TETE

Use of automation and simulation in large/commercial engine and application development

Göteborg, 19.11.2014, Dr. S.C.Fritz

Today‘s agenda

Demands of the exhaust gas legislation

Methodology - Which infrastructure is required?

Introduction of DoE and CAMEO

Use and improvement of CAMEO

Examples & Results

Summary!

Demands of the exhaust gas legislation

High speed Diesel engines from 75kW to 10.000kW

Propulsion & Power Generation

Marine & Offshore

Governmental

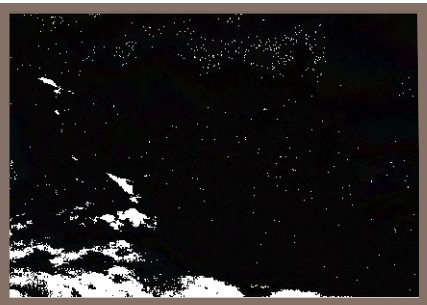
C&I, Agriculture Underground Mining

Rail, Mining, Oil & Gas

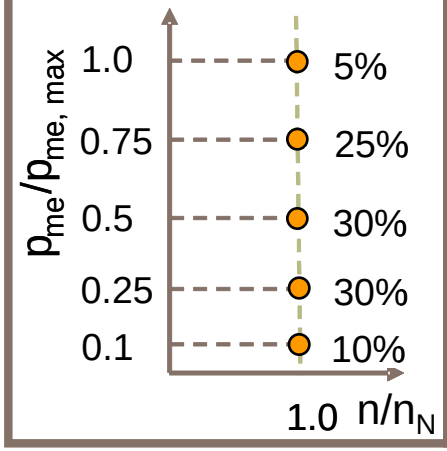
Power Generation

Demands of the exhaust gas legislation
Stationary emission cycles

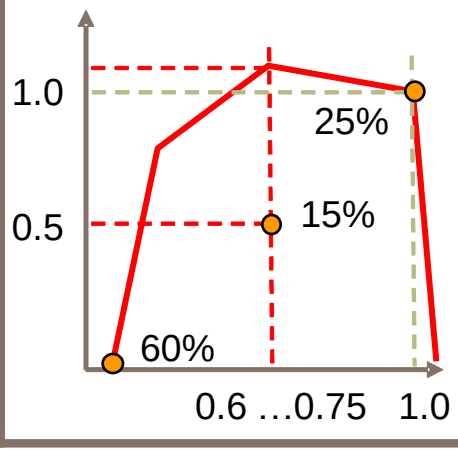
Power Gen	Rail	Const. & Industr.	Agriculture



