

Multi-point experimentation

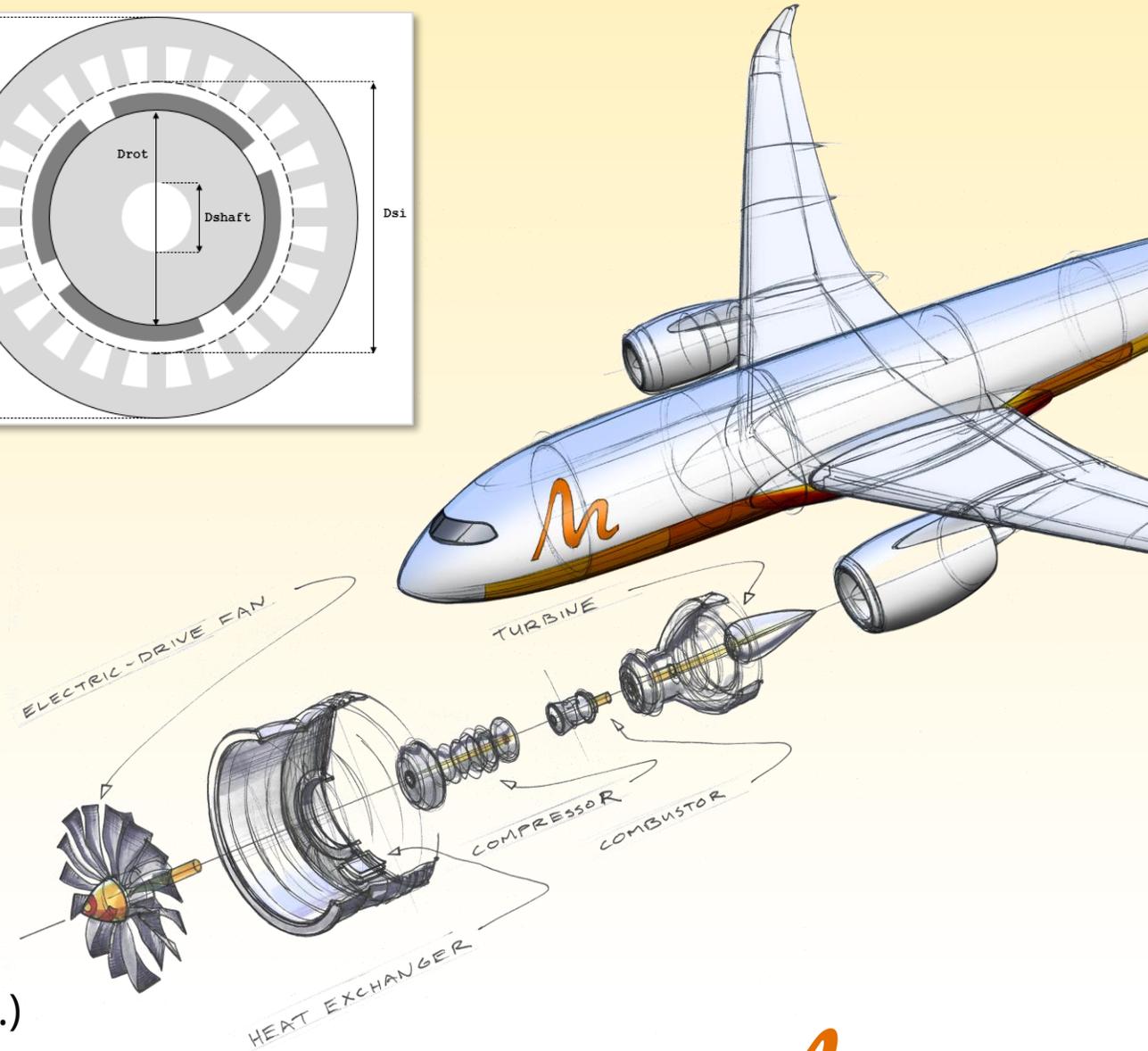
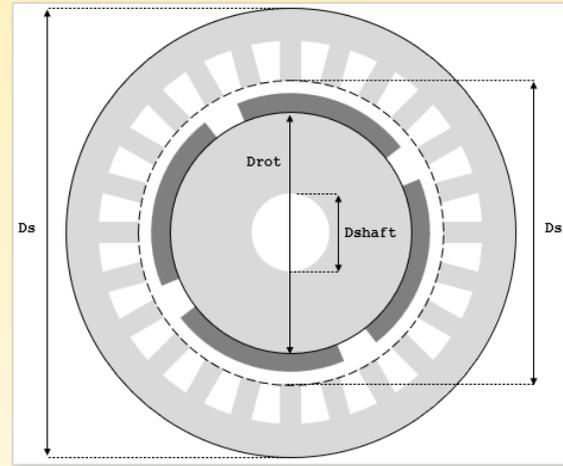
A workflow for **sizing** a system in **steady-state** for **multiple operating points**



Use case

- Sizing of a component or system
... in steady-state operation
- Early design phase
- What is the optimal design ?
... for given constraints
... and operation requirements
- Results
 - Design parameters (dimensions, ...)
 - Derived parameters (weight, inductance, ...)
 - KPIs (efficiency at low speed, torque limits, ...)

