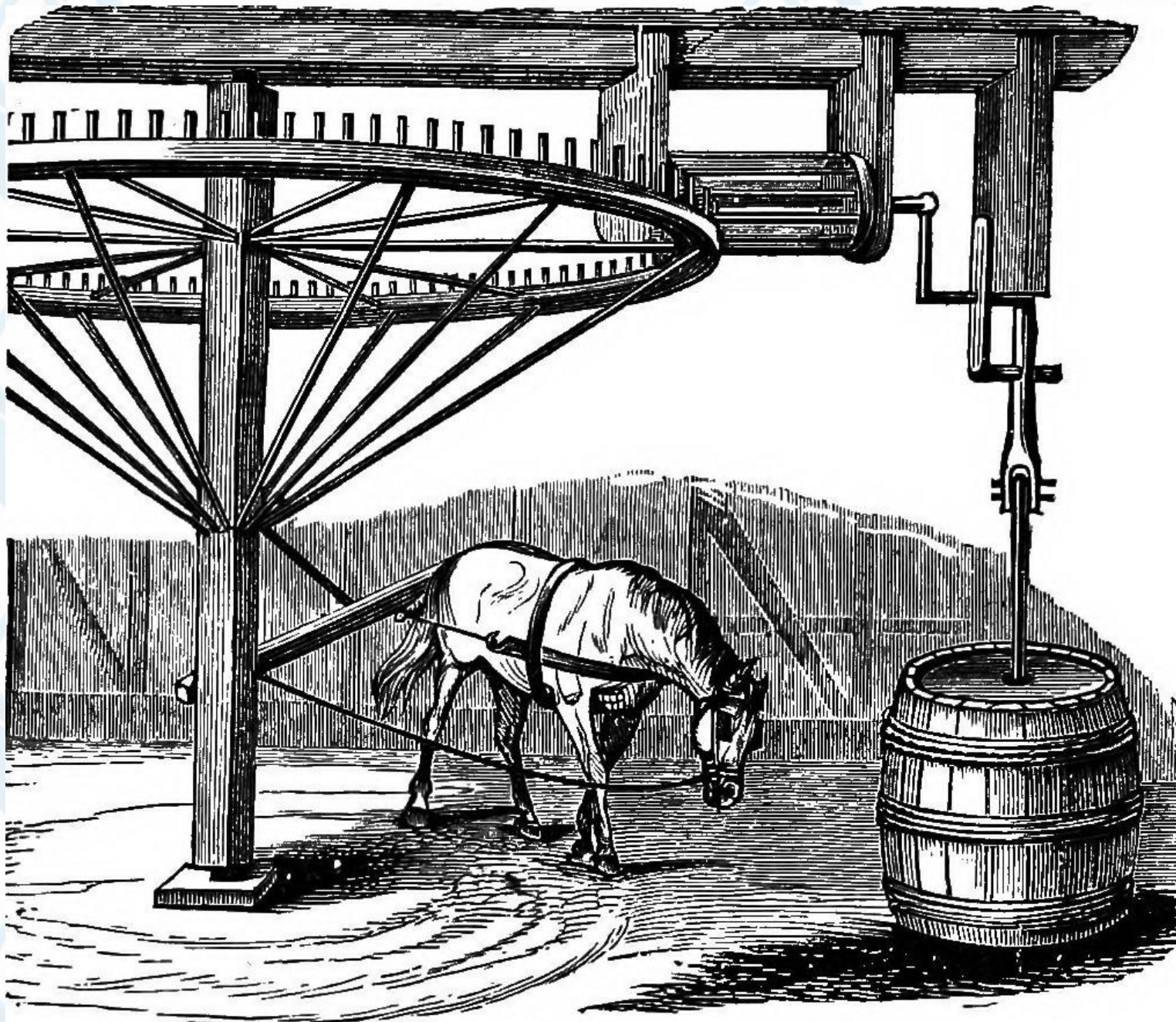


Process Analytical Technology creates smart production - How far are we today?

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Chemometrics & Analytical Technology
Department of Food Science

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From Flint, Charles, Louis, et. al :

"Milch cows and dairy farming; comprising the breeds, breeding, and management, in health and disease, of dairy and other stock; the selection of milch cows, with a full explanation of Guenon's method; the culture of forage plants, **and the production of milk, butter**, and cheese ... with a treatise upon the dairy husbandry of Holland; to which is added Horsfall's system of dairy management"

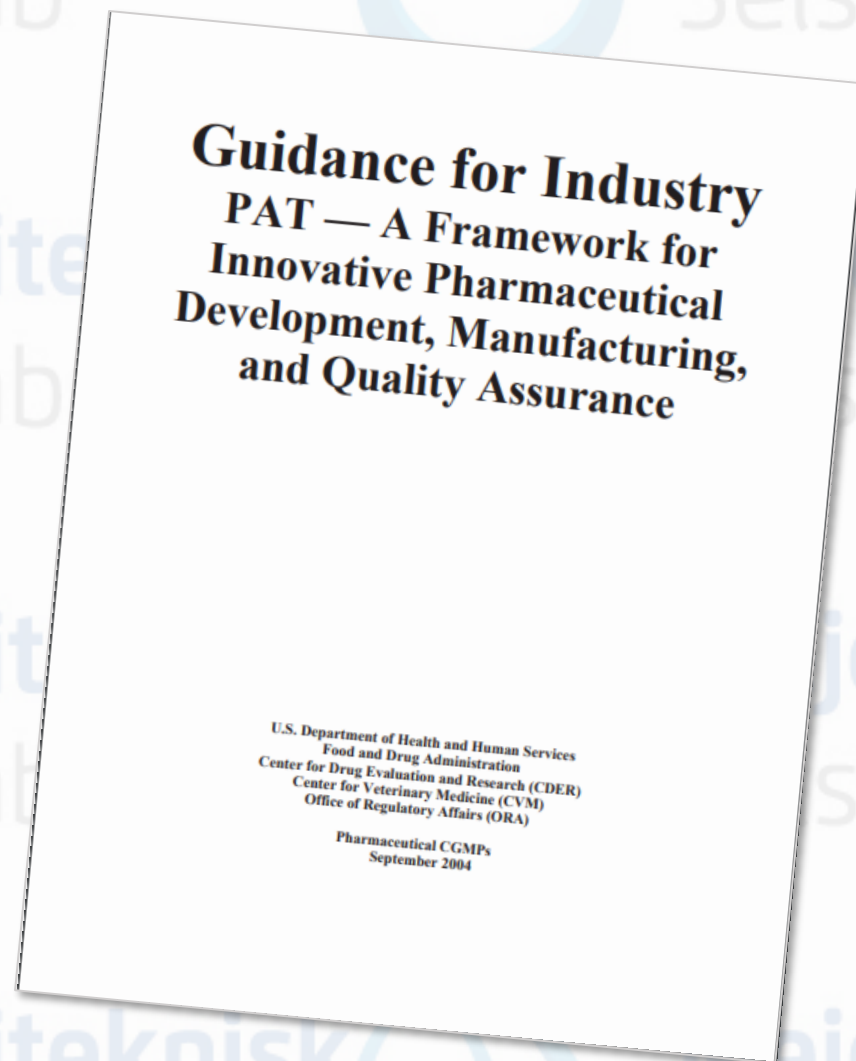
Published by Boston, Crosby, Nichols, Lee & co., **1860**

Fig. 109. Churning by Horse-power. — On large farms and inextensive dairies the churning is done by horse-power.

