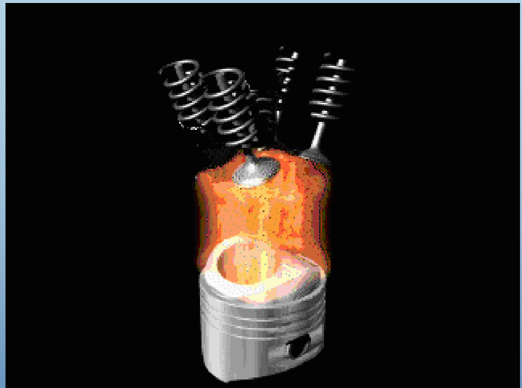
How a combustion analysis system can support ECU calibration ?



automotive testing expo 2008 europe

ASAM

TECHNOLOGY FORUM

DAY 1 – 6 MAY 2008

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Introduction

- The main challenge of modern vehicle development is to meet the emission regulations, while keeping customer's satisfaction (fuel economy, torque, noise,…), and reducing development costs.

- These three constraints leads to a complex equation to be solved by the engineers:

$$Success = f\,[\ min\ \{Emissions\},\ max\ \{Satisfaction\ \},\ min\ \{Costs\}]$$

Introduction

Competitive Market

- Need to propose new products (vehicles) more and more often with competitive prices

Emissions Regulations

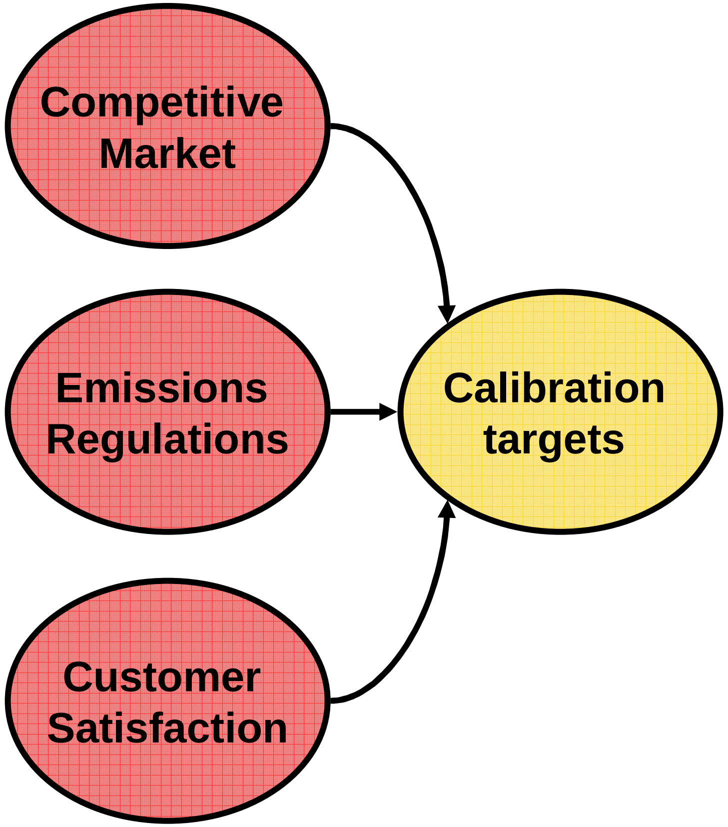
- Passenger cars: EURO5, EURO6, …
- Heavy Duty: Tier3, Interim Tier4, Tier4, …

Customer Satisfaction

- Consumers are more and more exigent: Performances / Consumption / Drivability / Noise

Calibration targets

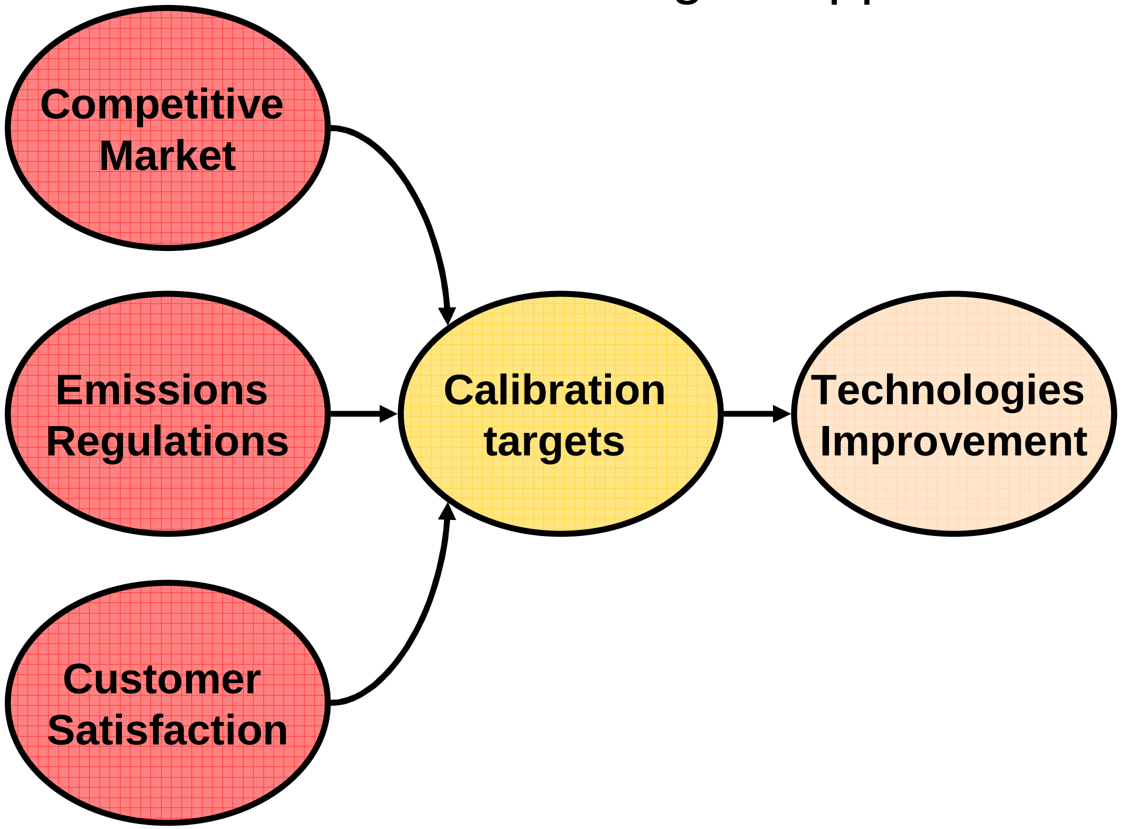
- These three inputs defines the calibration targets



- Performances (Power & Torque)
- Consumption (Fuel injection quantity)
- Pollution (Emission regulation target)
- Noise (Acoustic)
- Reliability (Durability & robustness)
- Drivability (Vibrations, brio)
- Altitude & Cold conditions (Cold start and altitude)

