From System KPP to Supersystem KPP

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Abstract

We will explore for your system-of-interest what its main functions are and its key performance parameters (KPP). As an architect, you should be able to explain how your key functions and KPPs serve your supersystem, as well as provide directions to the subsystems to what functionality and performance they need to deliver to your system. Combining this information with project information forms a project overview. The single sheet overview is a powerful means to keep focus in projects.

August 24, 2025
status: preliminary draft
version: 0

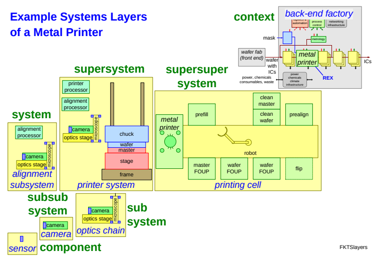
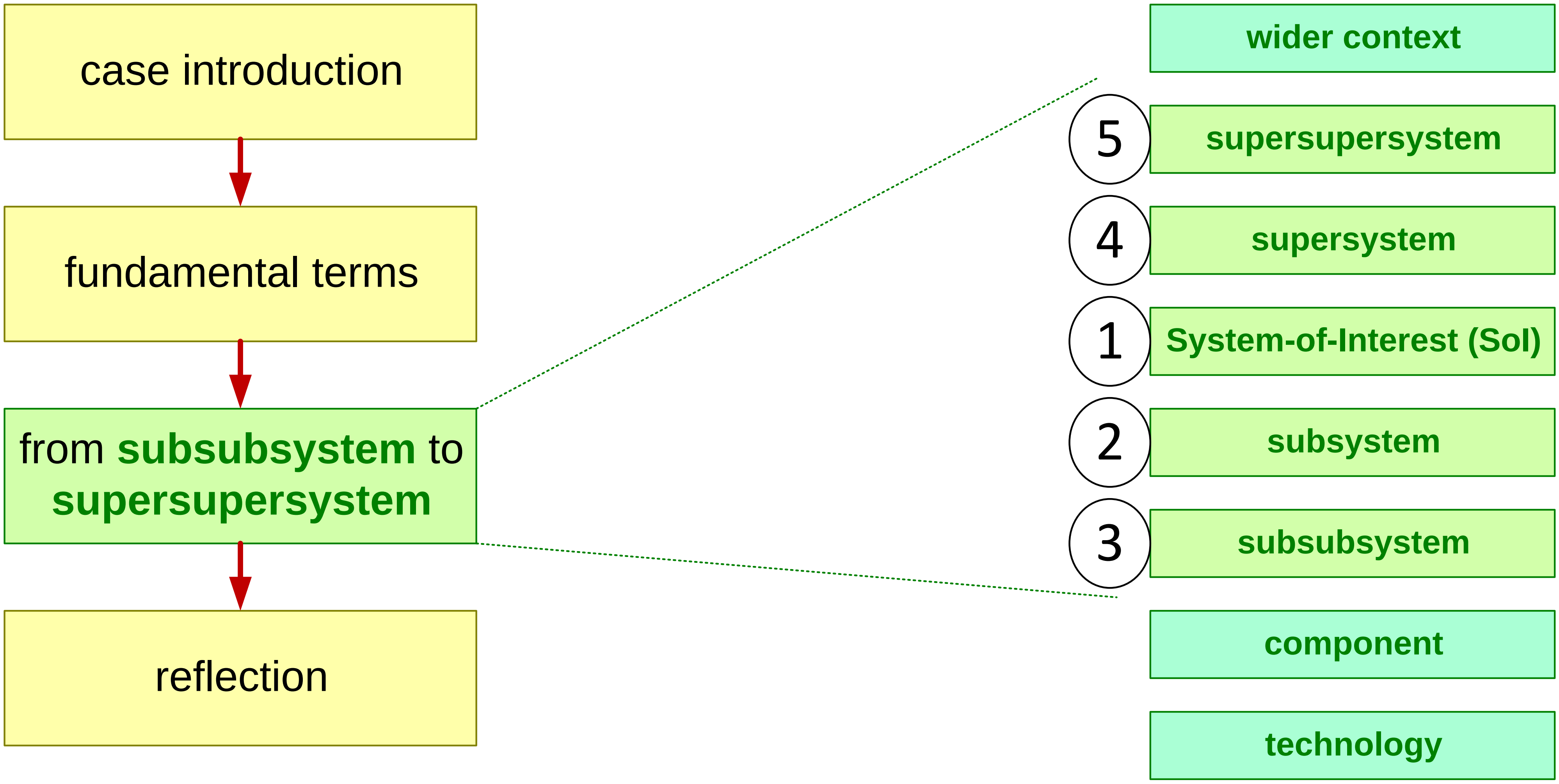


Figure of Contents™



We Use a Case as an Example

Replisaurus, a **start-up** that worked on a **copper printer** for wafers, based on electrolysis technology.

Bankrupt in 2011 in the aftermath of the **2008 financial crisis**

Gerrit has been consulting them from 2008 until 2011

Project Overview Metal Printer

Project overview Metal Printer R2

version 2.0. January 22, 2023
author: Gerrit Muller

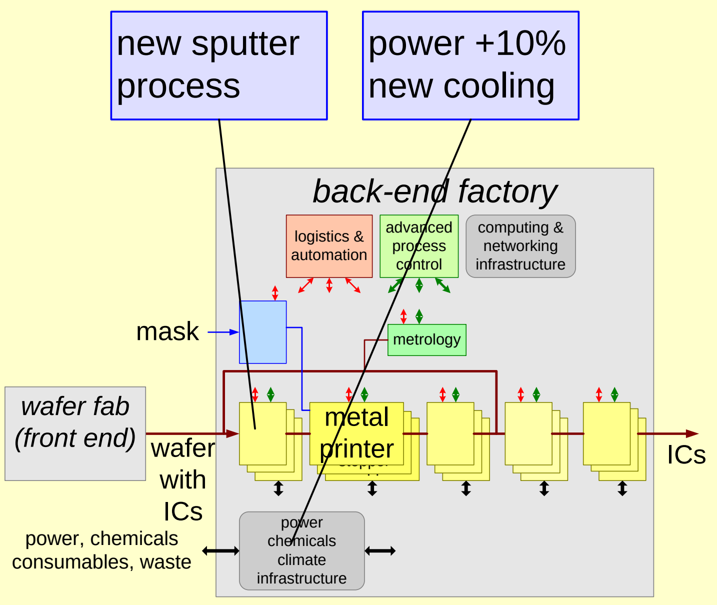
Project Goals

support production of node 1C	
process development	Q2 2022
volume production	Q2 2023
productivity	30,000 W/m
yield	95%

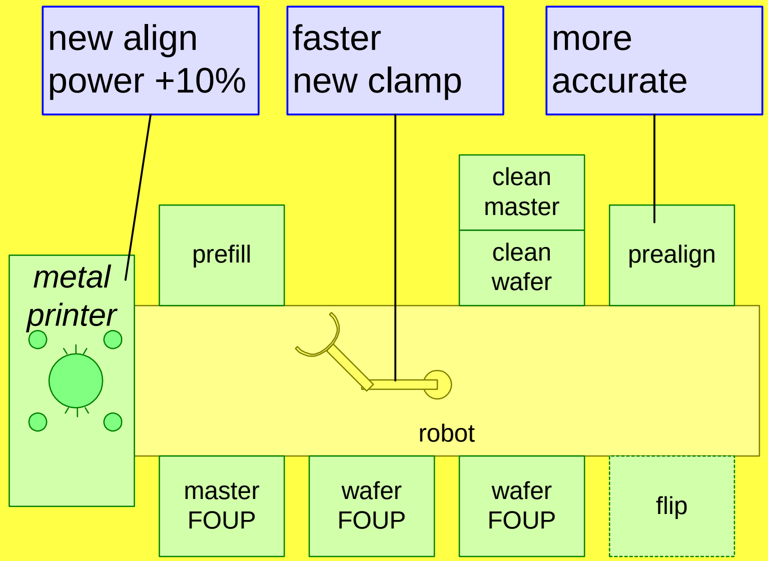
Key Performance Parameters

min. line width	100 nm
overlay	30 nm
throughput	100 WPH
MTBF	2000 hr
wafer size	300 mm
power	5 kW
clean room class	C
floor vibration class	D

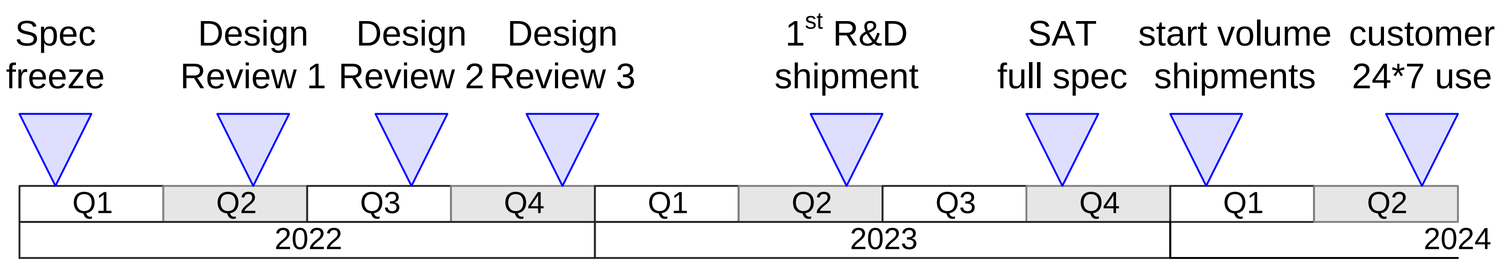
system context



system of interest



project master plan



changing enabling systems

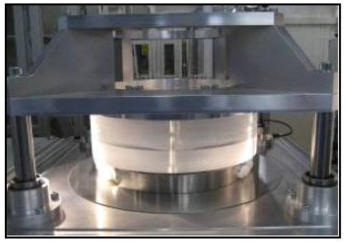
conditioned transport
calibration wafers
calibration metrology

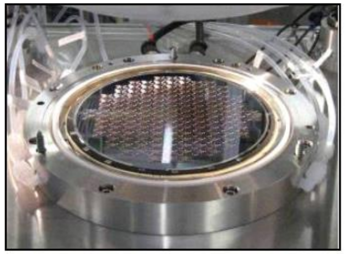
200mm ECPR tools

300mm ECPR tools. Can be configured with 200 or 300mm kits.

Case: Metal Printer

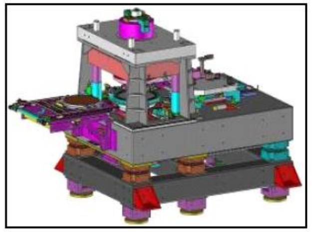
2006 R&D 1.0





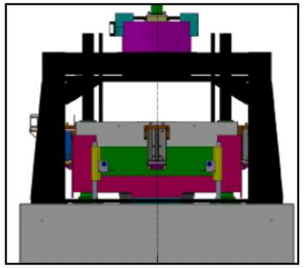
200mm hydraulic non-aligned tool for chamber & process development

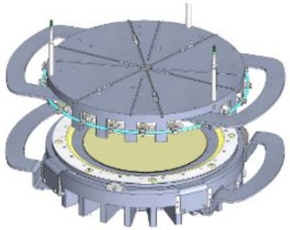
2007 REX 1.0



First aligned ECPR dev. tool. 200/300mm compatible.

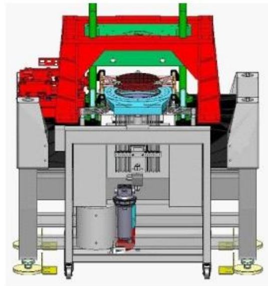
2008 R&D 2.0

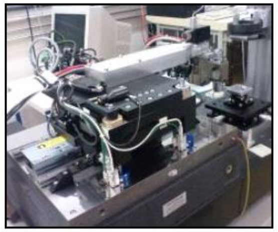


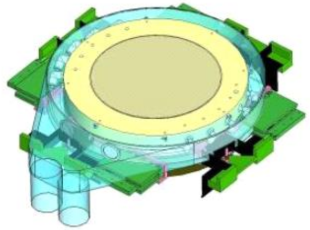


Integrated ECPR control. Non-aligned, Footprint, confinement

2009 REX 2.0

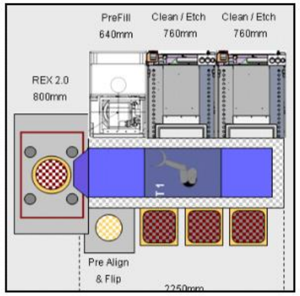


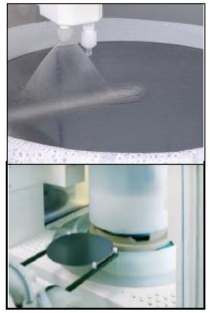


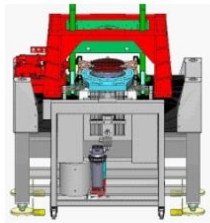


Production oriented print module. Cycle time, overlay, confinement & foot-print focus.