Dimensions of an electric motor

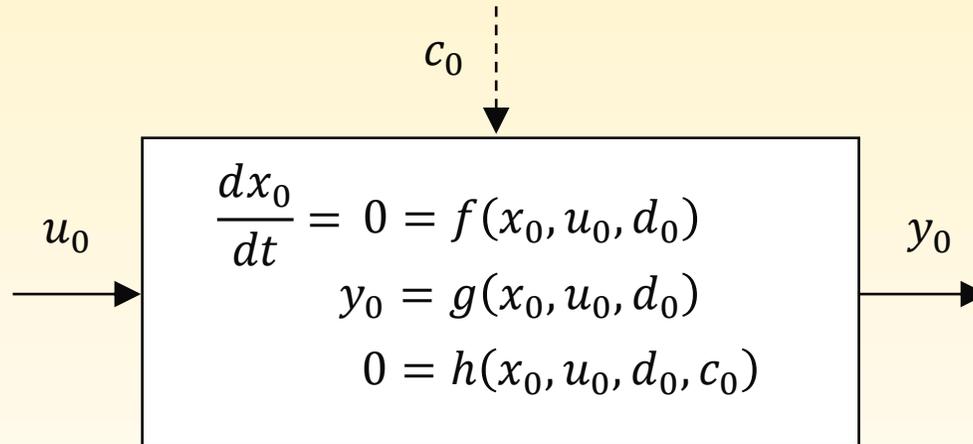


Single-point sizing model

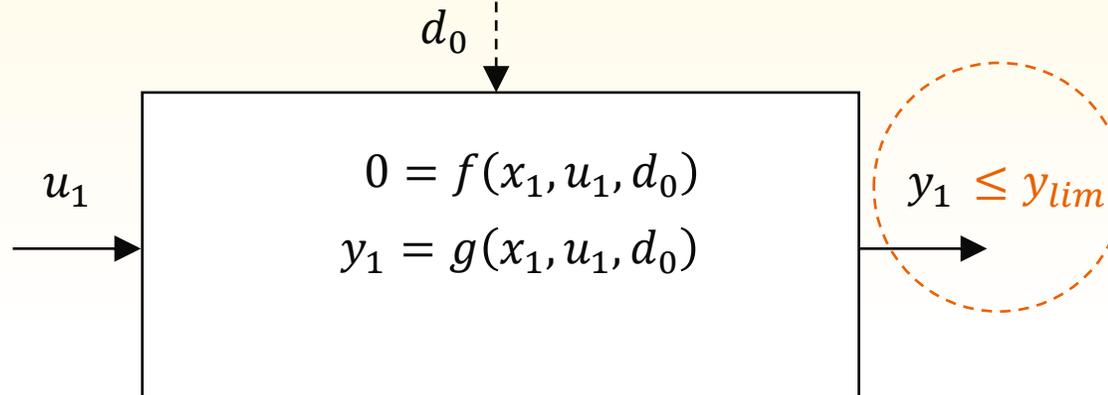
u_0 : model inputs
 y_0 : model outputs
 x_0 : model states
 d_0 : design variables
 c_0 : design constraints

$f(\dots)$: state model
 $g(\dots)$: output model
 $h(\dots)$: design model

Design operating point
("on-design")



