Quality as driver for Integrated Intelligent Manufacturing

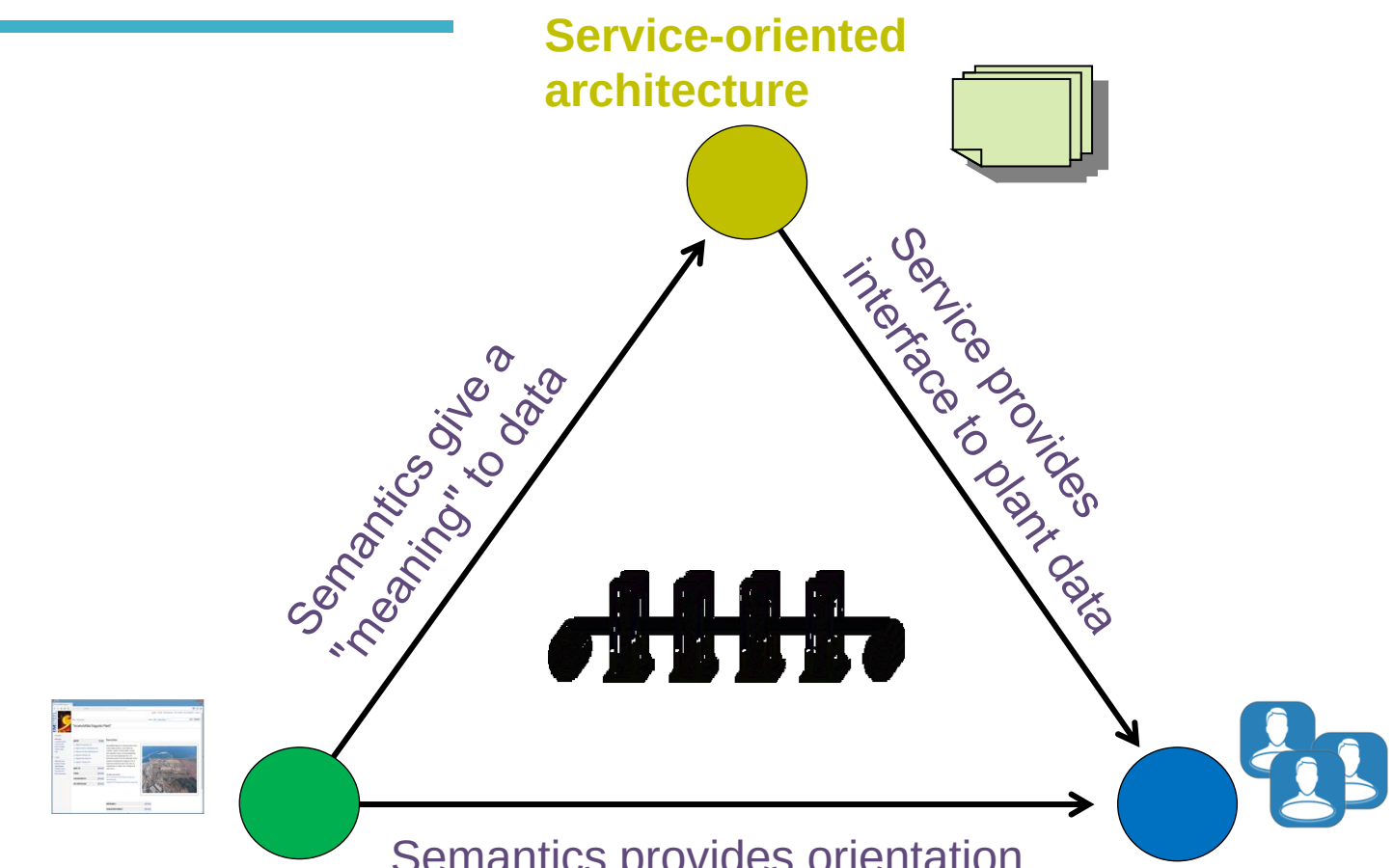
Distributed, autonomous control solutions

F. Marchiori
F. Avellino

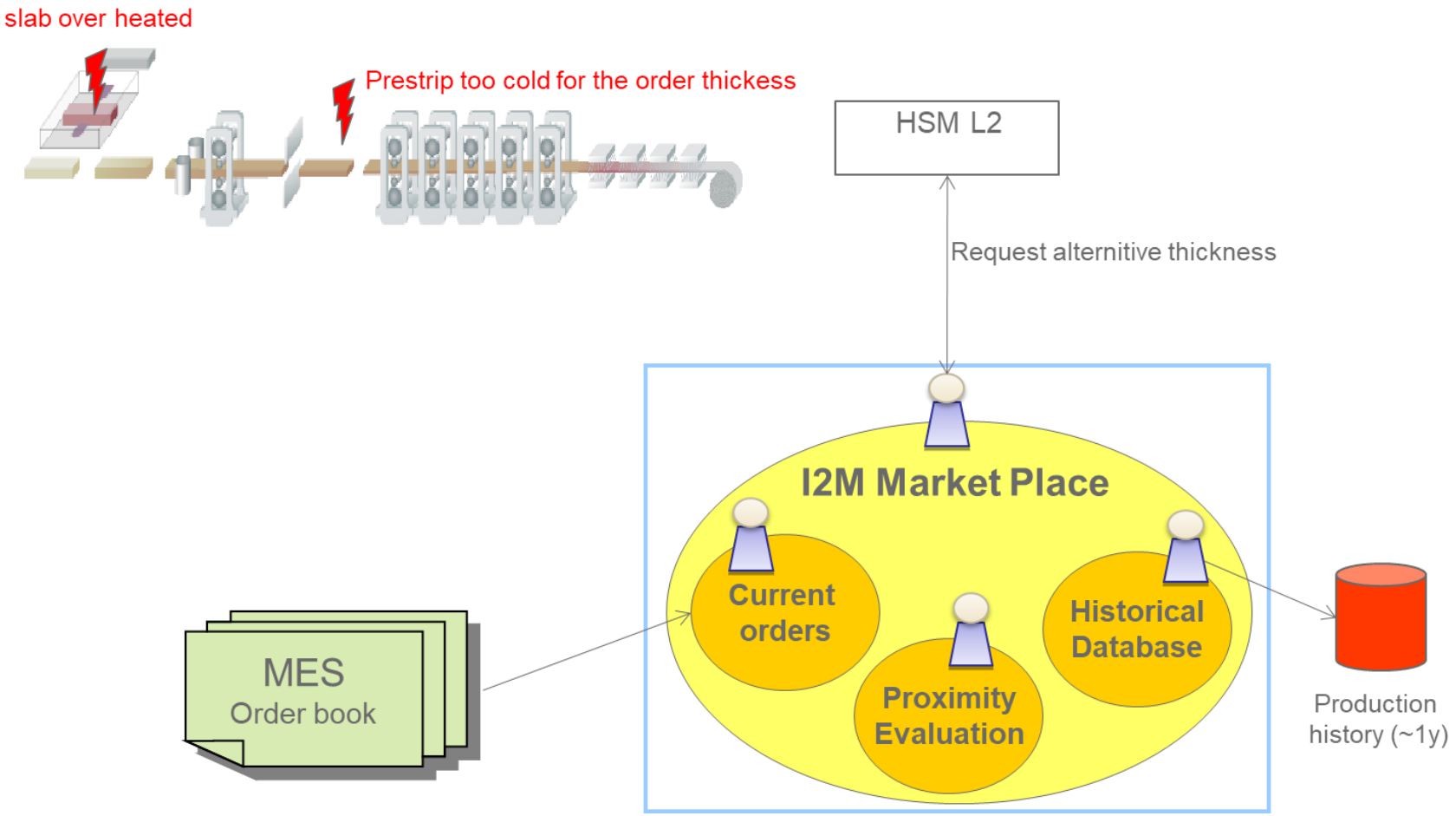
"Integrated Intelligent Manufacturing for Steel Industries“

(I2MSTEEL)

