Selection of KULI Core Components to Optimize Cooling Performance using modeFRONTIER

Allan Wang, Modine Manufacturing Company
Siddharth Jain, Modine Manufacturing Company
Nader Fateh, Esteco North America Inc

KULI User Meeting 2007

Component Selection

- Selection of components, such as charge air coolers (CAC), radiators (RAD) and oil coolers (OC), from a component library is typically a manual task, where the user will try different combinations of components to try to achieve some overall thermal or pressure loss objectives

Component Selection

- Due to the interaction of components it may frequently be hard to predict which combination will give the desired cooling performance, especially in cases where multiple performance criteria are being considered
- The user will often need to resort to trial and error

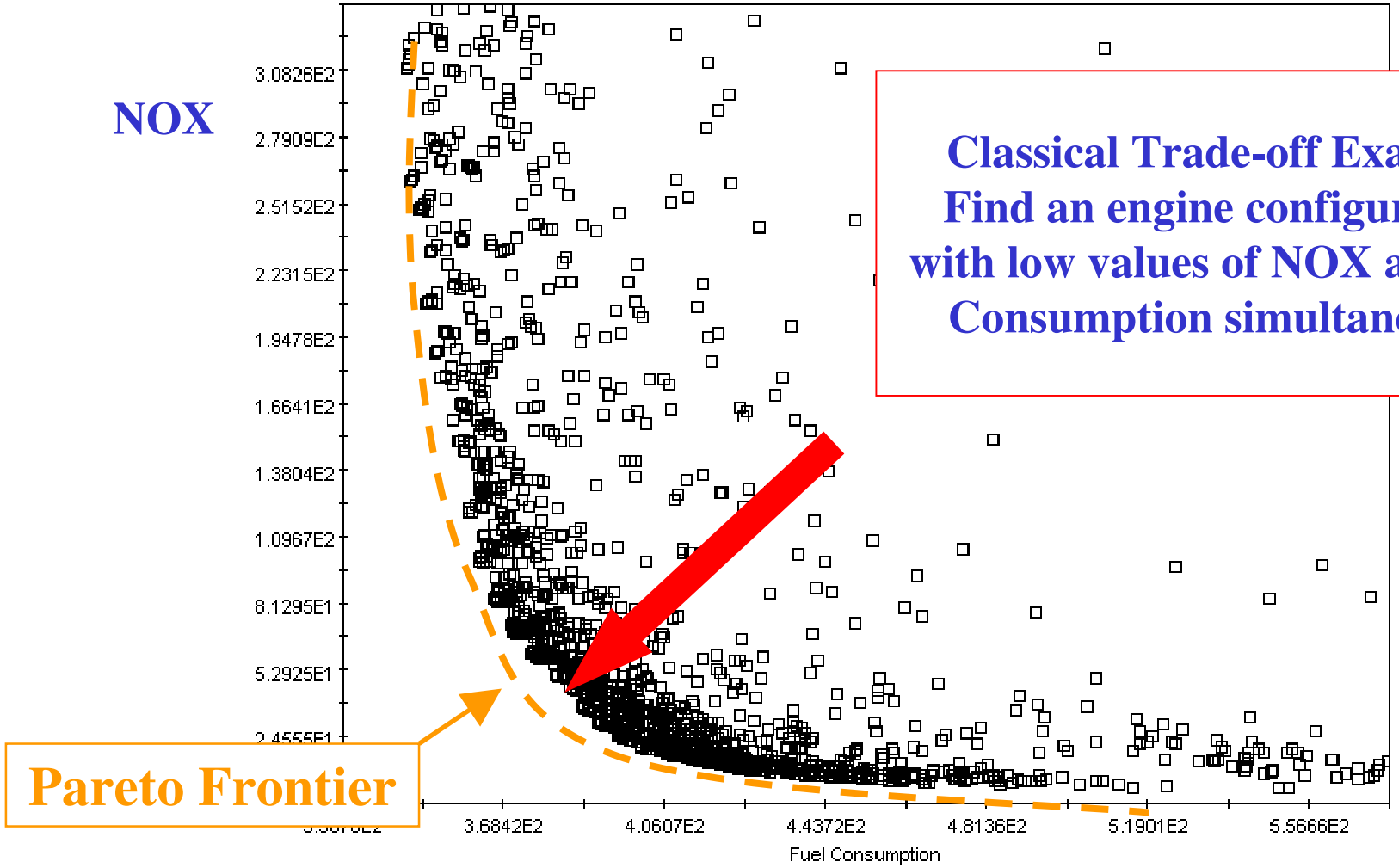
Component Selection

- In cases where a limited number of components is available, it may be possible to run analyses for all combinations, and then select those with the best characteristics
- However, the number of possible combinations increases significantly every time another component is included

The Trade-Off

- When Heat Transfer and Pressure Loss are being considered, there will likely be a classical trade-off: good Heat Transfer is usually obtained at the cost of increased Pressure Loss; a reduction in Pressure Loss is often achieved by sacrificing some Q performance

Pareto Frontier (Trade-Off Curve) Example



Classical Trade-off Example: Find an engine configuration with low values of NOX and Fuel Consumption simultaneously

Fuel Consumption

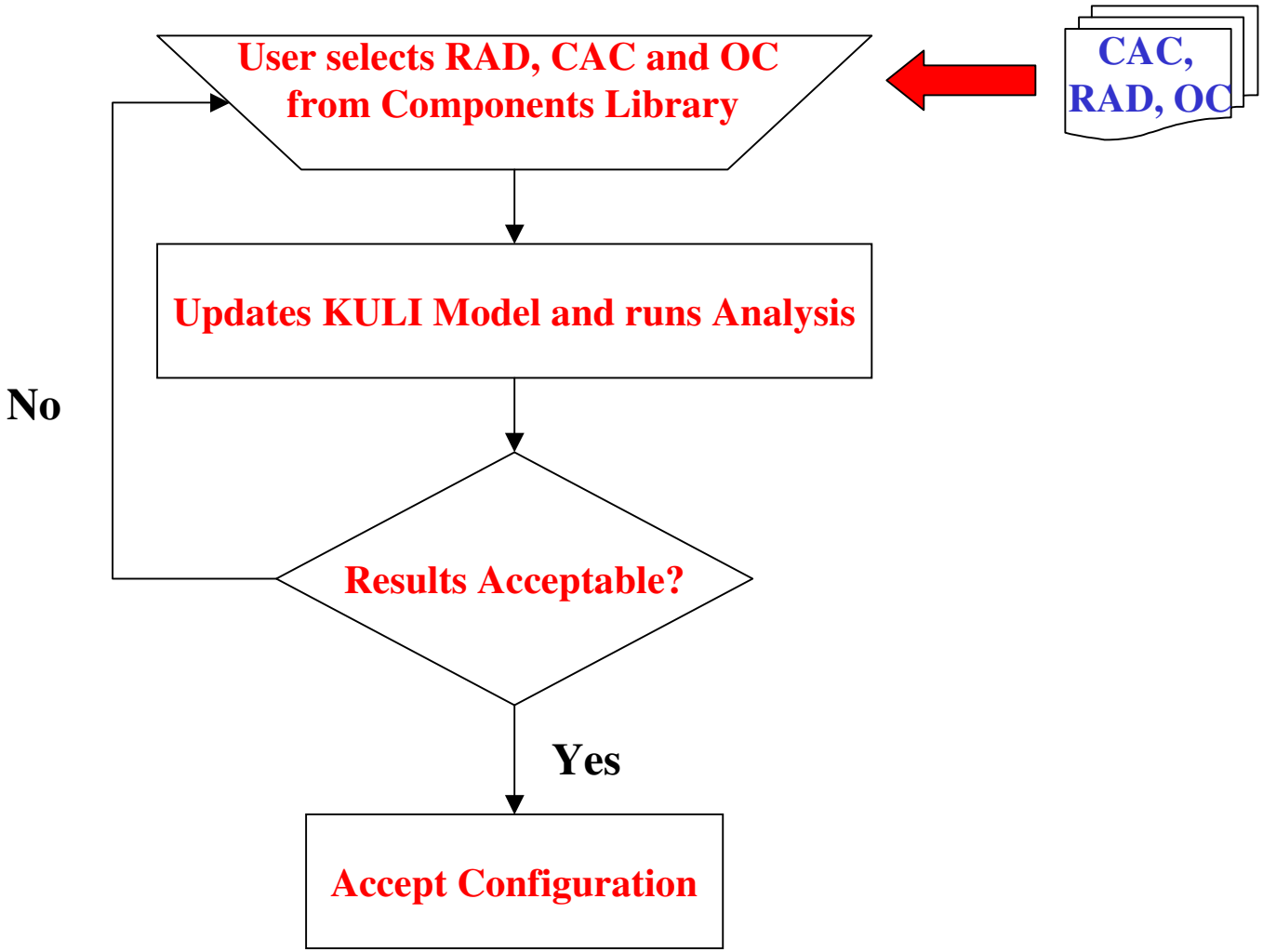
New Approach:
Use an Optimization Software