New technologies

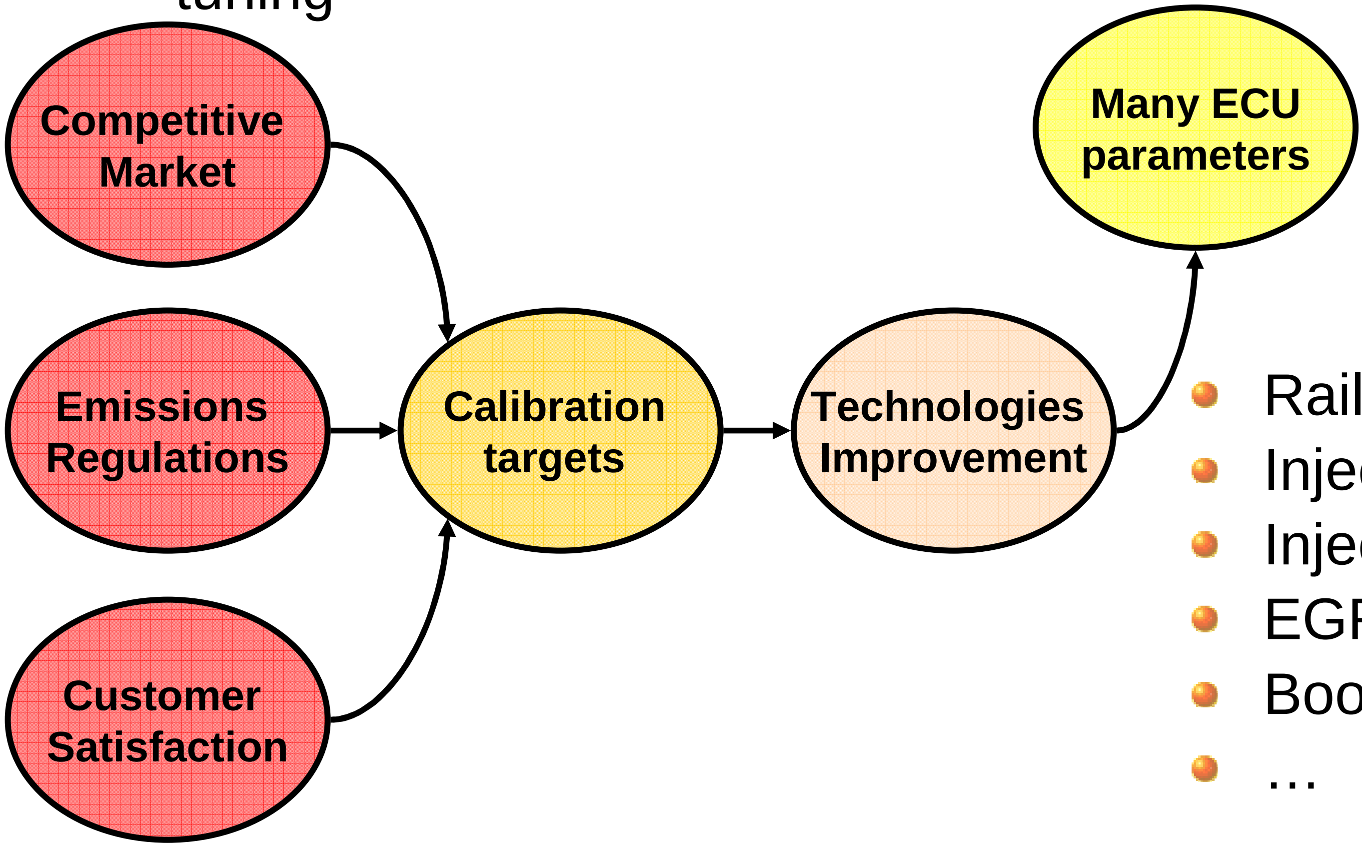
- To achieve these goals, engineers need to introduce more and more new technologies applied to thermal engine



- Common-rail,
- EGR
- DPF,
- VVT
- NOx Trap,
- Camless?
- …

Calibration parameters

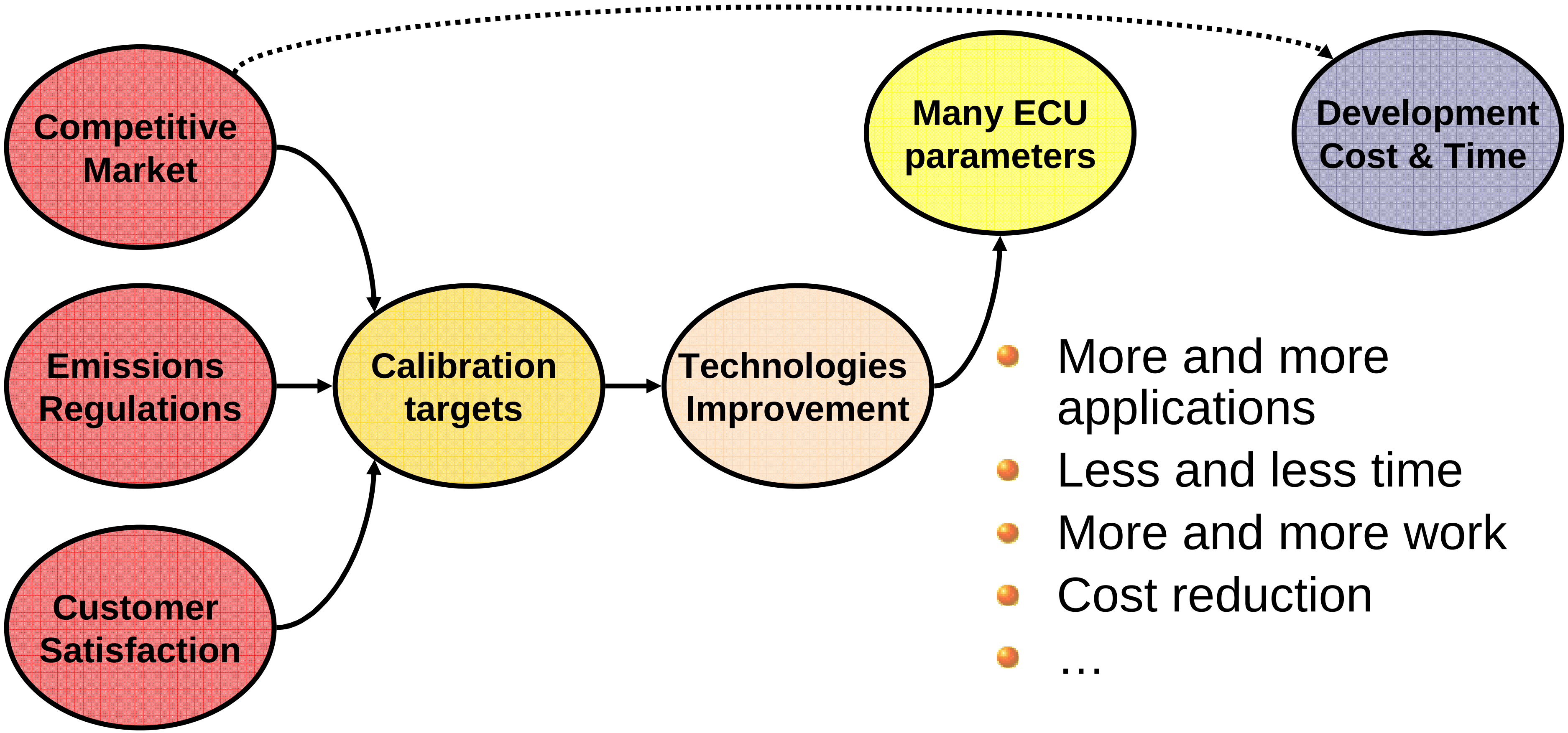
- This ends up with more and more freedom degrees in engine tuning



- Rail pressure
- Injection quantities
- Injection phasing
- EGR rate
- Boost pressure
- …

