

15<sup>th</sup> German LS-DYNA Forum

# Shape optimization for CFD analysis using LS-OPT, ANSA and LS-DYNA ICFD

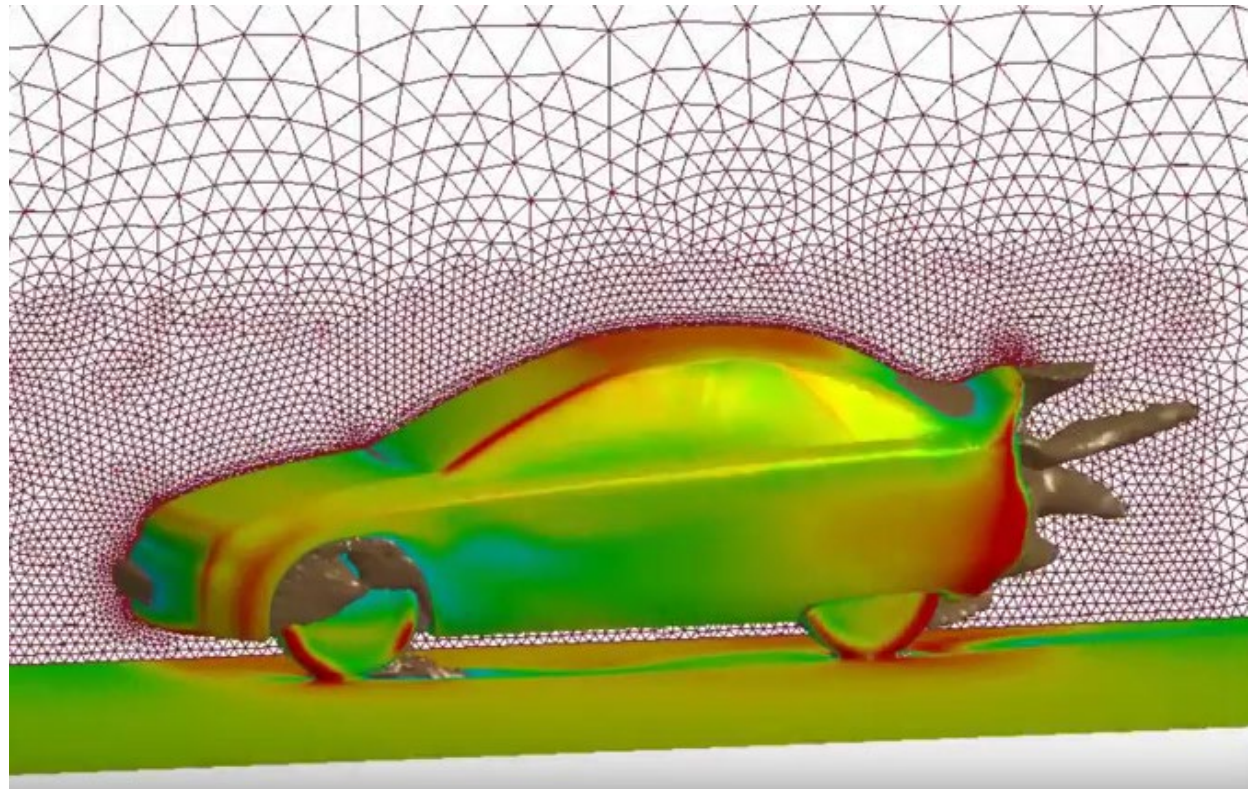
Facundo Del Pin (LSTC)

Katharina Witowski (DYNAmore GmbH)

**Bamberg, 16.10.2018**

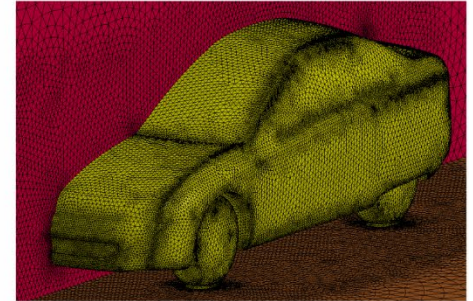
# Overview

- Problem description
- Setup in ANSA
- Setup in LS-OPT
- Results



## Problem description

- CFD model

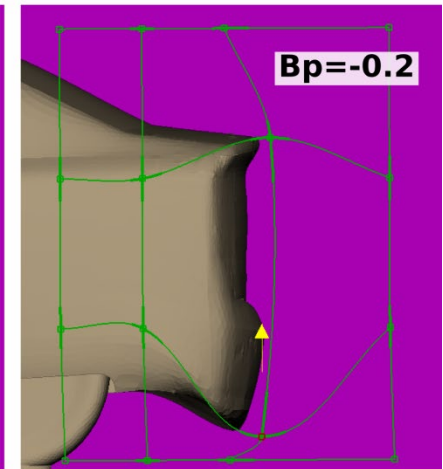
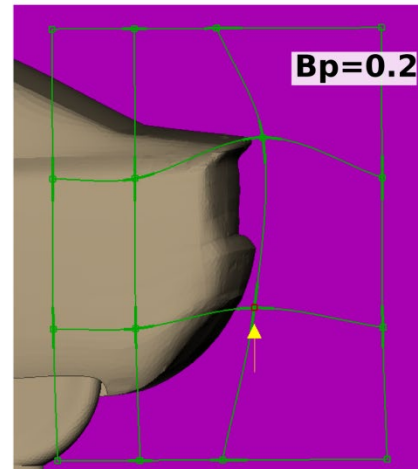
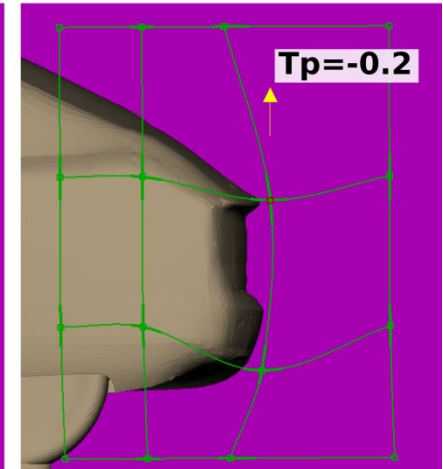
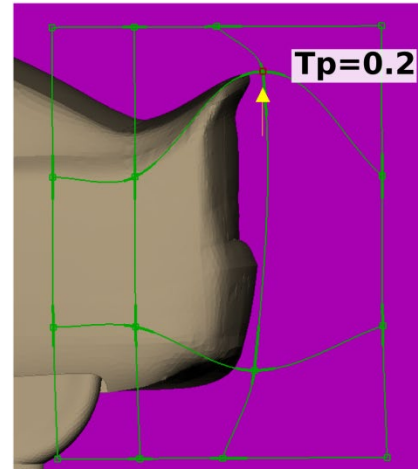
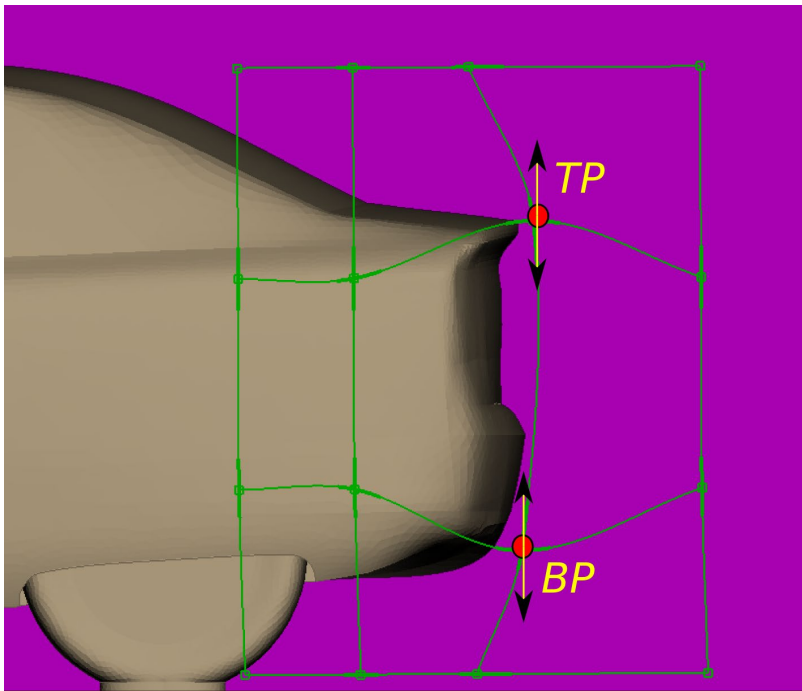


