Modelbased Predictive Control of 2-Stage Turbocharged Gasoline Engines

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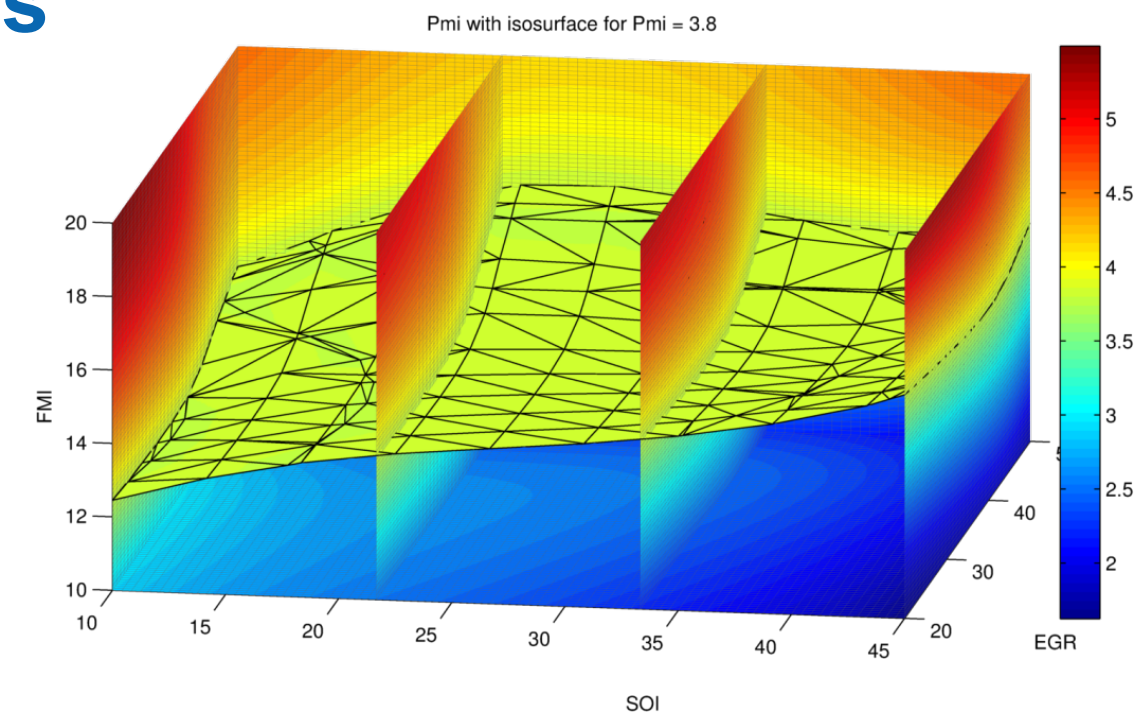

Agenda

- Engine Control
  - → Fundamentals
  - → Research@IRT
- Turbocharging for Gasoline Engines
  - → Fundamentals
  - → FVV Project

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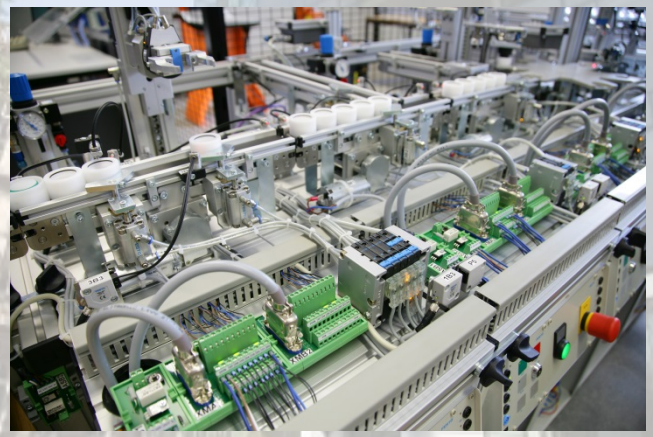
Institute of Automatic Control
RWTH Aachen University



