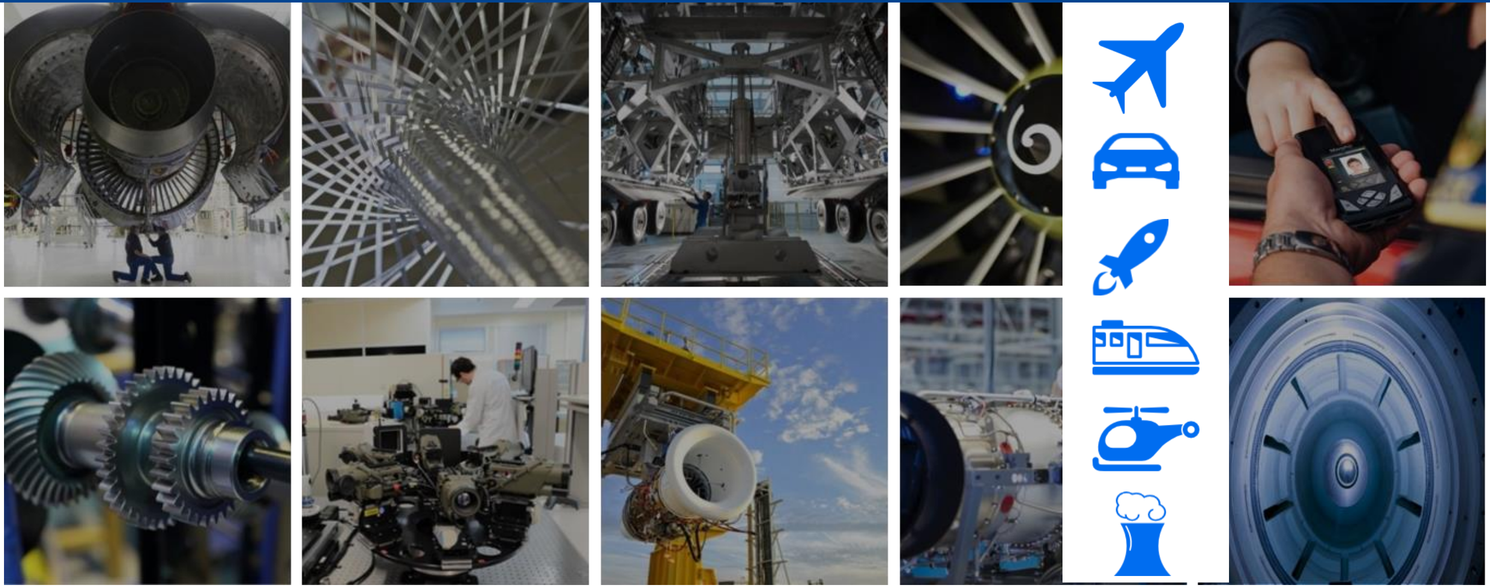
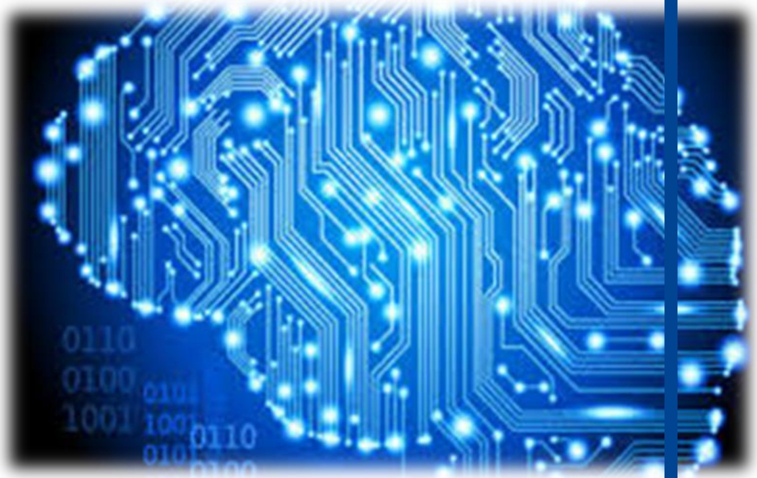


Simulation & Predictive Maintenance Application

28-May-2019

Key Takeaways

- Listening and Pivoting
- Collaboration
- Flexibility



SIMULATION & PREDICTIVE MAINTENANCE

SAFRAN APPROACH

SAFRAN – Simulation History

2015 Q1.

First Artificial Neural Network (ANN) to solve Structural Health Monitoring SHM problem

2016 Q1.

Assessment of random noise effect in SHM

EWSHM-2016 – Congress Bilbao (Spain)

2017 Q2.

ANN approach to predictive analysis of rotary industrial machines

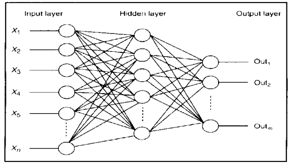
2018 Q1.

