Overview

Flight Ops Support

CFM56 General

Technical Features

Engine Certification & Testing

Operational Characteristcs

EGTMargin, OATL

Reduced TakeOff Thrust

Normal Operating Considerations

Flight phases, ops recommendations

CFM is a Joint Company of
Snecma, France
And
General Electric Co., U.S.A.

THE POWER OF FLIGHT

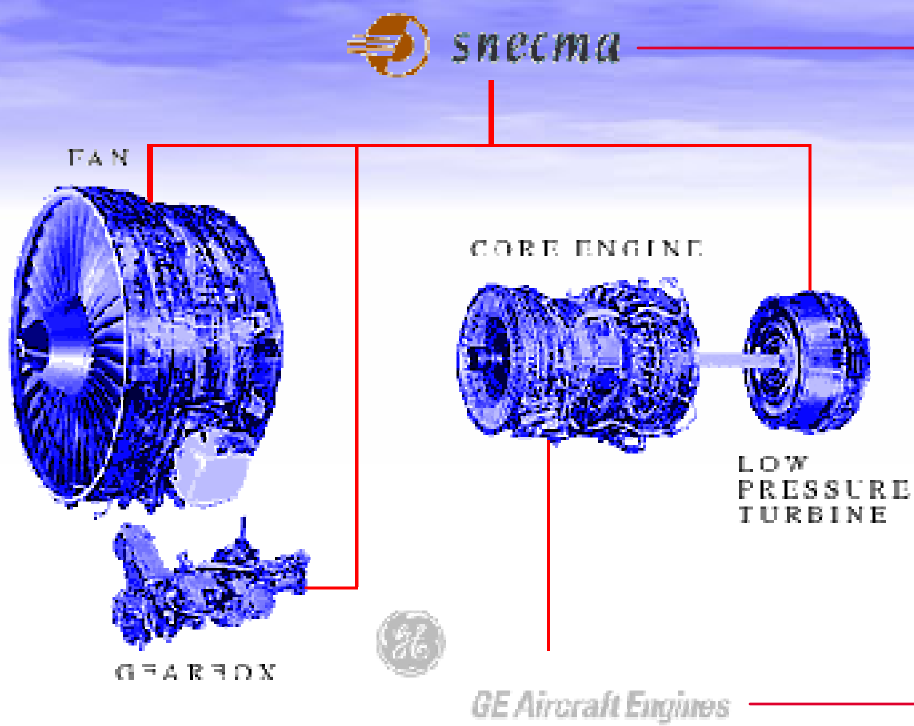
CFM General

A jointly owned company

EFECTIVE 50/50

WORK SPLIT

An effective division of labor dictates exactly how the companies allocate their manufacturing resources. This work split acknowledges the technological achievements of both Snecma's and GE Aircraft Engines' respective organizations



The CFM56 core is based on the GE F101 engine (developed for the B-1 bomber) and employs a single-stage high-pressure turbine to drive a nine-stage compressor. Correspondingly, a Snecma advanced four- or five-stage, low-pressure turbine drives the Snecma fan and booster.

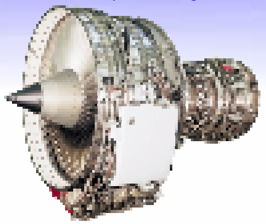
- LP system
- Installations
- Gearbox
- Controls and accessories

- Core engine
- System integration
- FADEC/MEC systems

cfm
THE POWER OF FLIGHT

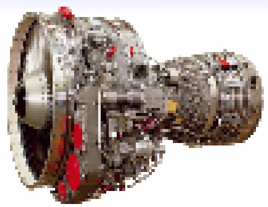
CFM General

CFM56-2 (1979)
22 / 24 Klb



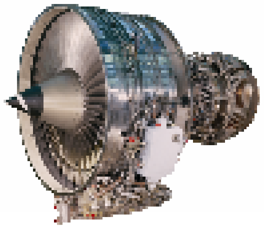
- DC8
- KC-135 FR
- C-135 FR
- E-3 (AWACS)
- KE-3 (Tanker)
- E-6

