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BULLETIN

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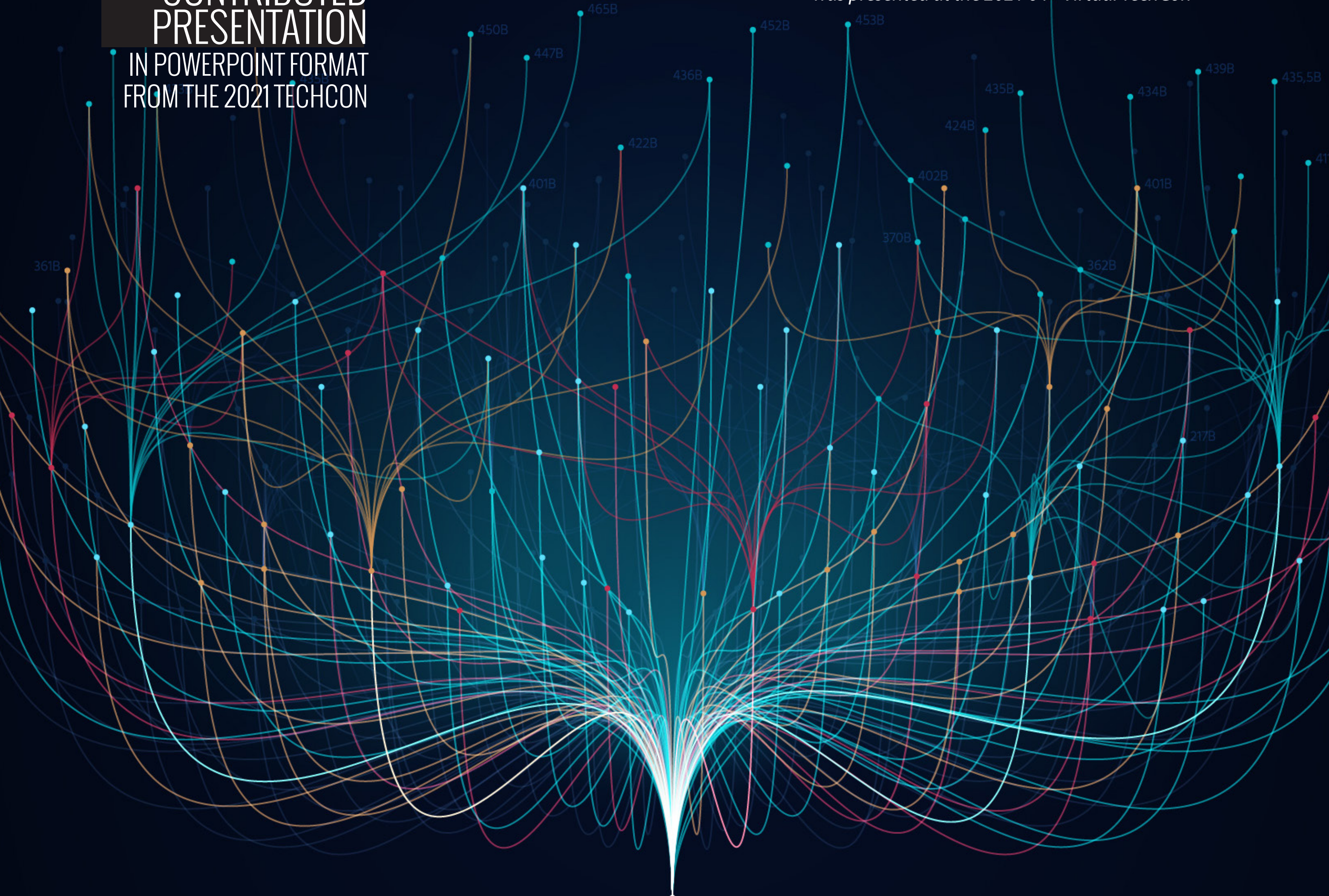
Automated Analysis of Vacuum Processes Using Artificial Intelligence

By Joe Brindley, Benoit Daniel, Victor Bellido-Gonzalez, Dermot Monaghan
Gencoa Ltd, Liverpool, United Kingdom

CONTRIBUTED PRESENTATION
IN POWERPOINT FORMAT FROM THE 2021 TECHCON

Adapted from a Powerpoint Presentation that was presented at the 2021 64th Virtual TechCon



