SMART FLEET MAINTENANCE SUMMIT 360

PROGNOSTIC EXPERT SYSTEM FOR RAILWAY FLEET MAINTENANCE

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Innovation & Technologies

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VOYAGEURS

HEADLINES

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01. INTRODUCTION

INTRODUCTION

COMMUNICATING TRAINS :
A NEW OPPORTUNITY TO OPTIMIZE MAINTENANCE

The emergence of **new generations of connected trains** has fundamentally transformed the rolling stock landscape.

Indeed, the introduction of on-board/wayside diagnostics systems presents a significant opportunity for reducing maintenance costs, while also having a strong positive impact on reliability, availability and quality of service.

Following this way, a new approach based on remote diagnosis and Condition Based Maintenance (CBM) has been incorporated into the SNCF maintenance process.

+ More than 300 natively connected NAT (Alstom)
+ More than 100 natively connected REGIO2N (Alstom)
+ More than 200 IoT connected trains
+ Logical and analogical data
+ Enhanced contextual information

INTRODUCTION

COMMUNICATING TRAINS :
A NEW OPPORTUNITY TO OPTIMIZE MAINTENANCE

DISTINCT MAINTENANCE TYPES

- Maintenance
  - Preventive
    - Scheduled
    - Predictive
  - Reactive

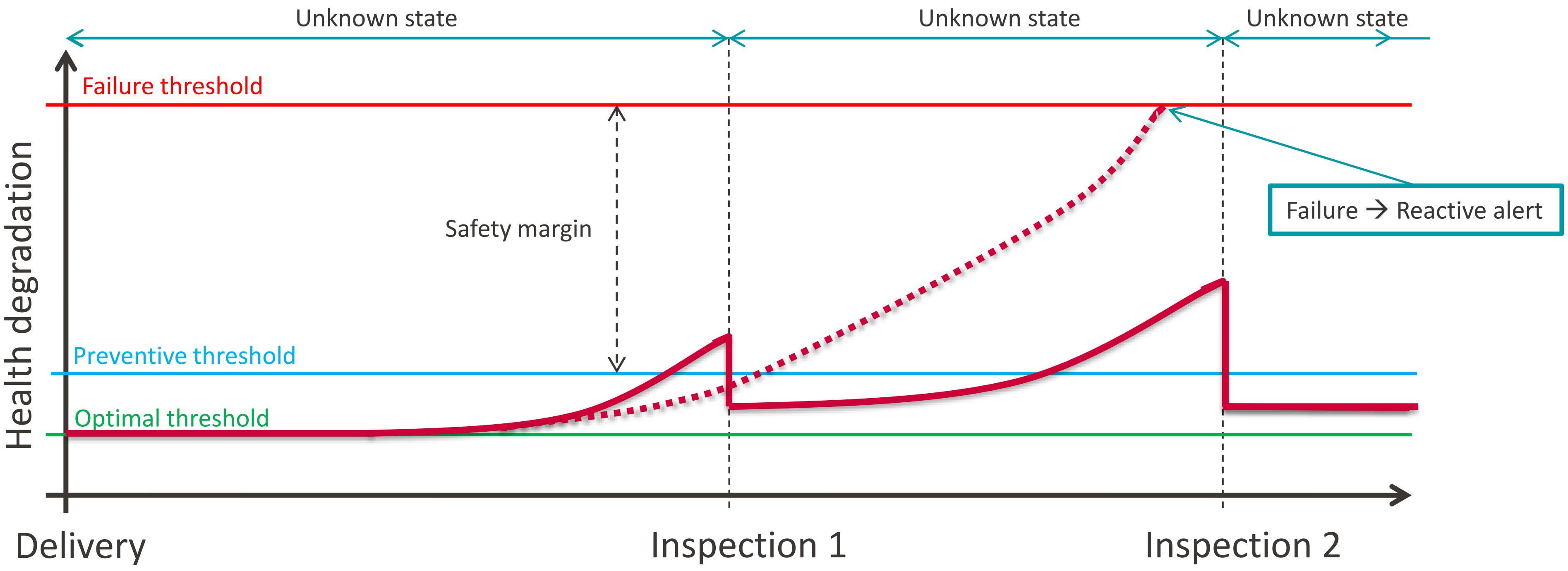
CHALLENGES

Reliability	“up time” and safety increase
Ownership cost	Minimize maintenance costs
Customers reputations	Up of availability and quality

To optimize dependencies between systematic, corrective and condition-based maintenance,
SNCF has set a maintenance solution based on real-time data analysis