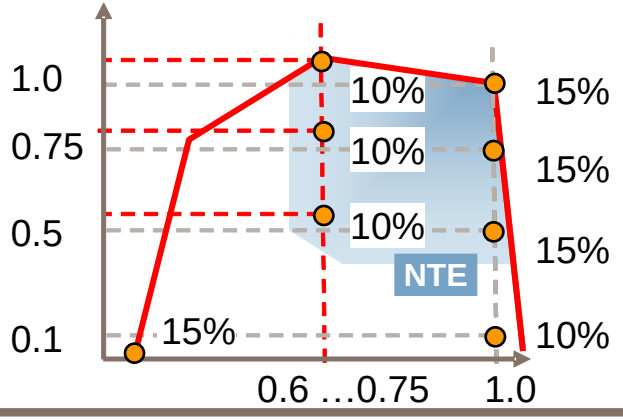
ISO 8178-4 D2- cycle



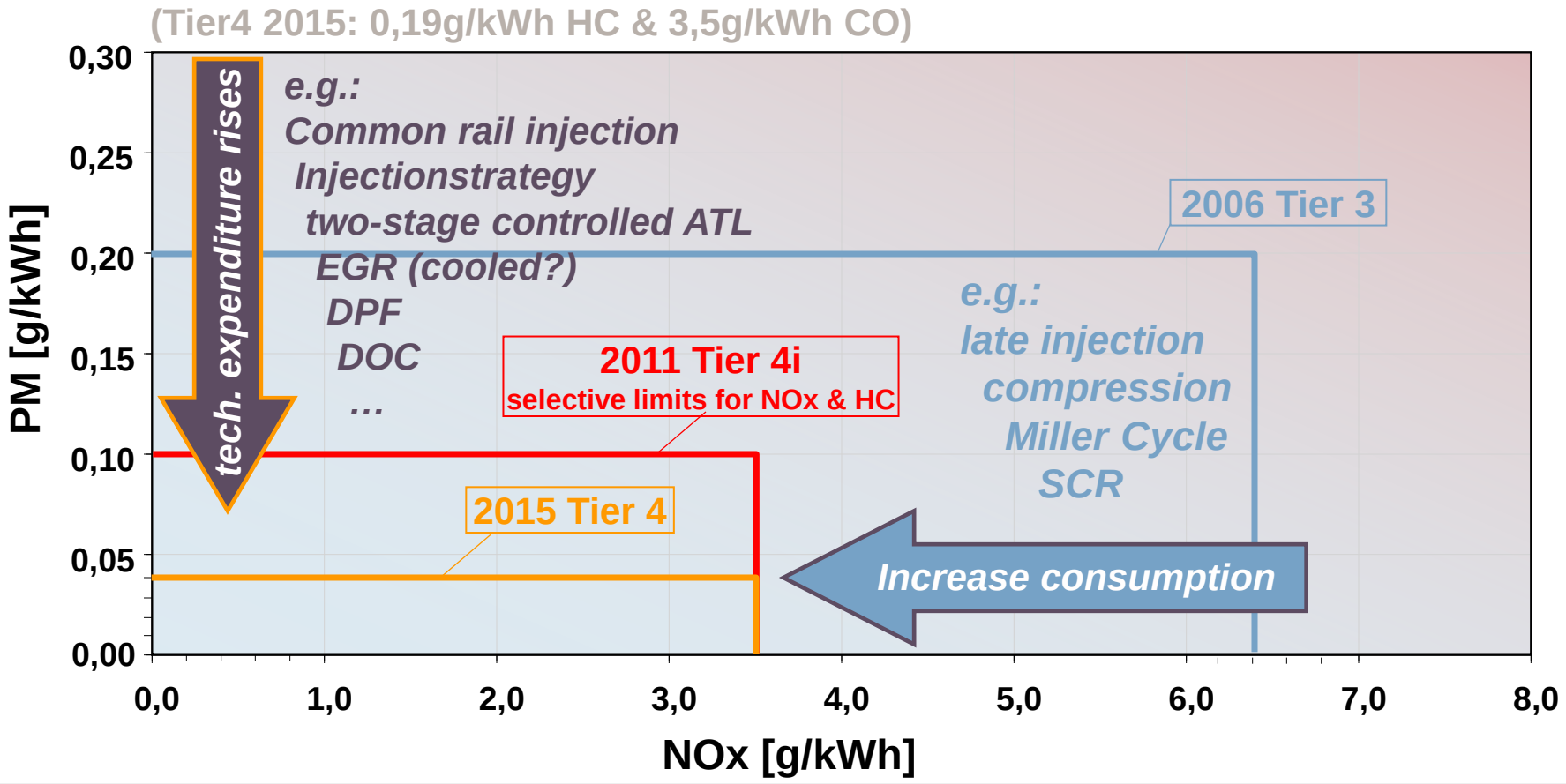
ISO 8178-4 F- cycle



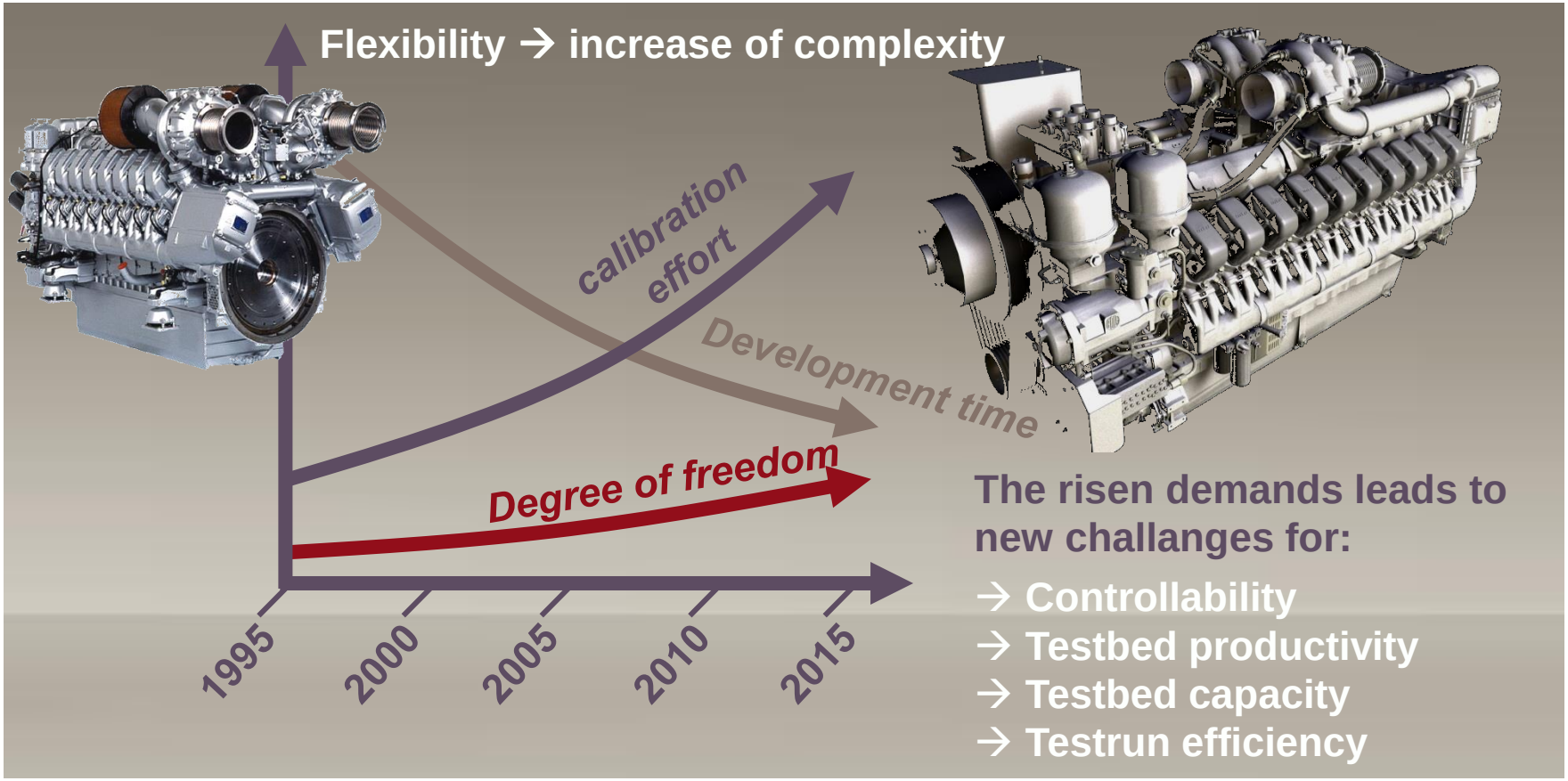
ISO 8178-4 C1- cycle (& NRTC <560kW)



US EPA-emission standards
for achievement >560kW mobile applications (C&I)



Consequence of the exhaust gas legislation
→ Application of Methodology!

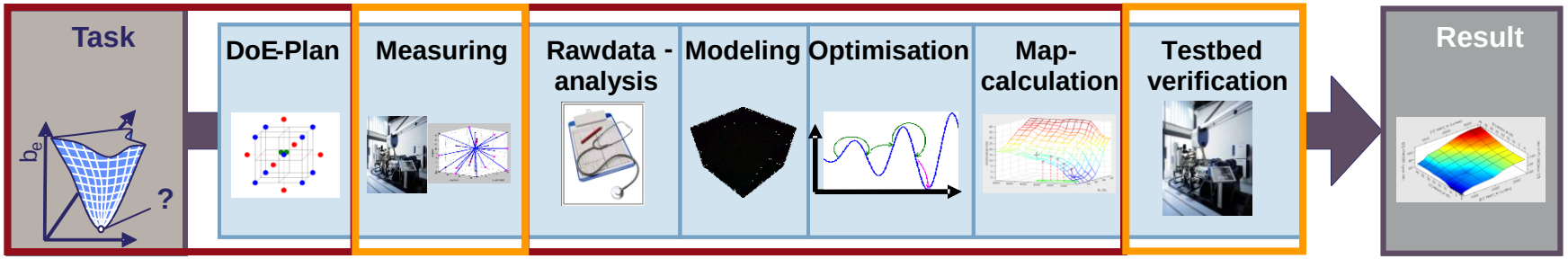


The risen demands leads to new challanges for:

- → Controllability
- → Testbed productivity
- → Testbed capacity
- → Testrun efficiency

Methodology
Which infrastructure is required?

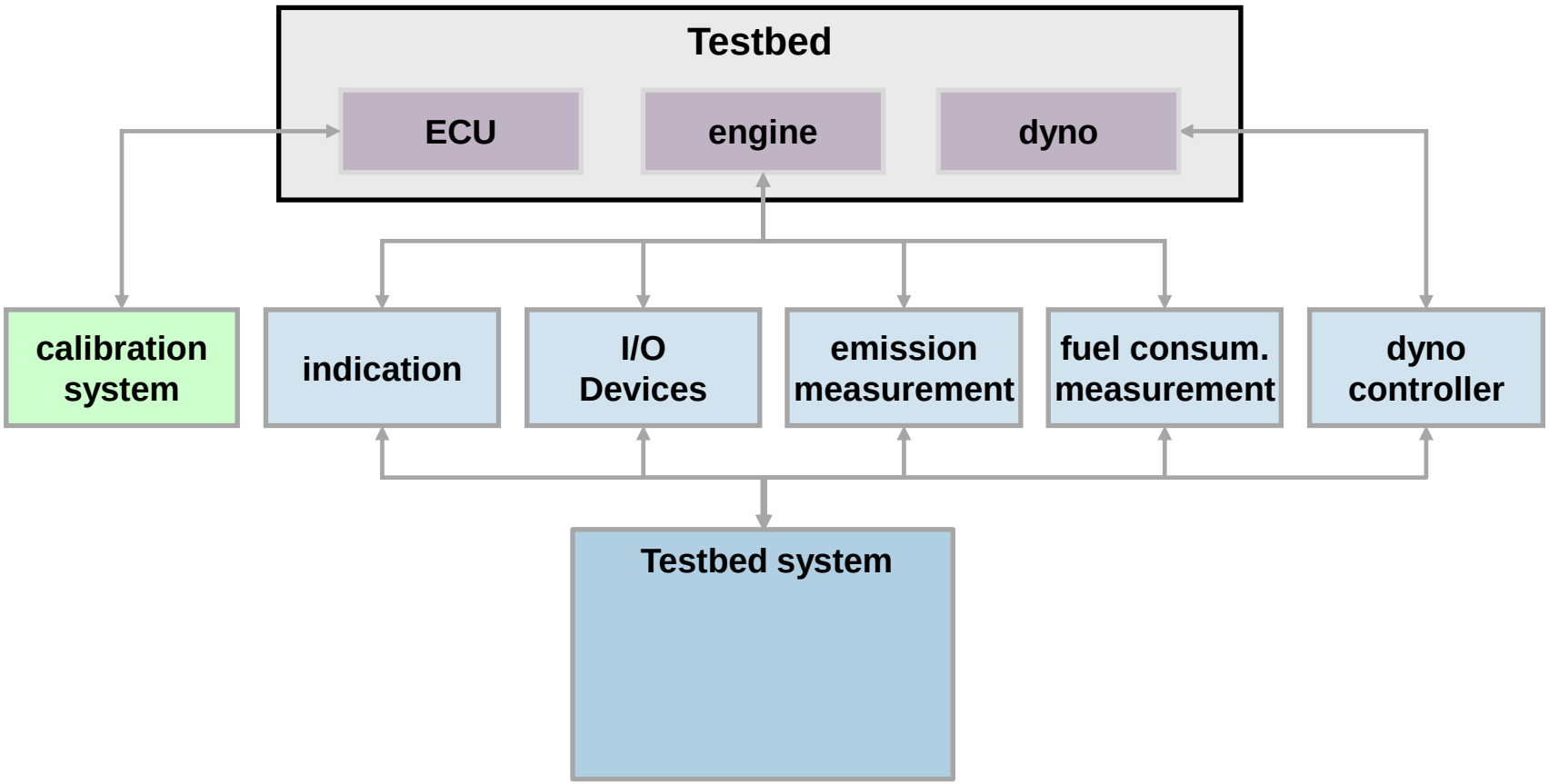
For the coping of future application duties design of experiment (DoE) is introduced to MTU since 2008 toward the following workflow.