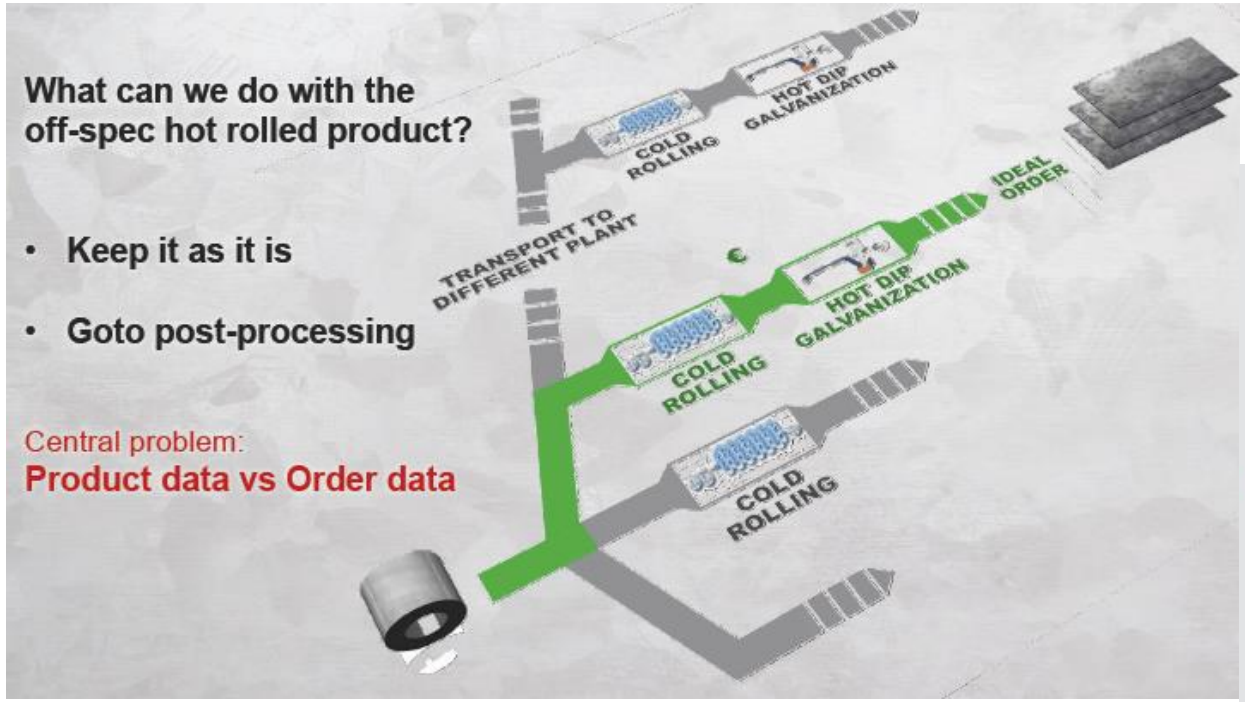
Object: Develop New paradigm



Use Case 1

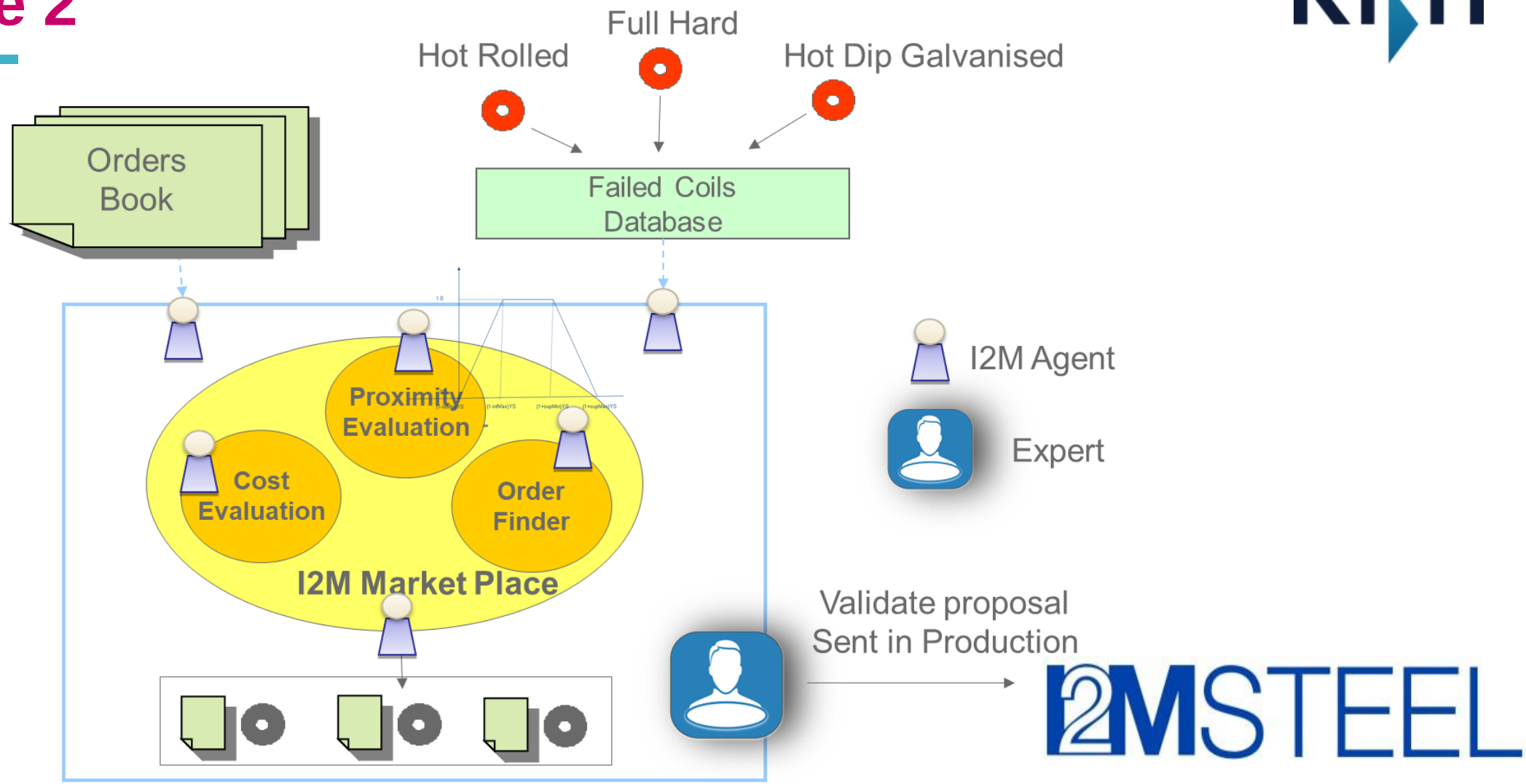

slab over heated
Prestrip too cold for the order thickess
HSM L2
Request alternitive thickness
I2M Market Place
Current orders
Proximity Evaluation
Historical Database
MES
Order book
Production history (~1y)

Use Case 2

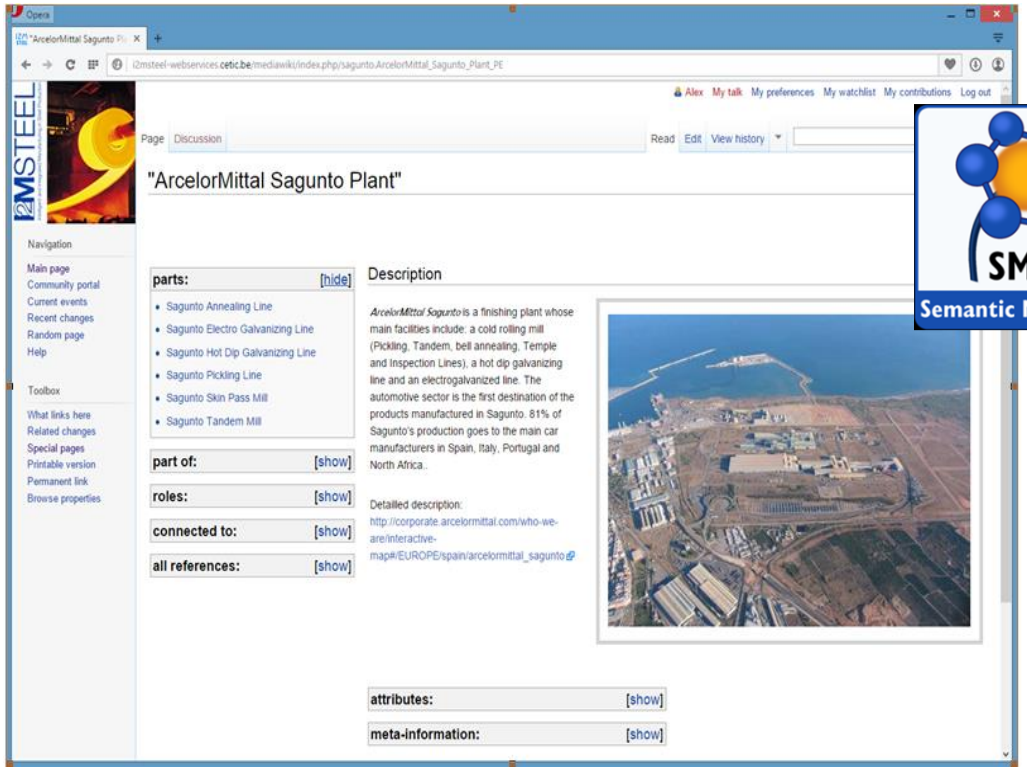


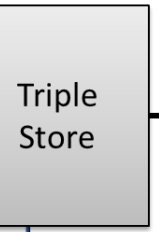
- **Off-spec products**
  - Example: product misses target thickness
- **Blind products**
  - Slabs being processed to coils, without having a specific order
- **Current solution**
  - Sell steel-product at a secondary market
  - **Lower profit**
- **Better: sell product on prime market**
  - Find a matching order = reallocate **during** processing
  - **Higher profit**

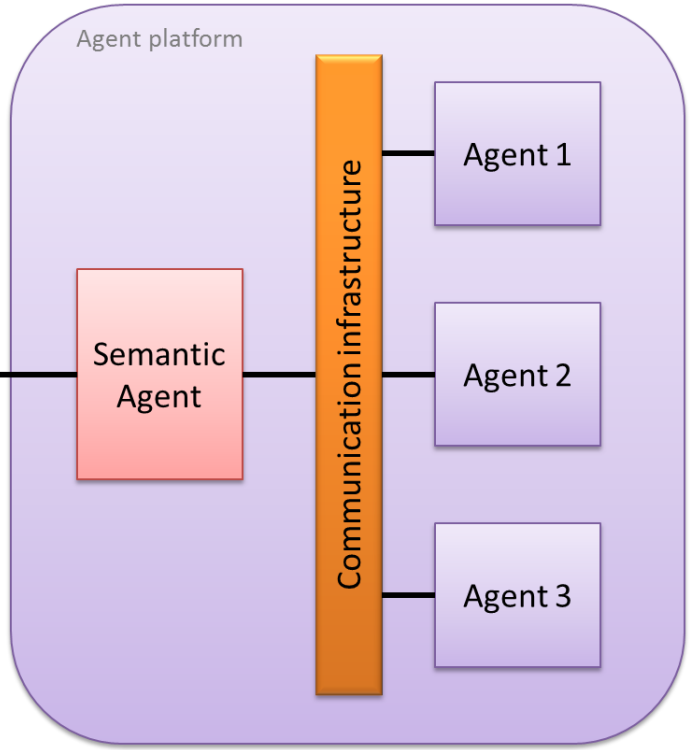
Use Case 2


Hot Rolled
Full Hard
Hot Dip Galvanised
Orders Book
Failed Coils Database
Proximity Evaluation
Cost Evaluation
Order Finder
I2M Market Place
I2M Agent
Expert
Validate proposal
Sent in Production

