Sustainable and affordable design

VDL FACTS AND FIGURES 2023

1953

Family business VDL Groep was founded in 1953

75% of our products are exported to **112** countries around the world

100+

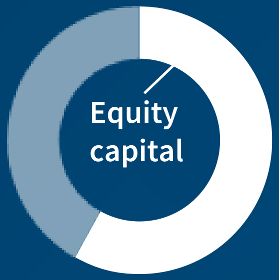
We consist of more than 100 companies

14.973

Employees in 19 different countries

Combined revenue

€6,4 billion



63,2%

of total assets

TOP 6

VDL Groep is in the top six on the Dutch reputation ranking

Source: RepTrak

THE WORLD OF VDL GROEP

VDL ETG

Science, Technology & Health

Mobility

Energy & Sustainability

Infratech

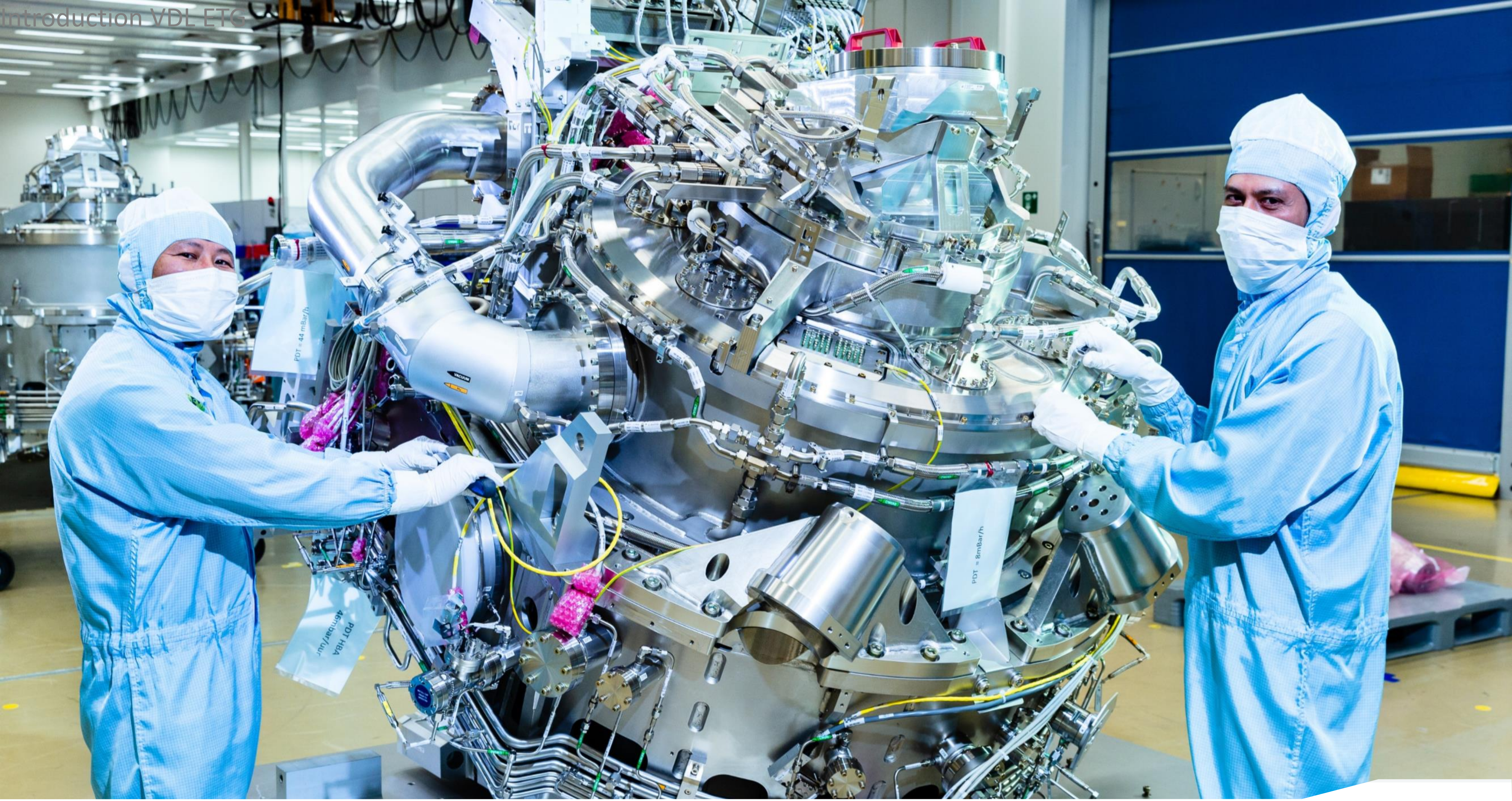
Foodtech

Extremely Large Telescope

Adaptive segmented main mirror

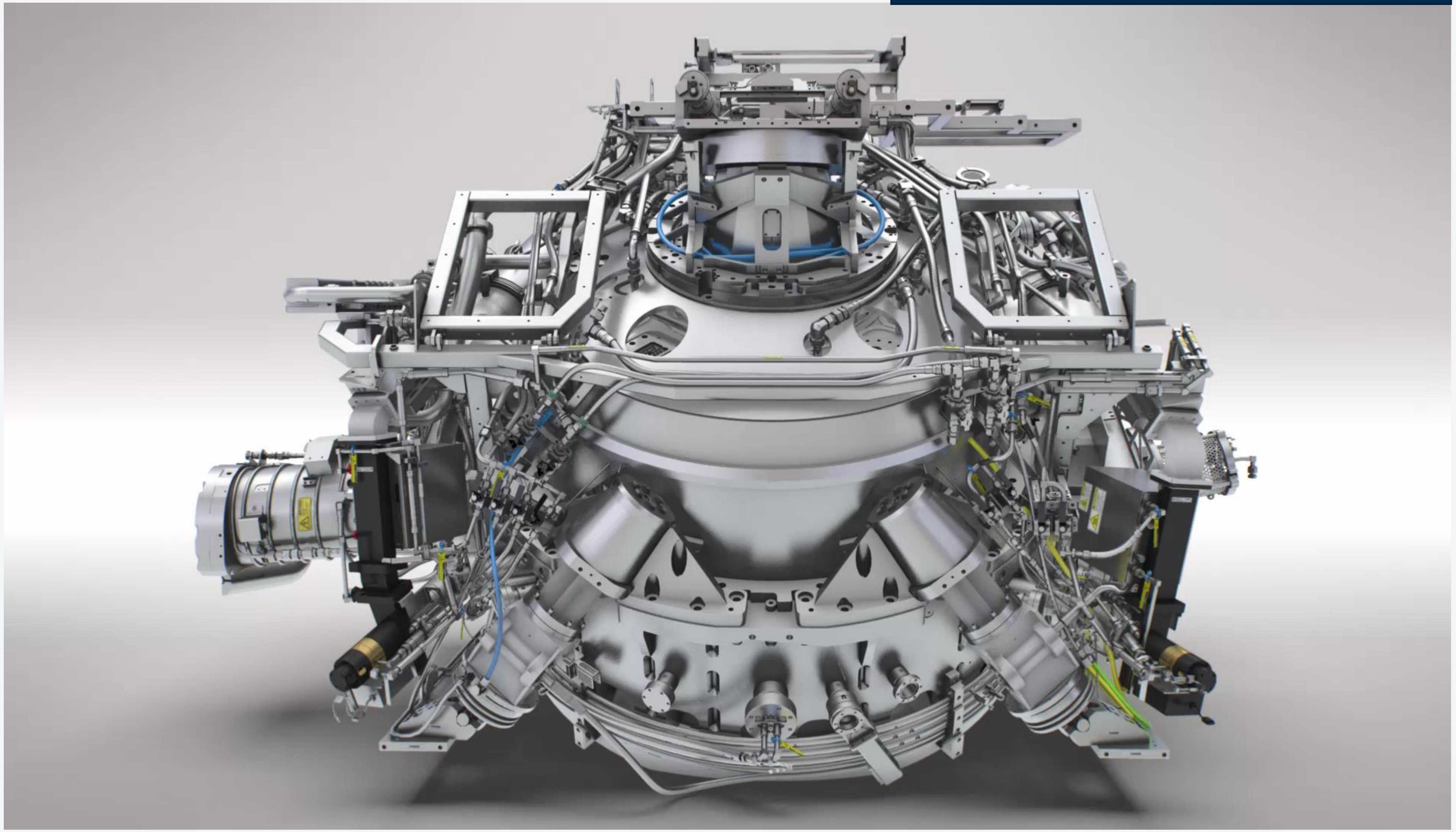
Product examples

Design and manufacturing of ElecronBeam systems


PDT = 44 mBar/h
PDT = 8mBar/h
PDT HBA
46mbar/uur

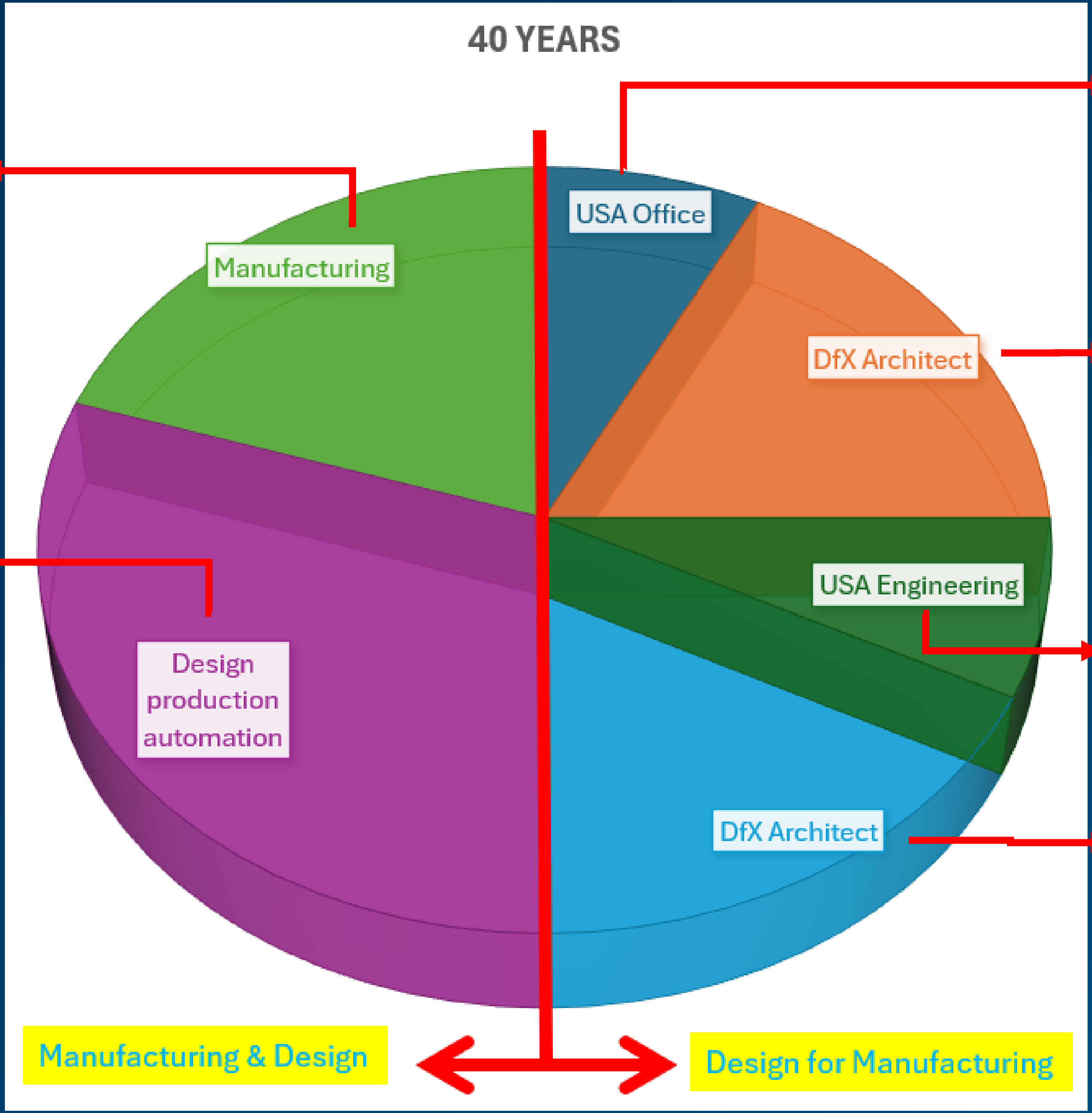
EUV light source

Light Source Vessel



How to machine the parts
How to setup parts
How to measure parts
How to weld parts
How to clean parts

Customer requirements
Module requirements
Part requirements
Qualification requirements
Assembly requirements
Test requirements



Cost efficiency
OEM localization
Standard requirements
Special process qualification