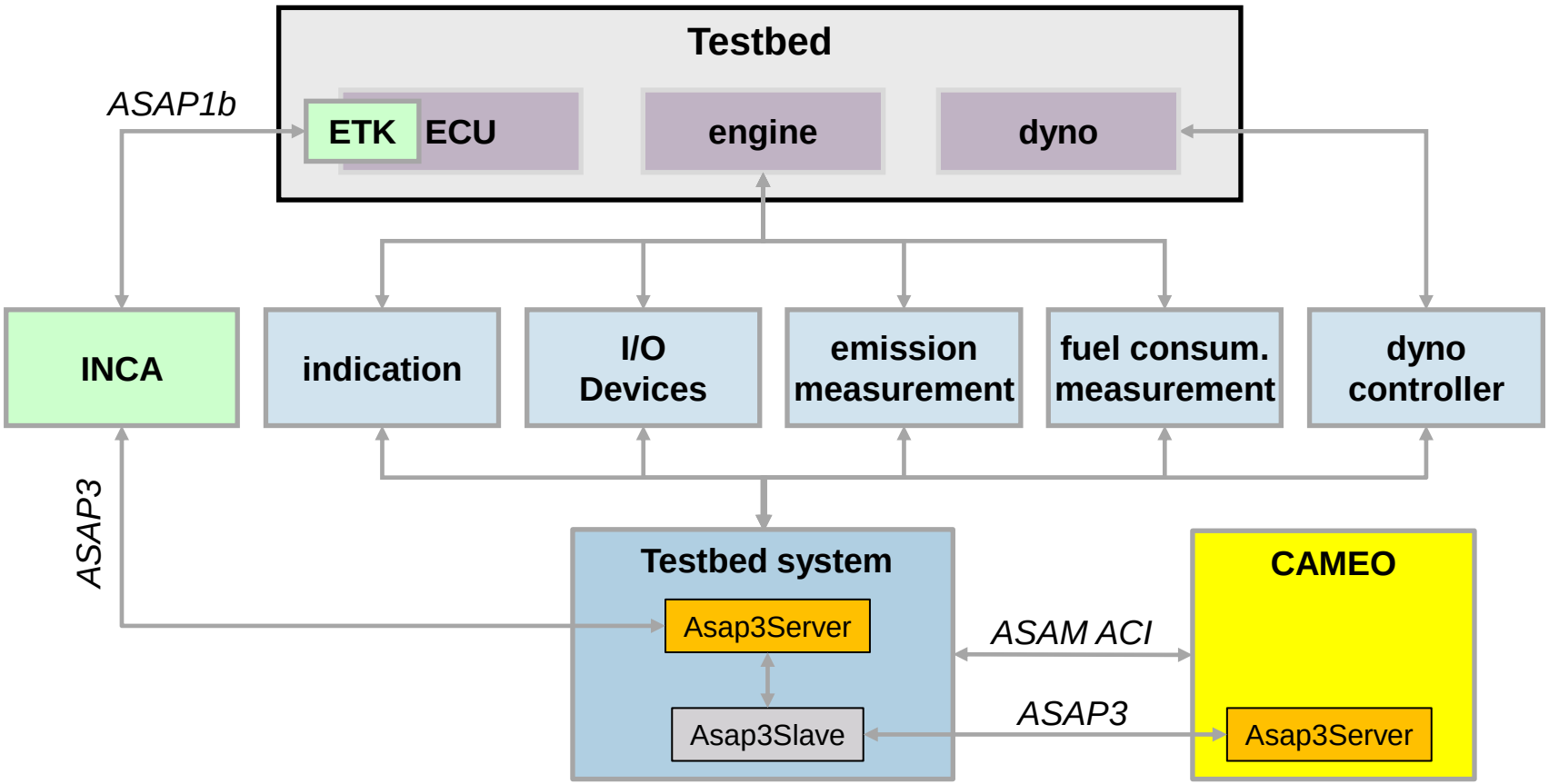
→ *Build up of methodical competence*

→ *Establishment of the technical requirements to maximize the level of automation with the measurement*

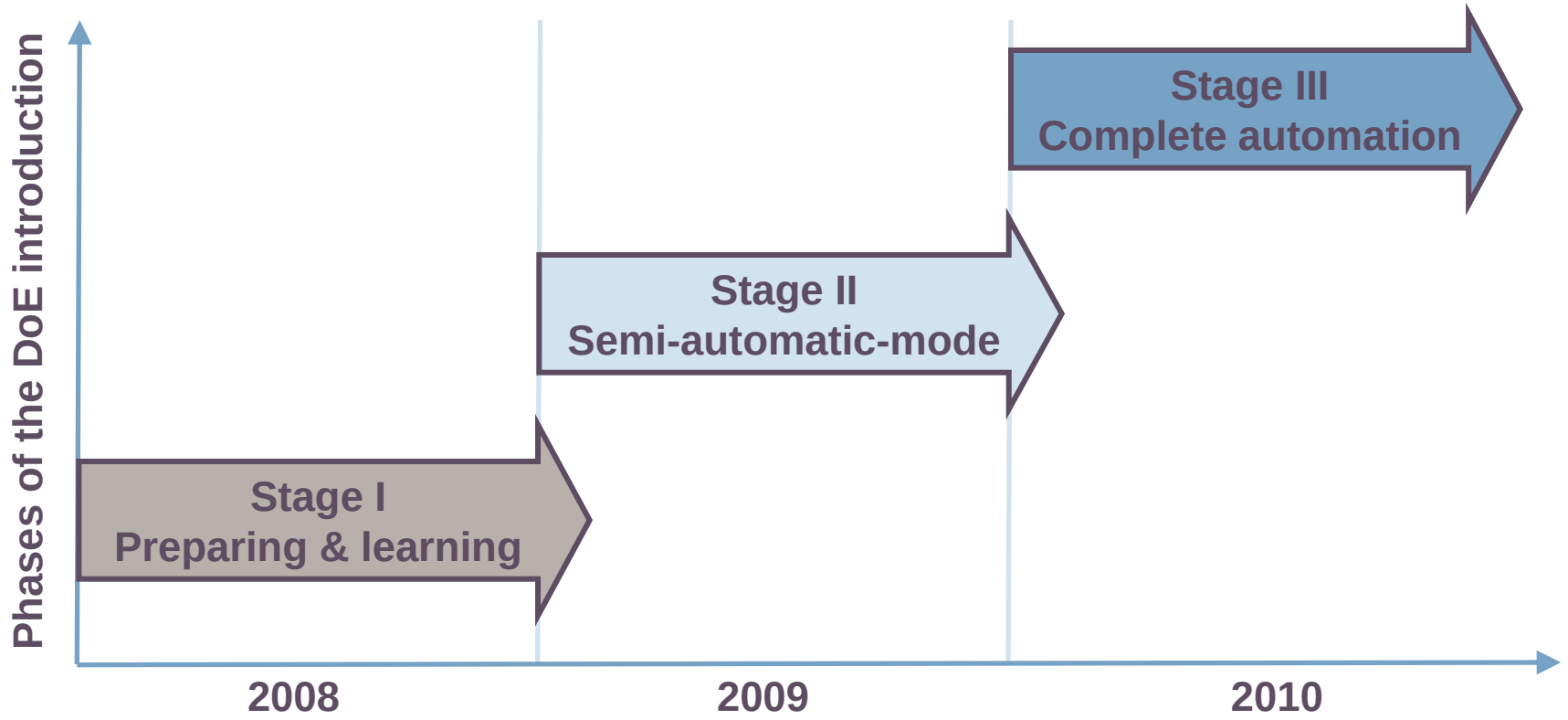
Methodology
Which infrastructure is required?



Methodology
Which infrastructure is required?



Introduction of DoE and CAMEO



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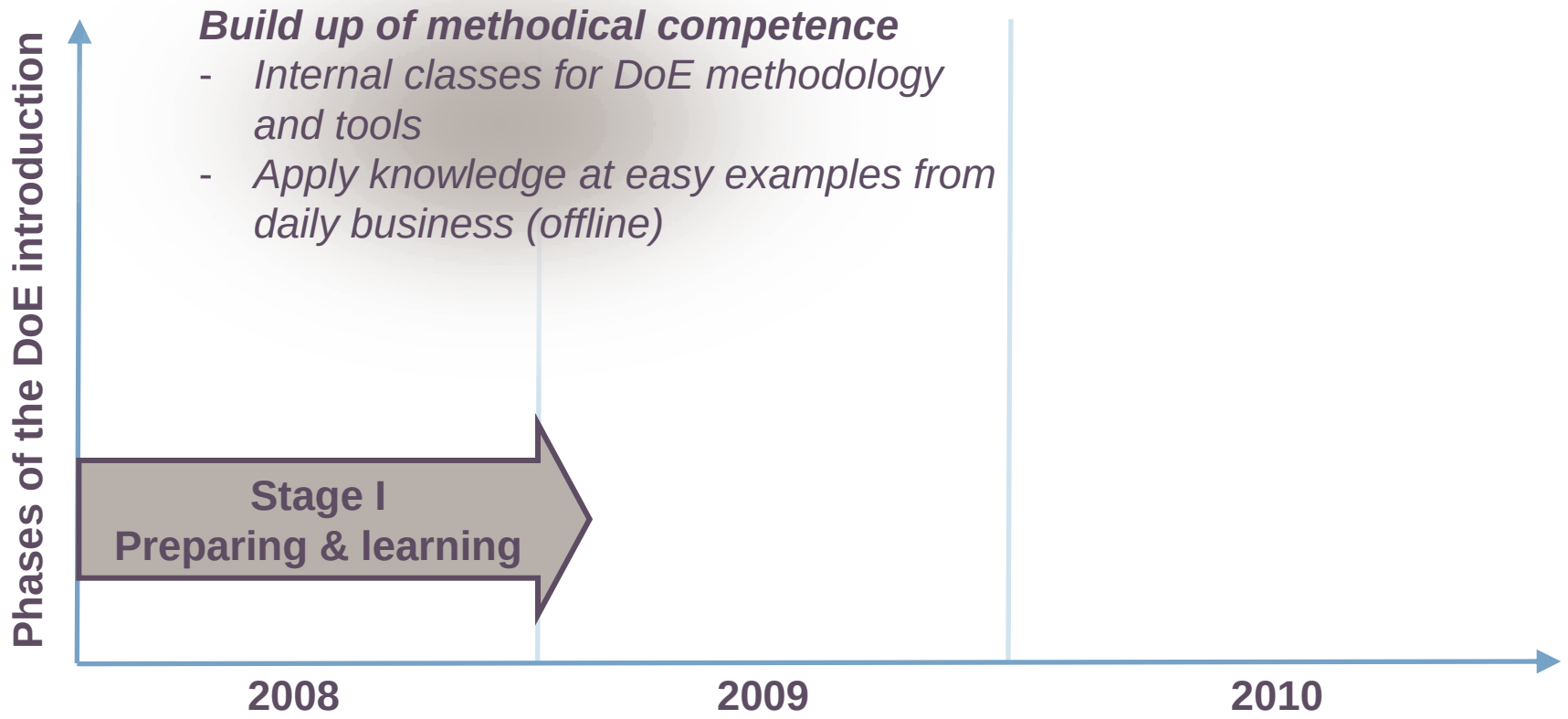