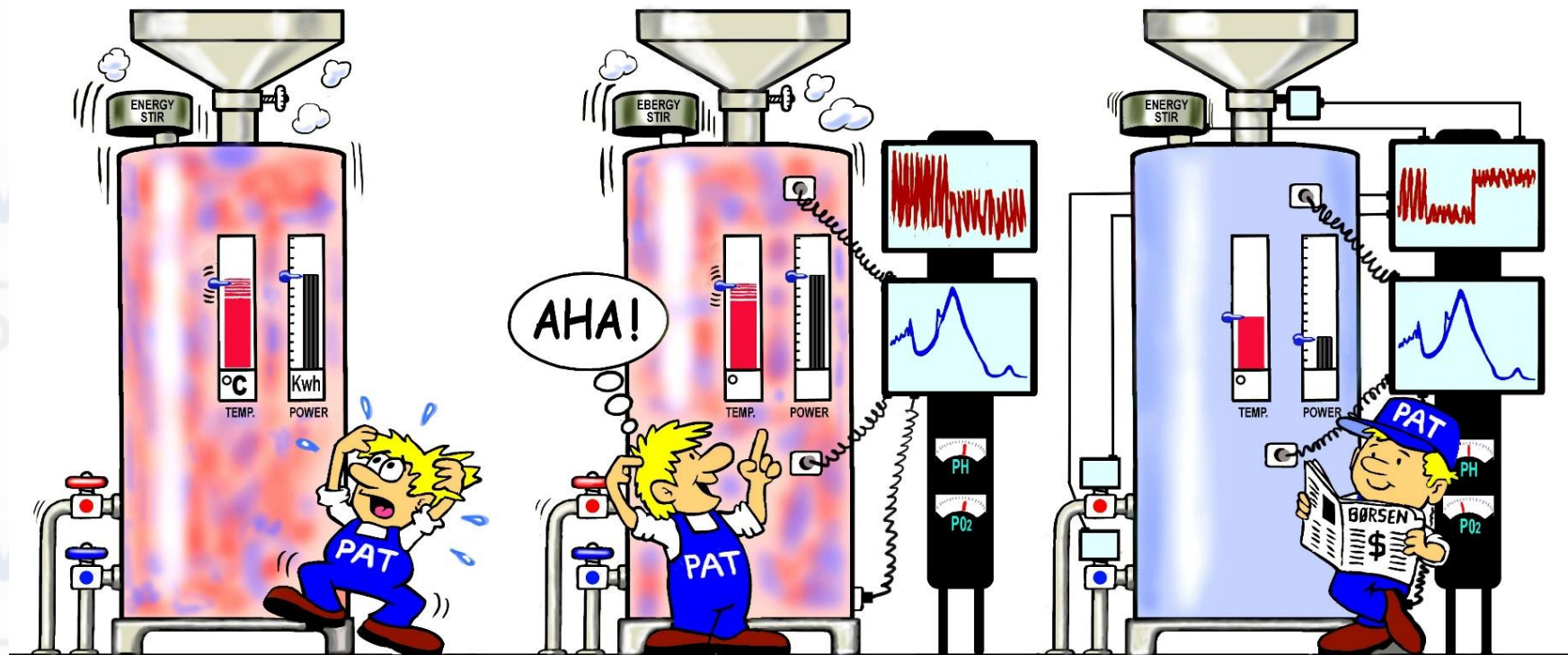
PAT – Process Analytical Technology

An 2004 initiative by the US FDA

- Reducing production cycle times
- Real time release
- Increasing automation
- Preventing rejects, scrap, and re-processing
- Improving energy and material use
- Increasing capacity
- Facilitating continuous processing



