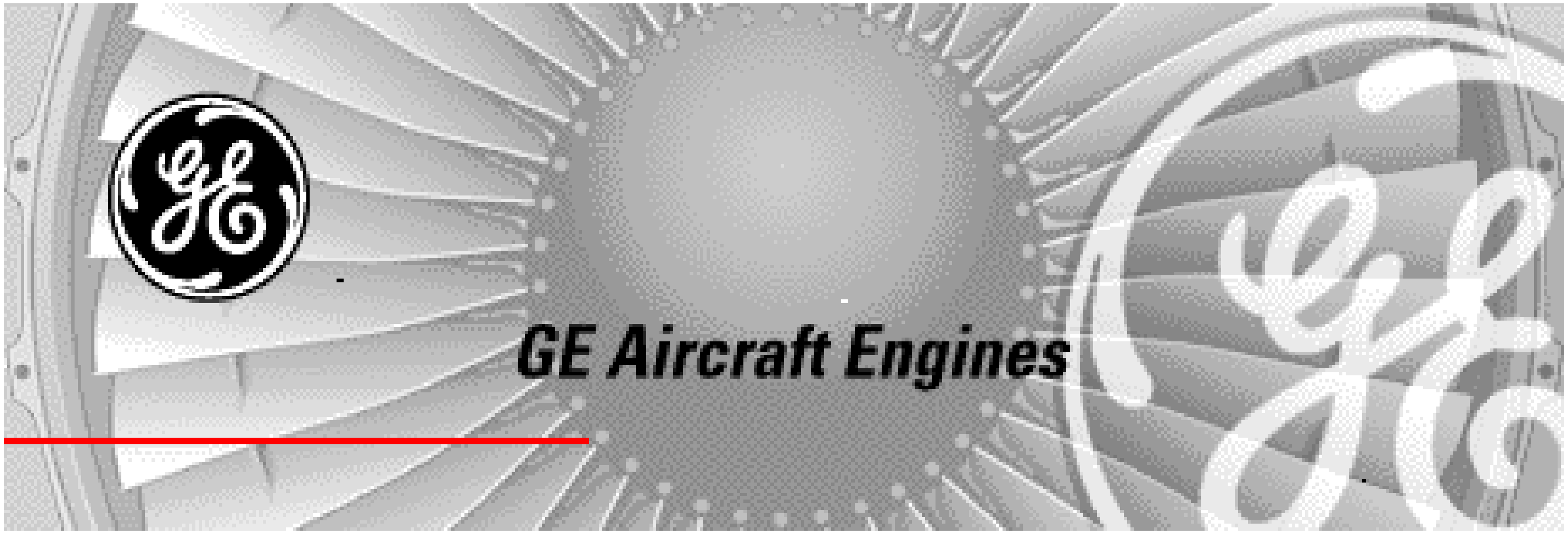
The Aircraft Engine Design Project- Engine Cycles Design Problem Overview