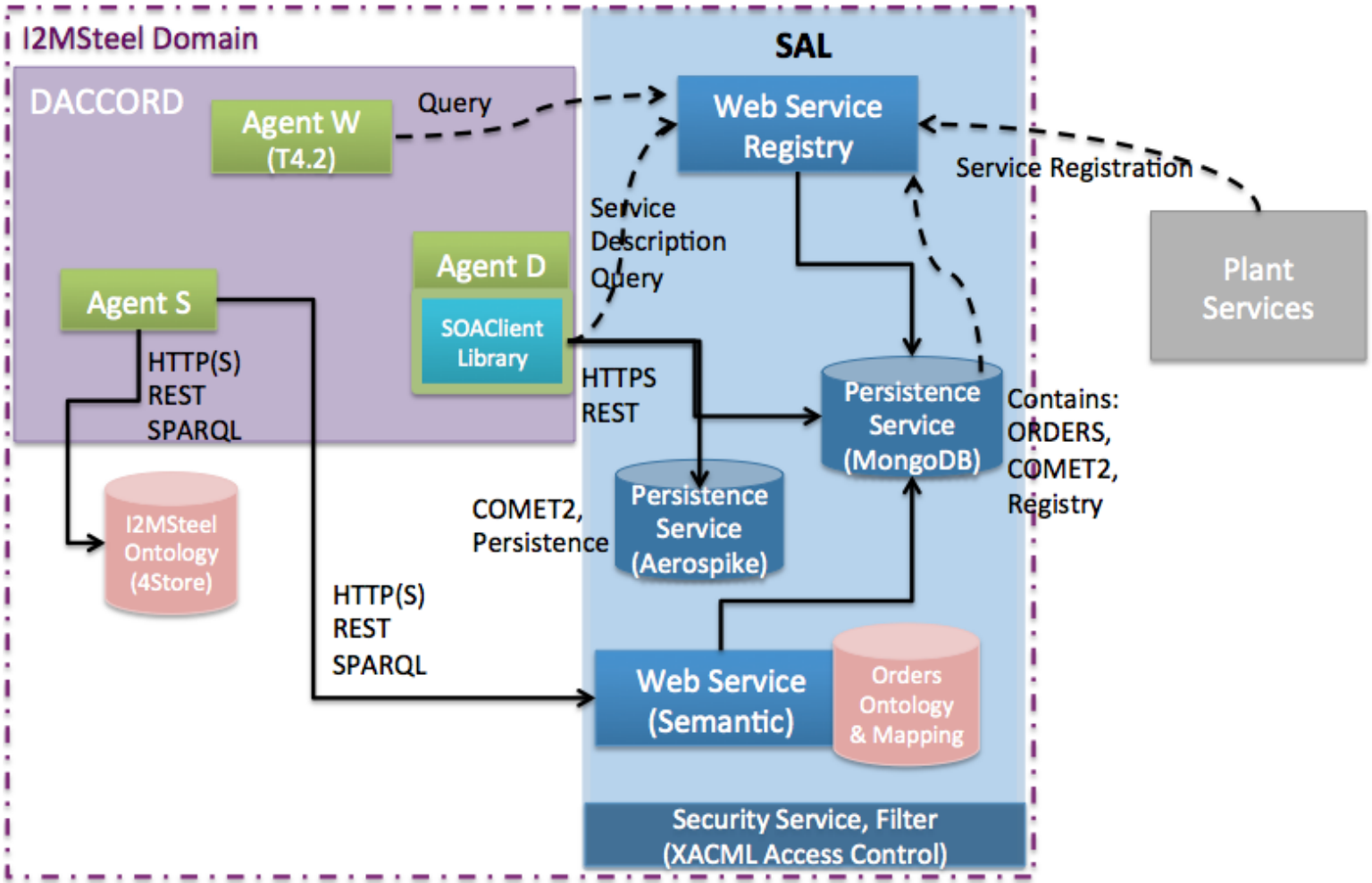
Implementation of semantics



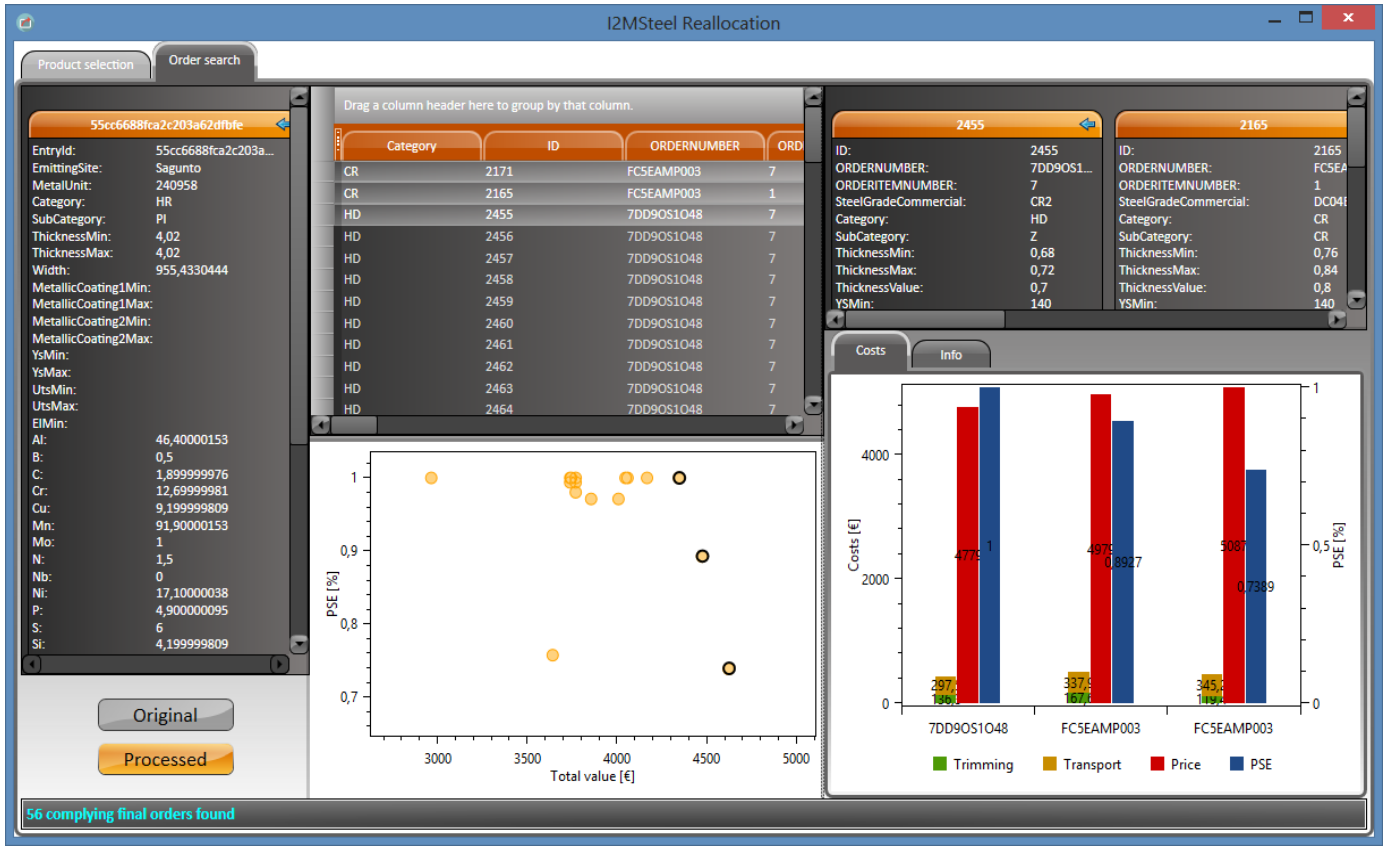


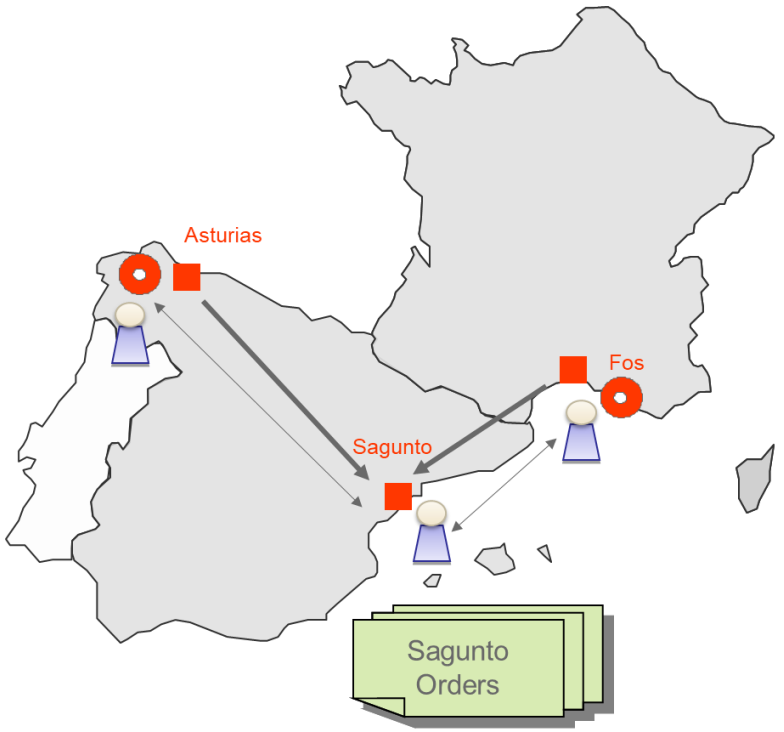


Implementation of service oriented architecture



Implemented system

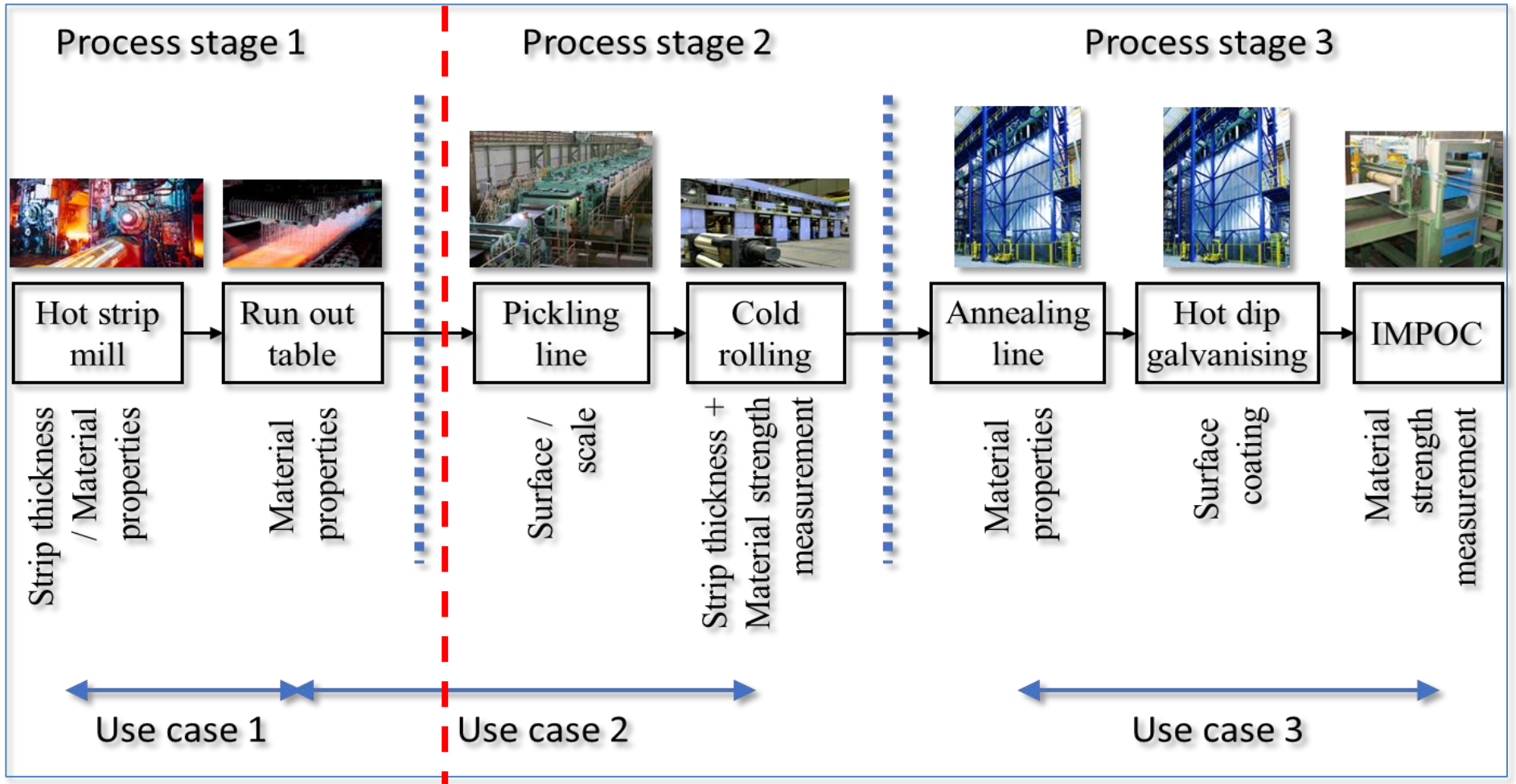




"Novel automatic model identification and online parameter adaption for supporting the industrial deployment of model-based material property process control “

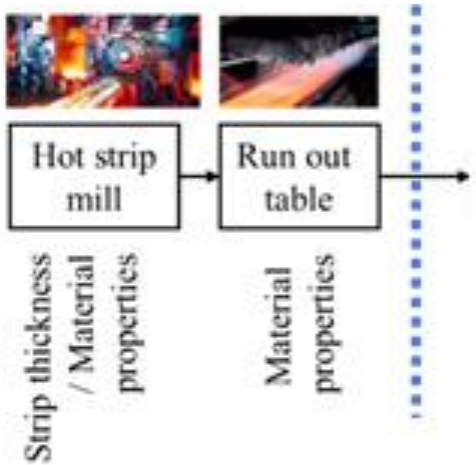
(AutoAdapt)

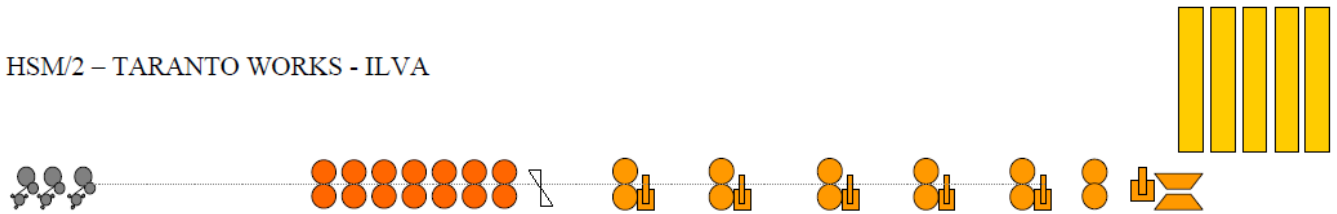
AutoAdapt project Objectives



- The aim of this project is to improve the *homogeneity* of material properties from *coil to coil* and *over coil length* throughout the whole process chain.