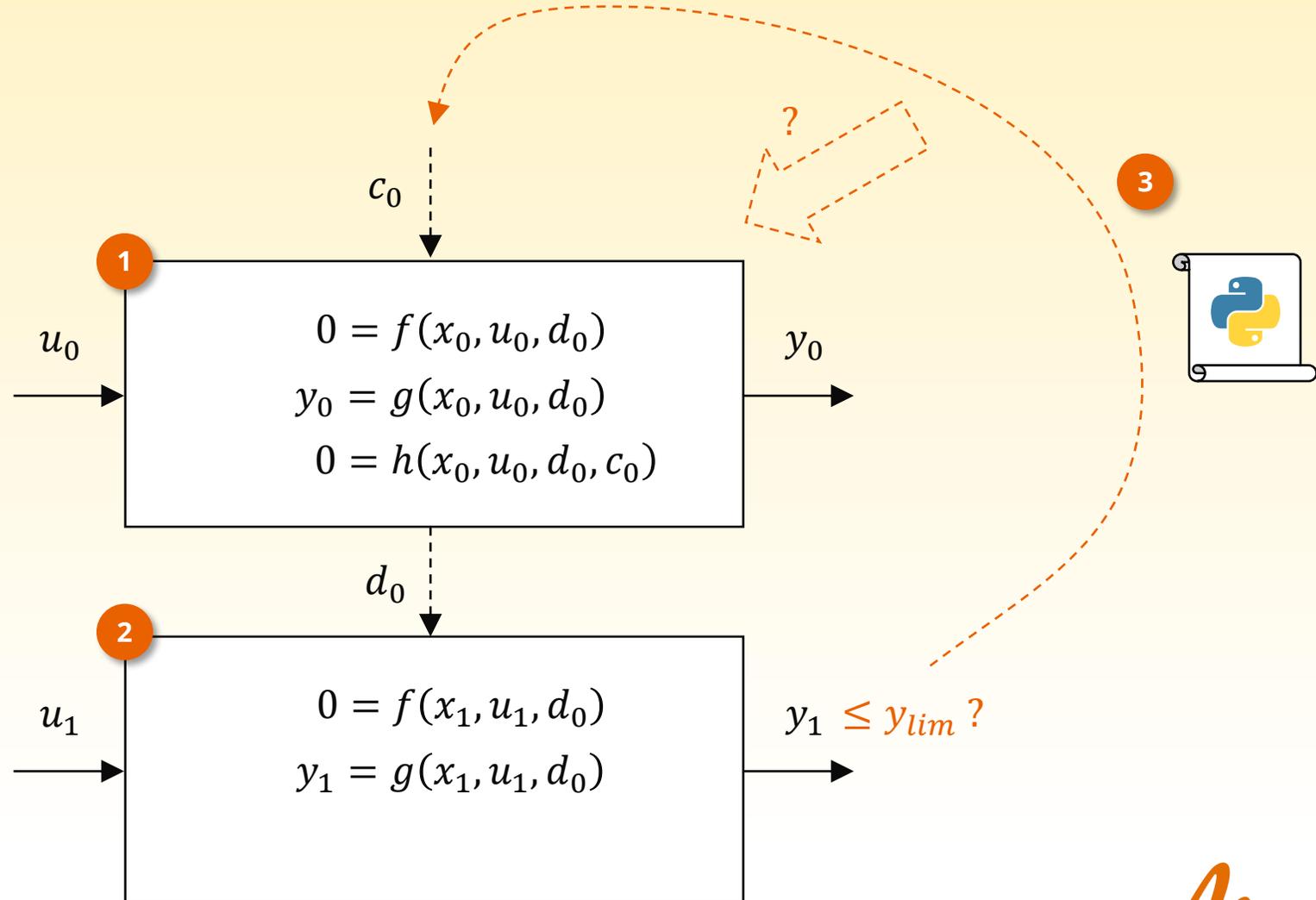
Some other operating point
("off-design")



The challenge:
Off-design requirements !?

Off-design requirements

Design operating point
("on-design")



Some other operating point
("off-design")

Challenges

*How can we solve for multiple operation points at once,