Structure of IRT

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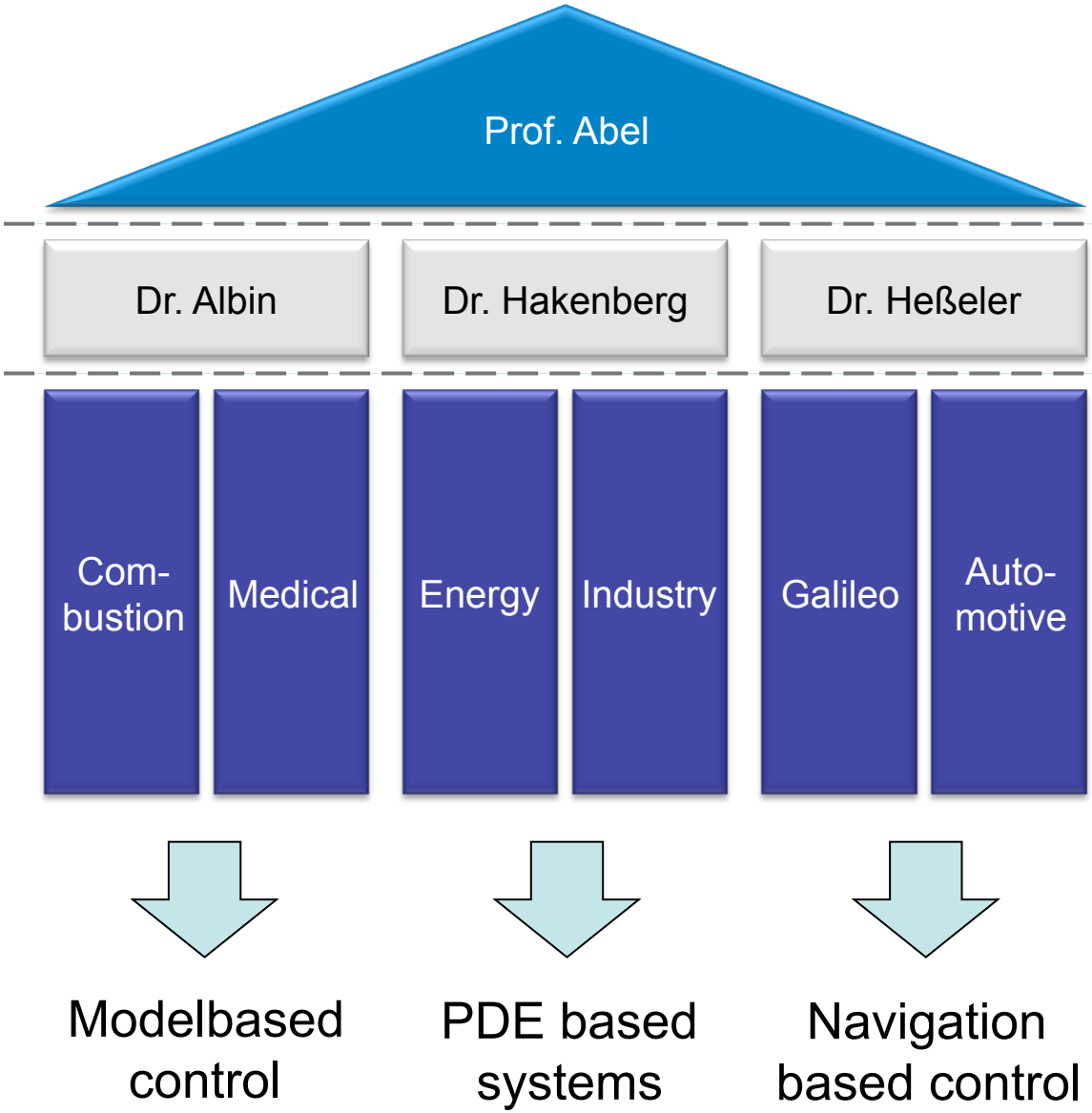

