

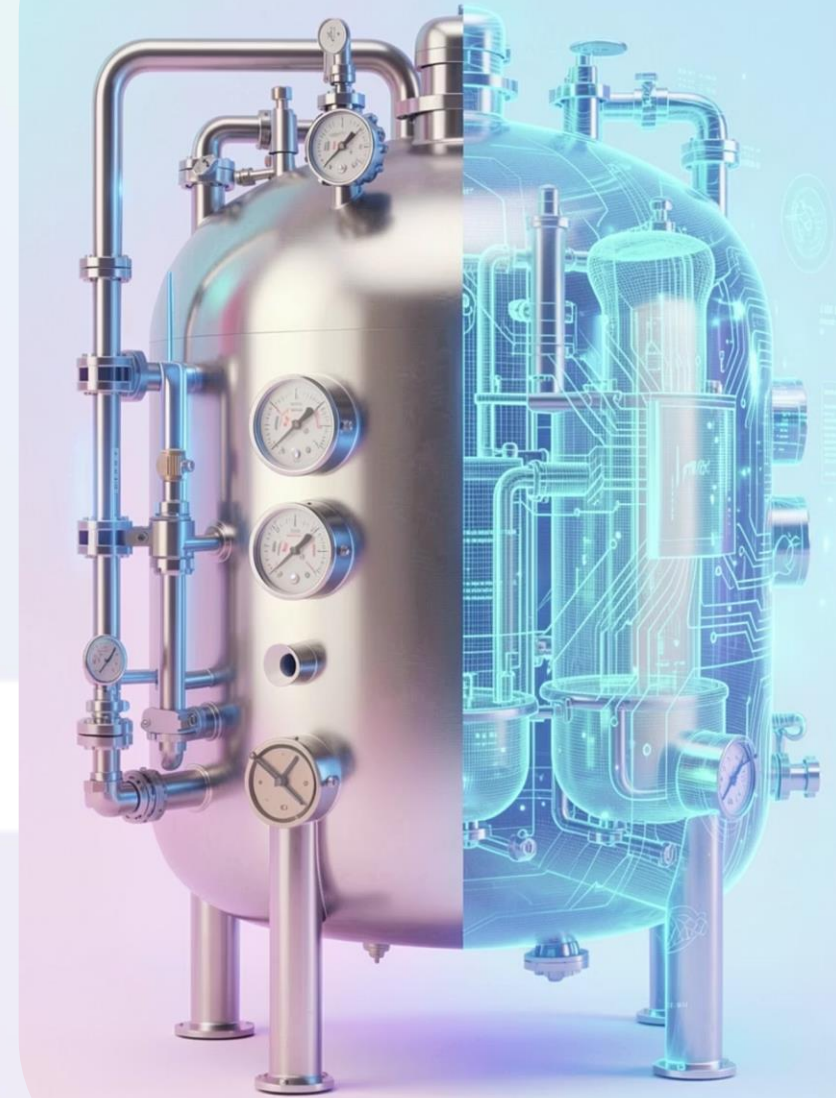
Digital Twins in Modern Fermentation

Integration of high-predictive models in Autonomous Fermentation

Yasmine JERAD
Business Developer - iMEAN

What is a Digital Twin ?

- **Virtual replica** of living biological systems inside a fermentor
- **Monitor** process parameters in real time
- **Predict** outcomes before they happen
- **Optimize** conditions continuously
- **Connect** online or control fermentors directly



Why Fermentation Development is Still Hard ?



CORE CHALLENGES



Biological Complexity



Non-linear System Behavior

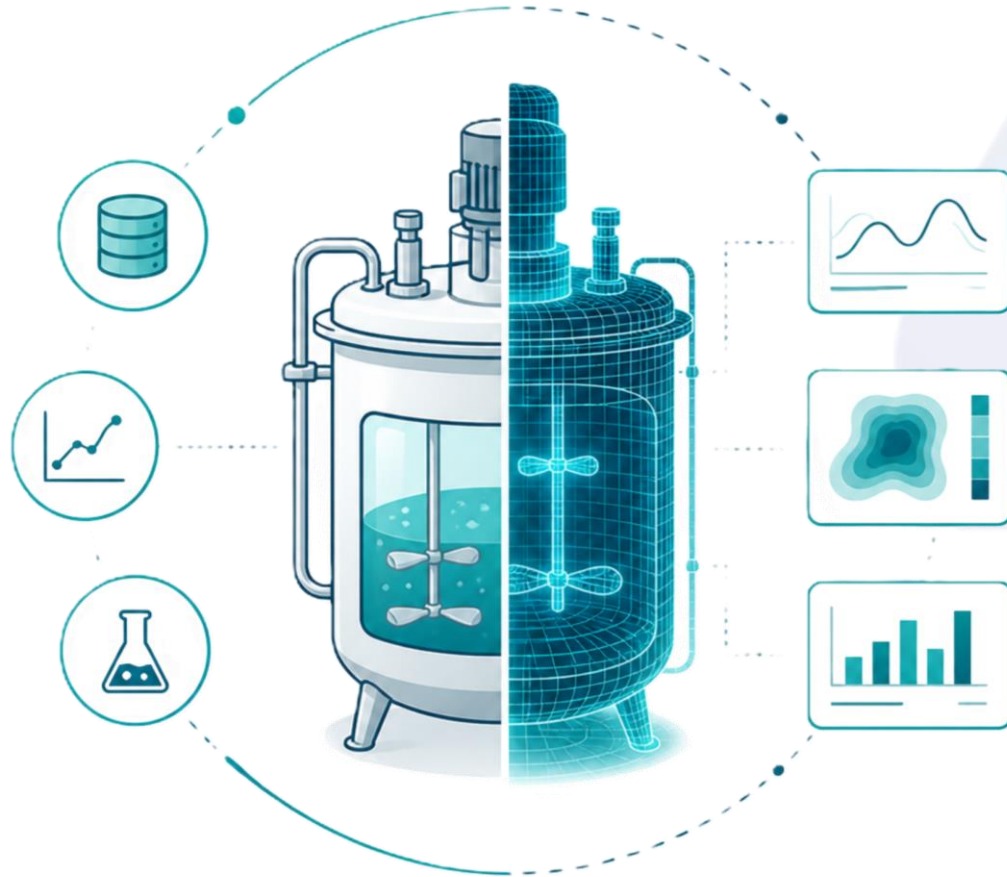


Scale-up Failures



**Trial-and-Error Cost &
Experimental Design Difficulty**

How Digital Twin Change the Game ?