- External aerodynamics of a ground vehicle
- Reynolds Number  $\sim 1.0e7$
- RANS turbulence model using realizable K-e
- Objective: fuel efficiency
  - maximize down force and minimize drag force, more relevance to drag force
  - Optimization objective function  
 **$\max(\text{down force} / \text{drag force}^2)$**

# Parameters

## ■ 2 Morphing Parameters

- TP: top point
- BP: bottom point



## Model modifications

- ANSA doesn't support LS-DYNA CFD input files
- Manual modifications:
  - \*MESH\_SURFACE\_ELEMENT → \*ELEMENT\_SHELL (3D)
  - \*MESH\_SURFACE\_ELEMENT → \*ELEMENT\_BEAM (2D)
  - \*MESH\_SURFACE\_NODE → \*NODE



# Setup in ANSA

Task Manager

Root	Type
OPTIMIZATION_TASK_1	Optimization item
/home/fdelpin/LSTC/LS-OPT/tests/ansa_c...	DV file
tp	Design Variable
tp	MORPH PARAMETER
bp	Design Variable
bp	MORPH PARAMETER
ansa_car.key	FE_output

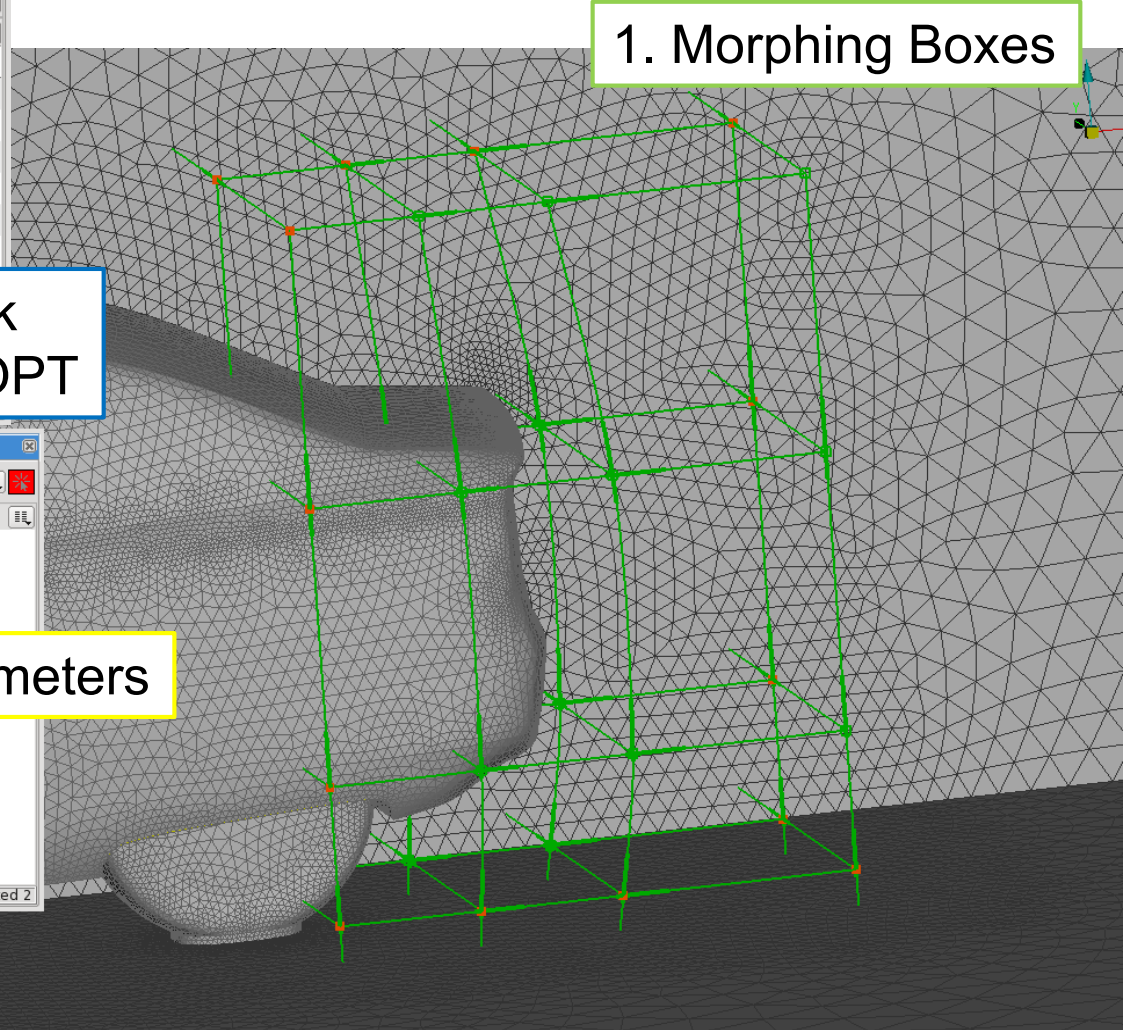
3. Optimization Task  
→ Interface to LS-OPT

