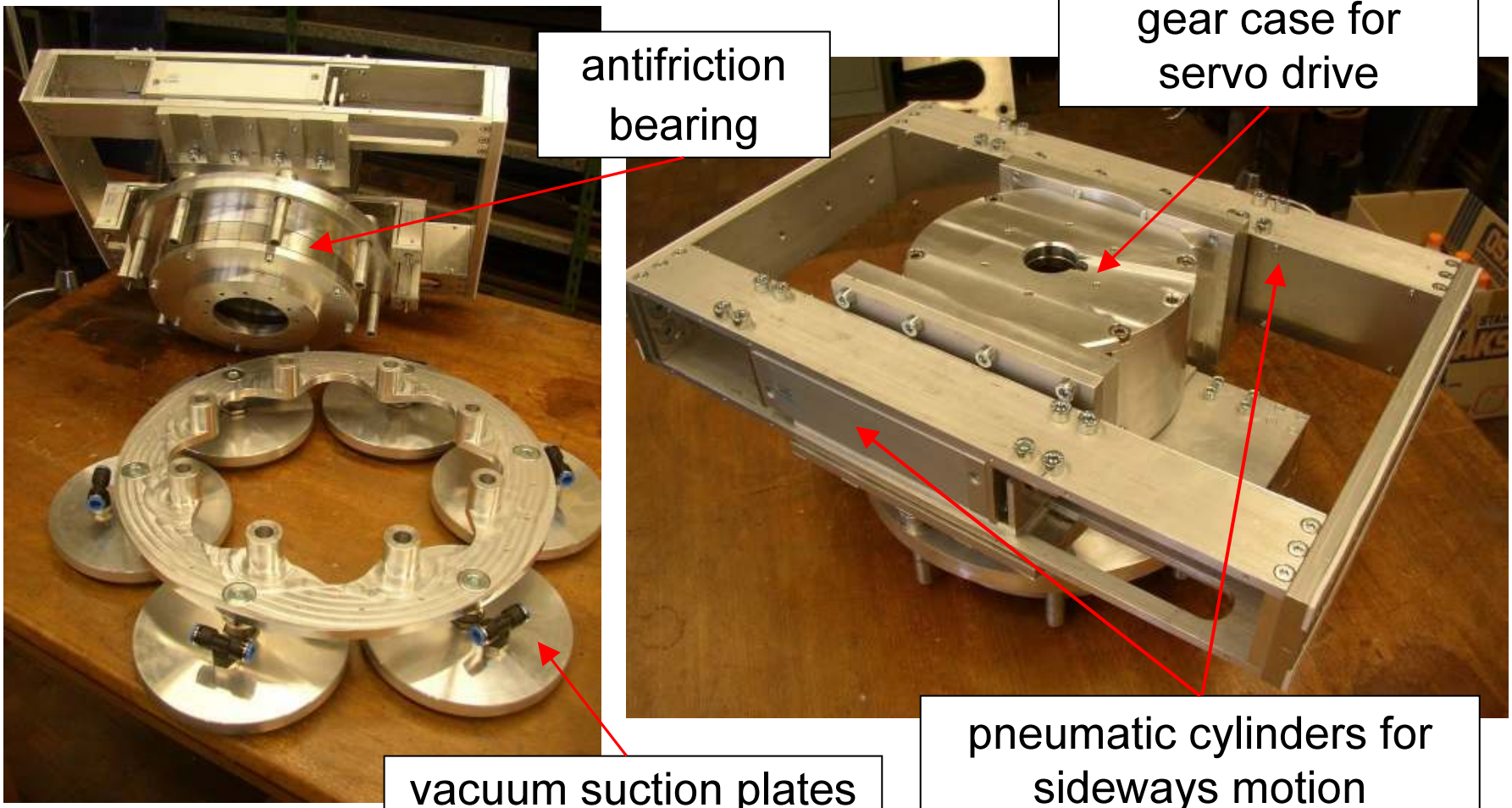
pneumatic cylinders

vacuum suction plates

aluminum parts

4.2 Support System

- Sub frame

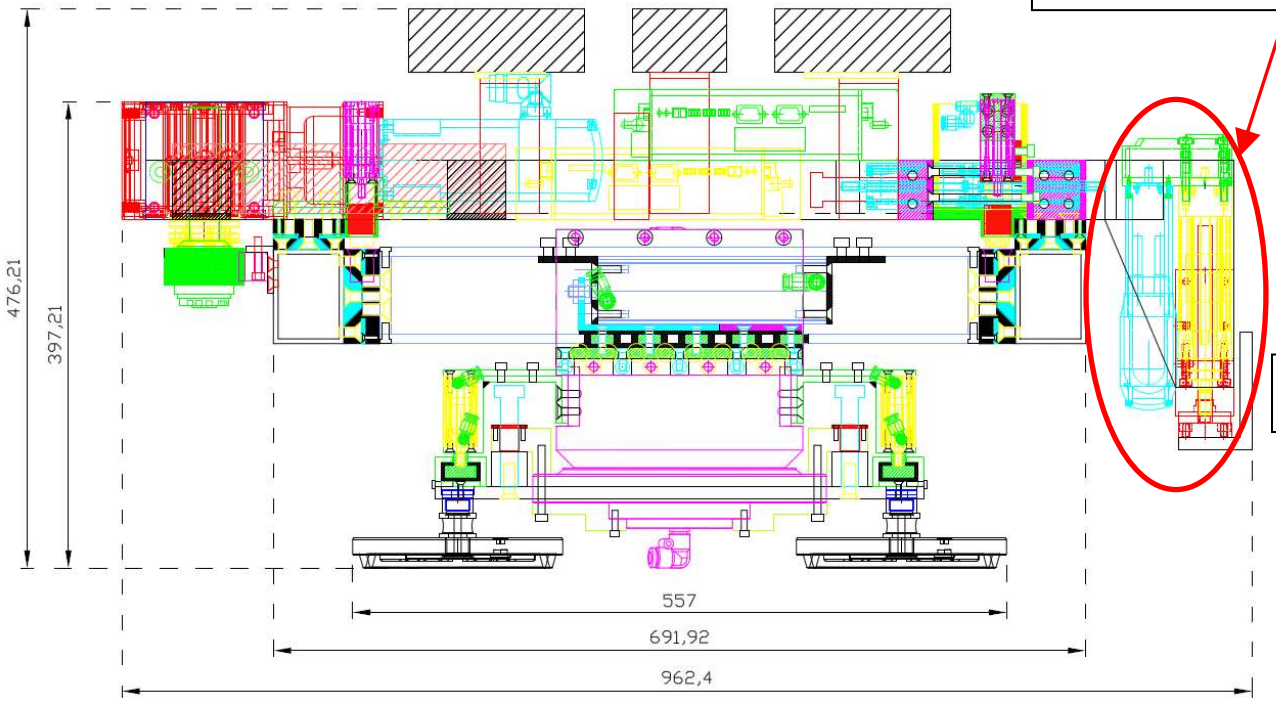


4.2 Support System