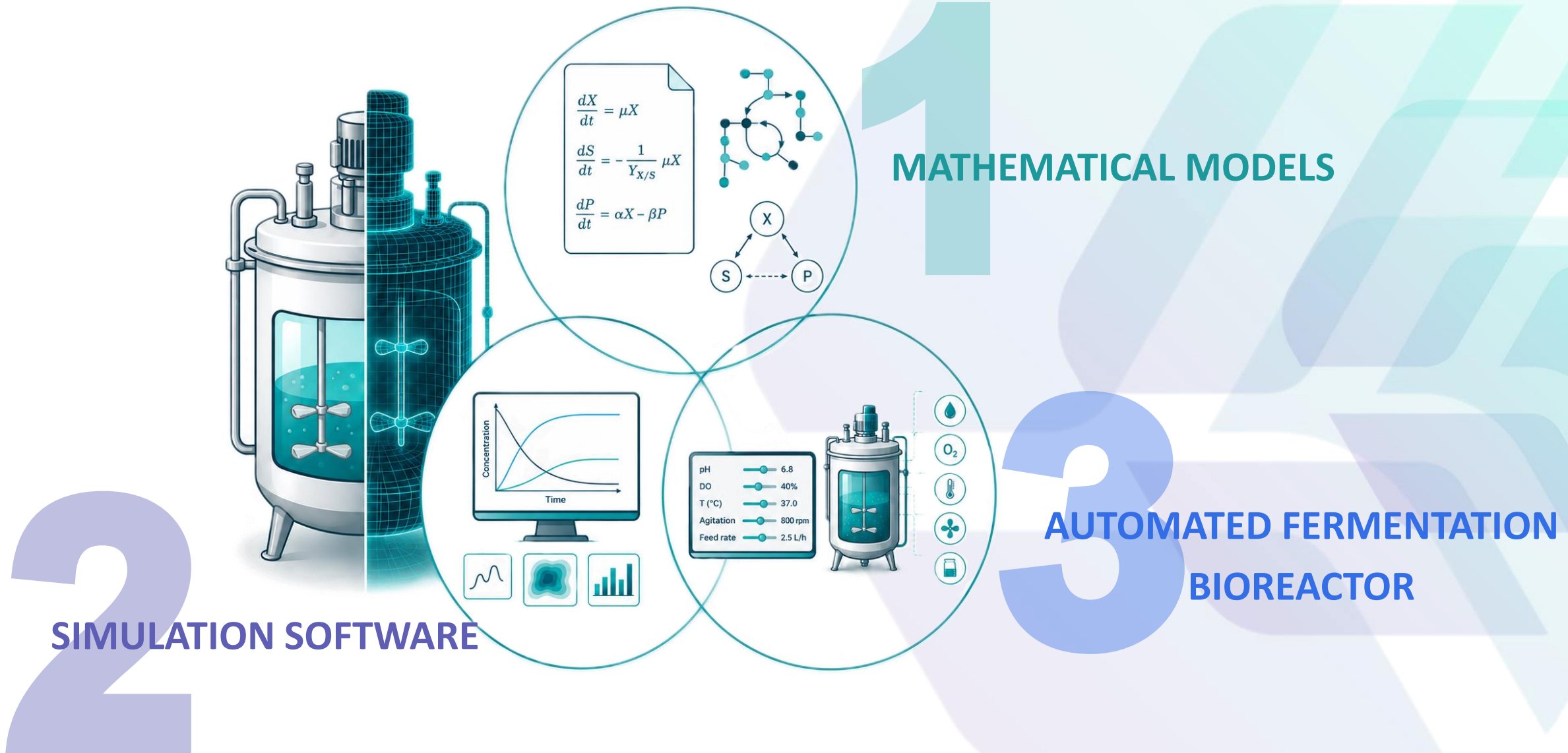


Scale-up Optimisation

**Enhanced predictability,
cutting failure rate by 75%**

Gain in R&D Costs & Time

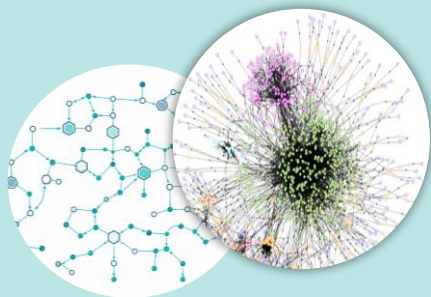
Digital Twin Workflow



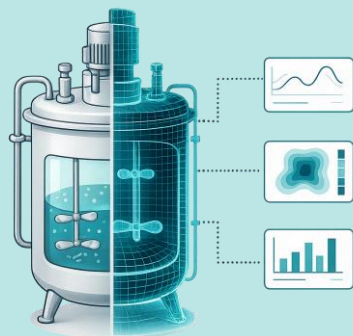
iMEAN × AlgoTech: Bridging Deep Biological Intelligence with Autonomous Bioreactor Infrastructure



