OPTIMIZATION OF EAS USING CFD

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&

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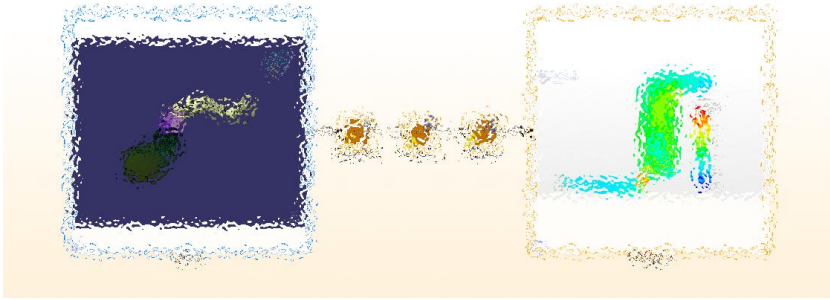
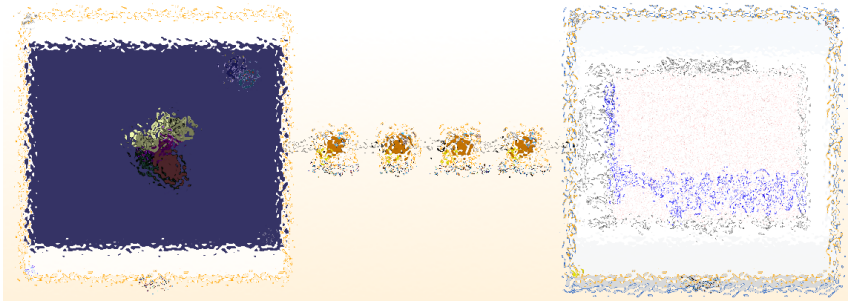
UNIVERSITY OF ROSTOCK & SCANIA

CONTENT

- INTRODUCTION
- BACKGROUND
- OBJECTIVES
- METHOD
- RESULTS
- SUMMARY
- FUTURE WORK
- Q & A



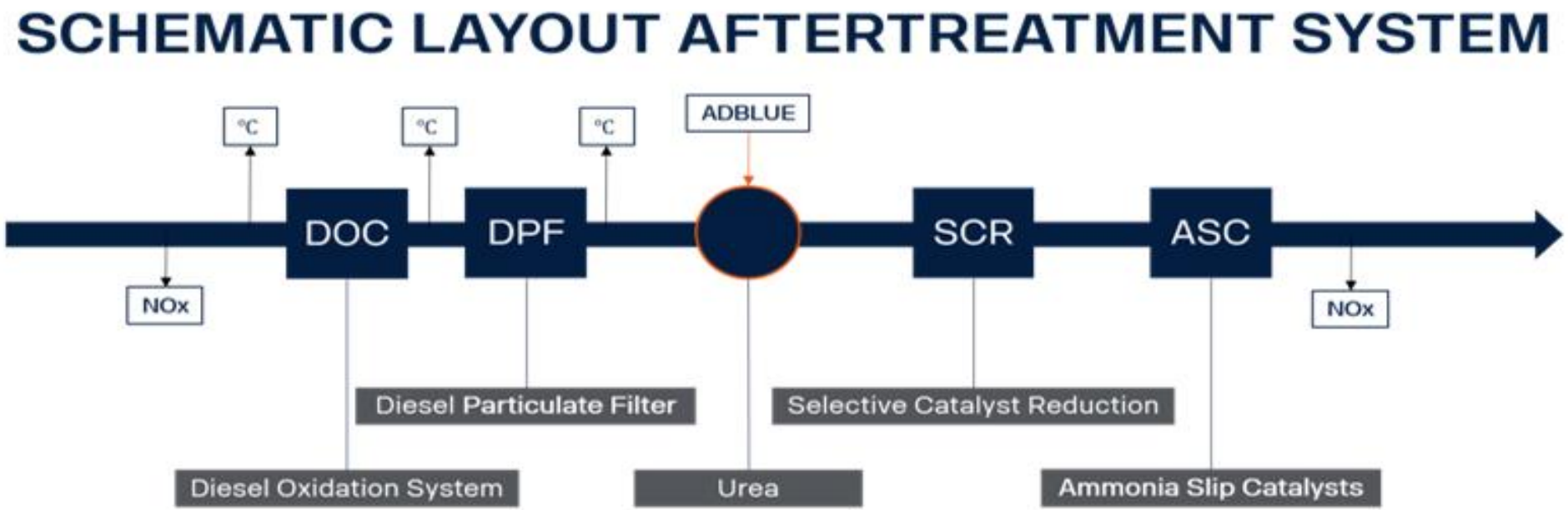
Flow CFD



Spray CFD

INTRODUCTION

- ABOUT EAS
- MIXING IN THE INTERNAL FINS
- PRESSURE DROP
- EVAPORATION PERFORMANCE



[1] Scania Aftertreatment course

BACKGROUND

- FREQUENT OPTIMIZATION AND DOE STUDIES @ NXPS.
- VARIOUS SOFTWARES.
- BETTER INTEGRATION NEEDED.
- MINIMUM DELIVERY TIME REQUIRED.
- SHOULD BE MULTIDISCIPLINARY.

Catia

ANSA

STARCCM+

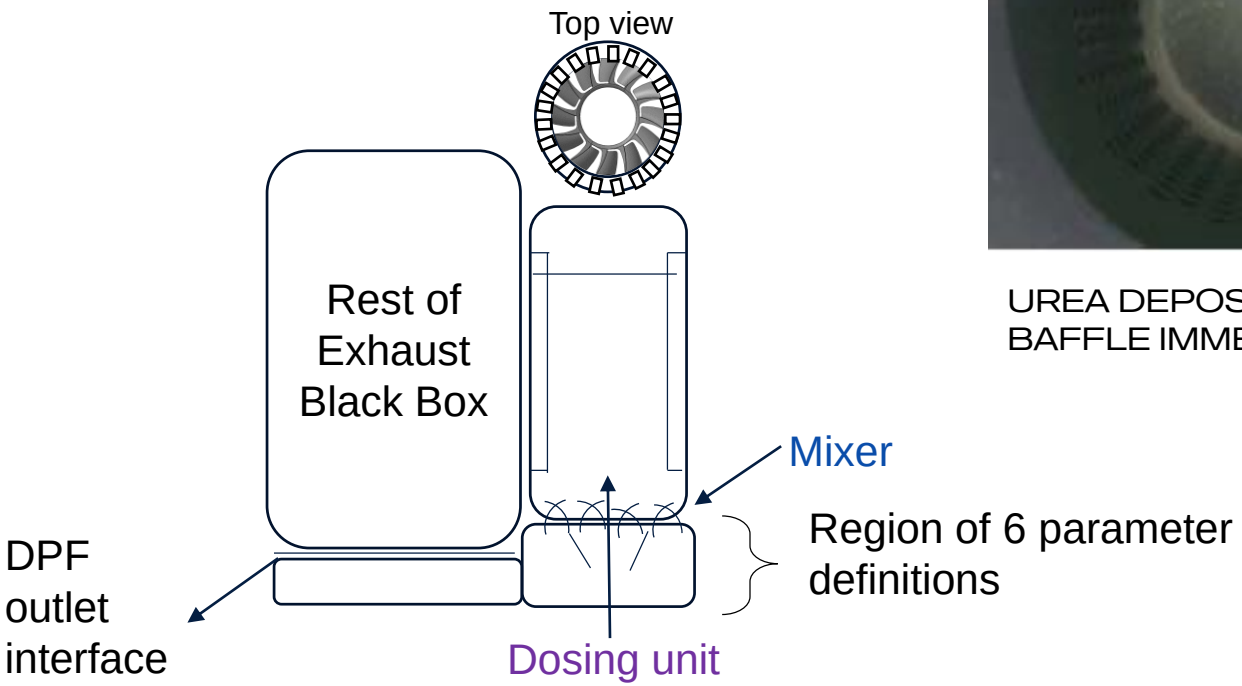
AVL FIRE

OpenFOAM

PROBLEM

- WALL DEPOSITS
- MIXING REQUIRED IN APPROPRIATE MEASURES AND CONDITIONS

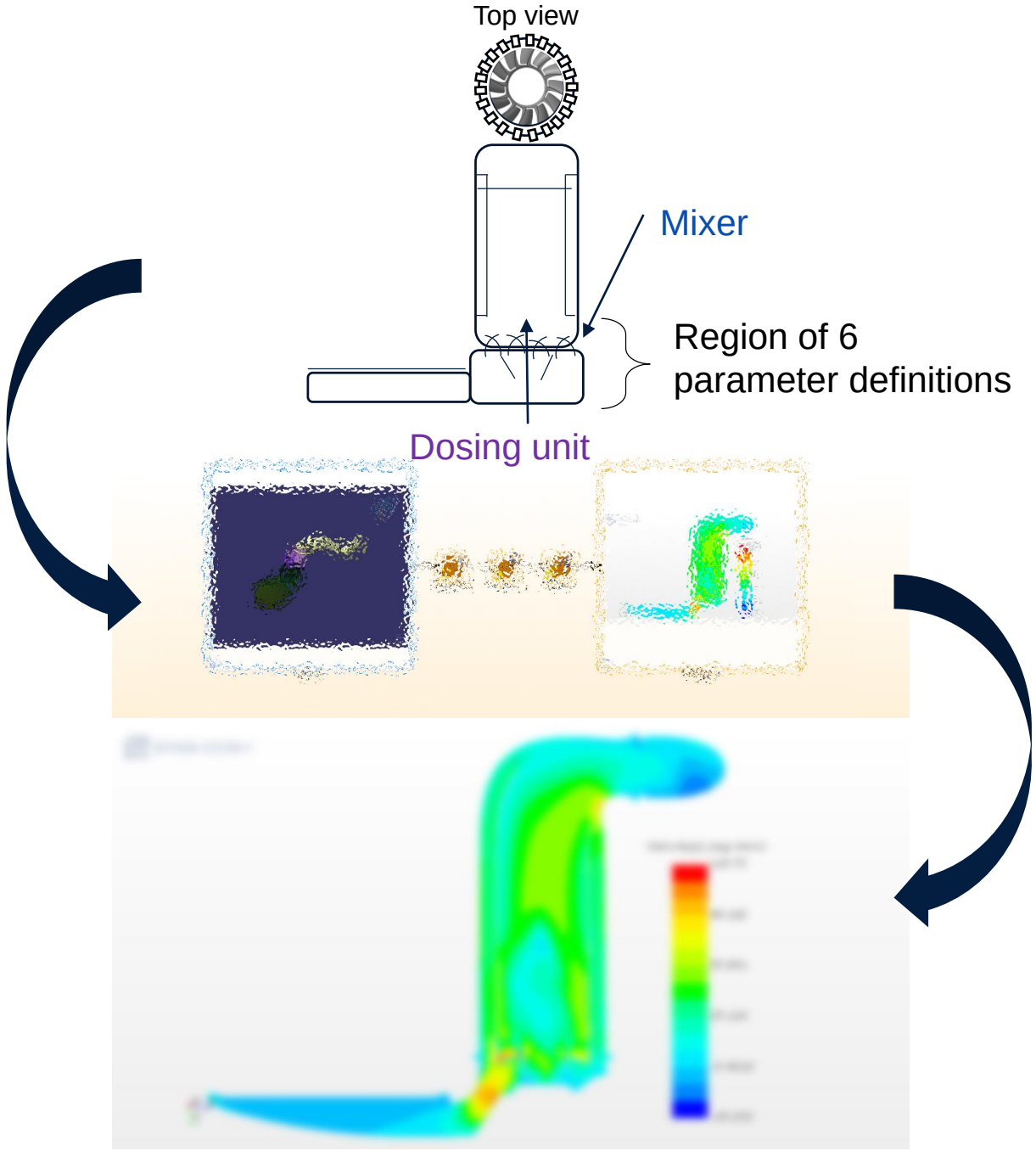
UREA DEPOSITS AT THE BOTTOM OF THE MIXING CHAMBER (LEFT) & BAFFLE IMMEDIATELY DOWNSTREAM OF THE MIXING CHAMBER (RIGHT)



[1] GUANYU ZHENG ET AL. “DESIGN OPTIMIZATION OF AN INTEGRATED SCR SYSTEM FOR EU V HEAVY DUTY DIESEL ENGINES”. IN: *SAE TECHNICAL PAPER SERIES* (2016).

OBJECTIVES

- AUTOMATE COMPLEX CFD PROCESSES.
- UNDERSTAND COMPETING OBJECTIVES.
- DEVELOP DOE/OPTIMIZATION PROCESS BLACK BOX.
- BUILD RESPONSE SURFACE MODELS TO UNDERSTAND DESIGN SPACE.

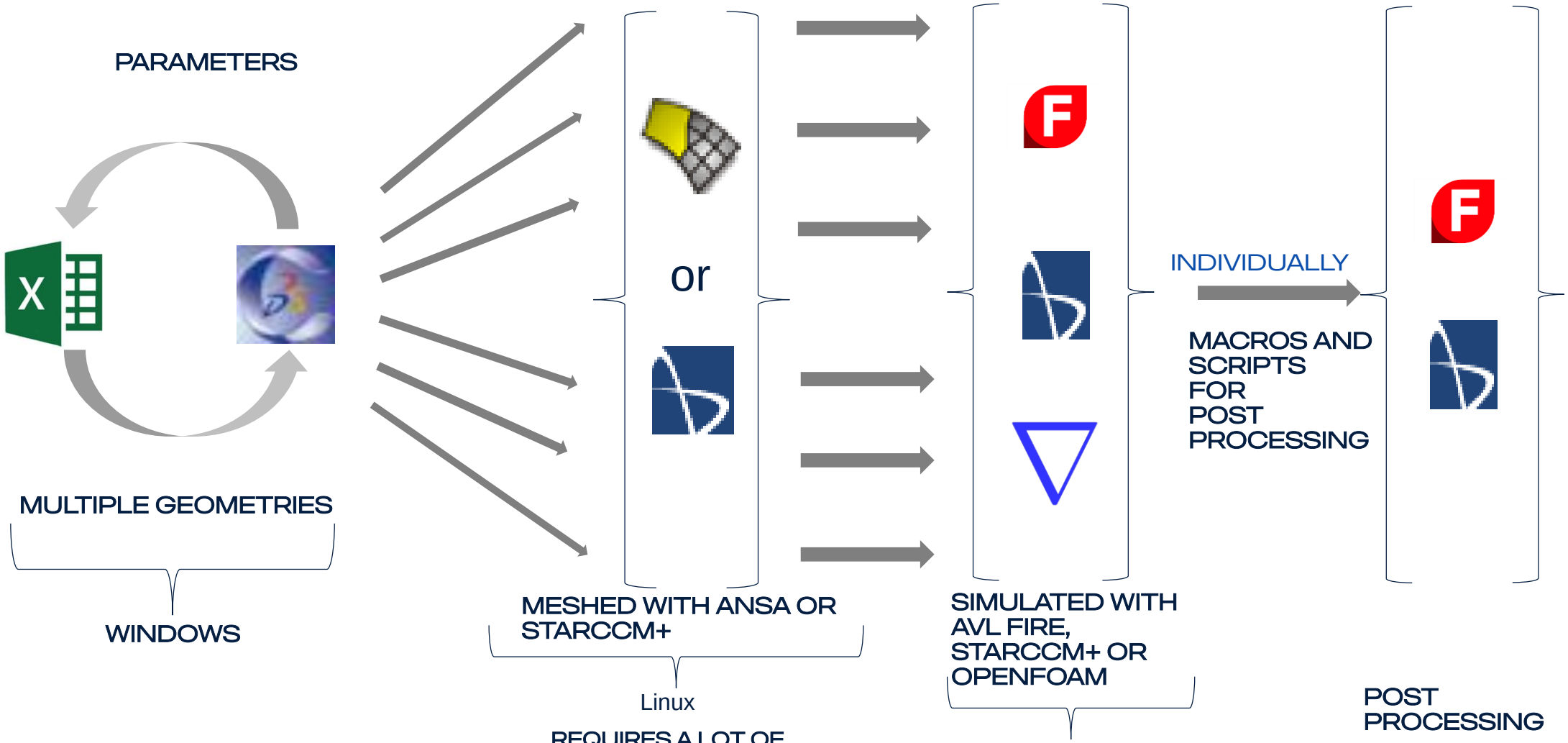


METHODS

FLOW & SPRAY CFD

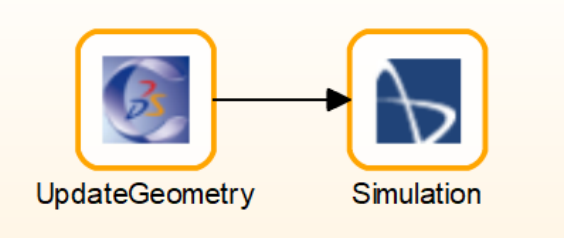
SCANIA

CURRENT DOE METHOD

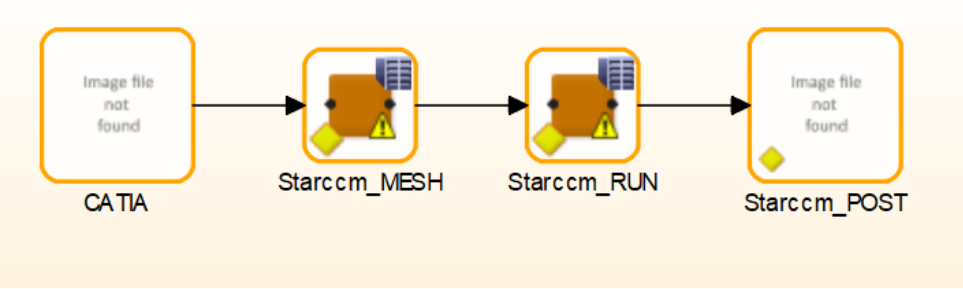


CURRENT KNOWLEDGEBASE

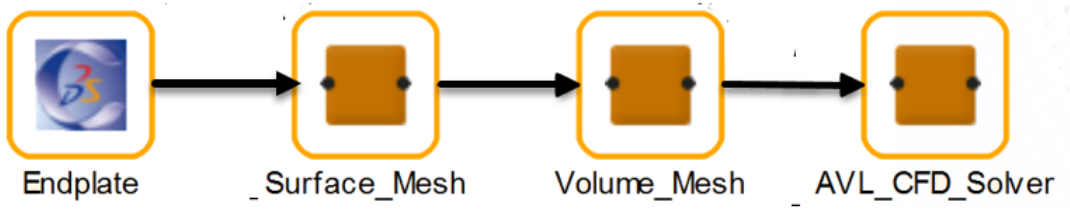
- WINDOWS BASED ONLY.
- NO CLUSTER INVOLVED.