- Multi-Objective Optimization Algorithms, such as Genetic Algorithms (GAs) are frequently use for “combinatorial optimization”, i.e. to find the combination(s) of a set of components which achieve(s) best system performance

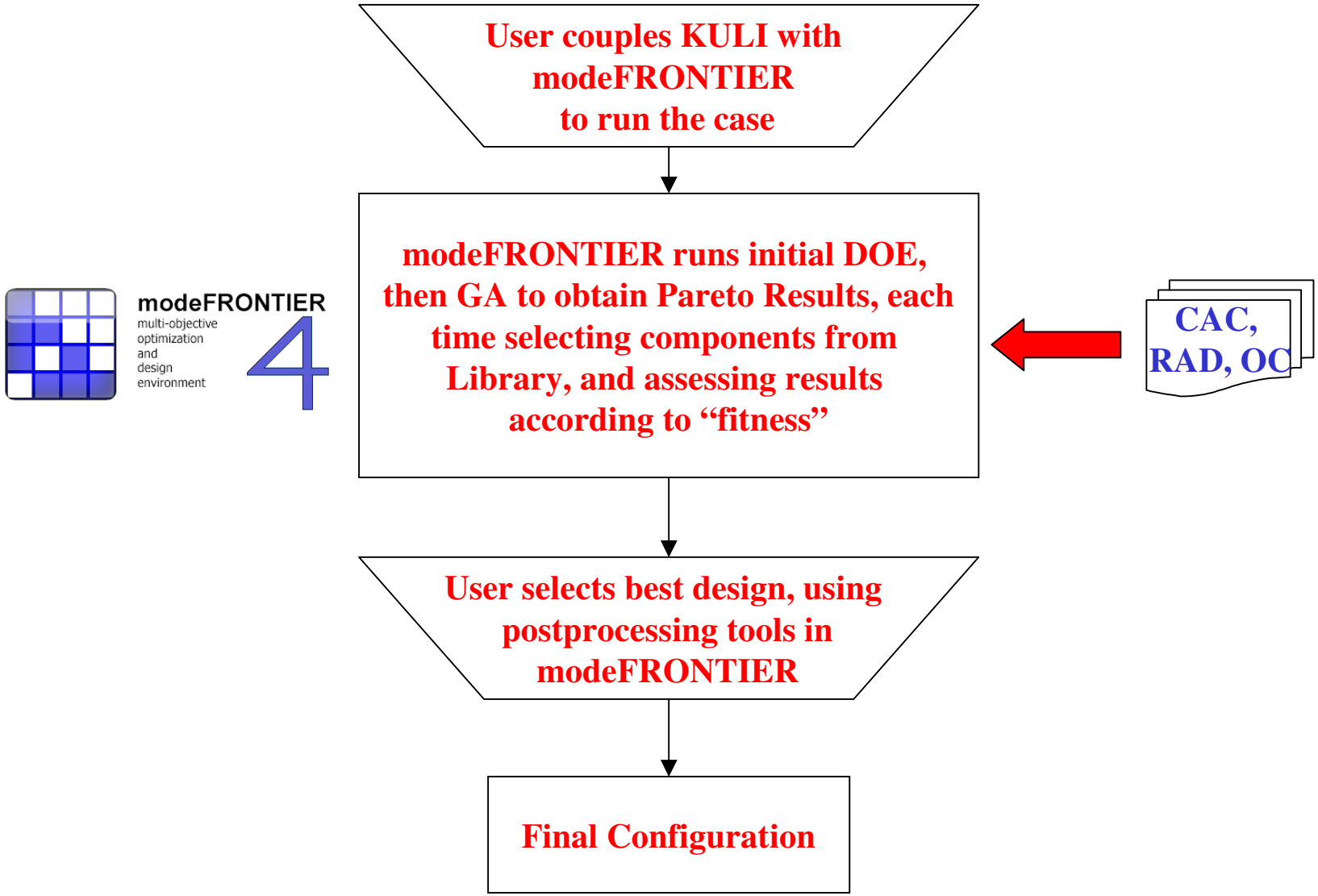
New Approach:
Use an Optimization Software

- This approach was applied to a test case run by Modine Manufacturing Company and Esteco North America, using the commercial PIDO (process integration and design optimization) software **modeFRONTIER** to send component filenames to **KULI**, run **KULI**, and extract the data

