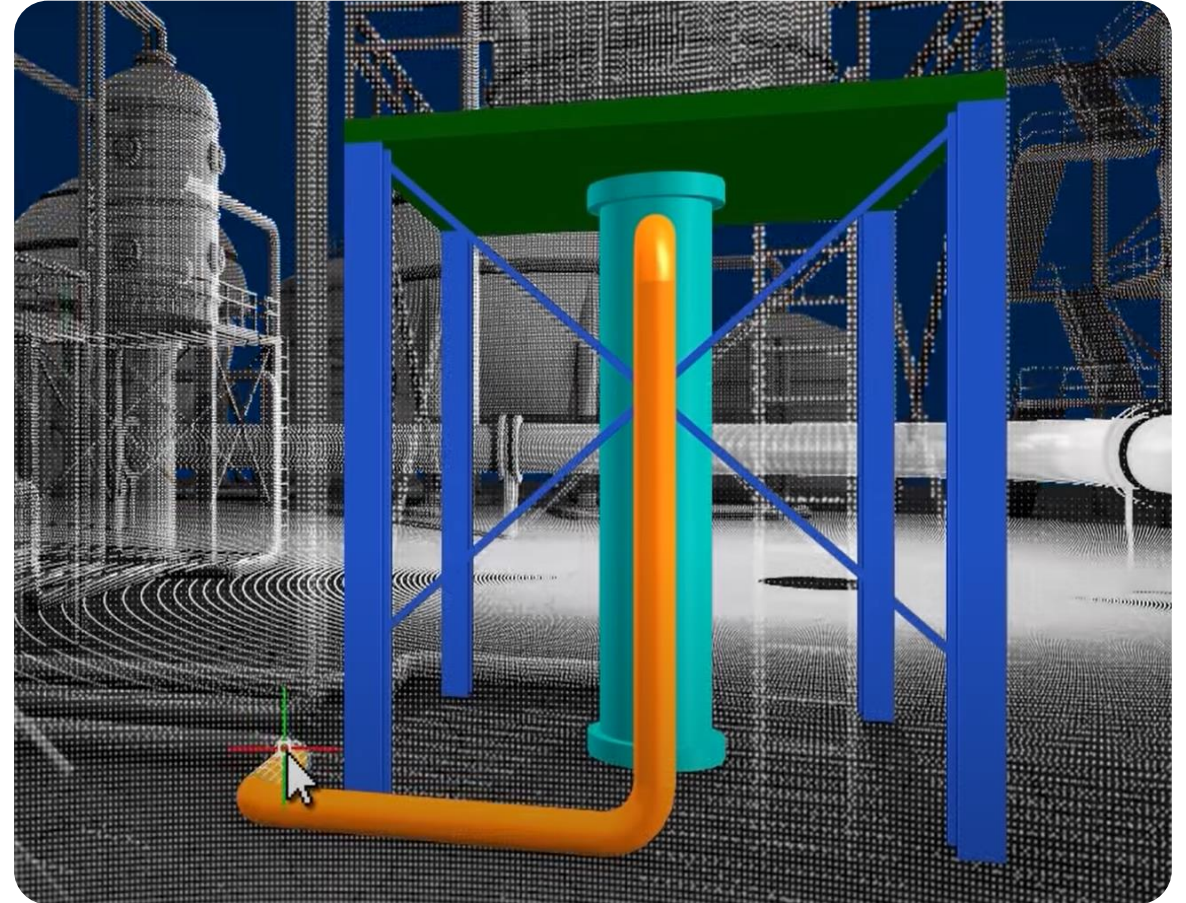


# Analyzing the Impact of Laser Scanner Parameters on AI Model Performance for Recognizing Objects

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# 3D Object Recognition in Point Clouds

- Digital Twin 3D representations are usually crafted from point clouds.
- Scan-to-BIM process remains
  - manual,
  - labor-intensive,
  - prone to errors,
  - and incurs significant costs due to the need for specialized labor.
- Recent approaches have been taking advantage of Deep Learning algorithms for automatic segmentation of point clouds.



Source: AVEVA LFM

# Goal

A comprehensive Design of Experiment (DoE) to systematically analyze the effects of laser scanner parameters on AI model performance, while assessing the cost-benefit of setting the best possible scanning parameters.