PAT – Process Analytical Technology



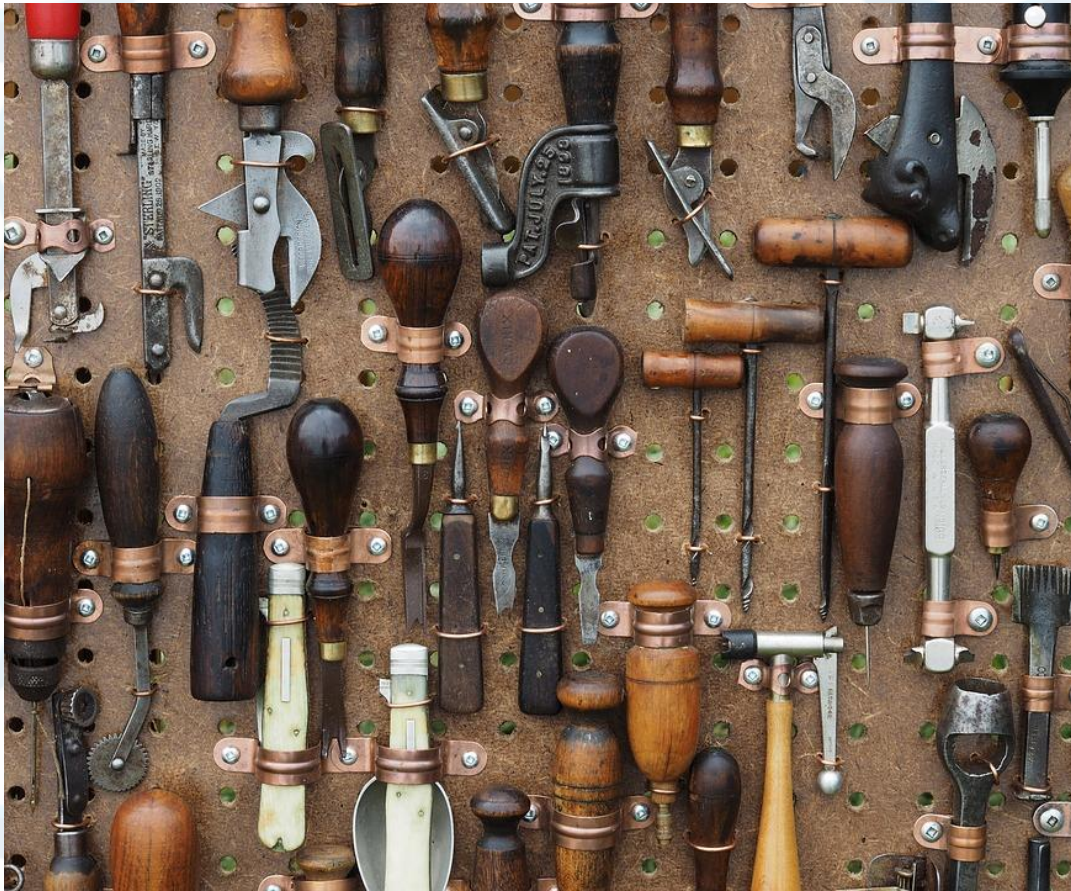
RECIPE BASED

MONITORED RECIPE BASED

MONITORED & CONTROLLED



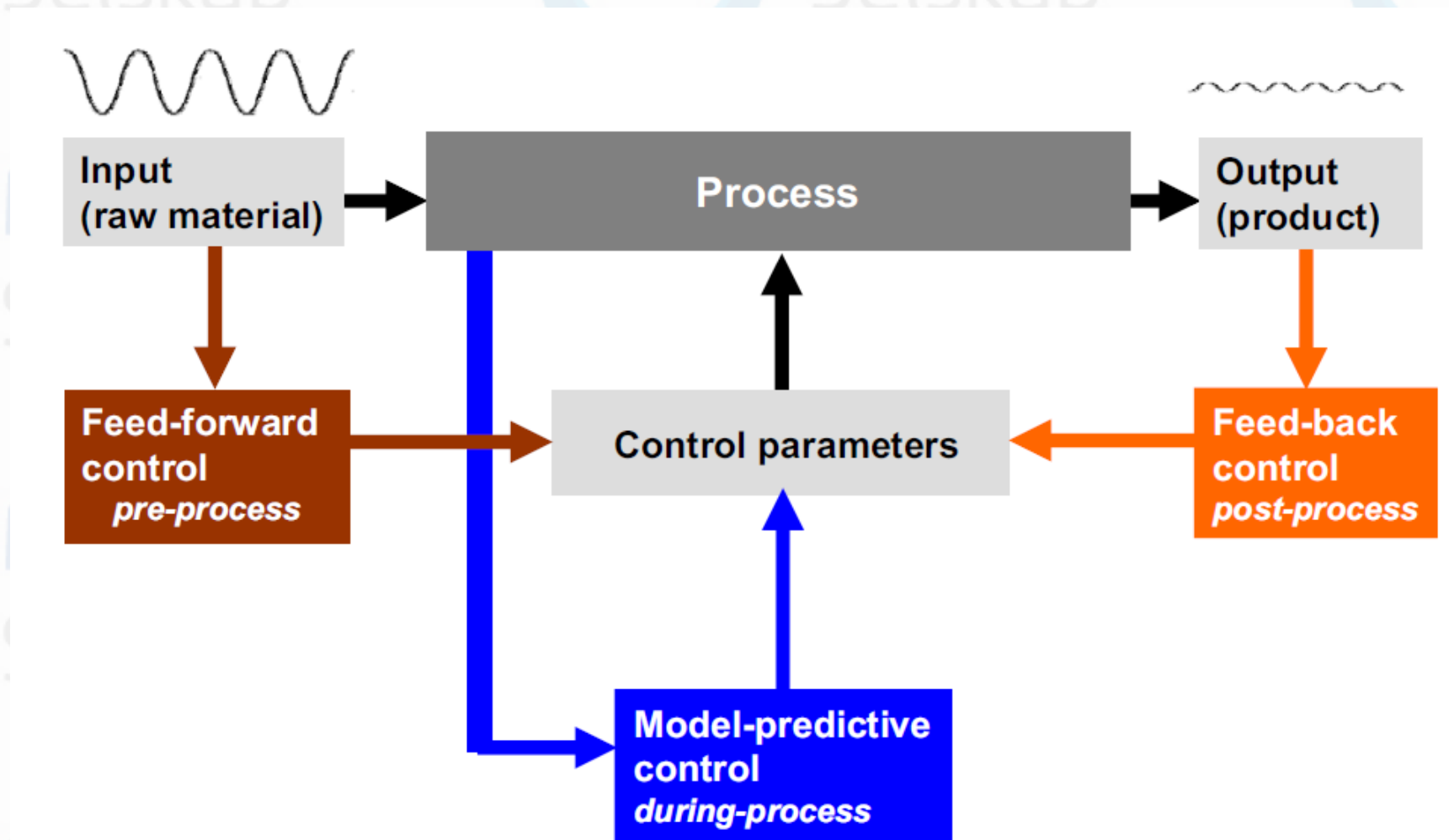
PAT – Process Analytical Technology



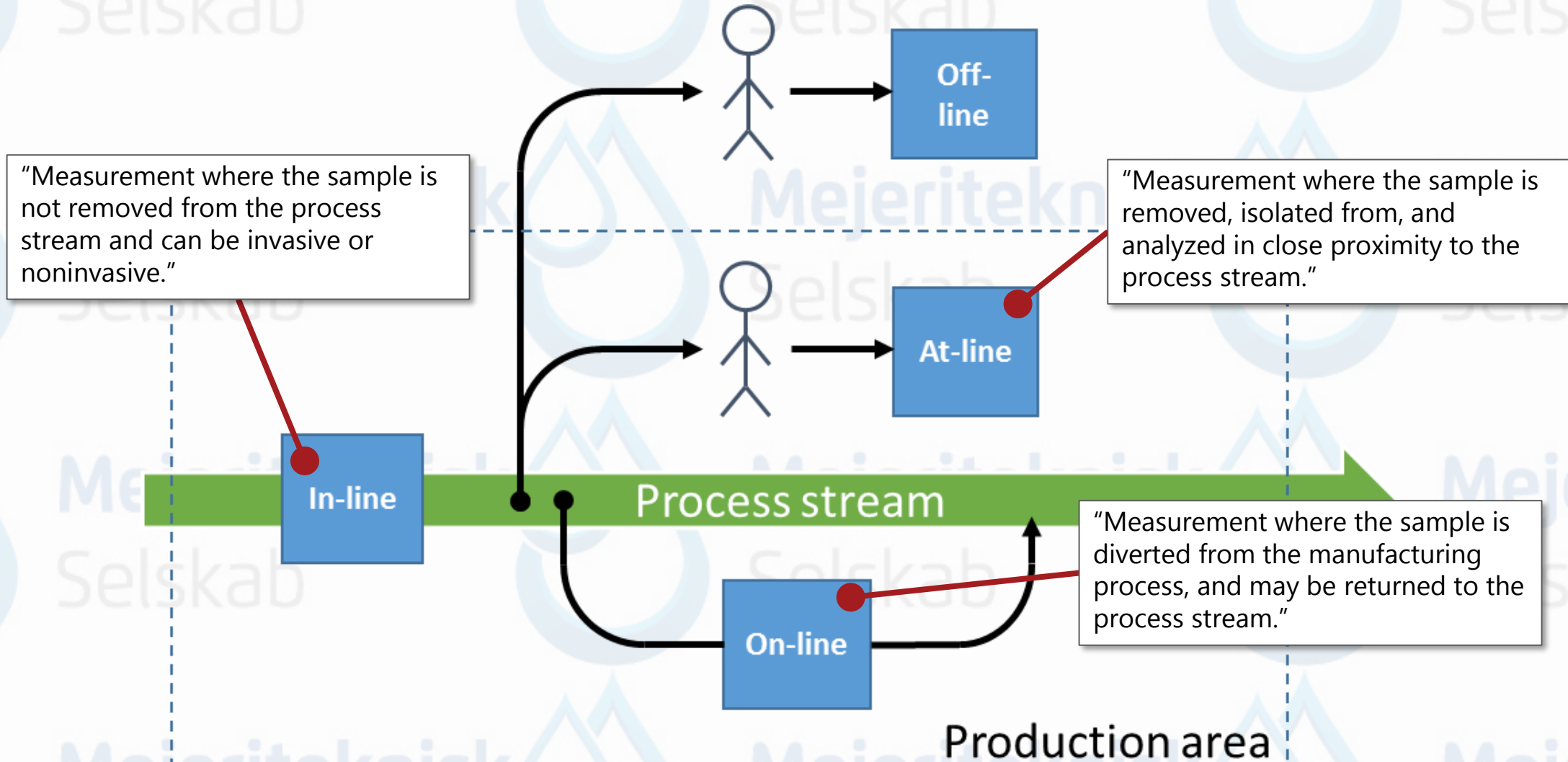
The four key PAT Tools

- Process analyzers
- Process control tools
- Multivariate tools for design, data acquisition and analysis
- Continuous improvement and knowledge management tools