CFM56-3 (1984)
18.5 / 20 / 22 / 23.5 Klb



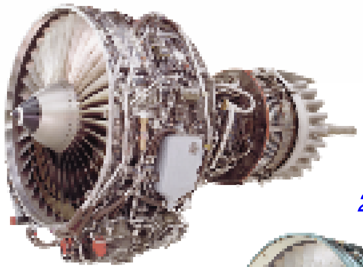
BOEING 737
300 / 400 / 500

CFM56-5A (1987)
22 / 23.5 / 25 / 26.5 Klb



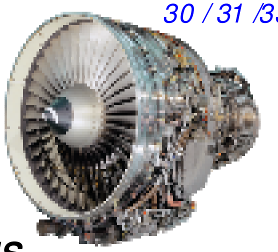
AIRBUS
A319 / A320

CFM56-5C (1991)
31.2 / 32.5 / 34 Klb



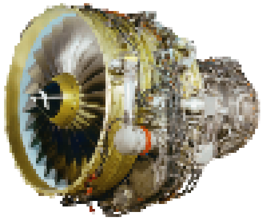
AIRBUS
A340

CFM56-5B (1993)
21.6 / 22 / 23.5 / 27
30 / 31 /33 Klb



AIRBUS
A318 / A319 / A320 / A321

CFM56-7B (1996)
19.5 / 20.6 / 22.7
24.2 / 26.3 / 27.3 Klb



BOEING 737
600 / 700 / 800 / 900

... 18 KLB TO 34 KLB ...
GROWTH CAPABILITY WITH COMMONALITY BENEFITS

THE POWER OF FLIGHT

CFM56 Family Today

as of August 31, 2005

- ***Around 20,000*** *CFM56 on commitment (options & spares included)*
- ***538*** *Operators / Customers & VIP*
- ***6,044*** *A/C /* ***15,135*** *engines in service*
- ***297****million Engine Flight Hours &* ***174*** *million Engine Flight Cycles*
- *1 aircraft departure every* ***3*** *seconds*

THE WORLD'S MOST POPULAR ENGINE

CFM56

as of August 31, 2005

Engine Fleet Status

CFM56 PROGRAM STATUS

(Data thru 08/31/05)

ROXRD - Data Center

		Aircraft	Engines *	Customers	Hours	Cycles
CFM56-2A	E3/KE3/E6	41	193	4	1 687 768	670 790
CFM56-2B	KC/RC135	464	1 948	4	10 263 957	4 500 089
CFM56-2C	DC8-70	105	524	18	15 035 695	6 285 378
CFM56-3	B737-300/400/500	1 969	4 498	192	146 703 033	105 142 255
CFM56-5A	A319/320	527	1 176	44	29 973 138	18 304 846
CFM56-5B	A318/319/320/321	928	1 954	83	20 893 453	12 370 746
CFM56-5C	A340	237	1 086	40	30 336 892	4 682 400
CFM56-7B	B737NG	1 773	3 756	153	42 138 177	21 961 902
Total		6 044	15 135	538**	297 032 113	173 918 406

** Engines delivered* ***one customer counted per engine model* *Issue date : September 20th, 2005*

EVERY four seconds, every single day, an aircraft with our engines takes off. CFM56 engines power more planes to mores places than any other engine in their thrust class; they've logged more than 247 million flying hours and nearly 60 billion miles. Reliably. Efficiently. Cost-effectively. Every four seconds, every single day.

THE POWER OF FLIGHT

Reliability Rates

(Rate/Number of events)

CFM56

as of August 31, 2005

12-Month Rolling Rate

CFM56 RELIABILITY RATES

(12 Month Rate ending 08/31/05 | Qty of Events)

ROXRD - Data Center

		Unpl. Removal**				Shop Visit**				I.F.S.D.**				A.T.O.***				A/C DEP. REL. %			
		Total*		Engine		Total*		Engine		Total*		Engine		Total*		Engine		Total*		Engine	
CFM56-2C	DC8-70	.067	18	.063	17	.055	15	.052	14	.059	16	.022	6	.123	4	.062	2	99.95	13	99.98	5
CFM56-3	B737-300/400/500	.035	338	.029	279	.098	962	.093	913	.004	38	.002	23	.011	40	.004	13	99.97	936	99.99	487
CFM56-5A	A319/320	.032	88	.026	73	.091	253	.087	241	.005	15	.004	11	.019	16	.010	8	99.89	858	99.92	692
CFM56-5B	A318/319/320/321	.011	54	.007	36	.023	116	.021	105	.001	6	.001	4	.014	20	.006	8	99.95	706	99.96	526
CFM56-5C	A340	.025	109	.023	97	.066	282	.062	267	.009	38	.005	21	.152	24	.032	5	99.62	605	99.81	302
CFM56-7B	B737NG	.015	164	.013	133	.014	144	.012	125	.002	21	.001	13	.011	30	.003	8	99.96	1092	99.97	798

