VDL ETG ALMELO

DRAFTING COURSE

FROM IDEA TO MANUFACTURING

Gesinus Mateman & Rick Timmer
VDL ETG T&D
2022.02.28

PLANNING

- Introduction (5min)
- Short introduction on production methods how they affect your work (5min)
- Product tolerance specification (25-30min)
  - Dimensional tolerances
  - Geometrical tolerances (GD&T Symbols)
- Coffee Break (10min)
- Part about Tolerance trains, how they affect TPD and why they are important (20-25min)
- Building a tolerance train(15-20min)
- Coffee Break(10min)
- Some examples and explanation of making TPD’s (15-20min)
- Assignment for drafting and feedback (max 1h)

INTRODUCTION

WHO ARE WE

Gesinus Mateman
Sr. Mechanical Design Engineer

- VDL ETG T&D Almelo
- Almost 25 years of work expierence
- Bachelor ME @Saxion Hogeschool

- gesinus.mateman@vdletg.com, +31 610180733

Rick Timmer,
Mechanical Design Engineer

- VDL ETG T&D Hengelo
- 1,5 years of work expierence
- Master ME @UTwente
- ASML EXE as Tooling Engineer

- Rick.timmer@vdletg.com, +31 611930575

PRODUCTION METHOD

HOW ARE YOU GONNA MAKE IT?

- You shoud have an idea what production technology you will use for a part, since it will affect the part’s
  - Dimensional accuracy
  - Material
  - Shape
  - Cost
  - …
- Course focus is on single piece and small series technologies

MOST COMMON MANUFACTURING TECHNOLOGIES FOR MACHINE CONSTRUCTION

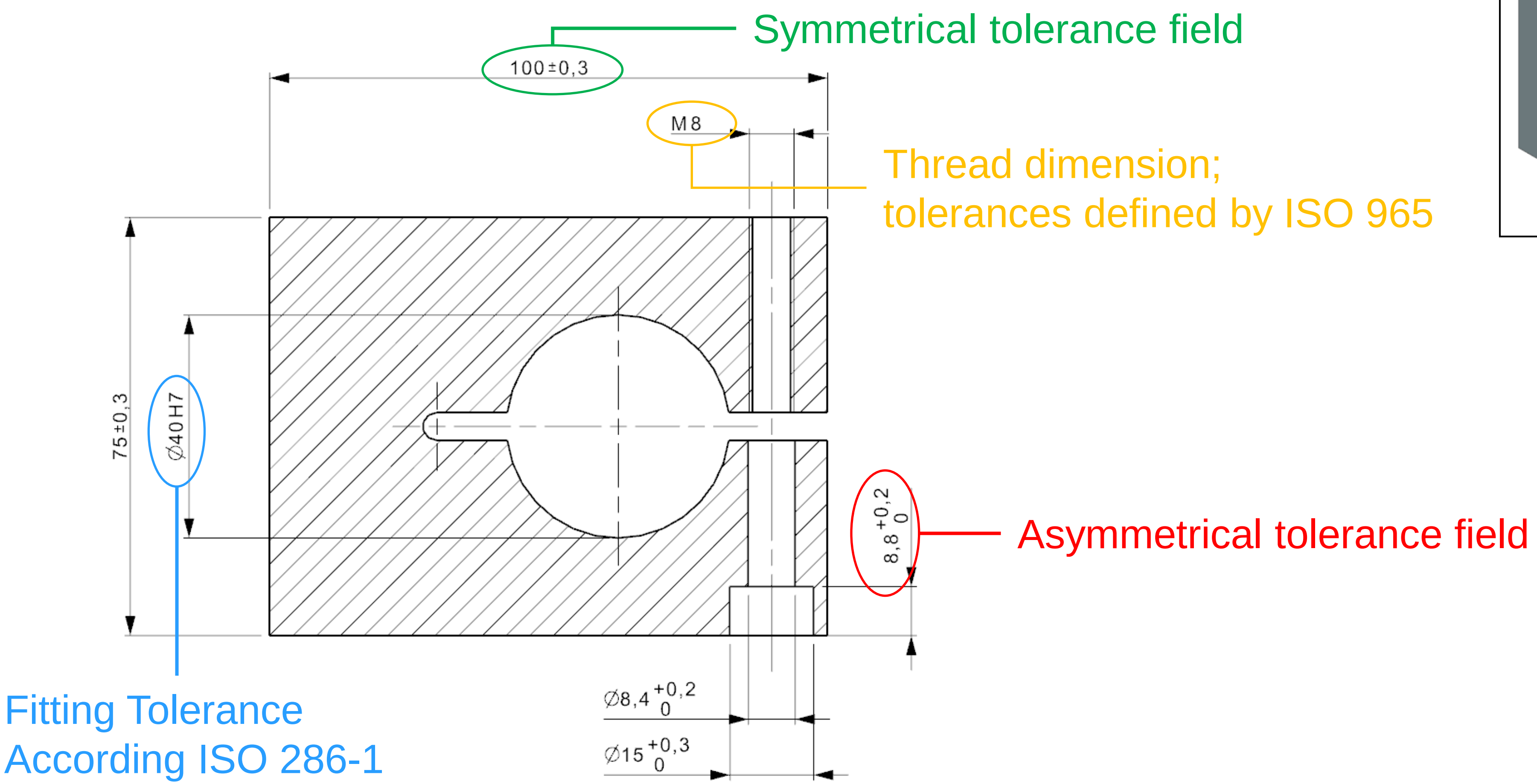
Manufacturing Technology	Typical Manufacturing Tolerance	Typical Applications	Remarks
Welding	≥ ±1 mm	Frames, Constructions	Apply post machining for accurate interfaces
Bending	≥ ± 0.5 mm / ± 0.5°	Frames, Brackets, Cover, Cabinets	Tolerance increases with material/ sheet thickness
Laser Cutting	≥ ±0.1 mm	Sheet metal parts	Tolerance increases with sheet thickness
Milling / Turning/ Drilling	≥ ±0.01 mm	General Machine Parts	
Grinding	≥ ±0.002 mm	High Precision parts	Manufacturing of High Quality Surfaces
EDM	≥ ±0.001 mm	High Precision parts, Leaf springs	Wire EDM, Plunger EDM

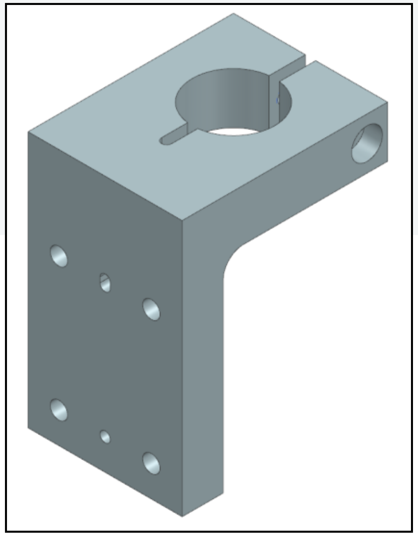
TOLERANCES IN PRODUCT DRAWINGS

KEY ELEMENT OF THE PRODUCT SPECIFICATION

- Dimensional Tolerances
- Geometric Tolerances (GD&T Symbols)

DIMENSIONAL TOLERANCES

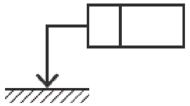


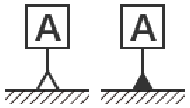


GEOMETRIC TOLERANCES

SELECTION OF THE MOST COMMONLY USED SYMBOLS (ISO 1101)

- ▱ Flatness
- ○ Roundness
- ⌓ Surface Profile
- // Parallelism
- ⊥ Perpendicularity
- ⌖ Position
- ◎ Concentricity/ Coaxiality
- ⌯ Symmetry
- ↗ Circular Run Out

