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NextGEng Project

WP3

International team-teaching pilot program

Deliverable 3.1c

Developed laboratory work, tailored seminars for course C1…C4

September 2023

TECHNICAL UNIVERSITY OF CLUJ-NAPOCA jamk Universidad de Jaén ISR www.isr.es Valmet BOSCH Invented for life

WP3	R3.1c - Developed laboratory work, tailored seminars for course C1...C4
Authors	Ciprian Rad
Short Description	This report presents the results of the laboratory worked, tailored seminars developed for courses C1...C4 within first round of course and laboratory upgrading process in WP3.
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1. Introduction

This report presents the outcomes of the course upgrading and team-teaching development carried out within WP3 of the NextGEng project.The implementation process led to the creation of **11 new laboratory activities and tailored seminars** were created in cooperation with industry partners, including ISR (3 labs), Valmet (4 labs), and Bosch (4 labs). These activities strengthen the applied dimension of the curriculum and enhance the connection between academic learning and industrial practice.

The development process was highly collaborative, involving **32 coordination meetings** across the co-teaching teams of courses C1–C4, with the participation of **15 higher-education teachers** and **10 industry experts**. This joint effort ensured alignment of content, consistent implementation across institutions, and the integration of industry-relevant competencies.

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In the next Chapters the produced laboratories modules are presented.

2. Laboratories topics

C1- Strength of materials

Project – Strength evaluation for guardrails (in collaboration with VALMET)

Laboratory – Stress and strain measurements for PCBs (in collaboration with BOSCH)

C2 - Industrial Automation

Laboratory 1 – PLC Electropneumatic Station Programming (in collaboration with ISR)

Laboratory 2 - Usability in heavy industrial machinery (in collaboration with VALMET)

Laboratory 3 - PLC Programming with Sequential Function Chart (SFC) (in collaboration with BOSCH)

C3 - Design Projects

Laboratory 1 – How to scope a project in an Industrial Tech Company - ClickUp example (in collaboration with ISR)

Laboratory 2 - Concept design of a test object for a pressing-based manufacturing process (in collaboration with VALMET)

Laboratory 2 - Ergonomic assessment and workplace design (in collaboration with BOSCH)

C4 - Quality Assurance and Applied Methods

Laboratory 1 – Industrial applications for CNC tooling measurement (in collaboration with ISR)

Laboratory 2 – Development Techniques (in collaboration with VALMET)

Laboratory 3 - Cell Force Calibration - “Smart function kit press” (in collaboration with BOSCH)

C1 – Strength of Materials

P - Strength evaluation for guardrails

P4 - VALMET

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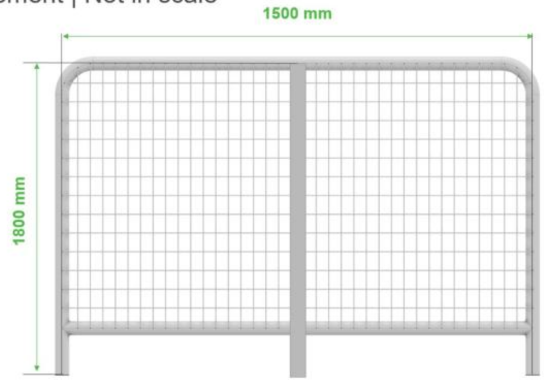
Project - Strength evaluation for guardrails

Guard element | Not in scale



Load case | Side view

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Project - Strength evaluation for guardrails

Project overview:

Objectives

- The objective of this project is to enable students to apply Strength of Materials principles to evaluate the structural performance of guardrails under static and dynamic (impact) loads. Students will analyze maximum stresses, deflections, and load cases for different materials (e.g., aluminum and stainless steel) and propose design improvements or support solutions that ensure compliance with safety and performance limits.

Pre-requisite

- Strength of Materials fundamentals – Stress, strain, bending, shear, torsion.
- Statics and Mechanics – Free-body diagrams, load distribution, boundary conditions.
- Beam theory – Euler–Bernoulli beam theory, combined loading.
- Material science basics– understanding of material properties such as modulus of elasticity, yield strength, permissible stresses.

Equipment used for the project

- VALMET equipment from factory

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Project - Strength evaluation for guardrails

Upon completion of this project, the student will be able to:

1) **Perform Structural Analysis Under Combined Loads** - calculate maximum stresses and deflections due to bending and torsion for different load cases (static and impact) and verify compliance with safety criteria.

2) **Evaluate and Compare Materials for Structural Applications -** analyze how different materials (e.g., aluminum vs. stainless steel) behave under identical loading and determine appropriate material selection for structural components.

3) **Propose Engineering Design Improvements** - propose feasible design modifications such as additional supports (center support, horizontal braces, diagonal supports, etc.) to increase allowable span while staying within deflection and stress limits.

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Content

- **Introduction** – Project overview and objectives
- **Problem Description** – Guardrail geometry, materials, and load cases
- **Material Properties** – Aluminum AW-6060 T5 and Stainless Steel 1.4404
- **Methodology** – Assumptions, analytical formulas, and calculation approach
- **Results** – Deflection and stress under static load and under impact load
- **Design Improvements** – Possible support configurations and material alternatives
- **Discussion** – Comparison, limitations, and interpretation
- **Conclusion**
- **Appendices** – Detailed calculations, diagrams, or FEM results

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The task of Strength of Materials, based on a real topic received from Valmet:

Valmet needs to carry out strength evaluation for guardrails that are higher than at present. Now reviews should be done with a railing 1600 mm high. The railing is a pipe profile 45 mm x 2 mm and made of aluminum AW-6060 T5, the material values of which are shown in the table below. The second handrail material under consideration is stainless steel 1.4404, which, in turn, measures 42.4 mm x 2 mm. The loading cases are static load, where the railing has 300 N/m as shown in the figure, and an impact load, where 90 kg collides with the railing at a speed of 1.6 m/s. The directions of the loads in both load cases as shown in the figure.

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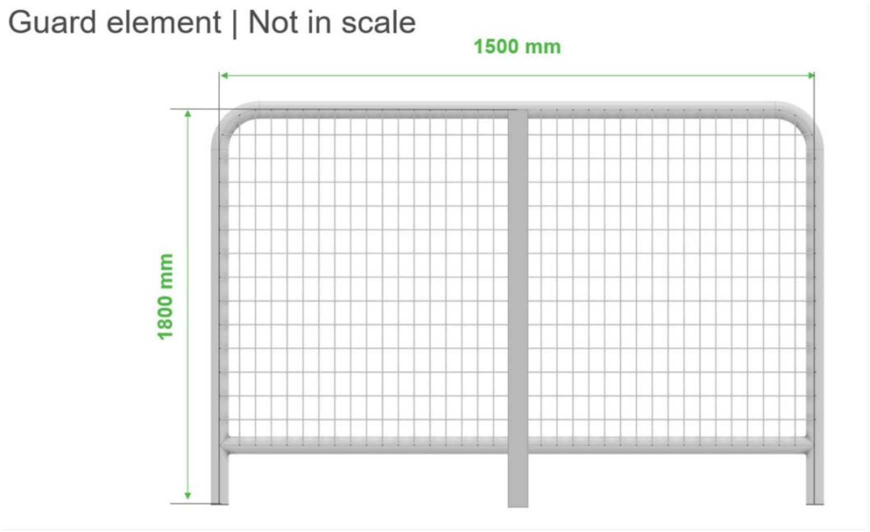
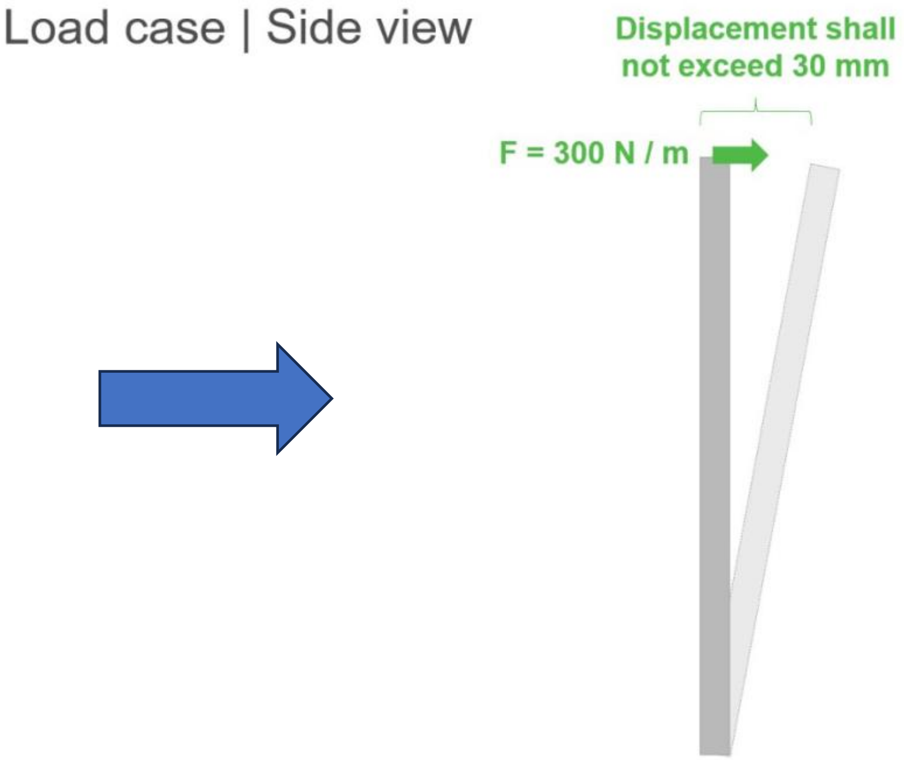
- ✓ The total deflection of the handrail shall be less than 30 mm as shown in the figure and the reference stress shall be below the permissible stress given in the table from the next slide.
- ✓ The railing element is as shown in the picture below, but the height is 1600 mm instead of the 1800 mm in the picture and the middle support of the picture is not considered.
- ✓ The lower ends of the railing are assumed to be fixed supports, and the mesh is not assumed to support the structure.





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For both materials, both load cases are calculated separately and together:

1. What is the maximum deflection and maximum reference stress at the given values. Distinguish which ones come purely from bending and which come from torsion.

2. What is the maximum possible span (1500 mm in figure) to keep to the permissible values of deflection and tension.

3. What kind of simple supports can be used to increase the span (support in the center as shown, horizontal support also in the middle, oblique support, etc).

Table 1. Material properties

Sr. No	Description	S235JR (Platform support & Door guard rail)	8.8 Bolt Grade	Aluminum AW-6060 T5 (Movable platform assembly & Guard rails)
1	Elastic Modulus, GPa	210	200	70
2	Poisson's ratio	0.3	0.3	0.33
3	Yield Strength, MPa	235	640	$t \leq 5mm = 150MPa$ $5 \leq t \leq 25m = 100MPa$
4	Ultimate Strength, MPa	360	800	$t \leq 5mm = 160MPa$ $5 \leq t \leq 25mm = 140MPa$
5	Density, kg/m3	7800	7850	2700
6	Proof strength (f_o) at heat affected zone MPa	-	-	60
7	Allowable limits, MPa	146#	640*	62#
8	Allowable limits at heat affected zone MPa	-	-	37$
9	Allowable limits for guard rail MPa	134@	-	57@

#Factor of safety 1.6 used against yield strength for material S235JR and Aluminum AW-6060 T5.
$Factor of safety 1.6 used against proof strength for material Aluminum AW-6060 T5.
@Factor of safety 1.75 used against yield strength for guard rail material.
*Yield strength is equal to the allowable limit for screws.

Table 2.1: Materials

Material	Modulus of elasticity	Yield strength ($R_{p0,2}$)	Ultimate strength (min.)	Allowable stress
1.4404	200 GPa	220 MPa	520 MPa	137.5 MPa [1]

Poisson's ratio 0.3, density 8000 kg/m^3.

1) Allowable stress, safety factor is 1.6 against yielding.

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C1 – Strength of Materials

L – Stress and strain measurements for PCBs

P5 - Robert Bosch SRL

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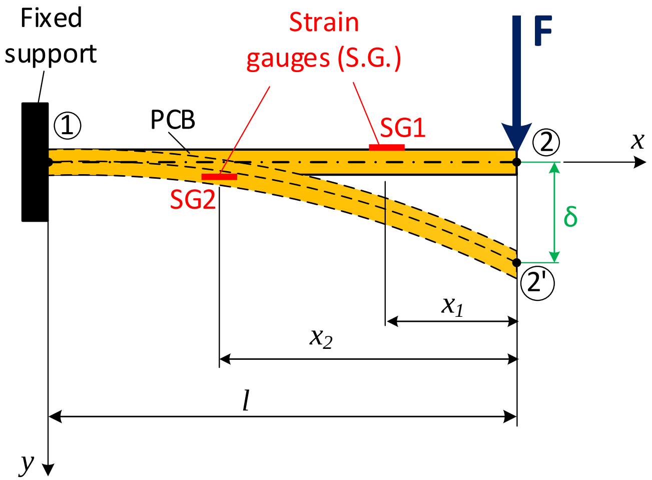
Stress and strain measurements for PCBs

Industrial application

Conceptualization

Theoretical application



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Stress and strain measurements for PCBs

Upon completion of this laboratory, the student will be able to:

1) Understand the theoretical background of the industrial application
2) Apply theoretical calculus for a real application (stress and strain study)
3) The principle of Strain Gauge technique
4) Perform strains measurements using SG technique
5) Perform theoretical calculus
6) Data acquisition and data interpretation.

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Content

- Introduction – PCBs and Strain Gauge technique
- Topic 1. Theoretical Background of the application
- Topic 2. Experimental measurements
- Topic 3. Theoretical and experimental results
- Conclusions
- References

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Introduction

Introduction

1. Printed Circuit Board (PCB)

A **printed circuit board (PCB)**, also called printed wiring board (PWB), is an electronic assembly that uses copper conductors to create electrical connections between components. Printed circuit boards provide mechanical support for electronic components so that a device can be mounted in an enclosure.
It takes the form of a laminated sandwich structure of conductive and insulating layers: each of the conductive layers is designed with a pattern of traces, planes and other features (like wires on a flat surface) etched from one or more sheet layers of copper laminated onto and/or between sheet layers of a non-conductive substrate.

PCBs can be single-sided (one copper layer), double-sided (two copper layers on both sides of one substrate layer), or multi-layer (outer and inner layers of copper, alternating with layers of substrate).
Multi-layer PCBs allow for much higher component density, because circuit traces on the inner layers would otherwise take up surface space between components. Multilayer PCBs make repair, analysis, and field modification of circuits much more difficult and usually impractical.

Printed circuit boards are used in nearly all electronic products. PCBs require additional design effort to lay out the circuit, but manufacturing and assembly can be automated.
Mass-producing circuits with PCBs is cheaper and faster than with other wiring methods, as components are mounted and wired in one operation. Large numbers of PCBs can be fabricated at the same time, and the layout has to be done only once.

Fig. 1. Printed circuit board (PCB) of a DVD player

Fig. 2. A PCB in a computer mouse

2. Strain Gauge technique

Strain gauge technique is the method of measuring the deformations of a part subjected to mechanical stress by means of strain gauges, which transform mechanical deformations into variations of electrical resistance.

The resistance of a transducer (strain gauge) is directly proportional to the length and resistivity of the material from which it is made, respectively inversely proportional to the cross-sectional area of the wire traversed by the current.

S.G.'s principle

If the strain gauge is mounted (glued) to a part subjected to mechanical stress, then it is possible to determine the strains (specific deformations, ε) of the part, as a result of the change in the electrical resistance of the strain gauge.

For this application, it's used a Wheatstone half-bridge containing in the adjacent arms, an active and an inactive (unsolicited) strain gauge - introduced in the circuit to compensate the effect of temperature variations. Inactive strain gauges, being in the same environmental conditions as active strain gauges, suffer the same thermal deformations.

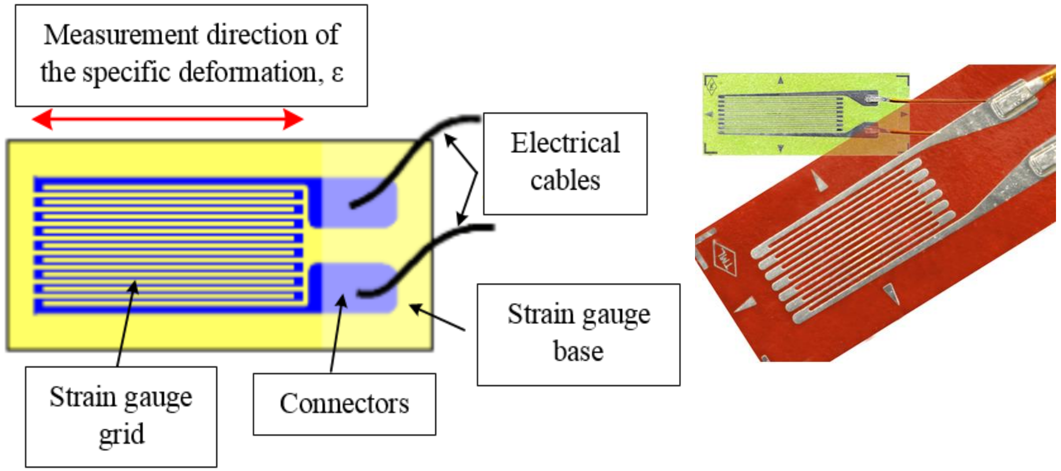

Fig. 3. Longitudinal Strain Gauges

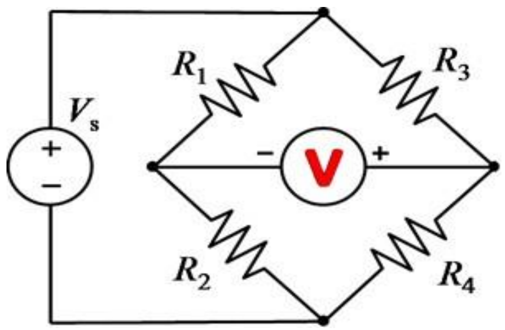

Fig. 4. Wheatstone bridge

The property of the Wheatstone Bridge is to sum up the effects in the opposite arms and subtract the effects in the adjacent arms.

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Topic 1. Theoretical Background of the application

Topic 1

Theoretical Background of the application

Laboratory Aim: Measurement of strains (ε) for a PCB subjected to plane bending using the strain gauge (SG) technique and comparison with theoretical values. Calculus of the normal stresses (σ) are also performed.

For this industrial application, the PCB is equivalent to a homogeneous and isotropic beam loaded with a concentrated force. According to Figure 5, the beam (PCB) have a fixed support in point 1 and the force is applied at the free end (point 2) by a press-kit.
The PCB cross-section dimensions, and elastic modulus (E) are known or calculated.

In order to measure the strains (ε), strain gauges were attached to the upper and lower fibers of the cross section, and the normal stress (σ) can be easily calculated by using Navier's formula. In addition, the displacements at free end of the PCB also can be measured.

Input data:

F [N];
l; x_1, x_2; h; b [mm];

Output data:

E [MPa];
σ [MPa];
ε [µm/m].

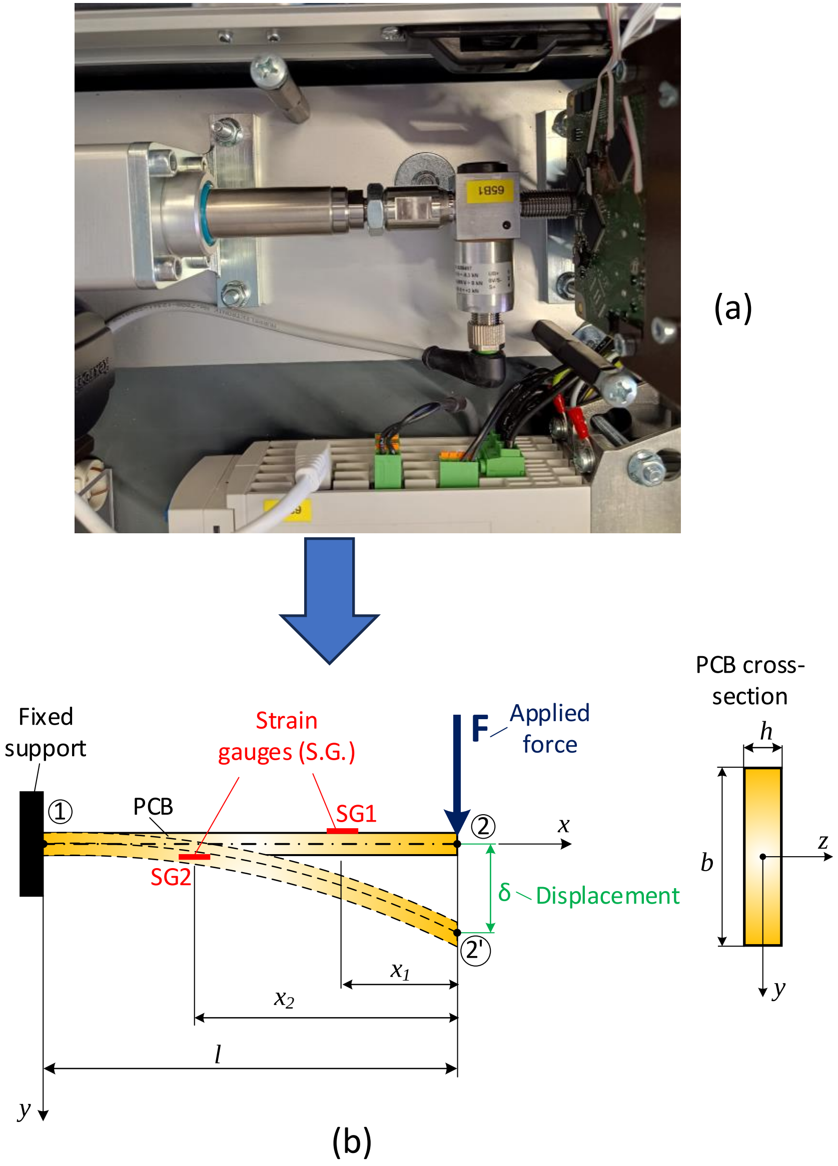


Fig. 5. a) Experimental set-up;
b) Simplified sketch of the subjected PCB

1.1. Reactions and efforts calculus

For theoretical calculus of reactions and efforts of the fixed PCB (or beam) a free-body diagram is necessary to be sketched (Figure 6). The case study is a fixed beam subjected to plane bending by an applied force F at the free end.

- The reactions (H_1, V_1, M_1) are calculated with the equilibrium equations, thus:

$$\sum F_x = 0 \rightarrow \boxed{H_1 = 0}$$

$$\sum F_y = 0 \rightarrow V_1 - F = 0 \rightarrow \boxed{V_1 = F}$$

$$\sum M_1 = 0 \rightarrow M_1 + F \cdot l = 0 \rightarrow \boxed{M_1 = -F \cdot l}$$

- Efforts are obtained in section cut "*x*" normal to geometrical axis (axis *x*), and the variation diagrams of efforts are presented in Figure 6.

Interval 1 – 2: $x \in (0; l]$

$$\boxed{T_{1-2} = F}$$

$$M_{1-2} = -F \cdot x$$

$$x = 0 \rightarrow \boxed{M_1 = 0}$$

$$x = l \rightarrow \boxed{M_2 = -F \cdot l}$$

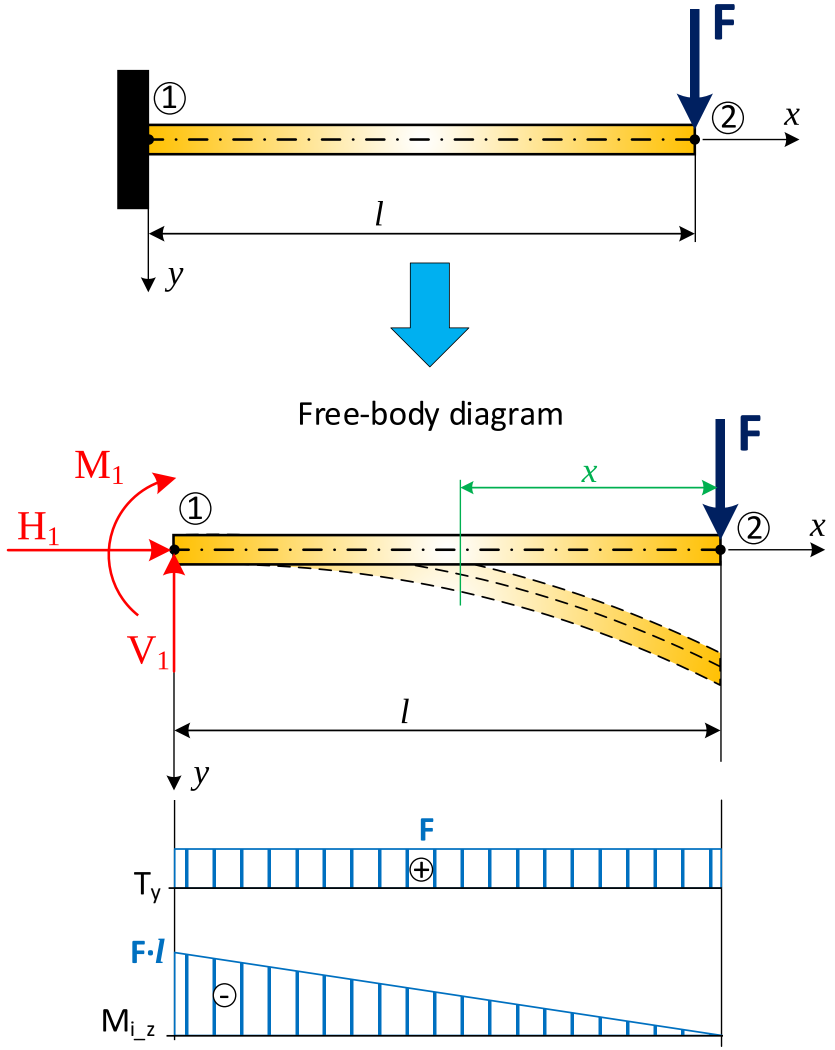
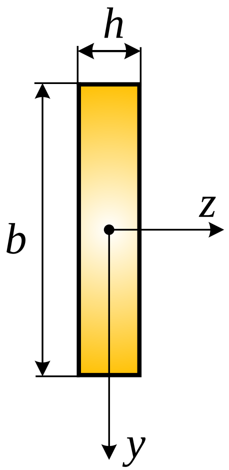


Fig. 6. Free-body diagram and efforts diagrams

a) Section properties

PCB cross-section



- The PCB with length *l* = 51.7 mm and rectangular cross-section has the following dimensions: width *b* = 90.8 mm; thickness *h* = 1.78 mm.
- The section properties can be calculated with usual formulas:

Section moduli (W_z): $$W_z = \frac{b \cdot h^2}{6} = \frac{90.8 \cdot 1.78^2}{6} = 47.948\ mm^3$$

Moment of inertia (I_z): $$I_z = \frac{b \cdot h^3}{12} = \frac{90.8 \cdot 1.78^3}{12} = 42.674\ mm^4$$

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b) Theoretical stress and strain

- Knowing the theoretical equation of displacement (δ) for the cantilever beam and the section properties, the Young's modulus (E) can be calculated with the formula:

$$\delta = \frac{F \cdot l^3}{3 \cdot EI_z} \rightarrow \boxed{E = \frac{F \cdot l^3}{3 \cdot I_z \cdot \delta}} \qquad (1)$$

Note: In the above formula, the force F = 2 N and the displacement δ = 0.1 mm are obtained as the difference between two successive positions of the motor rod.

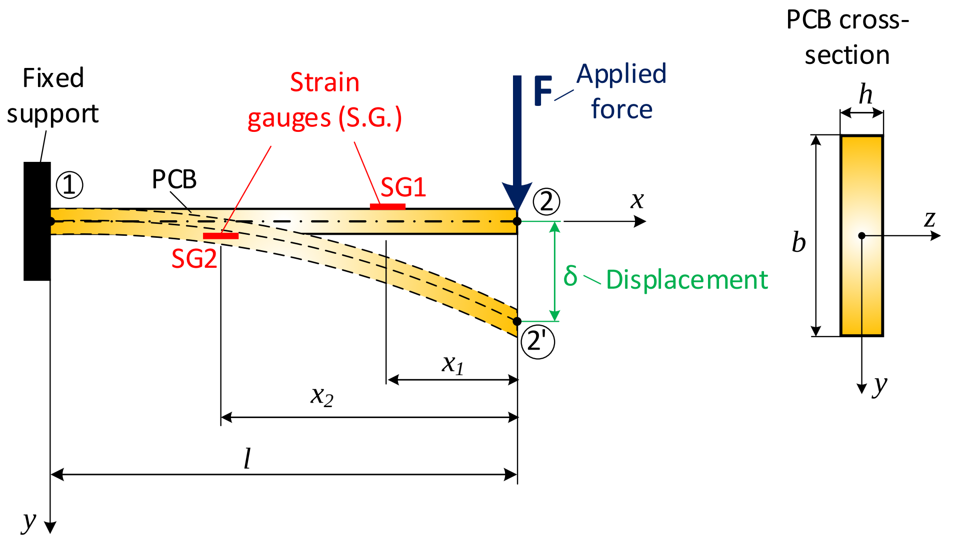

Fig. 7. Simplified sketch of the subjected PCB

- For theoretical calculus of normal stress (**$\sigma_{theoretic}$**), the Navier's formula is used:

$$\sigma_{theoretic} = \frac{M_i}{W_z} \qquad (2) \qquad \text{where:} \quad M_i = -F \cdot x_{1(2)} \qquad (3)$$

$$\boxed{\sigma_{theoretic} = \frac{(-F \cdot x_{1(2)})}{W_z}} \qquad (4)$$

where $x_{1(2)}$ are the distances from applied force to the strain gauges, and have the following values: x_1 = 20 mm, x_2 = 40 mm.

- The strains (**$\varepsilon_{theoretic}$**), are calculated by using Hooke's law:

$$\sigma = E \cdot \varepsilon \rightarrow \varepsilon_{theoretic} = \frac{\sigma_{theoretic}}{E} \qquad (5)$$

$$\varepsilon_{theoretic} = \frac{M_{i\_theoretic}}{E \cdot W_z} \qquad (6)$$

$$\boxed{\varepsilon_{theoretic} = \frac{(-F \cdot x_{1(2)})}{E \cdot W_z}} \qquad (7)$$

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Topic 2. Experimental measurements

Topic 2

Experimental measurements

For the experimental determination of the strains (ε), the experimental set-up presented in Fig. 8 is used.

Two strain gauges (or transducers) were attached to the PCB, as follows: a transducer (SG1) on the upper surface where the fibers are in tension after loading, respectively on the lower surface (SG2) where the fibers are compressed (see Fig.9). These strain gauges were attached at distances x_1 and x_2 from the free end, so as to be according to the mathematical model previously presented.

The PCB was clamped at one end by a clamping system (fixed support), and 4 successive forces were applied to the free end by means of the linear motor rod (loading system). To control the applied force, a force transducer was mounted on the motor rod.

The control of the force and the displacement (or position) of the rod is performed by the Rexroth specific software, and the data processing and acquisition provided by strain gauges is carried out with the HBM Spider 8 acquisition system.

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Experimental set-up

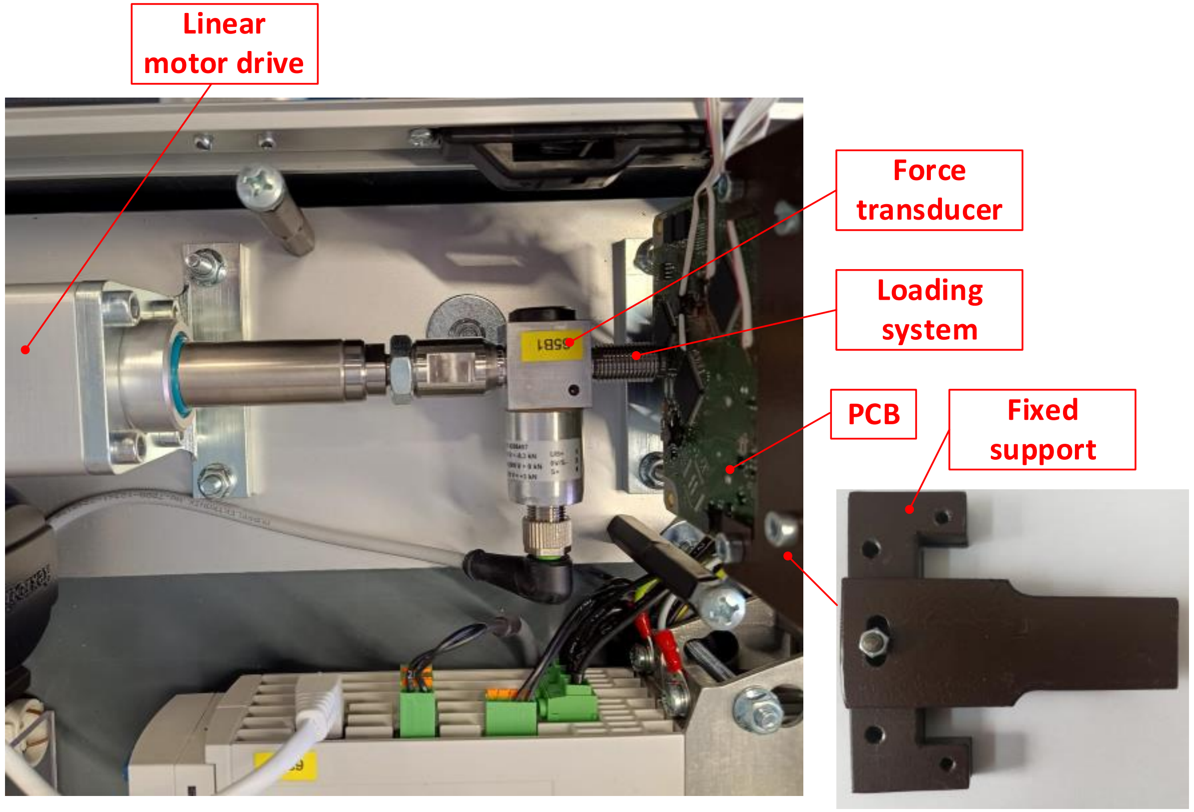

Fig. 8. Experimental set-up

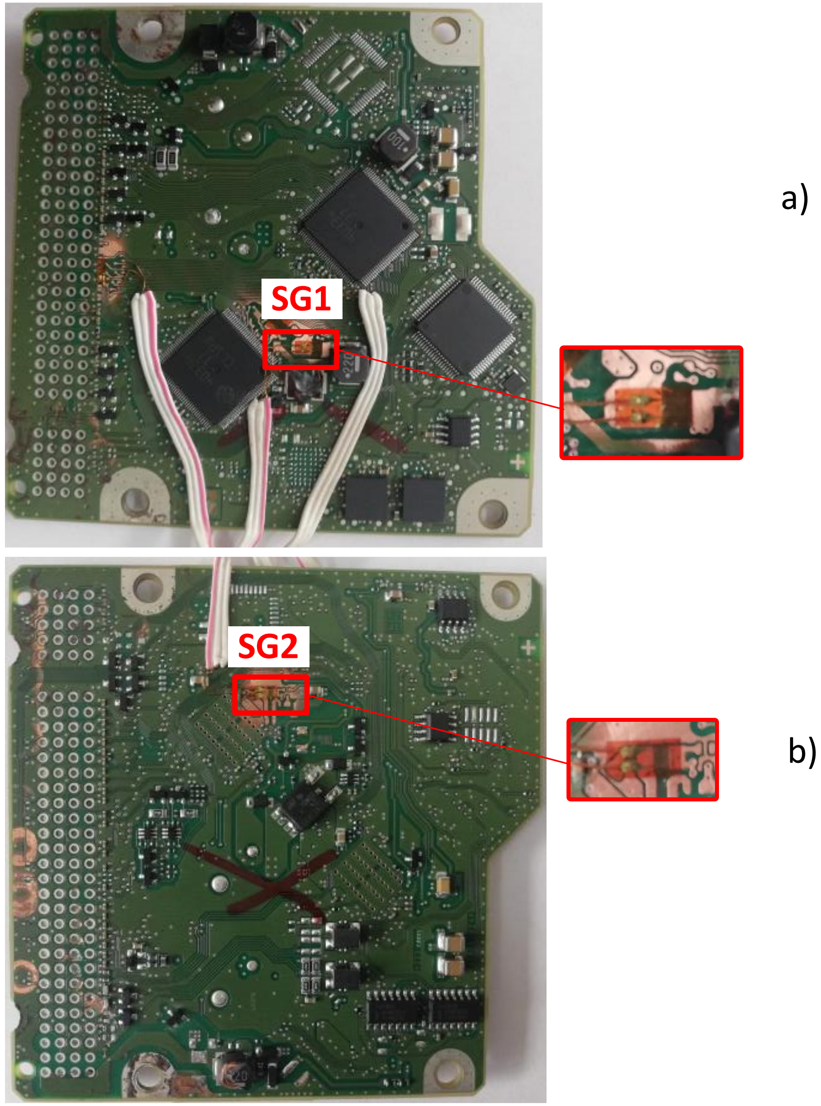

Fig. 9. PCB with Strain Gauges: a) Upper side (or fiber); b) lower side

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Experimental software

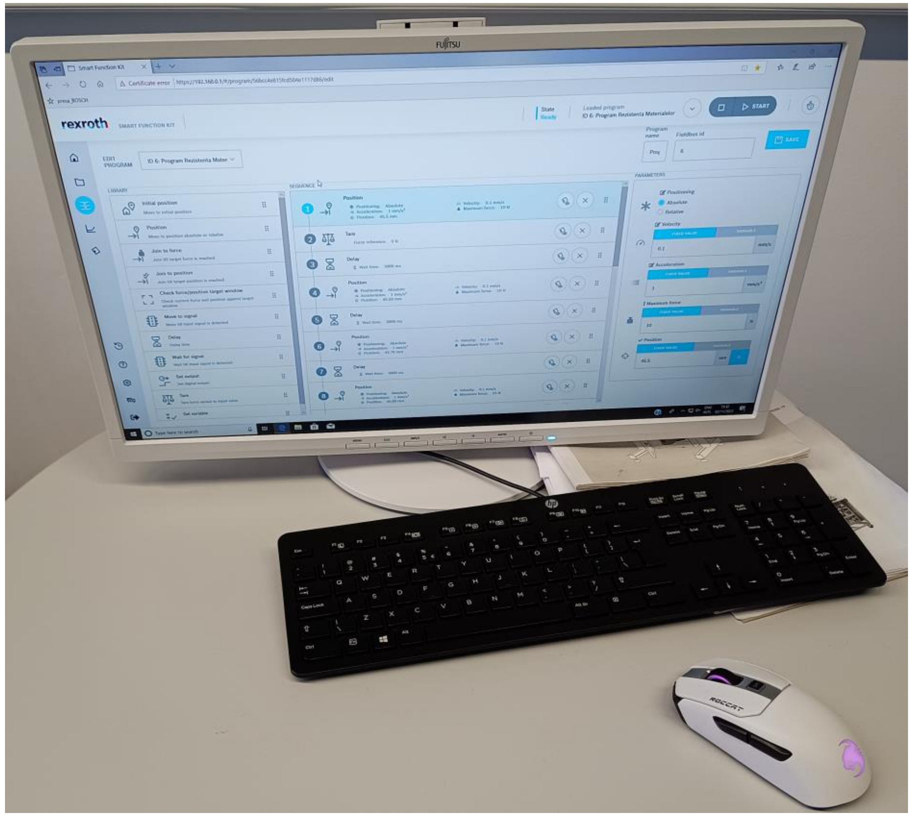

Fig. 10. Rexroth software

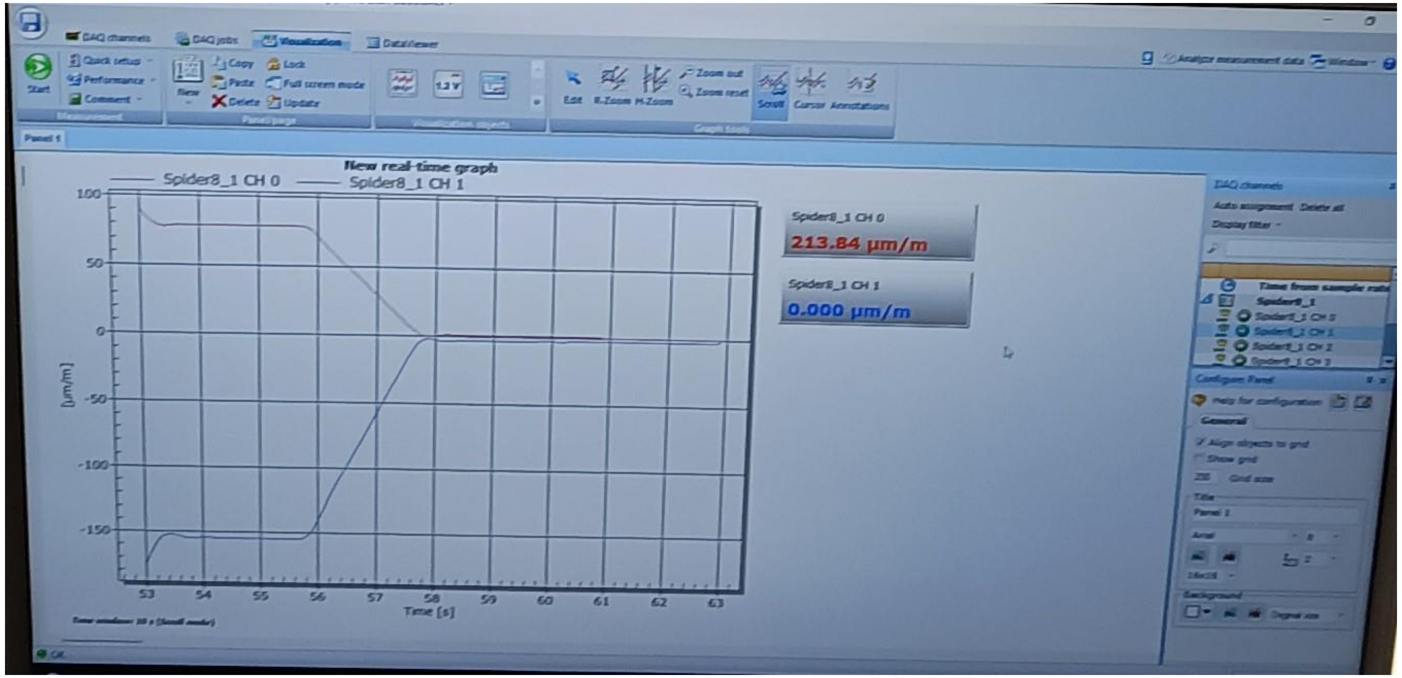

Fig. 11. HMB Spider 8 software

Topic 3. Theoretical and experimental results

Topic 3

Theoretical and experimental results

Summary

- Input data

Are known the following data:

- PCB length: *l* = 51.7 mm
- PCB rectangular cross-section: *b* = 90.8 mm; *h* = 1.78 mm
- Section properties: $W_z = 47.948\ mm^3$; $I_z = 42.674\ mm^4$
- Elastic modulus (eq.1): $E = 21.588{,}2$ N/mm^2

- Output data
- Theoretical stress: $\sigma_{theoretic} = \frac{-F \cdot x_{1(2)}}{W_z}$
- Theoretical strain: $\varepsilon_{theoretic} = \frac{-F \cdot x_{1(2)}}{E \cdot W_z}$
- Experimental strain ($\varepsilon_{exp.}$): from experimental measurements.

