SEAGATE

# Time Series Analytics of IoT Sensor Data
An Industry Challenge Perspective

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**Smart Nano NI**
A Strength in Places Fund project

# Seagate Is the Data Storage Industry Leader

We power the storage infrastructure for most of the world's data.

**>3 ZB**
Shipped Annually
(March '21)

**40+ Years**
Storage Innovation

**40K+**
Employees Globally

**$10B+**
Annual Revenue

# Where Is Seagate?

**HQs, Admin/Sales**    **Design**    **Manufacturing**    **Customer Support**

OUR GLOBAL PRESENCE – 46 locations across 20 countries



Beaverton, OR
Shakopee, MN
Springtown, N. Ireland
Danderyd, Sweden
Bloomington, MN
Amsterdam, Netherlands
Dublin, Ireland
Moscow, Russia
Sacramento, CA
Maidenhead, UK
Beijing, China
Munich, Germany
Fremont, CA
Tokyo, Japan
Paris, France
Hangzhou, China
Oklahoma City, OK
Dubai, UAE
Tianjin, China
Shanghai, China
Tel Aviv, Israel
New Delhi, India
Taipei, Taiwan
Houston, TX
Wuxi, China
Longmont, CO
Mumbai, India
Shenzhen, China
Round Rock, TX
Pune, India
Teparuk & Korat, Thailand
Hong Kong
Guadalajara, Mexico
Seremban, Malaysia
Chengdu, China
Johor, Malaysia
Shugart, Singapore
Penang, Malaysia
Woodlands, Singapore
São Paulo, Brazil

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# Seagate Springtown

- STST sits at the heart of the $26B worldwide data storage industry by 2026

- Site established 1993

- The largest of only 5 facilities of its type in the world

- One of two Wafer fabs in Seagate

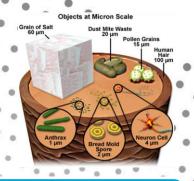- Supplies around 25% of global demand for read-write heads for hard drives
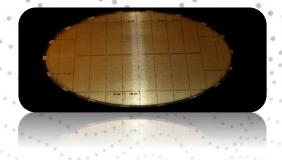
# Our People

We currently have over 1500 employees:

- 52 % Operators, 18 % Technicians,
- 20 % Engineers, 10% Management & Professionals
- 64% staff have greater than 10 years' service
- 86% male, 14% female
- 21 % Degree level, 11 % Masters, 5% PhDs
- 27 nationalities other than UK / Ireland

We have a global commitment to diversity, equity and inclusion

# From Wafer to Drive



Objects at Micron Scale



**Wafer**

**Disc Drive**

**Bar**

**Head Stack Assembly**

**Slider**

**Head Gimbal Assembly**

# Program Intent

# Goals

**Detection**

**Explainability**

**Scalability**

Detect and Contain Process excursions by Modelling IoT data collected from Semiconductor Equipment

Improve the explainability and interpretability of identified anomalies to increase solution adoption and root cause analysis capabilities

Establish a scalable solution with a low cost of ownership from a configuration and deployment perspective

# Value Proposition

Wafer Processing → Metrology & Electrical Testing → Downstream Product Build

An Exponential Increase in Anomaly Cost

$        $$$        $$$$$

Goal: Detect and Contain Anomalous Behaviour at the point of Processing by analysing IoT data

# The Challenge…

Areas of Complexity

High Data Dimensionality

Multi-modal Process Operations

Non-stationary Equipment Performance

Unlabelled & Infinite Faults

**Statistical & Six Sigma Methods**

Spike

Duration

Magnitude

Ramp

Upper and Lower Limit

Time

**Machine Learning**

Get Data

Train Model

Improve

2

1

3

4

5

Clean, Prepare
& Manipulate Data

Test Data
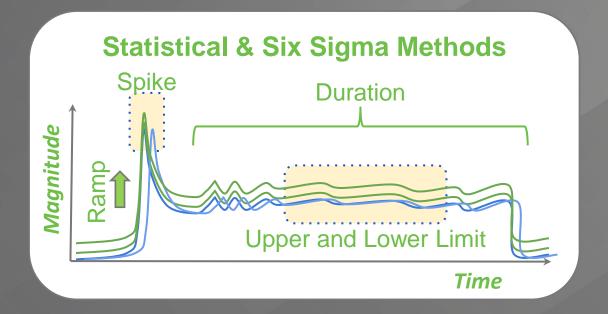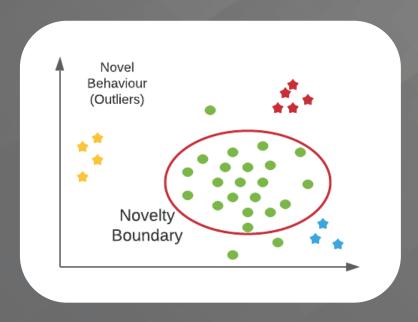
# Proposed Solution