Understand functional requirements
Translate to manufacturing technologies

DfX with Customer engineering

Design with Customer designers
Factory automation
Feasibility studies

Process requirements

System architecture

- Stiffness
- Dynamics
- Materials
- Tolerances

- Machine control
- Data control
- Diagnostics
- Predictive maintenance

System architect
DfX architect

Hardware Mechanical Architect

Environment Specialists

Process Requirements Physicist

Controls Software Architect

Power Electronics Architect

- Vacuum
- Contamination
- Temperature

- Power supply
- Drivers
- Cabling

Frames

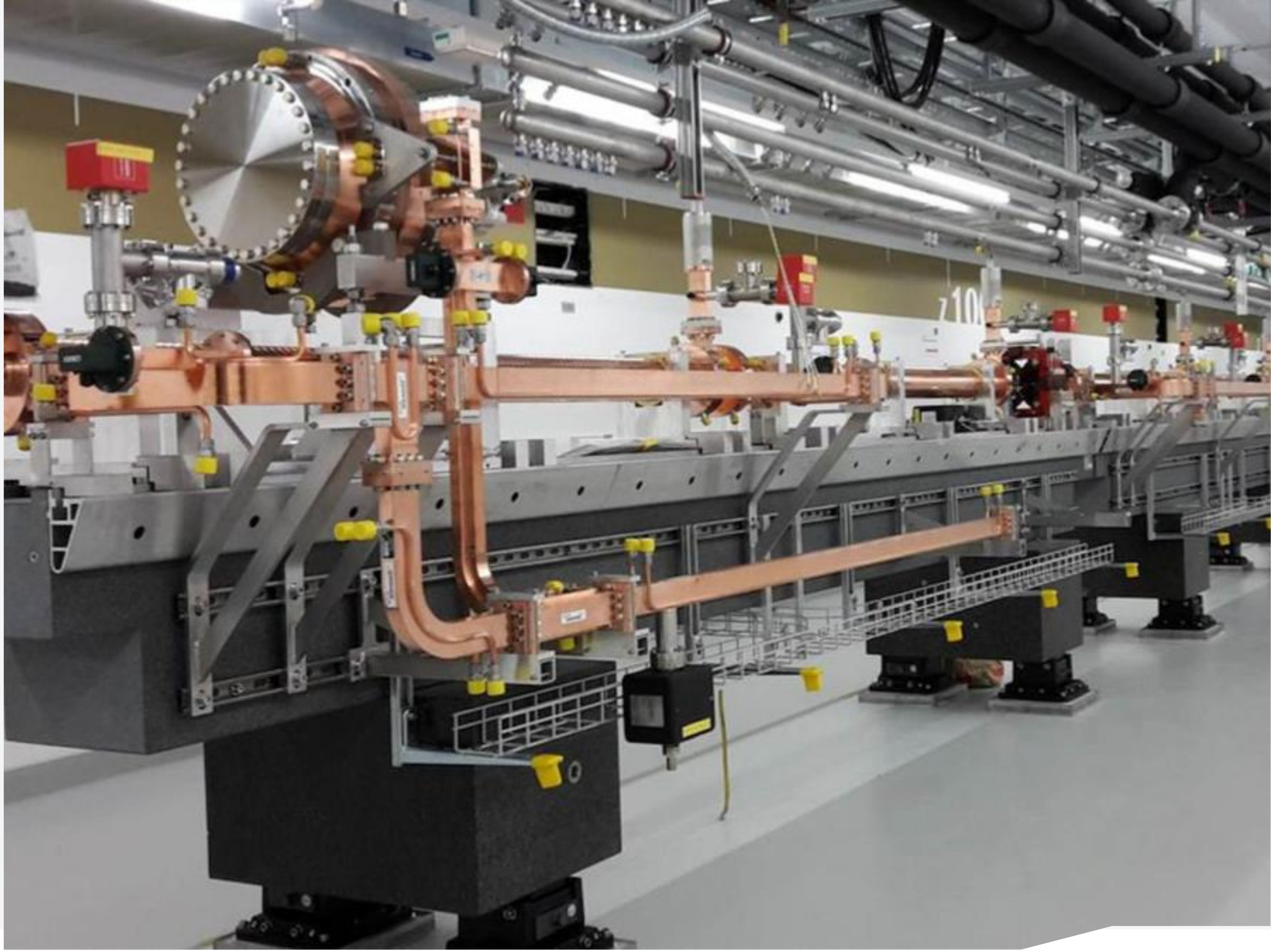
High-tech structures

- Structural dynamics
- Seismic
- Stability
- Changing loads
- Thermal
- Advanced machining
- Kinematic interfaces
- Tolerances
- Cost

Vacuum & beam

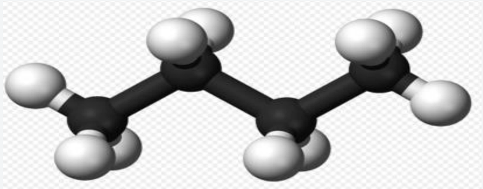
Cleanliness & high voltage

- Ultra-precision machining
- Brazing
- Diffusion bonding
- RF
- High-voltage
- Electro-magnetics
- Shielding
- Contamination control



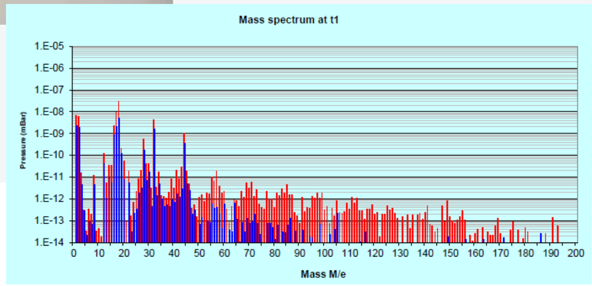
Molecular contamination

Production introduced contaminiation



- Organic cooling fluids, greases, finger prints, glues
  →Problem: Vacuum quality issues
  → Measurement: RGA
  →Cleaning strategy: Degrease, bake-out, assembly, RGA qualification

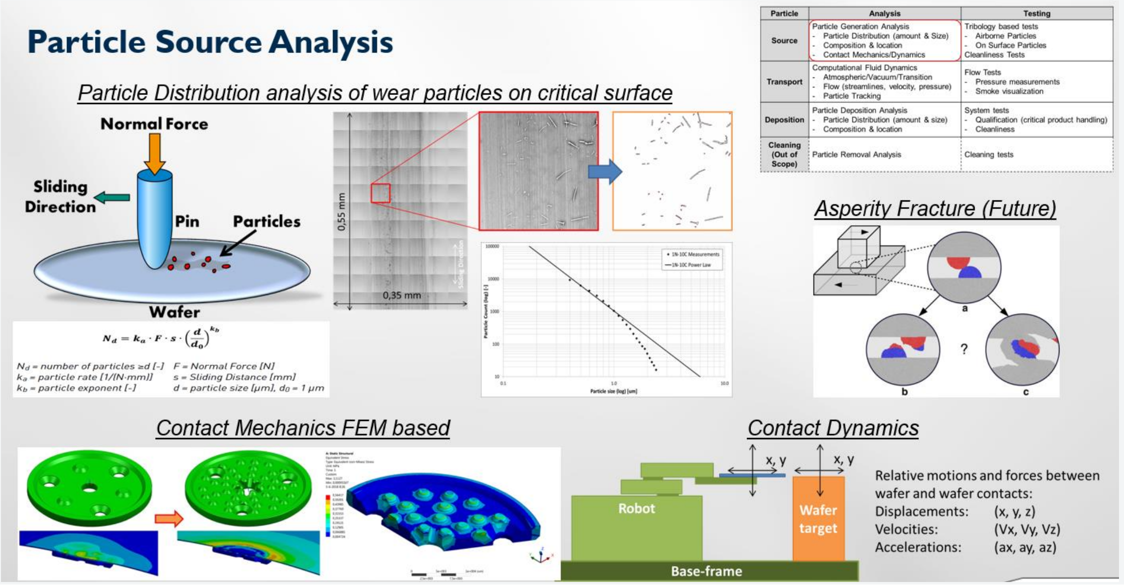
Production – Degrease – Bake out - Assembly – RGA qualification

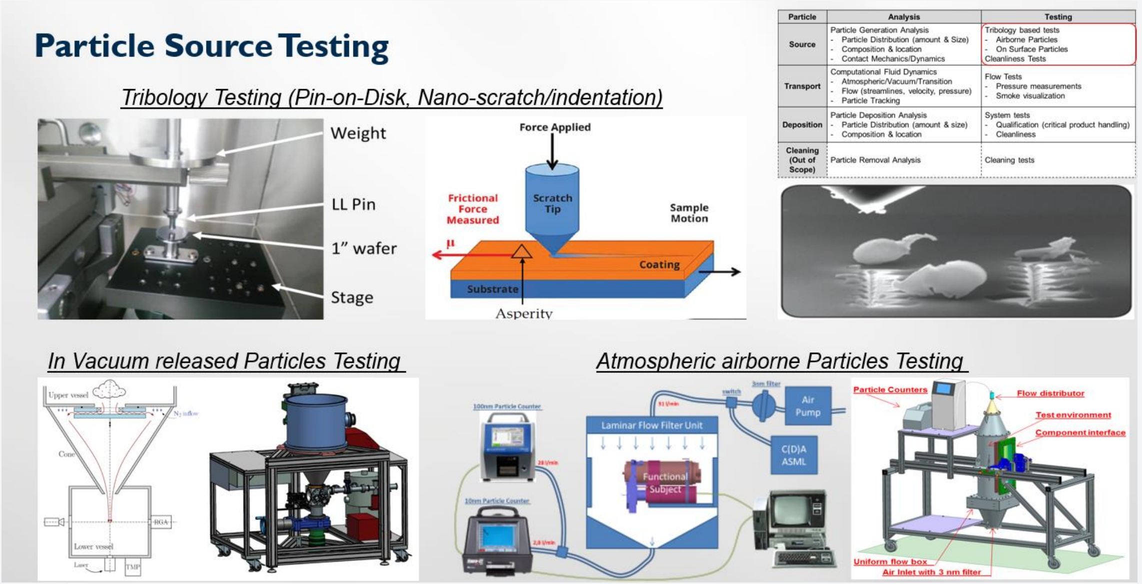


Particle contamination

Introduction by Manufacturing or Handling in the system

- Introduction by manufacturing should be removed mechanically, Brushing or Ultrasonic
- Introduction by Handling generated by contact between two materials. Avoid as much as possible. Big partical generators are gate valves because of the big contact surface.





Handling

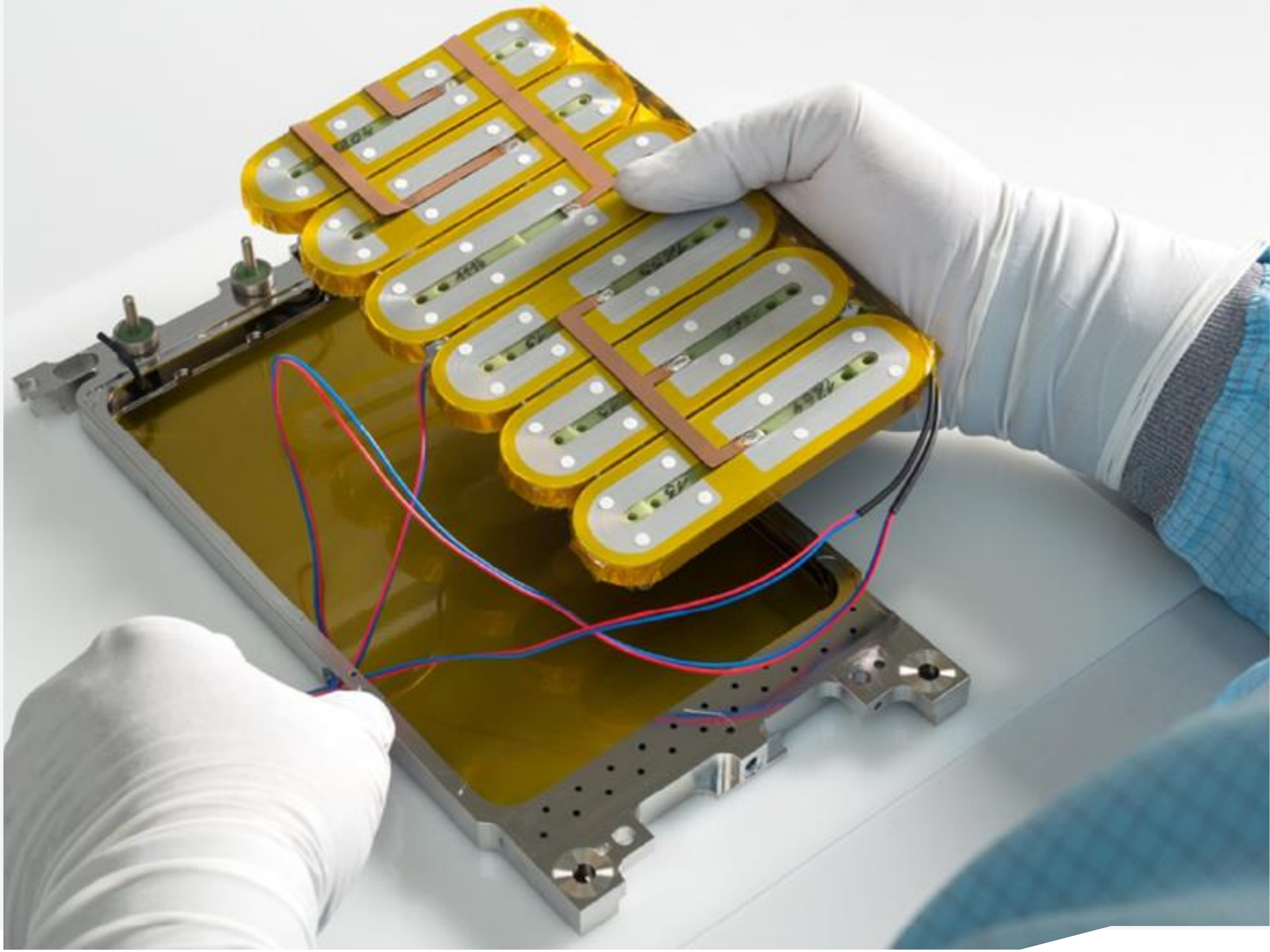
Ultimate control

- Motion control
- Machine logistics
- Reliability
- Contamination control
- Tribology
- Robots
- Load locks
- Diagnostics
- Cost

Positioning

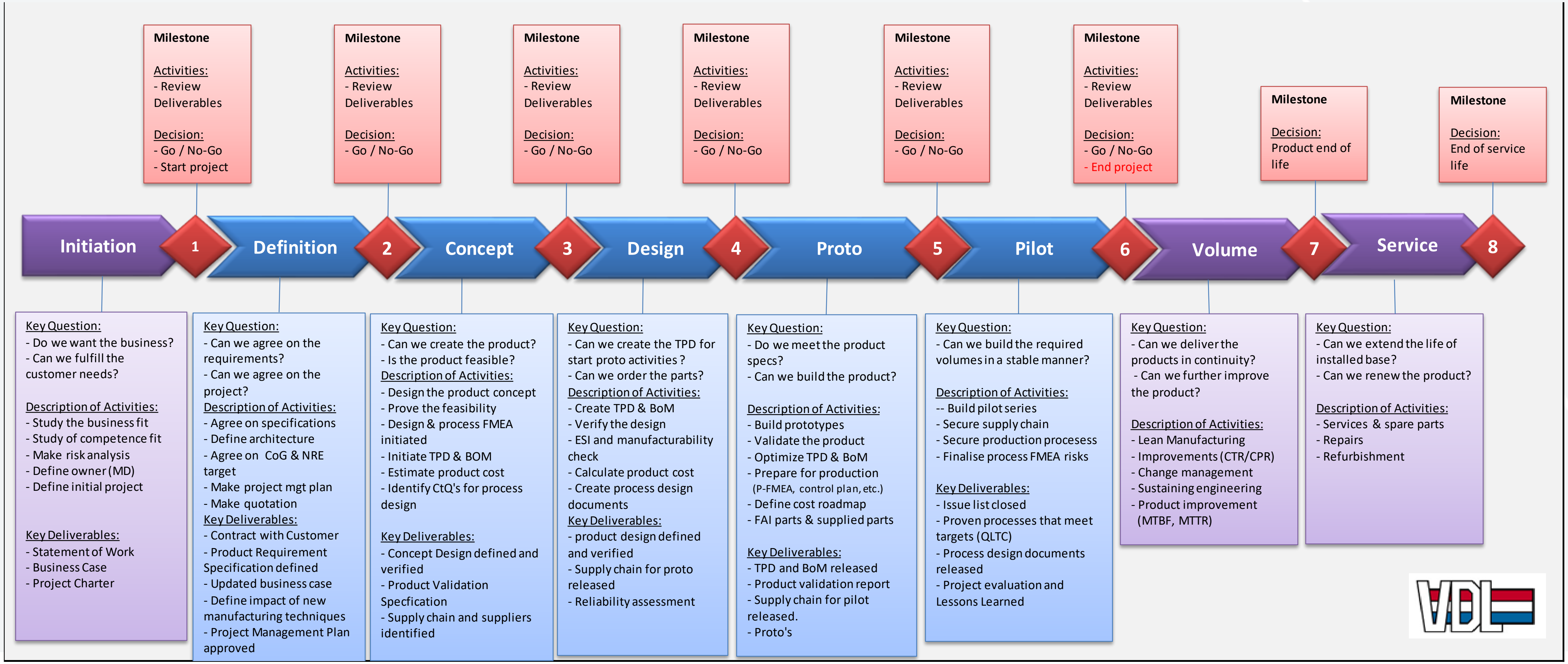
Ultimate control

- Motion control
- Machine control
- Reliability
- Contamination Control
- Tribology
- Actuators
- Cost