** (**Total** includes engine cause and other related engine events such as FOD, customer convenience,…)*

*** (Per 1000 EFH)*

**** (Per 1000 departures)*

Issue date : September 20th, 2005

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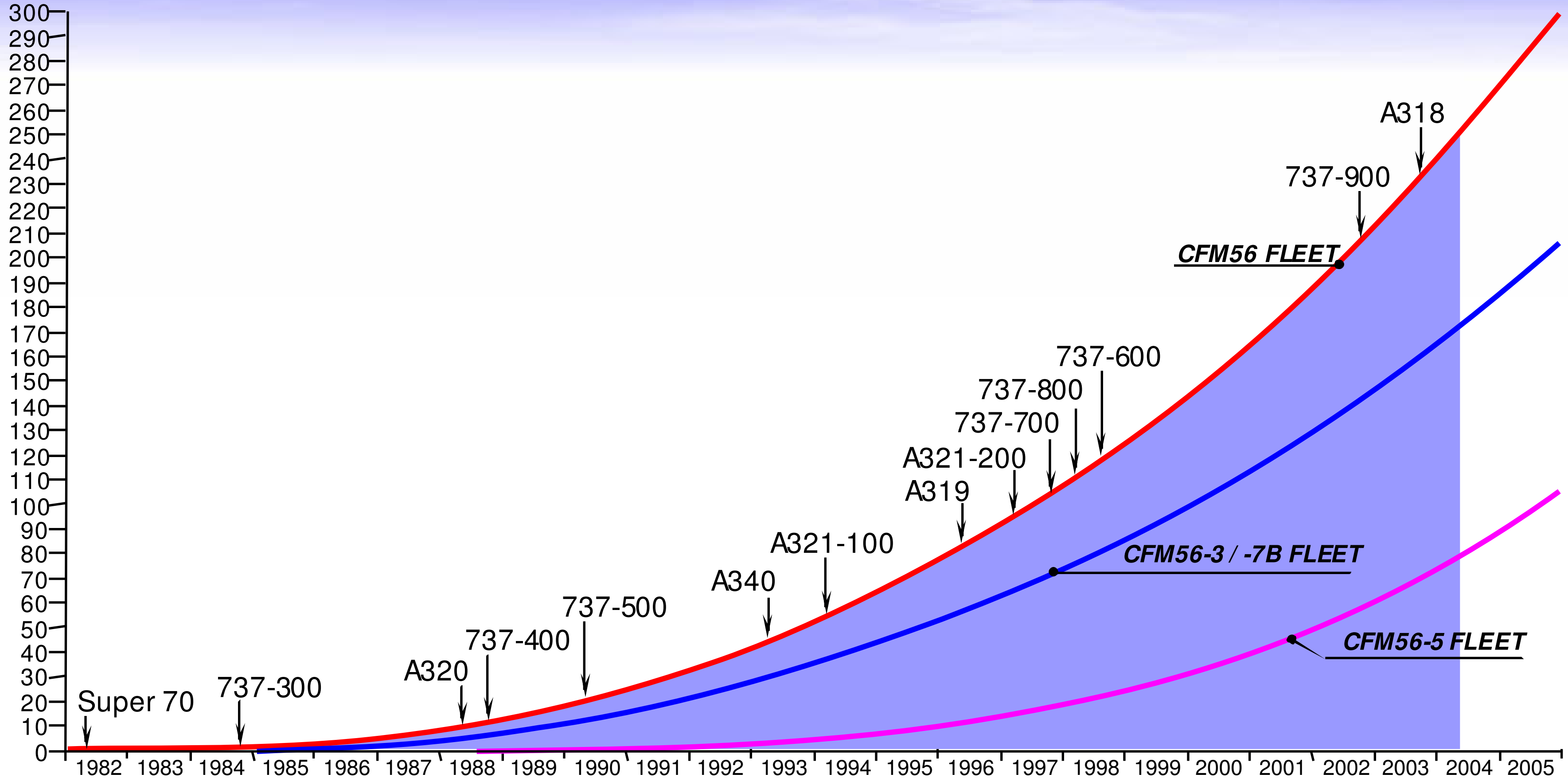
CFM General