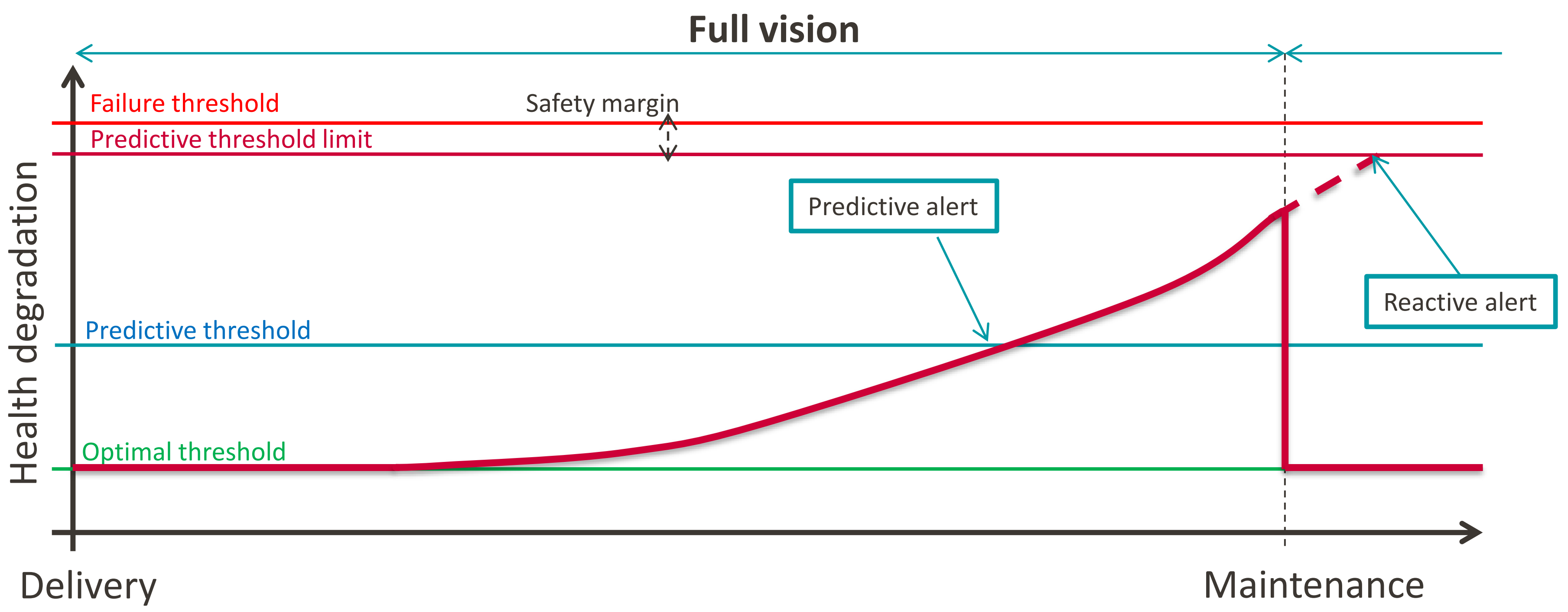
INTRODUCTION

OPTIMIZING MAINTENANCE



INTRODUCTION

OPTIMIZING MAINTENANCE



INTRODUCTION

REMOTE DIAGNOSIS AND PREDICTIVE MAINTENANCE USE CASES

Air production
Performance

Battery
Performance

Pantograph
Static effort and rising/falling time

HVAC
Performance

Passenger access
Performance

Traction
performance

Brake
performance

Toilet
tank levels









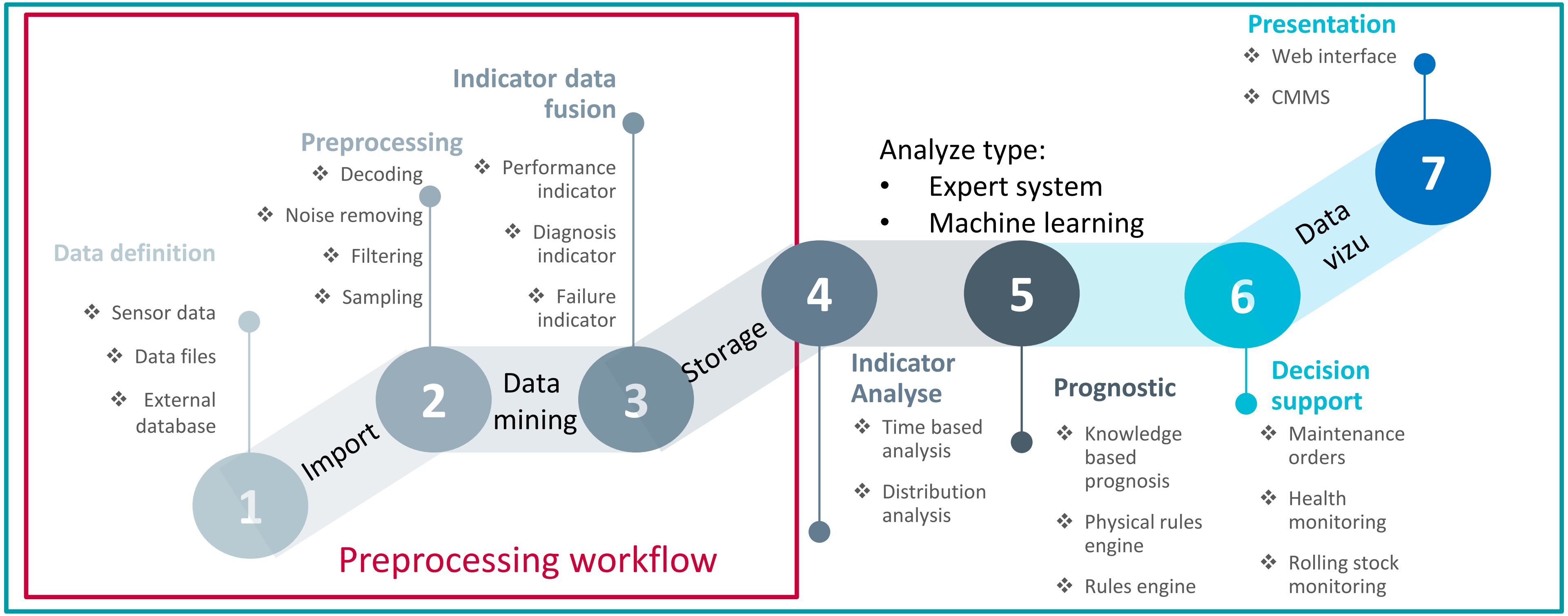
02. FROM RAW DATA TO INDICATOR DESIGN

FROM RAW DATA TO INDICATOR DESIGN

DATA WORKFLOW

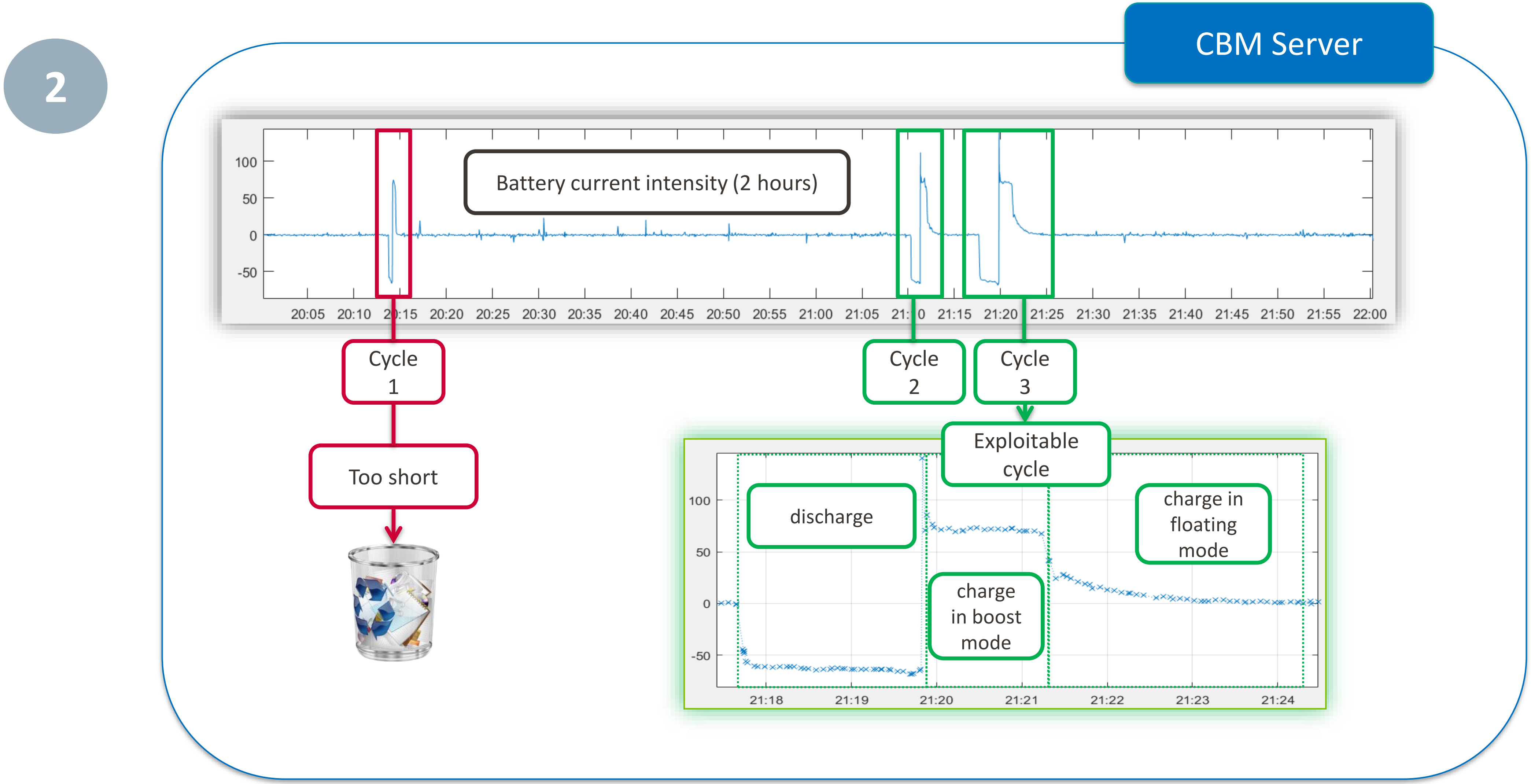
SNCF prognostic expert systems

(Verdun et al. - WCRR 2019)