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Topic 3

Theoretical and experimental results

After performing the experimental measurements, and theoretical calculus, the obtained results are introduced in *Results table*.

In this table, the theoretical values of the stresses for each strain gauge are given, and respectively the experimental and theoretical values of the strains. The strain ε_{SG2} have negative values because the 2nd strain gauge is attached to the lower fibers of the PCB cross-section and are compressed after loading.

Results table

Applied force [N]	Normal stress [MPa]		Strains [με]					
	$\sigma_{SG1\_theor.}$	$\sigma_{SG2\_theor.}$	$\varepsilon_{SG1\_theor.}$	$\varepsilon_{SG1\_exp.}$	Rel.dev.	$\varepsilon_{SG2\_theor.}$	$\varepsilon_{SG2\_exp.}$	Rel.dev.
3	1.25	- 2.50	57.96	58	0.06	-115.93	-116	0.06
5	2.09	- 4.17	96.61	94	2.77	-193.21	-193	0.11
7	2.92	- 5.84	135.25	135	0.18	-270.50	-272	0.55
9	3.75	- 7.51	173.89	173	0.51	-347.79	-350	0.63
11	4.59	- 9.18	212.54	208	2.18	-425.07	-421	0.96

- Relative deviation of ε: $$\boldsymbol{Rel.dev.} = \left| \frac{|\varepsilon_{exp}| - |\varepsilon_{theoretic}|}{|\varepsilon_{exp}|} \right| \cdot \mathbf{100} \rightarrow [\%]$$

The theoretical and experimental strain values were also presented in the graphs in Fig. 12 and a linear increase of them can be observed, which underlines the fact that the stress occurs in the elastic domain in which Hooke's law is valid. A good convergence of the results can be also observed, the errors obtained being below 3%.

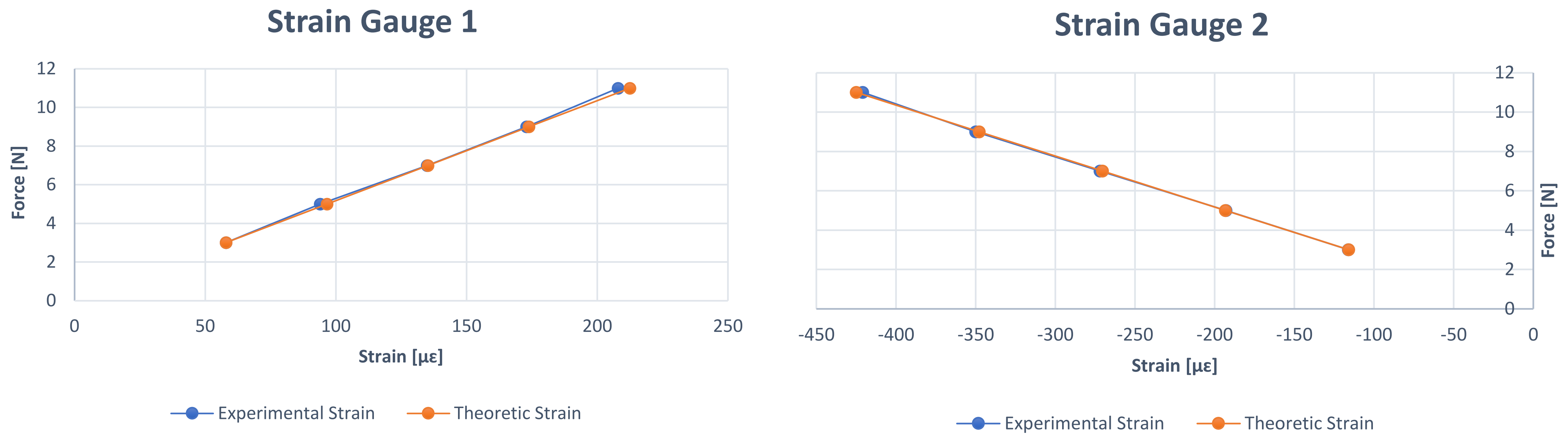

Fig. 12. Graphic strains

Conclusions

Conclusions

- Within this laboratory:

✓ It was presented the theoretical background of the Strain Gauge technique and, respectively of the industrial application;

✓ Theoretical calculations of efforts and normal stress were given;

✓ Experimental measurements of strains using SG technique to obtain experimental stress for a PCB were performed;

✓ A good convergence of the results was obtained $\varepsilon_{theoretic}$ versus $\varepsilon_{exp.}$, the relative deviation being below 3%;

- After completing this laboratory, the student will be able to:

✓ Correlate a real (industrial) application with the theoretical background;

✓ Perform experimental measurements of strains for a real case PCB

✓ Data acquisition with a dedicate software, and data comparison and interpretation, respectively;

✓ Calculate the efforts, normal stresses and strains using usual formulas;

✓ Compare and discuss the obtained results.

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References

1. Chvojan, J., Václavík, J., PCB Tests during Assembly and Splitting, Proceedings 2018, Vol. 2, pp. 472, 2018. doi:10.3390/ICEM18-05365
2. Huang, C.Y., Ying, K.C., Applying strain gauges to measuring thermal warpage of printed circuit boards, Measurement 2017, Vol. 110, pp. 239–248, 2017.
http://dx.doi.org/10.1016/j.measurement.2017.06.029
3. Printed circuit boardhttps://en.wikipedia.org/wiki/Printed_circuit_board - Wikipedia

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C2 – Industrial Automation

L1 – PLC Electropneumatic Station Programming

P3 - ISR Specular Vision

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About NextGEng Project

- Three-year Erasmus+ Cooperation Partnership project that started in October 2022
- International consortium consisting of 3 universities and 3 companies from European countries
- Project co-funded by the European Union and coordinated by Technical University of Cluj-Napoca, Romania

Technical University of Cluj-Napoca

Jamk University of Applied Sciences

University of Jaén

Integracion Sensorial y Robotica

Valmet Technologies Oyj

Rober Bosch SRL

About NextGEng Project

- **NextGEng Project** aims to create new pedagogical models that promotes international team-teaching with the support of new learning materials for existing courses in the curricula

NextGEng comprises three types of activities

Training

Tailored training program for teachers that sustain the skill improvement of HEI partners staff in new/innovative teaching methods.

International Team-Teaching

international pilot program.
Upgrade a set of engineering courses, belonging to the HEI partners curricula, in close collaboration with companies' partners.

CEL Projects

Cases of Experiential Learning projects.
Type of projects where students learn by doing in an international and multidisciplinary environment.

Co-funded by the European Union

PLC Electropneumatic Station Programming

Laboratory overview:

Objectives

- Designing the GRAFCET for a specific application
- Programming sequential controls using KOP language
- Use of specific software environments for simulation and programming

Pre-requisite

- Basic skills and knowledge of programming
- Basic IT knowledge
- Basic knowledge of electro-pneumatic circuits

Equipment used for laboratory

- Educational electropneumatic demonstrator
- KOP programming software
- Electro-Pneumatic simulation software

Co-funded by the European Union

Laboratory/seminar name

Upon completion of this laboratory/seminar, the student will be able to:

1) Extract the main features of a PLC programming problem posed
2) Elaborate a GRAFCET for a required application
3) Transfer the GRAFCET to KOP programming
4) Test the KOP program and debug

Co-funded by
the European Union

Content

- Introduction
- Experimental setup
- Project
    - Task 1
    - Task 2
    - Task 3
- Discussions

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NextGEng

Introduction

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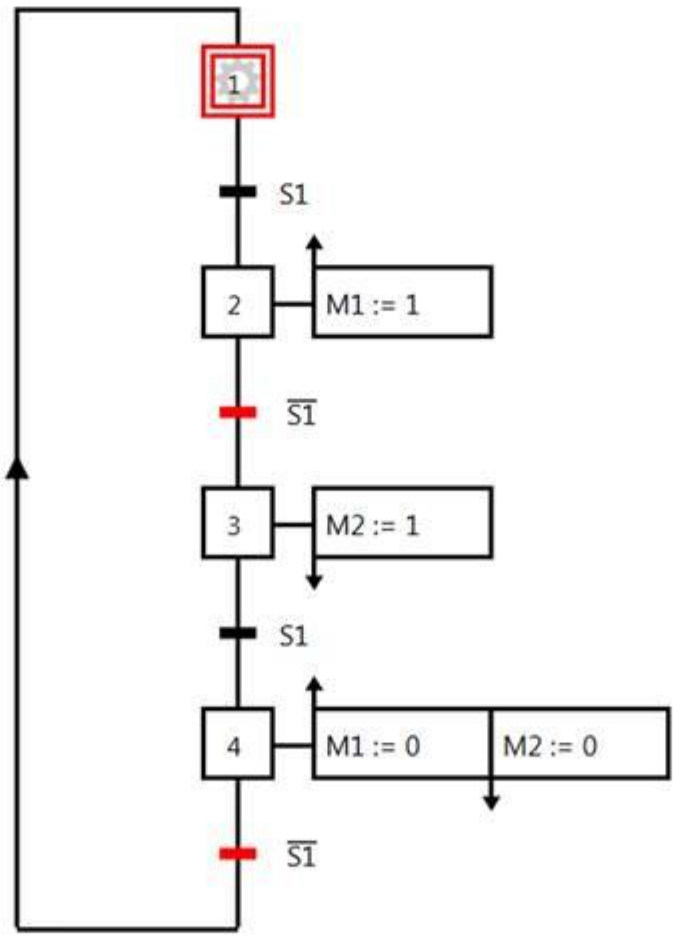
NextGEng

Introduction

GRAFCET

- Sequential control diagram, including stages and transitions.
- Each stage correspond to a stage of the cycle. During a stage, the system performs a task (e.g. cylinder expansion, wait for a signal or a timer). Therefore, actions (PLC outputs) can be activated during a stage.
- Transition between stages rely on conditions (e.g. sensor signals or activation of other stages).



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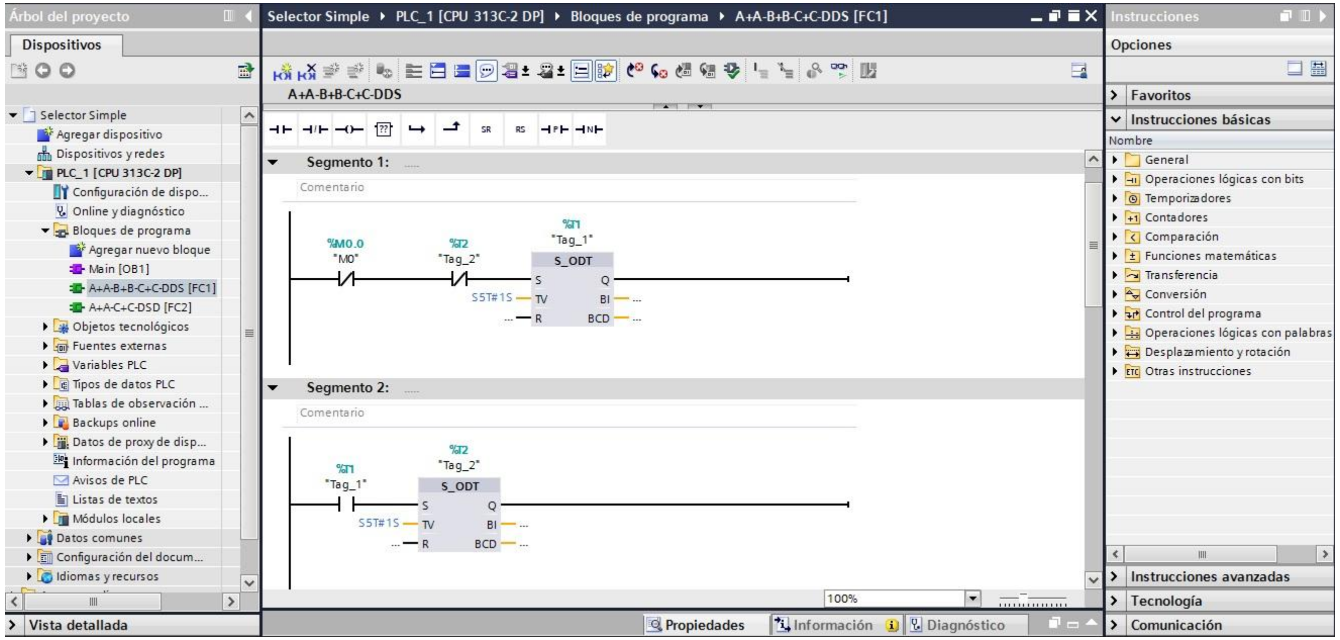
NextGEng

Introduction

KOP language

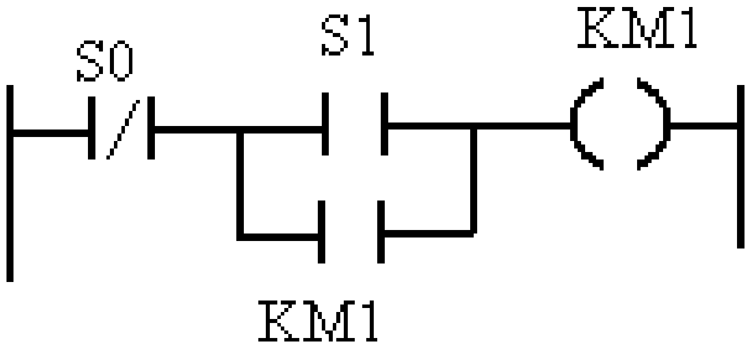
- Originally a method to document the design and construction of relay racks
- Widely used for PLC programming in industrial control applications



Introduction

KOP language

- Contacts (left) and coils (right)
- Contacts are operated by inputs or internal flags. Coils activate or deactivate outputs or internal flags.



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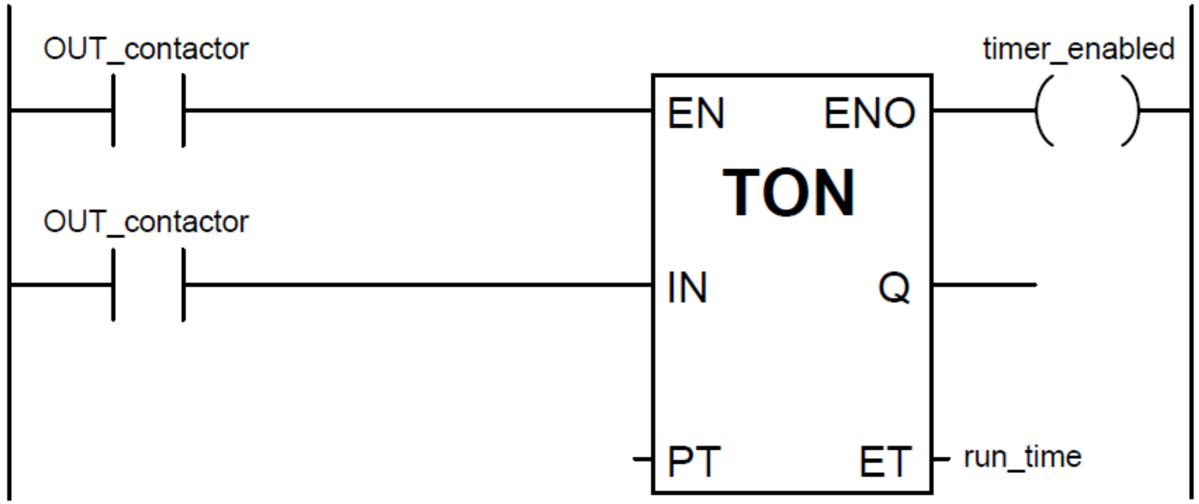
Introduction

KOP language - Timers

- Used for time delaying between signals
- Timer starts when input is activated. Once the time value is reached, it enables the output



Co-funded by
the European Union

Experimental setup

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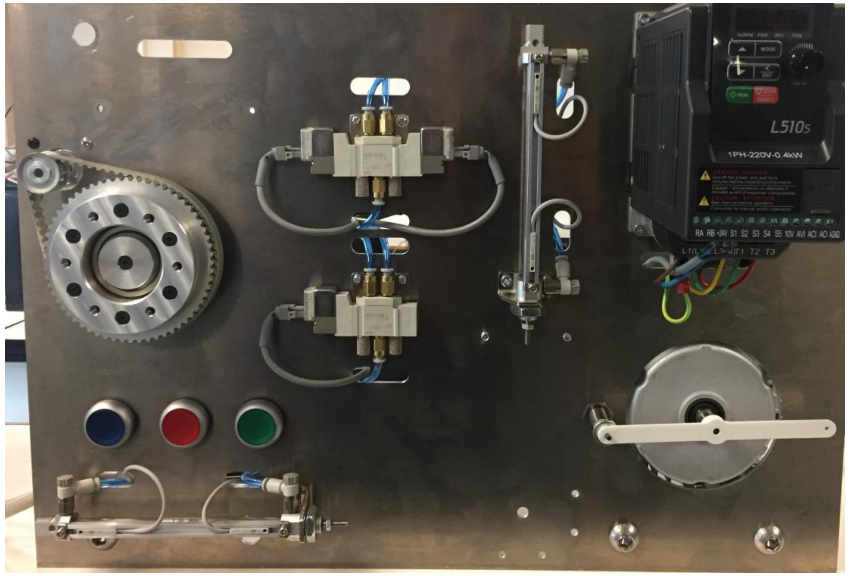
Experimental setup

Educational demonstrator

- Equipped with:
  - Two double acted cylinders, provided with limit switch on both ends. Cylinder A is operated by a bistable valve, B cylinder is operated by a monostable valve.
  - 3 illumination provided push buttons (red, green and blue).
  - Additional elements (not used during this practice session).



Project

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the European Union

Task 1

The first task is used for setup, tuning and calibration of the materials and software used during the session. To that end, the objective is to expand the A cylinder when pressing the green button and retracting it after pressing the red button. The objectives for this task are the following ones:

- GRAFCET design
- KOP programming
- Program testing and debugging

Task 2

It is now considered the following application: Once the green button is pressed, both cylinders must expand. Once they have expanded, red and blue lights will turn on. Cylinder A will retract after pressing red button, and cylinder B will retract after pressing blue button. Buttons can be pressed one after the other (red and then blue or blue and then red) or at the same time. Once the cylinder retracts, the corresponding light will turn off. The objectives for this task are the following ones:

- GRAFCET design
- KOP programming
- Program testing and debugging

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Task 3

It is now considered the following application: Once the green button is pressed, both cylinders must expand. Once they have expanded, cylinder A will retract after 1 second and cylinder B will retract 3 seconds after cylinder A is completely retracted. Red light will be on while cylinder A is fully expanded, and blue light will be on while cylinder B is completely expanded. The objectives for this task are the following ones:

- GRAFCET design
- KOP programming
- Program testing and debugging

Discussions

- Cost reduction through simulations – digital twins.
- Skills needed for Next GEneration Engineers

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C2 – Industrial Automation

L2 - Usability in heavy industrial machinery

P4 - VALMET

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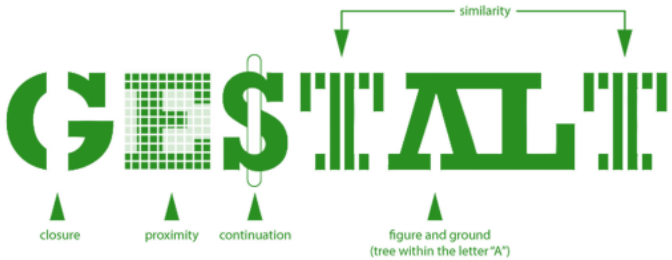
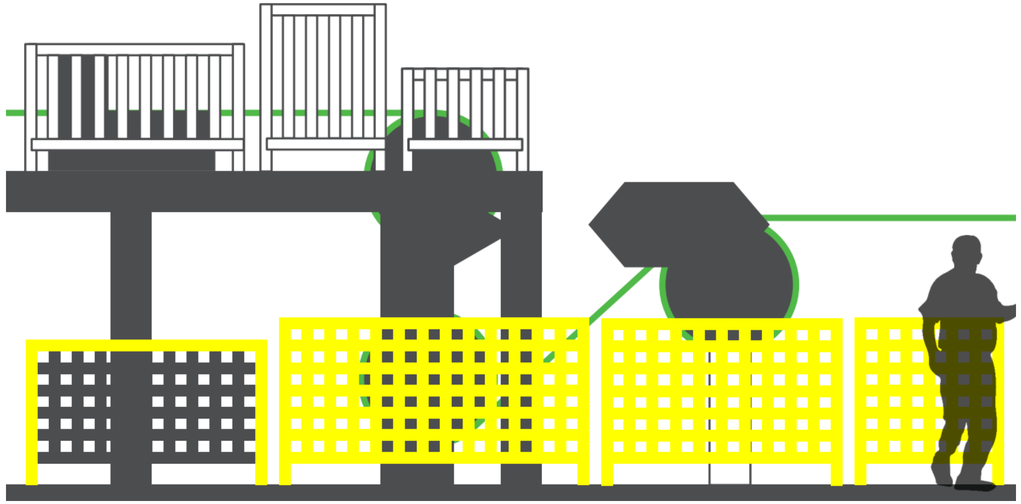
Usability in heavy industrial machinery





Visual noise reduction

Co-funded by
the European Union

Usability in heavy industrial machinery

Laboratory overview:

Objectives	• Evaluate the effectiveness of human–machine interfaces (HMIs) in heavy industrial machinery • Analyze the impact of ergonomic and safety design factors on operator usability • Investigate how factors such as control placement, visibility of indicators, and accessibility of emergency stops affect operator comfort, task performance, and overall safety
Pre-requisite	• Familiarity with Human–Machine Interaction (HMI) concepts • Basic concepts of ergonomics, usability, and interface design in industrial contexts.
Equipment used for laboratory	• PCs CODESYS

Usability in heavy industrial machinery

Upon completion of this activity, the student will be able to:

1) Assess usability factors in heavy industrial machinery, including ergonomics, interface design, and safety considerations
2) Evaluate operator performance by analyzing how different control layouts and interface designs affect efficiency, accuracy, and error rates
3) Apply usability principles to recommend improvements in the design of HMIs and control systems for heavy machinery

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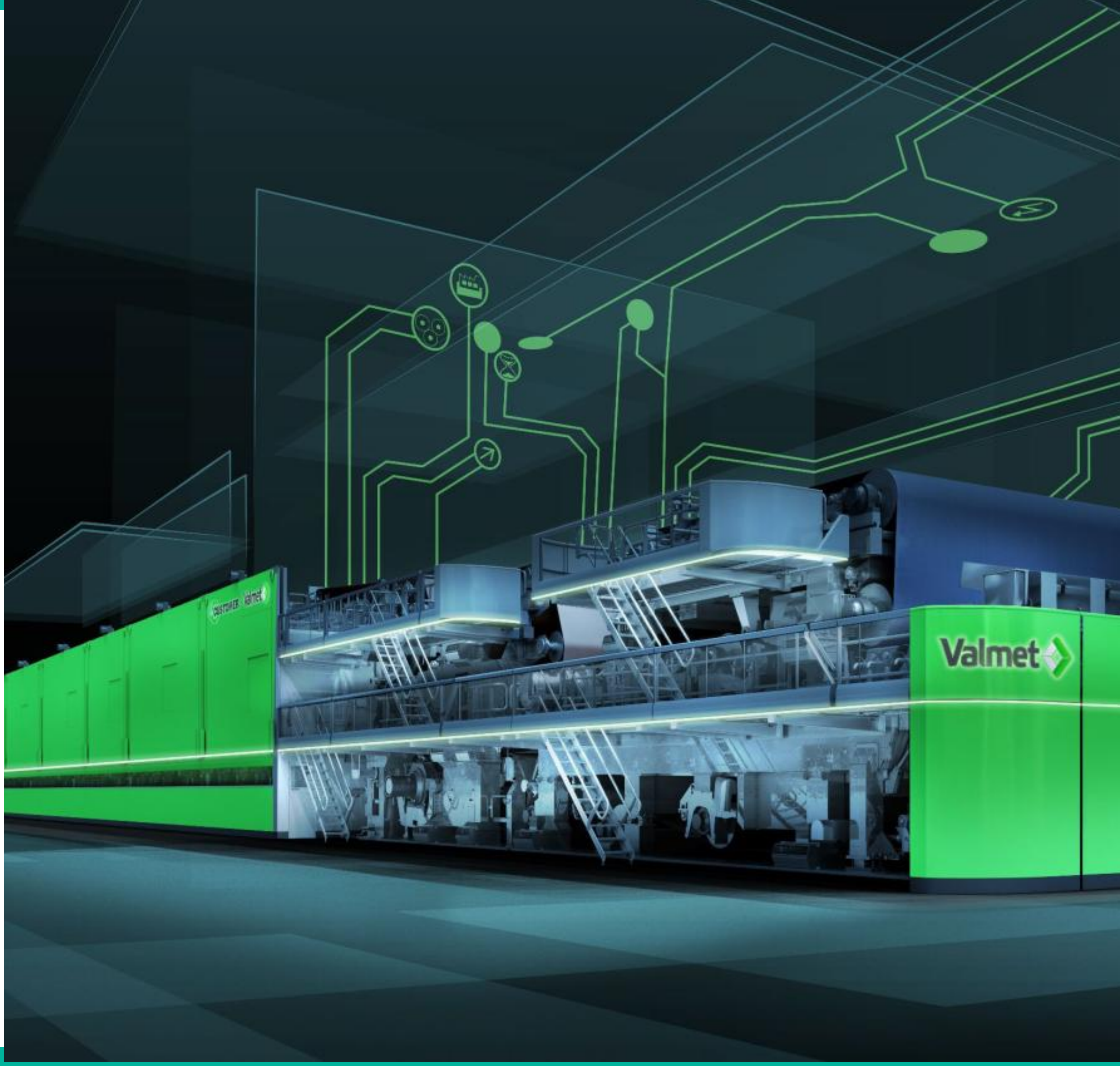
NextGEng

Content

- Introduction
- Company presentation
- Definitions and Theory
- Visual Noise
- Gestalt principles
- Summary, Discussions & Feedback



1 | Introduction

Overview

Today's focus is on usability and user experience. Specifically, their importance from the perspective of industrial automation and the physical machinery related to it.

The contents of this presentation is a miscellaneous selection of examples and principles related to this.

1. Introduction
2. Company presentation
3. Definitions and Theory
4. Visual noise
5. Gestalt principles
6. Summary

Why this topic?

- User interfaces, their usability and user experience are a huge part of industrial automation today
- A company that makes a technically perfect product but does not consider its human users cannot compete
- Even on a fully automated system that does not need human intervention when on operation, humans are still present: we manufacture, assemble, install, maintain, and ultimately disassemble it.
- These same lessons learned are applicable to digital systems and physical environments both

2 | Valmet Company Presentation

Valmet

Global presence creating a good platform for growth

EMEA
20 R&D centers
86 service centers
24 production units
76 sales offices
Head office

10,787
NET SALES EUR MILLION 1,876

NORTH AMERICA
3 R&D Centers
29 service centers
17 production units
11 sales offices

2,040
NET SALES EUR MILLION 1,058

SOUTH AMERICA
5 service centers
1 production units
8 sales offices

833
NET SALES EUR MILLION 718

CHINA
3 R&D Centers
5 service centers
6 production units
6 sales offices

2,323
NET SALES EUR MILLION 829

ASIA-PACIFIC
2 R&D Centers
11 service centers
6 production units
29 sales offices

1,565
NET SALES EUR MILLION 593

>130 service centers

>50 Production units

28 R&D centers

Personnel as in December, 2022

Global presence creating a good platform for growth

Valmet Flow Control SRL
(Formerly Neles)
Bucharest, Romania

EMEA
20 R&D centers
86 service centers
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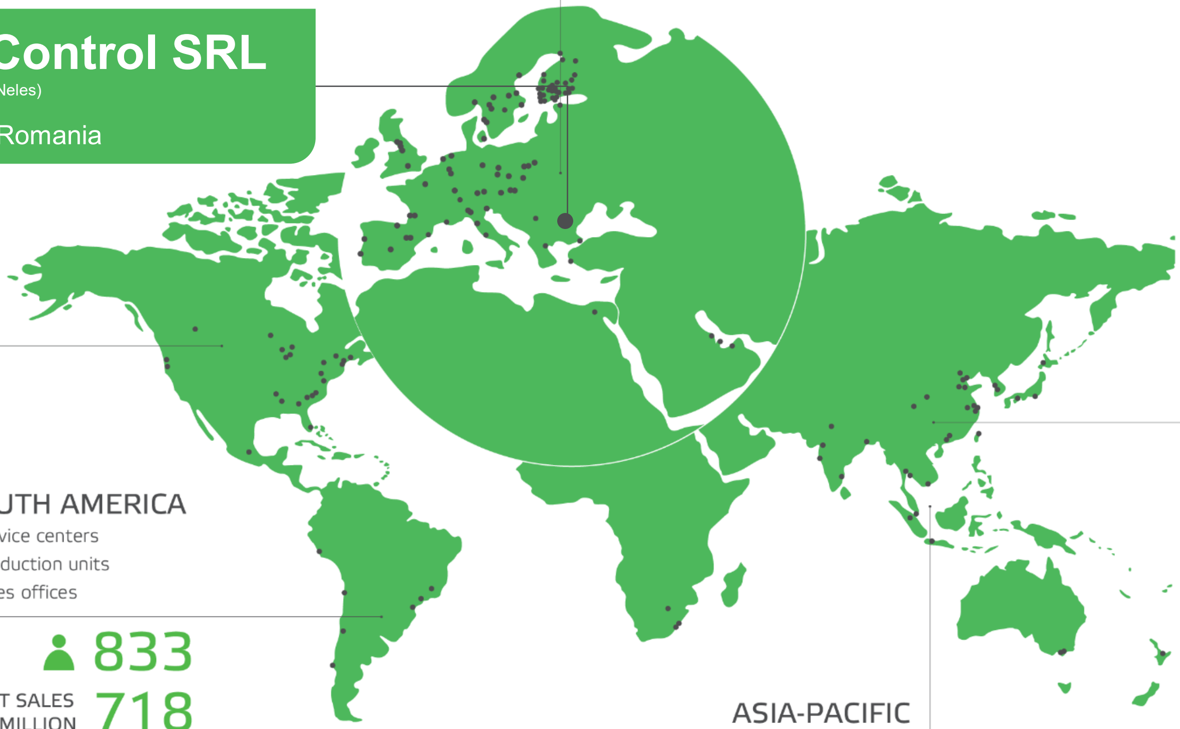

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Valmet

General overview of a paper/board machine | Tending side view

Headbox

- Hundreds of side-by-side nozzles sprays the pulp – a mixture of water and natural fibers – on top of a fabric.

Former (forming section)

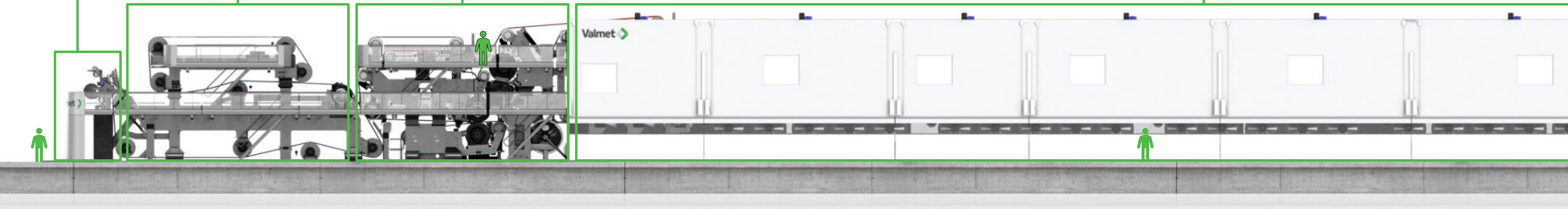
- The web is formed and moved between the fabrics, because the material is still too wet to hold its own weight.
- The speed of which the web is moving is typically ~1200-1600 m/min (~60-100 km/h).
- Water is removed mainly gravitationally, with some help of vacuums.

Press

- Water is removed mechanically by pressing the web between ”nips” that are created by two rolls .
- When the web enters the press section, it is already strong enough to support itself and so dry that the drying principle need to be changed (= forming is not viable anymore).

(Pre-)Dryer

- The web is dried to its final dryness with multiple groups of steam-heated cylinders.
- Drying section is covered with a hood, keeping the ambient temperature stable and ensuring good energy-efficiency.
- Temperature inside the hood is very high, up to 100-120°C. People are generally not allowed inside it when the machine is running.



General overview of a paper/board machine | Tending side view

Sizer

- Gluing and coatings are applied to the surface of the web to obtain the desired paper/board properties.
- Mainly the tensile strength and surface quality are being improved.

After-Dryer

- Coatings applied on the sizer section are dried.
- Functionalities and environment are identical to the pre-dryer.

Calender

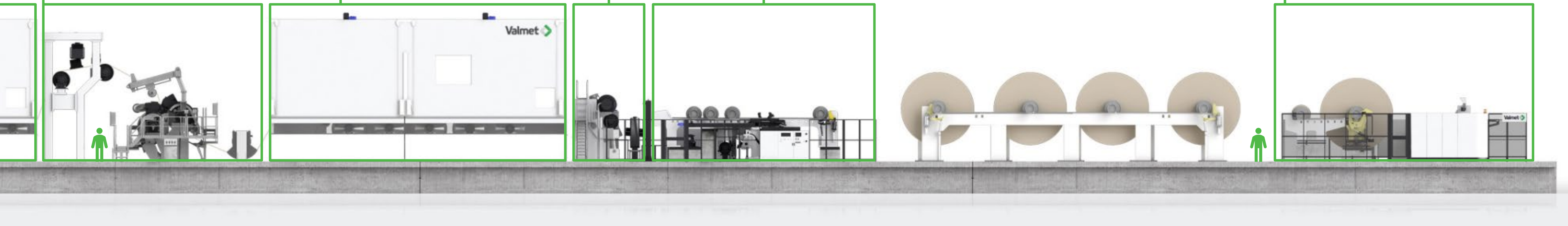
- Surface quality of the web is being improved in nips. The amount of nips may vary.
- This process step produces the desired thickness and a smooth and glossy finish.

Reel

- The finished product is rolled to large parent rolls.
- A temporary store of the parent rolls is located next to the reel section
- Weight of the rolls can be up to 100 tons.

Winder

- Large rolls are ”winded”: They are cut in the machine direction to smaller customer rolls that are better sized for further processing.
- Speeds are considerably higher than with the production process, of up to 3000 m/min (180 km/h).



3 | Definitions and theoretical background

Using a product, service, or system always creates an experience – good or bad – there is no such thing as no experience.

The common usability problem in industrial environments

It has been made possible, but not easy.

- Risto Väätänen,

Former Head of Design at Valmet

Valmet

Ensuring a holistic approach

Ergonomics
Safe and efficient use, anthropometrics

Usability
Learnability, faultlessness, memorability, efficiency, pleasantness of the usage…

User Experience (UX)
The sum of all aspects related to how the user interacts with or perceives the product or service

Customer Experience (CX)
The sum of all interactions that a customer has during their buying journey, including sales, marketing, delivery, after-sales support, spare parts…

Example (Airline)
Passenger seat dimensions and adjustment ranges; toilet layout and dimensions

Example (Airline)
Passenger seat cushioning material softness and texture; how easy and intuitive the adjustments are to make, toilet furniture designs and practicality

Example (Airline)
Entering the airplane, taxi, takeoff and landing, how you are greeted, finding your seat, in-flight services (food and drinks) and customer service, toilet availability, exiting the airplane…

Example (Airline)
Seeing ads for your flight/travel destination, buying the tickets, check-in and luggage drop-off, off-flight customer service, how you perceive the airline brand…

Ensuring a holistic approach

Valmet

4 | Visual noise

(why its reduction is an important usability consideration and not just aesthetics)

Definition of Visual noise

Visual noise is any visual feature useless to the users, distracting them from spotting important information amidst the unnecessary.

Any misleading visual stimulus, structural disharmony, or unnecessary complexity can also be considered visual noise.