THE POWER OF FLIGHT

Experience and Forecast



100M EFH IN 1997 … 200M IN 2002 … 300M IN 2005
A CFM-POWERED AIRCRAFT TAKES OFF EVERY 4 SECONDS

CFM56 Engine High Times

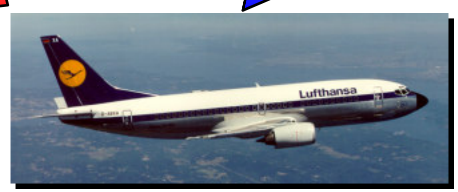
As of December 31, 2003

ENGINE	High Time Engine		Highest on Wing life*	
	TSN	CSN	EFH	EFC
CFM56-5A	41,247	30,684	30,631	15,300
CFM56-5B	22,761	19,966	22,628	13,985
CFM56-5C	48,300	9,345	31,899	6,491
CFM56-2C	50,775	19,985	22,614	8,541
CFM56-7B	24,500	13,945	24,500	12,571
CFM56-3	56,850	56,178	40,729	20,000

CFM56 engines built around the ***single stage HPT concept***

PROVEN OVER 242M EFH

40,729 hours / 17,504 cycles
First engine removal on Sept. 05, 2003



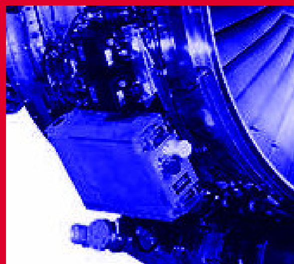
20,000 cycles

WORLDWIDE RECORD FOR CFM56-3
on-wing life without removal

World records for high cycle operations

* Longest intervals achieved on wing without removal

NEW ENGINES BUILT ON CFM56 RECORD-SETTING ON-WING EXPERIENCE



CFM56 General

Technical Features

Engine Certification & Testing

Operational Characteristics

EGTMargin, OATL.