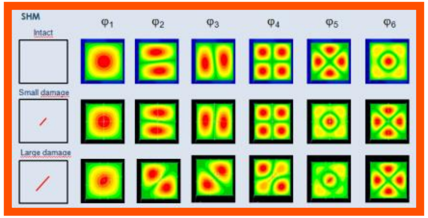
Marketing development & Customer seeking

Hydraulic Press
Hydro-electric generator
Variable Frequency Generator (VFG)
Automotive tire vulcanizing furnace applications

Today

First bench-markings with potential customers and collaborators





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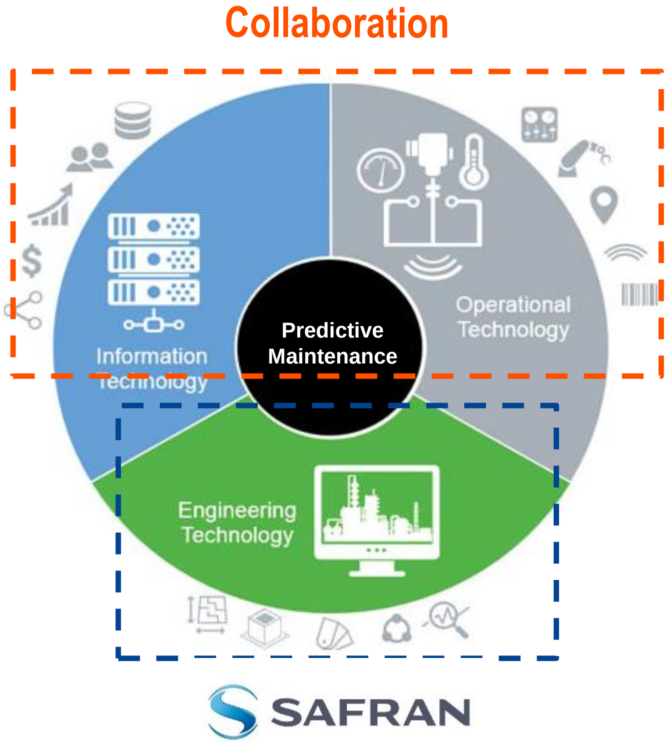
IT, OT and ET



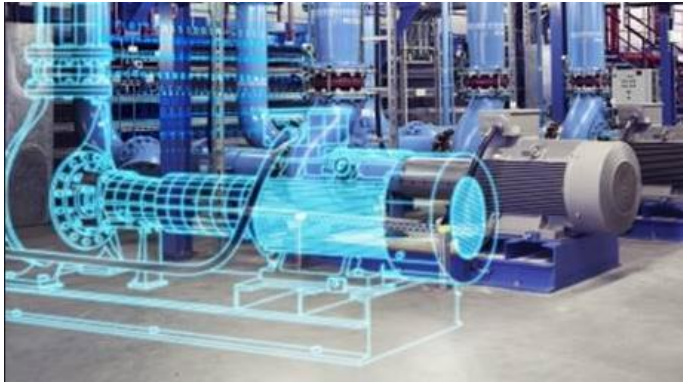
Smart Predictive Maintenance requires for three different Technologies: IT, OT and ET.

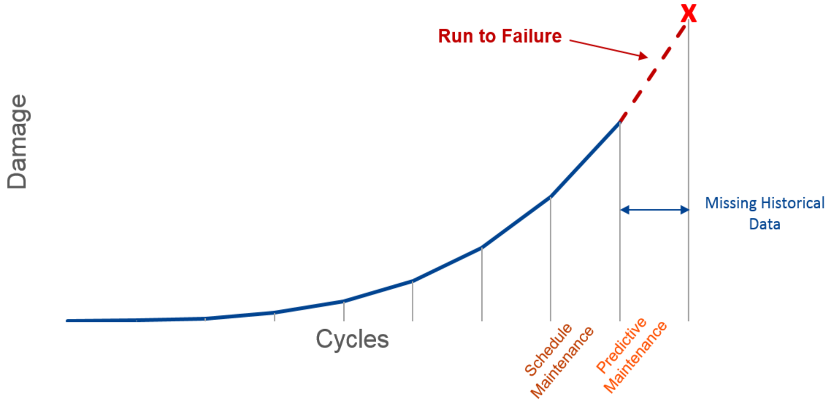
1. Information Technology **to analyze historical Big Data.**

