Precise modeling of design point performance for a UAV turboprop engine, under constraints of GasTurb software

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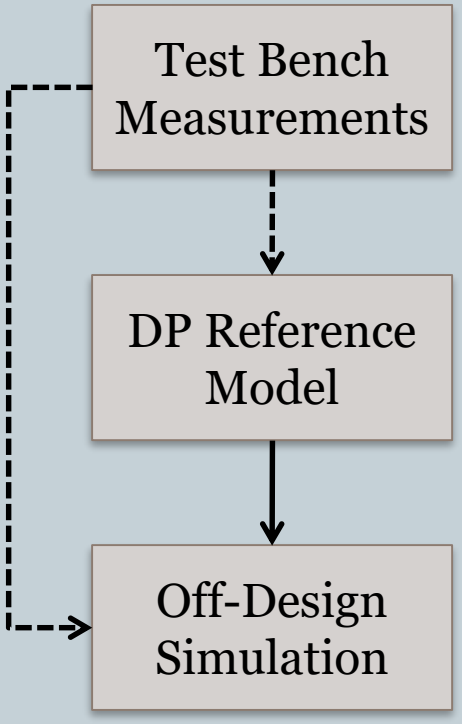
Outline

- Motivation
- Methodology steps
- First constraint: template selection
- Second constraint: cooling system representation
- Design point modeling
- Simulation results

Motivation

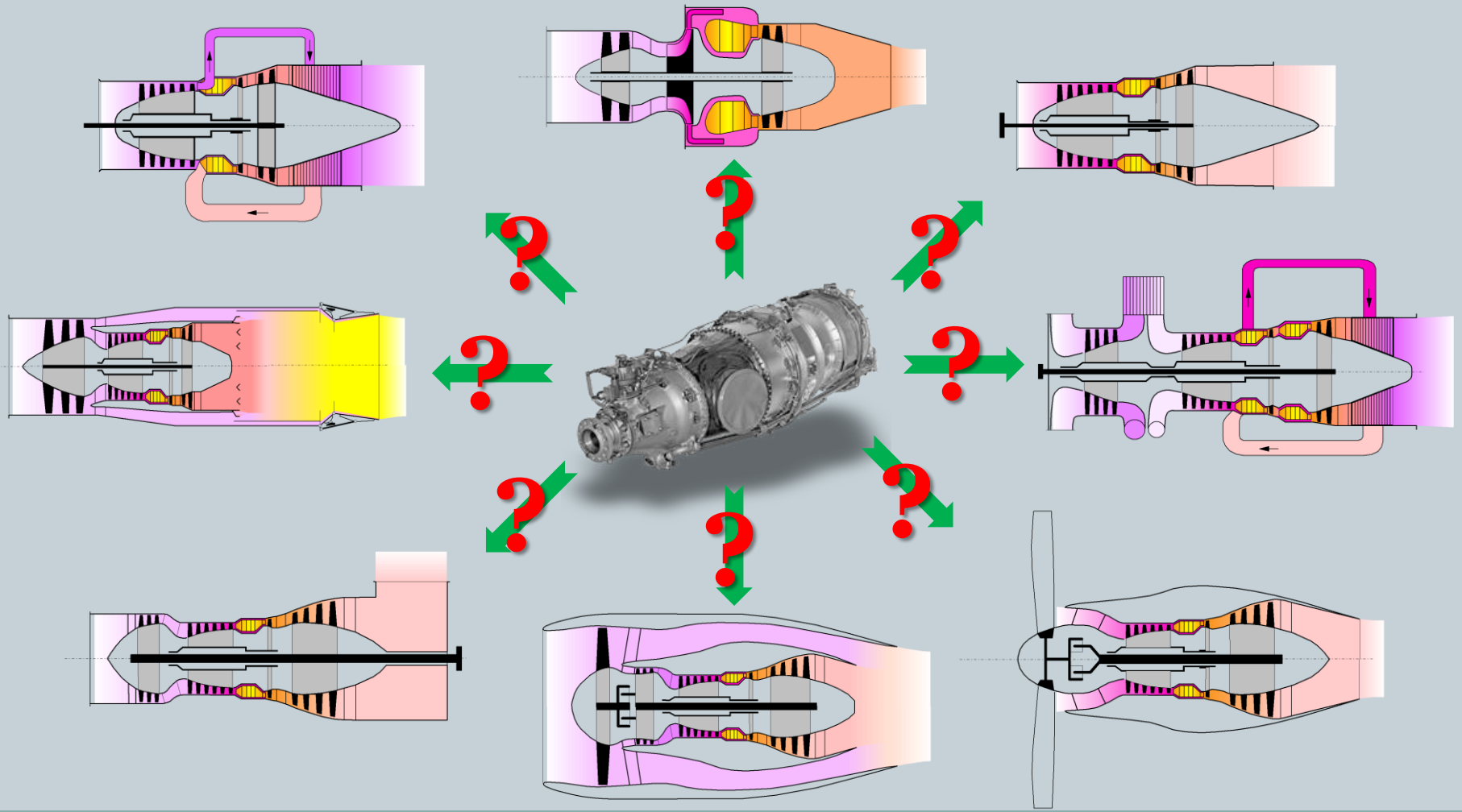
- Evaluate the benefits of adding a heat exchanger to an existing PT6A-67A engine.
  - Compose an off-design simulation using GasTurb software.
  - GasTurb uses a design point model as a reference point for off-design simulation.
  - Accurate off-design simulation requires a precise model for reference point.