FROM RAW DATA TO INDICATOR DESIGN

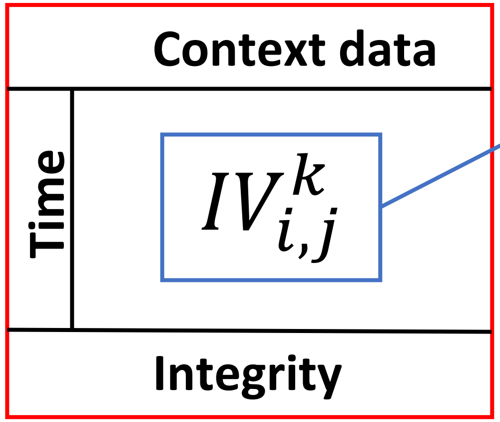
DATA PROCESSING : FILTERING AND MARKER CREATION



FROM RAW DATA TO INDICATOR DESIGN

DATA PROCESSING : HEALTH INDICATOR AGGREGATION INTO INDICATOR VECTORS

3

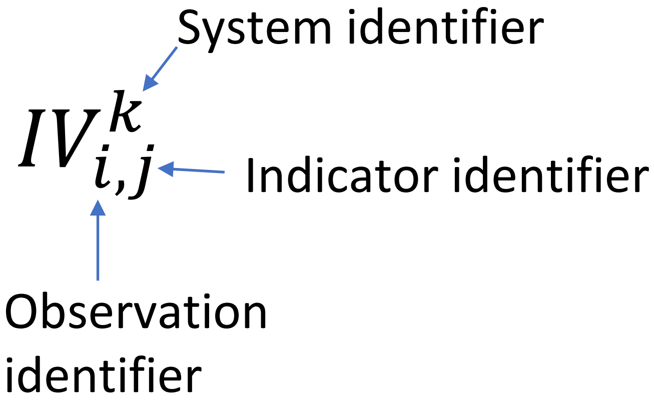


$IV = function(data(t))$

Example of function:

- minimum,
- maximum,
- time of reference,
- area,
- slope,
- inflexion point…

IV baseline system on train fleet:



FROM RAW DATA TO INDICATOR DESIGN

DATA PROCESSING : STRUCTURATION AND STORAGE OF INDICATOR VECTORS (IV)

3

n indicators

N observations (100 max)

Datetime, Context, Filter

$k = 1$

$$
\begin{array}{ccccc}
IV^1_{1,1} & & IV^1_{1,j} & & IV^1_{1,n} \\
 & & \vdots & & \\
\boxed{IV^1_{i,1}} & \dots & IV^1_{i,j} & \dots & IV^1_{i,n} \\
 & & \vdots & & \\
IV^1_{N,1} & & IV^1_{N,j} & & IV^1_{N,n}
\end{array}
$$