2. Operation Technology **to obtain data in streaming from real process.**

3. Engineering Technology **to identify physical behaviors and simulate run-to-failure data.**

Engineering Technology – Digital Twin





1. **Due to traditional Maintenance Cycles,** run-to-failure data **are normally** missing **from collected Data Base.**

2. **Run-to-failure data are necessary for** Smart Prediction.

3. **Digital Twins** simulate anomalies **to generate these data.**

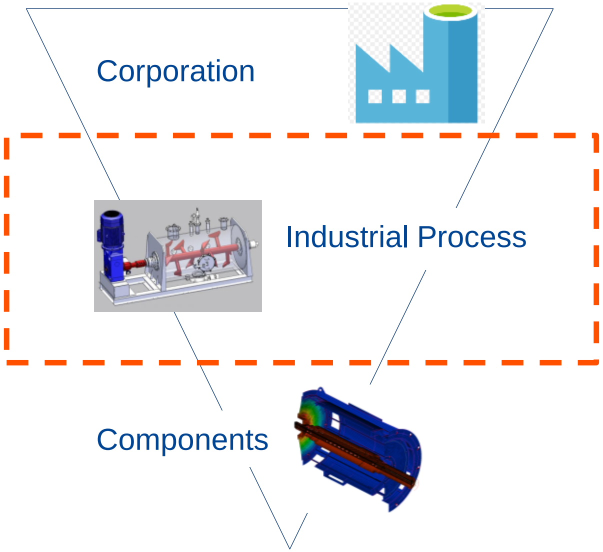
4. **Digital Twins follow** Physical Responses.

SAFRAN

Engineering Technology – Engineering Taxonomy

- **Digital Twins are applicable to any level of taxonomy.**
- **The whole corporation can be connected by using Simulated Process.**
- **Digital Transformation is mandatory for any company for future developments.**

Engineering Taxonomy



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INDUSTRIAL PROCESS APPLICATION

Hydraulic Press

Application – Hydraulic Press

Methodology

1. **Preliminary analysis:**
   - Monitor for collecting calibration data.

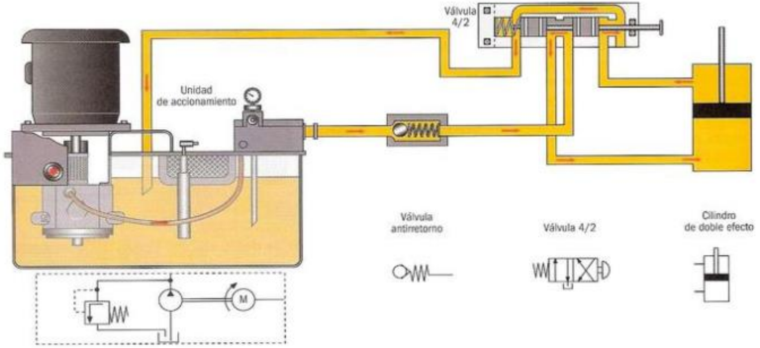
2. **Simulation model:**
   - Create Parametric Virtual Model with Simulink.
   - Correlate with calibration data.
   - Generate anomalies (Data Base).

3. **Neural Network supervised training:**
   - ANN generation/training with Deep Learning Toolbox.

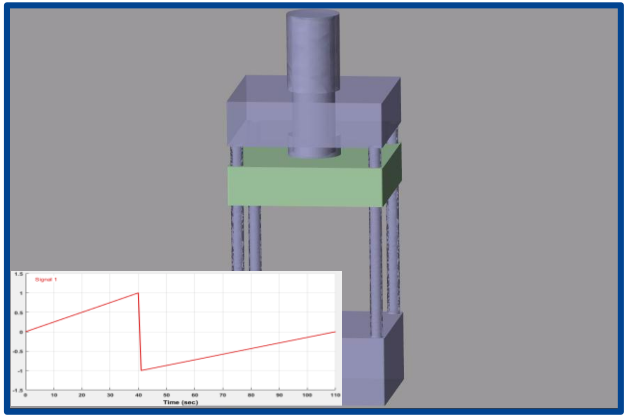
4. **Implementation of the predictive model:**
   - Synchronize active monitoring and predictive maintenance model.
   - Develop interface for friendly user experience with GUI Layout Toolbox.