- Concerning the process route of steel making, the algorithms, models and concepts which were developed and industrially tested are separated in three use cases.
- *Use case 1* is intended to be shown.

Use case 1
Hot Strip Mill and Run-Out Table

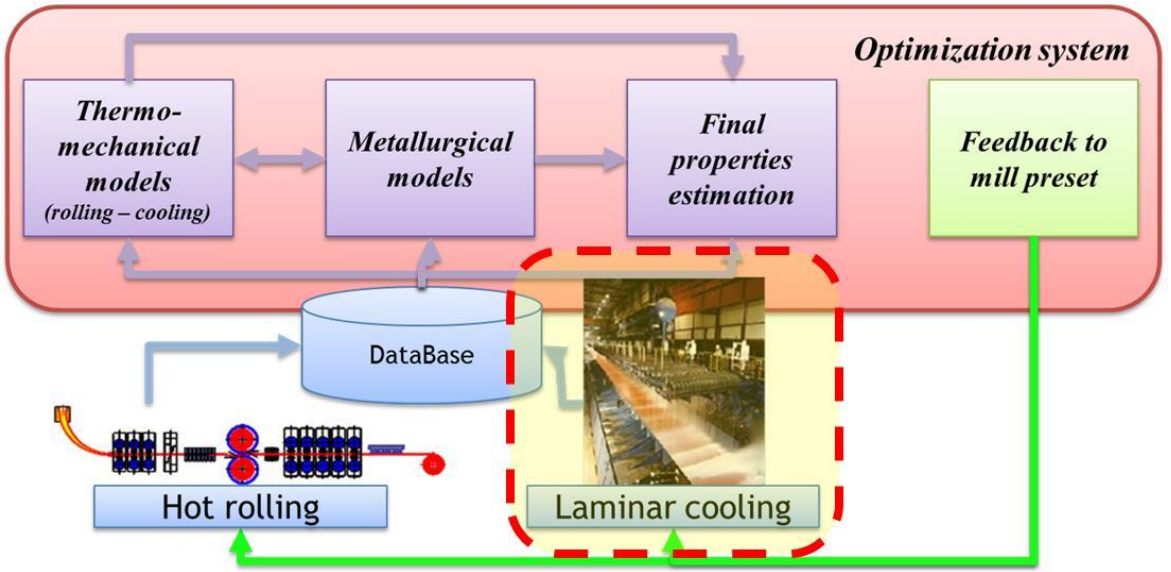




The work of use case 2 was carried out at the Hot Strip Mill (HSM) TN2 at ILVA Taranto (Italy)

"CSM microView" is a system allowing:

- online calculation of strip thermal evolution, microstructure parameters and mechanical properties
- creation of quality reports
- optimization of the main control parameter (the coiling temperature) with reference to mechanical and micro-structural targets



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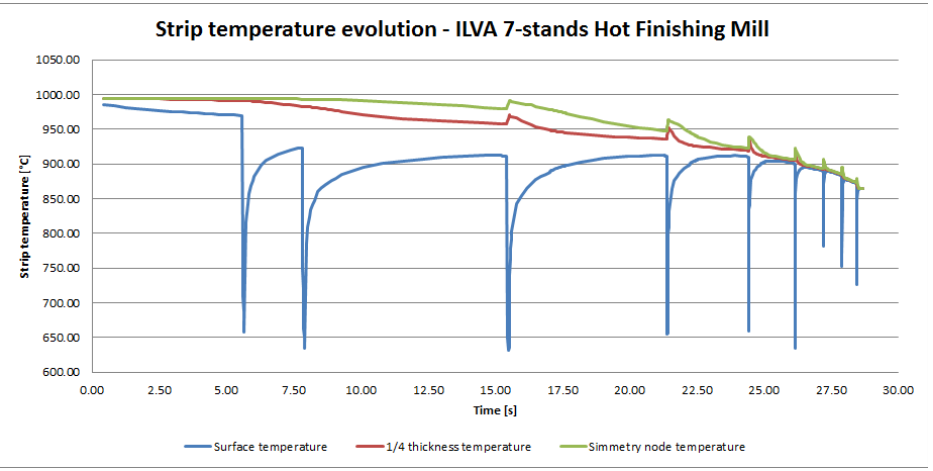
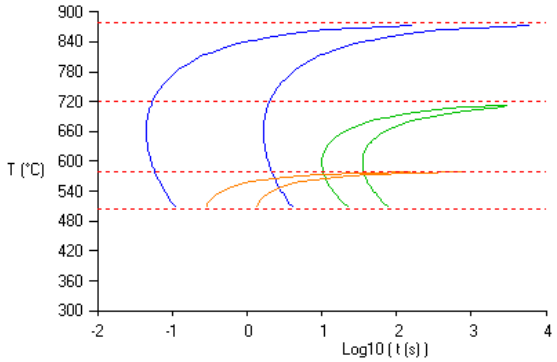
Calculation modules included in the microView