Reduced TakeOff Thrust

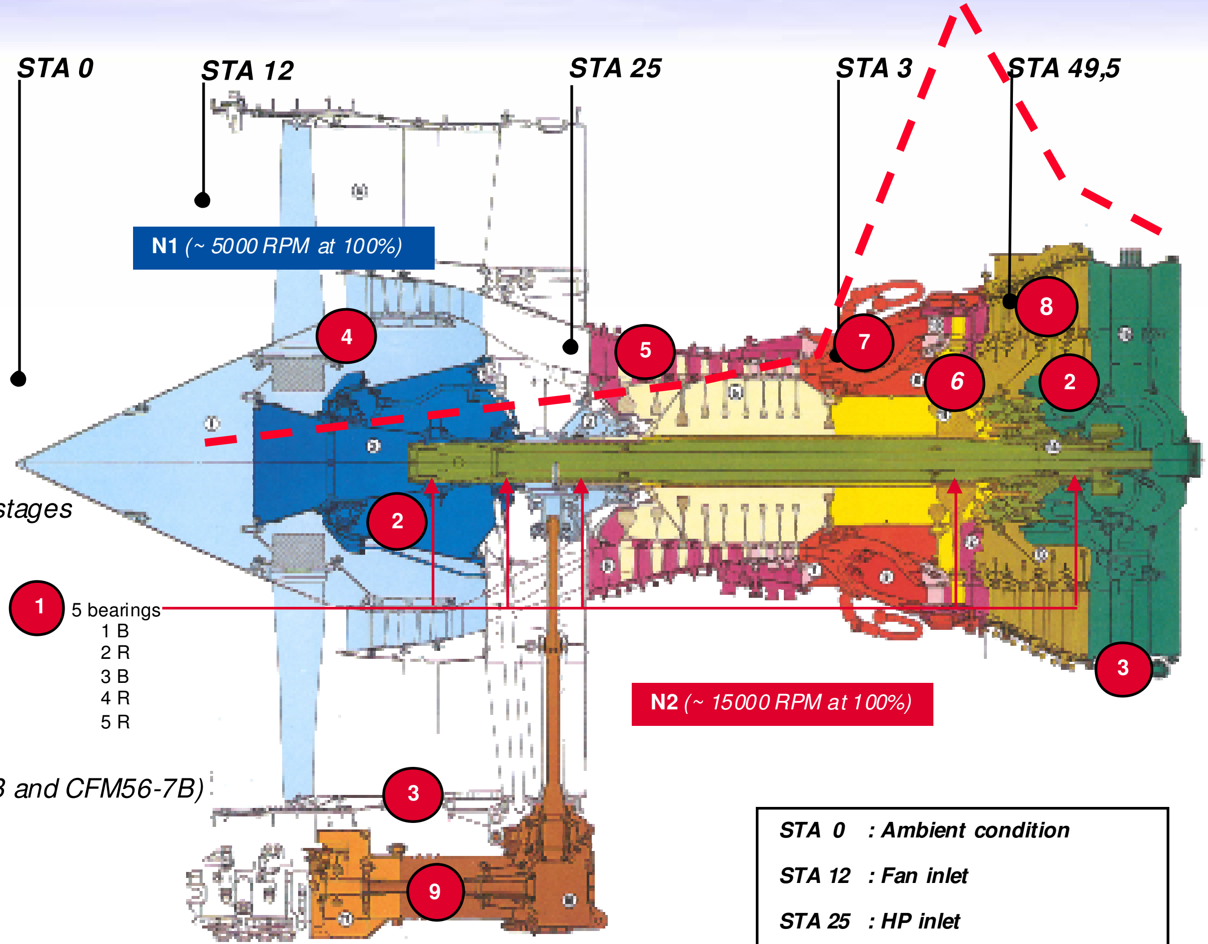
Normal Operating Considerations

Flight phases, ops recommendations

CFM56 Common Architecture

All CFM56 engines have

1. **5 bearings**
   - Ball (B) bearings absorb axial loads
   - Roller (R) bearings absorb radial loads
2. **2 sumps**
3. **2 frames**: Fan frame and turbine rear frame
4. **LPC**, Low Pressure Compressor
   - 1 fan stage
   - 3 or 4 booster stages
5. **HPC**, High Pressure Compressor
   - 9 rotor stages, 4 variable stages, 5 fixed stator stages
6. **HPT**, High Pressure Turbine
   - Single-stage turbine nozzle
   - Single-stage turbine rotor
7. **Combustor**
   - Single annular combustor
   - Dual annular combustor (optional on CFM56-5B and CFM56-7B)
8. **LPT**, Low Pressure Turbine
   - 4 or 5 stages
9. **3 gearbox** arrangements
   - Inlet, transfer, accessory



STA 0	: Ambient condition
STA 12	: Fan inlet
STA 25	: HP inlet
STA 3	: HP compressor discharge
STA 49,5	: EGT mesuring plane

