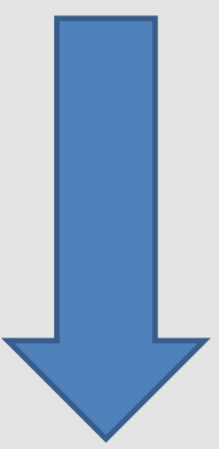


Virtualization of the DLR Turbine Test Facility NG-Turb

Next Generation Turbine Test Facility (NG-Turb)



Figure 1: Turbine test facility NG-Turb



Abstraction

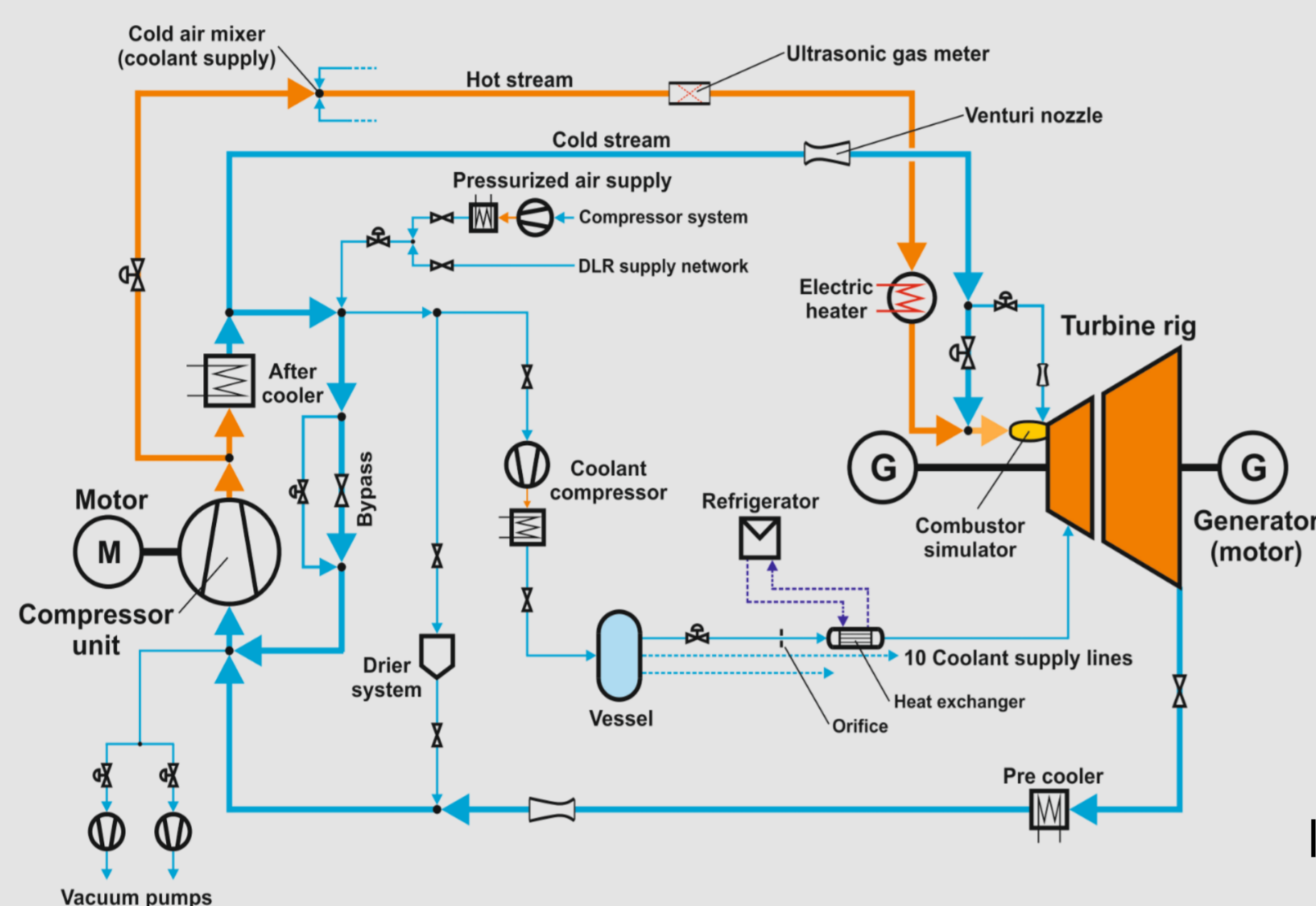
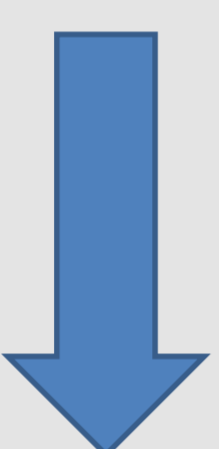


Figure 2: NG-Turb circuit diagram (schematic)