1 Mathematical Models



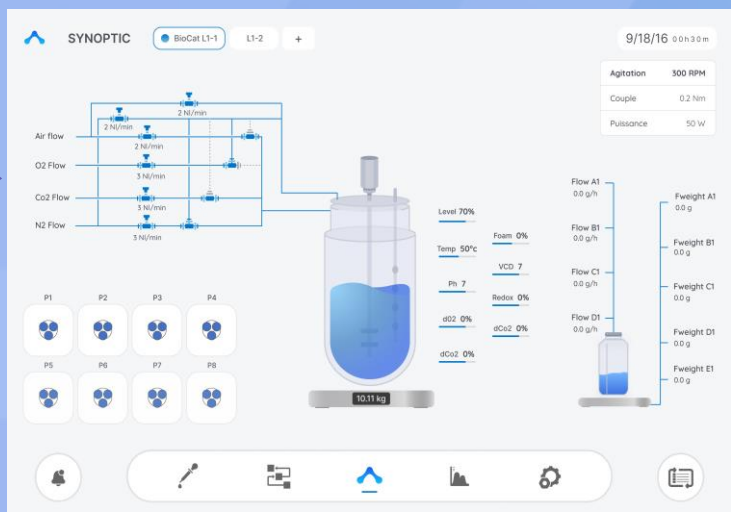
Digital Twin



2 Simulation Software



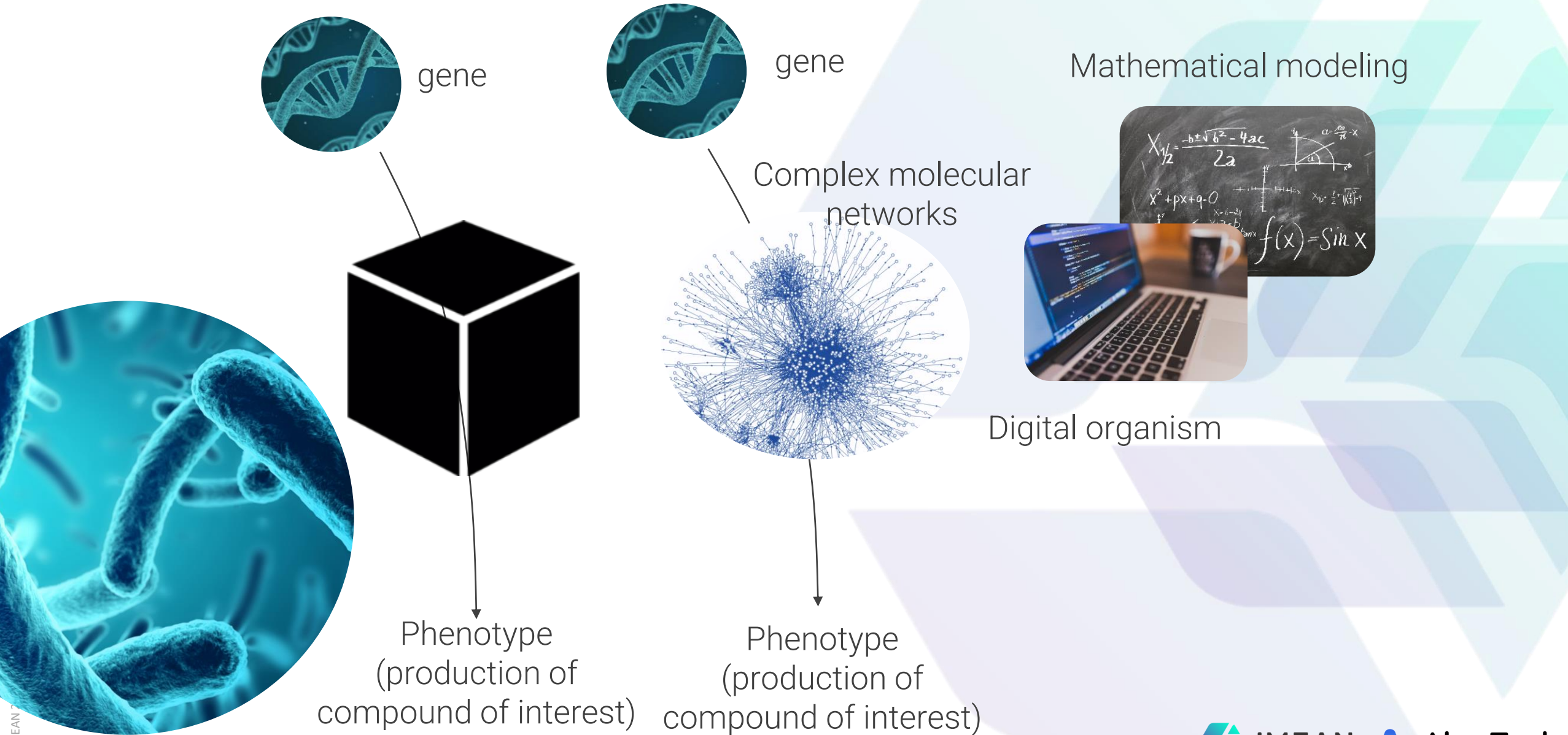
3 Automated Fermentation Bioreactor



Automated Monitoring, Control & Scale-Up production machine & compute capacity

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Digital Twin & Mathematical modelling

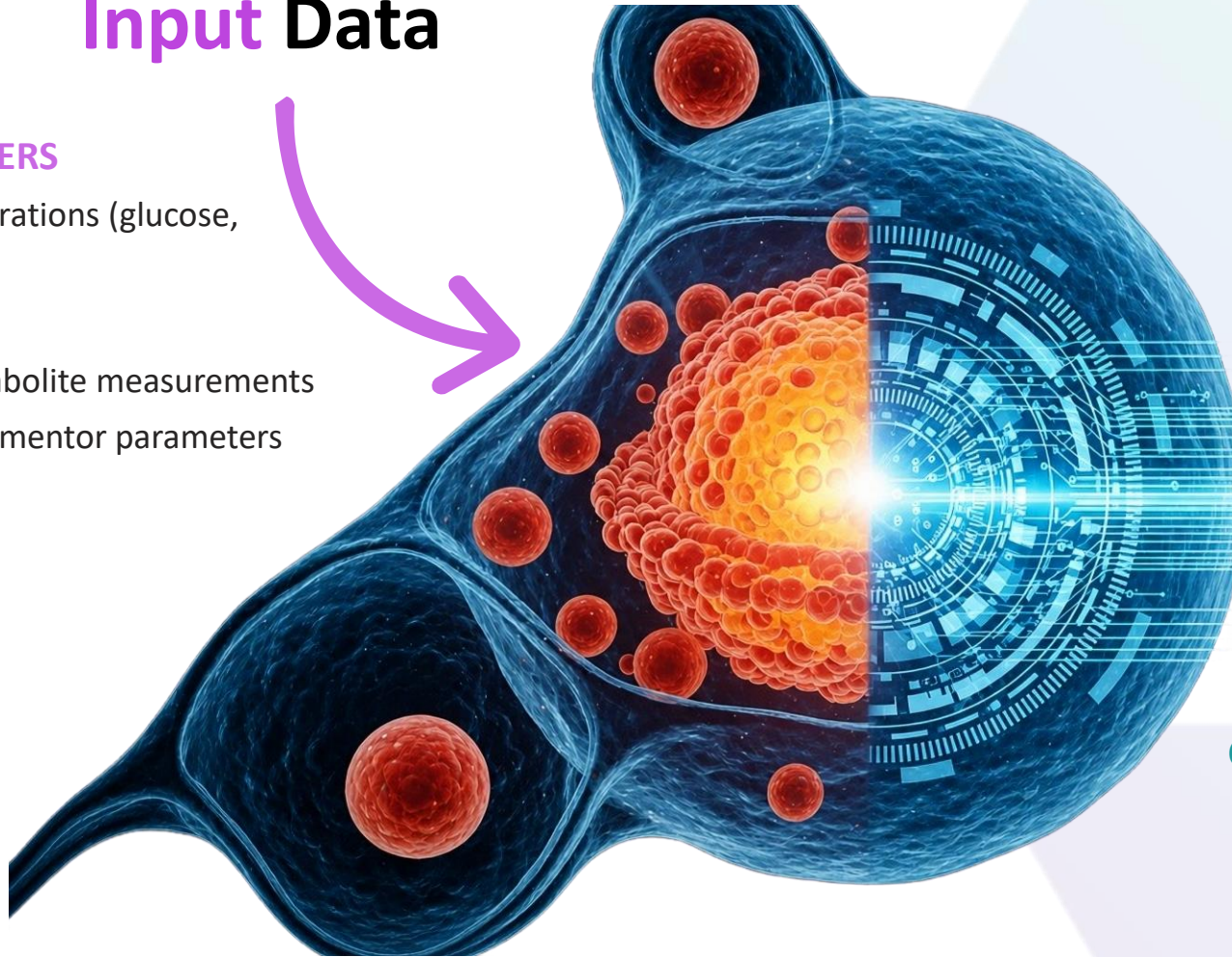


Digital Twin & Mathematical modelling

Input Data

PROCESS PARAMETERS

- Substrate concentrations (glucose, nitrogen, oxygen)
- pH, temperature,
- Biomass and metabolite measurements
- Feed rates and fermentor parameters