The PAT framework



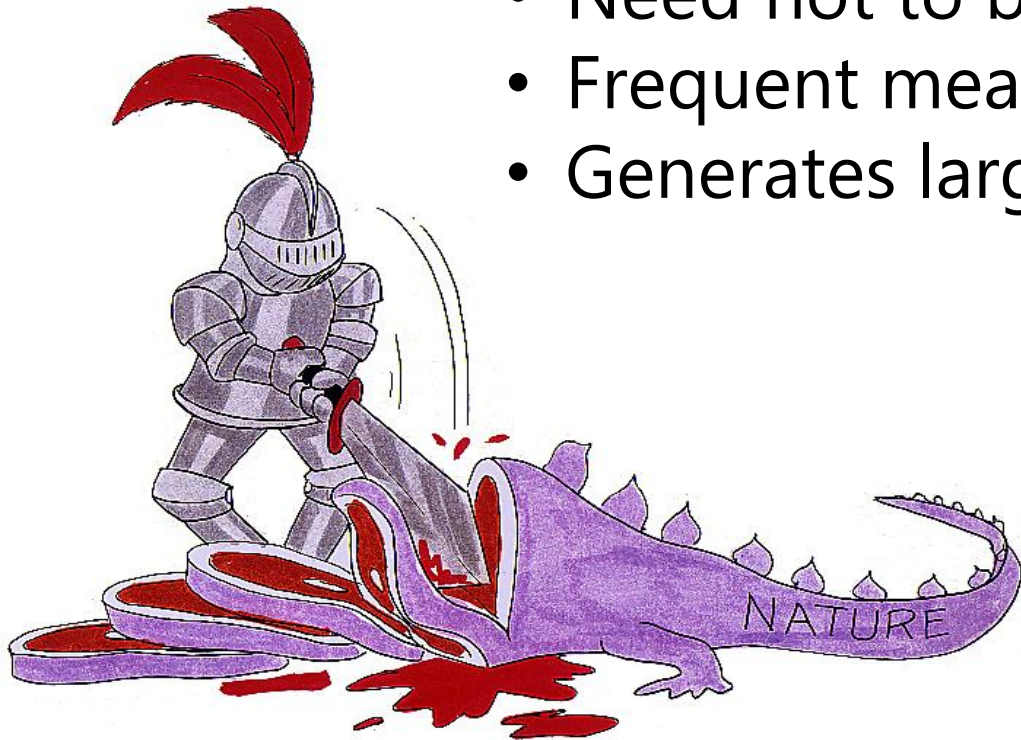
PAT Process analyzers - methods



PAT Process analyzers - characteristics

“The tools has evolved from univariate process measurements”

- Nondestructive
- Need not to be absolute
- Frequent measurements
- Generates large volumes of data