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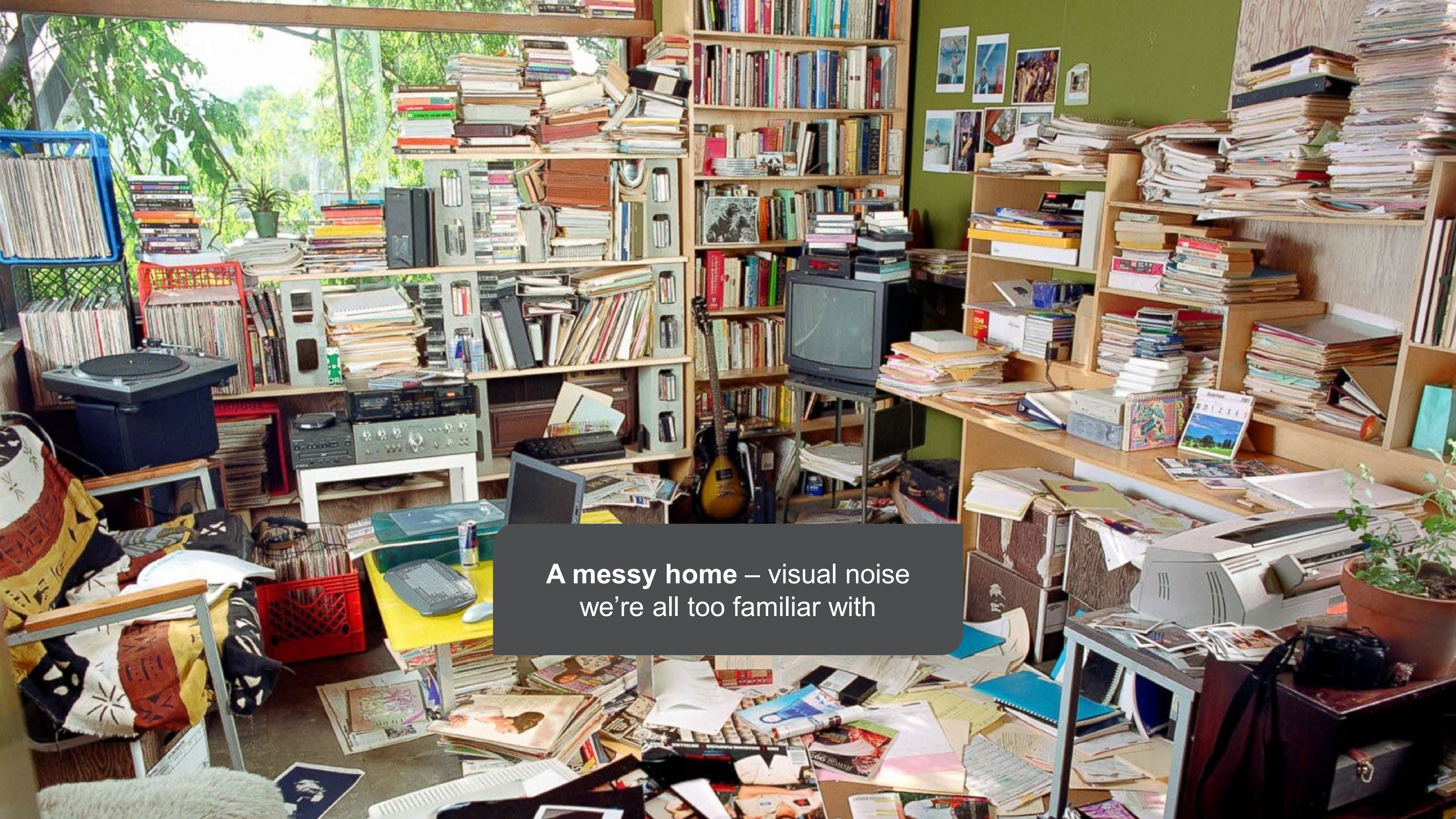
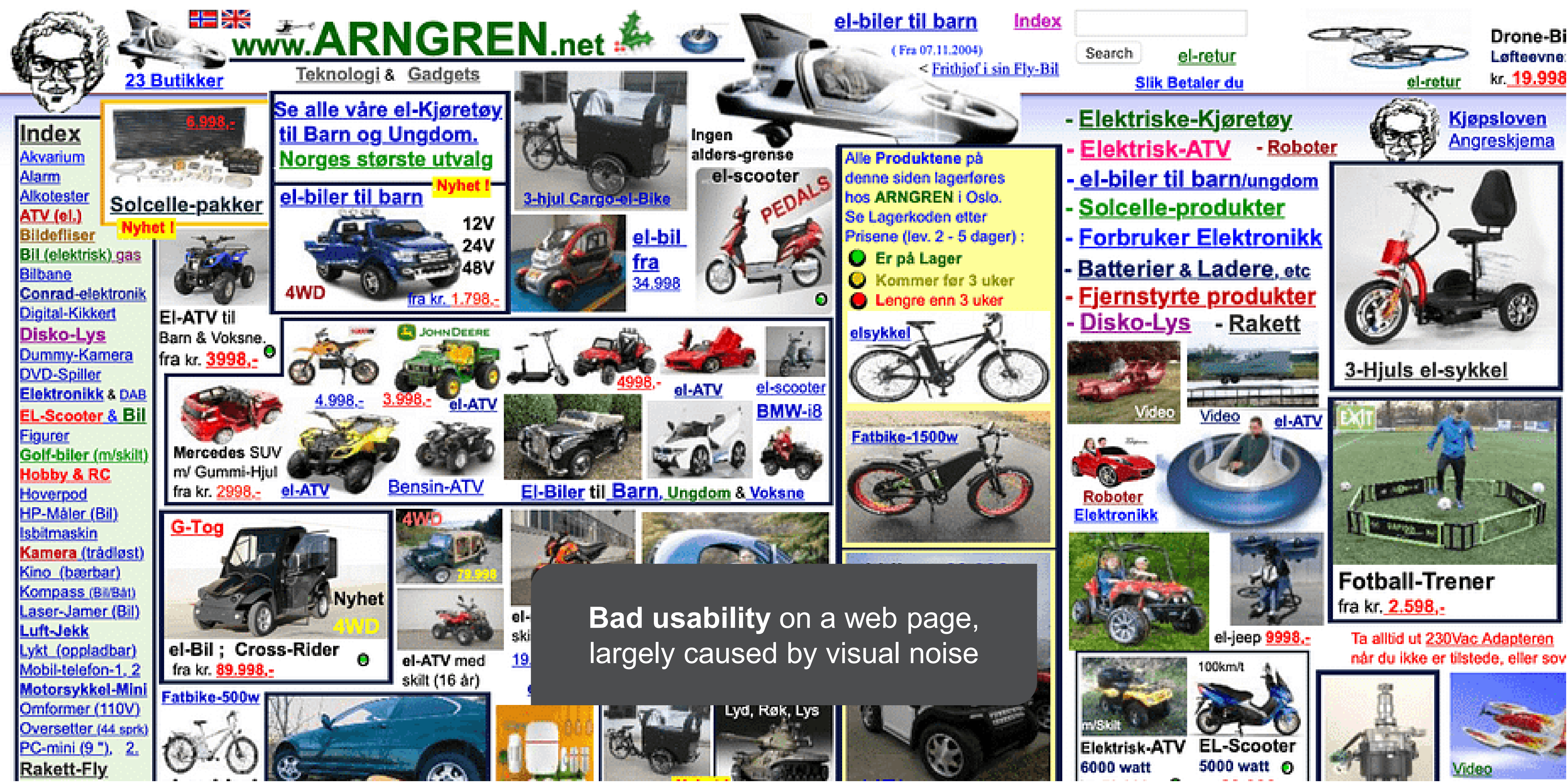
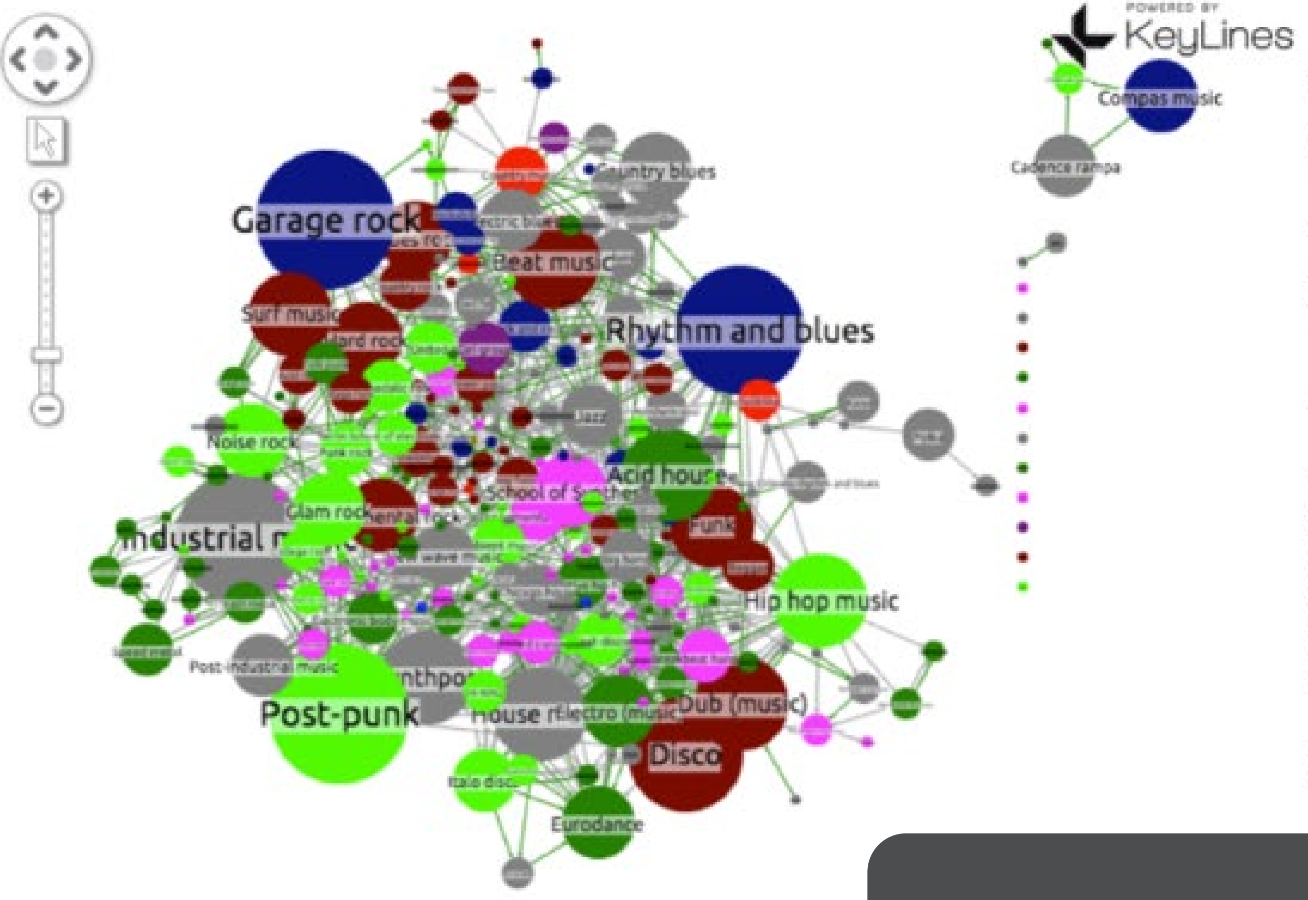
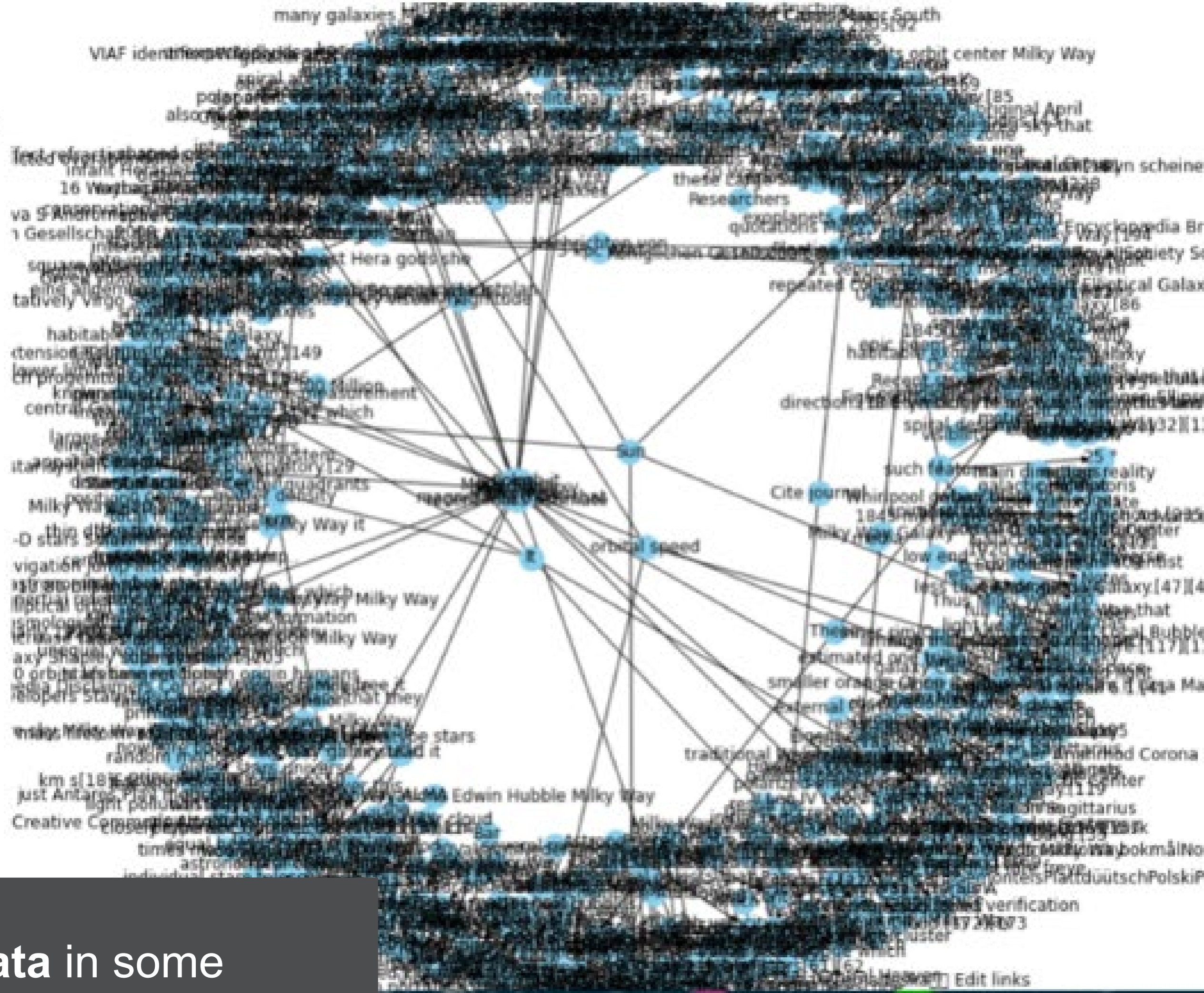


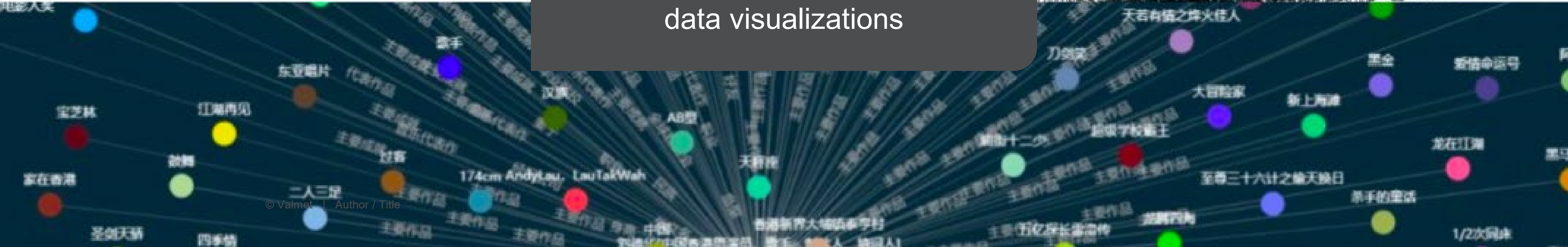
A messy home – visual noise we're all too familiar with



Bad usability on a web page, largely caused by visual noise

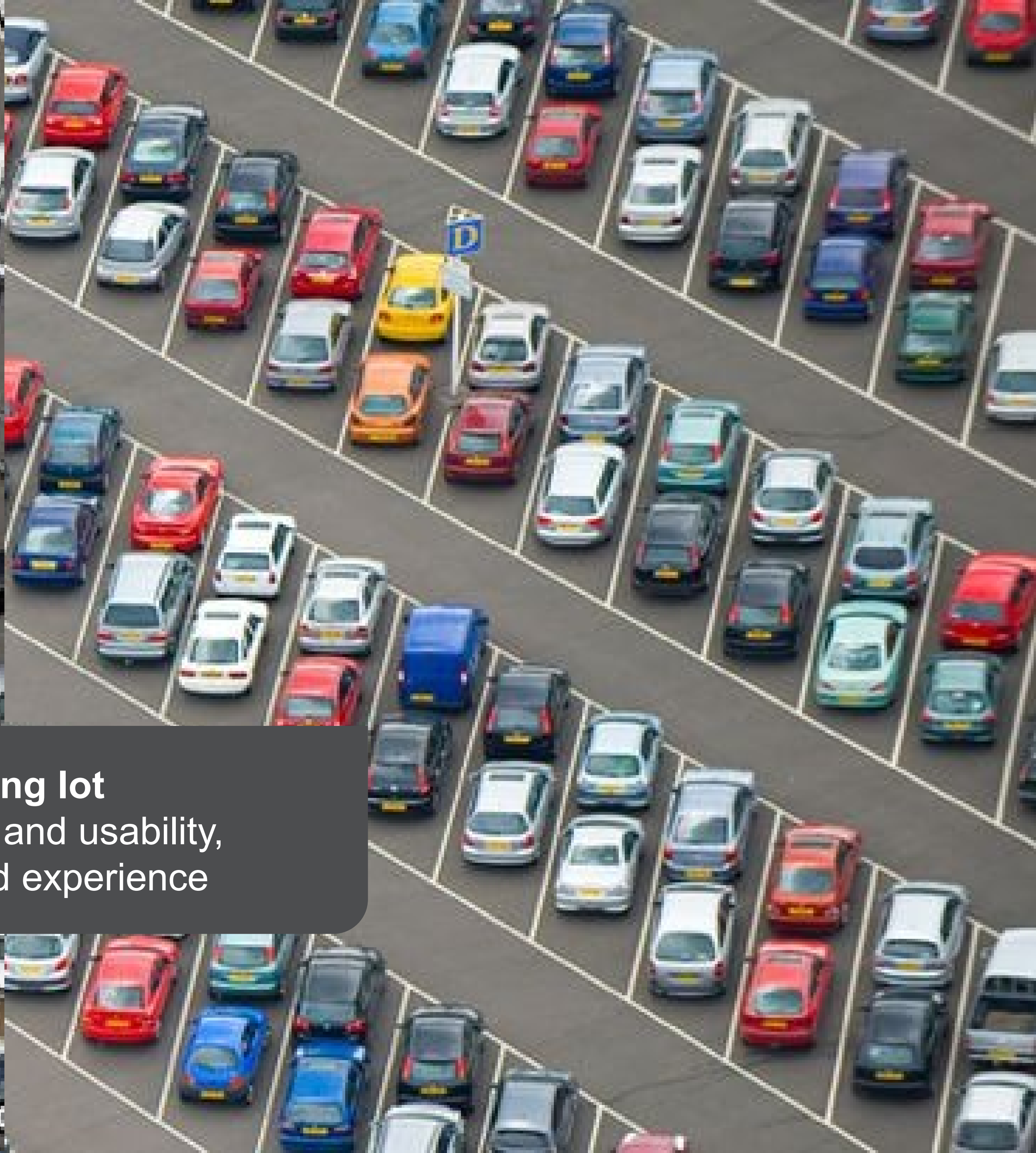






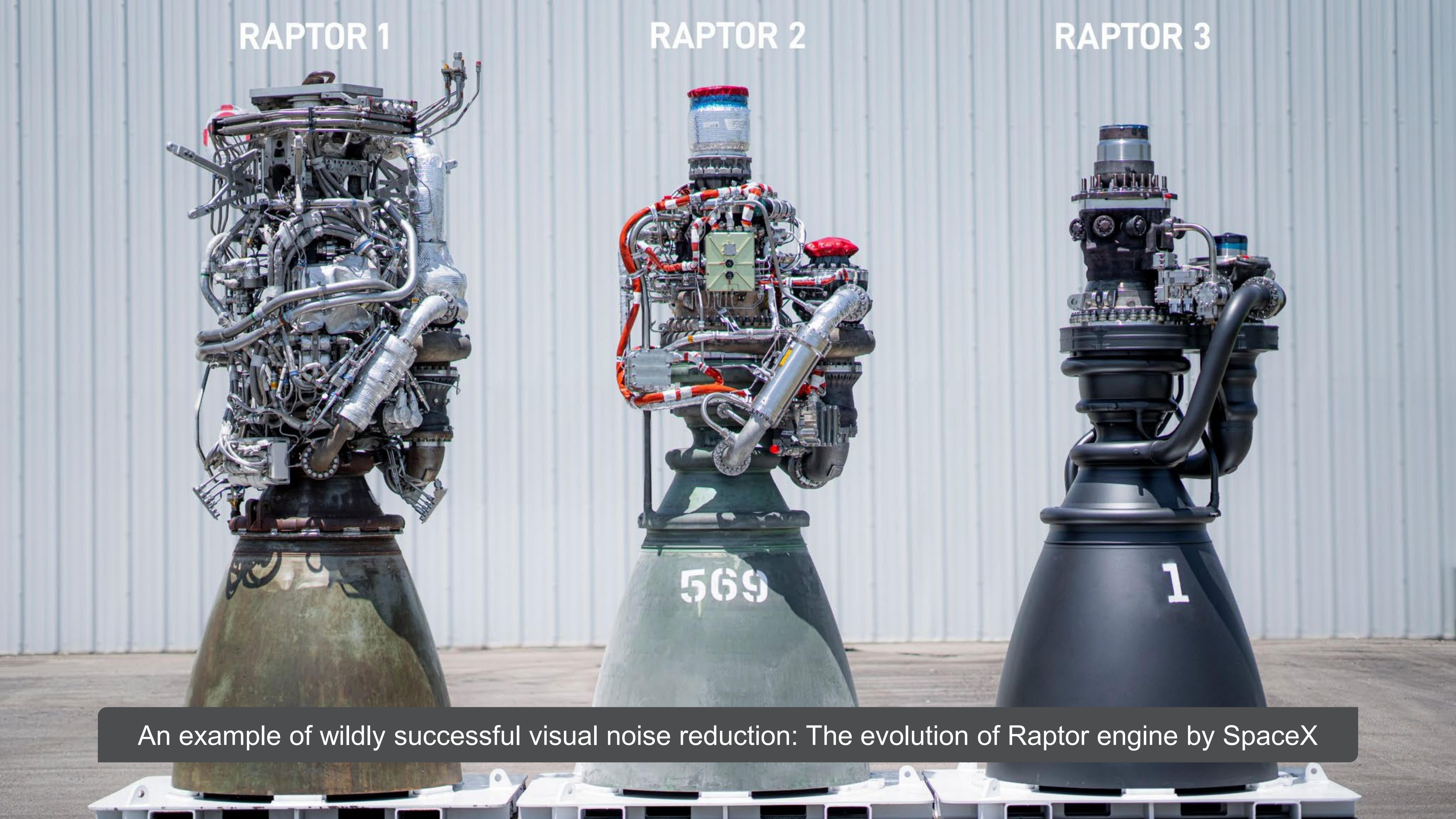
Cluttered data in some data visualizations


Cable management
Visual noise and usability,
bad vs good experience

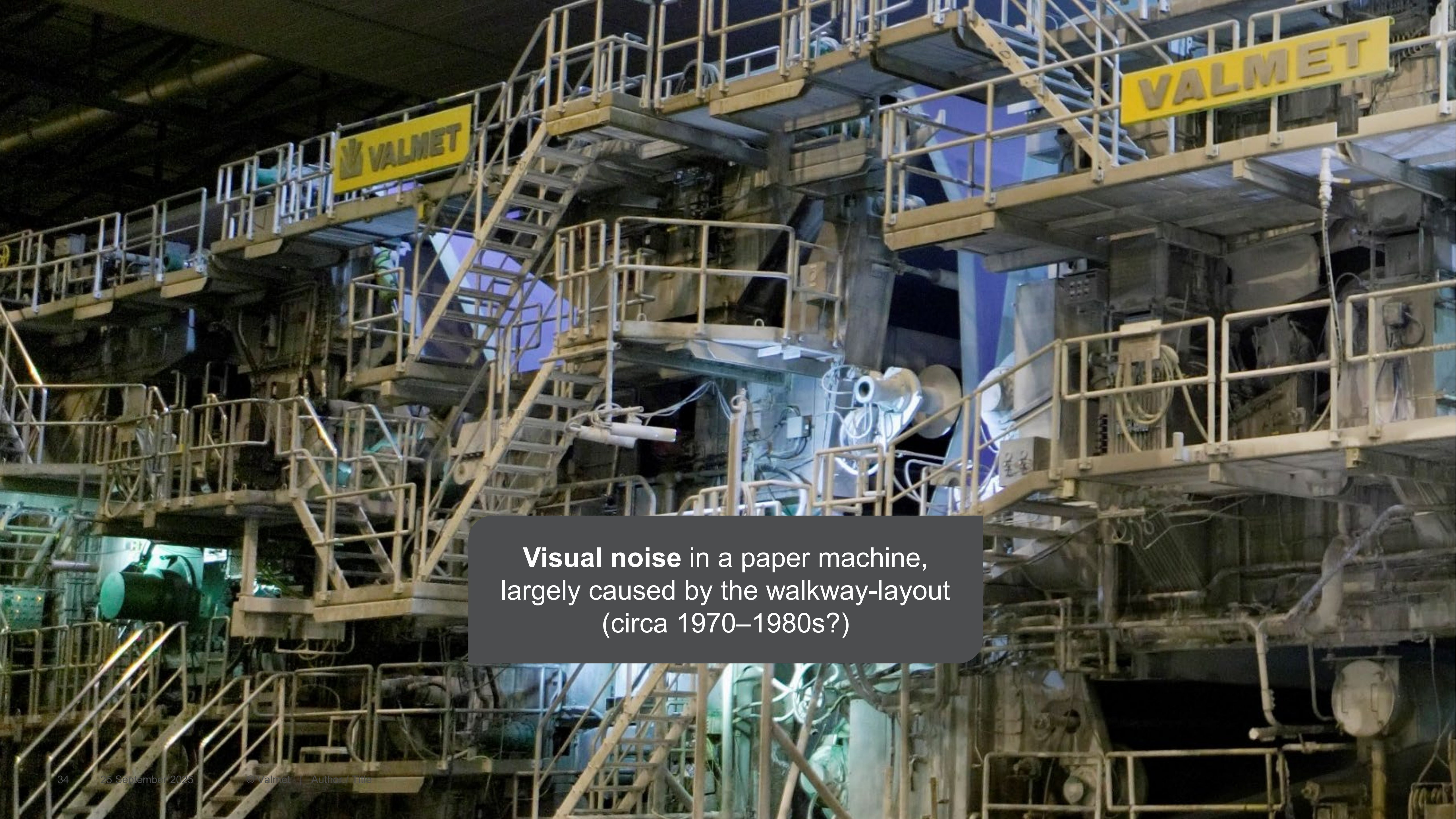


Parking lot

Visual noise and usability,
bad vs good experience



An example of wildly successful visual noise reduction: The evolution of Raptor engine by SpaceX

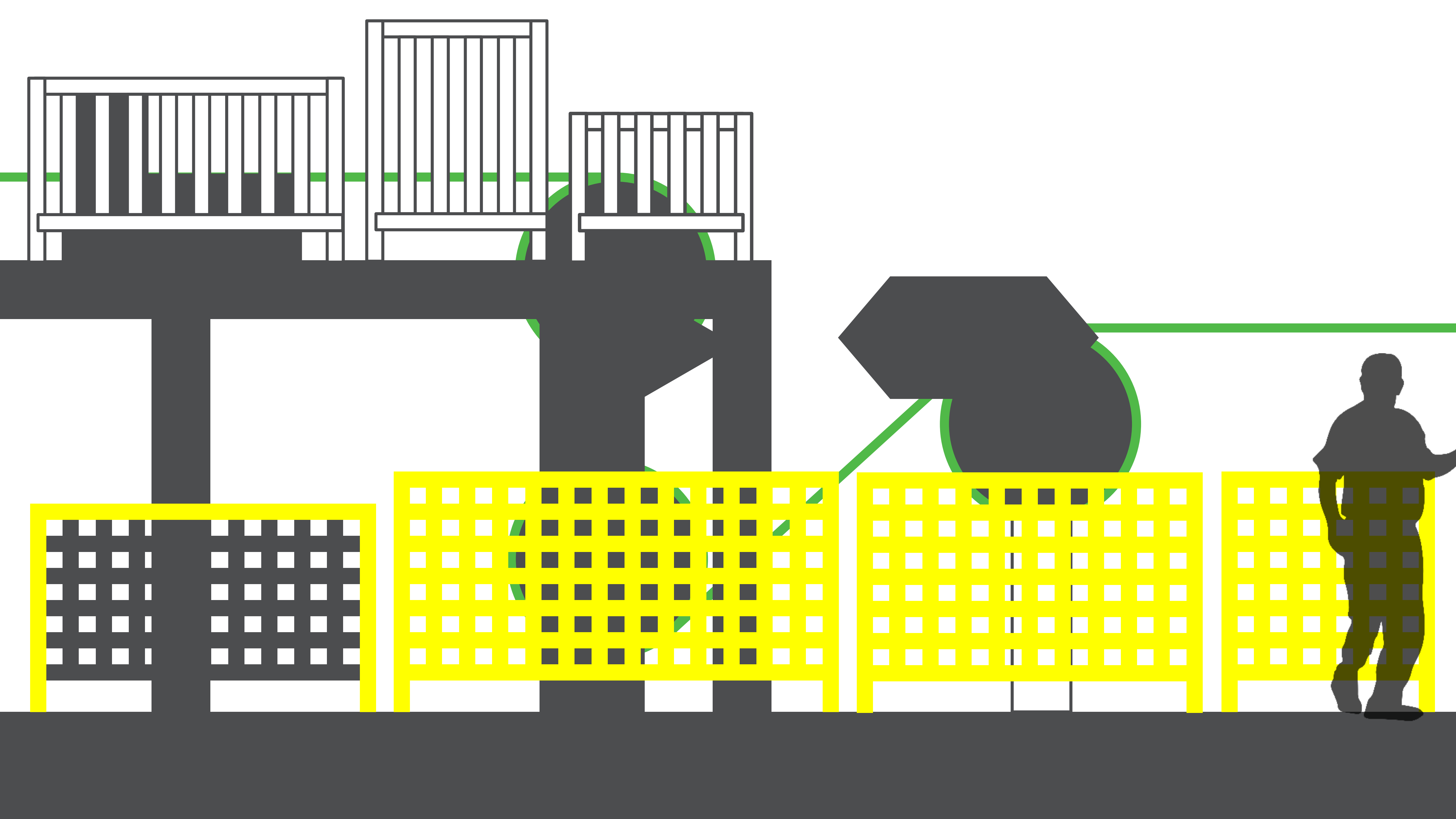


Visual noise in a paper machine, largely caused by the walkway-layout (circa 1970–1980s?)

OptiConcet M machine,
Valmet (early 2010s)

Visual noise reduction example

Even though this example is about the physical environment, it’s important to note that all the same principles can be applied also to graphical user interfaces

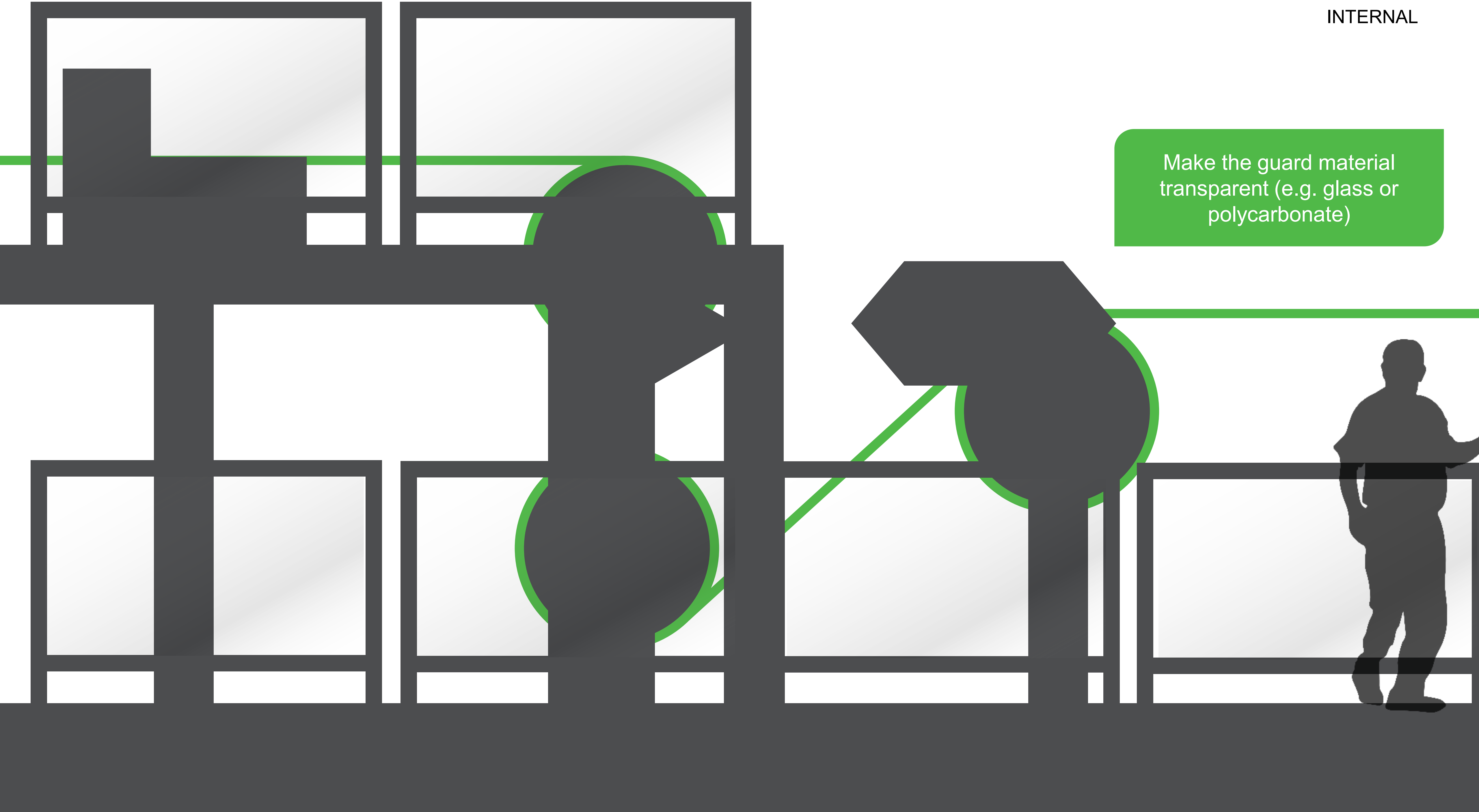



Adopt a well-reasoned use of colors (three different color schemes in guards reduced to one plus an odd-colored frame part changed)

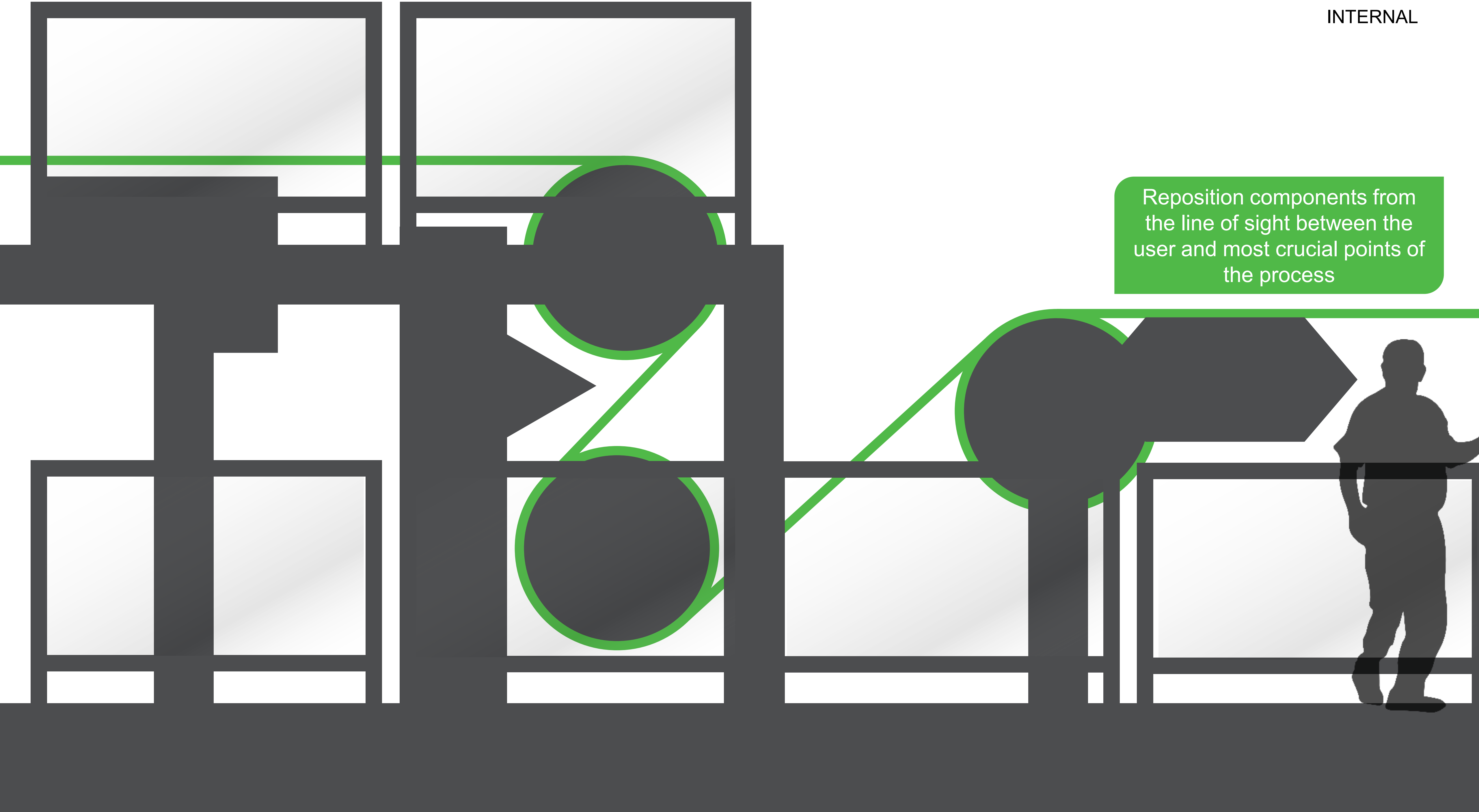
Kill one of the solutions in guards (two different styles)

Standardize guard heights

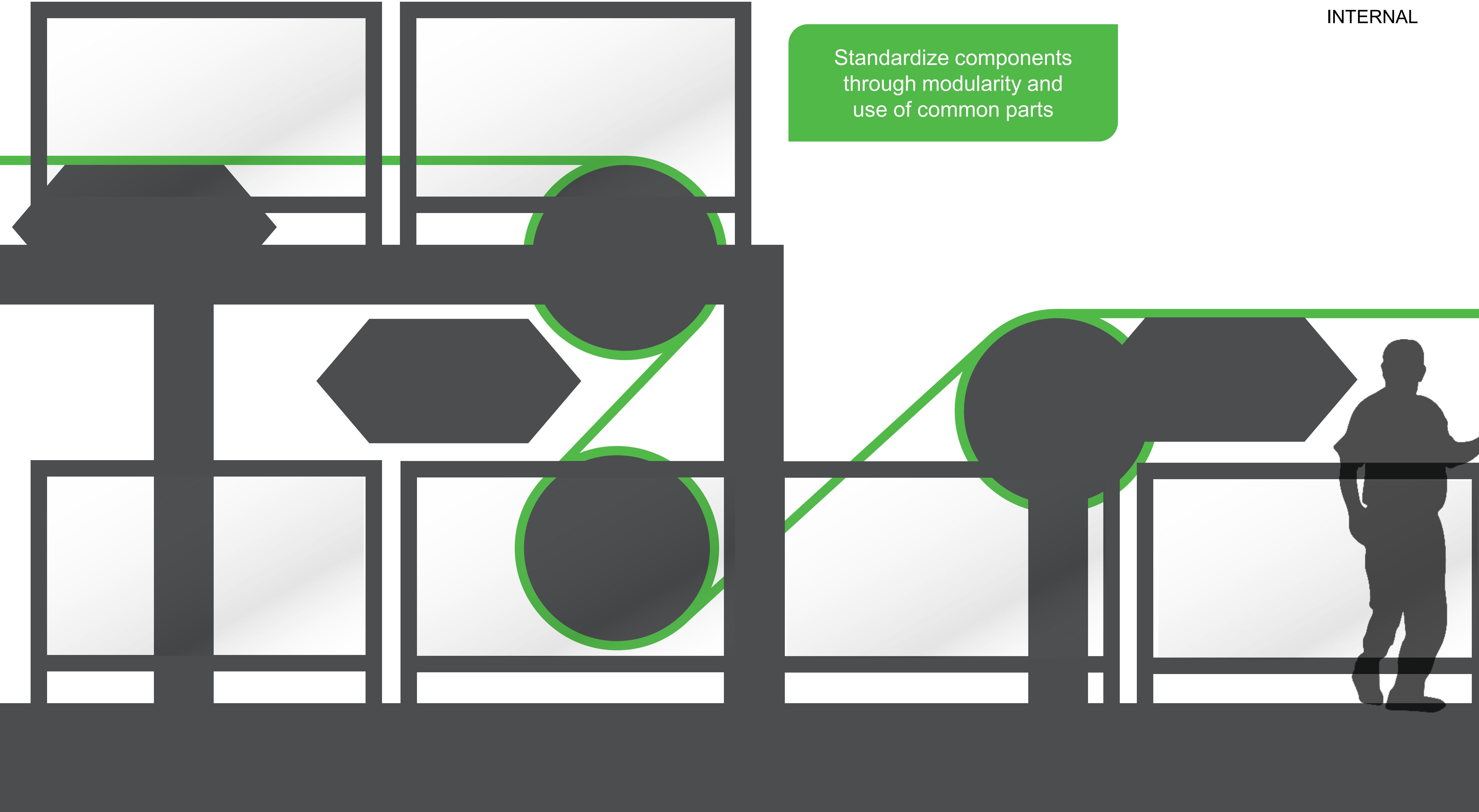
Standardize guard widths

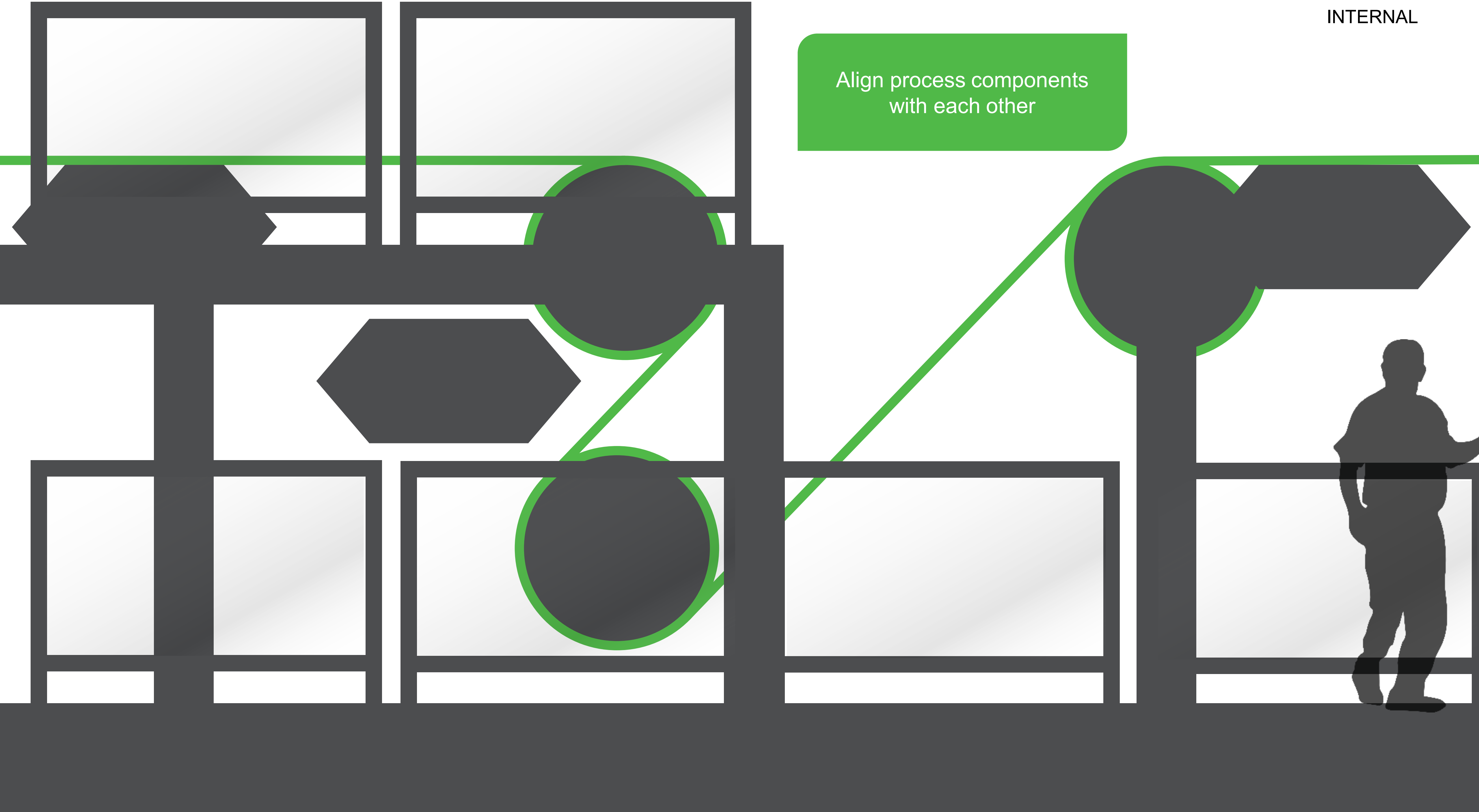


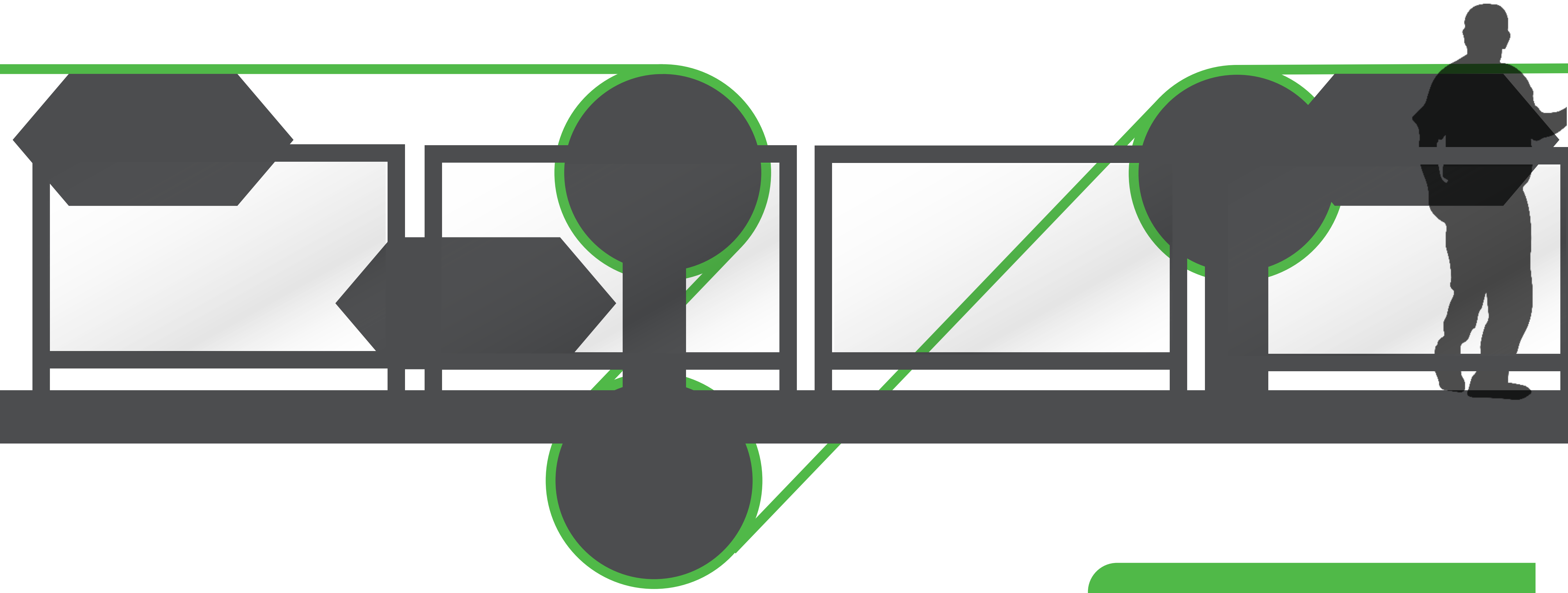
Make the guard material transparent (e.g. glass or polycarbonate)


