ENHANCED STEADY-STATE IN MODELON JET PROPULSION LIBRARY

AN ENABLER FOR INDUSTRIAL DESIGN WORKFLOWS

#OneModelon

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Enhanced Steady-State in Modelon Jet Propulsion Library – an Enabler for Industrial Design Workflows

- Industrial Design Workflows

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- Dynamic v/s Steady-state simulation

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- System-level example

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INDUSTRIAL DESIGN WORKFLOWS

A basic example:

V = R * I

"Typical" simulation

Off-Design Simulations

- ✓R is a known parameter
- ✓V (or I) is a known variable
- ➢I (or V) is computed

On-Design Simulations

- ✓Both V and I are known variables <u>at design point</u>
- ➢R is computed based on this point

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Wait… but there is no need to rearrange the equation?

Nice!
Let's discuss more.

Indeed, that is a-causality! And the best part… the Modelica compiler takes care of that!

INDUSTRIAL DESIGN WORKFLOWS

So, why do we need both on- and off-design modes?

On-Design answers "what should be my system design?"
Off-Design answers "how does my designed system behave?"

So on-design should happen first?

And off-design simulation should use the sizing from on-design

Exactly! And both modes are done with a single model.

If I understand correctly, the compiler will re-order the equations to solve a problem or the other… even if it's a single model?

Yes, the compiler will prepare both cases so we can switch mode without re-doing all the equation processing!

That can be quite a mess, no?

We have a great compiler team, and we can even write insights in our models to guide the compiler with our knowledge of physics

Amazing! You should write a paper on the topic!

Guess what…

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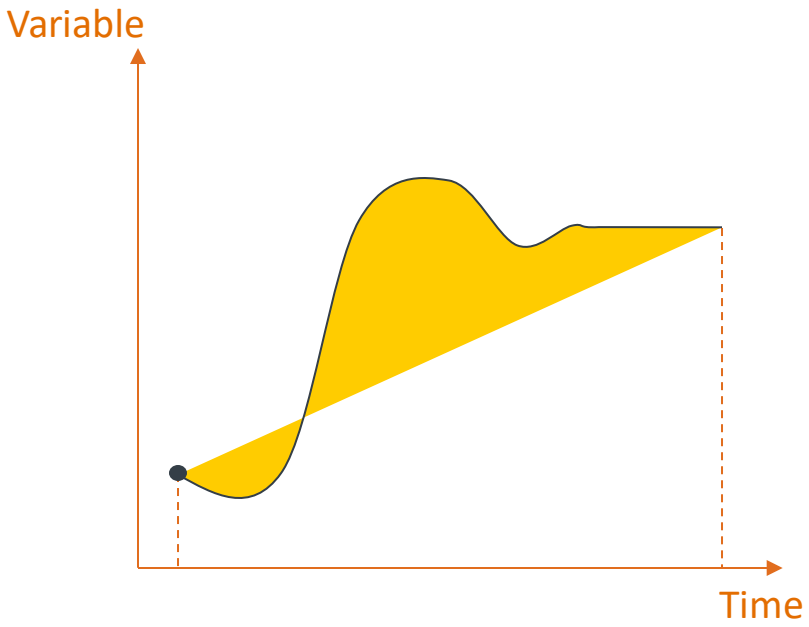
STEADY-STATE SIMULATION: WHAT IS IT?