## Modelling all data within a defined 'Golden Fingerprint'
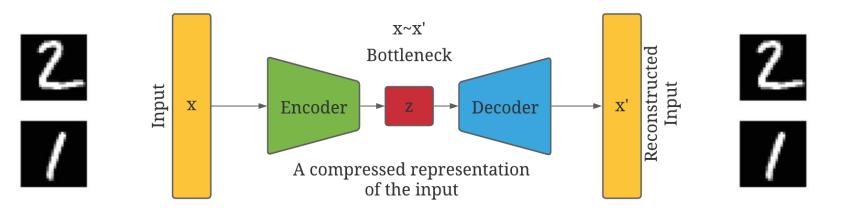


Modelling Objective:

- Learning normal operating sensor conditions

- Establish Novelty Boundary

- Capture entire sensor feature domain

- Detect Novelty behaviours for engineering review

# Deep Learning AutoEncoder

## Model Training
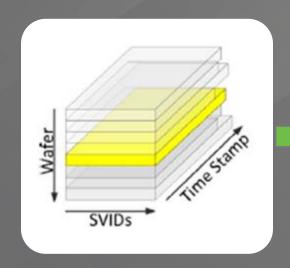


Good training set defined as a 'Golden Fingerprint' of 1's & 2's
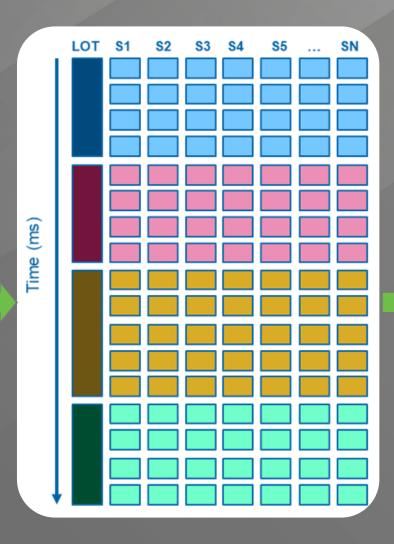
Model Testing New Unlabelled Samples