PARAMETERS

ID	Name	Type
1	tp	TRANSFORM
2	bp	TRANSFORM

total 2 | selected 2

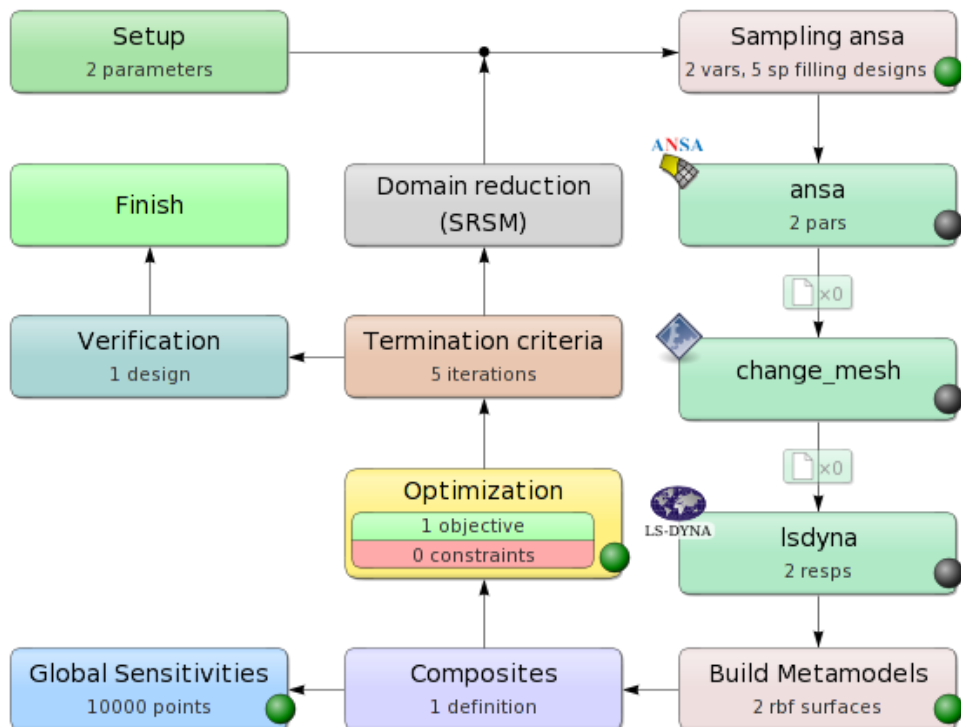
2. Morphing parameters



# Setup in LS-OPT

## ■ LS-OPT main GUI

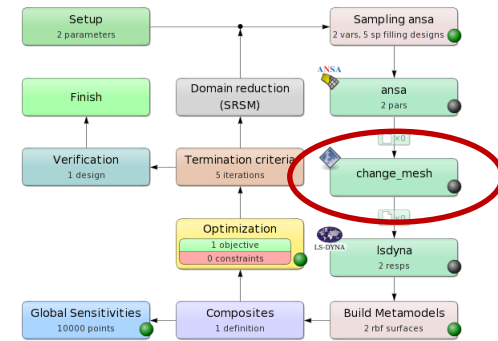
- Metamodel-based optimization
  - Optimization 1: Metamodel type linear
  - Optimization 2: Metamodel type RBF (Radial Basis Functions)
- Strategy sequential with domain reduction, 5 iterations



# Setup in LS-OPT

## ■ Stage python

- ANSA generates structural LS-DYNA input file
- Python script converts to CFD input file
- \*ELEMENT\_SHELL → \*MESH\_SURFACE\_ELEMENT
- \*ELEMENT\_BEAM → \*MESH\_SURFACE\_ELEMENT
- \*NODE → \*MESH\_SURFACE\_NODE



OPT Stage change\_mesh

Setup Parameters Histories Responses File Operations

General

Package Name User-Defined

Command  Browse

Do not add input file argument

Input File  Browse

Extra input files

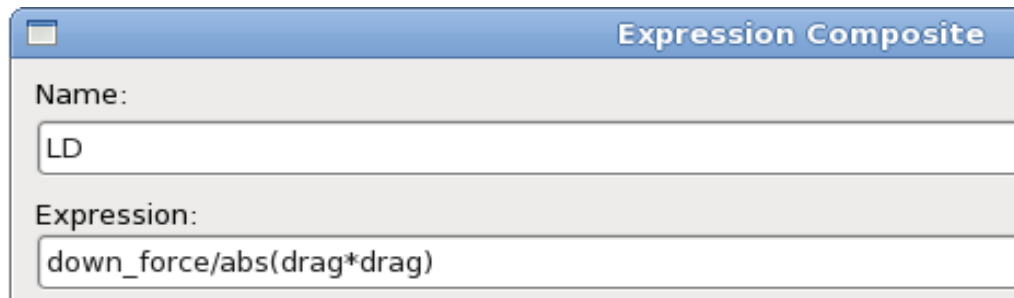


# Setup in LS-OPT

## ■ CFD responses extracted using GENEX

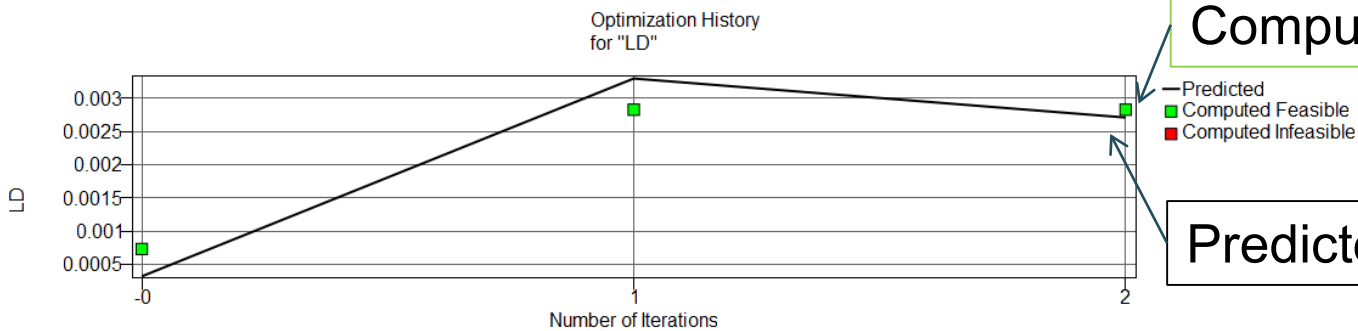
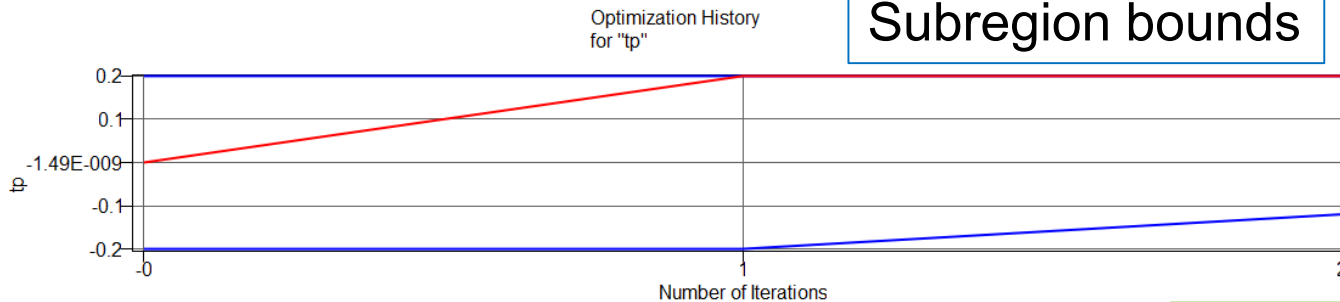
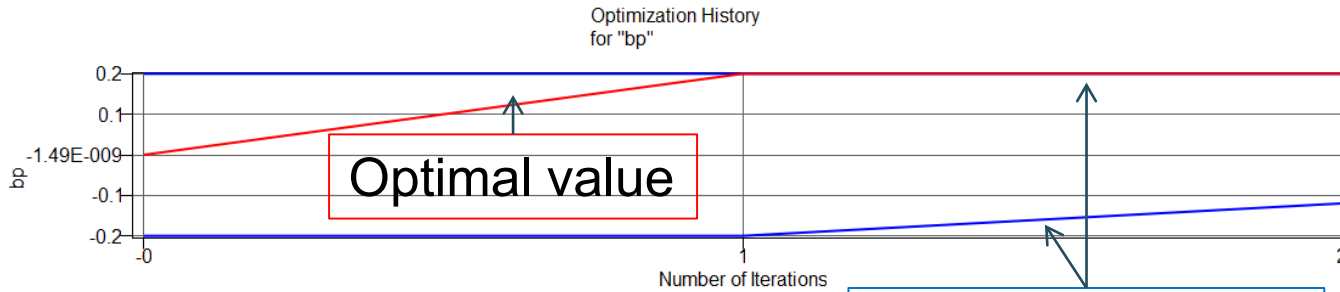