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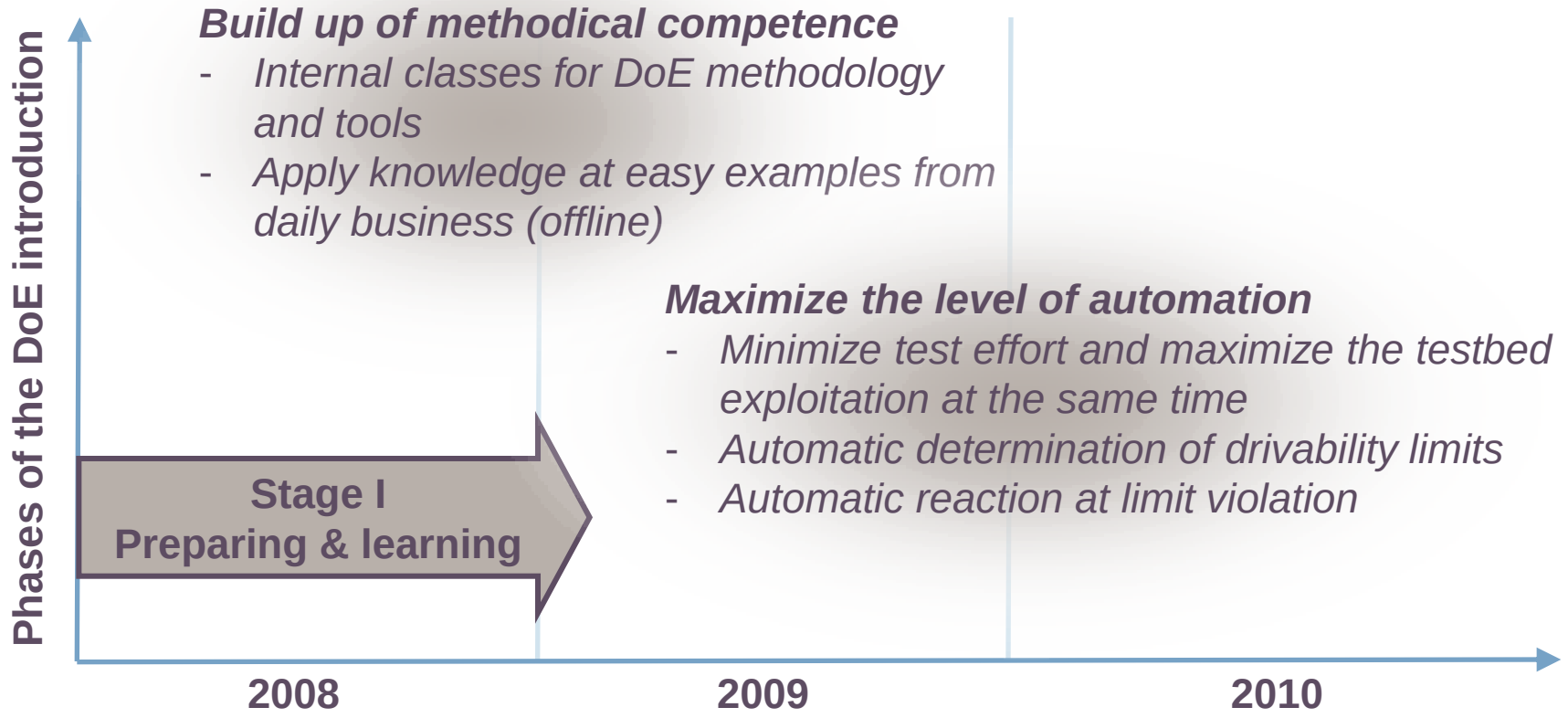

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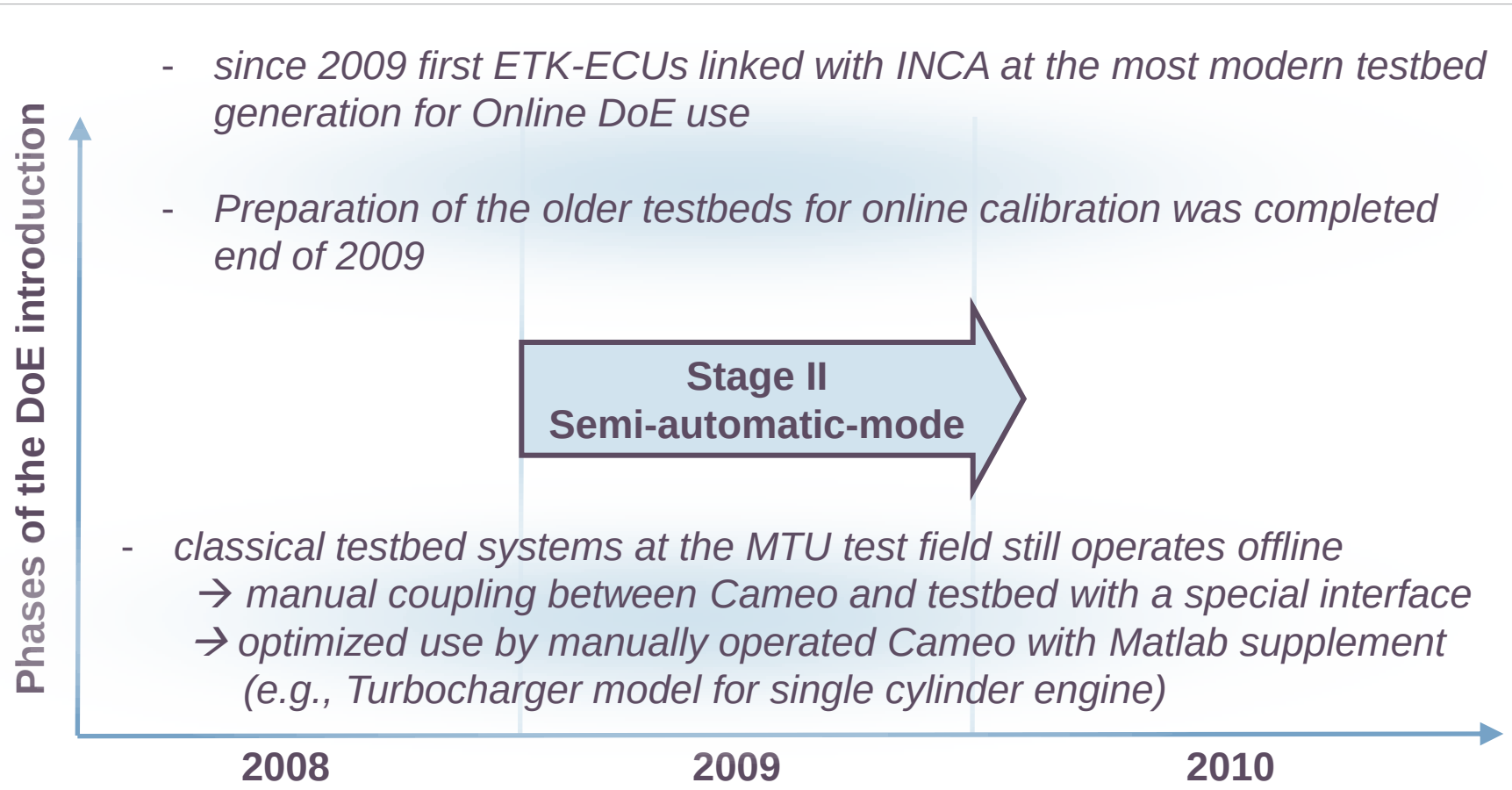