Development cost

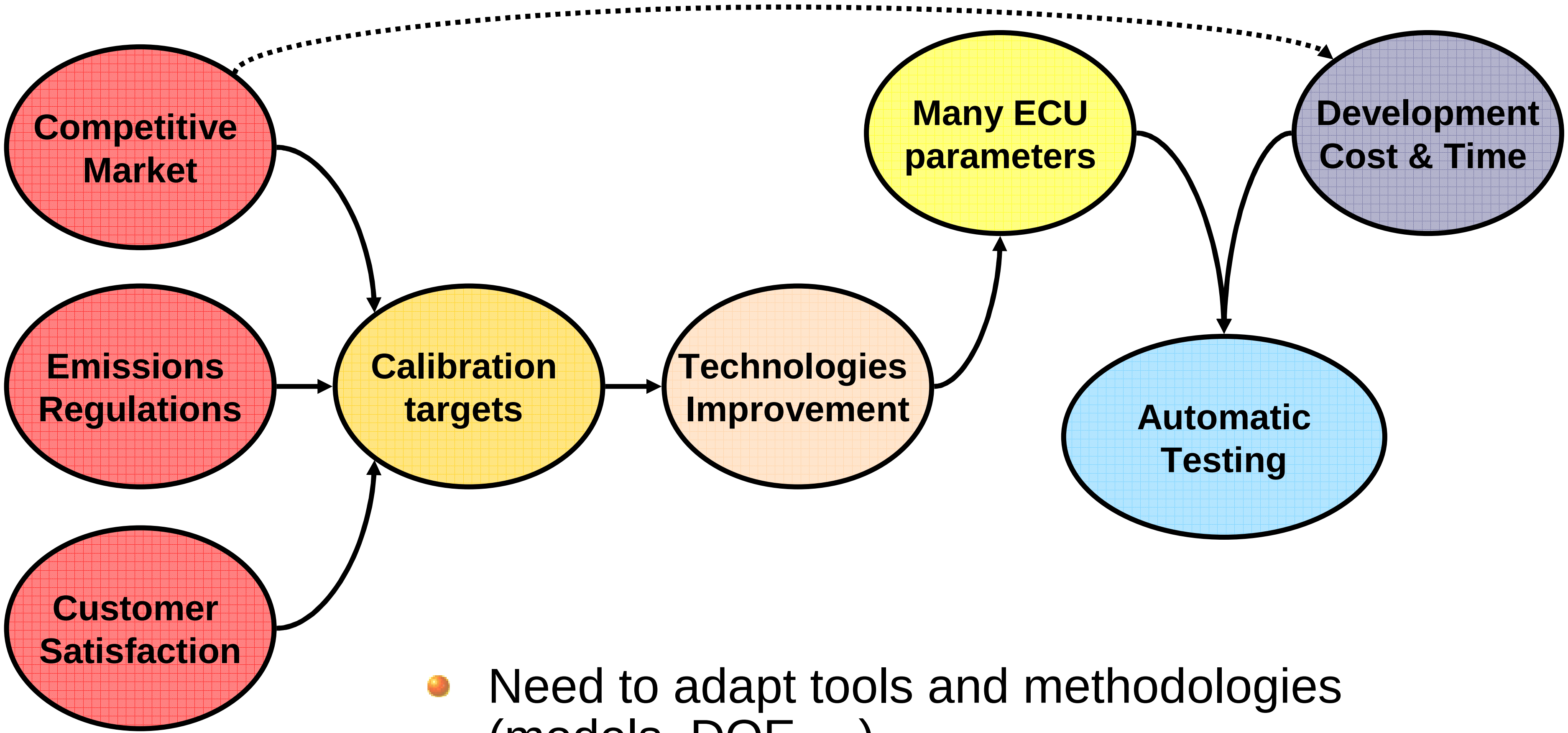
- With strong competitive market rules



- More and more applications
- Less and less time
- More and more work
- Cost reduction
- …

Testing

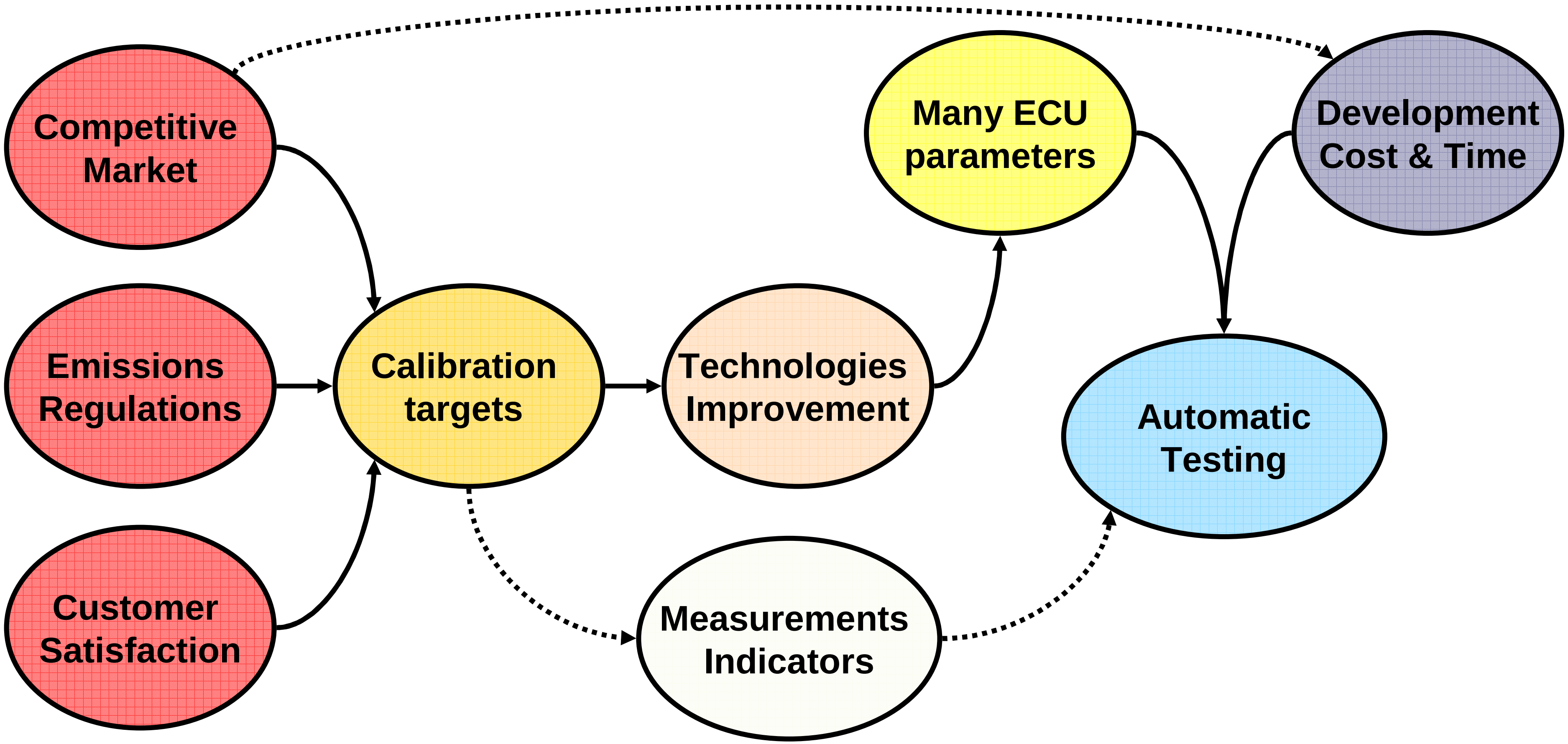
- Efficient testing systems are the only way to solve the equation



- Need to adapt tools and methodologies (models, DOE,…)
- Need of automatic testing capabilities