2010 Alpha 1.0



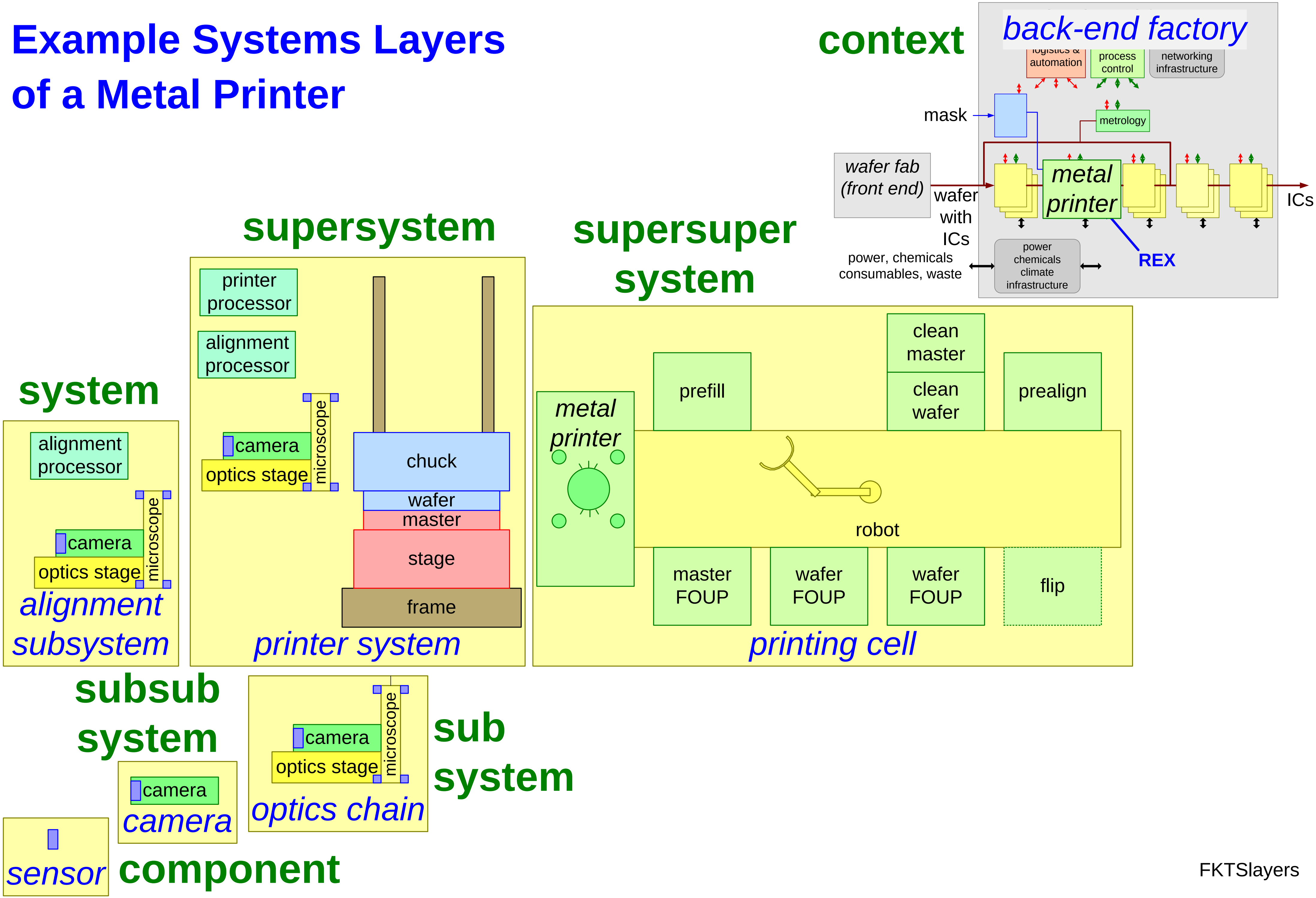




First integrated tool prefill – clean- print - seed etch.