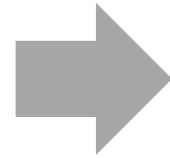
# DoE: factors and response variables

Factors:

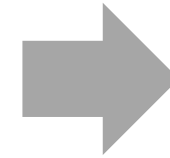
*Scanning  
parameters*

**X**

- Resolution
- Scan quality
- Scanner positions



**DoE**  
 $f(x)$



Response variables:

*AI model performance  
metrics*

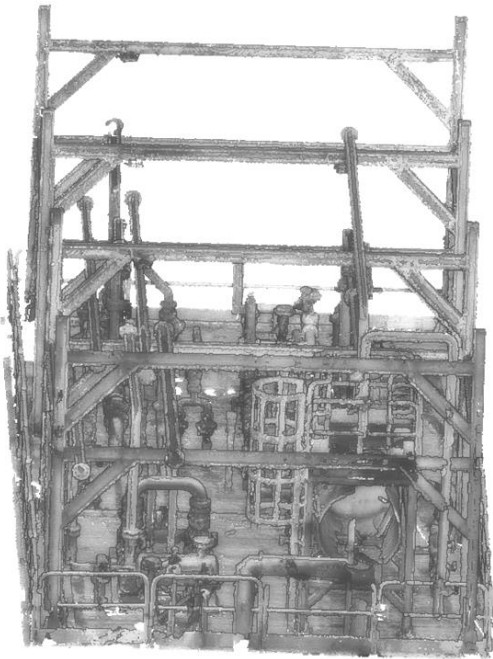
**Y**

- mIoU
- F-Score
- Recall
- Precision
- Time

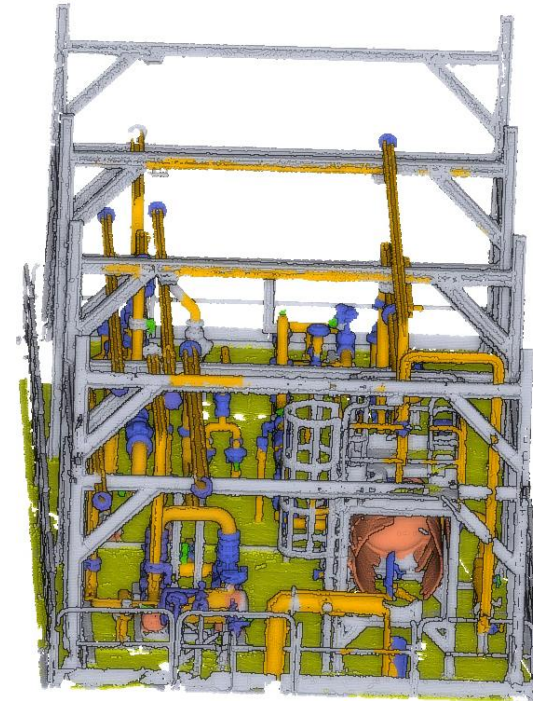


# AI performance: 3D instance segmentation in Point Clouds

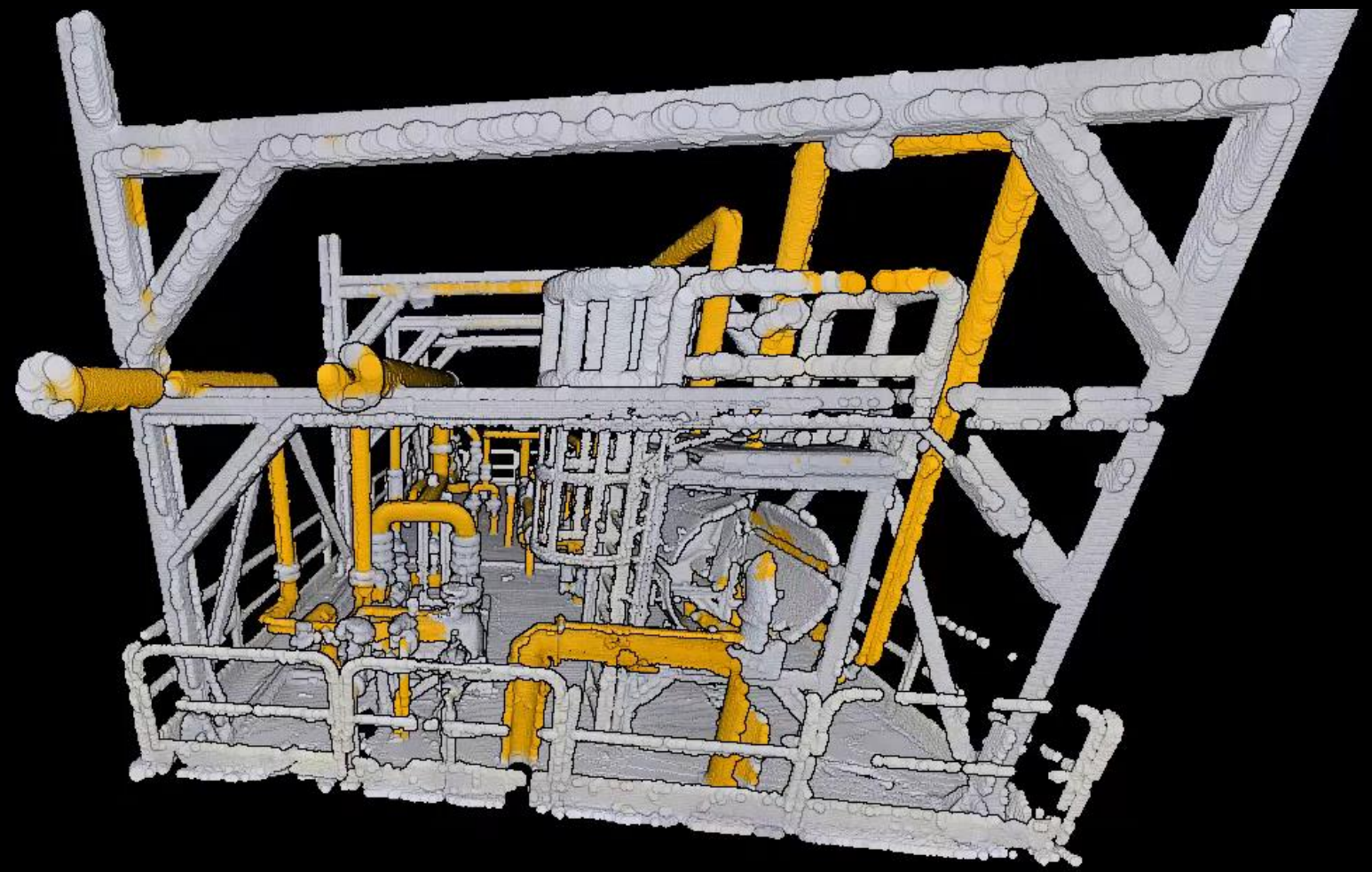
3D Point Cloud acquired in the Oil & Gas domain