Output Data

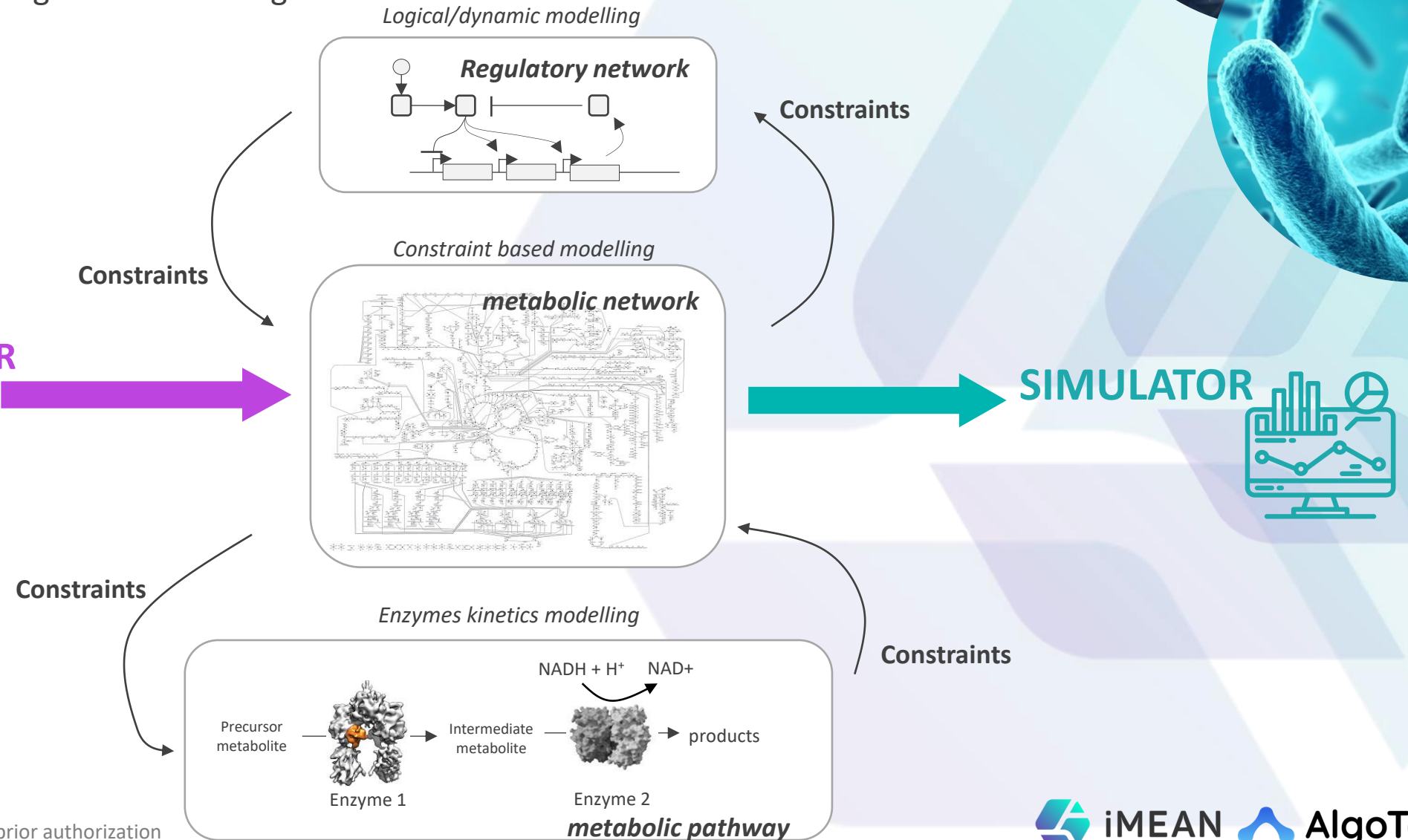
CELLULAR PERFORMANCE

- Predicted growth rate and productivity
- Production flux of molecule of interest
- Optimal feed and control strategies