- Dynamic



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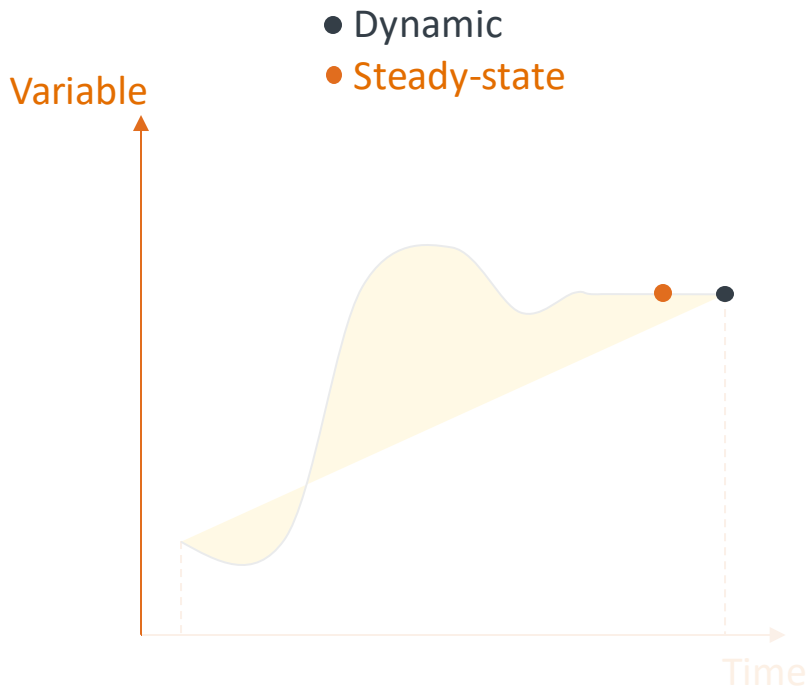
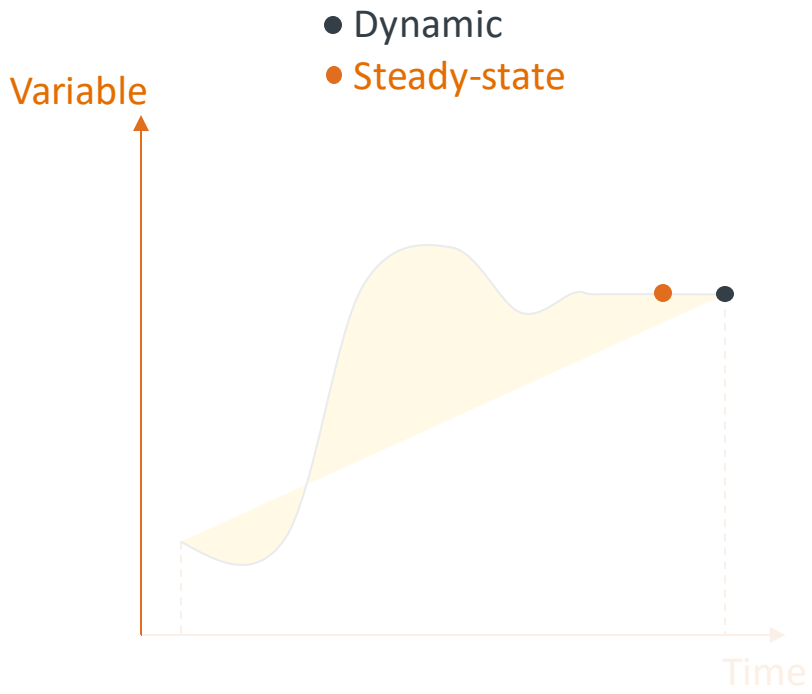


1. Define operating conditions of the modeled system
2. Solve the model to have all variables steady

STEADY-STATE SIMULATION: WHAT IS IT?



1. Define operating conditions of the modeled system
2. Solve the model to have all variables steady

- No notion of time, no history
- Direct results of interest
- Several magnitudes faster
- Easier results processing
- Facilitates sequential simulation

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Automatically derive the sensitivities for optimization

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Scaling of residual equations and iteration variables
Combination of residual and step norm as exit criterion

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Debugging

Log messages in XML format
Python package for parsing the log and data extraction, and user interaction with the equation system

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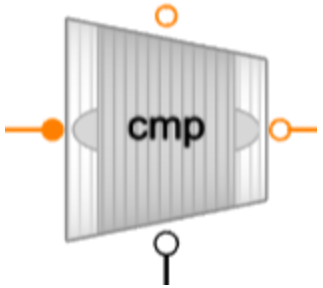
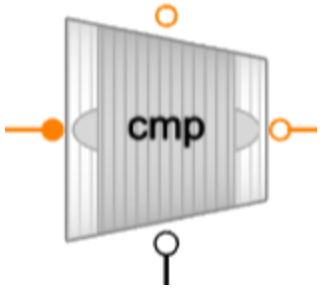
ENHANCED STEADY-STATE IN MODELON JPL



Physics-based Solving:
Vendor-specific language construct supported by Modelon’s compiler
Specify which equation should be a residual associated to which iteration variable
Holding of residuals or iteration variables is possible through parameter conditions

ENHANCED STEADY-STATE IN MODELON JPL



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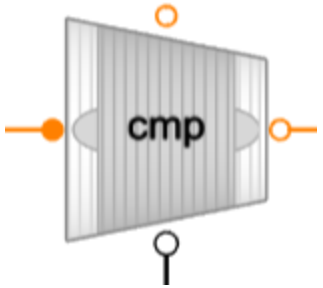