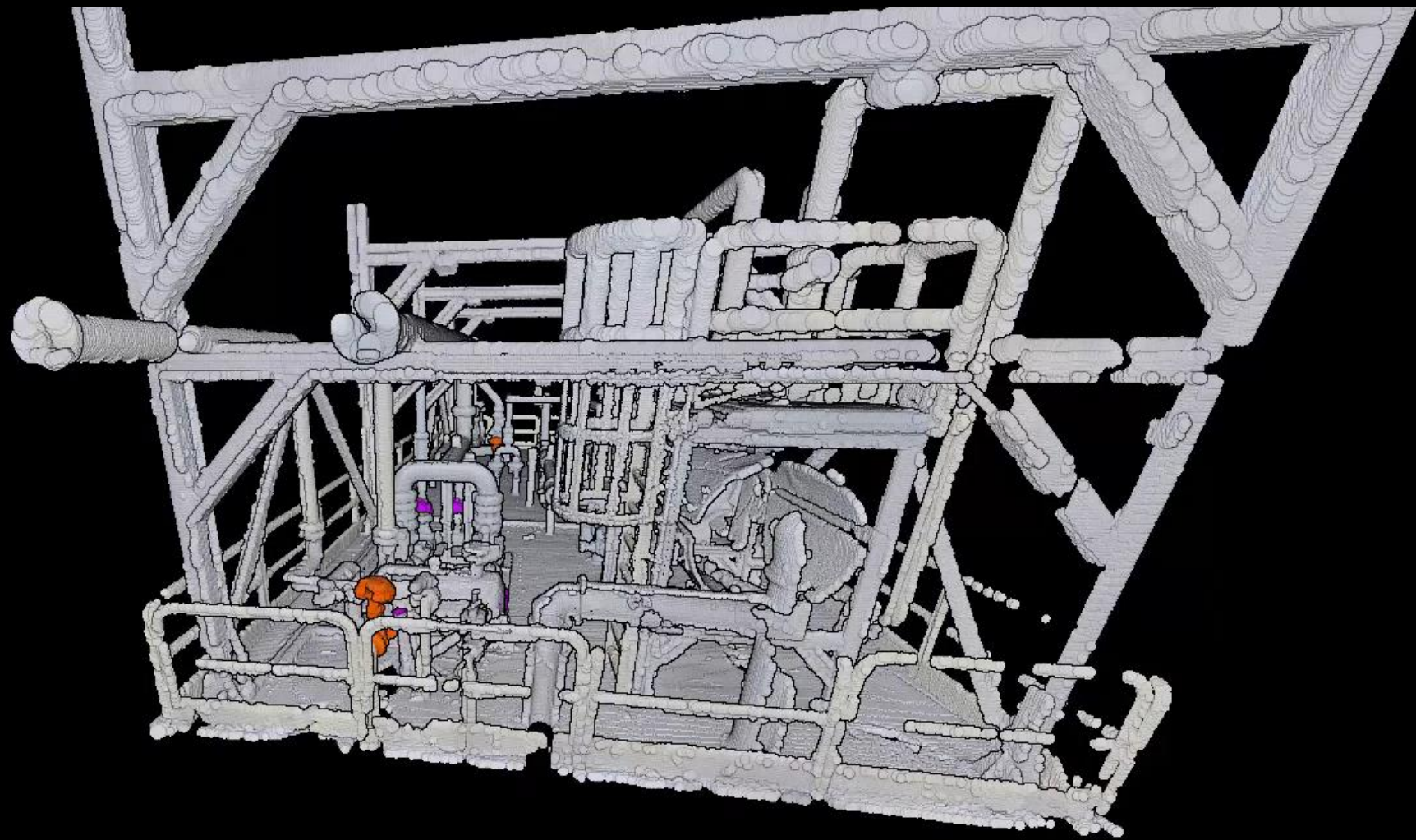
AI-based 3D Point Cloud Components Recognition



- Planar surface
- Pipe-like geometry
- Large equipments
- Structural
- Small sized components and measurement
- Medium size components



Pipes



Control valves | Motors

# DoE: factors levels and response variables weights

Factors	Levels	Values
Resolution	3	1/2, 1/8 & 1/16
Scan quality	2	3X & 4X
Number of scanning positions	5	1,2,3,5 & 9

Response variables	Goal	Weight
mIoU	Maximize	1
F-Score	Maximize	1
Recall	Maximize	1
Precision	Maximize	1
Time	Minimize	1

*Check how individual factors or their interaction...*



*Influence to the response variables and how we can optimize them.*



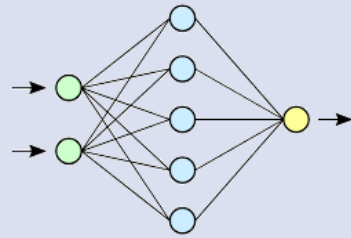
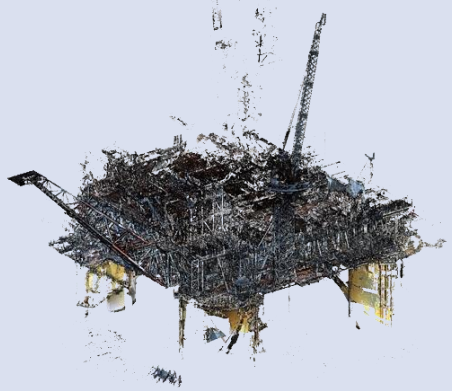