1 Head of Institute

3 Senior Engineers

approx.
30 PhD Students

approx.
80 student workers

IRT

Structure of IRT

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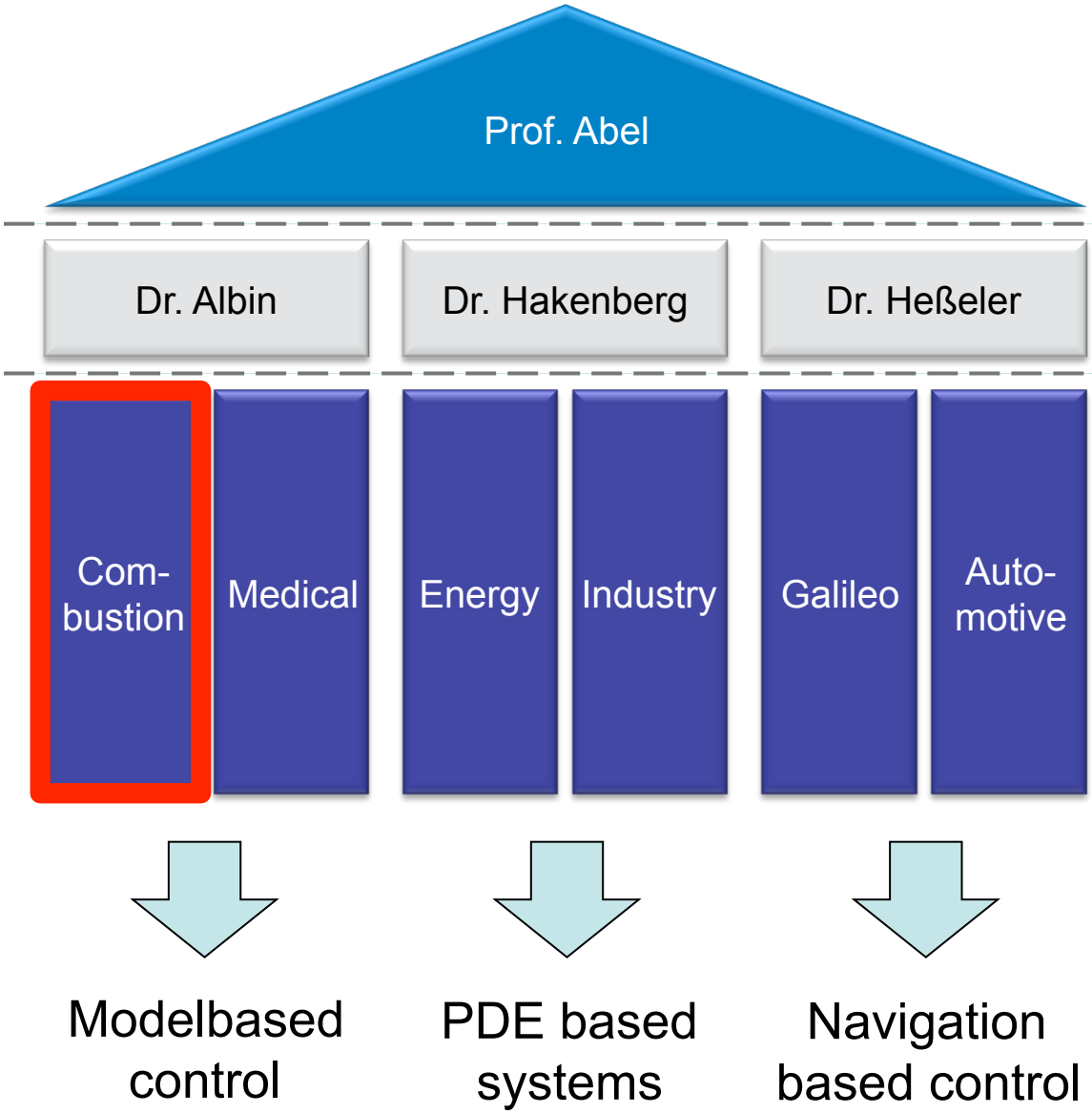

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Research on Combustion Necessary ?

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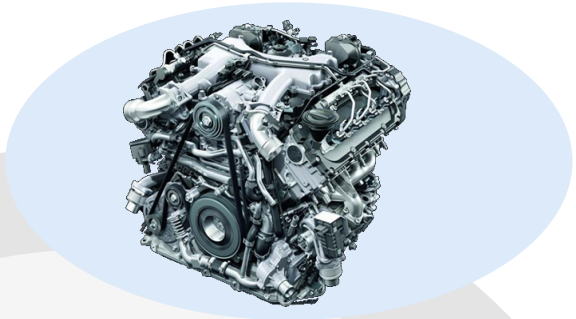

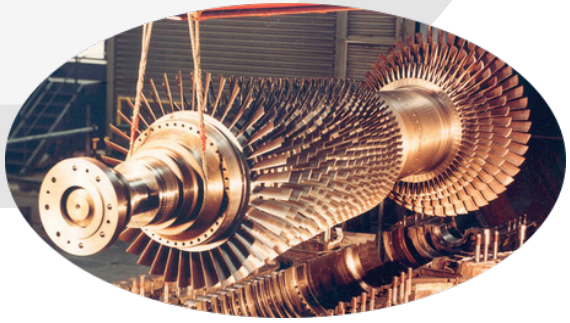

IRT

In the foreseeable future

combustion processes are indispensable

for mobile and stationary energy supply!

Criteria and Trends in Engine Development

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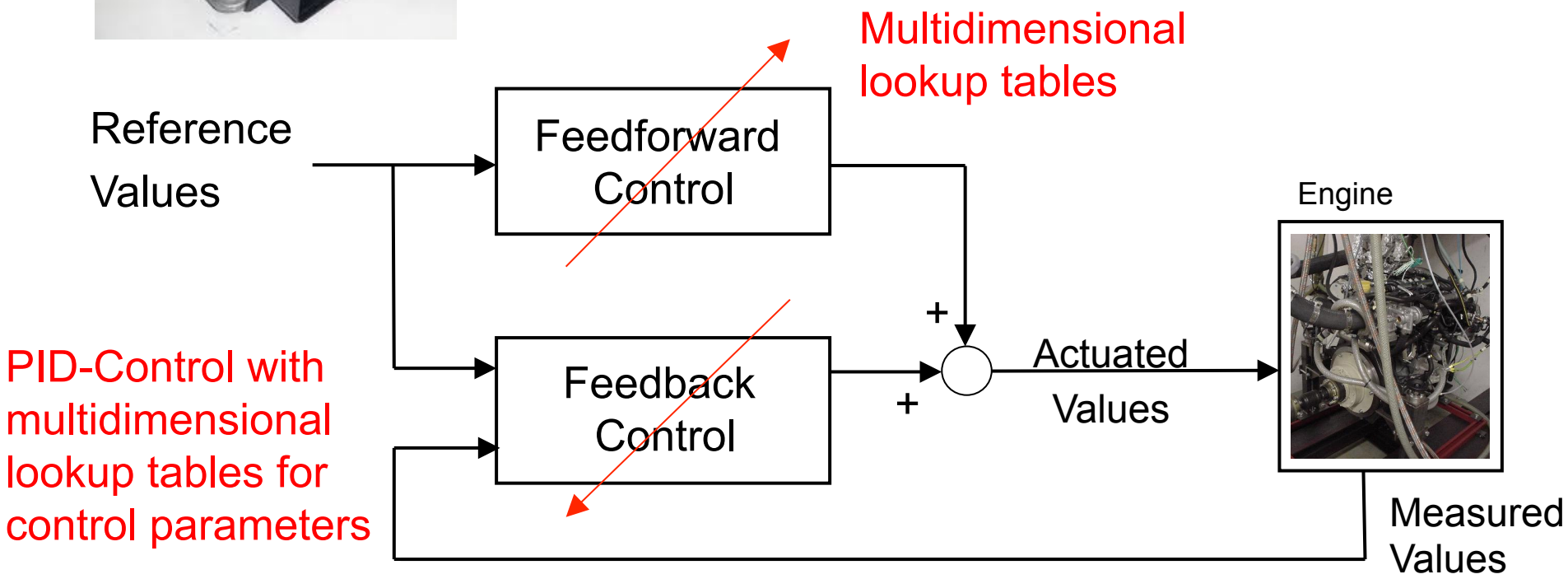
- Emission legislation
- Fuel consumption
- Drivability / Torque demand

Improvement of propulsion system

- New actuators (Variable Vale Train, Turbocharging)
- New sensors (Cylinder Pressure)

Series Engine Control Structure

- Effect on control algorithm ?



Effects on Control Algorithm

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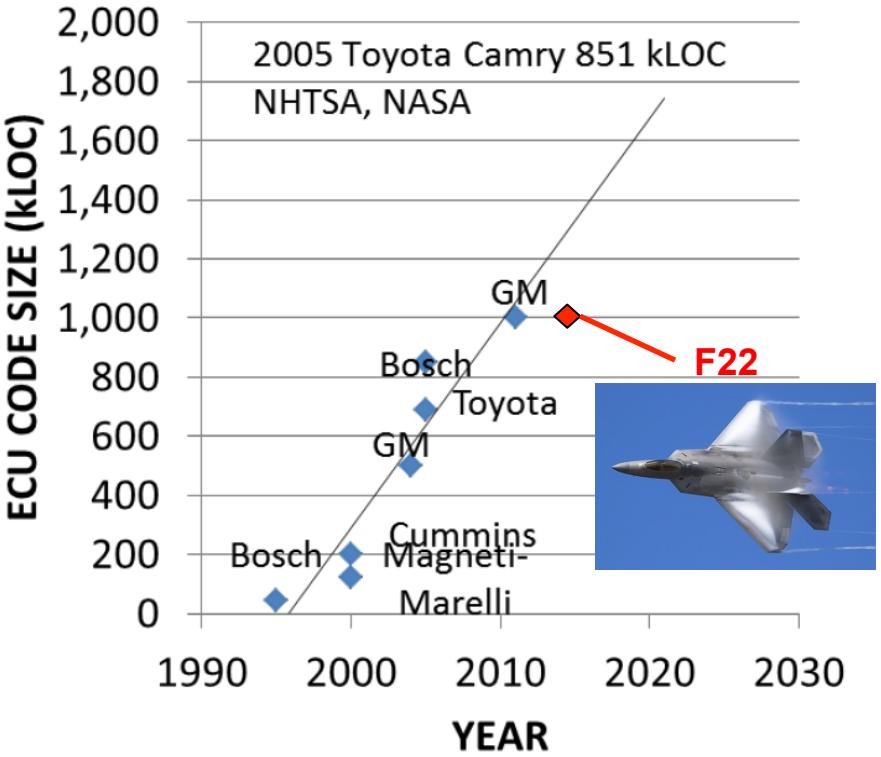
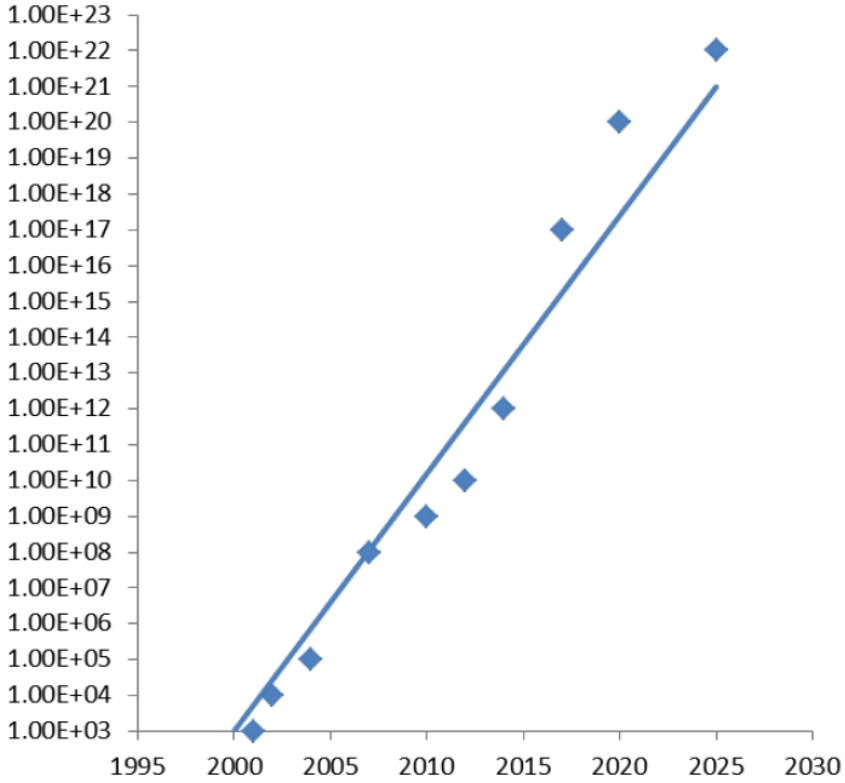


Software Lines of Code



Full Factorial Calibration Space

New control methods need to be developed in order to handle increased complexity

Engine Research @ IRT

Mission Statement:

- Develop new engine control concepts that are able to cope with the increasing complexity:
  Modelbased Predictive Control

Engine Research @ IRT

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- Reduced Order Models
  - → Where are physical models applicable and what kind of models are suitable?
  - → Where do we need data-driven models or grey-box-models?
  - → How to identify data-driven models (design-of-experiments and identification techniques)?

Engine Research @ IRT

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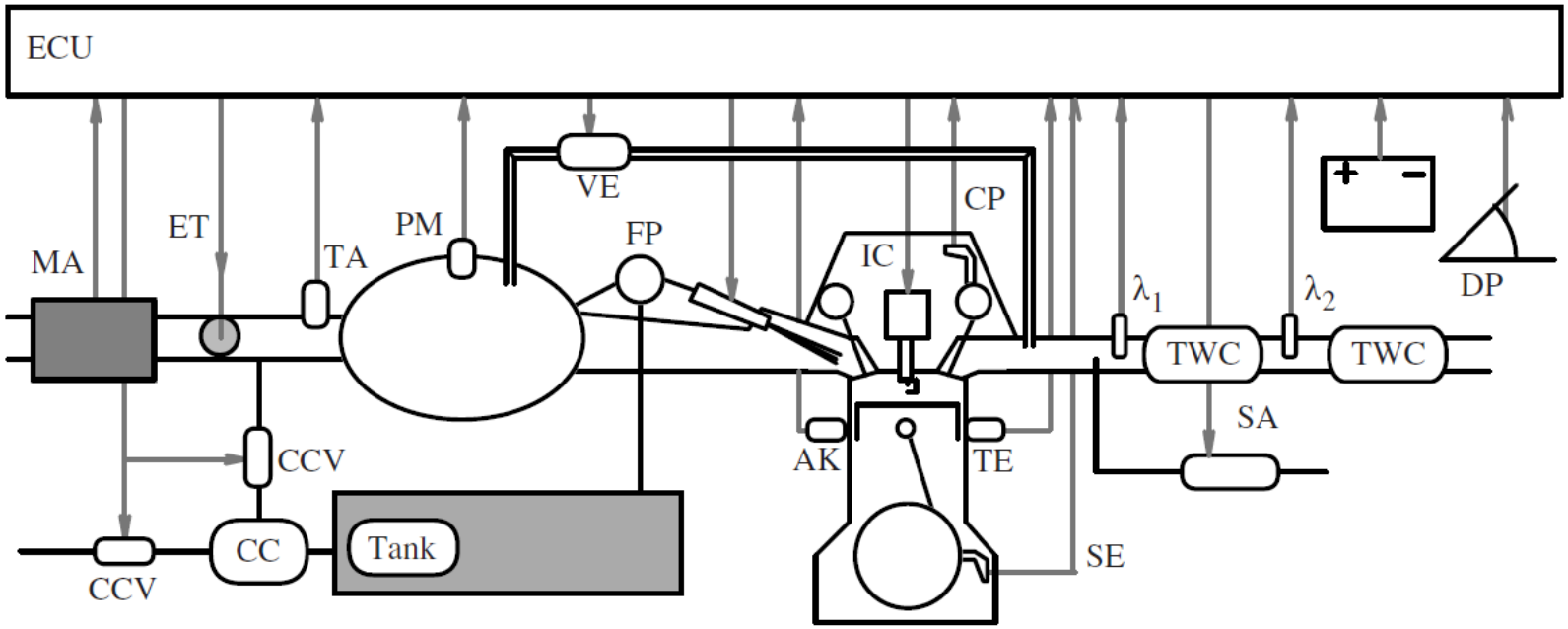
- Control Algorithm
  - → What kind of structure should controller have (choice of sensors, actuators and corresponding actuated, disturbance, controlled variables)?
  - → What to handle in feed-forward, what in feedback?
  - → How to formulate the control problem in order to fulfill all requirements on control algorithm?