Automated Analysis of Vacuum Processes Using Artificial Intelligence

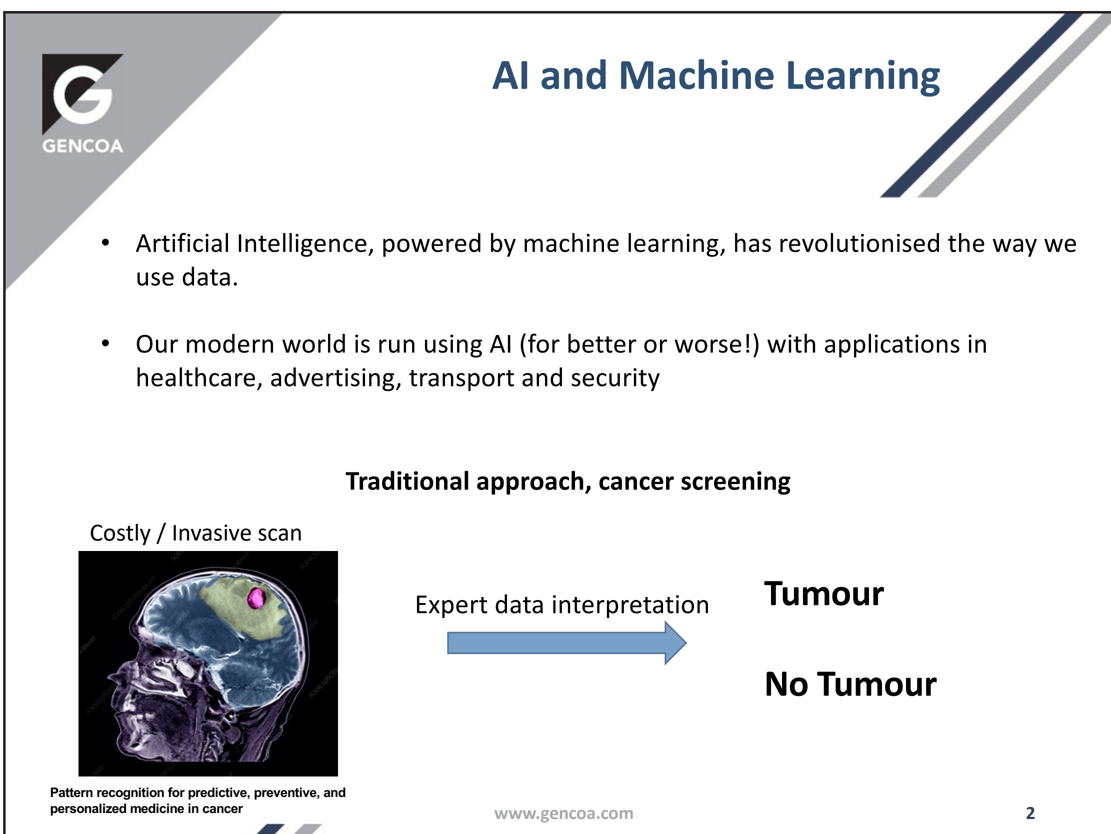
By Joe Brindley, Benoit Daniel, Victor Bellido-Gonzalez, Dermot Monaghan
Gencoa Ltd, Liverpool, United Kingdom

Vacuum deposition processes are being equipped with an ever-expanding array of sensors to gain more control over the process conditions. Unfortunately, this often presents the machine operator with too much data to be able to draw clear insights into the performance of the process. Machine learning algorithms are a powerful tool for analyzing large and complex sets of data and have been at the forefront of a revolution artificial intelligence.

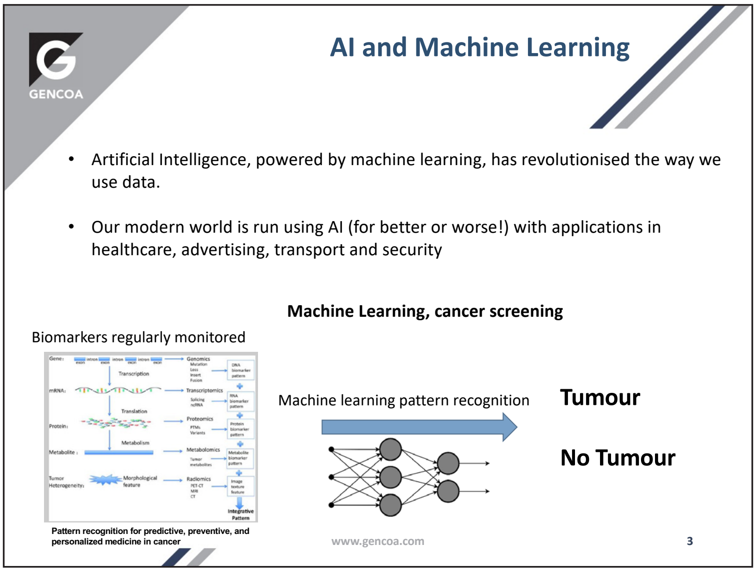
These techniques are ideally suited for analyzing problems encountered in vacuum processes, which are often expressed as "classification problems", i.e., identifying if a leak is present in the system or not. In particular, they can be applied to the automated analysis of optical emission spectra (OES) of plasma. OES provides critical information on the state or condition of a process. However, expert knowledge is often required to be able to interpret the data, and in some cases, the spectra are too complex to extract key information using the human eye alone. This paper will present the application of a machine learning A.I. to the automated analysis of magnetron and remote plasma OES data. Examples include leak detection, organic contamination detection and the identification of organic molecules from cracking patterns.