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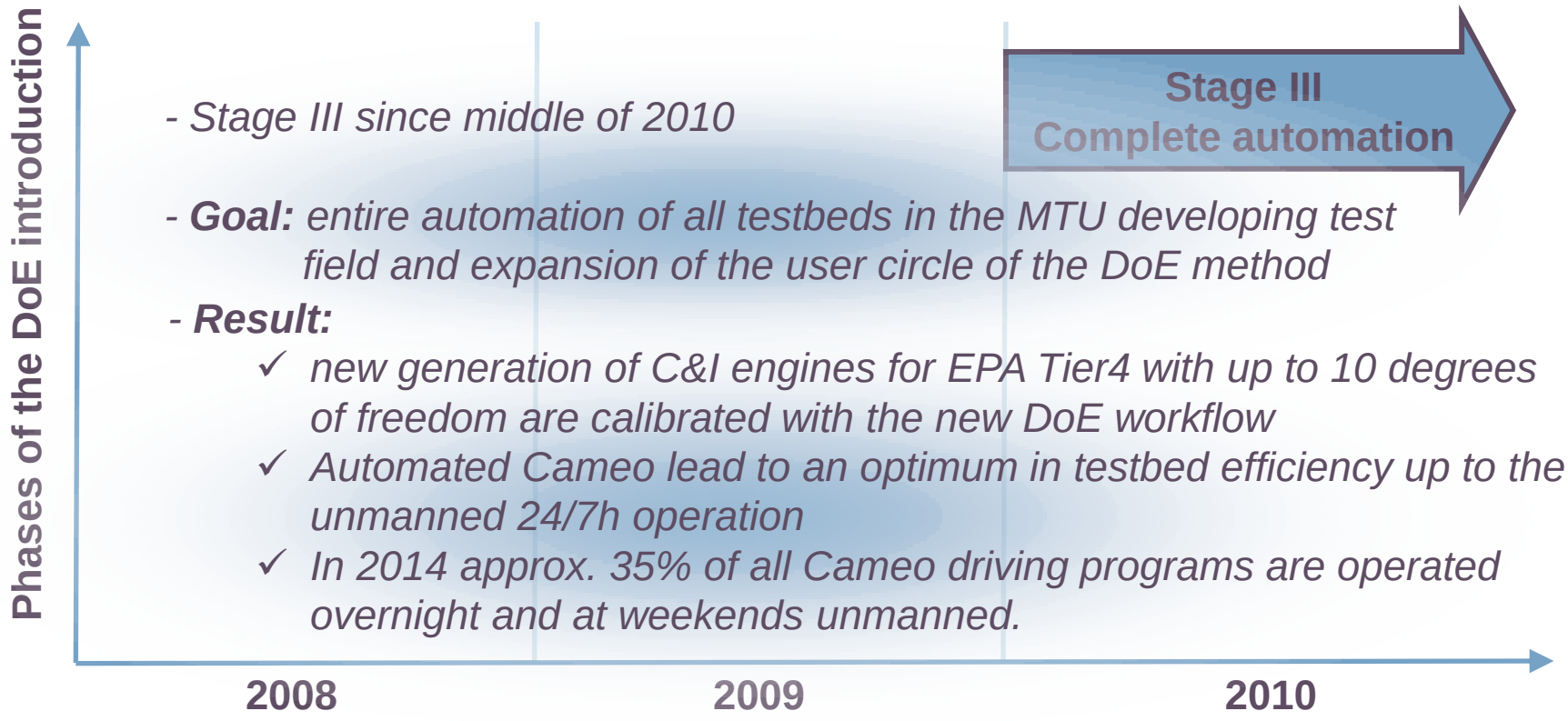


Use and improvement of CAMEO

Cameo as part of the daily calibration and automation business

- *increasing acceptance → use of Cameo increases*
- *Increasing knowledge → higher demands for the driving programs*
- *Cameo experts → DoE schedule, Driving programs and evaluations*
- *Cameo administration → local databases*

Some Knowledge from the day business

- *While evaluation it was recognized that with some uses the expected optima lay beyond the measured test rooms*
- *the use of local databases often complicated the access to existing driving programs*
- *There are special tasks, which cannot be realized with Cameo standard functions*

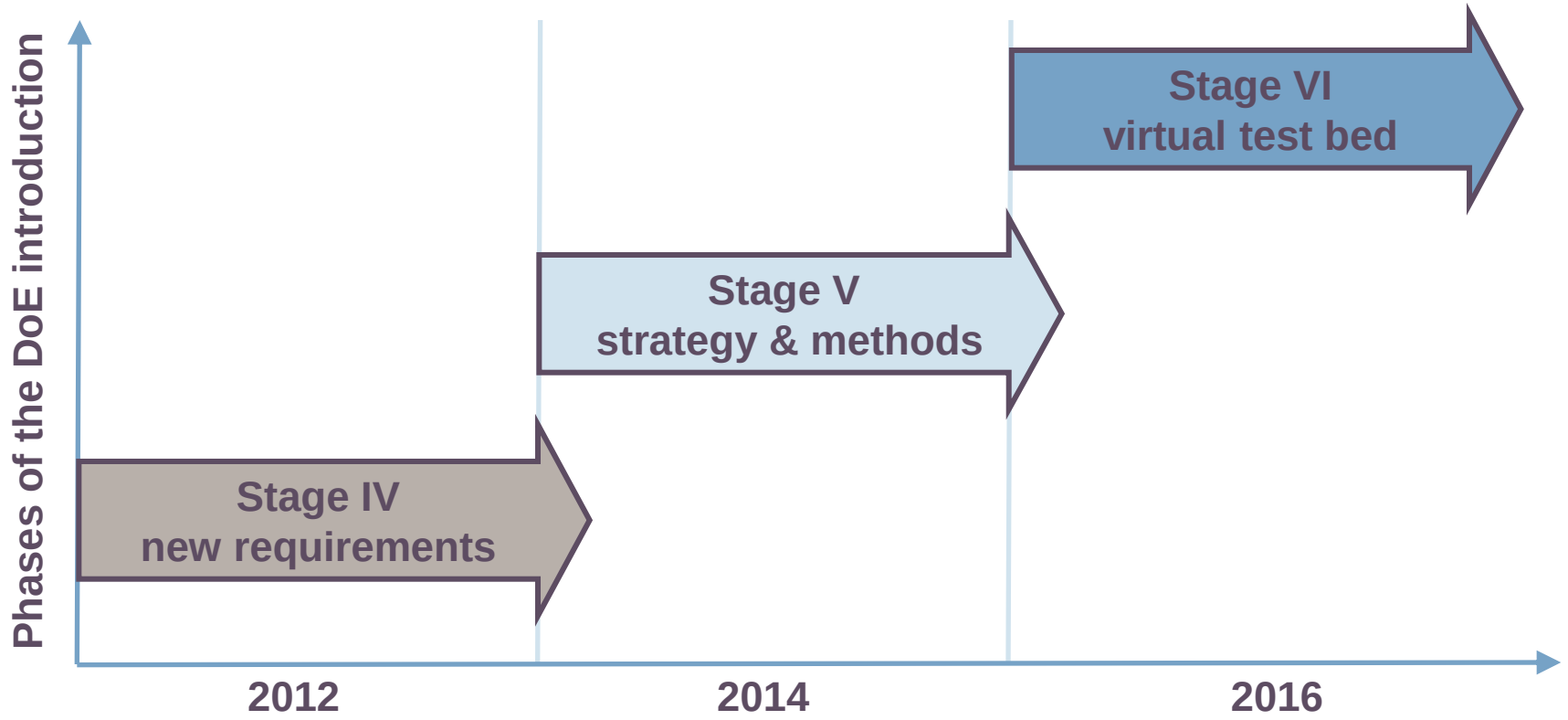
Use and improvement of CAMEO

Everything can be still made better than it is!!!

- *find out what works fine, what not*
- *find optimization potential for*
  - *test program management and administration*
  - *larger design spaces*
- *are there tasks which cannot covered with standard Cameo?*

→ Improve Cameo and DoE for special MTU tasks.