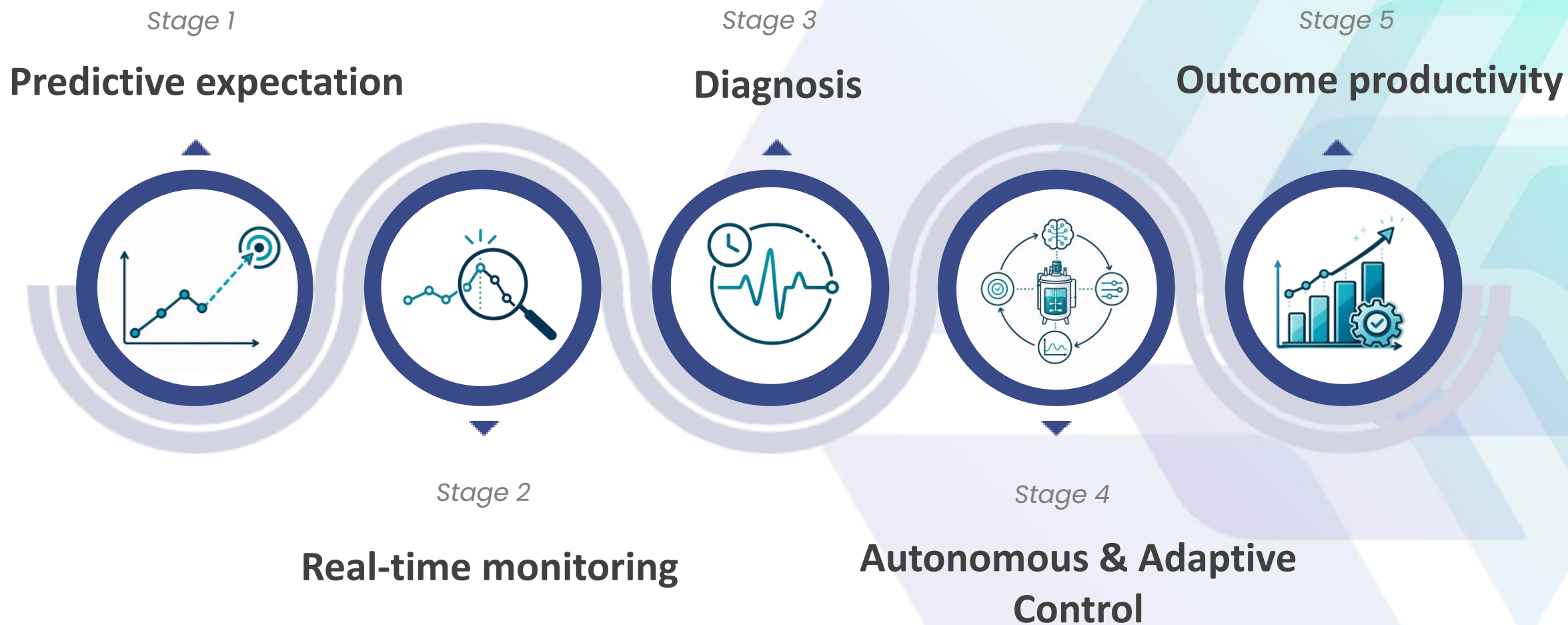
Digital Twin & Mathematical modelling

Complex living organism modelling

MEDIUM FERMENTOR
SPECIFICITIES



From Monitoring to Self-Driving Bioprocesses





CASE STUDY – Pharma Protein Production



Yeast

Strain mathematical models

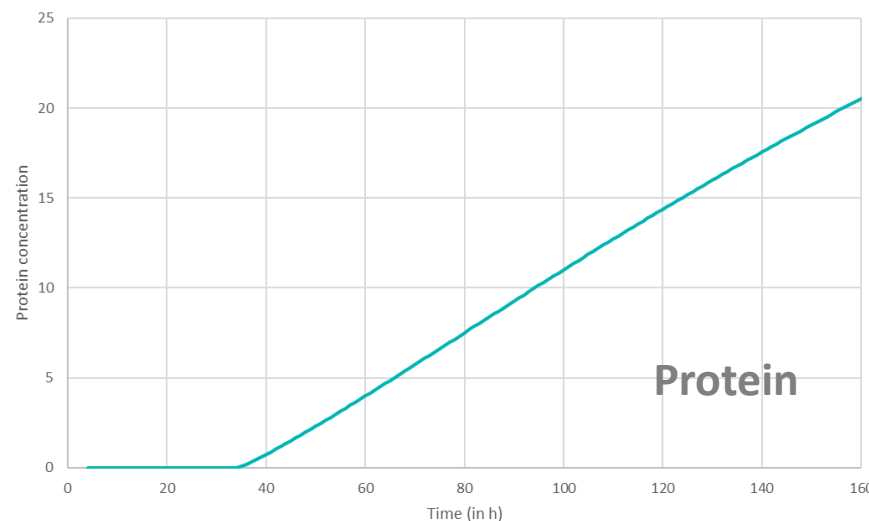
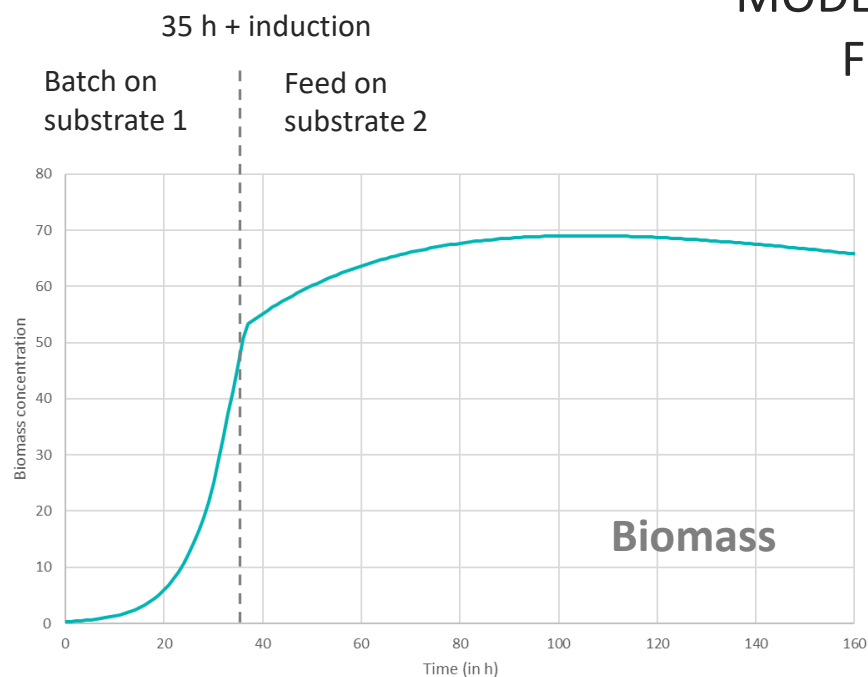
- Genome-scale metabolic model
- Cellular burden module
- Protein production and secretion machinery



Process parameters

- Feed-batch

MODEL PREDICTION OF EXPECTED FERMENTATION PROFILE



Expected Titer
21



Expected Productivity
0,13/h

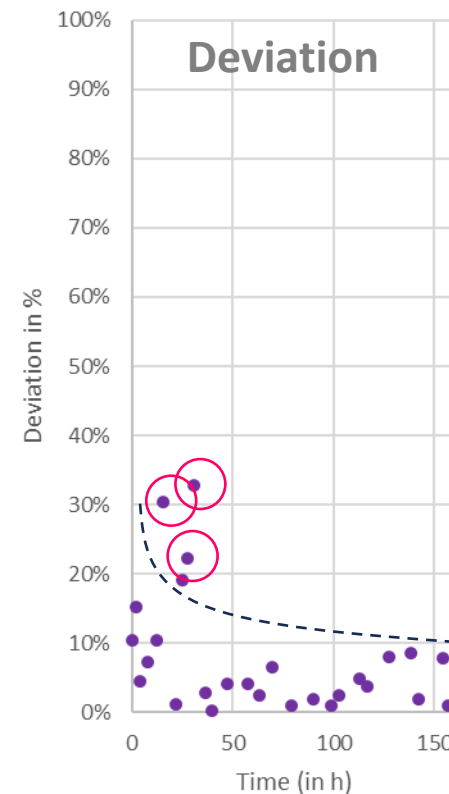
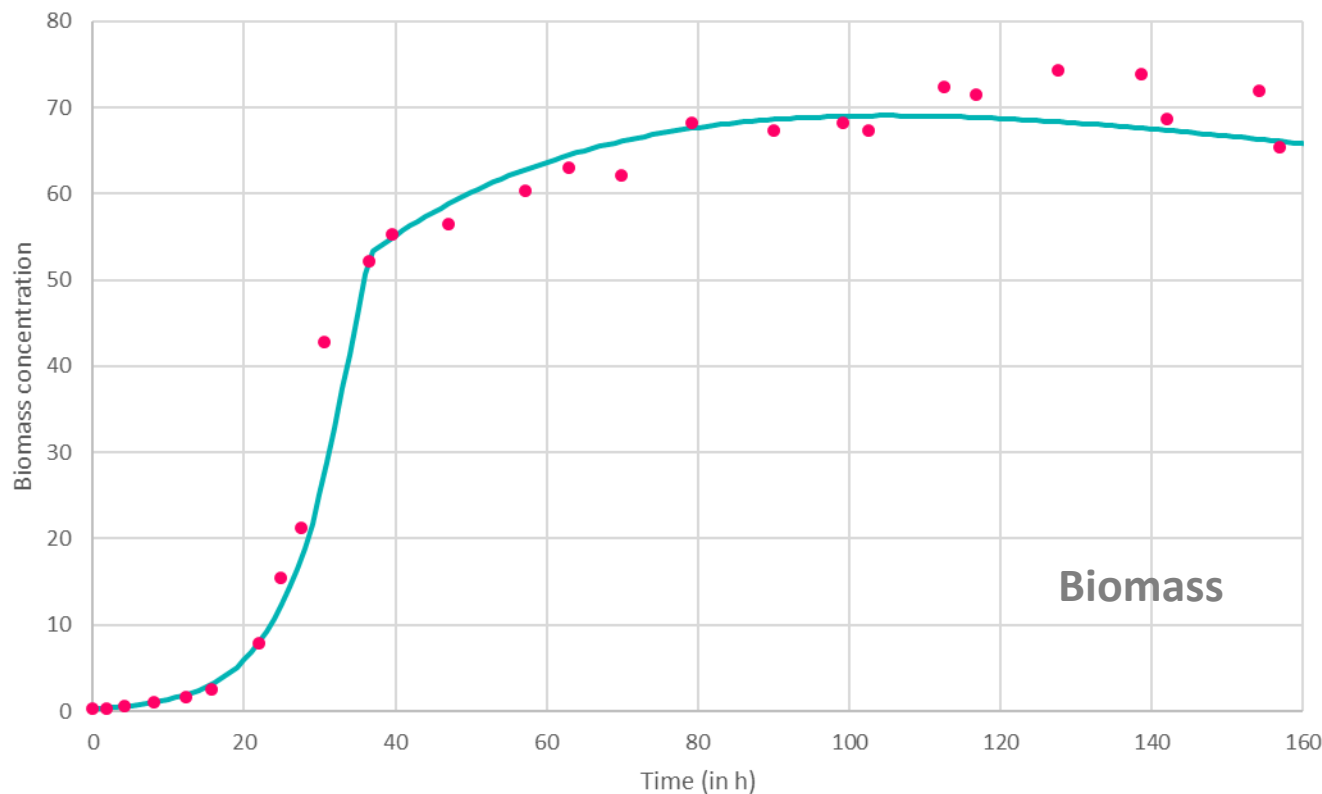


CASE STUDY – Pharma Protein Production



Run Fermentation

- Experimental data collection



Accuracy
(1/Mean Absolute
Percentage Error)