# Encoder Data Structure - Treating Sensor Data as an Image
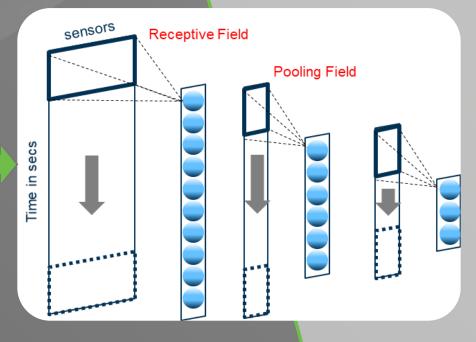


Raw Trace
Sensor Data

Pre-Processed
Array
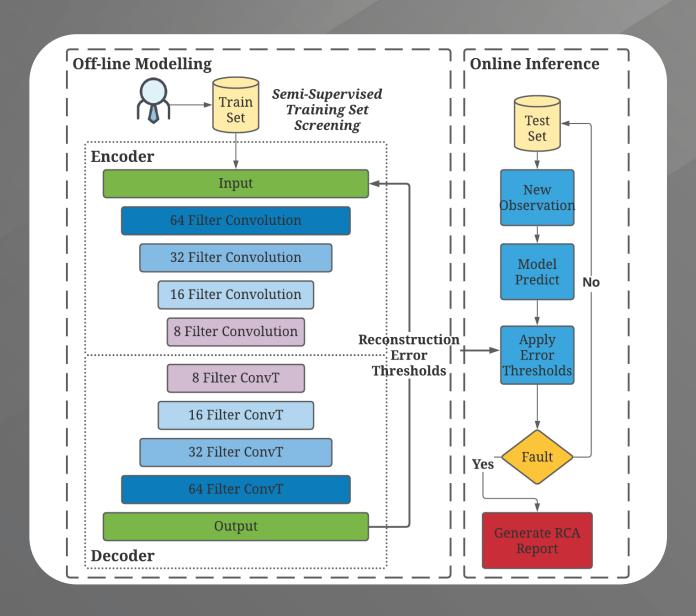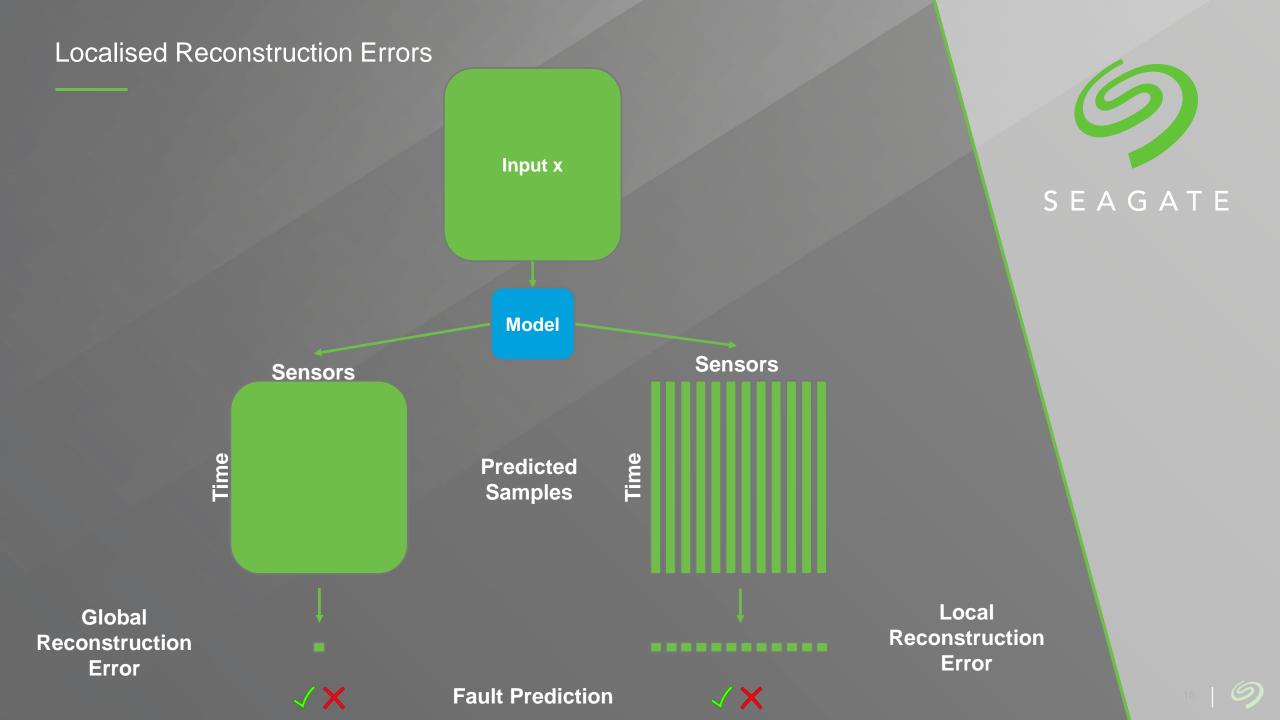
Deep Learning
Encoder

# Model Workflow

# Localised Reconstruction Errors



Input x

Model

Sensors

Sensors

Time

Time

Predicted Samples

Global Reconstruction Error

Local Reconstruction Error

Fault Prediction

✓ ✗

✓ ✗

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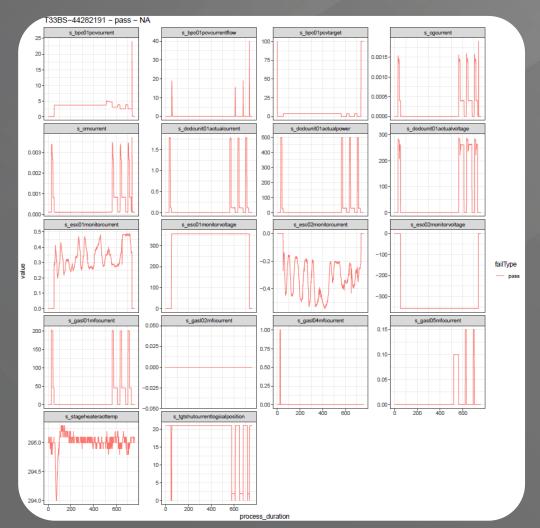
# Case Study