Reposition components from the line of sight between the user and most crucial points of the process

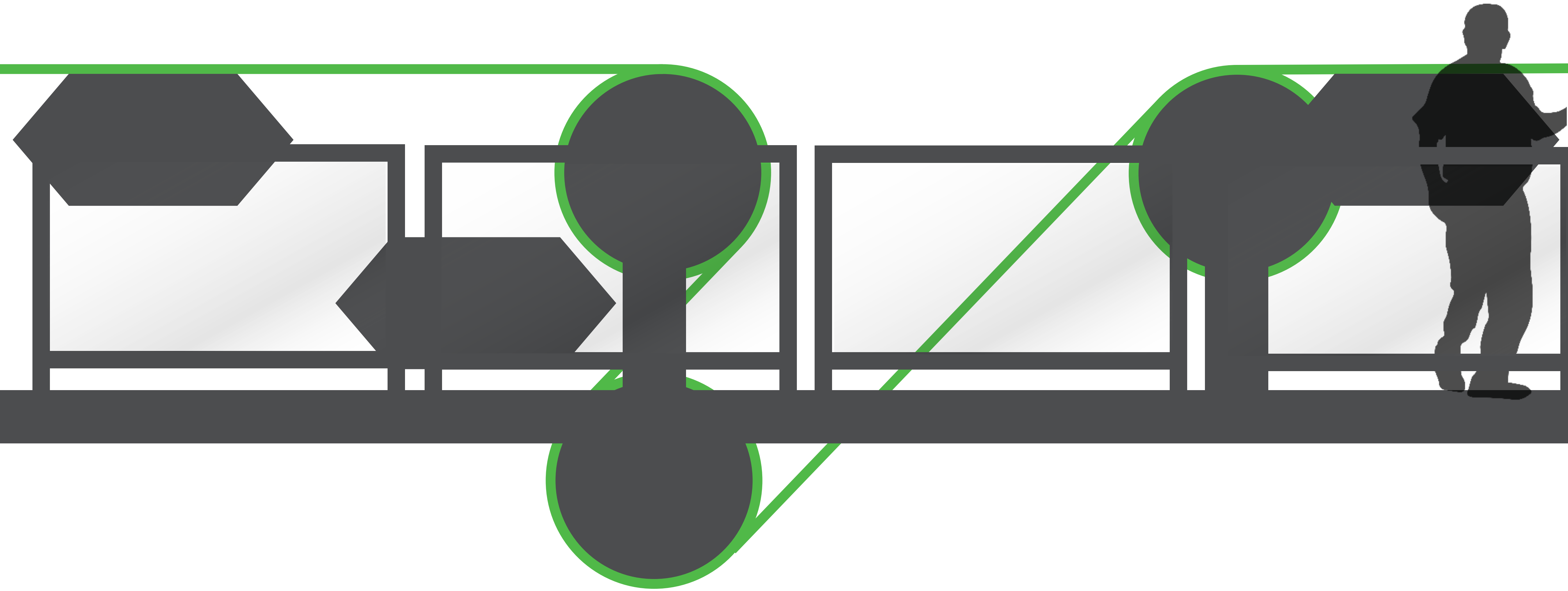
Standardize components through modularity and use of common parts




Align process components
with each other

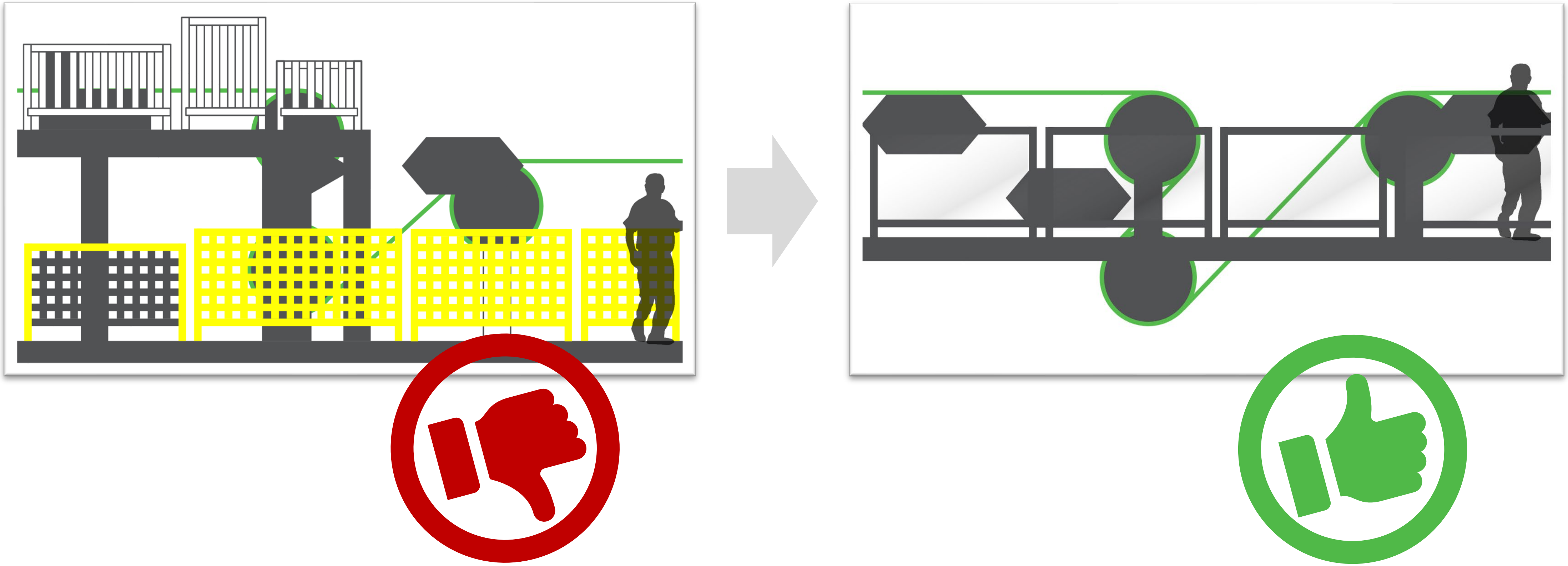


Bring the process at a comfortable height for observation and maintenance (either by moving components or bringing the walkway higher



Takeaways from the visual noise reduction example

- With these changes we improved the usability of this machine section significantly
- Notice how the aesthetics improved significantly. These two things usually go hand-in-hand.



Rule of thumb

Less is more

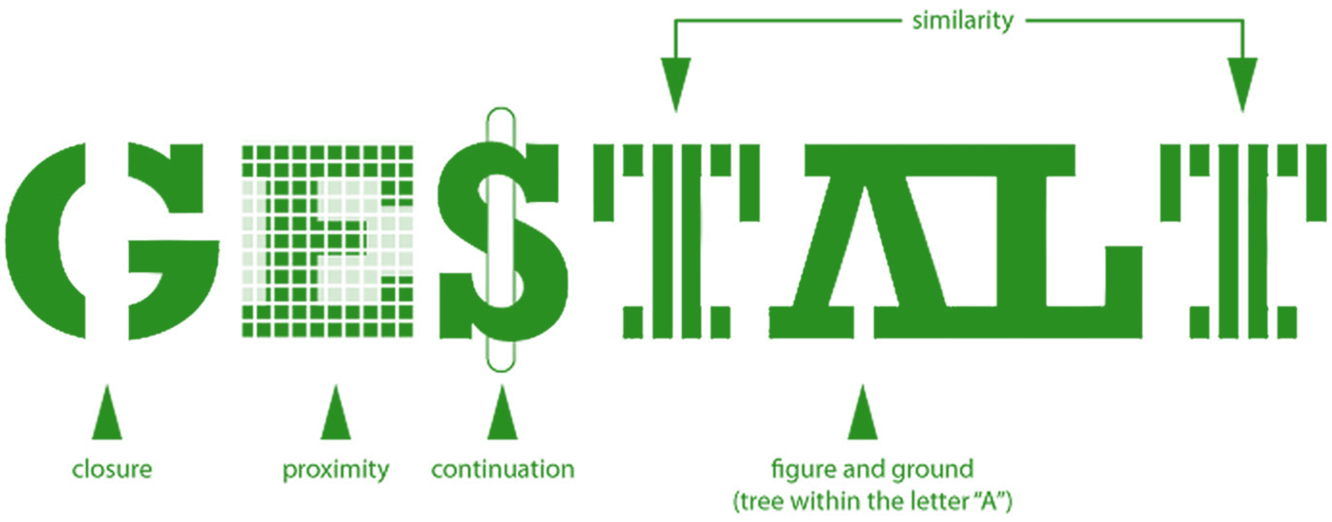
Whenever two competing solutions seem equally feasible, proceed with the one with less distinctive features.

The user does not need to see the complexity that lies beneath the surface.

5 | Gestalt principles

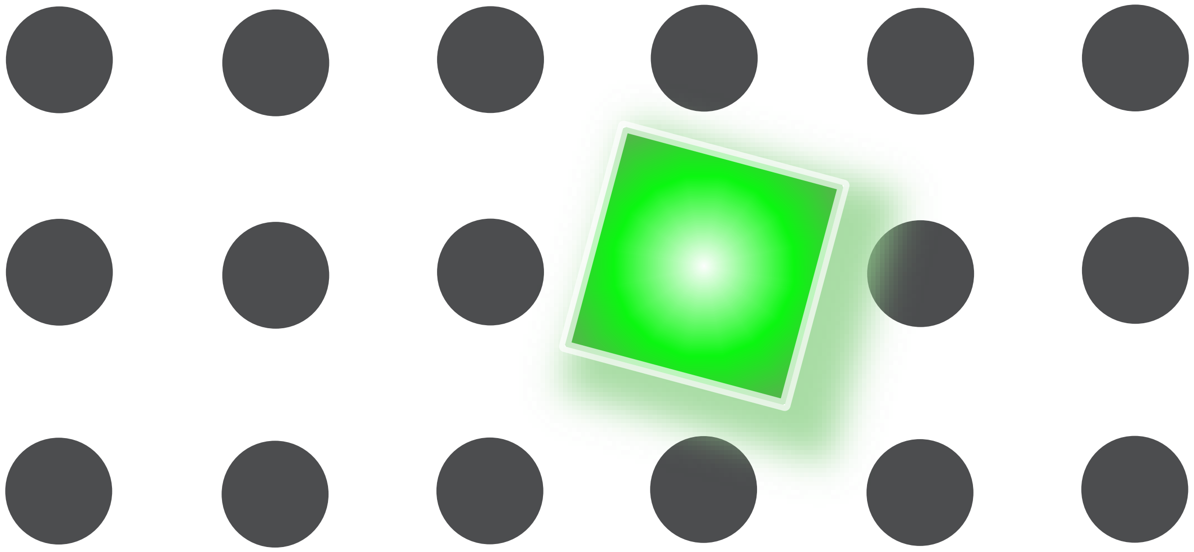
Gestalt Principles

- Gestalt Principles (also called “Gestalt laws”) are principles of human perception that describe how humans group similar elements, recognize patterns and simplify complex images when we perceive objects
- Whatever we view, our brains constantly try to make sense of what we see
- This automatic and continuous perceptual process becomes harder when we see noise, clutter, and complexity
- The perception process can be helped, and cognitive load can be reduced by following the Gestalt principles
- The amount of Gestalt Principles varies depending on the source and context. Typically 6 or 7 are proposed
- The following pages give one of these principles (Focal point) as an example, but all the rest are worth studying on another time



Picture: https://www.neurosciencemarketing.com/blog/articles/gestalt-principles.htm

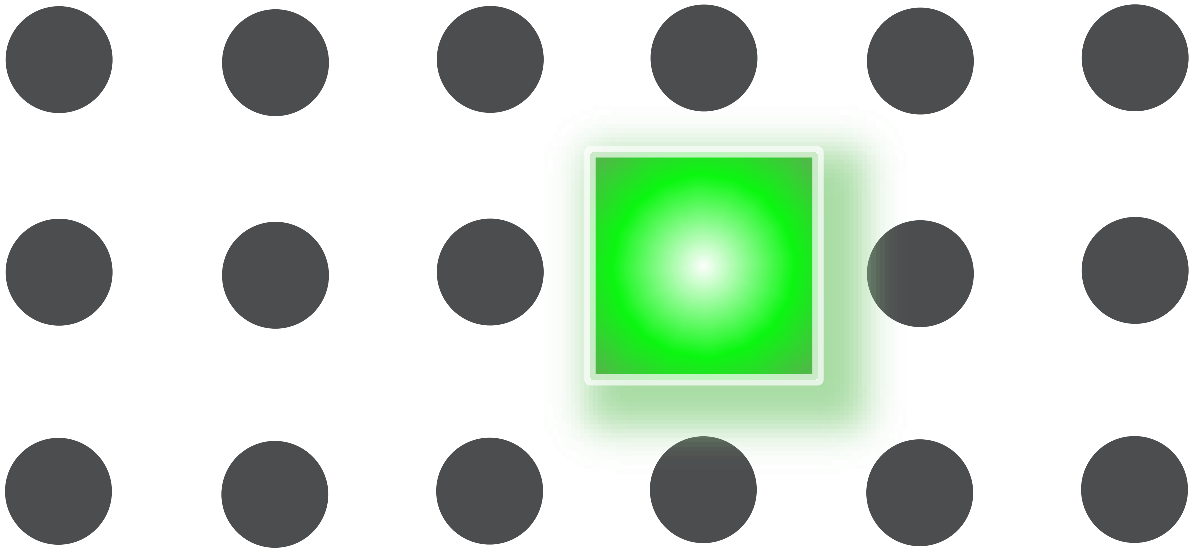
Gestalt Principles | **Focal point**



The focal point principle states that whatever stands out visually will capture and hold the viewer's attention first.

When you look at the image above, for example, the first thing you notice is the green square because it's different from all the black circles around it. It's the first point of interest that grabs your attention, and from there, your attention moves to other parts of the image.

Gestalt Principles | **Focal point**



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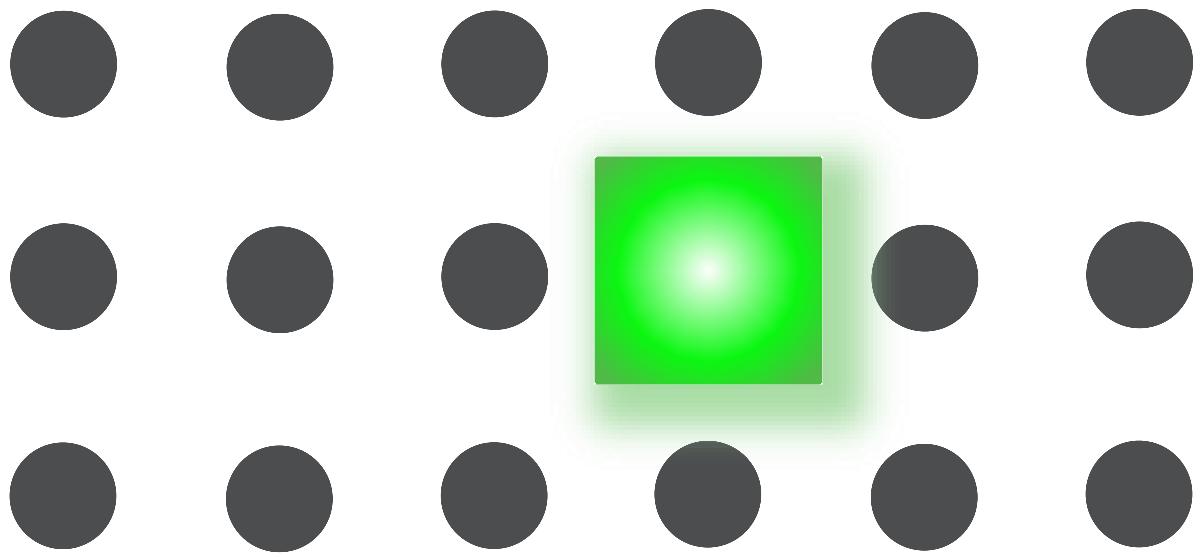

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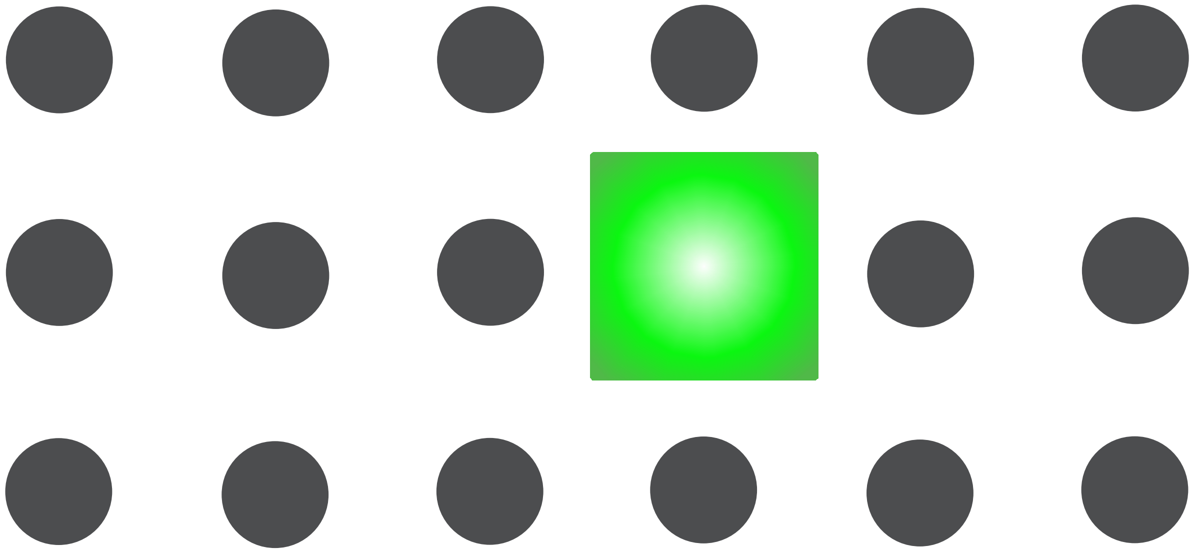

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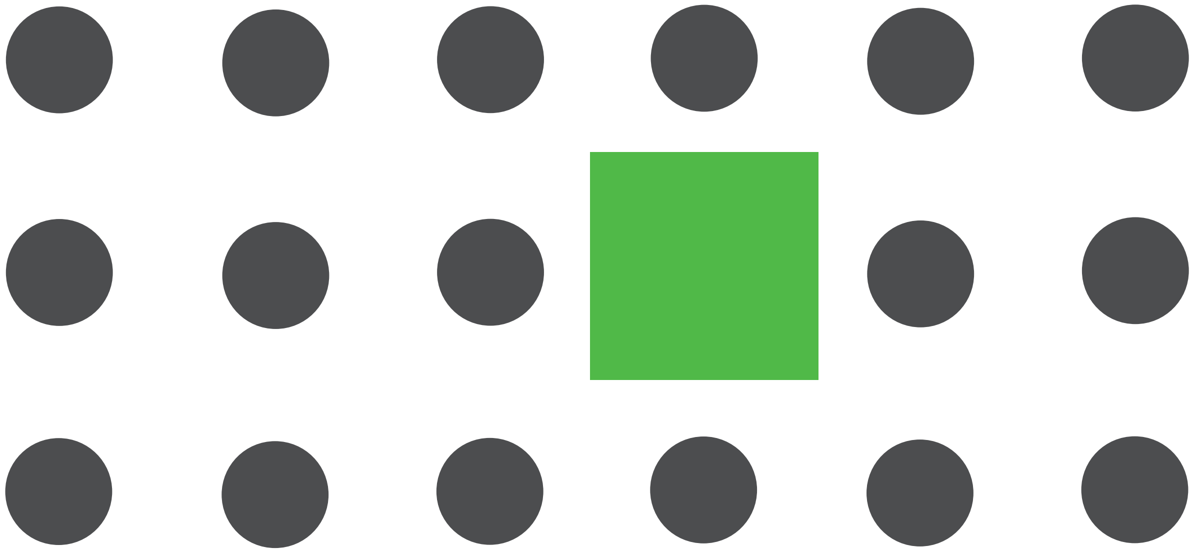

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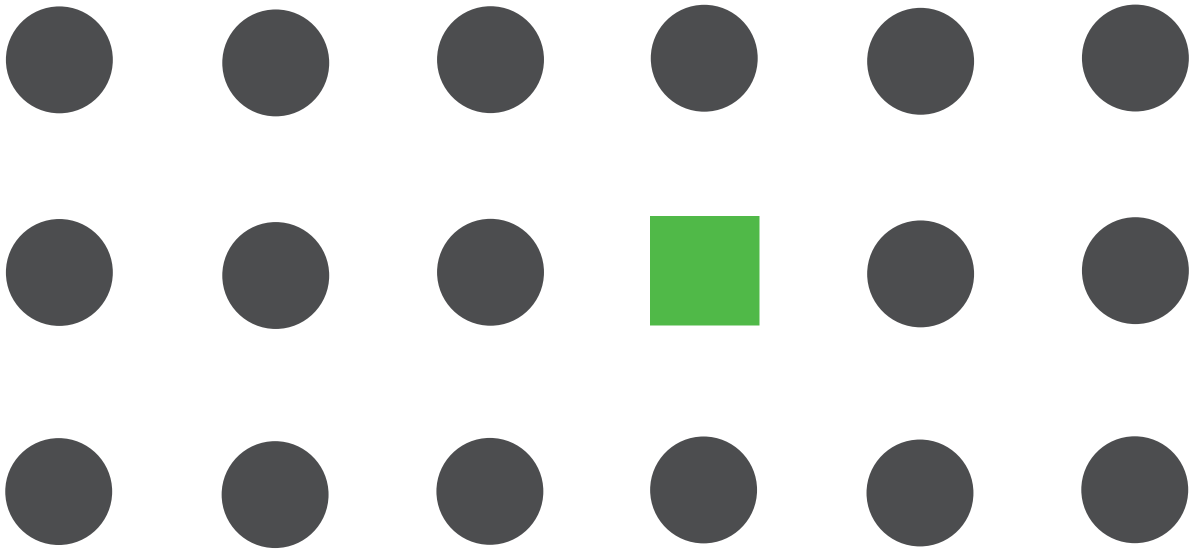

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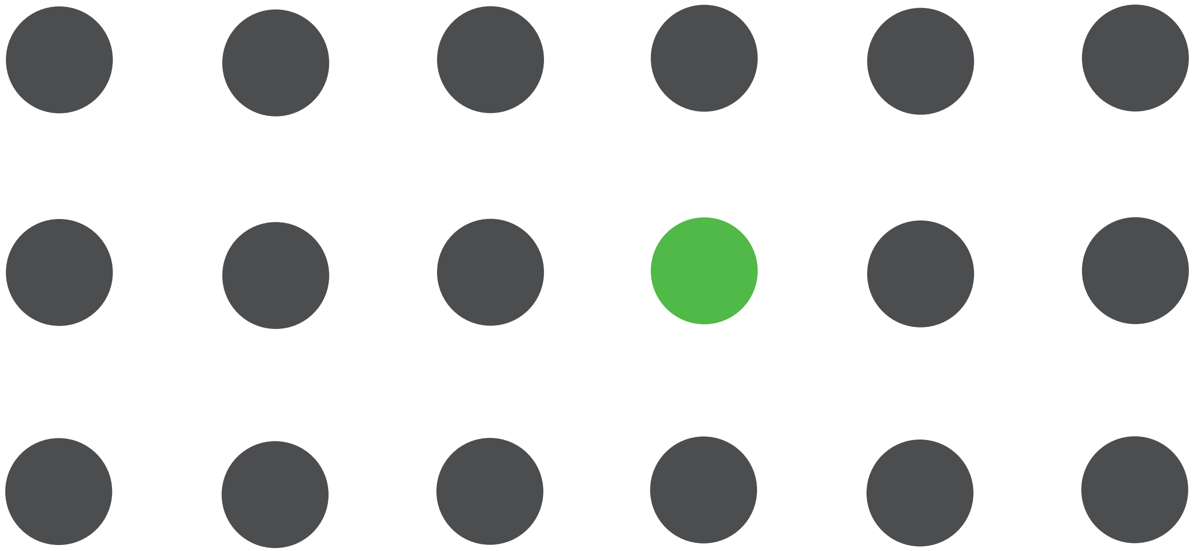
Gestalt Principles | **Focal point**

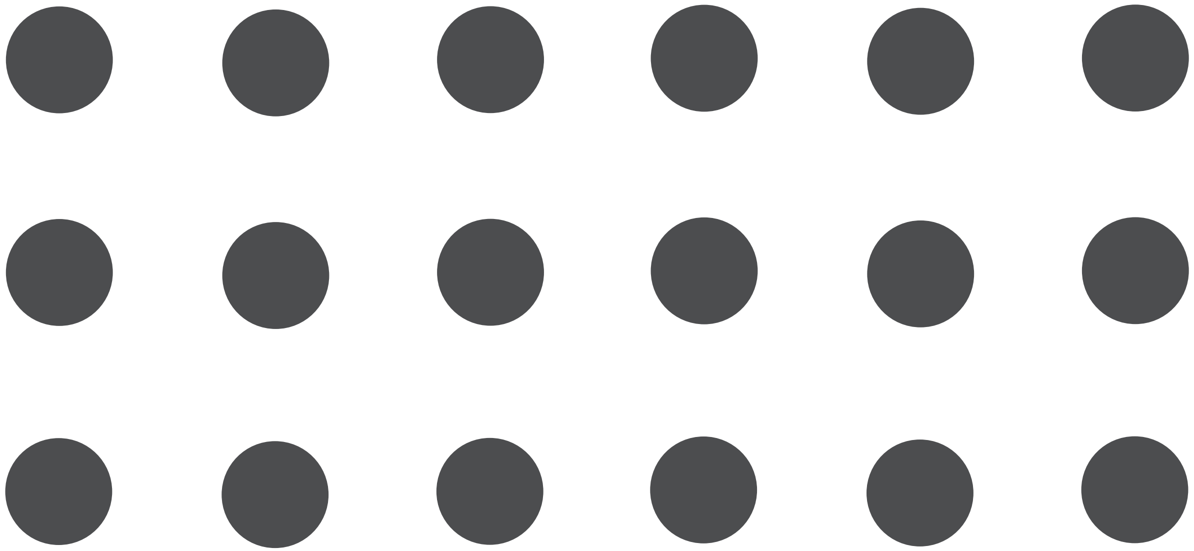


The focal point principle states that whatever stands out visually will capture and hold the viewer's attention first.

When you look at the image above, for example, the first thing you notice is the green square because it's different from all the black circles around it. It's the first point of interest that grabs your attention, and from there, your attention moves to other parts of the image.

Valmet

Gestalt Principles | **Focal point**



The focal point principle states that whatever stands out visually will capture and hold the viewer's attention first.

When you look at the image above, for example, the first thing you notice is the green square because it's different from all the black circles around it. It's the first point of interest that grabs your attention, and from there, your attention moves to other parts of the image.

Gestalt Principles | **Focal point**

A collection of local control boxes from the internet. Is it obvious in each case which button is the emergency stop button?
With the emergency stop button, it is well-justified to have a strong focal point like this. But with every other control, the visual cues can be more discreet and elegant.

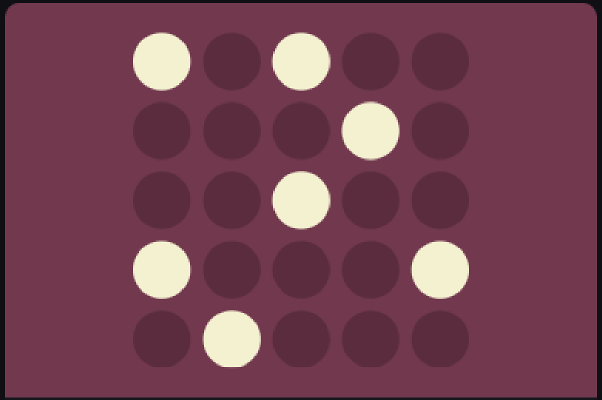
Image: Unknown source

6 | Summary

Summary

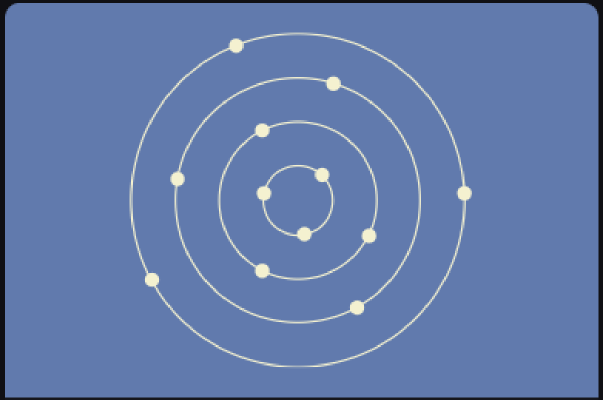
- **Ensure a holistic approach**
  - Ergonomics < Usability < User Experience < Customer experience
  - Physical and digital aspects and services should form one, coherent and seamless customer experience – these cannot be three separate things
- **Visual noise** is unnecessary complexity and misleading visual stimulus
  - Eliminate all such features for better user experience and usability
- **Gestalt laws** can be utilized to guide the users' attention
  - Highlight what is important for the users, such regular use or maintenance points
  - De-emphasize what is not relevant for the users (= not regular use cases), such as technical parts
  - Carefully prioritize the elements to highlight, as it easily becomes visual noise
- **Further reads**:
  - Laws of UX, "A collection of best practices that designers can consider when building user interfaces" (applicable also to physical products): www.lawsofux.com

Laws of UX



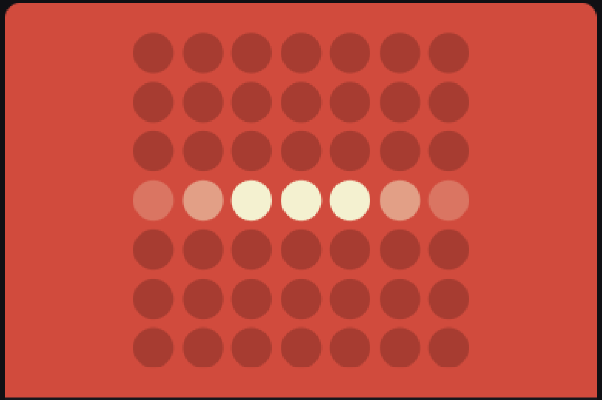
Law of Similarity

The human eye tends to perceive similar elements in a design as a complete picture, shape, or group, even if those elements are separated.



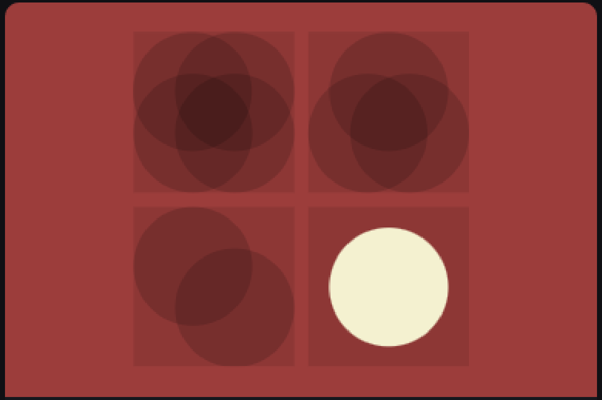
Law of Uniform Connectedness

Elements that are visually connected are perceived as more related than elements with no connection.



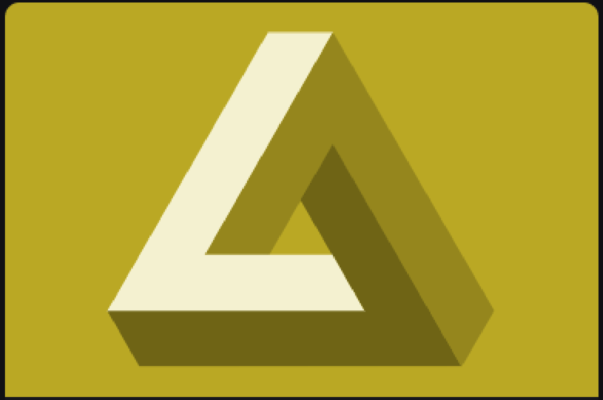
Miller’s Law

The average person can only keep 7 (plus or minus 2) items in their working memory.



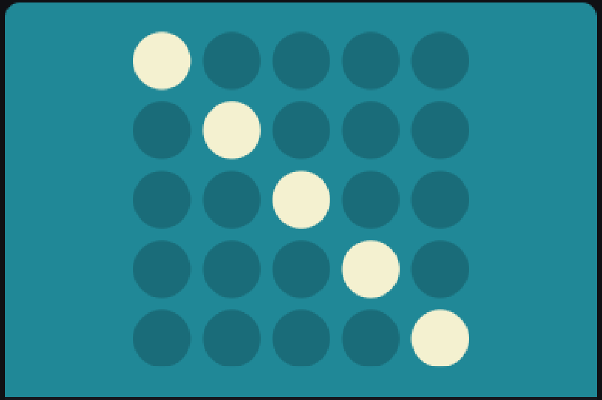
Occam’s Razor

Among competing hypotheses that predict equally well, the one with the fewest assumptions should be selected.



Paradox of the Active User

Users never read manuals but start using the software immediately.



Pareto Principle

The Pareto principle states that, for many events, roughly 80% of the effects come from 20% of the causes.

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C2 – Industrial Automation

L3 – PLC Programming with Sequential Function Chart (SFC)

P5 - BOSCH

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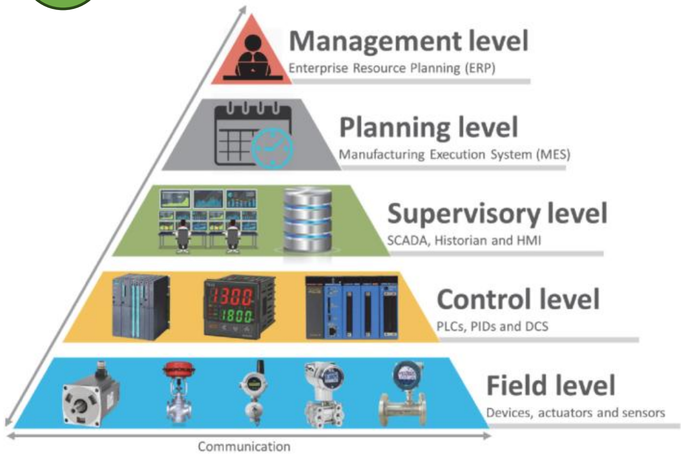
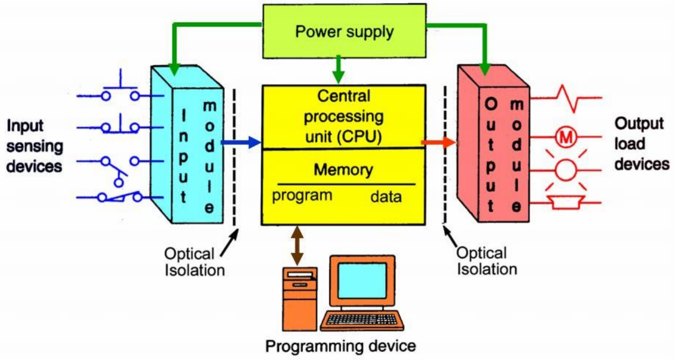
L2 – PLC Programming with Sequential Function Chart (SFC)

1 **Industrial Control System**



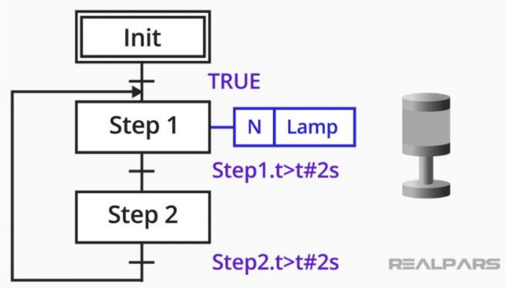
2 **PLC System**



Source: Rahman, Moksadur, et al. 'A Framework for Learning System for Complex Industrial Processes'. AI and Learning Systems - Industrial Applications and Future Directions, IntechOpen, 17 Feb. 2021. Crossref, doi:10.5772/intechopen.92899.