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Physics-based Solving instructions at component level enables system assembly and solving is deduced from topology
Use of generally accepted choices for iteration variables and residual equations from gas turbine community

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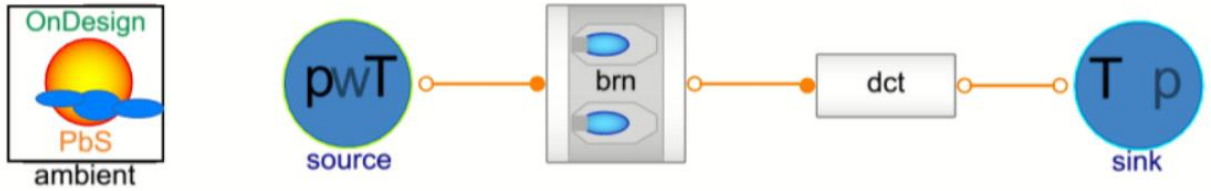
COMPONENT EXAMPLE: BURNER

Physics-based Solving with Jet Propulsion Library & OCT

1. FMU generation

In this experiment, we will illustrate how it is possible to change the type of input on the burner from Fuel-to-Air-Ratio (FAR) to fuel mass flow rate (wFuel) after recompilation, on a burner instance:



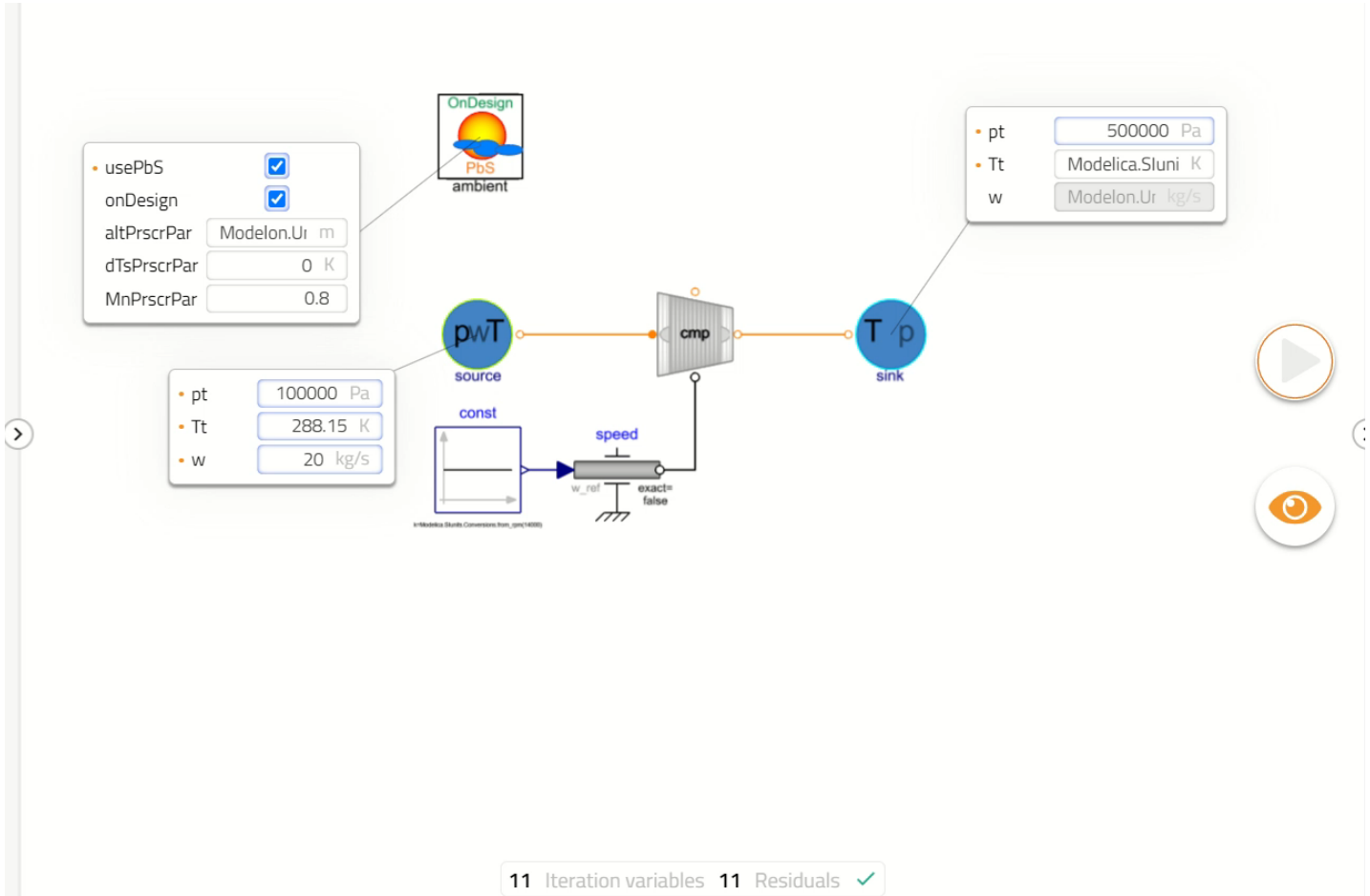
In [1]:
```
modelName = "JPL_PbS_Tests.Burner.PbS_far"
```