Measurement indicators

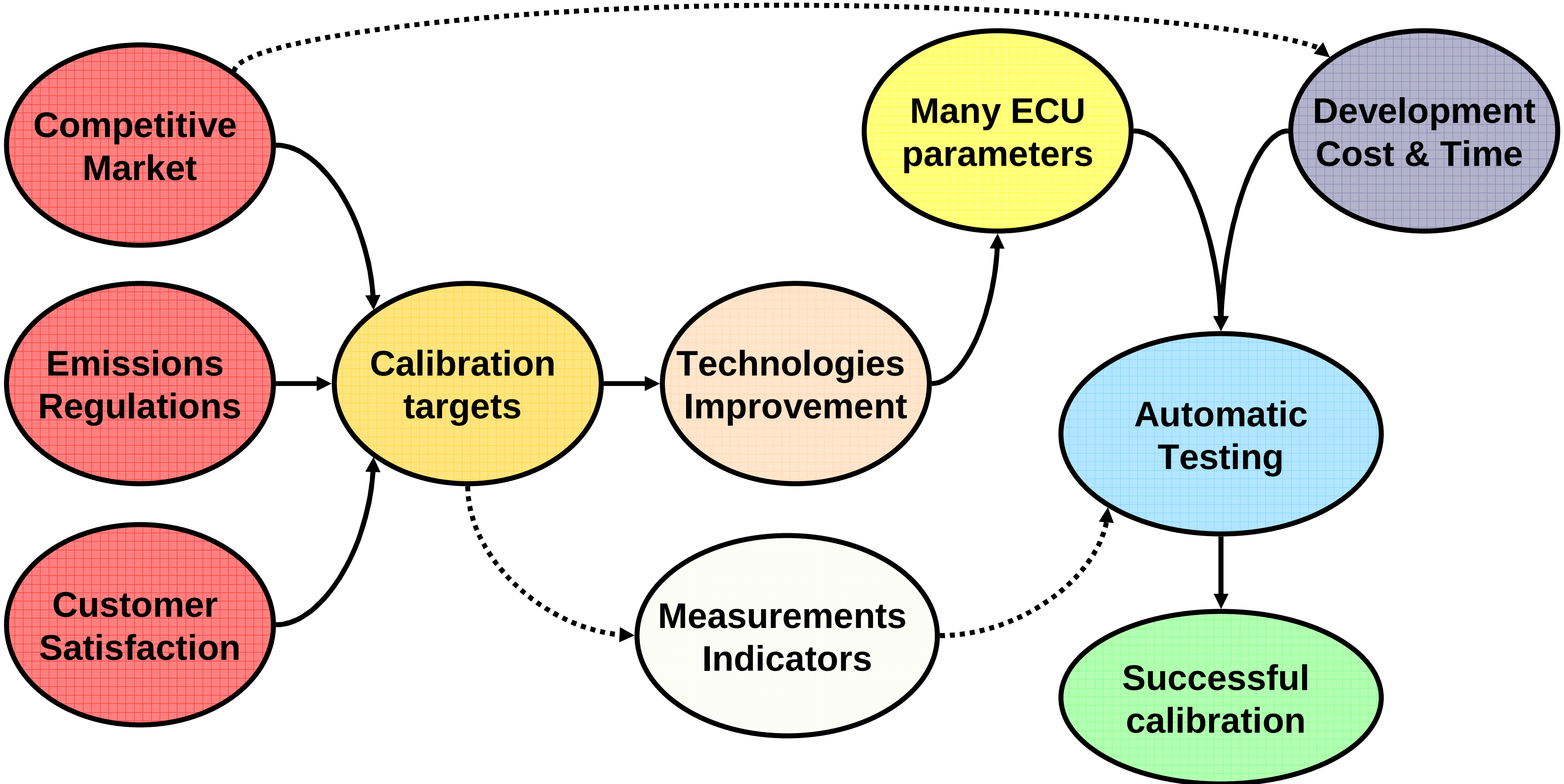
- Need of good indicators to achieve calibration targets



- The pertinence and quality of the indicators are the keys of efficient testing

Successful Calibration

- Improved testing capabilities coupled with good indicators can warranty a successful calibration with all these constraints



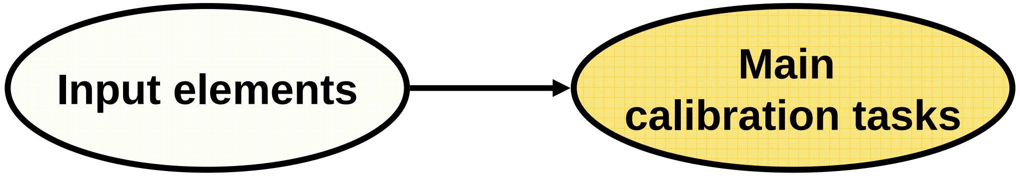
- Need of efficient measuring devices to provide good indicators

Calibration process (1/3)

Input elements

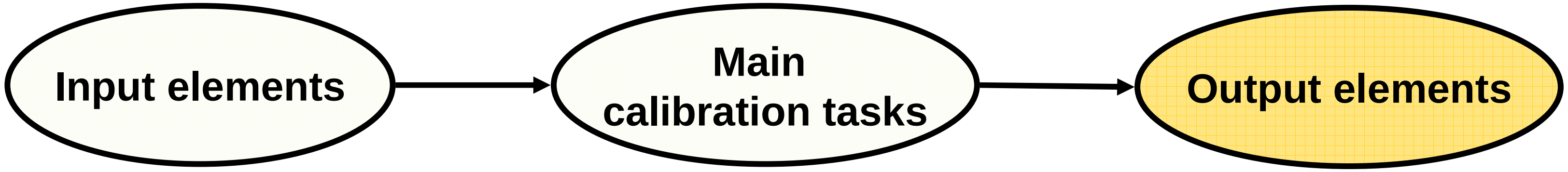
- Vehicle definition (inertia, gearbox…)
- Engine technical specification (Engine, Turbocharger, injection, EGR, post treatment…)
- Targets:
  - Performances (Power & Torque)
  - Consumption (Fuel injection quantity)
  - Pollution (Emission regulation target)
  - Noise (Acoustic)
  - Reliability (Durability & robustness)
  - Drivability (Vibrations, brio)
  - Altitude & Cold conditions (Cold start and altitude)
- Engine control system: ECU (Hard + soft + calibration).
- Initial set of data, obtained most of the time with capitalization on former engine, or with simulation tools.

Calibration process (2/3)



- Full load (Maximum performances)
- Warm emissions zone (Normalized cycles and consumerists cycles)
- Warm zone outside of the emission zone (zone not concerned by cycles and under 90% of full load)
- Controllers tuning (Boost pressure, EGR, Knock)
- Cold corrections / light off (Emission zone □ MVEG cycle)
- Drivability
- Engine cranking
- Specific post treatment systems (DPF)
- OBD: tuning of diagnosis strategies on vehicle
- Monitoring and safety functions

Calibration process (2/3)



- Deliverable of the activity is the engine calibration for the vehicle.
- This must permit to fulfill all defined goals in a robust way, that is to say, including production dispersion.
- Trace ability and documentation about different steps that led to the final calibration is also an essential element of the activity.

