The SAMANTA platform

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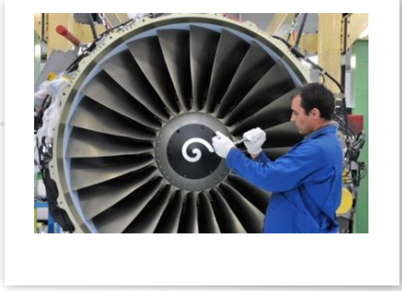
Snecma and Health Monitoring

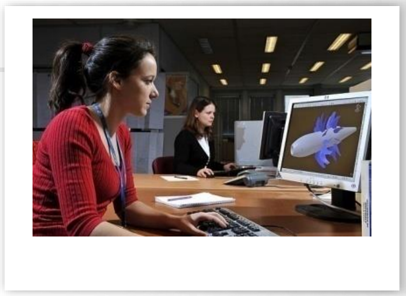
Snecma, Key figures

Revenue in Billion €* 5,9

Employees worldwide * 14 662

Sites worldwide 35

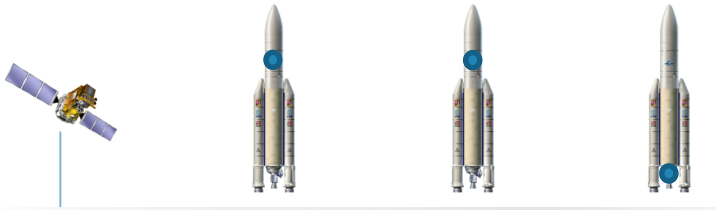




* *As of 2013 December 31st*

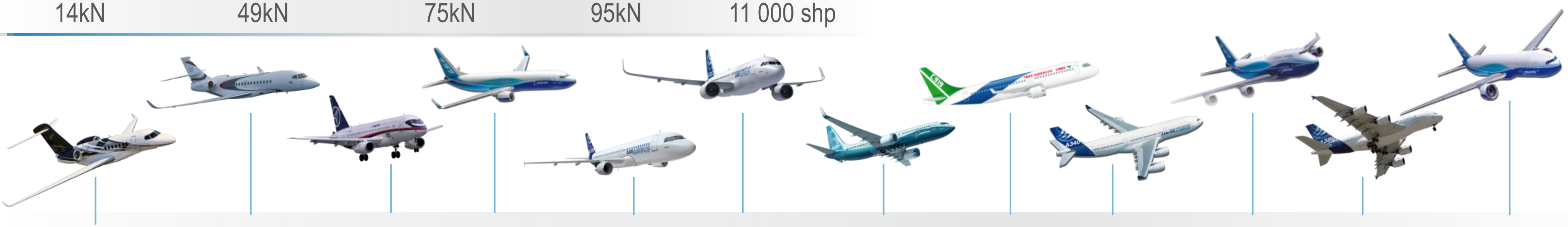
Thrust: from 9 grams to 135 000 kilograms

(1) PowerJet (50/50 Snecma-NPO Saturn)
(2) CFM International (50/50 Snecma-GE)
(3) EPI (ITP, MTU, Rolls-Royce, Snecma)
(4) En coopération avec GE



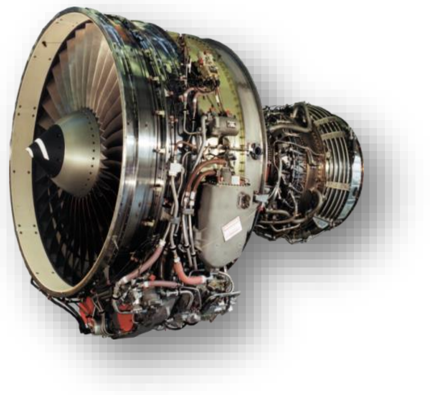
Satellites	Ariane 5	Ariane 5	Ariane 5
PPS ® 1350	HM7B	Vinci	Vulcain ® 2
90 mN	64,8 kN	180kN	1340 kN (main stage)

Alpha Jet	Mirage F1	Rafale	Mirage 2000	A400M
Larzac ®	Atar	M88	M53	TP400 [3]
14kN	49kN	75kN	95kN	11 000 shp



Citation Longitude	Falcon 5X	SSJ100	737	A320	A320neo	737MAX	C919	A340	747	A380	777
Silvercrest ®1C	Silvercrest®1D	SaM146[1]	CFM56-7B[2]	CFM56-5B[2]	LEAP-1A[2]	LEAP-1B[2]	LEAP-1C[2]	CFM56-5C[2]	CF6[4]	GP7200[4]	GE90[4]
9 500 to 12 000 lb	9 500 to 12 000 lb	15 400 to 17 800 lb	19 500 à 27 300 lb	21 600 to 33 000 lb	21 500 to 33 000 lb	21 500 à 28 000 lb	21 500 to 30 000 lb	31 200 to 34 000 lb	52 500 to 72 000 lb	70 000 to 85 100 lb	93 700 to 115 300 lb

CFM56, THE worldwide civil engine aircraft best-seller



CFM56-5B

Nearly 105 millions of cumulative flight hours

More than 5 895 engines in service at 198 operators

Thrust range: 21 600 to 32 000 lb

Applications : Airbus Family A318, A319, A320, A321

A320

CFM56-7B

More than 195 millions of cumulative flight hours

9 801 engines in service at 265 operators

Thrust range : 19 500 to 27 300 lb

Applications : Boeing Family 737-600, 737-700, 737-800, 737-900

Boeing 737-800

As of 2013 Agust 31st

CFM a 50/50 joint company of Snecma (Safran) and GE.