k

System identifier

$IV^k_{i,j}$

Indicator identifier

Observation identifier

$k = L$

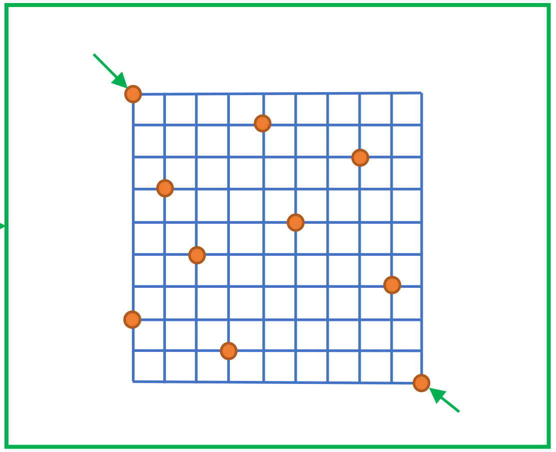
Number of systems

$IV^L_{N,n}$

Number of indicators

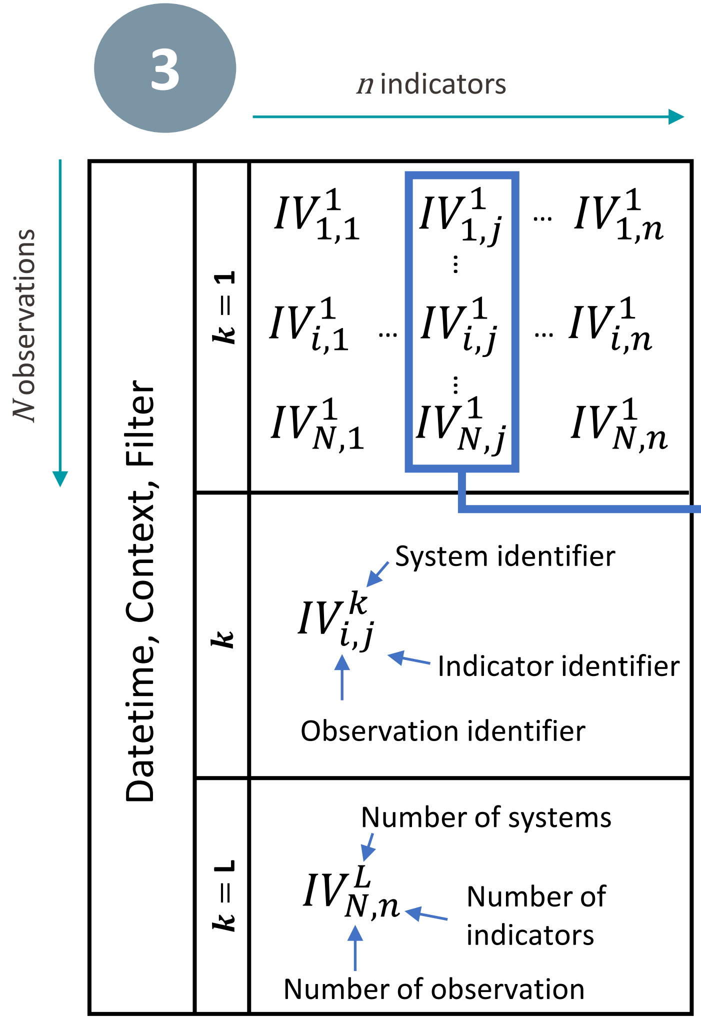
Number of observation

Map of computed indicators for at a same time

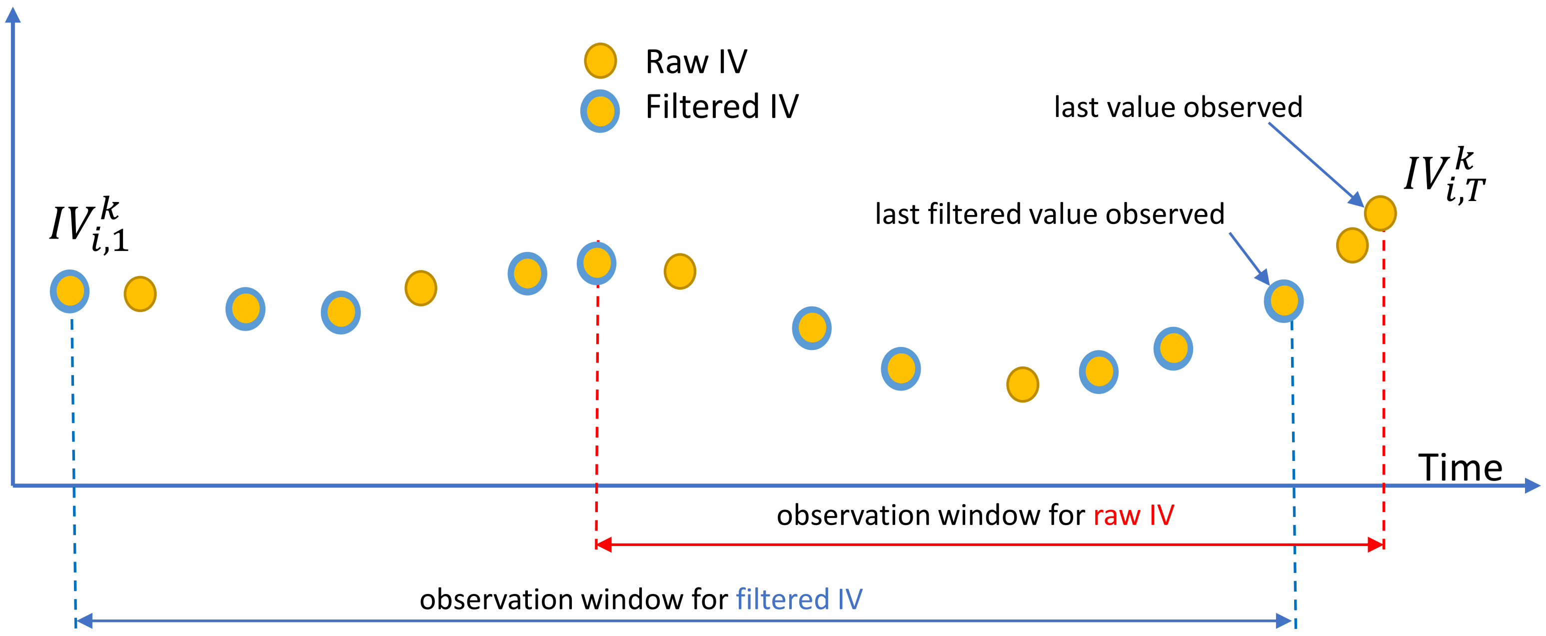


FROM RAW DATA TO INDICATOR DESIGN

DATA PROCESSING : STRUCTURATION AND STORAGE OF INDICATOR VECTORS (IV)



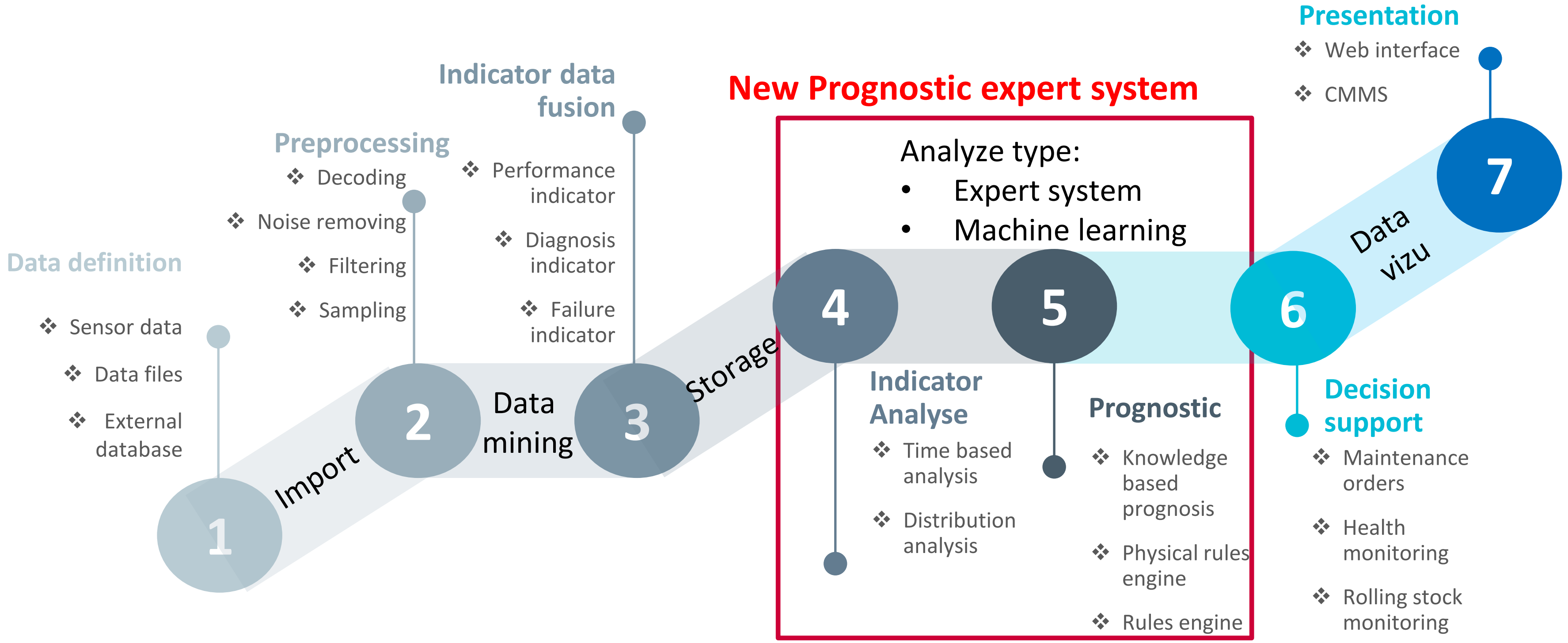
Observation window for the same indicator



03. PROGNOSTIC EXPERT SYSTEM BASED ON FLEET STATISTICS

FUTUR SIGNALING SYSTEM

NEW PROGNOSTIC EXPERT SYSTEM BASED ON FLEET STATISTICS



03.

PROGNOSTIC EXPERT SYSTEM BASED ON FLEET STATISTICS

HYPOTHESES

HYPOTHESES

DATAFRAME HYPOTHESIS

Accuracy: each dataframe is plenty accurate to describe the functionality of a system in a way that a physical action on the system has a direct influence on the dataframe.

Amount of data: many dataframes have been collected in this study and their number will increase in time.