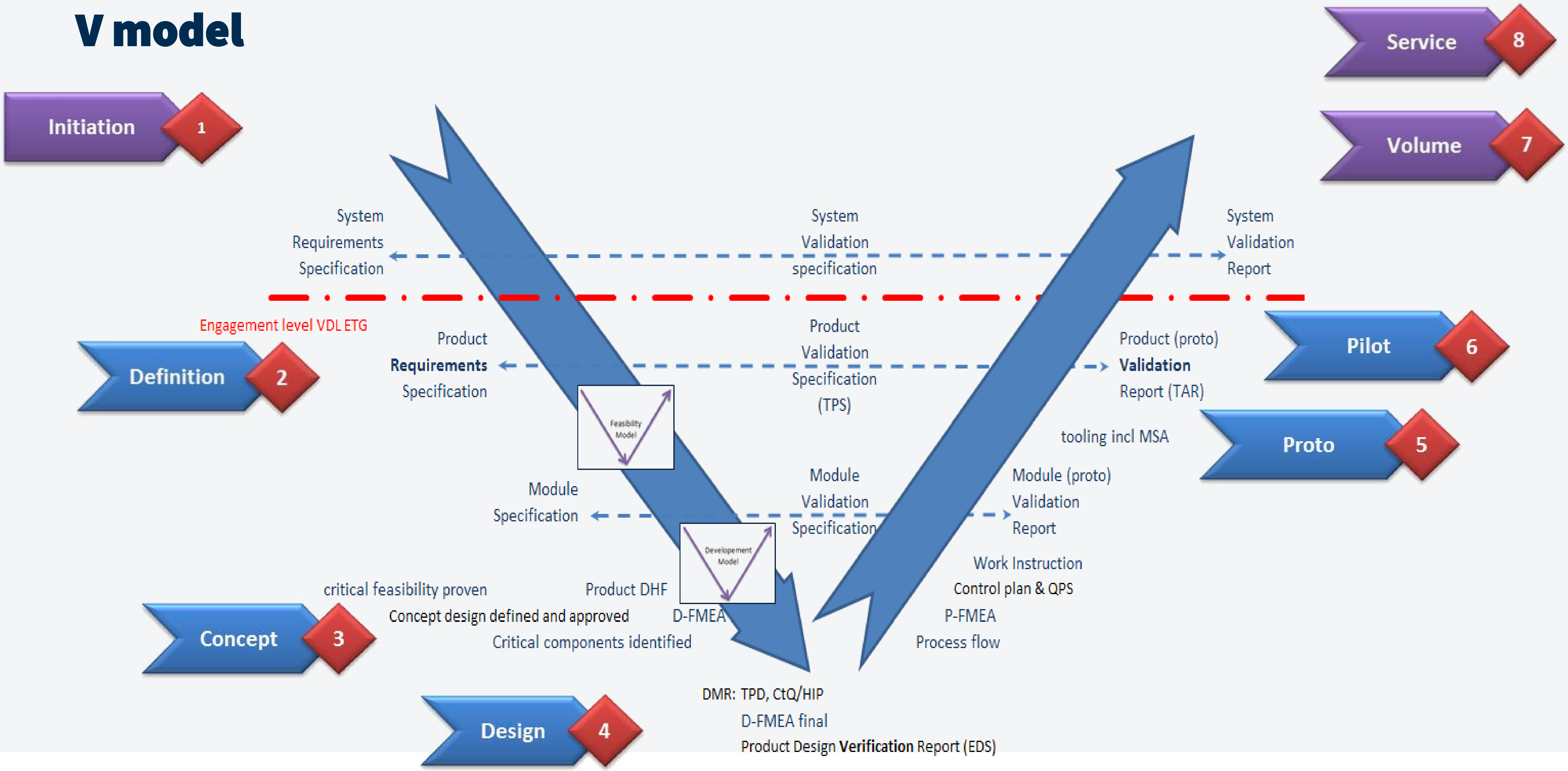


Product Generation Process

Milestones in development and production

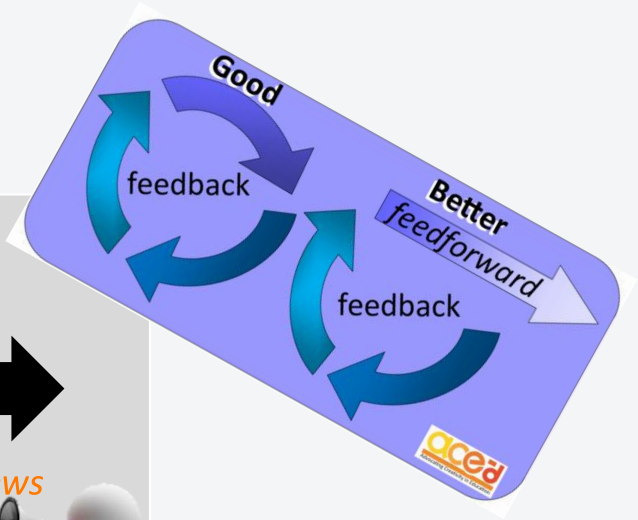


V model



Service 8
Volume 7
Initiation 1
System Requirements Specification
System Validation specification
System Validation Report
Engagement level VDL ETG
Definition 2
Product Requirements Specification
Product Validation Specification (TPS)
Product (proto) Validation Report (TAR)
Pilot 6
Feasibility Model
tooling incl MSA
Proto 5
Module Specification
Module Validation Specification
Module (proto) Validation Report
Developement Model
Work Instruction
Control plan & QPS
P-FMEA
Process flow
critical feasibility proven
Concept design defined and approved
Critical components identified
Product DHF
D-FMEA
Concept 3
DMR: TPD, CtQ/HIP
D-FMEA final
Product Design Verification Report (EDS)
Design 4

Early Supplier Involvement (ESI)



Standard approach

Input → Design & TPD creation → Output

Design knowledge

Integration knowledge (ME&EE)

Knowledge

Error

Reviews

Issues

ESI *Early Supplier Involvement*

Input → Design & TPD creation → Output

Design
- manufacturability → Know capabilities Machines
Build
Fastlane to go to High Volume Manufacturing MR1.3
- faster work preparation
- concurrent build tool development
- Use customer service tooling

Knowledge

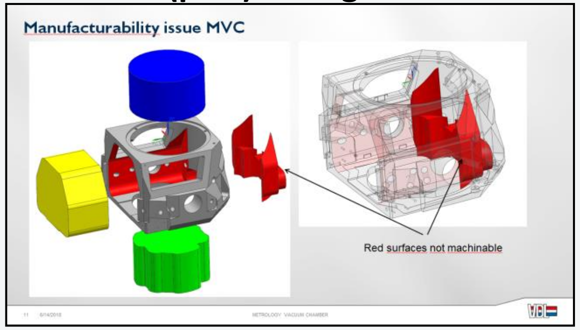
Error

Reviews

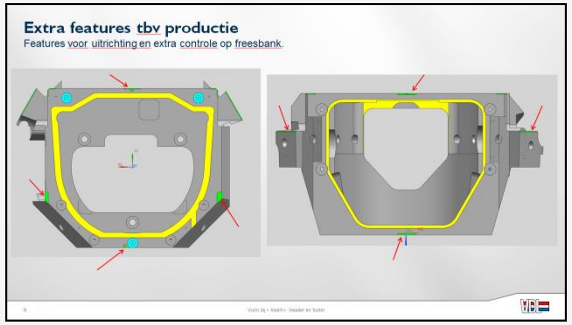
Issues

Shared manufacturability input

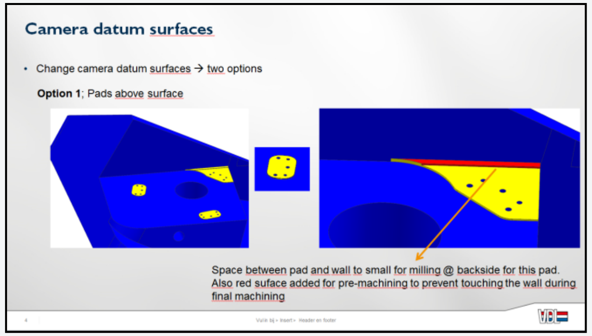
Chamber (pre-)milling



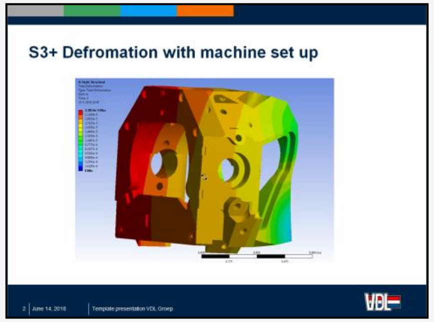
Supplier interfaces



Production boundaries

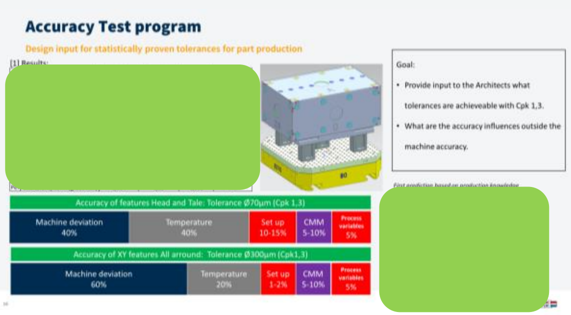


Set Up deformations



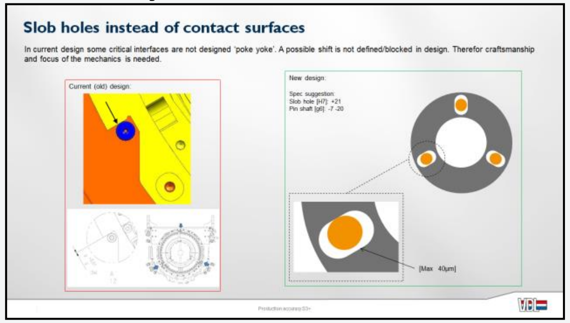
Input for tolerances

Test program input

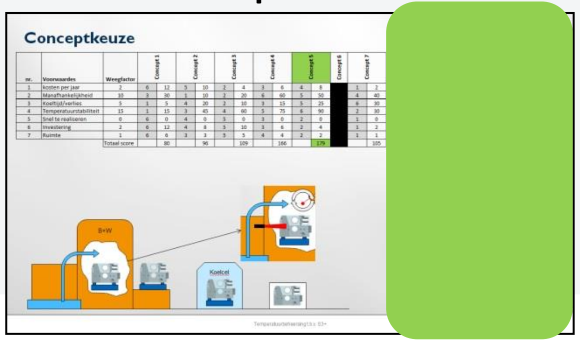


Chamber tolerances

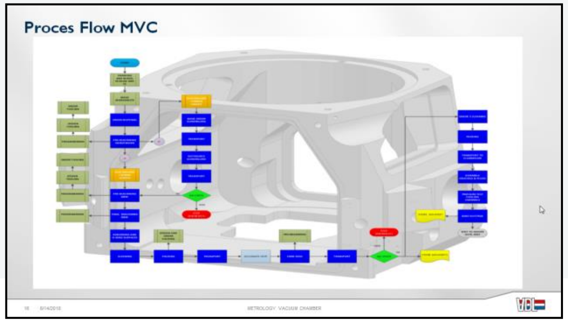
Assembly feedback



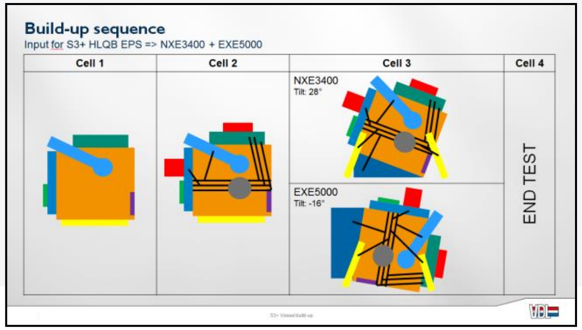
Production temp control



M-flow input



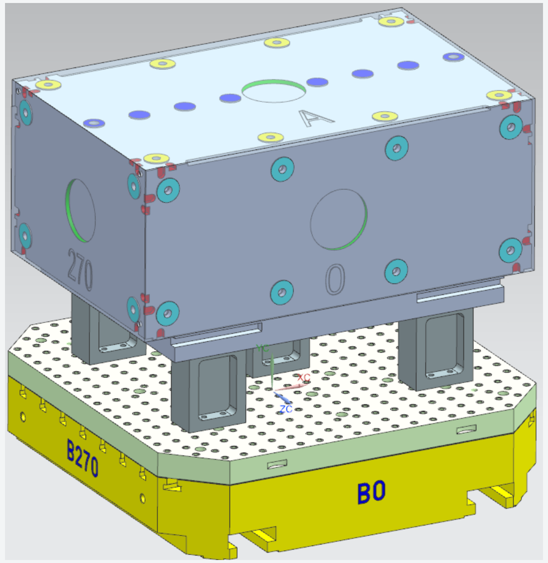
HLQB Process flow input



Accuracy Test program

Design input for statistically proven tolerances for part production

[1] Results:



Goal:

- Provide input to the Architects what tolerances are achieveable with Cpk 1,3.
- What are the accuracy influences outside the machine accuracy.