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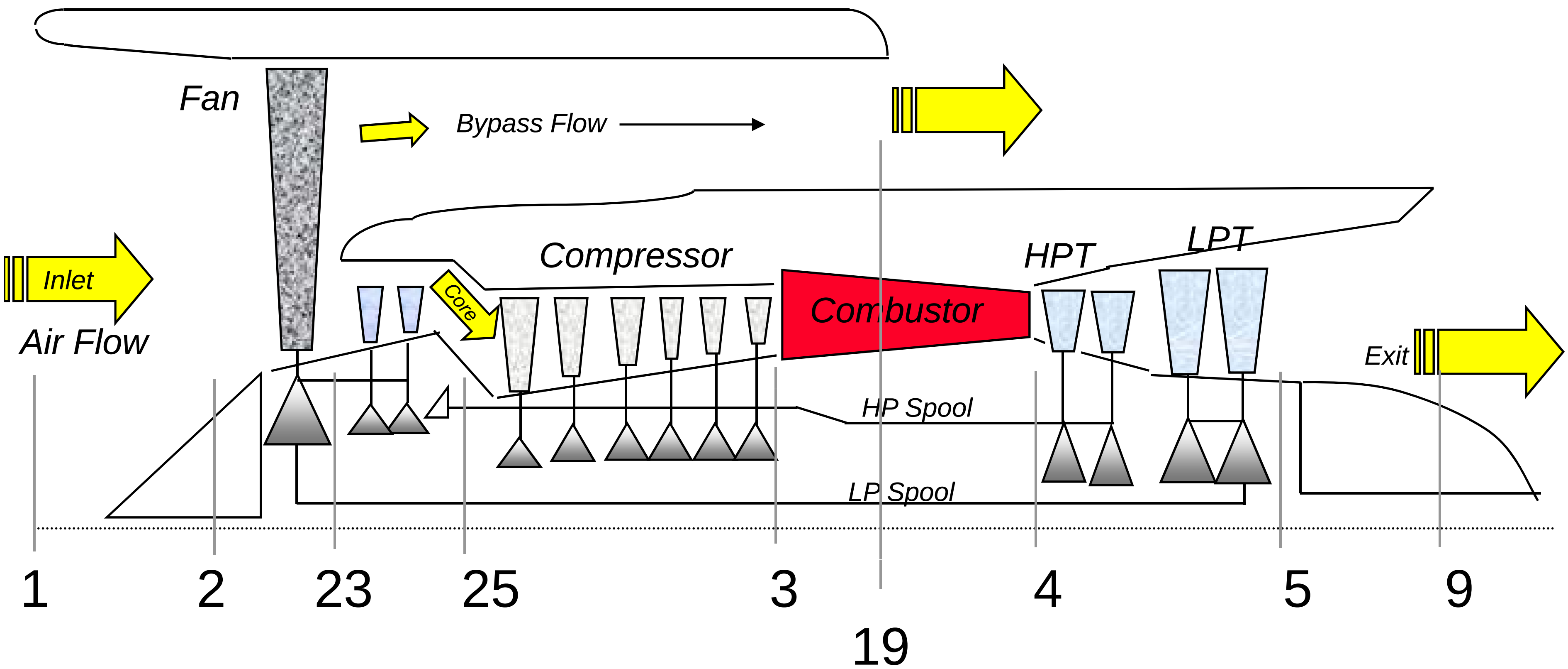
The Aircraft Engine Design Project- Engine Cycles

A new aircraft application is soliciting proposals for a candidate engine. Your design team has been asked to put together a proposal that meets the intended aircraft requirements. In addition, because of the significant costs of jet fuel, your marketing team has learned that engine fuel burn capability will be the tie breaking figure of merit in the airframer's final decision.

Your company has a turbofan configuration that has been certified and is in service. This engine or a modified version will be used as the basis for a configuration to meet the aircraft/engine system requirements.

CFM56-3



Separated Flow Turbofan Cross-Section with Booster Stages

Also for a Turbo-fan:
Bypass ratio= Bypass Flow/ Core Flow

Aircraft Application Requirement

1. Aircraft Takeoff Thrust Requirement at Sea Level /MN =.0/Tamb=59F	36000 lbf
2. Maximum Specific Fuel Consumption (SFC) at takeoff	0.320 (lbm /hr)/lbf

Engine Design Guidelines- Baseline Engine: Separated Flow Turbofan

1. Inlet- Isentropic with inlet Mach Number (M1) =	0.4
Inlet Diameter	50 inches
2. Fan: Pressure Ratio (station 23 to 2)	1.5
Adiabatic Efficiency	.87
Bypass Ratio (BPR)	6.0
3. Booster stages: (station 25 to 23)	
a. additional PR	2.0
b. adiabatic efficiency	.87
4. Compressor Pressure Ratio	8.0
Adiabatic Efficiency	.83
Maximum Compr Discharge Temp	1200 F
5. Combustor- no pressure drop	100% efficiency
6. High Pressure Turbine	
a. Adiabatic efficiency	.87
b. High Pressure Turbine Inlet Temperature	2200 F
c. Uncooled blades	
7. Low Pressure Turbine	
a. Adiabatic efficiency	.89
b. Uncooled turbine blades	

8. Exhaust (core and bypass stream): isentropic expansion to ambient pressure

Design Team

Your design team has been formed to determine if the baseline engine can be used to meet the intended aircraft application. If necessary, the team may consider certain cycle parameter changes (see below and page 9) for the new design to meet the requirements.

Deliverables:

Part A: Preliminary Design Review- With the provided information and some appropriate assumptions, determine if the baseline engine configuration meets the aircraft design requirements. Your team's first deliverable is a working cycle model (a tool that enables you to calculate the thermodynamic cycle and engine performance) and the assessment of the baseline engine configuration.

Part B: Final Design Review- Your marketing team has requested additional features to enhance your chances of having the winning proposal. Consider different options using your cycle deck to improve SFC (i.e. vary fan pressure ratio, bypass ratio, turbine inlet temperature etc. within the design guidelines given on page 9). Define a configuration which minimizes SFC for the target thrust level and explain your parameter choice from first principles.

Note:

Due to time and budget constraints the upper management has decided that extensive multi-dimensional optimizations cannot be considered – your managers are relying on your knowledge and skills to apply thermodynamic principles to define the best solution

Deliverables continued:

Document all necessary assumptions as well as additional work or research you completed to support your conclusions. Be prepared to present your findings to a panel of reviewers. The presented material should include ...

- your conclusions,
- solution approach,
- supporting calculations,
- assumptions utilized,
- pertinent references used.

Problem Details

Thermodynamic parameters

1. Gas properties
   a. Gamma (function of temperature)
      Use: γ = 1.4000 for inlet , fan, and compressor, bypass
      γ = 1.3333 for combustor, HPT, LPT, and core exhaust
   b. Specific heat
      Use Cp (compressor) = .2400 BTU/(lbm-deg R)
      Cp(combustor) = .2743 BTU/(lbm-deg R)
      Cp(turbine) = .2743 BTU/(lbm-deg R)

2. Gas constant (R)	53.35	(ft-lbf)/(lbm-deg R)
3. Energy constant (J)	778	(ft-lbf)/BTU
4. Gravitational constant (gc)	32.17	(ft-lbm)/(lbf sec^2)
5. Fuel heating value (FHV)	18550	BTU/lbm
6. Sea level, ambient conditions		
Ambient temperature (Tamb,Ts0)	59	F
Ambient pressure (Ps0)	14.696	psia

Part II: Design Guidelines

Consider varying the following parameters when improving your design:

- Inlet Diameter
- Bypass Ratio
- Fan Pressure Ratio
- Compressor Pressure Ratio
- High Pressure Turbine Inlet Temperature

  For every 100 deg F increase, you must bleed 2% of the compressor exit air to provide turbine cooling. You may consider this air available to do work in the low pressure turbine

Limitations:

1. Maximum turbine exit temperature (T5) 1700 F
2. Compressor Discharge Maximum Temperature (T3) 1200 F
3. Maximum inlet diameter for Ground Clearance 62.0 inches.
4. Core size limitations: You *may* consider changing the core engine airflow in the range of –20% to + 50% relative to the baseline engine.

Items for consideration at the Final Design Review

1. For each of the design parameters you have defined, discuss why you selected the value you did. Provide a first-principles based explanation for why each individual parameter results in an improvement over the baseline design (for example h-s or T-s diagrams might be used to illustrate your changes in the cycle design and their implications).

2. Did you decide to change the physical size of the core engine? What did you consider when making this decision? Discuss the relevant trade-offs that were considered.

3. Comment on what other unspecified physical or technological constraints may limit the magnitude of changes to efficiencies, pressure ratios, or maximum temperature levels.

Helpful Resources

Suggested References:

1) 16.Unified "Thermodynamics & Propulsion" Lecture Notes

2) Cumpsty, N., "Jet Propulsion", Cambridge University Press, 2002.

3) Jet Engine Concepts: www.geae.com/education/engines101

4) For some virtual reality pictures and movies: www.cfm56-airshow.com

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