- Sub frame

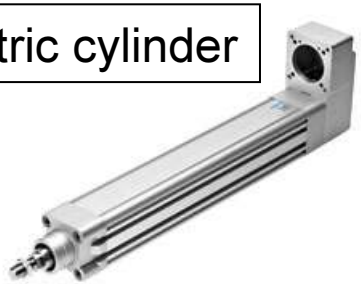
4.2 Support System

- Components



electric cylinder with servo drive and guiding unit

electric cylinder



servo drive

guiding unit

4.2 Support System

- Telescoping chuck

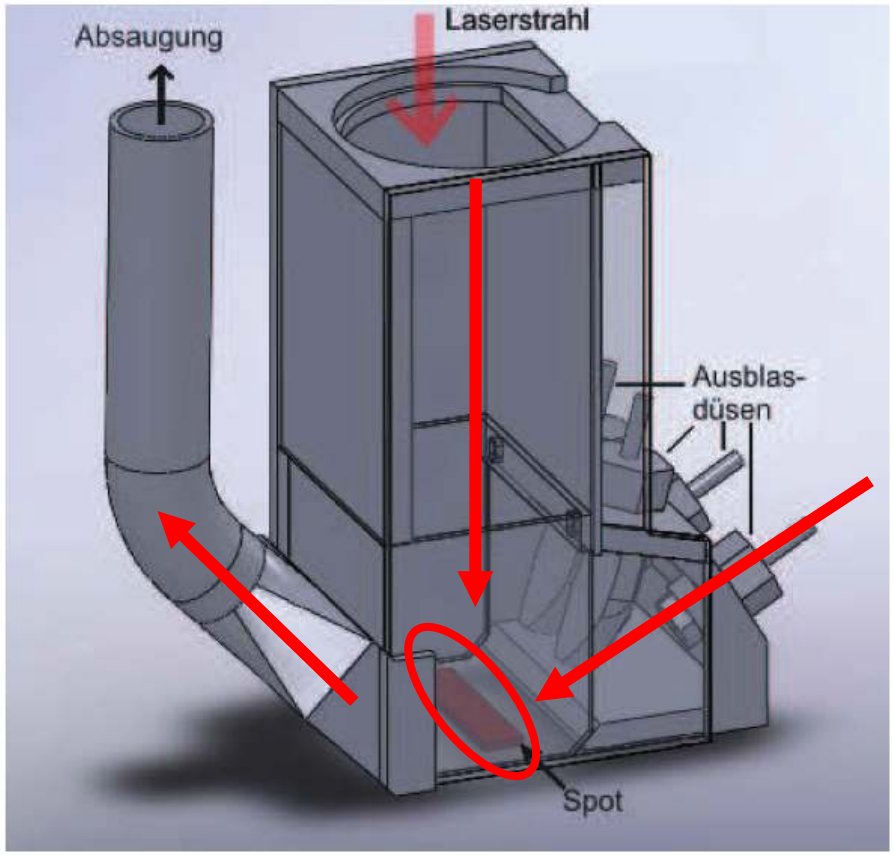
1st step

2nd step

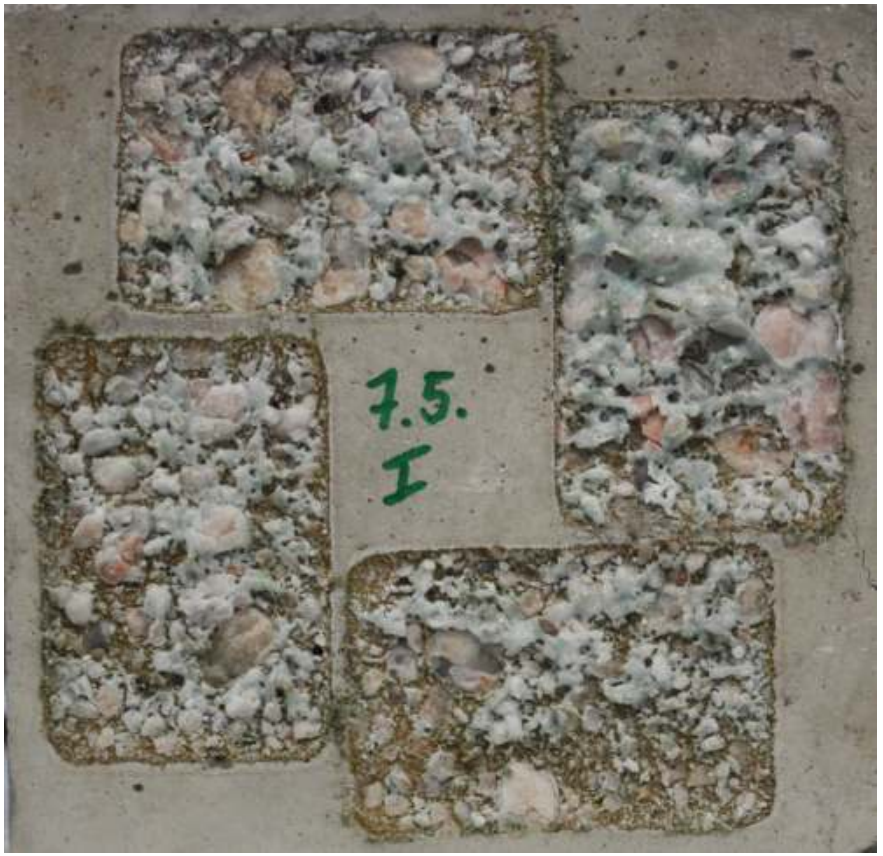
3rd step

4.2 Support System

- Laser processing head (attachment)