Strip thermal model



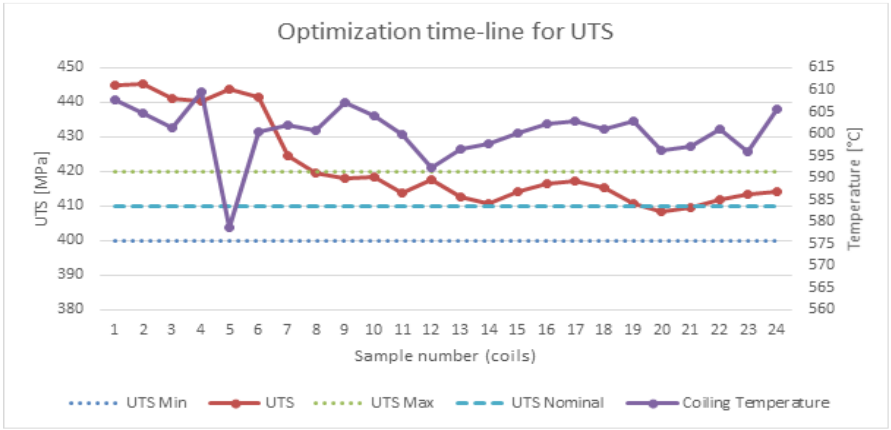
Finite difference based strip thermal evolution

Metallurgical model



Physical-empirical based approach and Artificial Neural Network

Optimization module



Nonlinear constrained multi-target optimization procedure

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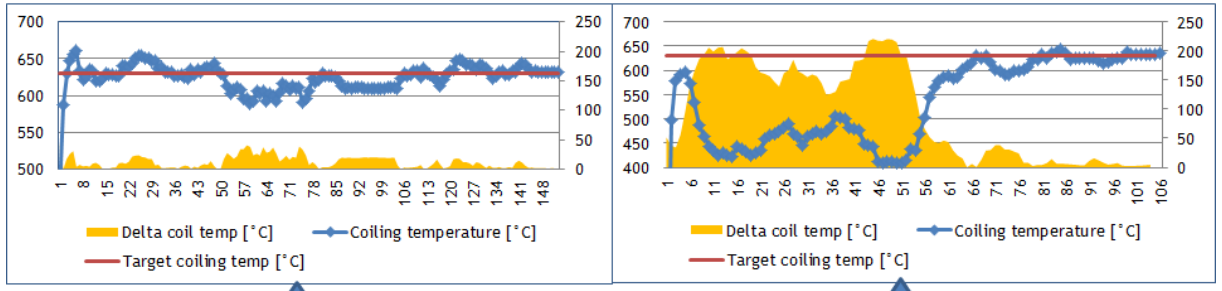
Selection and organization of main information

- List of materials (chemical compositions from the industrial partner) and plant characteristics
- Properly filtered on-field signals

List of selected materials

Chemical range [%]	Thickness level	Steel name	Width [mm]	Thickness [mm]
0,035<C<0,1 0,18<Mn<0,75	Low	S235JR+M	1500	2.00
		DD11	1500	2.00
	Medium	S235JR+M	1500	4.00
		CS TYPE B	1676	4.55
	High	CS TYPE B	1828	6.35
		DD11	1000	6.00
0,13<C<0,17 0,5<Mn<1,2	Low	S275JR+M	1500	2.00
		S235J2+M	1160	2.10
	Medium	S235J2+M	1180	4.70
		SS GR.36 TYPE 1	1524	4.80
	High	SS GR.36 TYPE 1	1524	6.41
		SS GR.36 TYPE 1	1828	6.45
0,18<C<0,2 1,3<Mn<1,4	Low	S355J2+M	1350	2.70
	Medium	S355JR+M	975	2.00
HSLA	Low	S315 MC	1005	1.80
		S315 MC	1005	1.80
	Medium	S355J2C+M	1680	4.51
		S355J2C+M	1680	4.51
	High	S275JR+M	1500	8.00
		S355J2+M	1500	8.00

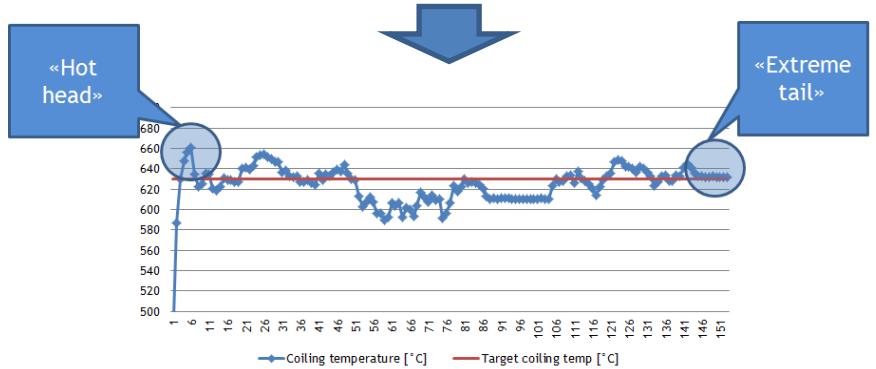


Coil OK
Moderate delta temperature (<50 °C)

Coil not OK
Considerable delta temperature (>50 °C)

Direct level data filtering examples:

comparison with max values and extremes cut-off



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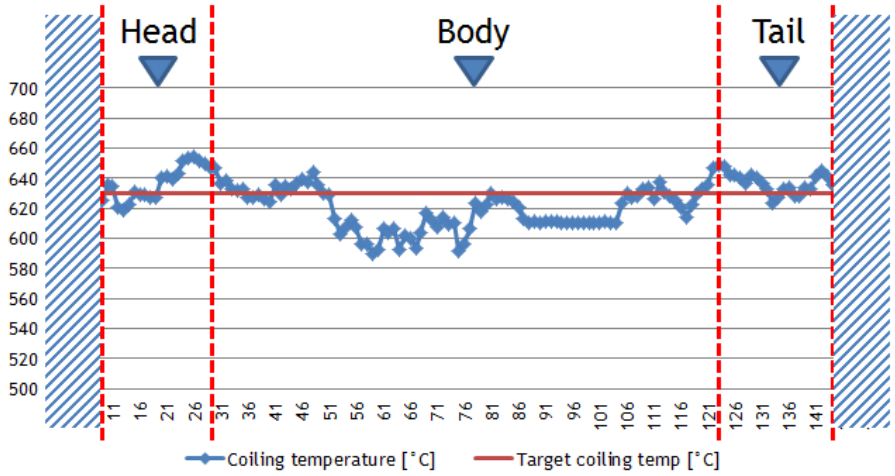
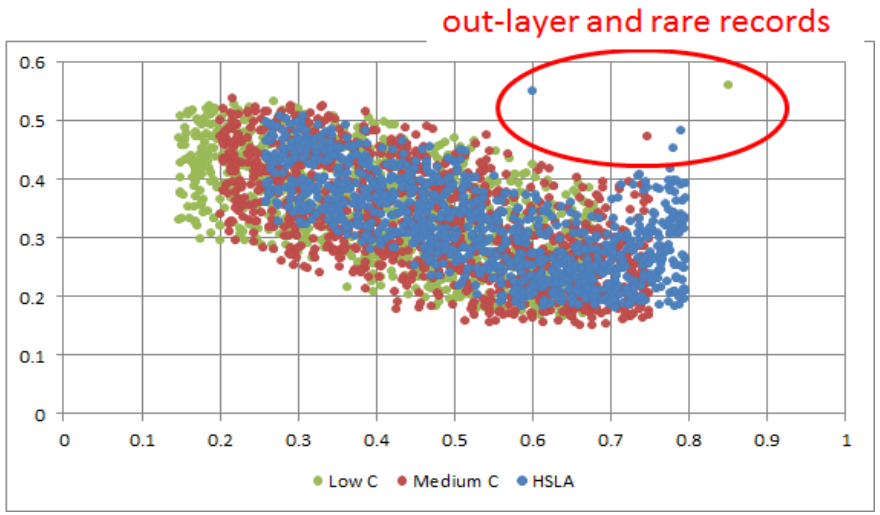
Out-layers discarding and reporting





ANN

Strip	Id Slab	Thickn	Width	Cast	Order	Quality	Chemical
4G84999	1U30065	3,45	1.220,00	U64984	45923.4	SEMW06	DLS545

Steel	%
CARBON	0,0820
MANGANESE	0,8410
PHOSPHORUS	0,0540
SULPHUR	0,0080
SILICON	0,2170
ALUMINIUM	0,0280
CALCIUM	0,0030
COPPER	0,0670
NICKEL	0,0560
CHROMIUM	0,7560
MOLYBDENUM	0,0090
TIN	0,0120
NIOBIUM	0,0030
VANADIUM	0,0030
TITANIUM	0,0030
BORON	0,0008
NITROGEN	0,0087
OXYGEN	0,0000