3 IEC 61131-3:2013

- Ladder Logic Diagram (LD)
- Function Block Diagram (FBD)
- Instruction List (IL)
- Structured Text (ST)
- Sequential Function Chart (SFC)



The modular Mechatronics Training System mMS 4.0

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NextGEng

L2 – PLC Programming with Sequential Function Chart (SFC)

Laboratory overview:

Objectives	• Programming sequential controls with Sequential Function Chart (SFC) • Use CODESYS IDE for simulation and programming
Pre-requisite	• Basic skills and knowledge of programming • Basic IT knowledge • Basic knowledge of electro-pneumatic circuits
Equipment used for laboratory	• The modular Mechatronics Training System mMS 4.0 • Station 1 : Rack station

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L2 – PLC Programming with Sequential Function Chart (SFC)

Upon completion of this laboratory, the student will be able to:

1) Use SFC as a graphic approach for structuring basic, intermediate and complex PLC sequential controls
2) Solve practical sequential controls programming case studies using SFC
3) Use CODESYS IDE for simulation and programming using SFC

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Content

- Introduction
- Experimental setup
- Project – mMS4.0: Rack station
  - ➢ Task 1 – Transferring workpieces
  - ➢ Task 2 – Sorting workpieces
  - ➢ Task 3 – LED signaling function
- Simulation results
- Experimental results
- Summary

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Introduction

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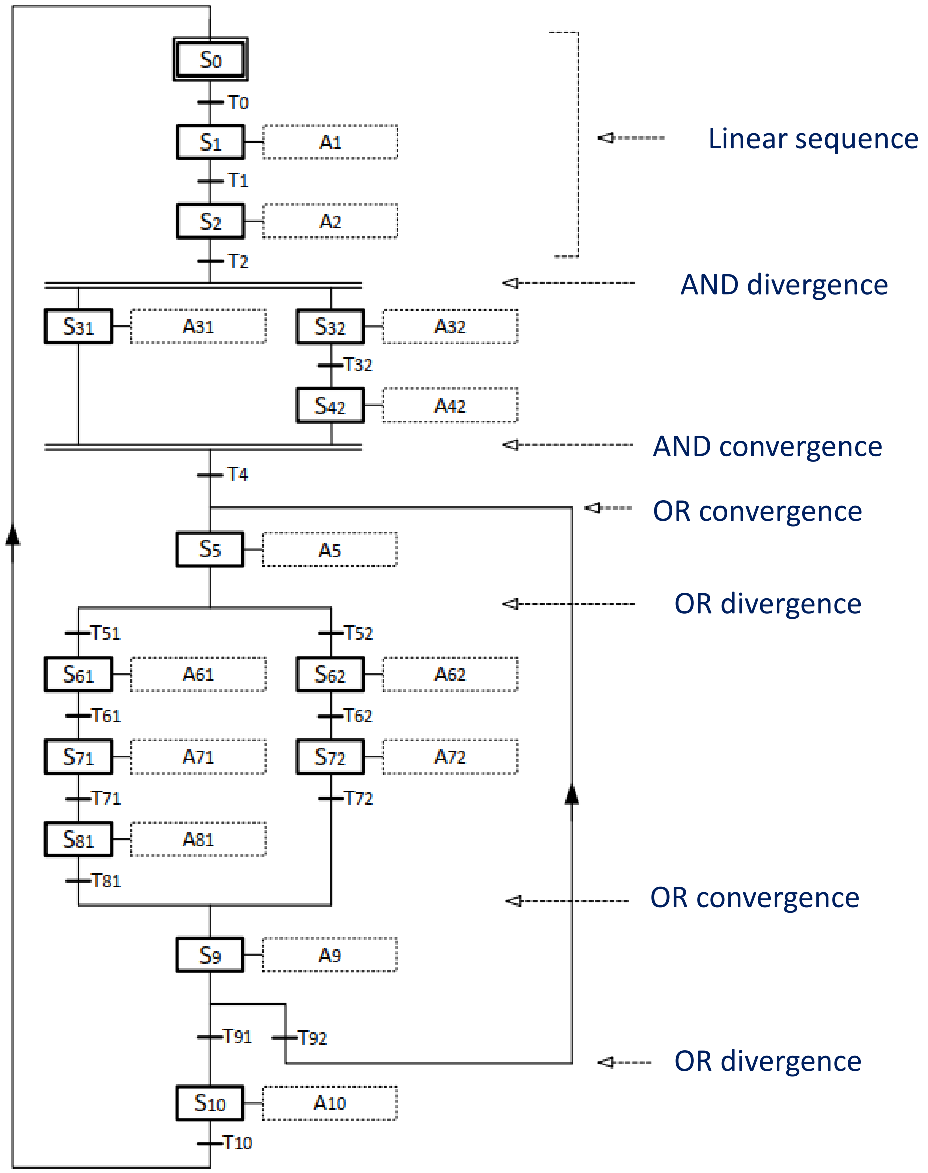
Structured programming using SFC

Structuring industrial applications

- IEC61131-3 (SFC–Sequential Function Chart)
- SFC is derived from GRAFCET
- GRAFCET is used for sequence representation
- SFC can be implemented in implicit and explicit form
- SFC is used for structuring industrial application



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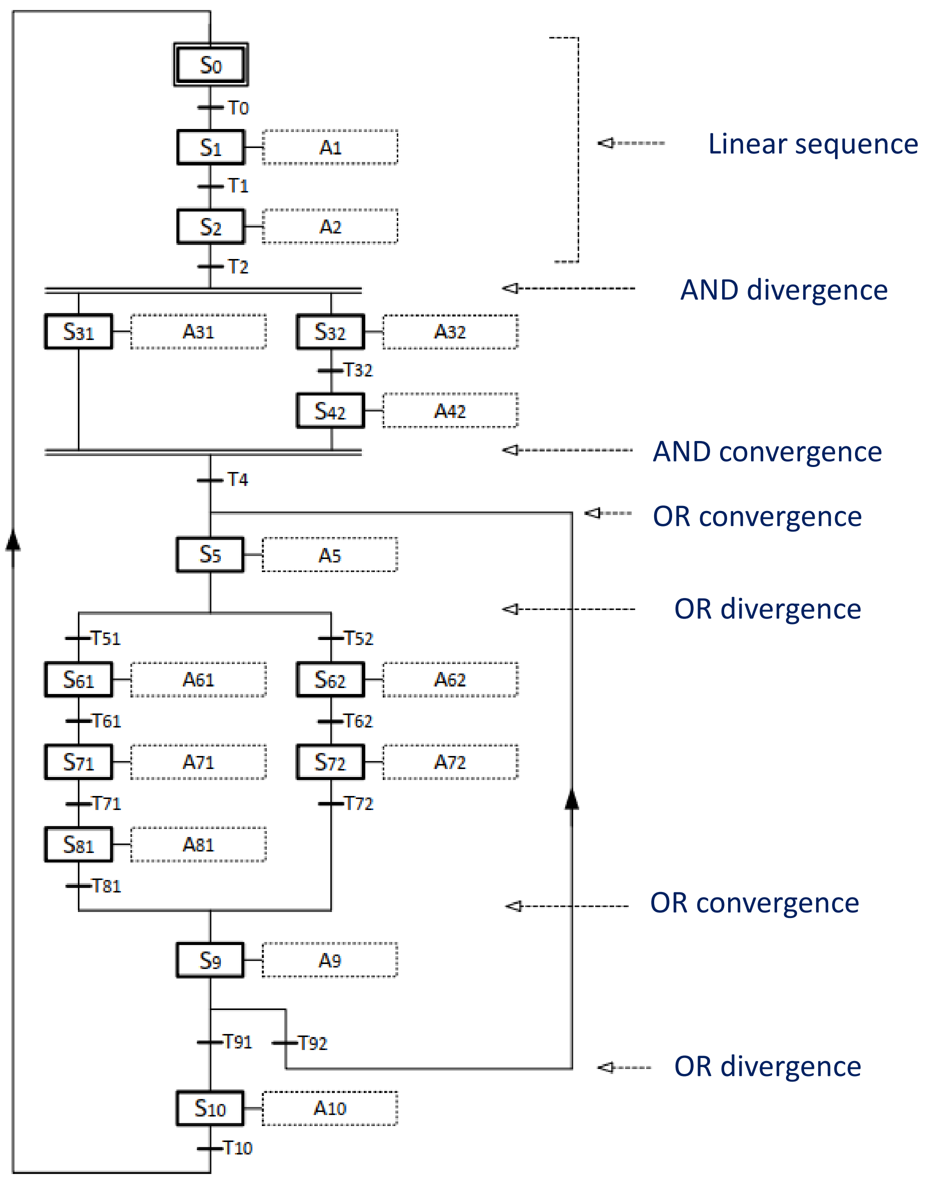
SFC structuring rules

- Linear sequences
- Simultaneous branches
- Alternative branches

Enough to represent any sequential application

- Steps (initial and normal steps)
- Transitions
- Actions

Structuring elements



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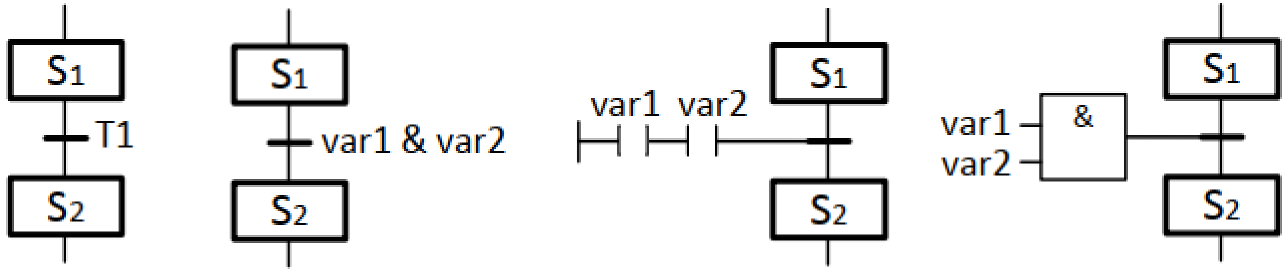
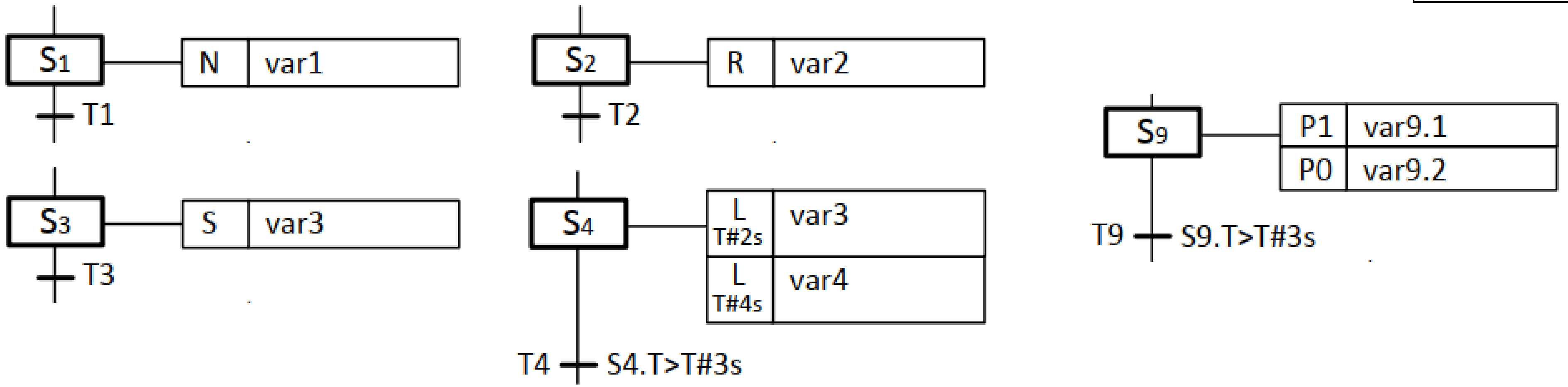
SFC structuring rules

Transitions implementation - examples



Action implementation - examples



Action type	IEC 61131-3 description
N	**N**on-stored
R	overriding **R**eset
S	**S**et (**S**tored)
L	time **L**imited
D	time **D**elayed
P	**P**ulse
SD	**S**tored and time **D**elayed
DS	**D**elayed and **S**tored
SL	**S**tored and time **L**imited
P1	**P**ulse (rising edge)
P0	**P**ulse (falling edge)

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Experimental setup

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Experimental setup

The modular Mechatronics Training System mMS 4.0

- **The modular Mechatronics System mMS 4.0** consists of three flexible, exchangeable and expandable stations: rack (**Station 1**), processing (**Station 2**), and storage (**Station 3**) for the realization of a **complete automation process**.
- **mMS 4.0** addresses the **assembly of a cube**, from the removal out of a rack to processing with a pressing machine, and through to the high-rack warehouse.
- The **modular concept** of mMS 4.0 is consistently aligned with the **educational path of the mechatronics training**.

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Experimental setup

The modular Mechatronics Training System mMS 4.0

The modular Mechatronics System mMS 4.0 consists of three flexible, exchangeable and expandable stations: rack, processing, and storage. For the realization of a complete automation process.

Your benefits with mMS 4.0:

Original standard components from industry

- DC motors
- Servo motors
- Control technology: relay, PLC, motion control, CNC
- Linear motion technology
- Pneumatic drives
- Hydraulic drive (optional)
- Sensor technology and RFID
- Cartesian robot or 3-axis CNC
- Standard machine control panel
- Fieldbus and Ethernet communication

Modular, scalable training system – from single module to full plant

Industry 4.0 integrated

- HMI – Human Machine Interface
- RFID – Radio Frequency Identification
- Open Core Engineering from Rexroth – winner of the Hermes Award

Various programming options

- PLC programming (according to IEC 61131-3):
  - Instruction List (IL)
  - Structured Text (ST)
  - Sequential Function Chart (SFC)
  - Function Block Diagram (FBD, STL)
  - Ladder Diagram (LD)
  - Continuous Function Chart Editor (CFC)
- **Open Core Engineering** offers more ways of programming
  - Java (APP)
  - C/C++
  - C#
  - Microsoft Excel, PowerPoint
  - Matlab/Simulink
  - and more

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Experimental setup

Industry 4.0 Laboratory at Technical University of Cluj-Napoca

mMS4.0: Rack station

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Experimental setup

mMS4.0 – Rack station most important components

- Machine control panel
- Conveyor belt
- 2 separating racks
- Sensor technology analog/digital
- Removal unit
- Profibus coupler
- Safety technology (optional)
- Connected Industry 4.0: Open Core Engineering, HMI & RFID (optional)

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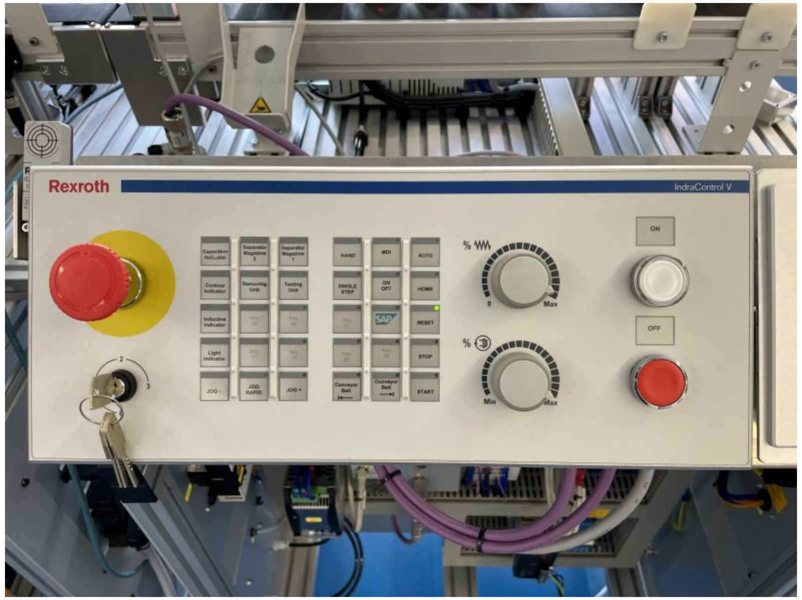
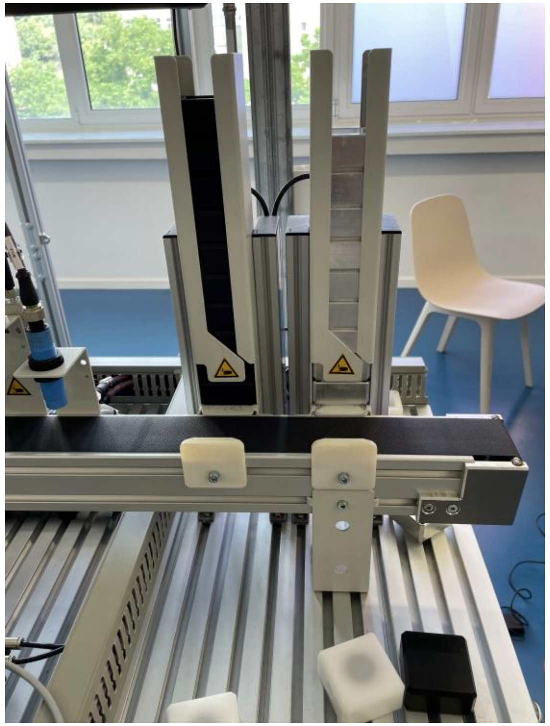
Experimental setup

mMS4.0 – Rack station most important components



Machine control panel

Conveyor belt with DC motor and light barrier



2 separating racks

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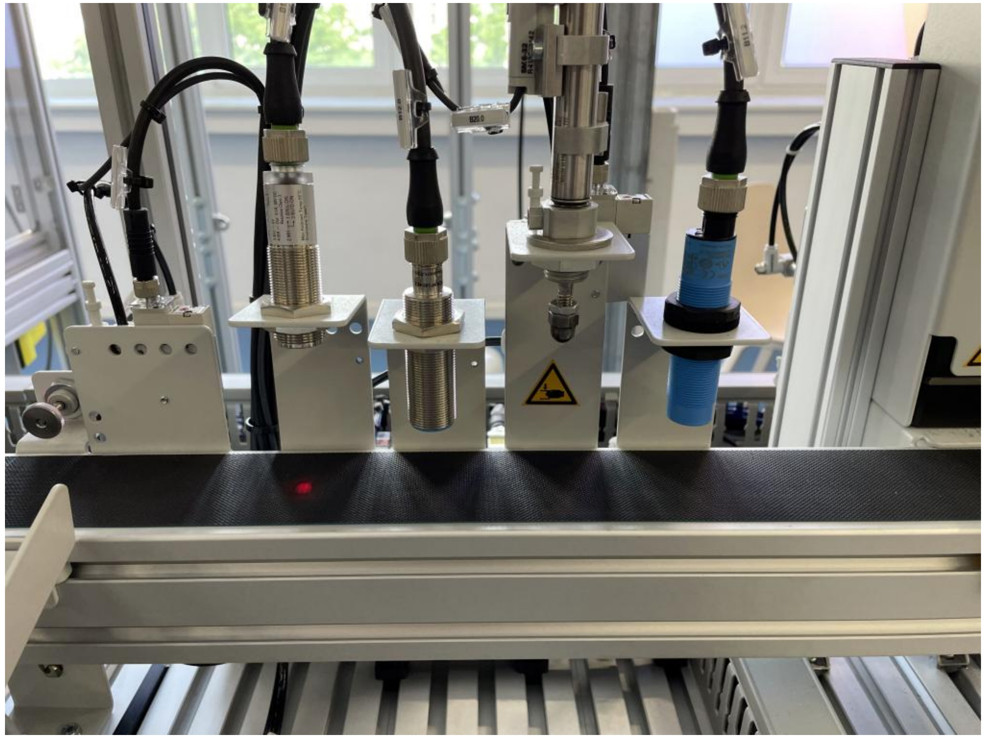
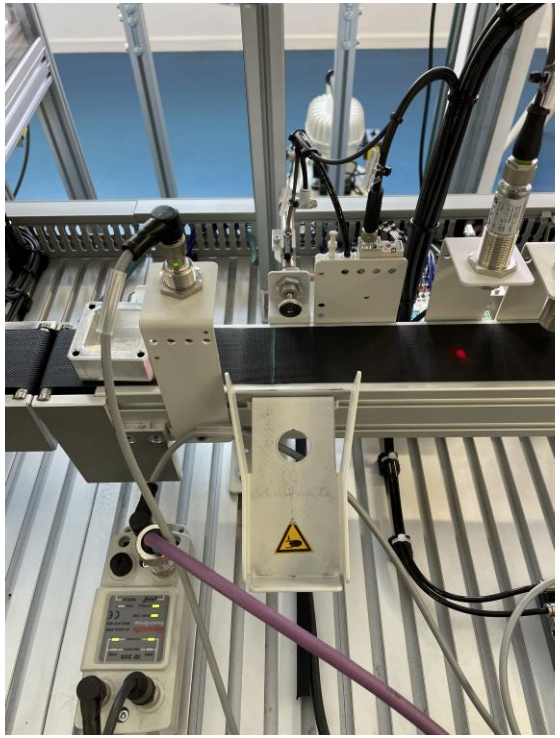
Experimental setup

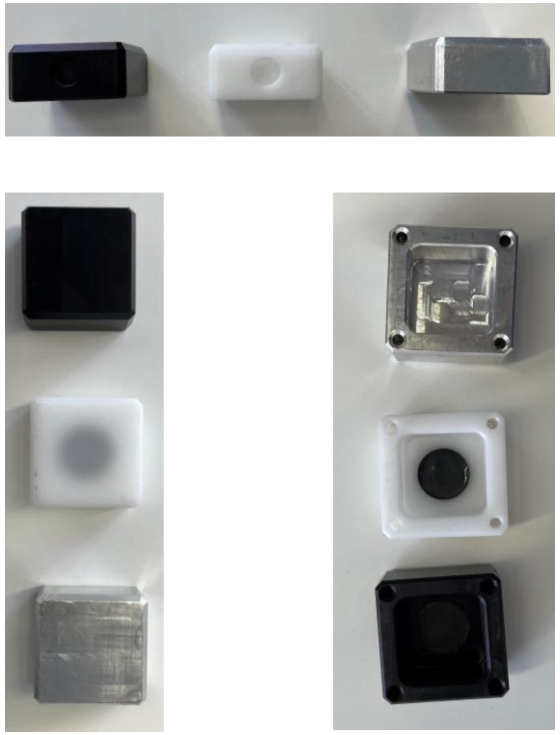
mMS4.0 – Rack station most important components



Sensor technology analog/digital



Removal unit



Workpieces (halved cubes)

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Experimental setup

mMS4.0 – Rack station I/O mapping list

- will be used for experimental implementation on the rack station

Name	Direction	Type	Variable Address	Comment
ButtonStart	In	Bool	%IX111.6	Start Button
ConvEndSensor	In	Bool	%IX10.2	Conveyor End Sensor
NokCylinderExtend	In	Bool	%IX12.3	Removal Unit Cylinder Unit
SensCylinderOut	In	Bool	%IX10.5	Magazine 1 extended cylinder Sensor
SensCylinderIn	In	Bool	%IX10.4	Magazine 1 retracted cylinder Sensor
bWorkpiecePresent	In	Bool	%IX11.2	Capacitive Sensor
bWorkpieceInductive	In	Bool	%IX12.0	Inductive Sensor
StartButtonLed	out	Bool	%QX104.6	Start Button Indicator
Mag1PartOut	out	Bool	%QX11.0	Magazine 1 Extend Cylinder
NOKCylinder	out	Bool	%QX11.3	Removal unit Extend cylinder
ConveyorDirEnd	out	Bool	%QX12.0	Conveyor Start direction Station 2
ConveyorDirStart	out	Bool	%QX12.1	Conveyor Start direction Tower 1

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Project – mMS4.0: Rack station

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Project - mMS4.0: Rack station

Project definition

➢ Rack station from mMS4.0 system will be used for this project. Workpieces (halved cubes with different colors and materials) are transferred or sorted out using the conveyor belt, separating racks and removal unit. The presence and material of the workpieces is detected via sensors (capacitive, inductive and light barrier sensors). GRAFCET rules are used for structuring the sequential control while SFC is used as the implementation language for PLC using CODESYS IDE.

Project task

➢ Task 1 – Transferring workpieces
➢ Task 2 – Sorting workpieces
➢ Task 3 – LED signaling function

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Task 1 – Transferring workpieces

Task 1 definition

- A pneumatic cylinder pushes a workpiece (halved cubes) out of the separator magazine 1 on the conveyor belt. The belt transports the workpiece past the testing unit. A sensor at the end of the belt (light barrier) detects the workpiece and the belt drive stops the motion. To start the sequence, the START push button is to be operated and the sequence is to be stopped when the light barrier is interrupted.

To Do List

- Create the SFC program that performs the functions of the sequence described in the GRAFCET diagram
- Use only qualifier N (no saving) in the actions of the steps
- Test de program on the rack station

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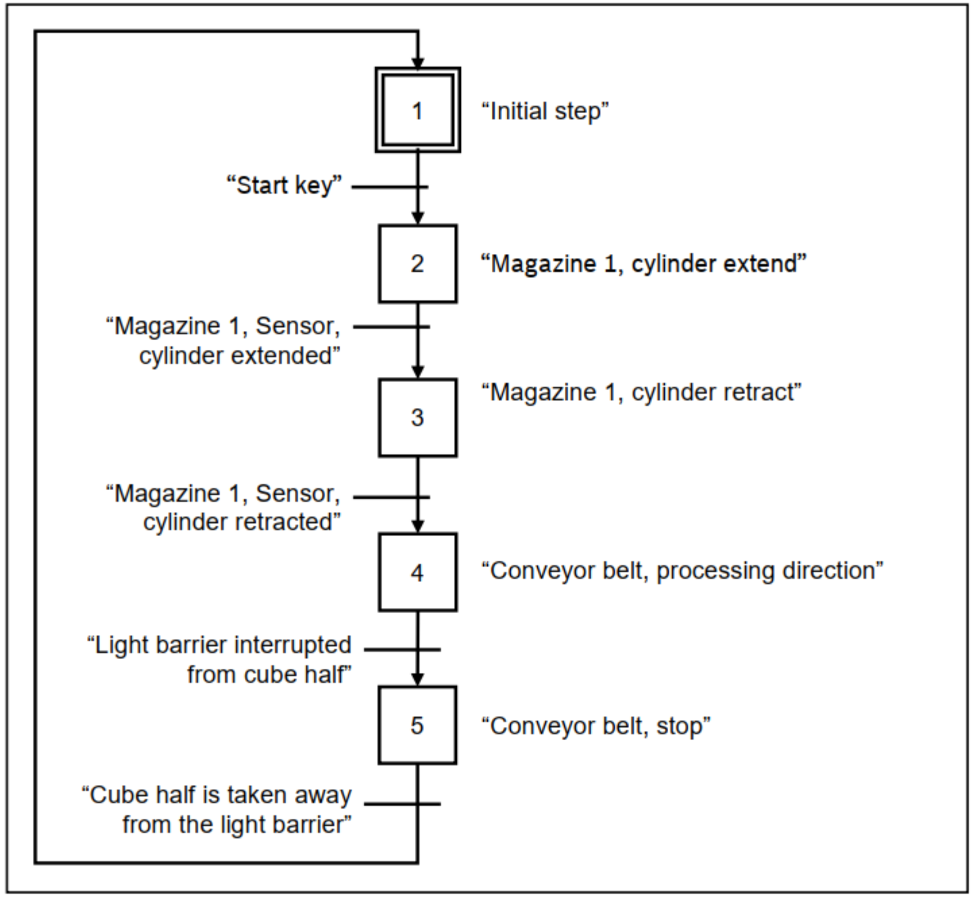
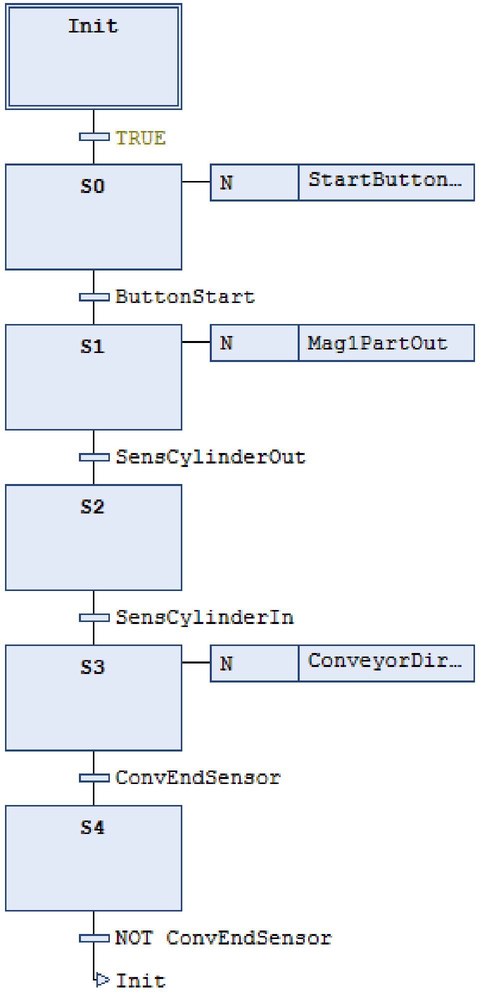
Task 1 – Transferring workpieces



GRAFCET automatic sequence



SFC implementation

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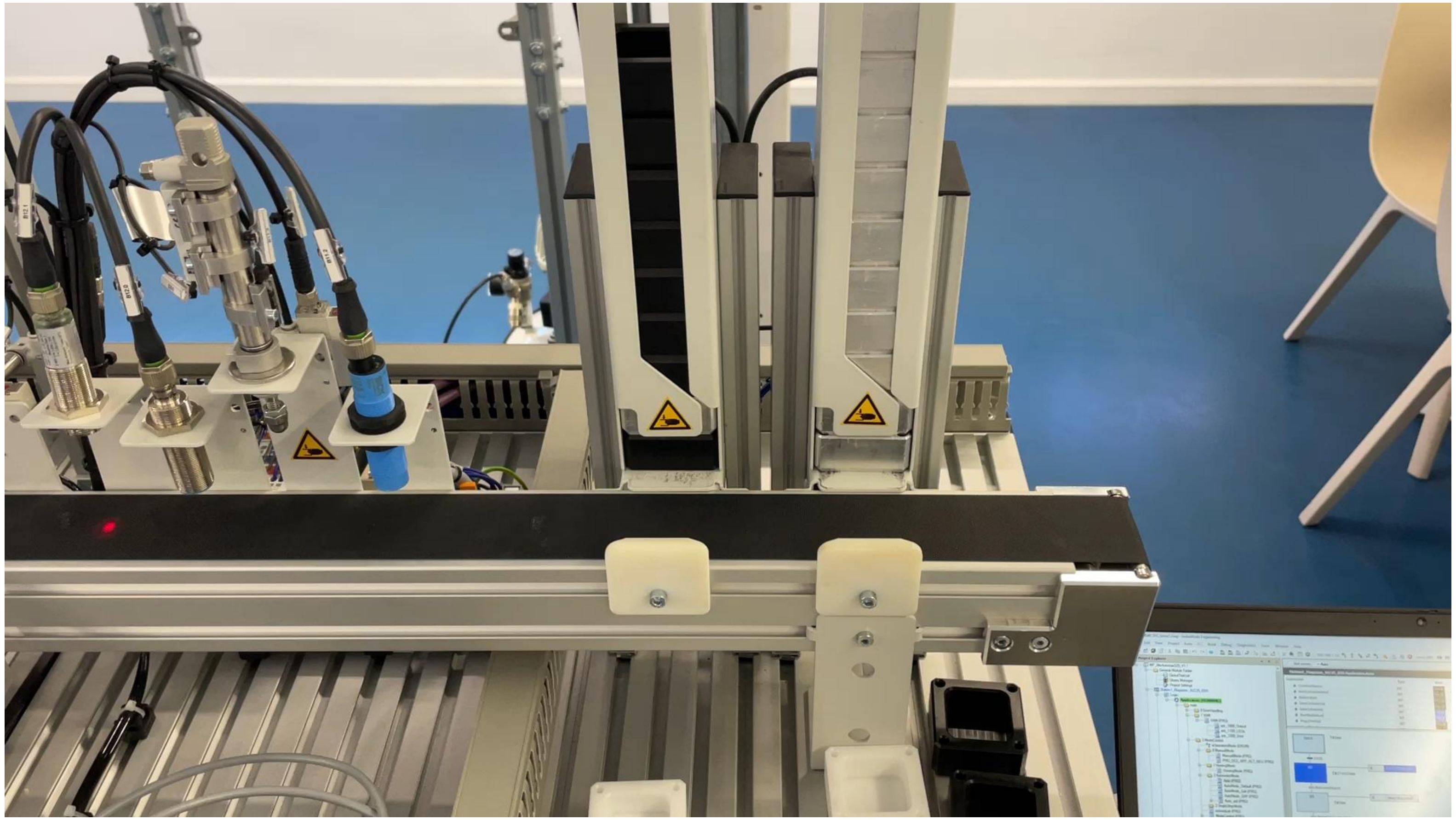
NextGEng

Task 1 – Transferring workpieces



Task 1 – experimental results

Task 2 – Sorting workpieces

Task 2 definition

- Extend the project by the following sorting function. Use the inductive sensor to identify metallic workpieces transferred on the conveyor belt. If the workpiece detected at the end of the conveyor belt is metallic than reverse the motion of the belt and eject the workpiece in the removal unit using the removal cylinder. If the workpiece is plastic the belt drive stops the motion.

To Do List

- Create the program that performs the functions of the sequence described in the GRAFCET diagram.
- Use only qualifier N (no saving) in the actions of the steps.
- Test de program on the rack station

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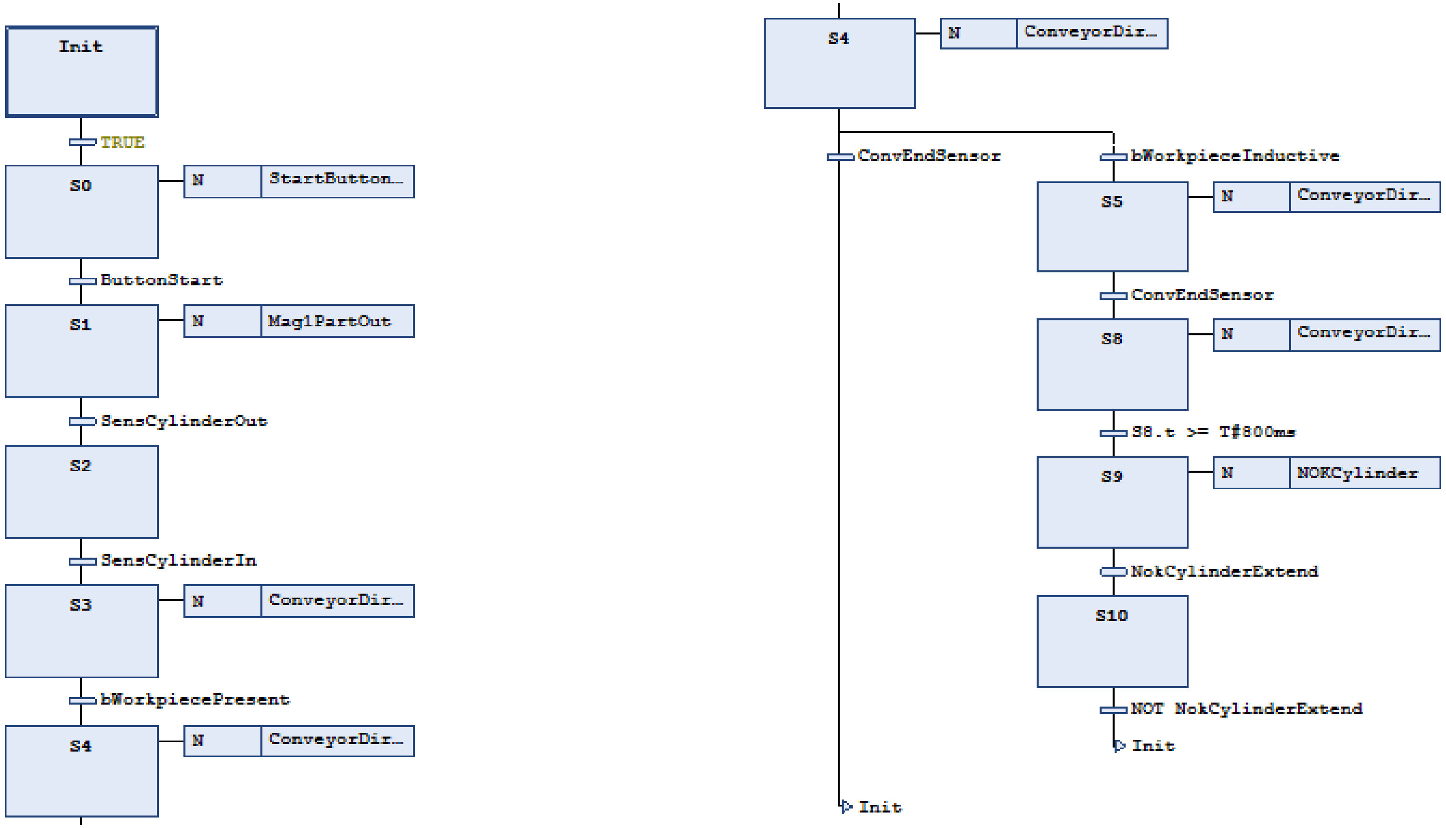
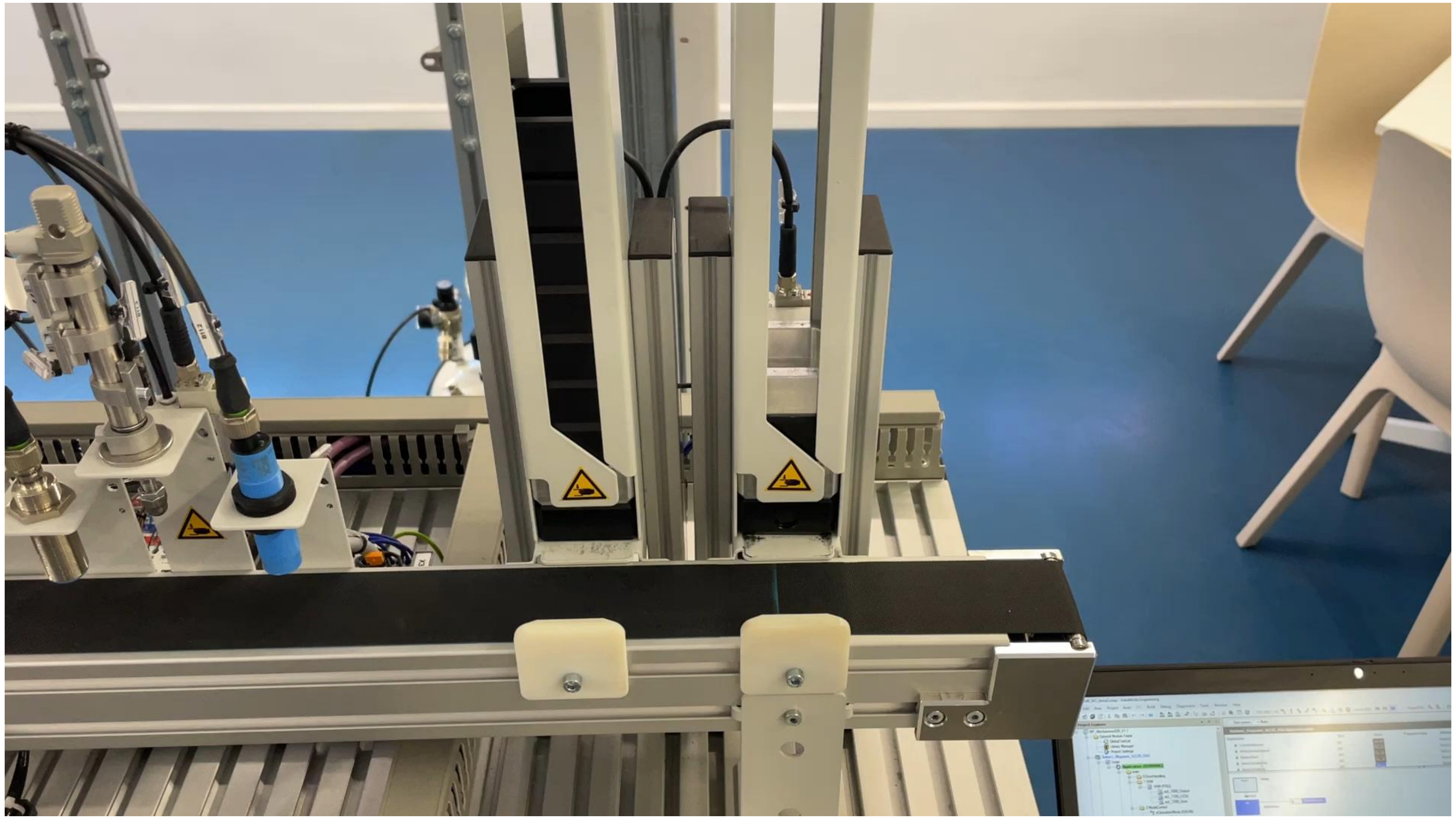
Task 2 – Sorting workpieces



SFC implementation

Task 2 – Sorting workpieces



Task 2 – experimental results

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Task 3 – LED signaling function

Task 3 definition

- Extend the project by the following signaling function. The LED from the START button will blink with a predefined frequency and after the START button is pressed the LED turns off.