Run script that defines the library paths and compiler options:

In [2]:
```
import sys
sys.path.insert(1, 'C:/Users/ClementCoic/Documents/0_Developement/P545-JPL/JetPropulsion/Resources/Python')
import jplUtilities
import importlib
importlib.reload(jplUtilities)
from pyfmi import load_fmu
from oct.steadystate.nlesol import FMUProblem, Solver
```

Speed x1

COMPONENT EXAMPLE: COMPRESSOR



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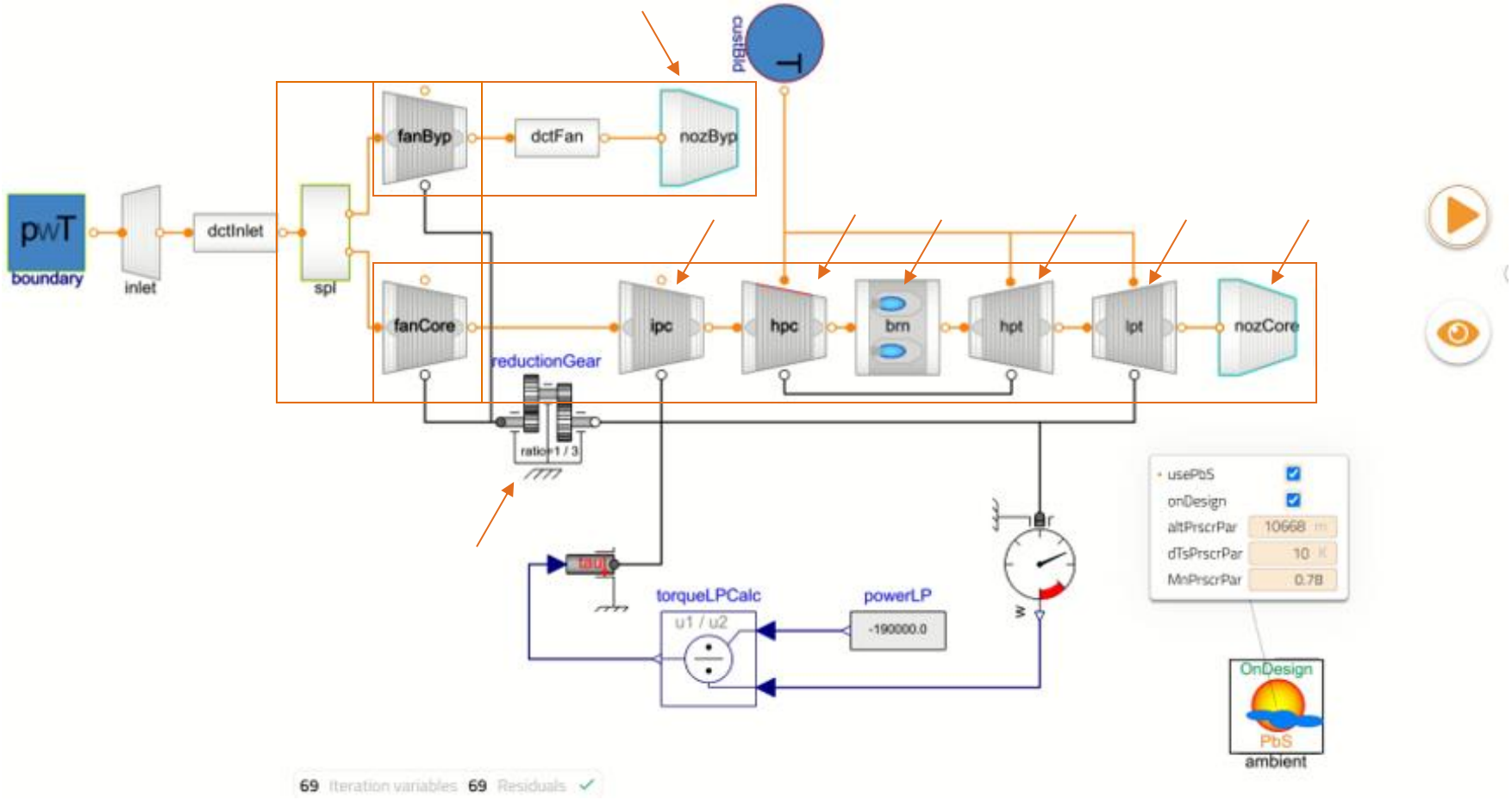
GEARED TURBOFAN