## The experiment

## Oil & Gas Platform



Training dataset



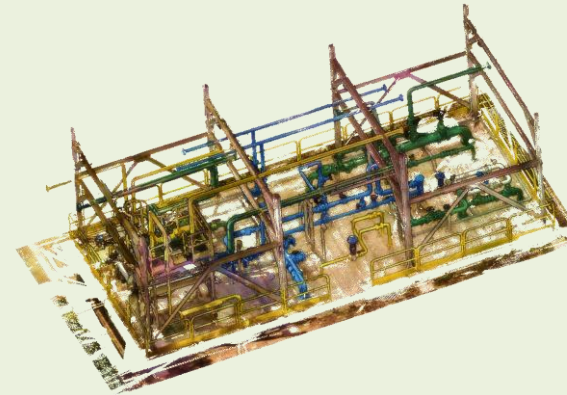
**Fixed Scanning  
Parameters Values**  
(limited conclusions)

**AI Model  
Training**  
SoftGroup for 3D Instance  
Segmentation on Point Clouds

## Oil & Gas Mockup



Test dataset



**Multiple Scanning  
Parameters Values**  
(DoE Factors Levels)

Best combination of  
*testing* scanning  
parameter values

**DoE output**

# Oil & Gas Mockup

- Goal
  - Scanning parameters to ensure object recognition in 3D point clouds
- Specification
  - 1:1 scale
  - 5m x 7,5m x 15m (H x W x L)
  - ~25 tons



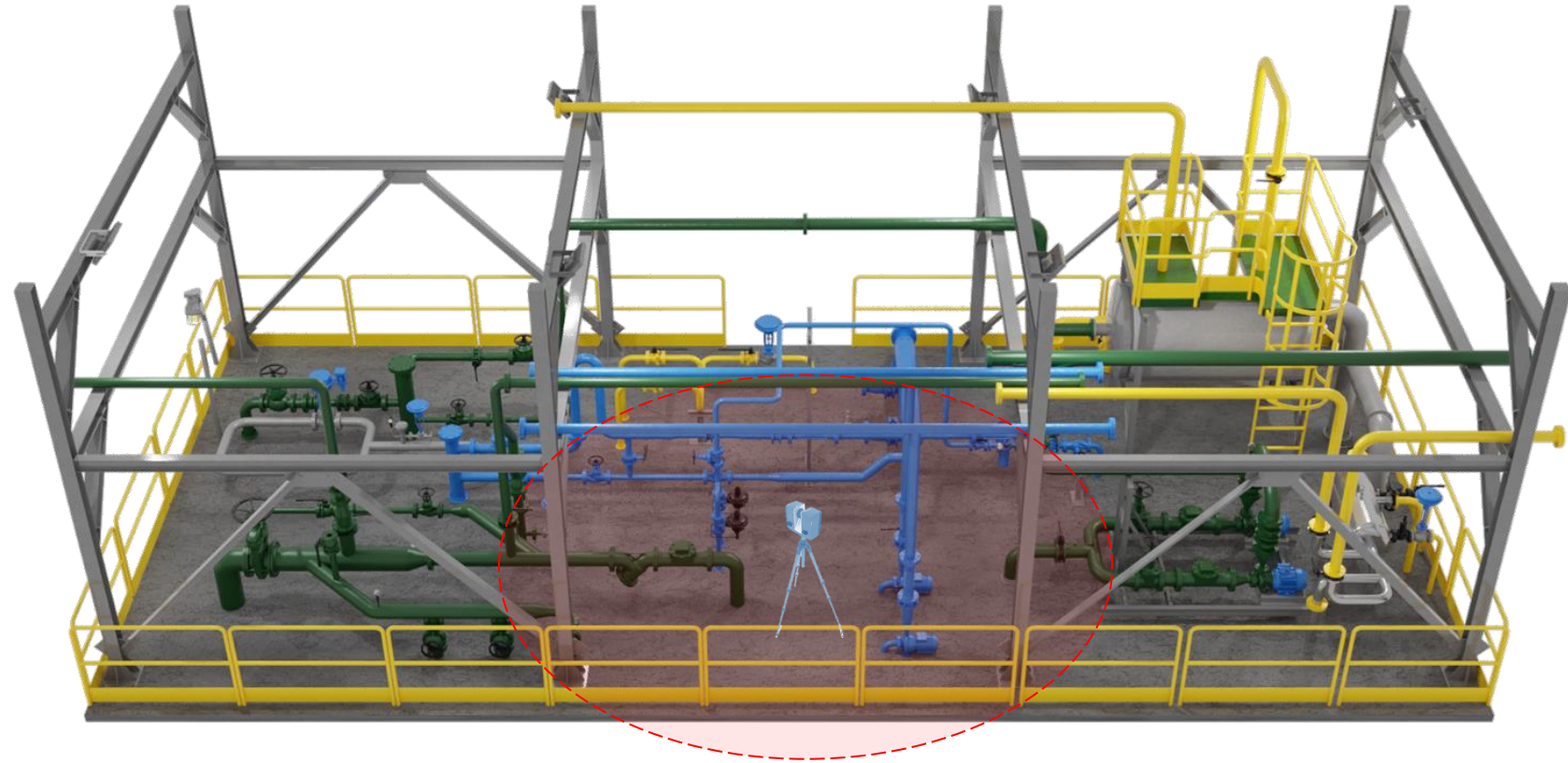
# The experiment: *execution conditions*