To Do List

- Use LD and/or ST to implement de blinking function (see next slide for an example of LD/ST implementation)
- Use the predefined BLINK function from CODESYS
- Test de program on the rack station

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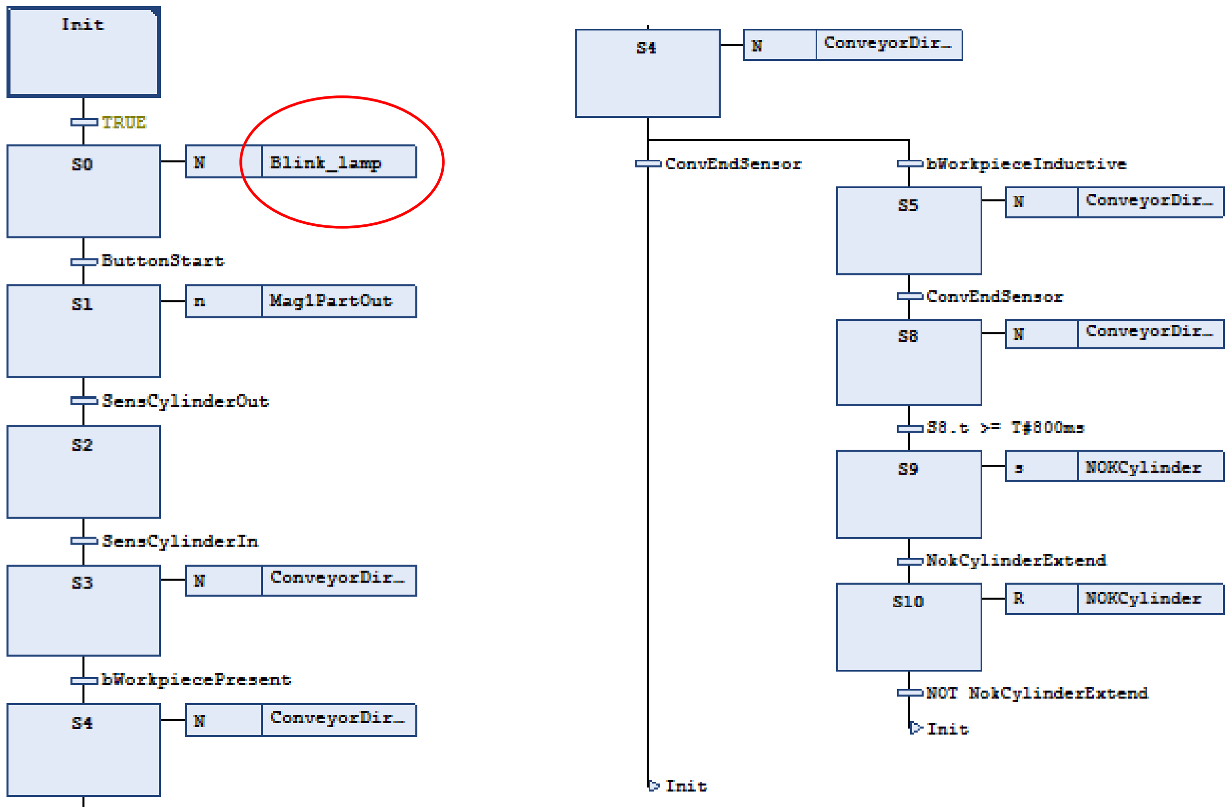
Task 3 – LED signaling function



SFC implementation

```
PROGRAM Blink_lamp
VAR
    Timer1 : TON;
    Timer2 : TOF;
    StartButtonLed      AT %QX104.6:    BOOL;          //  RIGHT KEYPAD LED_15
END_VAR
```

```
Timer1(In := NOT StartButtonLed, PT:= T#500MS);

IF Timer1.q = TRUE
THEN
Timer2(In:= TRUE, PT:=T#500MS);
END_IF

IF Timer2.Q = TRUE
THEN
Timer1(in := FALSE);
Timer2(IN := FALSE);
END_IF
StartButtonLed := Timer2.Q;
```

Task 3 – LED signaling function

Task 3 – experimental results

Simulation results

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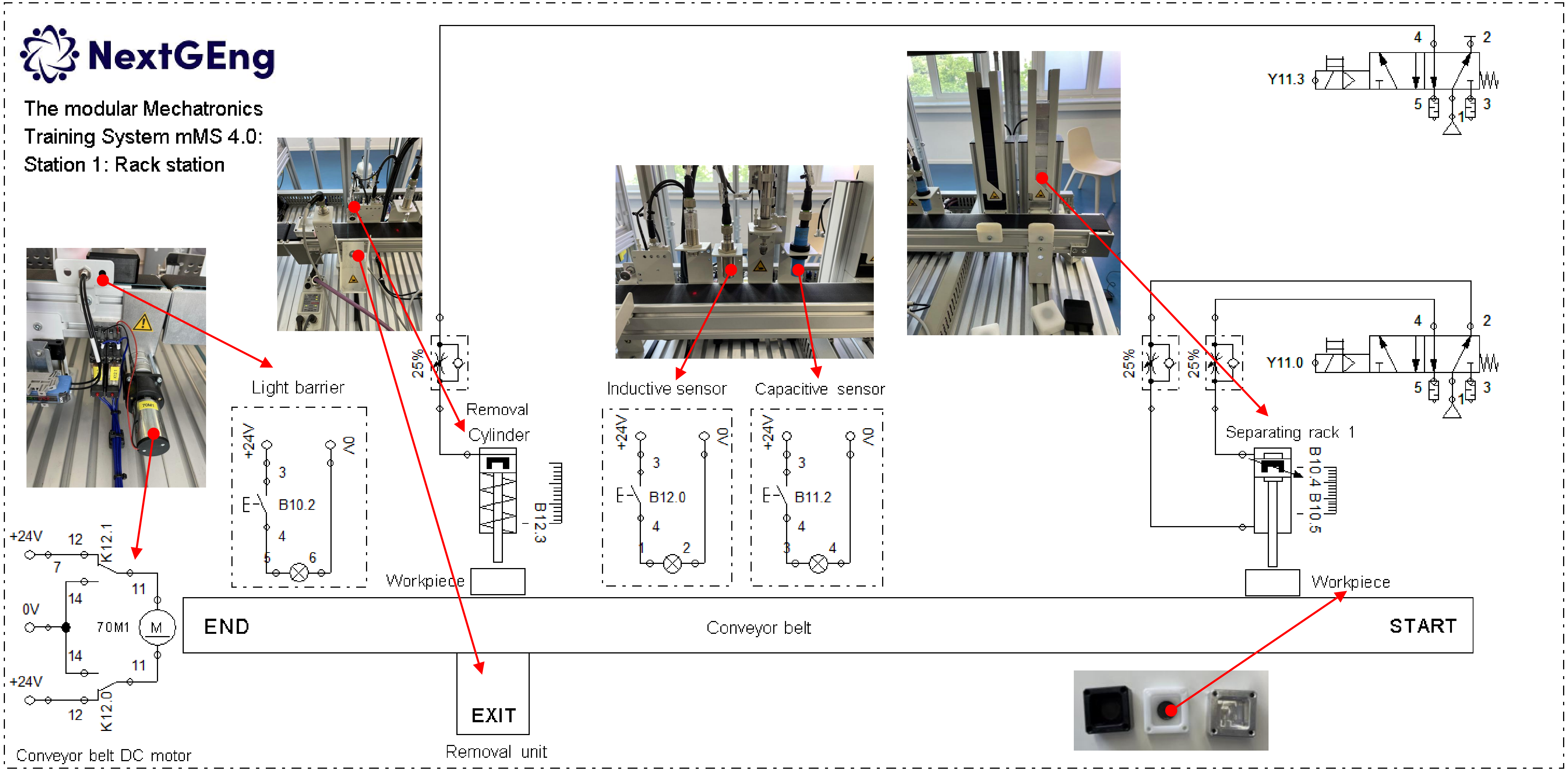
Electro-pneumatic circuit



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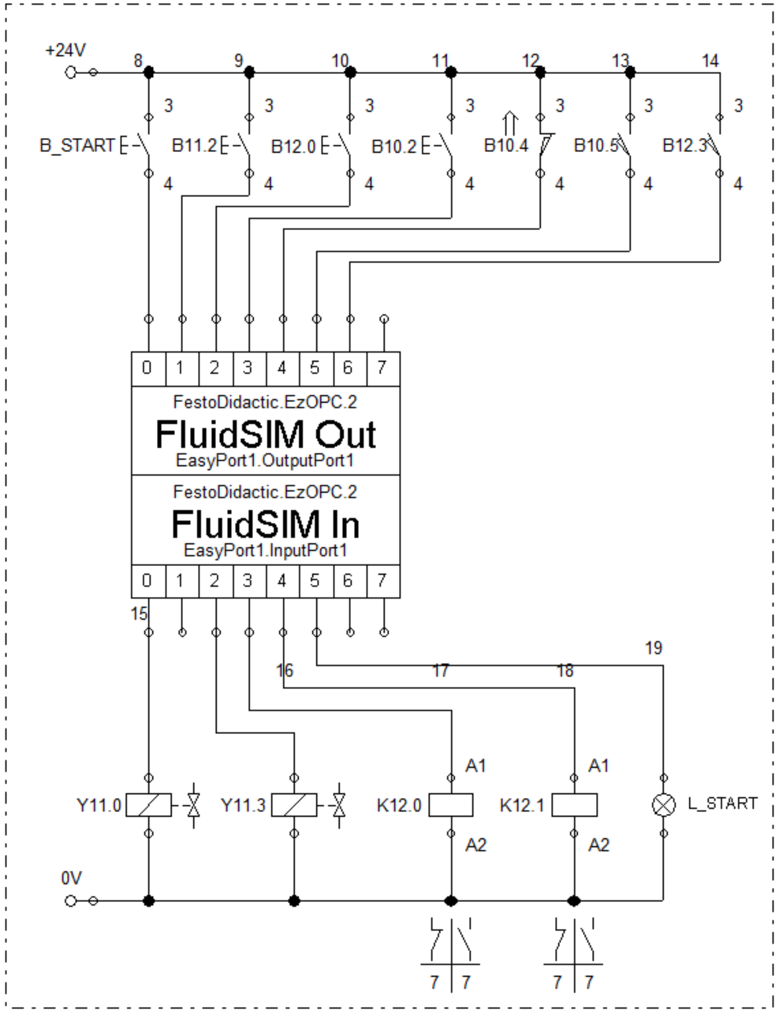
NextGEng

Electro-pneumatic circuit



Name	Attribute	Type	CODESYS address	Comments
B_START	[Input]	BOOL	INPUT0.0	Start Button
B11.2	[Input]	BOOL	INPUT0.1	Capacitive Sensor
B12.0	[Input]	BOOL	INPUT0.2	Inductive Sensor
B10.2	[Input]	BOOL	INPUT0.3	Conveyor End Sensor (light barrier)
B10.4	[Input]	BOOL	INPUT1.0	Magazine 1 retracted cylinder Sensor
B10.5	[Input]	BOOL	INPUT1.1	Magazine 1 extended cylinder Sensor
B12.3	[Input]	BOOL	INPUT1.4	Removal Unit Cylinder Sensor
Y11.0	[Output]	BOOL	OUTPUT0.0	Magazine 1 Extend Cylinder
Y11.3	[Output]	BOOL	OUTPUT0.2	Removal unit Extend cylinder
K12.0	[Output]	BOOL	OUTPUT0.3	Conveyor direction End
K12.1	[Output]	BOOL	OUTPUT0.4	Conveyor direction Start
L_START	[Output]	BOOL	OUTPUT0.5	Start Button Indicator LED

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Experimental results

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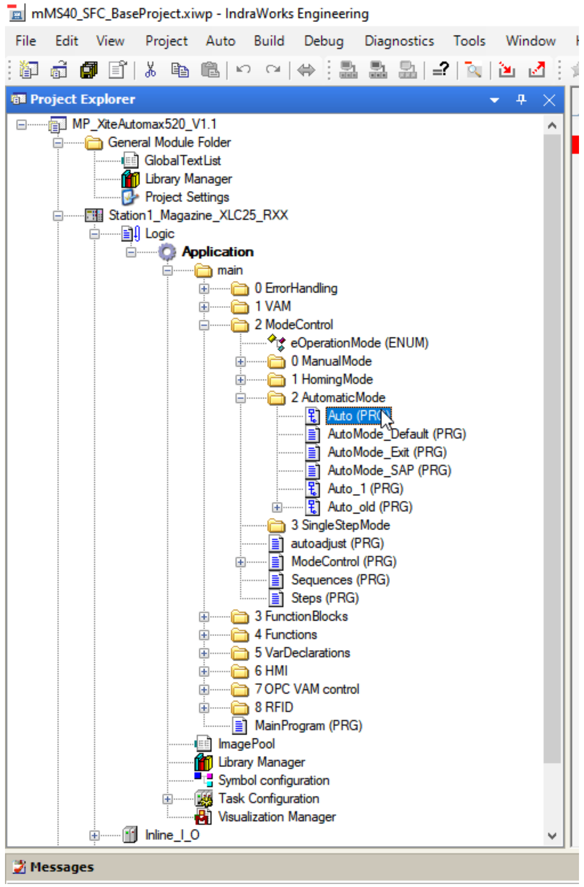
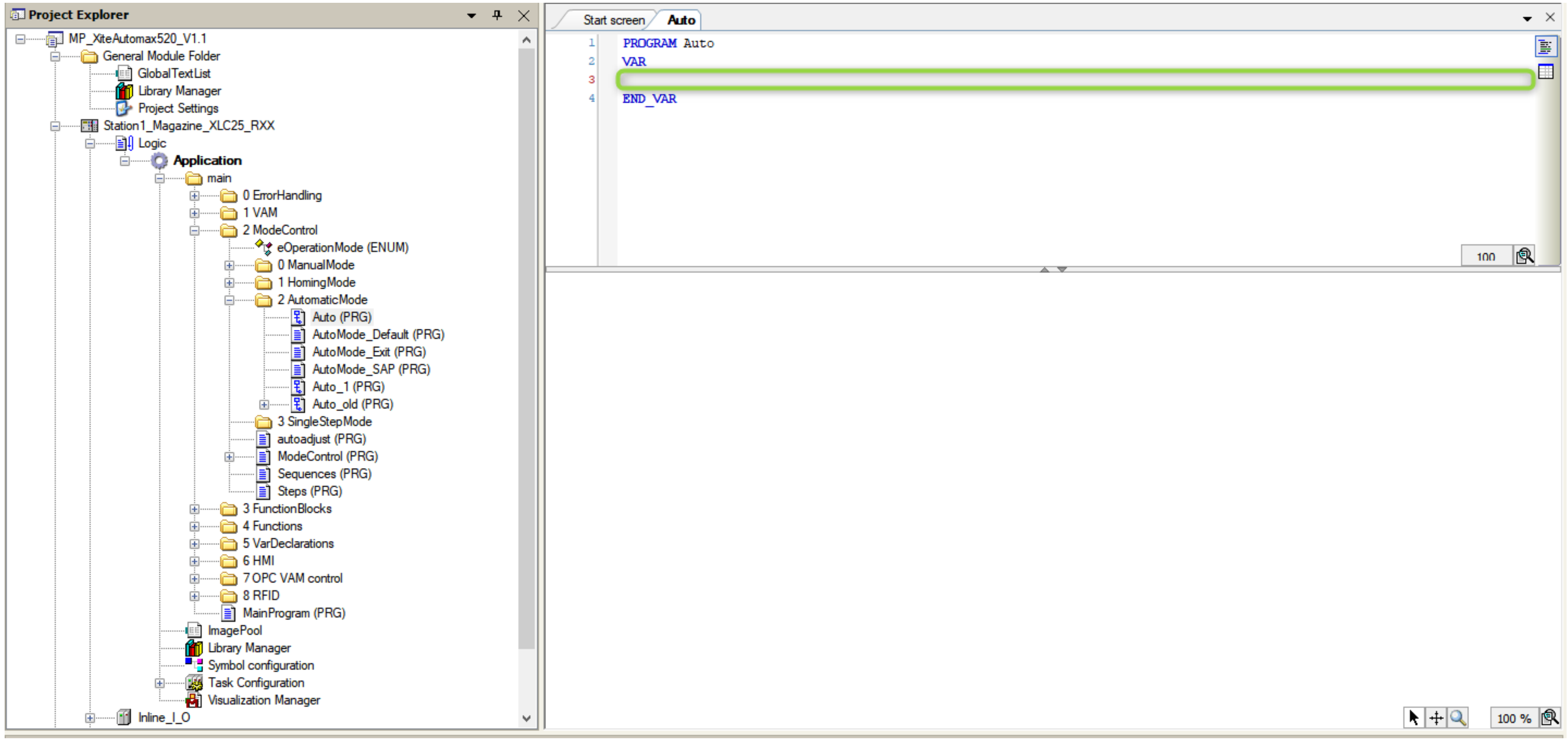
Project - mMS4.0: Rack station

Project configuration steps





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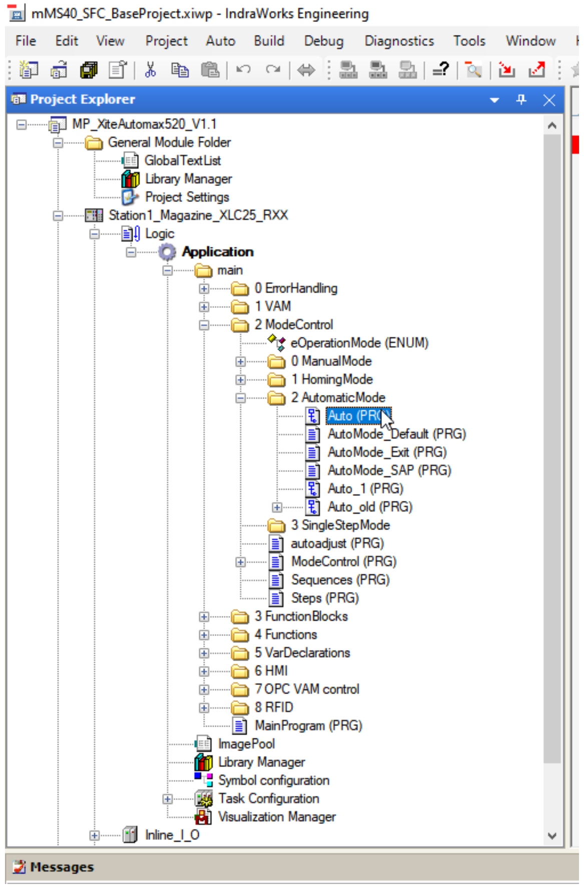
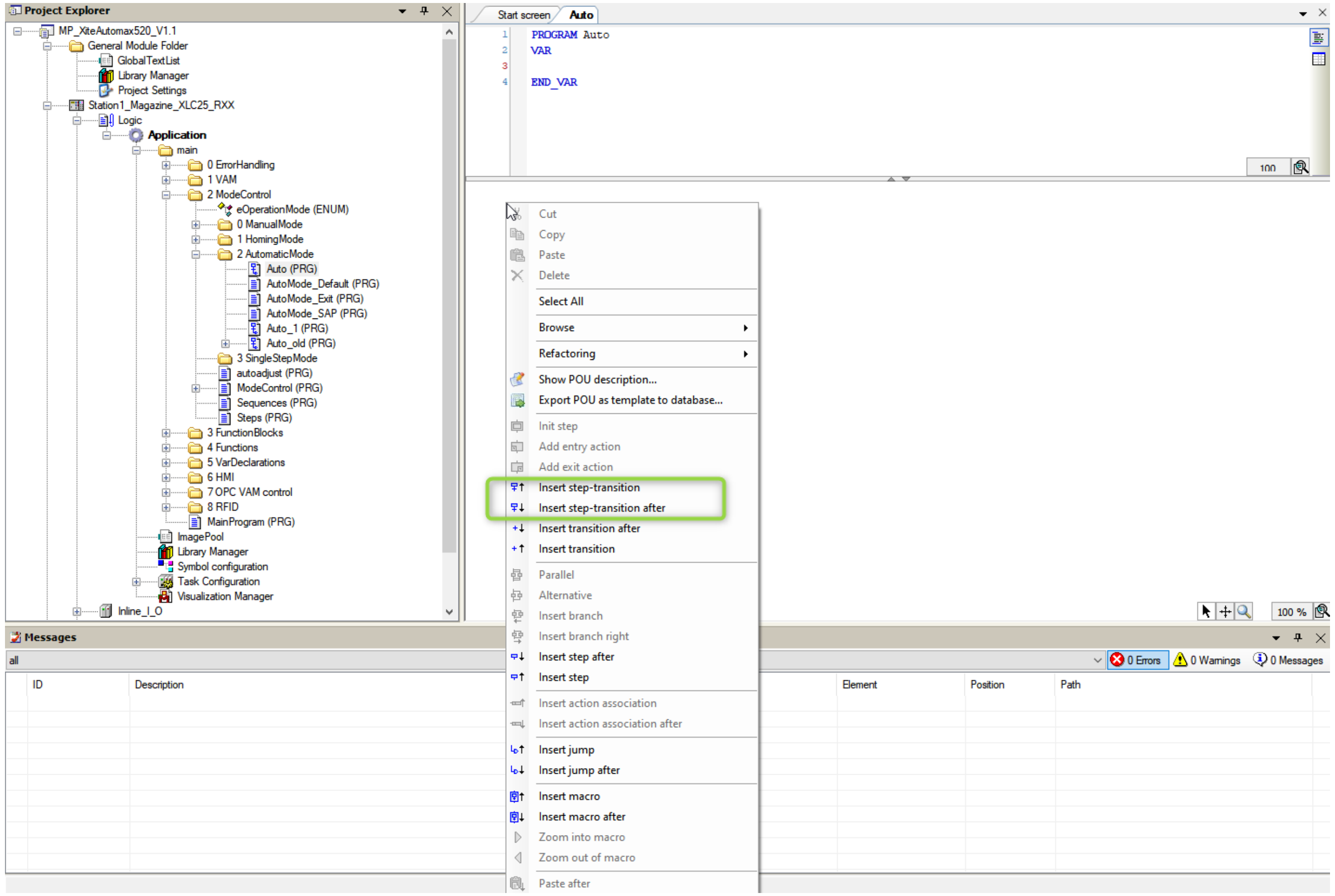
NextGEng

Project - mMS4.0: Rack station

Project configuration steps





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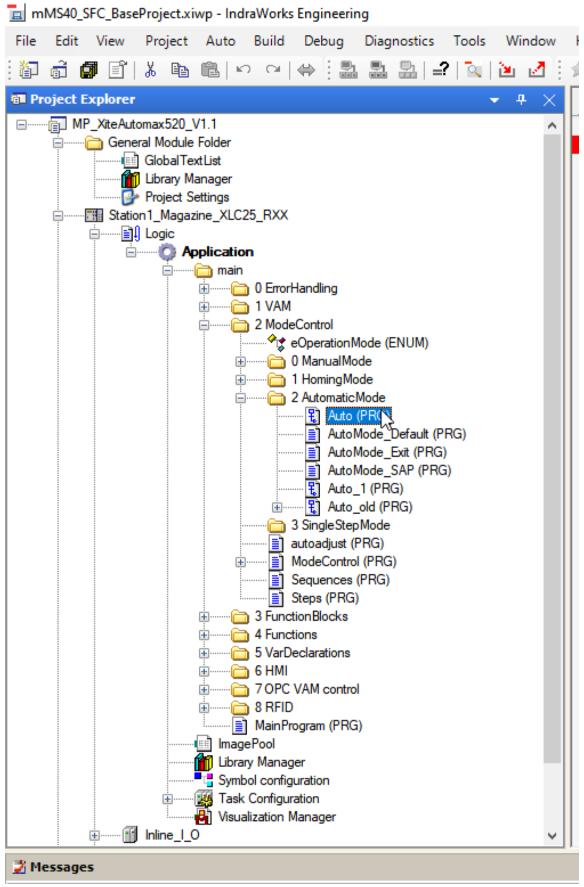
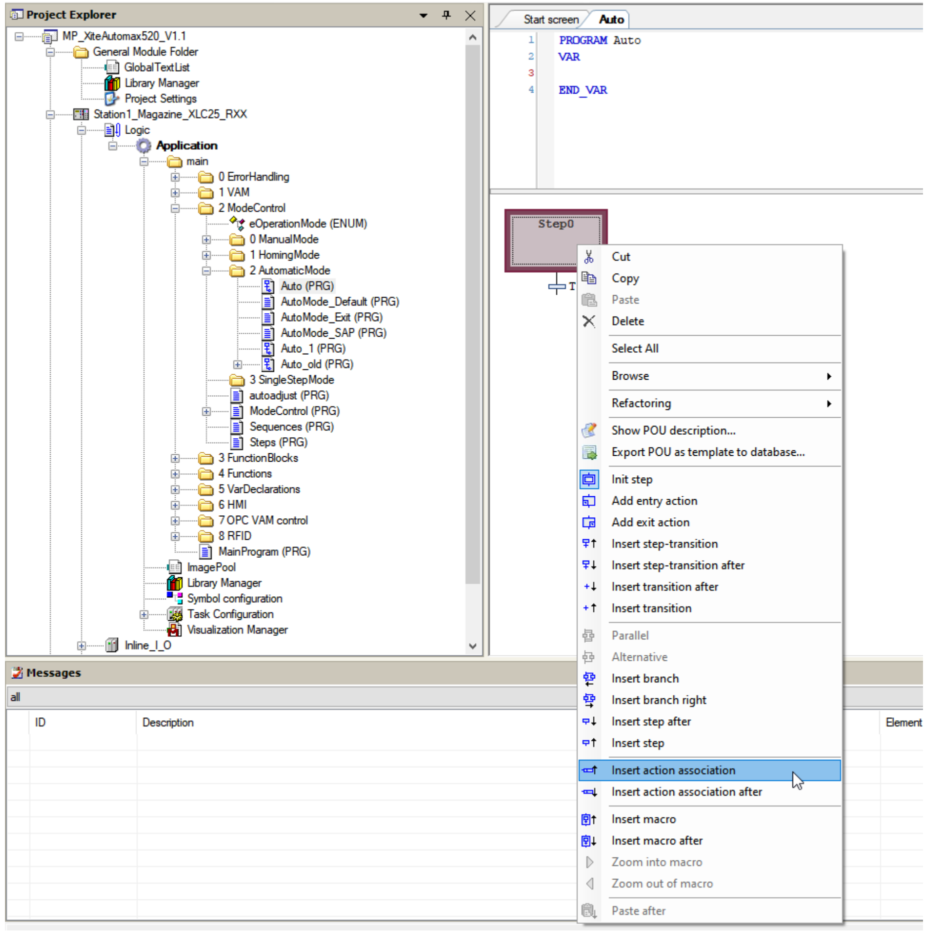
NextGEng

Project - mMS4.0: Rack station

Project configuration steps





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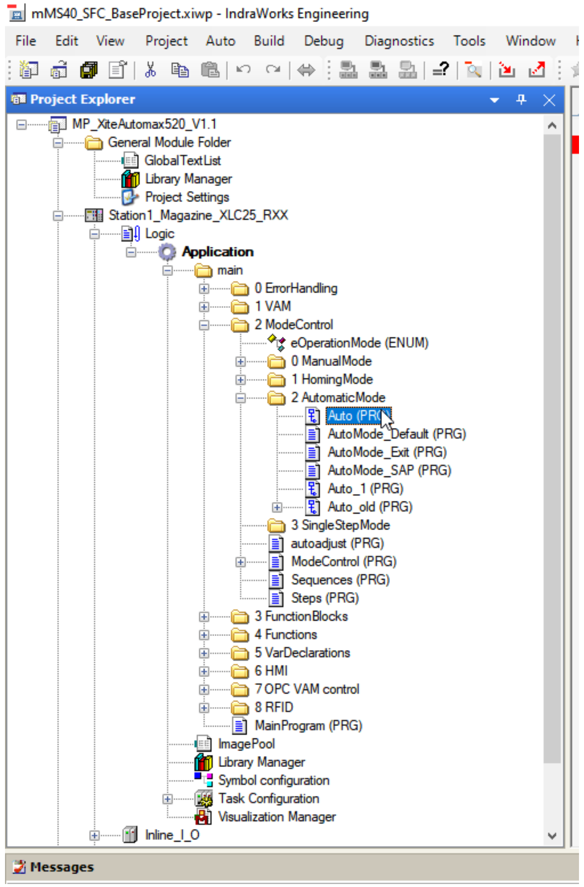
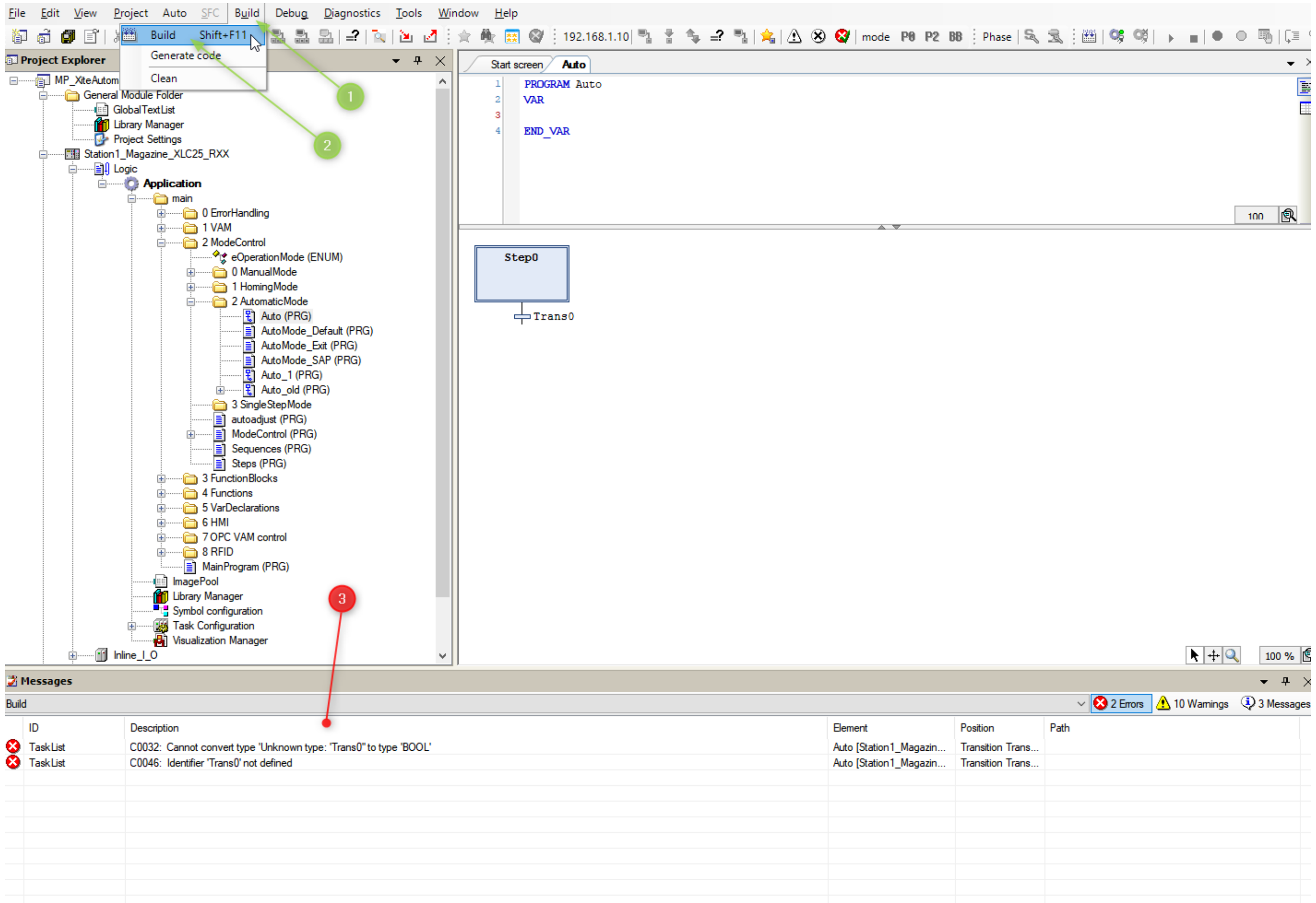
NextGEng

Project - mMS4.0: Rack station

Project configuration steps





Summary

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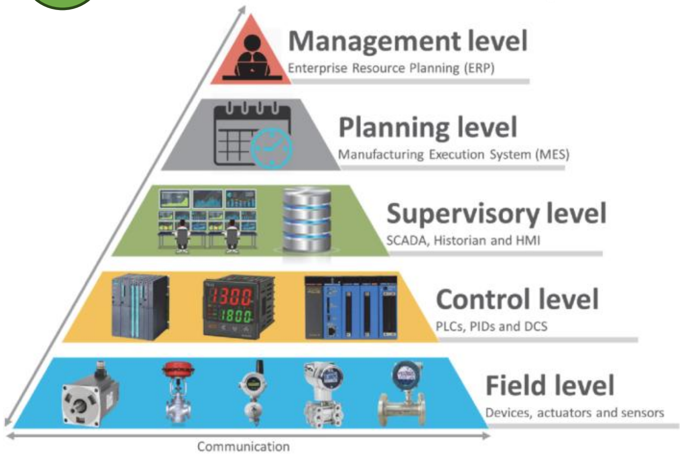
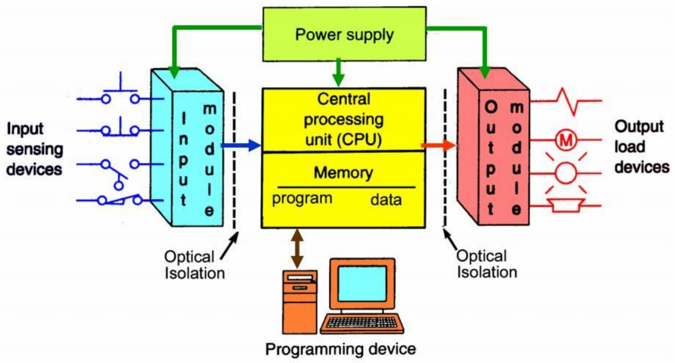
L2 – PLC Programming with Sequential Function Chart (SFC)

1 **Industrial Control System**



2 **PLC System**

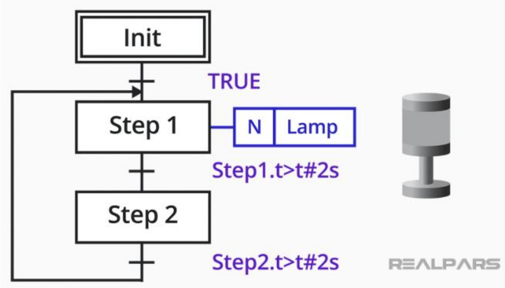


Source: Rahman, Moksadur, et al. 'A Framework for Learning System for Complex Industrial Processes'. AI and Learning Systems - Industrial Applications and Future Directions, IntechOpen, 17 Feb. 2021. Crossref, doi:10.5772/intechopen.92899.

3

IEC 61131-3:2013

- Ladder Logic Diagram (LD)
- Function Block Diagram (FBD)
- Instruction List (IL)
- Structured Text (ST)
- Sequential Function Chart (SFC)



The modular Mechatronics Training System mMS 4.0

4

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Sustainable development through Industry 4.0

Towards sustainable development

- To achieve these targets **engineering know-how** and **green skills** are needed for **Next GEneration Engineers**

- **Engineering know-how** means that engineers should be aware that an **efficient material and energy use, minimization of waste generation, reduction of fossil fuel use**, etc. in the development process of **engineering product/system/service** influence/impact the environment in a good way on long term

- **Green skills** are the knowledge, abilities, values and attitudes needed to live in, **develop and support a sustainable and resource-efficient society**

Thank you!

Kiitos!

Gracias!

Mulțumesc!

<u>Contact:</u>

- Ciprian RAD
- E-mail: ciprian.rad@mdm.utcluj.ro

NextGEng

nextgeng.eu

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C3 – Design Projects

L1 - How to scope a project in an Industrial Tech Company (ClickUp example)

P3 - ISR

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About NextGEng Project

- Three-year Erasmus+ Cooperation Partnership project that started in October 2022
- International consortium consisting of 3 universities and 3 companies from European countries
- Project co-funded by the European Union and coordinated by Technical University of Cluj-Napoca, Romania

Technical University of Cluj-Napoca	Integracion Sensorial y Robotica
Jamk University of Applied Sciences	Valmet Technologies Oyj
University of Jaén	Rober Bosch SRL

About NextGEng Project

- **NextGEng Project** aims to create new pedagogical models that promotes international team-teaching with the support of new learning materials for existing courses in the curricula

NextGEng comprises three types of activities

Training

Tailored training program for teachers that sustain the skill improvement of HEI partners staff in new/innovative teaching methods.

International Team-Teaching

international pilot program.
Upgrade a set of engineering courses, belonging to the HEI partners curricula, in close collaboration with companies' partners.

CEL Projects

Cases of Experiential Learning projects.
Type of projects where students learn by doing in an international and multidisciplinary environment.

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ISR Team

"With a background in Industrial Engineering (Jaén, Toulouse, Munich and Utah), I dedicated my first working stage to research in Industry 4.0 in general, being part of GRAV, R&D Group at UJA. After that, I had the opportunity to learn in some companies such as everis - NTTData (Madrid) or DDS (Frankfurt). I am currently part of the ISR management team, where I play the role of Co CEO & Production Director, having also been part of the Business Development team previously".

Juan Gómez García, Co CEO at ISR

How to scope a project in an Industrial Tech Company

Developer

iSR.es Specular Vision

https://isr.es/en/home/

Customer

ASPÖCK SYSTEMS

https://www.aspoeck.com/en

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How to scope a project in an Industrial Tech Company

Upon completion of this laboratory/seminar, the student will be able to:

1) Identify and scope requirements
2) Approach a development proposal
3) Develop a project planning
4) Manage a simplified project plan in ClickUP

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Content

1. Introduction
2. Project approach
3. Customer agreement ()
4. Project Manager Role
5. Project Planning
6. Case study

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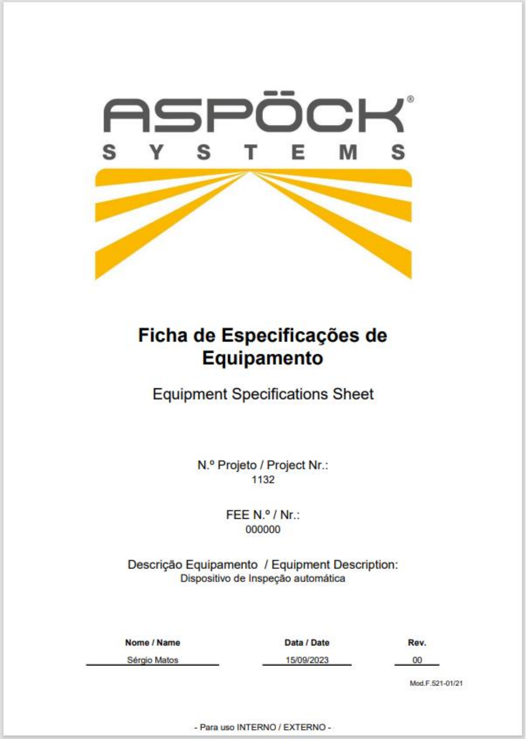
NextGEng



ASPÖCK SYSTEMS

Ficha de Especificações de Equipamento

Equipment Specifications Sheet

N.º Projeto / Project Nr.:
1132

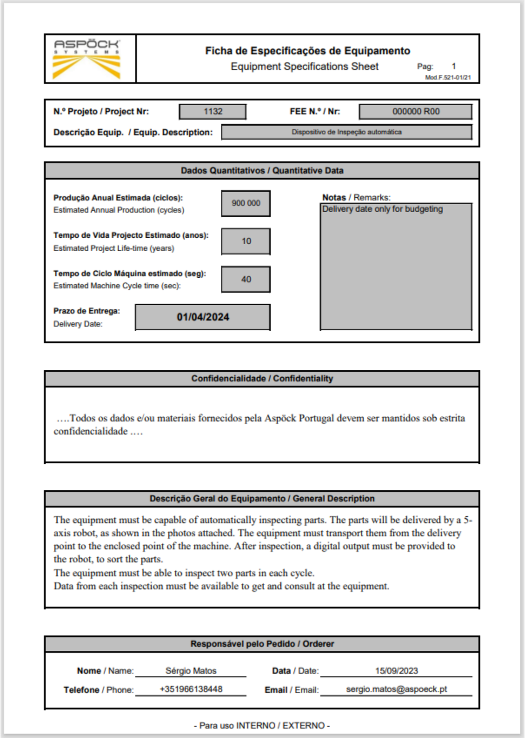
FEE N.º / Nr.:
000000

Descrição Equipamento / Equipment Description:
Dispositivo de Inspeção automática

Nome / Name	Data / Date	Rev.
Sérgio Matos	15/09/2023	00

Mod.F.521-01/21

- Para uso INTERNO / EXTERNO -



Ficha de Especificações de Equipamento
Equipment Specifications Sheet — Pag: 1
Mod.F.521-01/21

N.º Projeto / Project Nr: 1132 — **FEE N.º / Nr:** 000000 R00
Descrição Equip. / Equip. Description: Dispositivo de Inspeção automática

Dados Quantitativos / Quantitative Data

Produção Anual Estimada (ciclos): Estimated Annual Production (cycles)	900 000
Tempo de Vida Projecto Estimado (anos): Estimated Project Life-time (years)	10
Tempo de Ciclo Máquina estimado (seg): Estimated Machine Cycle time (sec):	40
Prazo de Entrega: Delivery Date:	01/04/2024

Notas / Remarks: Delivery date only for budgeting

Confidencialidade / Confidentiality

….Todos os dados e/ou materiais fornecidos pela Aspöck Portugal devem ser mantidos sob estrita confidencialidade ….

Descrição Geral do Equipamento / General Description

The equipment must be capable of automatically inspecting parts. The parts will be delivered by a 5-axis robot, as shown in the photos attached. The equipment must transport them from the delivery point to the enclosed point of the machine. After inspection, a digital output must be provided to the robot, to sort the parts.
The equipment must be able to inspect two parts in each cycle.
Data from each inspection must be available to get and consult at the equipment.

Responsável pelo Pedido / Orderer

Nome / Name: Sérgio Matos — **Data** / Date: 15/09/2023
Telefone / Phone: +351966138448 — **Email** / Email: sergio.matos@aspoeck.pt

- Para uso INTERNO / EXTERNO -

Introduction

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Introduction

ClickUp

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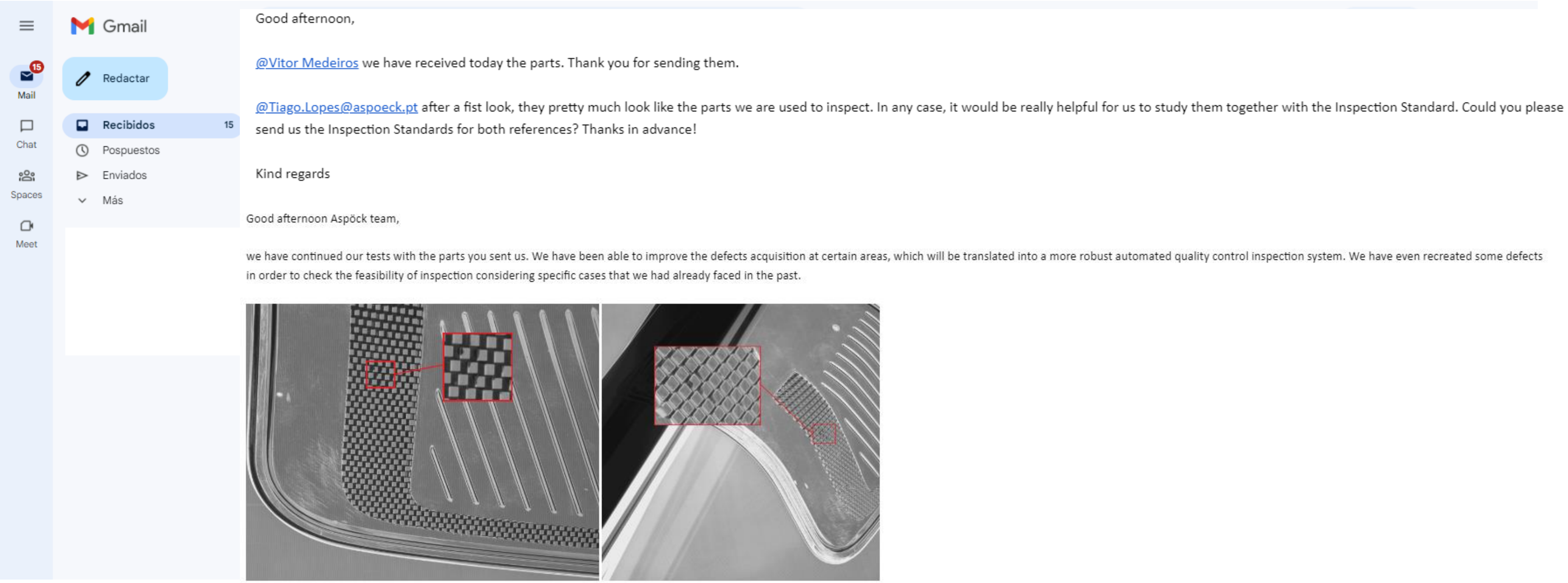
NextGEng



Good afternoon,

@Vitor Medeiros we have received today the parts. Thank you for sending them.

@Tiago.Lopes@aspoeck.pt after a fist look, they pretty much look like the parts we are used to inspect. In any case, it would be really helpful for us to study them together with the Inspection Standard. Could you please send us the Inspection Standards for both references? Thanks in advance!

Kind regards

Good afternoon Aspöck team,

we have continued our tests with the parts you sent us. We have been able to improve the defects acquisition at certain areas, which will be translated into a more robust automated quality control inspection system. We have even recreated some defects in order to check the feasibility of inspection considering specific cases that we had already faced in the past.

Topic 1 – Project Approach

Project Approach

What? – How? – When?

- Do we understand thoroughly what we have to do?
- Is there any information that is not clear enough and might be a risk?
- Are the customer expectations fully aligned with our project proposal?
- Are we able to identify which problems may occur during the development?

Asunto: RE: ISR - Aspöck. Surface Quality Control

Good afternoon David,

In attachment I am sending the Inspection standard for both lenses.

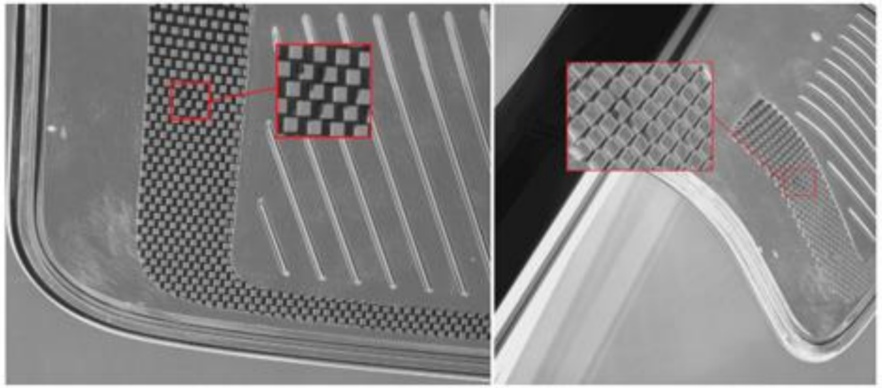
You can check both and compare with the parts that you now have.
In order for you to understand better our quality standards and the parts itself, I propose a MS TEAMS meeting.
We will be on holidays from 31st of July till 16th of August. After that will be convenient for us. What do you think?

Waiting for your feedback.

Cumprimentos | Best Regards

Tiago Lopes
Industrial Processes - Injection

ASPÖCK SYSTEMS



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iSR.es

OIT RL Inspection System
Specifications

ASPÖCK
SYSTEMS

Topic 2 – Customer agreement

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Customer agreement

The project starts when “the customer accepts your proposal”

Purchase Order

- Define milestones
- Give quotation
- Technical scope
- Estimated delivery dates
- Acceptance methods
- Limitations and considerations

INTEGRACIÓN SENSORIAL Y ROBÓTICA, SL
C/Mercedes Lamarque nº1
23009 Jaén
Phone number: 953 45 74 70
NIF: ESB23757164

iSR ® SPECULAR VISION

ASPÖCK PORTUGAL, SA
Rua do Paraíso, S/N
Zona Industrial de Rebordões
3720-796 VILA DE CUCUJÃES
VAT no: PT500643024

Number	Page	Date	Document
23066	1/1	04/10/2023	Quotation

Aspöck - OIT RL System

Description	Quantity	Total
Concept		
Optical Inspection Technology - OIT RL System **OIT Software Annual License**		
Material		
1 OIT RL System: - Vision System (11 cameras and optics) - Electronics and lighting (required electronics and 6 automated lighting systems) - Mechanical hardware (automatic door + maintenance doors + enclosure + main structure + actuators) - Electrical-Electronic (electrical cabinet + 3 screens -user interface and Scada- + PC + Switch + wiring) - Security elements and sensors - 2 x ABB Robots IRB 1200 0.9m		
Labour		
Mechanical design Electrical and Electronic design Software design: Communications and vision algorithms Development of electromechanical system Manufacture and integration of complete system Software development: Vision, Software Communications, PLC/HMI		
Set and follow -up		
Comissioning and installation of the system in customer site (Transport included following Incoterm DDP) Follow up and tuning period while validating the system: 2 weeks - 3 workers included		
Training and documentation		
Operators training with ISR experts included Documentation of the system included		
Note		
Further specifications about the system are defined in document: ***OIT RL Inspection System Specs - ISR***		

Enjoying Engineering

Total:
Discount (%)
Total:

IVA not included. All the amounts provided for in this document must be increased with the legally applicable percentage for VAT that is in force at all times.