Different testing contexts

- All calibration tasks described before are going through different phases of:
  - Steady state engine testing at test bed
  - Transient testing in chassis dyno, and/or high dynamic test beds
  - Vehicles transient testing
  - Validation on vehicles in customer's conditions

Indicating for indicators

- A combustion analysis system, so-called indicating system, is necessary for almost every tasks of the calibration process.
- It provides necessary information (⇔) indicators for the calibration:
  - IMEP, PMAX, DPDA …
  - CA10, CA50, CA90 …
  - KNOCK …
  - NOISE …
- These indicating calculations must be available for all potential clients systems, in all testing contexts:
  - At test cell
  - In the vehicle

D2T Combustion analysis system

OSIRIS:

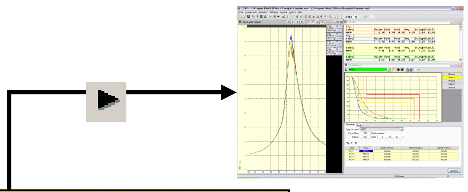
- Recording and monitoring of engine data,
(in-cylinder pressure, injectors needle lift, ignition or injection control signals),
- Real time calculations based on measurements
(in-cylinder pressure analysis, combustion analysis, statistics …),
- Display of all measured or calculated data
- Monitoring of critical parameters (maximum pressure, knock,…)
- **Data server** for all clients systems

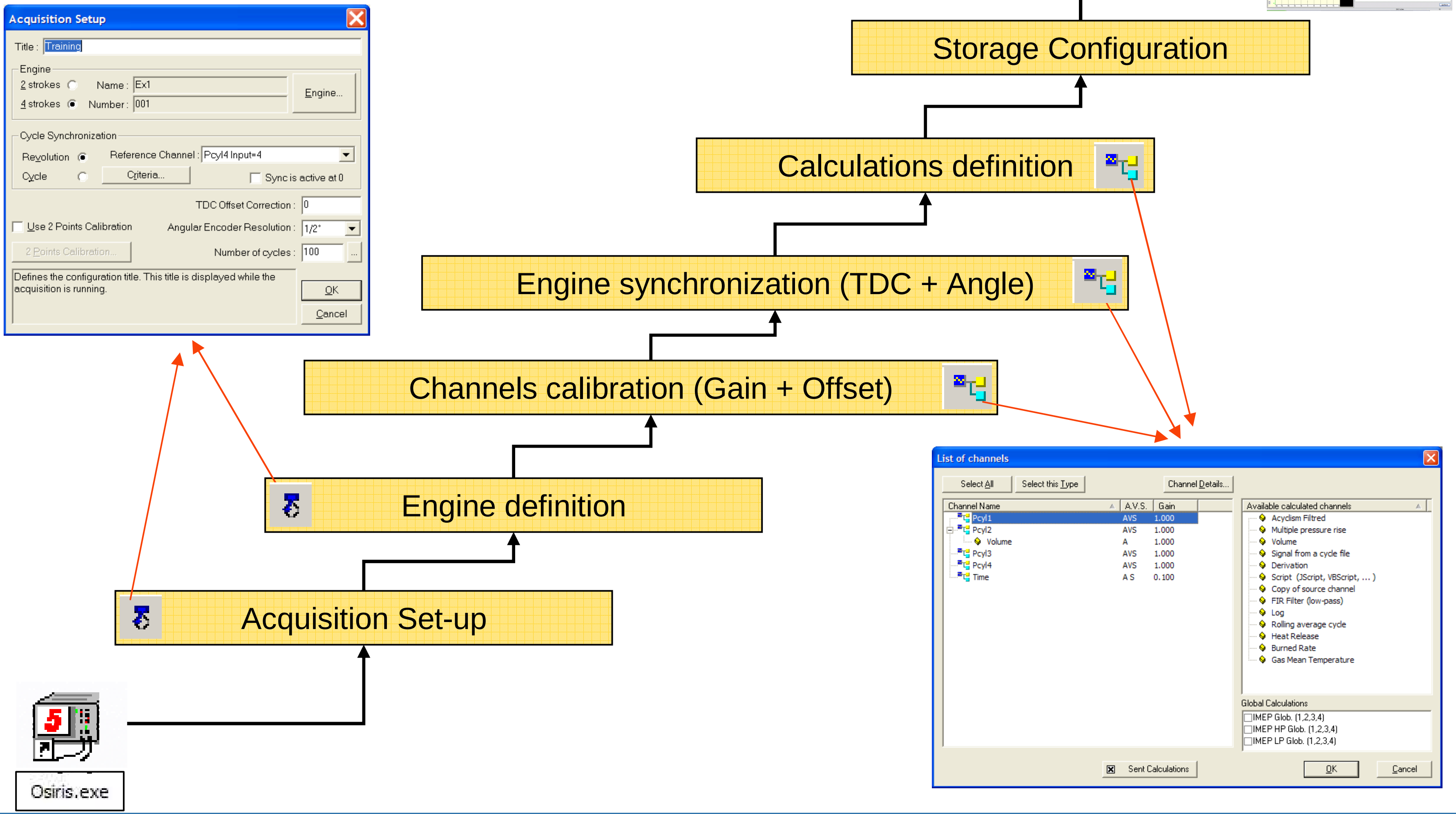
D2T Electronic encoder

- FFR-M Version 3
  - Management of multiple singularities targets (3 x 20-2 for instance)
  - Compatible with cold start (start generating pulses on first rev.)
  - Improved performances
  - ➔ Necessary tool for in-vehicle applications

A turnkey system

- Six quick steps, and OSIRIS is ready:



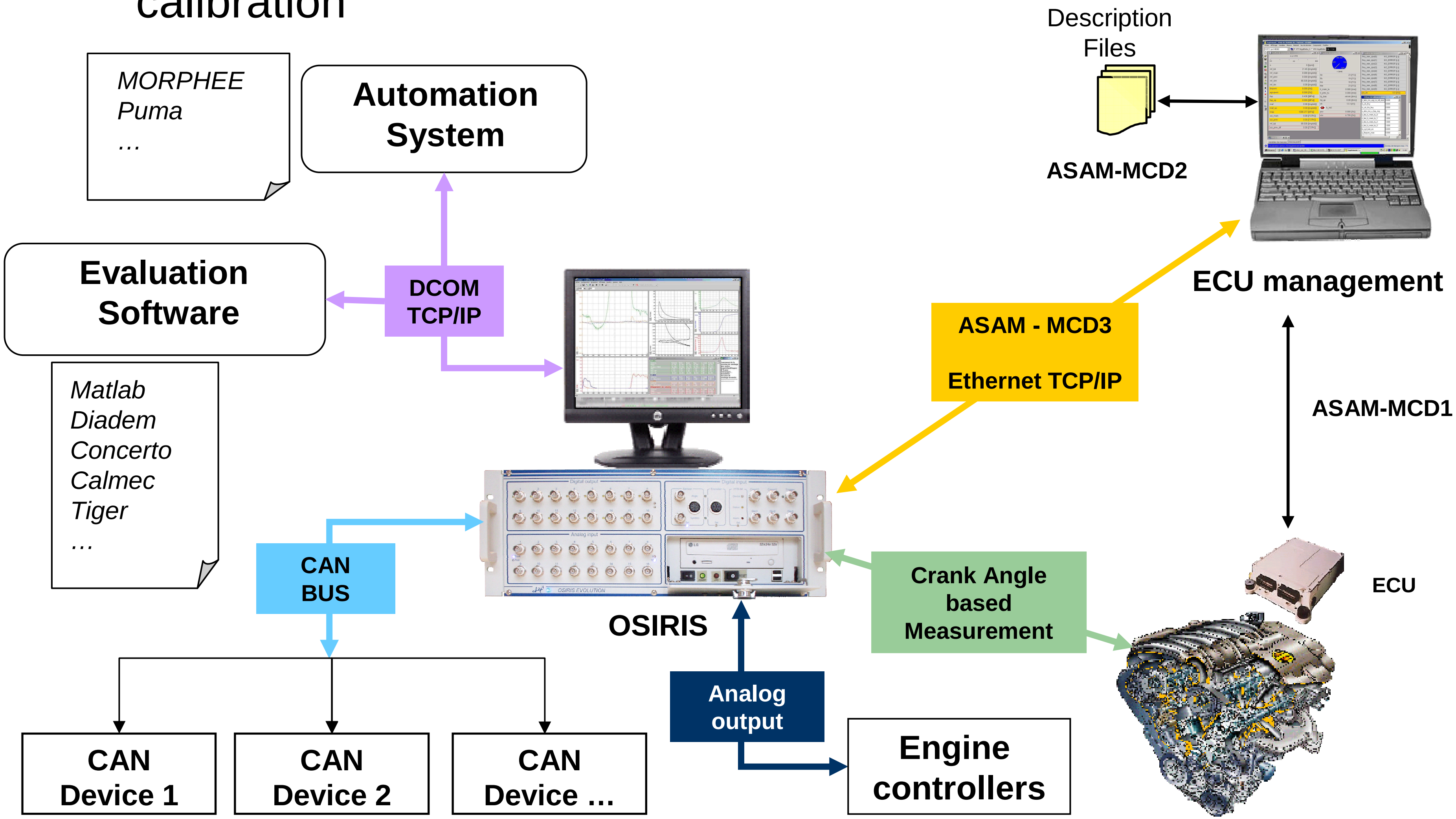


An open system

- **Compatible with main encoders suppliers:**
  - AVL 364, 365 ; KISTLER ; ONOSOKKI …
- **Compatible with all engine targets:**
  - 60-2 ; 48-2 ; 40-2 ; 3 x 20-1…
- **Interface with main charge amplifiers suppliers:**
  - KISTLER SCP platform ; AVL MICRO IFEM
- **Compatible file format with main post-processing tools:**
  - Concerto ; Diadem ; Excel ; Matlab…
- **Compatible with main automation system:**
  - MORPHEE ; PumaOPen ; Stars …
- **Standard interfaces for calibration:**
  - Analog outputs, CAN-bus, MCD3