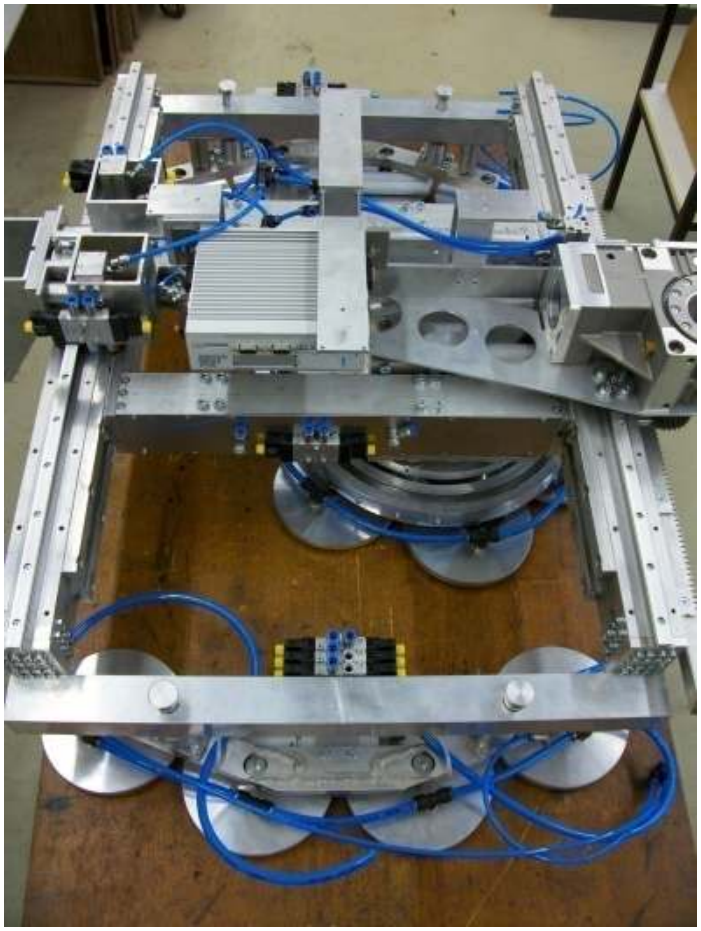
Laser processing head MANOLA



Testing results MANOLA

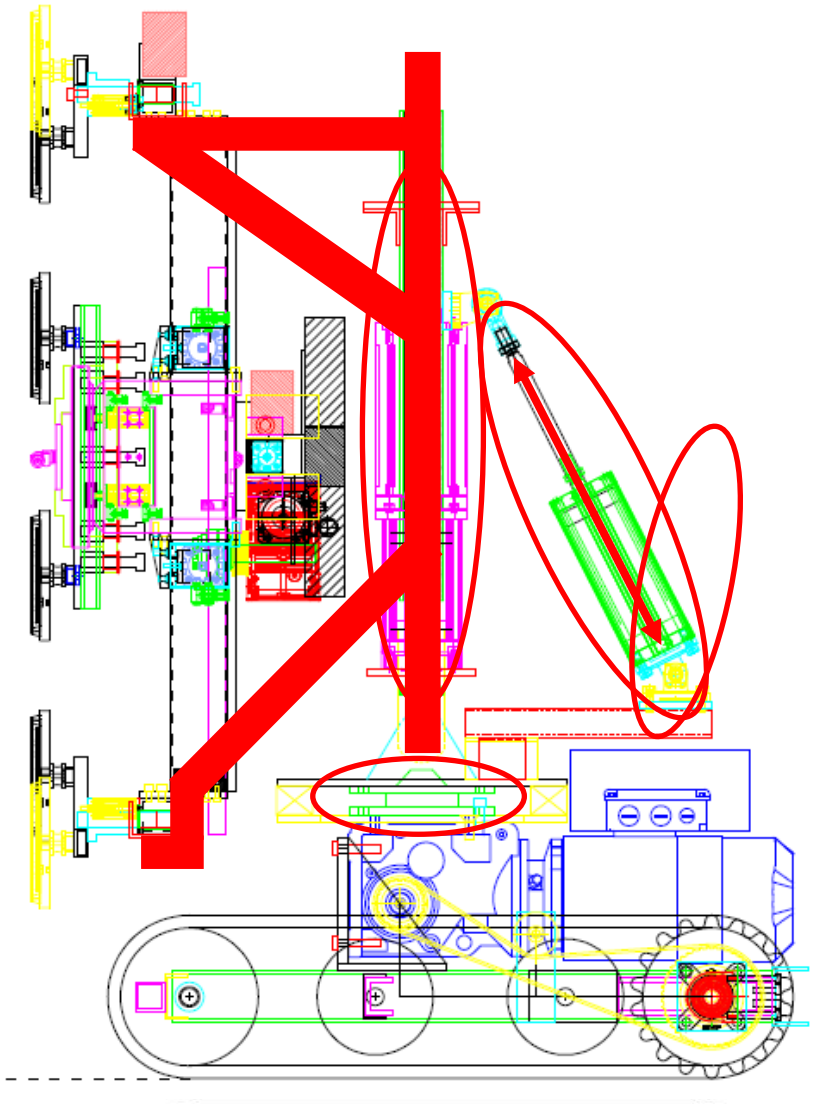
4.2 Support System

- Main frame, sub frame and traverse



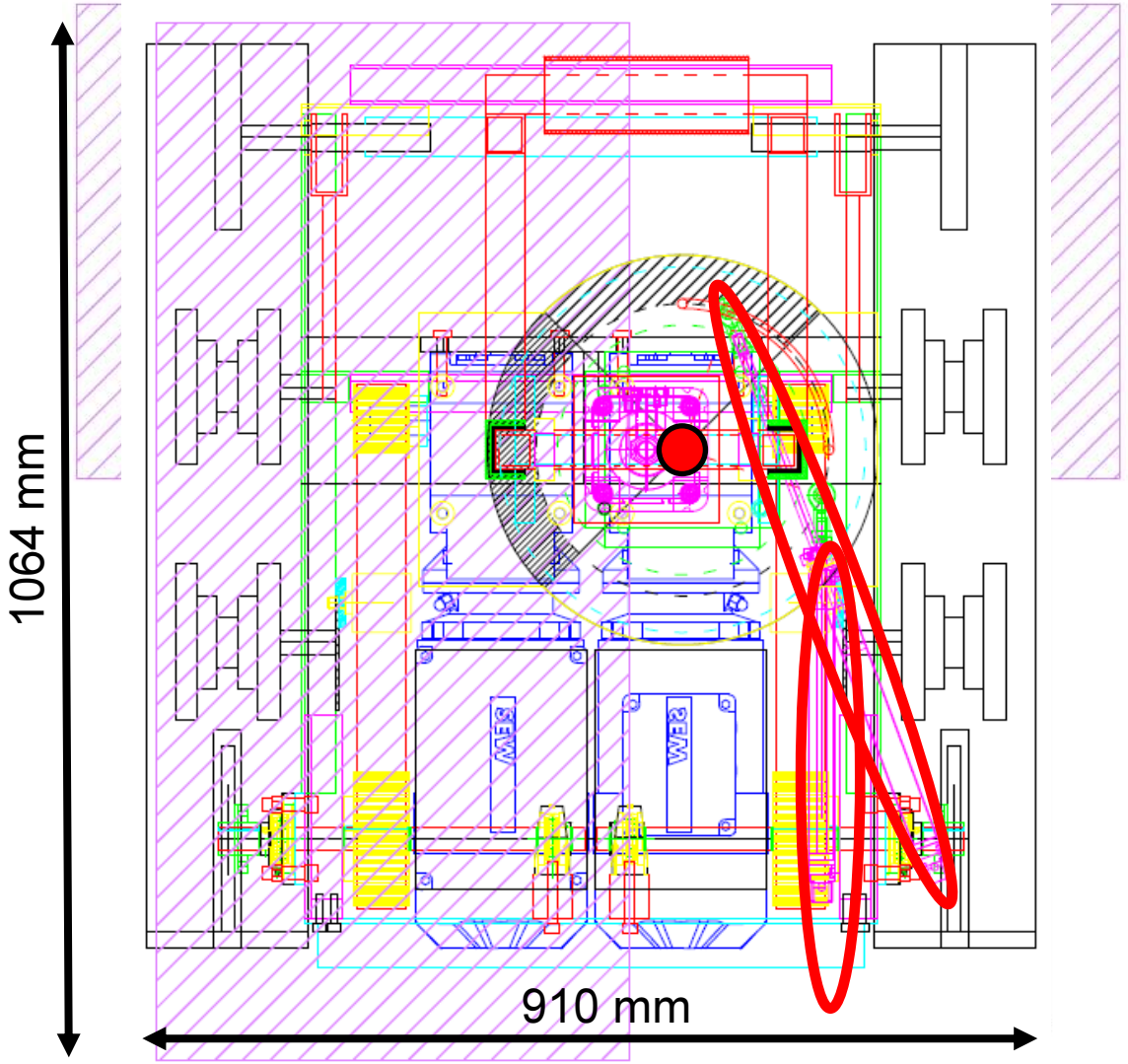
4.3 Trolley

- Components
  - rotary bearing
  - cylinder for 90° turns
  - supporting device
  - cylinder for lifting / kneeling of the supporting device
  - cylinder for pushing the supporting device up or pulling it down



4.3 Trolley

- Components
  - Cylinder for 90° turns
  - Center of rotation
  - Cylinder in initial position
  - Cylinder in extended position (supporting device turned by 90°)
  - Dimensions



4.3 Trolley

- Undercarriage fitted with rubber tracks

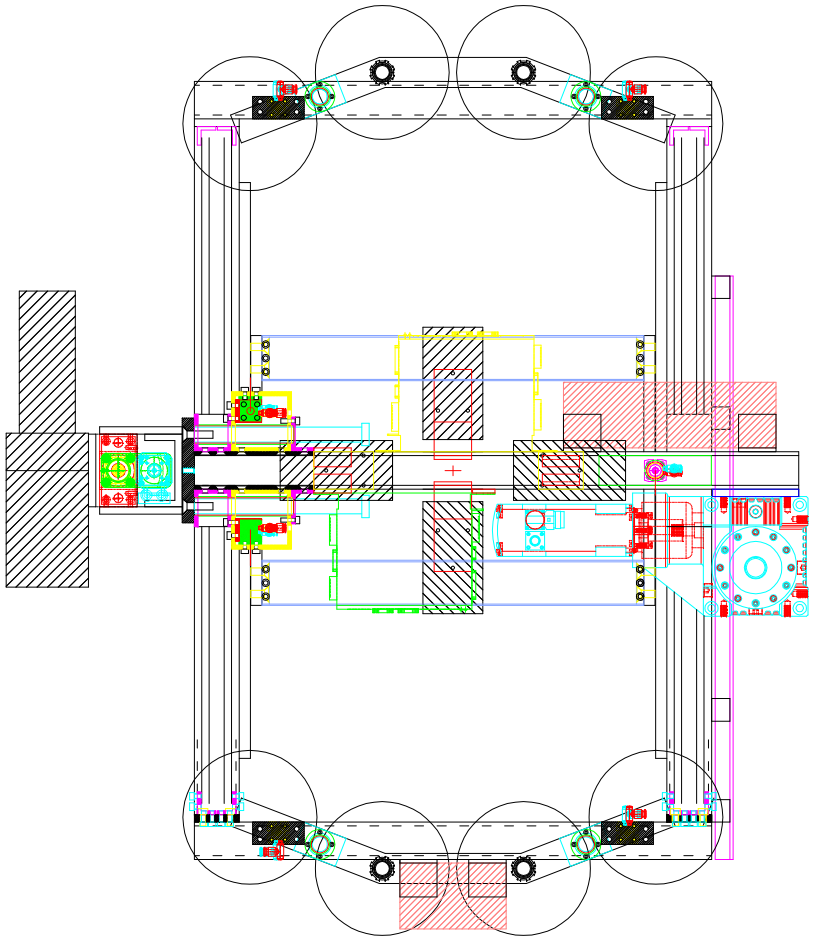
4.4 Positioning System

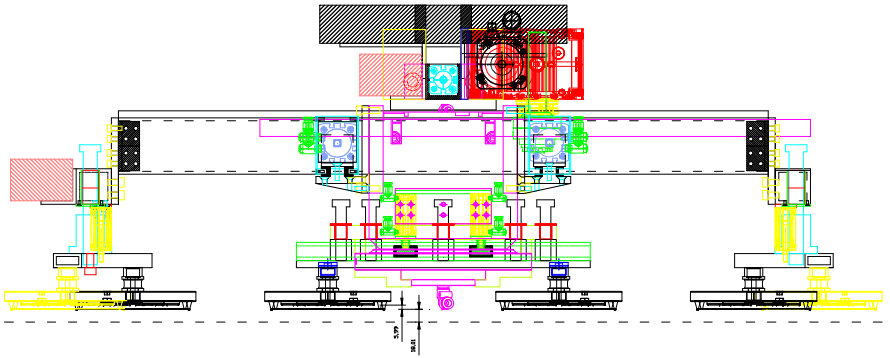
- Four distance laser sensors are used as a simplified positioning system
- Devices are mounted to the traverse that runs over the whole main frame of the manipulator
- Generation of reading points used for mapping

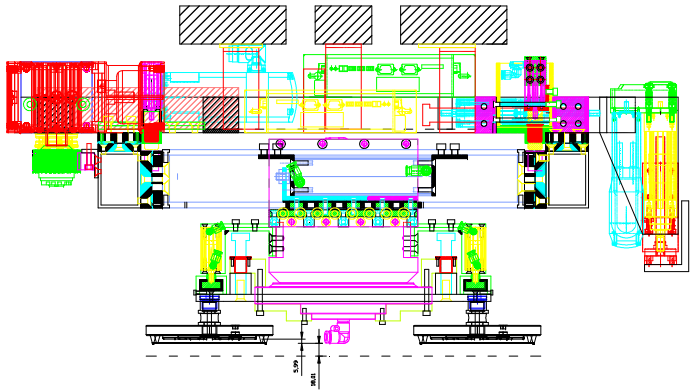
Distance laser sensor

4.4 Positioning System

- Positioning of distance laser sensors







4.5 Control System

- Information processing
  - by use of a CompactRIO-System
- Information transfer
  - WLAN