Application – Hydraulic Press

1. Model of the hydraulic press
- Hydraulic double acting cylinder
- 4 ways - 2 positions valve
- Pump
- Safety valve



2. Control
- Controlled by a variable time signal, piloting the main valve.

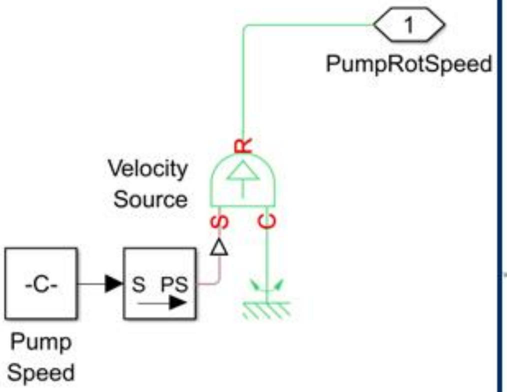


3. Monitoring
- Only 3 sensors: Position, Up-press, Down-press.

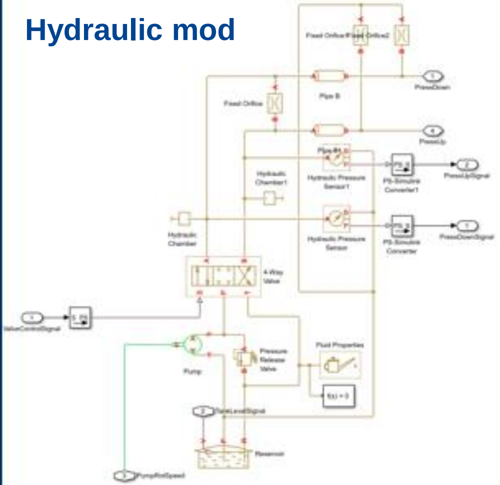
Application – Hydraulic Press

Simulink - 1D Virtual Model

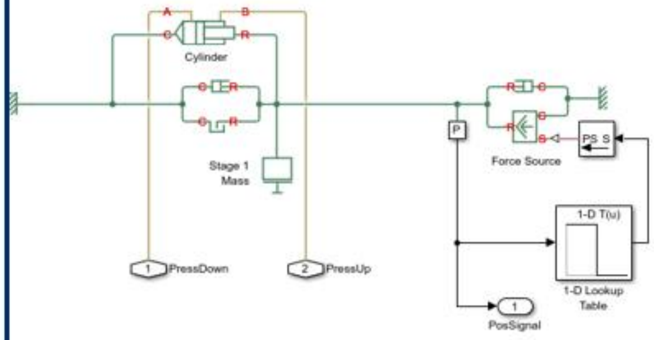
Electric mod



Hydraulic mod



Mechanical mod



Application – Hydraulic Press

1. Anomalies simulation
- Parametric model → scenarios (anomalies progressive growth or abrupt).

2. Anomalies list
- Decrease of Pump rotation speed.
- Delay of the control valve.
- Pressure of the safety valve.
- Valves leakages.
- Bypass between up and down circuits.
- Hydraulic lines leakages.

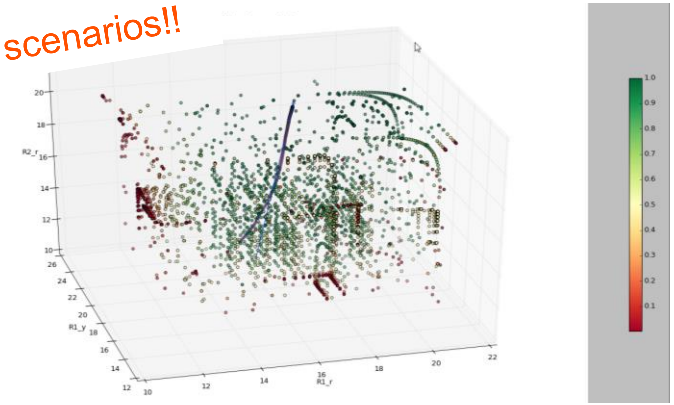
3. Sensitivity analysis of anomalies
- Sensor impact.