with a common design solution?*

*How can we extend the original sizing problem,
with constraints for the additional operating points?*

Multi-point sizing

A systematic and general workflow that ...

... does not rely on an external loop

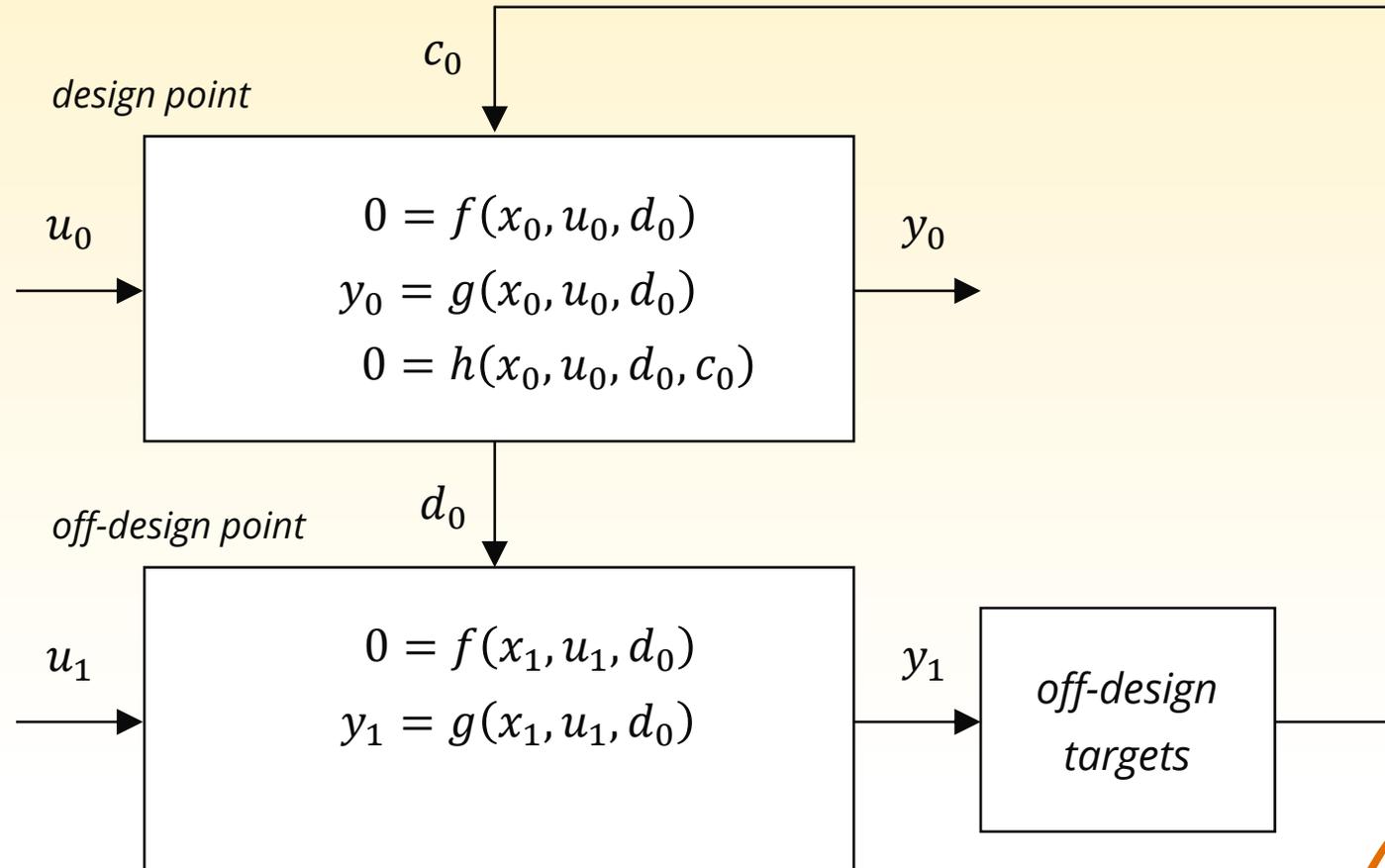
... re-uses the single-point model and design process

