Motivation
The thermal performance requirements of air cooled electronic control units (ECUs) increase continuously due to the growing extent of implemented functionality and thus higher power loss density and the trend of miniaturization. To meet these targets, it is mandatory to enhance the convective heat transfer to the ambient air flow by means of optimizing the surface topology of heat sink geometries.

Introduction
In order to quantify the cooler performance for a given power loss \( P_v \) and air flow, either the cooler temperature or the derived scalar quantity Thermal Resistance \( R_{th} \) is usually chosen as a primary output variable:

\[
R_{th} = \frac{T_{surf} - T_{amb}}{P_v}
\]

with the heater surface temperature \( T_{surf} \) and the constant ambient temperature \( T_{amb} \). Furthermore, the objective material volume of the heat sink as an indirect estimation for the manufacturing costs is of relevance and used as secondary output variable. It is not unusual that optimal cooler design and low cooler mass are in conflict with each other, therefore, a multi-objective optimization has to be performed in order to compromise for a design.

Realization
In order to tackle this task, several different approaches were implemented in both, optiSLang and optiSLang inside ANSYS Workbench utilizing different computational fluid dynamics programs (CFD), namely scStream (Cradle), FloEFD (Mentor Graphics) and CFX (ANSYS) as it can be seen in Fig. 1 (see next page). These procedures all have their own benefits and draw backs. In standalone optiSLang for example any scriptable software can be used as shown in Fig. 1a) - c) (see next page). The method shown in Fig. 1b) (see next page) even relies on implementing Excel with its powerful Visual Basic utilities in order to control calculations, simulations and several batch scriptable programs. In this case, VBA, VBS, windows batch, scStream, ANSYS APDL and Python was used.
This approach is functional, but includes the handling of several interfaces introducing a high level of complexity. In Fig. 1d) – e) ANSYS Design Modeler and CFX was used in order to generate and calculate parametrized geometries controlled by optiSLang. The benefit of this approach is that geometry generation, calculation and result evaluation is done in one framework. With this solution however, the user is obliged to use CFD solutions implemented into ANSYS.

Results
The examined geometry in the following results is a simple solid metal fin-heatsink structure with a heating boundary condition at the base. In Fig. 2a) the sensitivity analysis of the cooler $R_{th}$ is shown for fin height, fin spacing and air flow direction, all varied according to an Advanced Latin Hypercube algorithm. In Fig. 2b) the corresponding Pareto front is shown giving insight in the multi objective optimization. In Fig. 2c) the geometry was fixed and the air flow angle was varied. In this analysis the maximum temperature of the cooler is evaluated. Local and global minima are present depending on alignment of the air flow. Based on these sensitivity analyses, a subsequent optimization based on a Metamodel of Optimal Prognosis (MOP) can be performed without the need of additional CFD simulations.

Summary
The presented workflows and results serve as a proof of concept study. It has to be verified that this approach is also suitable for complex geometries.

Authors
Dr. Waldemar Smirnov AE / EDT3
David Klemm AE / EDE2 (Robert Bosch GmbH)

Figure 1: Implementation of workflows. a) standalone optiSLang, d), e) optiSLang inside ANSYS Workbench.

Figure 2: a) $R_{th}$ value of cooler with fins depending on geometry with indicated isoline, b) Pareto plot depending on cooler volume and c) sensitivity analysis of air flow vector depending on maximum cooler temperature.

DYNARDO TRAINING
At our training, we provide basic or expert knowledge of our software products and inform you about methods and current issues in the CAE sector.

Info Days and Webinars
During our info days and webinars, you will receive an introduction to performing complex, non-linear FE-calculations using optiSLang, multiPlas, SoS and ETK. At regular webinars, you can easily get information about all relevant issues of CAE-based optimization and stochastic analysis. During an information day, you will additionally have the opportunity to discuss your specific optimization task with our experts and develop first approaches to solutions.

Training
For a competent and customized introduction to our software products, visit our basic or expert training clearly explaining theory and application of a sensitivity analysis, multidisciplinary optimization and robustness evaluation. The training is not only for engineers, but also perfectly suited for decision makers in the CAE-based simulation field. For all training there is a discount of 50% for students and 30% for university members/PHDs.

Info
You will find all information as well as an overview of the current training program at:

www.dynardo.de/en/training