(ALSTOM R2N IDF : ~1000 doors, ~500 batteries, ~800 HVAC…)

Independency: each system being completely independent from one to another

=> The numerous dataframes allows a relevant computation of fleet statistics

HYPOTHESES

DISTRIBUTION HYPOTHESIS

Health status: the health of a system differs from one train to another depending on several parameters such as manufacturing quality, delivery date, operating conditions, aging or maintenance operations quality.

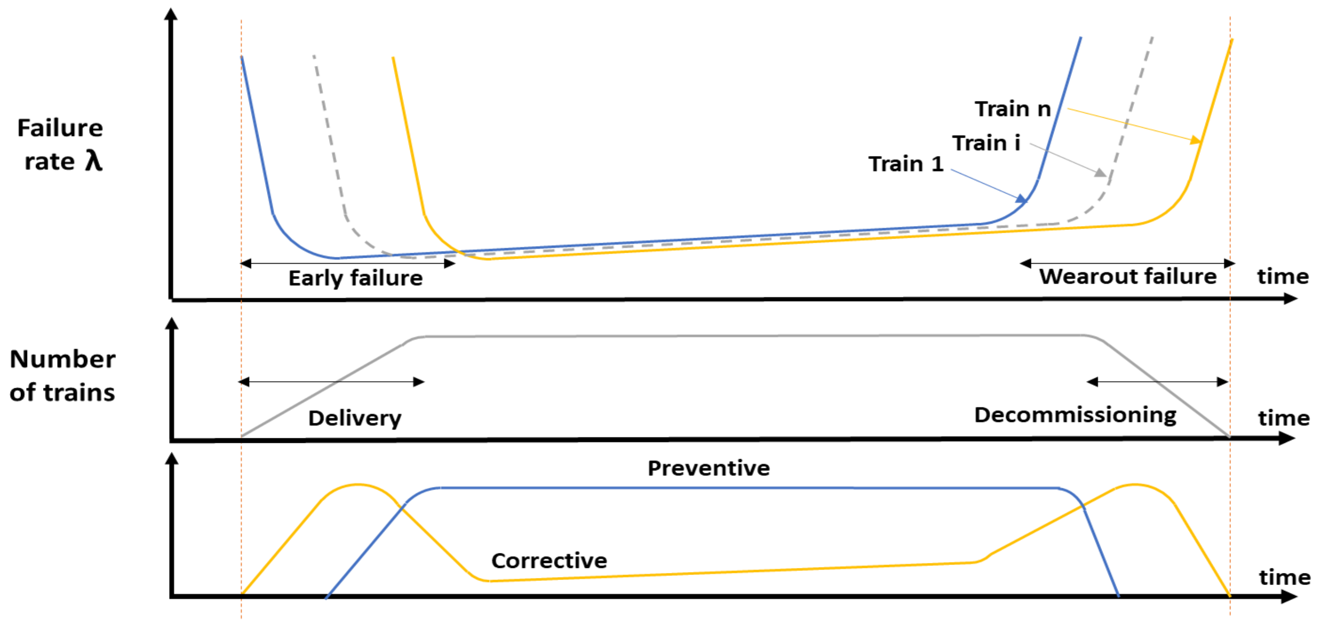
Maintenance quality: systematic maintenance is effective enough and reliability is suitable.

=> Most systems are healthy and only some of them must be repaired.

=> Distribution of health states through the whole train fleet is suitable for statistical computations

HYPOTHESES

AGEING, MAINTENANCE NEED AND OPERATIONAL EFFECTS



Time effect: ageing effect, maintenance operations, modifications or upgrades have an impact on the health state

Maintenance need: the need for reactive maintenance is higher during the delivery and the end-of-life period

=> bathtub curve of the failure rate

=> The distribution shape will also change in time and thus the signaling system must follow the maintenance need

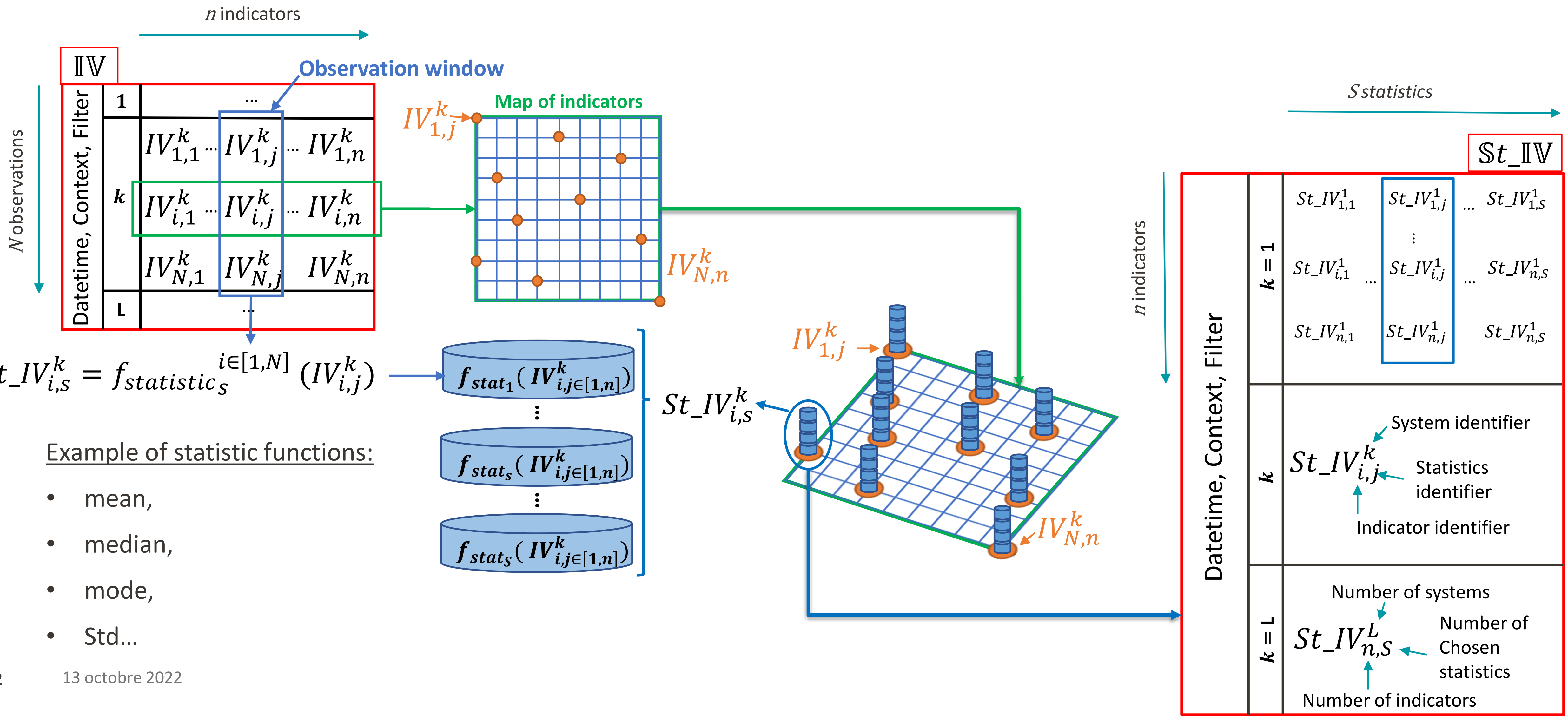
03.

PROGNOSTIC EXPERT SYSTEM BASED ON FLEET STATISTICS

DATA POST-PROCESSING

DATA POST-PROCESSING

From Indicator Vector (IV) to Statistical Indicator Vector(St_IV)



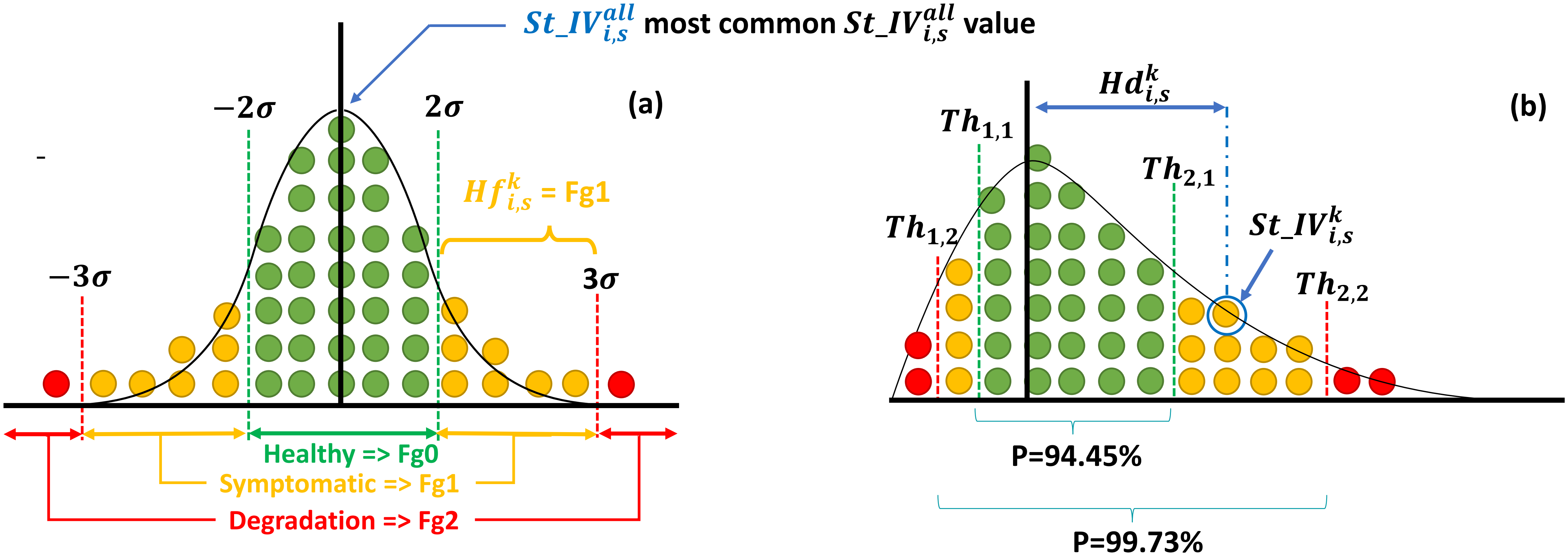
$$St\_IV_{i,s}^{k} = f_{statistic_s}^{i\in[1,N]}(IV_{i,j}^{k})$$

Example of statistic functions:

- mean,
- median,
- mode,
- Std…

DATA POST-PROCESSING

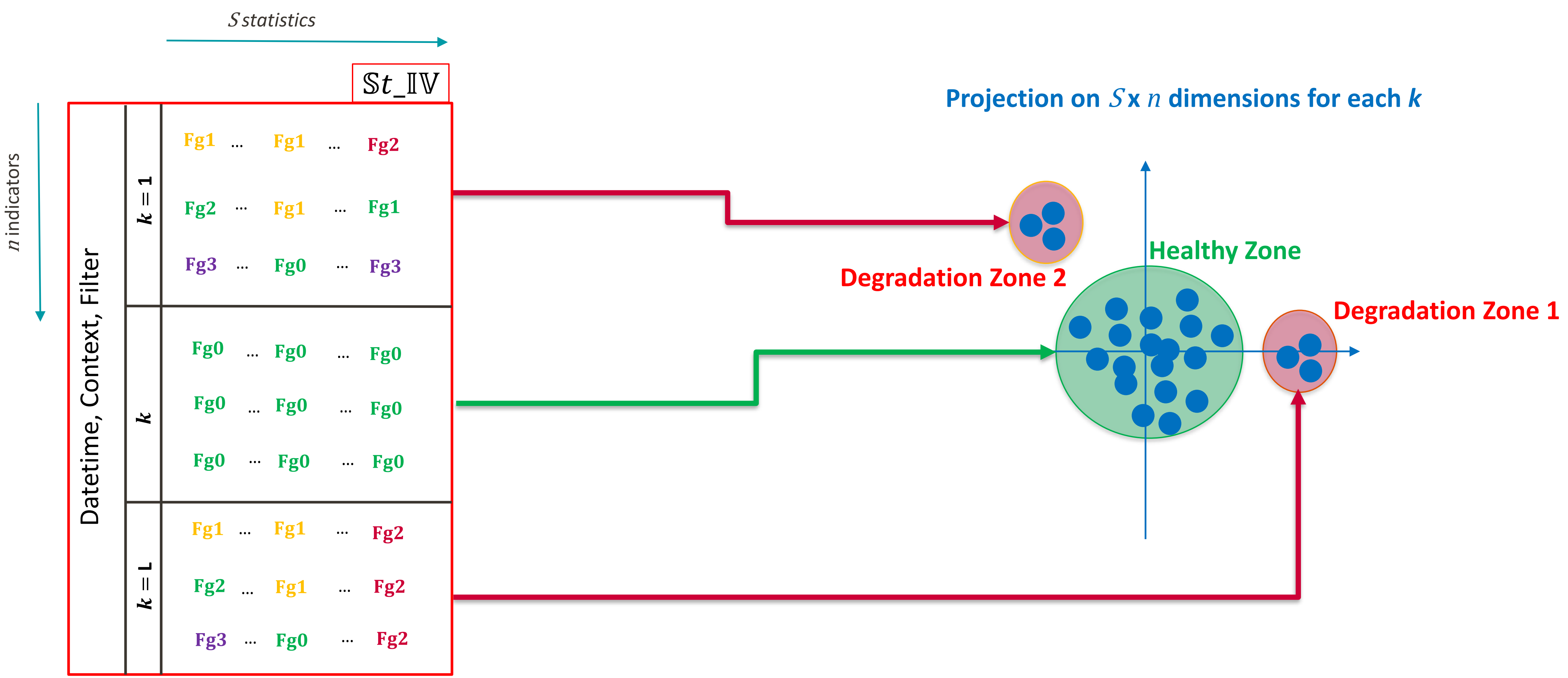
Distribution for each indicator for the complete fleet



=> Others complex distributions (« unknow ») will be treated with a Kernel density estimation