4. Damage Qualification
- Determine damage boundaries for alerts.

Anomalies

```
input.pumprotatingfactor=1;                % Pump rotating speed modification factor speed*factor
input.sequencedelayfactor=1;               % Delay factor to multiply on the valve actuacting sequence time*factor
input.pressreleasesettingfactor=1;         % Release valve pressure activation modification factor press*factor
input.pressreleaseregulationfactor=1;      % Release valve pressure range modification factor press_range*factor
input.pressreleaseleakagefactor=1;         % Release valve leakage area modification factor area*factor
input.valveleakagefactor=1;                % Actuating valve leakage area modification factor area*factor
input.valvederivativefactor=1;             % Actuating valve derivation area modification factor area*factor
input.pressdownleakagefactor=1;            % Pressure down line leakage area modification factor area*factor
input.pressupleakagefactor=1;              % Pressure up line leakage area modification factor area*factor
```

+ 2500 scenarios!!



Application – Hydraulic Press

1. Data base

- **NN Dataset & Training is developing by switching Input-Output.**

2. ANN Generation

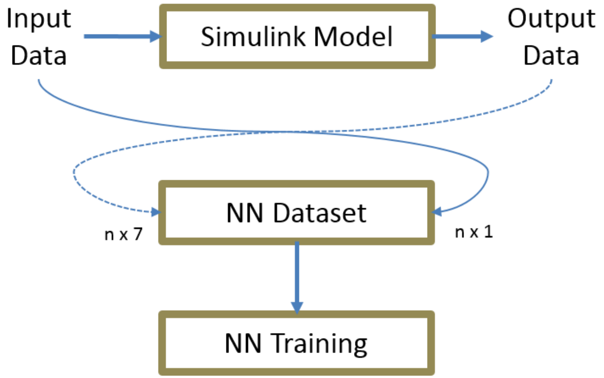
- **Build the ANN architecture with Deep Learning Toolbox.**