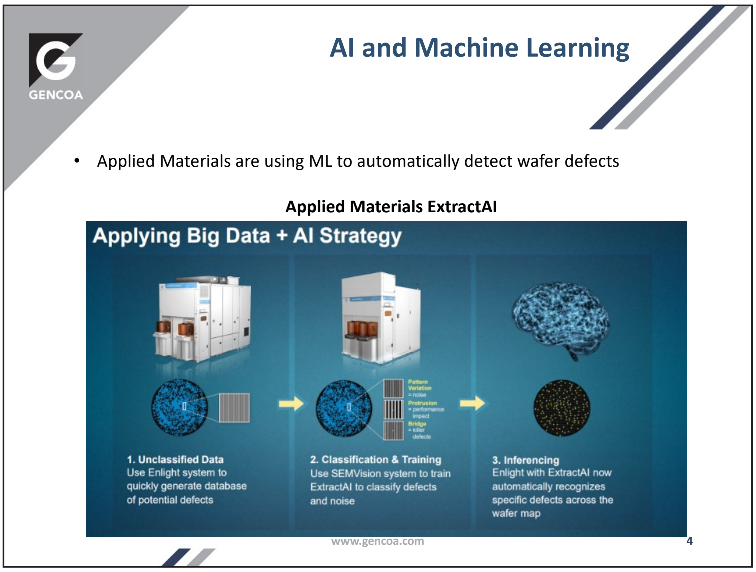
Note from Managing Editor: We are delighted to share with the readers of the Bulletin some of the interesting Powerpoint Presentations from past TechCons. We hope you find them as interesting as we do.

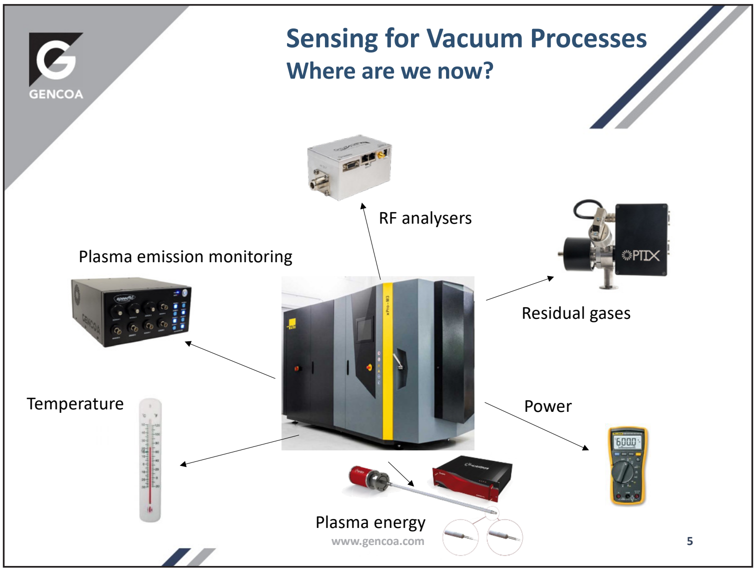
Sue Taube/Managing Editor



AUTOMATED ANALYSIS OF VACUUM PROCESSES USING ARTIFICIAL INTELLIGENCE

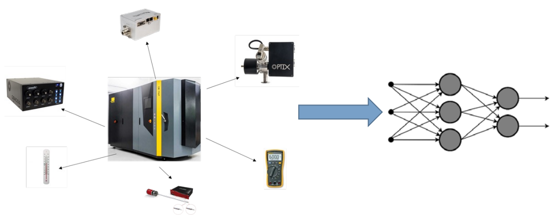






AI and Machine Learning
For Vacuum Processes

- ML methods and tools are developed to the extent that they can be "democratised"
- How can we exploit this technology within our industry



Chamber condition

Process state

Leak detection

Vacuum quality

Materials properties

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AI based leak detection

- Current methods of leak detection are slow and invasive
- Either base pressure is reached (e.g. 1E-5 mbar) and residual gases are analysed
- Or a rate-of-rise test is performed at base pressure
- Can we use gas partial pressure data to train an AI to identify leaks
  - much faster ?
  - without intervention?

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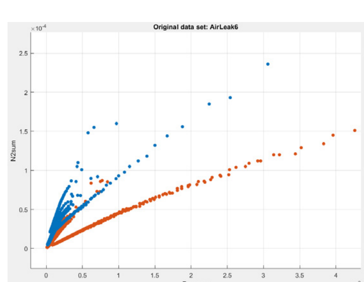
AI based leak detection
Training data

- Optix used to record partial pressures during pumpdown
- A small turbo pumped system was used for speed of data collection



- Variation of leak rate
- Time exposed to atmosphere
- Recording of total pressure
- Partial pressure of N_2,O, OH, H, Ar, CO_2
- **3700 data sets**

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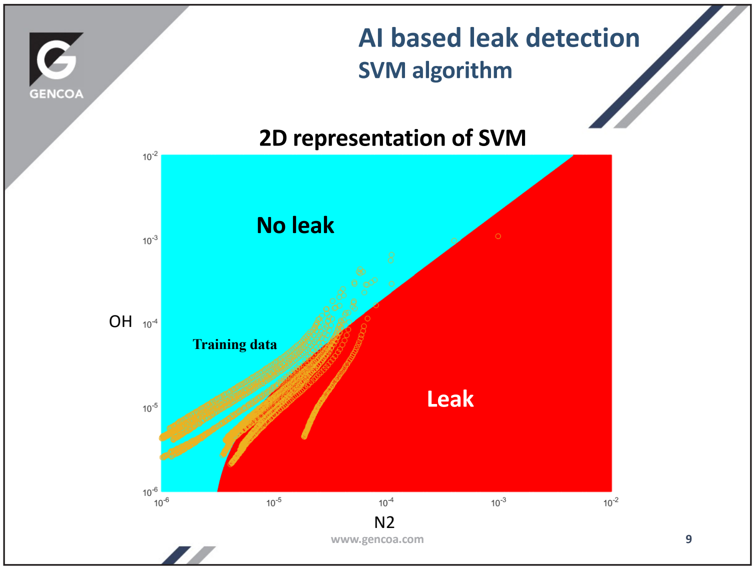