Average estimated

	Hea		Bod		Ta	
	av.	dev.	av.	dev.	av.	dev.
Ferri	94,30	2,62	55,51	20,76	90,63	0,82
Grain	6,11	1,04	3,89	0,10	4,10	0,41
Perli	5,70	2,62	1,95	3,51	7,73	1,35
Marten	0,00	0,00	0,10	0,18	0,42	0,41
Bainit	0,00	0,00	43,04	24,56	1,26	1,71

Run out table

	Hea		Bod		Ta	
	av.	dev.	av.	dev.	av.	dev.
Speed(m/s)	5,60		5,62		6,77	
Fin.	836,25	14,55	850,47	5,70	827,49	18,81
UFC exit	729,16	30,71	664,76	23,24	704,50	4,59
Interm.	597,97	119,14	323,75	31,34	385,31	16,20
Coling	449,38	170,01	102,74	5,20	131,22	13,19

Average estimated mechanical properties

	Head				Body				Tail			
	Av.	min	max.	StdDe	Av.	min.	max.	StdDe	Av.	min.	max.	StdDe
YS	430,72	412,27	455,44	18,56	460,59	453,07	467,04	4,60	458,40	455,95	463,13	2,95
UTS	517,66	502,90	536,87	14,19	548,16	534,60	558,50	8,29	536,73	534,78	539,82	1,95
El%	26,00	25,78	26,33	0,20	24,90	23,33	26,81	1,12	24,95	23,70	25,78	0,85
HV10	164,26	158,69	166,83	3,46	204,06	169,56	226,06	19,74	171,24	169,18	173,46	1,80

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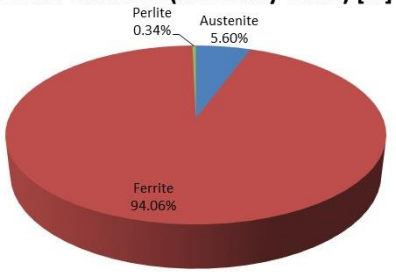
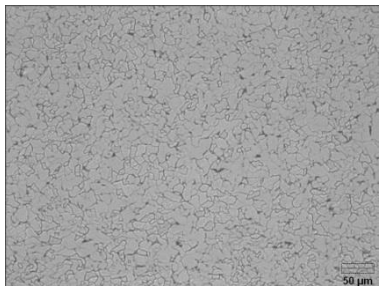
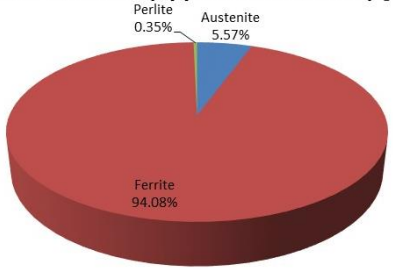
Microstructure forecasting

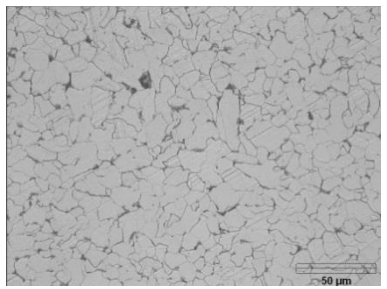
Phase fractions (simmetry node) [%]



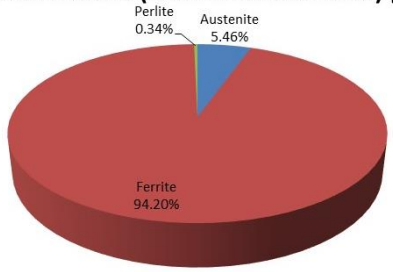


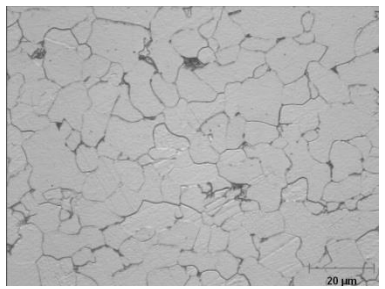
Phase fractions (upper surface node) [%]

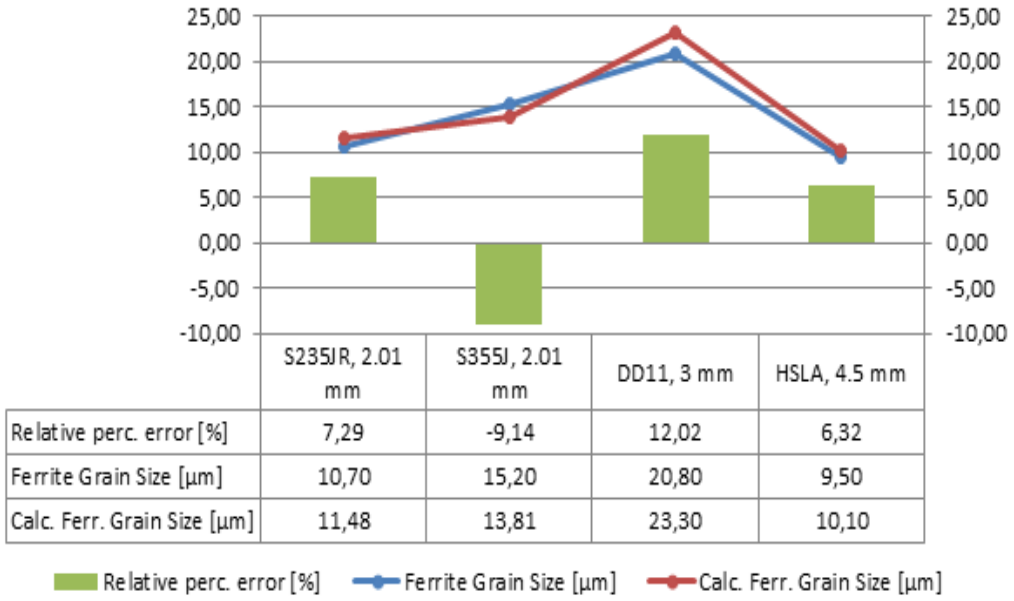




Phase fractions (bottom surface node) [%]







	S235JR, 2.01 mm	S355J, 2.01 mm	DD11, 3 mm	HSLA, 4.5 mm
Relative perc. error [%]	7,29	-9,14	12,02	6,32
Ferrite Grain Size [µm]	10,70	15,20	20,80	9,50
Calc. Ferr. Grain Size [µm]	11,48	13,81	23,30	10,10

Composition (wt%)			
C	0.060	Mn	0.224
P	0.008	S	0.008
Si	0.015	Al	0.028
Cu	0.245		

Final rolling temperature [°C]	870
Coiling temperature [°C]	655
Slab reheating temperature [°C]	1164

Perlite [%]	8.3
Ferrite Grain Size [µm]	10.7
Calc. Ferr. Grain Size [µm]	11.48
Relative perc. error [%]	7.3

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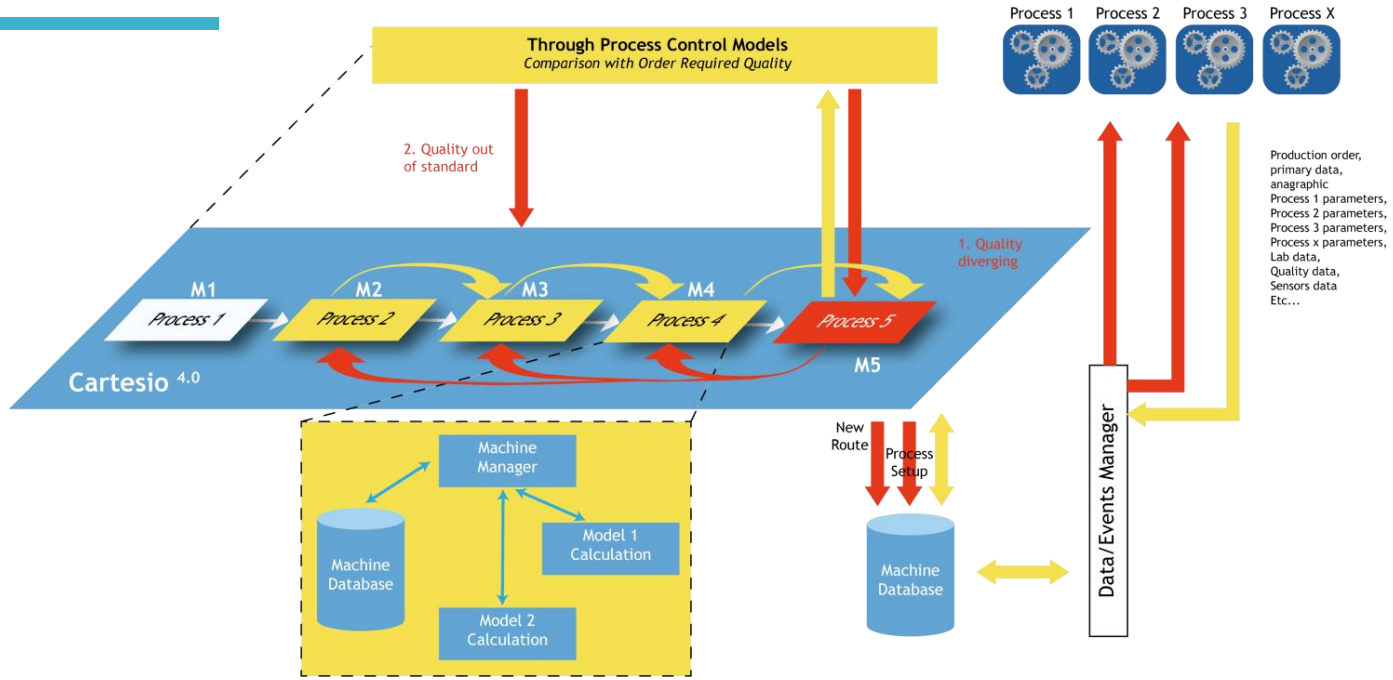
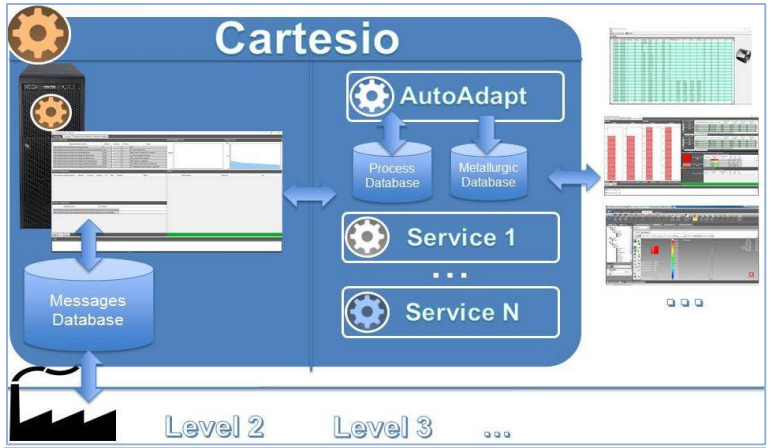
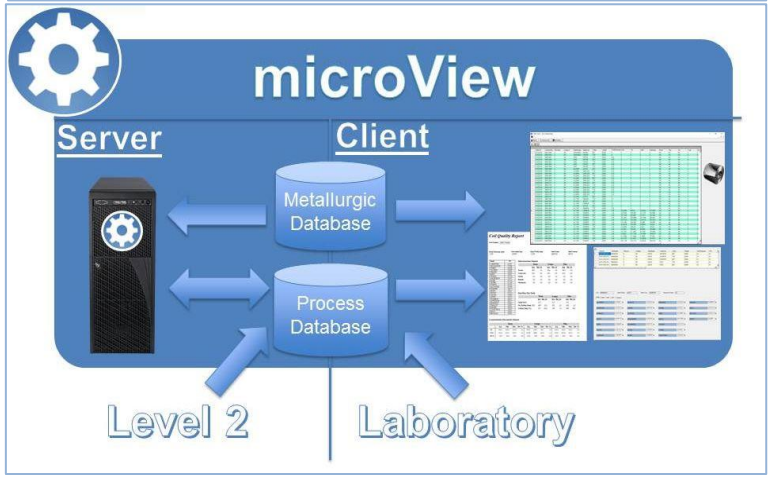
Cartesio platform