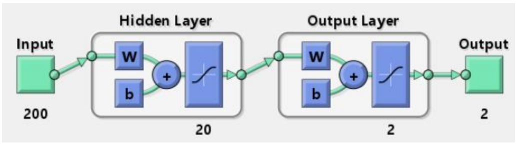
3. Training

- **Adjust relative neural parameters to reach desired values.**

4. Validation

- **Iterative process using physical inputs to validate ANN and Virtual Model.**

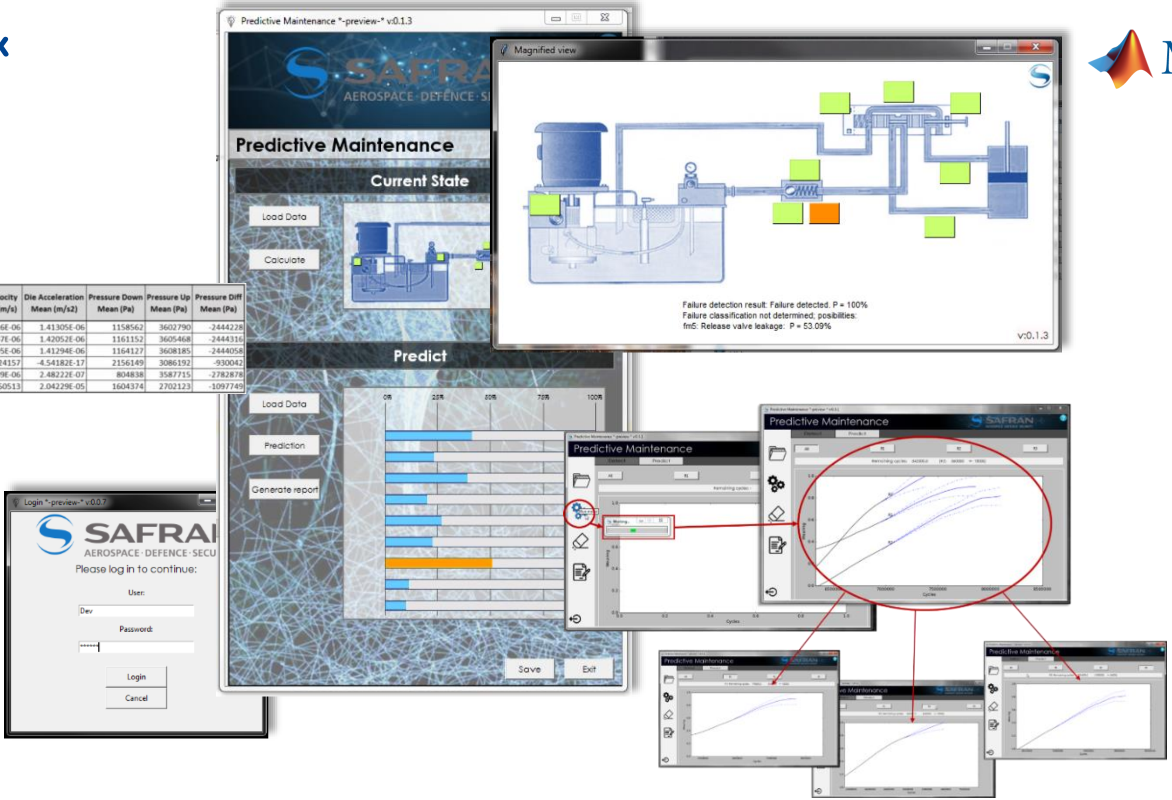




Supervised learning process

Application – Hydraulic Press

GUI Layout Toolbox



Measure Nº	Die Position Mean (m)	Max Die Position (m)	Die Velocity Mean (m/s)	Die Acceleration Mean (m/s2)	Pressure Down Mean (Pa)	Pressure Up Mean (Pa)	Pressure Diff Mean (Pa)
1	0.23887042	0.84838813	-1.06516E-06	1.41305E-06	1158562	3602790	-2444228
2	0.23889914	0.84838824	-1.06437E-06	1.42052E-06	1161152	3605468	-2444316
3	0.23892645	0.84838844	-1.06495E-06	1.41294E-06	1164127	3608185	-2444058
4	0.5804348	0.79657293	0.00724157	-4.54182E-17	2156149	3086192	-930042
5	0.19327594	0.82691477	-1.3889E-06	2.48222E-07	804838	3587715	-2782878
6	0.42341755	0.84832075	0.00350513	2.04229E-05	1604374	2702123	-1097749

MathWorks®

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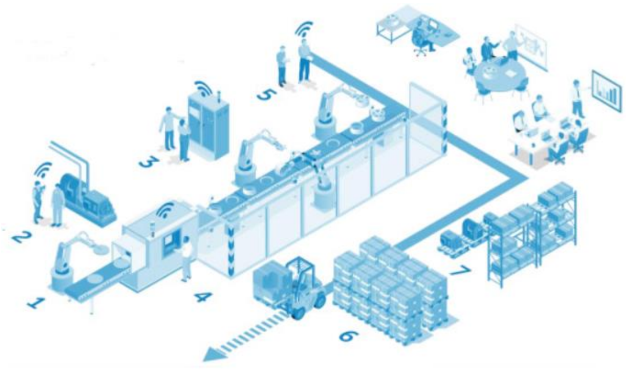
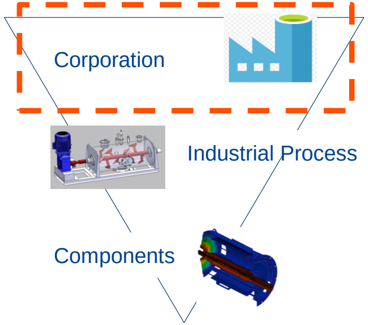
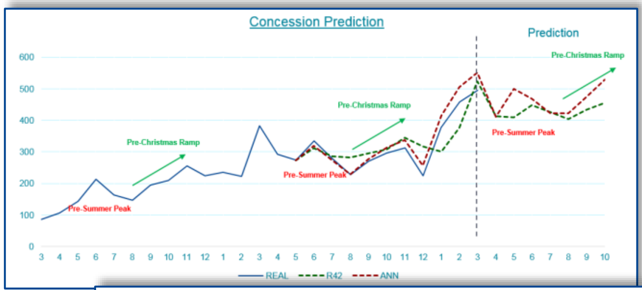
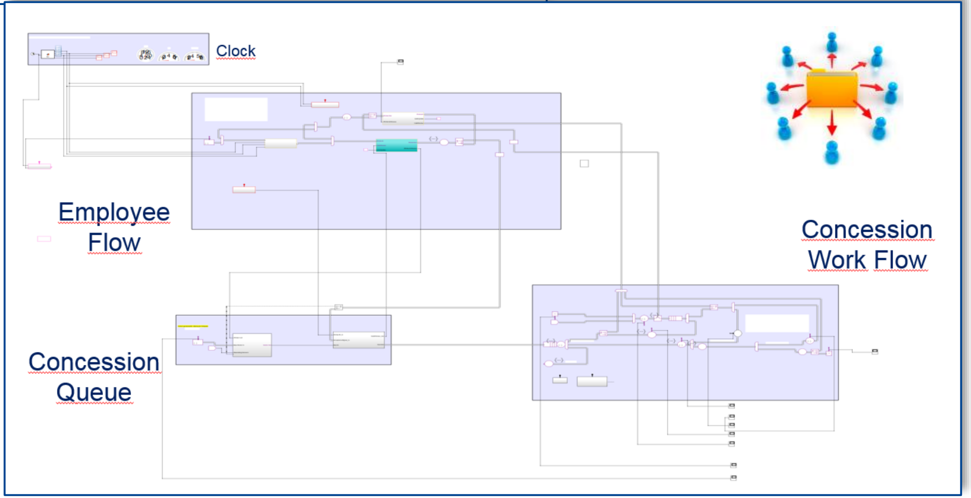
SAFRAN SIMULATION APPLICATIONS