Manual Procedure



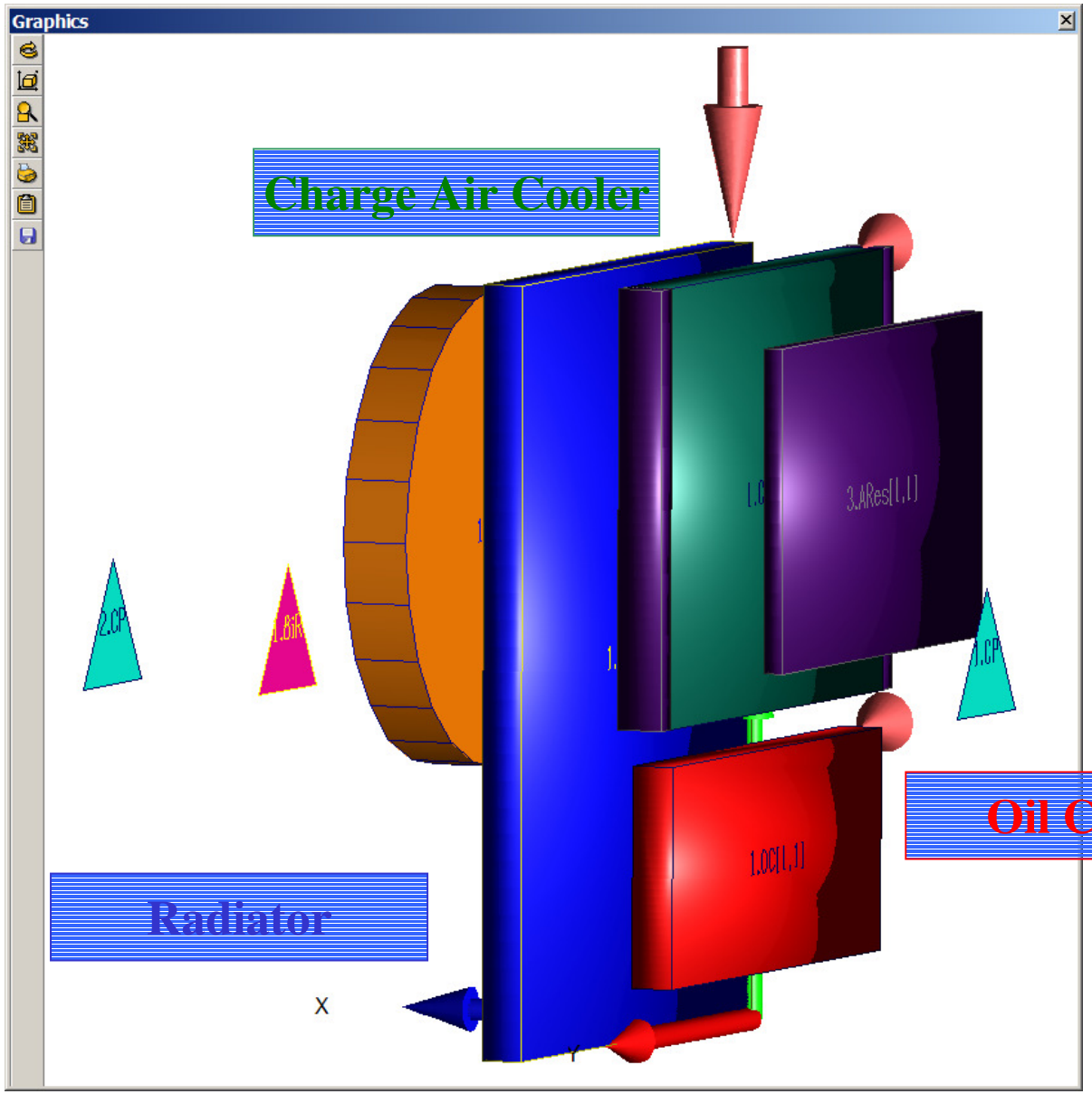
Automated Procedure



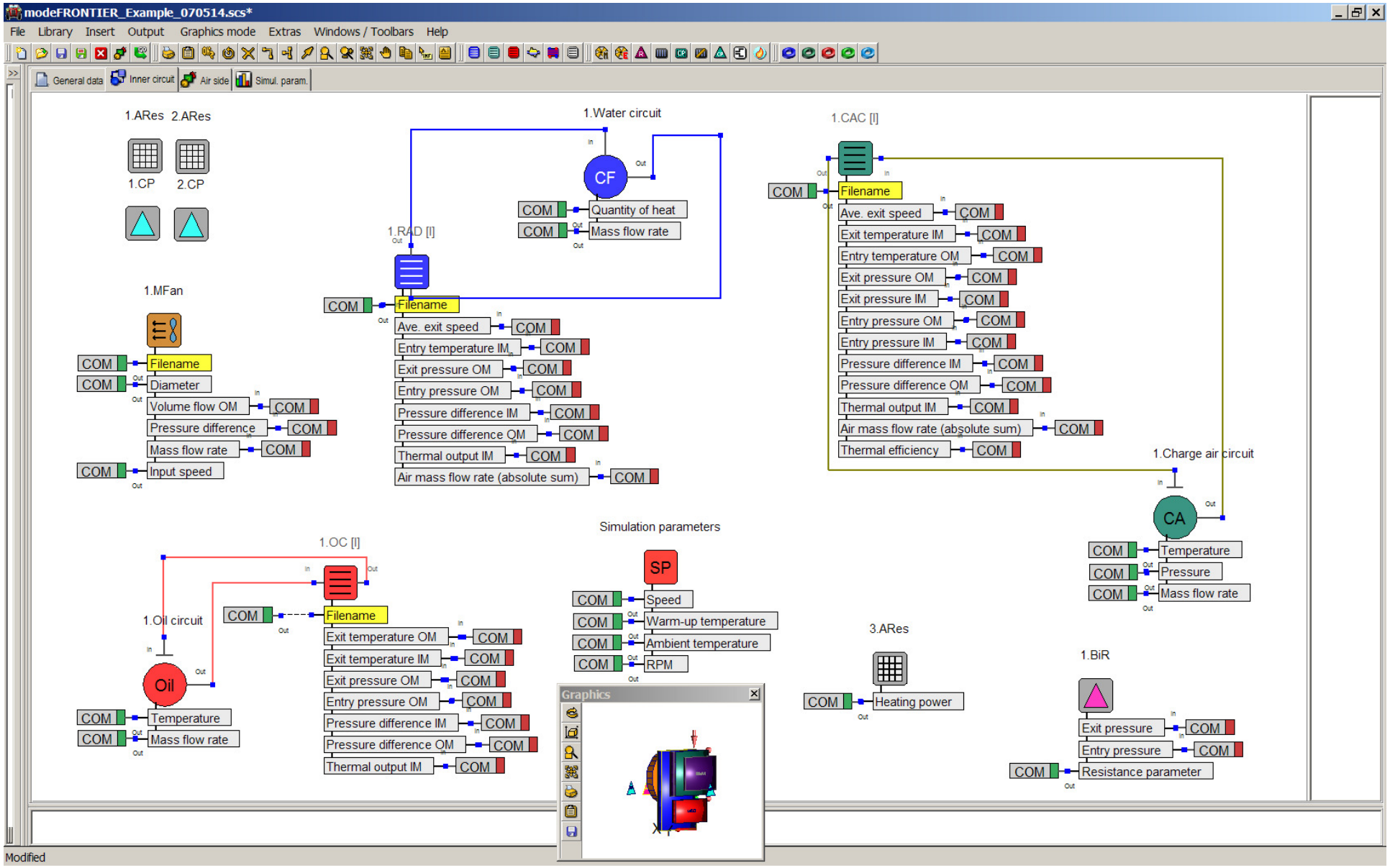
Test Case

- The test case selected comprised 3 components which were to be selected from a library:
  - Charge Air Cooler (11)
  - Radiator (10)
  - Oil Cooler (7)
- This gave a total of 770 possible combinations to select from

Test Case – KULI Model



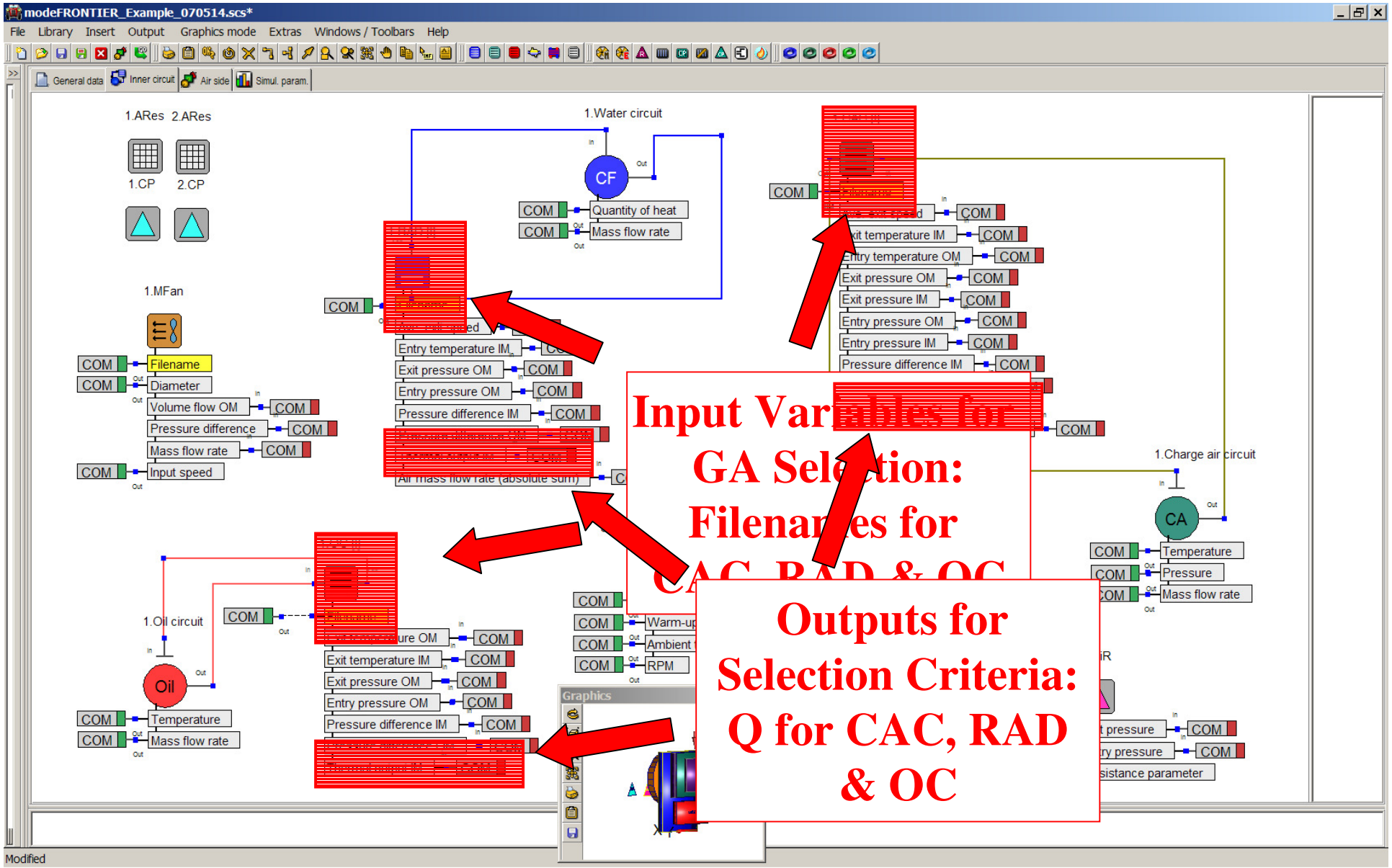
Test Case - KULI Model



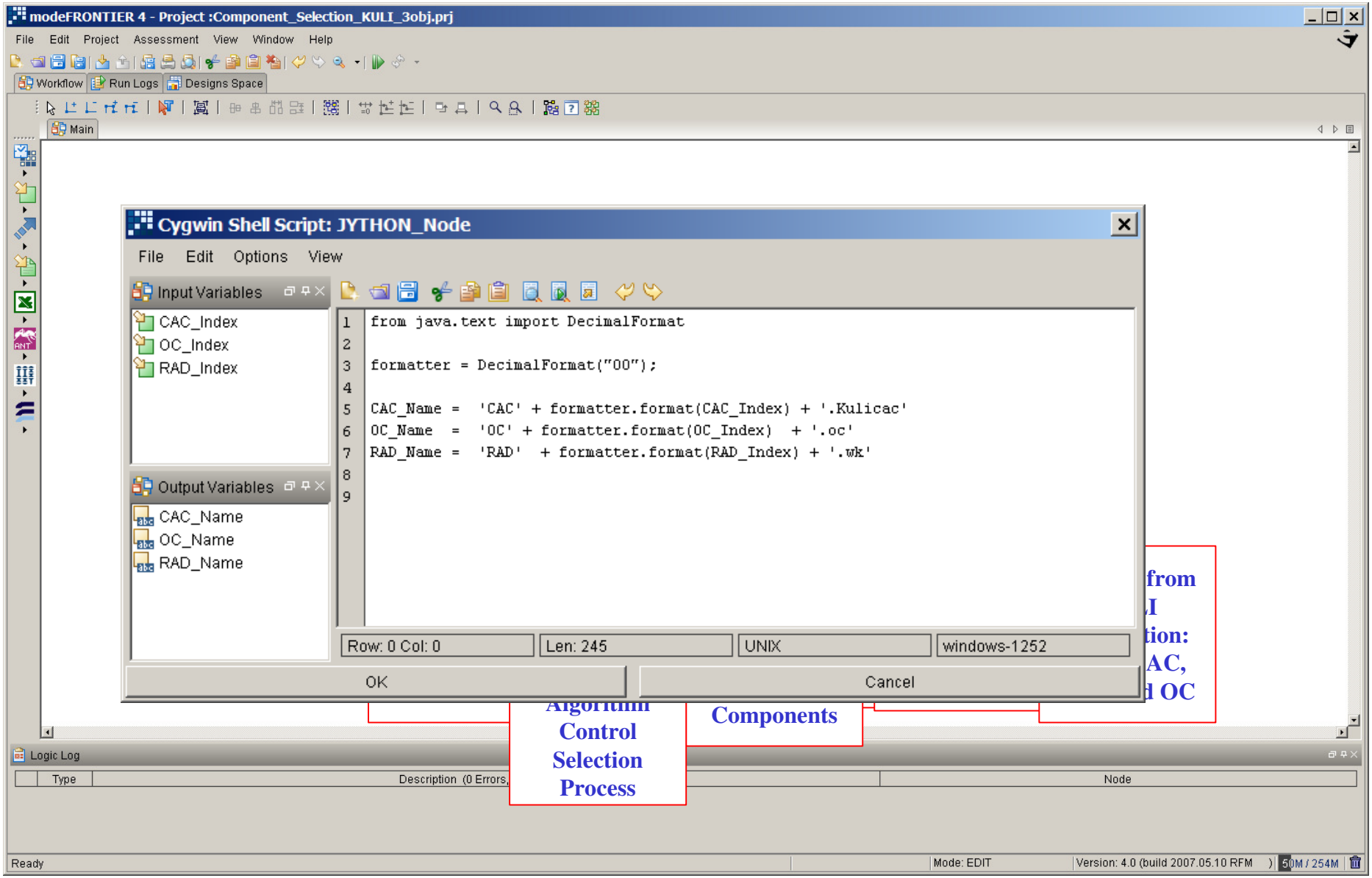
Test Case 1: Objectives

- The test case was first run with 3 objectives: maximize the heat transfer in the 3 components, CAC, RAD and OC
- modeFRONTIER was set to run an initial population of 20 configurations, and then 10 generations of the multi-objective genetic algorithm, MOGA-II
- This gave a total of 200 runs

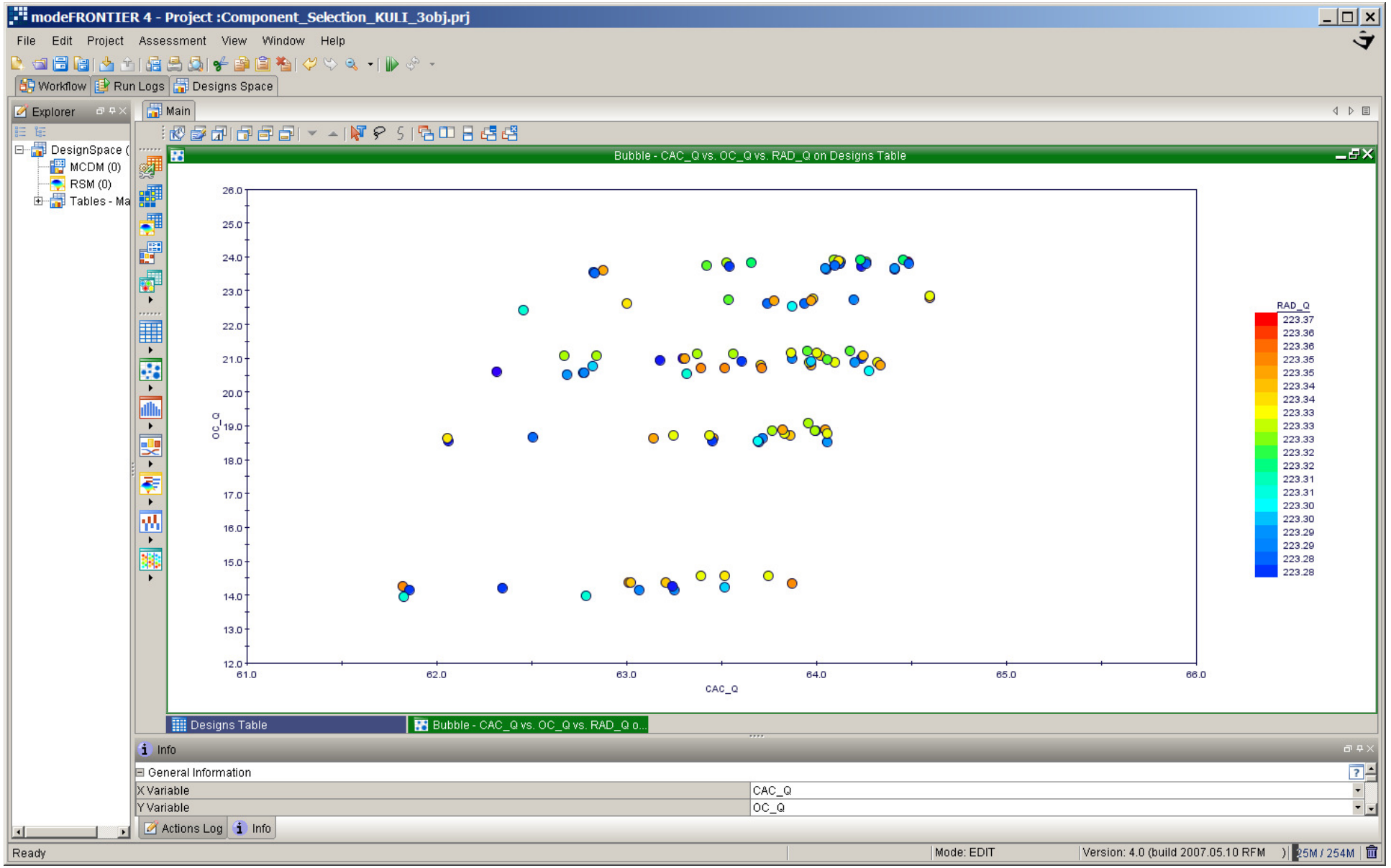
KULI Model: Inputs & Outputs



modeFRONTIER Workflow

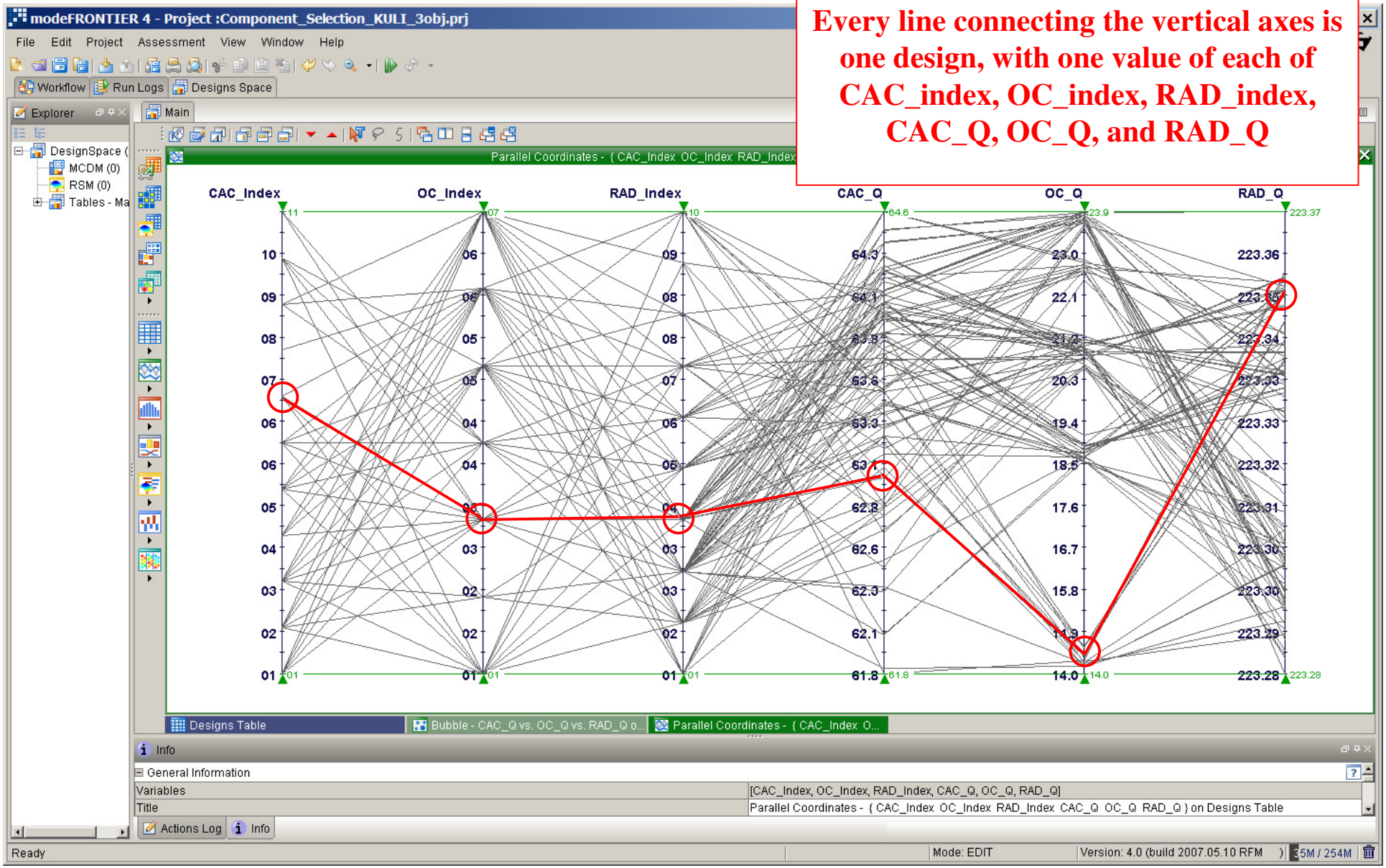


Results: Bubble Chart

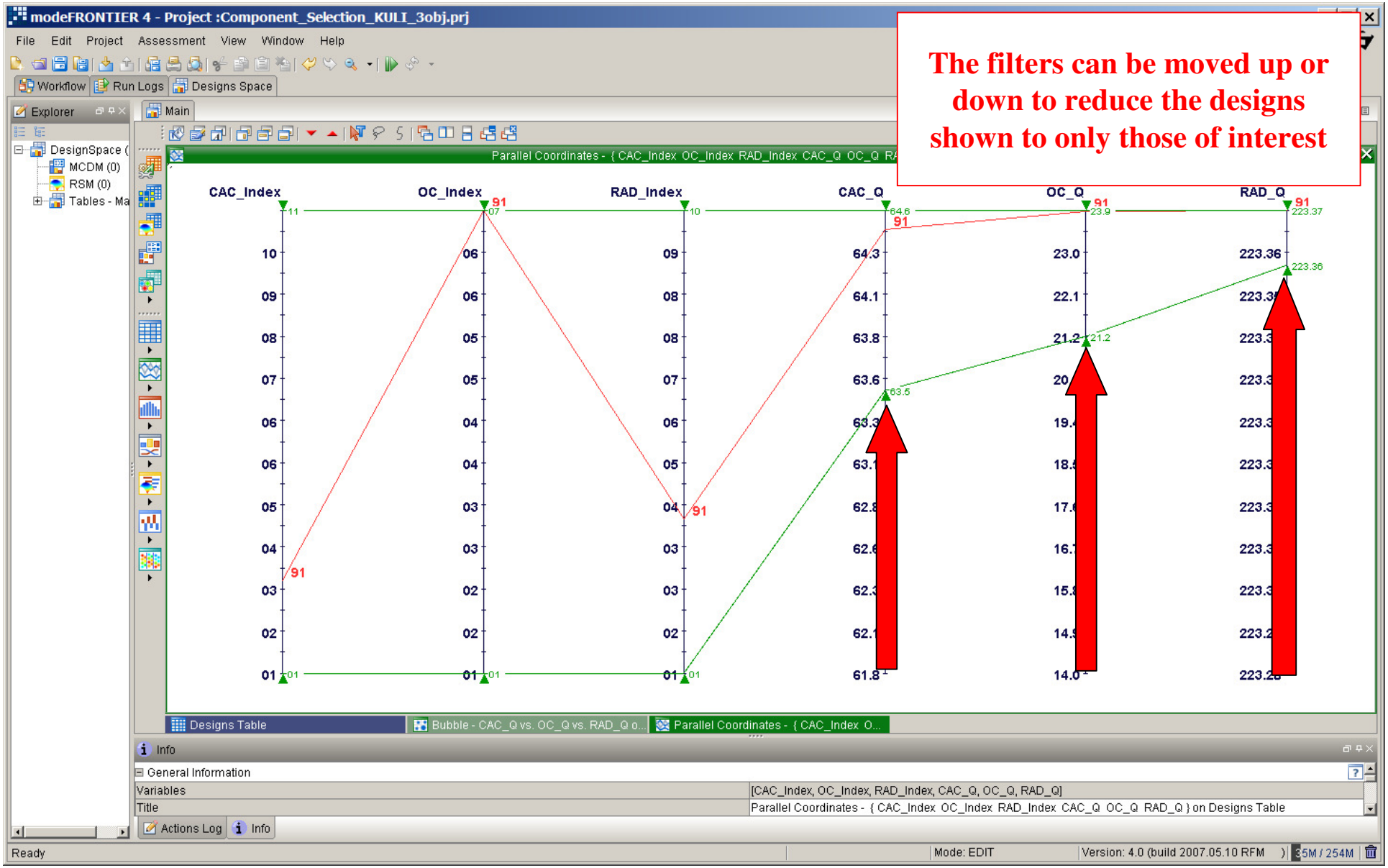


Results: Parallel Chart

Every line connecting the vertical axes is one design, with one value of each of CAC_index, OC_index, RAD_index, CAC_Q, OC_Q, and RAD_Q



Results: Parallel Chart - Filtering



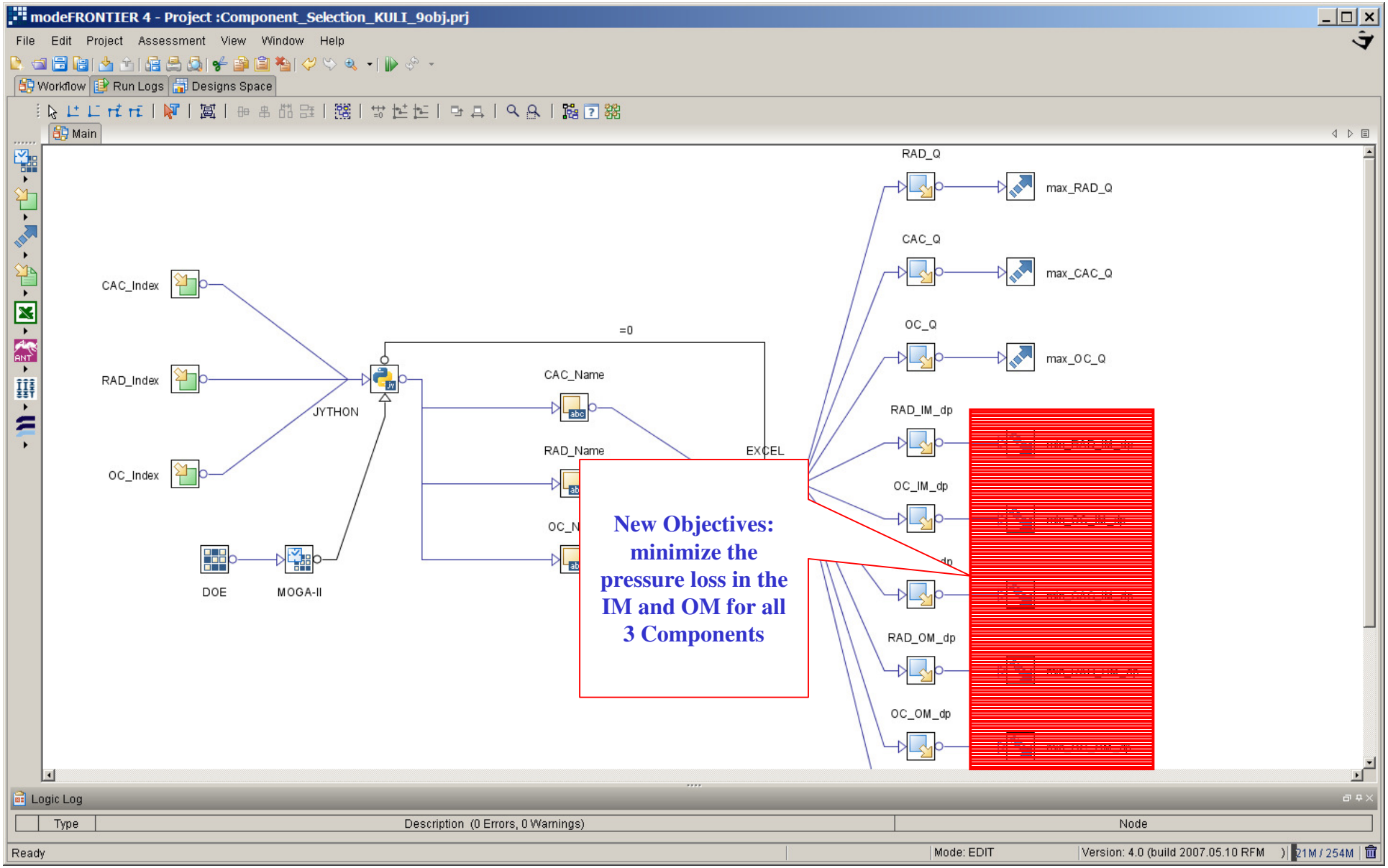
Test Case 1: Result

- In this case, the best design was number 91:
  - CAC03
  - OC07
  - RAD04
- There was no apparent trade-off, as all three outputs were simultaneously high

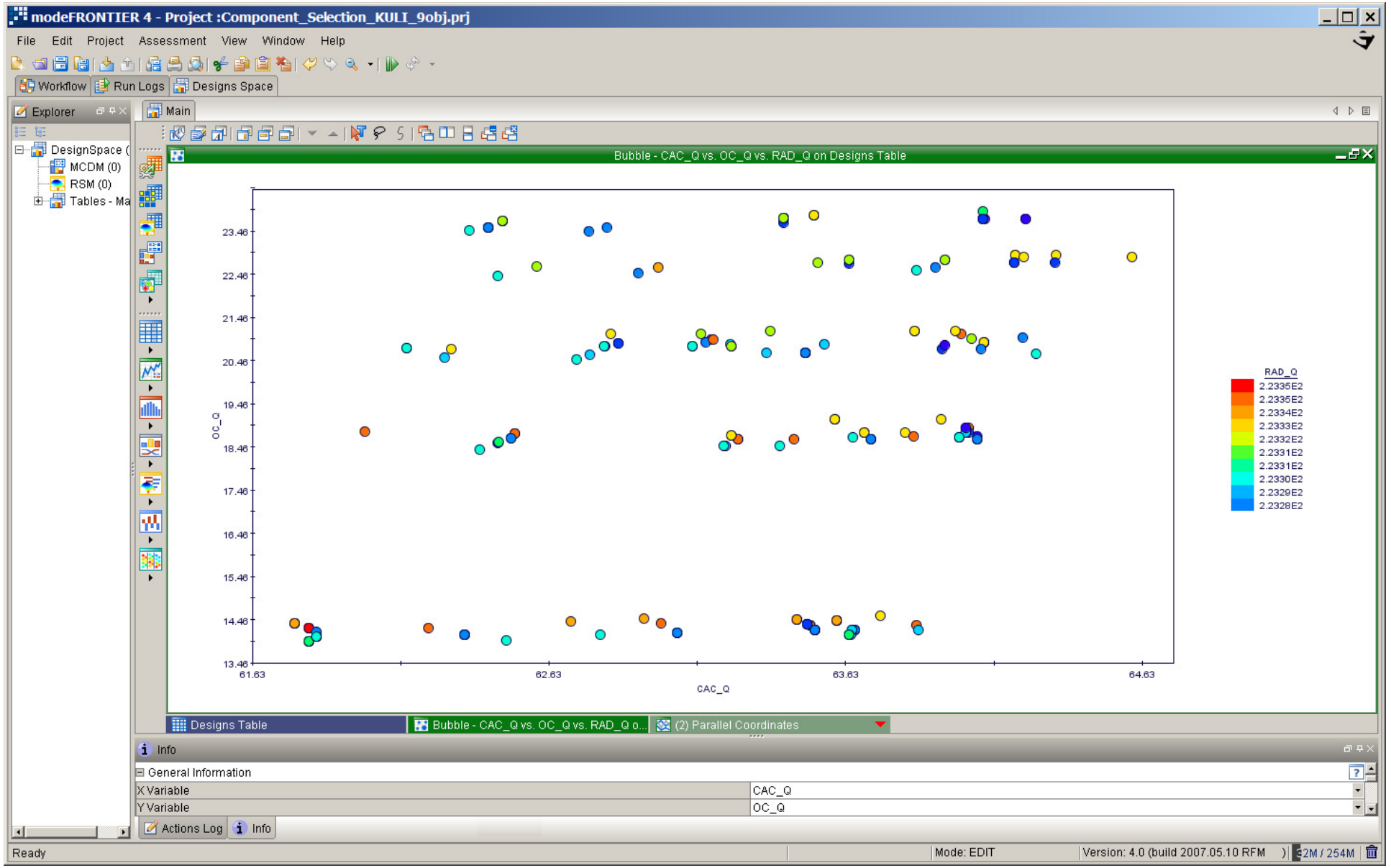
Test Case 2: 9 Objectives

- The test case was then run with 9 objectives: maximize the heat transfer in the 3 components, CAC, RAD and OC, and minimize both the inner and outer medium pressure drops for all 3 components
- Again, modeFRONTIER was set to run an initial population of 20 configurations, and 10 generations of MOGA-II giving a total of 200 runs

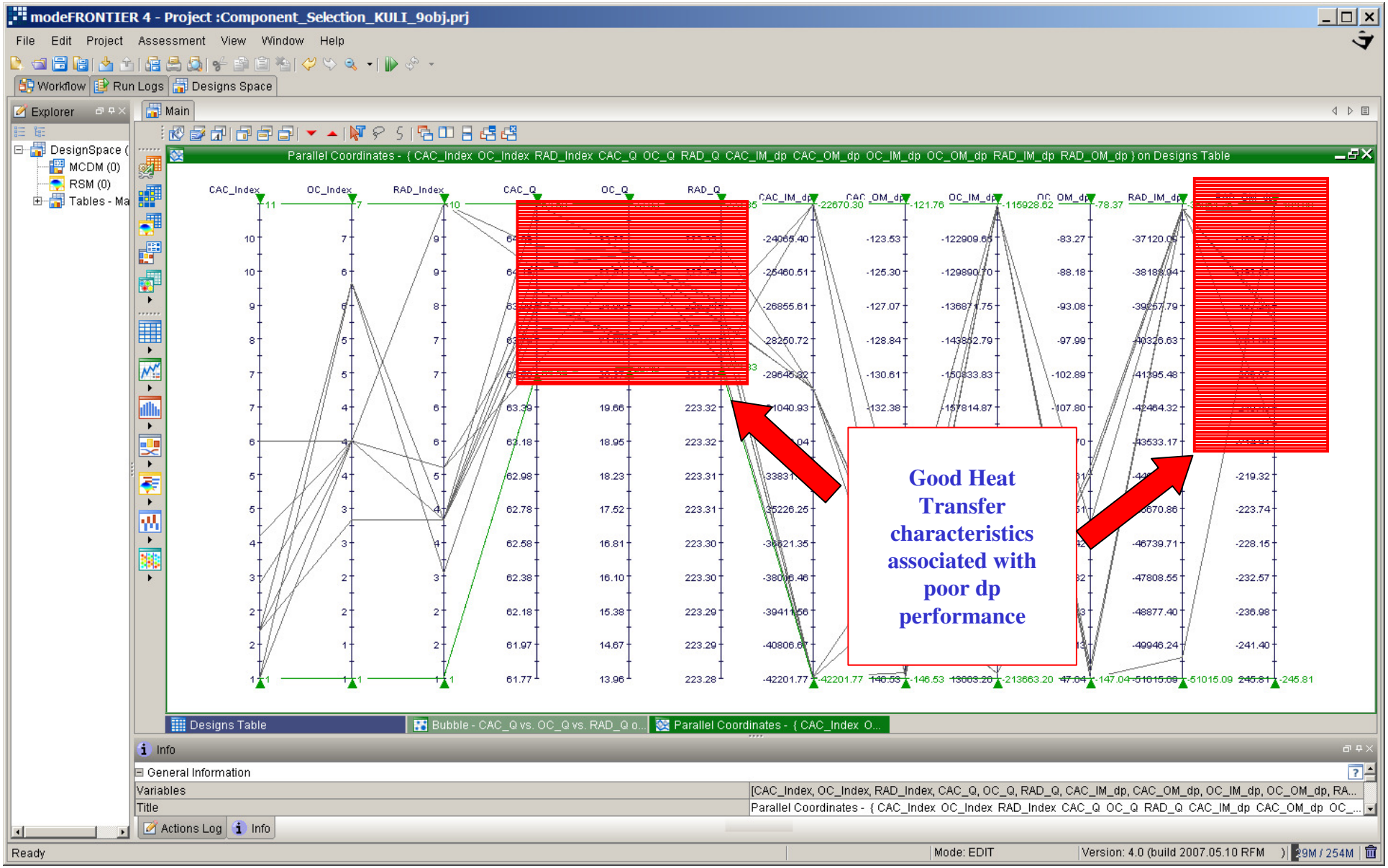
Workflow – 9 Objectives



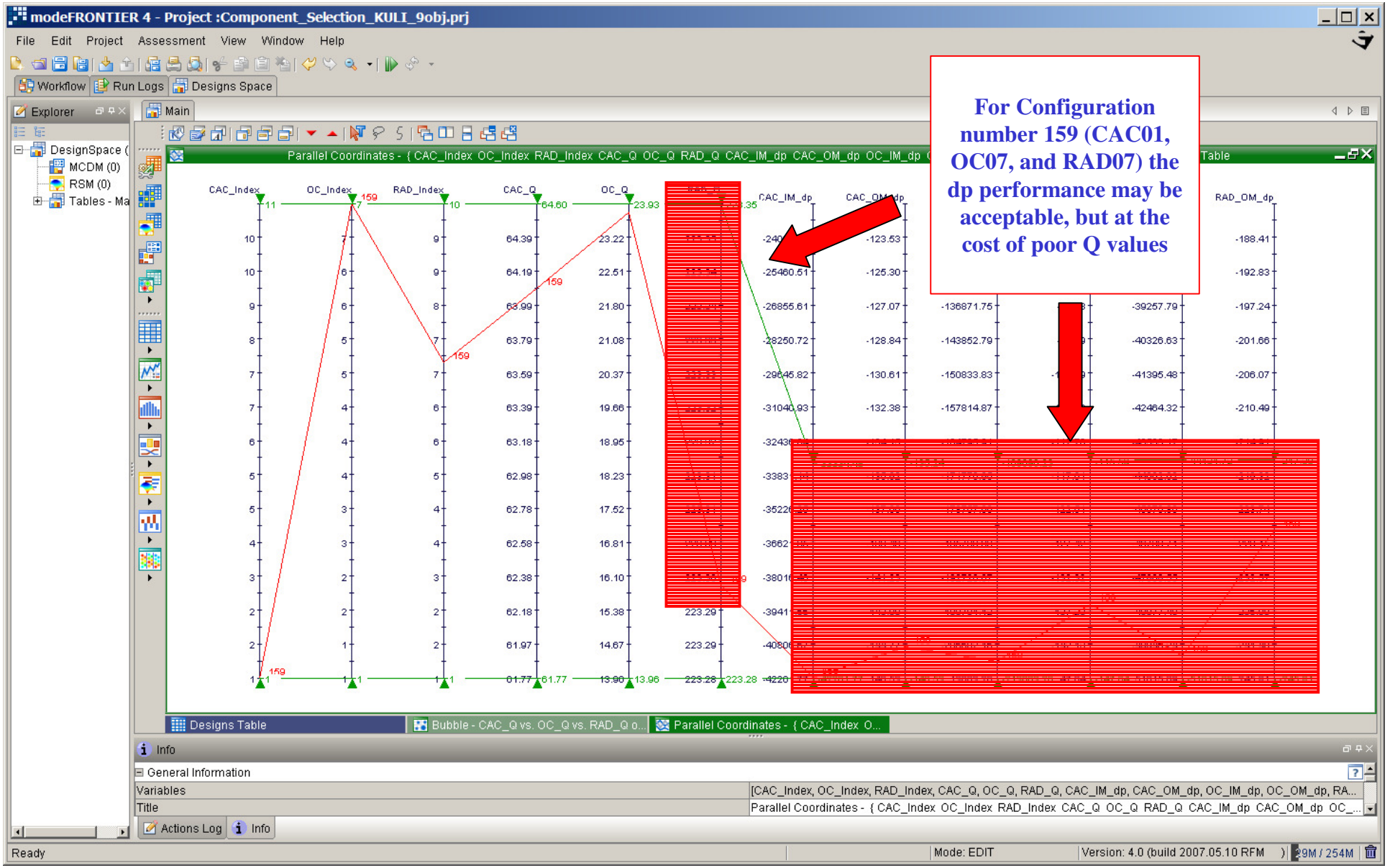
Results: Bubble Chart – 9 Objectives



Results: Parallel Chart – 9 Objectives



Results: Parallel Chart – 9 Objectives

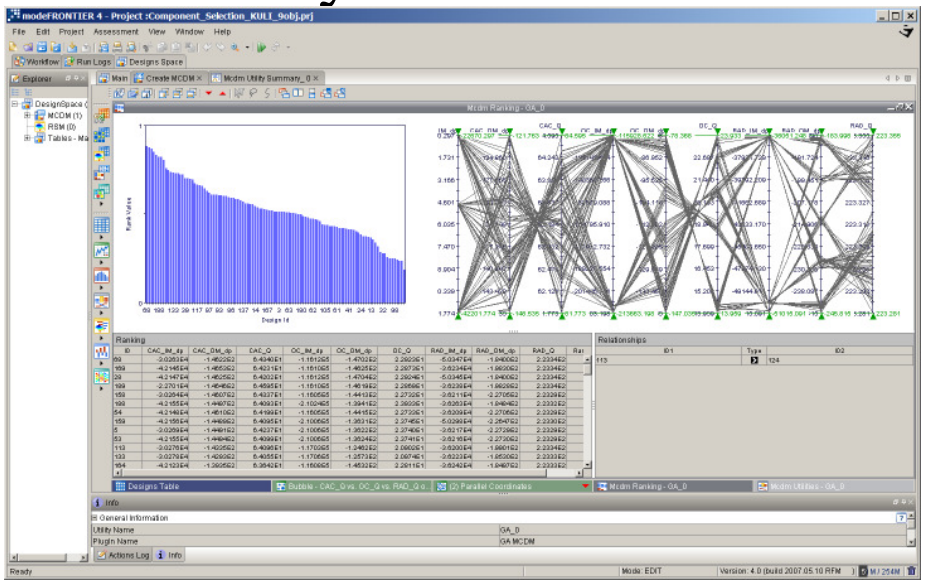


Test Case 2: Results

- It can be seen in this case that there is a trade-off decision to be made. The user will need to decide whether to give higher priority to Q or dp, or to accept the best compromise. This is a design decision
- In this case it was shown how the parallel charts in modeFRONTIER could be used to filter throught the results, and select based on subjective preference

Test Case 2: Results

- An alternative method would be to use the Multi-Criteria Decision Making Tool (MCDM) in modeFRONTIER to postprocess the multi-objective results
- In MCDM the user would apply the preferences numerically, and use one of the algorithms available to try to maximize the utility function



General Remarks

- Coupling KULI to modeFRONTIER is straight-forward using the COM interface. KULI 7 allows filenames as COM objects, and these can be used as variables in an optimization
- When there are several performance criteria being assessed, it is unlikely that one combination of components will be optimal for all outputs
- A decision will need to be made based on the trade-off: the designer will need to choose a configuration from among the Pareto optimal solutions available

General Remarks (contd)

- The tools in modeFRONTIER to do this are the parallel chart and the MCDM
- In the cases chose here to demonstate the method, there were only 770 possible combinations, and hence it would have been feasible to run all of them, and then select using the decision making tools
- In more complex case, however, there could be orders of magnitude more. In such cases, the use of a program like modeFRONTIER would be a valuable tool in component selection

Thank you