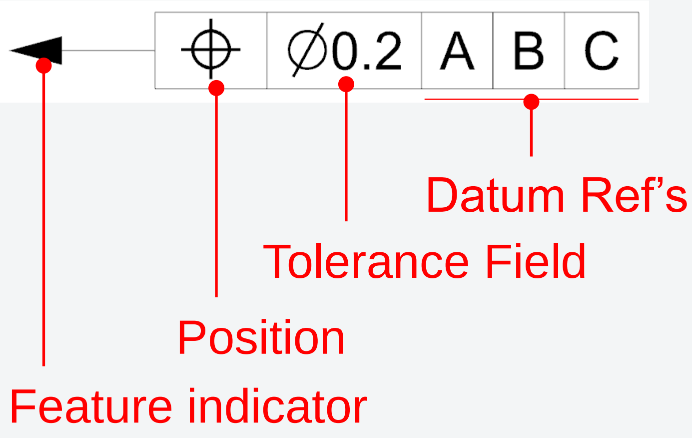

Tolerance Feature Control Frame

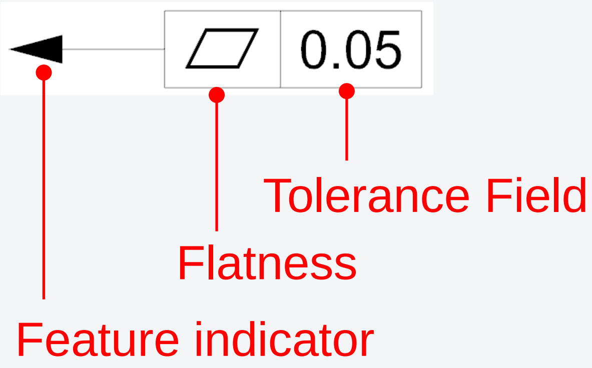


Datum Reference

Datum Target

Theoretically Exact Dimension

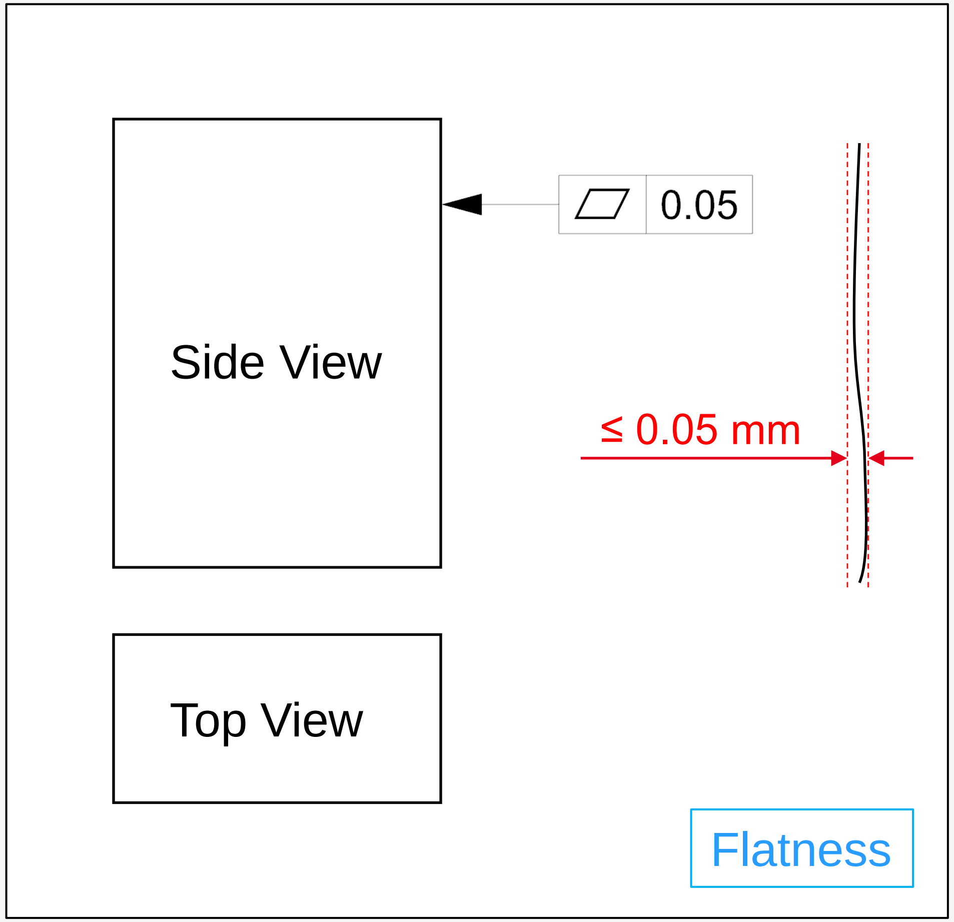


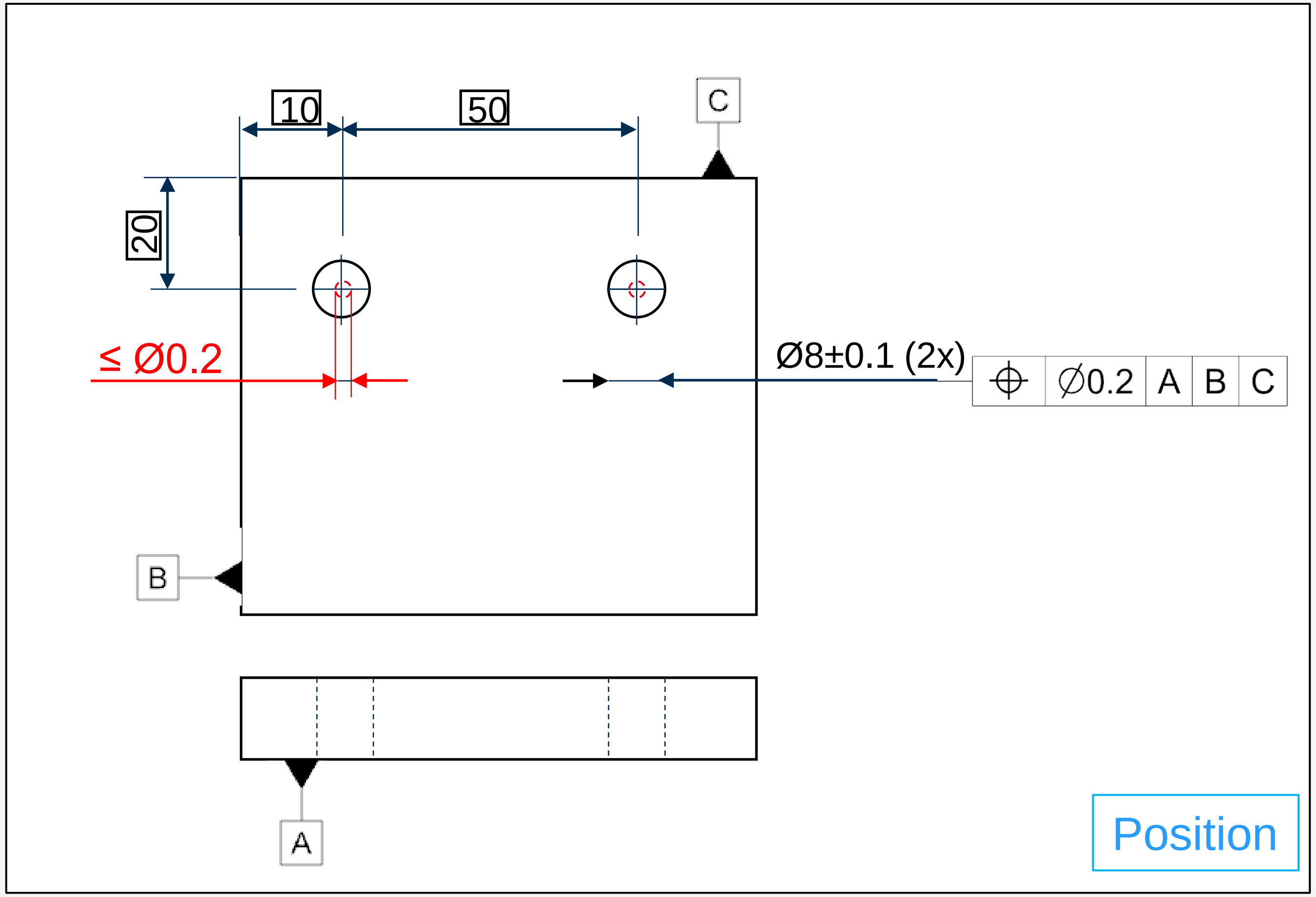


https://www.keyence.com/ss/products/measure-sys/gd-and-t/symbol-list/

GEOMETRIC TOLERANCES

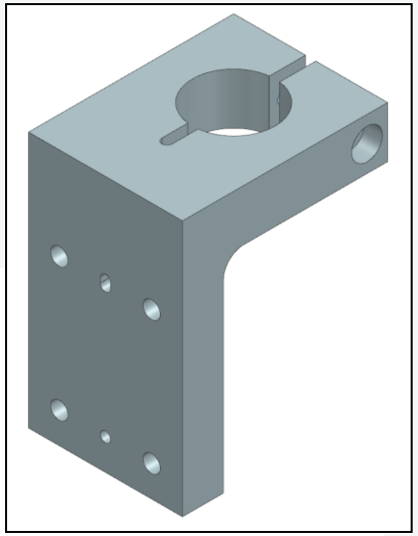
HOW TO USE

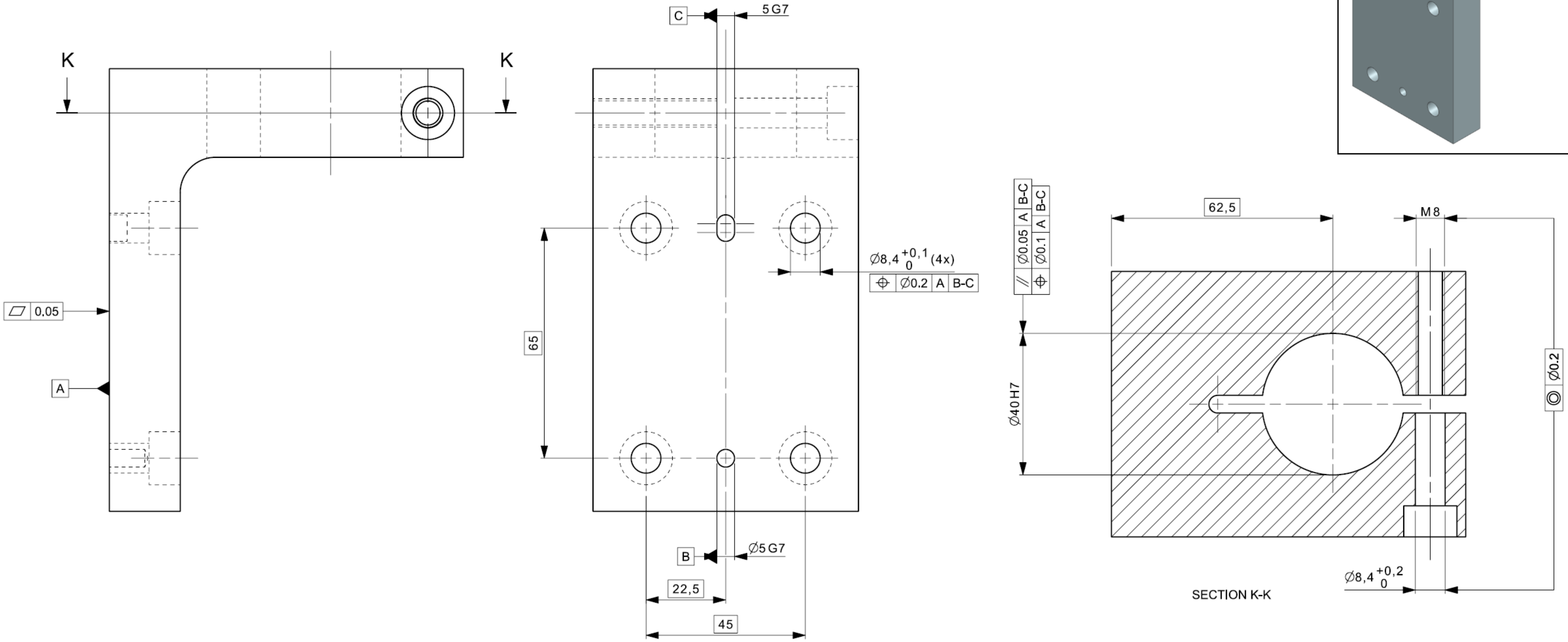




GEOMETRIC TOLERANCES

APPLICATION EXAMPLE





COFFEE BREAK

TOLERANCE TRAIN

HOW DO YOU MAKE IT FIT?

- What is a tolerance train
- Why do you use it
- How do you use it
- Example

- With help from Willem Willemsen

WHAT IS A TOLERANCE TRAIN?