PAT Process analyzers : Near-infrared spectroscopic

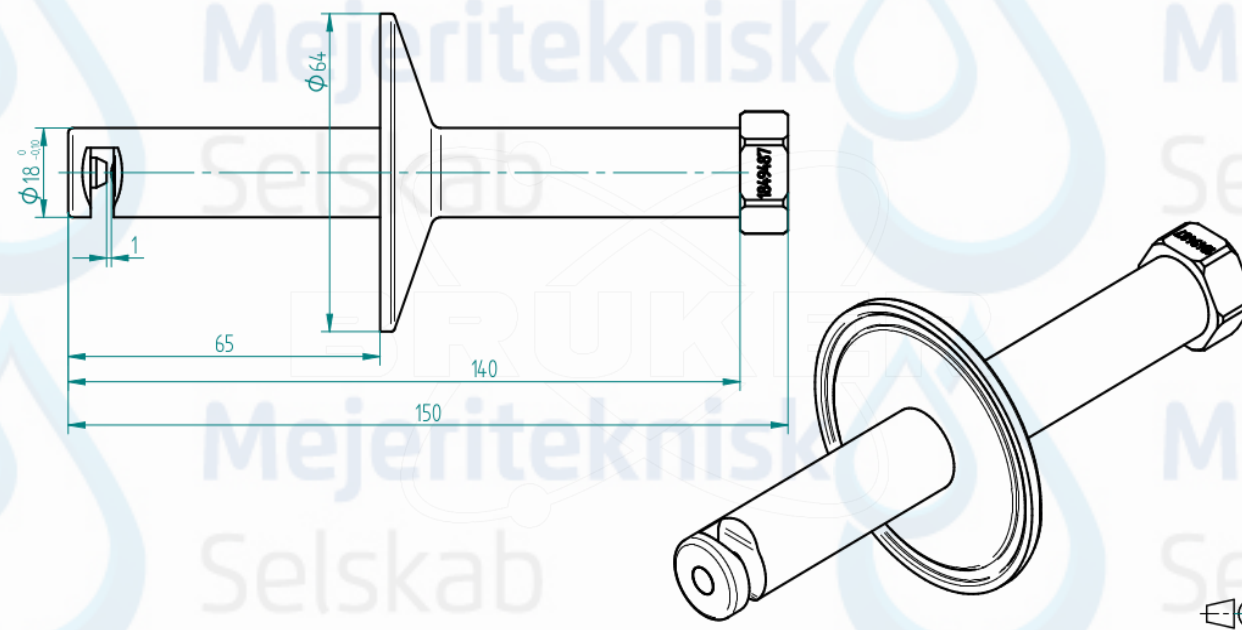


PAT Process analyzers : NIR In-line



NIR transfection probe IN271F-02 modif.
1849487

Bruker Optik

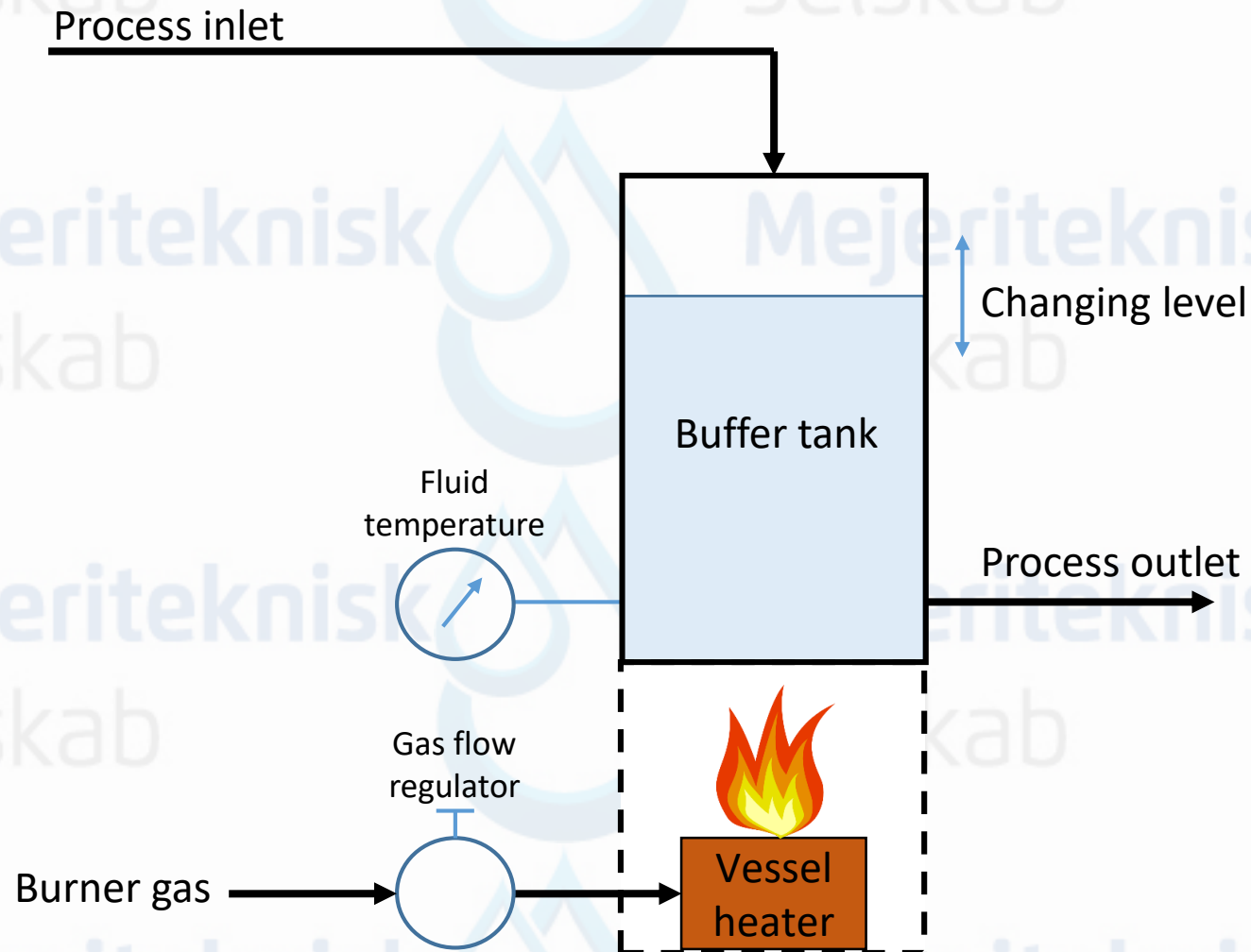


PAT Process control tools

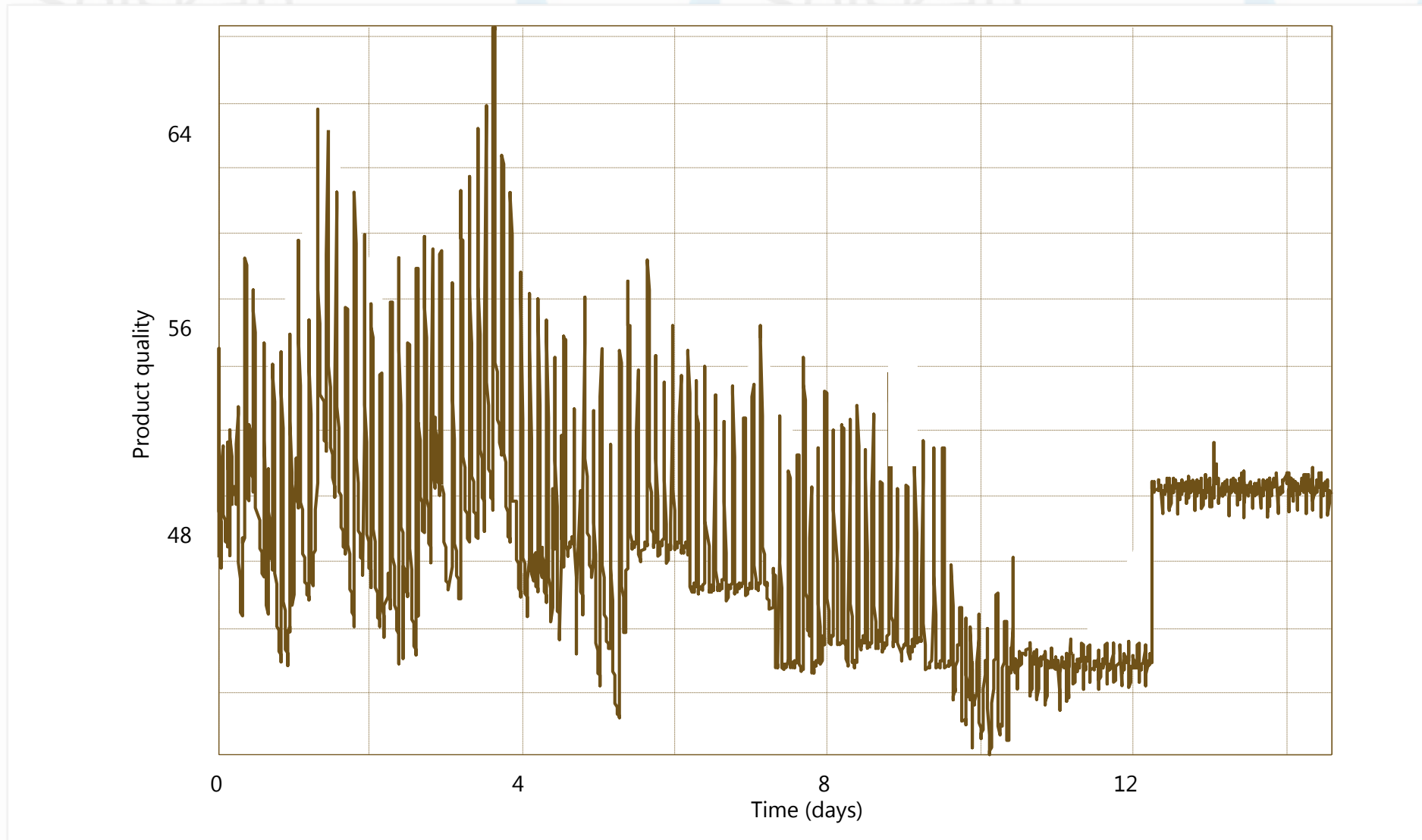
- Identify and measure critical material and process attributes relating to product quality
- Design a process measurement system to allow real time or near real time (e.g., on-, in-, or at-line) monitoring of **all** critical attributes
- Design process controls that provide adjustments to ensure control of all critical attributes
- Develop mathematical relationships between product quality attributes and measurements of critical material and process attributes



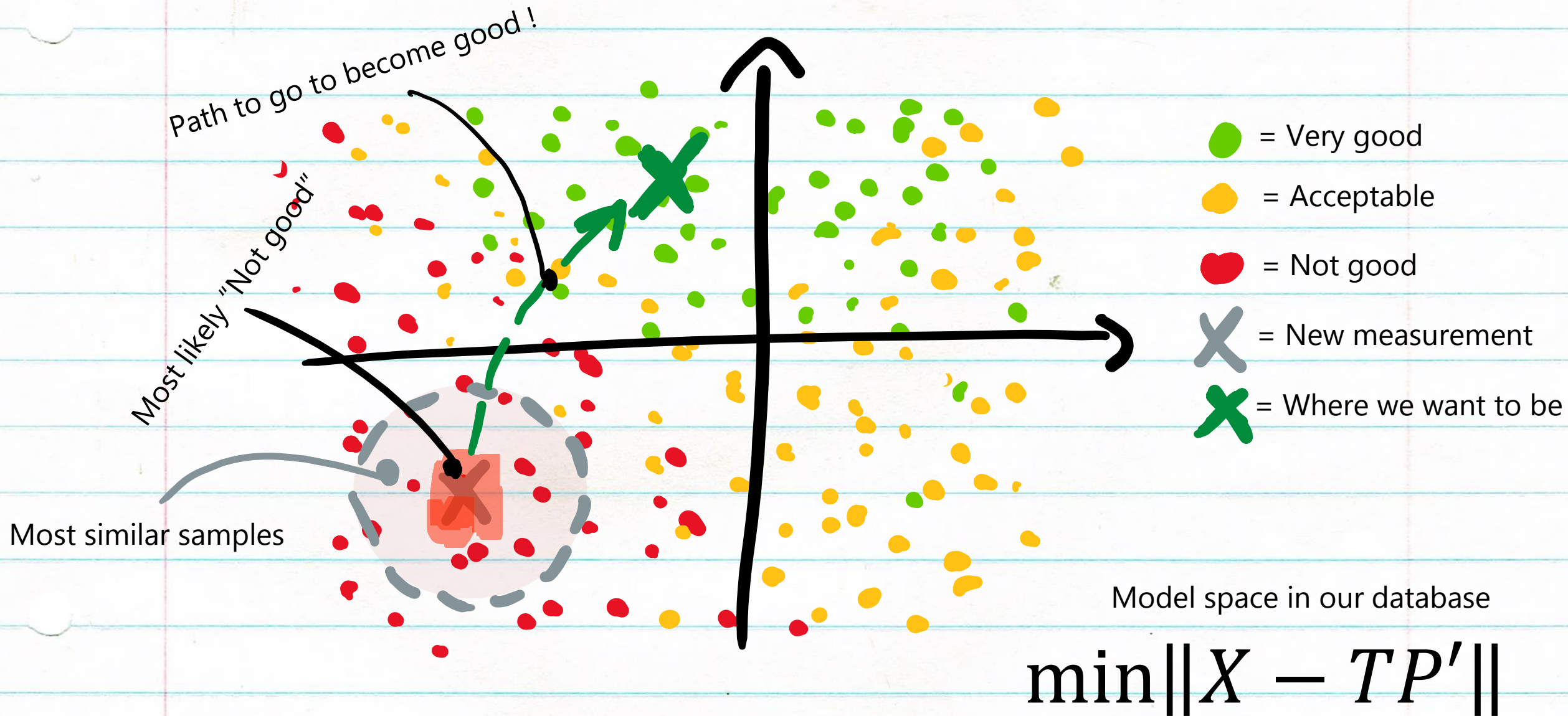
PAT control tools – it is complex even if it is simple !