WLAN Camera

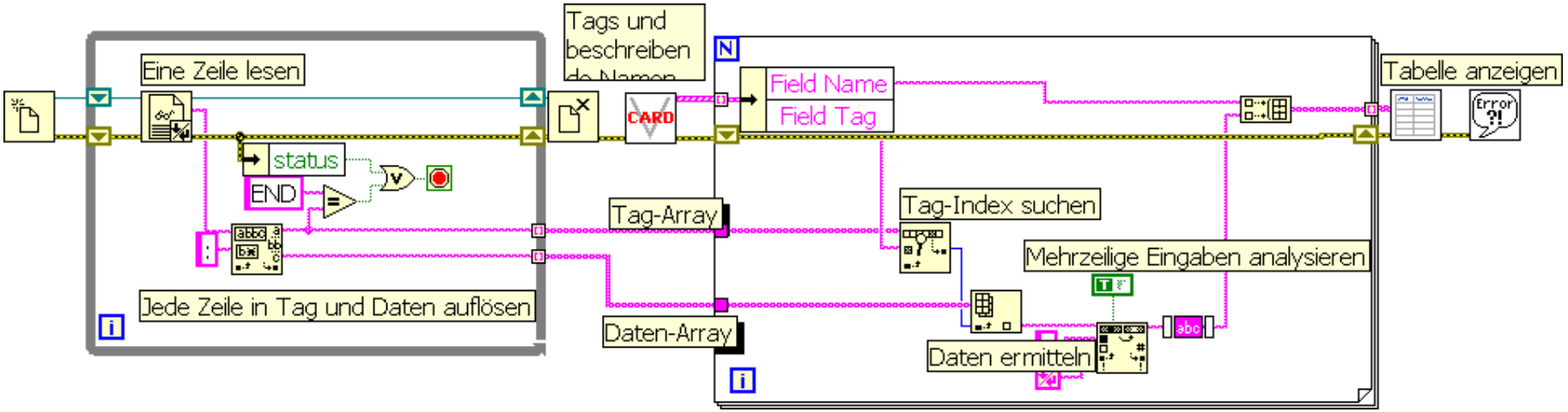
CompactRIO

WLAN Router

Laptop

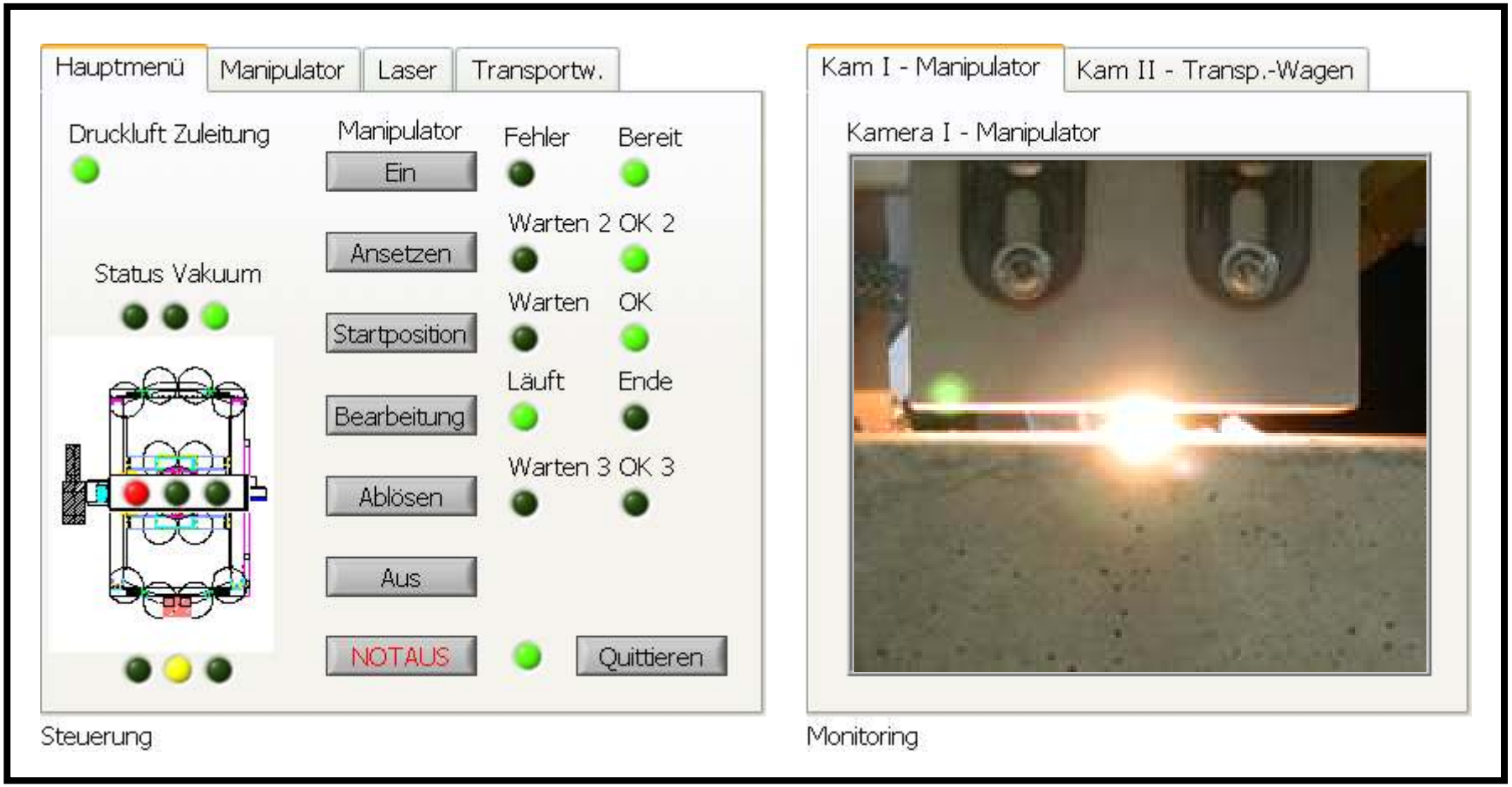
4.7 Programming

- „LabView“ software by National Instruments



4.8 Operator Interface

- MANOLA operator interface with LabView



5. Outlook

- Support system
  - Construction is almost finished
  - Subsequent: installation of control unit with components and cables
- Trolley
  - Currently under construction, will be finished parallel to the support system
- Implementation and adjustment of the control system
  - Will follow upon completion of both, the support system and the trolley
- Phase of testing
  - Testing of the support system without and with processing head

Thank you for your attention!