Health Monitoring

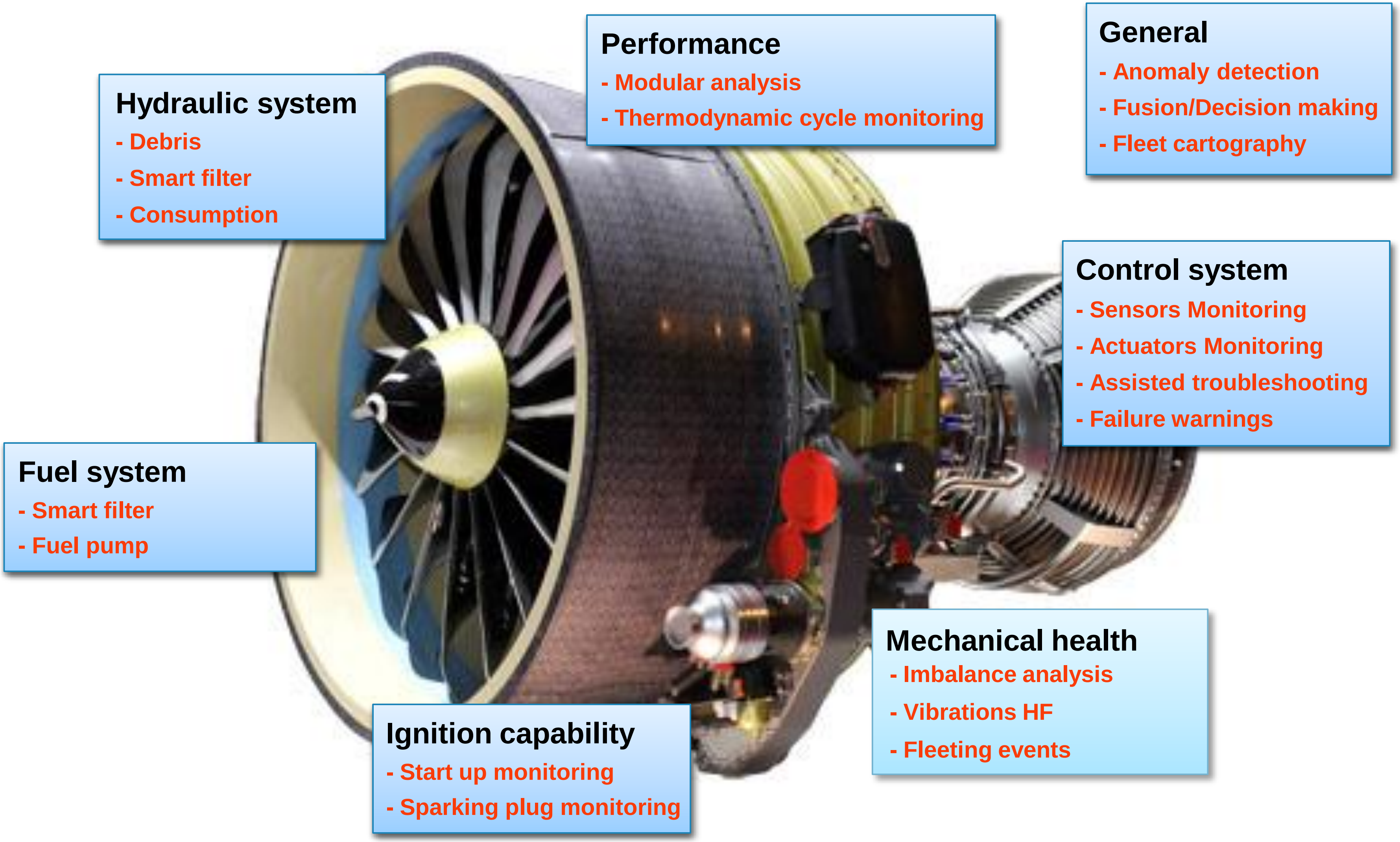
- **Health Monitoring is a nearly real-time monitoring of system parameters in order to:**
  - Detect signs of failure
  - Predict the remaining time before a required intervention (inspection or maintenance)
  - Identify faulty components

- **Improve operational aircraft availability**
  - Aircraft takes off on time, lands on time at destination
  - Reduction of operational events
  - Planning and optimization of maintenance
  - Reduction of stopping time engine

- **Reduce maintenance costs**
  - Assisted troubleshooting (isolating the faulty element)
  - Limit secondary damage

- **Note: The health monitoring is a maintenance function, no impact on the current flight and aircraft safety**

Engine systems monitored



Hydraulic system
- Debris
- Smart filter
- Consumption

Performance
- Modular analysis
- Thermodynamic cycle monitoring

General
- Anomaly detection
- Fusion/Decision making
- Fleet cartography

Control system
- Sensors Monitoring
- Actuators Monitoring
- Assisted troubleshooting
- Failure warnings