## ■ Objective



# Results (linear metamodel)

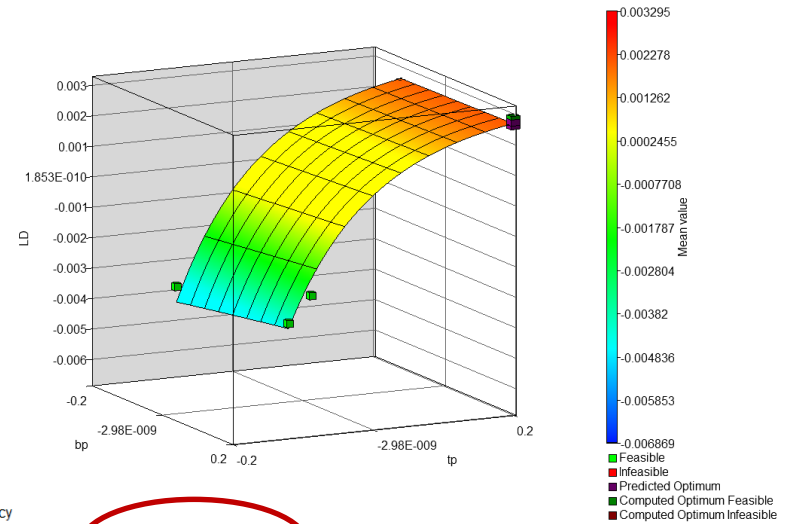
## ■ Convergence: Optimization History



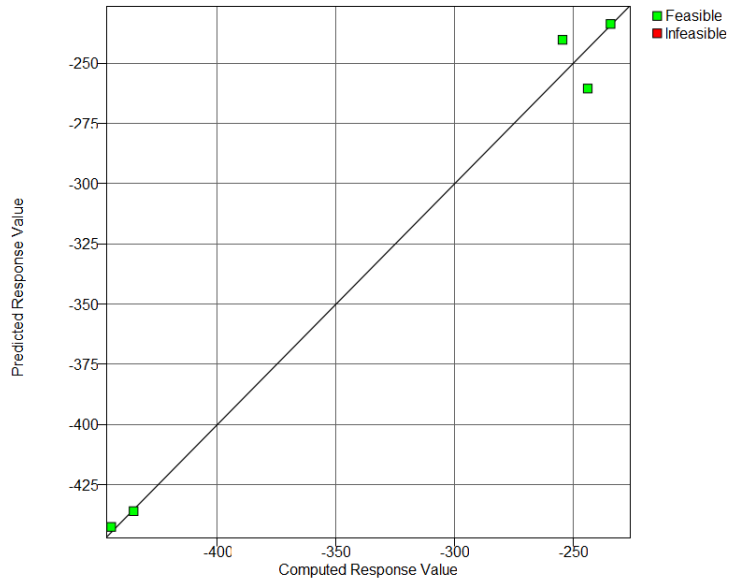
# Results (linear metamodel)

## Metamodel accuracy

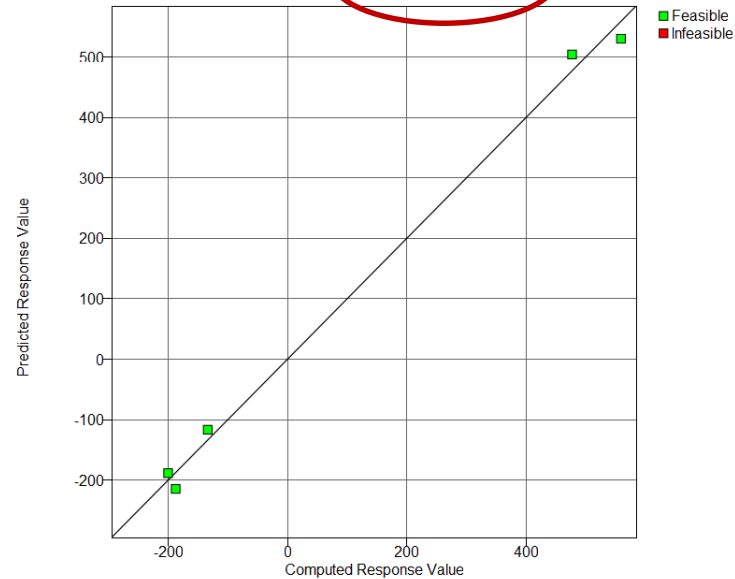
- Surface plot with points
  - Points are close to surface
- Error measures (only for responses)
  - RMS error
  - SPRESS → predictive capability!



Metamodeling Accuracy  
For Response Function "drag\_avg"  
Linear: RMS Err = 9.84 (3.05 %), Sqrt PRESS = 17.4 (5.38 %), R-sq = 0.99