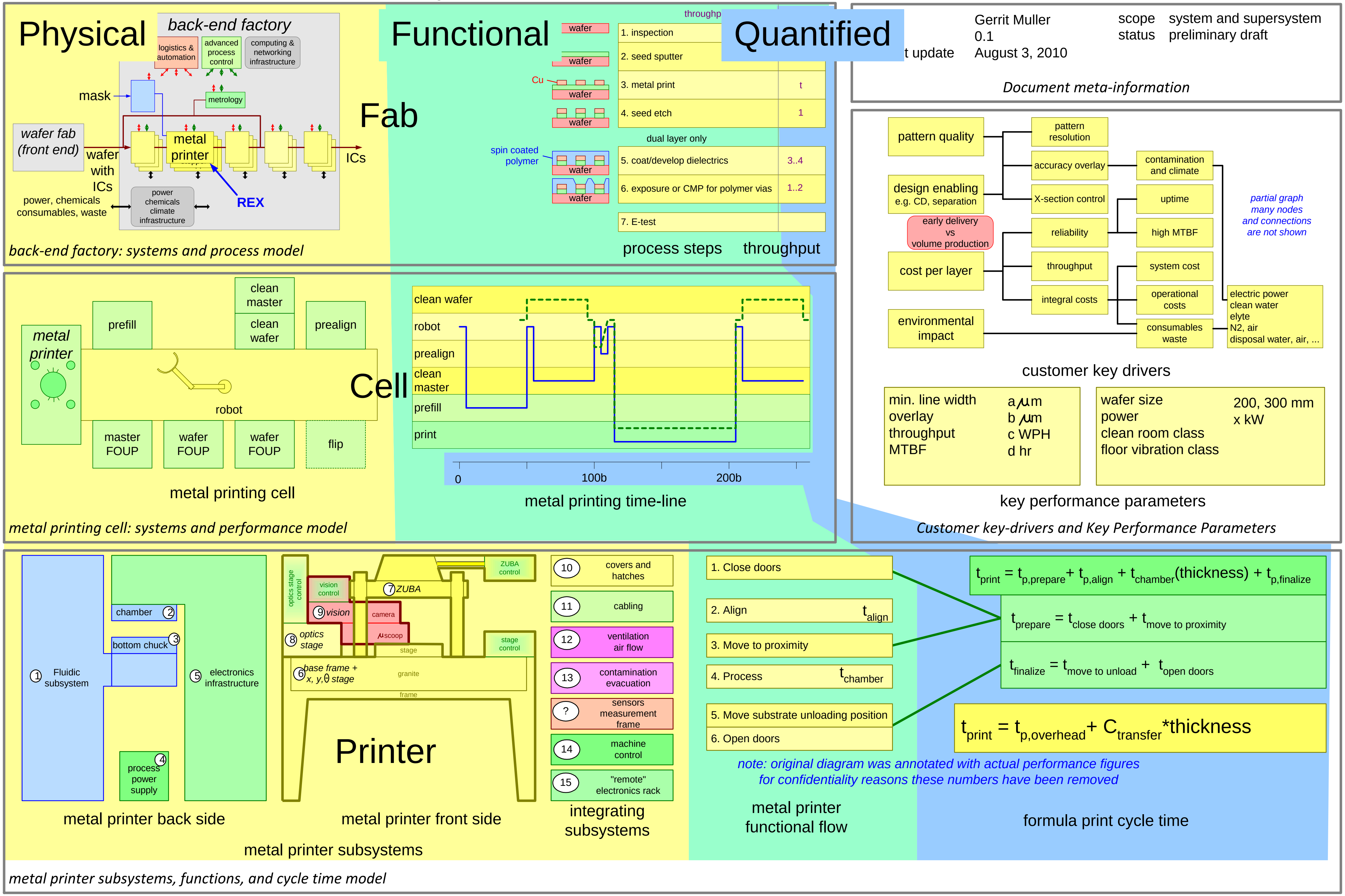
courtesy Replisaurus

Example Systems Layers of a Metal Printer

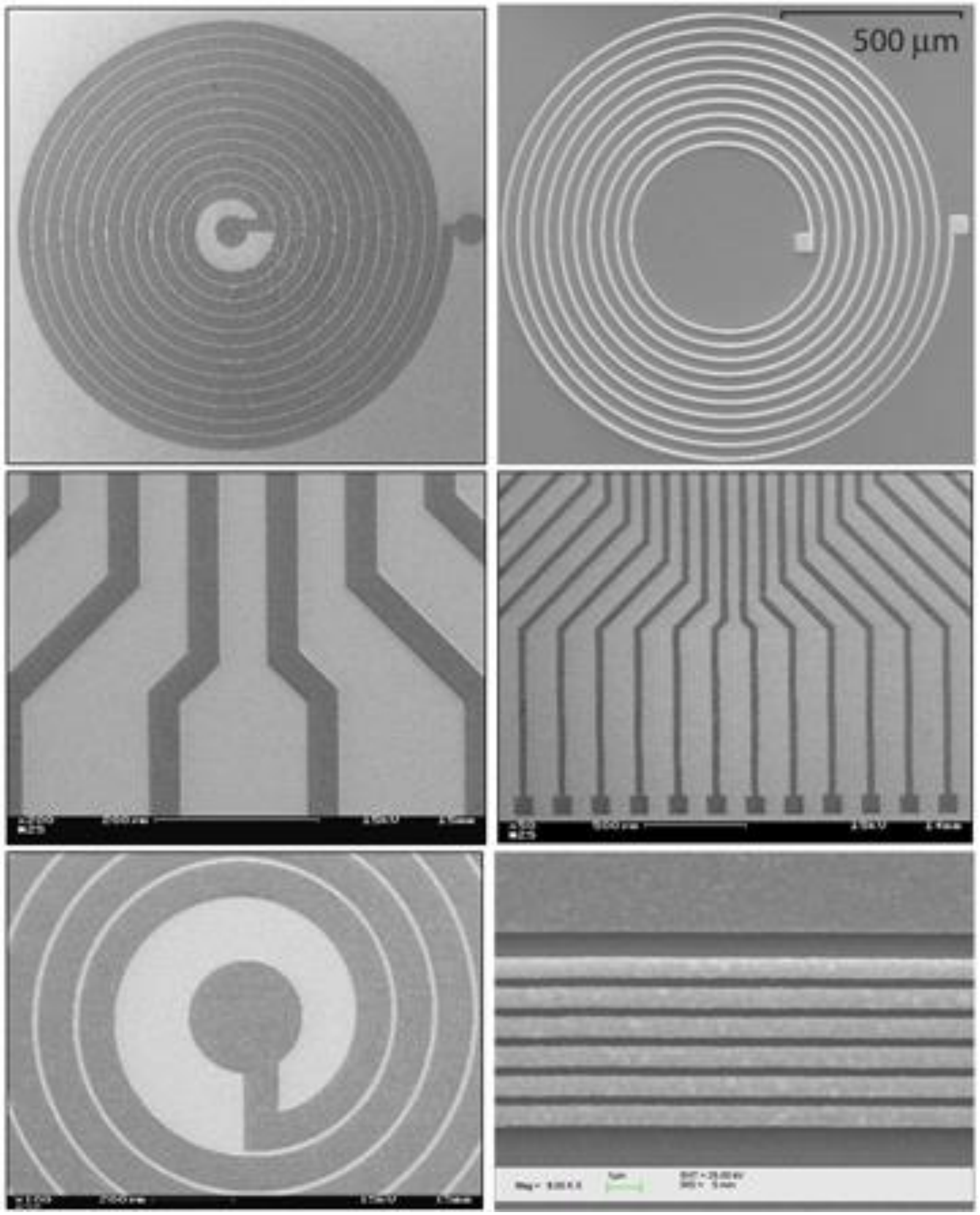


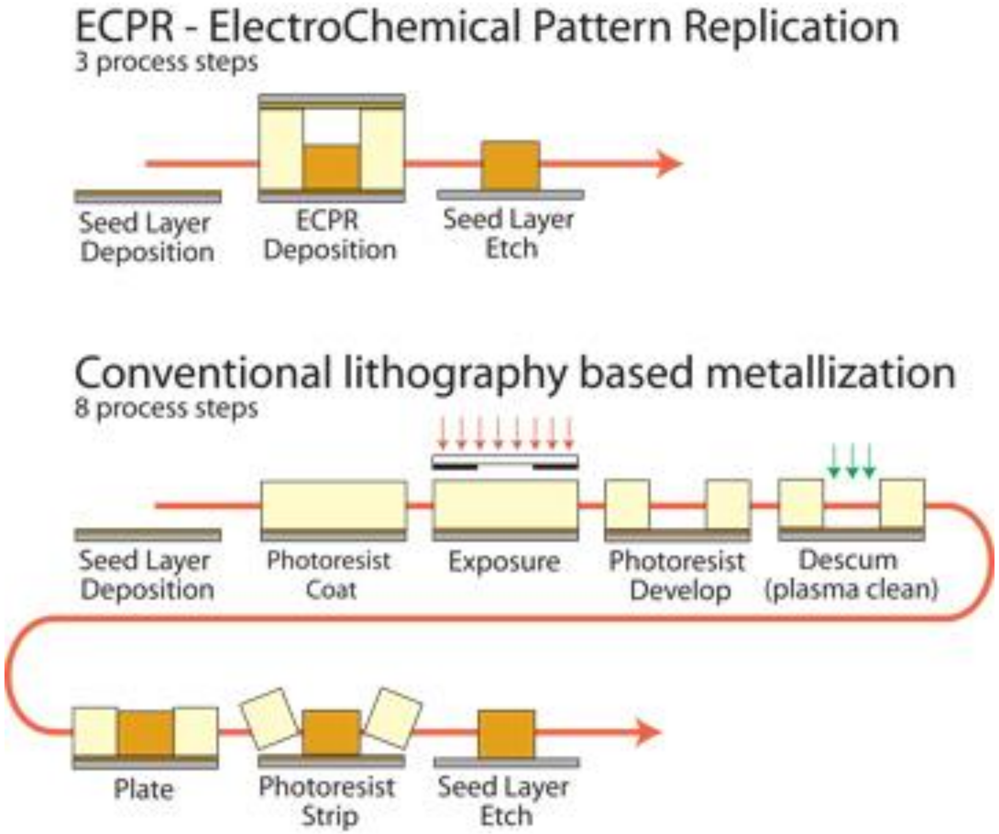
FKTSlayers

Metal Printer: 3 Levels of Systems on 1 A3 (all numbers have been removed for competitive sensitivity) CTEAmetalPrinterA3



Application of the OEM System



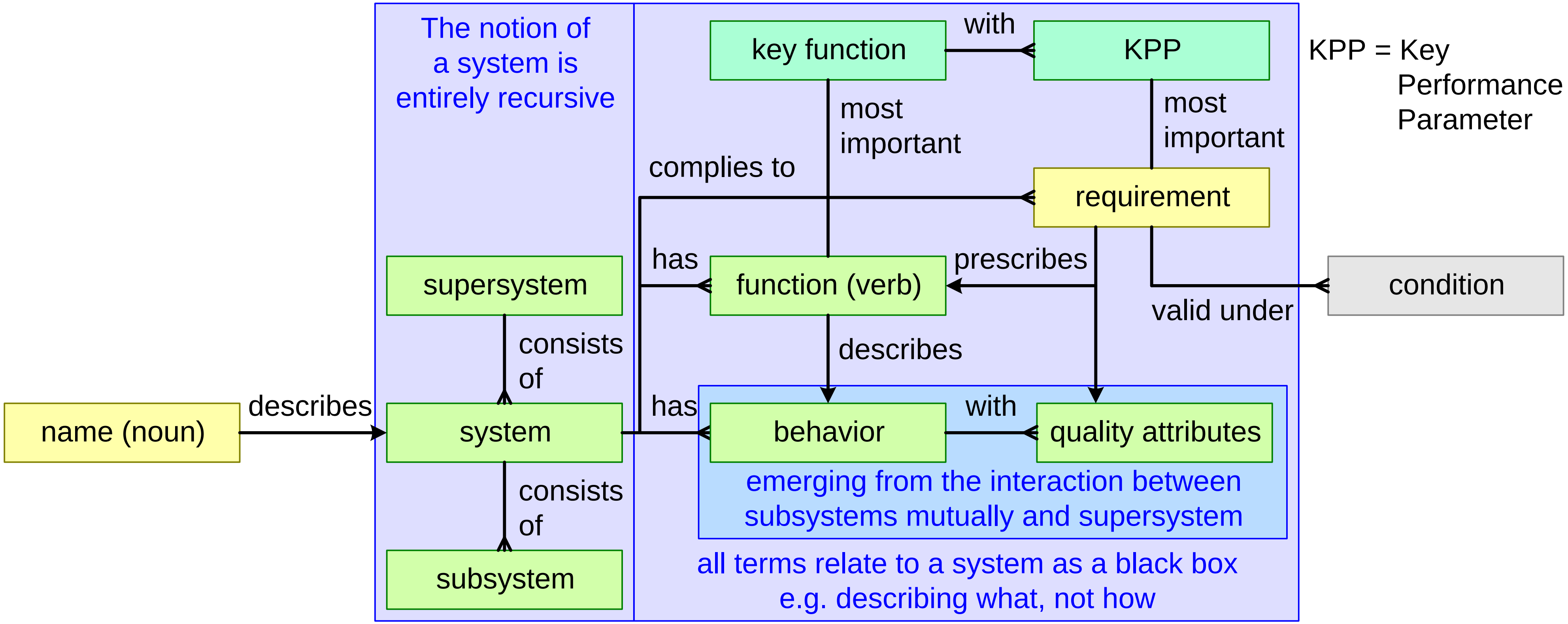


A metal printer

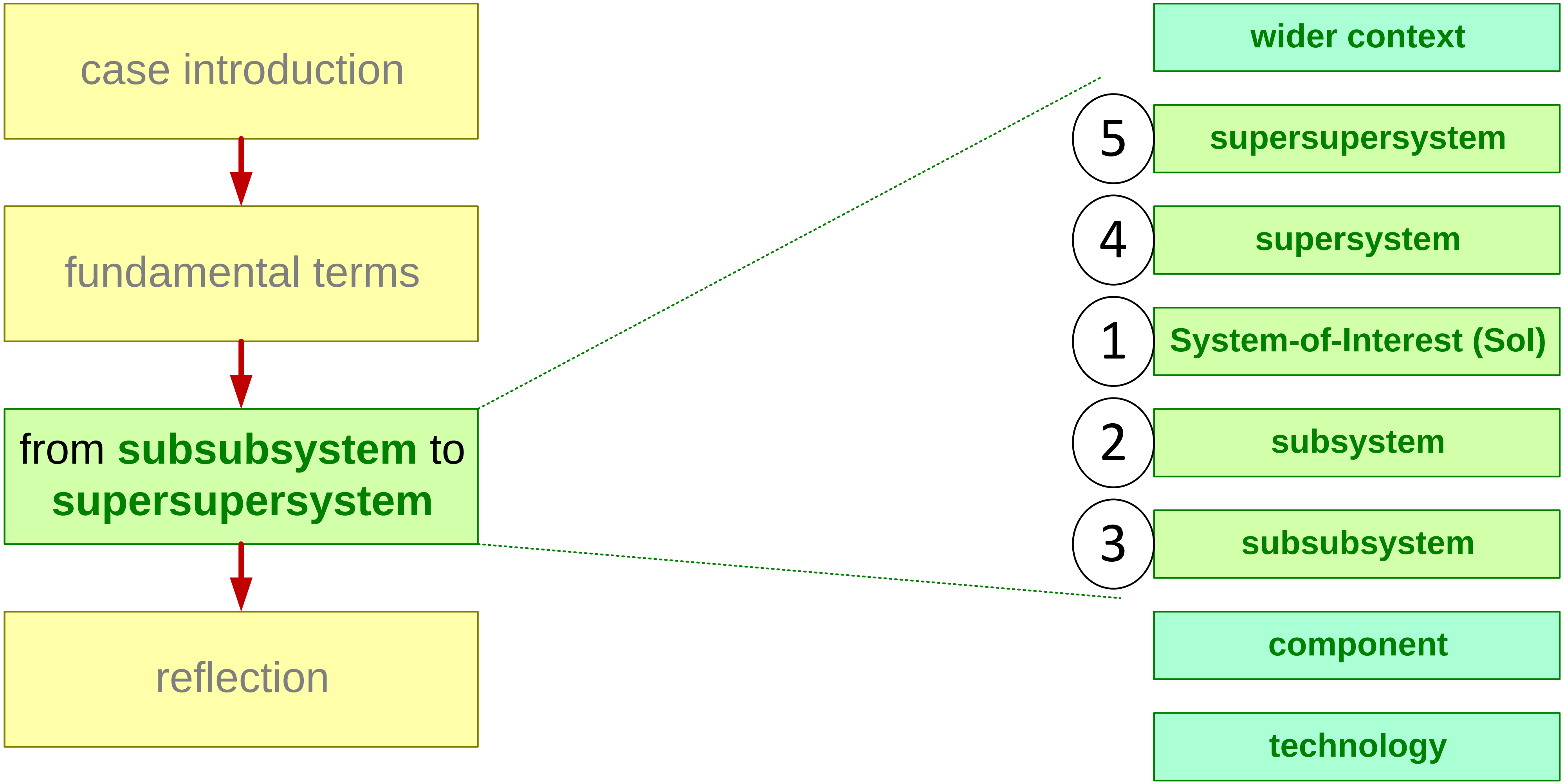
replaces 6 process step by 1 process step.

It prints an entire wafer at once.

Systems Engineering Theory: Relevant Terms



Time to Work and to Be Active



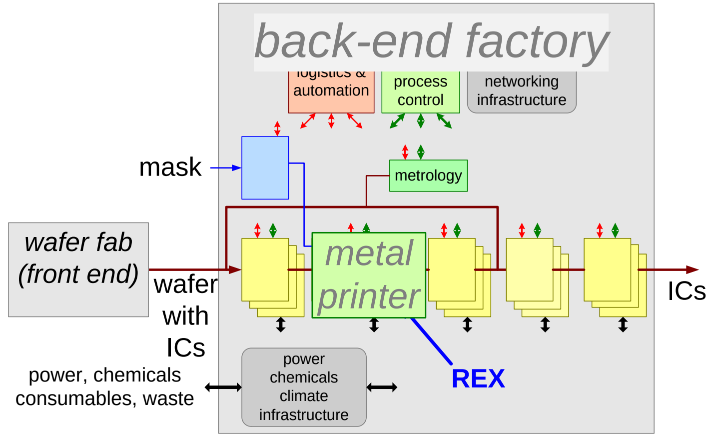
What is your System-of-Interest?

Please go to

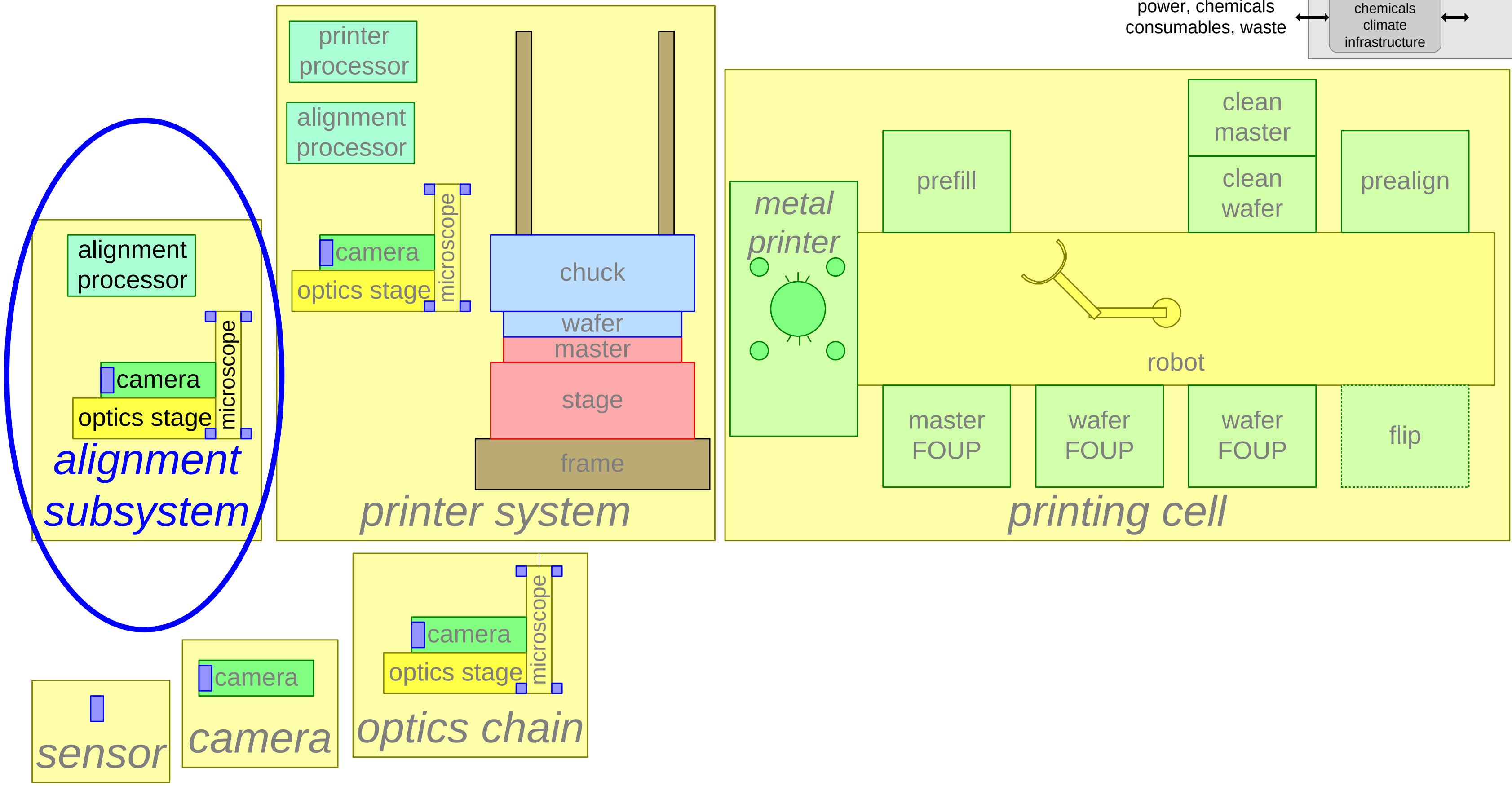
<link to a shared spreadsheet on ASML intranet>

- Go to the row with your seat number
- Fill in your name (column B)
- What is your System-of-Interest (Column C)

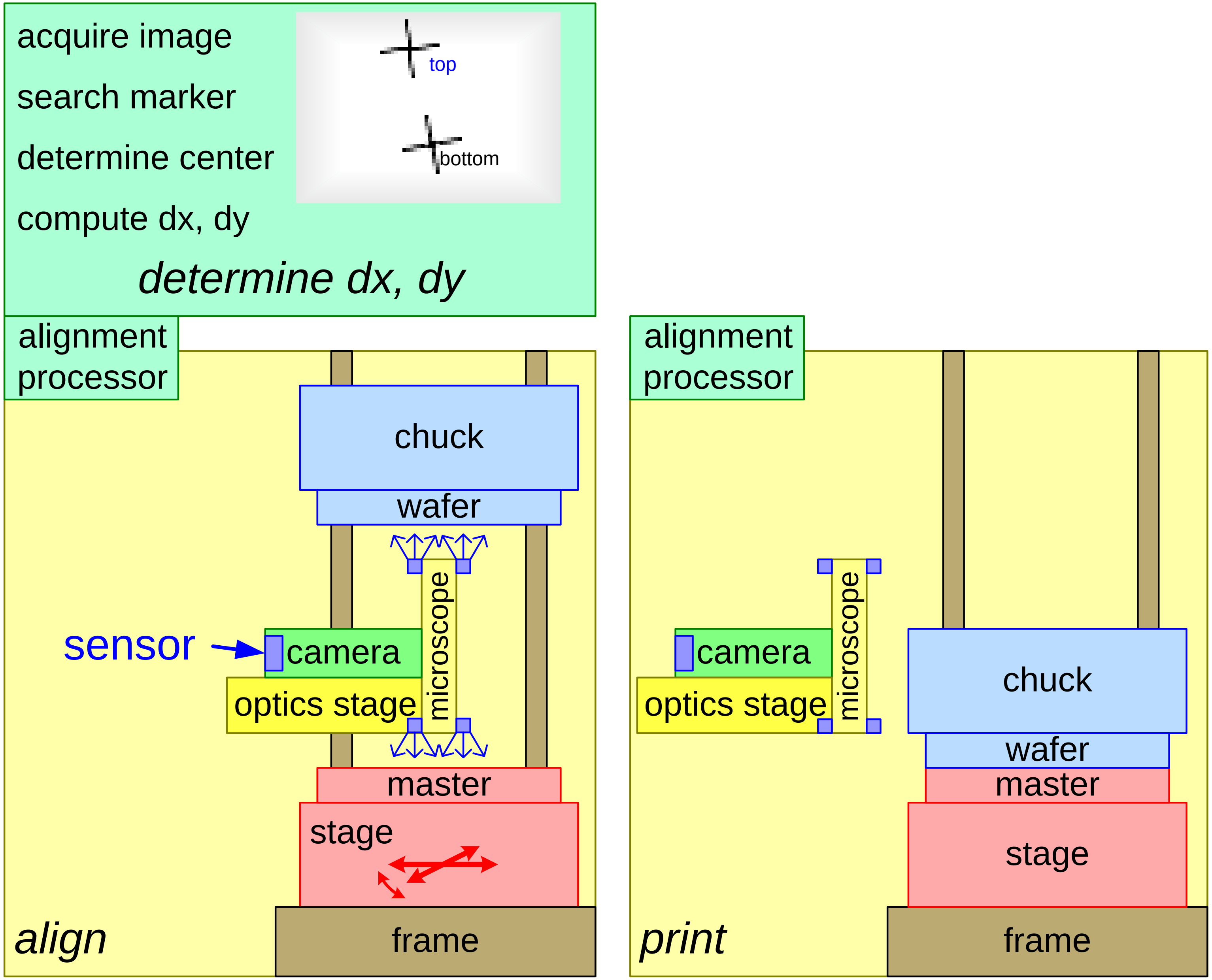
The System-of-Interest: Alignment



Alignment



Basics of Alignment Function



Metal Printer Alignment

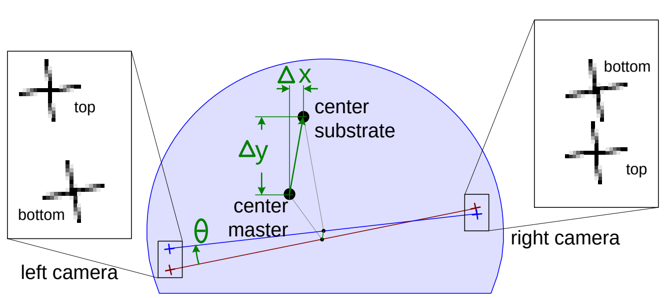
Author: Gerrit Muller

AAMBSEalignment A3 Version 0, April 11, 2023

KPPs

overlay	1 µm
t_{align}	10 s
$t_{calibrate}$	5 min.
Search field	20 * 20 mm
marker field	1 mm

alignment algorithm

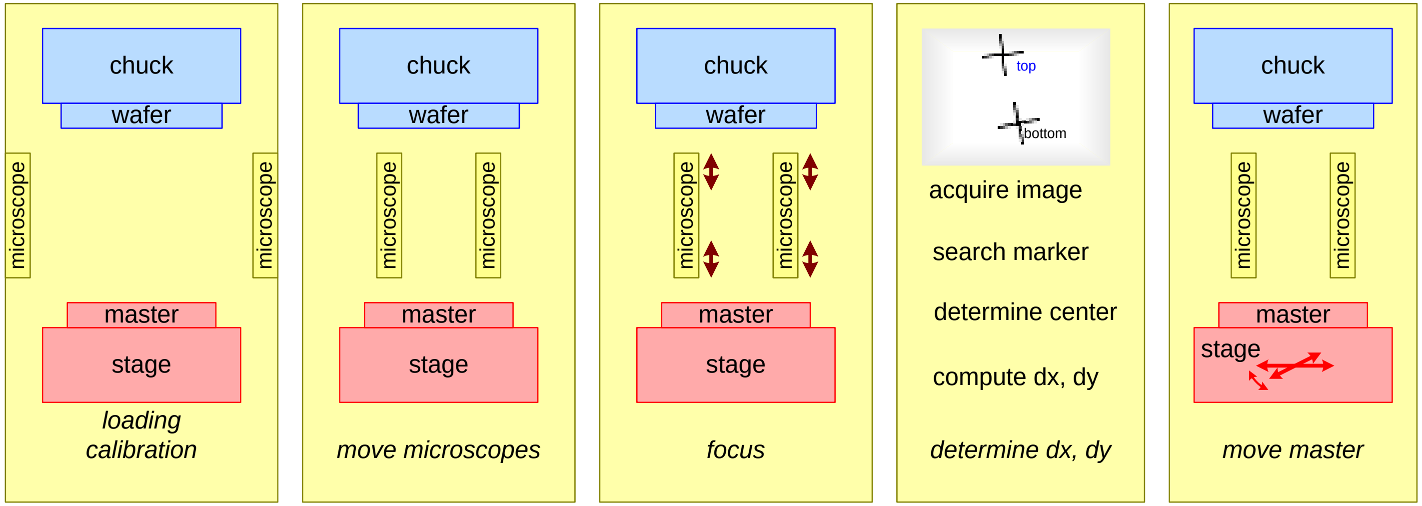


workflow

requires microscopes to be φ_x and φ_y corrected

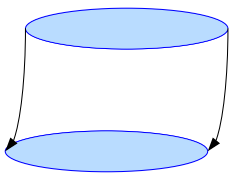
1. move microscopes to markers
2. focus master by lens movement
3. focus substrate by lens movement
4. acquire images
5. find markers
6. compute marker centers
7. compute wafer centers and θ
8. move master **Δ**x,**Δ**y,θ
9. repeat 4..8 to verify alignment
10. remove microscopes

assumes marker position to be known coarsely and markers to be within microscope FOV



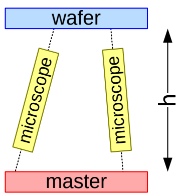
alignment challenge

1st order
ZuBa move imperfect
Microscope not perfectly vertical



vertical move causes some translation and rotation causing

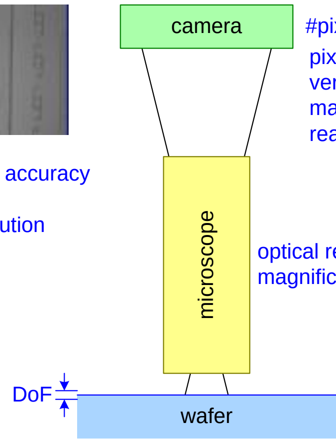
$(dx,dy)_{left}$ $(dx,dy)_{right}$



imperfect vertical axis causes dx, dy offsets

$dx = \varphi_x * h$

physical diagram



#pixels ~= 5M

pixel resolution versus maximum Field of View read-out and processing time

measurement accuracy determines required resolution

optical resolution magnification

displacement determines required Field of View

What are the Key Functions and KPPs of your SoI?

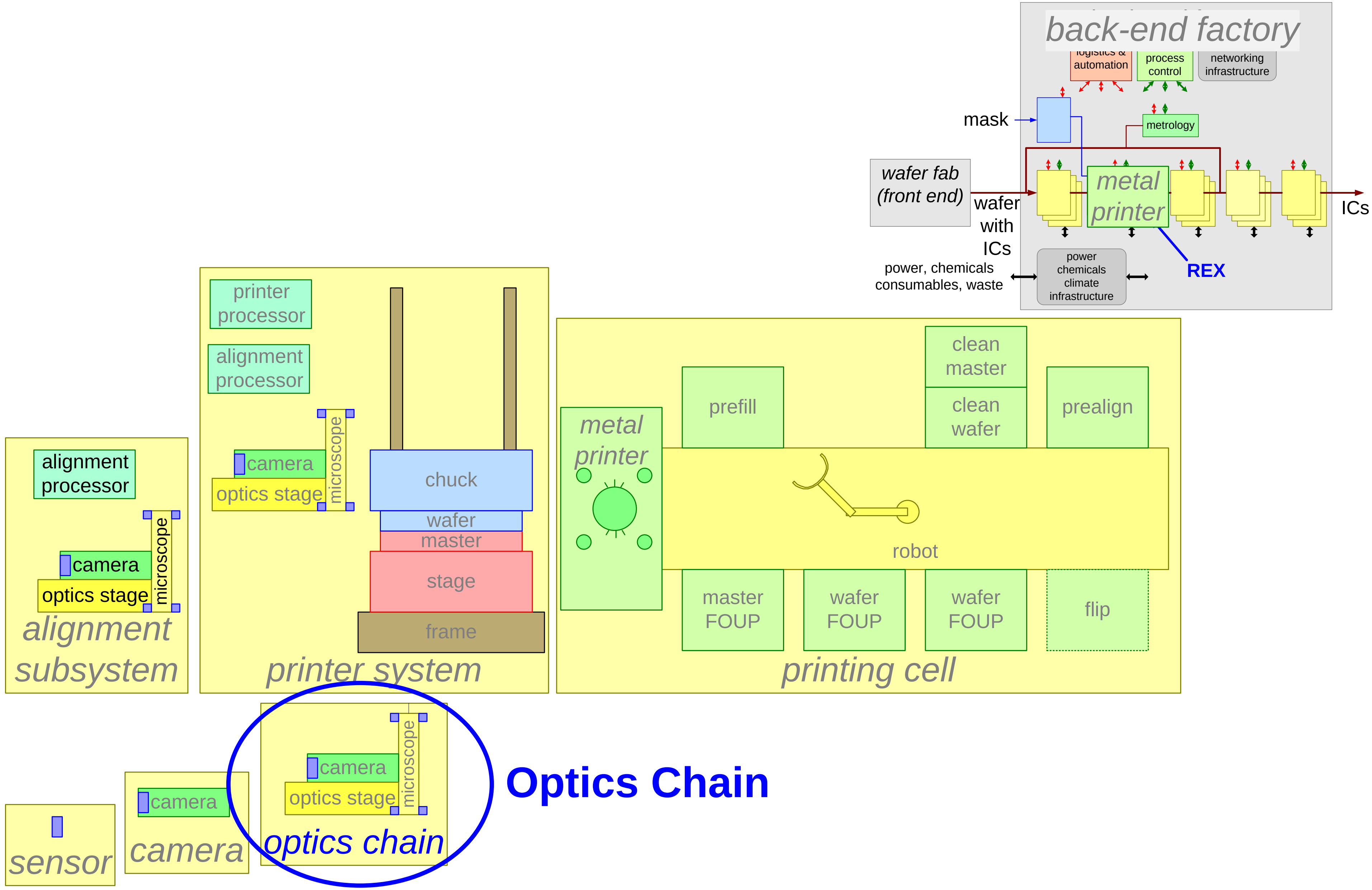
- Name 3 key functions of your SoI
- Name 3 KPPs of your SoI
- Quantify these KPPs
- How confident are you about your SoI answers?

Potential KPPs Alignment

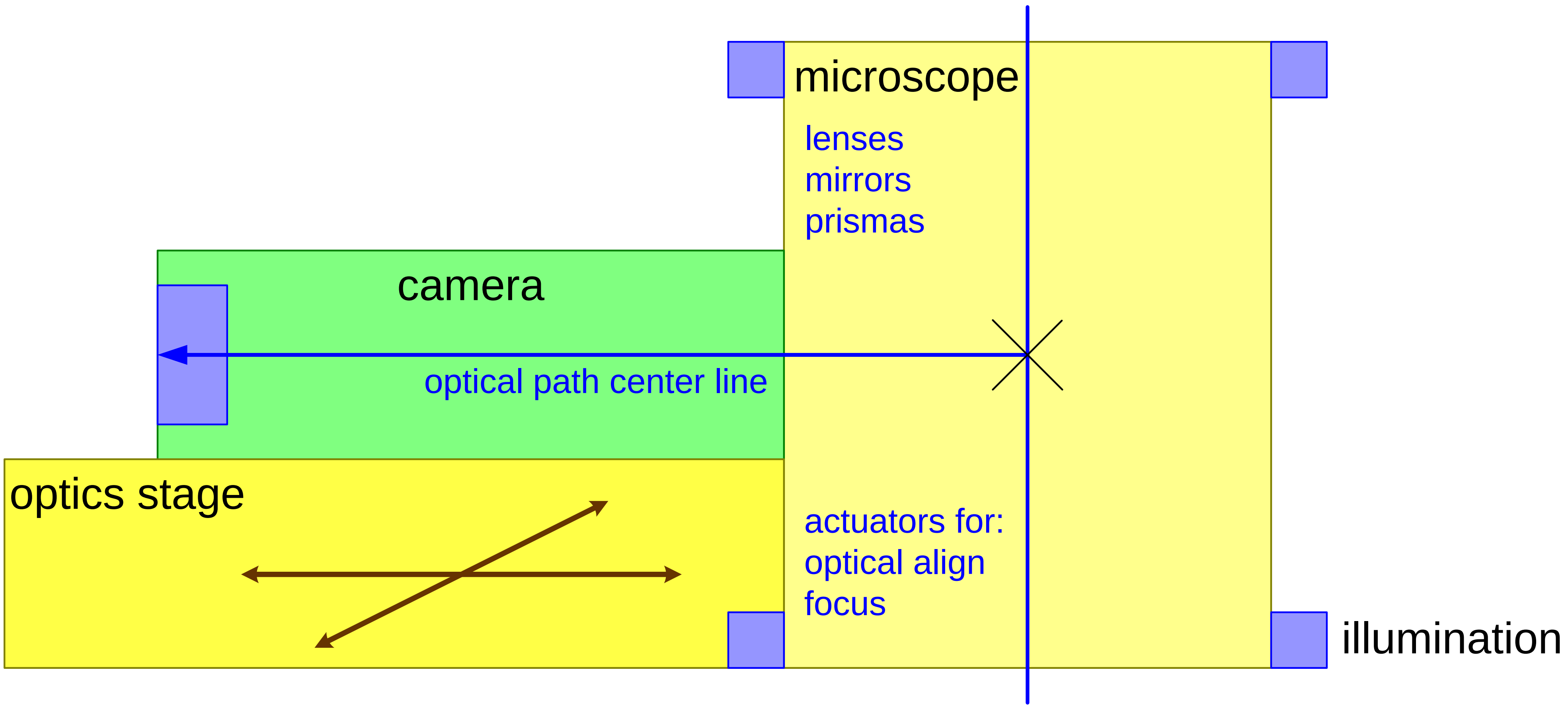
Possible
Key Performance Parameters
of the alignment subsystem

- dx, dy after alignment
- alignment cycle time
- robustness for markers, patterns, wafers, temperature
- cost, weight, size subsystem

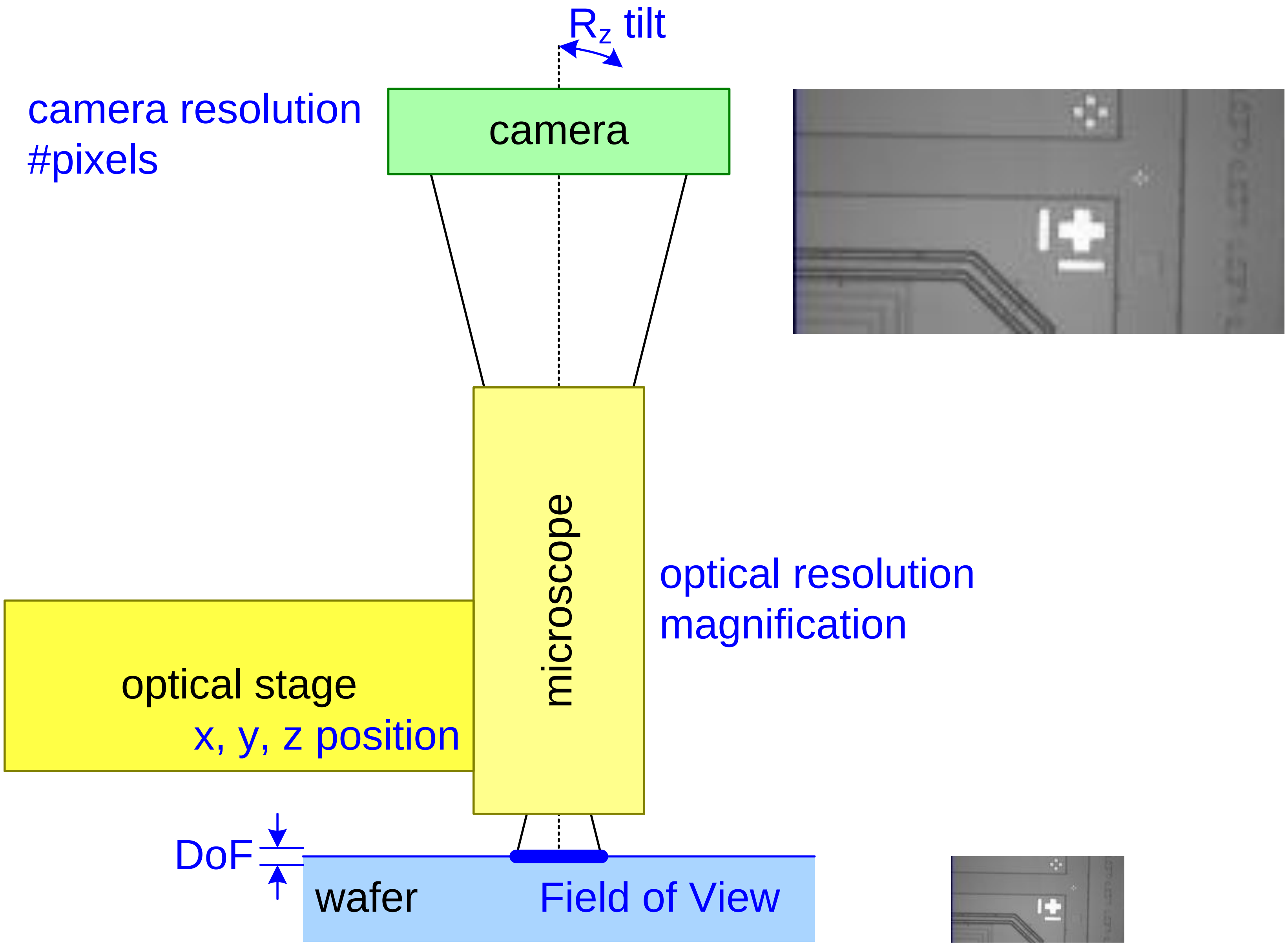
The Optics Chain



Optics Chain Block Diagram



Optics Chain



What are the Key Functions and KPPs of your Subsystem?

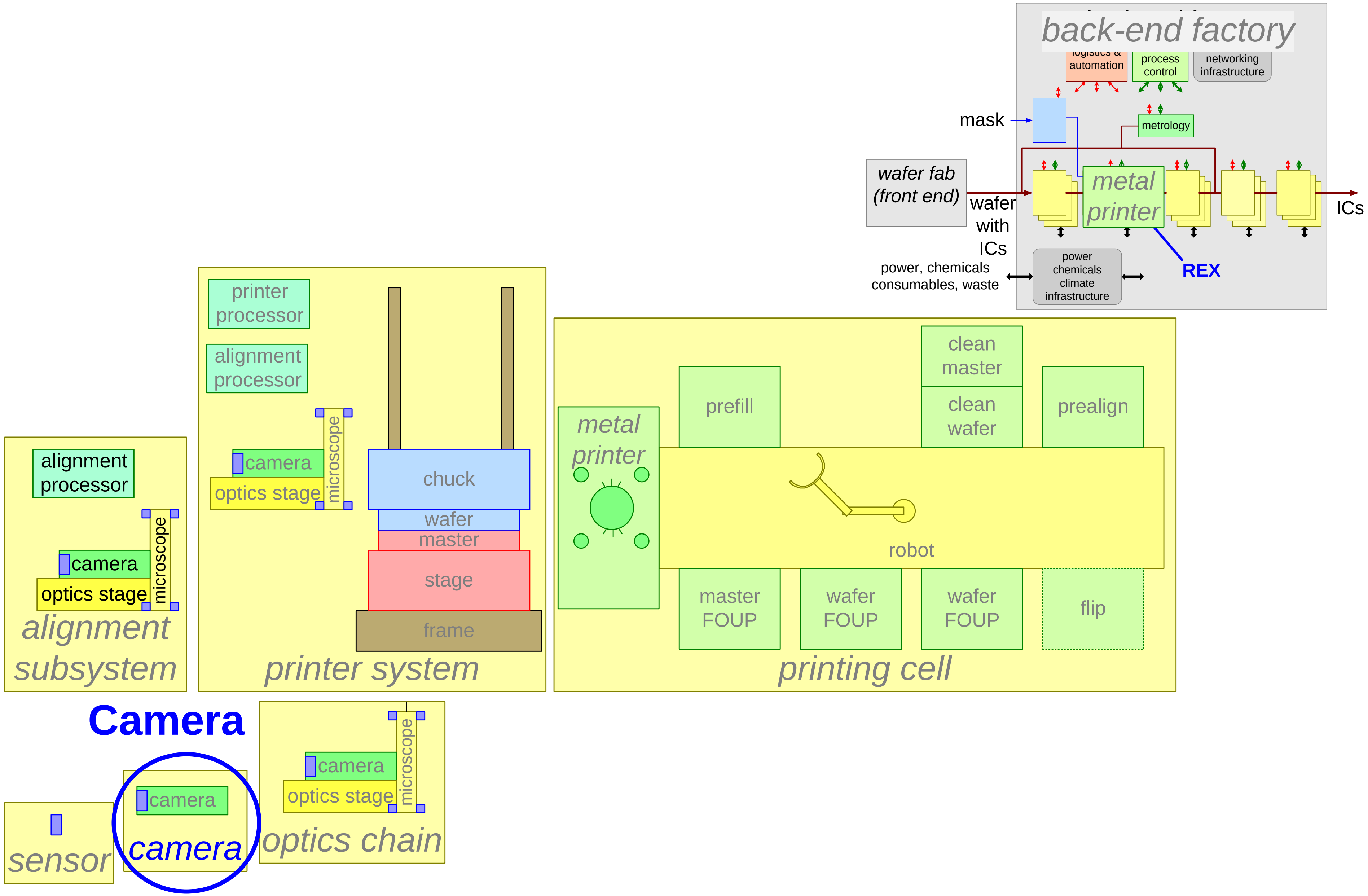
- Name 1 subsystem that is essential for your SoI KPPs
- Name 3 key functions of this subsystem essential for your SoI KPPs
- Name 3 KPPs of this subsystem essential for your SoI KPPs
- Quantify these KPPs
- How confident are you about your subsystem answers?

Potential KPPs Optics Chain

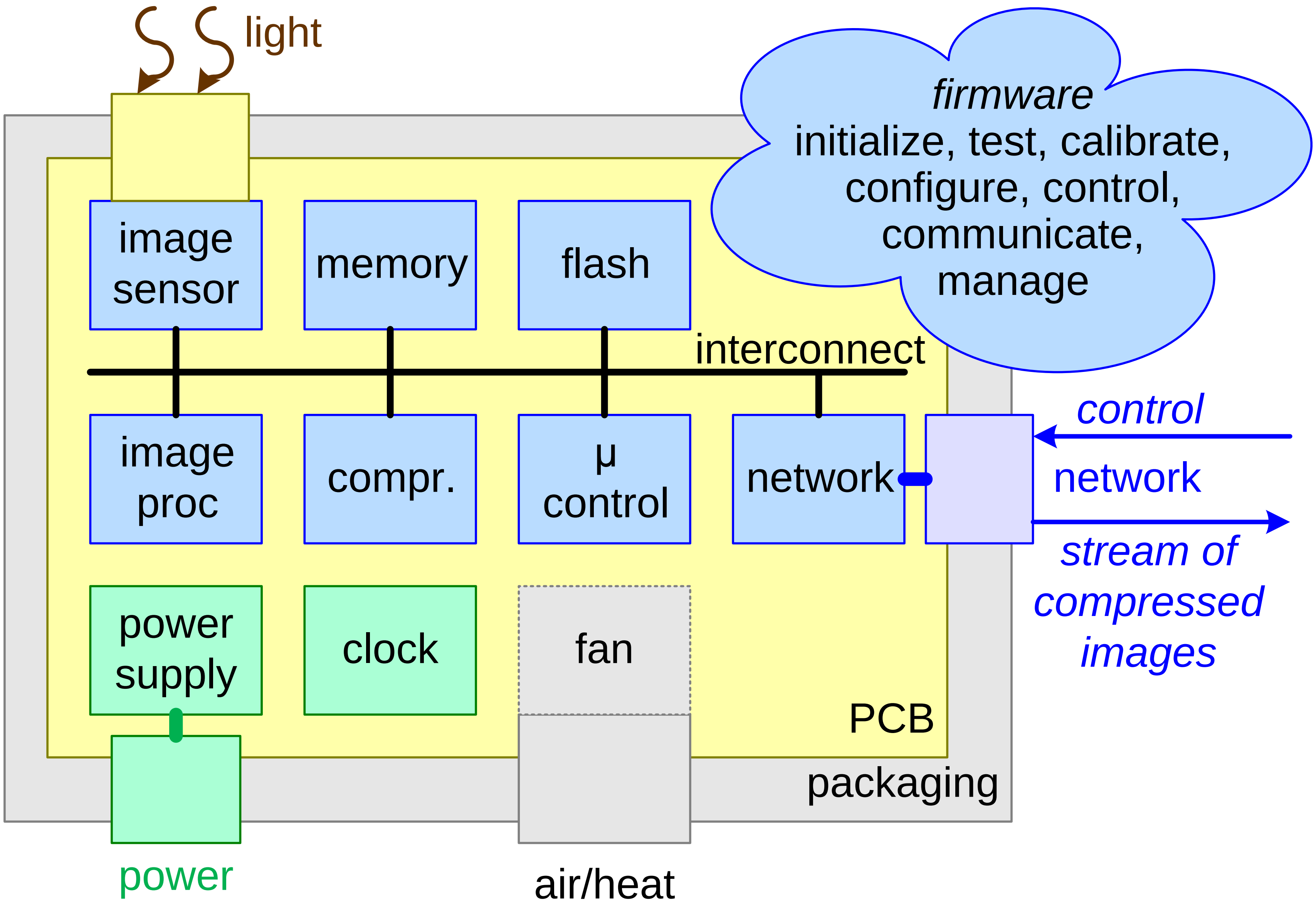
Possible
Key Performance Parameters
of the optics chain

- position and angle stability
- wafer-to-sensor image quality (resolution, uniformity, color range)
- vertical size
- acquisition performance (frame rate, acquisition time)
- stage performance (speed, stability, reproducability)
- focus performance
- x, y range
- thermal stability
- cost, weight, size stage+optics

The Camera


back-end factory
automation
process control
networking infrastructure
mask
metrology
wafer fab (front end)
metal printer
wafer with ICs
ICs
power, chemicals consumables, waste
power chemicals climate infrastructure
REX
printer processor
alignment processor
camera
optics stage
microscope
chuck
wafer
master
stage
frame
printer system
alignment processor
camera
optics stage
microscope
alignment subsystem
metal printer
prefill
clean master
clean wafer
prealign
robot
master FOUP
wafer FOUP
wafer FOUP
flip
printing cell
Camera
sensor
camera
camera
camera
optics stage
microscope
optics chain

Camera Block Diagram



What are the Key Functions and KPPs of your Subsubsystem?

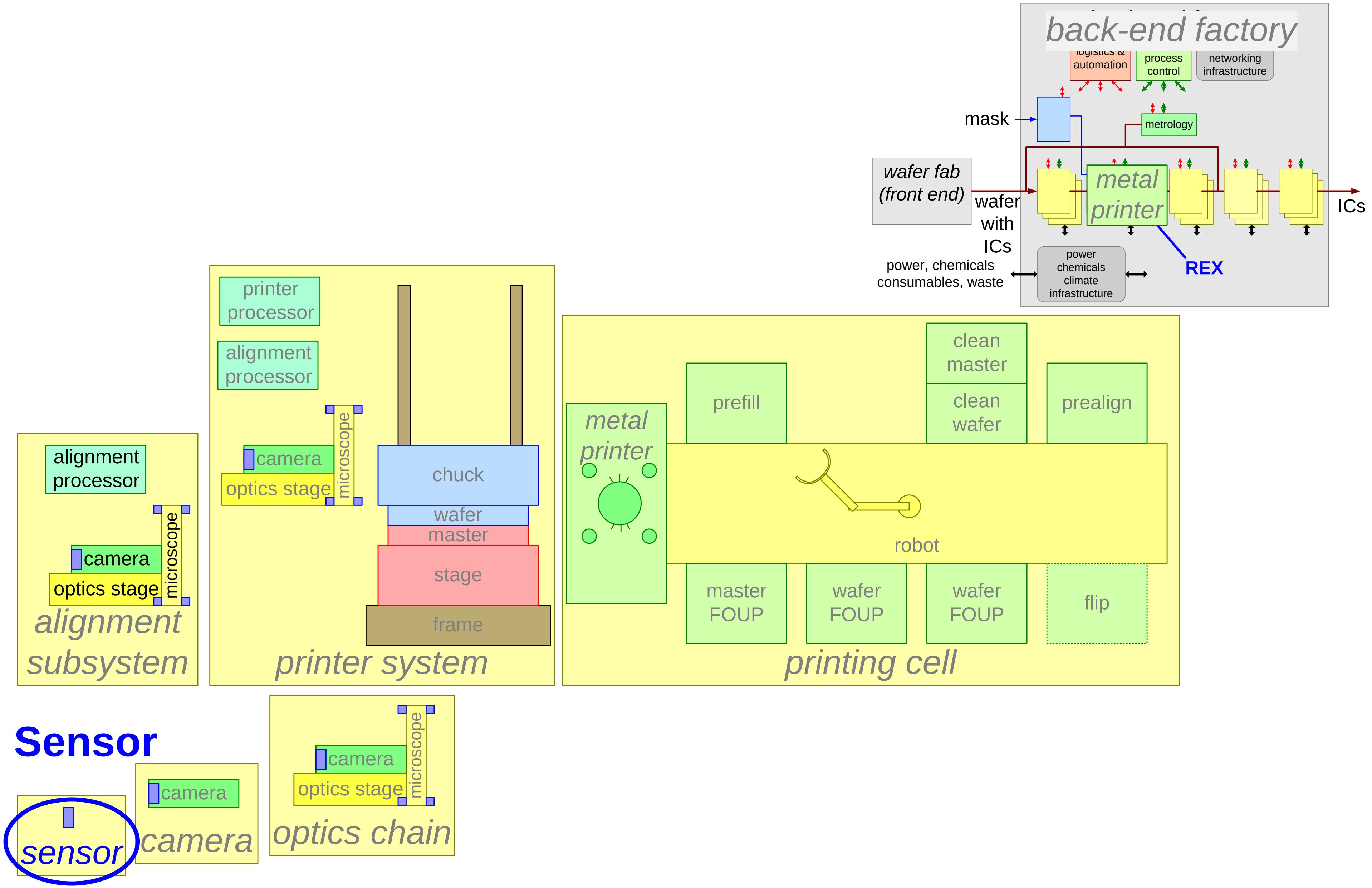
- Name 1 subsubsystem that is essential for your subsystem KPPs
- Name 3 key functions of this subsubsystem essential for your subsystem KPPs
- Name 3 KPPs of this subsubsystem essential for your subsystem KPPs
- Quantify these KPPs
- How confident are you about your subsubsystem answers?

Potential KPPs Camera

Possible
Key Performance Parameters
of the camera

- image quality (resolution, uniformity, color range)
- acquisition performance (frame rate, acquisition time)
- camera size, weight
- camera energy consumption, thermal stability
- camera cost price
- storage capacity
- compression rate and quality
- communication performance

The Sensor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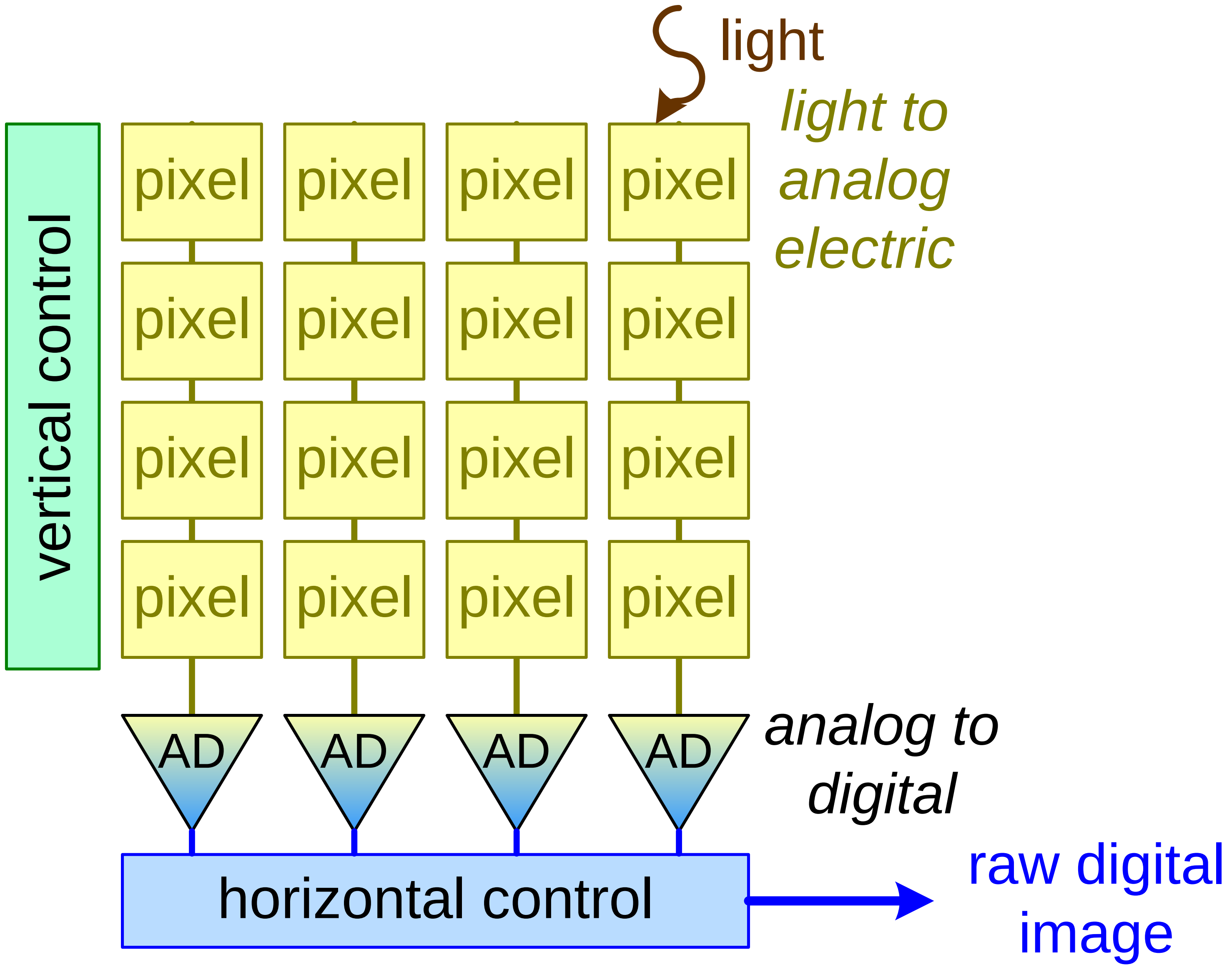
optics stage
microscope
alignment subsystem
Sensor
sensor
camera
camera
camera
optics stage
microscope
optics chain

Sensor Block Diagram

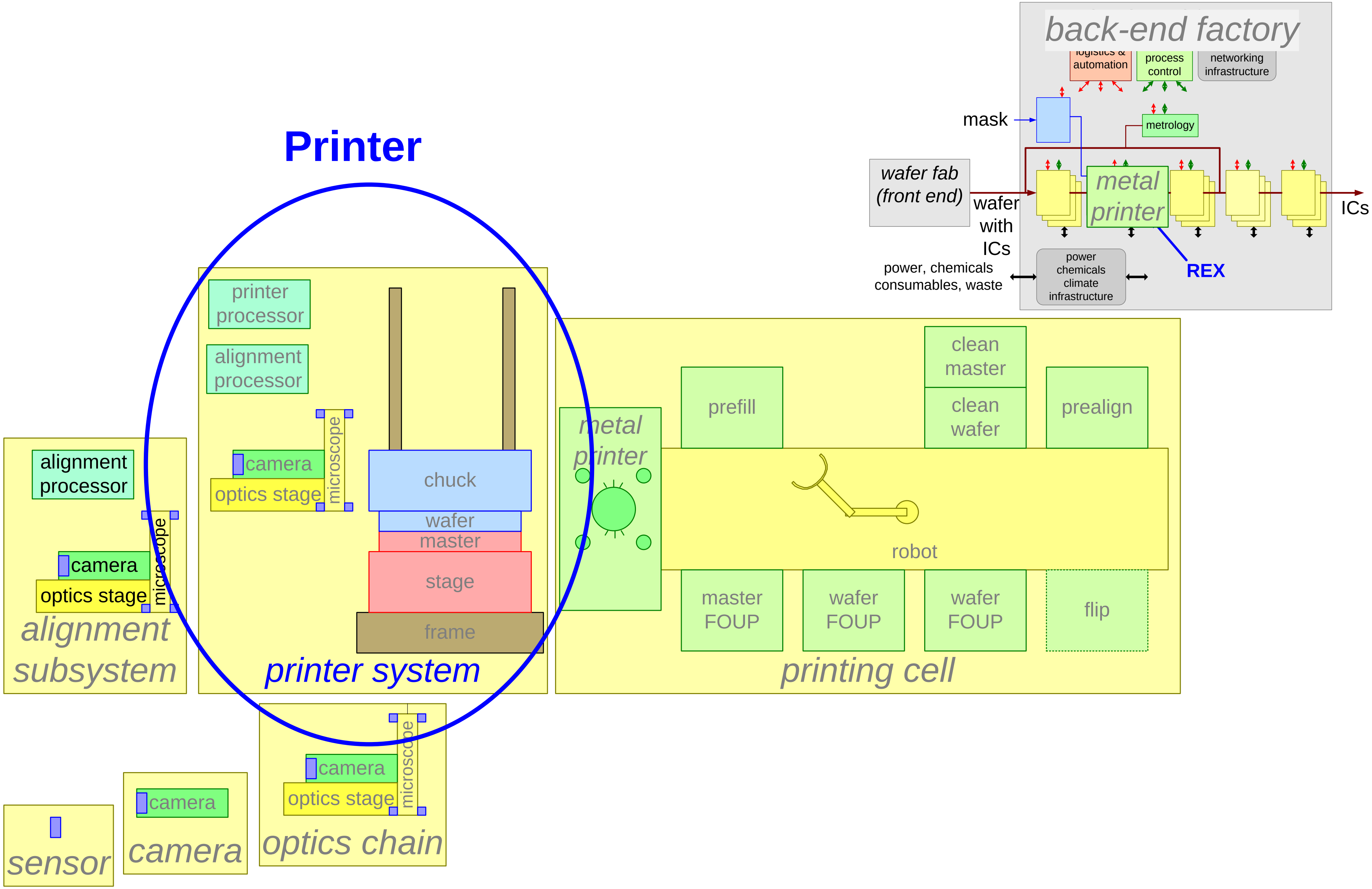


Potential KPPs Sensor

Possible
Key Performance Parameters
of the sensor

- spatial resolution
- contrast resolution
- frame rate
- image acquisition time
- image uniformity
- sensor size
- energy consumption
- cost price
- color range
- sensitivity

The Printer



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wafer FOUP
wafer FOUP
flip
printing cell
sensor
camera
camera
camera
optics stage
microscope
optics chain

What are the Key Functions and KPPs of your Supersystem?

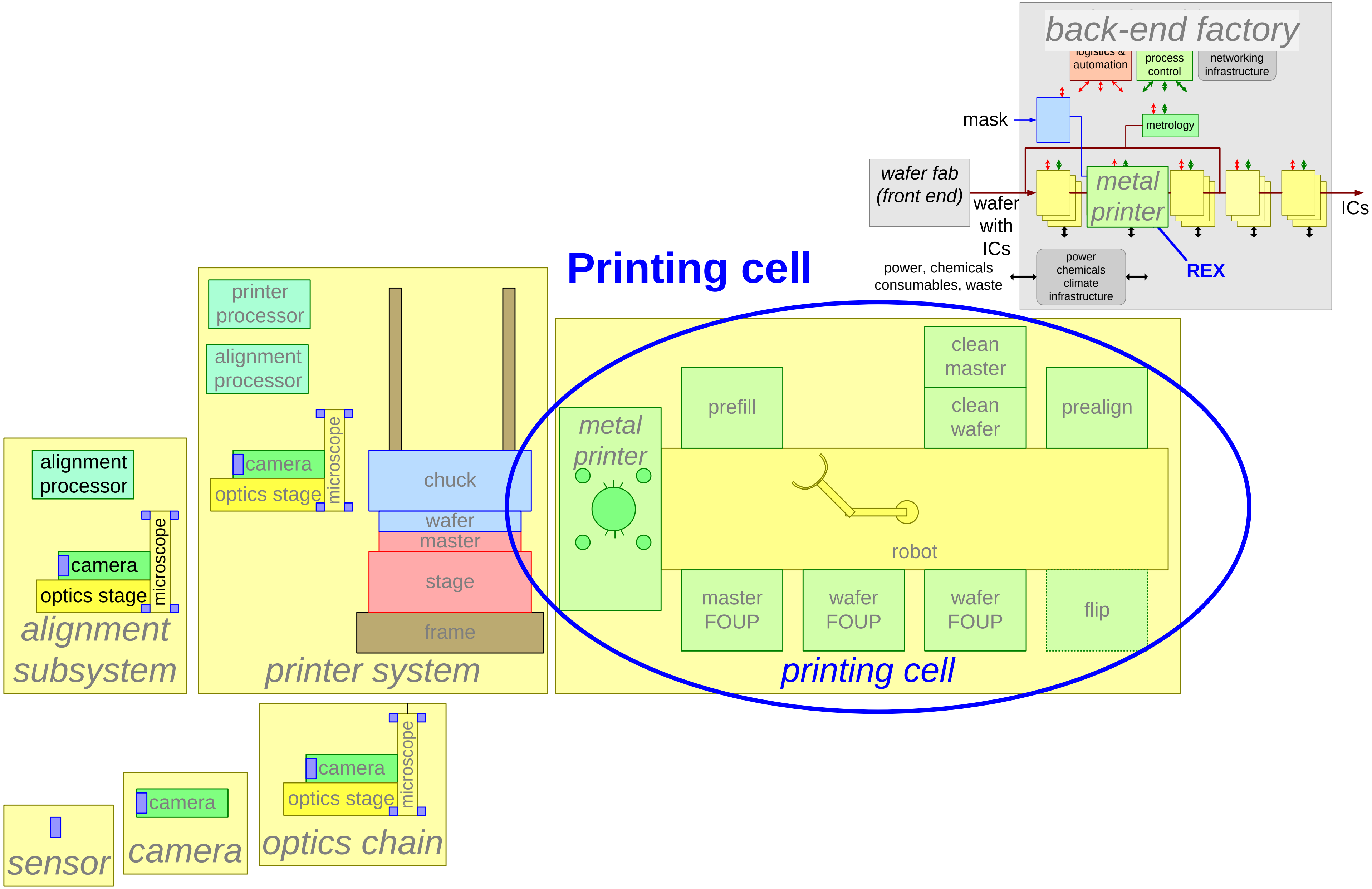
- Name a supersystem that is needs your system KPPs
- Name 3 key functions of this supersystem needing your system KPPs
- Name 3 KPPs of this supersystem needing your system KPPs
- Quantify these KPPs
- How confident are you about your supersystem answers?

Potential KPPs of the Printer

Possible
Key Performance Parameters
of the printer system

- print quality (pattern resolution, cross section control)
- overlay (=positioning accuracy)
- throughput
- reliability (uptime, high MTBF)
- robustness for markers, patterns, wafers, temperature
- integral costs (system cost, operational costs)
- consumables and waste
- fab interoperability (wafers and information)
- footprint

The Printer



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camera
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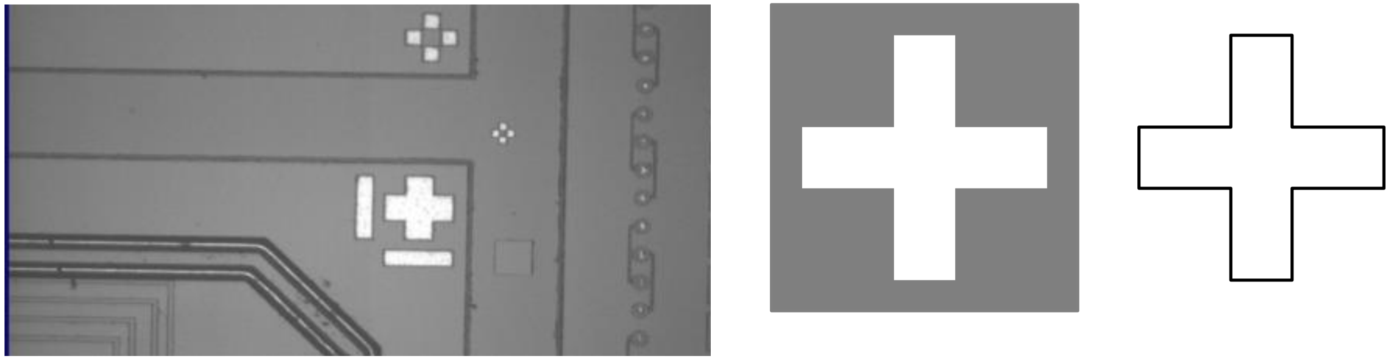
microscope
optics chain

How Process can Influence Alignment



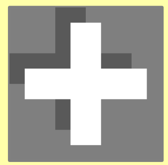
Context: process influence on alignment

what if little contrast

what if slow transition

what if wafer surface height varies

what if shadows

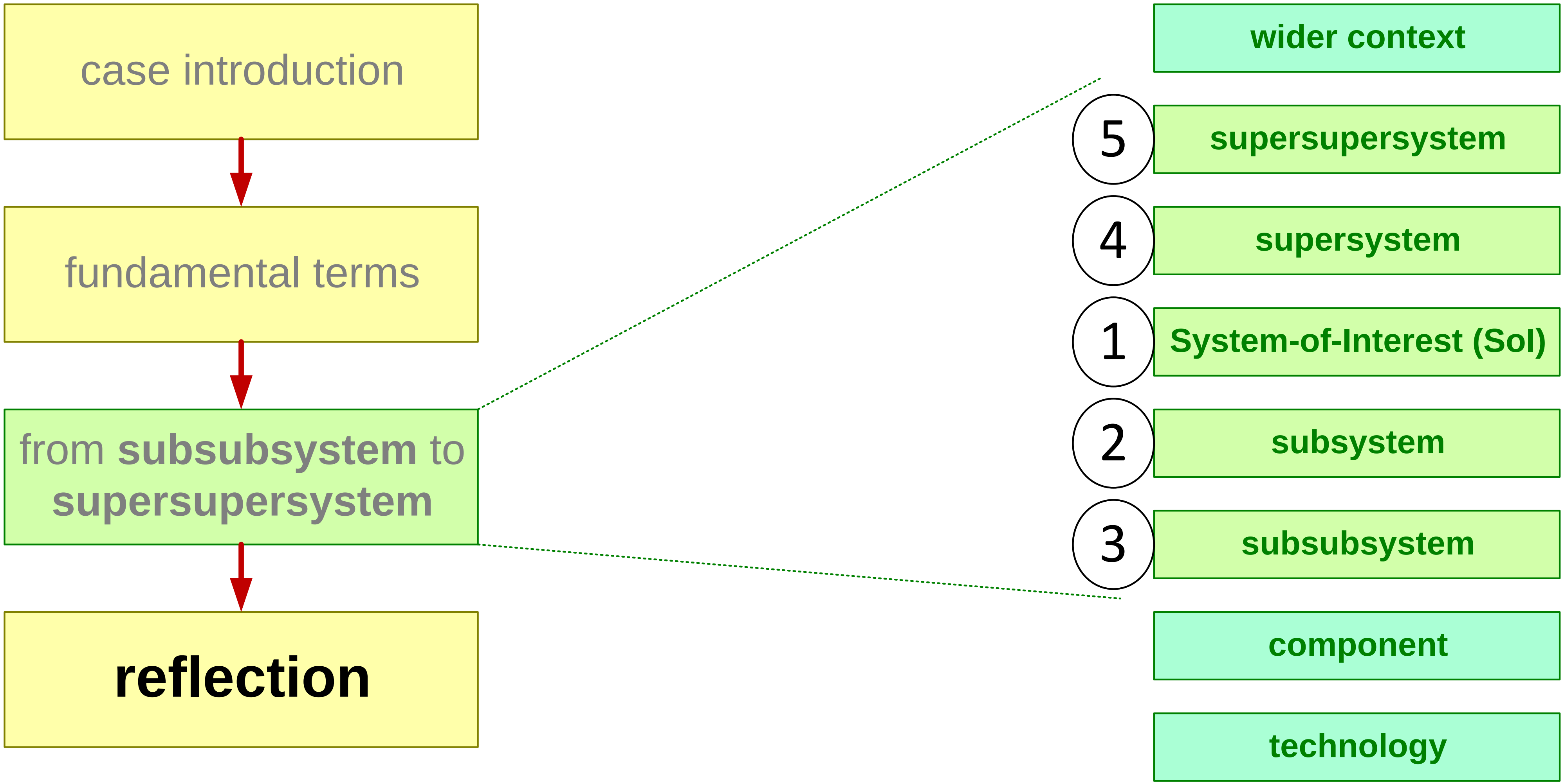


what if marker is damaged

What are the Key Functions and KPPs of your Supersupersystem

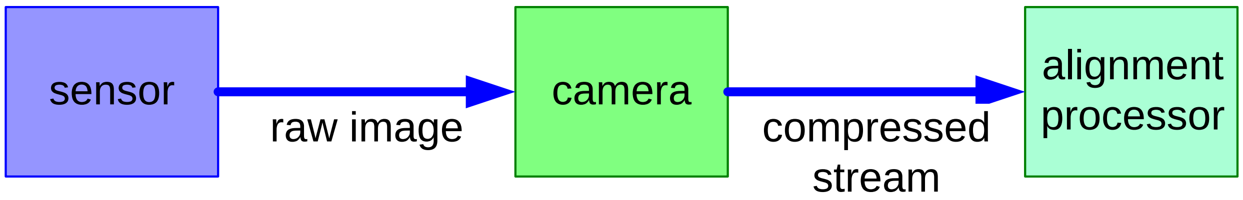
- Name a supersupersystem that is needs your supersystem KPPs
- Name 3 key functions of this supersupersystem needing your supersystem KPPs
- Name 3 KPPs of this supersupersystem needing your supersystem KPPs
- Quantify these KPPs
- How confident are you about your supersupersystem answers?

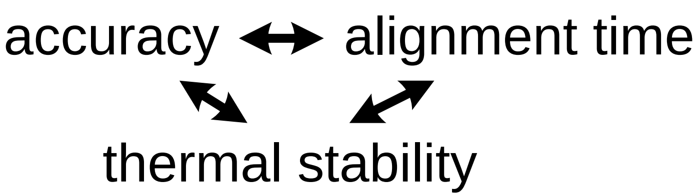
Time for Reflection



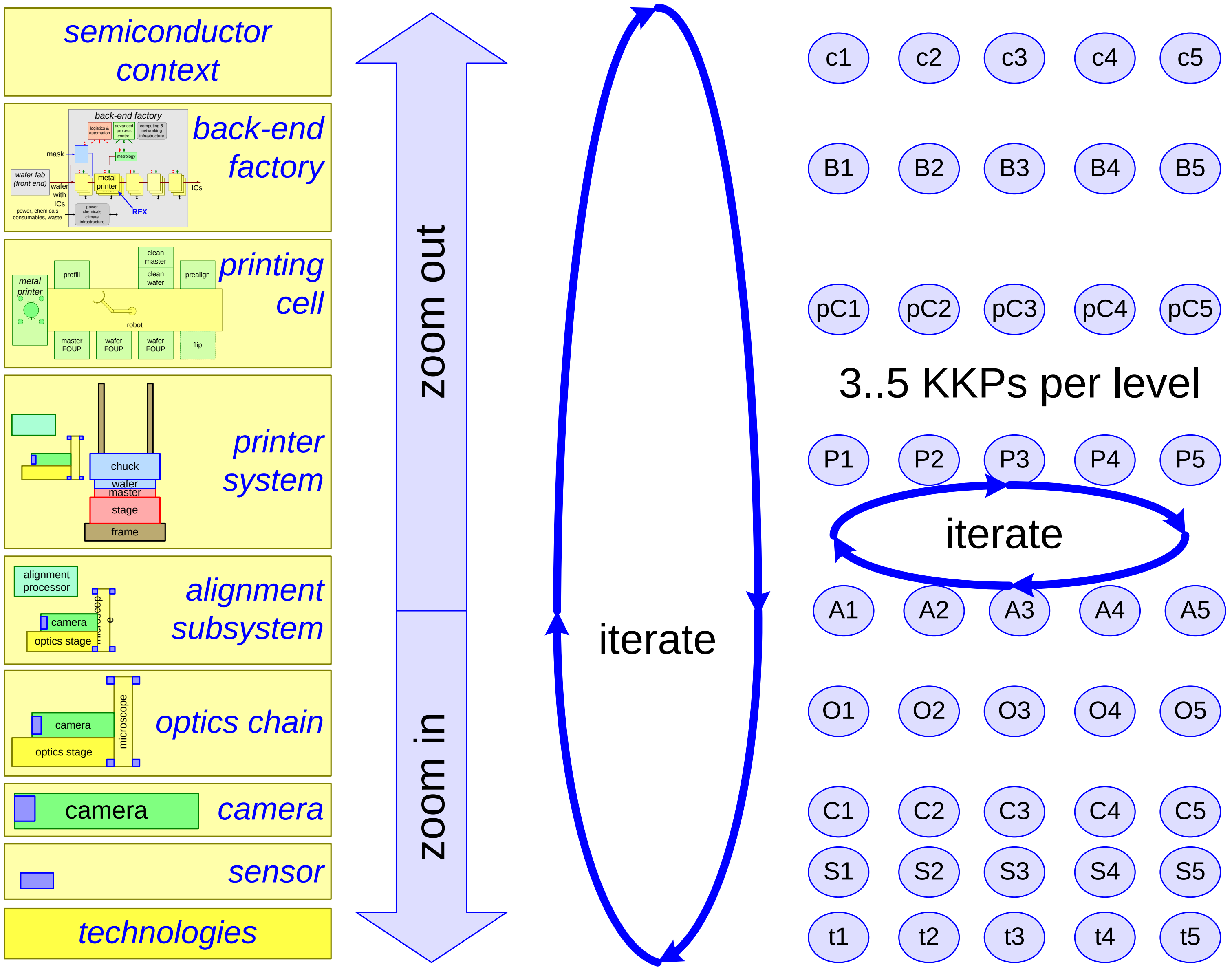
Part of the Design Space

	benefits	*disadvantages*
high resolution	accurate dx, dy	long acq time long transfer time long calculation time high energy consumption
large FoV	easy to find markers	long acq time long transfer time high energy consumption
red light	visibility marker	low optical resolution
blue light	high optical resolution	poor visibility marker
continuous on	thermal steady state	requires continuous cooling





Architecting: 8 Orders Zoom in-out



What are your Reflections?

- What is your **personal range**?
- Where do you want to know more?
- What are the **benefits** of this seminar for you?
- What are the **concerns** of this seminar for you? E.g., what would you like to change?