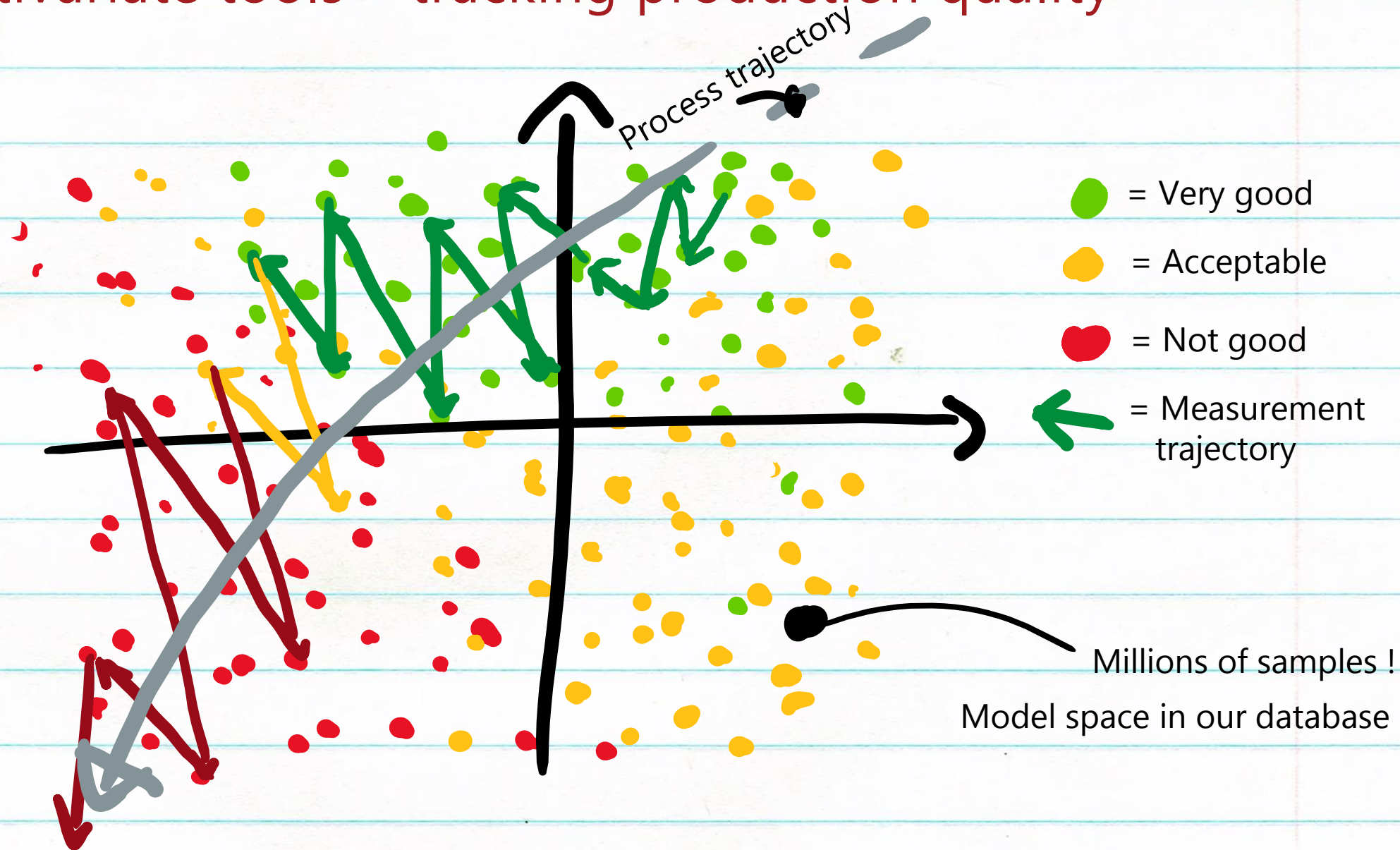
PAT control tools : frequency and understanding