Cartesio System entities:

- Service

Communicating with the plant through interface tables

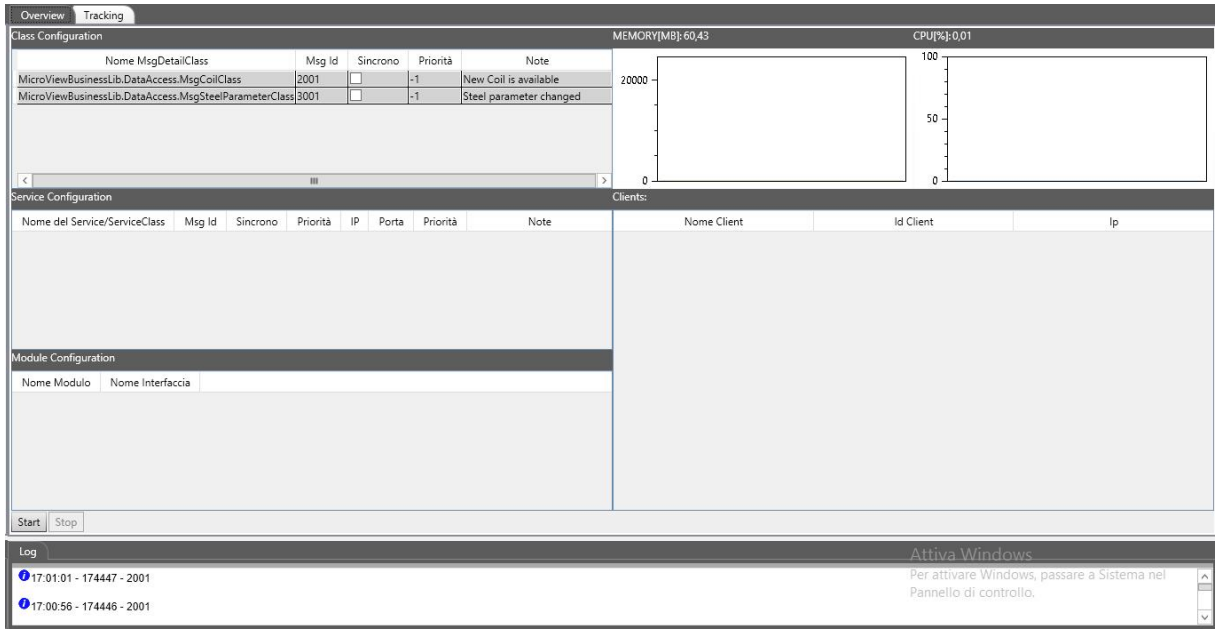
- Module

DLL that deals with launching mathematical models.

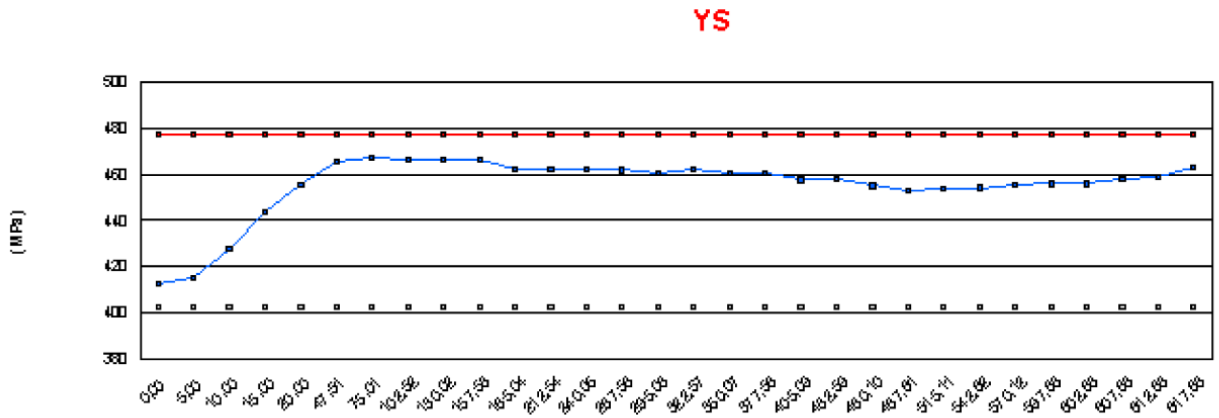
- Message

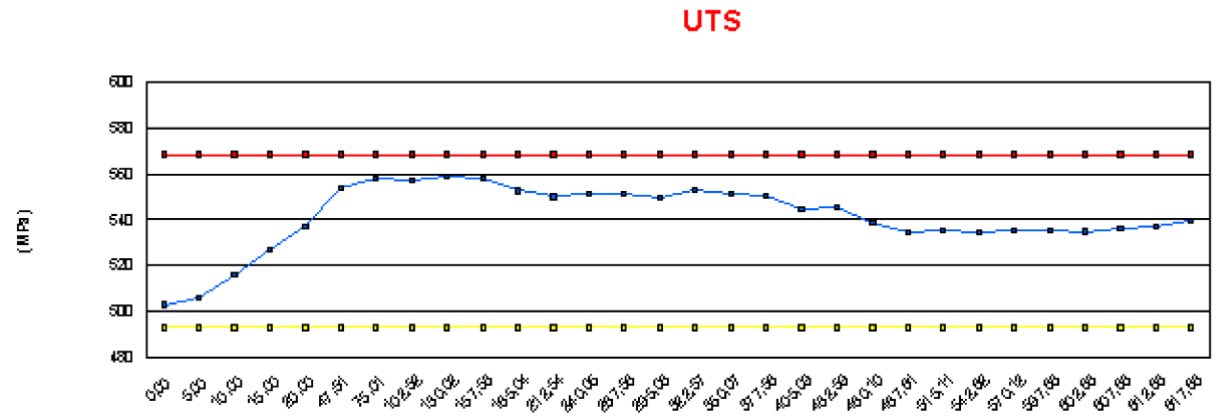
Entity used to notify a service to perform certain operation