First prediction based on production knowledge

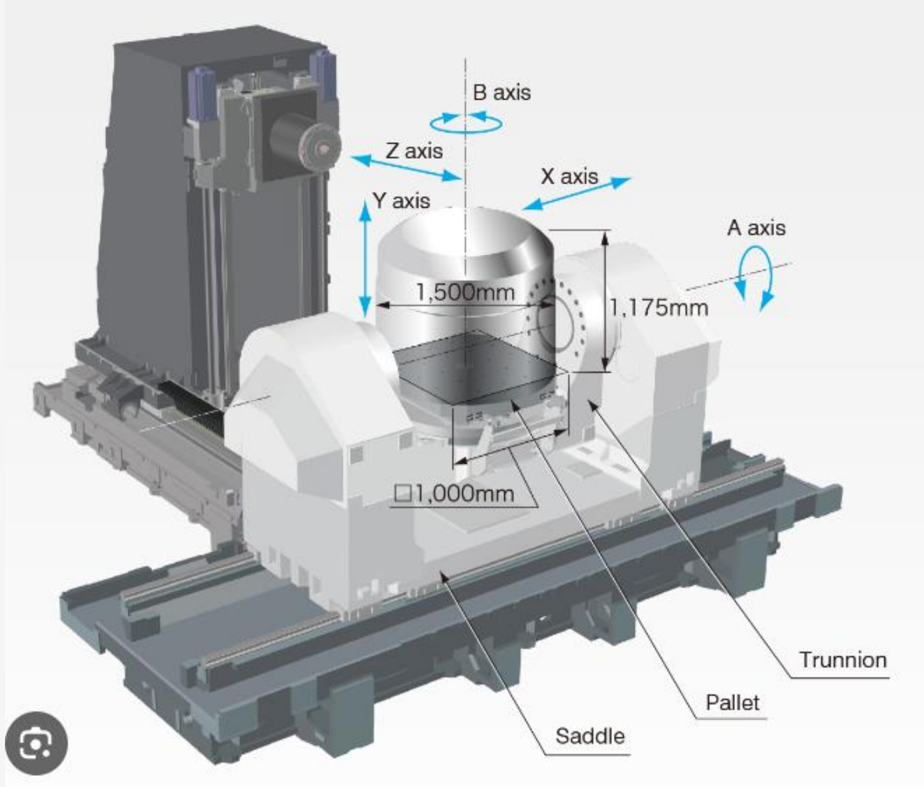
Accuracy of features Head and Tale: Tolerance Ø70µm (Cpk 1,3)				
Machine deviation 40%	Temperature 40%	Set up 10-15%	CMM 5-10%	Process variables 5%

Accuracy of XY features All arround: Tolerance Ø300µm (Cpk1,3)				
Machine deviation 60%	Temperature 20%	Set up 1-2%	CMM 5-10%	Process variables 5%

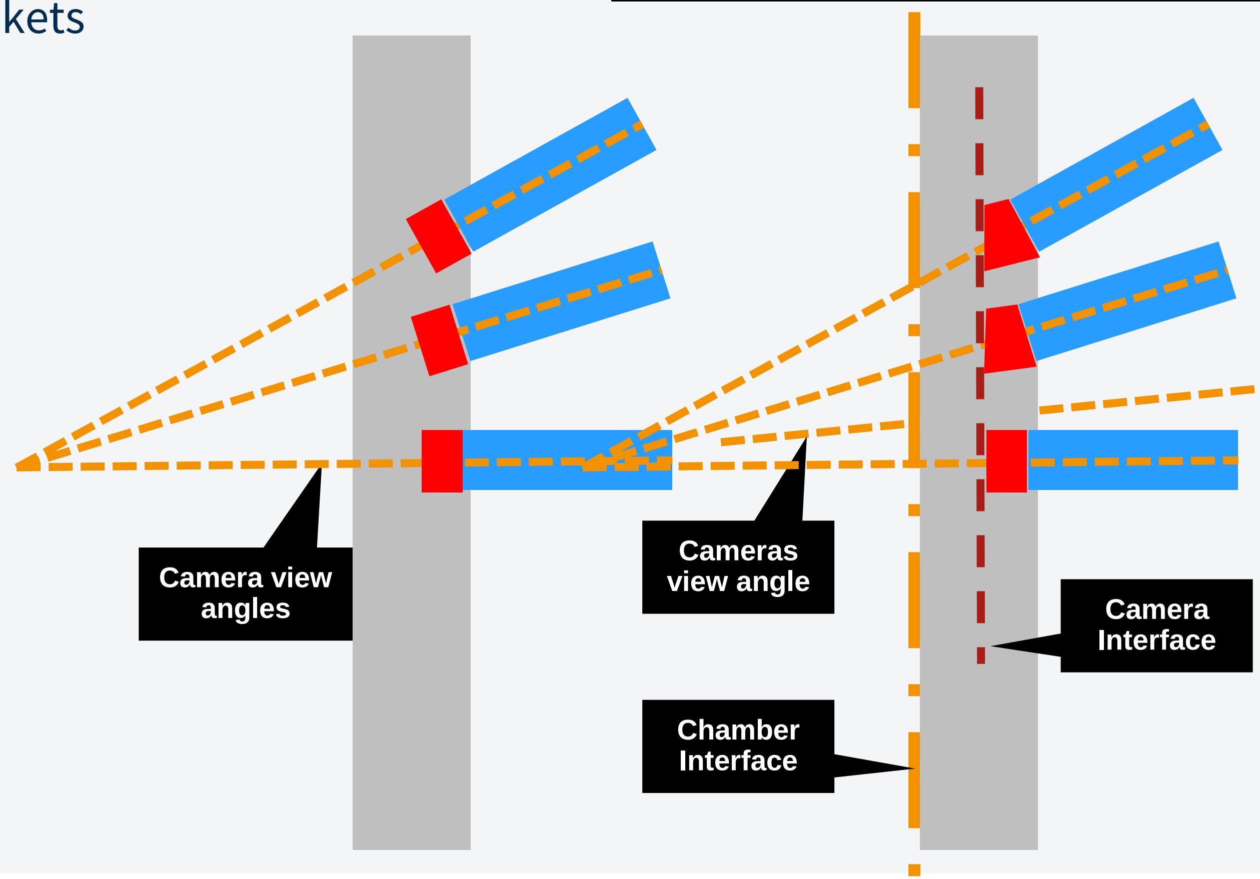
Camera interface solution

VDL: accurate interface using 4 of 5 axis machine

- Requirement is camera view angle in two directions
- Split accuracy between door and Camera brackets



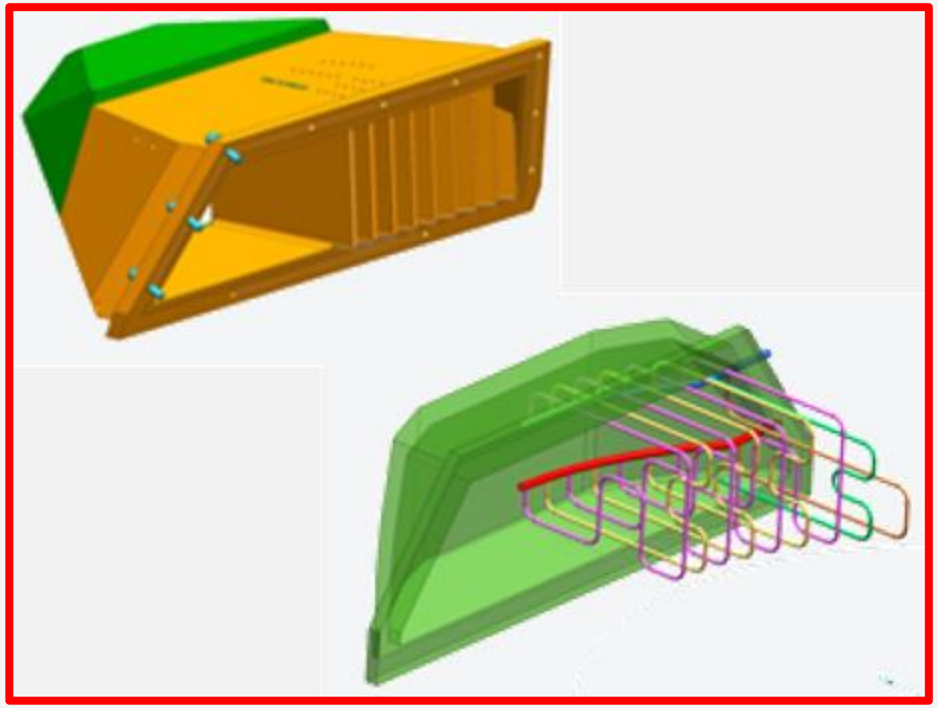
- SPC analysis, gap analysis and process capability, provided data that was needed to define the metrology interface accuracy
- Therefore second angle was moved to the camera brackets
- At the start of the design this became clear.



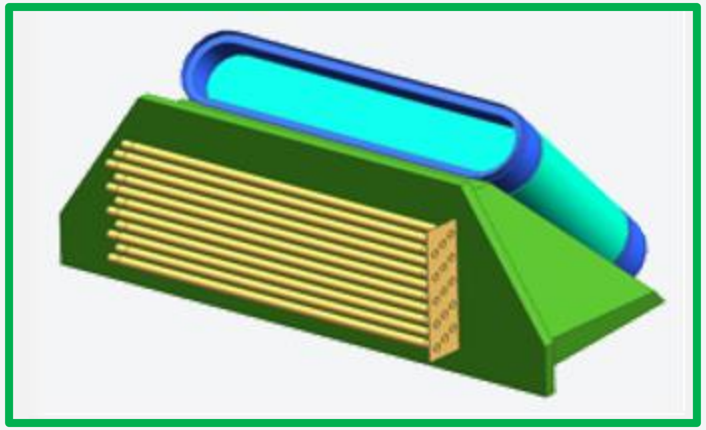
Simplify the design during design

Close cooperation with cooler manufacturer and analyse what is available in the market

- Complex gundrilling and bended design transferred into a straight tubular cassette design



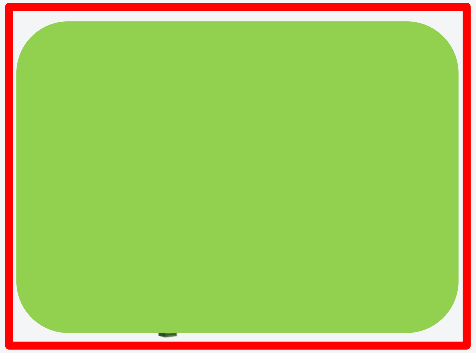
Simplified design



Structural frames with dynamic requirements

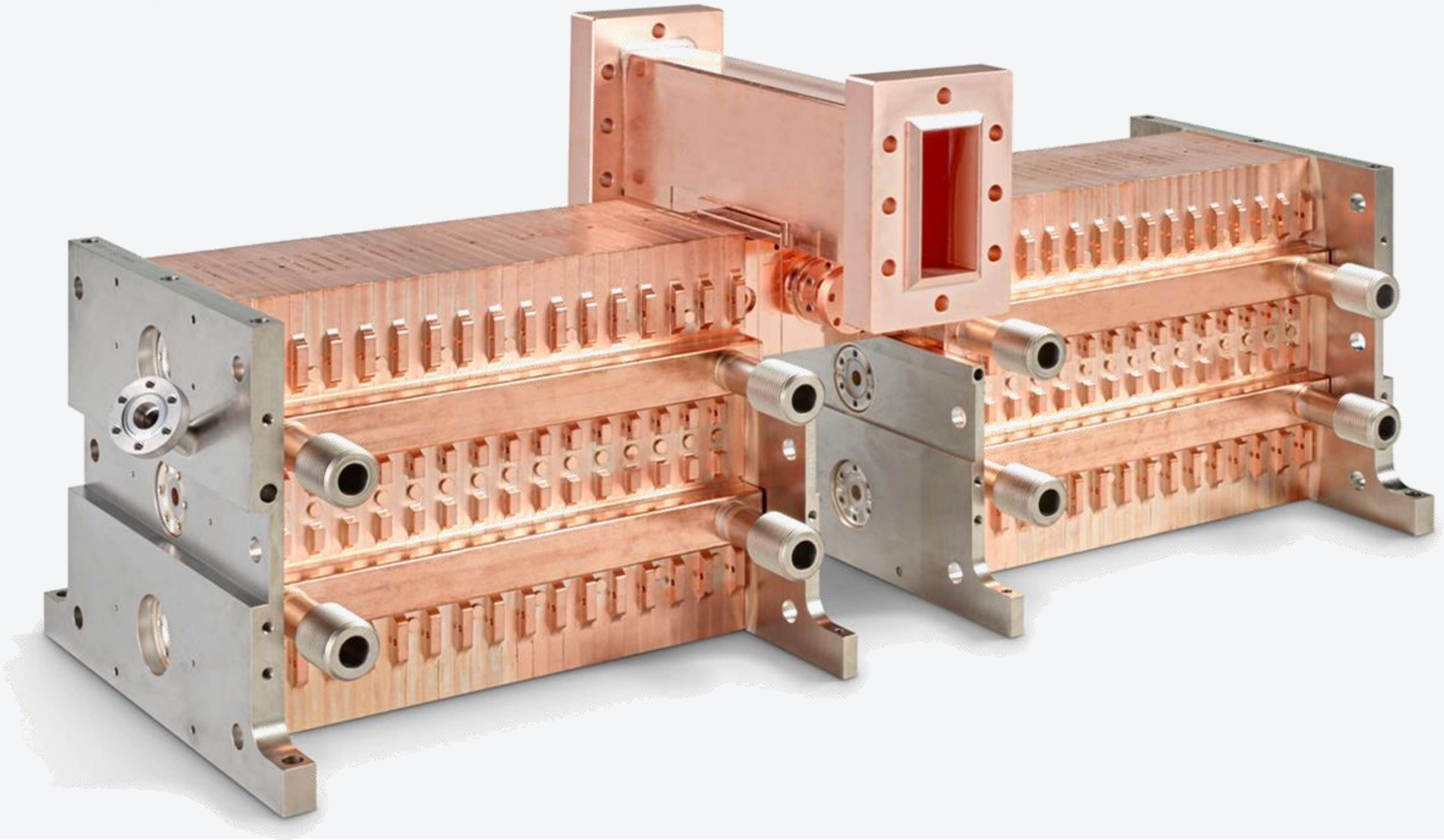
Transfer Tubular frame to Sheet metal frame