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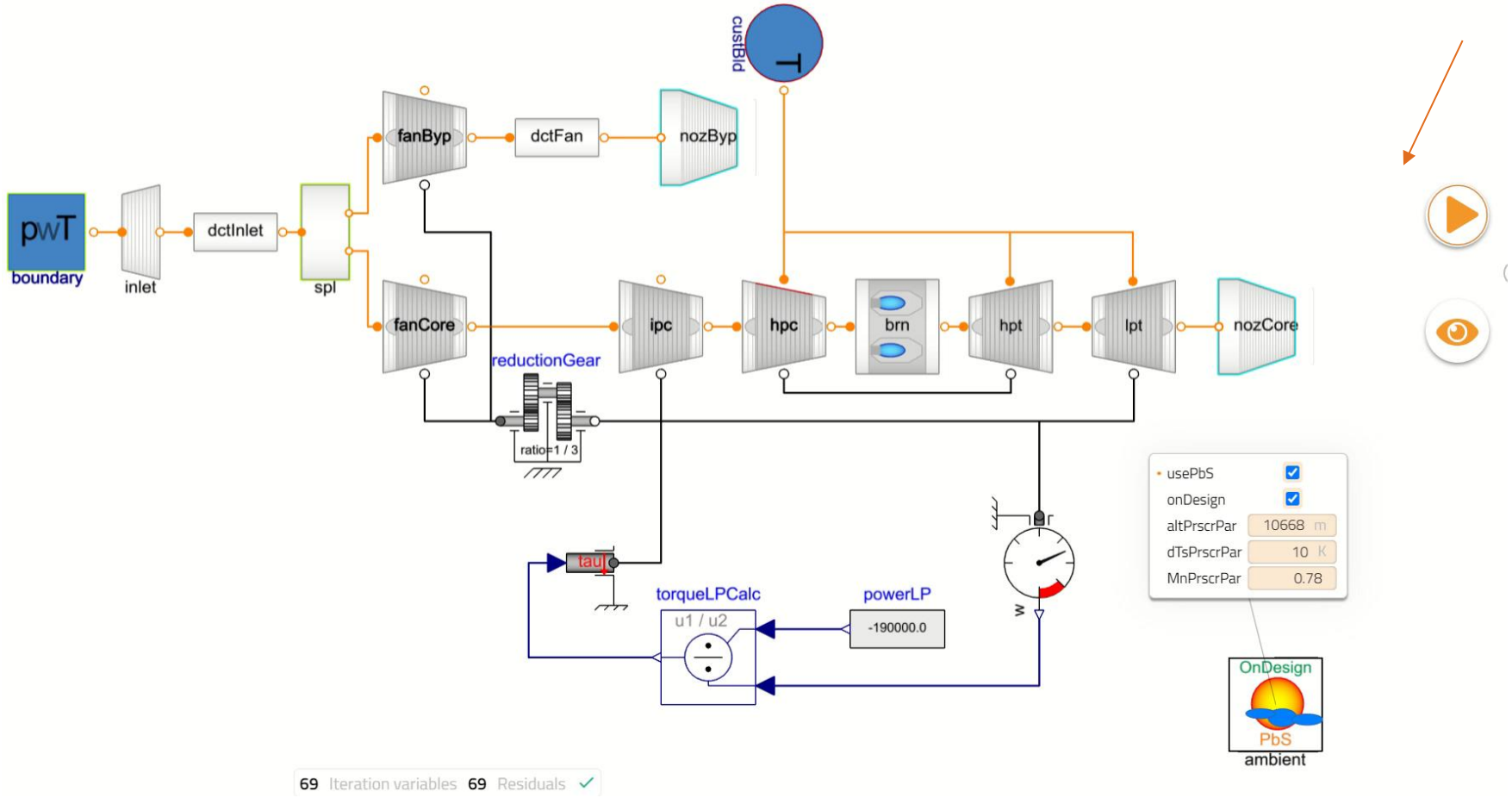

Speed x1

GEARED TURBOFAN: RESULTS & DISCUSSIONS

	Top of climb	Cruise	Take-off
Thrust	24 kN	18 kN	92.5 kN
Day type	ISA	ISA	Hot day (ISA+15 K)
Altitude	35000 ft	35000 ft	0 ft
Mach Number	0.78	0.78	0.25
Type	On-Design	Off-Design	Off-Design

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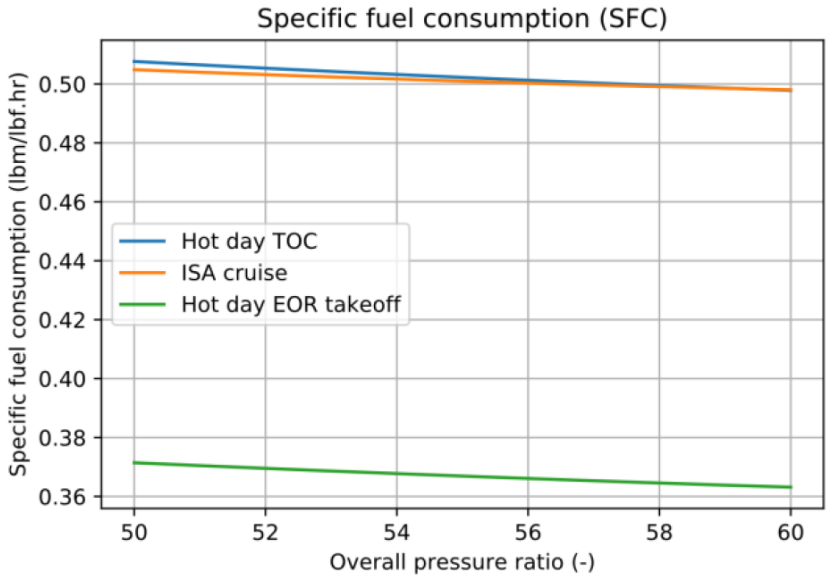