Incoterm: DDP

Please, indicate nº of order: ____________.

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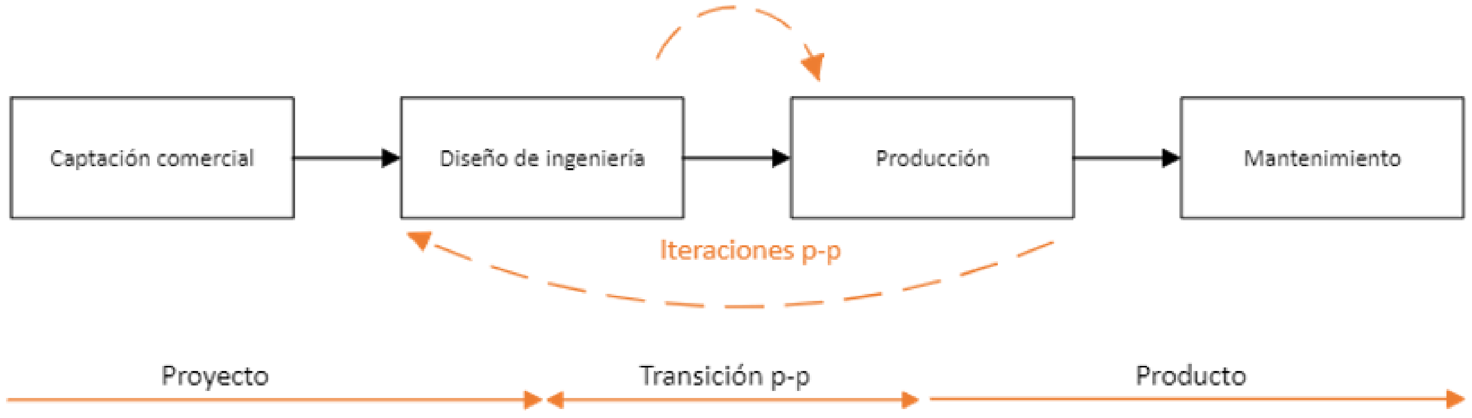

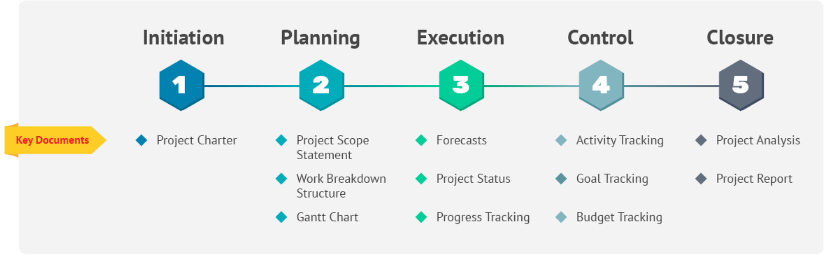

Topic 3 – Project planning

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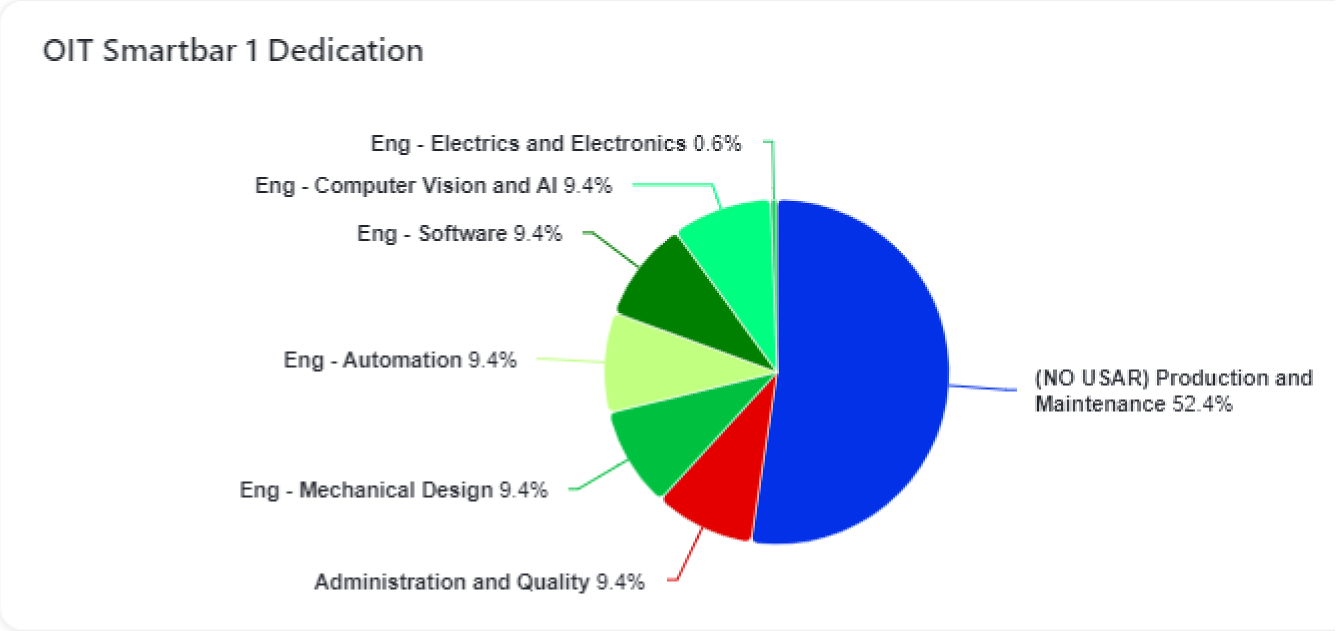
Project planning

Let's organize the project

TASKs:

- Transfer information to managers and teams
    - Help managers to define tasks
- Plan milestones according to customer’s needs
- Ensure technical and delivery date compliance
- Broadcast the objectives to managers



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Project planning

Tasks

Tasks + NUEVA TAREA AÑADIR DESCRIPCIÓN AÑADIR COMENTARIO

18 jul. 〉 9/4/24

P&M - Electrics | P&M - Electronics | P&M - Hardware Integration | P&M - Manufacturing | P&M - Software and Machine Vi... — 1 TAREA

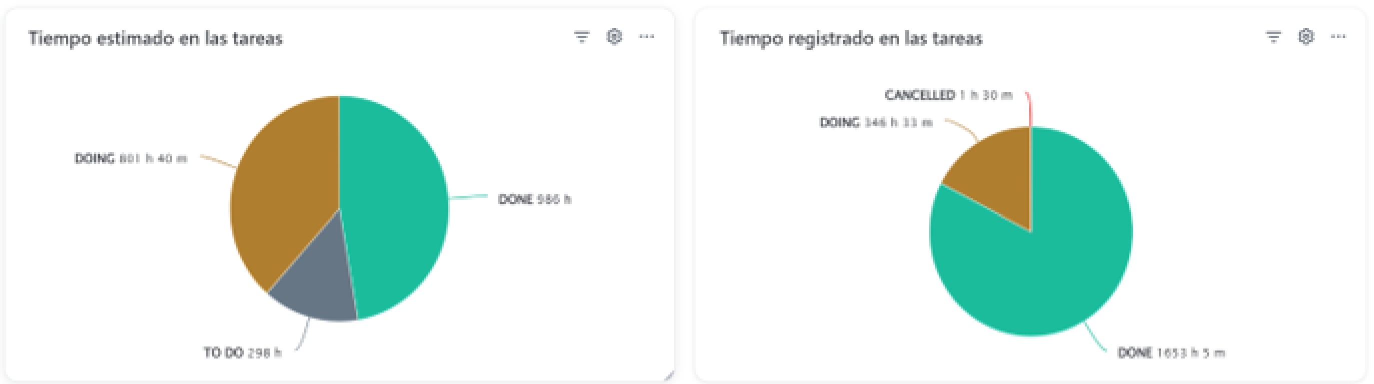
	PERSONA ASIGNADA	FECHA ...	FECHA LÍMITE	DURACIÓN E...	TIEMPO REGI...
Planning meeting P&M					0:00:00
+ Nueva tarea					

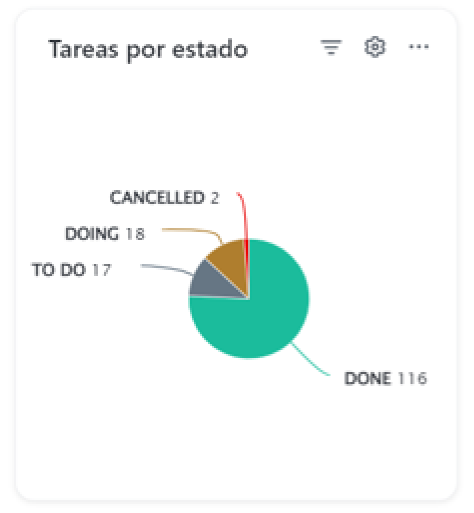
Project Management | Eng - Mechanical Design — 1 TAREA

	PERSONA ASIGNADA	FECHA ...	FECHA LÍMITE	DURACIÓN E...	TIEMPO REGI...
MECHANICAL DESIGN FINISHED		6 nov.	6 nov.		0:00:00
+ Nueva tarea		nov. 6	nov. 6		

Eng - Automation — 17 TAREAS

	PERSONA ASIGNADA	FECHA ...	FECHA LÍMITE	DURACIÓN E...	TIEMPO REGI...
Order & receive Kuka Robots (kuka)		4 sep.	30 nov.	2h	0:00:00
Order & receive PLC and accessories (fluitronic)		11 sep.	30 nov.	2h	0:00:00
HMI design		13 sep.	23/1/24	32h	20:00:00
PLC-Software program design		13 sep.	23/1/24	70h	0:00:00
Select electrical actuator		8 nov.	8 nov.	2h	0:00:00
Order & receive electrical actuators (acp)		10 nov.	30 nov.		0:00:00
Kuka robot analysis		1 dic.	1 dic.	25h	0:00:00
Kuka program design		5 dic.	5 dic.	24h	0:00:00





Topic 4 – Project manager role

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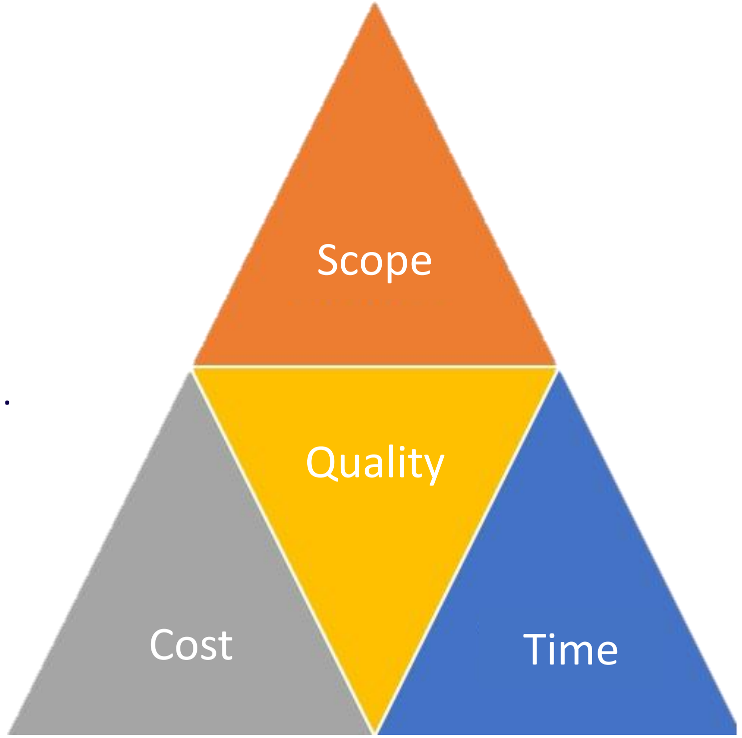
Project manager role

Subtitle

- Be a diligent, respectful and caring steward
- Create a collaborative environment in the project team
- Engage effectively with stakeholders
- Focus on value: continuous assessment of the project to ensure alignment with value/benefit creation.
- Recognize, evaluate and respond to system interactions.
- Demonstrate leadership behaviour
- Adapt according to context
- Embed quality in processes and deliverables
- Navigate complexity
- Optimize responses to risks
- Embrace adaptability and resilience
- Enable change to achieve the intended future state



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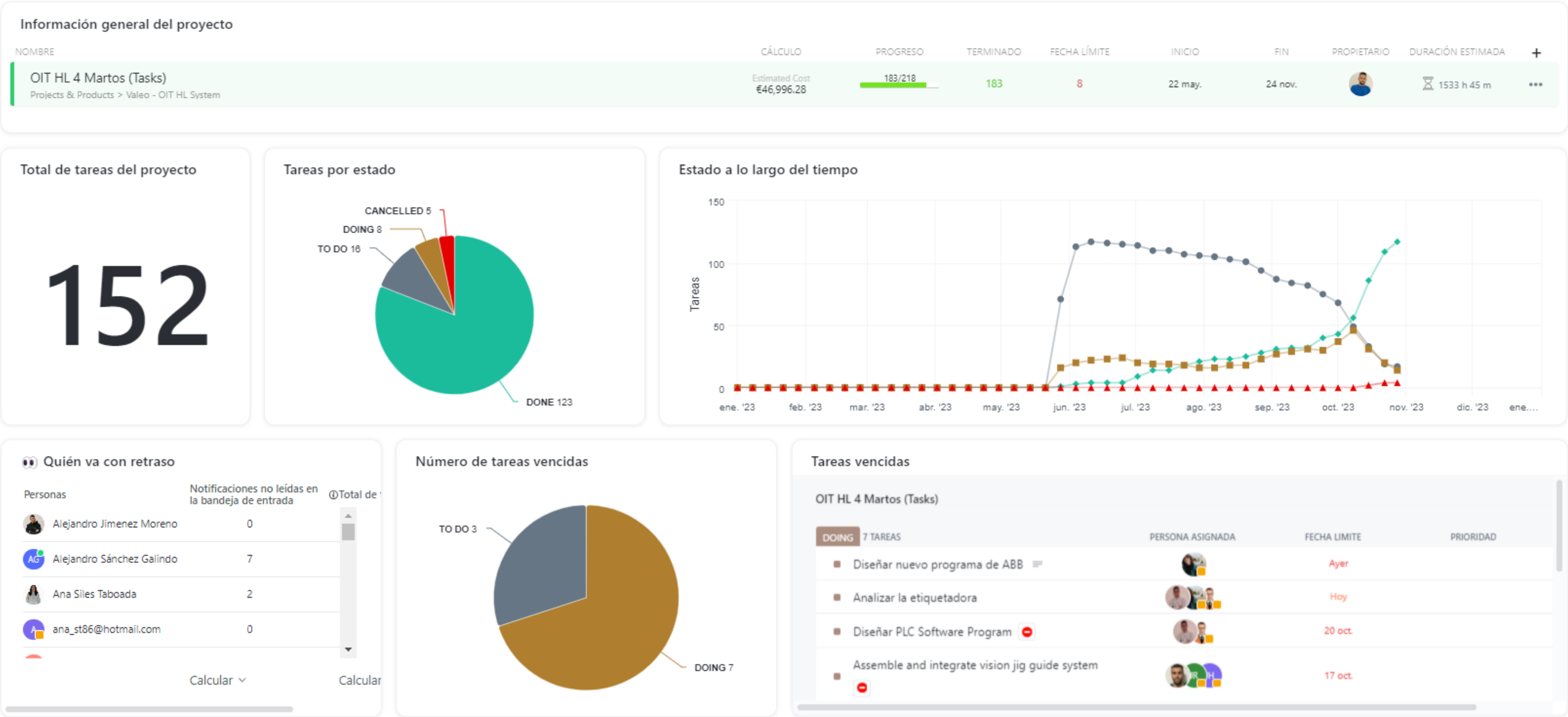
Project manager role



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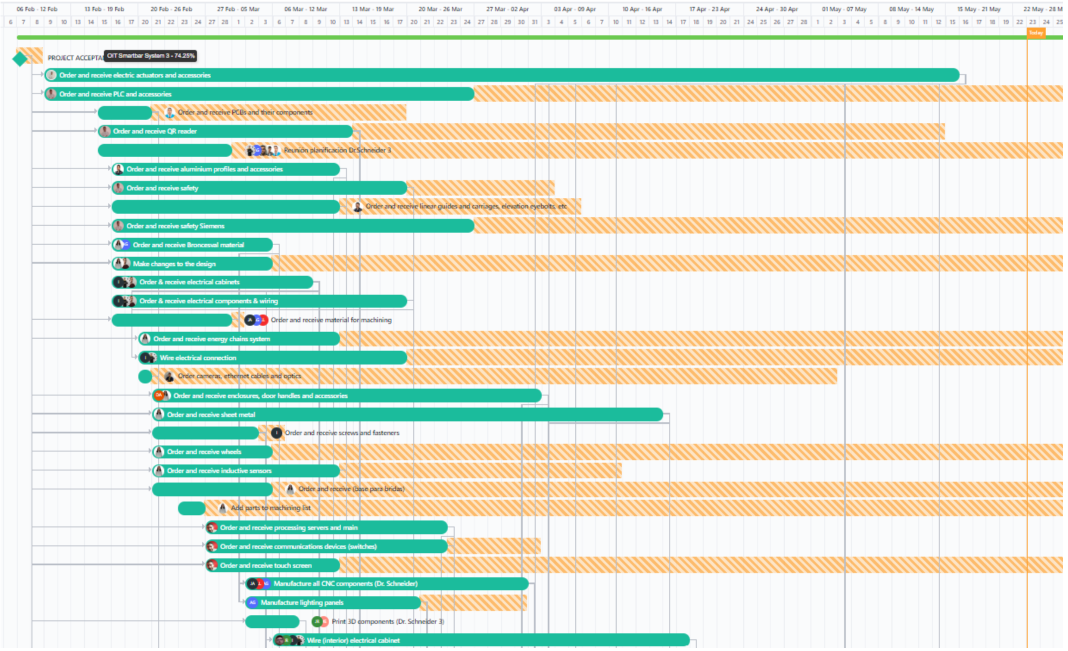

ClickUp

Topic 5 – Case study

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NextGEng

Case study

Scenario & data

- Customer: Aspöck
- Place: Portugal
- Delivery Date: 01/04/2024
- Documents: Equipment Specifications Sheet, ISR Offer, Aspöck-ISR emails.

Descrição Geral do Equipamento / General Description
The equipment must be capable of automatically inspecting parts. The parts will be delivered by a 5-axis robot, as shown in the photos attached. The equipment must transport them from the delivery point to the enclosed point of the machine. After inspection, a digital output must be provided to the robot, to sort the parts. The equipment must be able to inspect two parts in each cycle. Data from each inspection must be available to get and consult at the equipment.

Requisitos Documentais / Documental Requirements

Documentação a Validar ao Longo do Projeto / Documentation to Validate Throughout the Project	OK	NOK	N/A
Apresentação de Projecto Preliminar / Preliminary Project Presentation			
Apresentação de Planeamento do projecto / Project Planning Presentation			
Declarações de Conformidade de acordo com Directivas CE aplicáveis / Conformity Declarations according with applicable CE Directives			
Manual de Utilização e Manutenção em Língua Portuguesa / User and Maintenance Manual in Portuguese Language			
Modo Operatório / Operation Procedure			
Desenho Técnico / Technical Drawing (2D, 3D)			
Diagramas Técnicos (esquema elétrico, pneumático, outros) / Technical Diagrams (electrical, pneumatics, others)			
Certificado de Garantia / Warranty Certificate			
Matrícula do Equipamento com certificação CE fixada no equipamento / Equipment registration with CE certification fixed on the equipment			
Plano de Manutenção / Maintenance Plan			
Lista de peças de desgaste / Spare Parts List			

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C3 – Design Projects

L2 - Concept design of a test object for a pressing-based manufacturing process

P4 - VALMET

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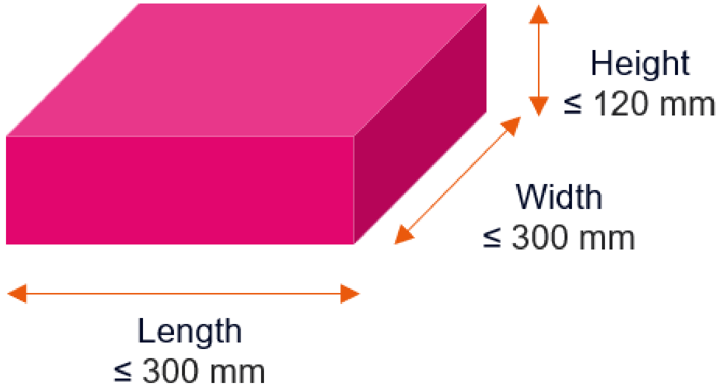
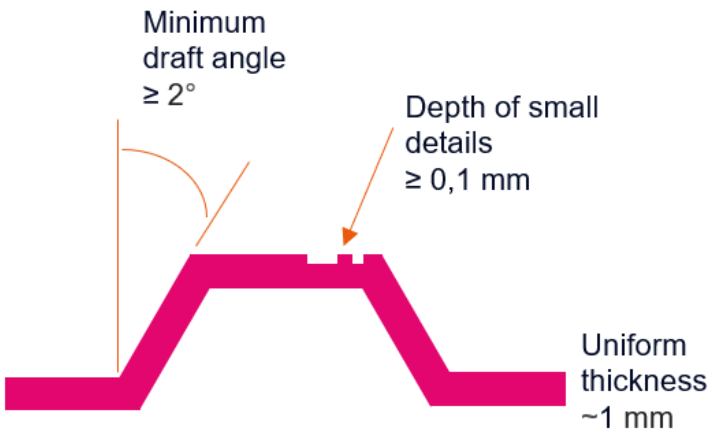
Concept design of a test object for a pressing-based manufacturing process





Valmet

Minimum letter height ~3 mm

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NextGEng

Concept design of a test object for a pressing-based manufacturing process

Laboratory overview:

Objectives	• The objective is to design a concept test object that satisfies real industrial constraints for a pressing-based manufacturing process. Students will interpret Valmet's technical requirements, create a functional and manufacturable geometry containing varying features (slopes, corners, depths, details, and mechanisms), and prepare a digital 3D model suitable for later mold development.
Pre-requisite	• Basic understanding of CAD modeling (preferably CATIA V5/V6 or similar). • Ability to interpret engineering drawings, technical limits, and dimensional constraints.
Equipment used for laboratory	• PCs with CATIA V5/V6 or similar

Concept design of a test object for a pressing-based manufacturing process

Upon completion of this activity, the student will be able to:

1) **Apply industrial constraints to a functional 3D design** - integrate real manufacturing requirements—such as draft angles ≥2°, uniform 1 mm thickness, minimum detail sizes, and maximum footprint—into a coherent, manufacturable test object.

2) **Create and validate a complex CAD model that includes feature variety** - produce a digital model containing required geometries (steep/gentle walls, rounded/sharp corners, deep/shallow shapes, intersections, small text, and optional mechanisms) while ensuring compliance with all technical limitations.

3) **Demonstrate engineering reasoning in balancing design creativity with technical feasibility** - justify their design decisions, evaluate manufacturability, and reflect on how design constraints influence product geometry and performance.

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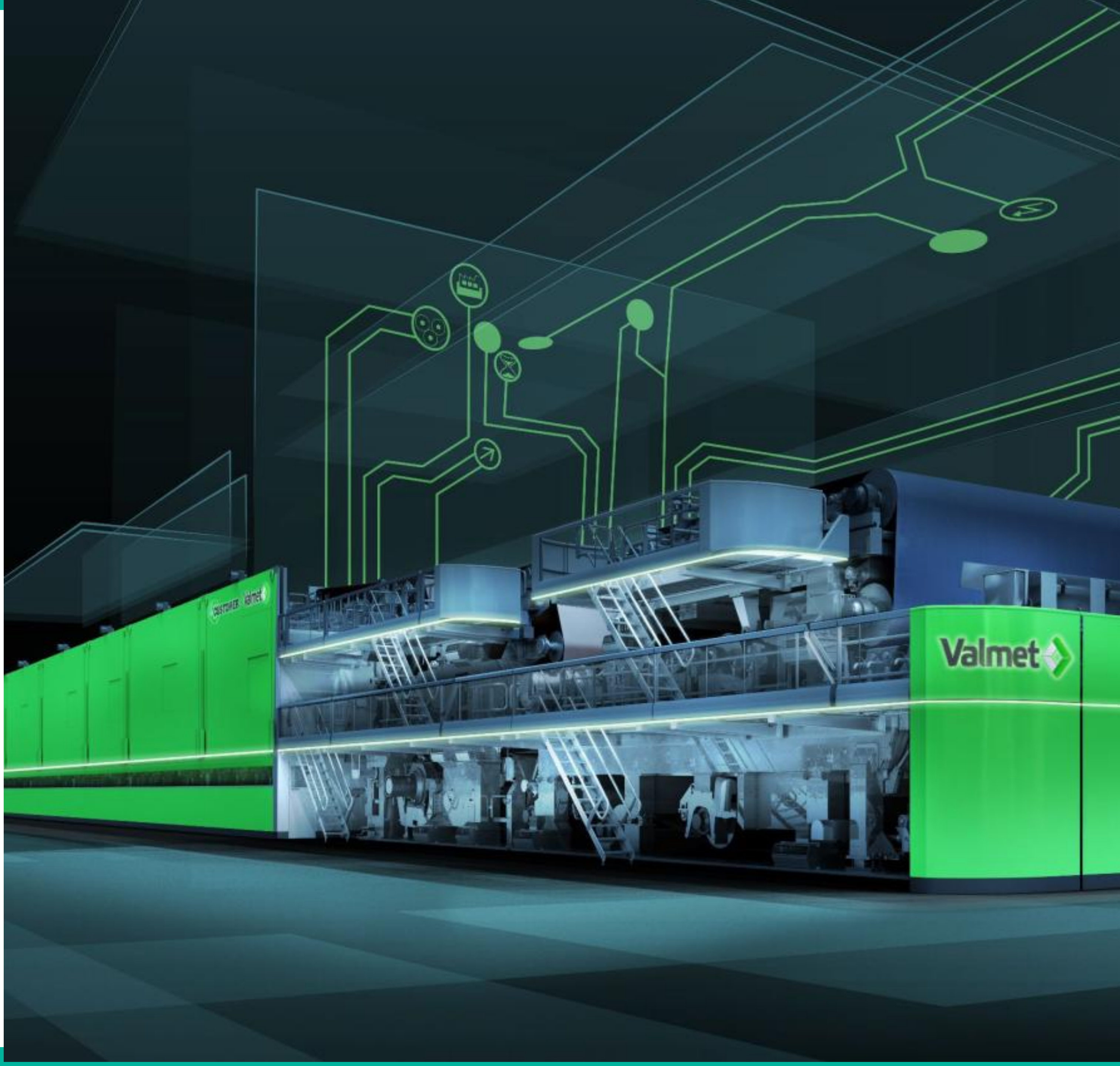
NextGEng

Content

- Introduction
- Features to be included
- Technical limitations
- Other ideas
- Expected output
- Summary, Discussions & Feedback



Introduction

- Valmet is developing a new, pressing manufacturing process for pulp-based products
- A test object with a variety of purpose-designed geometries is needed to find the correct process parameters and validate that the machine is working as intended.
- The ultimate goal is to build a mould that can be used to produce this test object. However, this laboratory exercise is limited to the concept design of the test object.

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Features to be included

- Walls of different steepness (different angles): At least one steep wall and one gently sloped wall
- Corners of varying sharpnessess: At least one rounded corner and one sharp corner
- Shapes of varying depths: At least one deep shape and one shallow shape
- Intersections and points of discontinuity
  - These can represent, for example, different compartments on a clamshell-type food packaging
- Small details of varying sizes
  - For example logos, small text, and other kinds of detailed imprints
  - Utilizing Valmet's logo and/or the company's other brand elements should be preferred
- Pivoting element(s) and/or other kinds of mechanisms that allow for rotation or moving of the parts of the object in relation to each other
  - E.g. hinge on a clamshell-type food packaging
- Surfaces of various complexities: flat, single curvature, double curvature, and complex double curvature. One or more of these should contain a changing radius.

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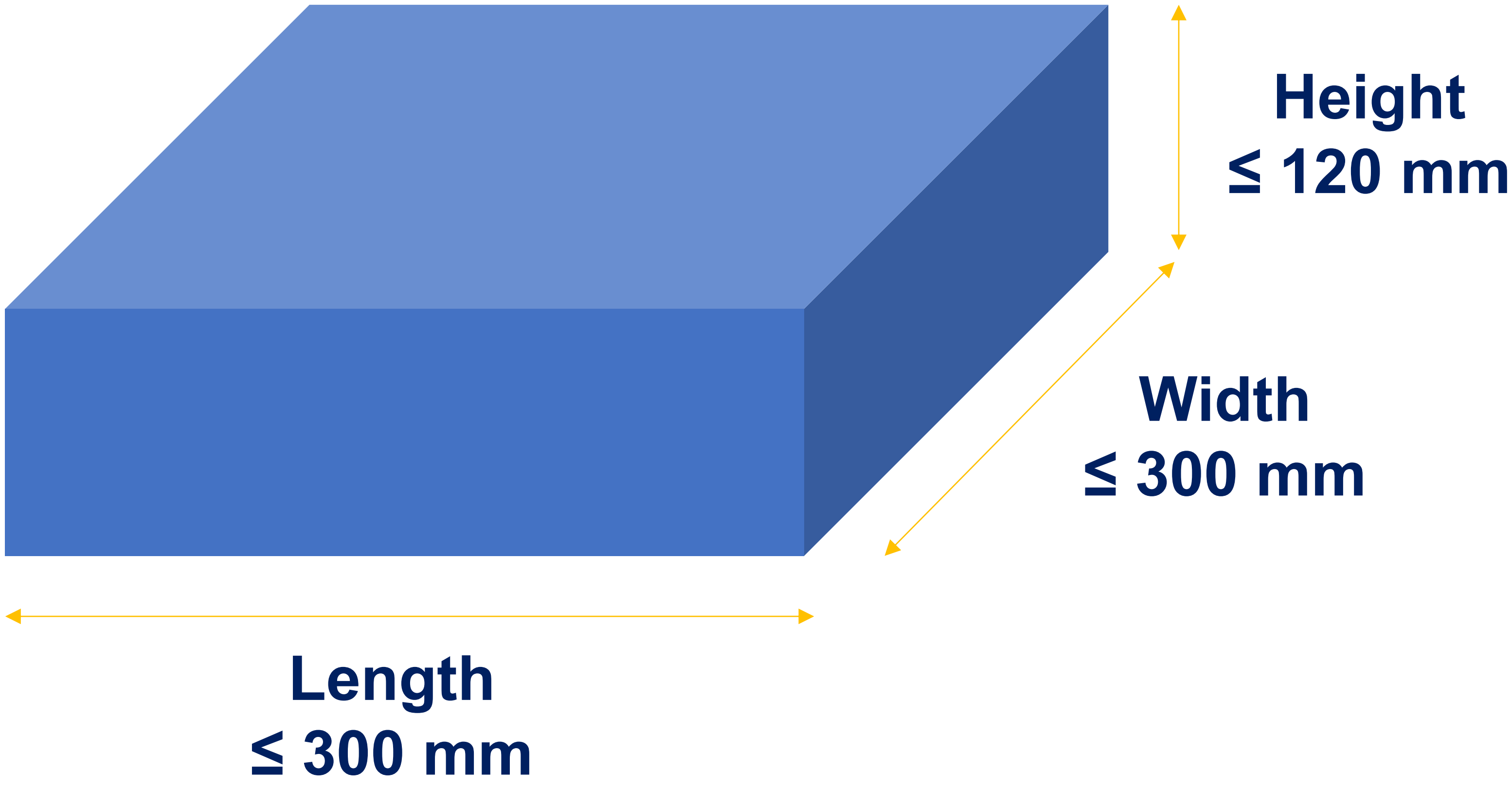
Technical limitations | Maximum dimensions



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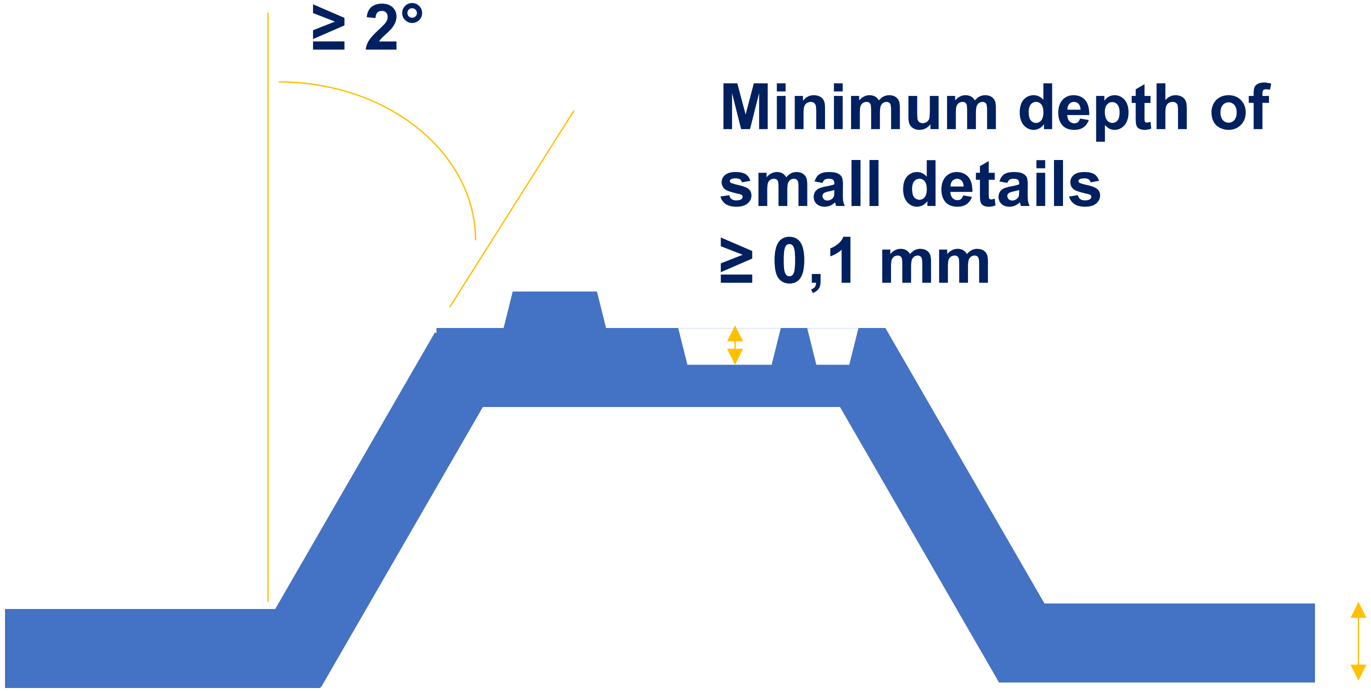
TECHNICAL UNIVERSITY OF CLUJ-NAPOCA
jamk
Universidad de Jaén
iSR www.isr.es
Valmet
BOSCH Invented for life

Technical limitations | Details, side view

Minimum draft angle ≥ 2°

Minimum depth of small details ≥ 0,1 mm



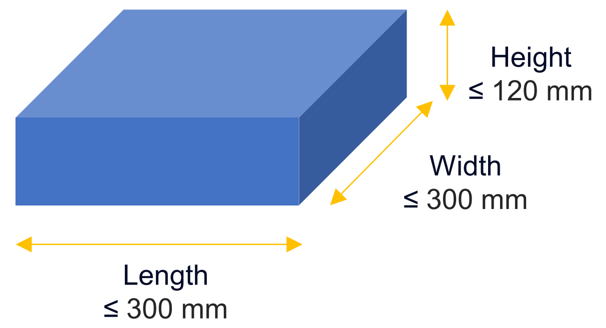
Uniform thickness ~1 mm

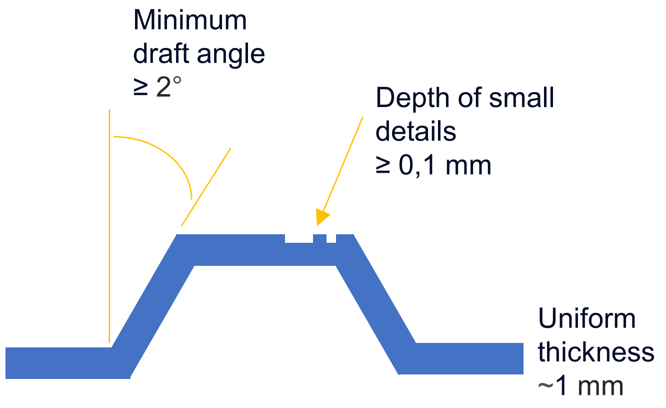
Technical limitations | Details, top view

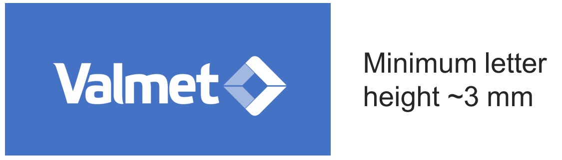
Minimum letter height ~3 mm

Technical limitations | Recap

- 300 x 300 mm of maximum footprint
- Maximum height of 120 mm
- Minimum draft angle of 2 degrees
  - This ensures the shape can be produced (and removed from the pressing tool) with a linear, vertical motion. Sand cast objects and their design principles are the closest analogy here when it comes to drafts. Unlike sand casting, it is not possible to use mold cores/slides.
- Minimum detail size: If text is considered, the minimum depth of letters should be around 0,1 mm and the minimum height of letters around 3 mm.
- The wall thickness of the object should be roughly uniform and around 1 mm







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Valmet
BOSCH Invented for life

Other ideas

- The purpose of this object is similar to what is used in test objects in 3D printing as pictured. (“Calibration object” could be another useful term here.)
- However, the process is completely different, and so should the shapes.
- Including Valmet’s brand elements and making the shape appear more intriguing / visually interesting is considered beneficial (the pictured object would be probably an example of the opposite of this). These features shall not compromise the technical feasibility of this object.

https://www.thingiverse.com/thing:2656594

Expected output

- Preferred output: Native CATIA V5 or V6 model or step-model
- Contact if needed:
  - juhani.salonen@valmet.com (primarily email only)
  - niina.merilaita@valmet.com (email or a Teams meeting)

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Thank you!

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C3 – Design Projects

L3 – Ergonomic assessment and workplace design

P5 - Robert Bosch SRL

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About NextGEng Project

- Three-year Erasmus+ Cooperation Partnership project that started in October 2022
- International consortium consisting of 3 universities and 3 companies from European countries
- Project co-funded by the European Union and coordinated by Technical University of Cluj-Napoca, Romania

TECHNICAL UNIVERSITY OF CLUJ-NAPOCA — **Technical University of Cluj-Napoca**

jamk — **Jamk University of Applied Sciences**

Universidad de Jaén — **University of Jaén**

ISR www.isr.es — **Integracion Sensorial y Robotica**

Valmet — **Valmet Technologies Oyj**

BOSCH Invented for life — **Robert Bosch SRL**

About NextGEng Project

- **NextGEng Project** aims to create new pedagogical models that promotes international team-teaching with the support of new learning materials for existing courses in the curricula

NextGEng comprises three types of activities

Training

Tailored training program for teachers that sustain the skill improvement of HEI partners staff in new/innovative teaching methods.

International Team-Teaching

international pilot program.
Upgrade a set of engineering courses, belonging to the HEI partners curricula, in close collaboration with companies' partners.

CEL Projects

Cases of Experiential Learning projects.
Type of projects where students learn by doing in an international and multidisciplinary environment.

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Ergonomic assessment and workplace design

- The topic discussed in this laboratory involves students in finding ergonomic based solutions for design, redesign and improvement of a manual assembly workstation

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Ergonomic assessment and workplace design

Upon completion of this laboratory, the student will be able to:

1) **Use an Ergo Checklist for workplace ergonomic assessment**
2) **Apply the ergonomics principles and criteria for workstation redesign etc.**
3) **Use anthropometric data for workstation redesign**
4) **Compare different redesign solutions and select the best redesign alternative**

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Content

- Introduction
- Ergonomic assessment
- Recognize and present potential choices for enhancing body posture with reasoned arguments (only for UTCN students)
- Identify and provide potential approaches in design phase of the manual assembly workstation and (only for web based)
- Comparison of solutions
- Conclusions

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Introduction

Introduction

Ergonomic assessment and workplace design

Objective: To determine ergonomic factors with the aim of providing for employee safely, healthily, and productively workplace

Ergonomics is highly relevant for workers for several reasons:

- Health and safety
- Wellbeing
- Increased productivity
- Reduce absenteeism & improve people retention
- Cost saving

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Introduction

Ergonomic assessment and workplace design

Brief overview about ergonomics

- **Ancient times to 19th century** – observation how tools and objects were design foe ease of use. In the 15th century Leonardo da Vinci demonstrated early ergonomics principles including studies on human proportions.
- **Post world war –** study of ergonomics expanded into various domains including transportation. Medicine and office equipment. In 1949 term of ergonomics was officially coined by British psychologist K.E Murrell and gained recognition as a discipline.
- **Today –** ergonomics is applied in diverse fields including aerospace, healthcare, computer science, automotive design and more.

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Introduction

Ergonomic assessment and workplace design

Materials and methods

- **Conduct an ergonomic assessment** for a manual assembly workstation utilizing workbook from Enclosure1
- **Available materials:** Enclosure1 – Ergonomic assessment, Enclosure2 Work steps for manual station Enclosure3 Guideline for ergonomic evaluation
- **Available tools:** Roulette, Luxmeter
- **Expected results** Identify workstation improvements based on ergonomic findings

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- Ergonomic assessment of manual workplace

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• Ergonomic assessment of manual workplace

For UTCN students

Manual Workplace description

- The workstation is a pre-existing station specifically created for assembling automotive components
- From health and safety perspective an ergonomics evaluation needs to be conducted, aiming for an acceptable results. If deviations are found, remedial measures, which can range from immediate actions to long-term solutions, should be implemented accordingly.