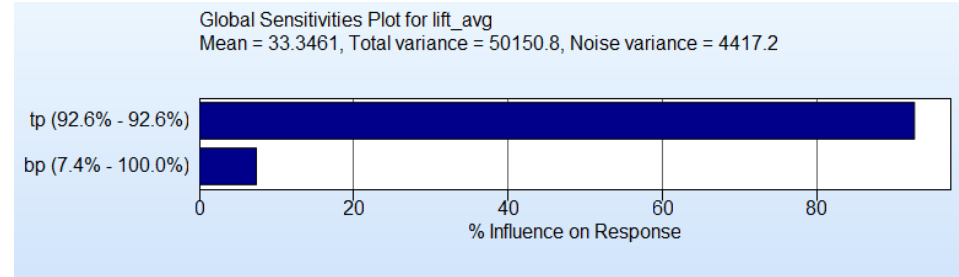
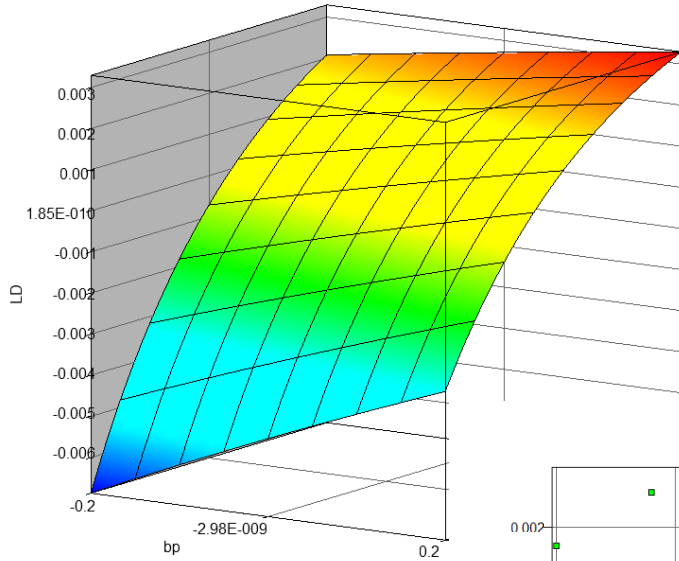


Metamodeling Accuracy  
For Response Function "lift\_avg"  
Linear: RMS Err = 23.3 (22.7 %) Sqrt PRESS = 77.1 (74.9 %), R-sq = 0.995

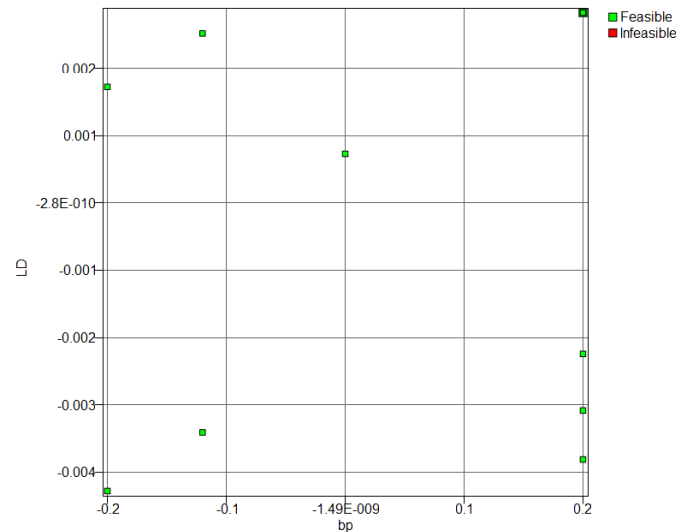


# Results (linear metamodel)

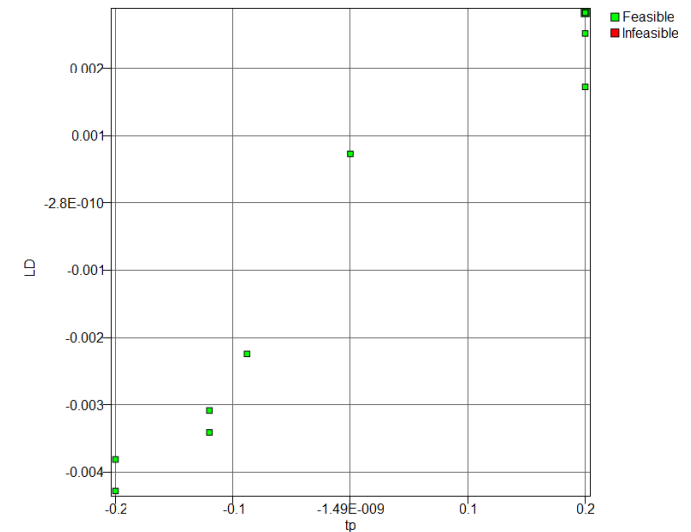
## Sensitivities



Scatter Plot  
Variable "bp" vs. Objective "LD"  
(Results of All Iterations)

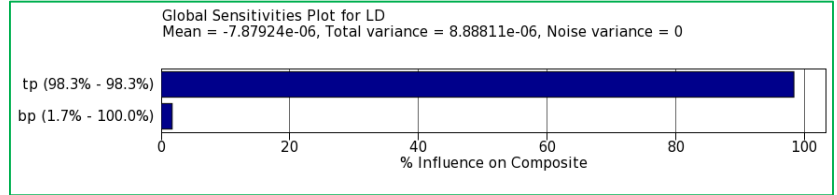


Scatter Plot  
Variable "tp" vs. Objective "LD"  
(Results of All Iterations)