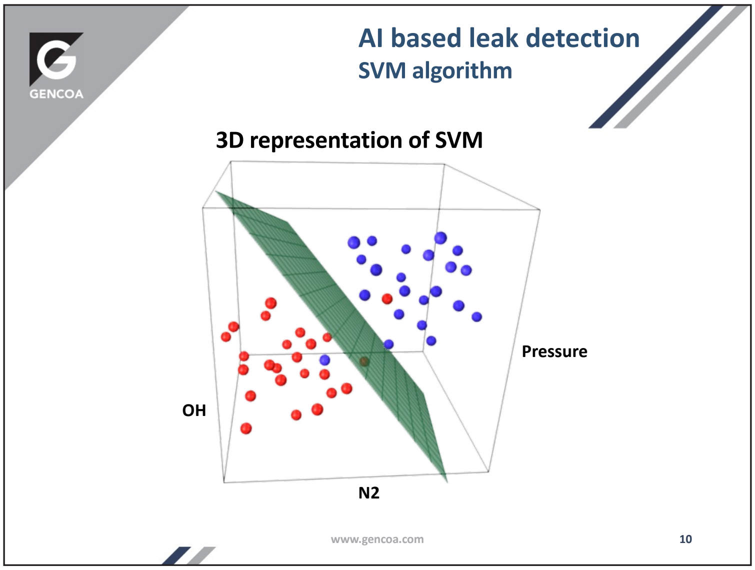

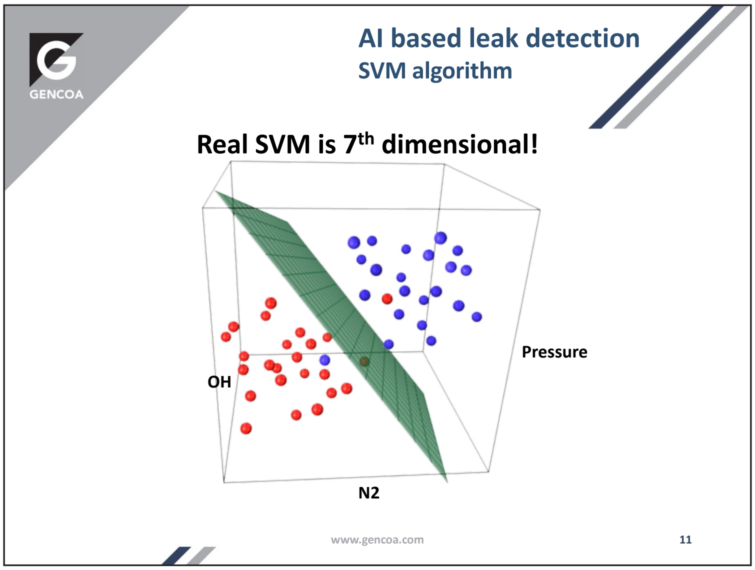

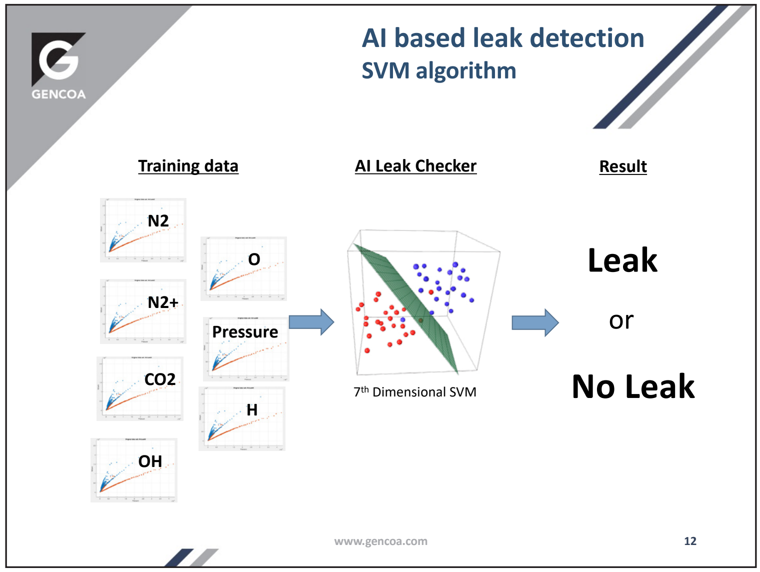
GENCOA
AI based leak detection
SVM algorithm
Training data
AI Leak Checker
Result
N2
O
N2+
Pressure
CO2
H
OH
7th Dimensional SVM
Leak
or
No Leak
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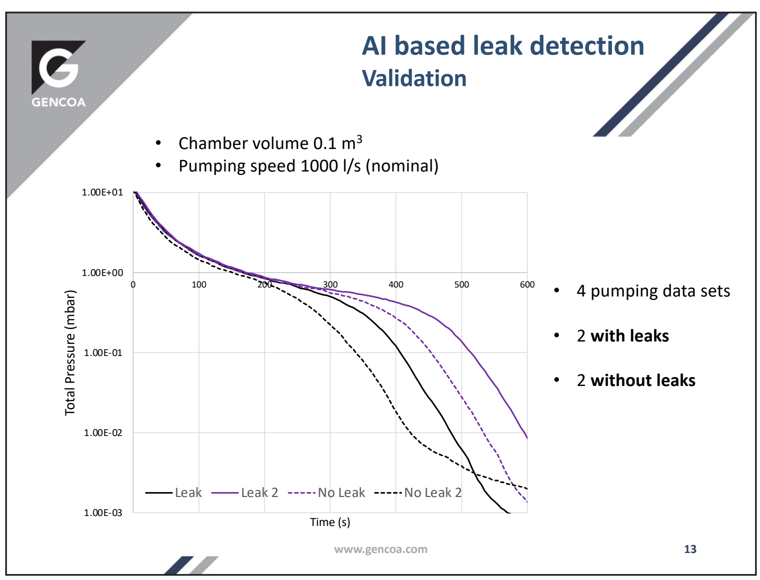
GENCOA
AI based leak detection
Validation
Chamber volume 0.1 m3