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• Ergonomic assessment of manual workplace

For web version

Manual Workplace description

- The workstation is a pre-existing station specifically created for assembling automotive components
- Due to capacity reasons, workplace needs to be duplicated.
- From health and safety perspective an ergonomics evaluation needs to be conducted on existing station aiming for an acceptable result. If deviations are found, remedial measures should be implemented accordingly in design of the new station.

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• Ergonomic assessment of manual workplace

Manual Workplace

Available materials:

- Work instruction from manual station is described in Enclosure 1
- Guideline for ergonomic evaluation Enclosure 2
- Workplace with dimensions (for web laboratory) Enclosure2.2
- Ergonomic checklist Enclosure 3
- https://www.ergo.human.cornell.edu/CUErgoTools/REBA%206.xls
- **Available tools:**
- Roulette, Luxmeter, dynamometer

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Improvement solutions

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Improvement potentials

- Working height adjustable
- Different arrangement of materials
- Alternate body posture standing/sitting
- Design jobs and tasks to fit people, rather than expecting people to adapt to poor work designs

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C4 – Quality assurance and Applied Methods

L1 - Industrial applications for CNC tooling measurement

P3 - ISR

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Company

- Integración Sensorial y Robótica (ISR) is a Technology Based Company, which origins are in the Research Group of Robotics, Automation and Computer Vision (GRAV) of the University of Jaén. It was created in March 2016 with headquarters in Jaén.

PEOPLE

+40

+6M

ACCUMULATIVE SALES

EXPERIENCE

+7

+30

CUSTOMERS

Valeo

FM LOGISTIC

ACERINOX

COSENTINO

DR. SCHNEIDER UNTERNEHMENSGRUPPE

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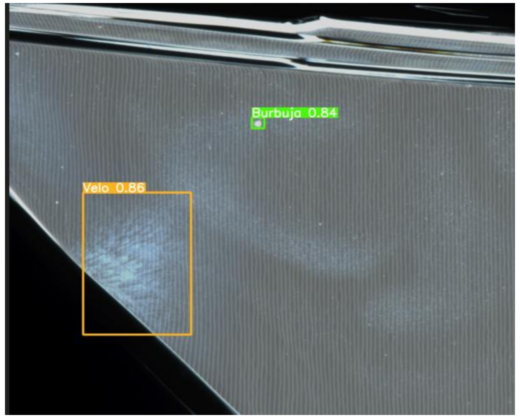
NextGEng

Computer Vision & AI Area

- Computer Vision and Artificial Intelligence team builds the "vision" capability of software and intelligent systems, allowing them to interpret and analyze images and videos in a similar way to human perception.



Industrial applications for CNC tooling measurement

- High-precision contact measurement sensor 'Renischaw sprint'

- Non-contact measurement using Computer Vision 'MIDAS'

Industrial applications for CNC tooling measurement

Upon completion of this laboratory/seminar, the student will be able to:

1) Learn some Computer Vision basic concepts.
2) Know the importance of CNC tooling measurement.
3) Understand the difference between contact and non-contact measurement.

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Content

- Introduction
- Contact measurement
- Non-contact measurement
- Contact vs non-contact measurement
- Conclusions

Introduction

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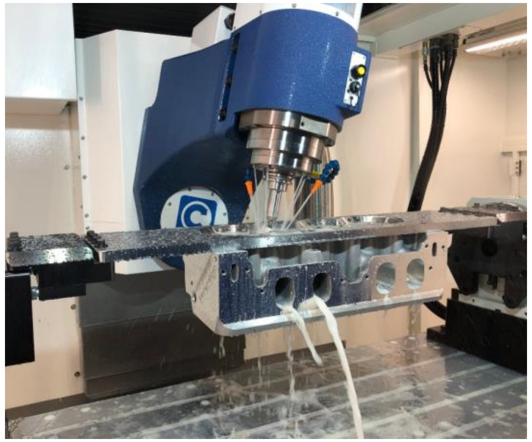
Introduction

What is a CNC (Computer Numerical Control) machine?

- A CNC refers to an automated system that uses a computer to control and coordinate the operations of machine tools and other manufacturing equipment in the industry.
- The operator first designs the desired shape on the computer using special software. Then, the design is converted into instructions that the CNC machine can understand. These instructions are basically precise coordinates and movements of cutting tools or workpieces.



Introduction

What is a CNC (Computer Numerical Control) machine?

- CNC systems have a wide range of applications and are used in the manufacturing of components for industries such as aerospace, automotive, medical, electronics, and more. They are also used in woodworking, metalworking, cutting materials like plastic and wood, and many other areas of industry and engineering.

Añadir imágenes

Introduction

Tool within a tool holder

- The tool refers to the cutting or working piece used to shape or cut a material in the CNC machine.
- The tool holder must securely and firmly hold the tool to prevent any movement.
- The accuracy of tool measurement is extremely important in the CNC machining process becase it ensures that the cutting geometry is exact.

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NextGEng

Introduction

Measurement

- The tool measurement systems within CNC tool holders operate by using specialized measuring devices integrated into the tool holder or the machine tool itself.
- These systems are designed to provide accurate measurement of the tools used in the machining process. In this case, contact and non-contact measurement will be presented.

Contact measurement

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Contact measurement

How is it performed? An example: Renishaw tool setter

- Contact tool measurement in CNC machines are conducted using a measurement device that makes physical contact with the tool.

1	Probe Initialization
2	Tool Insertion
3	Contact and Measurement
4	Data Capture
5	Comparison with Specifications
6	Update and Adjustment
7	Recording and Documentation
8	Safety and Reliability

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Non-contact measurement

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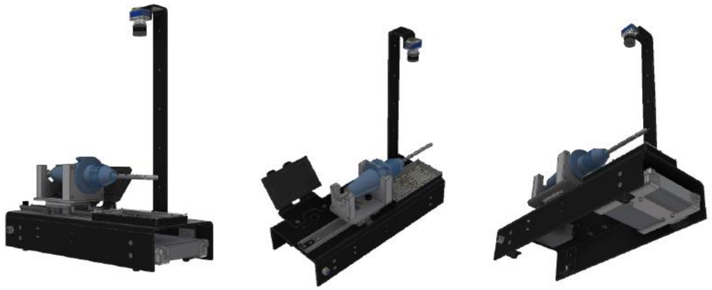
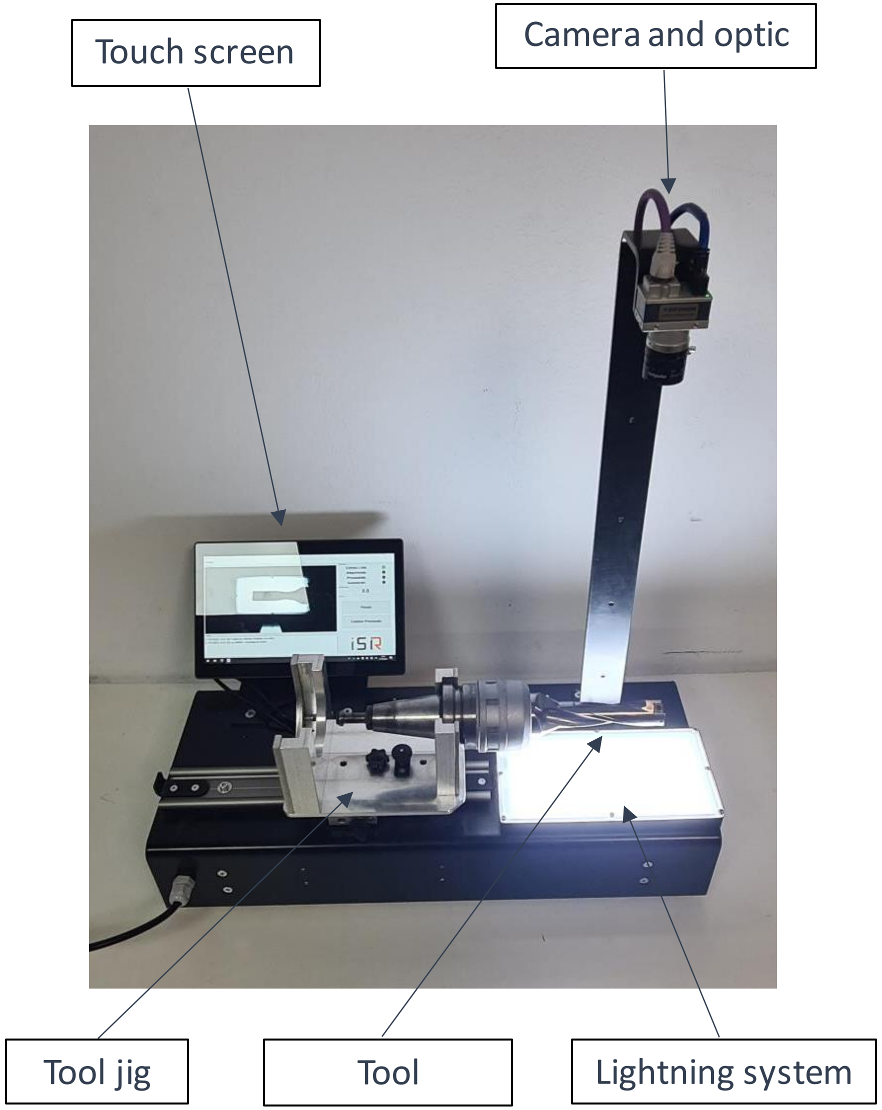
Non- contact measurement

How is it performed? An example: MIDAS from ISR

- Non-contact measurement for CNC tools are based on technologies that allow for precise measurement without the need of direct physical contact with the tool.
- Our prototype aims to optimize the measurement process, saving time and minimizing error associated with manual measurement too. In addition to its precision, the prototype is designed to be easily accessible and understandable for the operator.





Non- contact measurement

Image acquisition

- For this project, a matrix camera from Teledyne Dalsa and a 16 mm optic will be used.
- Using the objects mentioned before, a single capture of the tool is obtained thanks to the LED lighting panel.
- The use of intense and directional LED lighting beneath a tool helps accentuate its edges and contours. This is especially valuable when employing image processing algorithms to detect and measure specific features. The contrast provided by the LED panel enhanced the quality of the measurement.

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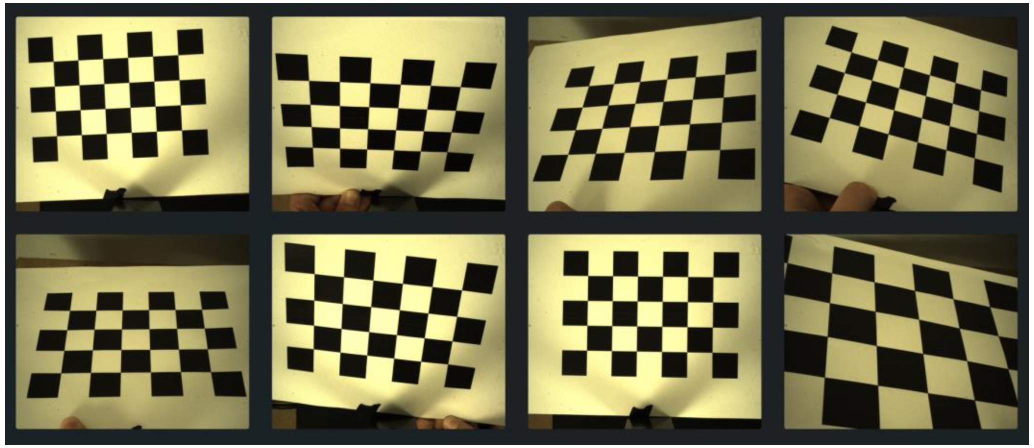
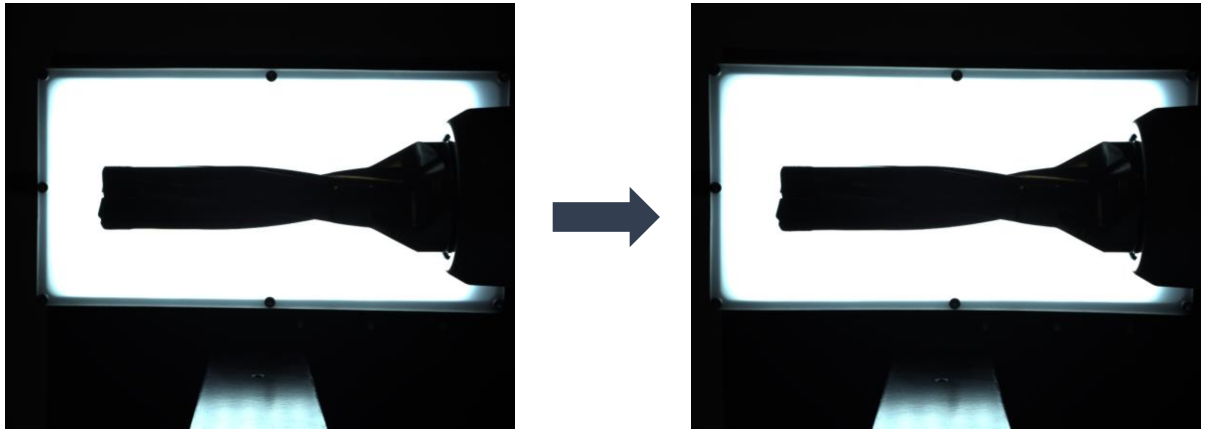
Non- contact measurement

Calibration

- An algorithm has been developed for calibration using a chessboard pattern to compensate for radial distortion. These distortion occur due to the curved shape of the lenses and can cause objects at the edge of the image to appear distorted.
- Camera calibration allows for the estimation and correction of these distortions, resulting in more precise and distortion-free images.

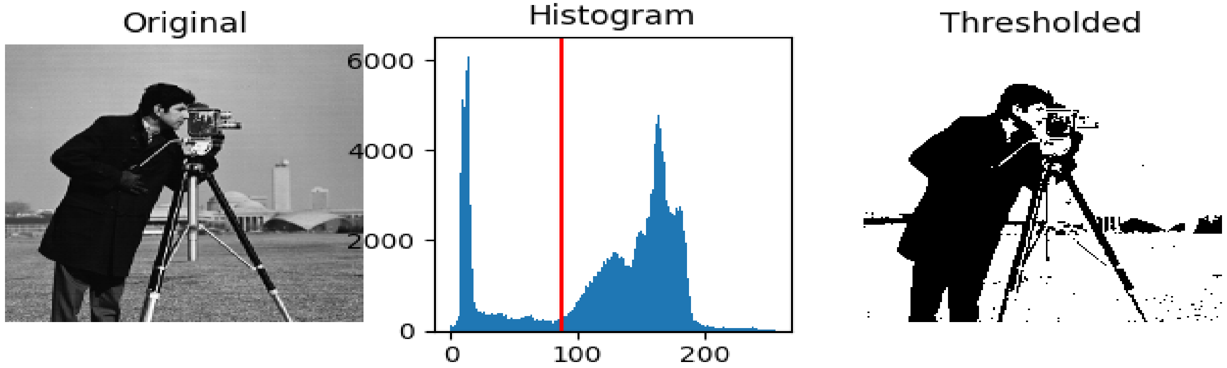




Non- contact measurement

Computer vision algorithms

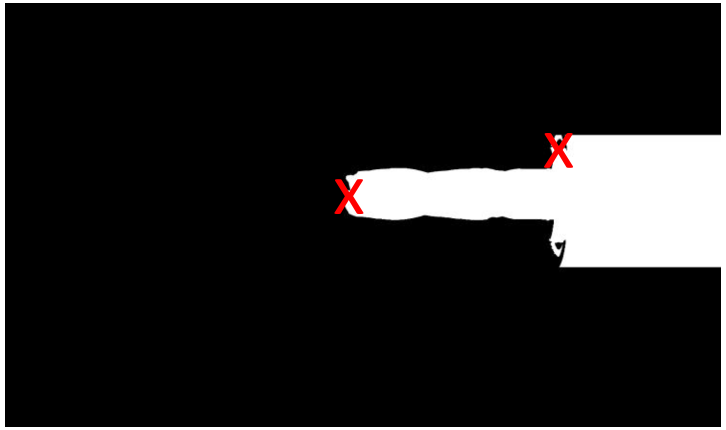
- Once the captures of the tools are obtained, a measurement algorithm is developed. For this algorithm, 2 necessary points for the measurement are obtained, the highest point of the tool and the base point of the tool on the tool holder.
- To obtain these points, an image thresholding is performed. Image thresholding is a fundamental technique in image processing used to separate objects or regions of interest from the background in a digital image. It works by converting a grayscale image into a binary image, where pixels are classified as either foreground or background based on their intensity levels.

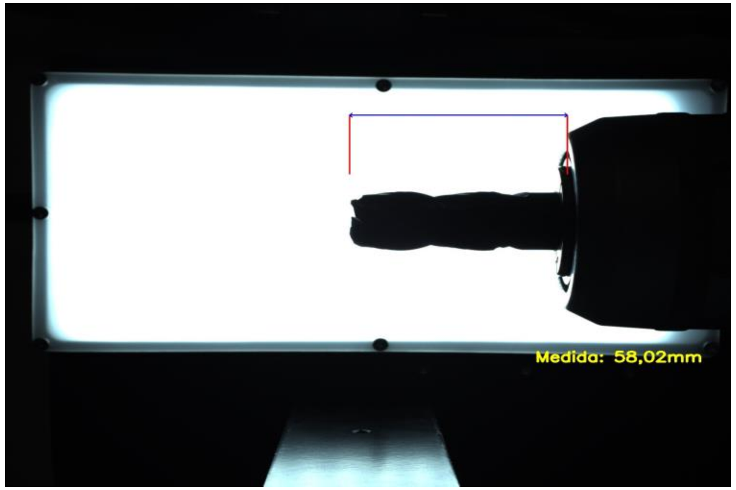


Non- contact measurement

Computer vision algorithms

1. Threshold the acquisition to get a black and white image (0-255).
2. Find the contours in the image and get the bigger one.
3. Go through all the points of the contour searching for certain conditions to get the necessary points (the ones with a red x).
4. Measure the distance in pixels between these two points.
5. Calculate the distance in pixels to milimetres using the resolution of our images (mm/px)

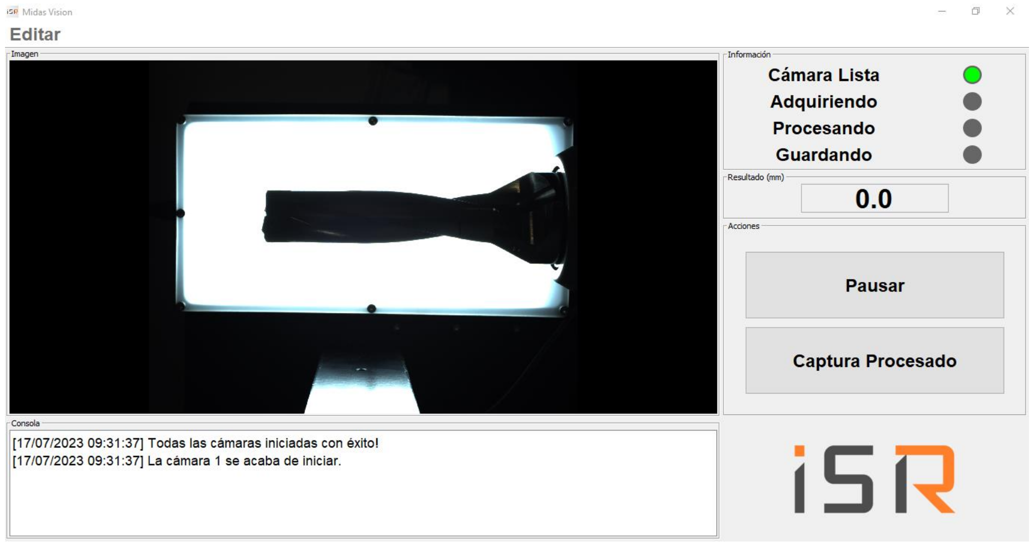


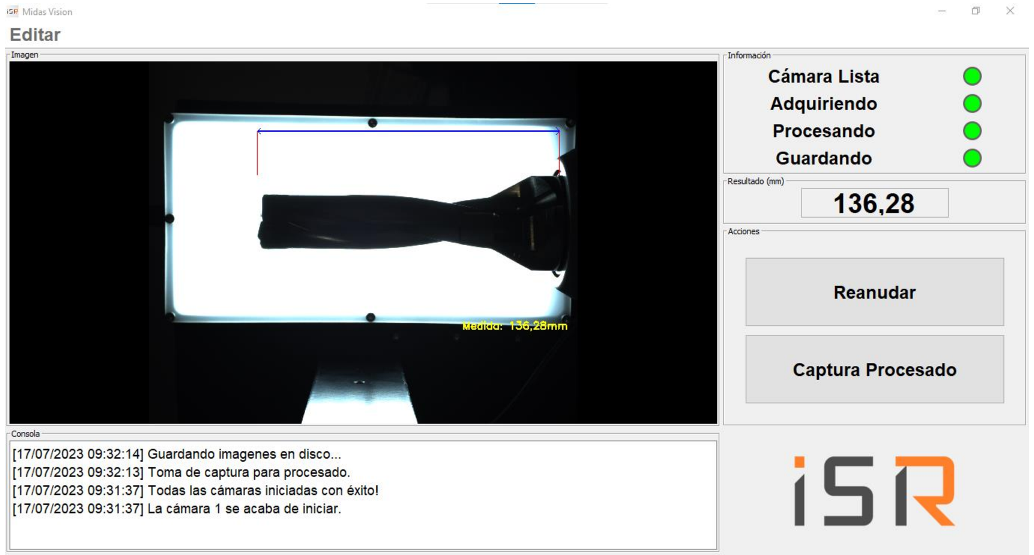


Non- contact measurement

User interface

- Once the vision algorithms are designed, implemented and optimized, the next step is to create an intuitive and user-friendly interface for the application, considering that the system is equipped with a touchscreen. The touchscreen enables intuitive and straightforward interaction, facilitating parameter configuration, image visualization and measurement.
- This interface is designed with user experience in mind, aiming to provide a simple and efficient interaction. It will allow the user to perform tasks such as taking measurement and viewing the results obtained.





Contact vs non-contact measurement

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Contact vs non-contact measurement

- Contact measurement and non-contact measurement are two distinct approaches to obtaining precise measurement in the field of engineering and metrology. Each has its own advantages and disadvantages, and the choice between the two methods depends on various factors, including the type of application and the required precision tolerances
- Contact measurement are known for their high precision. By making direct contact with the work piece, they provide very precise and reliable measurement.
- They work well on both smooth and rough surfaces. They can adapt to a wide variety of materials and textures
- They are slower compared to non-contact measurement, especially in complex measurement systems.
- The probe or measuring instrument may experience wear over time, which can affect the accuracy of the measurement.

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Contact vs non-contact measurement

- Non-contact measurement tend to be faster than contact measurement, especially in automated systems.
- They can adapt to a wide variety of shapes and sizes of work pieces and are ideal for delicate or fragile pieces
- Although they are highly precise, in some cases, they may have slightly lower precision than contact measurement.
- They can be susceptible to interference caused by environmental conditions such as inadequate lighting or vibrations

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Conclusions

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Conclusions

- Non-contact measurement offer several significant advantages, making them an extremely attractive option in a wide range of metrology and manufacturing applications because it's speed and efficiency, the flexibility and the preservation of surface integrity.
- For high-precision applications where tolerance is critical, contact measurement are often the preferred option.

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C4 – Quality Assurance and Applied Methods

L2 - Development Techniques

P4 - VALMET/Juhani Salonen

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Module name

LEAN product design and development: Basics + Practical Exercise by Valmet

Updated **11.10.2023**
Juhani Salonen
Industrial Design Manager
juhani.salonen@valmet.com

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NextGEng

C4 Laboratory exercise (Valmet) NextGEng-project

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How might we... **enable quick removal and reinstallation of guard rail safety panels on a paper machine?**

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- The solution should allow the attachment of different types of panels with varying materials and thicknesses. For example, the panel can be a 1,5–3 mm thick stainless steel or aluminum plate.
- Removal of the panel element needs to be done with a tool, so it is not possible to remove it without one. In this context, ”a tool” can be interpreted flexibly (e.g., a hexagon-shaped bar can be understood as a tool). A wingnut, for example, is not a possible solution because it requires no tools.
- It is beneficial if no other parts than the panel come off as a result of the removal (e.g. no loose screws or nuts)
- It must be easy and fast to put the panel back. Optimally, doing so does not require a tool to do so. Think of most locks, like the lock on your bicycle on your front door: Most require a key (= tool) to open them, but for closing and locking them back.
- It is beneficial if the panels don’t need to be (fully) supported by the user during the re-installation during the fastening/locking
- The costs of the solution should be relatively low to make it viable to install on tens or even hundreds of guard rails per paper machine
- The solution should not include sharp edges or get dirty too easily
- However, ***don’t get too technical, especially during the first session***

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NextGEng

First iteration round | Ideas

- Prepare the matrix. Pick names for the rows and columns from the lists provided and/or come up with some of your own
- You can alter the number of rows or columns to what you find suitable. The target is to produce around **24–50 ideas** during this session. Do, for example, a matrix of 5x5, 4x6, 6x6, 4x7, 4x8, 4,9 or bigger.
- There can be more than one idea in one cell

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First iteration round | Ideas

Fill the matrix

- Produce the ideas as quickly and dirtily as possible: one(ish) sentence to describe the idea or a very quick 10–30 second drawing to illustrate the underlying principle
- One idea can be just a partial solution, it does not need to solve all details (combining of ideas can be done later)
- If you get stuck or otherwise run out of ideas, use Google, ChatGPT, or any other means you deem suitable for extra ideas and inspiration
- Media can be whatever takes you there quickly enough: Written description or quick sketches with pen and paper, Snipping Tool, Greenshot or Paint
- Merely written descriptions may not be enough to concretize the ideas – visualize whenever applicable!
- Never shoot down an idea during this session: just fill in everything you came up with, even (or especially!) if your assumption is that the idea is not feasible

First iteration round | Ideas

- If you run out of time during this session, you can fill the rest in afterward.Once you're finished, send the material to **juhani.salonen@valmet.com** and Kirsi
- If you filled the matrix physically with Post-It notes or similar, send a photograph. If you did it digitally, send it as an Excel, PowerPoint, or other common file format.
- Deadline: **At the end of this session**

First iteration round | Ideas

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Second iteration round | Concepts

- First visualizations and/or short descriptions of the most promising ideasThe target is **10** visualizations per pair or person
- You can combine two or more ideas for one visualization if needed

- Visual description + additional written descriptions to the level where the idea can be effectively communicated to others
- Possible media: Pen and paper, PowerPoint shapes, the roughest possible 3D model...

  If you run out of time during this session, you can fill the rest in afterward.Once you're finished, send the material to **juhani.salonen@valmet.com** and Kirsi

  Send the materials digitally. If you made the concepts as physical drawings, send photographs/scans from them.

  Deadline: **At the end of this session**

Third iteration round | 3D sketch and presentation

- Out of the feasible ideas you produced in the previous two sessions, select the most promising oneIf you lack a critical piece of information, make an educated guess
- Start by sharing your best idea(s) with a pair to get feedback; each selects their best idea and works on it individually

- Make a rough 3D model and/or good visualizations from it
- Export the 3D model (.step or native Catia model), and make a 1–3 slide PowerPoint presentation where the concept is explained in sufficient detailSend the material to **juhani.salonen@valmet.com** and Kirsi
- Deadline: **15.10.2023**

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C4 – Quality Assurance and Applied Method

L3 –Cell Force Calibration - "Smart function kit press"

P5 - Robert Bosch Company

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Calibration “Smart function kit press”

The aim of this activity is to calibrate a force sensor to assure that it gives precise measurement values for force.

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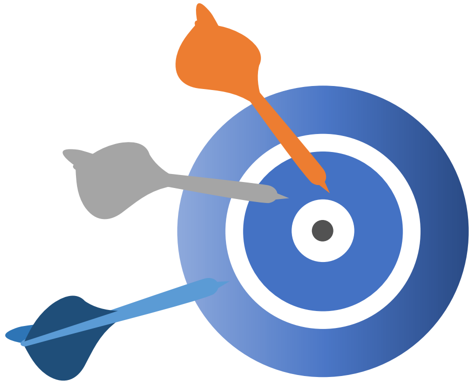
NextGEng

Objectives



Upon the completion of this laboratory, the student will be able to:

1) Understand the concepts about force sensors and the calibration principles
2) Prepare and configurate the equipment for calibration
3) Calibrate a force sensor
4) Calculate the uncertainties and interpret the results of the calibration
5) Prepare the documentation for the whole calibration process.

Content

Introduction

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Why Calibrate?

Calibration

Four main reasons for having an instrument calibrated:

1. To establish and demonstrate traceability.

2. To ensure that the readings of the instrument are consistent with other measurements.

3. To determine the accuracy of the instrument readings.

4. To establish the reliability of the instrument e.g. that it can be trusted.

https://www.youtube.com/watch?v=psvw2tPLkKQ&ab_channel=RohdeSchwarz

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Uncertainty value

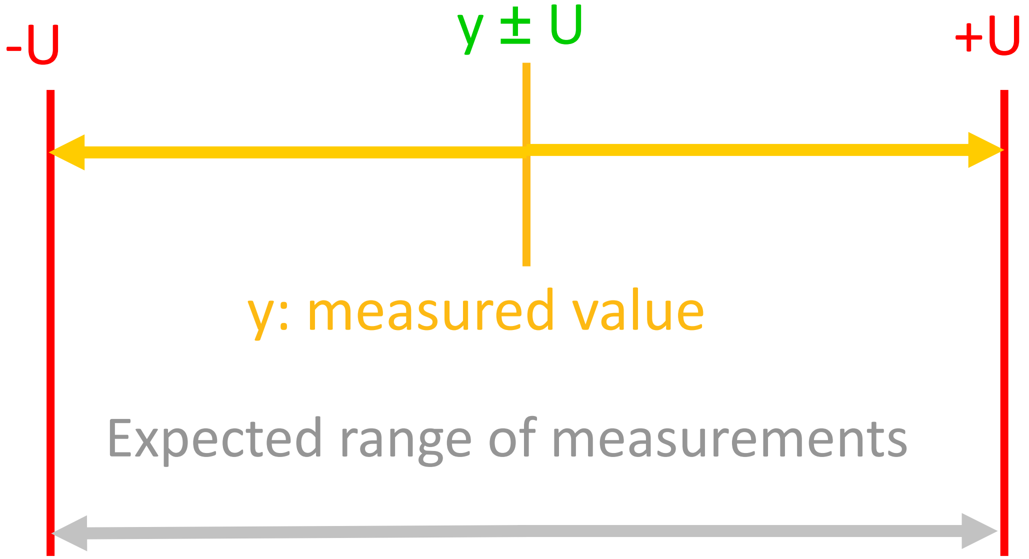
Measurement uncertainty - ISO/IEC 98-3:2008 confirmed in 2023

- is a parameter - which is associated with the result of a measurement, which characterizes the dispersion of values that can reasonably be attributed to the measurand;
- is a range - the limits of the range of values which, with a certain probability, includes the true value of the measurand;

[Guides to the expression of uncertainty in measurement]

Measured value = value ± uncertainty.

E.g: 2,034 m ± 0,004 m or 2,034 m ± 0,2%



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Guide to the Expression of Uncertainty in Measurement

(GUM)

1. A measured quantity X, whose value is not known exactly, is considered as a stochastic variable with a probability function.

2. The **result x** of the measurement is an estimate of the expectation value.

3. The **standard uncertainty u(x)** is equal to the square root of an estimate of the variance.

4. **Type A evaluation.** Expectation and variance are estimated by statistical processing of repeated measurements.

5. **Type B evaluation.** Expectation and variance are estimated by other methods. The most commonly used method is to assume a probability distribution e.g. a rectangular distribution, based on experience or other information.

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The GUM method

Identify all the important components of measurement uncertainty

- There are many sources that can contribute to the measurement uncertainty. Apply a model of the actual measurement process to identify the sources. Use measurement quantities in a mathematical model.

Calculate the standard uncertainty of each component of measurement uncertainty

- Each component of measurement uncertainty is expressed in terms of the standard uncertainty determined from either a type A or type B evaluation.

Calculate the combined uncertainty

- The principle: The combined uncertainty is calculated by combining the individual uncertainty components according to the law of propagation of uncertainty.
- In practice: a) For a sum or a difference of components, the combined uncertainty is calculated as the square root of a sum of the squared standard uncertainties of the components; b) For a product or a quotient of components, the same "sum/difference" rule applies for the relative standard uncertainties of the components.

Calculate the expanded uncertainty

- Multiply the combined uncertainty with the coverage factor k.

State the measurement result on the form Y = y ± U

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How to calculate the uncertainty

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Mean and Standard deviation

For a set of values x_i, i = 1,. .. , n, which may be repeated observations, obtained independently, of some quantity, formula for their mean x¯ and standard deviation.

- **Mean:**

$$\bar{x} = \frac{x_1 + x_2 + x_3 + \cdots + xn}{n}$$

- **Standard deviation:** $S = \pm\sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{x})^2}$

Where:

Xi – Value of the first measurement;

$\bar{x}$ – the arithmetic mean of the results of the measurements taken into consideration

n - number of repeated measurements

- **Standard deviation of the mean:** $S_m = \frac{S}{\sqrt{n}}$

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Measurement of uncertainty

- **Standard measurement uncertainty:** u (x) is the expression of the uncertainty value in the dispersion (s or σ). It contains the measurement error or the effect of several influential elements.

$$s = u(x)$$

- **Expanded measurement uncertainty** is the multiple of the measurement dispersion. It contains all the effects of random and systematic factors as well as dispersion factors. The coverage factors k are the uncertainty multipliers:

$$U = k \cdot u(x)$$

- **Coefficient of variation** - the ratio between the standard deviation and the arithmetic mean of the determinations, expressed as a percentage. An internal quality control sample is taken into consideration.

$$CV = \frac{S \cdot 100}{\bar{x}}$$

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Combined standard measurement uncertainty

Combined standard uncertainty: u(y) is the resultant, the combination of one or more standard uncertainties. Based on their role or participation in the size of the measurement error, they can be weighted.

$$u(y) = \sqrt{\sum_{i=1}^{n} u(x_i)^2}, \text{ where n is number for standard uncertainties}$$

$$U_c = \pm\sqrt{\sum_{i=1}^{n}(U_i)^2} = \pm\sqrt{U_{B1}^2 + U_{B2}^2 + U_{B3}^2 + U_{B4}^2 + \cdots + U_{Bn}^2},$$

where U_{Bi} is the value of the sources

Extended combined standard uncertainty: U_c = 2 * u_C , (if k = 2)

Force cell calibration

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Equipment and instrument

Force etalon

Thermometer

Factors for uncertainty

- Repetability
- Resolution
- Uncertainty of the calibration certified

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Experimental results

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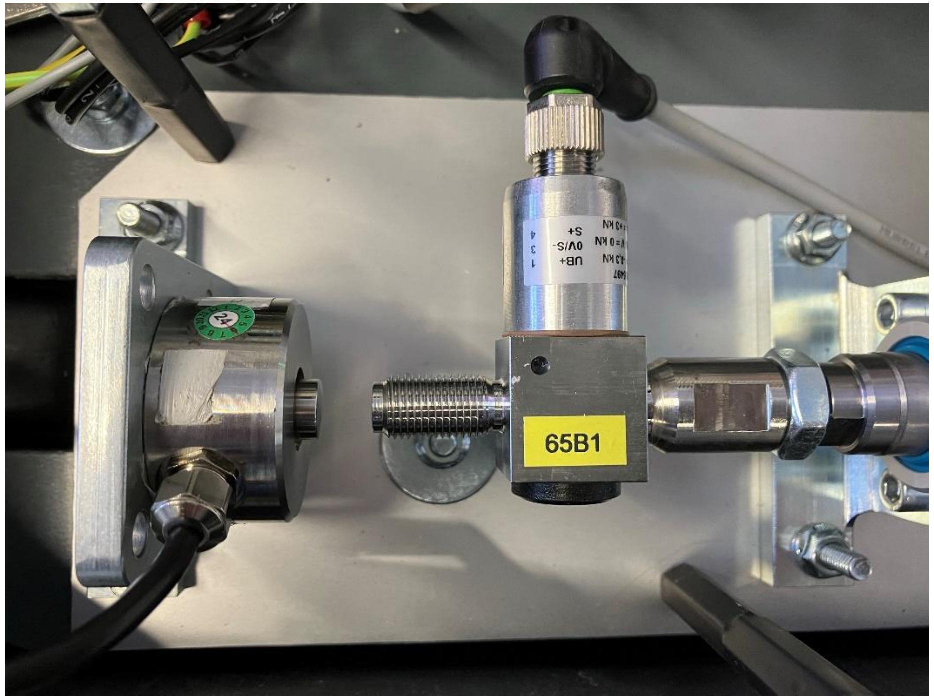
Steps

1. Verification of the press functionality

The press can be actuated by values which will be verifyied



2. Positioning the cell force

The cell force must be centered in the center of the stroke of the press position.

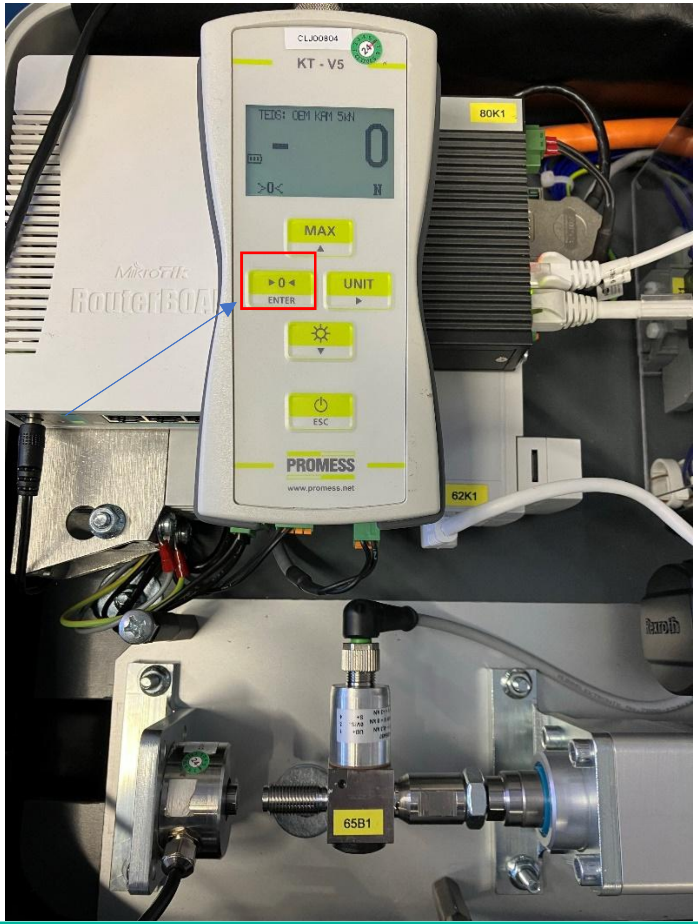
Steps

3. Start the measurement

Press ON button

4. Put on zero, the initial value

Put on zero, the initial value.



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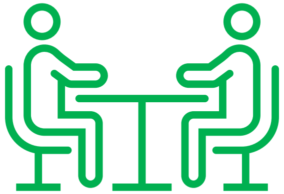
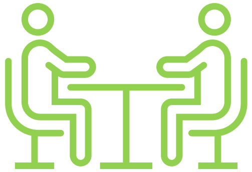
Teams





- ➢ Now we have an interactive activity.
- ➢ We split you into 3 groups and give you access to a Room in Teams platform
- ➢ Please access the jamboard file by phone using the qr code and give us the results for uncertainties when you have the next results after the measurements.
- ➢ As you can see on the next slides each team can see its results for the measurements
- ➢ After each group has a result, each group has to present it to us.

Group 1 - Cell Force Results

Forta la 0.5 kN								
Nr.	Nominal(Mi)	USL	Val. Referinta/X	Val.masurata/M	LSL	Eroare/ e	%Tol	U.M
1	250.000	252.500	250.000	249.800	247.500	-0.2	-1	N
2	250.000	252.500	250.000	250.400	247.500	0.4	2	N
3	250.000	252.500	249.400	250.100	247.500	0.1	0	N
4	250.000	252.500	249.100	250.000	247.500	0.0	0	N
5	250.000	252.500	249.400	250.300	247.500	0.3	2	N
6	250.000	252.500	249.800	250.100	247.500	0.1	0	N
7	250.000	252.500	250.100	250.100	247.500	0.1	0	N
8	250.000	252.500	249.400	250.200	247.500	0.2	1	N
9	250.000	252.500	249.800	250.200	247.500	0.2	1	N
10	250.000	252.500	250.400	250.100	247.500	0.1	0	N

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Group 2 - Cell Force Results

Forta la 0.5 kN								
Nr.	Nominal(Mi)	USL	Val. Referinta/X	Val.masurata/M	LSL	Eroare/ e	%Tol	U.M
1	500.000	502.500	500.200	500.400	497.500	0	4	N
2	500.000	502.500	498.900	500.200	497.500	0	2	N
3	500.000	502.500	499.900	500.200	497.500	0	2	N
4	500.000	502.500	502.000	500.300	497.500	0	3	N
5	500.000	502.500	499.000	500.500	497.500	1	5	N
6	500.000	502.500	506.000	500.500	497.500	1	5	N
7	500.000	502.500	499.000	500.500	497.500	1	5	N
8	500.000	502.500	506.000	500.400	497.500	0	4	N
9	500.000	502.500	506.000	500.500	497.500	1	5	N
10	500.000	502.500	509.000	500.700	497.500	1	7	N

Group 3 - Cell Force Results

Forta la 0.5 kN								
Nr.	Nominal(Mi)	USL	Val. Referinta/X	Val.masurata/M	LSL	Eroare/ e	%Tol	U.M
1	350.000	352.500	350.000	349.800	347.500	-0.200	-1.400	N
2	350.000	352.500	350.000	350.400	347.500	0.400	2.800	N
3	350.000	352.500	349.400	350.100	347.500	0.100	0.700	N
4	350.000	352.500	349.100	350.000	347.500	0.000	0.000	N
5	350.000	352.500	349.400	350.300	347.500	0.300	2.100	N
6	350.000	352.500	349.800	350.100	347.500	0.100	0.700	N
7	350.000	352.500	350.100	350.100	347.500	0.100	0.700	N
8	350.000	352.500	349.400	350.200	347.500	0.200	1.400	N
9	350.000	352.500	349.800	350.200	347.500	0.200	1.400	N
10	350.000	352.500	350.400	350.900	347.500	0.900	6.300	N

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