... evaluates multiple operating points at once

... extends the original design equations with constraints for off-design results

... helps us manage the added complexity of the larger sizing problem

Multi-point



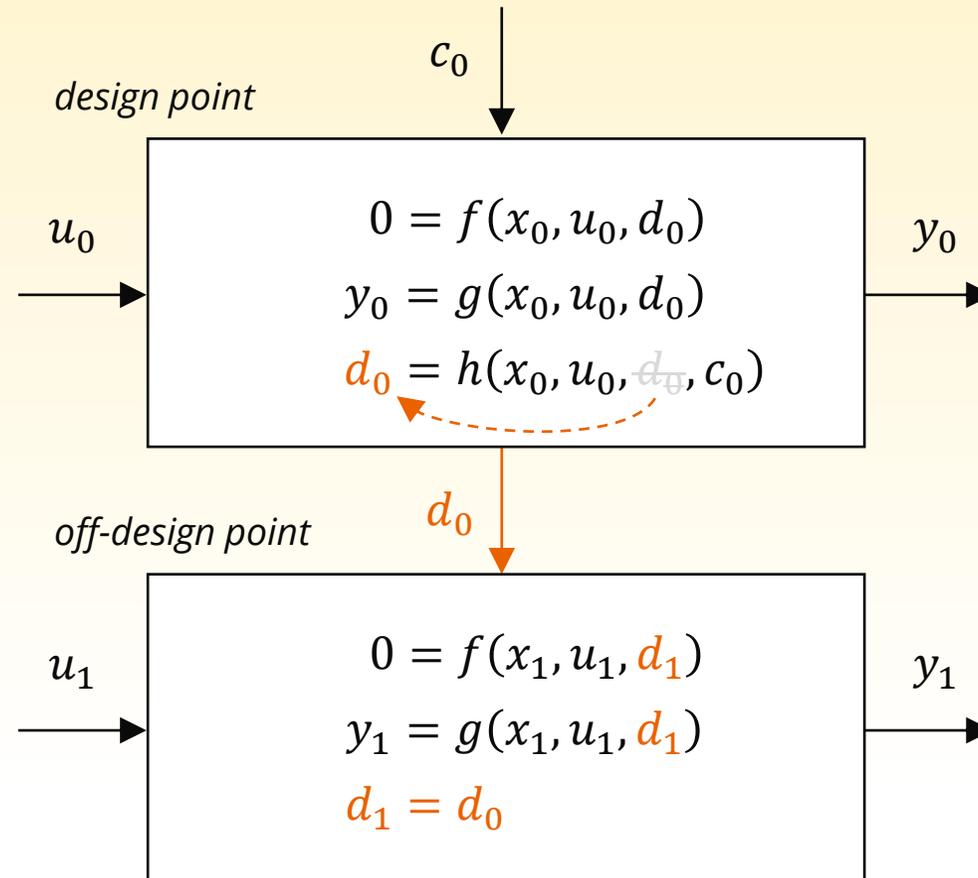
Multi-point: Coupled design

Modifier

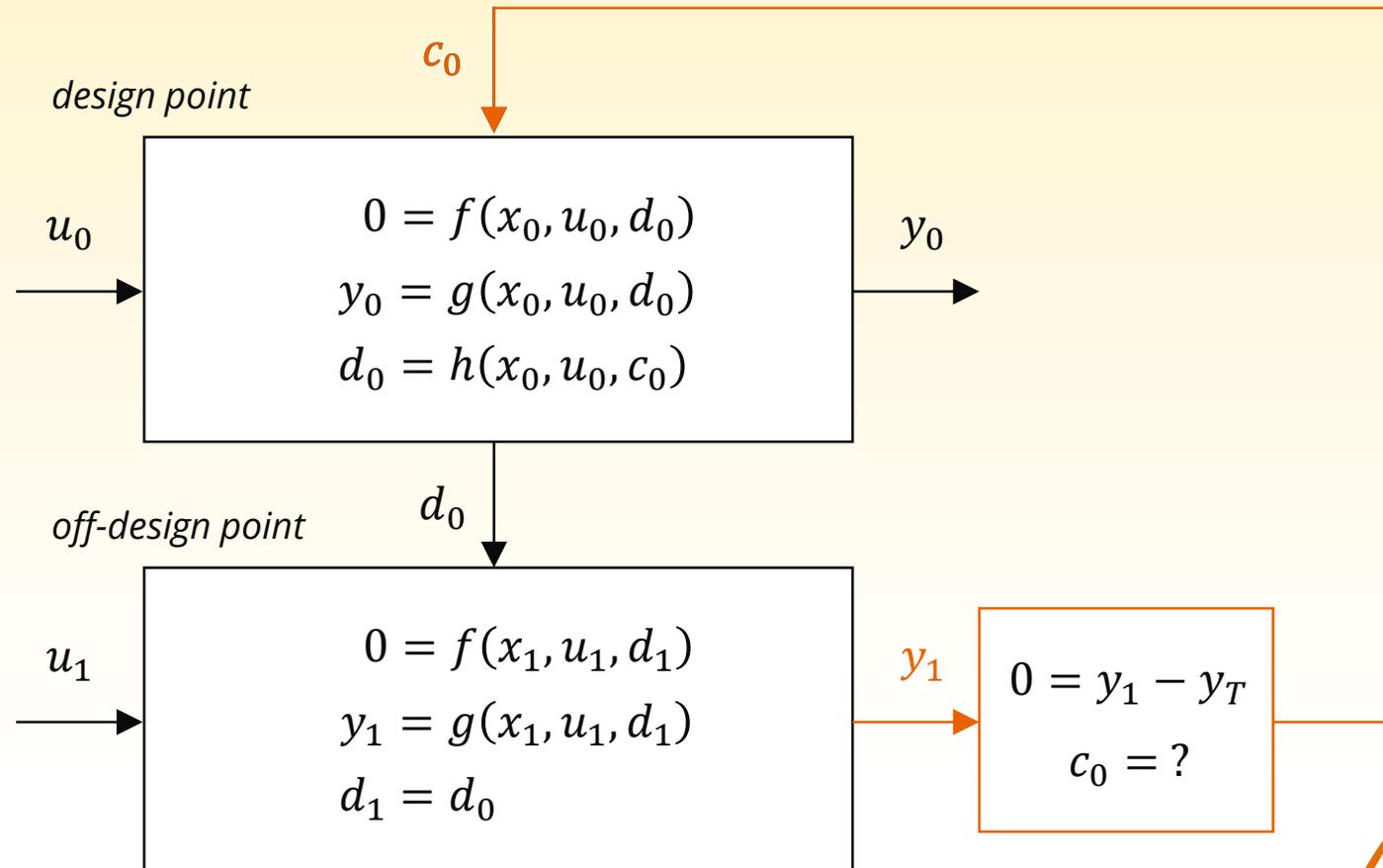
```
SinglePointModel modelB(d = modelA.d);
```