Volume : 562 m<sup>3</sup>

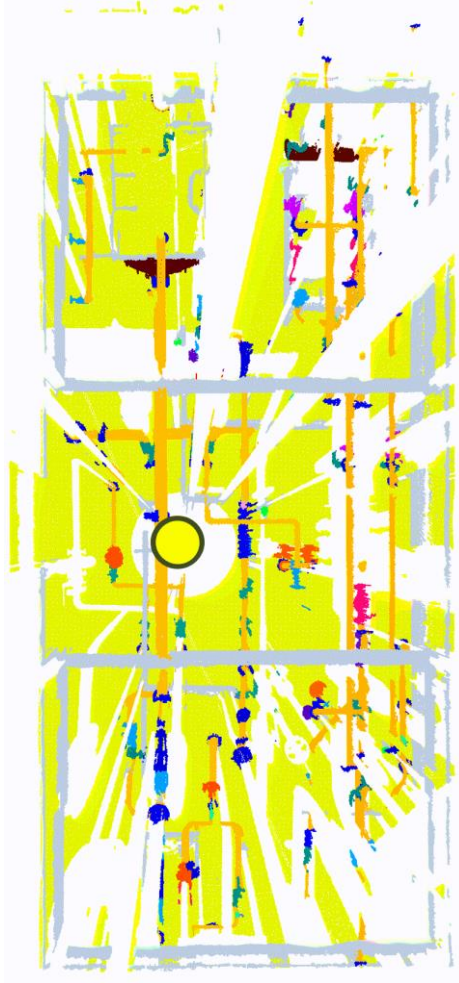
7,5m x 15m x 5m



Laser Scanner, Faro Focus S 150



# Data acquisition: *N* scanning points



#N scans per number of positions



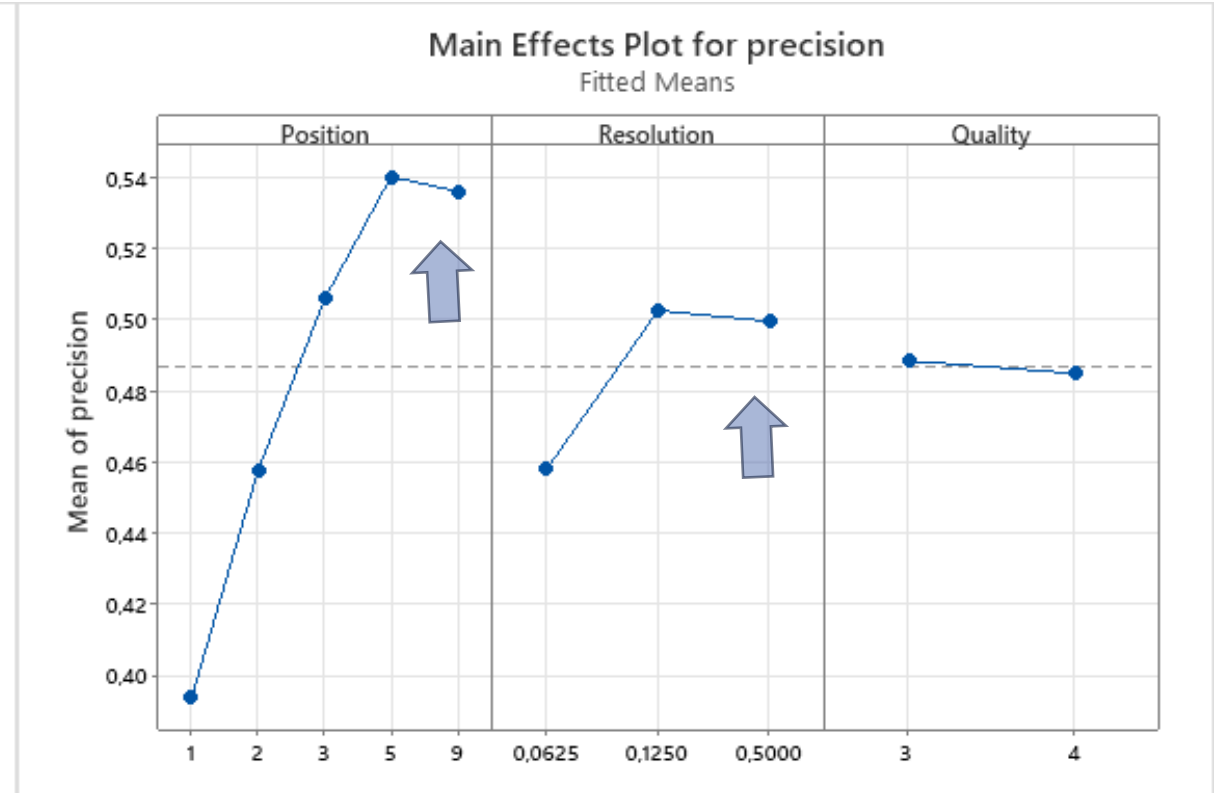
$\#Scans = positions * resolution * quality$

- Resolution: 3 levels
- Quality: 2 levels
- 6 clouds



## Results

# Factor effects for different metrics



# Response optimization: *all response variables*

## Parameters

Response	Goal	Lower	Target	Upper	Weight
mIoU	Maximum	0,2111	0,6695		1
F-score	Maximum	0,2353	0,5625		1
Recall	Maximum	0,2117	0,5346		1
Precision	Maximum	0,2631	0,5934		1
Time	Minimum		0,05	6,22	1

*Higher resolution and quality bring diminishing returns - it is possible to optimize for time*

## Solution

Position	Resolution	Quality	mIoU Fit	F-score Fit	Recall Fit	Precision Fit	Time Fit	Composite Desirability
9	1/8	3	0,648	0,5245	0,5042	0,5460	0,3596	0,909



# Response Optimization: *focus on point segmentation*

## Parameters

Response	Goal	Lower	Target	Upper	Weight
mIoU	Maximum	0,2111	0,6695		1
Time	Minimum		0,05	6,22	1

## Solution

Position	Resolution	Quality	mIoU Fit	Time Fit	Composite Desirability
9	1/8	3	0,648	0,3596	0,909

*If optimizing for segmentation mIoU: high number of positions increased performance (larger covered area)*

# Response Optimization: *focus on object detection*

## Parameters

Response	Goal	Lower	Target	Upper	Weight
Recall	Maximum	0,2117	0,5346		1
Precision	Maximum	0,2631	0,5934		1
Time	Minimum		0,05	6,22	1

## Solution

Position	Resolution	Quality	Recall Fit	Precision Fit	Time Fit	Composite Desirability
5	1/8	3	0,5119	0,5560	0,2746	0,9262

*If optimizing for instance detection: more scanning positions did not increase performance*

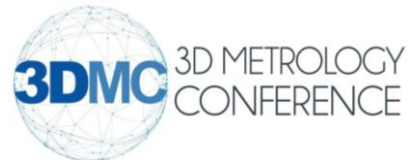
# Concluding remarks

- Critical analysis or limitations
  - Fixed scanning parameters values for model training
- Higher resolution and quality bring negligible benefits to AI performance
- As expected, the higher the number of scanning positions, the better the AI model performance (mIoU)
- More scanning positions do not increase performance per instance

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