92%

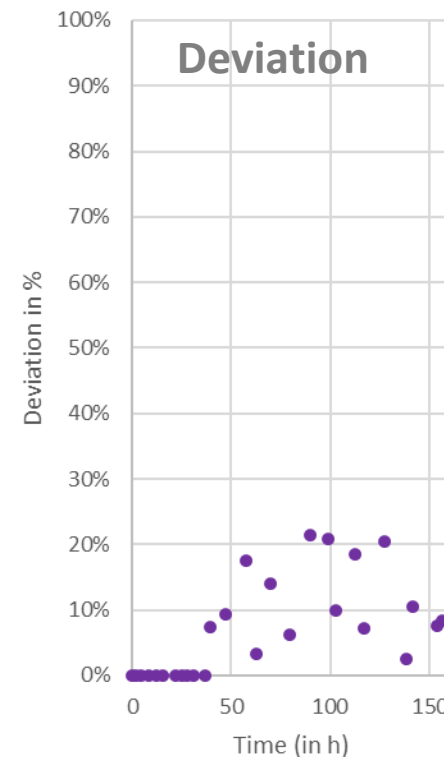
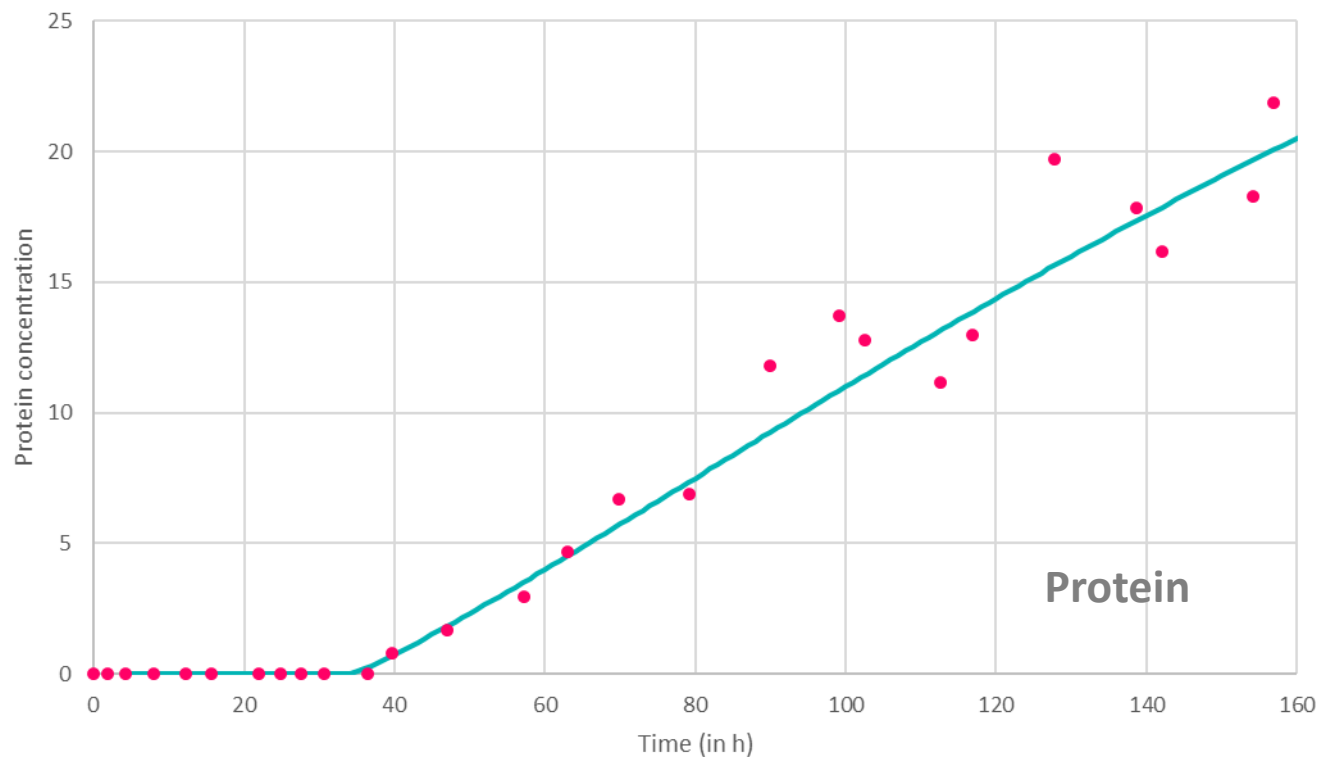


CASE STUDY – Pharma Protein Production



Run Fermentation

- Experimental data collection



Accuracy
(1/Mean Absolute
Percentage Error)
93%



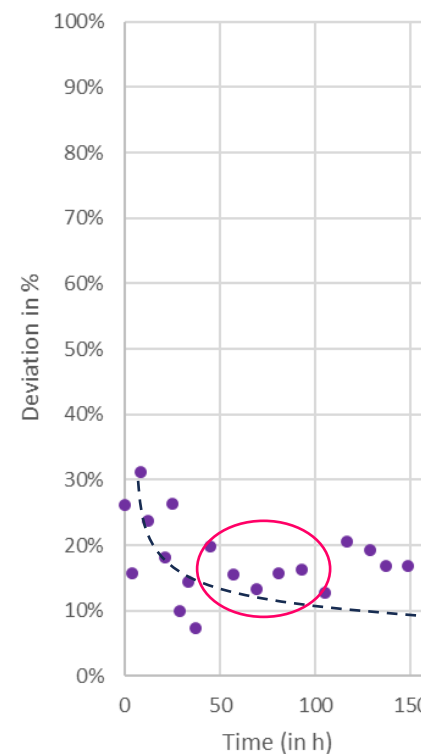
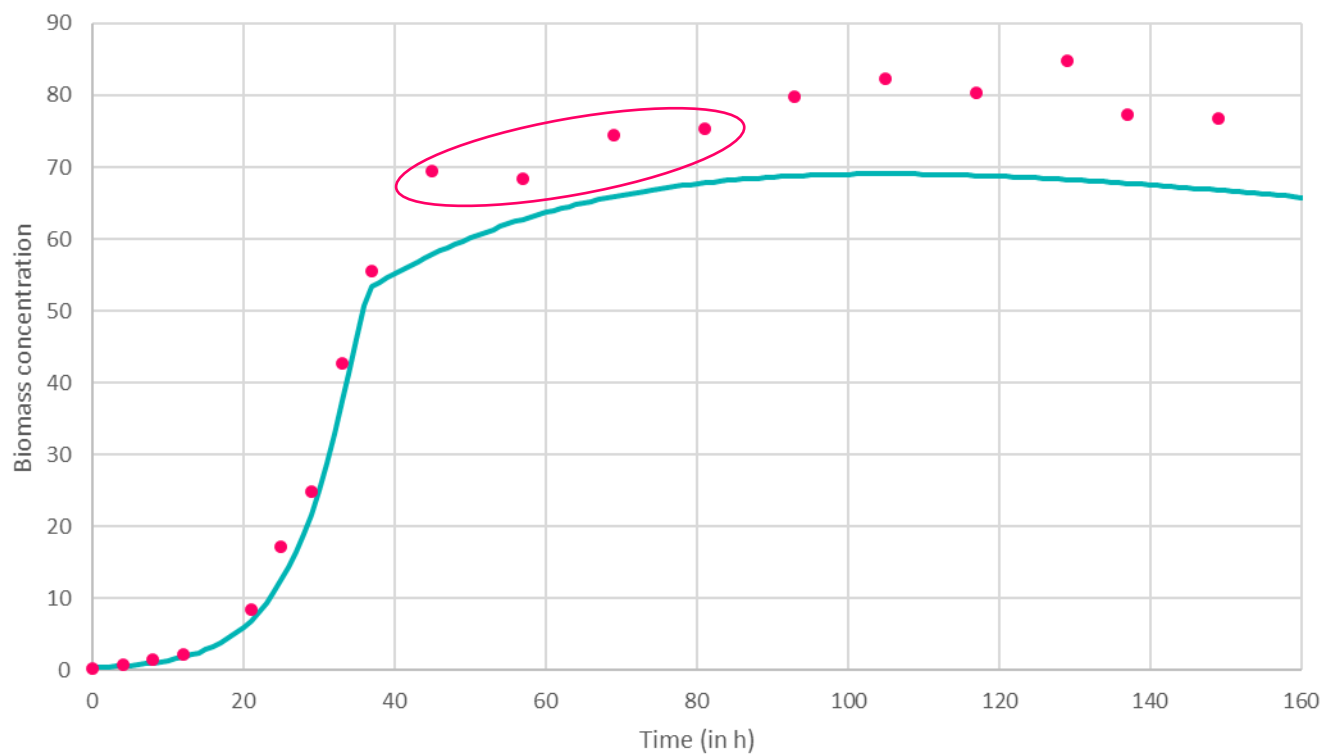
CASE STUDY – Pharma Protein Production