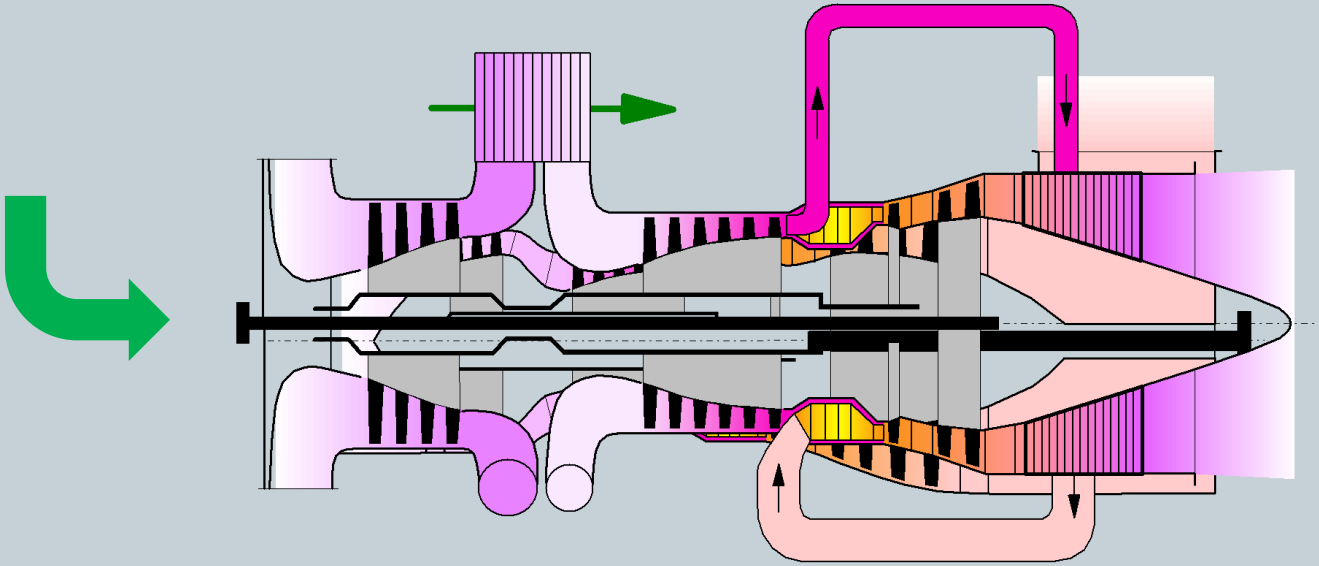
Methodology steps

- Select an appropriate engine template.
- Perform fine tuning so that the simulation results match the actual engine's performance in design point.

Template selection within GasTurb



First constraint: template selection



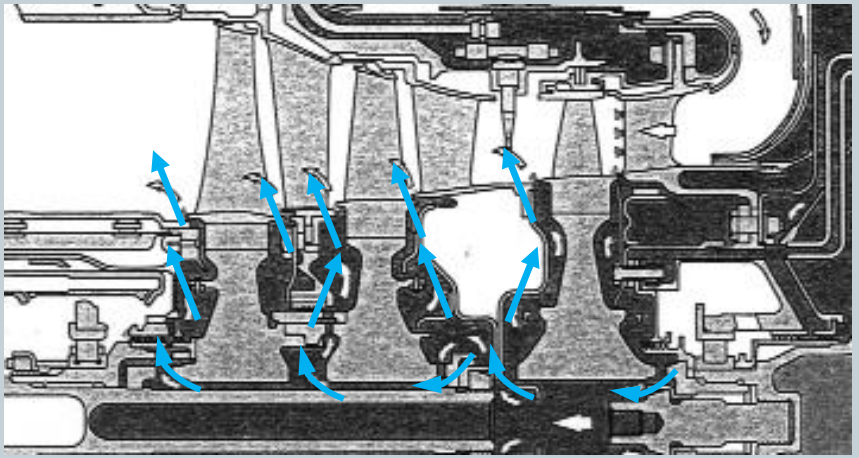
turboshaft with booster driven by HP spool

intercooled recuperated turboshaft with booster driven by HP spool

Second constraint: cooling system representation

PT6A-67A

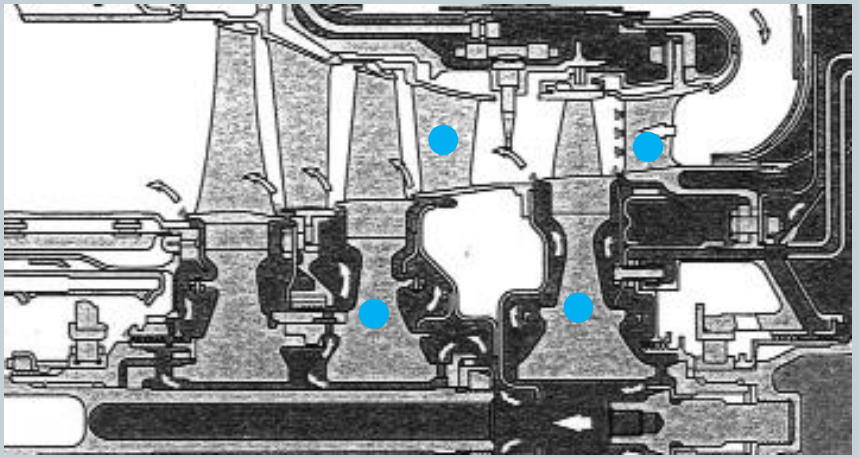
- Cooling air enters HP turbine rotor.
- Splits to 2 paths: 1st stage of PT rotor and the guide vanes.
- Splits to 2 paths: 2nd stage of PT rotor and the guide vanes.



Second constraint: cooling system representation

GasTurb

- Single value for the temperature of the cooling air.
- Has 4 fixed points for entering of the cooling air: 1) HPT GV 2)HPT Rotor 3) PT GV 4) PT Rotor



Design point modeling

- Steady state DECK software was used to generate
  - input data (forced variables)
  - comparison data (control variables)
- GasTurb was operated in the Test Analysis mode.
- Iterations mode of GasTurb was used to estimate
  - Various losses
  - Coefficients
  - Components efficiencies

Design point modeling

Calculated Values					
Output Shaft	[kWatt]	894.8026	Fuel Flow	[kg/sec]	0.085983
Net Trust	[Nt]	803.4379	PSFC	[kg/(kW*h)]	0.3459
Output Torgue	[Nt-m]	5026.309	Gas Gen. Speed	[RPM]	36204.7
A8	[m²]	0.060645	Engine Airflow	[kg/sec]	4.667466

Pressures			
Comp. Inlet P1	[kPa]	101.3253	
Interstage P2.5	[kPa]	418.8151	
Comp. Delivery P3	[kPa]	943.2441	
Exhaust P7	[kPa]	108.5579	
P2.5 Bleed (Interstage)	[kPa]	368.5592	
P3 Bleed (Comp. Del.)	[kPa]	943.2441	

Temperatures		
Comp. Inlet T1	[K]	288.15
Interstage T2.5	[K]	464.48
Comp. Delivery T3	[K]	610.38
EGT T7	[K]	823.03
ITT	[K]	993.61

Pressure Ratios		
P2.5 / P1		4.13337
P3 / P1		9.30909
P7 / Pamb		1.0714
P2.5 Bleed/ P1		3.63736
P3 Bleed/ P1		9.30909

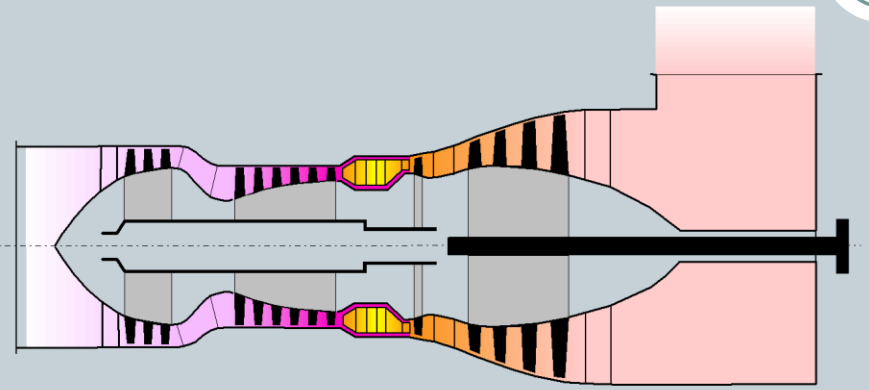
Forced variable	
Control variable	

Simulation results

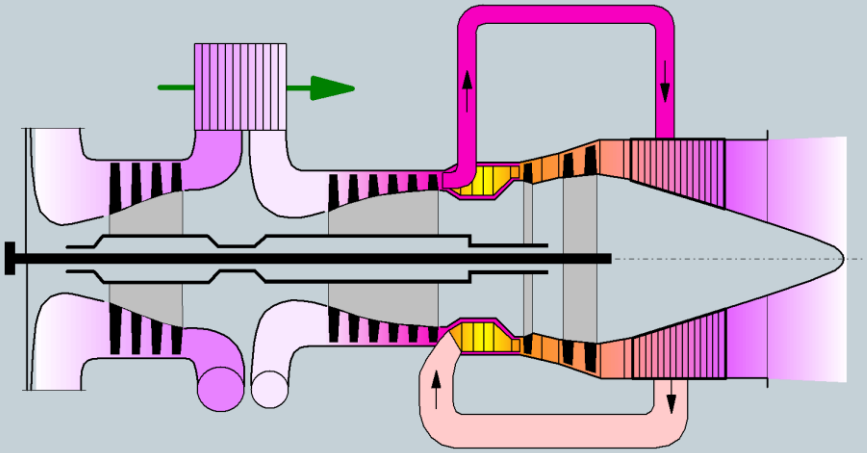
	Deck	GasTurb	Error
Output Shaft Power [kW]	894.8026	894.84	-0.0042%
Net Thrust [Nt]	803.4379	803.437	0.0001%
PSFC [kg/(kW*h)]	0.3459	0.3459	0.0000%
Wf [kg/sec]	0.085983	0.085983	0.0006%
A8 [m²]	0.060645	0.060645	0.0002%
R8 [m]	0.138939	0.138938	0.0001%
Wa [kg/sec]	4.667	4.667	0.0000%
NG [RPM]	36204.7	36204	0.0019%
P02 [Kpa]	101.325	101.325	0.0000%
P025 [kPa]	418.82	418.81	0.0012%
P03 [kPa]	943.24	943.24	0.0000%
P08 [kPa]	108.56	108.552	0.0074%
T02 [K]	288.15	288.15	0.0000%
T025 [K]	464.48	464.48	0.0000%
T03 [K]	610.38	610.38	0.0000%
T045 [K]	993.61	993.61	0.0000%
T08 [K]	823.03	823.03	0.0000%
P03/P02	9.30909	9.30906	0.0003%
P08/Pamb	1.0714	1.07132	0.0075%

Component	Isentr. Eff.	P/P
LP Compressor	0.8243	4.218
HP Compressor	0.8033	2.252
Combustor	0.995	0.97
HP Turbine	0.8824	3.435
Power Turbine	0.8827	2.357
LP Spool Mech.	0.9779	-
HP Spool Mech.	0.9650	-

Model transformation

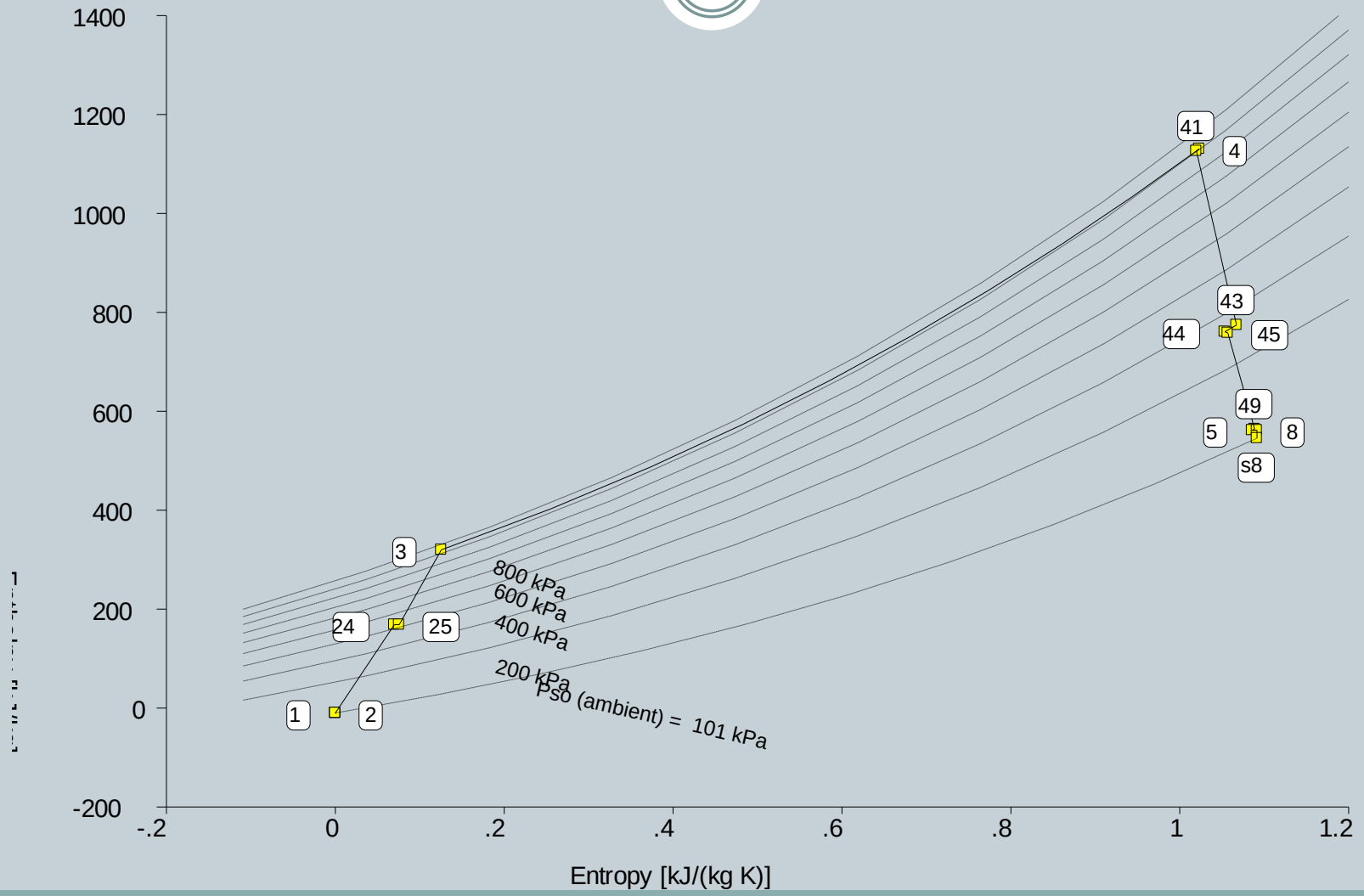


turboshaft with booster driven by HP spool



intercooled recuperated turboshaft with booster driven by HP spool

Model transformation



Summary

- A need in precise DP model with an option for the HE.
- Lack of adequate engine template in GasTurb software.
  - Usage of combination of two semi-adequate templates
- Incompatibility between the software's and the actual PT6 turbine cooling mechanism.
  - Proper adjustment of air cooling capacity
- Model adjustment with high accuracy.
- Transfer of adjusted model to the compatible template with HE option.