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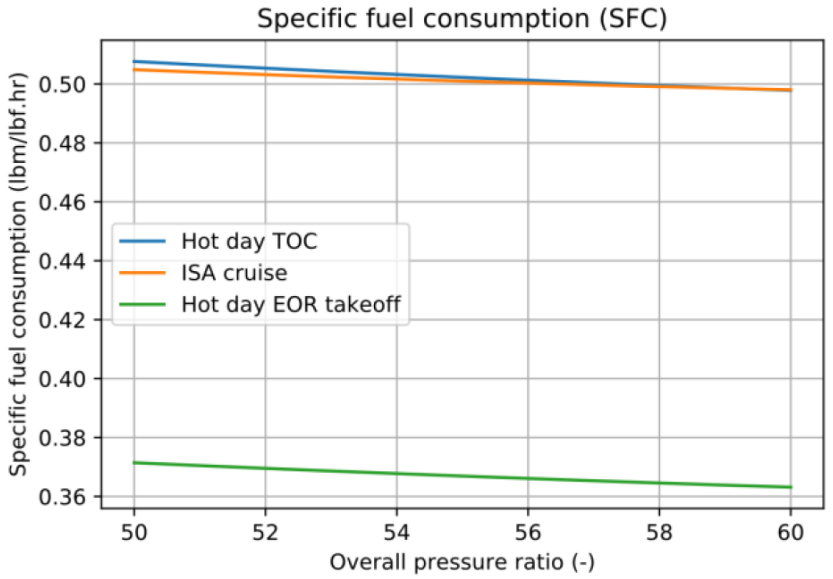
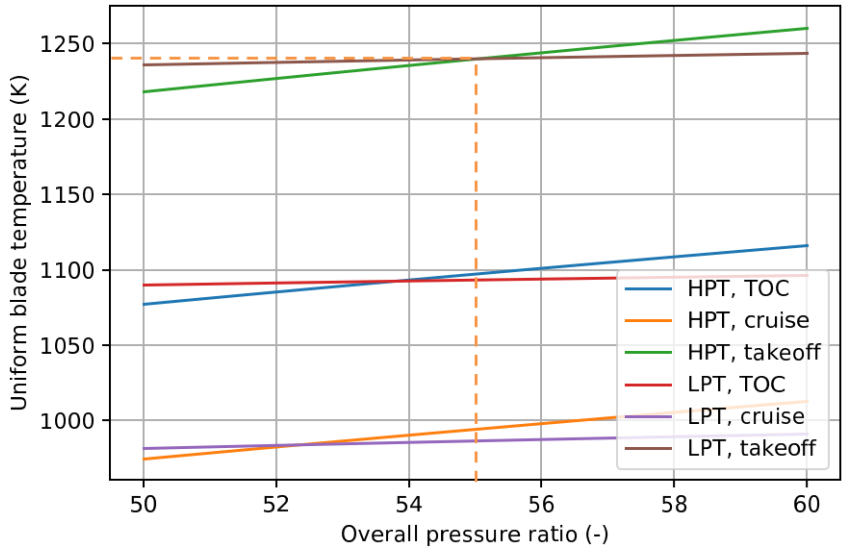
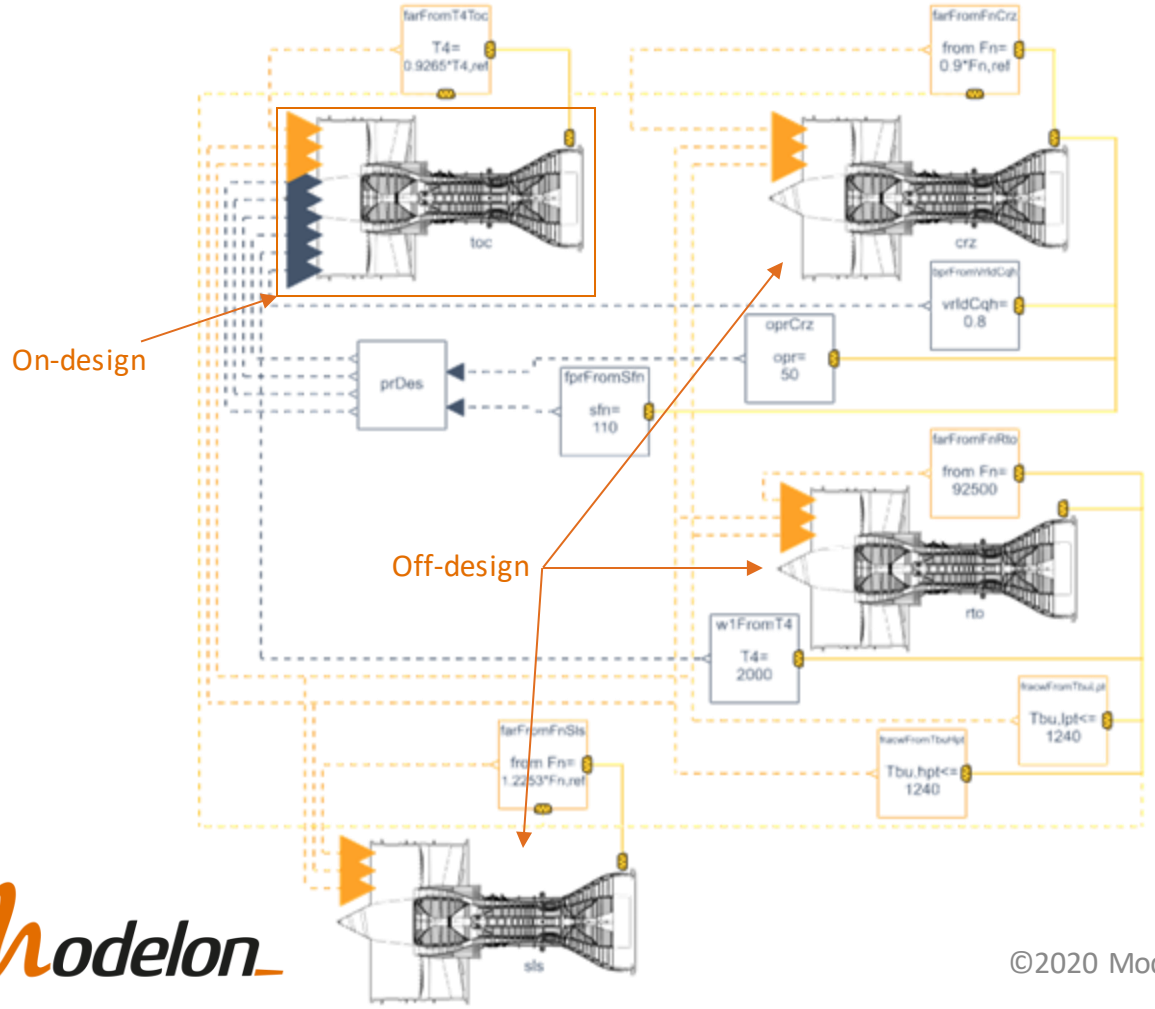




There are constrain requirements that could be violated on other mission profile points.