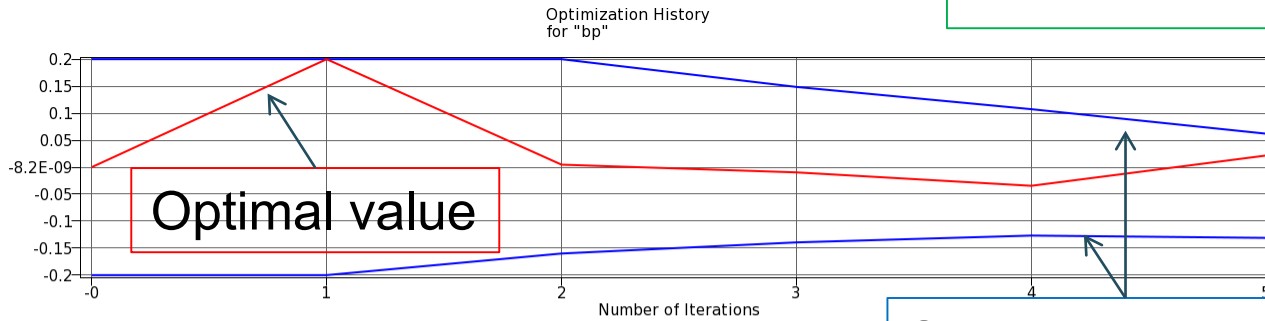


# Results (RBF)

## Convergence: Optimization History



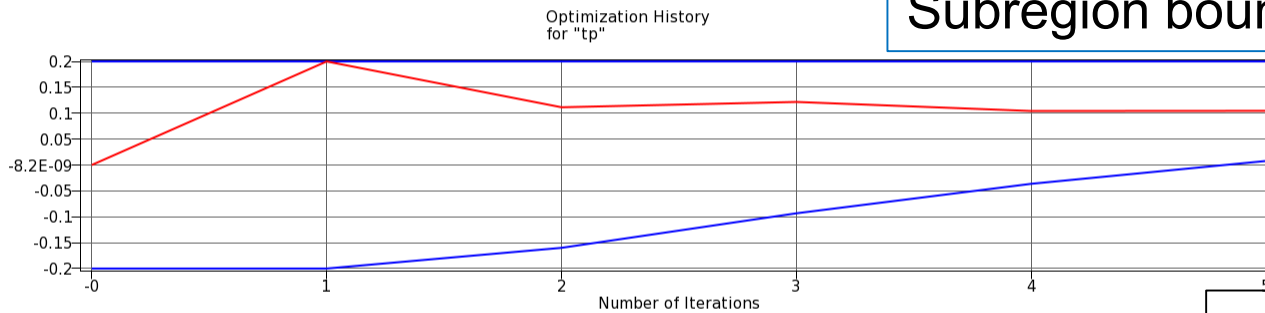
bp



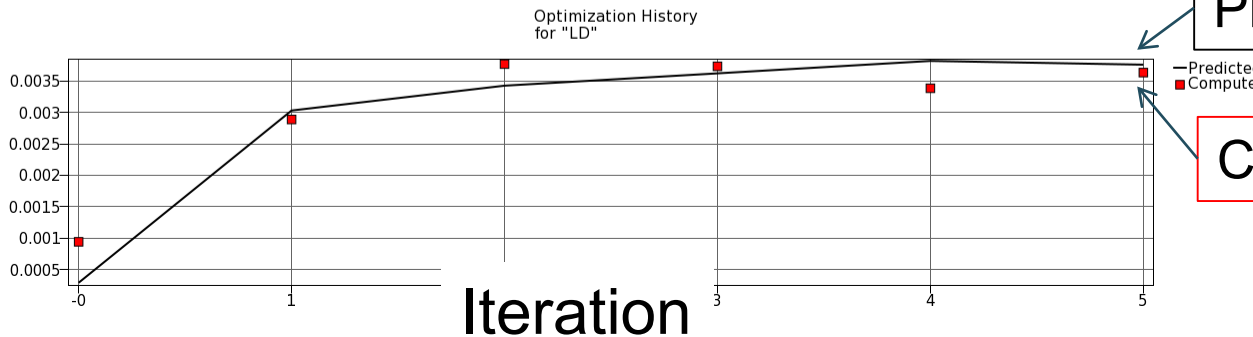
converged?  
 GSA → bp not significant

Subregion bounds

tp



LD

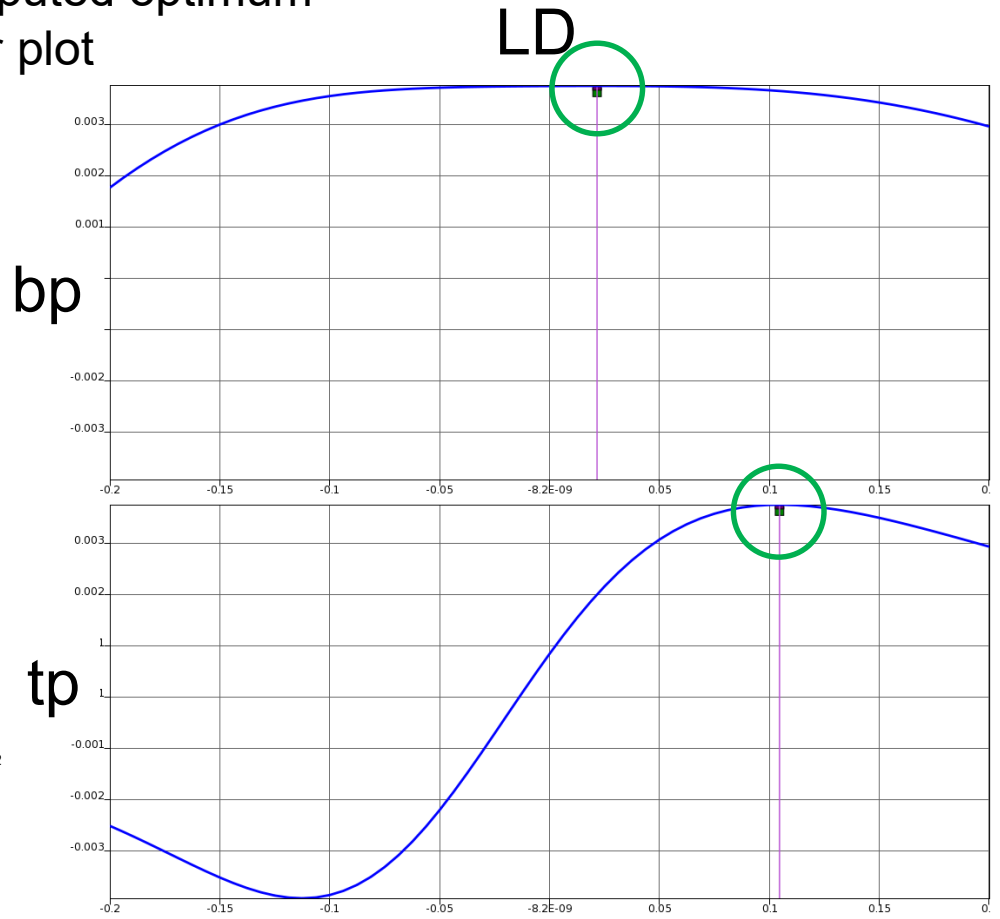
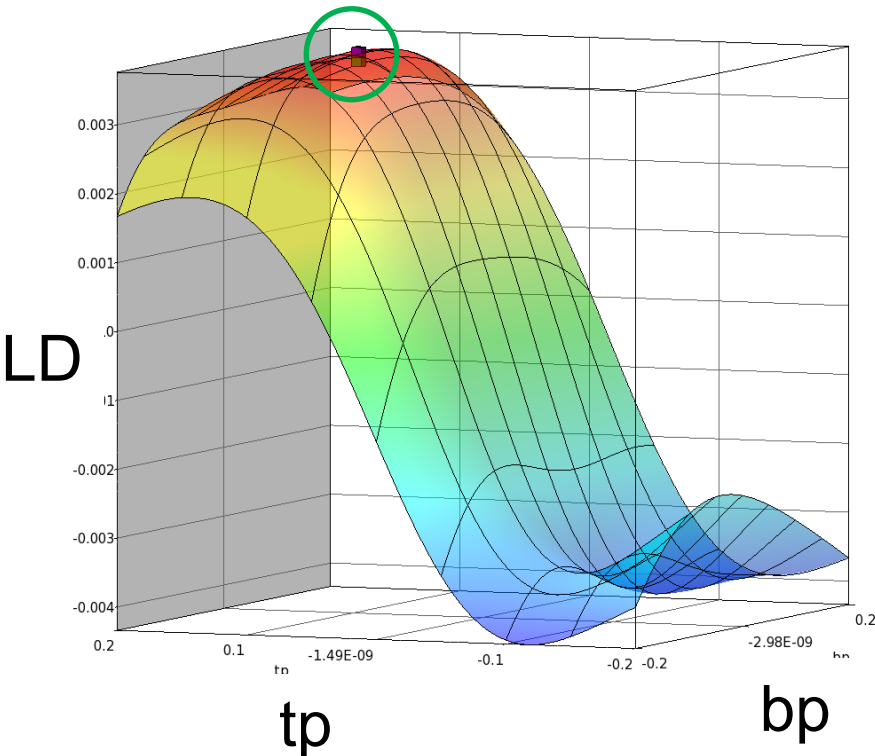


Predicted optimum

Computed optimum

# Results (RBF)

- Metamodel with predicted and computed optimum
- 3D Surface plot and 2D interpolator plot

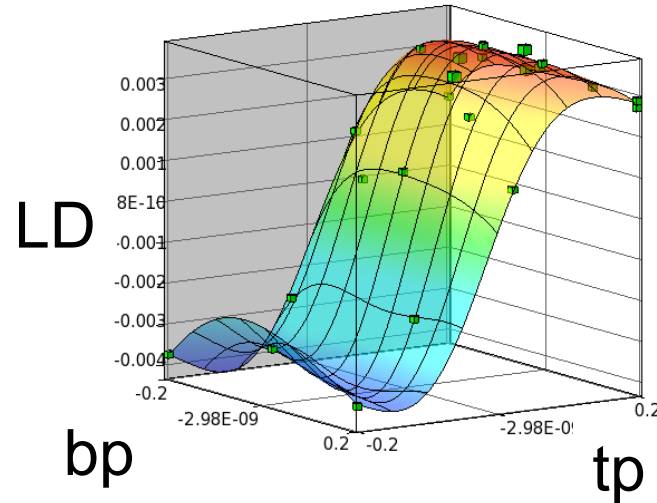




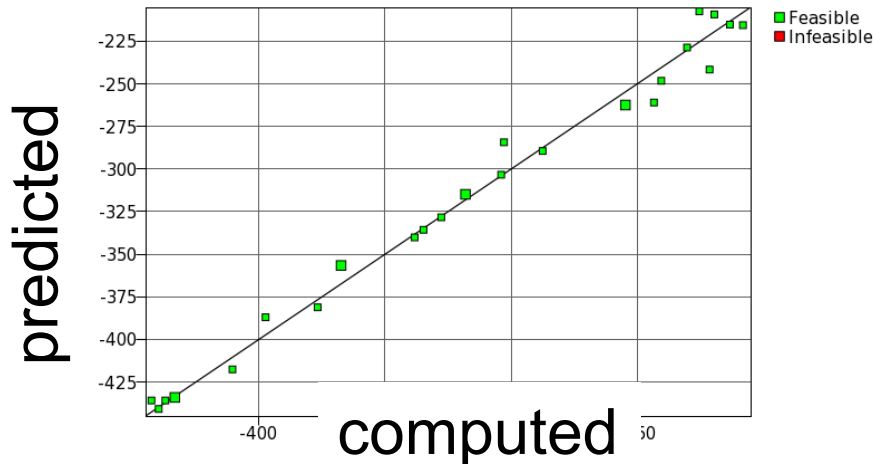
# Results (RBF)

## Metamodel accuracy

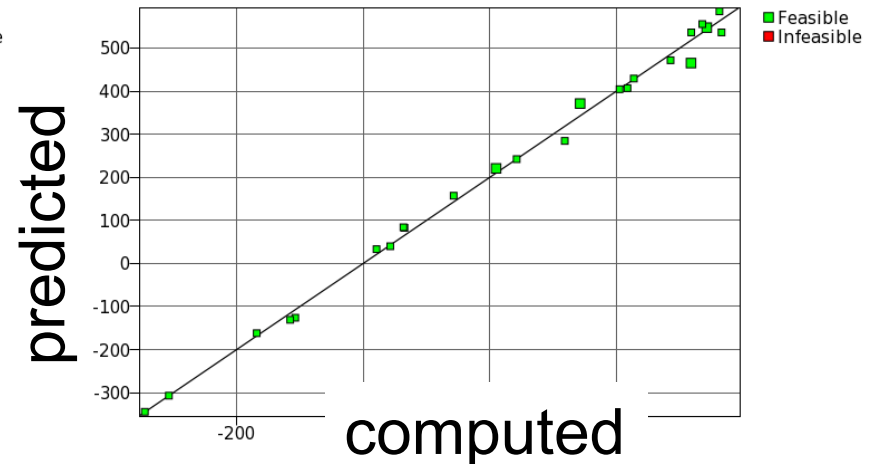
- Surface plot with points
  - Points are close to surface
- Error measures (only for responses)
  - RMS error
  - SPRESS → predictive capability!



Metamodeling Accuracy  
For Response Function "drag avg"  
RBF Net: RMS Err = 9.21 (2.92 %), Sqrt PRESS = 14.7 (4.65 %), R-sq = 0.968



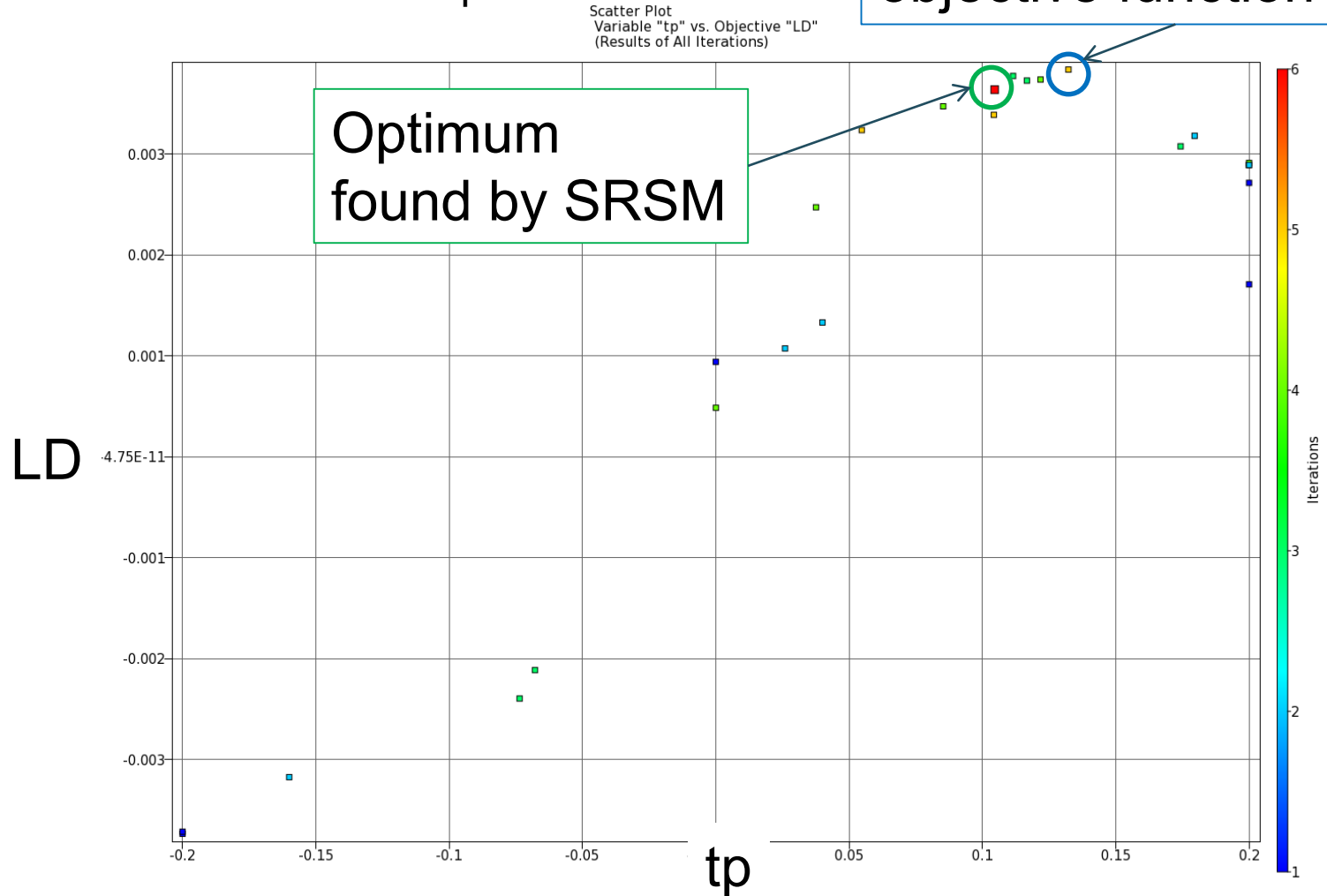
Metamodeling Accuracy  
For Response Function "lift avg"  
RBF Net: RMS Err = 19.4 (8.63 %), Sqrt PRESS = 44.3 (19.7 %), R-sq = 0.993



# Results (RBF)

■ Simulation results: Scatter plot

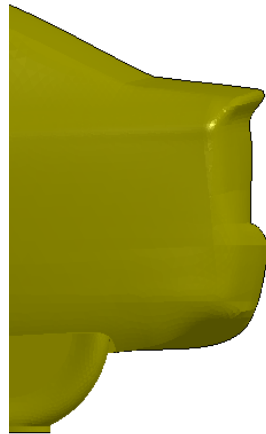
Point with highest objective function value



# Results (RBF)

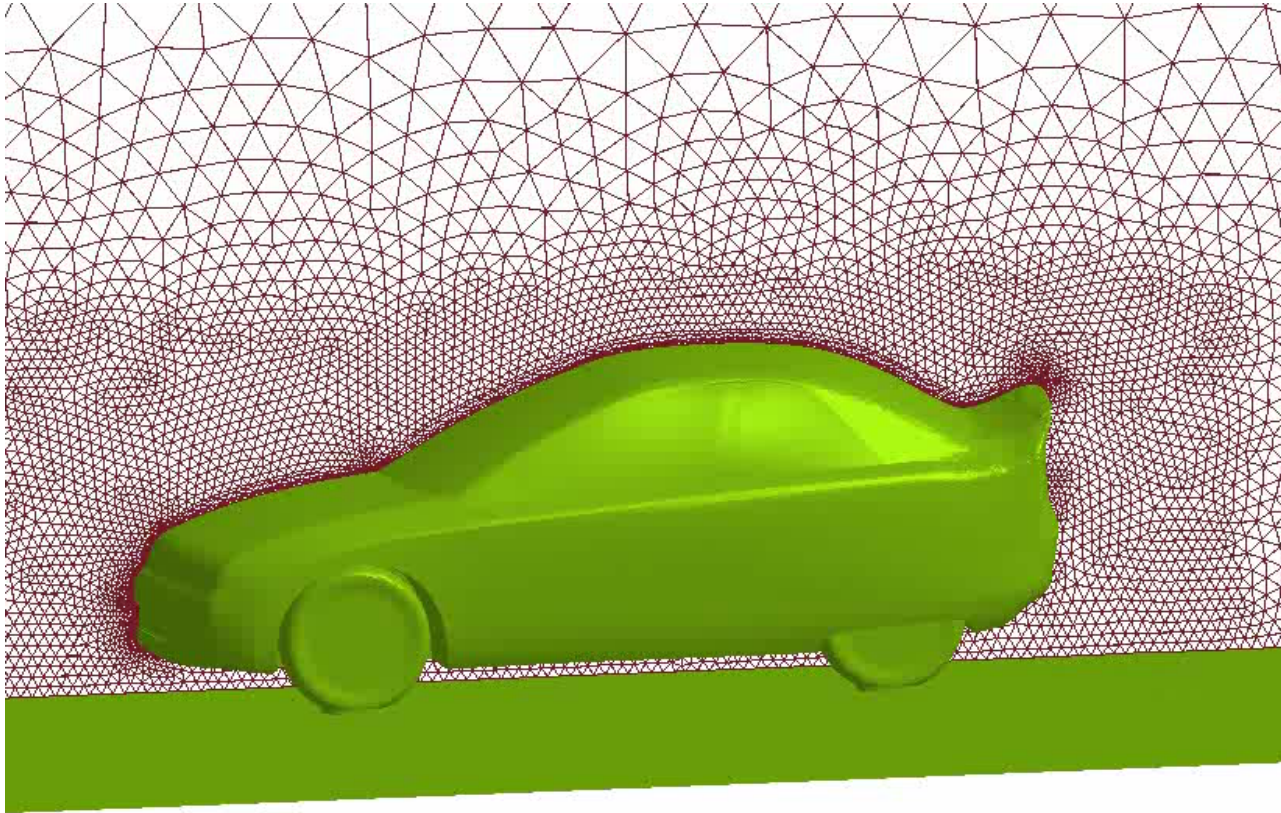
## ■ Optimal design

	Initial design	Optimal design (6.1)	„Best“ design (5.2)
bp	0.0	0.022	0.062
tp	0.0	0.105	0.132
LD predicted	-	0.00376	0.00366
LD computed	0.00094	0.00364	0.00384



# Results (RBF)

- Optimal design



# More Information on the LSTC Product Suite

- Livermore Software Technology Corp. (LSTC)

  - [www.lstc.com](http://www.lstc.com)

- LS-DYNA

  - Support / Tutorials / Examples / FAQ

    - [www.dynasupport.com](http://www.dynasupport.com)

  - More Examples

    - [www.dynaexamples.com](http://www.dynaexamples.com)

  - Conference Papers

    - [www.dynalook.com](http://www.dynalook.com)

  - European Master Distributor

    - [www.dynamore.de](http://www.dynamore.de)

- LS-PrePost

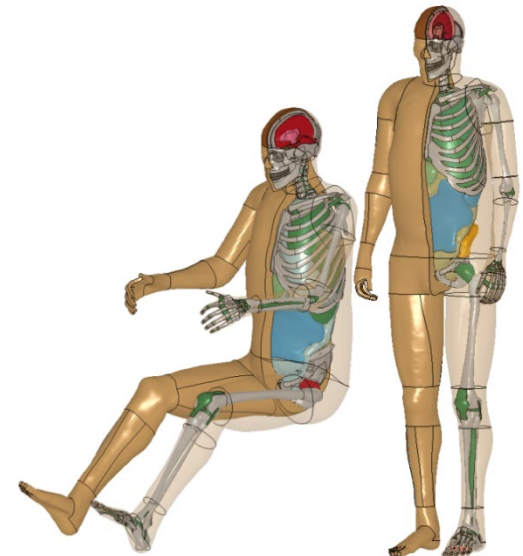
  - Support / Tutorials / Download

    - [www.lstc.com/lsp](http://www.lstc.com/lsp)

- LS-OPT / LS-TaSC

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