Use and improvement of CAMEO



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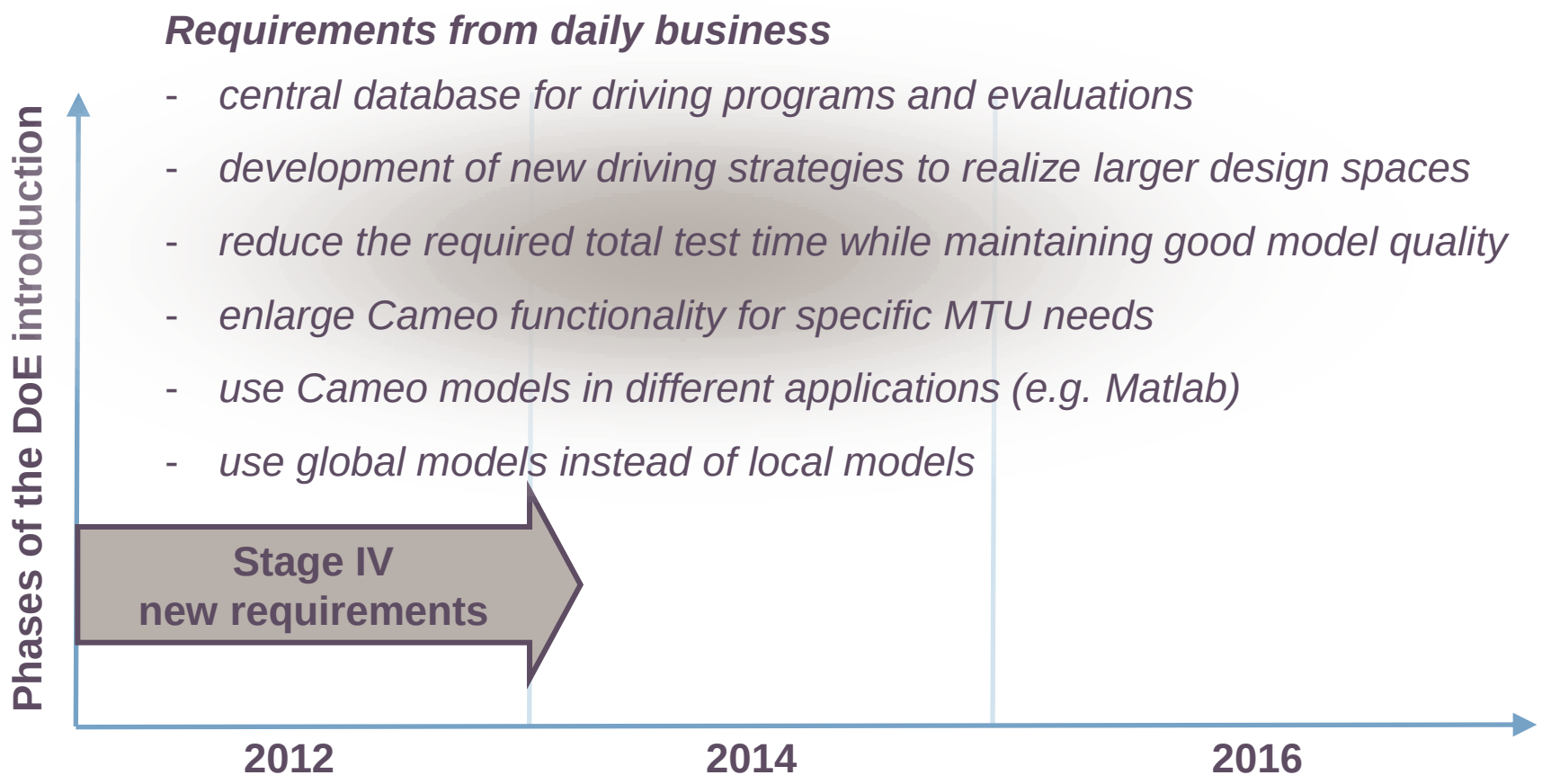

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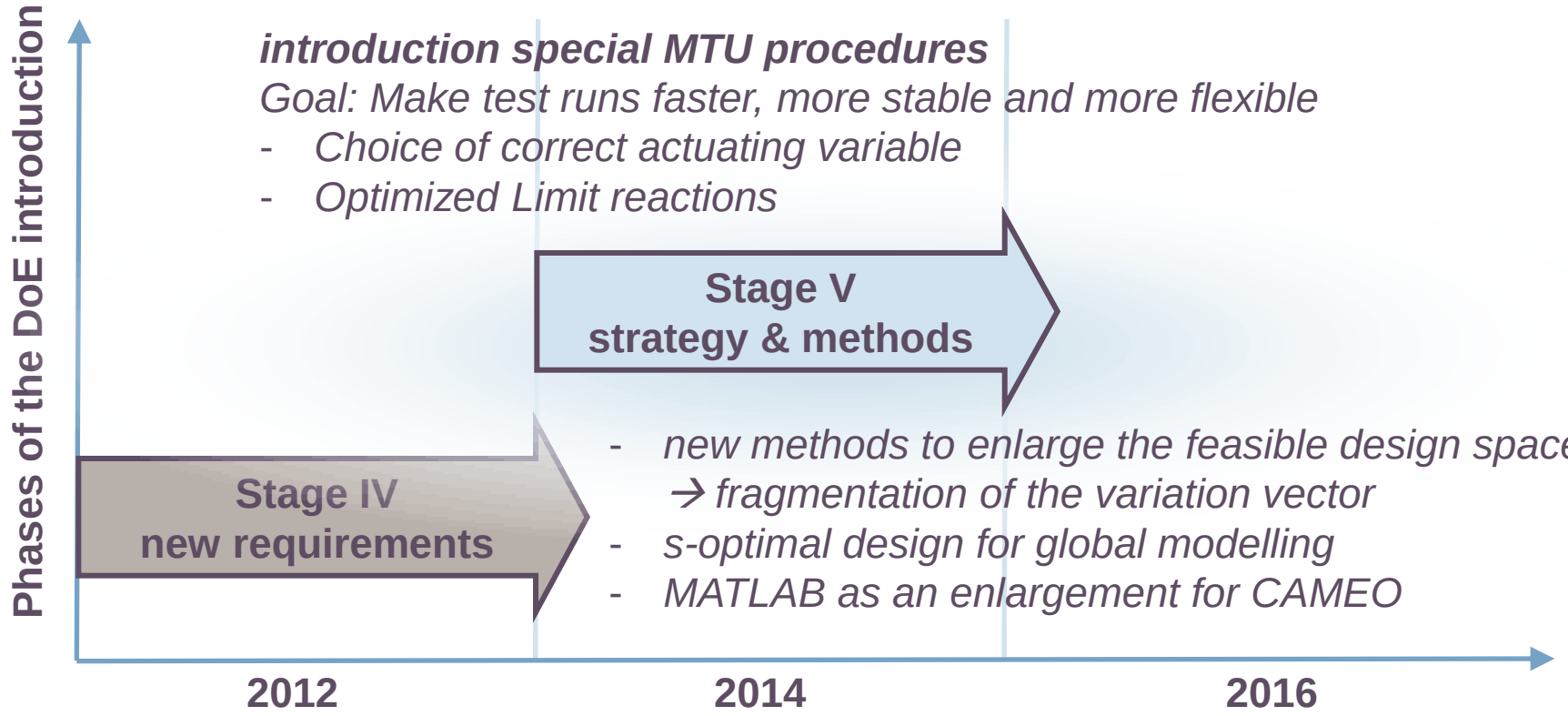
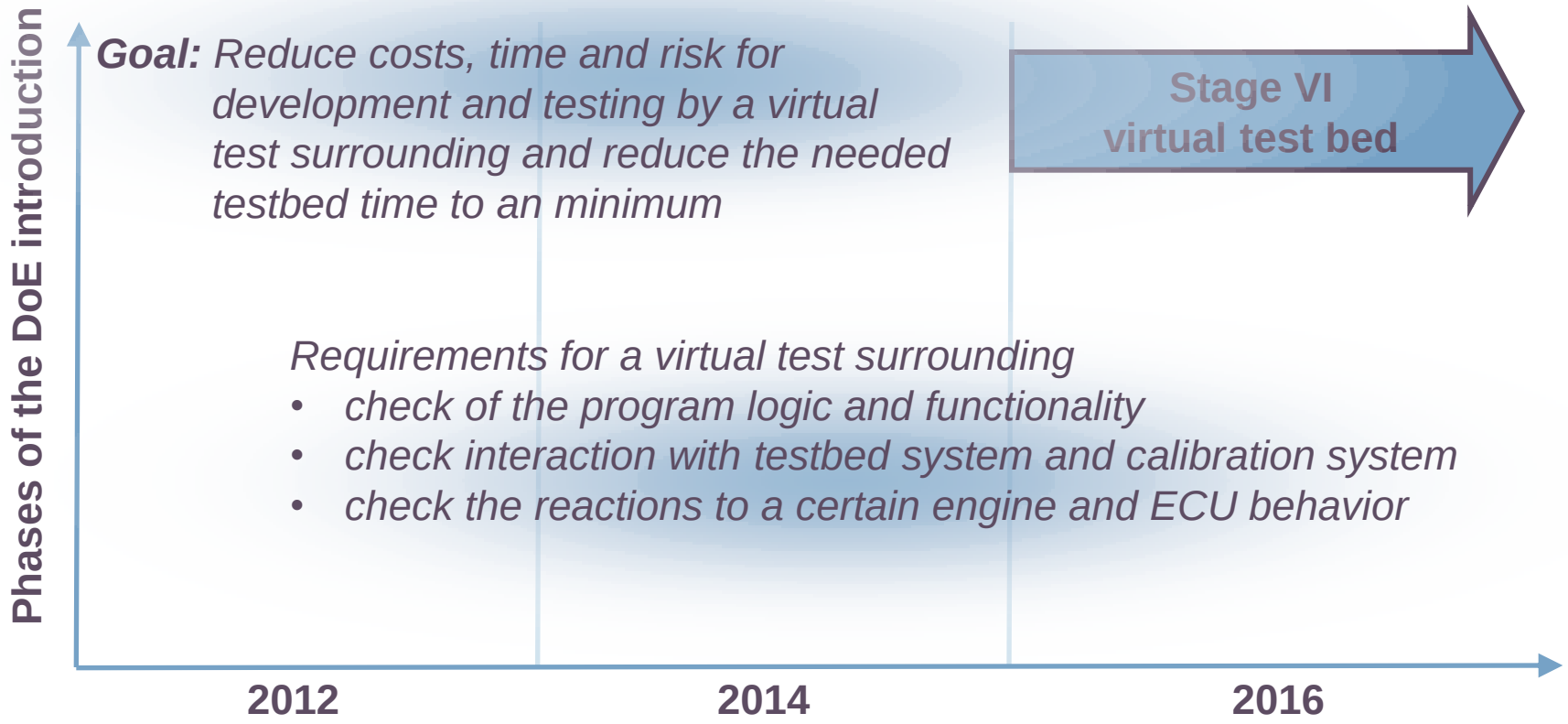