Easy Interfaces

- OSIRIS provides all necessary interfaces for a successful calibration



Application example

- DCOM TCP/IP ⬄Indicated cycle values on transient testing

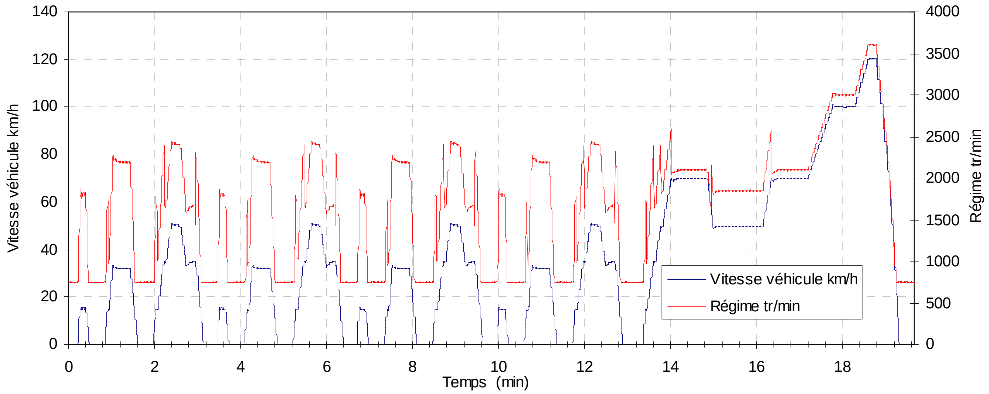
MORPHEE

DCOM TCP/IP

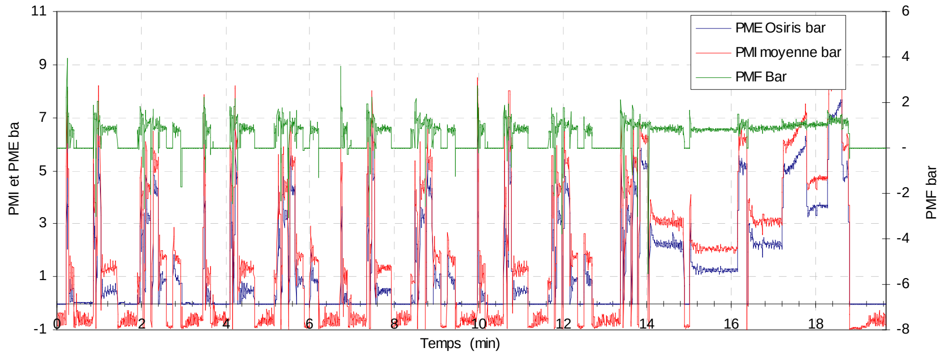
BMEP measurement

IMEP calculation

OSIRIS



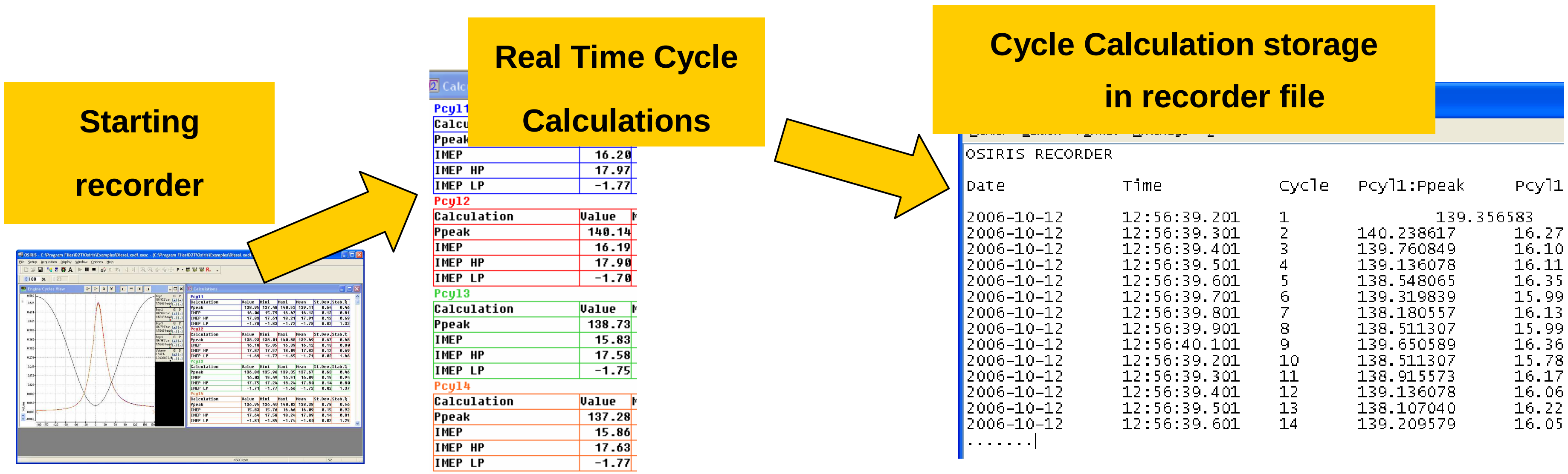
Acquisition on a ECE / EUDC cycle



FMEP calculation
Over the normalized cycle

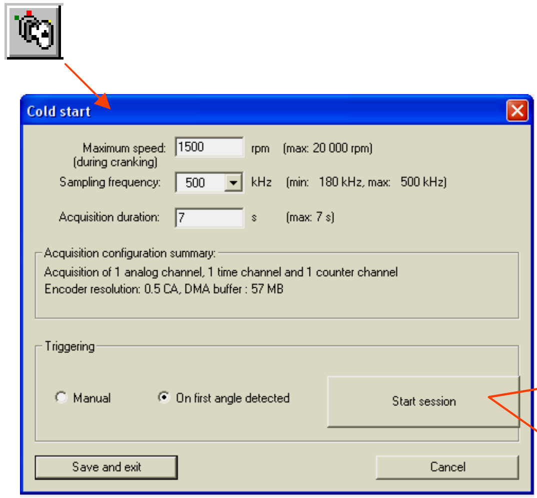
Great storage capacity

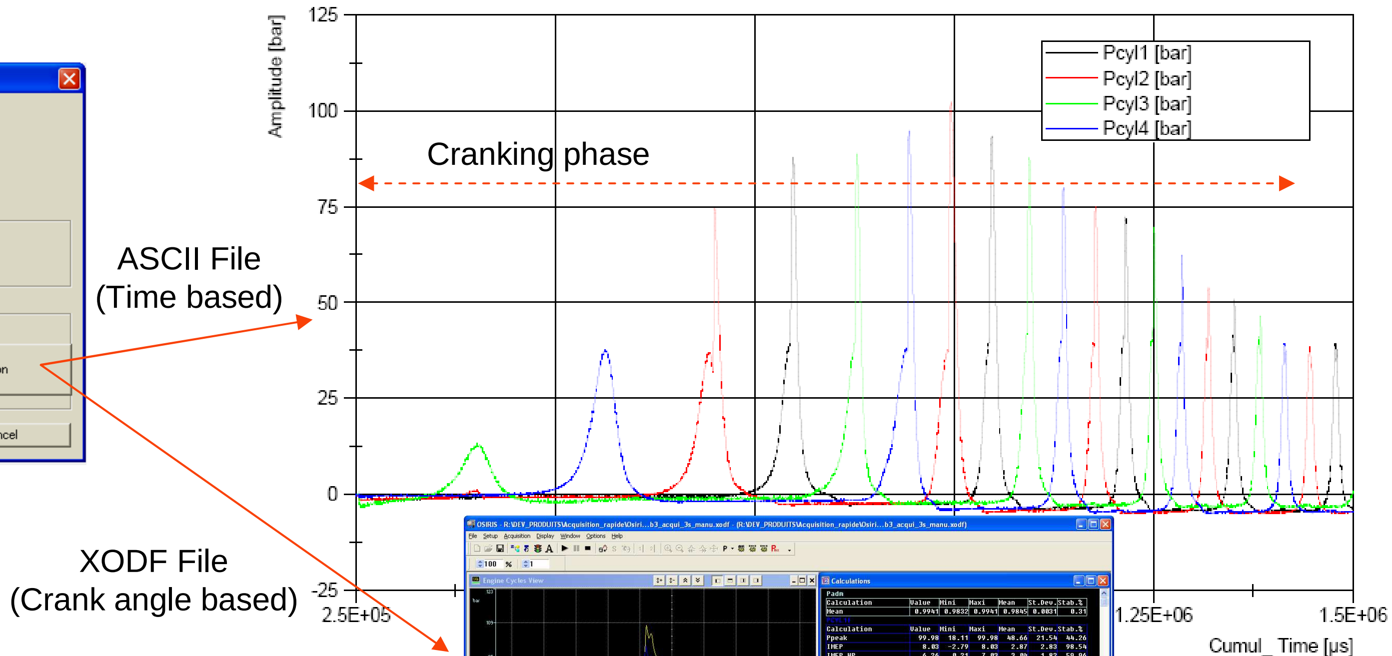
- ASCII Storage of ALL cycle by cycle calculation with no limit in time but disk space.
- Application examples :
  - IMEP storage on complete NMVEG or FTP 75
  - Ppeak recording on Mountain Peak climbing road (>1H)
  - …

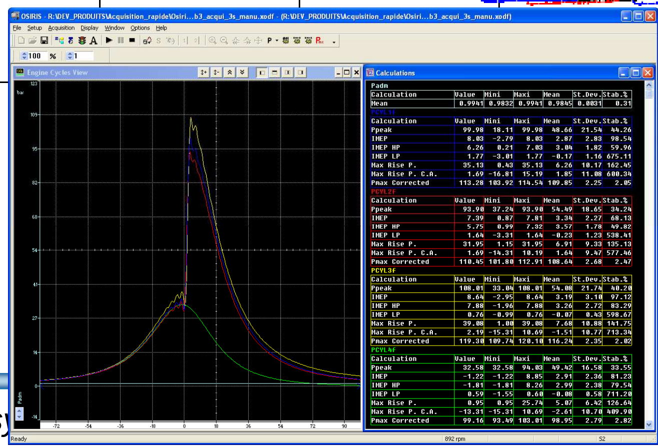


Cold start

Provide valuable information to the engineer on the critical phase of engine cranking in terms of emission

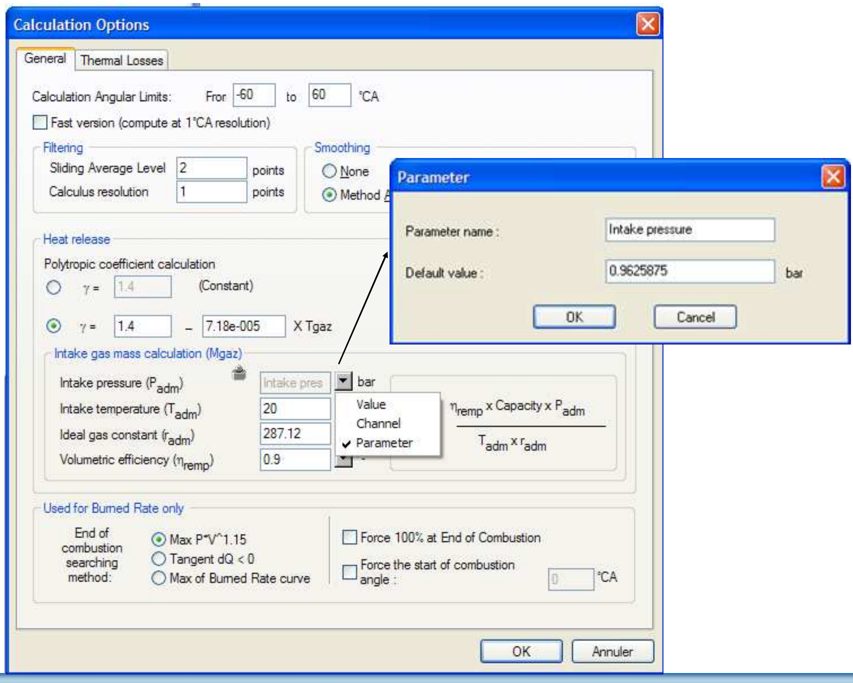


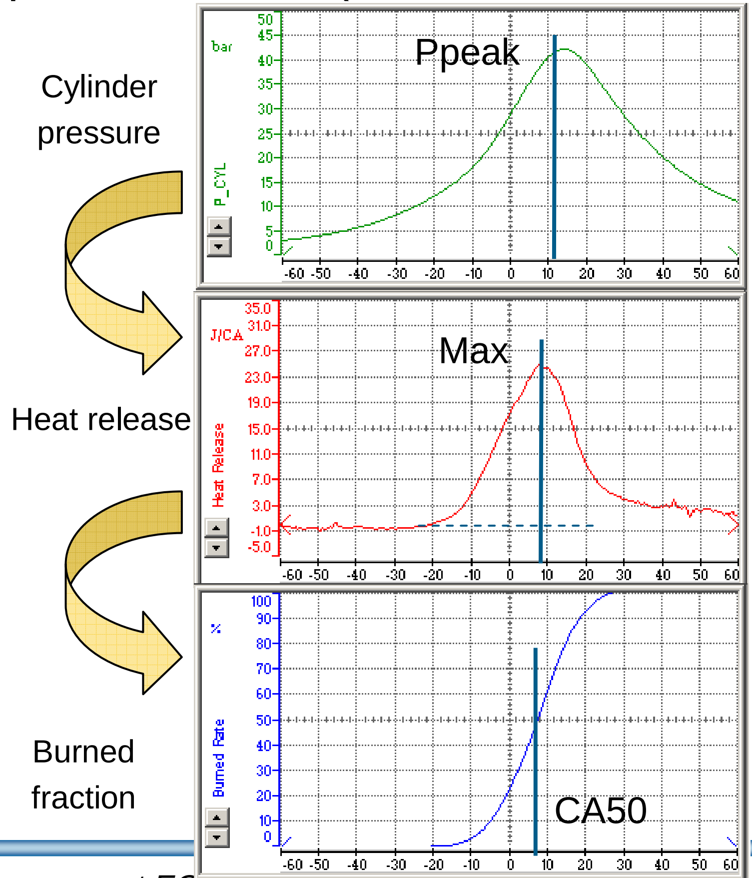




Heat release

- OSIRIS provides standard thermodynamic calculation for heat release. It is based on thermodynamic principles applied to the closed system made by gas mix mass admitted in the cylinder. This calculation is more or less complex depending on the hypothesis made (Wall losses, gas and material temperature, …)