Virtualization

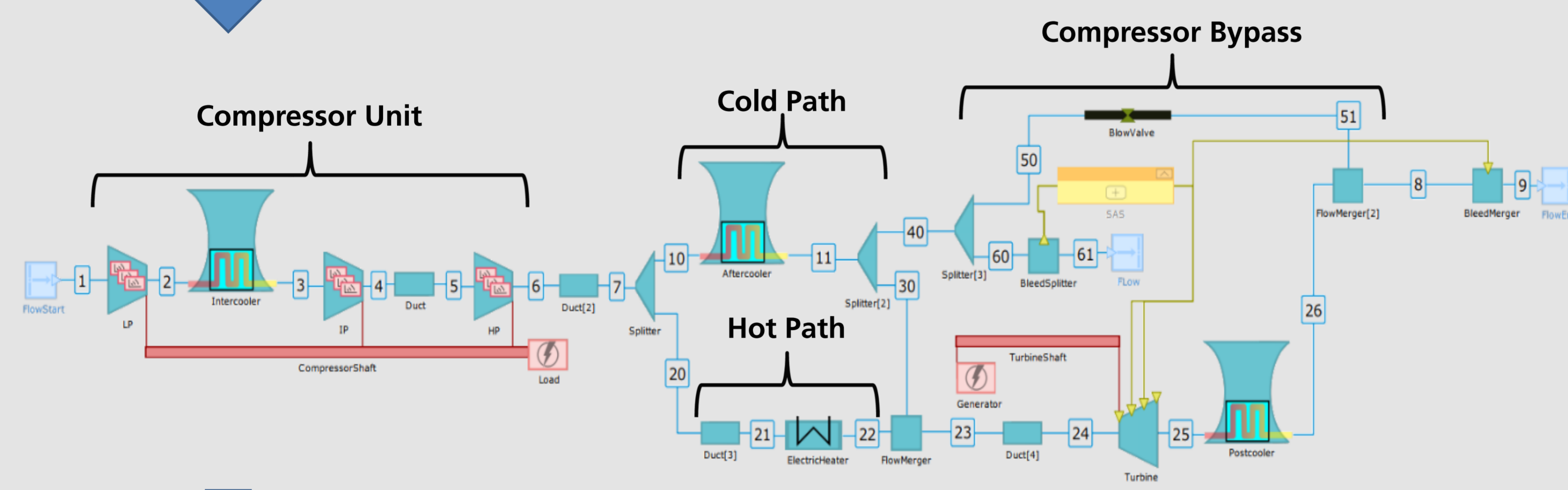
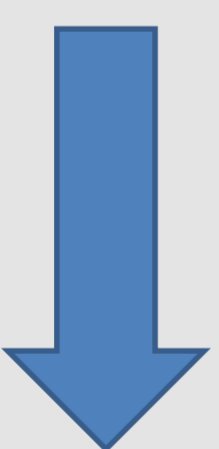


Figure 3: NG-Turb circuit (GTlab)