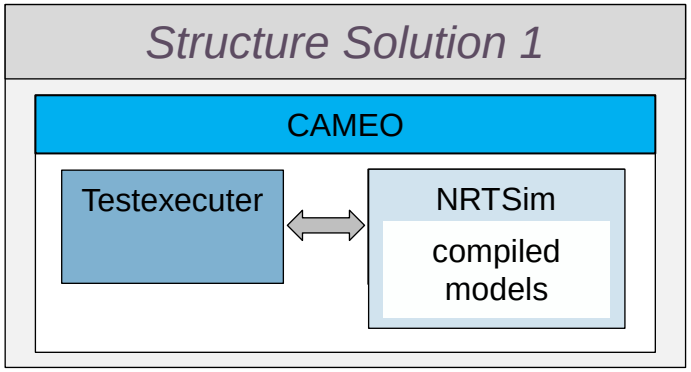
Use and improvement of CAMEO

Separate development and test of new strategies or methods from the testbed



Virtual test surrounding
Solution 1

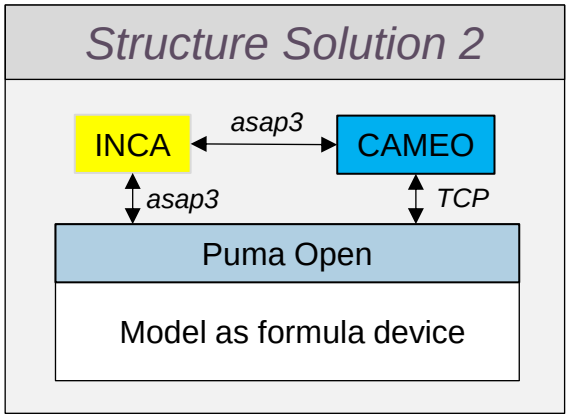
To evaluate easy driving programs, strategies and functionality during Cameo runtime, easy data models (local or global) can be used to represent the engine behavior



- *With NRTSIM or iDoE models from Matlab-Simulink can be provided and use with Cameo during runtime*
- *Usually existing Cameo models are used*
- *The models must be compiled in Matlab accordingly*
- *To provide the compiled Simulink models Matlab realtime workshop is required*

Virtual test surrounding
Solution 2

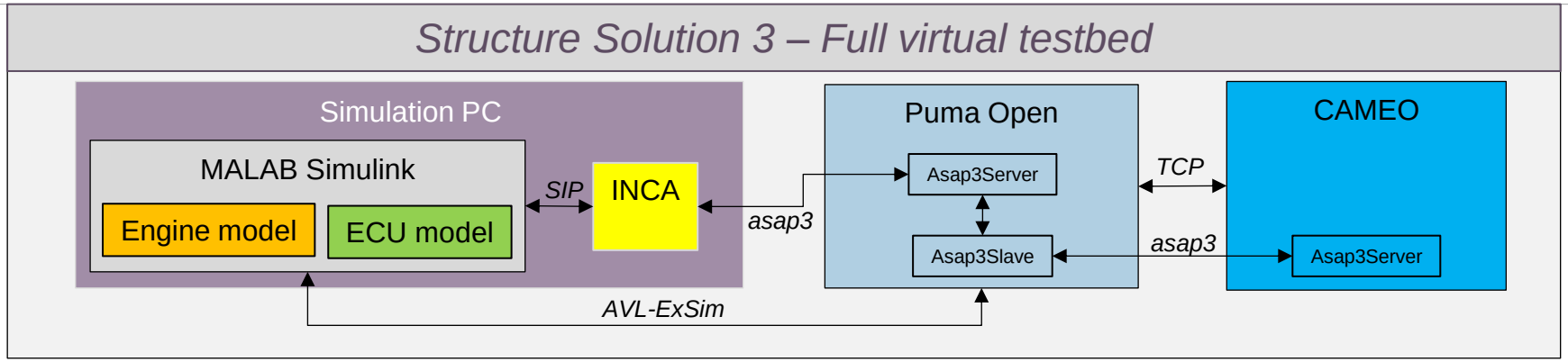
For the evaluation of more complexe applications which do not need ECU response during Cameo runtime, we also can use easy data models as "engine model"



- *With the formula device or with ArteLab models can be provided to the Puma-Simulator and use with Cameo during runtime*
- *Usually existing Cameo polynomial models are used*
- *For ArteLab the models must be compiled in Matlab accordingly*
- *To provide the compiled Simulink models Matlab realtime workshop is required*

For the evaluation of driving programs with direct interaction to the testbed system, this kind of virtual test surroundings is at least necessary.

Virtual test surrounding
Full virtual testbed



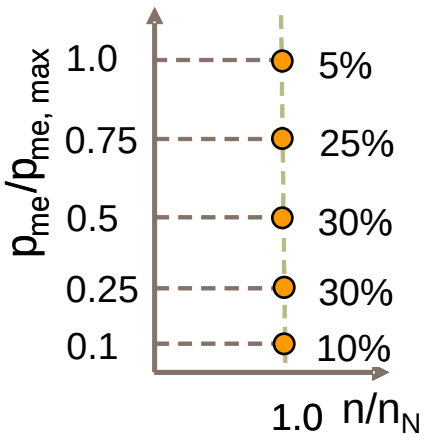
- *Engine and ECU model is performed at a special simulation PC in Simulink during Cameo runtime*
- *The communication between ECU and INCA needs INCA-SIP Interface*
- *The communication between Engine and Puma needs ExSim-Interface*

If we need the real engine and ECU behavior during Cameo runtime this kind of test surrounding is needed for evaluation

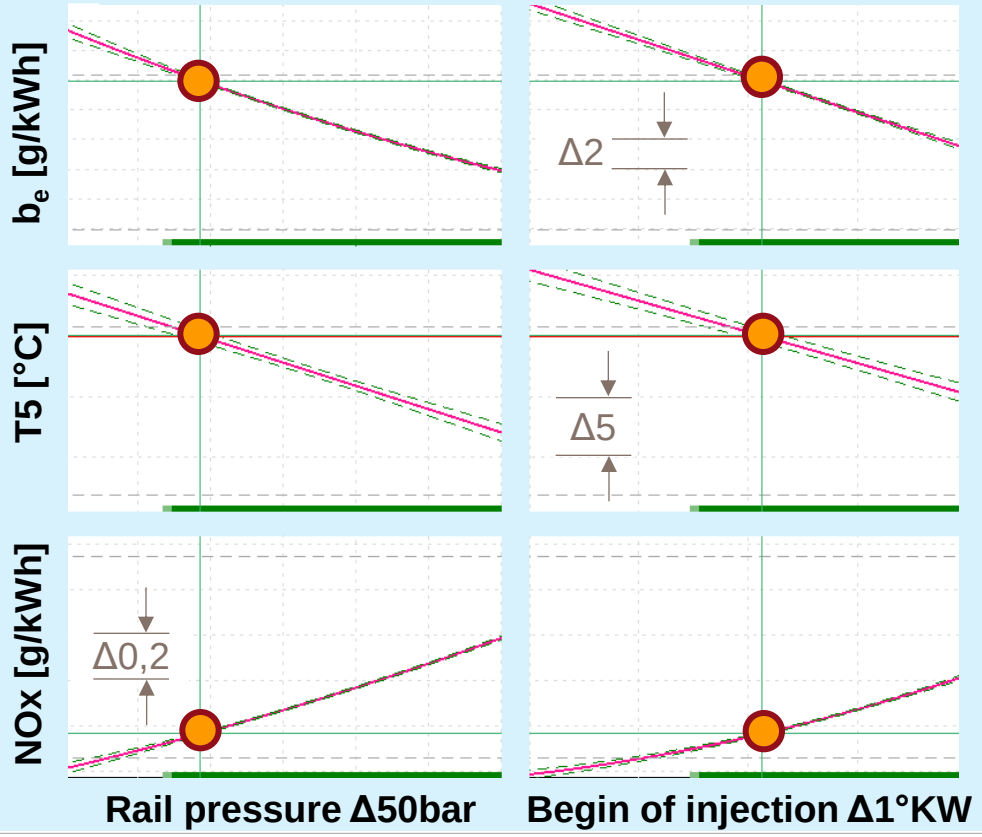
→ *Direct transferability of the Simulation to the testbed*

Example & Results
Comparison of variants with different local restrictions

ISO 8178-4 D2 cycle



Operatingpoint D2_1 (100% pme)



Example & Results
Comparison of variants with different local restrictions

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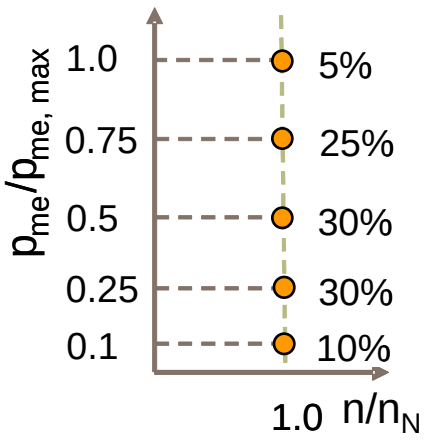
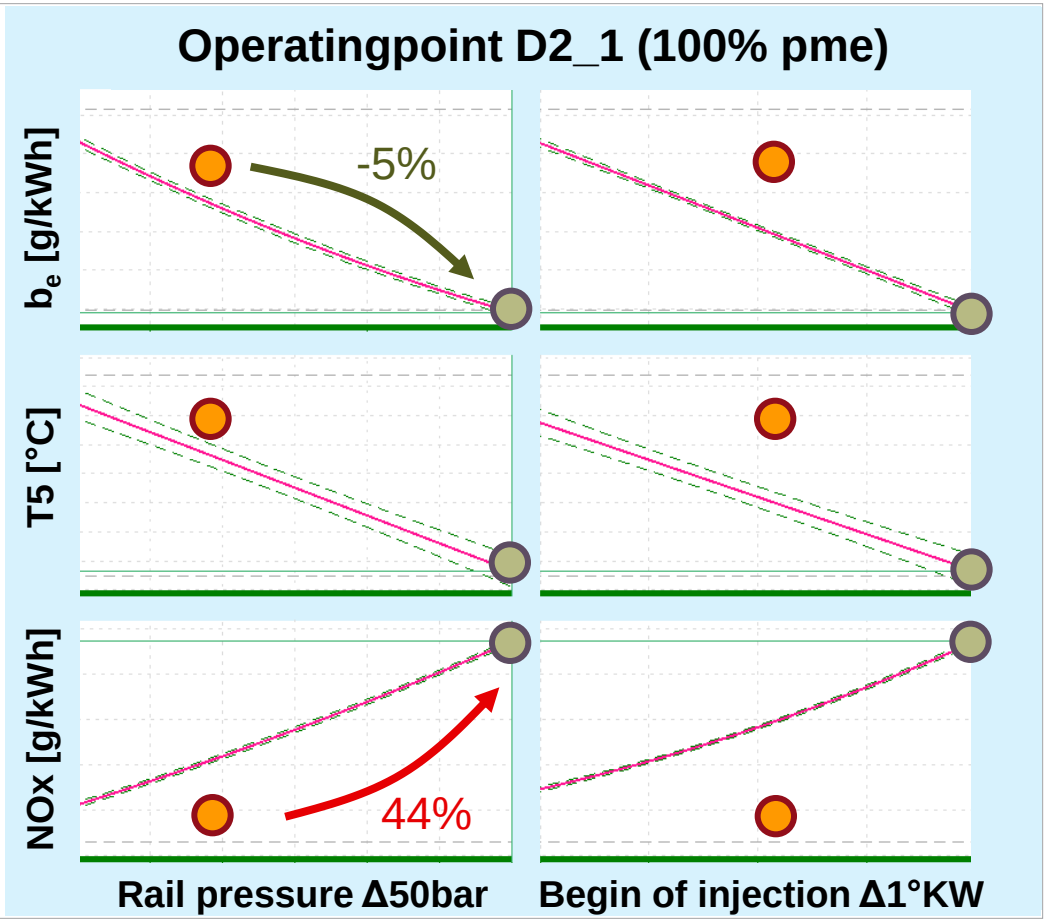


Effect of decreasing charge air temperature by 10% in the full load point during D2 cycle optimization



Example & Results
Comparison of variants with different local restrictions

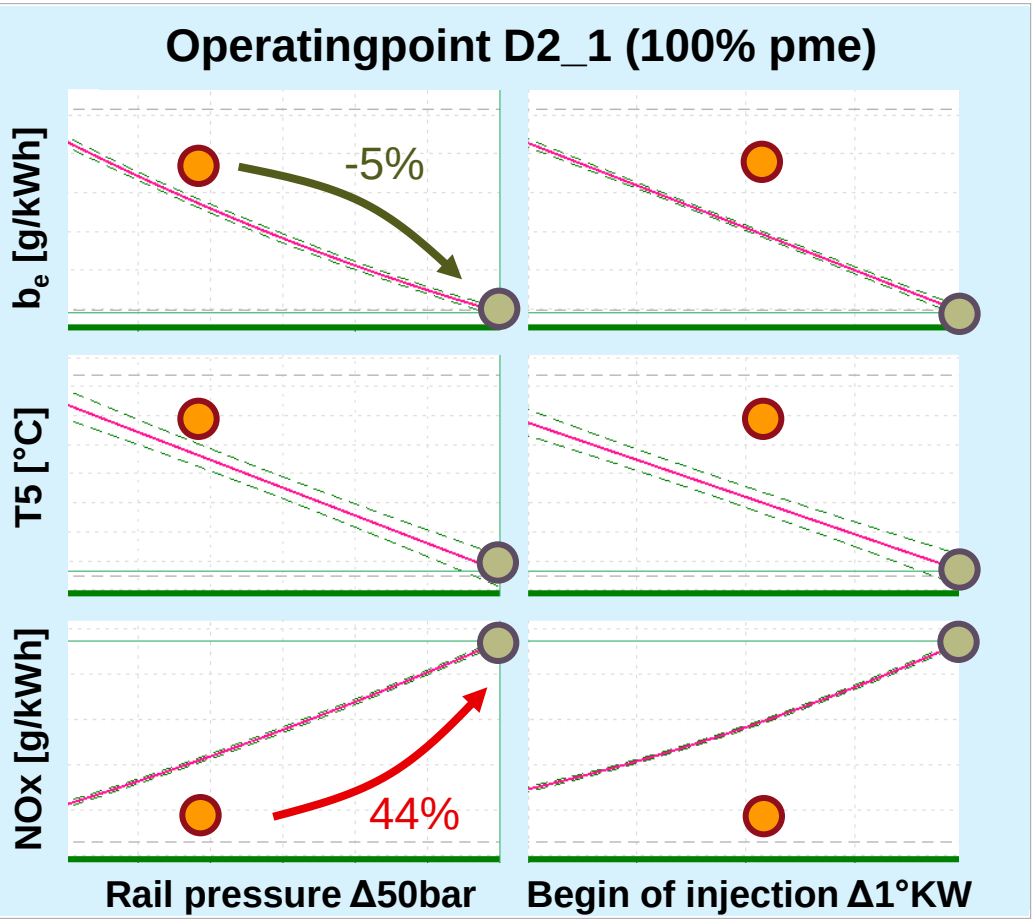
ISO 8178-4 D2 cycle

pme	SB	Rail	NOx	b_e
100	-18	-17	44 ↑	5 ↓
75	30	0	5 ↓	2 ↑
50	0	7	7 ↓	2 ↑
25	-87	4	28 ↓	8 ↑
10	19	-8	7 ↑	0

percentage quotation

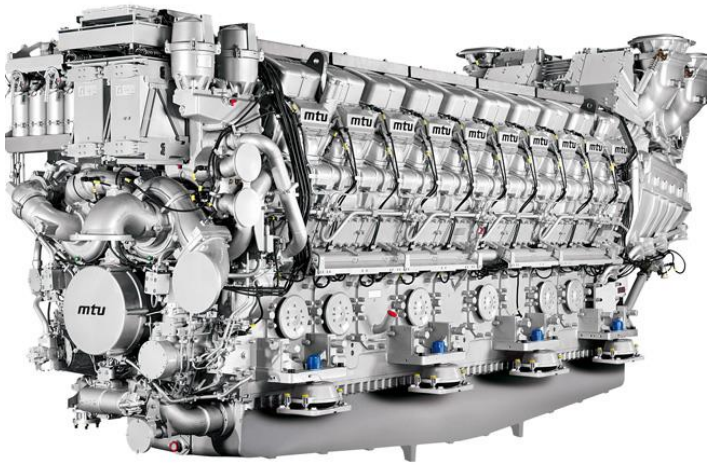
D2 cycle optimisation

b_e	**-3%**
NOx	**±0%**
HC	**-2%**
PM	**-13%**



Example - Stage II
IMO-cycle optimisation at 20VBR8000M71L

- IMO certification by EPA for E2-cycle (generator curve) and the E3-cycle (propeller curve)
- each cycle is built up of 4 operating points at which the full load point is same for both cycles and must be measured, hence, only once.
- Measuring time per operating point ≈ 3 to 4h | B_H ≈ 1720kg/h ≈ 2020l/h (b_e ≈ 189g/kWh)



→ the DoE method approx. saved 15 hours of testing compared with the conventional “hand made” calibration.

→ With a consumption of approx. 2000l/h arises a saving potential of approx. 30000€

Summary
→ Application of Methodology!

The increase of the legislation leads to more degrees of freedom and a higher application expenditure

- ***Application of Methodology → Control of the complexity***
- ***Automation→ Optimization of the test bed capacity***

The introduction and optimization of the automation with the measurement requires interventions in the ECU and in the test bed (realized in 1.5 years!!!)

Model-based approach delivers many advantages, as for example

- ***by the cycle calibration,***
- ***map calibration for different applications***

Virtual test bed

→ Cost-effective development and testing of driving programs and strategies

New ways demand new methods!