- CADEXCHANGE USED
- POSTPROCESING REQUIRES LOCAL INSTALLATION
- NO ANSA INVOLVED.



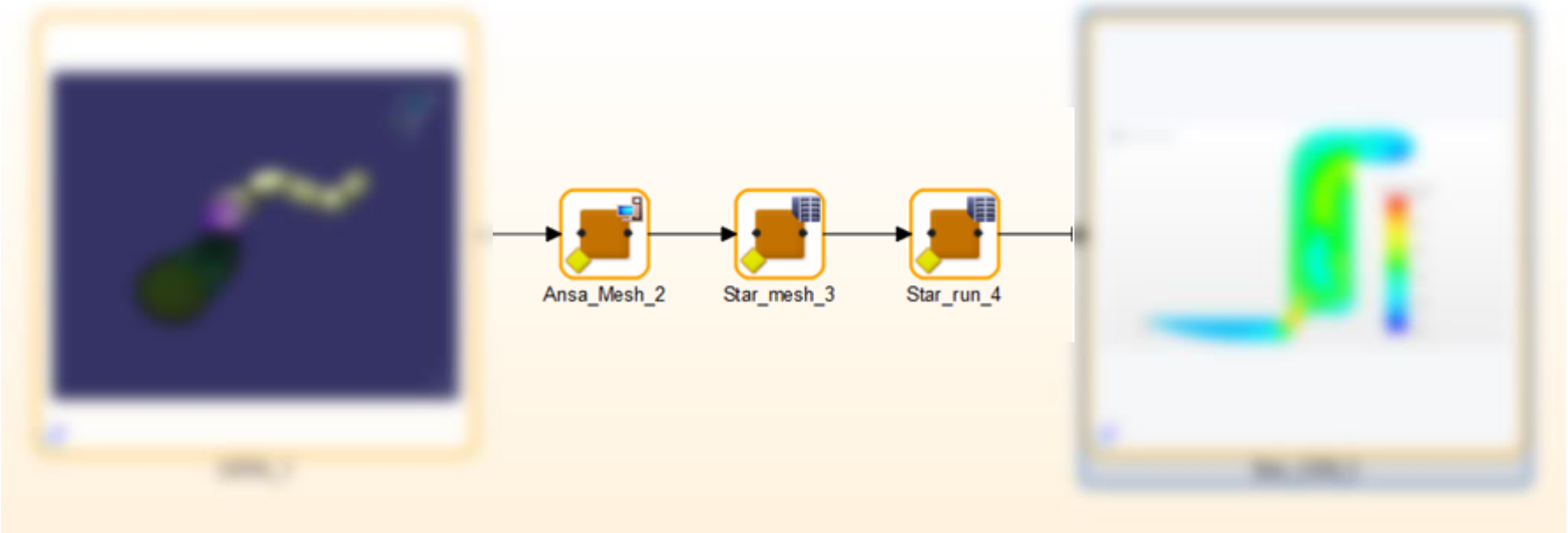
- NOT USEFUL FOR NXPS (PROBABLY)
- LOT OF DUMMY VARIABLES



FLOW with STAR-CCM+

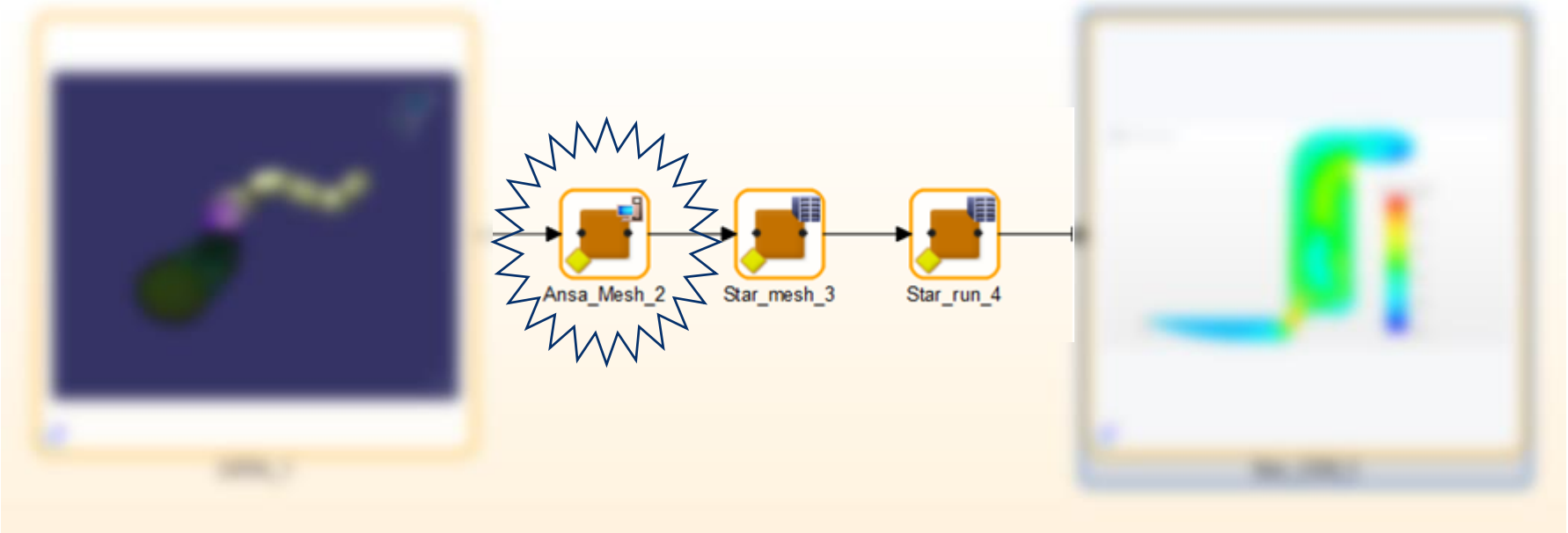
SCANIA

HEEDS-INTRODUCING



WINDOWS	LINUX	CLUSTER	CLUSTER	WINDOWS
≈22S	≈46S	≈11MIN	≈UNDER 1MIN	≈UNDER 2 MIN

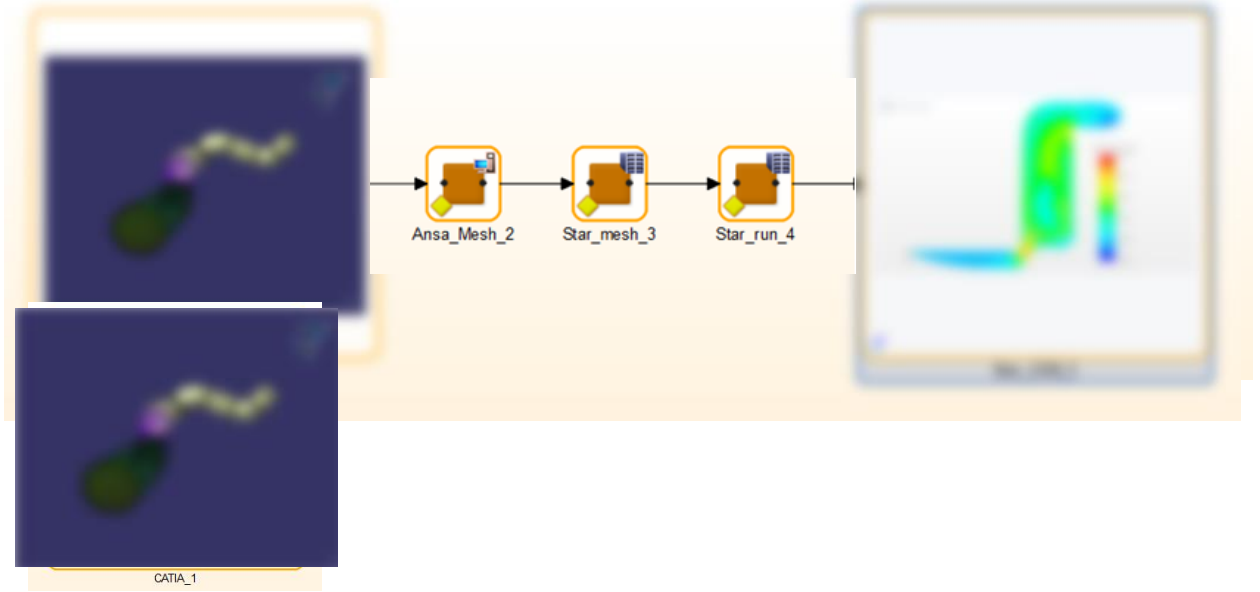
HEEDS-INTRODUCING

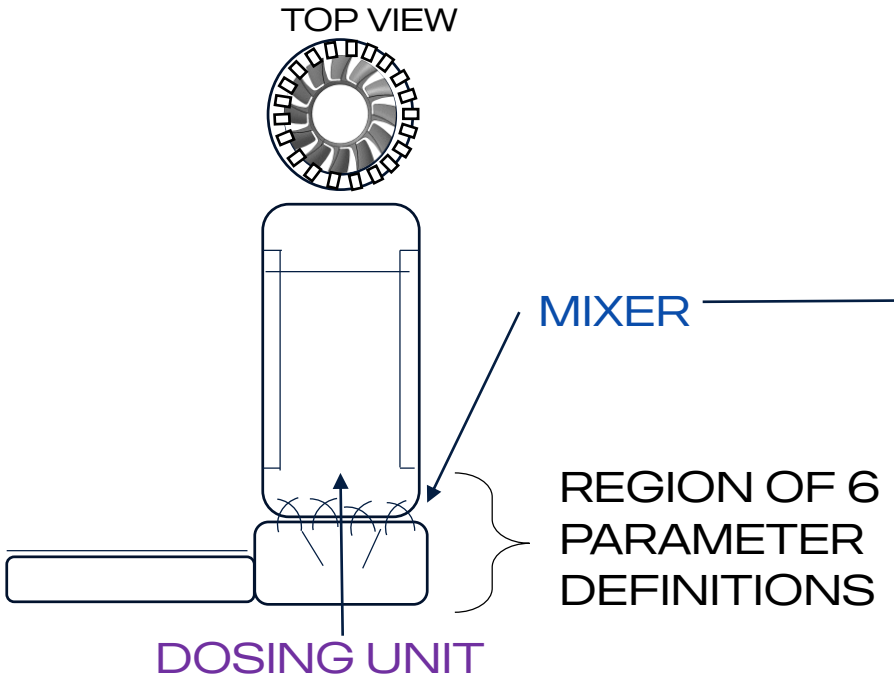


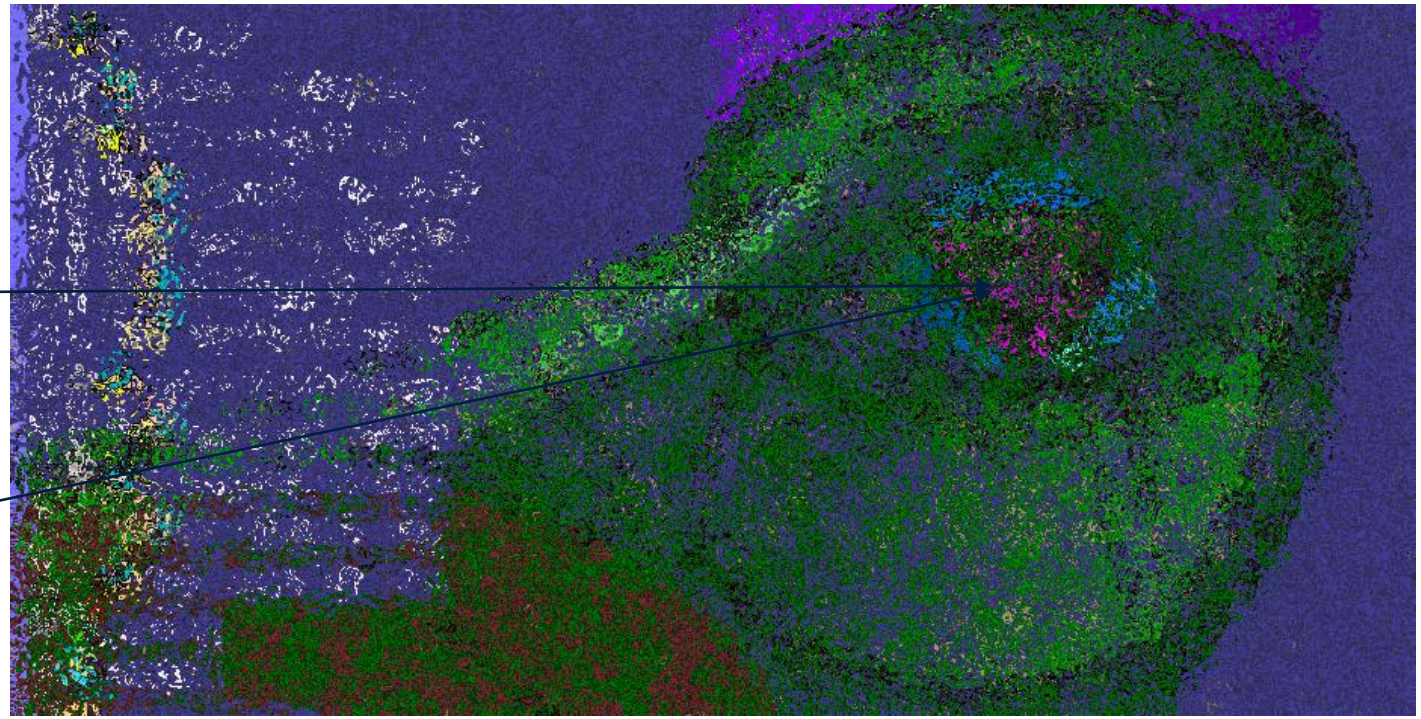
WINDOWS	LINUX	CLUSTER	CLUSTER	WINDOWS
≈22S	≈46S	≈11MIN	≈UNDER 1MIN	≈UNDER 2 MIN

CATIA_1

- PARAMETERS SAMPLING
- AUTOMATED
- JUST TAG!