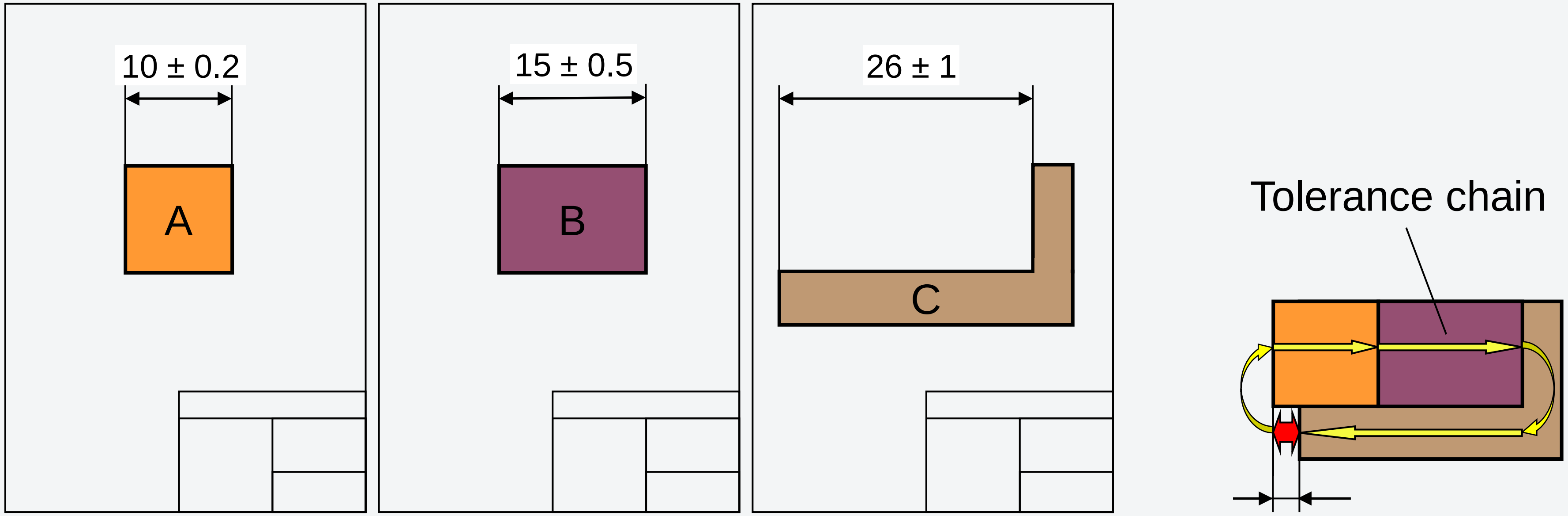
A TRAIN THAT IS NEVER LATE

- Goal is to check whether everything fits
- Determine clearances for placement and assembly
- Cheaper manufacturing (only high tolerance where required)
- Posibility for statistical computation

- Important links:
- https://www.nadro.nl/mark/iso-passingstelsel.html
- https://www.gdandtbasics.com/gdt-symbols/

HOW DOES IT LOOK

- Every part has variations (mechanical, sensor, actuator, optical, etc.)
- Tolerance is the allowed variation of a part as defined by it's specifications.



- The tolerance chain connects the tolerances. The chain is always closed, C – B – A = ?

DEFINITIONS

Stepped appoach

1. Describe the **purpose and background**
2. Define **Critical Distance** & **Machine State**
3. Make a **sketch**
4. Make a **diagram**
5. Make the **Tolerance Table**
6. Evaluate the **budget (capability)**
7. **Draw conclusion** & **make recommendation**

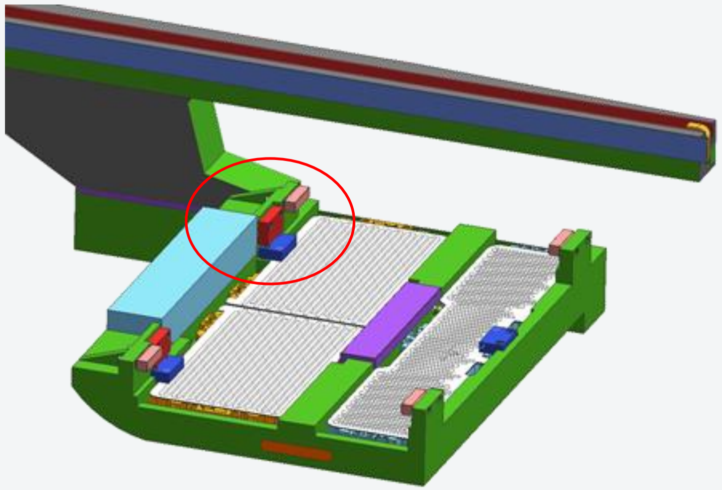
(Steps 3–4:)

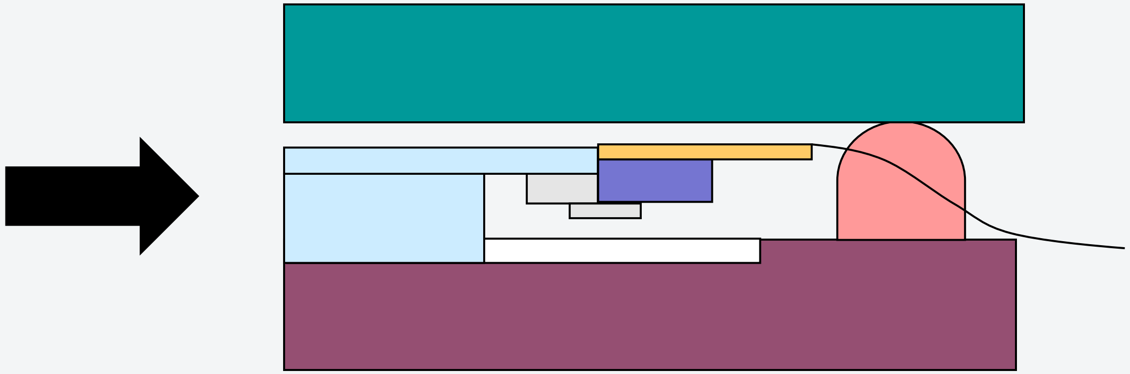
a. Interfaces
b. Tolerance chain
c. External influences
d. Vectors

Block 1 (steps 1–3)

Block 2 (steps 4–7)

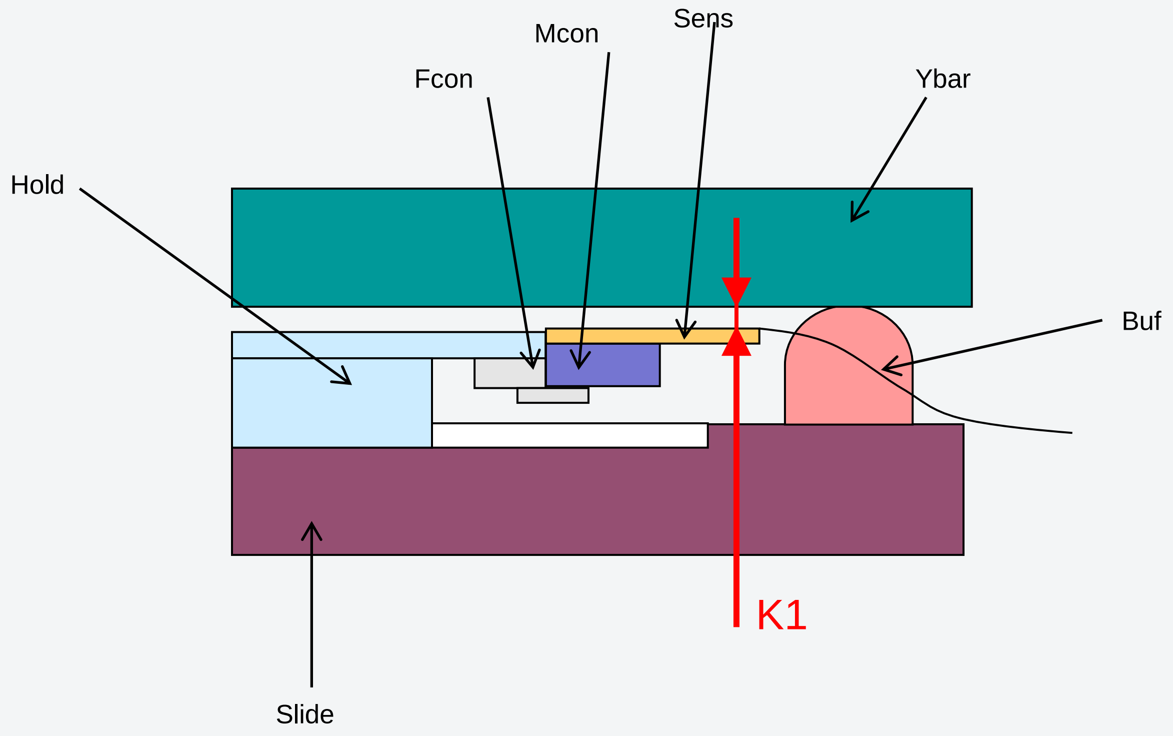
EXAMPLE





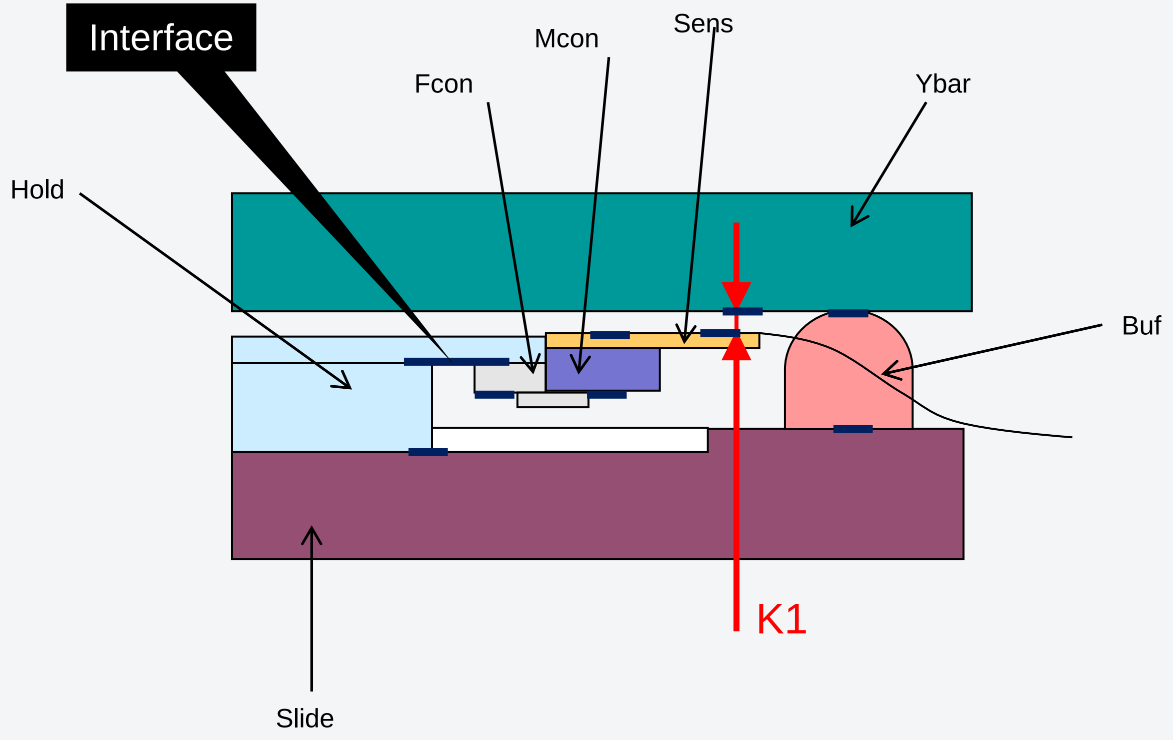
SKETCH

- Simplify to keep it manageable, but keep a clear link with reality (define part names).
- Stick to visual style as described in the GID:



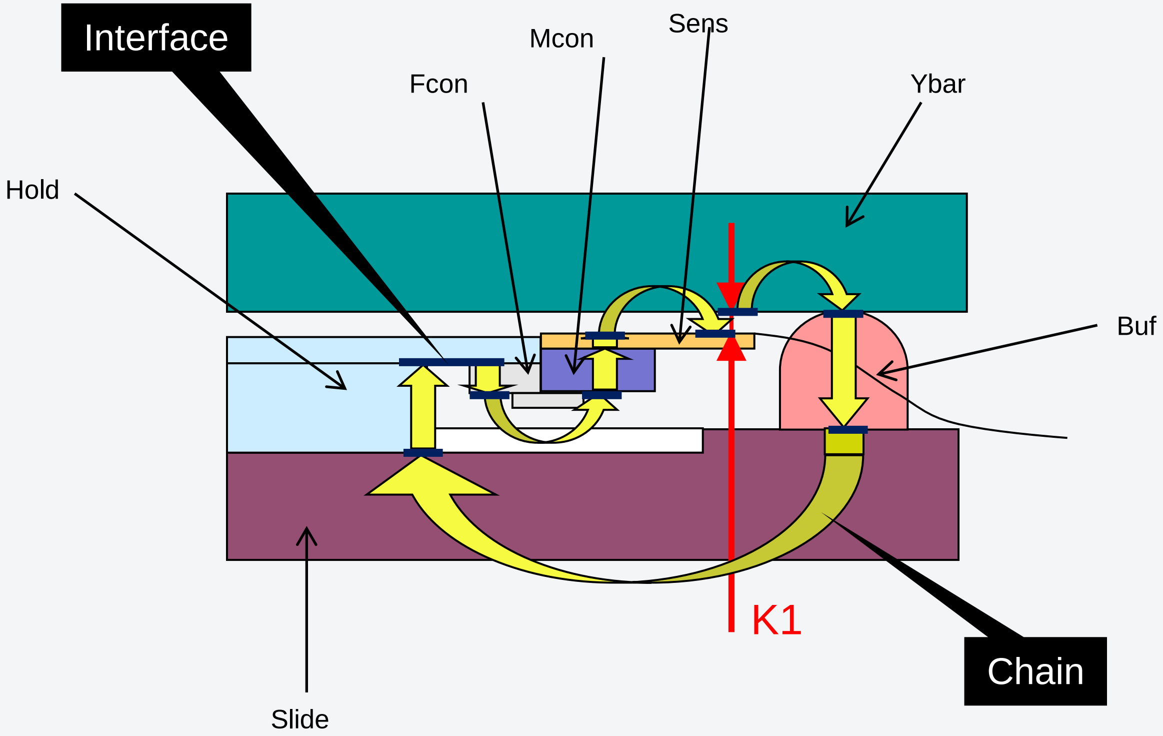
SKETCH

- Simplify to keep it manageable, but keep a clear link with reality (define interfaces).
- Stick to visual style as described in the GID:



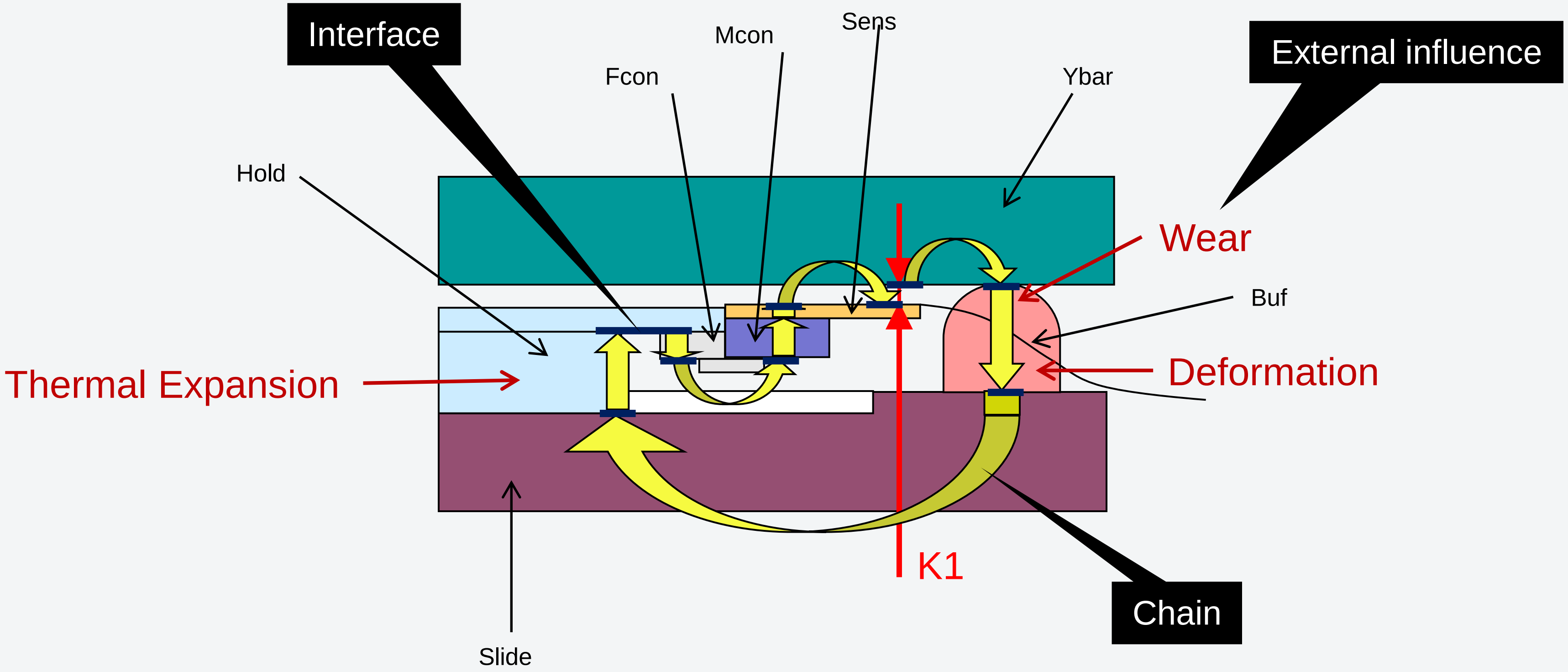
SKETCH

- Simplify to keep it manageable, but keep a clear link with reality (define chain).
- Stick to visual style as described in the GID:



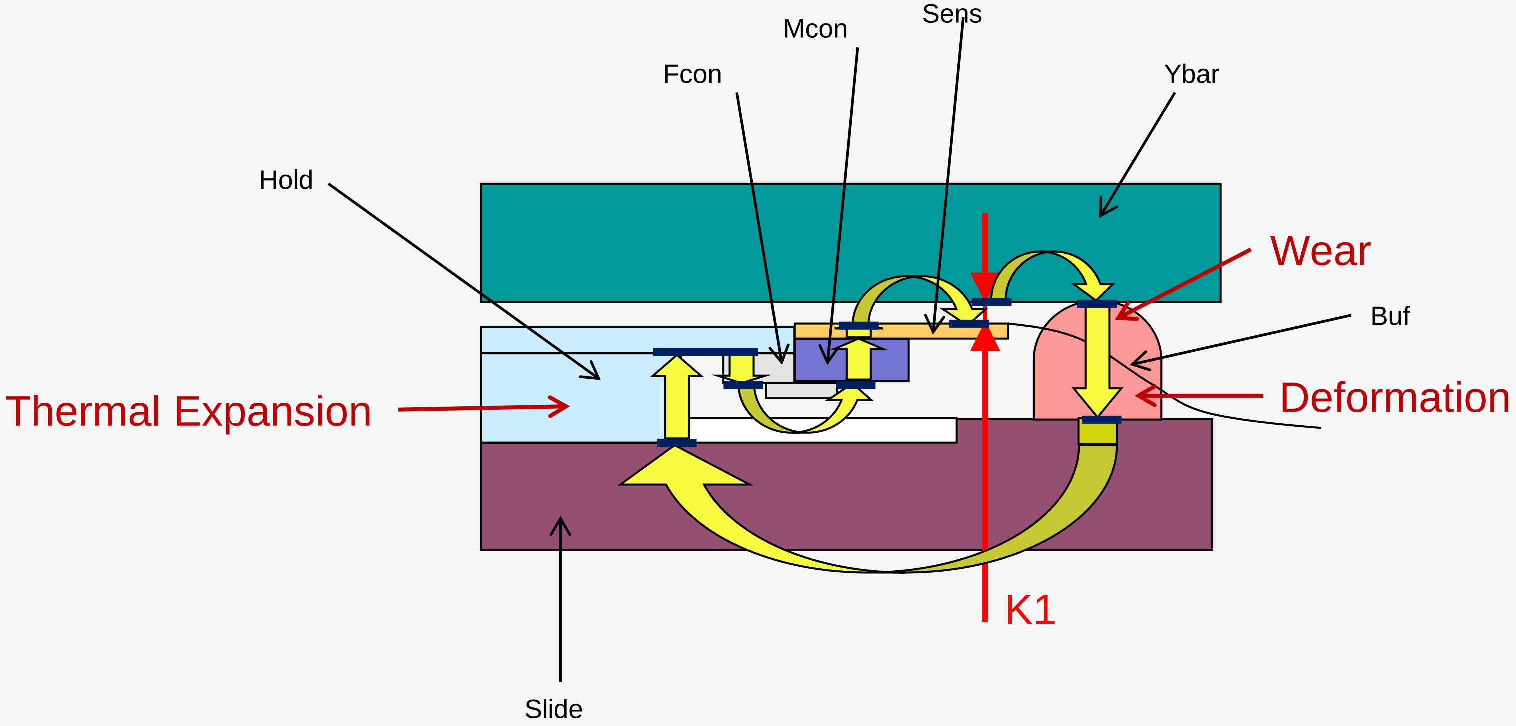
SKETCH

- Simplify to keep it manageable, but keep a clear link with reality (define external influences).
- Stick to visual style as described in the GID:



SKETCH

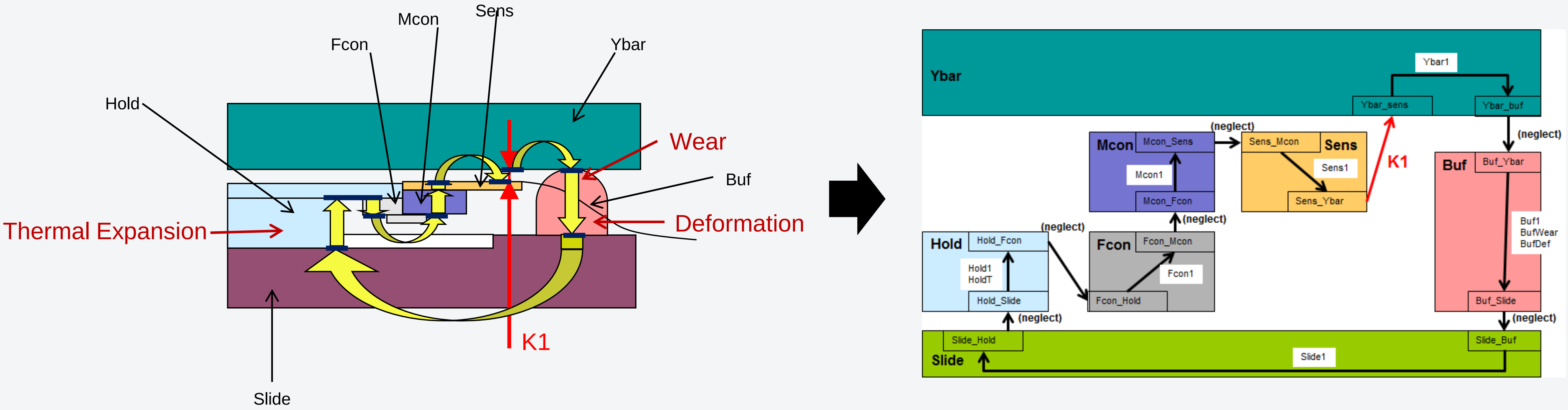
- Simplify to keep it manageable, but keep a clear link with reality (complete).
- Stick to visual style as described in the GID:



DIAGRAM

Purpose of a diagram: error reduction and additional details

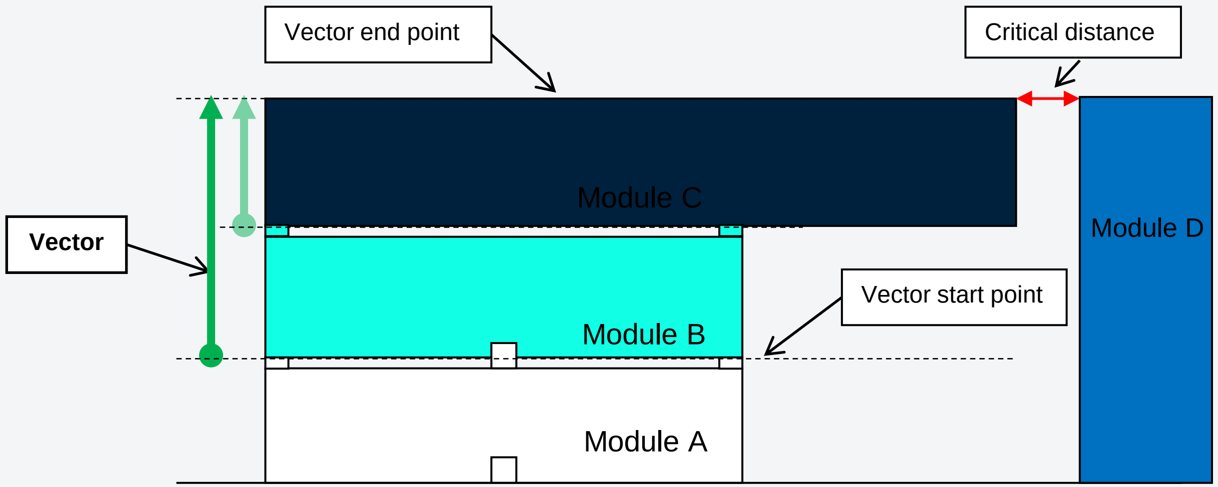
- Module/part = Rectangle (Convention: simplified shapes of sketch, keep relative position as exploded view)
- Interface = Rectangle inside Module/part (Convention: “from” part name_”to” part name)
- Tolerance = Arrow

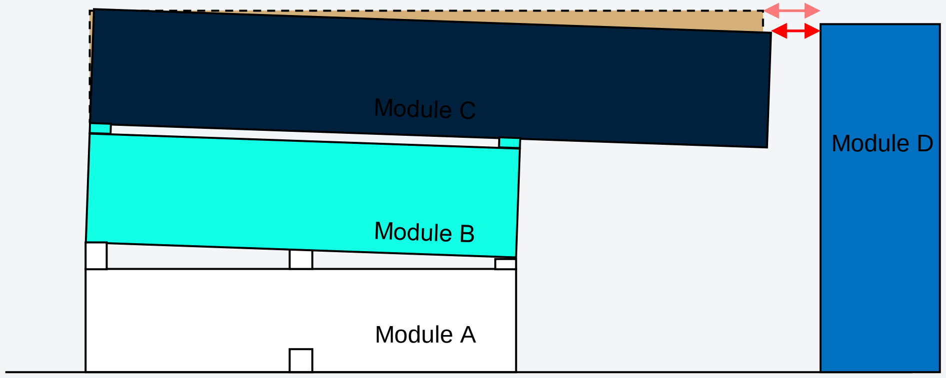


VECTOR

Yes important but not for now

- Vectors are used to calculate the displacement of parts caused by angular variations of their interfaces
- Start = interface plane with rotation tolerance, End = Critical distance
- Vector is always perpendicular to the direction of the critical distance
- Not all vectors are relevant. Long vectors are usually large contributors





TOLERANCE TABLE

Fill the table

- Copy “ID’s”, “From” and “To” from Diagram to the Tolerance table.
- Fill in the values in de column that corresponds with the critical distance
- Mention the source of the values in the Ref. (or remarks) column
- Fill in the S/L (Statistic or Linear) column

2		Sensor to Y-bar										
3		Machine state		X	Y	Z	Rx	Ry	Rz	S/L		
4	ID	From	To		+/- [um]			+/- [urad]			Remarks	Ref.
6	Ybar1	Ybar_sens	Ybar_buf			20				s	Manufacturing tolerances	
7	Buf1	Bur_Ybar	Buf_Slide			100				S	Manufacturing tolerances	
8	BufWear	Bur_Ybar	Buf_Slide			100				L	Max wear at end of lifetime certainly achiev	
9	BufDef	Bur_Ybar	Buf_Slide			20				L	Max deformation at maximum force occurs r	
10	Slide1	Slide_Buf	Slide_hold			20				s	Manufacturing tolerances	
11	HoldT	Holde_Slide	Hold_Fcon			10				l	Temperature effects	
12	Hold1	Holde_Slide	Hold_Fcon			100				s	Manufacturing tolerances	
13	Fcon1	Fcon_hold	Fcon_Mcon			200				s	Manufacturing tolerances	
14	Mcon1	Mcon_Fcon	Mcon_sens			200				s	Manufacturing tolerances	
15	Sens1	Sens_Mcon	Sens_Ybar			50				s	Manufacturing tolerances	

TOLERANCE TABLE

Statistic or Linear?

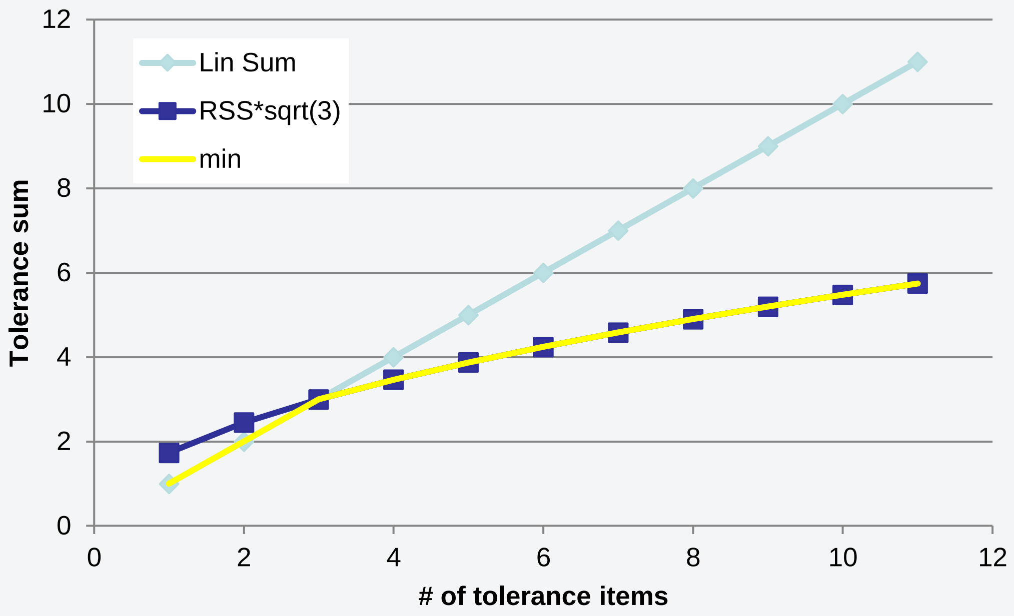
Guidelines to determine if a tolerance is Statistic or Linear:

Count Linear	Count Statistical
• Play • Wear • Deformation • Shrink (e.g. adhesive) • Strokes for calibration • Vibrations e.g. servo-error • Contributors from processes with bad process control • Parts from selection process (quality bins, cherry picking)	• Generally: good process control • Manufacturing errors • Adjustment errors • Measurement Errors • Contributions which are the sum of 5 or more independent sub-contributors Mechanism: averaging Precondition: independent sources

T_Real = T_Lin + T_Stat * √3, with:

$$T\_Lin = \sum_{n=1}^{M} T_{i\_lin}$$

$$T\_Stat = \sqrt{\sum_{n=1}^{N-M} T_{i\_stat}^{2}}$$



TOLERANCE BUDGET

- Fill in value for K. This could be derived from a requirement, CAD, nominal design analysis, etc.
- The sheet will add up the individual items to a tolerance sum.
- If the sum and K are known, the Capability is calculated.

2		Sensor to Y-bar										
3		Machine state		X	Y	Z	Rx	Ry	Rz	S/L		
4	ID	From	To		+/- [um]			+/- [urad]			Remarks	Ref.
6	Ybar1	Ybar_sens	Ybar_buf			20				s	Manufacturing tolerances	
7	Buf1	Bur_Ybar	Buf_Slide			100				S	Manufacturing tolerances	
8	BufWear	Bur_Ybar	Buf_Slide			100				L	Max wear at end of lifetime certainly achiev	
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10	Slide1	Slide_Buf	Slide_hold			20				s	Manufacturing tolerances	
11	HoldT	Holde_Slide	Hold_Fcon			10				l	Temperature effects	
12	Hold1	Holde_Slide	Hold_Fcon			100				s	Manufacturing tolerances	
13	Fcon1	Fcon_hold	Fcon_Mcon			200				s	Manufacturing tolerances	
14	Mcon1	Mcon_Fcon	Mcon_sens			200				s	Manufacturing tolerances	
15	Sens1	Sens_Mcon	Sens_Ybar			50				s	Manufacturing tolerances	
16												
18	Sum			0	0	687	0	0	0		Sensor to Y-bar	
23	K1	Sens_Ybar	Ybar_sens			500					Safe clearance for easy connection	
24	Capability					0,73						

DRAW CONCLUSION

What is Capability?

- Capability = Requirement / Sum (of all tolerances)

Sum			450	
K			300	
Capability			0,67	

- What is the right capability in which phase of the project?

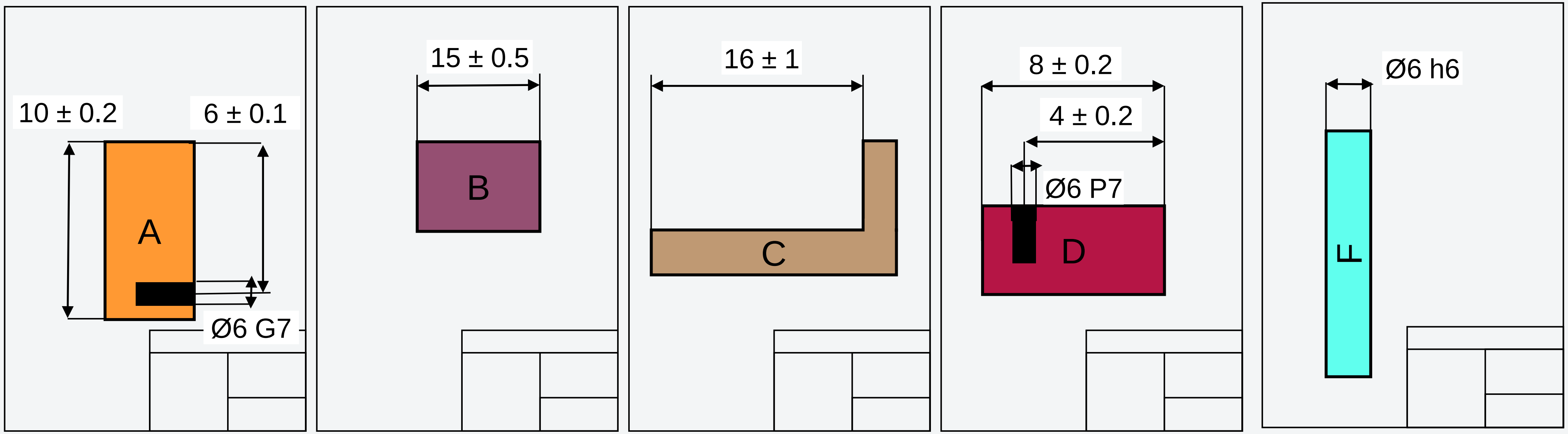
Capability C	Budget confidence level	
C ≥ 2	Safe. There is a factor 2x margin for unknown and/or missing budget items.	Generally Ok for concept design
1.3 ≤ C < 2	Critical but acceptable when there is a good knowledge about all the budget items and the budget is accepted after review.	Generally Ok for detailed design
1.0 < C < 1.3	Very critical and in general not acceptable in the design phase.	Generally Nok for detailed design
C ≤ 1.0	Not acceptable.	Nok for detailed design

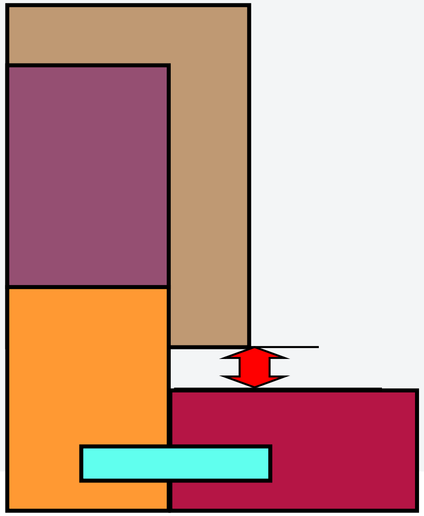
BUILDING A TOLERANCE TRAIN

MAKE IT FIT!

- Now lets make a tolerance train for a simple system.

COMPONENTS AND ASSY





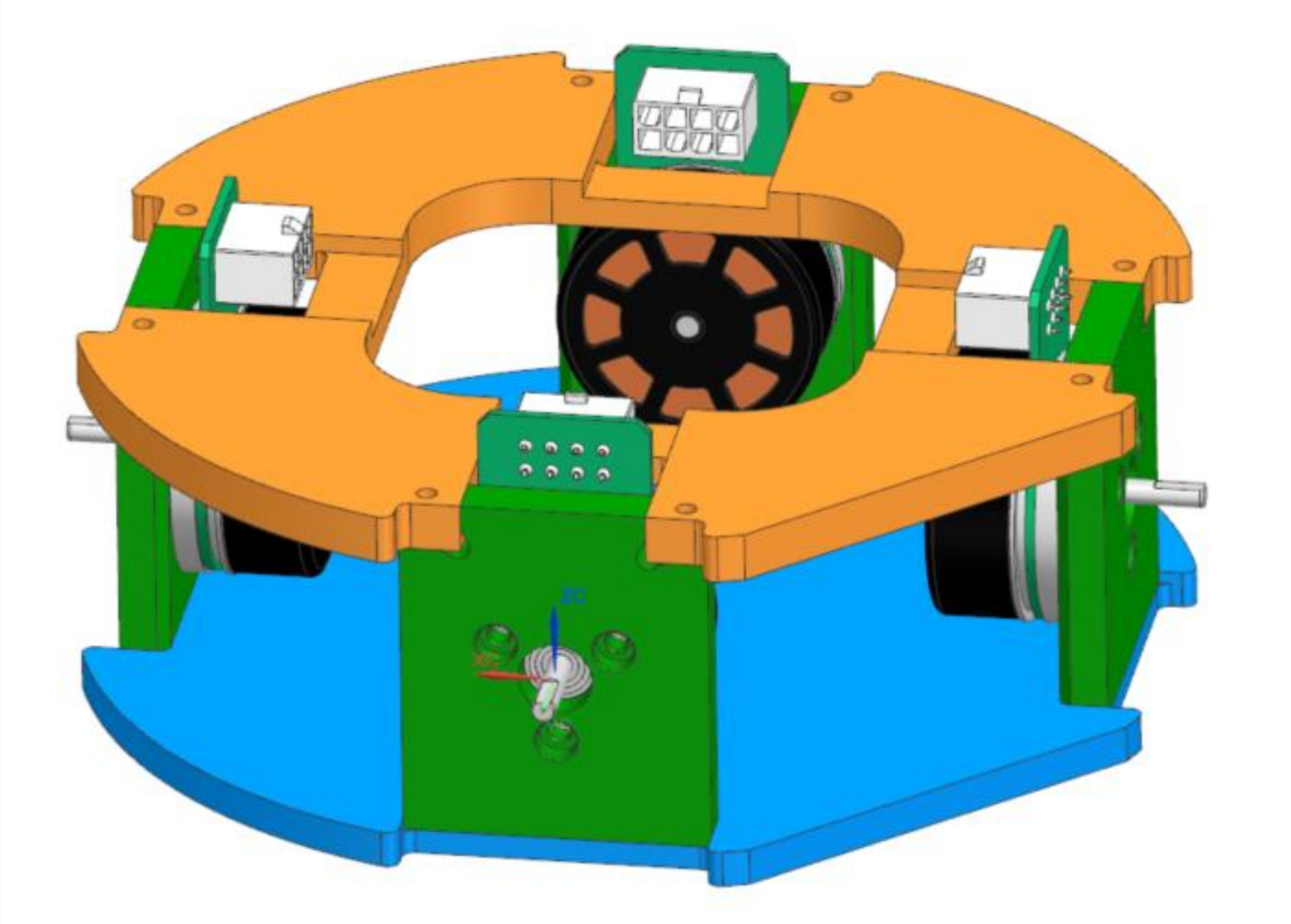
COFFEE BREAK

TPD EXAMPLE AND ASSIGNMENT

DRAW SOMETHING!