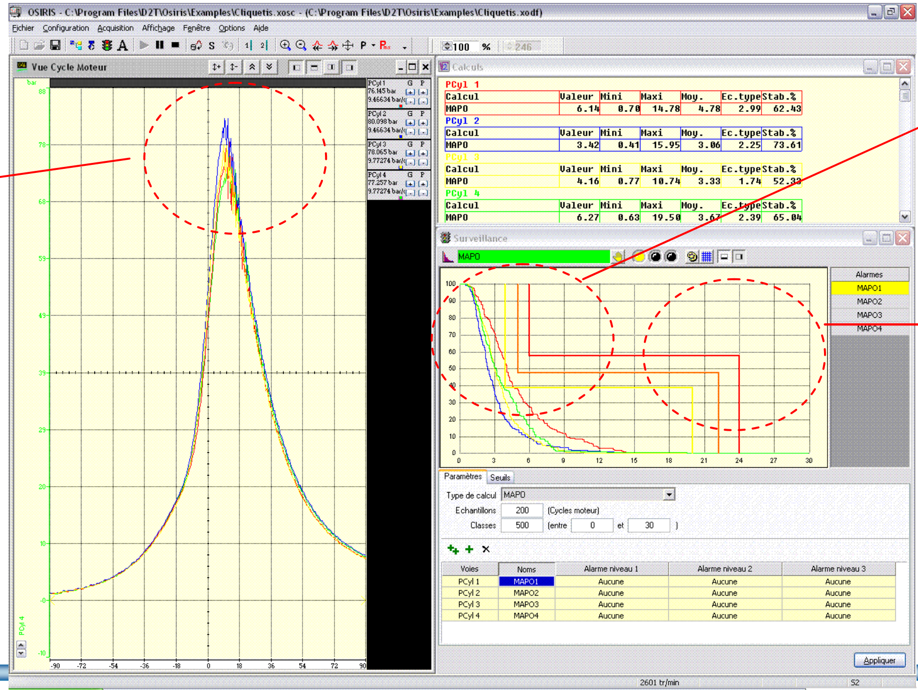


Knock tuning

- OSIRIS proposes two calculation methods of the knock level from a cylinder pressure trace:
  - **KNOCK** : Energy analysis in the frequency domain
  - **MAPO** : Maximum Amplitude of Pressure Oscillations
- It provides online tuning of knock thresholds for alarms management

➔ Necessary tool for gasoline or natural gas engine tuning

Knocking cycles



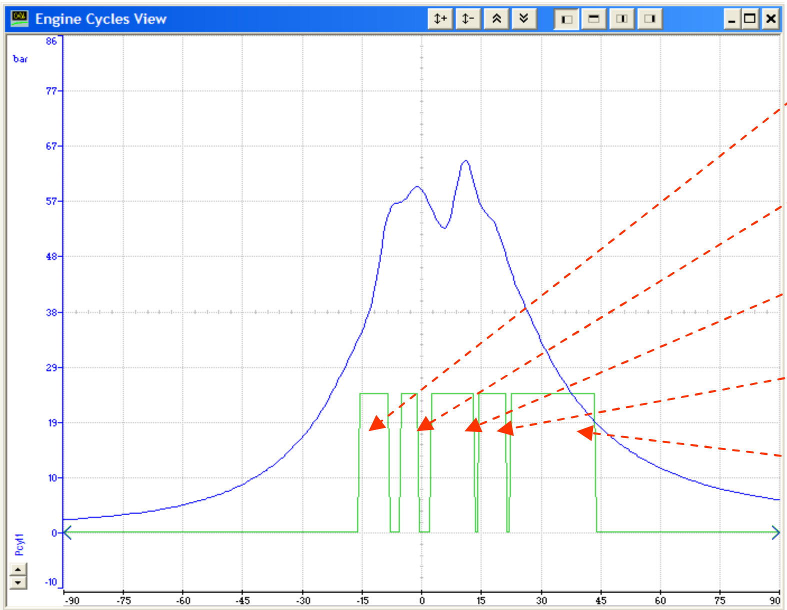
Statistical distribution of knock level

3 levels of thresholds, function of engine speed, with associated alarms

Multiple pressure gradients

- Multiple pressure gradients ⇔ This library detects injection angular windows (up to 5), using only cylinder pressure and computes for each window the maximum pressure rise and its location in the cycle.

➔ Tuning tool for compromise performances / noise



Calculations

Pcyl1

Calculation	Value	Mini	Maxi	Mean	St.Dev.	Stab.%
dPdAmax comp	???	???	???	???	???	???
dPdAmax comp angle	???	???	???	???	???	???
1-Start angle	-16.00	-17.50	-15.50	-15.90	0.62	3.93
1-End angle	-8.00	-9.00	-8.00	-8.25	0.34	4.07
1-dPdAmax	4.41	4.29	4.66	4.52	0.13	2.96
1-dPdAmax angle	-10.00	-10.50	-10.00	-10.15	0.23	2.26
2-Start angle	-4.50	-5.50	-4.50	-4.70	0.33	7.06
2-End angle	-0.50	-1.50	0.00	-0.65	0.39	60.08
2-dPdAmax	0.92	0.74	1.04	0.89	0.09	10.34
2-dPdAmax angle	-2.50	-3.50	-2.00	-2.55	0.42	16.29
3-Start angle	2.50	2.00	3.50	2.70	0.40	14.81
3-End angle	12.50	12.50	13.00	12.90	0.20	1.55
3-dPdAmax	3.49	3.13	3.56	3.43	0.13	3.66
3-dPdAmax angle	8.50	8.50	9.00	8.55	0.15	1.75
4-Start angle	14.50	14.50	15.00	14.55	0.15	1.03
4-End angle	21.00	21.00	22.00	21.35	0.32	1.50
4-dPdAmax	-0.74	-0.74	-0.49	-0.61	0.09	14.83
4-dPdAmax angle	17.00	17.00	17.50	17.20	0.24	1.42
5-Start angle	22.50	22.50	23.50	22.85	0.32	1.40
5-End angle	41.00	40.00	43.50	41.15	1.23	2.98
5-dPdAmax	-0.80	-0.86	-0.67	-0.79	0.05	6.44
5-dPdAmax angle	41.00	38.50	43.00	40.50	1.36	3.36

And also …

- **Combustion noise**: equivalent to a « noisemeter »
➔ give access to the engine noise in dB (including engine block attenuation and human ear A filter), based on the cylinder pressure.

- **Rotational vibration analysis**:
➔ based on an instantaneous speed measurement, allows to analyze vibrations due to speed variations.

- **Needle lift analysis**:
➔ allows to characterize the injection system, when it is equipped with needle lift sensors (lift durations, phase,…)

Conclusion

- An efficient combustion analysis system is a key device through the calibration process of an application
- It is used at every steps of the calibration process, at the test cell or inside a vehicle
- It has become a compulsory system for a successful calibration
- It must provide easy connection with all standard systems
- It must provide synchronization solution with the engine in all environments

→ **OSIRIS** from **D2T**, with its new electronic encoder (**FFR-M**) and its recent developments such as **MCD3** and **CAN bus** interfaces is one of these key system for a successful calibration.

Thanks for your attention

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