PAT Multivariate tools – qualitative understanding

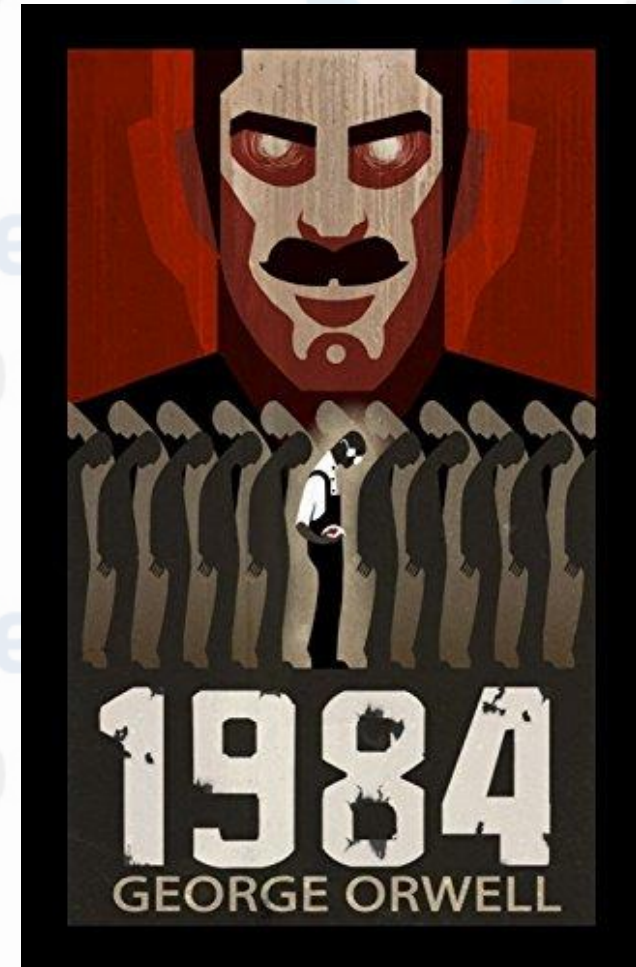


PAT Multivariate tools – tracking production quality

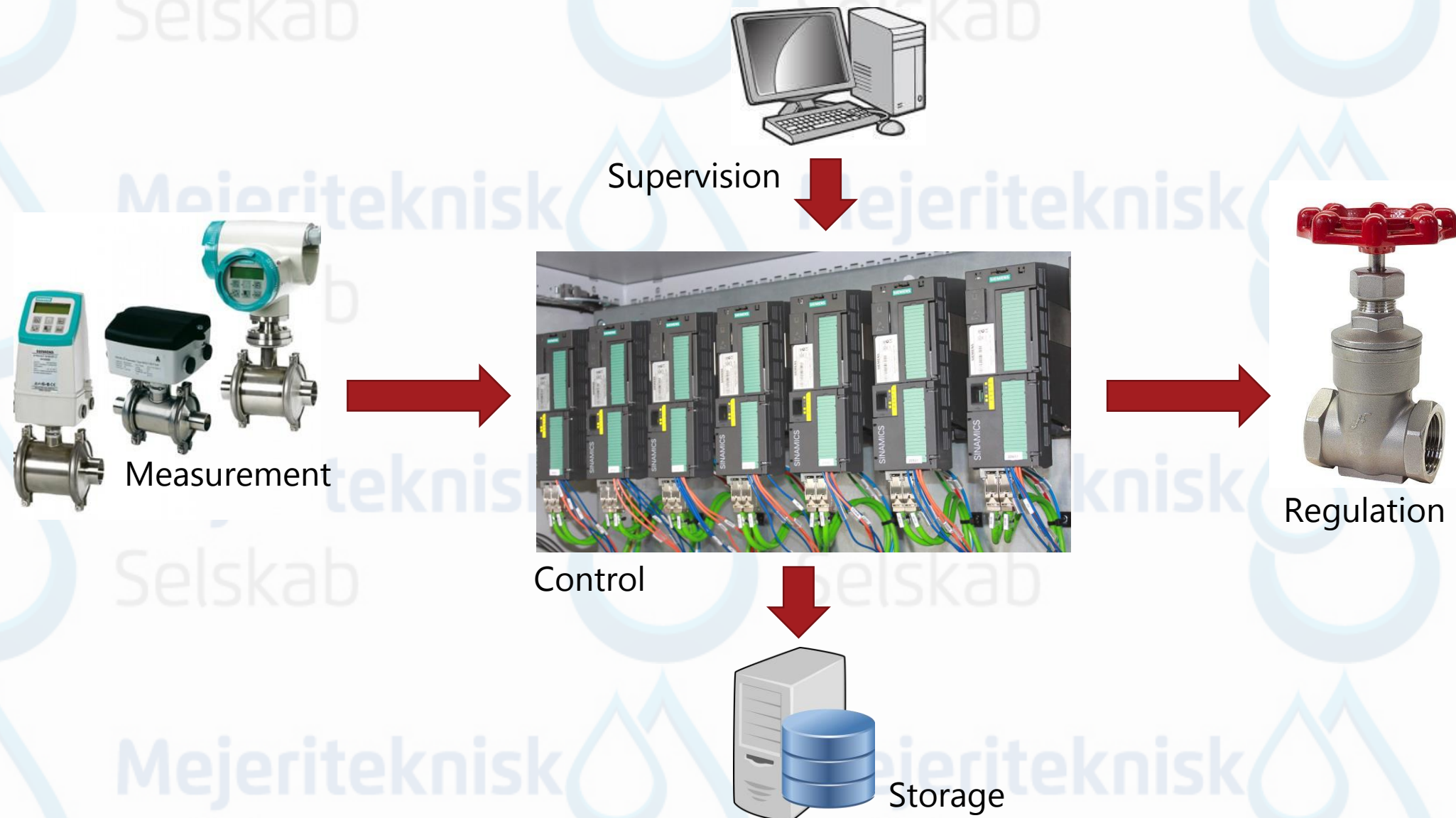


PAT knowledge management tools

- Continuous learning through data collection
- A knowledge base can be of most benefit when it consists of scientific understanding of the **relevant multifactorial relationships** (e.g., between formulation, process, and quality attributes) as well as a means to evaluate the applicability of this knowledge in different scenarios (i.e., generalization).