Pumping speed 1000 l/s (nominal)
1.00E+01
1.00E+00
1.00E-01
1.00E-02
1.00E-03
0
100
200
300
400
500
600
Total Pressure (mbar)
Time (s)
Leak
Leak 2
No Leak
No Leak 2
4 pumping data sets
2 with leaks
2 without leaks
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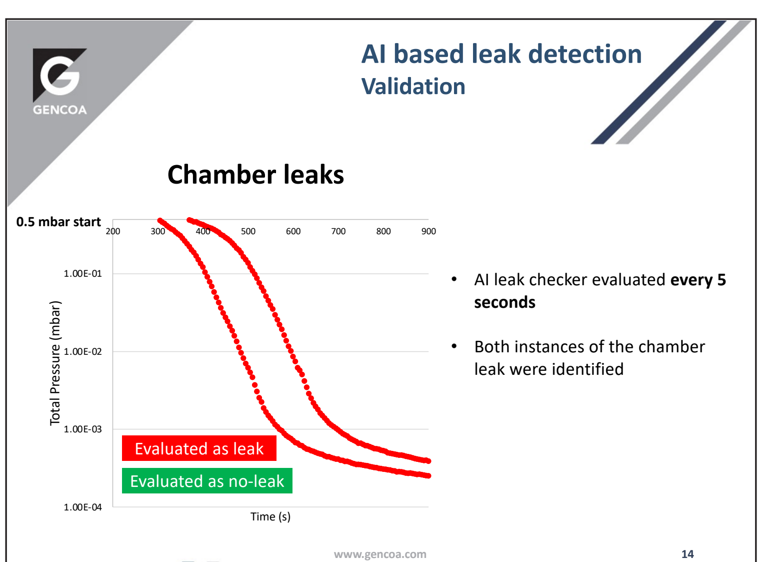
GENCOA
AI based leak detection
Validation
Chamber leaks
0.5 mbar start
200
300
400
500
600
700
800
900
1.00E-01
1.00E-02
1.00E-03
1.00E-04
Total Pressure (mbar)