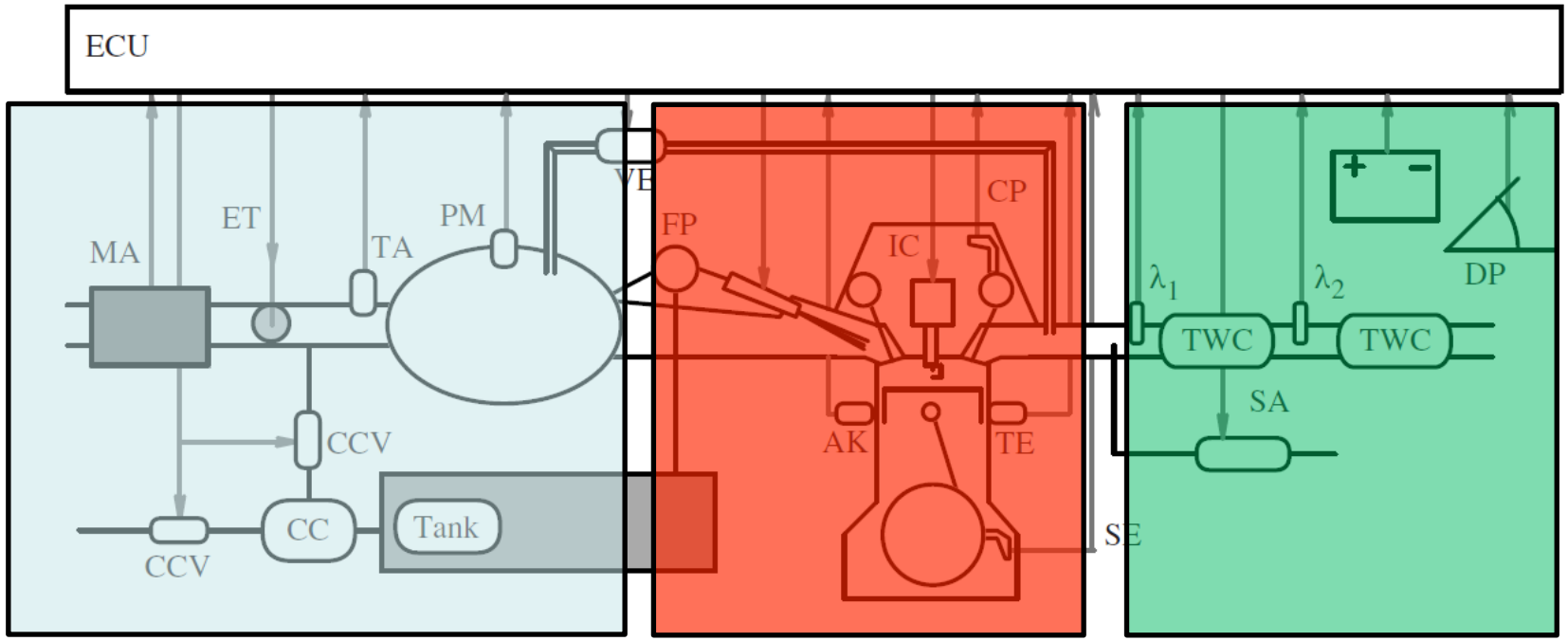
Gasoline Engine: Sensors / Actuators



AK	knock sensor	PM	manifold pressure sensor	VE	EGR valve
CP	camshaft sensor	ET	electronic throttle	SA	secondary air valve
IC	ignition command	TA	intake air temperature sensor	TWC	3-way catalyst
MA	air mass-flow sensor	TE	cooling water temperature sensor	ECU	controller
SE	engine speed sensor	CC	active carbon canister	CCV	CC control valves
FP	fuel pressure control	$\lambda_{1,2}$	air/fuel ratio sensors	DP	driver pedal

Lino Guzzella (2009): Introduction to Modelling and Control of ICE Systems

Engine Control Structure



Air Path

Fuel Path / Combustion Process

Exhaust Aftertreatment

Selected Projects @ IRT

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Premixed Charge Compression Ignition
(Gasoline / Diesel)

Premixed Charge Compression Ignition
(Dual-Fuel Engines in Ships)