Binding equation

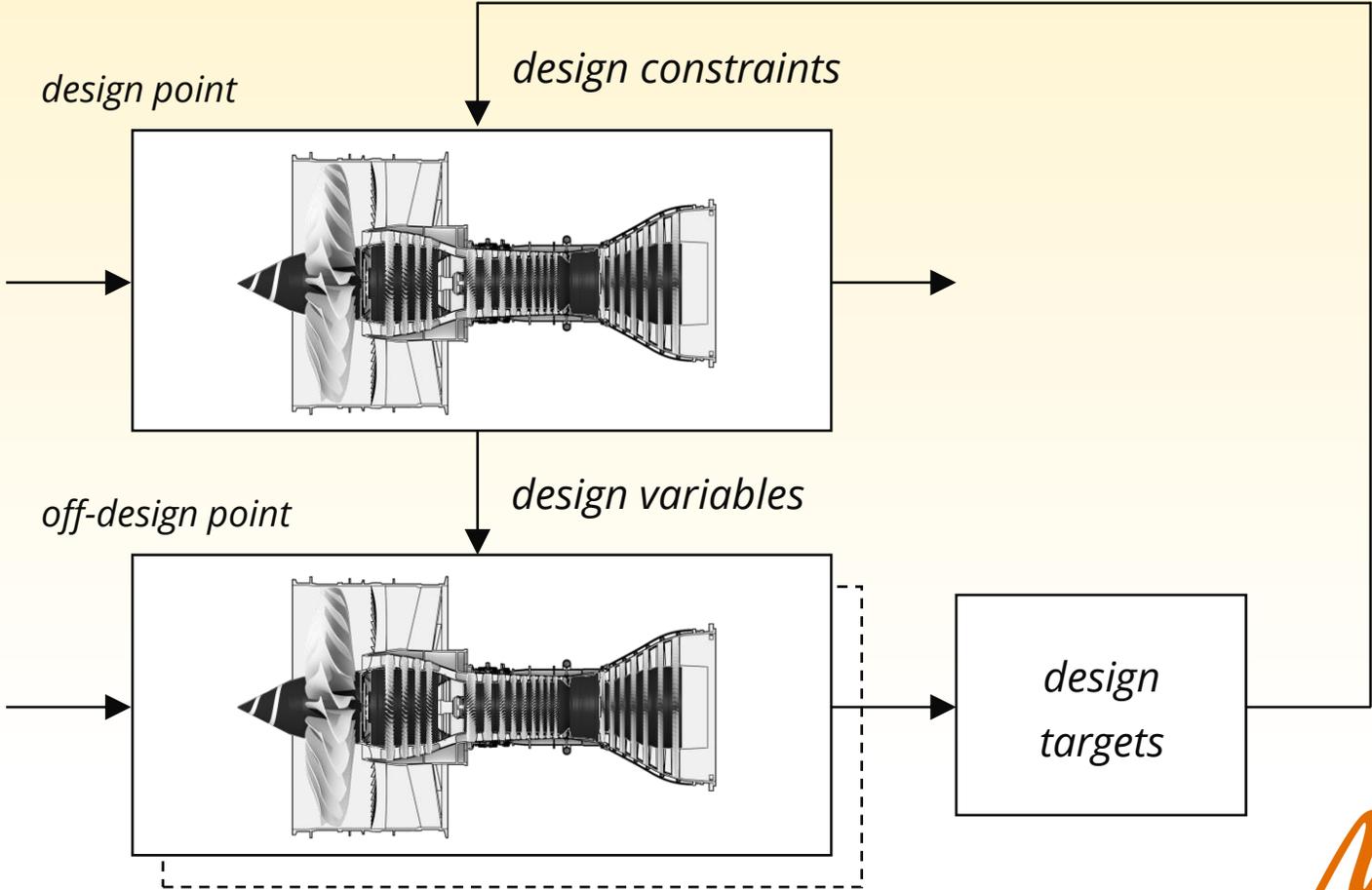
```
Real d = x + y;
```



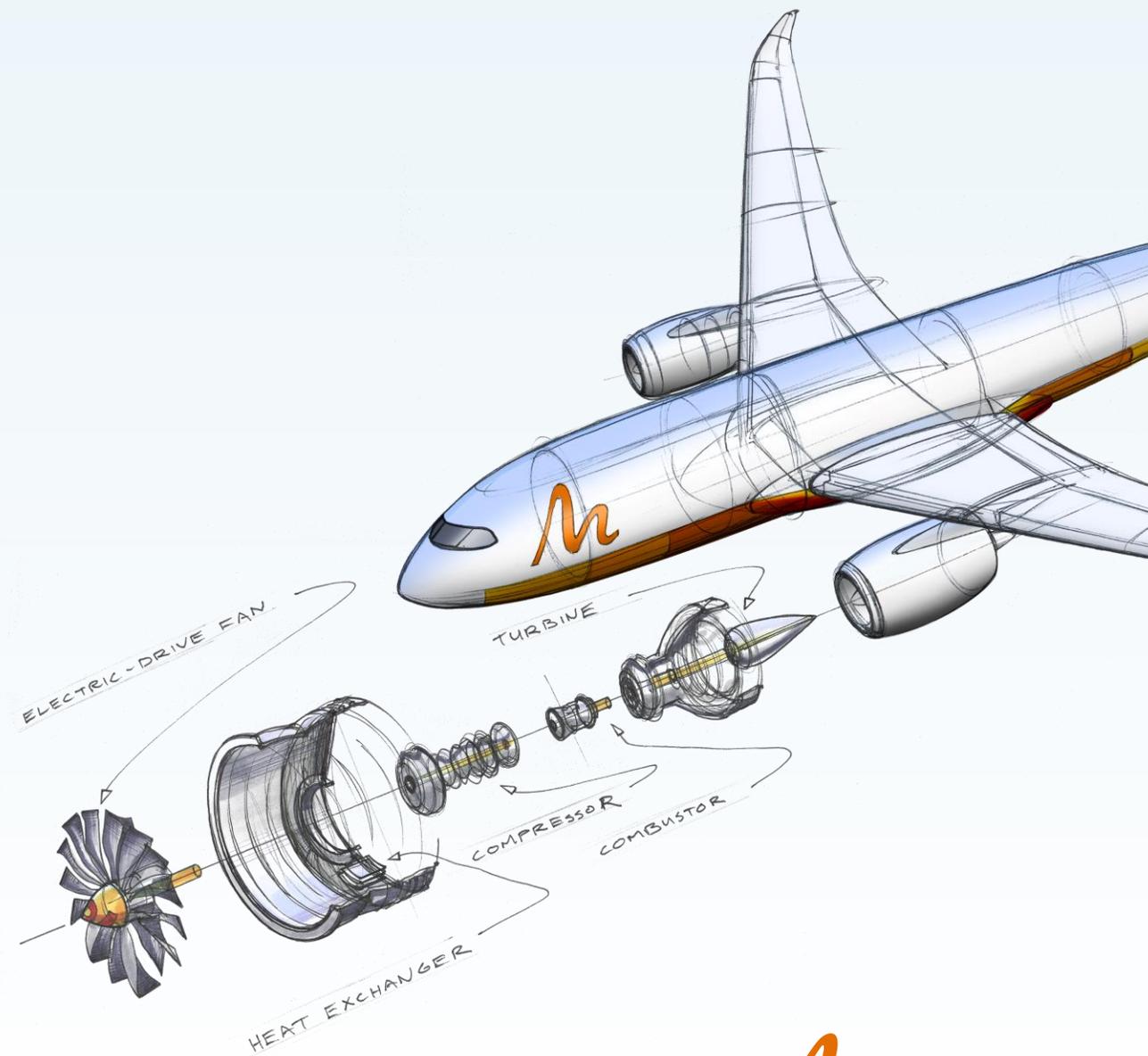
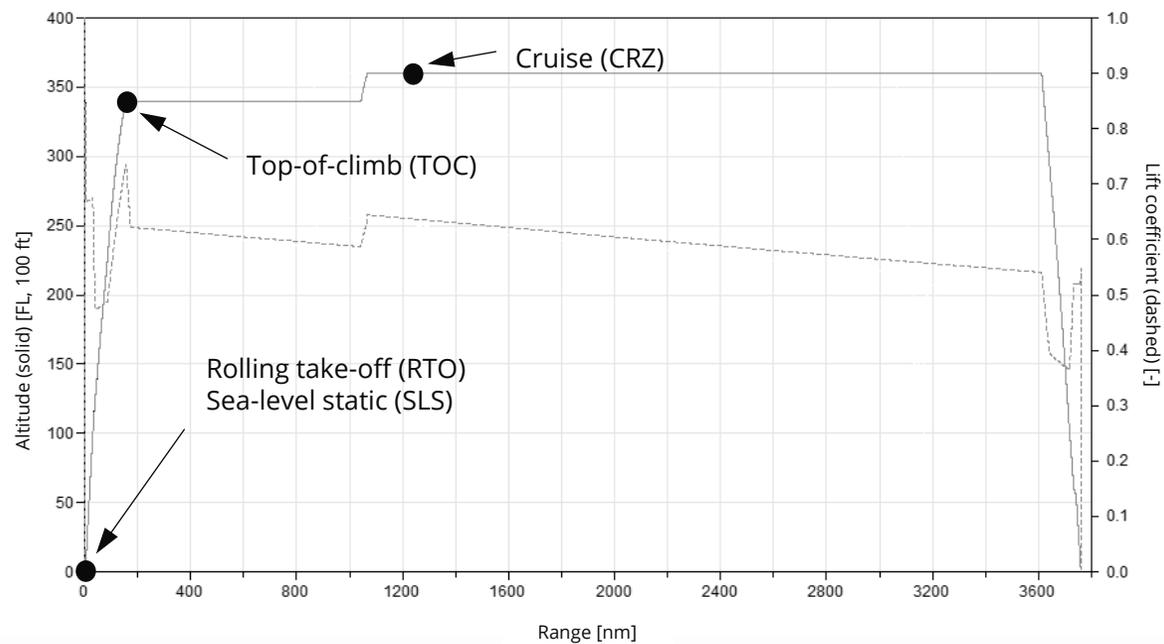
Multi-point: Off-design constraints



Multi-point