GEARED TURBOFAN: MULTIPOINT DESIGN



On-design and Off-Design simulations are modeled in a single model
We ensure that the design meets the constrains in all off-design points
If not, the design is automatically modified

(At each step of the convergence, the design is propagated to all off-design models)

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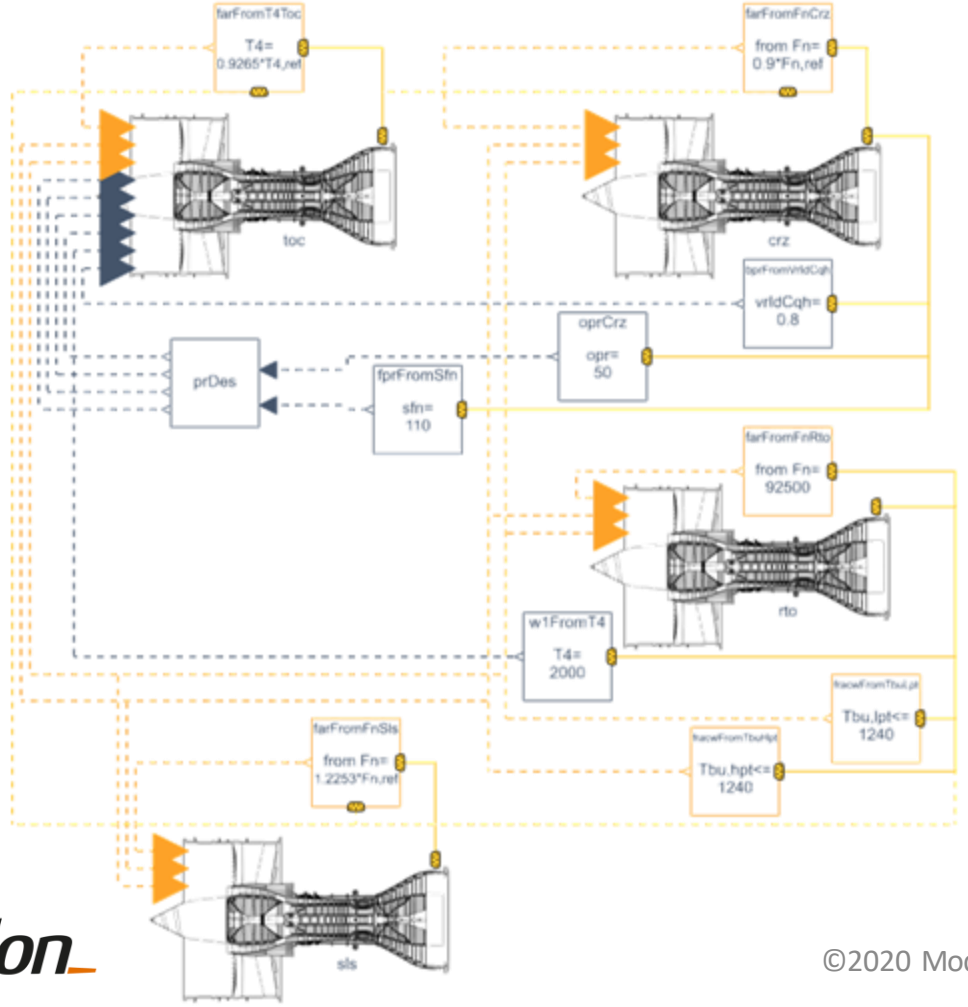

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More about multi-point design at
https://www.youtube.com/user/modelonweb

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CONCLUSION

- Introduced terminology
  - Simulation modes: on- and off-design
  - Steady-state
- Industrial design workflow
- Robust and efficient steady-state simulation of JPL with OCT or Modelon Impact
- Demos at component and system levels
- Graphical multi-point design

QUESTIONS?

Thank you for your time

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