DATA POST-PROCESSING

Classification, clustering and failure signature

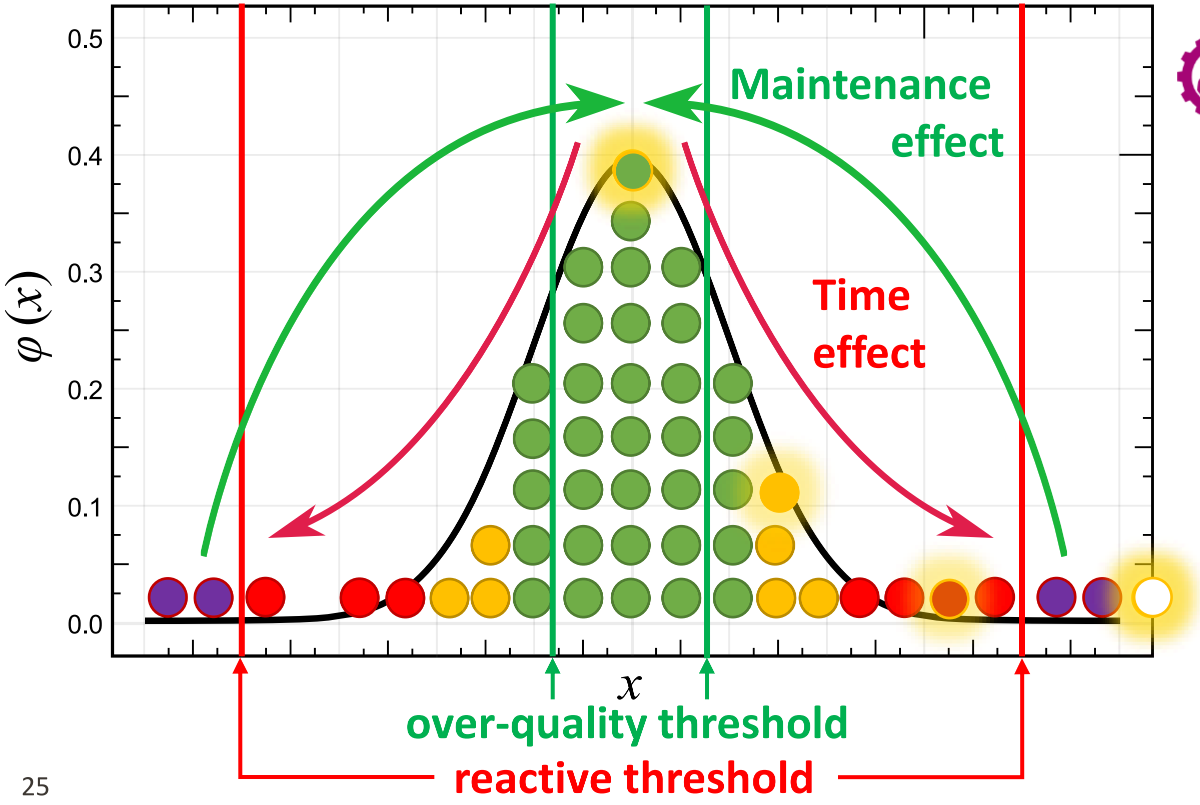


DATA POST-PROCESSING

Maintenance distribution overview

=> What happened if we let the system unregulated over lifetime ?

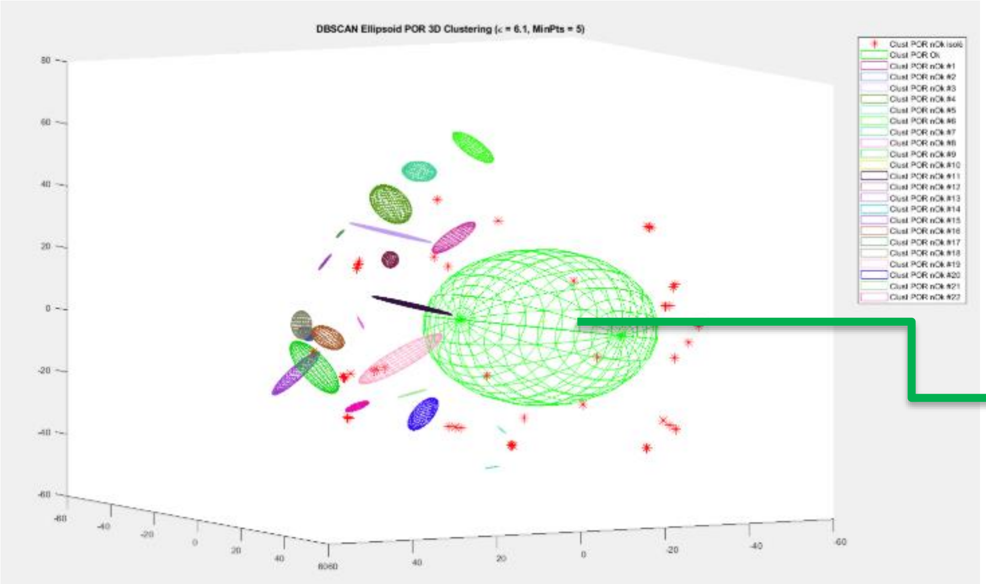
=> Why boundaries are needed and useful ? And how we give senses to those boundary ?



04. CONCLUSION AND PERSPECTIVES

CONCLUSION

Promising results have already been observed:



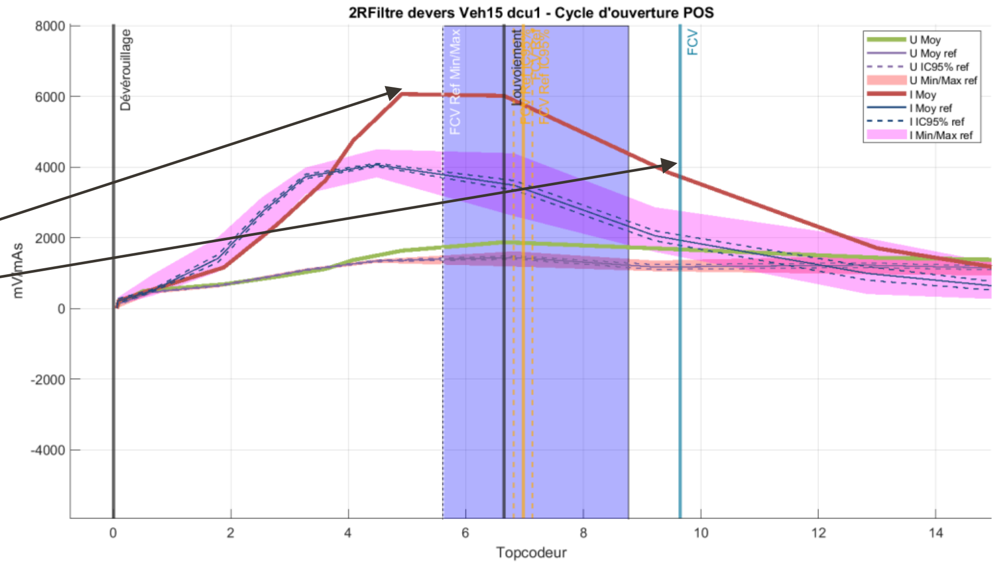
Healthy Zone

Next study will be dedicated to:

- Analyze future results obtained by this prognostic system over a year of exploitation
- Verify starting hypotheses and how results may impact the development of the expert system
- Implement the human in-the-loop system in the whole fleet maintenance statistics system
- Implement auto-generator indicators to increase the potential number of features identification (problem of curse of dimensionality).