imagination at work

L'orange
YOUR POWERFUL INJECTION

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MEYER WERFT
PAPENBURG 1795

HAMMONIA
REEDEREI

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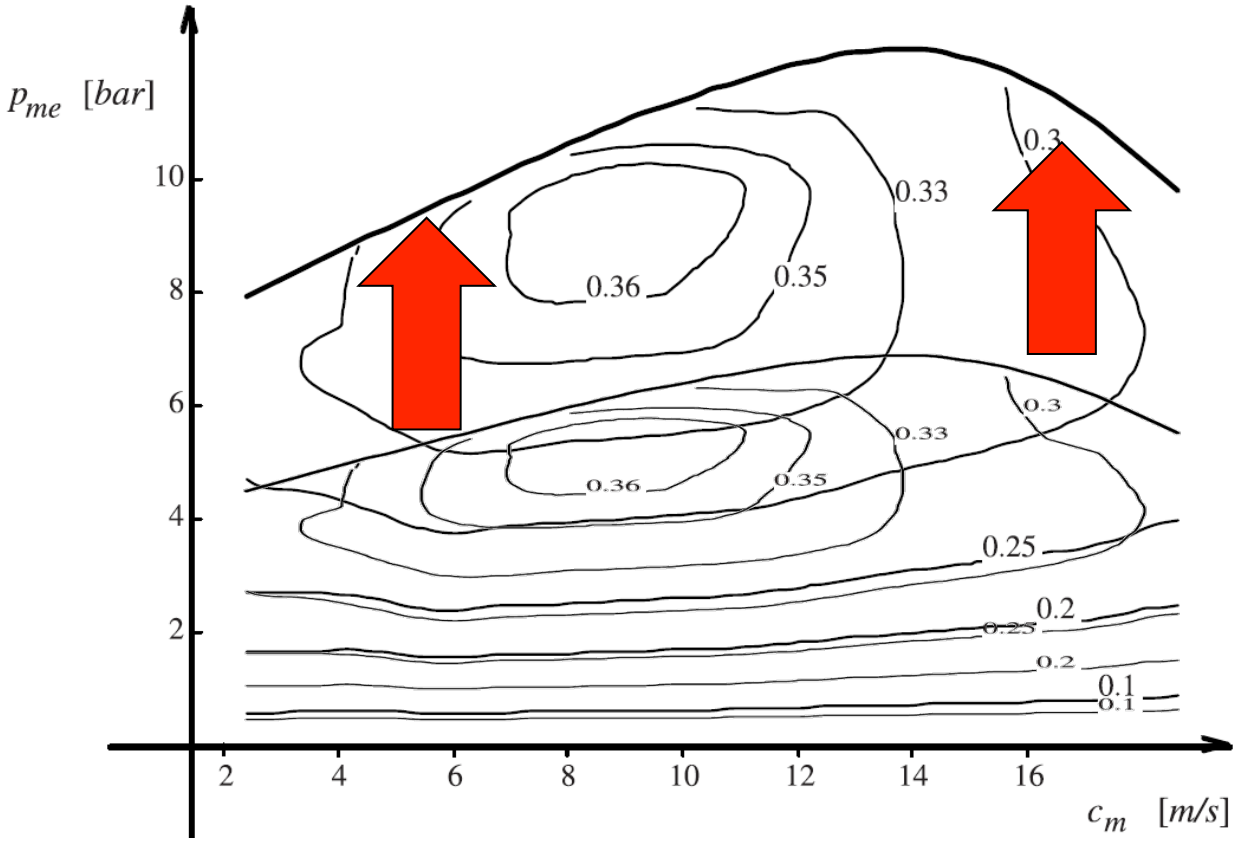
Turbocharging

- Make a small engine act like a big engine



Reduction of engine size

Lino Guzzella (2009): Introduction to Modelling and Control of ICE Systems

Dimensioning of Turbocharger

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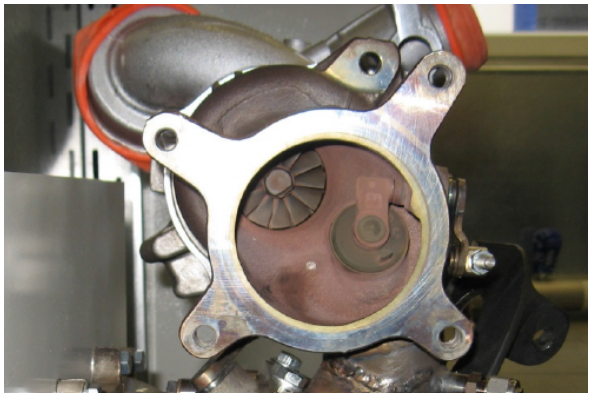
- Increase of specific power output



Conflict of aims for dimensioning!

- High stationary charging pressure and operation with high efficiency
  - → Use of „big“ turbocharger stage with high mass moment of inertia
- High „low-end-torque“ at low engine speeds → improvement of transient behaviour (Turbo-Lag)
  - → Use of „small“ turbocharger stage with low mass moment of inertia

Modern Air Path Structures

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Increase flexibility to handle conflict of aims

- Variable Turbine Geometry
- 2-Stage Turbocharging
  - → Use a big turbocharger and a small turbocharger
- Diesel engines have long history on turbocharging
- Gasoline engines just recently started turbocharging
  - → Diesel engines turbocharging is used to decrease emissions
  - → Exhaust gas is hotter, which makes actuating / sensing more difficult
  - → Requirements on control are higher than for diesel engines
  - → Almost no papers on 2-stage control of gasoline engines (BorgWarner, FEV/VKA)

Requirements on Controller

- Track charging pressure without overshoots
  - → negative impact on drivability
- Track charging pressure as quick as possible
  - → accelaration of car (Time 0 -> 100 km/h)
- Economic criteria
  - → Reduce exhaust back pressure / fuel consumption

Thanks a lot for your attention!

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