Run Fermentation

- Experimental data collection

NEW BATCH



Consistent too high
biomass detected

since 43 h

Threshold of
warning



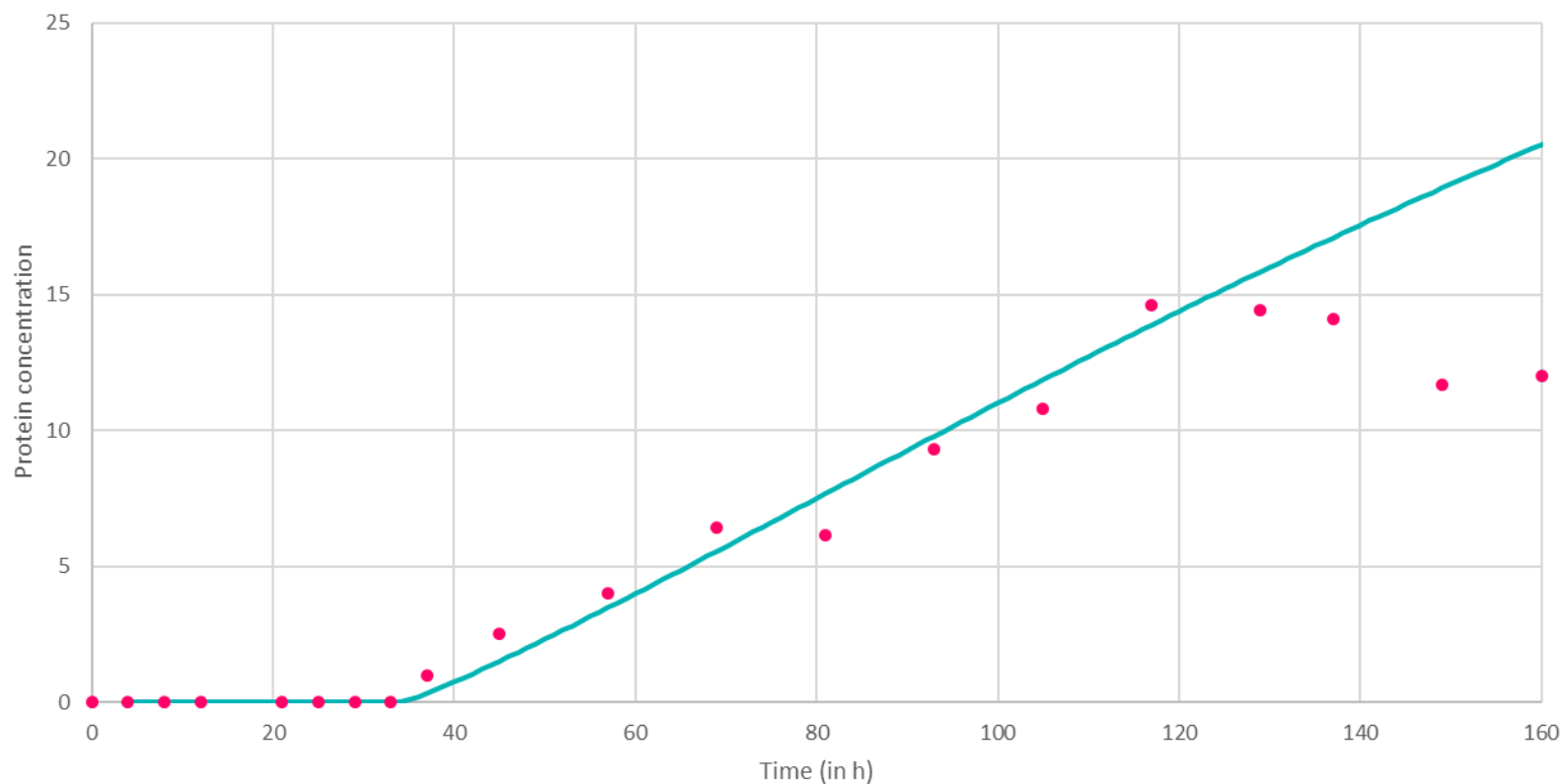
CASE STUDY – Pharma Protein Production



Run Fermentation

- Experimental data collection

NEW BATCH DATA



Consequences

Loss of production

38%

Seen at 120h



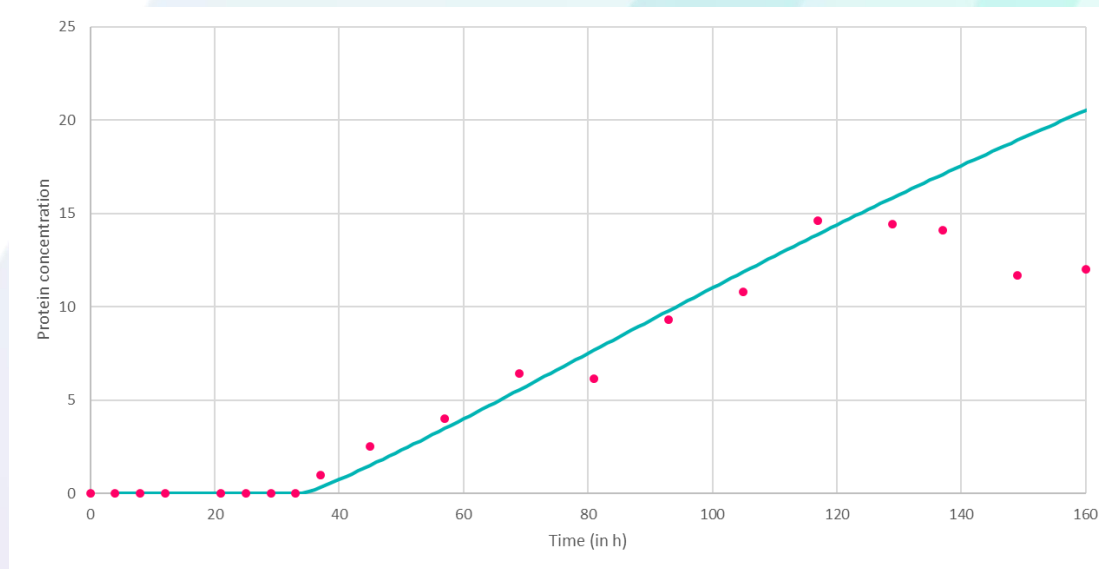
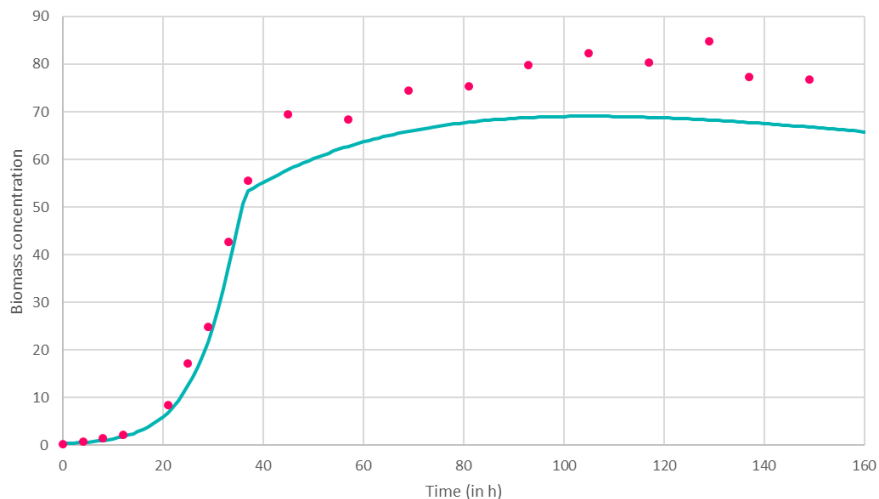
iMEAN