PRELIMINARY RESULTS

Example of identified clusters

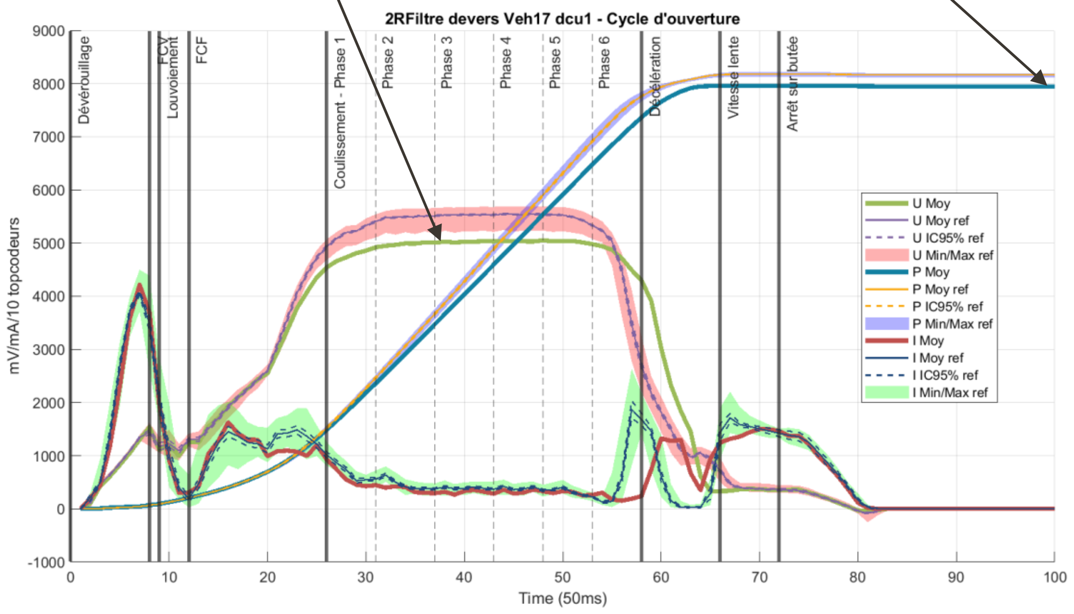


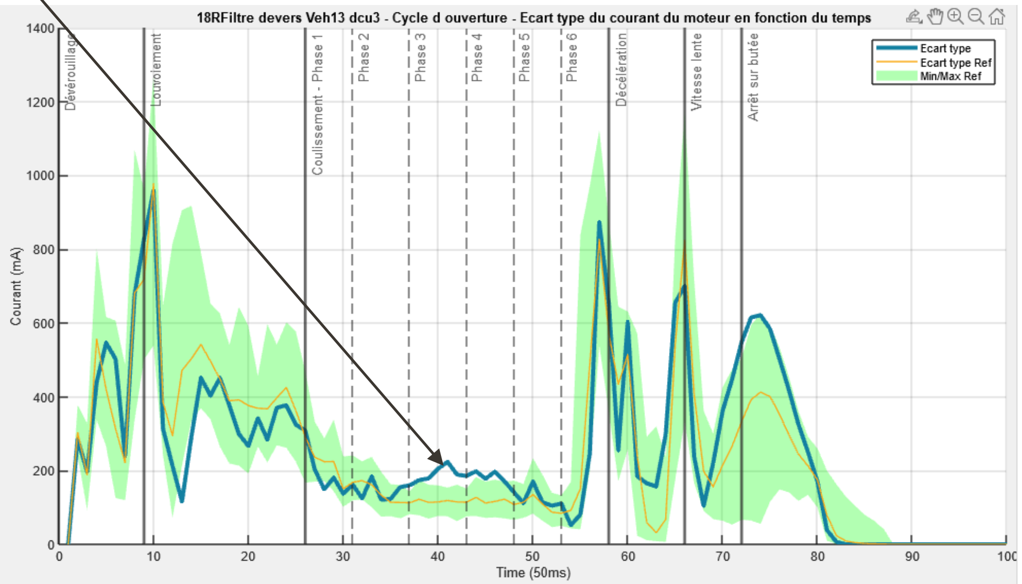
Cluster 4 : Unidentified failure

Cluster 1 : Access door with end-stop problem

Cluster 2 : Tough sliding movement

Cluster 3 : Access door with motorization problem





PRELIMINARY RESULTS

Predictive maintenance IHM

Operation R2N_VL200K_AV sur rame 3R 5700005

Tracabilité éditée le 2022-08-23 17:08:21

Programmation PHP :	Non programmée
Début visite :	Non programmée
Fin visite :	Non programmée

Taches validées par CBM

Tâches	VE1NV11 5700005		VI2NV12 5714005	VI1NV13 5721005				VI2NV14 5754005	VI1NV15 5762005				VI2NV16 5774005	VI1NV17 5783005				VE2NV20 57070	
DCU com a 7 14 21 28 jour	✓	✓		✓	✓	✓	✓		✓	✓	✓	✓		✓	✓	✓	✓	✓	✓
Date (jours)	-	-		0	0	0	0		0	0	0	0		0	0	0	0	-	-
	2	1		3	4	5	6		7	8	9	10		11	12	13	14	15	16
POR_FCF				*2022-08-23* ✓	*2022-08-23* ✓	*2022-08-23* ✗	*2022-08-23* ✓		*2022-08-23* ✗	*2022-08-23* ✓	*2022-08-23* ✓	*2022-08-23* ✓		*2022-08-23* ✗	*2022-08-23* ✗	*2022-08-23* ✗	*2022-08-23* ✗		
POR_Effort_ouverture				*2022-08-23* ✓	*2022-08-23* ✓	*2022-08-22* ✓	*2022-08-22* ✓		*2022-08-23* ✓	*2022-08-22* ✓	*2022-08-22* ✓	*2022-08-22* ✓		*2022-08-22* ✓	*2022-08-12* ✓	*2022-08-23* ✓	*2022-08-23* ✓		
POR_Butée_Ouverture				*2022-08-23* ✗	*2022-08-23* ✗	*2022-08-23* ✗	*2022-08-22* ✗		*2022-08-23* ✓	*2022-08-22* ✗	*2022-08-22* ✗	*2022-08-22* ✓		*2022-08-23* ✗	*2022-08-19* ✓	*2022-08-23* ✗	*2022-08-23* ✗		

Exporter en image Imprimer

?	Inconnue / indéterminée
✓	Validée
✗	Non validée
✓ (gris)	Donnée (validée) non fiable / Dernier état connu
✗ (gris)	Donnée (non validée) non fiable / Dernier état connu
date	Date du dernier cycle de fichiers reçu

ANY QUESTIONS ?

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