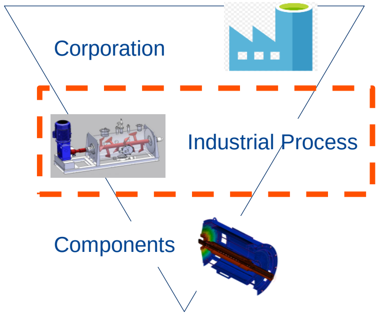
Application – Work Load Distribution

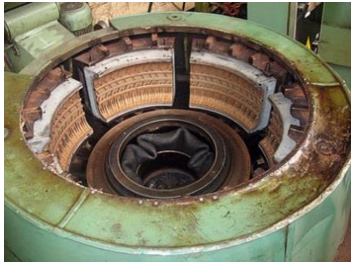


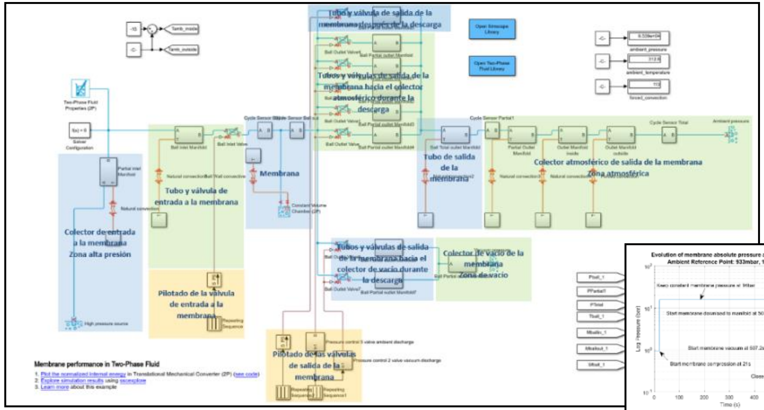


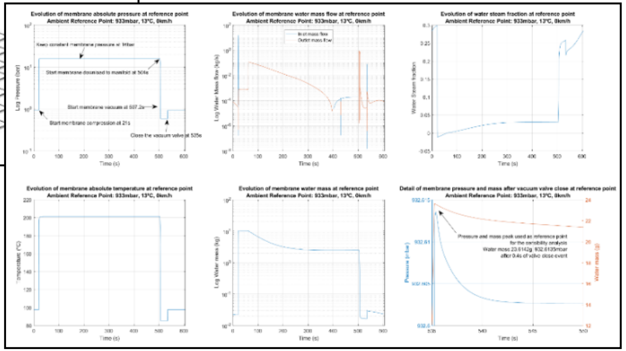


Application – Tire Vulcanizing Furnace

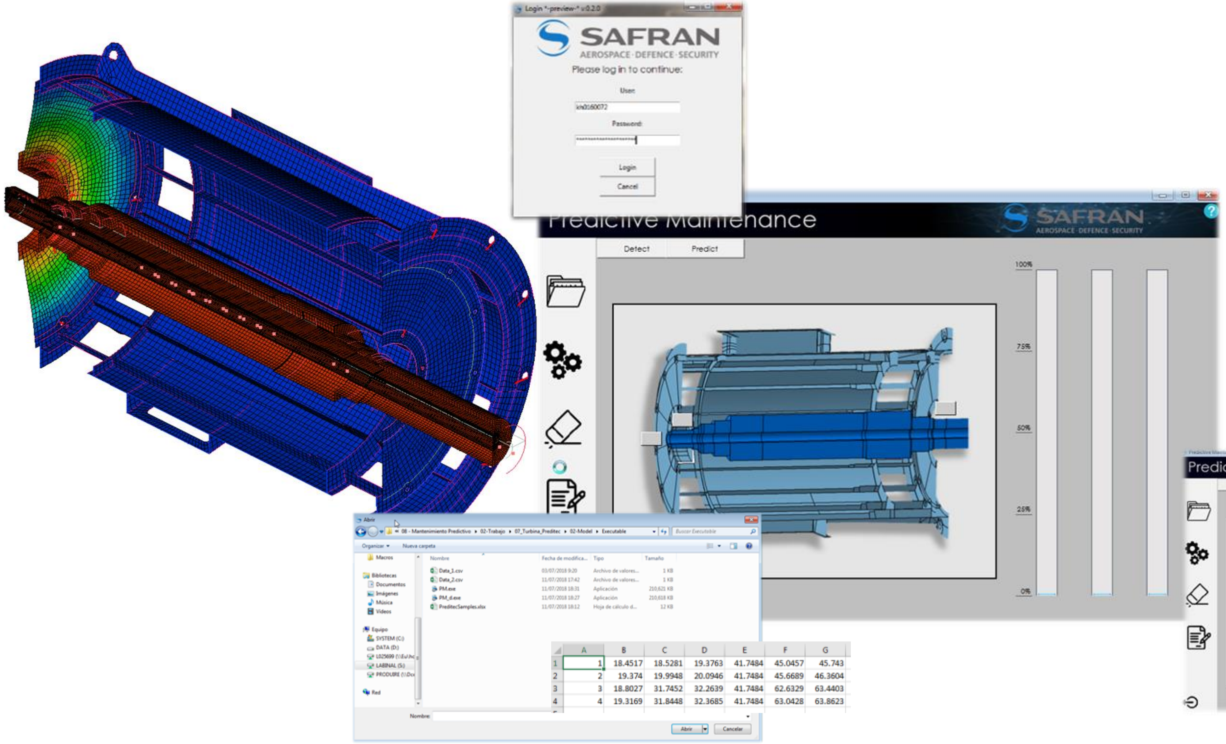


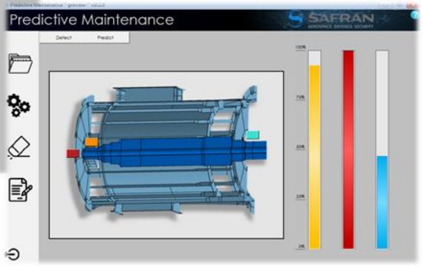


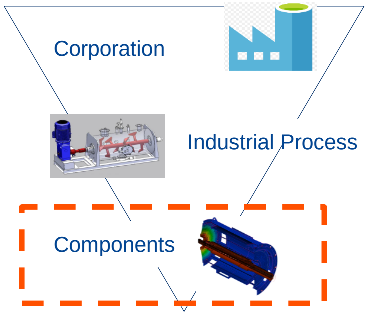