Application

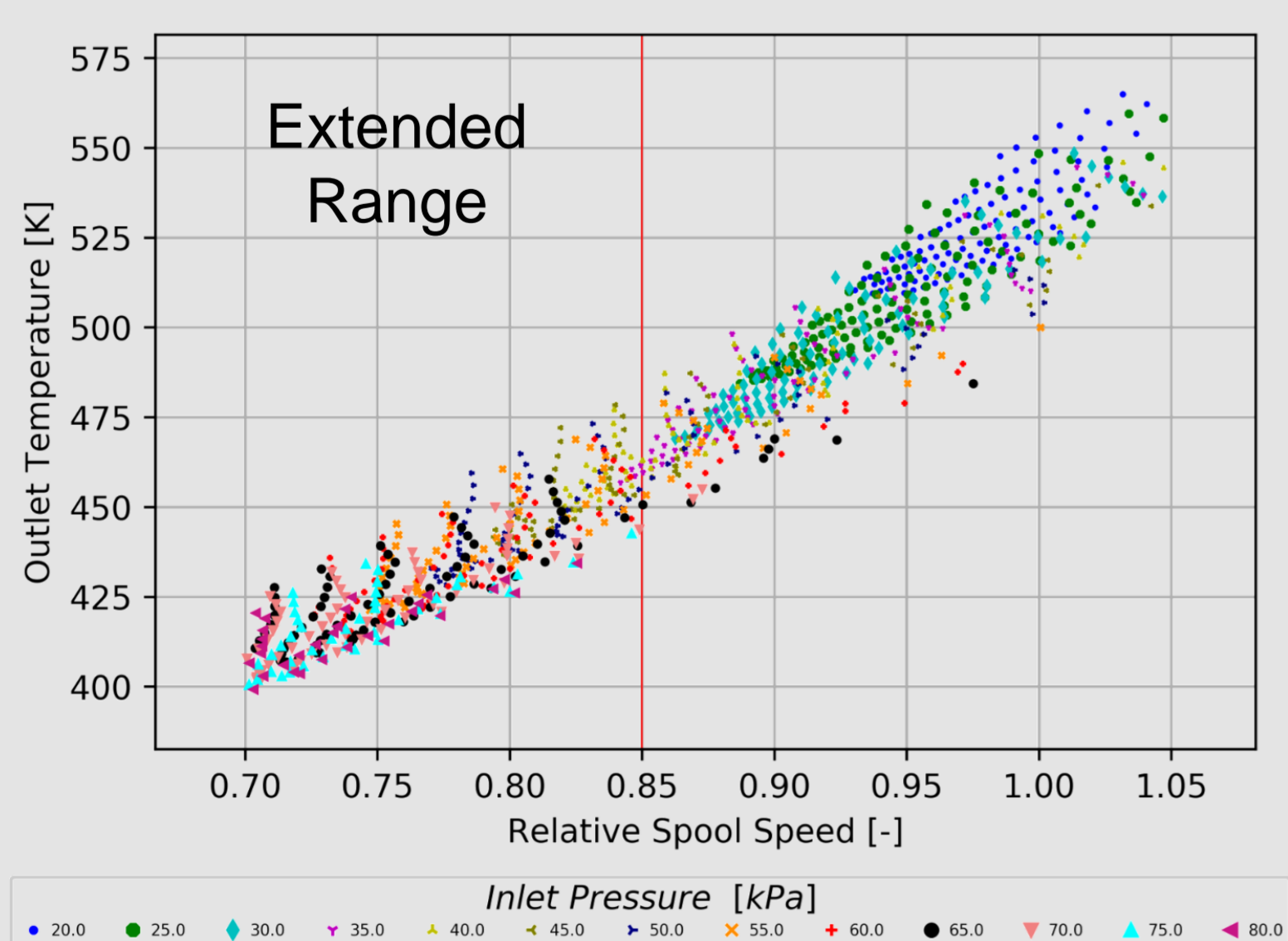


Figure 4: Simulation of the compressor unit with extended spool speed range

Topics and characteristics:

- Aerodynamic investigations of high-, intermediate- or low-pressure turbines
- Simulation of cooling (realistic density ratio)
- Application of combustor simulators (combustor-turbine interaction)
- Closed circuit (Independent variation of Mach- and Reynolds-number)
- 650 temperature measuring points and 600 pressure tapings are possible
- More than a kilometer of piping
- Flow circuit with three main paths (hot and cold path, compressor bypass)
- More than 12 auxiliary units (Cooling air, drier, cooler, heater, etc.)

Main performance data:

- Gear compressor (3 stages, pressure ratio ≤ 14 , mass flow ≤ 10 kg/s)
 - One or two-shaft turbine configurations up to $2\frac{1}{2}$ stages
 - Turbine inlet pressure ≤ 195 kPa
 - Turbine inlet temperature ≤ 540 K
 - Turbine shaft power $\leq 1,800 / 1,000$ kW (1st / 2nd shaft)
 - Turbine speed $\leq 8,000 / 13,000$ RPM (1st / 2nd shaft)
 - Turbine tip diameter ≤ 900 mm
 - Cooling air supply: (≤ 450 kPa, ≤ 2 kg/s)
- ⇒ Feasibility of parameter combinations needs to be pre-checked

Why is a virtual representation needed?

- Prediction of operating states and feasible operation conditions for future rig tests
- Optimization of the operational performance:
 - Reduce power and auxiliary media consumption
 - Improve process stability
 - Increase testing time
 - Reduce operating cost
- Assessment of cycle modifications, for instance, how is it possible to:
 - Reduce the compressor outlet temperature?
 - Reach lower turbine pressure ratios?
 - Optimize the use of water cooler and electric heater?

Approach via the Gas Turbine Laboratory (GTlab)

Interactive environment for preliminary design and simulation of aero engines and stationary gas turbines

- DLR in-house developed plugin-based software framework with GUI
- Platform independent
- High modularity for the extension of different functionalities
- Central data model as a basis for the exchange of input and output data
- Initial developed for open cycle simulations ⇒ Adaption for closed circuit are now integrated

Virtualization:

- Digital representations of the thermodynamic behavior for the main components (Fig. 3)
 - Compressor
 - Water cooler
 - Electric heater
 - Different valves and piping elements
- Thermodynamic synthesis of the performance components and adaption of the existing models for steady state simulations

Application:

- Sufficient agreement with manufacturer component calculations and measurement data at compressor design points
- Quantification of control variable influences for certain operating points through parameter studies in consideration of given test bench limits
- Compressor simulation shows the potential of lower spool speeds to reach needed lower outlet temperatures and turbine pressure ratios (Fig. 4) ⇒ Leads to realized implementation
- Comparison with real compressor measurement data shows deviations at off-design conditions ⇒ Create compressor maps based on continually growing measurement data

Outlook:

- Completing the compressor map generation
- Validate simulations to further measurement data
- Implement transient calculation methods (facility heating up and cooling down)
- Increase the level of details in the simulations

Contact: