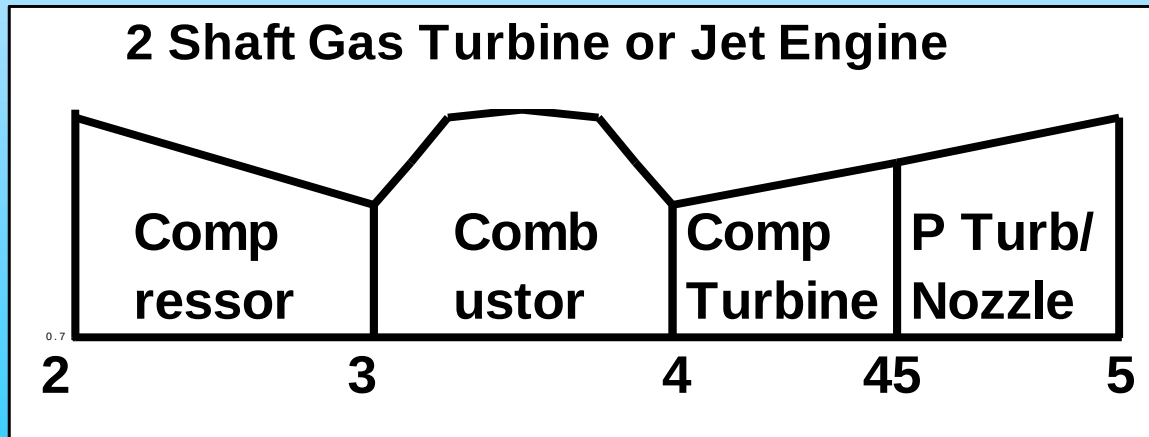
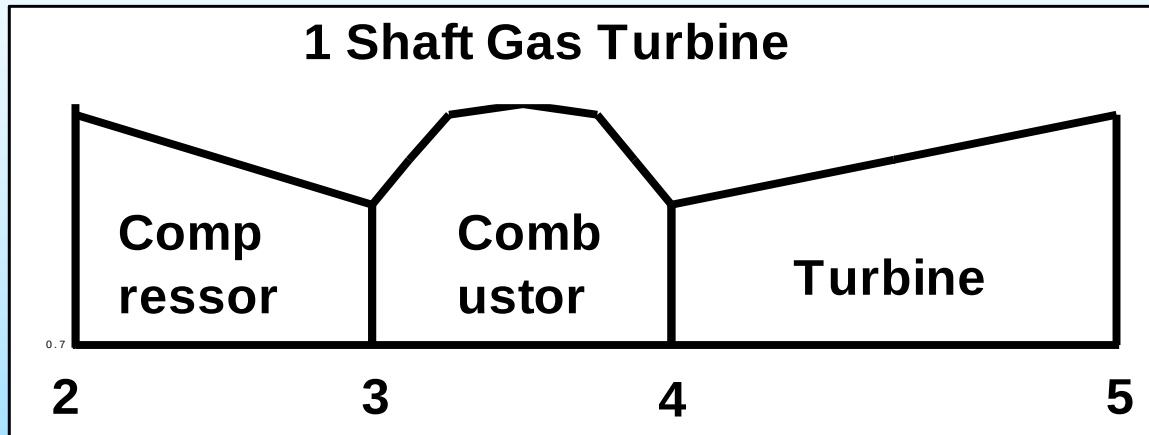


INTRODUCTION TO GAS TURBINE CONTROL

Professor Pericles Pilidis
Thermal Power & Propulsion

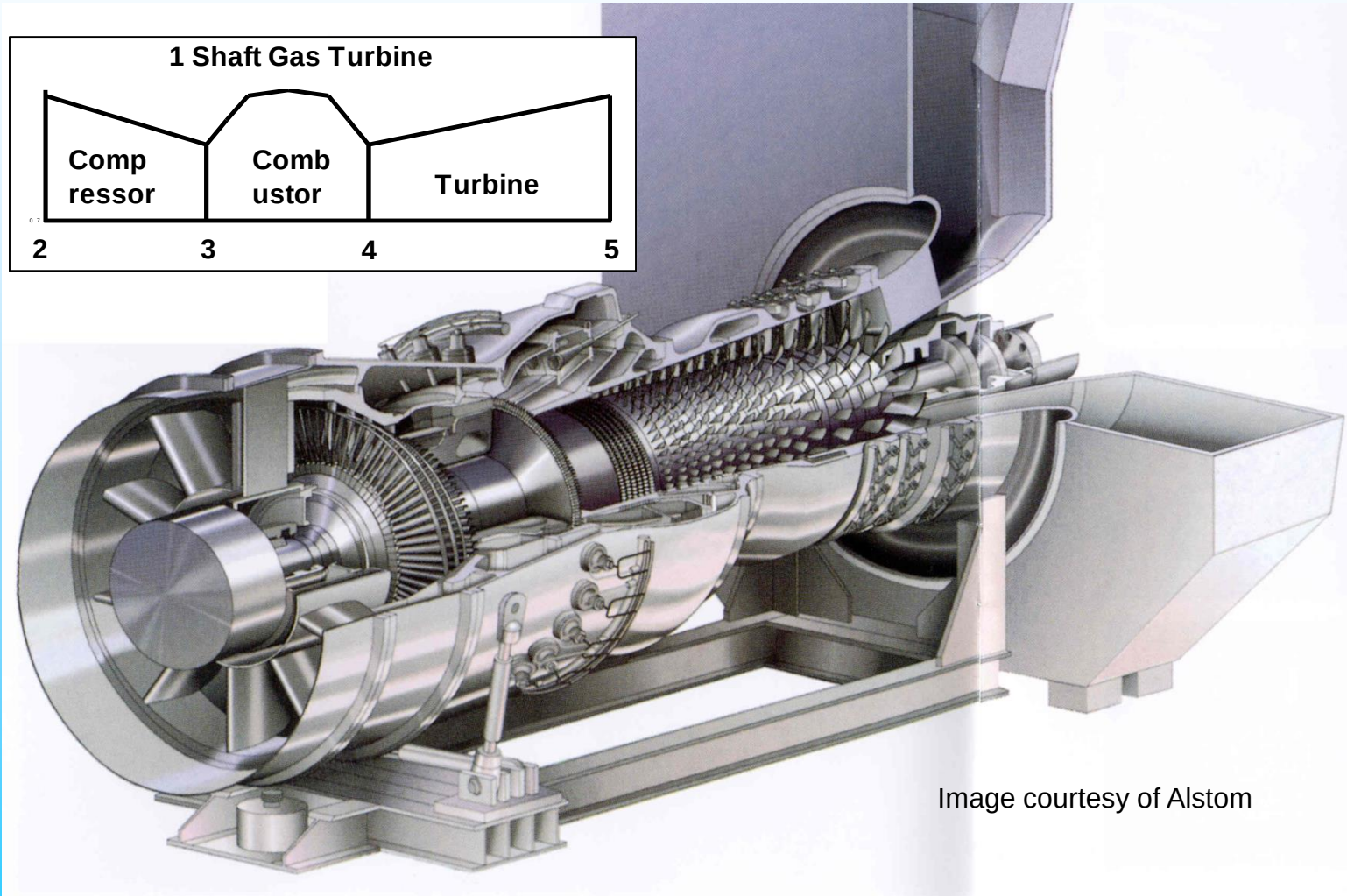
Introduction to Gas Turbine Control



**Discuss 2
Types of
Gas Turbine**

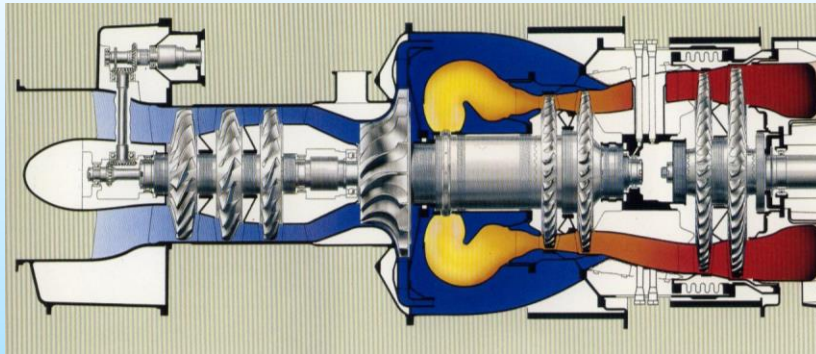
**Note Station
Numbers**

Introduction to Gas Turbine Control

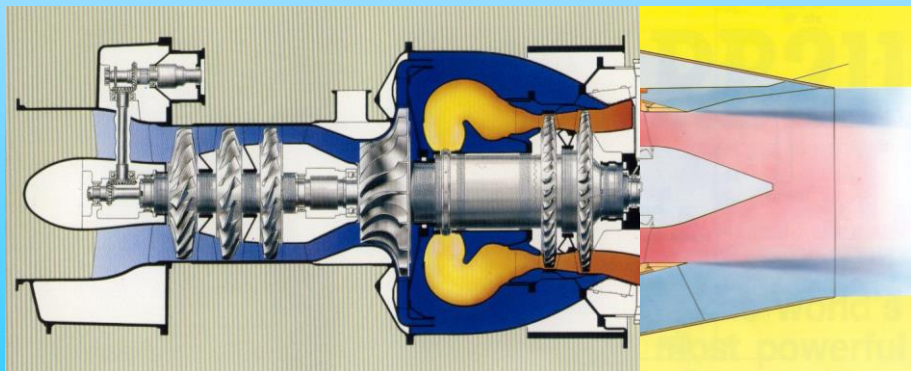


THE 2 SHAFT GT OR THE JET ENGINE

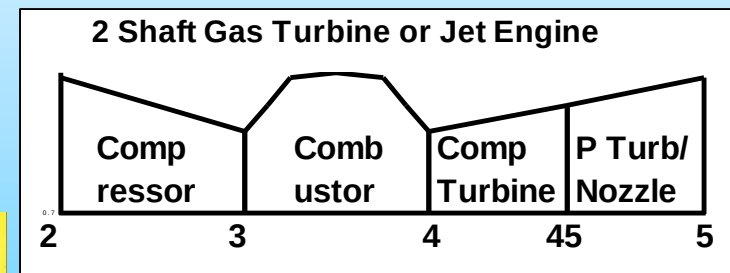
Convert Pressure Energy into Kinetic Energy



<---Gas Generator--->

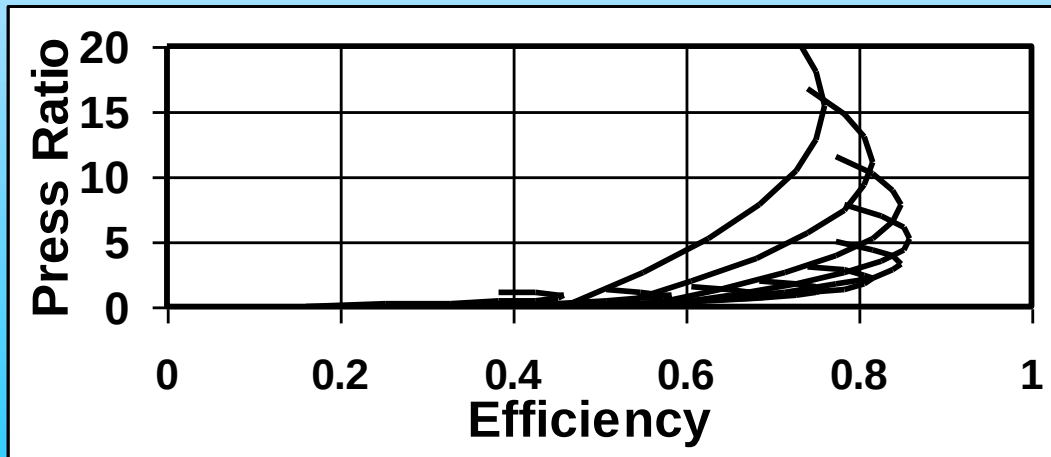
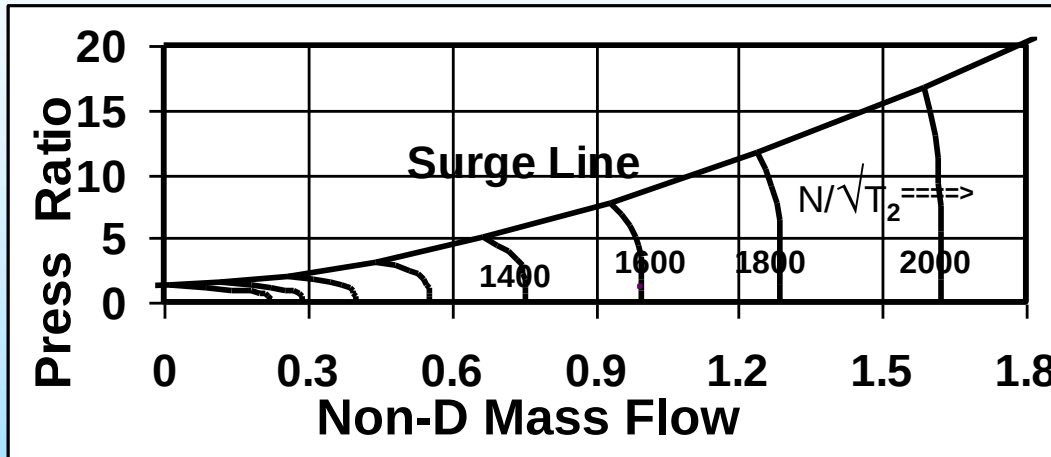


Mechanical Power
Power Turbine



Thrust
Propelling Nozzle

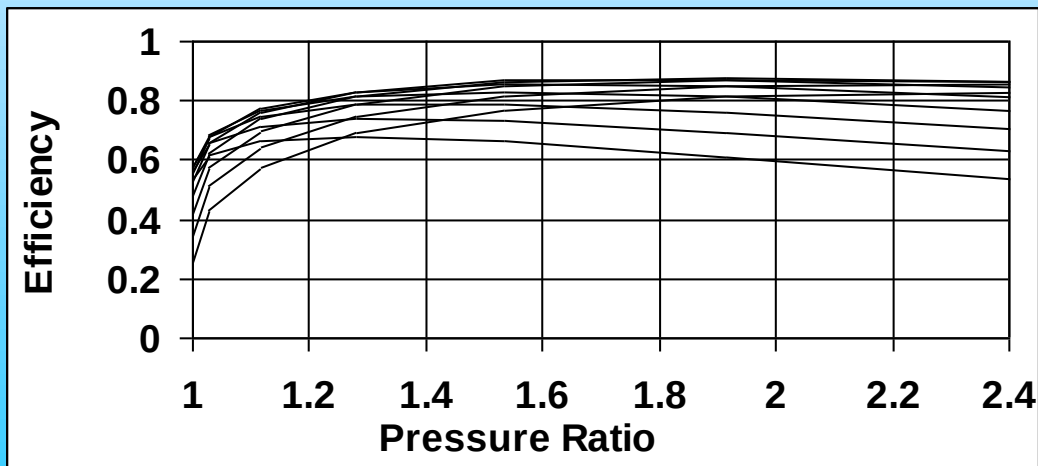
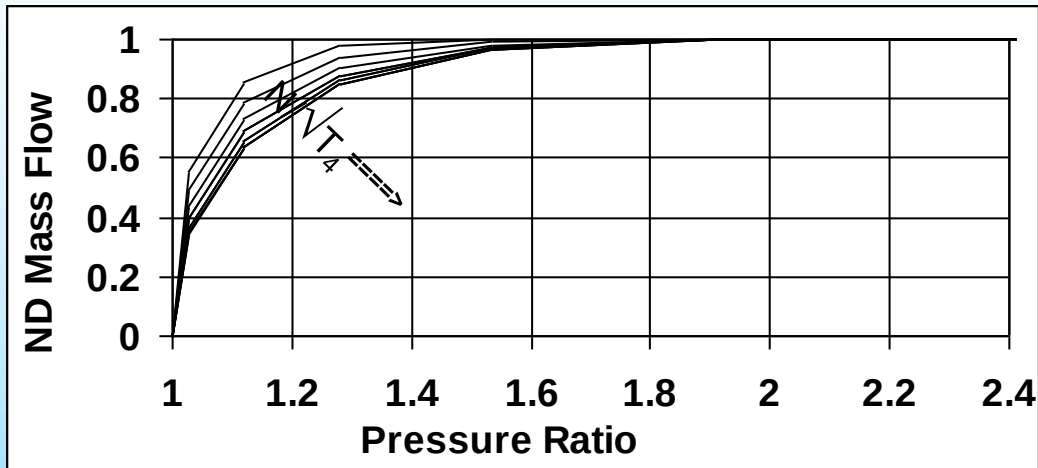
Introduction to Gas Turbine Control



**Compressor
Performance
Map or
Characteristic:
Describes
Compressor
Behaviour**

$$W_2 \sqrt{T_2/P_2}$$

Introduction to Gas Turbine Control



**Turbine
Performance
Map or
Characteristic:
Describes
Turbine
Behaviour**

$$W_4 \sqrt{T_4 / P_4}$$

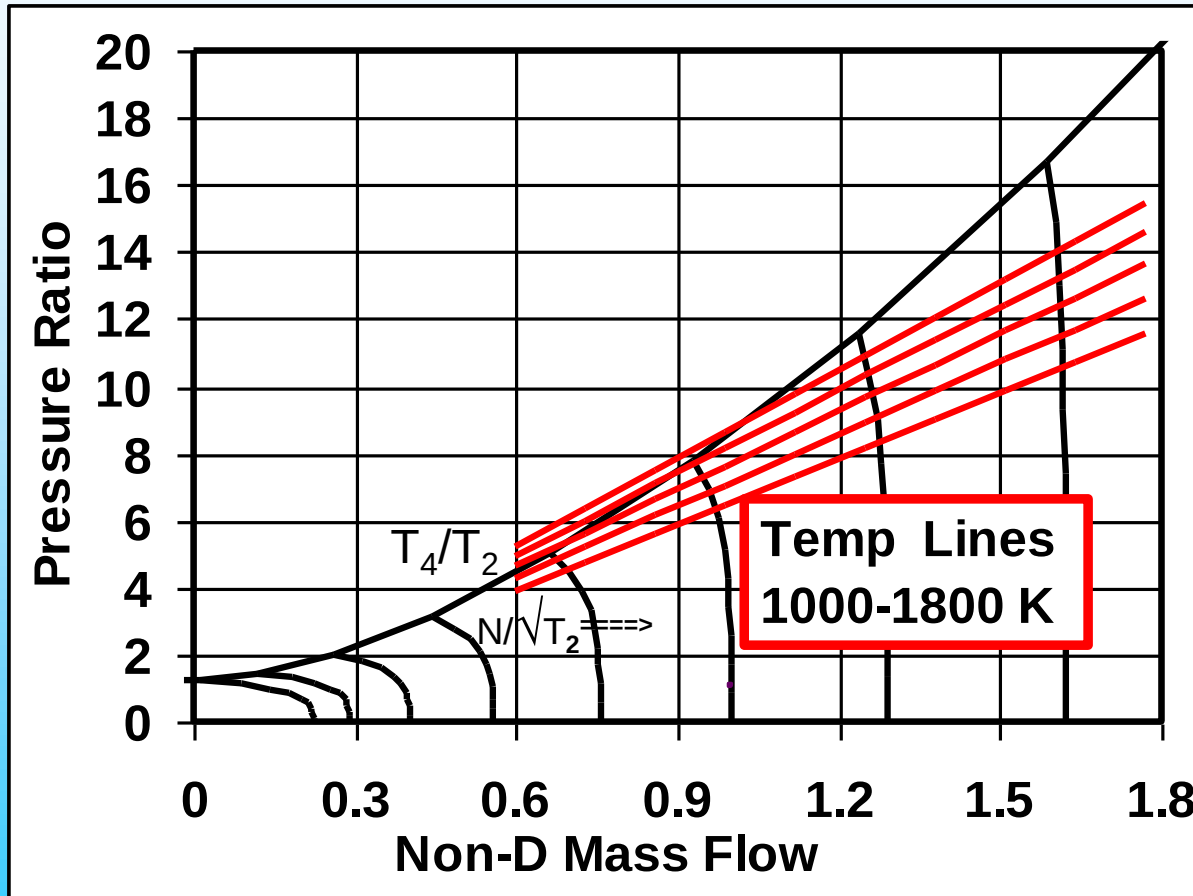
Assume Choked Turbines/Nozzles

Useful approximation, may be valid over a range of operation in some engines

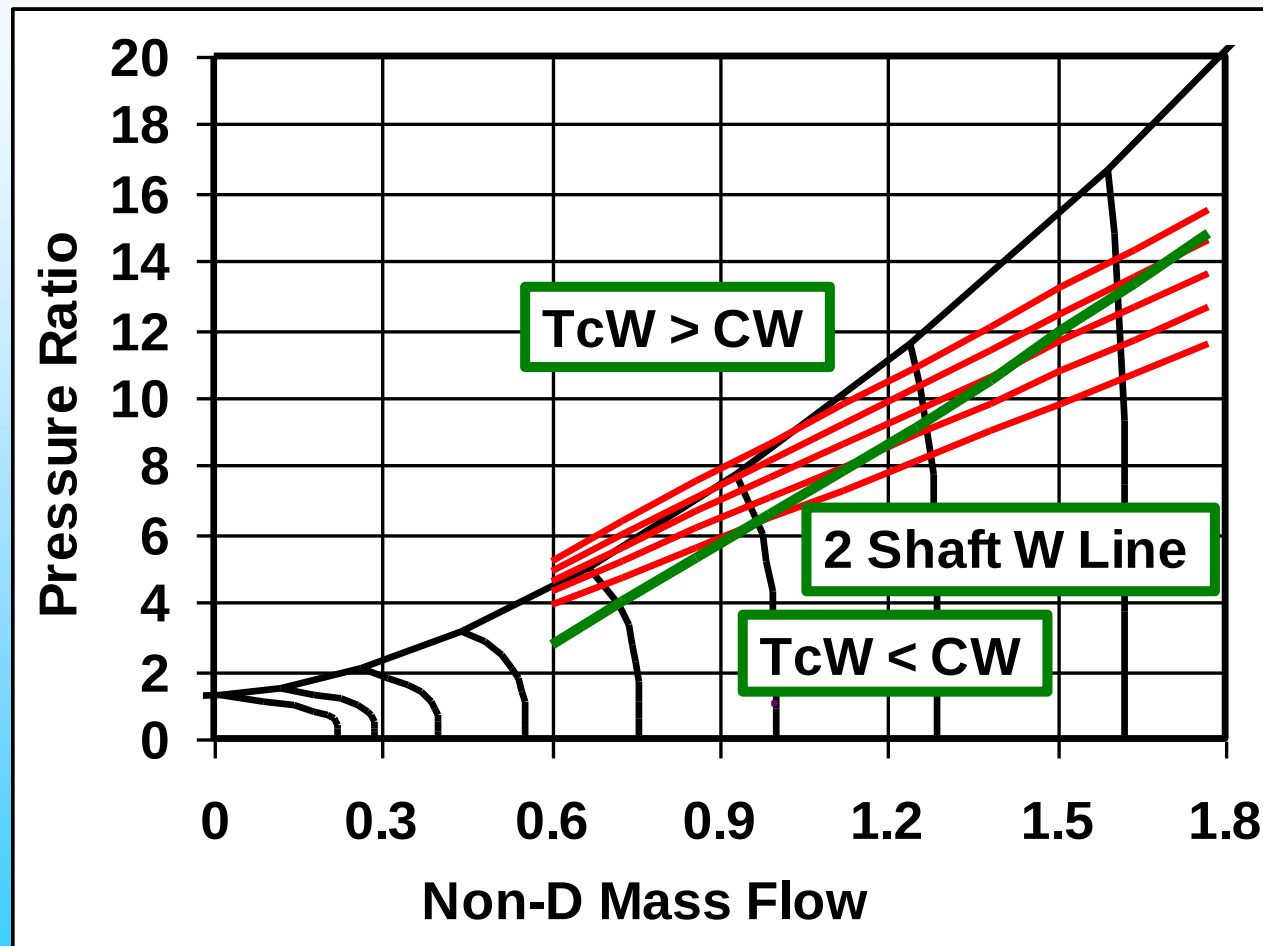
$$(WT^{0.5}/P)_4 = C_4 - \text{proportional to } A_{\text{NGV}4}$$

$$(WT^{0.5}/P)_{45} = C_{45} - \text{proportional to } A_{\text{NGV}45}$$

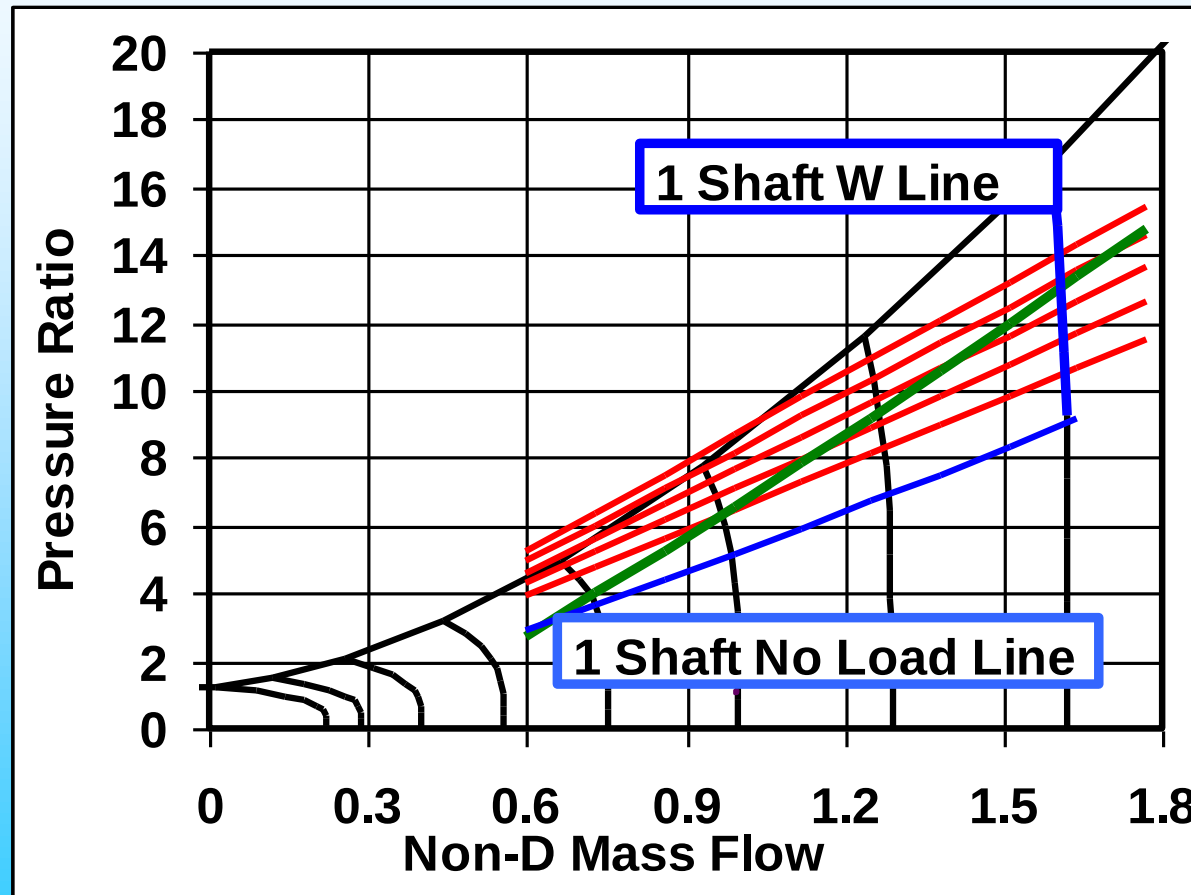
$$\text{therefore } P_4/P_{45} = C_a \quad \text{and} \quad T_4/T_{45} = C_b$$



**Constant
 T_4 lines
arising from
turbine NGV
restricting
the flow**

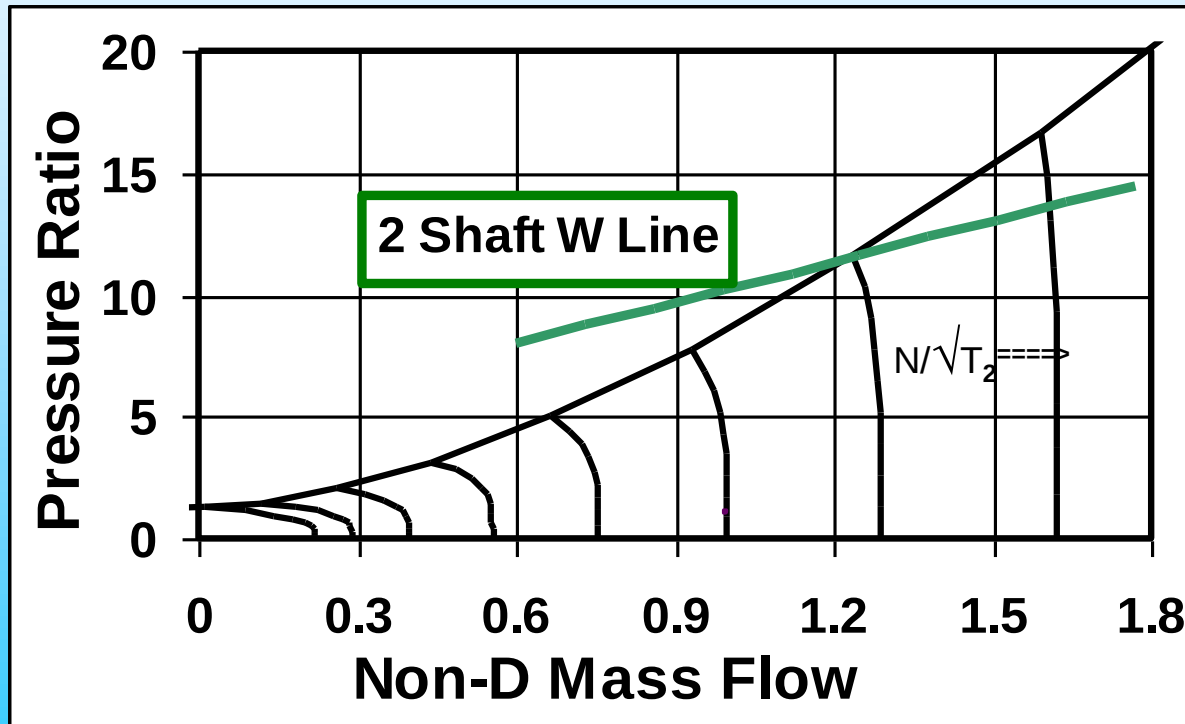


**2 Shaft
Engine
Working
Line**



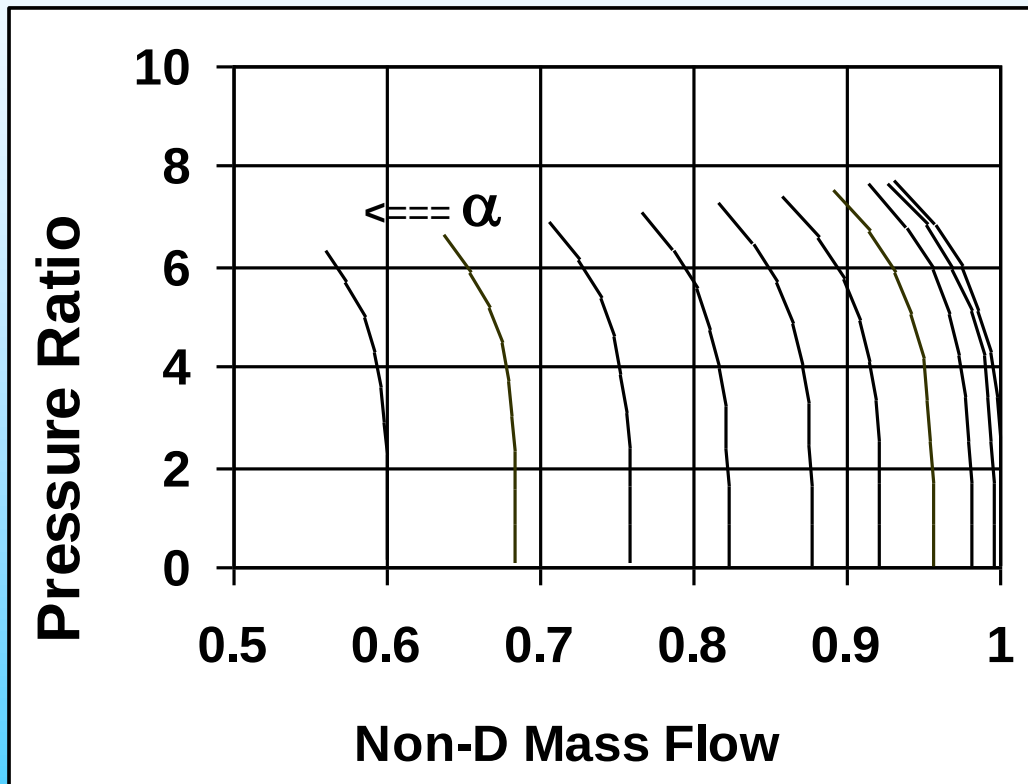
**1 Shaft
Engine
Working
Line**

WORKING LINE MISMATCH



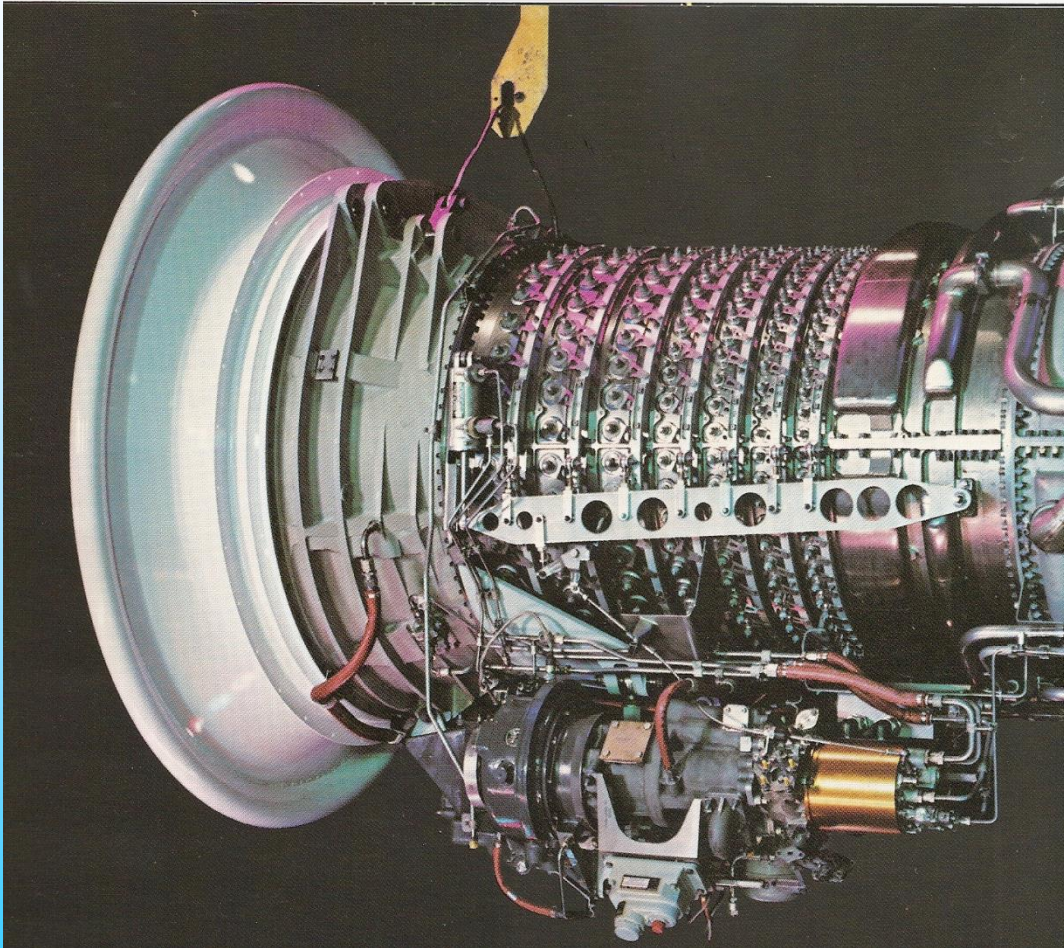
Correct With

- Var. Stators
- Bleed Valves
- V.A. Nozzles
or NGVs



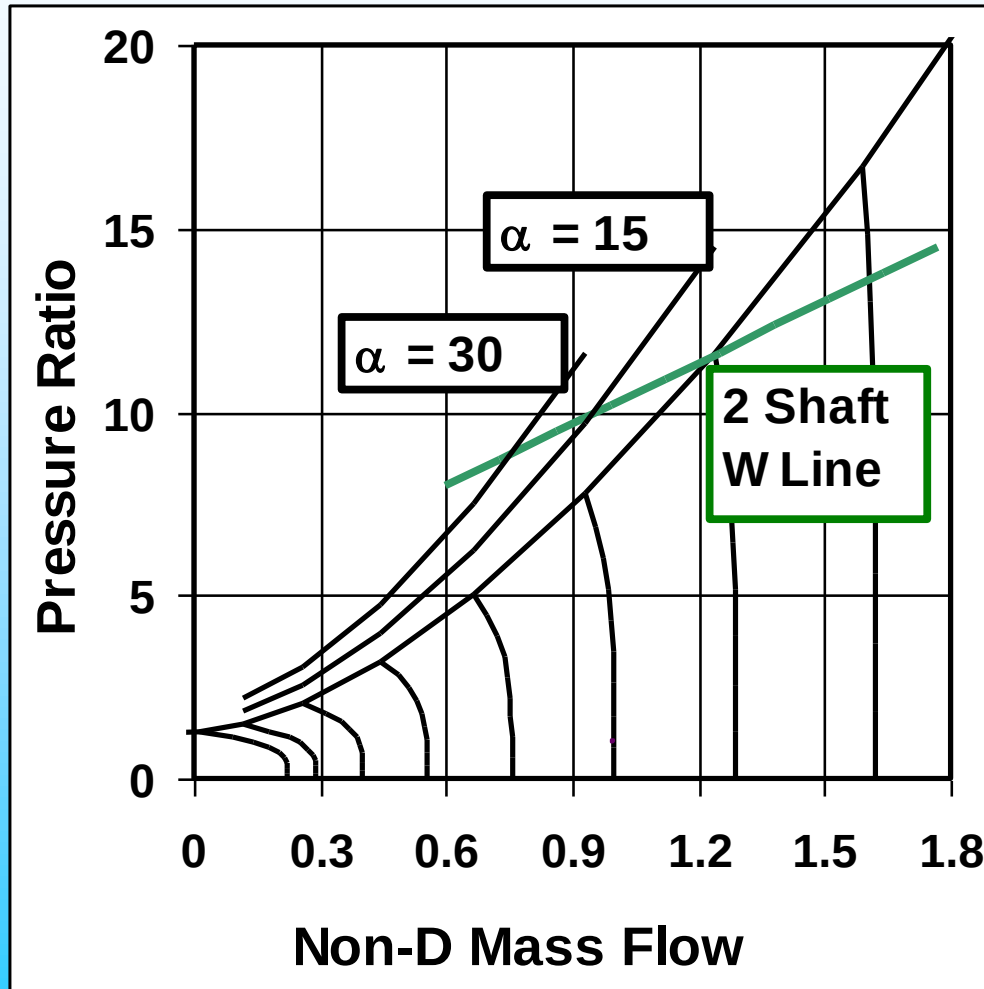
**Compressor
Variable Stators**

**Raise Surge Line
Reduce ND Mass
Flow at Constant
 $N/\sqrt{T_2}$**



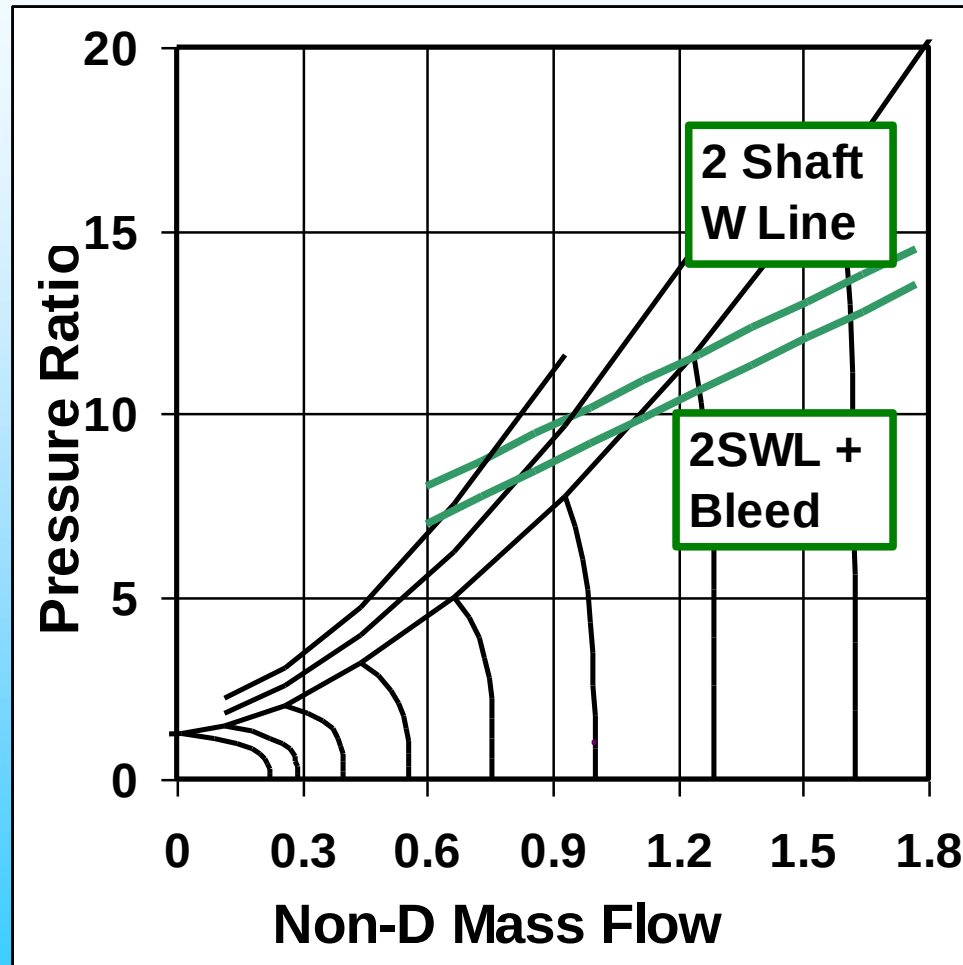
Compressor Variable Stators

Image courtesy of
General Electric



**Compressor
Variable Stators**

**Raise
Surge Line**



**Compressor
Bleed Valves**

**Lower Operating
Line**

Compressor Bleed Valves

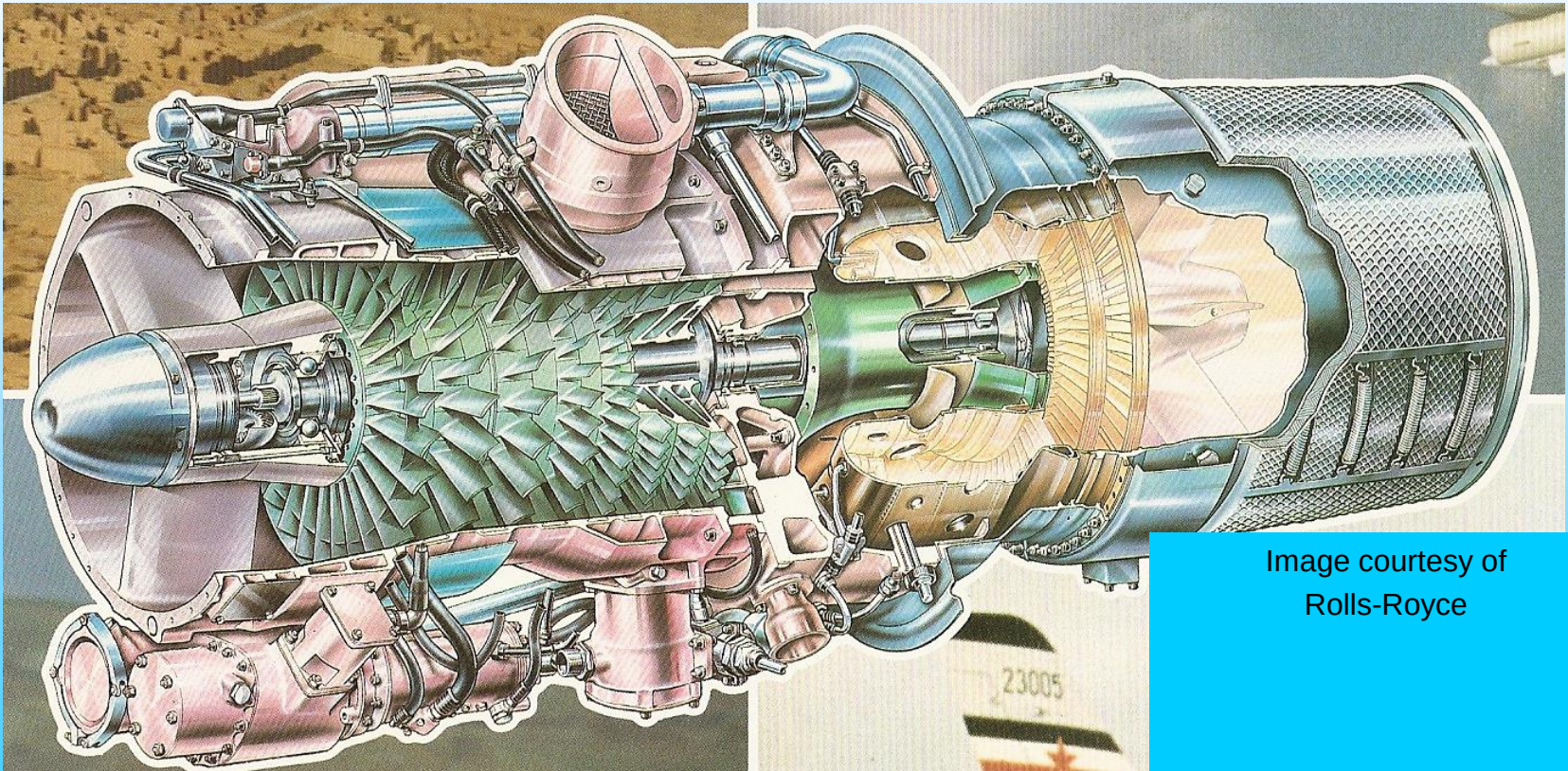
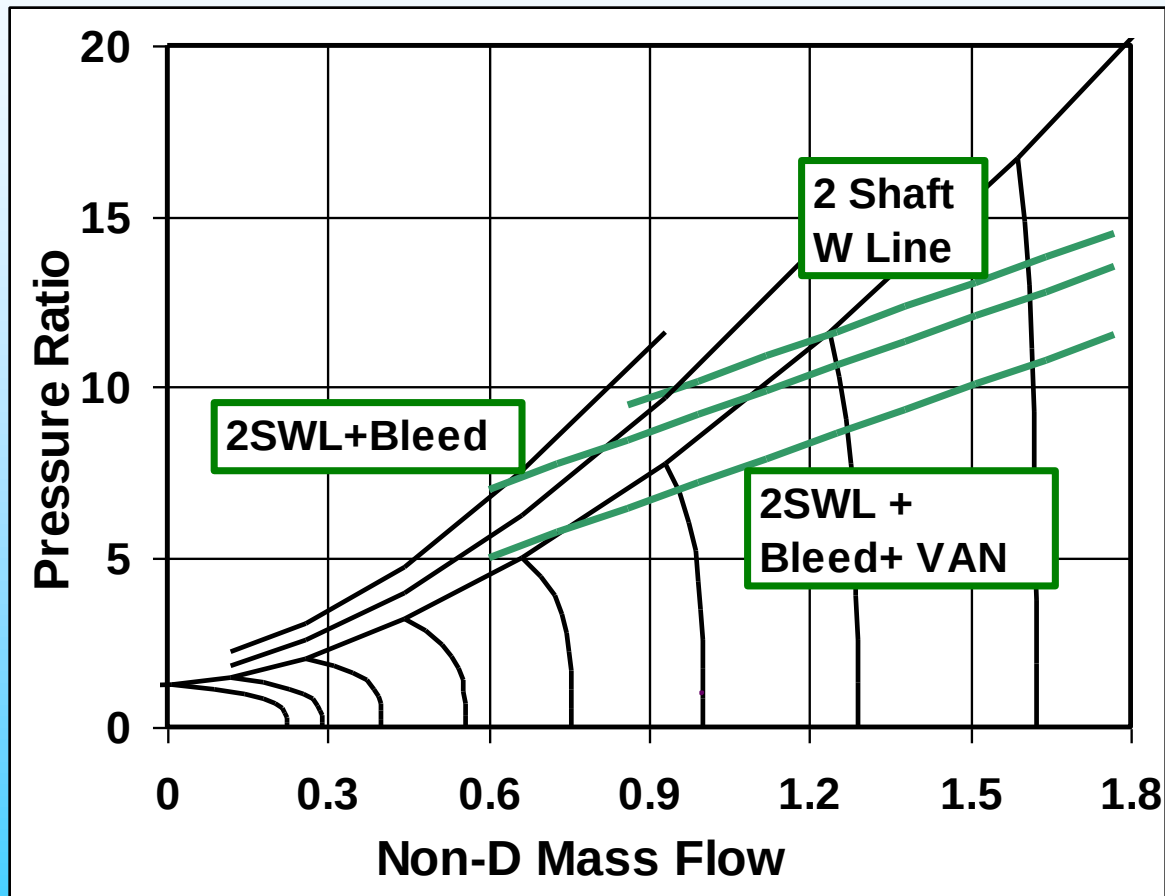
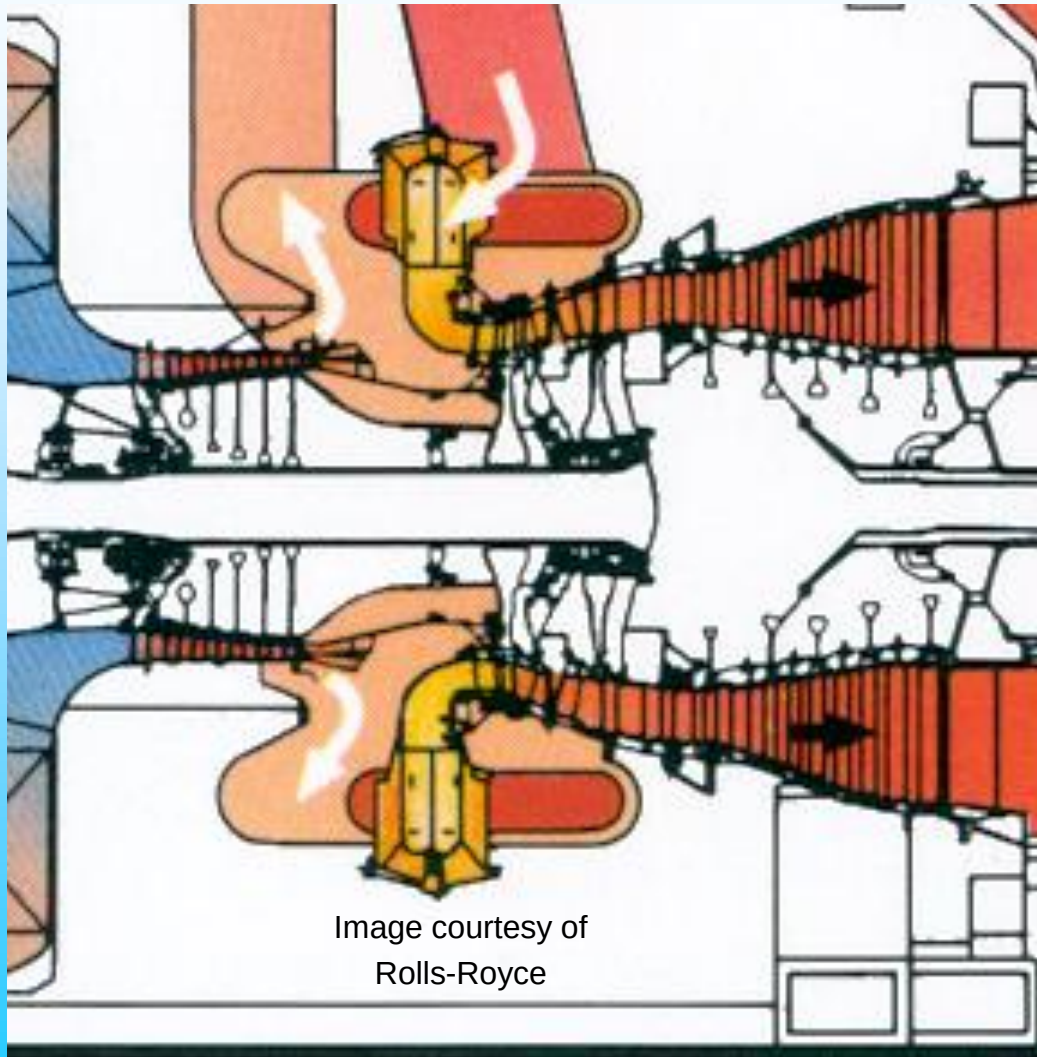


Image courtesy of
Rolls-Royce



**Variable Area
Nozzle/NGVs**

**Area increase
lowers
operating
line**



**Variable Area
Nozzle/NGVs**

**Area increase
lowers
operating
line**

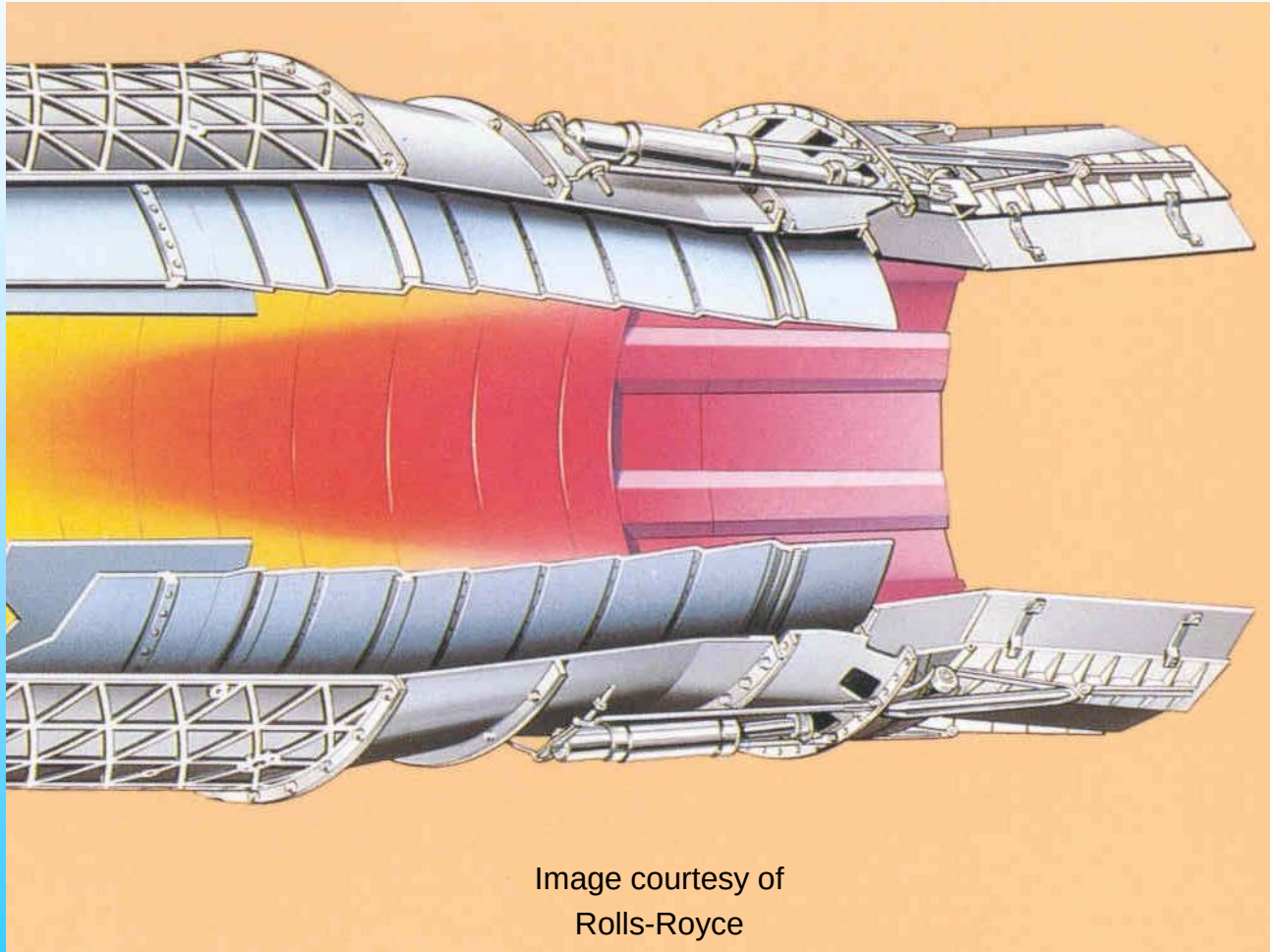


Image courtesy of
Rolls-Royce

**Variable Area
Nozzle/NGVs**

**Area increase
lowers
operating
line**

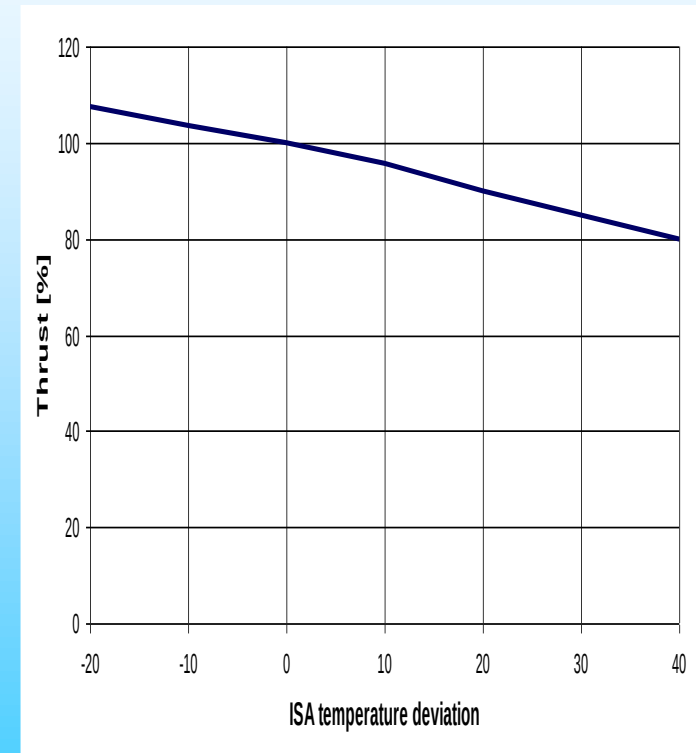
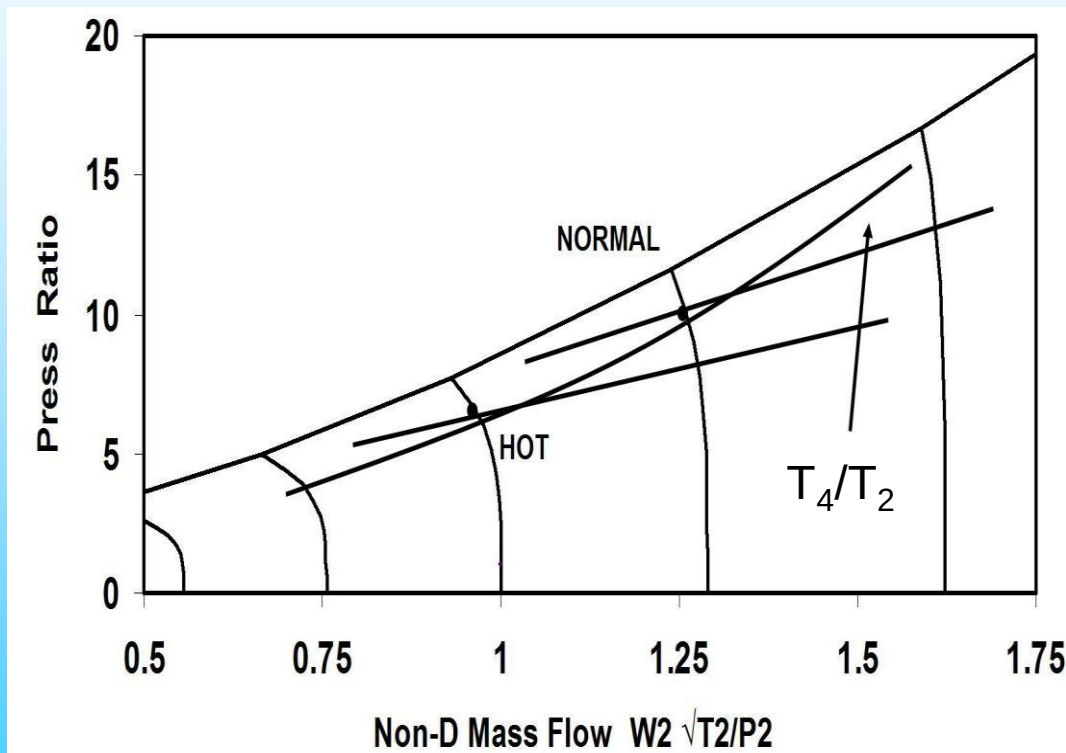
Off Design Performance

Environment Ambient Temperature
 Altitude
 Flight Speed
Power Setting

Transient Performance

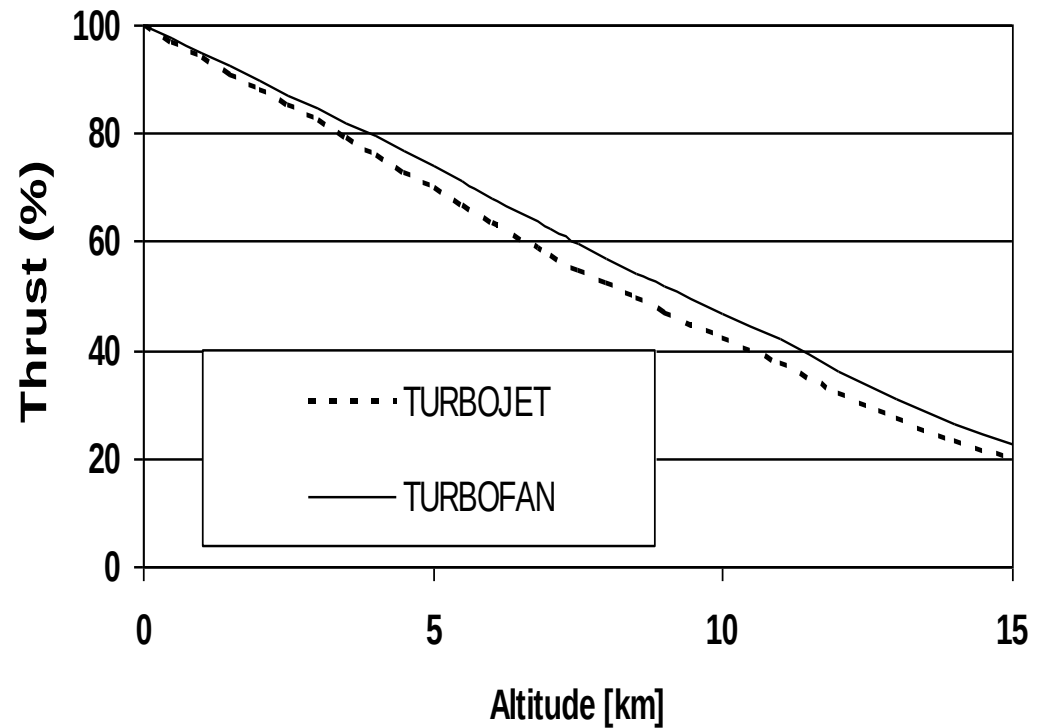
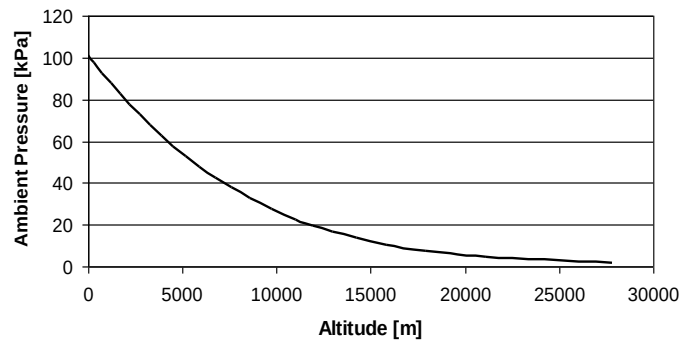
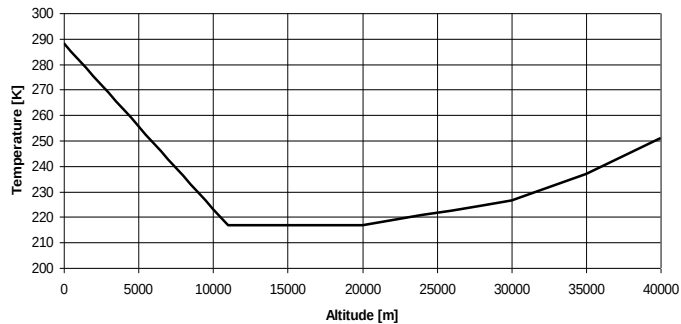
Change in Power Setting

Off Design Performance - Ambient Temperature

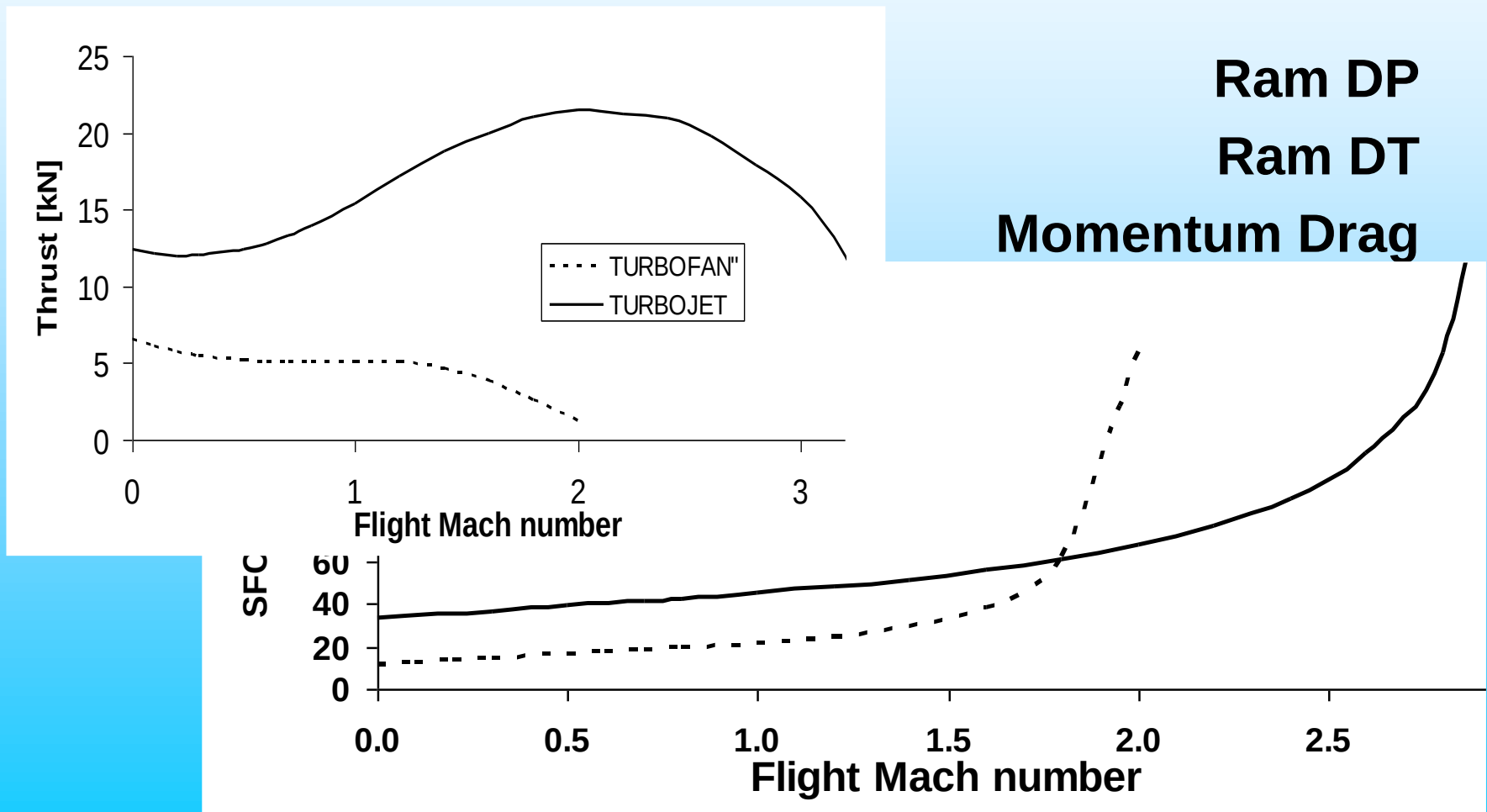


Off Design Performance - Altitude

Variation of ambient temperature



Off Design Performance - Flight Speed



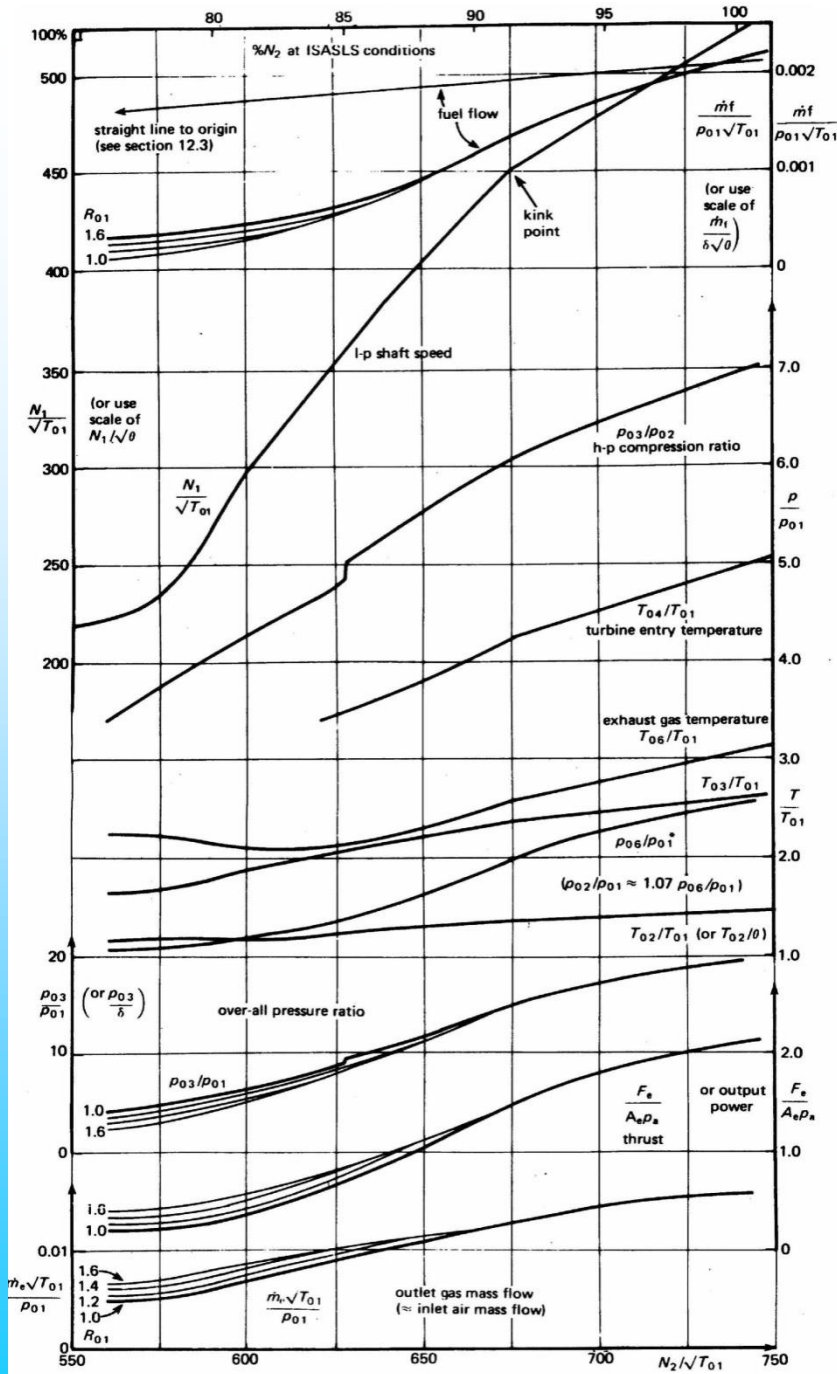
Introduction to Gas Turbine Control

Off Design Performance - Effect of Power Setting

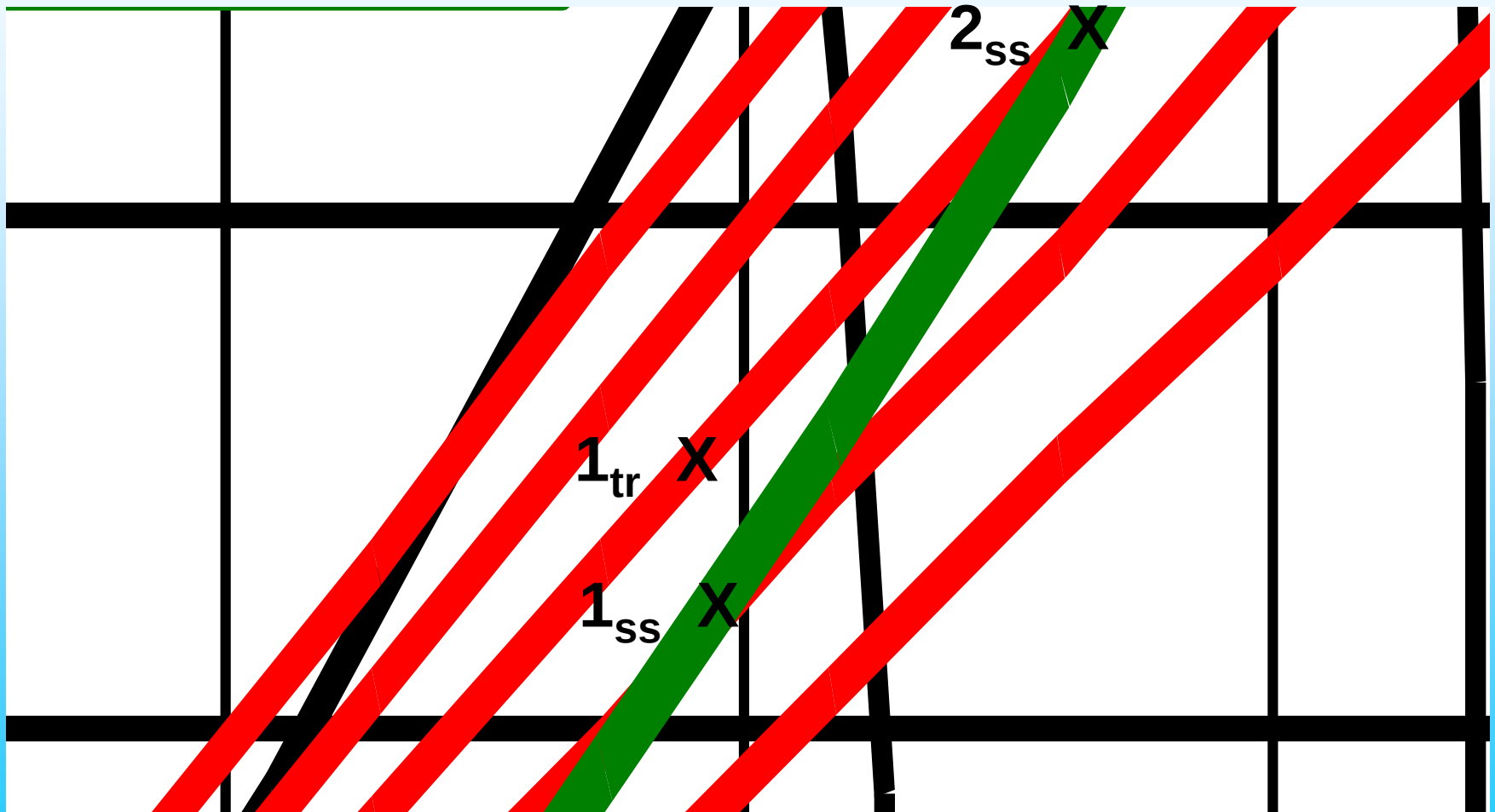
From:

Hartman R. T. C, Gas Turbine Engineering, Applications, Cycles, Characteristics.

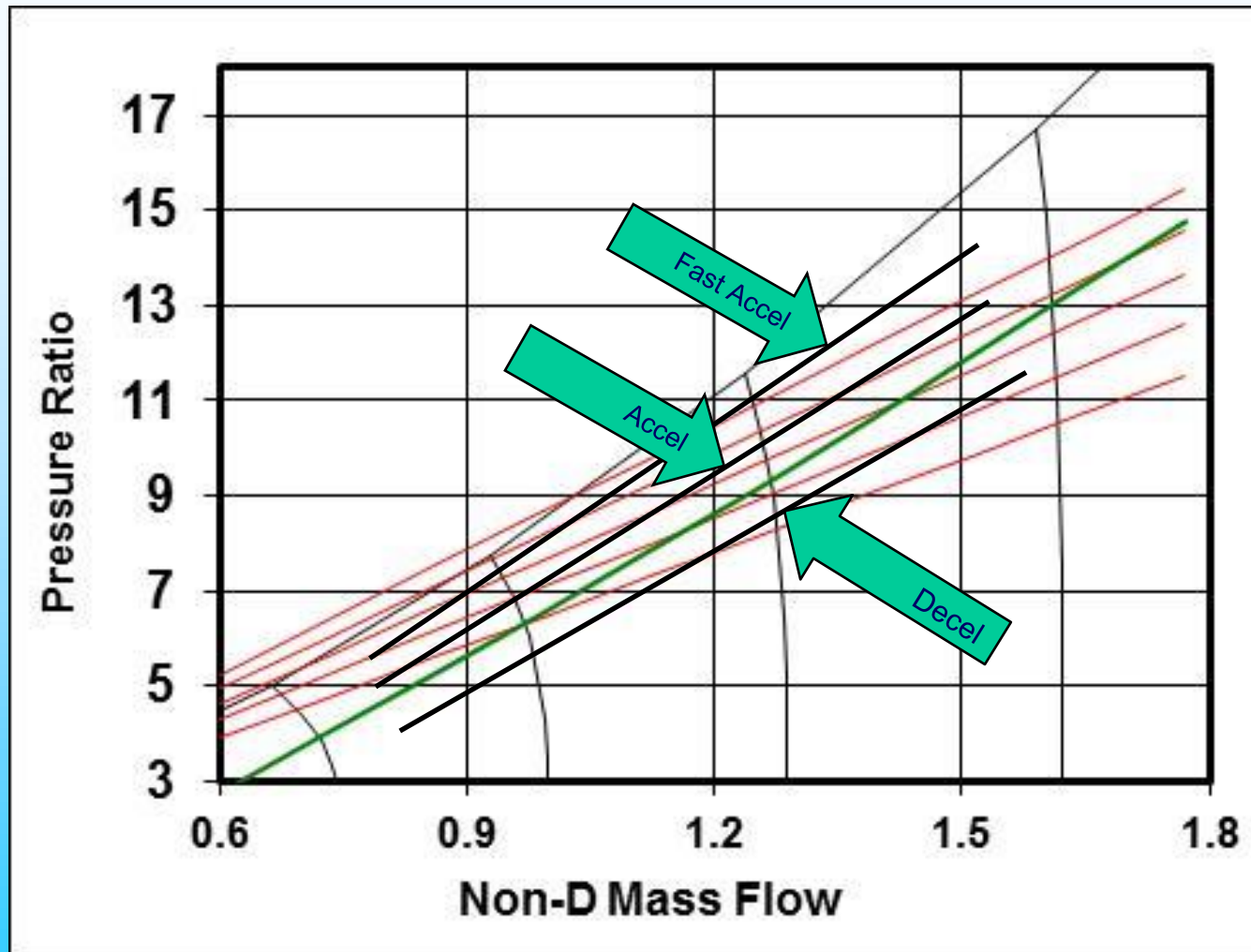
The MacMillan Press LTD, London and Basingstoke



Transient Performance



Transient Operating Lines



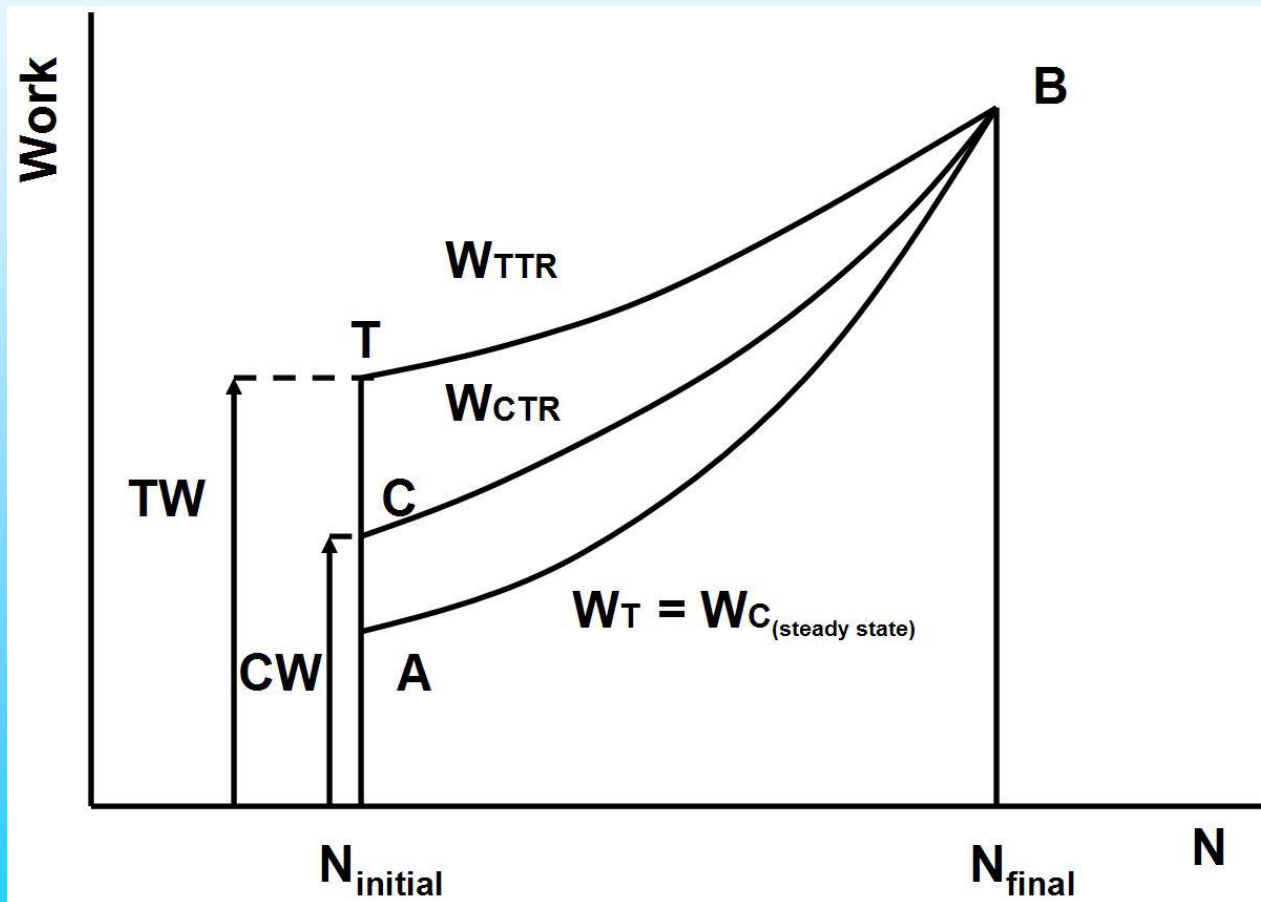
Fuel Schedules

Transient Performance

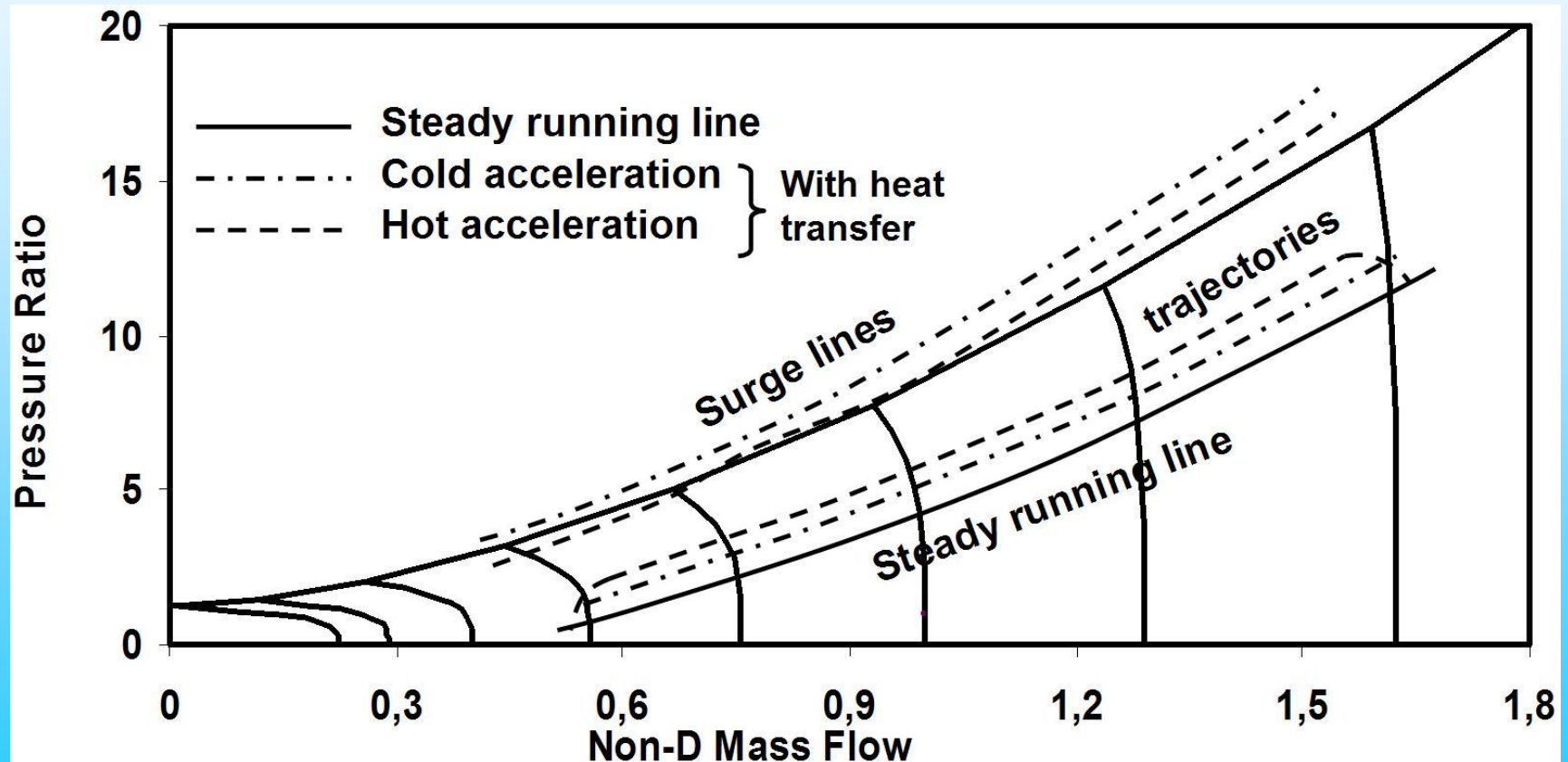
$$TW = W_4 \, Cp_4 \, T_4 \, (1 - T_{45}/T_4)$$

$$CW = W_2 \, Cp_2 \, T_2 \, (T_3/T_2 - 1)$$

Transient Performance



Transient Performance

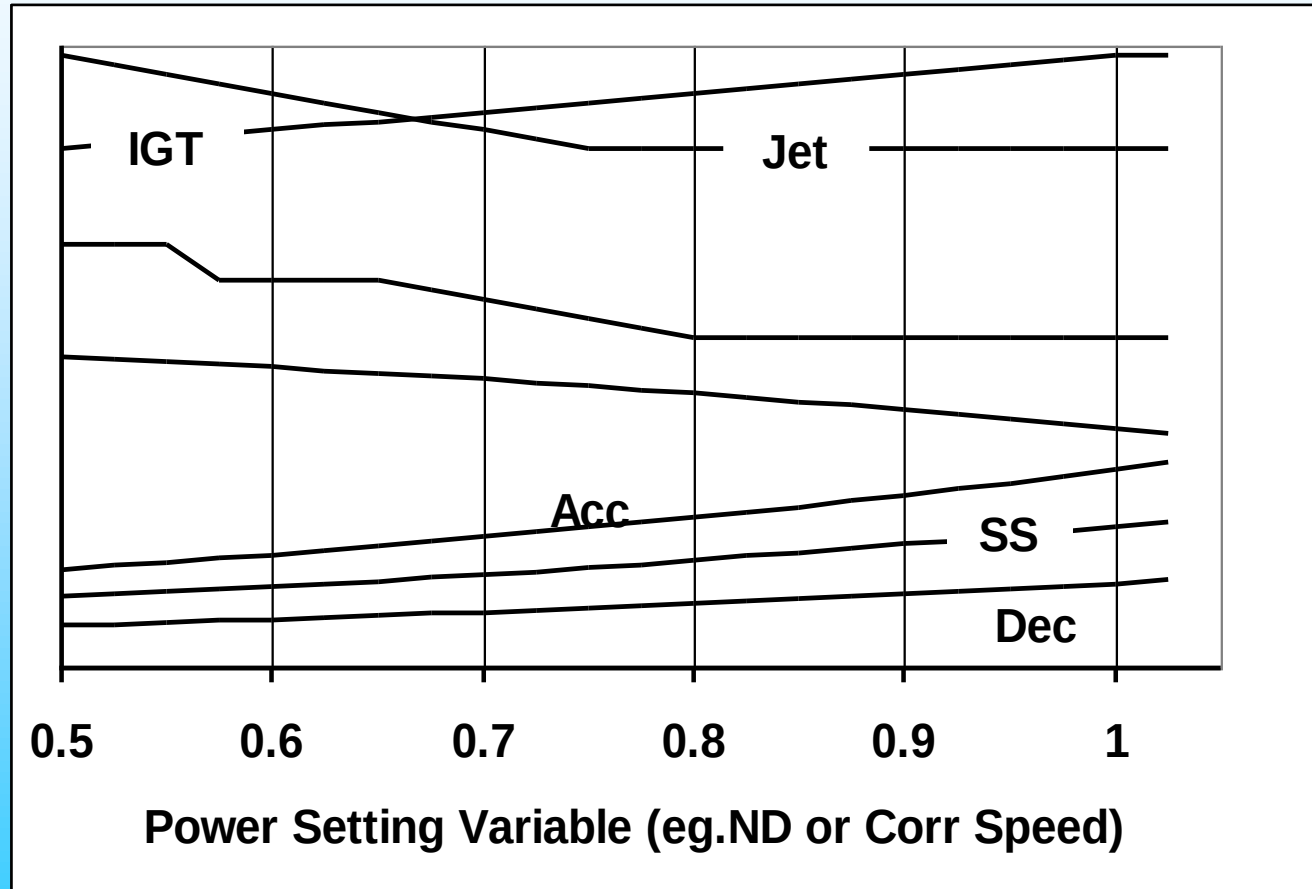


**Variable Area
Nozzle/NGVs**

Bleed Valves

Var. Stators

Fuel Flow



In addition
the control
system has
to ensure
the engine
is operating
within
suitable
limits