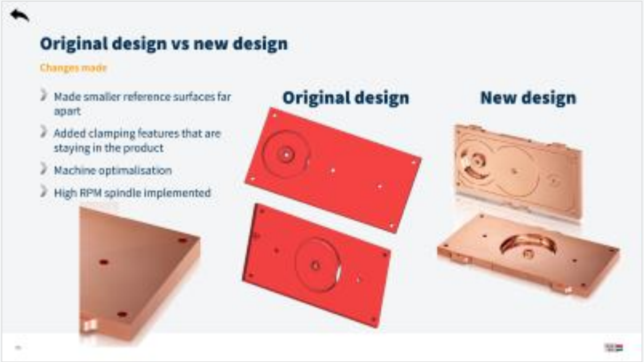
- Proposed to change into sheet metal frame to:
  - Separate the functions of SISO, Vibration Isolation and Seismic restraints
  - Increase the stiffness of the frame to meet system dynamics requirements
  - Improve ‘Build and Adjust’
  - Create more volume utilities
  - Improve manufacturability

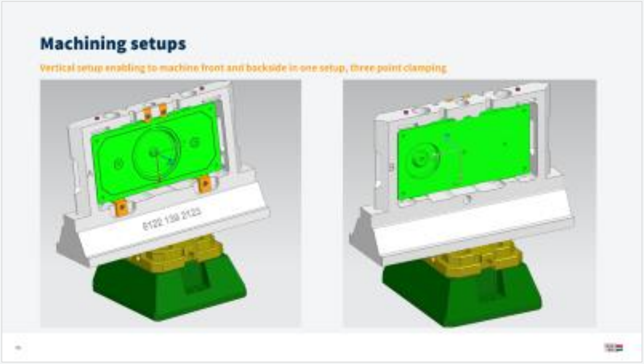


Total assy accellerator

Length accuracy of



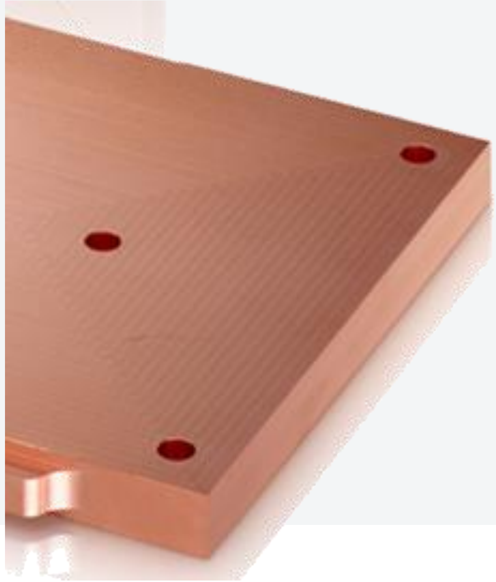




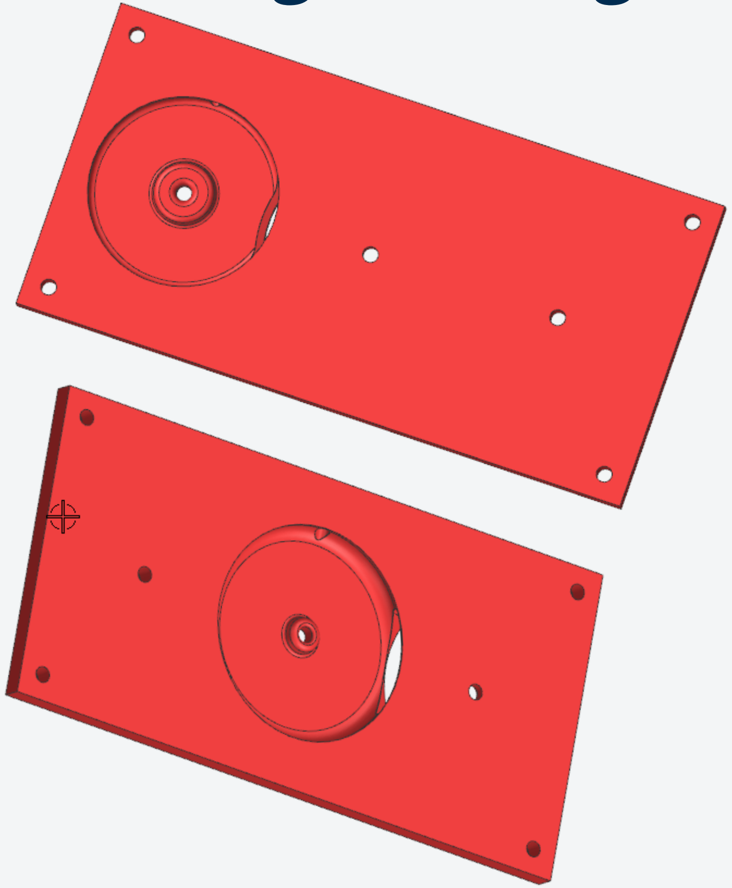
Original design vs new design

Changes made

- Made smaller reference surfaces far apart
- Added clamping features that are staying in the product
- Machine optimalisation
- High RPM spindle implemented



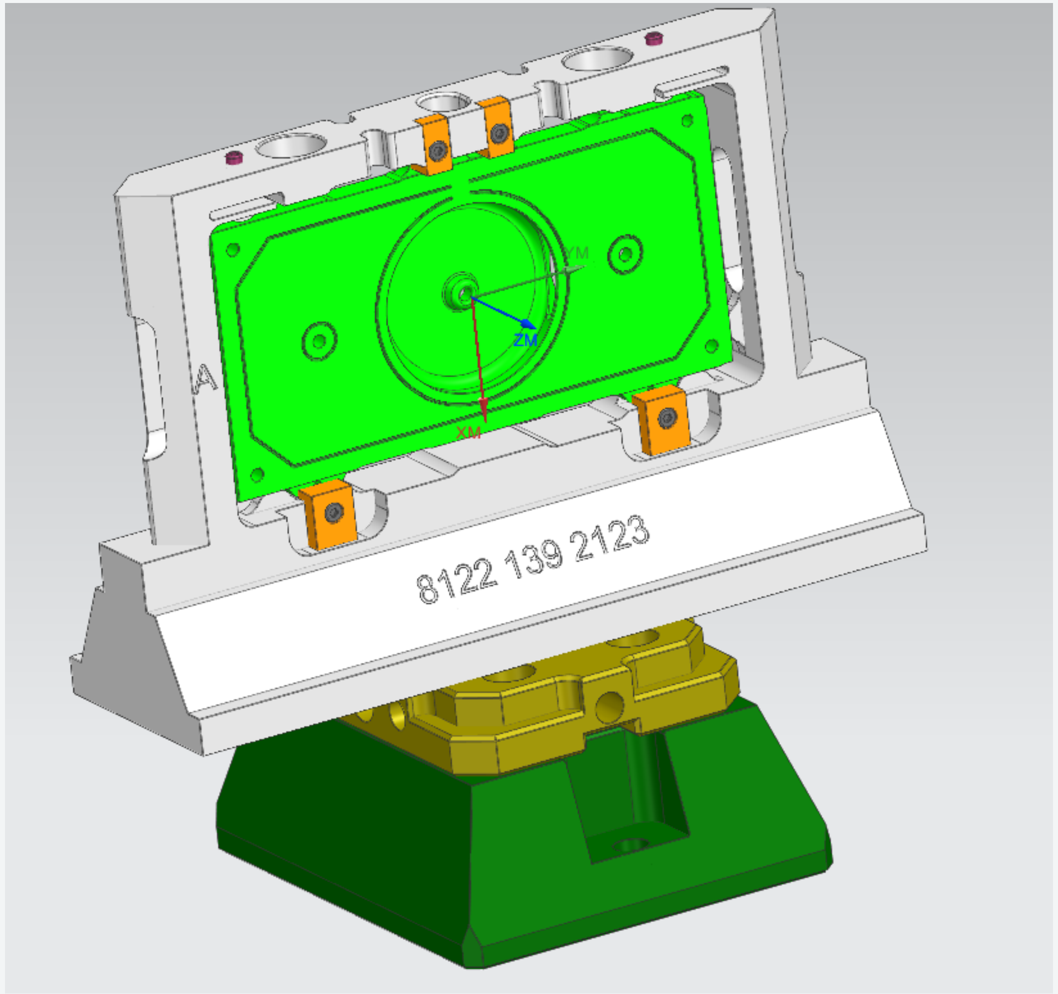
Original design

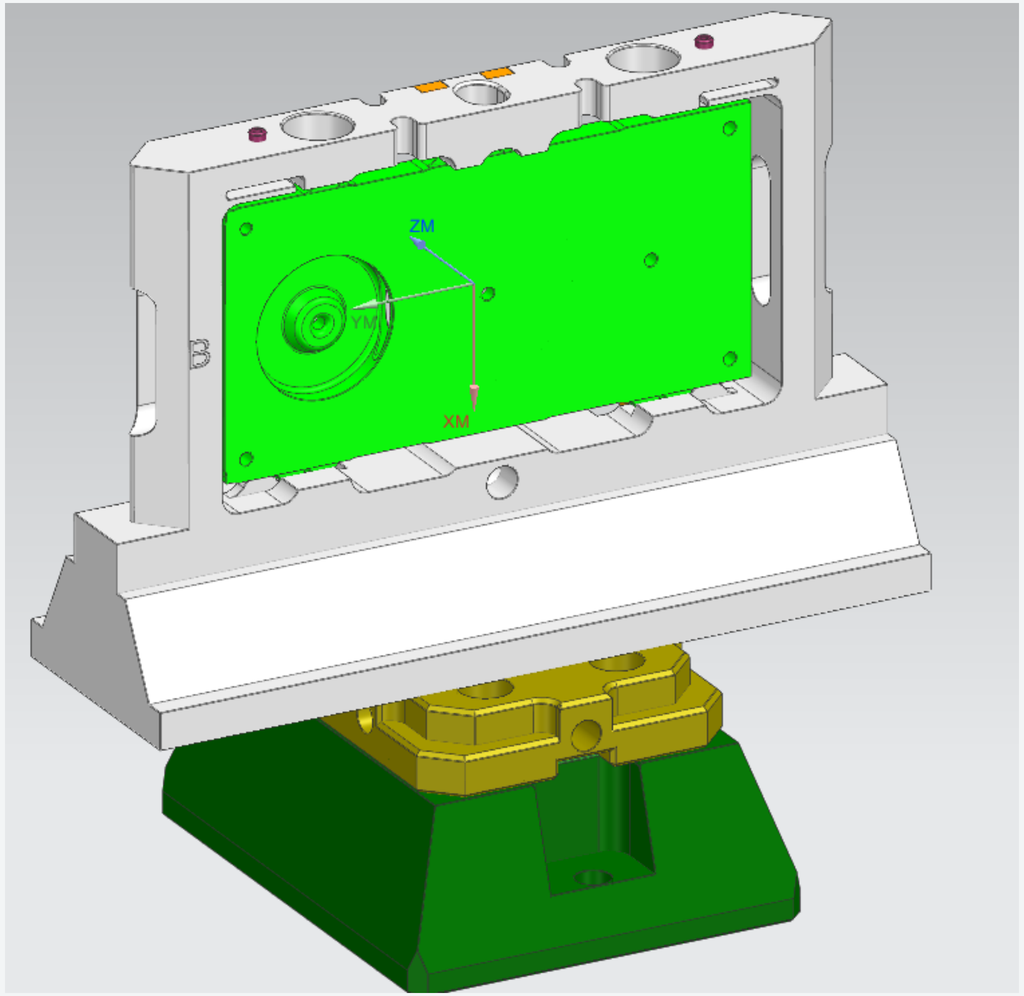


New design

Machining setups

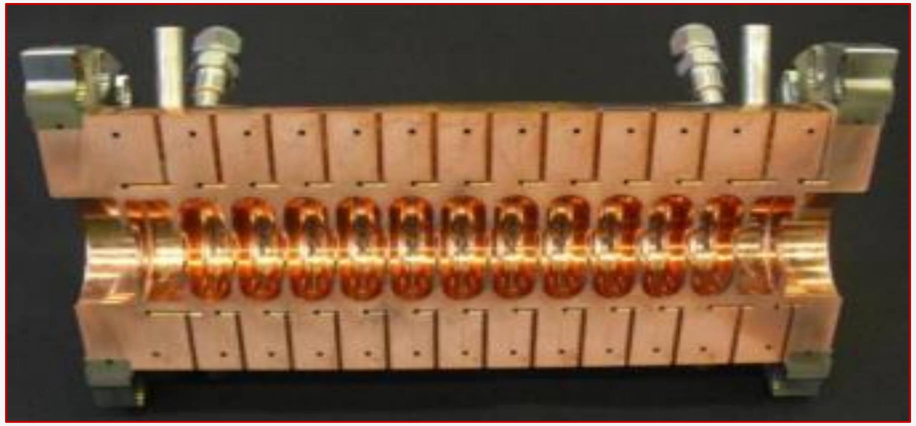
Vertical setup enabling to machine front and backside in one setup, three point clamping