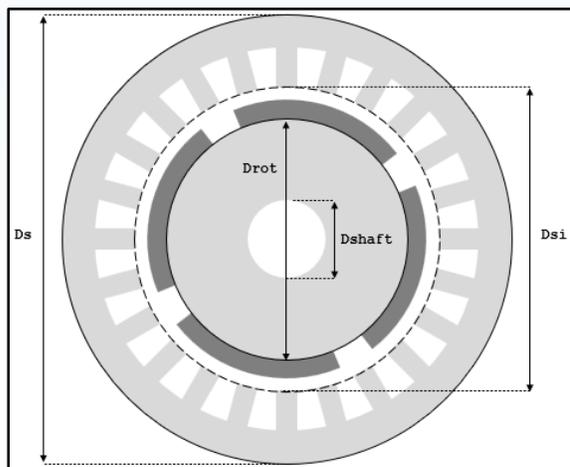


Demo

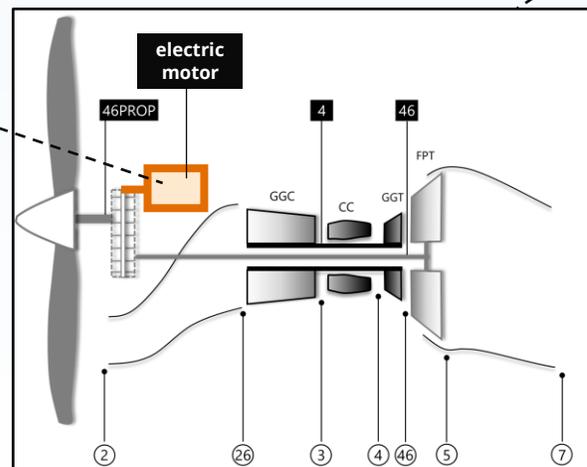


Demo

Dimensions of an electric motor



Turboprop engine (boosted)



Multi-point sizing

A systematic and general workflow that ...

... does not rely on an external loop

... re-uses the single-point model and design process

... evaluates multiple operating points at once

... extends the original design equations with constraints for off-design results

... helps us manage the added complexity of the larger sizing problem

Resources

Help Center

- *Tutorial: Enhanced Turbojet Multi-point*
https://help.modelon.com/latest/tutorials/enhanced_turbojet_multipoint/

Models

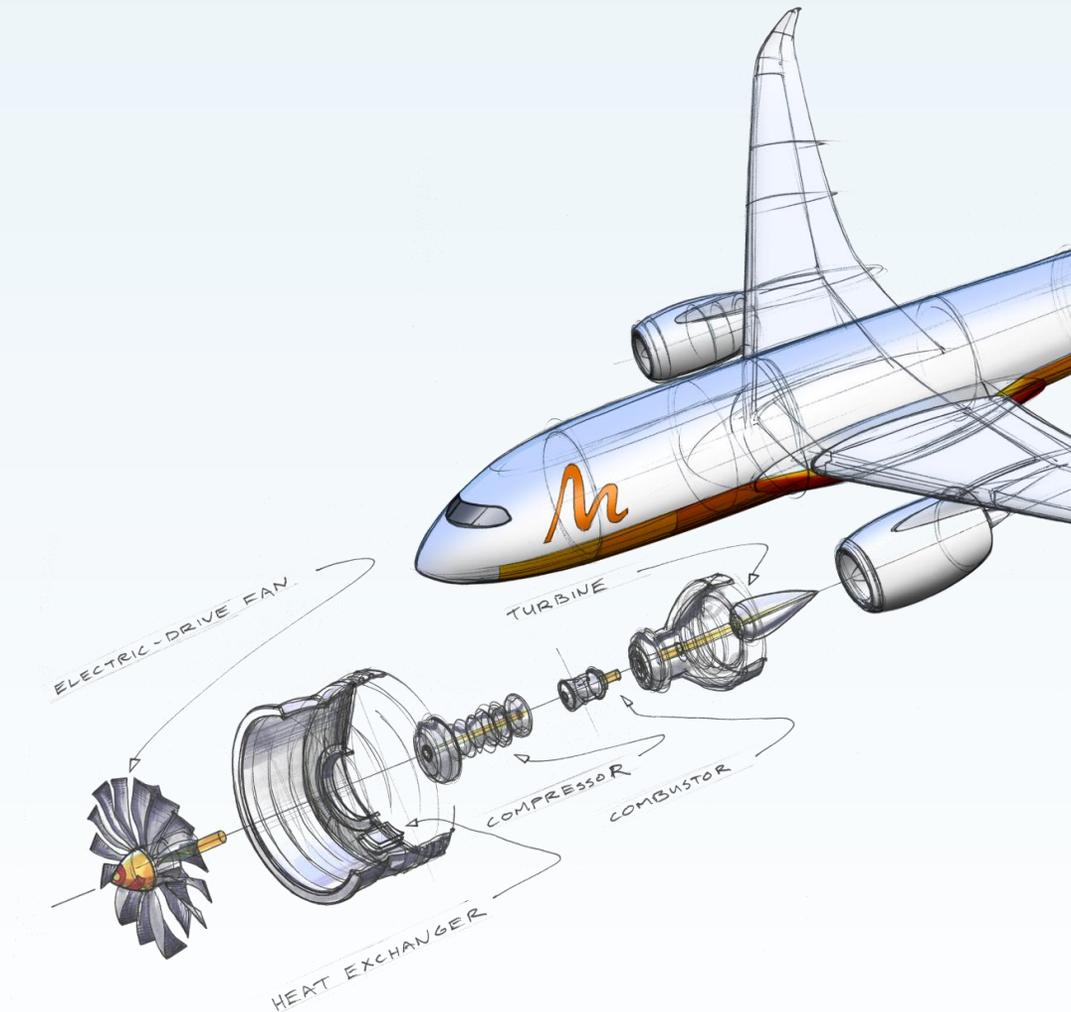
- `IndustryExamples.Aerospace.Propulsion.HybridTurboprop.Parallel`
- `Electrification.Machines.Experiments.Design.Multipoint`

Video presentations

- *Select Trade-Offs in Parallel Hybrid Turboprop Cycle Design*
<https://www.youtube.com/watch?v=1dvLiWh-jms&t=302s>
- *Multi-Point Design Strategies, part 1: Geared Turbofans for Aerospace Engines*
<https://www.youtube.com/watch?v=ZEH1DFADRFE>

Articles

- M. Sielemann, et al. (2022). *Select Trade-Offs in Parallel Hybrid Turboprop Cycle Design*
<https://doi.org/10.1115/GT2022-81629>
- M. Sielemann, et al. (2020). *Multi-Point Design of Parallel Hybrid Aero Engines*
<https://doi.org/10.2514/6.2020-3556>





Accurate Simulations. Better Decisions.