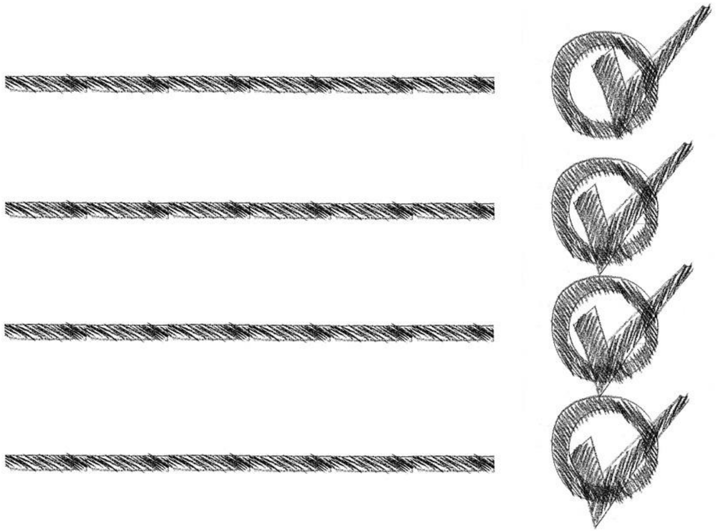
Application – Electric Generator







LESSONS LEARNT



Lessons learnt

- Listening customers to pivot from SHM to Simulation & Predictive Maintenance.

- Finding collaboration to keep growing knowledge and portfolio.

- Adapt processes to be flexible for customer demands.

POWERED BY TRUST

Iván Pérez

ivan.perez-salido@safrangroup.com