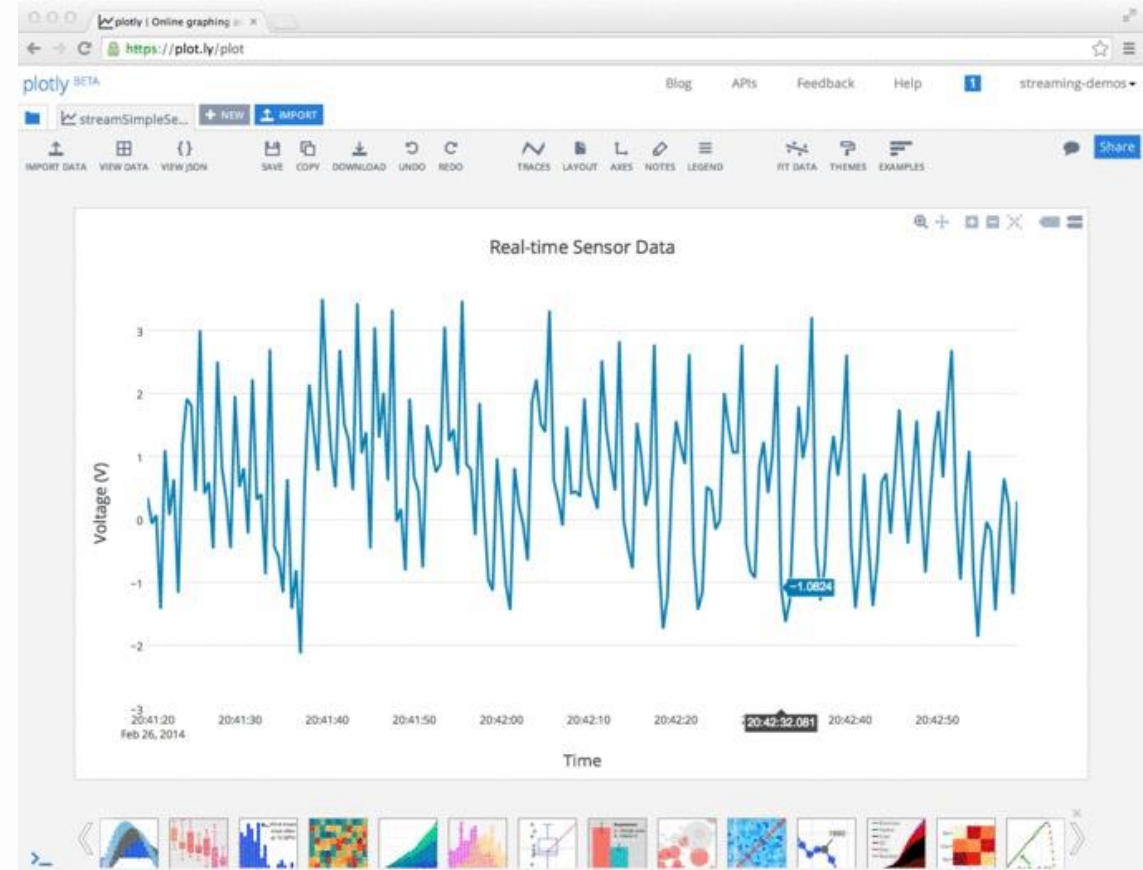


PAT knowledge management – SCADA and historic data

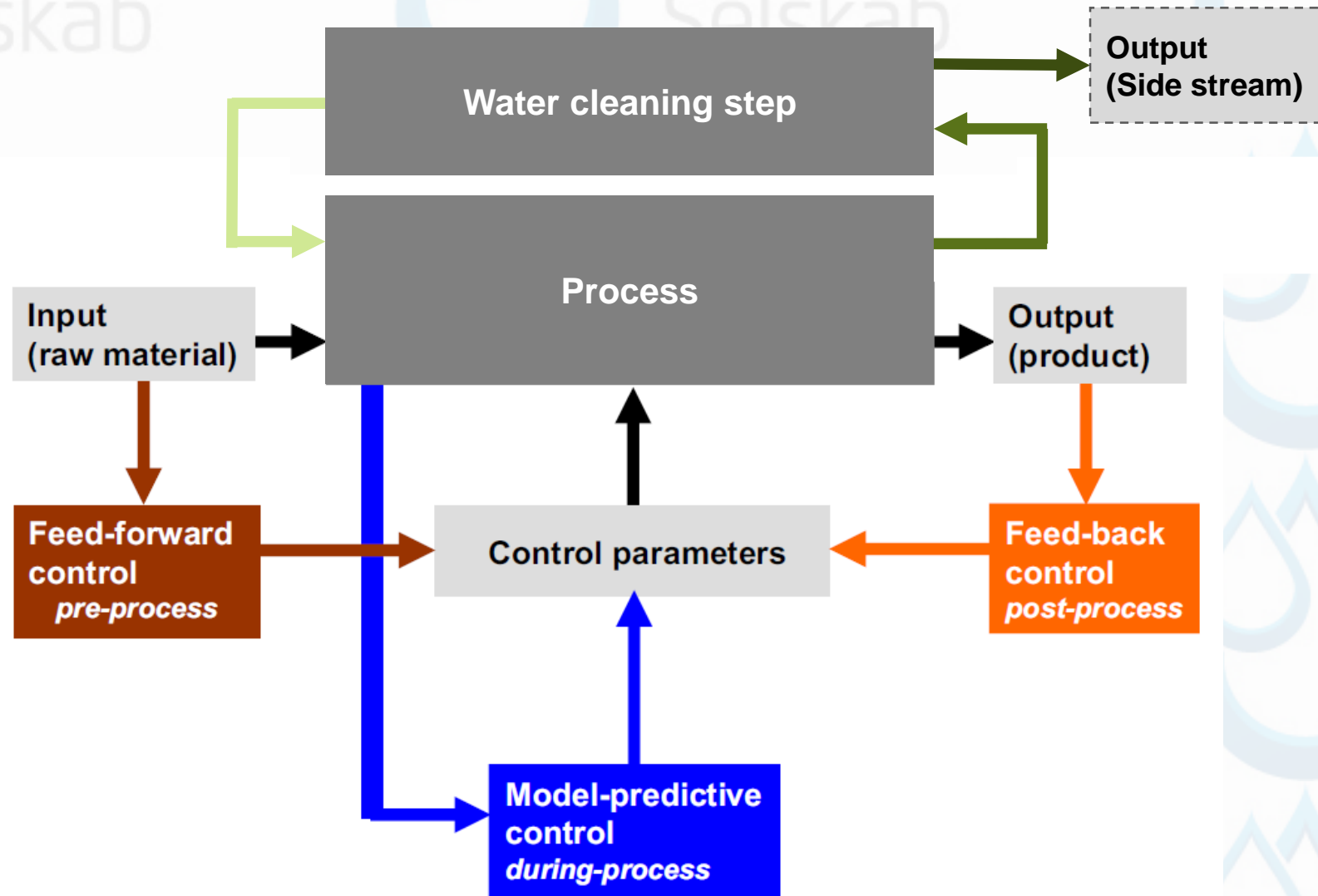


PAT knowledge management – SCADA and historic data

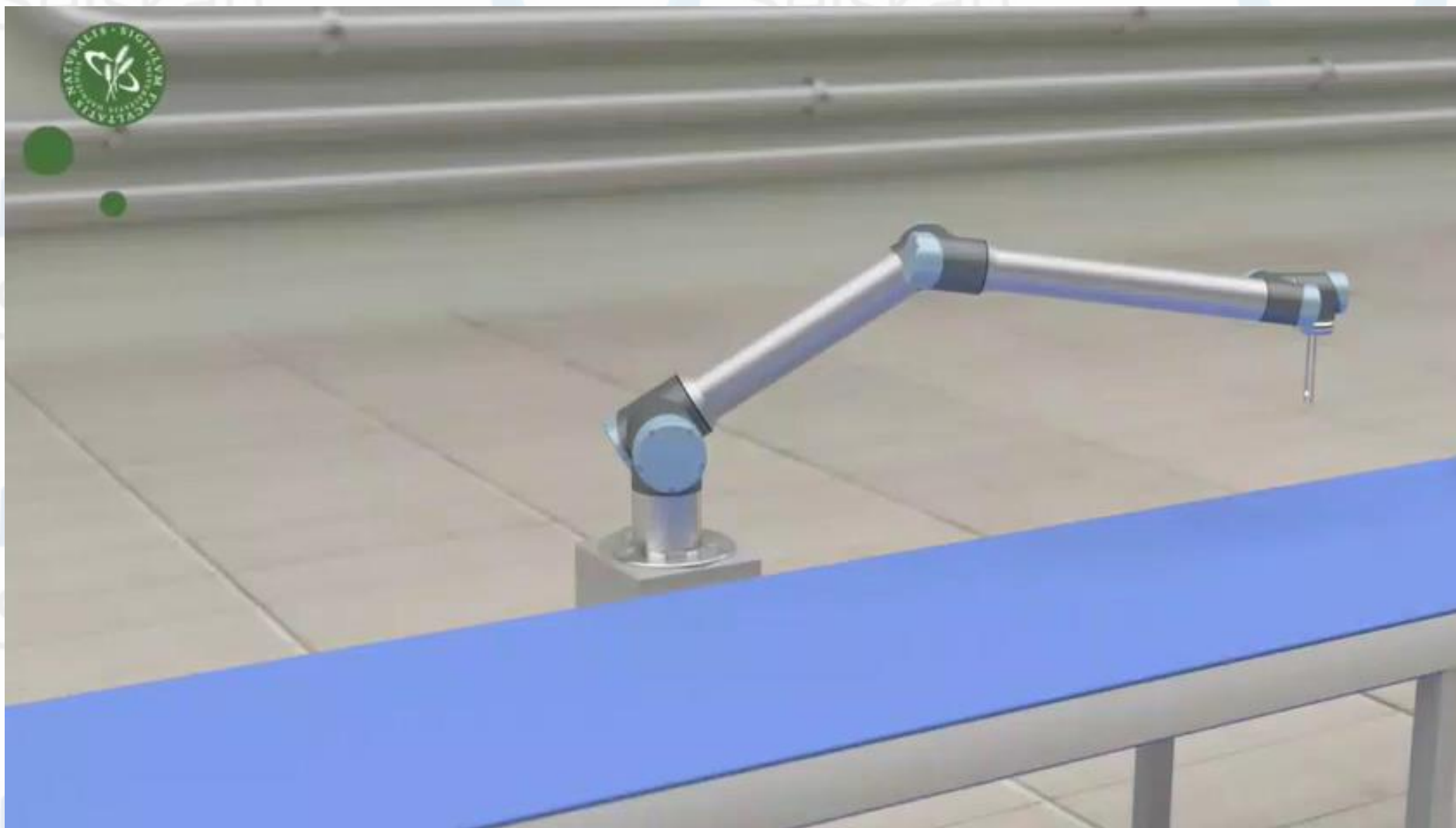
- Data needs to be available
- In most companies I visit, massive and multifactorial data extraction is surprisingly difficult
- Low data retention should be a pre-2019 problem
- We call them data graveyards!



Future PAT : An outlook



SayCheese: Automated on-line measurement of cheese



Mejeriteknisk
Selskab

“**Measurement** is the first step that leads to control and eventually to improvement. If you can't **measure** something, you can't understand it. If you can't understand it, you can't control it. If you can't control it, you can't improve it”

— **H. James Harrington**



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