- Assembly in 3 components

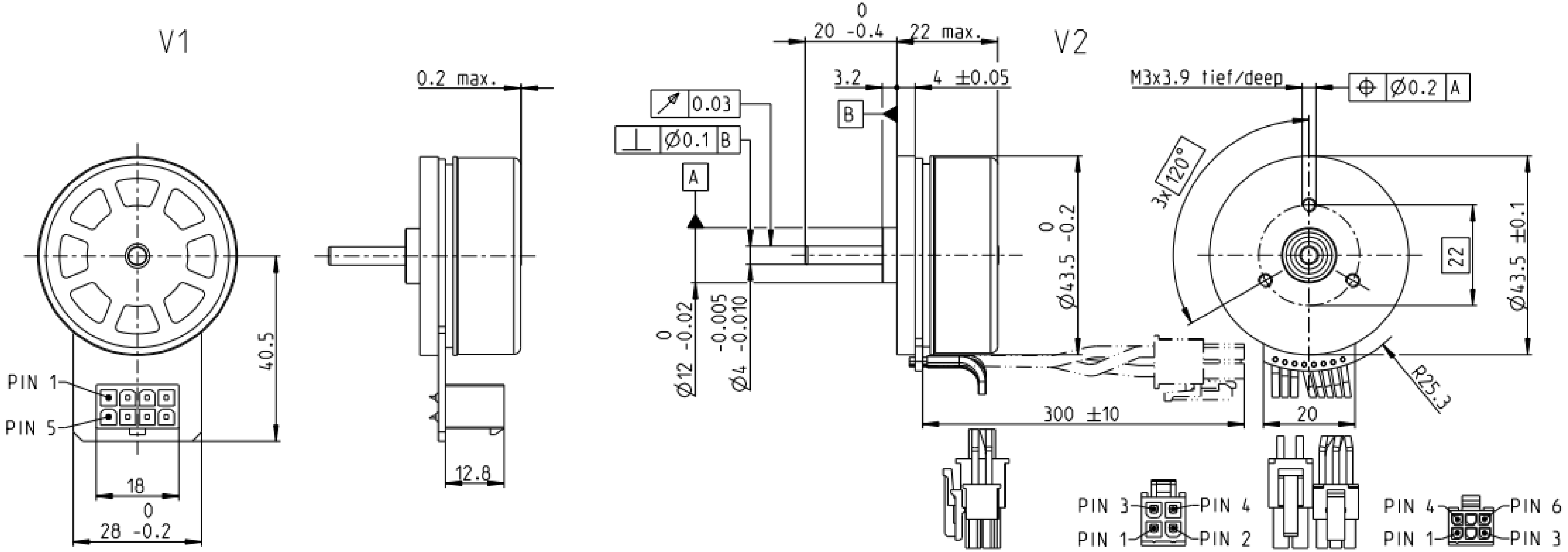
ASSEMBLY



VENDOR COMPONENT USED

EC 45 flat ∅43.5 mm, brushless, 60 watt

Open Rotor

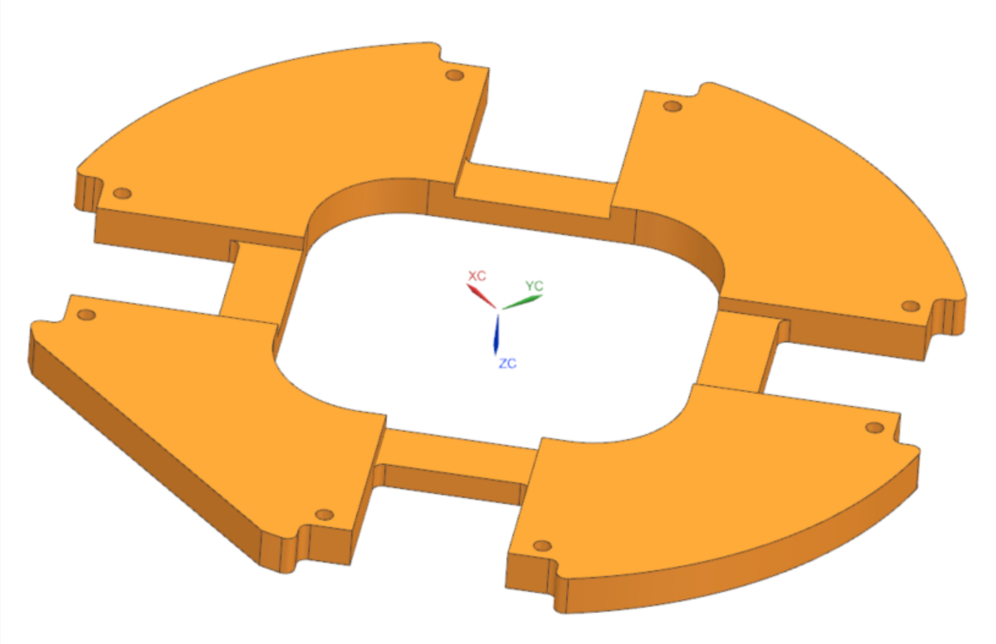


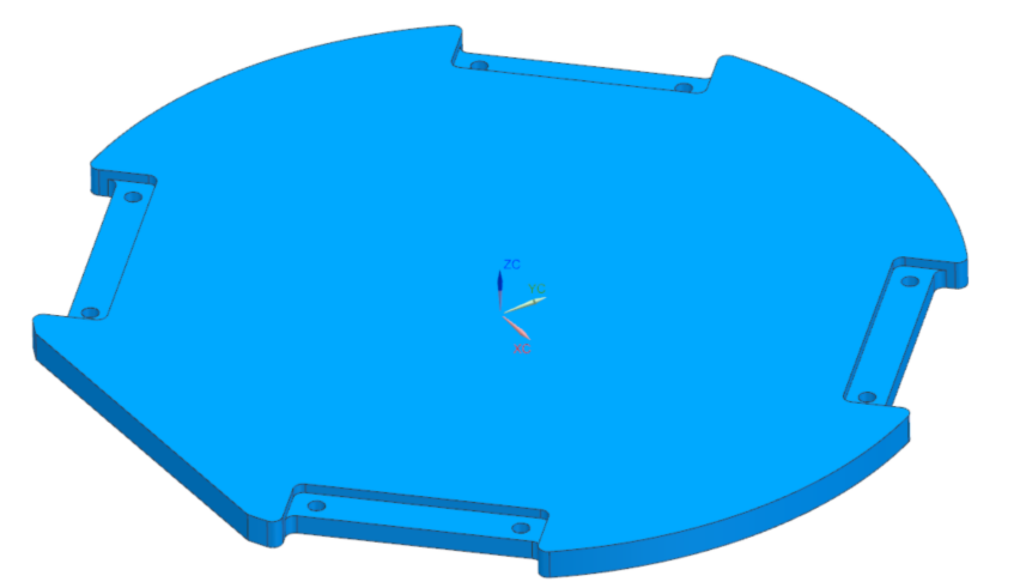
M 1:2

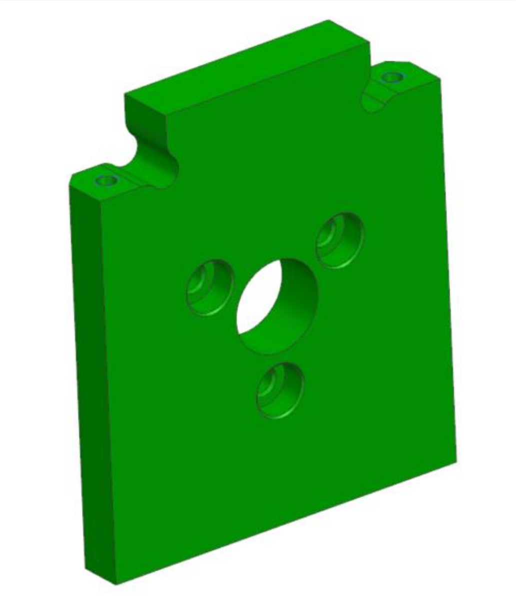
Stock program
Standard program
Special program (on request)