Mechanical positioning and alignment






Accelerator technology

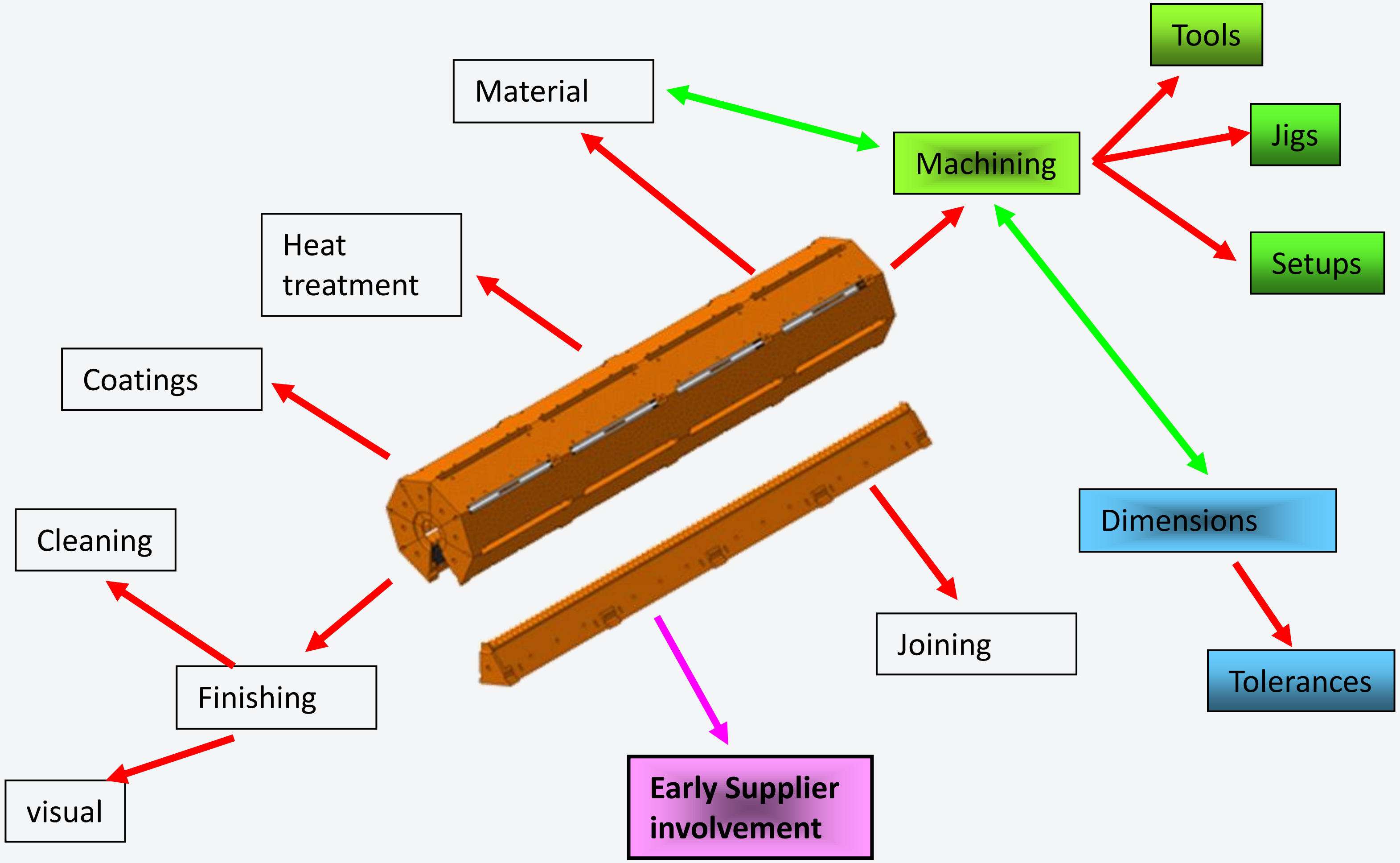
- Ultra high precision machining
  - Shape accuracy typically < 1 µm
  - Surface roughness typically < 25 nm
  - Optical mirror finish without polishing
  - Milling and grinding ceramics, EDM, Brazing
- Reduction of high-voltage breakdown rate due to low surface roughness
- UHV (< 10-9 mbar) compatibility

CERN

PAUL SCHERRER INSTITUT

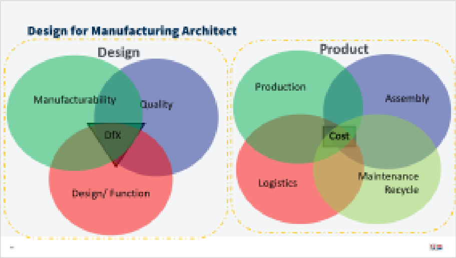
PSI

Design of a Part



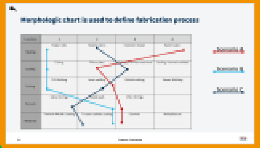
Production technology

How to create a part, integration or separation



Product Requirements

Physicist



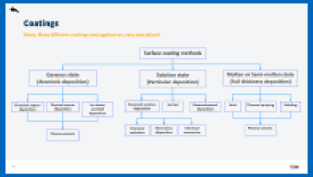
Solid

Milling
[CNC Milling and Turning Working Process. Perfect Machines Technology (youtube.com)]
Turning
Drilling
Grinding
Lapping
EDM / ECM
Etching
Laser abrasion

Coatings

- Corrosion protection
- Non-stick coating
- Traction coating
- Slide coatings
- Wear resistance
- Dry lubrication

Wet paint
Powder coating
CVD, PVD, ALD
Electroless plating
Thermal spray
Laser deposition



3D printing

- Powder removal
- Annealing
- Support structure
- Wire cutting
- Cleaning/Etching
- Tumbling
- Blasting

Joining

Fasteners, nuts & bolts, screws, clamps, shackles.
Riveting, Bolting, Shrink fitting, folding

Mechanical
Fusion & Welding
Brazing & Soldering
Adhesively bonded

Fusion, Solid-state, Pressure - Welding
TIG, MIG, MAG, Ebeam, Laser, friction stir, friction, explosion.

Torch or manual brazing, induction brazing, resistance brazing, and vacuum brazing.

Anaerobic adhesives: Acrylic-based Curing: absence of air.
Cyanoacrylates adhesives: “instant glues” Curing UV
Epoxy adhesives Curing heated
Hot glue, curing cooling

Casting Forging

1. Sand Casting
2. Permanent Mold Casting
   - Gravity die casting
   - Low pressure die casting
   - Die Casting
   - Vacuum die casting

Morphologic chart is used to define fabrication process

Functions	1	2	3	4
Heating	Heater rods	Heating wires	Induction heater	Band heater
Cooling	Tubing	Pillow plate	Cooling channels machined	Cooling channels welded
Joining	TIG Welding	Laser welding	Orbital welding	Ebeam Welding
Vacuum	Calrez O-rings	Metal seals	Viton O-rings	
Materials	Titanium Nitride Coating	Tunsten carbide coating	Ceramics	Molybdenum

Scenario A

Scenario B

Scenario C

Solid production

Vacuum chamber production

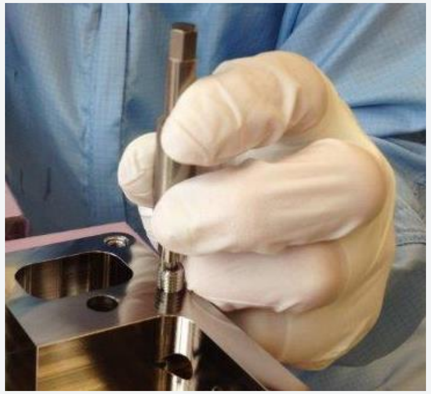
Raw material

Machining

Finishing

Cleaning

Measurement



Assembly

Bake-out, RGA

Blacklight Inspection

Guide for CNC-production tolerances

ISO 2768; Year: 1989

Table 1 — Permissible deviations for linear dimensions except for broken edges
(external radii and chamfer heights, see table 2)

Values in millimetres

Tolerance class: Designation	Tolerance class: Description	Permissible deviations for basic size range: 0,5[1)] up to 3	over 3 up to 6	over 6 up to 30	over 30 up to 120	over 120 up to 400	over 400 up to 1 000	over 1 000 up to 2 000	over 2 000 up to 4 000
f	fine	±0,05	±0,05	±0,1	±0,15	±0,2	±0,3	±0,5	—
m	medium	±0,1	±0,1	±0,2	±0,3	±0,5	±0,8	±1,2	±2
c	coarse	±0,2	±0,3	±0,5	±0,8	±1,2	±2	±3	±4
v	very coarse	—	±0,5	±1	±1,5	±2,5	±4	±6	±8

1) For nominal sizes below 0,5 mm, the deviations shall be indicated adjacent to the relevant nominal size(s).

Table 1 — General tolerances on straightness and flatness

Values in millimetres

Tolerance class	Straightness and flatness tolerances for ranges of nominal lengths: up to 10	over 10 up to 30	over 30 up to 100	over 100 up to 300	over 300 up to 1 000	over 1 000 up to 3 000
H	0,02	0,05	0,1	0,2	0,3	0,4
K	0,05	0,1	0,2	0,4	0,6	0,8
L	0,1	0,2	0,4	0,8	1,2	1,6

Table 2 — General tolerances on perpendicularity

Values in millimetres

Tolerance class	Perpendicularity tolerances for ranges of nominal lengths of the shorter side: up to 100	over 100 up to 300	over 300 up to 1 000	over 1 000 up to 3 000
H	0,2	0,3	0,4	0,5
K	0,4	0,6	0,8	1
L	0,6	1	1,5	2

Table 3 — General tolerances on symmetry

Values in millimetres

Tolerance class	Symmetry tolerances for ranges of nominal lengths: up to 100	over 100 up to 300	over 300 up to 1 000	over 1 000 up to 3 000
H	0,5			
K	0,6		0,8	1
L	0,6	1	1,5	2

Table 4 — General tolerances on circular run-out

Values in millimetres

Tolerance class	Circular run-out tolerances
H	0,1
K	0,2
L	0,5

ISO 286-2 (DIN 7154); ISO system of limits and fits (IT grades)

General tolerances found on drawings compared with accuracy grades

Dimension		IT (Tolerance class)																General tolerance	
		3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	±0.1 mm	±0.2 mm
		Tolerance																	
[mm]		[µm]																[µm]	
From	To																		
1	3	2	3	4	6	10	14	25	40	60	100	140	250	400	600			200	400
3	6	2.5	4	5	8	12	18	30	48	75	120	180	300	480	750			200	400
6	10	2.5	4	6	9	15	22	36	58	90	150	220	360	580	900	1500		200	400
10	18	3	5	8	11	18	27	43	70	110	180	270	430	700	1100	1800	2700	200	400
18	30	4	6	9	13	21	33	52	84	130	210	330	520	840	1300	2100	3300	200	400
30	50	4	7	11	16	25	39	62	100	160	250	390	620	1000	1600	2500	3900	200	400
50	80	5	8	13	19	30	46	74	120	190	300	460	740	1200	1900	3000	4600	200	400
80	120	6	10	15	22	35	54	87	140	220	350	540	871	1400	2200	3500	5400	200	400
120	180	8	12	18	25	40	63	100	160	250	400	630	1000	1600	2500	4000	6300	200	400
180	250	10	14	20	29	46	72	115	185	290	460	720	1150	1850	2900	4600	7200	200	400
250	315	12	16	23	32	52	81	130	210	320	520	810	1300	2100	3200	5200	8100	200	400
315	400	13	18	25	36	57	89	140	230	360	570	890	1400	2300	3600	5700	8900	200	400
400	500	15	20	27	40	63	97	155	250	400	630	970	1550	2500	4000	6300	9700	200	400
500	800			34	50	79	122	195	314	500	790	1200	1950	3140	5000	7900	12200	200	400
800	1280			41	60	95	147	235	378	600	950	1430	2350	3780	6000	9500	14700	200	400
1280	2048			48	70	111	172	275	442	700	1110	1660	2750	4420	7000	11100	17200	200	400
2048	3277			55	80	127	197	315	506	800	1270	1890	3150	5060	8000	12700	19700	254	400

Machine type required

Production methodes																	
					I.T. (Tolerance class)												
	Min. IT	Max. IT	Min. Ru (µ")	Max. Ru (µ").	IT 3	IT 4	IT 5	IT 6	IT 7	IT 8	IT 9	IT 10	IT 11	IT 12	IT 13	IT 14	IT 15	IT 16
Honen																		
Holes	3	6	2	32	2			32										
Flat	4	6	4	32		4		32										
Grinding																		
Round	3	5	4	32	4		32											
Centerfalse	4	6	16	125		16		125										
Flat (horizontal)	4	6	4	32		4		32										
Flat (vertical)	7	8	32	125					32	125								
Turning																		
<200	6	8	32	125				32		125								
>200	7	9	63	125					63		125							
Automatic	6	8	32	125				32		125								
Ultra precision	3	3	0	0	<2													
Milling																		
<500	9	11	32	125							32		125					
>500	10	12	63	500								63		500				
Ultra precision	3	3	0	0	<2													
Bore																		
Bore	6	8	32	125				32		125								
Bore + Reaming	6	8	32	125				32		125								
Drilling																		
Small	9	11	63	250							63		250					
Small + Reaming	6	11	32	250				32					250					
Big	10	13	63	250							63				250			
Big + Reaming	10	13	63	250							63				250			

Remark for the production methode
Without preparation (normal production methode)
With preparation
With preparation and a lot of attention to realize
Not to realize with this production methode

Max. IT	Normal production tolerance
Min. IT	With preparation and a lot of attention to realize
Max. Ru.	Normal production roughness
Min. Ru.	With preparation and a lot of attention to realize