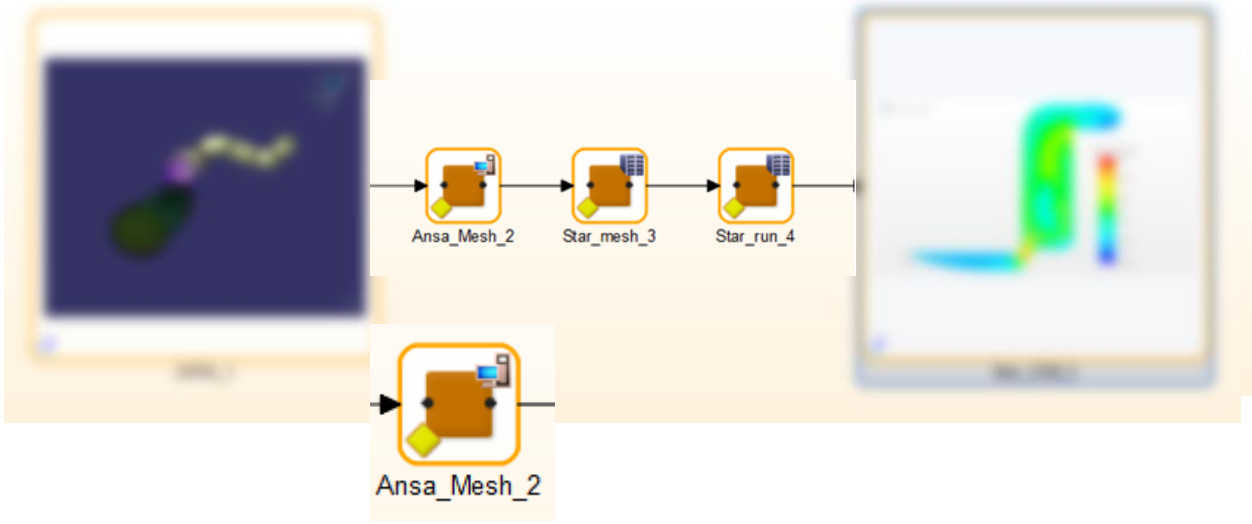


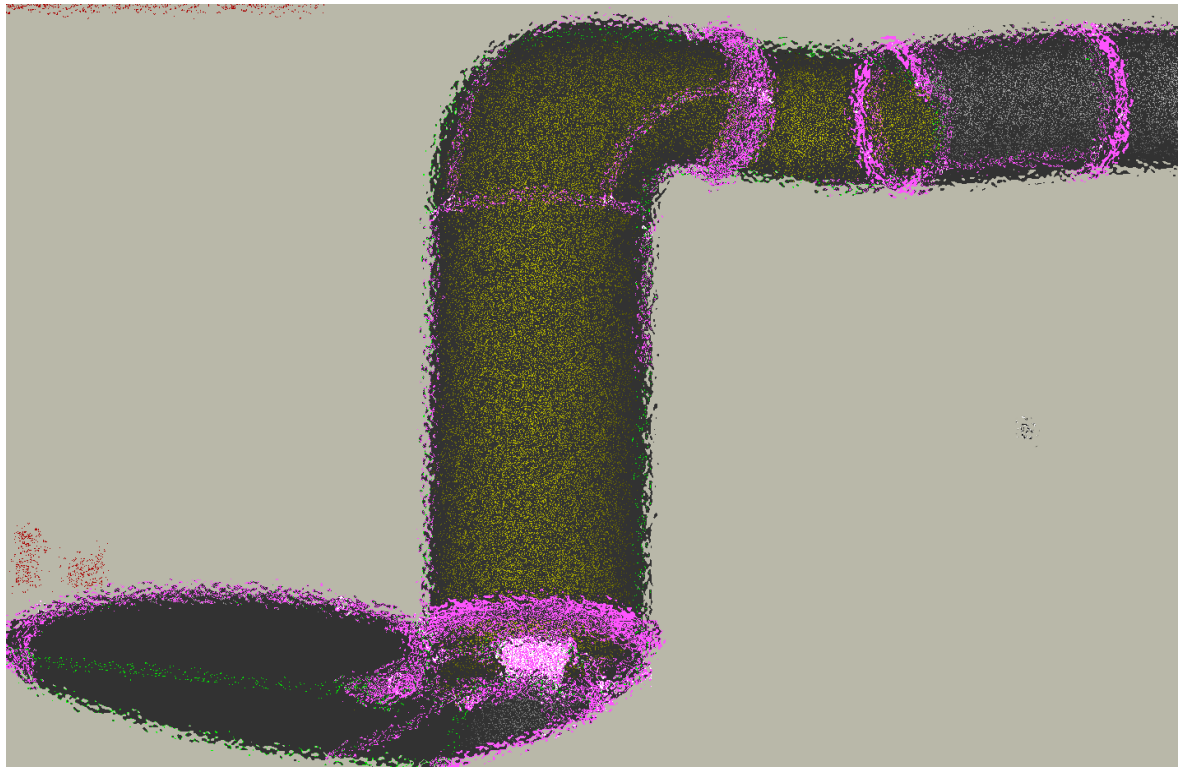




ANSA_2

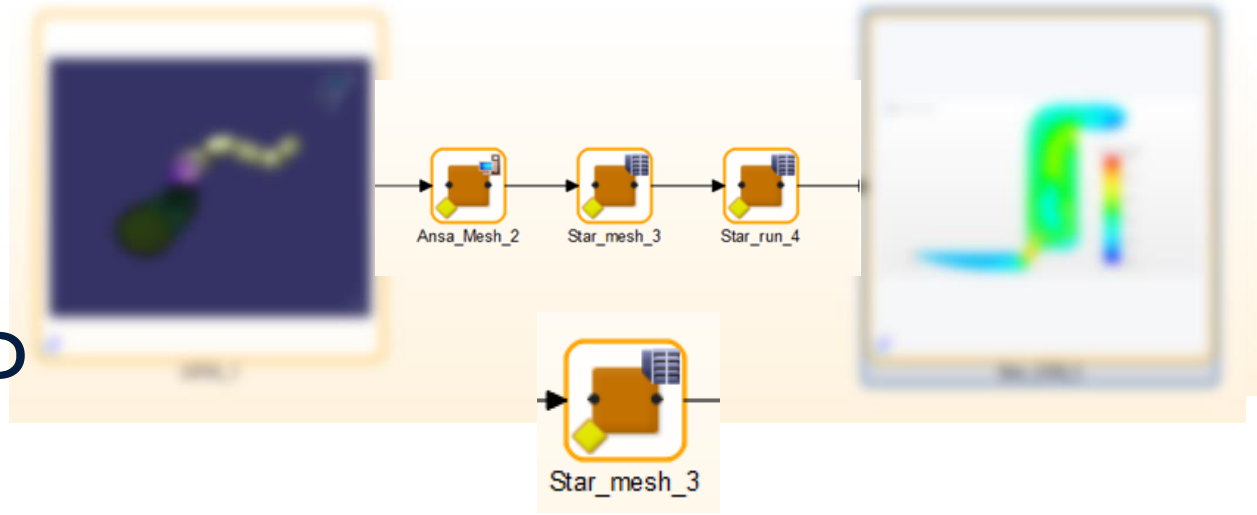
- IMPORT LAST.
- RUN PYTHON.
- EXPORT STL.

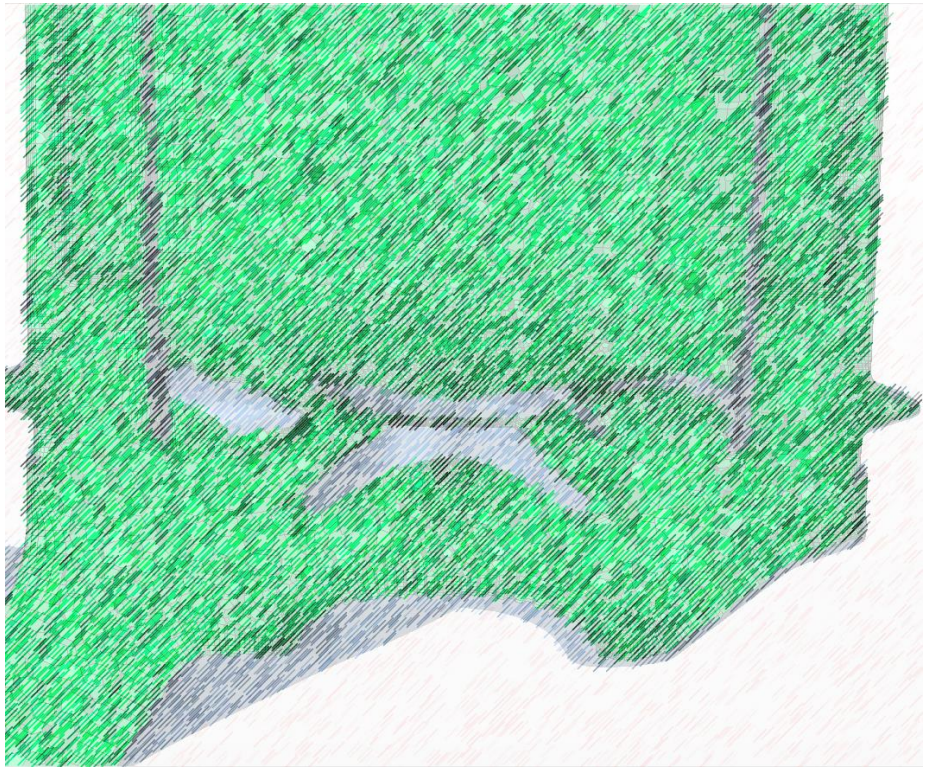




STAR_MESH_3

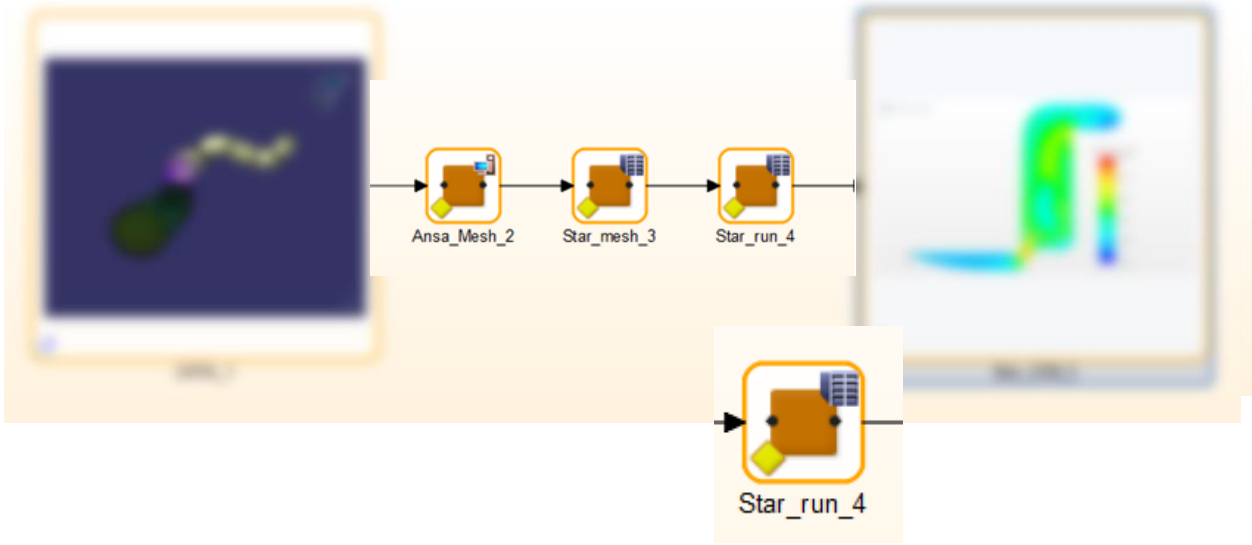
- IMPORT STL.
- UPDATE ON PREDEFINED STARCCM+ FILE.
- RUN MACRO.
- EXPORT VOLUME MESH.

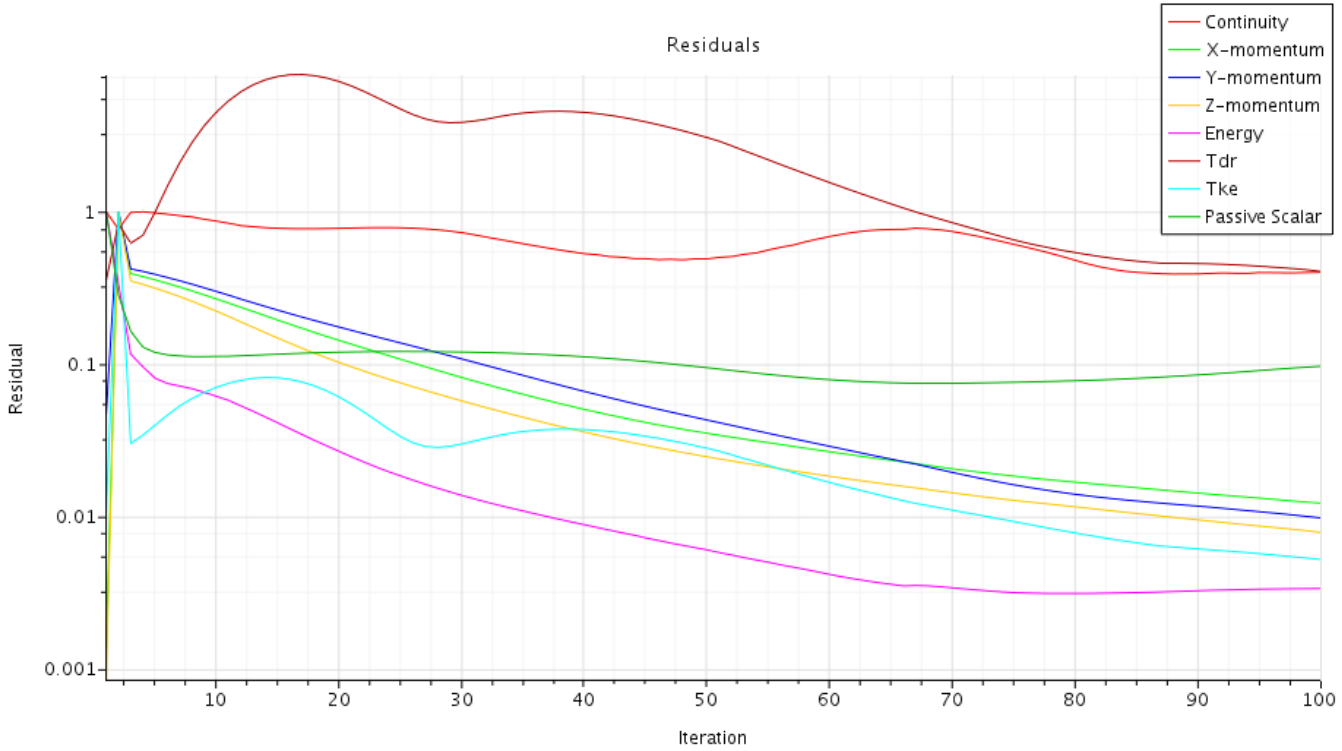




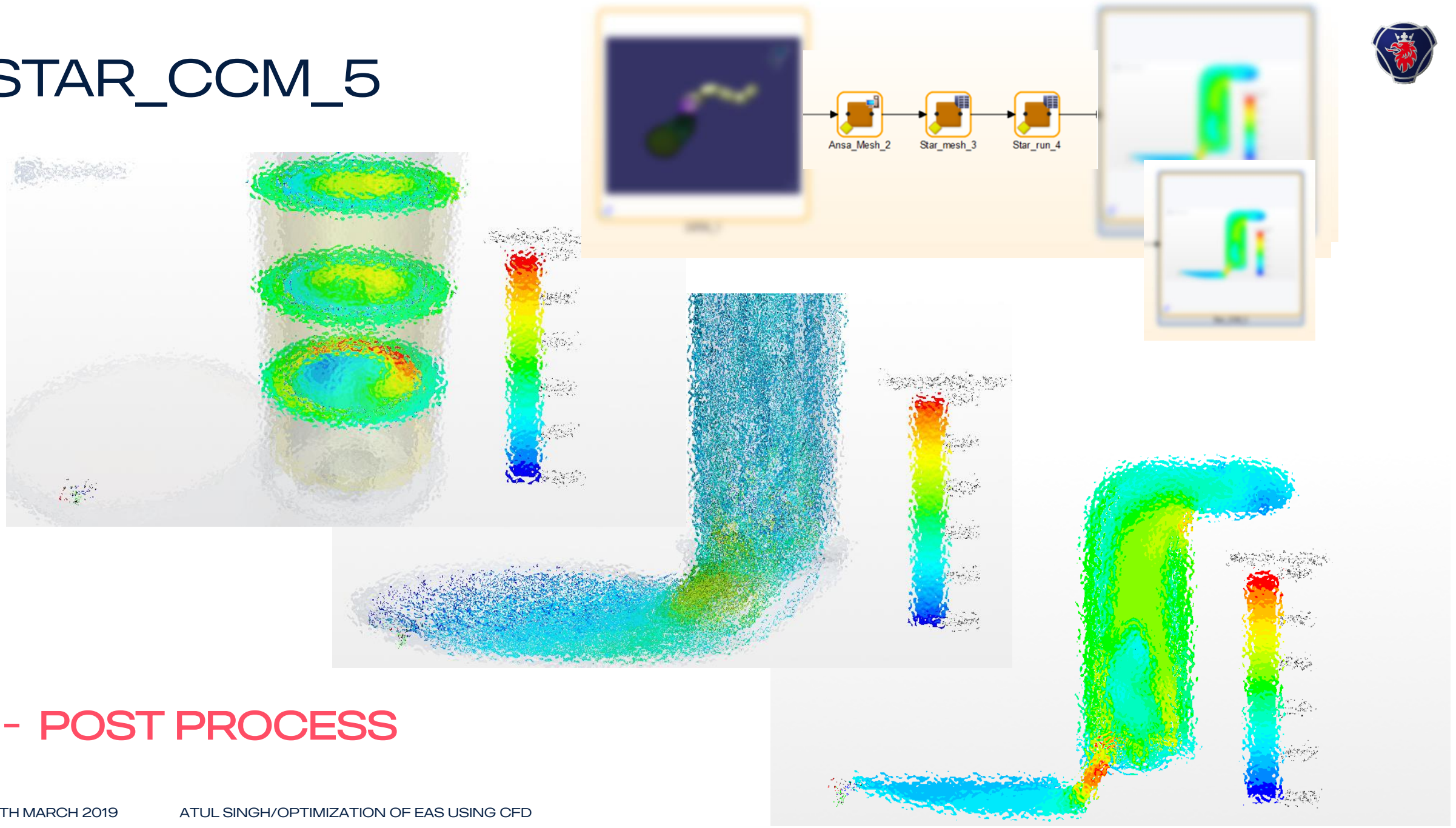
STAR_RUN_4

- IMPORT VOLUME MESH.
- RUN!
- EXPORT FINISHED SIM FILE.





STAR_CCM_5

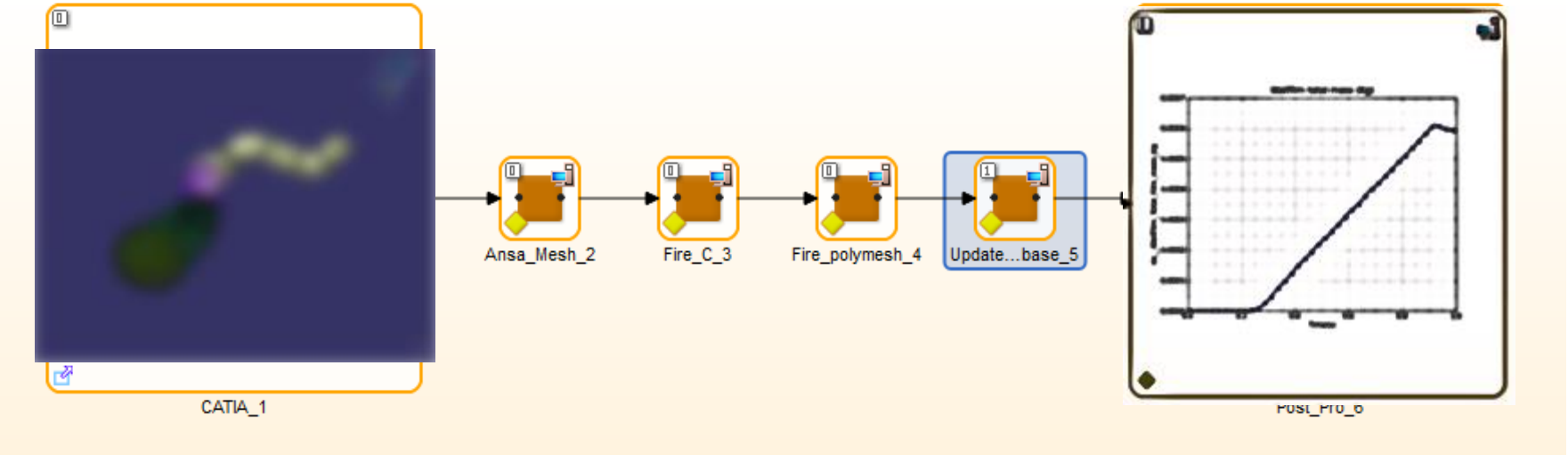


- POST PROCESS

FLOW with AVL-FIRE

SCANIA

HEEDS-INTRODUCING-SPRAY CFD



WINDOWS	LINUX	LINUX	LINUX	LINUX + CLUSTER	LINUX
≈46S	≈1M:5S	≈30S	≈3M:40S	≈1H:50M	≈20S

RESULTS

STAR-CCM+

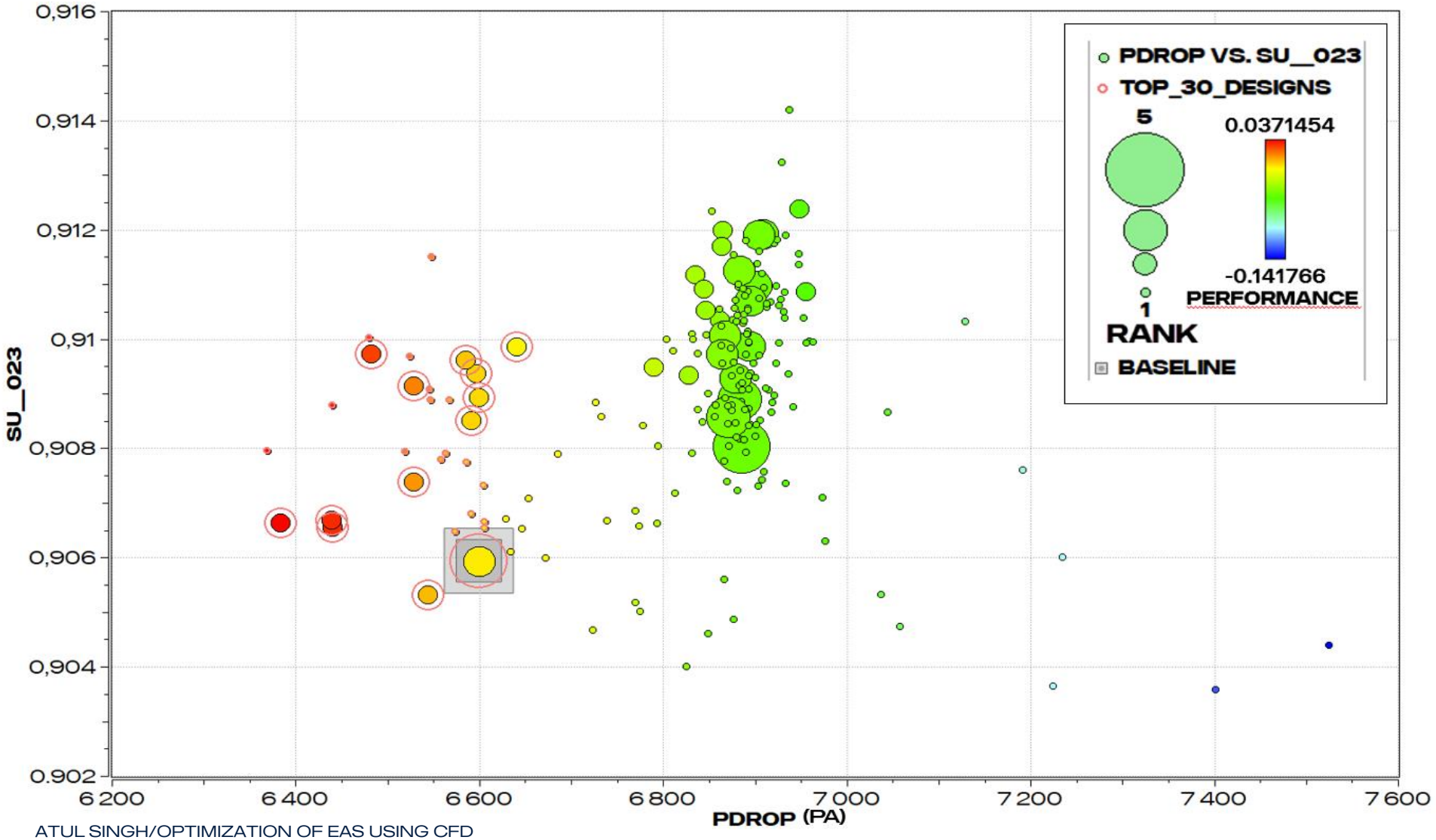
STARCCM+

- MULTI OBJECTIVE PARAMETER OPTIMIZATION, SHERPA, 200 EVALS
- WEIGHTED SUM SHERPA, PARAMETER OPTIMIZATION, 250 EVALS
- DOE SCREENING RESPONSE, 50 EVALS

MULTI OBJECTIVE PARAMETER OPTIMIZATION, SHERPA, 200 EVALS

STARCCM+

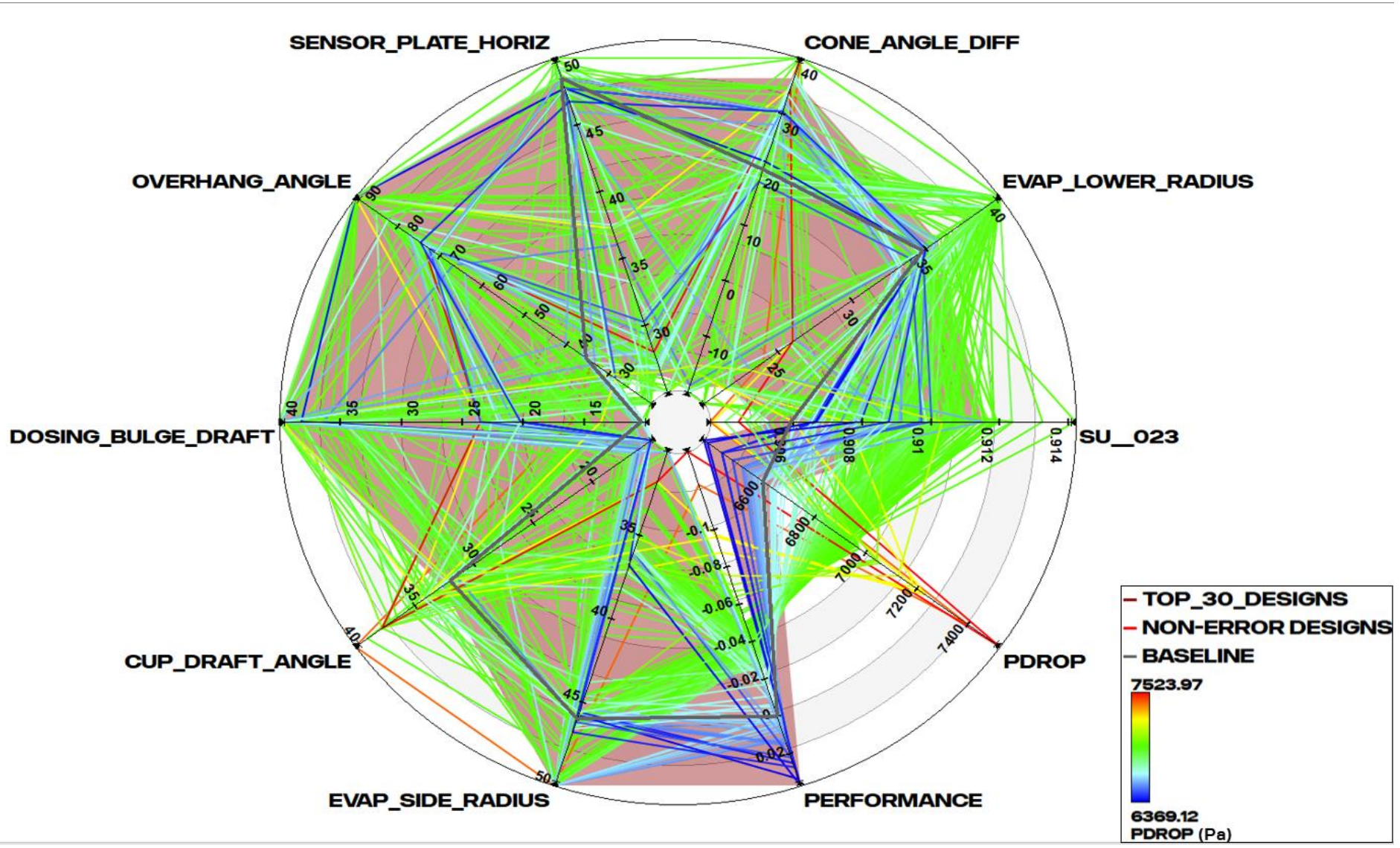
- TRADEOFF PLOT
- FROM ORIGINAL RUN OF 200 EVALS



MULTI OBJECTIVE PARAMETER OPTIMIZATION, SHERPA, 200 EVALS

STARCCM+

- RADIAL PLOT



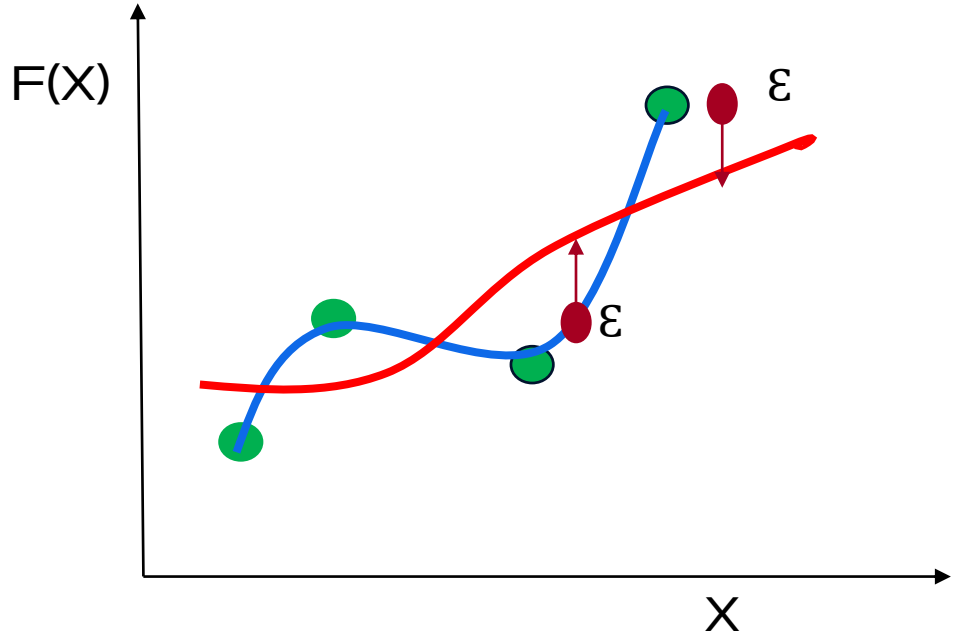
RESPONSE SURFACE METHOD

- APPROXIMATE MODEL
- SETS UPON A DOE / OPTIMIZATION
- ⬆EVALUATIONS = ⬆RSM

INTERPOLATION

APPROXIMATION

VALIDATION



RESPONSE SURFACE METHOD

Cross V value of 0.00187 is:
0.207% of actual minimum (0.903587)
0.205% of actual mean (0.909041)
0.204% of actual maximum (0.914216)

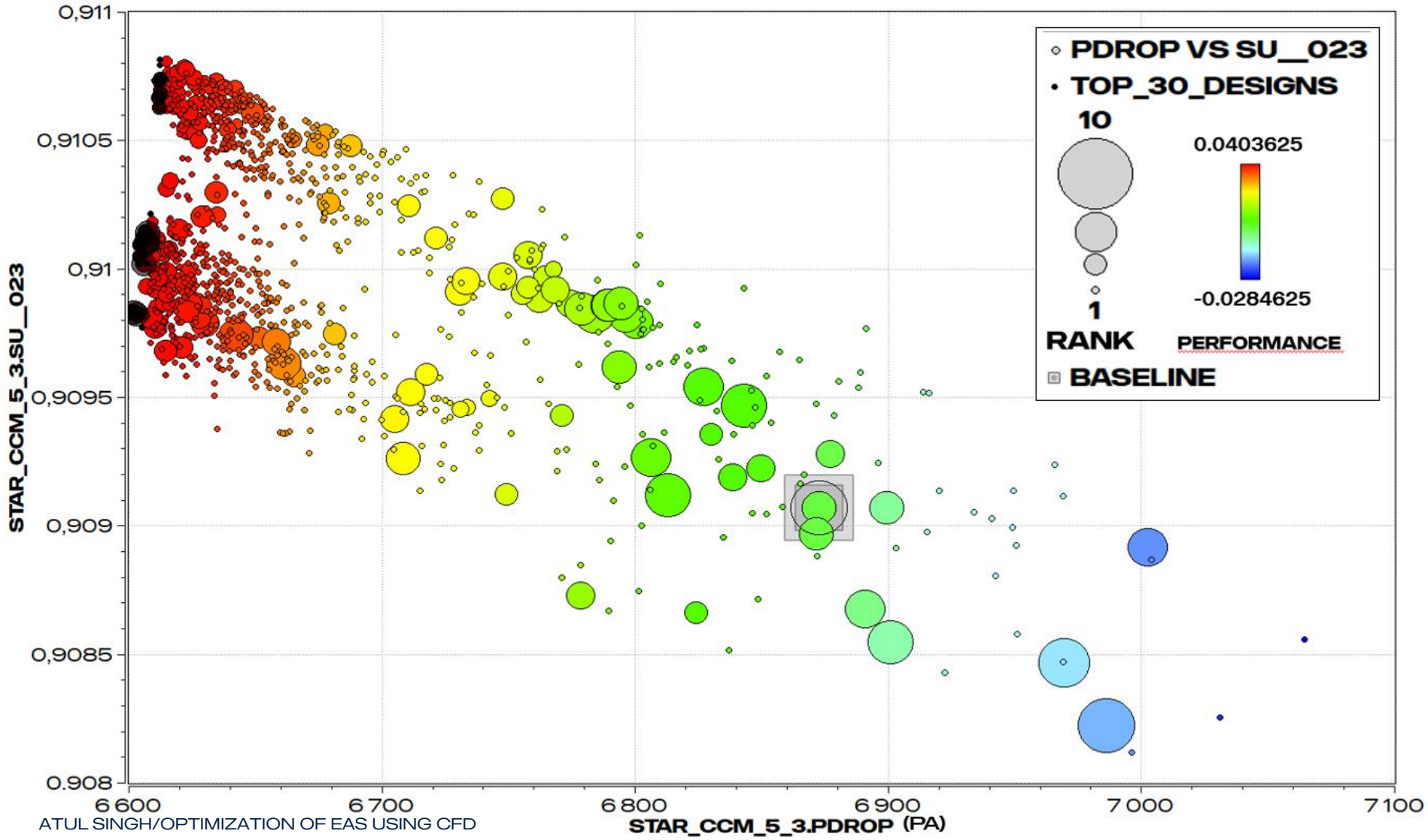
Name	Design Set	Response	Type	Function	Order	Tuning	Shape	R2	R2adj	RMSE	Cross V	PRESS
SU__023_Kr_Lin_GP	Non-Error Designs	SU__023	Kriging	Linear	1	Gaussian Process	7,50673	1		5.43e-6	0.00187	0.00185
Pdrop_Kr_Lin_GP	Non-Error Designs	Pdrop	Kriging	Linear	1	Gaussian Process	0,412384	0.826		66.5	130	129

Cross V value of 130 is:
2.05% of actual minimum (6369.12)
1.91% of actual mean (6836.08)
1.73% of actual maximum (7523.97)

- CROSS V VALUES SHOW QUALITY OF RSM
- NOTE, R2 < 1 ⟷ NOISY DATA/ FEW EVALS.

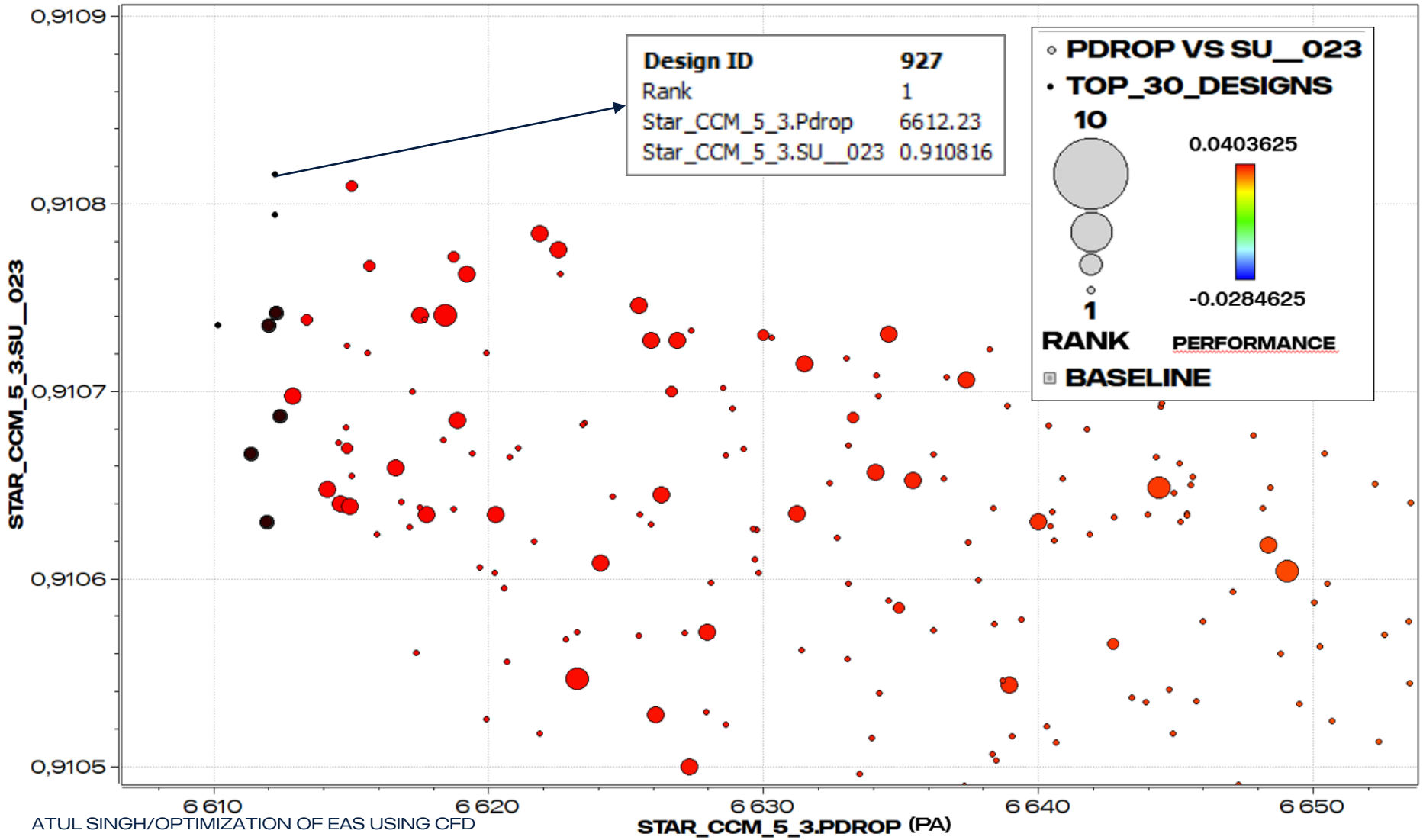
RESPONSE SURFACE METHOD

- DESIGN SPACE WHERE NEEDED



RESPONSE SURFACE METHOD

- DESIGN SPACE WHERE NEEDED
- BEST PDROP 6612.23PA
- BEST SU 0.910816
- @#927



RESPONSE SURFACE METHOD

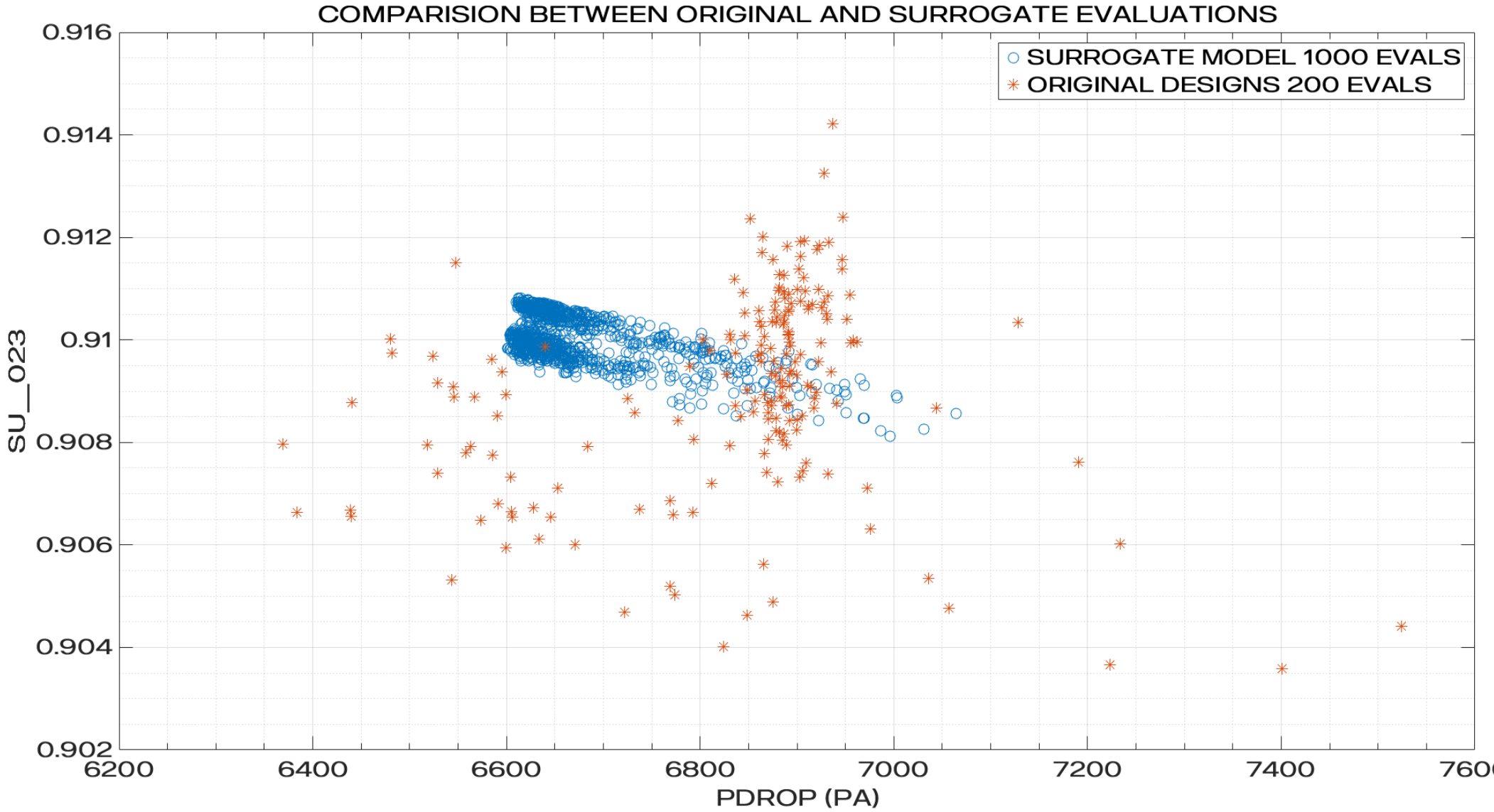
	RSM	OBTAINED	OBTAINED DIFFERENCE	RSM SUGGESTED
PDROP(PA)	6612.23	6422	-2.96 %	1.91%
SU	0.910816	0.911641	0.090 %	0.205%

Cross V value of 0.00187 is:
0.207% of actual minimum (0.903587)
0.205% of actual mean (0.909041)
0.204% of actual maximum (0.914216)

Name	Design Set	Response	Type	Function	Order	Tuning	Shape	R2	R2adj	RMSE	Cross V	PRESS
SU__023_Kr_Lin_GP	Non-Error Designs	SU__023	Kriging	Linear	1	Gaussian Process	7,50673	1		5.43e-6	0.00187	0.00185
Pdrop_Kr_Lin_GP	Non-Error Designs	Pdrop	Kriging	Linear	1	Gaussian Process	0,412384	0.826		66.5	130	129

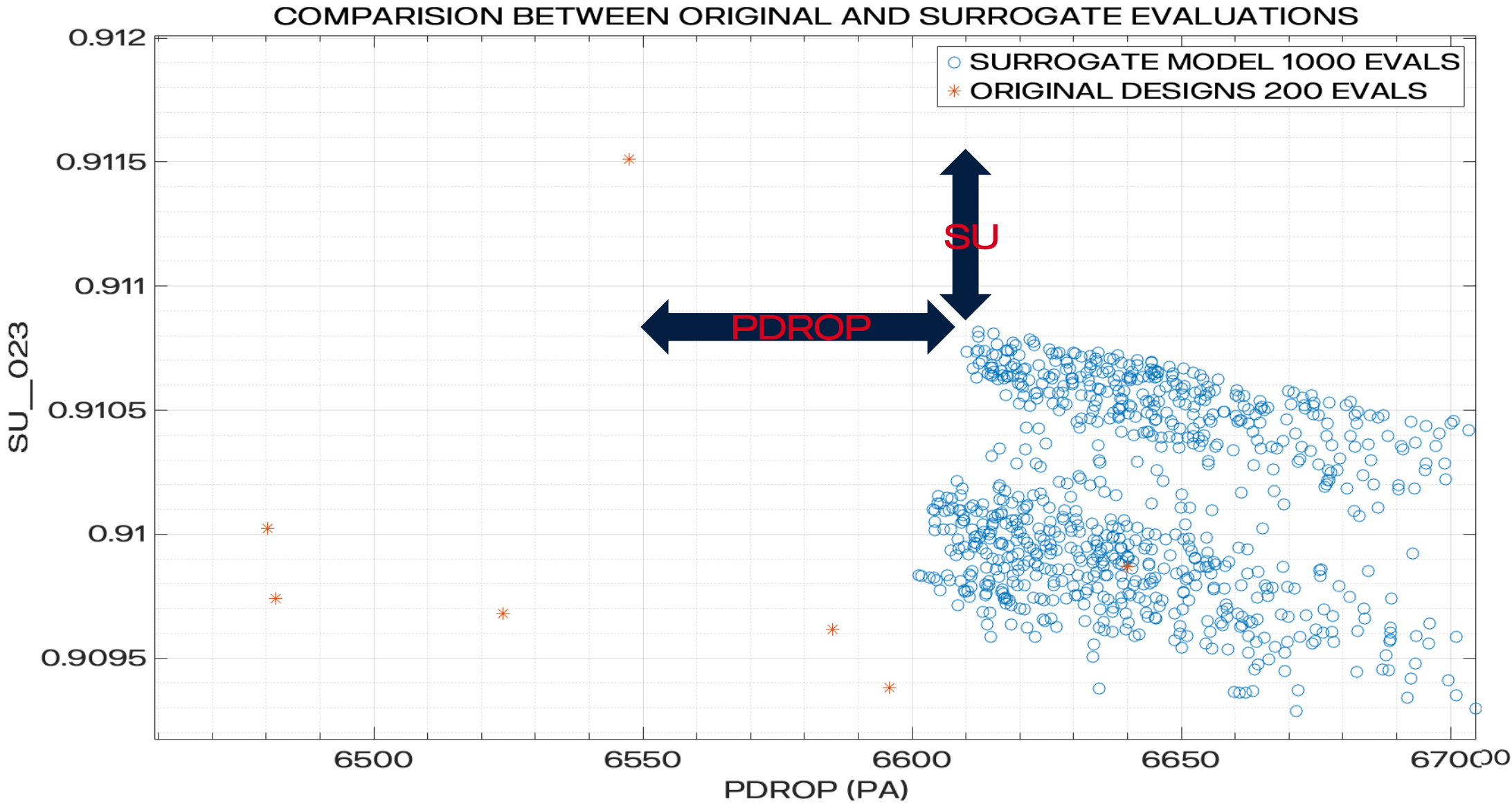
Cross V value of 130 is:
2.039% of actual minimum (6369.12)
1.91% of actual mean (6836.08)
1.733% of actual maximum (7523.97)

COMPARISON-MO SHERPA



COMPARISON-MO SHERPA

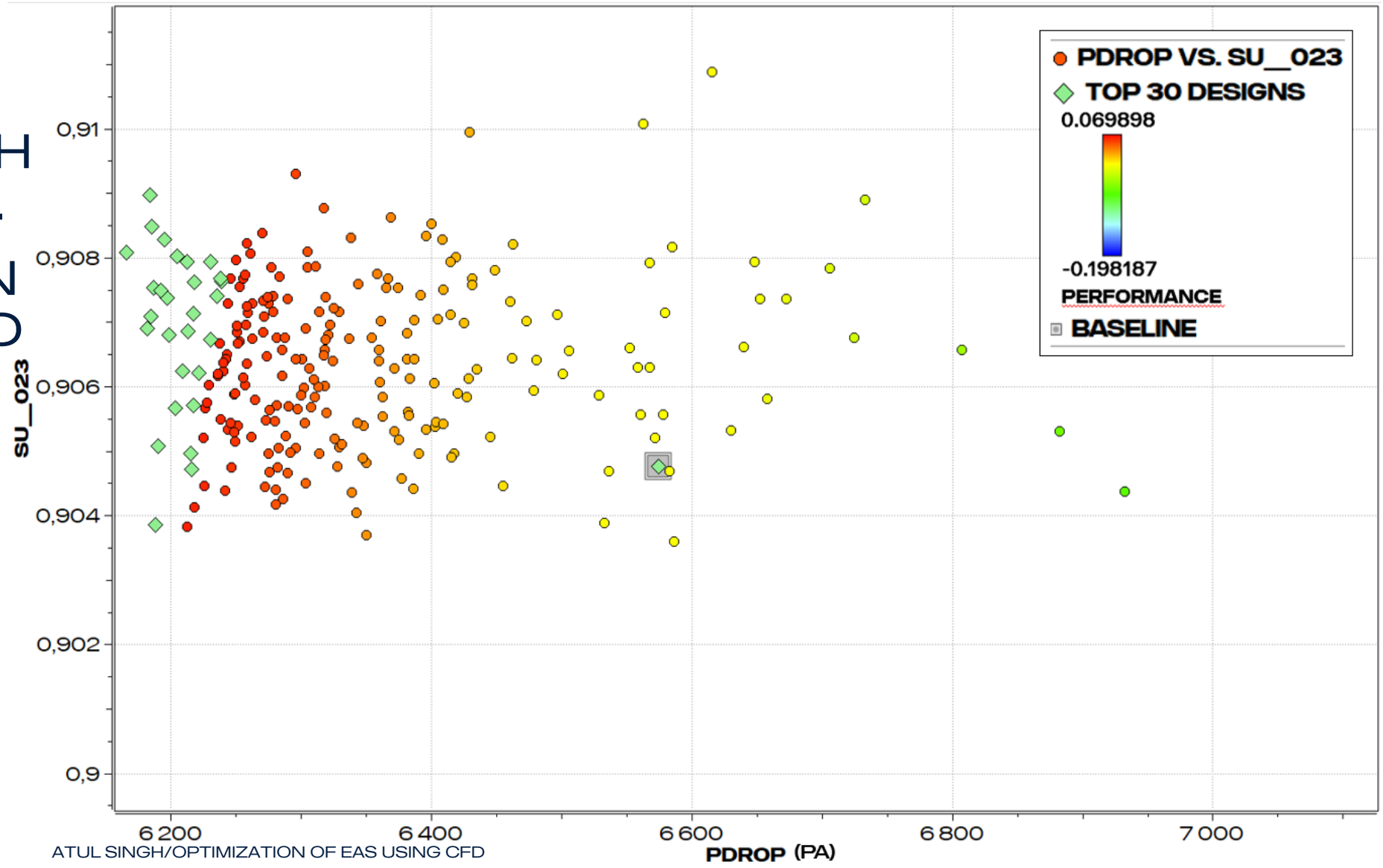
- The 2% difference



WEIGHTED SUM SHERPA, PARAMETER OPTIMIZATION, 250 EVALS

STARCCM+

- WEIGHTED SUM TO BOTH OBJECTIVES.
- BEST DESIGN RECOMMENDED.



WEIGHTED SUM SHERPA, PARAMETER OPTIMIZATION, 250 EVALS

STARCCM
+

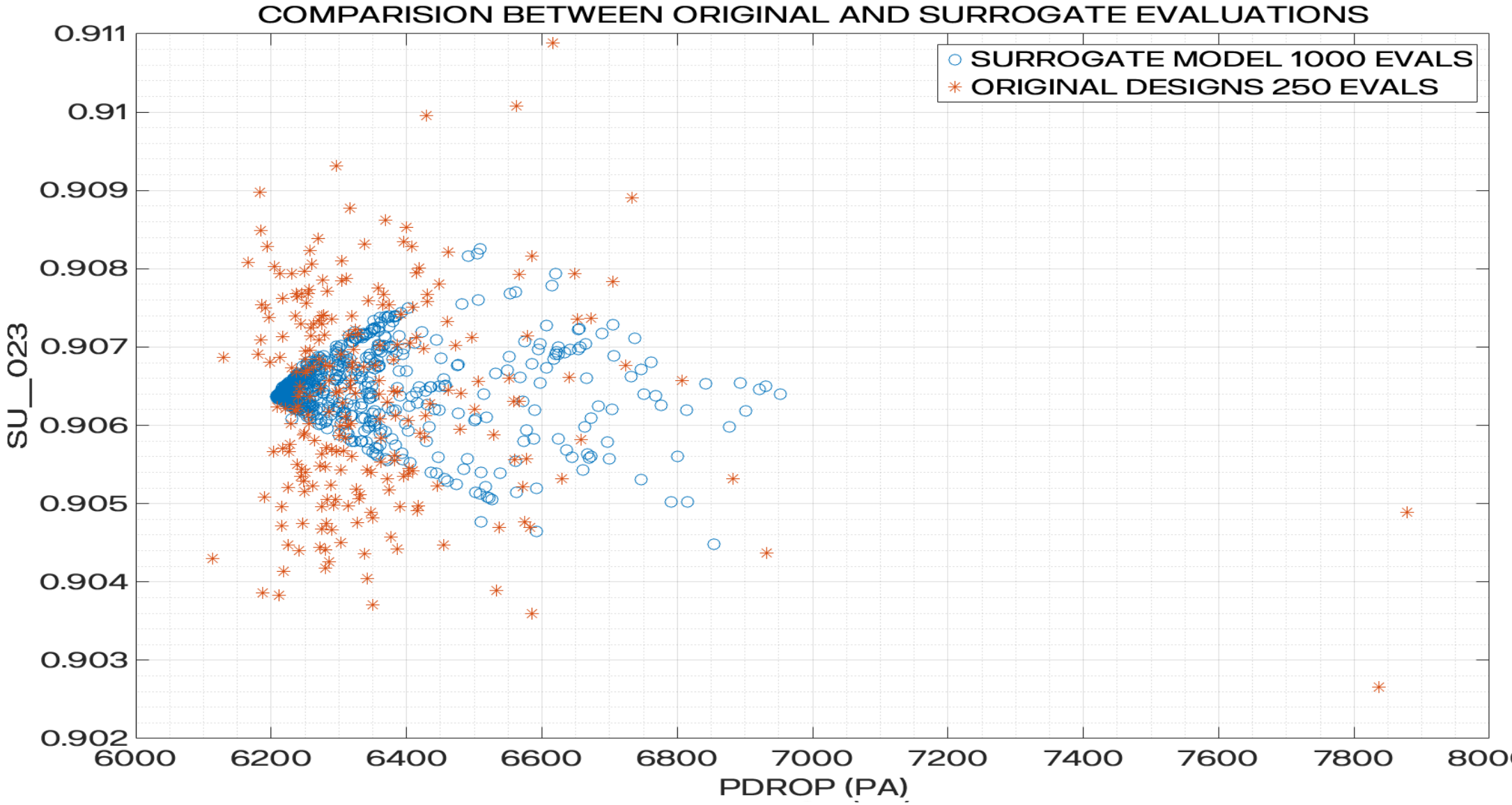
	RSM	OBTAINED	OBTAINED DIFFERENCE	RSM SUGGESTED
PDROP(PA)	6201.1	6341.28	2.21 %	0.737%
SU	0.906474	0.907626	0.12 %	0.143%

Cross V value of 0.00129 is:
0.143% of actual minimum (0.902659)
0.143% of actual mean (0.906373)
0.142% of actual maximum (0.910883)

Name	Design Set	Response	Type	Function	Order	Tuning	Shape	R2	R2adj	RMSE	Cross V	PRESS
SU__023_Kriging_Lin_GP	Non-Error Designs	SU__023	Kriging	Linear	1	Gaussian Process	2,01657	0.915		0.00038	0.00129	0.00129
Pdrop_Kriging_Lin_GP	Non-Error Designs	Pdrop	Kriging	Linear	1	Gaussian Process	0,102838	0.979		27.4	46.8	47

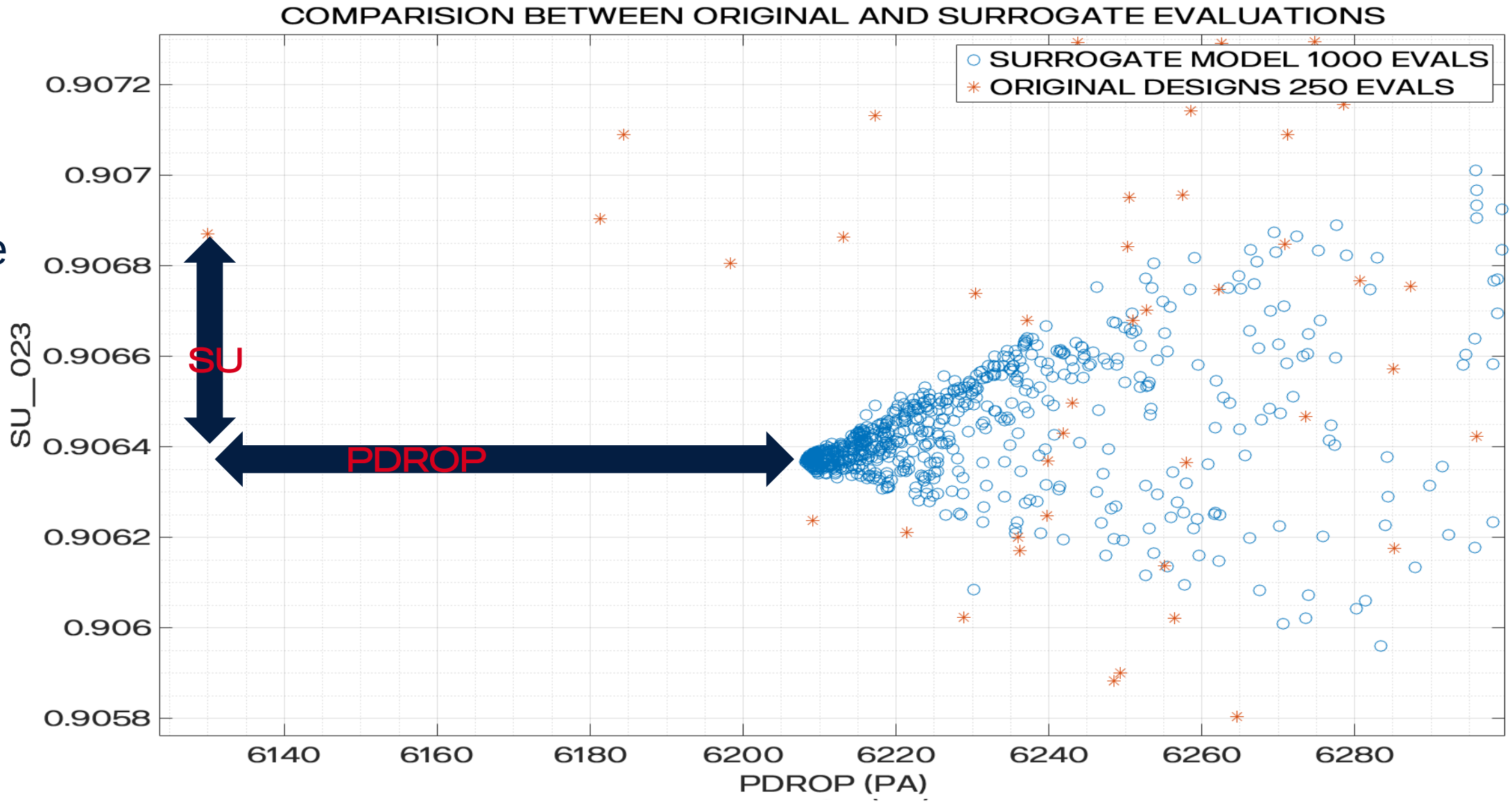
Cross V value of 46.8 is:
0.766% of actual minimum (6113.23)
0.737% of actual mean (6357.32)
0.594% of actual maximum (7877.99)

COMPARISION-WEIGHTED SUM



COMPARISION-WEIGHTED SUM

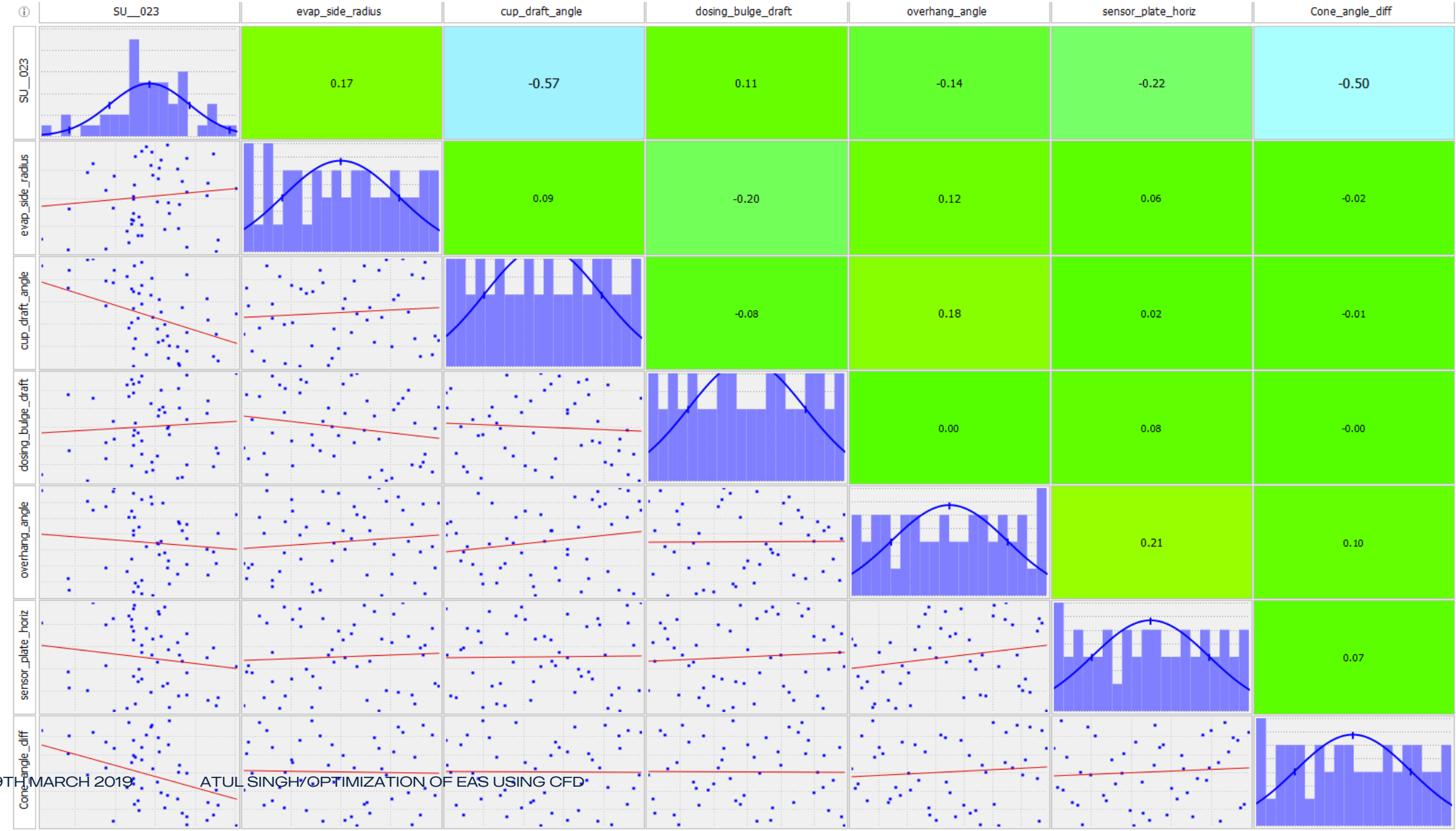
- The difference



DOE 50 EVALUATION

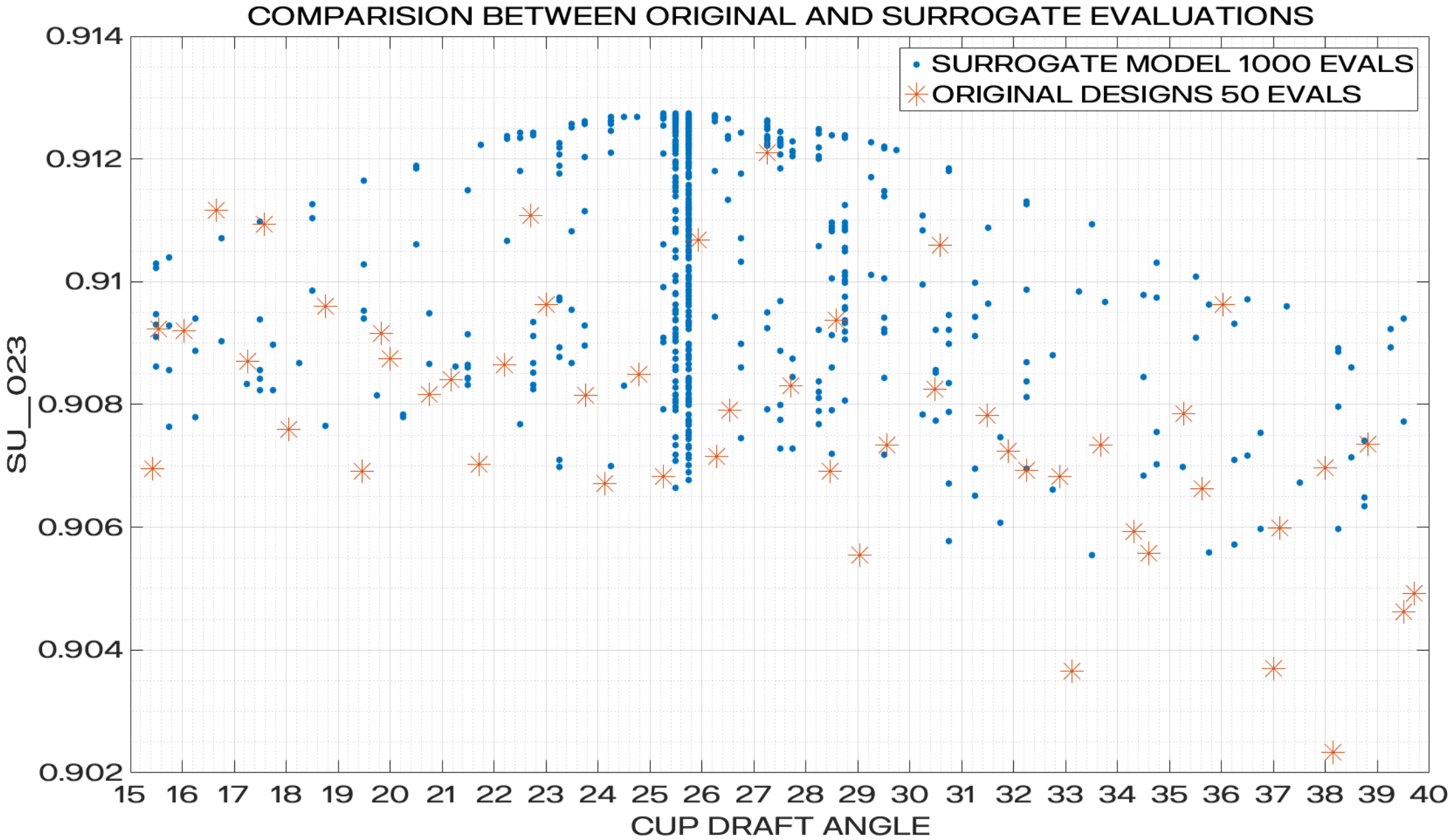
STARCCM+

- CUP DRAFT ANGLE
- CONE ANGLE DIFF



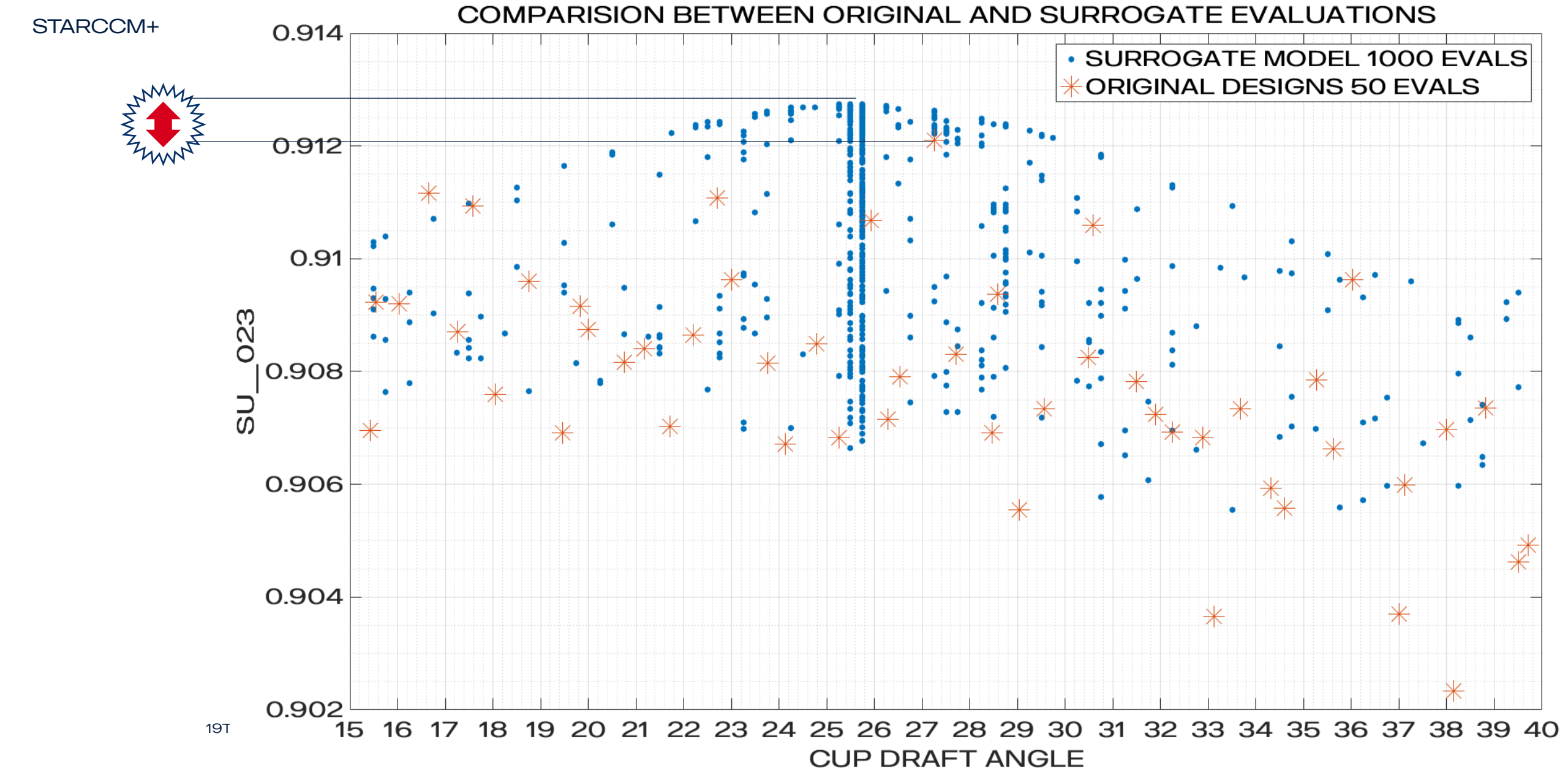
DOE 50 EVALUATION

STARCCM+



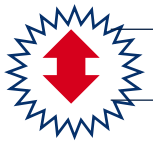
DOE 50 EVALUATION

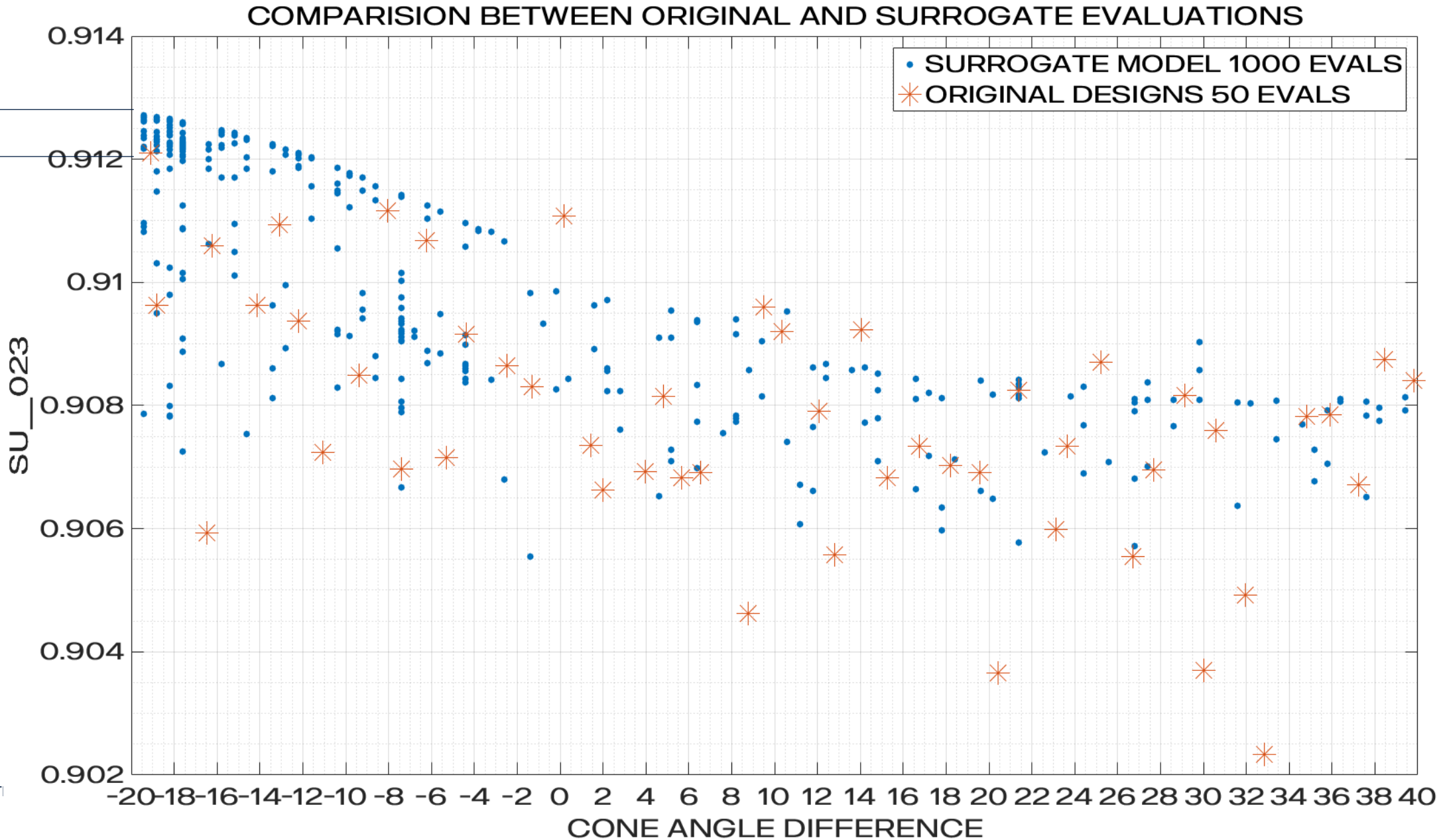
STARCCM+



DOE 50 EVALUATION

STARCCM+

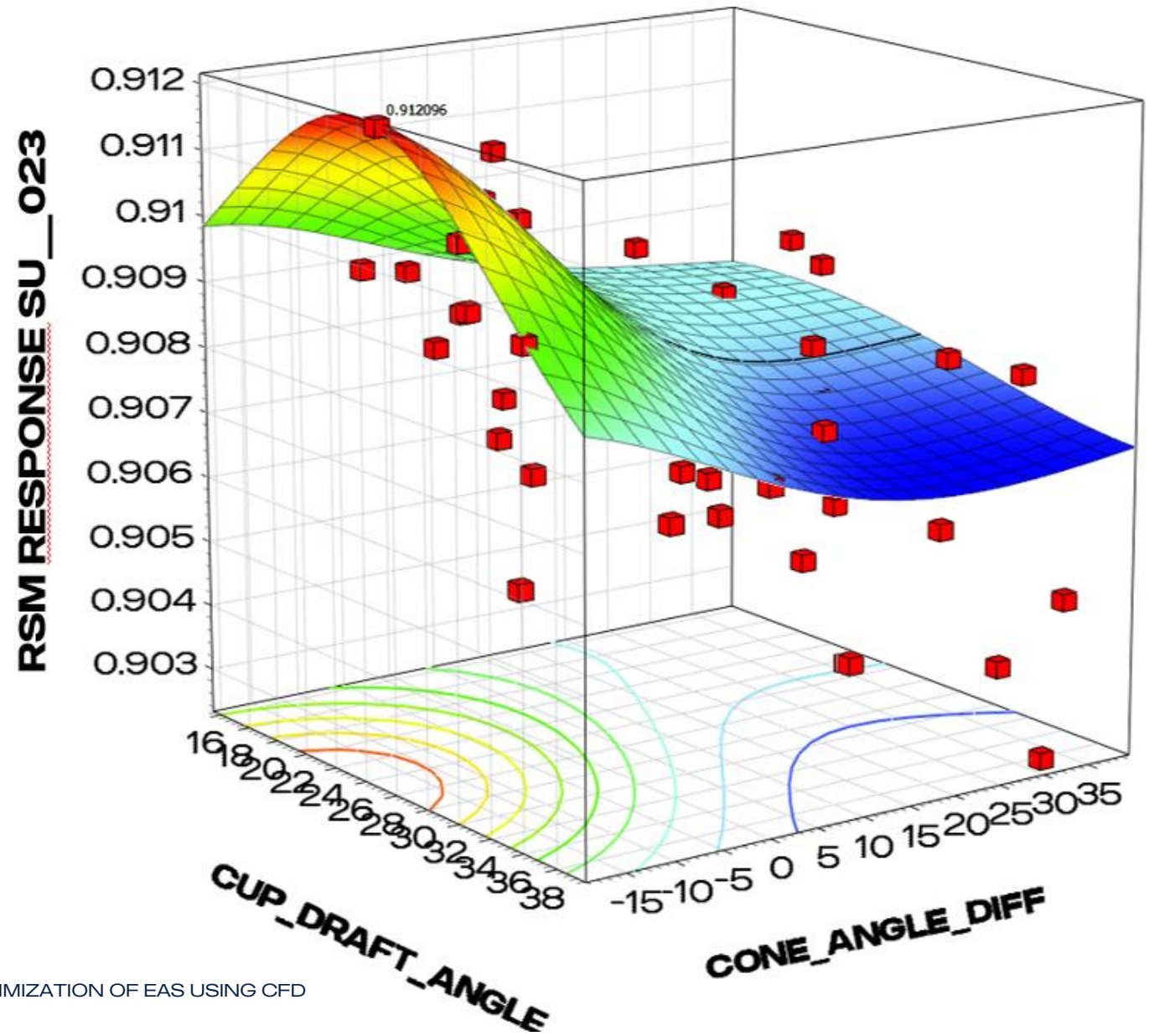




STARCCM+

DOE 50 EVALUATION

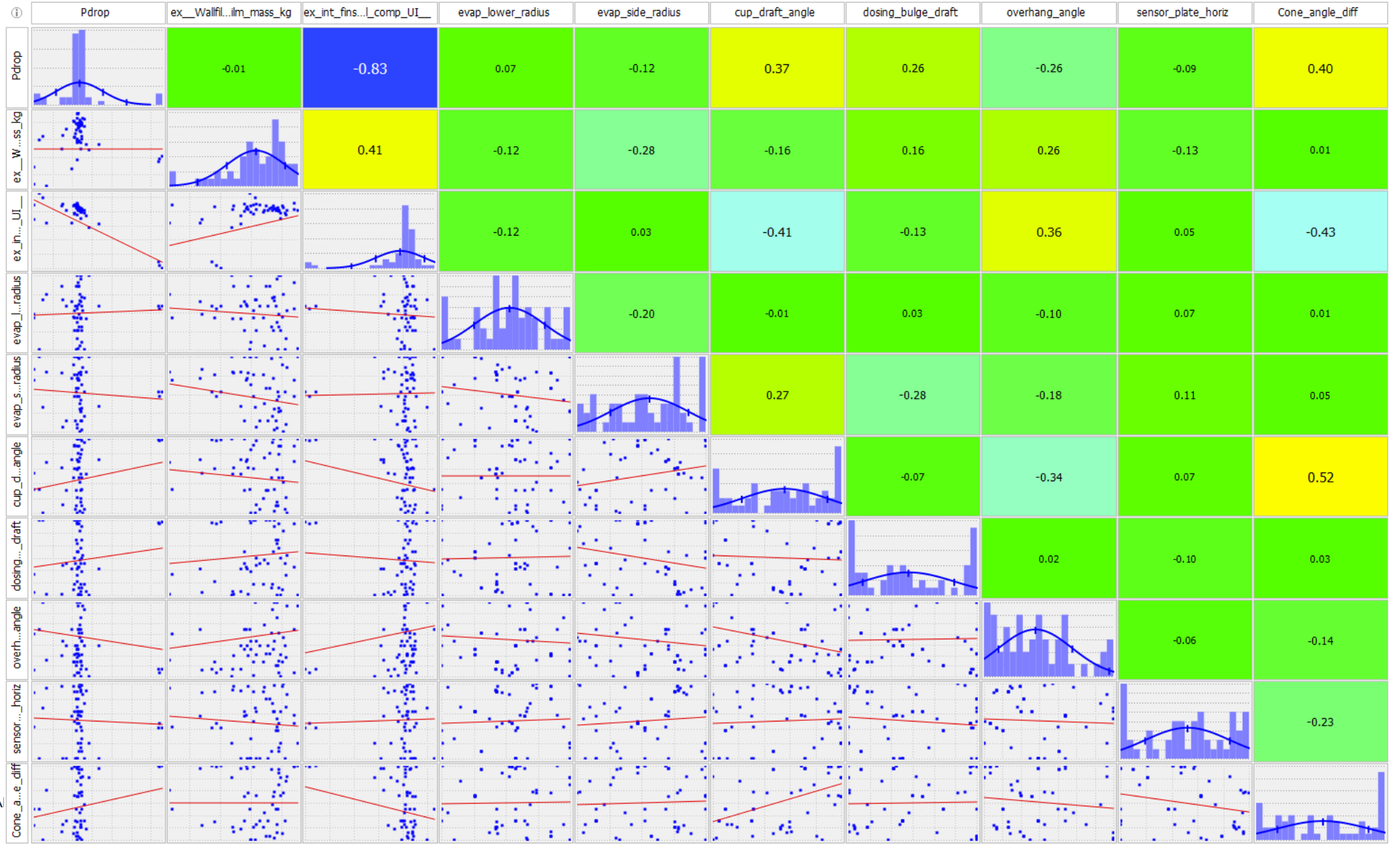
- HEADING TO MOUNTAIN.



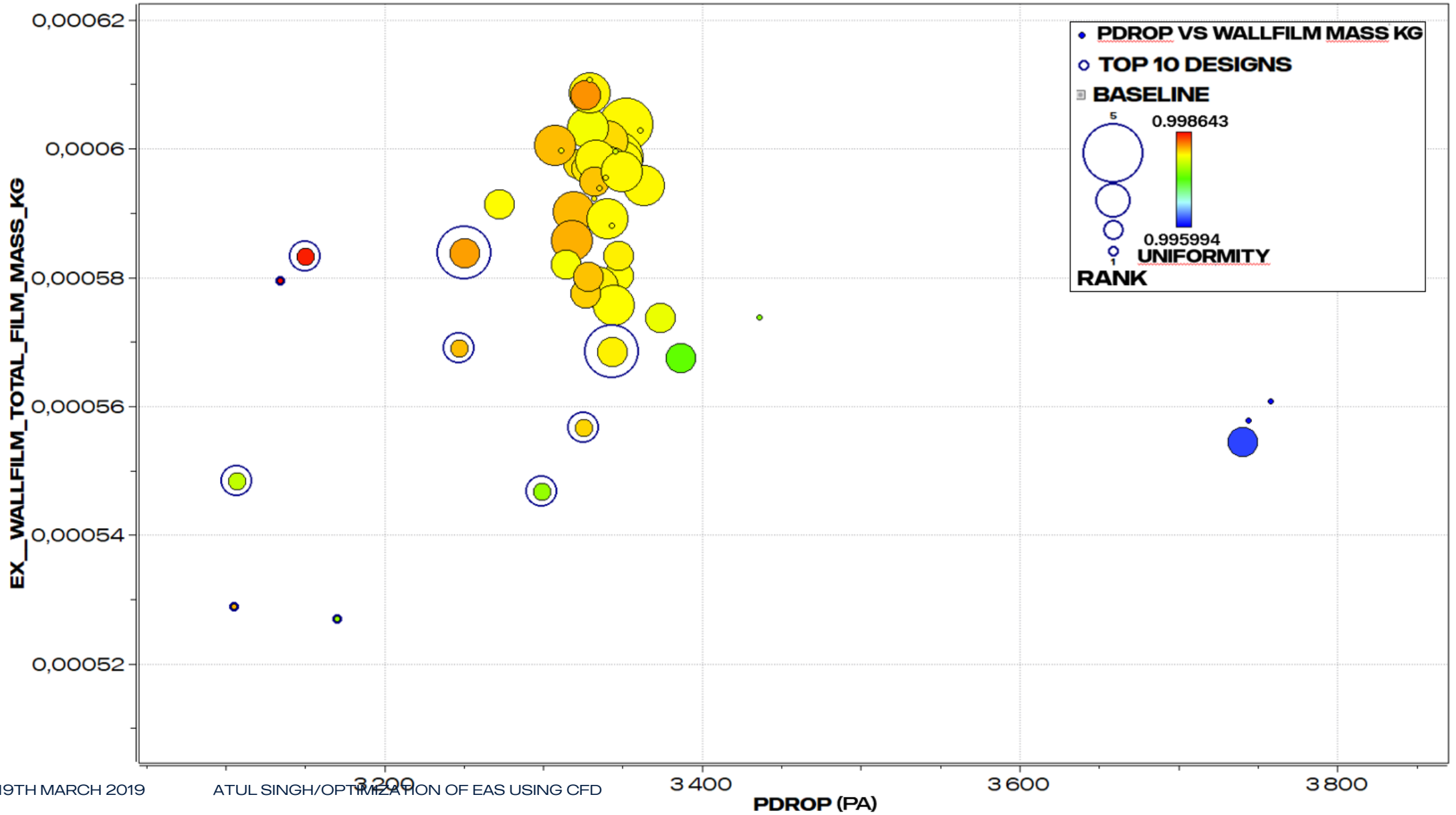
AVL FIRE

PROCESS DEMO

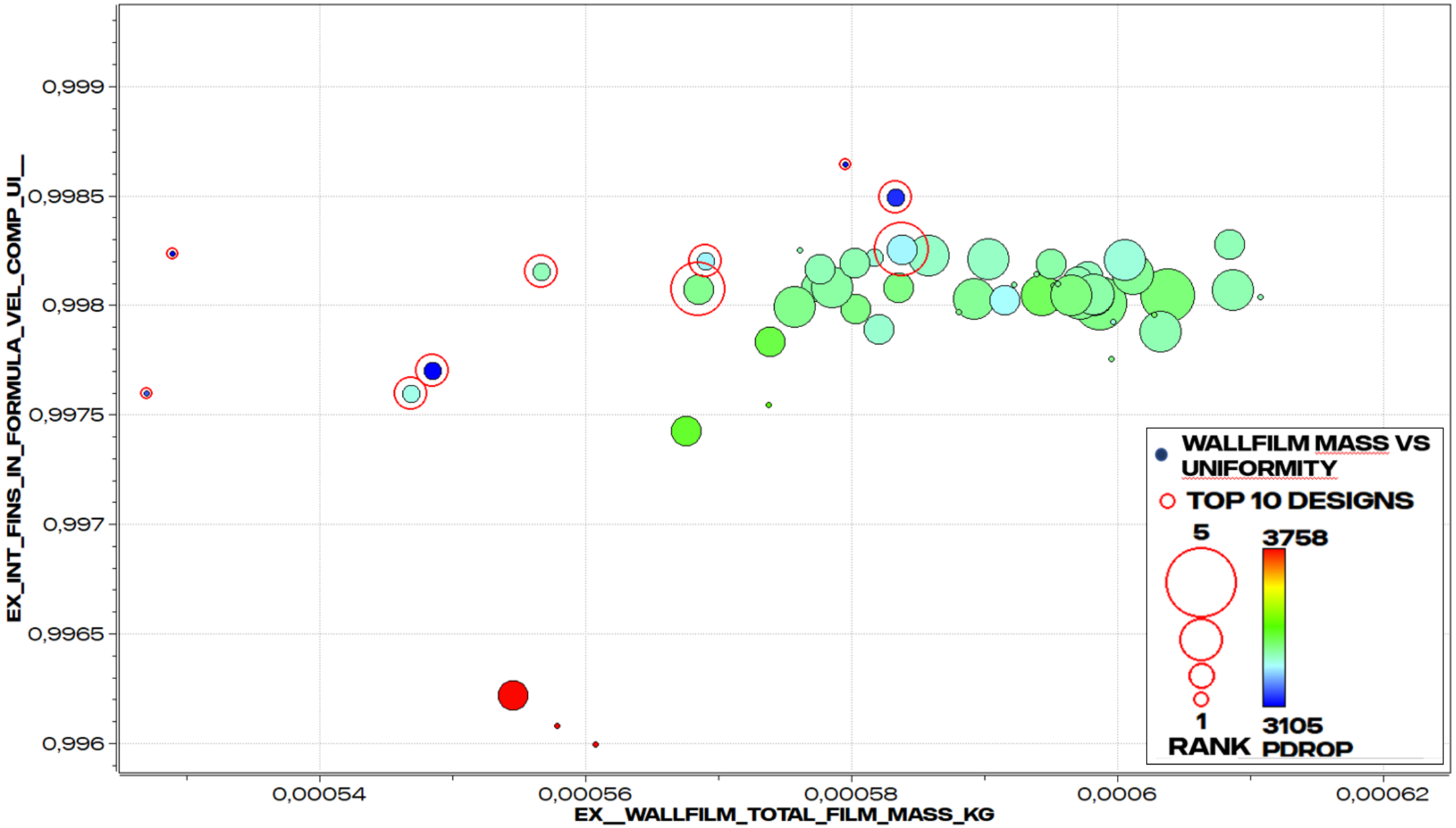
AVL FIRE


Pdrop
ex__Wallfil...ilm_mass_kg
ex_int_fins...l_comp_UI__
evap_lower_radius
evap_side_radius
cup_draft_angle
dosing_bulge_draft
overhang_angle
sensor_plate_horiz
Cone_angle_diff
Pdrop -0.01 -0.83 0.07 -0.12 0.37 0.26 -0.26 -0.09 0.40
ex__W...ss_kg 0.41 -0.12 -0.28 -0.16 0.16 0.26 -0.13 0.01
ex_in..._UI__ -0.12 0.03 -0.41 -0.13 0.36 0.05 -0.43
evap_l...radius -0.20 -0.01 0.03 -0.10 0.07 0.01
evap_s...radius 0.27 -0.28 -0.18 0.11 0.05
cup_d...angle -0.07 -0.34 0.07 0.52
dosing..._draft 0.02 -0.10 0.03
overh...angle -0.06 -0.14
sensor..._horiz -0.23
Cone_a...e_diff

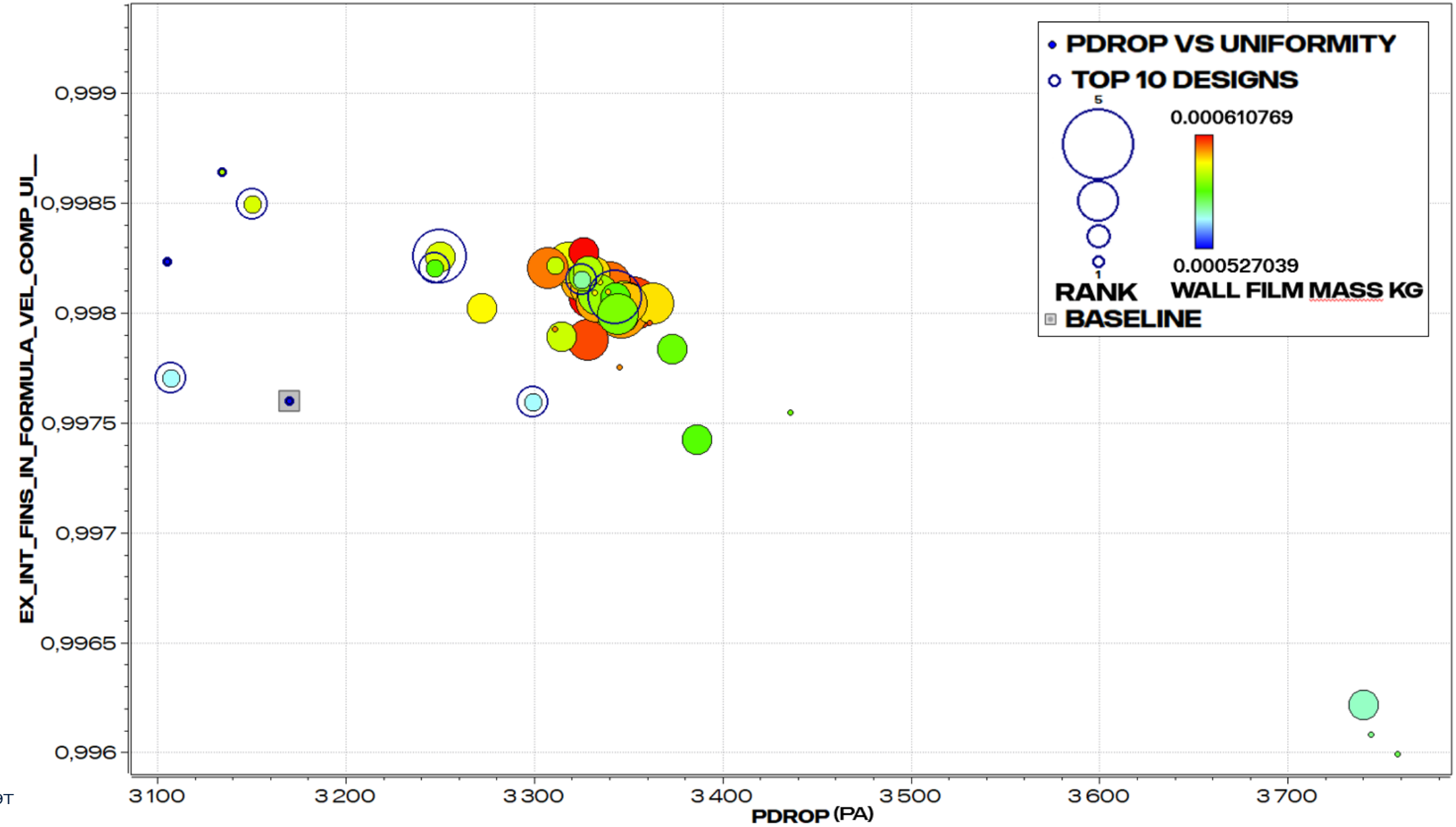
→ AVL FIRE


PDROP VS WALLFILM MASS KG
TOP 10 DESIGNS
BASELINE
5
0.998643
0.995994
UNIFORMITY
1
RANK
EX__WALLFILM_TOTAL_FILM_MASS_KG
0,00062
0,0006
0,00058
0,00056
0,00054
0,00052
3 200
3 400
3 600
3 800
PDROP (PA)

→ AVL FIRE

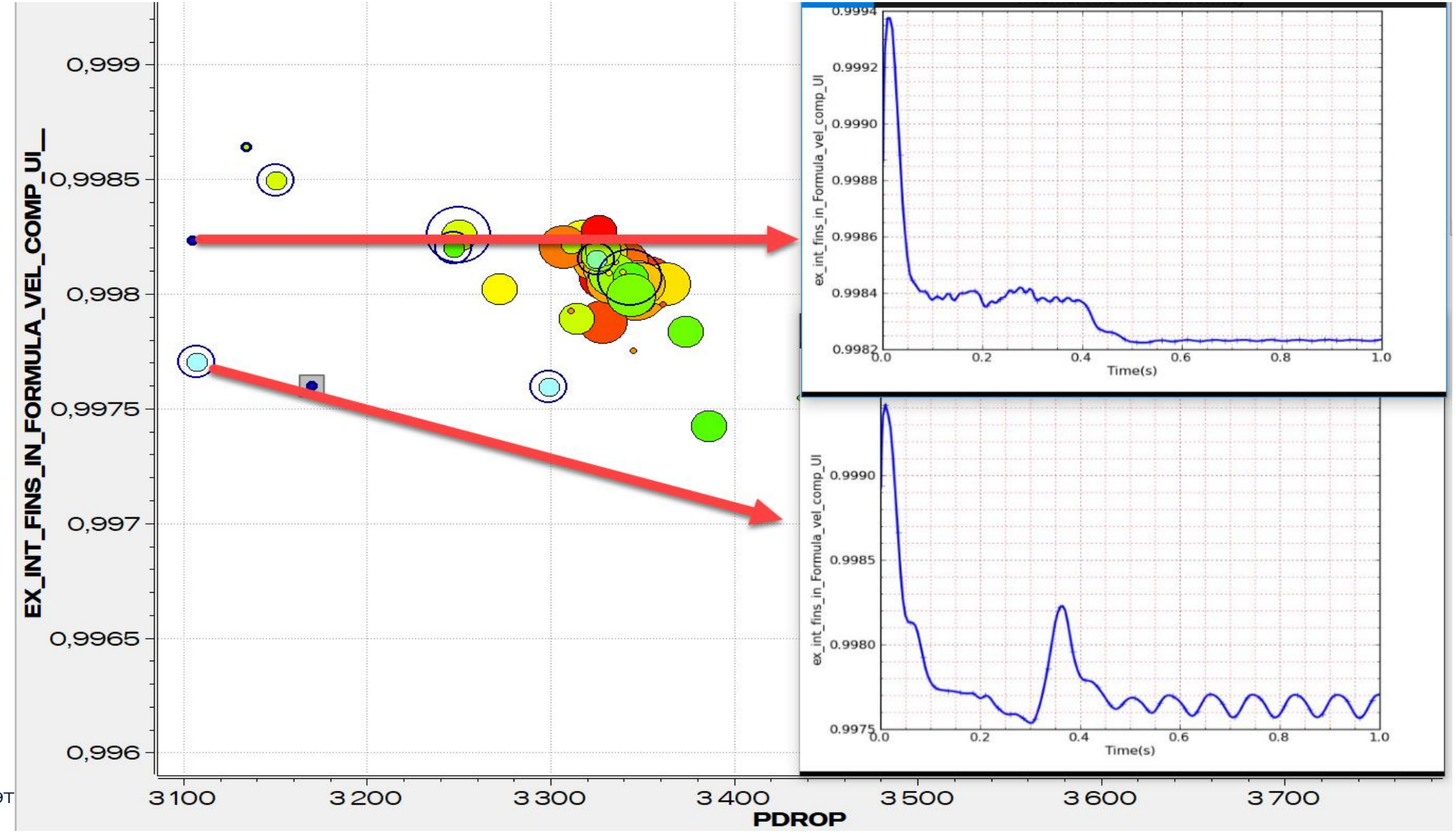

0,999
0,9985
0,998
0,9975
0,997
0,9965
0,996
EX_INT_FINS_IN_FORMULA_VEL_COMP_UI__
0,00054
0,00056
0,00058
0,0006
0,00062
EX__WALLFILM_TOTAL_FILM_MASS_KG
WALLFILM MASS VS UNIFORMITY
TOP 10 DESIGNS
5
1
RANK
3758
3105
PDROP

→ AVL FIRE


PDROP VS UNIFORMITY
TOP 10 DESIGNS
5
1
RANK
0.000610769
0.000527039
WALL FILM MASS KG
BASELINE
EX_INT_FINS_IN_FORMULA_VEL_COMP_UI_
0,999
0,9985
0,998
0,9975
0,997
0,9965
0,996
3 100
3 200
3 300
3 400
3 500
3 600
3 700
PDROP (PA)

AVL FIRE – PDROP VS UI

AVL FIRE



SUMMARY

SUMMARY

- AN AUTOMATED PROCESS BLACKBOX.
- (STARCCM + AND AVL FIRE) + HEEDS = ⬇ DELIVERY TIMES*.
- OBJECTIVES BEHAVIOUR UNDERSTOOD.
- OPTIMIZATION METHODS UNDERSTOOD.
- INTEGRATED!
- RSM TO EXPLORE POSSIBLE DESIGN SPACES IN MATTER OF MINUTES.

*AT THE COST OF SETUP TIME

VISION

SCANIA

POSSIBILITIES

- RESOURCE PRE-ALLOCATION
- SOFTWARES WITH ACOUSTIC WORKFLOWS.
- OTHER DIFFERENT DISCIPLINES

THANK YOU

SCANIA