Fuel system
- Smart filter
- Fuel pump

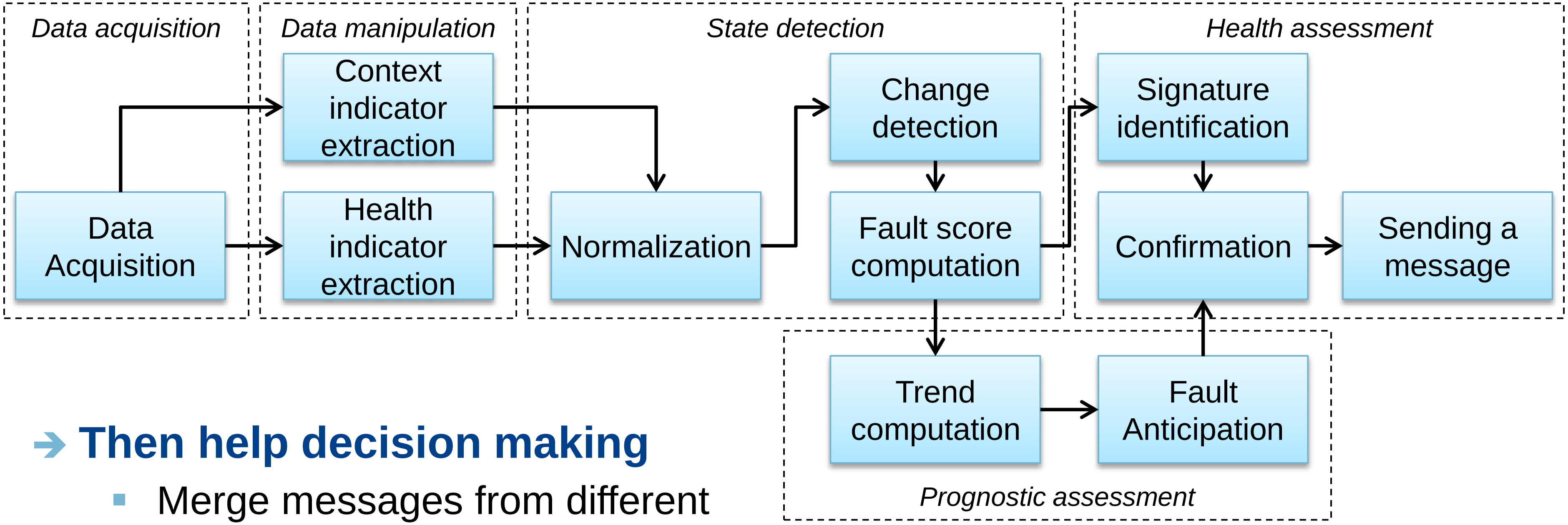
Ignition capability
- Start up monitoring
- Sparking plug monitoring

Mechanical health
- Imbalance analysis
- Vibrations HF
- Fleeting events

Faults diagnose

➔ Building alert messages from acquired measurements

- Using physical models
- Learning behavior using mathematical models
- Identification of fault signatures, drifts detection, component targeting



➔ Then help decision making

- Merge messages from different diagnose sources

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Introduction to SAMANTA

Snecma Algorithm Maturation ANd Test Application

Introduction to SAMANTA

➔ What is SAMANTA ?

- SAMANTA (Snecma Algorithm Maturation ANd Test Application) is an environment for **Design, Development** and **Maturation** of algorithms based on 3 items

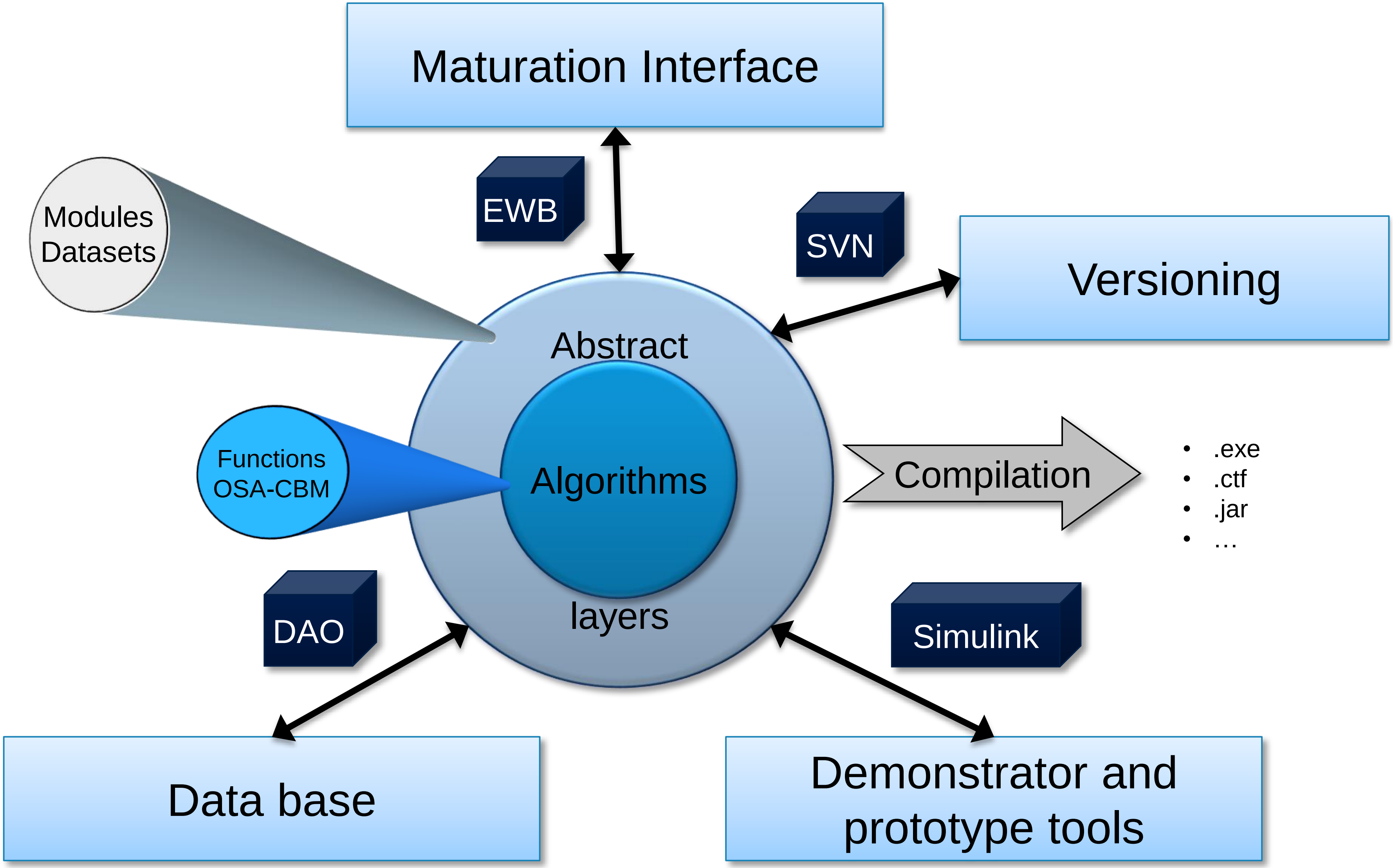
➔ Why develop this platform ?