# Example Sensor Traces – Vacuum Deposition

## 18 Sensors
## ~ 600 samples @ 2Hz
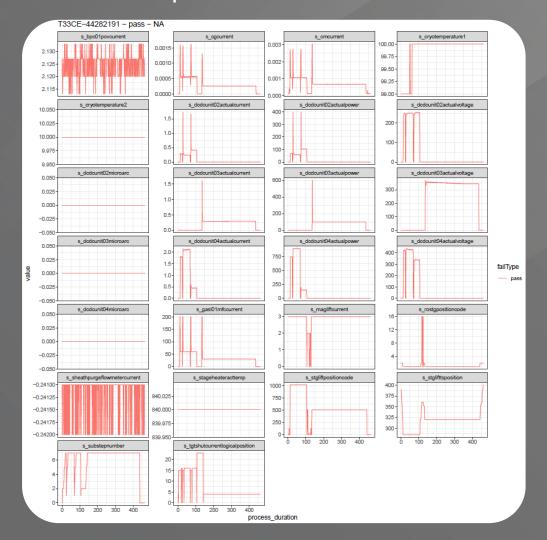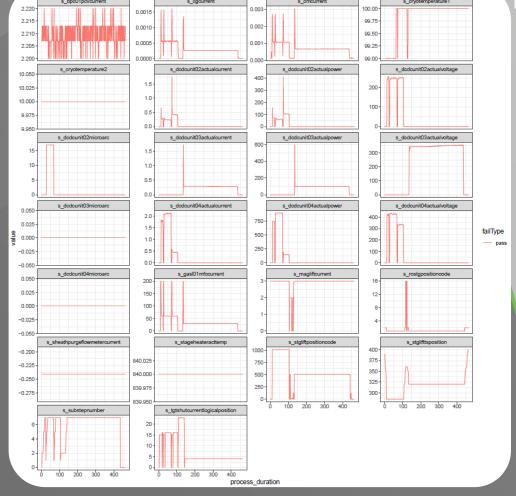
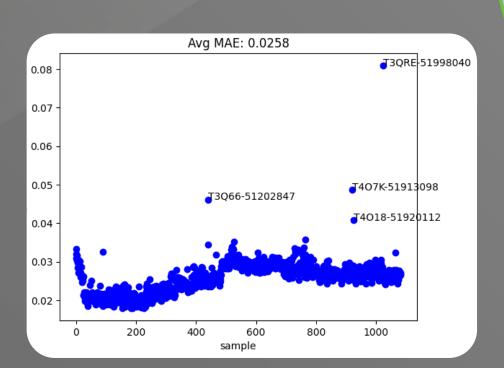# Example Sensor Traces – Vacuum Deposition

28 Sensors
~ 500 samples @ 2Hz
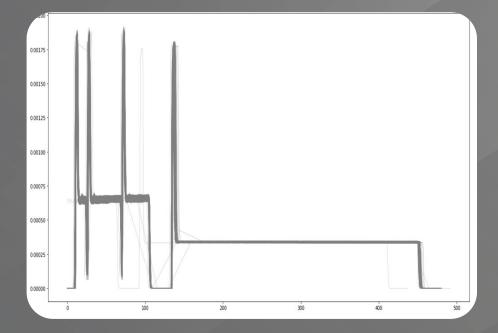
# Case Study: Vacuum Deposition
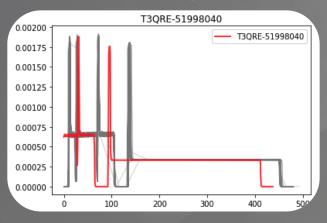


**Raw Trace Examples**
**An overlay of historical raw traces to demonstrate the expected sensor trace shape**



Avg MAE: 0.0258

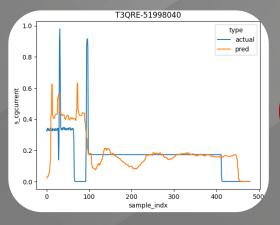T3QRE-51998040
T4O7K-51913098
T3Q66-51202847
T4O18-51920112

**Aggregated Reconstruction Errors**
**MAE of each observation for a single sensor that helps visualise the overall reconstruction error rate by processing time**
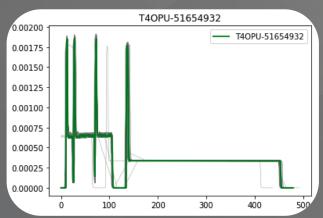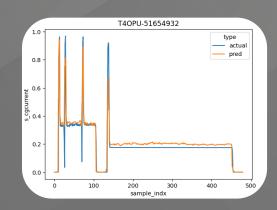
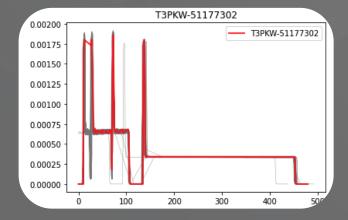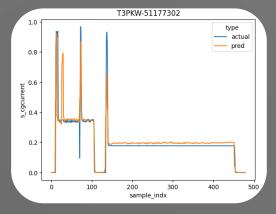SEAGATE

# Case Study: Vacuum Deposition



**Fail**
**Missing Data**

**Pass**
**Expected sensor shape**
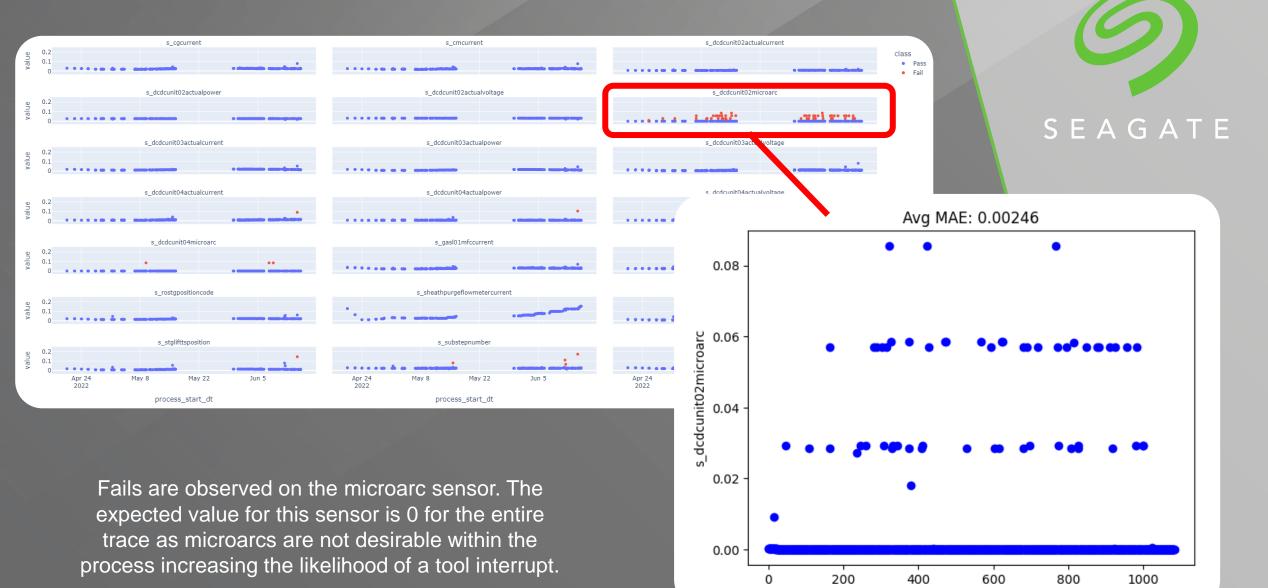
**Fail**
**Missing Deposition Spike**

# Case Study: Vacuum Deposition



Fails are observed on the microarc sensor. The expected value for this sensor is 0 for the entire trace as microarcs are not desirable within the process increasing the likelihood of a tool interrupt.

Areas of Weakness

Poor IIOT Collection Strategies

Significant Equipment Maintenance

Excessive Sensor Drift

Model Management

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# In Summary…

Problem Statement → Traditional Solutions → Proposed Solution → Case Study → Limitations
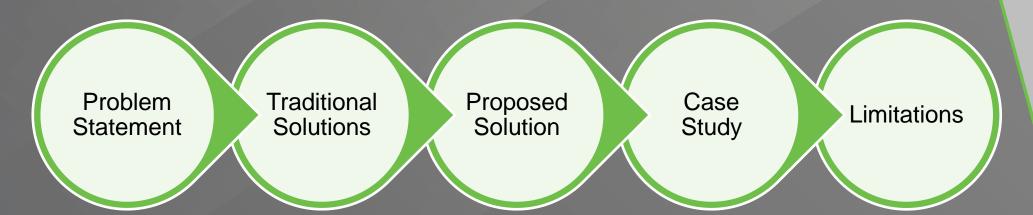
MAXIMIZING DATA'S POTENTIAL

# Thank You

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