Time (s)
Evaluated as leak
Evaluated as no-leak
AI leak checker evaluated every 5 seconds
Both instances of the chamber leak were identified
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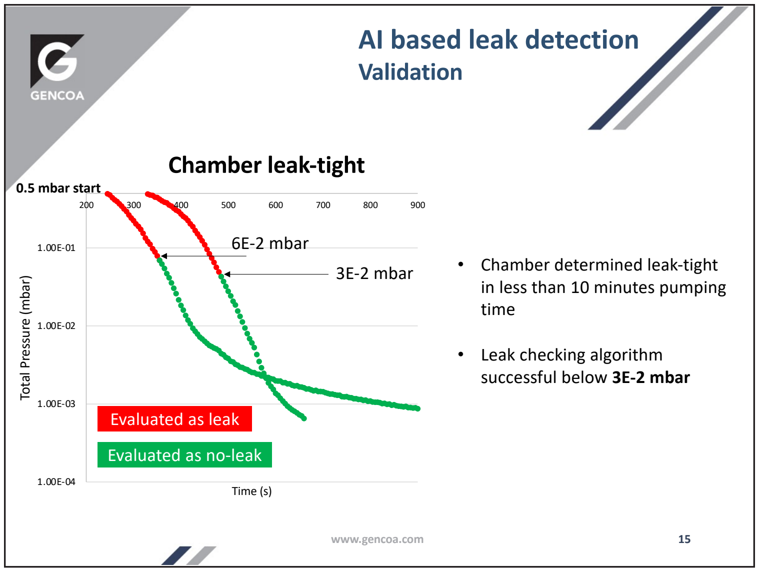
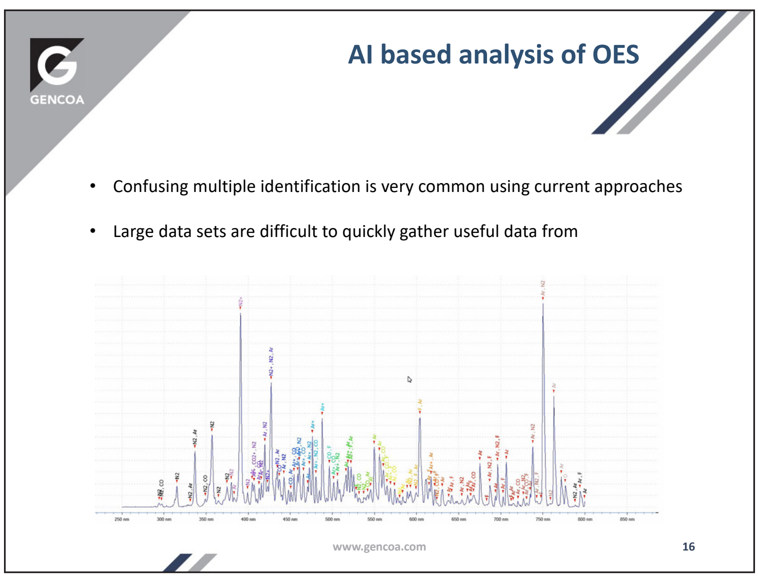
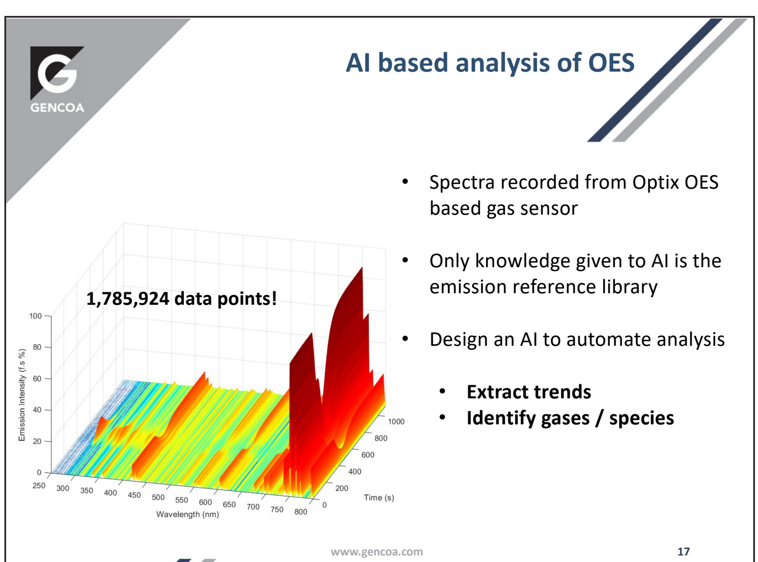
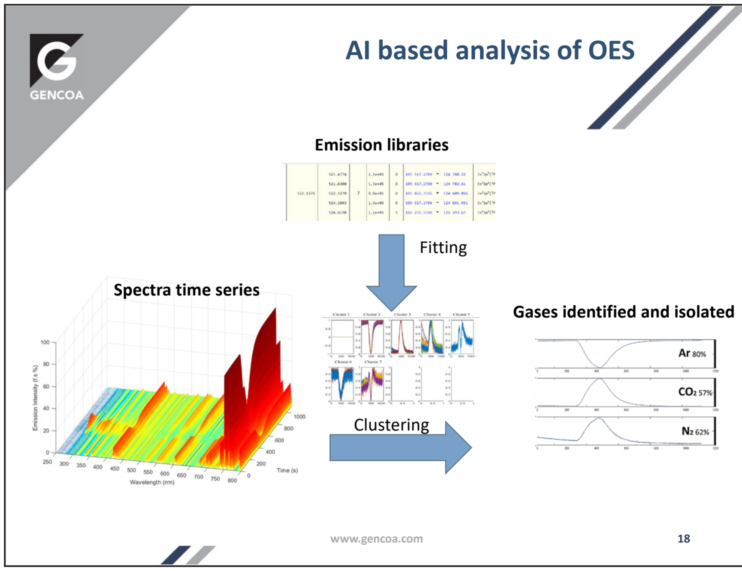
AUTOMATED ANALYSIS OF VACUUM PROCESSES USING ARTIFICIAL INTELLIGENCE








GENCOA
AI based analysis of OES
Emission libraries
Fitting
Spectra time series
Gases identified and isolated
Ar 80%
CO2 57%
N2 62%
Clustering
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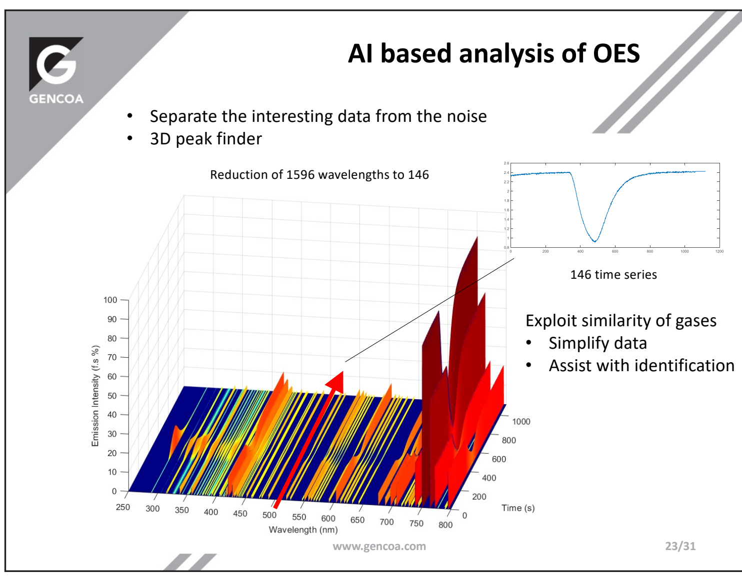
GENCOA
AI based analysis of OES
• Separate the interesting data from the noise
• 3D peak finder
Reduction of 1596 wavelengths to 146
146 time series
Exploit similarity of gases
• Simplify data
• Assist with identification
Emission Intensity (f.s %)
Wavelength (nm)
Time (s)
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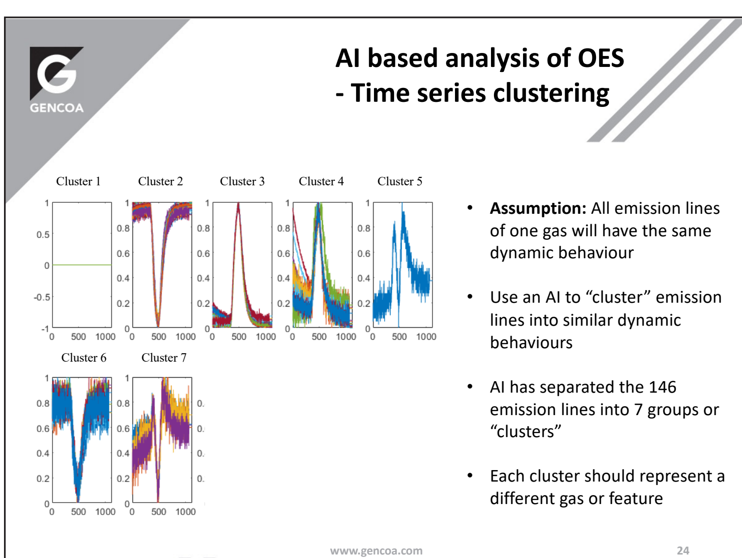
GENCOA
AI based analysis of OES
- Time series clustering
Cluster 1
Cluster 2
Cluster 3
Cluster 4
Cluster 5
Cluster 6
Cluster 7
• Assumption: All emission lines of one gas will have the same dynamic behaviour
• Use an AI to "cluster" emission lines into similar dynamic behaviours
• AI has separated the 146 emission lines into 7 groups or "clusters"
• Each cluster should represent a different gas or feature
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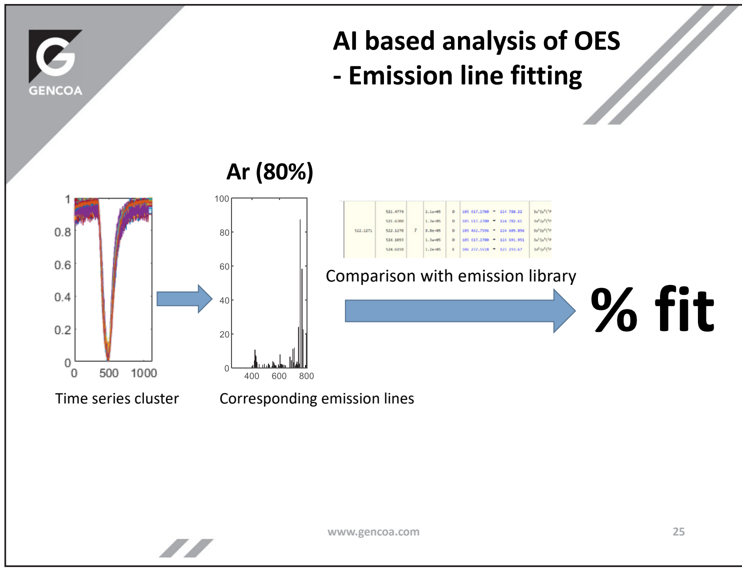

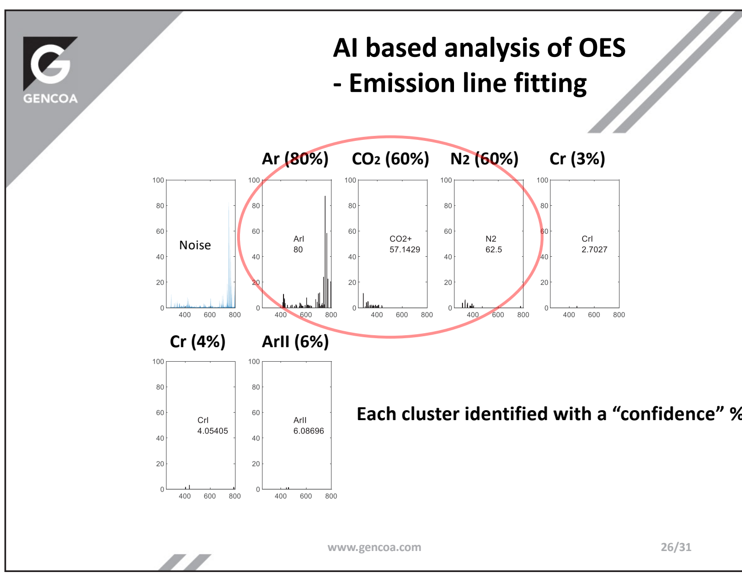

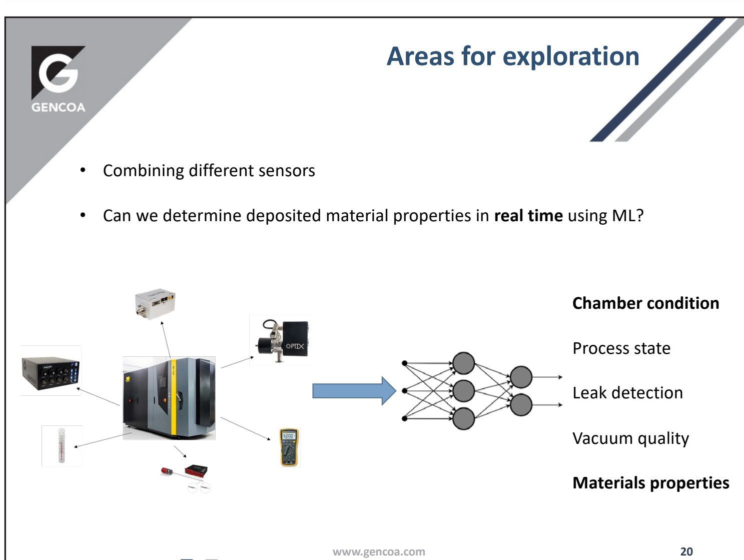

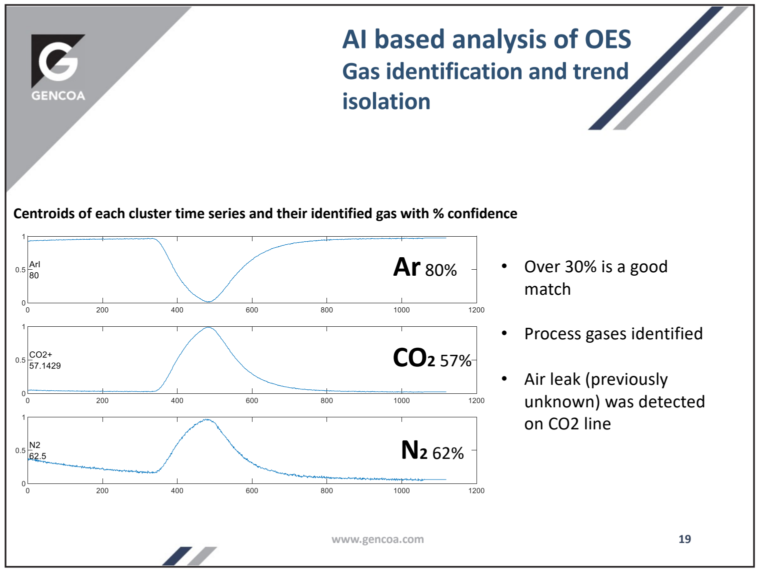

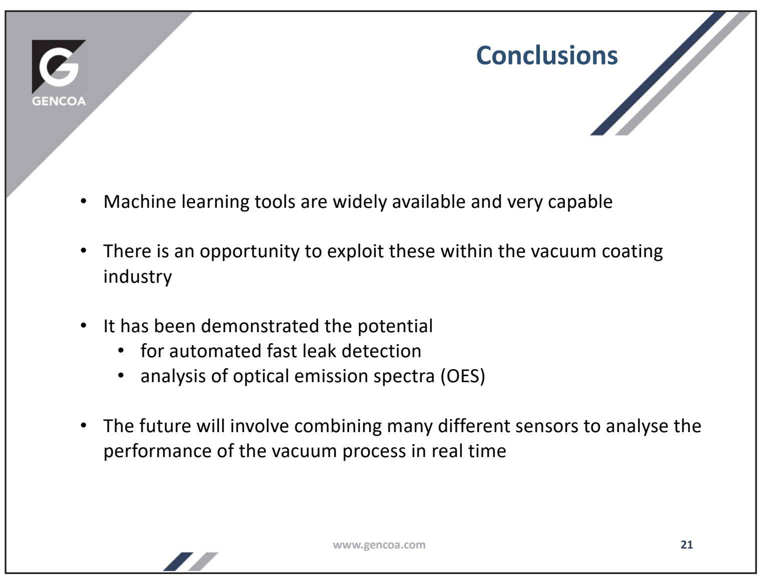

About the Author: Joe Brindley

Joe holds a PhD in Mechanical Engineering from the University of Strathclyde, where he researched feedback control algorithm design with applications in reactive sputtering . Since joining Gencoa as a Research and Development Engineer in 2012 he has been responsible for the development of the company's sensing and control products. This includes bringing to the market Gencoa's Optix gas sensor and authoring of patented algorithms for automation of sputter processes. Joe is currently working on the application of machine learning and AI to vacuum process control and is the industrial supervisor for a PhD research project on this topic.