- To enable engineers to quickly and easily lay out algorithms without special knowledge in mathematics or computer science
- To facilitate exchanges between algorithm designers through scripts/displays/ common and consistent operations
- To capitalize on algorithms
- To create a complete interface between algorithms, data and associated documents

➔ Why with MATLAB?

- To quickly and easily create a platform giving the freedom to design algorithms through written code or through connecting blocks in Simulink

SAMANTA environment



- .exe
- .ctf
- .jar
- …

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Presentation of SAMANTA objects

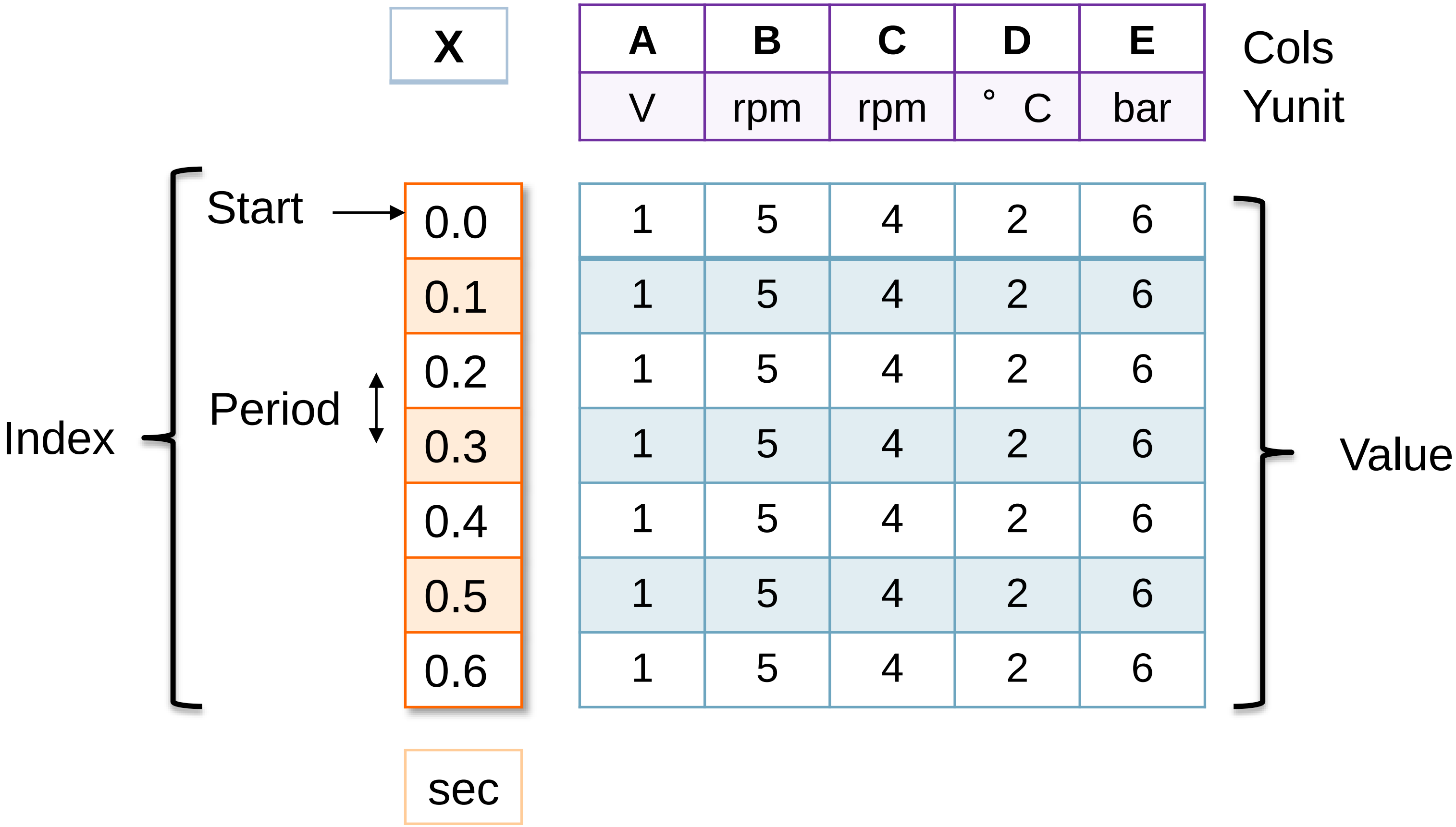
Signal, Opset, Mnode

SAMANTA objects – the signal

- **Algorithms process input data and produce results. These data come from:**
  - Flight measures or flight tests
  - Intermediate results produced by other algorithms

- **The SAMANTA *signal* is a structure containing and formalizing data through a standard:**
  - Table of values
  - Associated properties

SAMANTA objects – the signal



A	B	C	D	E	
V	rpm	rpm	° C	bar	

Cols

Yunit

X					
0.0	1	5	4	2	6
0.1	1	5	4	2	6
0.2	1	5	4	2	6
0.3	1	5	4	2	6
0.4	1	5	4	2	6
0.5	1	5	4	2	6
0.6	1	5	4	2	6
sec					

Index

Start →

Period ↕

Value

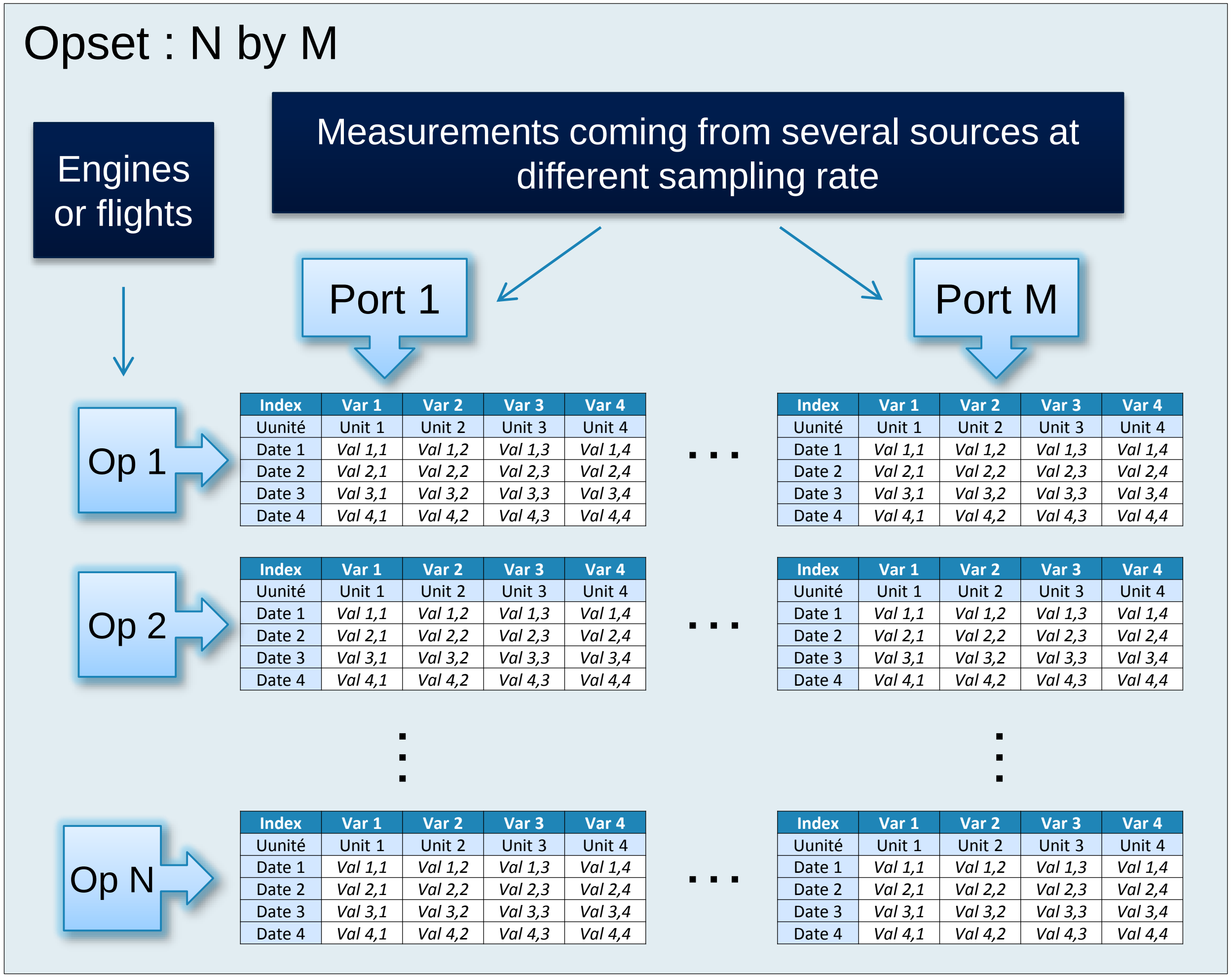
SAMANTA objects – the opset

- **It is necessary to store the signals in MATLAB files: the SAMANTA object *opset* defines a list where to store the signals.**
  - Pointer to a backup file (.mat)

- **The *opset* is a sheet with n leaves, called** operations
  - Each operation comprises a series of signals
  - Signals must be similar from one operation to another
  - Easy access to all the information stored in the structure of the opset

- **The *opset* is serializable**
  - It is suitable for any method of execution of the algorithm

SAMANTA objects – the opset



Opset : N by M

Engines or flights

Measurements coming from several sources at different sampling rate

Port 1

Port M

Op 1

Index	Var 1	Var 2	Var 3	Var 4
Uunité	Unit 1	Unit 2	Unit 3	Unit 4
Date 1	*Val 1,1*	*Val 1,2*	*Val 1,3*	*Val 1,4*
Date 2	*Val 2,1*	*Val 2,2*	*Val 2,3*	*Val 2,4*
Date 3	*Val 3,1*	*Val 3,2*	*Val 3,3*	*Val 3,4*
Date 4	*Val 4,1*	*Val 4,2*	*Val 4,3*	*Val 4,4*

. . .

Index	Var 1	Var 2	Var 3	Var 4
Uunité	Unit 1	Unit 2	Unit 3	Unit 4
Date 1	*Val 1,1*	*Val 1,2*	*Val 1,3*	*Val 1,4*
Date 2	*Val 2,1*	*Val 2,2*	*Val 2,3*	*Val 2,4*
Date 3	*Val 3,1*	*Val 3,2*	*Val 3,3*	*Val 3,4*
Date 4	*Val 4,1*	*Val 4,2*	*Val 4,3*	*Val 4,4*

Op 2

Index	Var 1	Var 2	Var 3	Var 4
Uunité	Unit 1	Unit 2	Unit 3	Unit 4
Date 1	*Val 1,1*	*Val 1,2*	*Val 1,3*	*Val 1,4*
Date 2	*Val 2,1*	*Val 2,2*	*Val 2,3*	*Val 2,4*
Date 3	*Val 3,1*	*Val 3,2*	*Val 3,3*	*Val 3,4*
Date 4	*Val 4,1*	*Val 4,2*	*Val 4,3*	*Val 4,4*

. . .

Index	Var 1	Var 2	Var 3	Var 4
Uunité	Unit 1	Unit 2	Unit 3	Unit 4
Date 1	*Val 1,1*	*Val 1,2*	*Val 1,3*	*Val 1,4*
Date 2	*Val 2,1*	*Val 2,2*	*Val 2,3*	*Val 2,4*
Date 3	*Val 3,1*	*Val 3,2*	*Val 3,3*	*Val 3,4*
Date 4	*Val 4,1*	*Val 4,2*	*Val 4,3*	*Val 4,4*

Op N

Index	Var 1	Var 2	Var 3	Var 4
Uunité	Unit 1	Unit 2	Unit 3	Unit 4
Date 1	*Val 1,1*	*Val 1,2*	*Val 1,3*	*Val 1,4*
Date 2	*Val 2,1*	*Val 2,2*	*Val 2,3*	*Val 2,4*
Date 3	*Val 3,1*	*Val 3,2*	*Val 3,3*	*Val 3,4*
Date 4	*Val 4,1*	*Val 4,2*	*Val 4,3*	*Val 4,4*

. . .

Index	Var 1	Var 2	Var 3	Var 4
Uunité	Unit 1	Unit 2	Unit 3	Unit 4
Date 1	*Val 1,1*	*Val 1,2*	*Val 1,3*	*Val 1,4*
Date 2	*Val 2,1*	*Val 2,2*	*Val 2,3*	*Val 2,4*
Date 3	*Val 3,1*	*Val 3,2*	*Val 3,3*	*Val 3,4*
Date 4	*Val 4,1*	*Val 4,2*	*Val 4,3*	*Val 4,4*

SAMANTA objects – the mnode

- **The SAMANTA *mnode* (short for "module node") is intended for data algorithmic processing.**

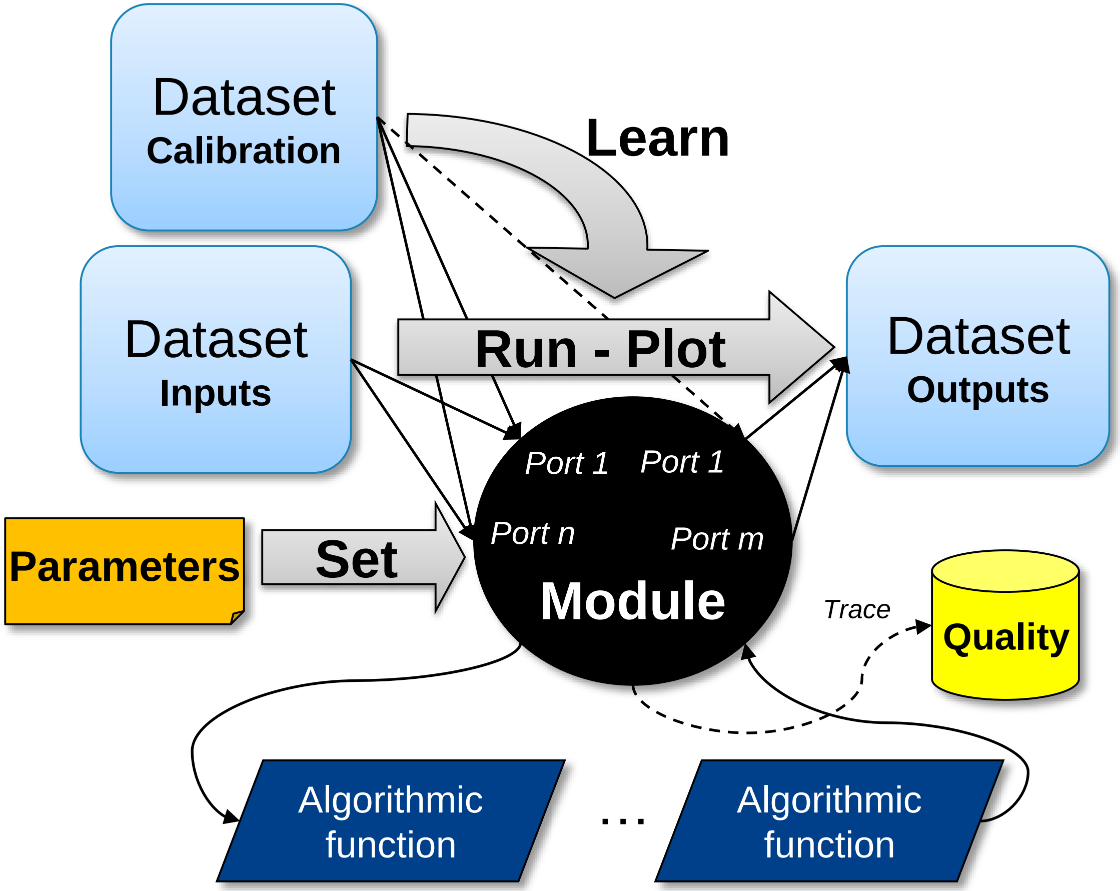
- **It allows the wrapping of any kind of algorithm**
  - Uniform interface
  - Standard handling through a graphical interface

- **The module operation is a sequence of several tasks:**
  - Initialization, parameter validation, data accumulation, learning from accumulated data, processing performance on the inputs, display, ...

- **The user also has different methods to use *mnode* including:**
  - **Set** for parameterization
  - **Run** for execution
  - **Learn** for learning
  - **Plot** for display

SAMANTA objects – the mnode

➔ Summary of the *mnode* operation:



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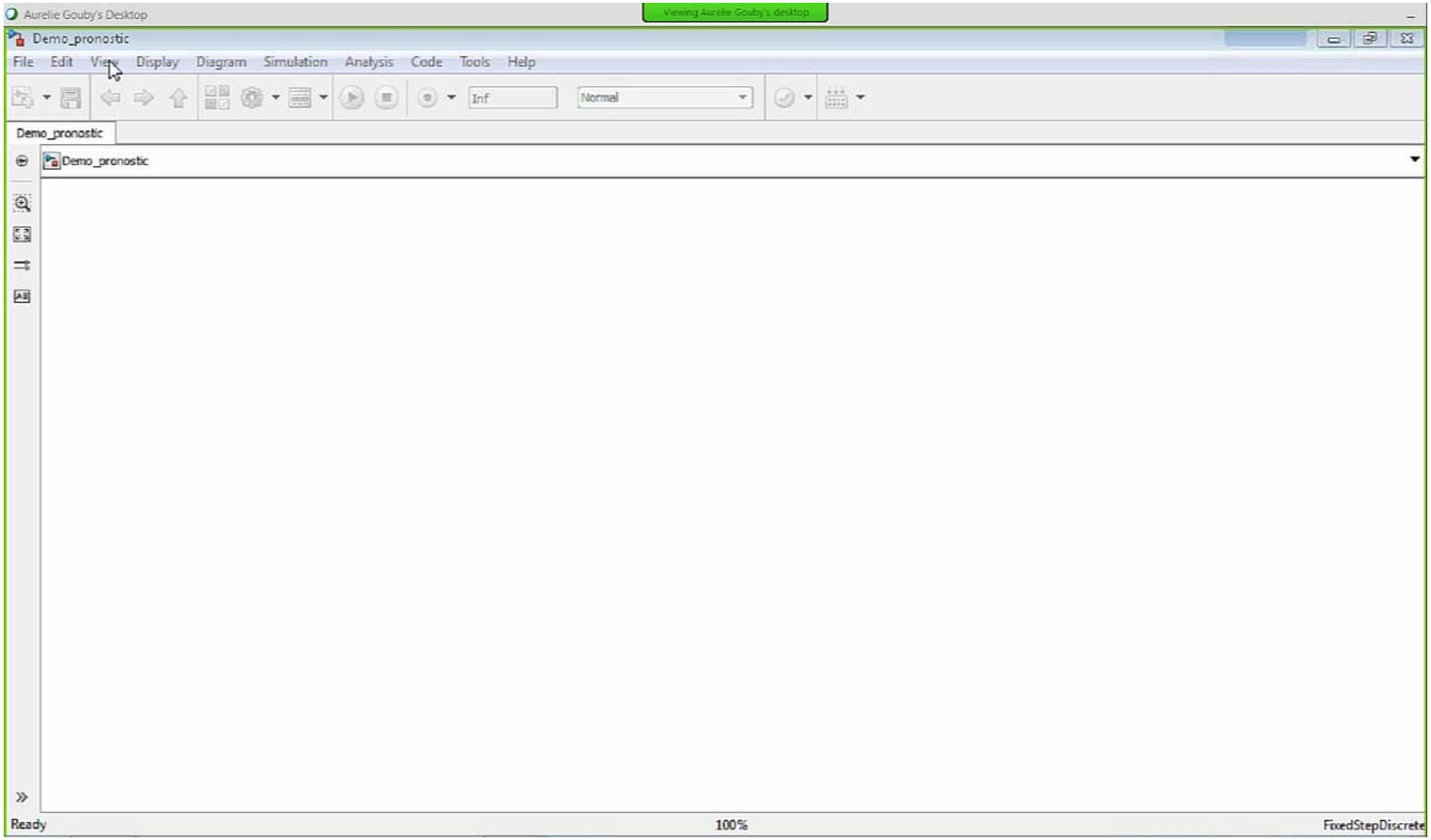
Utilizations

With MATLAB or Simulink

SAMANTA utilization with Simulink

➔ SAMANTA platform can be used via SIMULINK



SAMANTA utilization with a MATLAB script

- **The SAMANTA platform can be used through MATLAB**
  - Create SAMANTA objects you want to use:
    - Treatment Module: *mnode*
    - Input: *opset*
  - Set treatments:
    - Set modules
  - Run treatments
    - Depending on the execution mode selected: run, learn
  - Show results:
    - Via module: plot run mode
    - Via the generated data (*opset*)

- **In 'SCRIPT' mode, execution is a sequence of treatments, each one playing successively its entire *opset* input set and generates an output *opset***

SAMANTA : methods used for the PHM

➔ **The SAMANTA platform makes use of following MathWorks toolboxes:**

- Control System Toolbox
- Database Toolbox
- Fuzzy Logic Toolbox
- MATLAB Compiler
- Optimization Toolbox
- Robust Control Toolbox
- Signal Processing Toolbox
- Stateflow
- Statistics Toolbox
- System Identification Toolbox
- Wavelet Toolbox

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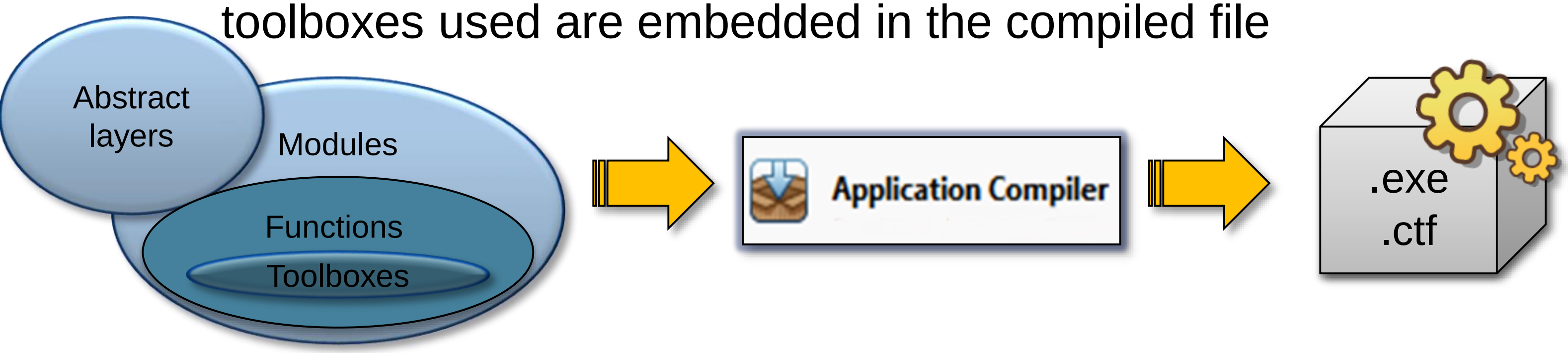
Algorithms compilation and MPS usage

Next steps

Algorithms compilation

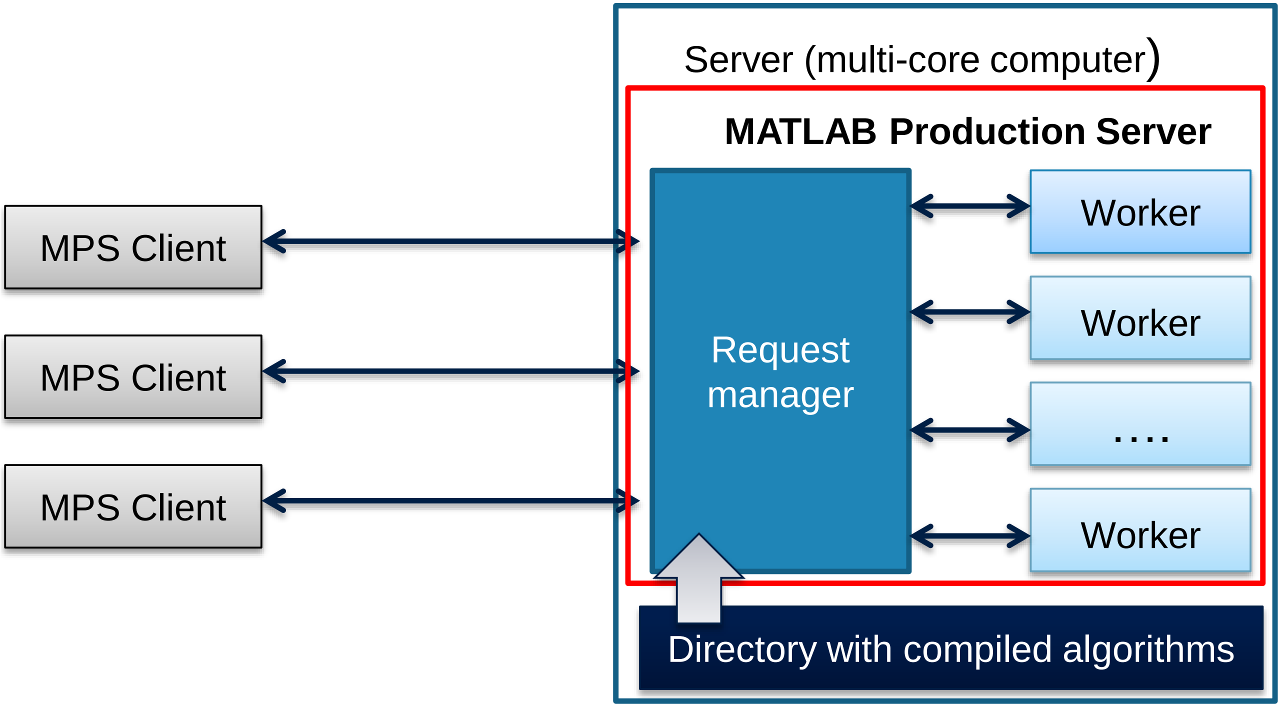
- **SAMANTA algorithms can be compiled to be easily run in an environment without MATLAB.**
  - We use the MATLAB Compiler to create a compiled file from a SAMANTA application (.exe .ctf, .jar, ...)
  - Abstract layers, codes of underlying modules and functions as well as toolboxes used are embedded in the compiled file



- **Once compiled, the SAMANTA algorithms can be used in the same way as in MATLAB thanks to the MCR (Matlab Component Runtime):**
  - Opset reading / processing/ writing
  - Graphic displays specific to modules

Use of compiled algorithms with the MPS

➔ Example of using MPS to deploy SAMANTA algorithms



Manager	Distributes client requests among the Workers depending on availability (load balancing)
Worker	An instance of MCR that treats a client request at a time
Directory	MPS readable directory where the compiled algorithms are deployed
MPS Client	Client application to be developed with MPS client API available in Java or C #

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Conclusion

Conclusion

- **The SAMANTA platform was created in 2007 and about 160 modules were designed since then**
  - Today about 15 engine monitoring algorithms have been developed, tested and matured through this platform and modules
  - The next step for Snecma is to compile these algorithms to be able to export them and use them in an operational environment thanks to the MPS

- **Thirty people are now using this platform in several companies of the SAFRAN Group**
  - Snecma, Turbomeca, Safran Engineering Services, Sagem,…
  - Among all regular users of the platform, only 1/3 have a computer science background

Thanks for your attention