Part Numbers

3 COMPONENTS TO BE TOLERANCED AND PUT TOGETHER

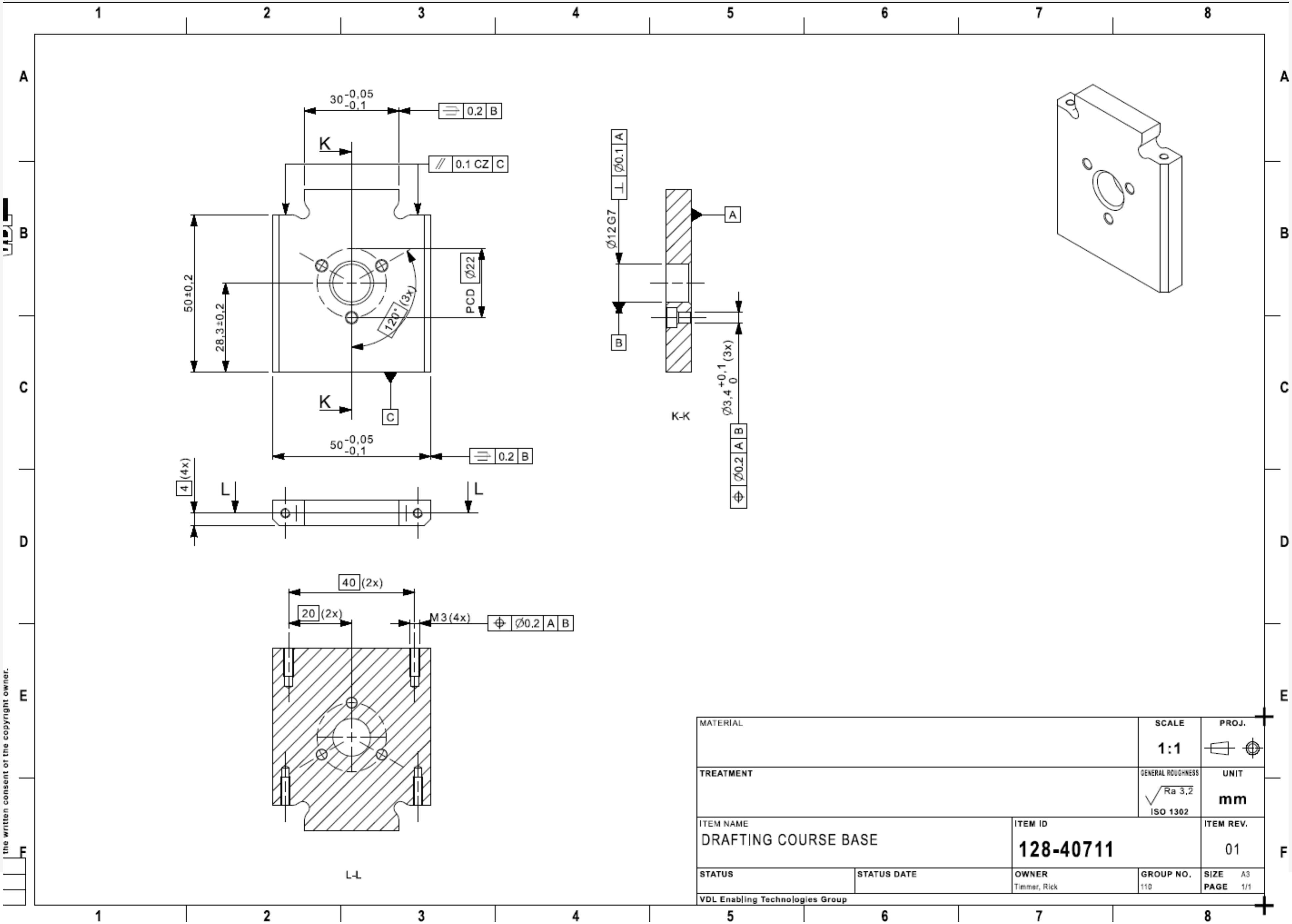




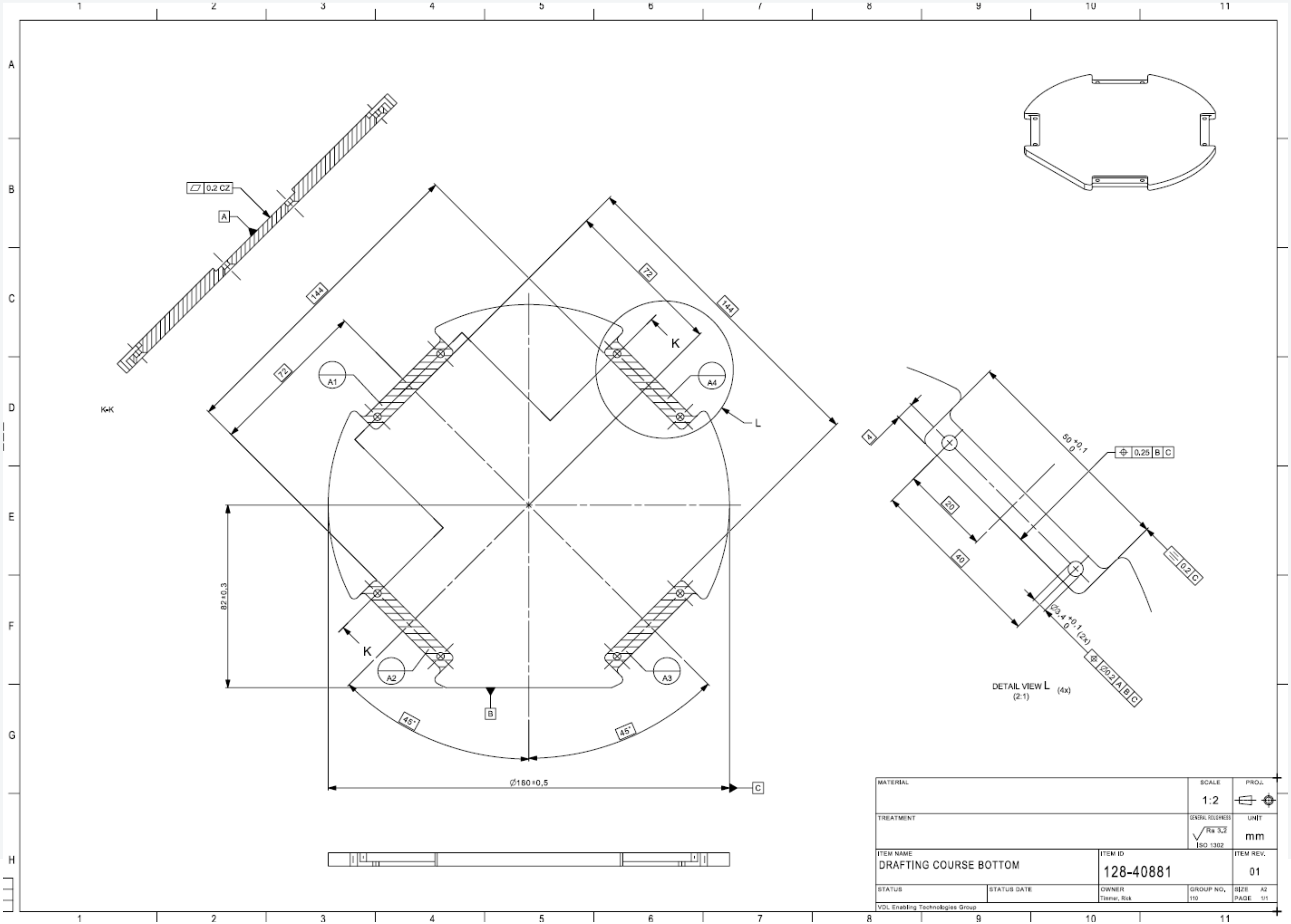


HOW MUCH CAN YOU TOLERATE? ;)

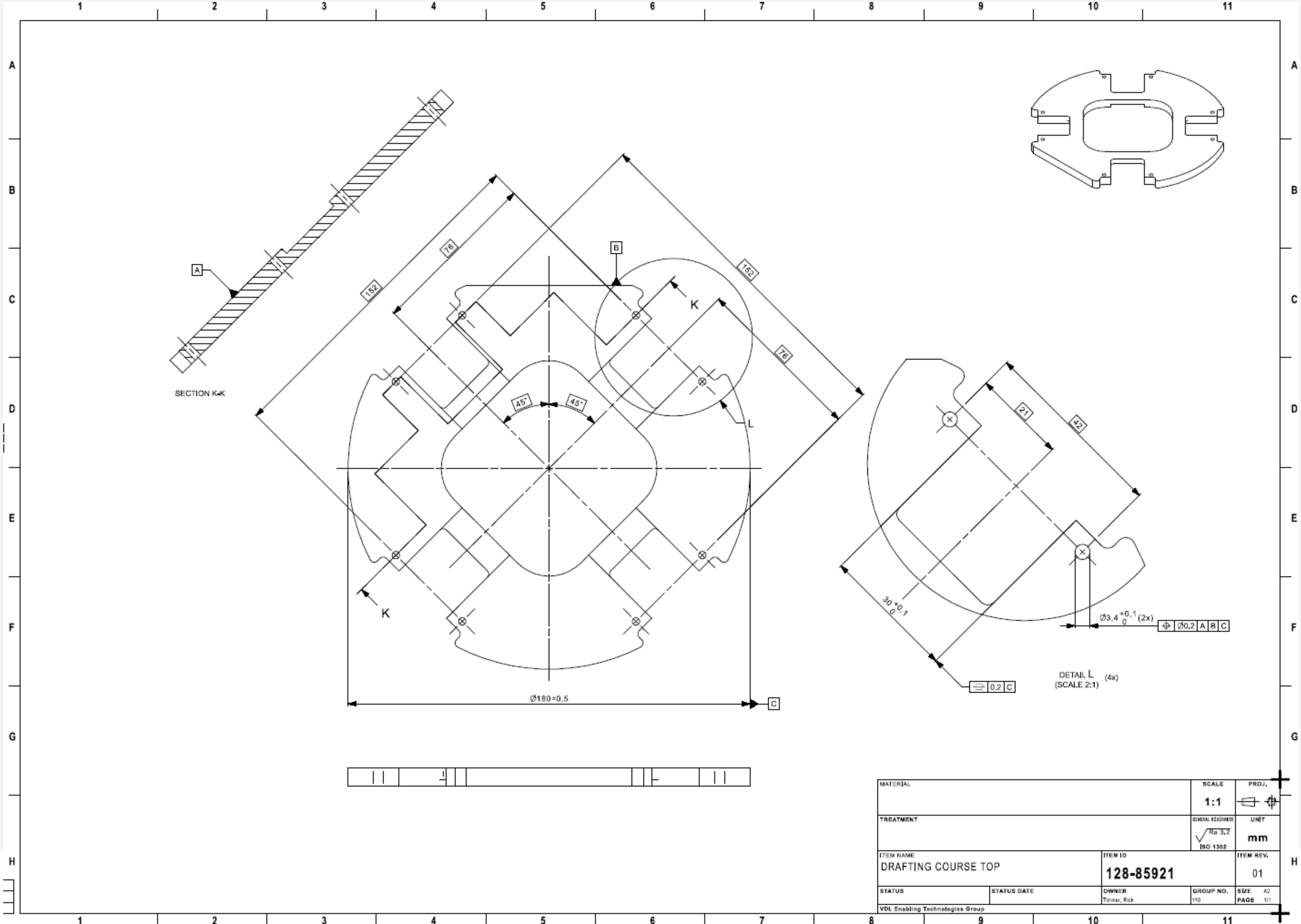
- Stepfiles through mail
- Also have printed out versions
- Think about tolerances and how they might stack up
- If required make a small tolerance train



K-K
L-L
MATERIAL
TREATMENT
SCALE
1:1
PROJ.
GENERAL ROUGHNESS
Ra 3,2
ISO 1302
UNIT
mm
ITEM NAME
DRAFTING COURSE BASE
ITEM ID
128-40711
ITEM REV.
01
STATUS
STATUS DATE
OWNER
Timmer, Rick
GROUP NO.
110
SIZE A3
PAGE 1/1
VDL Enabling Technologies Group



0.2 CZ
A
144
72
72
144
K
K
A1
A2
A3
A4
L
K-K
82±0,3
45°
45°
B
Ø180±0,5
C
4
50 +0,1 0
0.25 B C
20
40
0.2 C
Ø3,4 +0,1 0 (2x)
Ø0,2 A B C
DETAIL VIEW L (4x)
(2:1)
MATERIAL
SCALE
1:2
PROJ.
TREATMENT
GENERAL ROUGHNESS
Ra 3,2
ISO 1302
UNIT
mm
ITEM NAME
DRAFTING COURSE BOTTOM
ITEM ID
128-40881
ITEM REV.
01
STATUS
STATUS DATE
OWNER
Timmer, Rick
GROUP NO.
110
SIZE A2
PAGE 1/1
VDL Enabling Technologies Group


SECTION K-K
A
B
C
K
L
152
76
45°
21
42
Ø180±0,5
30 +0,1 0
Ø3,4 +0,1 0 (2x)
Ø0,2 A B C
0,2 C
DETAIL L (4x)
(SCALE 2:1)
MATERIAL
SCALE
1:1
PROJ.
TREATMENT
Ra 3,2
ISO 1302
UNIT
mm
ITEM NAME
DRAFTING COURSE TOP
ITEM ID
128-85921
ITEM REV.
01
STATUS
STATUS DATE
OWNER
Timmer, Rick
GROUP NO.
110
SIZE A2
PAGE 1/1
VDL Enabling Technologies Group

	#### Simple budget without tolerance pool or tilt/rotation influences											
	Module A accuracy											
	Machine state		X	Y	Z	Rx	Ry	Rz	S/L			
ID	From	To		+/- [um]			+/- [urad]			Remark	Ref.	Status
	Ain	Aou			100				S			
	B in	B out			500				S			
	C in	C out			1000				S			
	D in	D out			200				S			
	F in	F out			4				S			
	Apin	Apout			6				S			
Sum			0	0	1810	0	0	0		Module A accuracy		
K					1004					Required accuracy (=EPS spec.)		
Capability					0,55							