Machining, tolerances, material and temperature

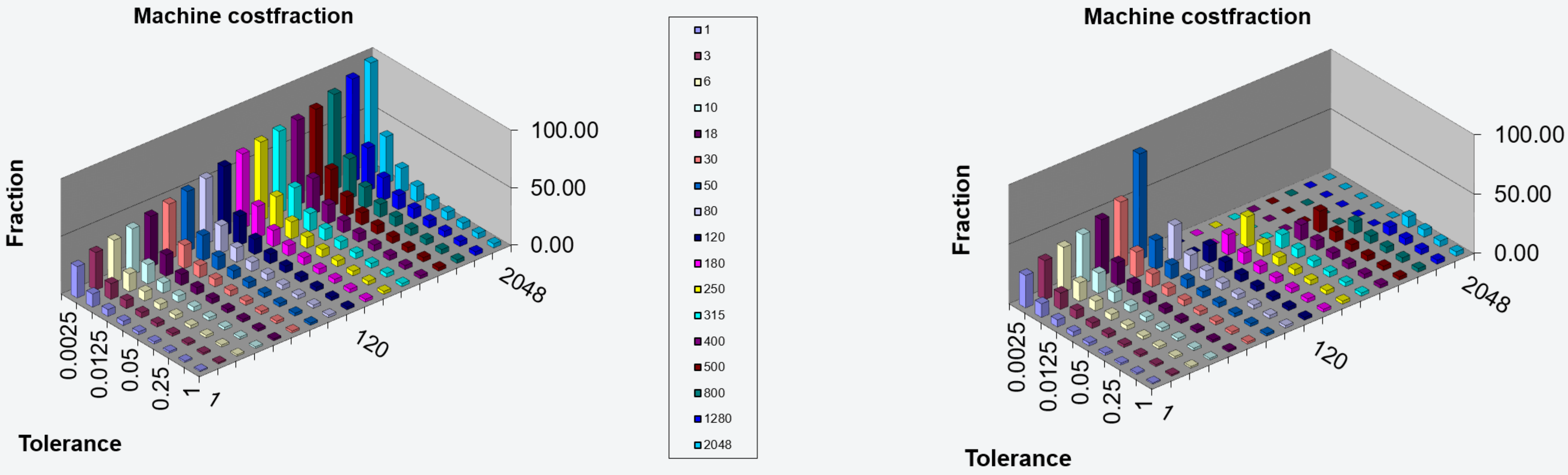
Dim. [mm]	Tolerance field [mm]									Temp expansion dimension (")
	1.000	0.400	0.200	0.100	0.040	0.020	0.0050	0.0020	0.0010	
	Machining (production) costfraction									
<0,04	1.00	1.15	1.24	1.37	1.60	2.01	2.82	4.69	9.99	
1.00	1.00	1.34	1.62	2.01	2.73	3.85	6.83	13.22	31.60	0.000001
3.00	1.20	1.61	1.94	2.41	3.28	4.63	8.20	15.88	37.96	0.000003
6.00	1.35	1.81	2.18	2.71	3.68	5.20	9.21	17.83	42.63	0.000006
10.00	1.47	1.97	2.37	2.95	4.01	5.66	10.03	19.42	46.45	0.000009
18.00	1.62	2.17	2.62	3.25	4.42	6.24	11.06	21.43	51.29	0.000017
30.00	1.76	2.37	2.85	3.54	4.82	6.80	12.05	23.36	55.96	0.000028
50.00	1.92	2.58	3.10	3.86	5.24	7.40	13.13	25.47		0.000047
80.00	2.08	2.79	3.35	4.17	5.67	8.01	14.21	27.62		0.000076
120.00	2.22	2.98	3.59	4.47	6.07	8.57	15.23			0.000113
180.00	2.38	3.19	3.84	4.78	6.50	9.17	16.32			0.000170
250.00	2.51	3.37	4.06	5.05	6.86	9.69				0.000236
315.00	2.61	3.50	4.21	5.25	7.13	10.08				0.000298
400.00	2.71	3.65	4.39	5.46	7.43	10.50				0.000378
500.00	2.82	3.78	4.55	5.67	7.71	10.90				0.000472
800.00	3.05	4.09	4.92	6.13	8.35	11.82				0.000756
1280.00	3.30	4.43	5.33	6.64	9.05					0.001209
2048.00	3.56	4.79	5.77	7.19						0.001935
3277.00	3.86	5.18	6.24	7.79						0.003096

AL	2.40E-05
ST	1.20E-05
StSt	1.70E-05
^Temp	1.00E+00
Mat	2.40E-05

Costfraction, size, tolerance, temperature relation

Influence of the size of the part and tolerance is directly translated in cost

- Size of the part has a big influence on the tolerances that can be achieved.
- Definition of Reference A-B-C is extremely important
- When size of parts increase make local references to create local accurate patterns

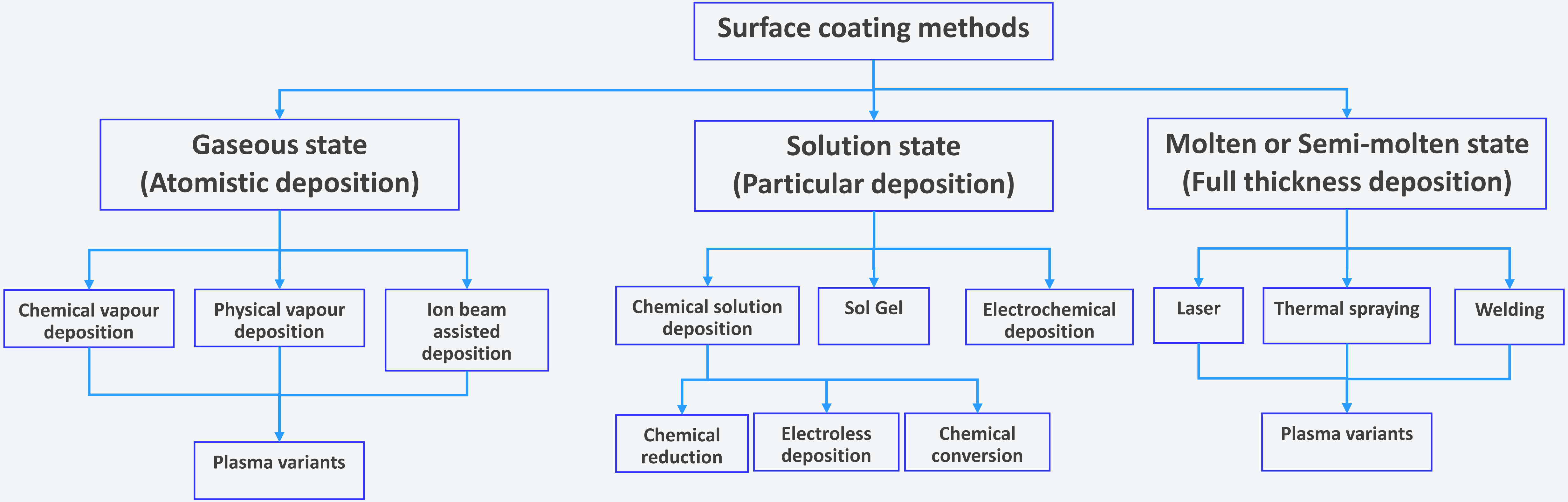


Tolerances discussions

Z (also leads to Rx and Ry)

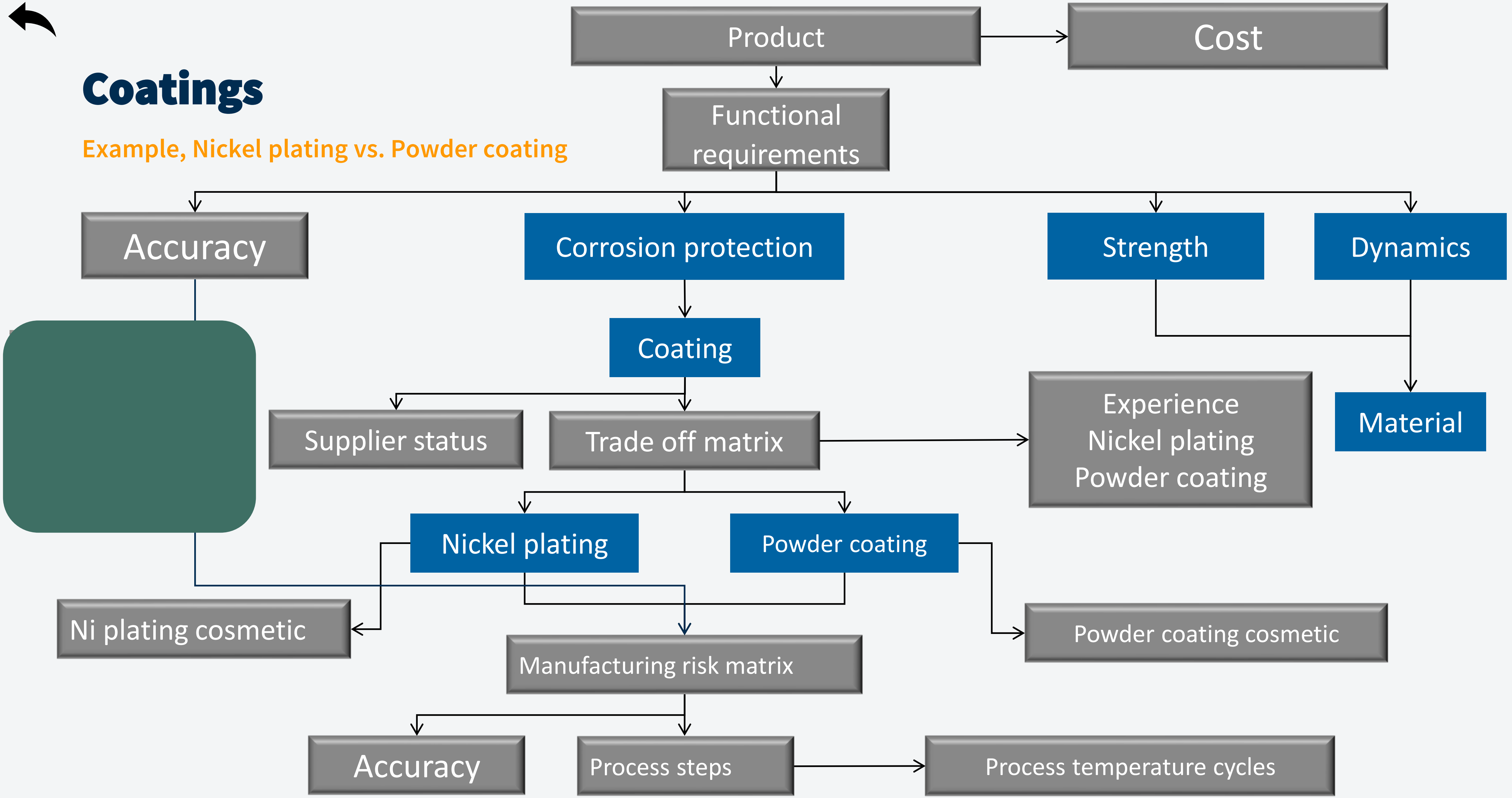
Coatings

Many, Many different coatings and appliances, very specialized



Coatings

Example, Nickel plating vs. Powder coating



Joining

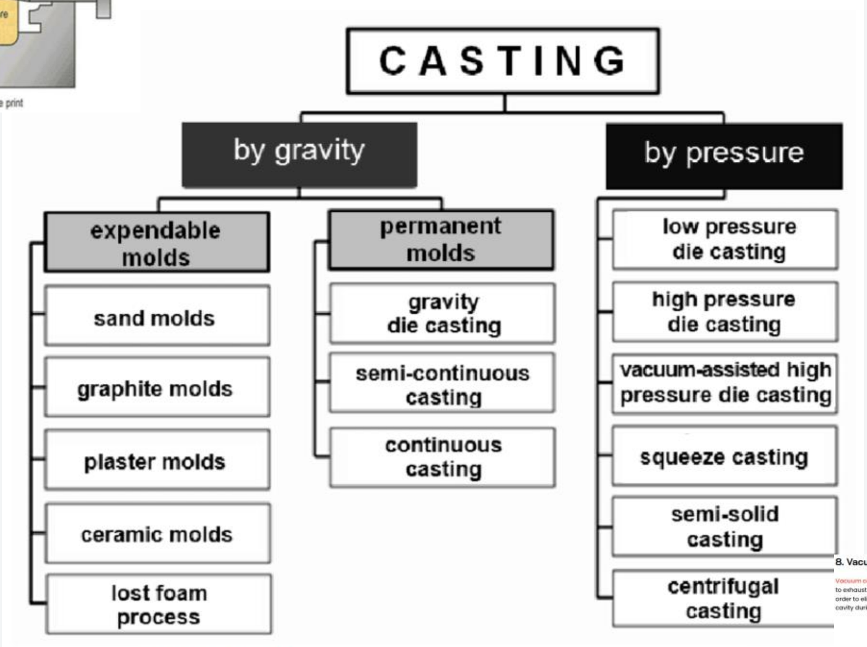
Welded chamber to machined from solid

- Welded chamber
  - Leakage issues
  - Build up tolerances
  - Finishing
- Solid block available ☑
- Machined from solid
  - Redesign necessary
  - Lead time reduction 6wks
  - Cost reduction (29%)
  - Return on investment 18 products

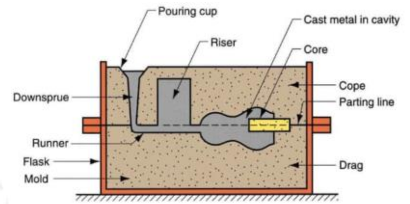
24 machining operations + Welding operation

3 machining operations

Casting processes

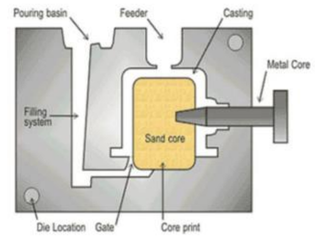


1. Sand Casting Process



2. Gravity Die Casting

Gravity die casting, also typically known as permanent mold casting, uses reusable molds made of metal, like steel, graphite etc. to fabricate metal and metal alloys. This type of metal casting can manufacture various parts like gears, gear housing, pipe fittings, wheels, engine pistons, etc.



3. Pressure Die Casting

There are two types of pressure die casting depending on the pressure. Namely, the low-pressure die casting and the high-pressure die casting. High pressure die casting is more popular for mass production of complex geometries that require high precision. Whereas, for large and simple parts production, low-pressure die casting is a preferable casting process.

In this type of metal casting, non-ferrous metals and alloys such as zinc, tin, copper and aluminum are injected into a reusable mold coated with a lubricant at high pressure. Thus, high pressure is maintained throughout the rapid injection process to avoid metal hardening. Finally, after completion of the process, extraction of casting and finishing takes place to remove any excess material.

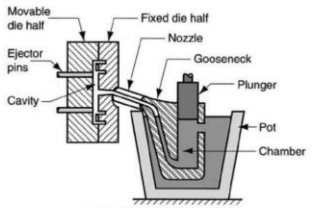


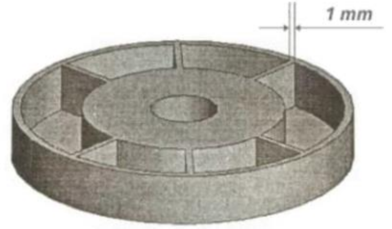
Figure: Hot chamber die casting

4. Investment Casting

Investment casting, also known as lost-wax casting, is a process that invests wax pattern with refractory material and a binding agent to shape a disposable ceramic mold, and then molten metal is poured into the mold to make metal castings. Investment casting is an expensive and labor-intensive process and can be used for mass production or in complex castings to produce metal casting products ranging from gears, bicycle trunks, moto discs, and spare parts in blasting machines.

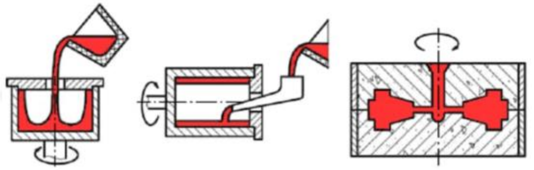
5. Plaster Casting

The plaster casting process is similar to sand casting, except that the mold is made of a mixture called 'Plaster of Paris'. Due to the low thermal conductivity and heat capacity of plaster, it cools the metal more slowly as compared to sand, which helps in attaining high accuracy, especially for thin cross-section parts. However, it is not suitable for high-temperature ferrous materials.