microView
Overview/tracking section



Overview/tracking section GUI





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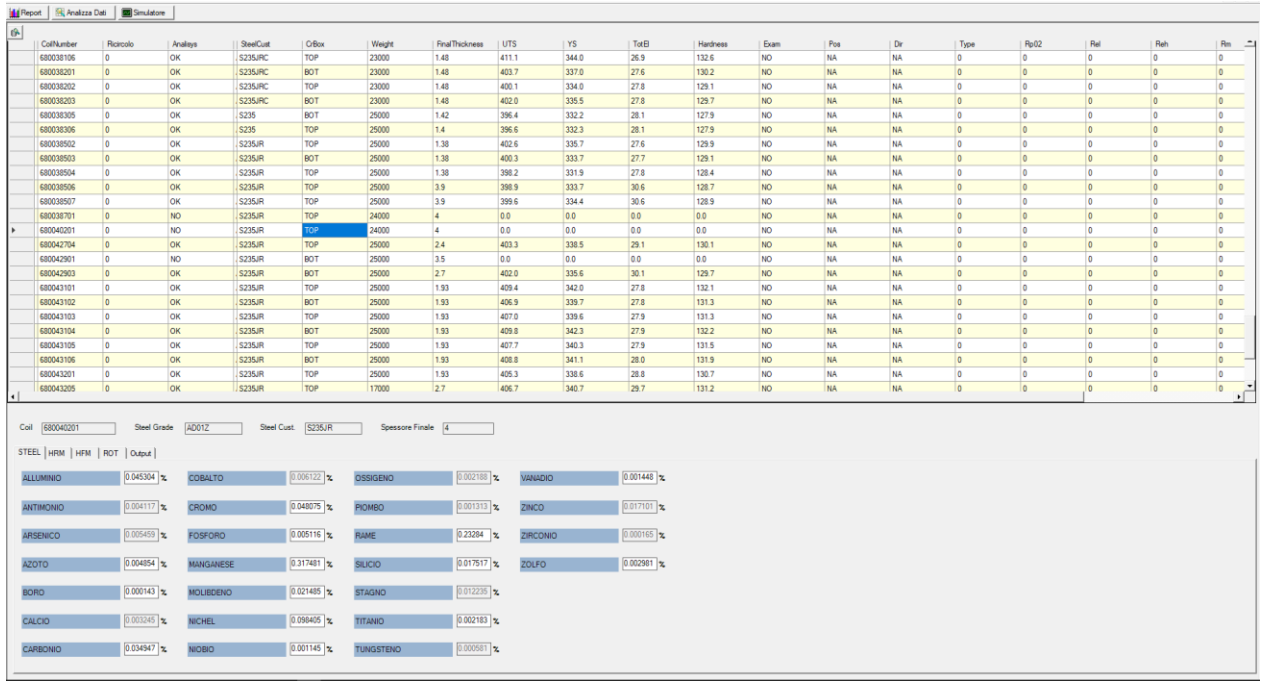
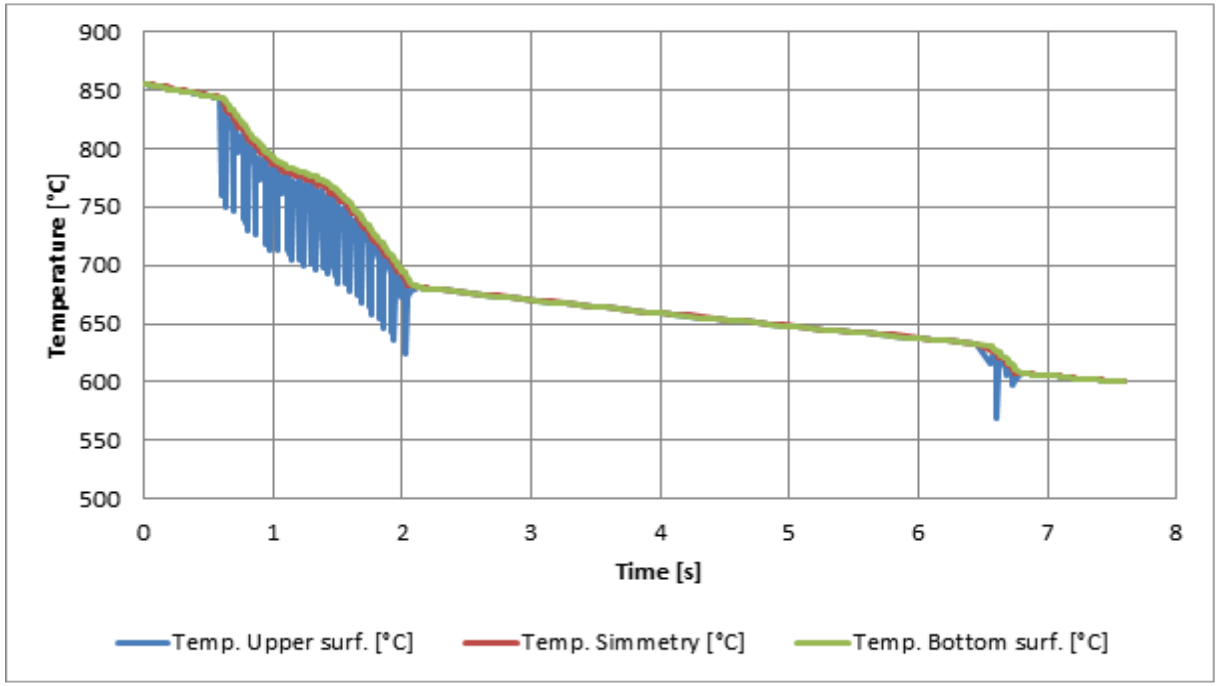
microView
Simulation section



Simulation section GUI



Example:

Re-calculated thermal evolution on the run-out table

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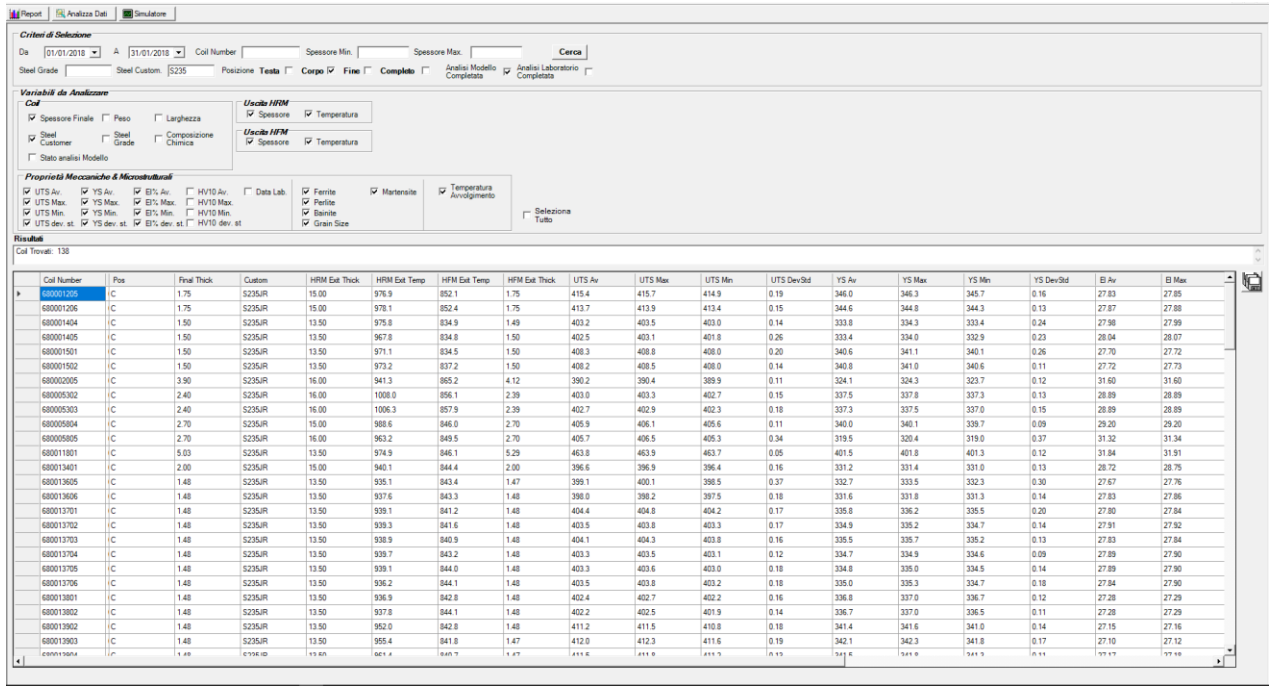
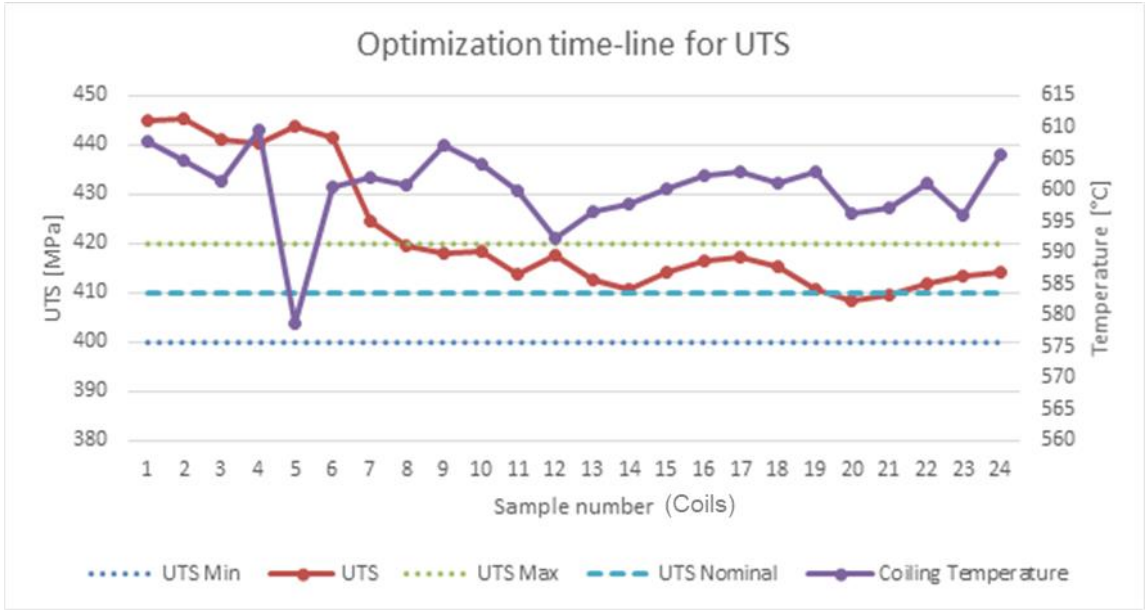
microView
Optimization section



Optimization section GUI



Example:

Optimization time-line for a selected mechanical property (UTS)

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Thank you for the attention:

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