AlgoTech



CASE STUDY – Pharma Protein Production



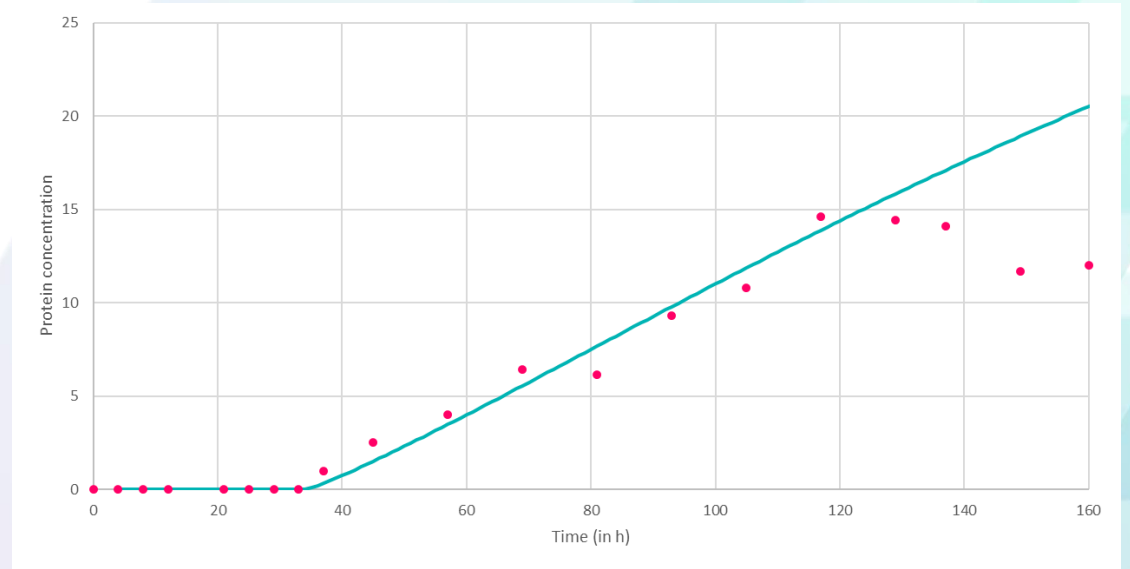
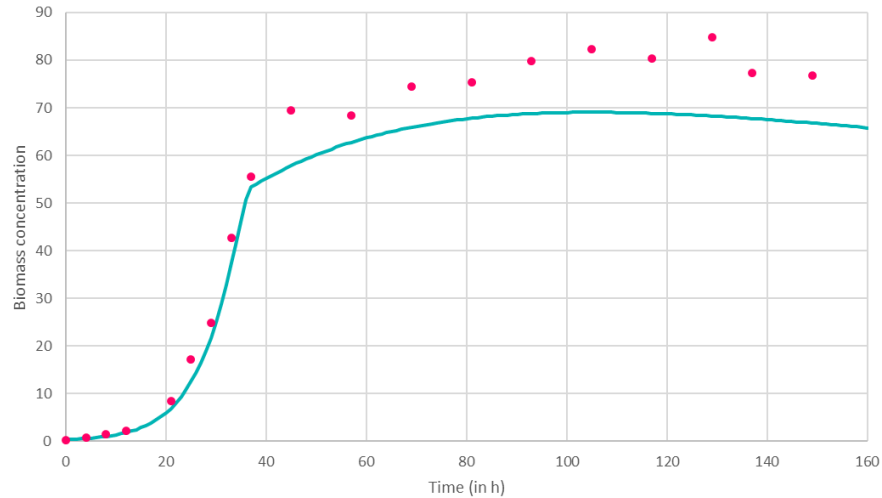
OPERA

Generation of hypothesis

Validated hypothesis : Cell population with loss of function (mutation) in the production of the protein of interest



CASE STUDY – Pharma Protein Production



OPERA

Gain & Recommendations :

- Real-time analysis of the problem
- Leads to stabilize protein expression
- Possibility of earlier harvest



Harvest time reduce by half
Immediate resolution

Why iMEAN's Digital Twins & AlgoTech Changes the Game ?



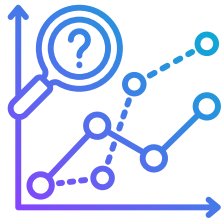
3×

R&D Cost Reduction



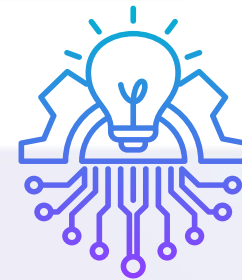
32%

Derisk



6M

Solutions Explored

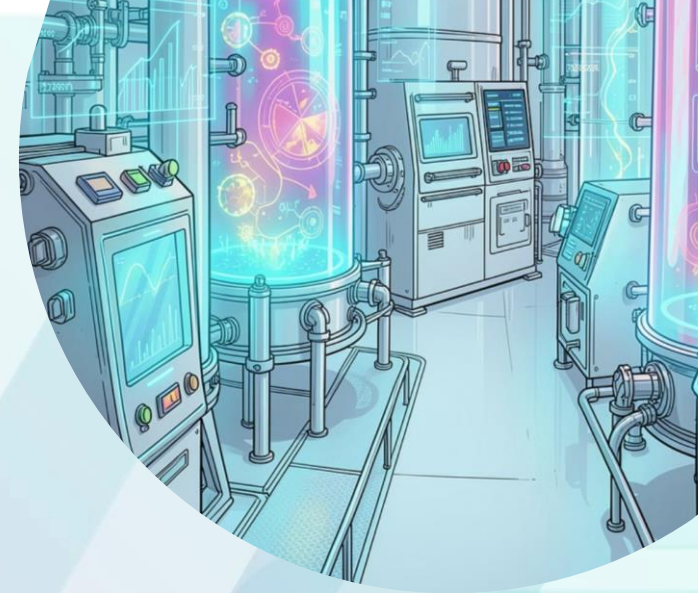


>90%

Prediction Accuracy

KEY TAKEAWAY

- ❖ **Digital Twins Are Validated & Ready for Industrial Fermentation**
- ❖ **Main value delivered from experiences to maintain process robustness**



Thank you for your time and attention !

Contact information



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