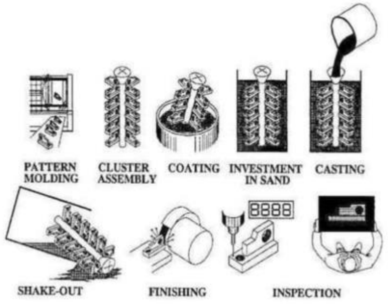
6. Centrifugal Casting

Centrifugal casting, also known as roto casting, is a process for industrially manufacturing cylindrical parts with centrifugal forces. This type of metal casting uses a preheated spinning die in which the molten metal is poured. The centrifugal forces help to distribute the molten metal within the die at high pressure.



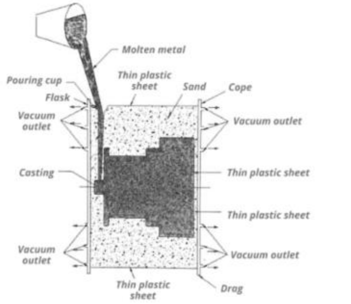
7. Lost-Foam Casting

Lost-foam casting method is similar to investment casting with the difference that it uses foam for the pattern instead of wax. Once the pattern is formed, coating with a refractory ceramic takes place by dipping, coating, spraying, or brushing. Then, the molten metal is poured into the mold to form the desired product.



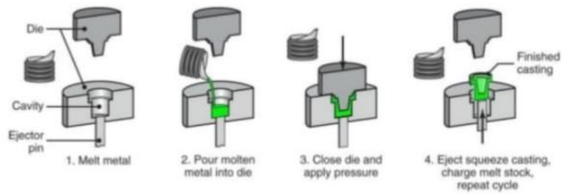
8. Vacuum Casting

Vacuum casting, as the name suggests, is the type of casting where production occurs under vacuum pressure of 100 bar or less to exhaust gas from the mold cavity. In this process, molten metal is poured into the mold cavity inside a vacuum chamber in order to eliminate bubbles and air pockets. The vacuum evacuation of the die cavity reduces the entrapment of gases within the cavity during the metal injection process. Finally, the metal is cured in a heating chamber and removed from the mold.



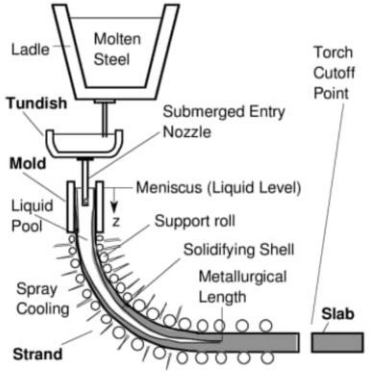
9. Squeezing Casting

Liquid forging or squeeze casting is a hybrid metal forming process that merges permanent mold casting and die forging in a single step. In this process, a specific amount of molten metal alloy is injected into a die, and pressure is applied to shape it. Then, the metal part is heated over melting temperature and extracted from the die.



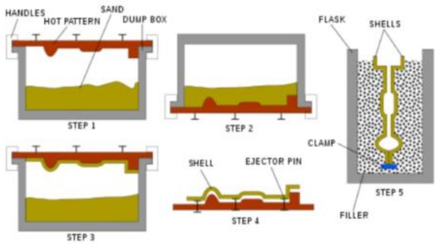
10. Continuous Casting

As the name suggests, it allows consistent mass production of metal profiles with a constant cross-section. This type of casting is popular in the production of steel bars. Also, the vertical cast creates semi-continuous casting like billets, ingots, bars, etc.



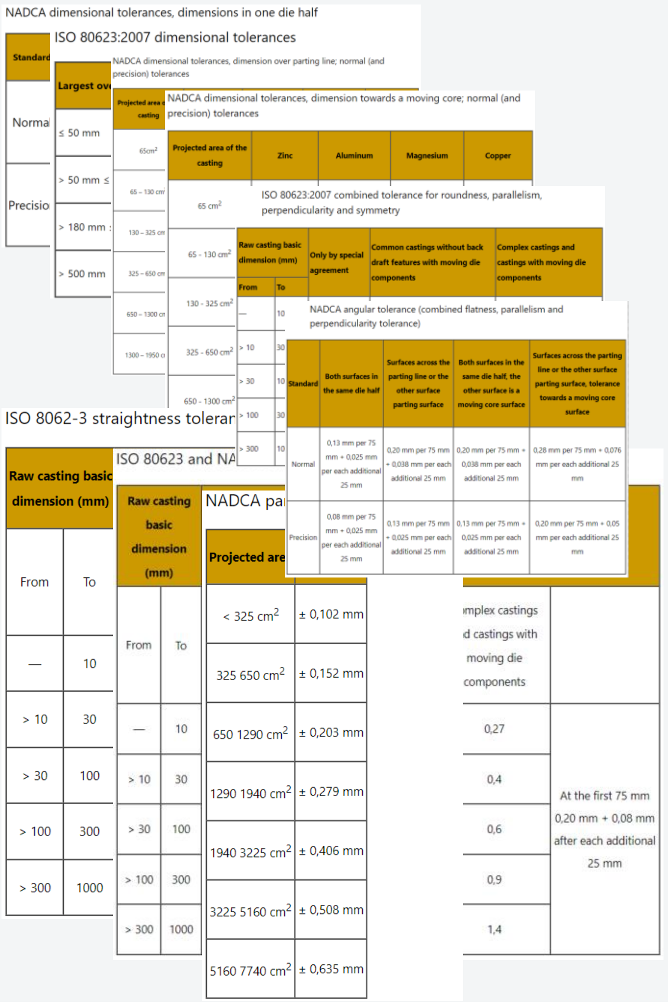
11. Shell Molding

Shell molding is an expendable mold casting process. It is similar to the sand casting process except for that the hardened shel of sand forms the mold cavity instead of a flask of sand. The sand used is finer than that utilized in sand casting and it is mixed with a resin so that it can be heat treated and hardened into the shell around the pattern.



Tolerancing High pressure Die castings

ISO 8062-1…3



The table presents the grades and dimension intervals, which are workable for high pressure die castings.

Raw casting basic dimension (mm)		Dimensional casting tolerance grade DCTG									
From	To	1	2	3	4	5	6	7	8	9	10
—	10	±0,09	±0,13	±0,18	±0,26	±0,36	±0,52	±0,74	±1	±1,5	±2
10	16	±0,1	±0,14	±0,2	±0,28	±0,38	±0,54	±0,78	±1,1	±1,6	±2,2
16	25	±0,11	±0,15	±0,22	±0,3	±0,42	±0,58	±0,82	±1,2	±1,7	±2,4
25	40	±0,12	±0,17	±0,24	±0,32	±0,46	±0,64	±0,9	±1,3	±1,8	±2,6
40	63	±0,13	±0,18	±0,26	±0,36	±0,5	±0,7	±1	±1,4	±2	±2,8
63	100	±0,14	±0,2	±0,28	±0,4	±0,56	±0,78	±1,1	±1,6	±2,2	±3,2
100	160	±0,15	±0,22	±0,3	±0,44	±0,62	±0,88	±1,2	±1,8	±2,5	±3,6
160	250	—	±0,24	±0,34	±0,5	±0,7	±1	±1,4	±2	±2,8	±4
250	400	—	—	±0,4	±0,56	±0,78	±1,1	±1,6	±2,2	±3,2	±4,4
400	630	—	—	—	±0,64	±0,9	±1,2	±1,8	±2,6	±3,6	±5
630	1 000	—	—	—	—	±1	±1,4	±2	±2,8	±4	±6
1 000	1 600	—	—	—	—	—	±1,6	±2,2	±3,2	±4,6	±7

Tolerance ± mm

ISO 8062:1994 Casting tolerance grades (CTG)

The tolerance grade is described with CT. It varies depending on the casting method and also on used material and alloy. Normal high pressure die casting tolerance grade is CT 57 for aluminum and magnesium, CT 68 for copper and CT 46 for zinc.

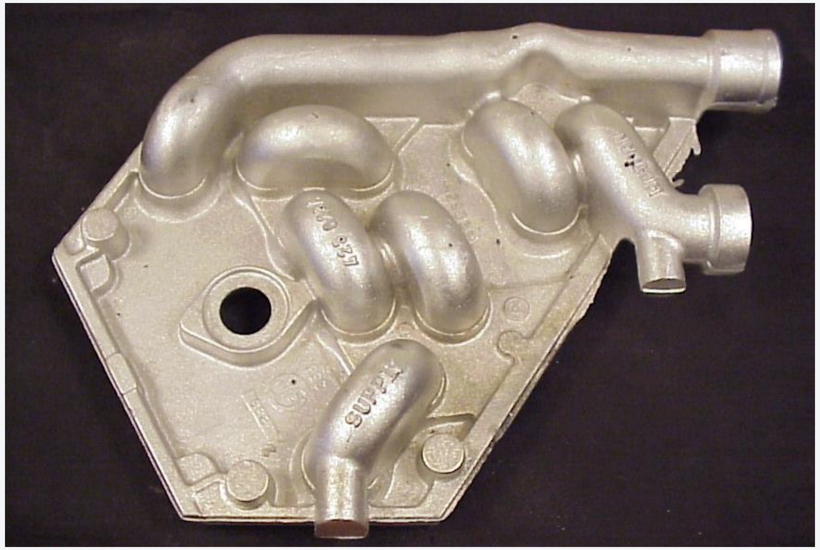
Raw casting basic dimension (mm)		Casting tolerance grade CTG										
From	To	4	5	6	7	8	9	10	11	12	13	14
0	10	0,26	0,36	0,52		1,00	1,5	2,0	2,8	4,2	-	-
10	16	0,28	0,38	0,54	0,78	1,10	1,6	2,2	3,0	4,4		
16	25	0,30	0,42	0,58	0,82	1,20	1,7	2,4	3,2	4,6	6,0	8,0
25	40	0,32	0,46	0,64	0,90	1,30	1,8	2,6	3,6	5,0	7,0	9,0
40	63	0,36	0,50	0,70	1,00	1,40	2,0	2,8	4,0	5,6	8,0	10,0
63	100	0,40	0,56	0,78	1,10	1,60	2,2	3,2	4,4	6,0	9,0	11,0
100	160	0,44	0,62	0,88	1,20	1,80	2,5	3,6	5,0	7,0	10,0	12,0
160	250	0,50	0,70	1,00	1,40	2,00	2,8	4,0	5,6	8,0	11,0	14,0
250	400	0,56	0,78	1,10	1,60	2,20	3,2	4,4	6,2	9,0	12,0	16,0
400	630	0,64	0,90	1,20	1,80	2,60	3,6	5,0	7,0	10,0	14,0	18,0
630	1000	1,00	-	1,40	2,00	2,80	4,0	6,0	8,0	11,0	16,0	20,0
1000	1600	1,6	-	-	2,2	3,0	4,6	7,0	9,0	13,0	18,0	23,0

Tolerance ± mm

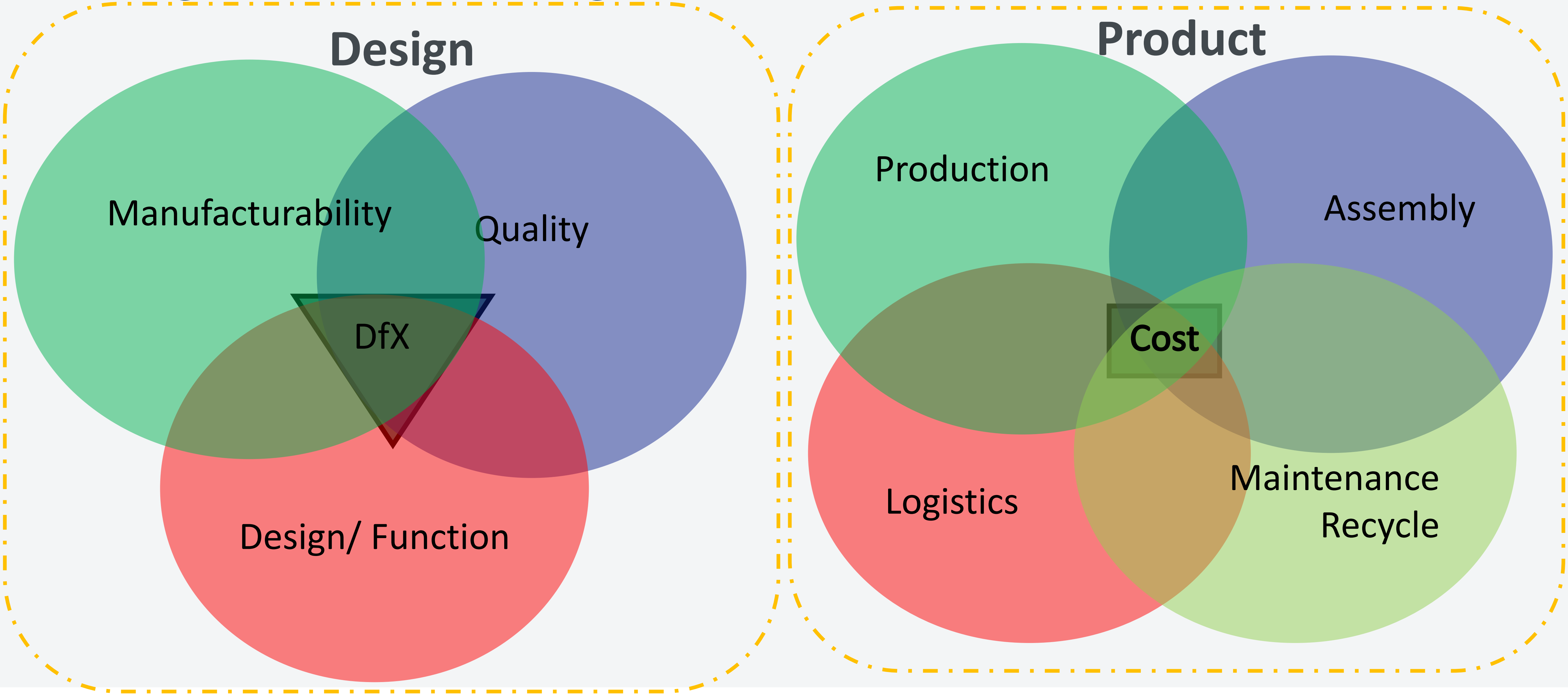
Casting example

Process steps

- Sand mold top and bottom
- Core production
- Assembly
- Casting
- Brake out part & cores
- Remove cast extensions
- Dot peening
- Cleaning
- Quality inspectoin



Design for Manufacturing Architect



Questions