Flow path air temperature rise

CFM56-3 vs -7B Design

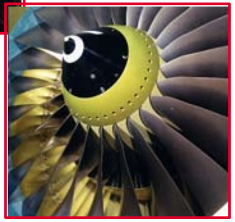
cfm
The Power Of Flight

Spinner shape

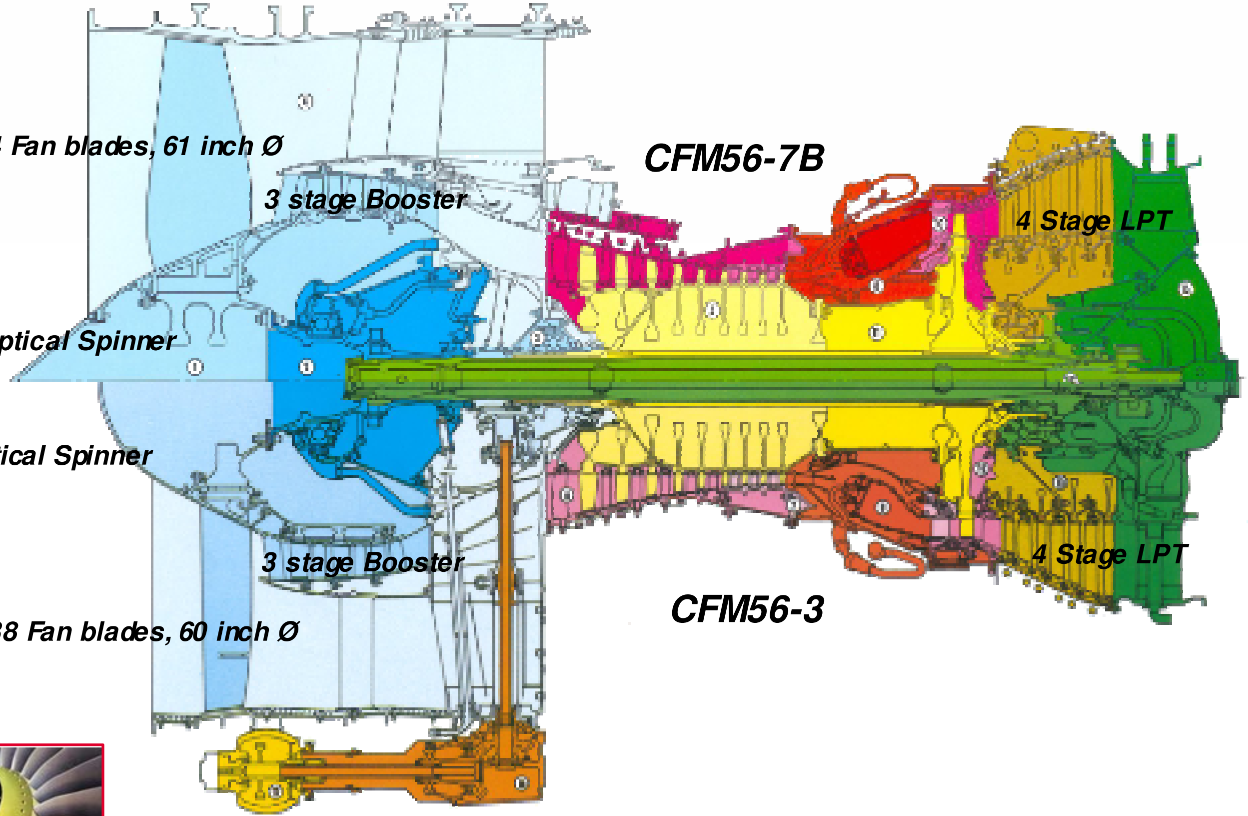
- ***Conical***: *Provides best ice accretion characteristics (minimizes)*
- ***Elliptical***: *Provides best hail ingestion capability*
- ***Coniptical***: *A compromise between ice accretion characteristics and hail ingestion capability*

Conical

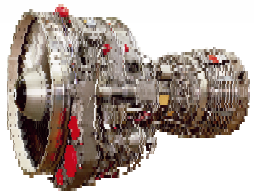
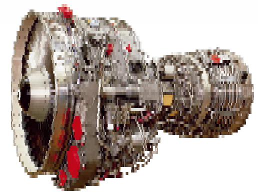
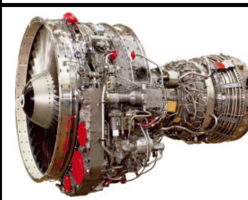
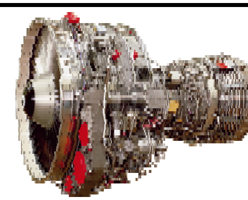
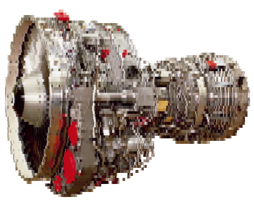
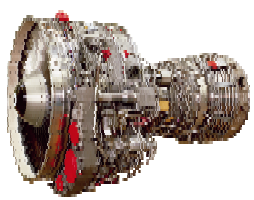
Elliptical



Coniptical



CFM56-3 Family

	-3B1 -3C1 18.5 Klbs	-3B1 -3C1 20.0 Klbs	-3B2 -3C1 22.0 Klbs	-3C1 23.5 Klbs
Boeing 737-300				
Boeing 737-400				
Boeing 737-500				

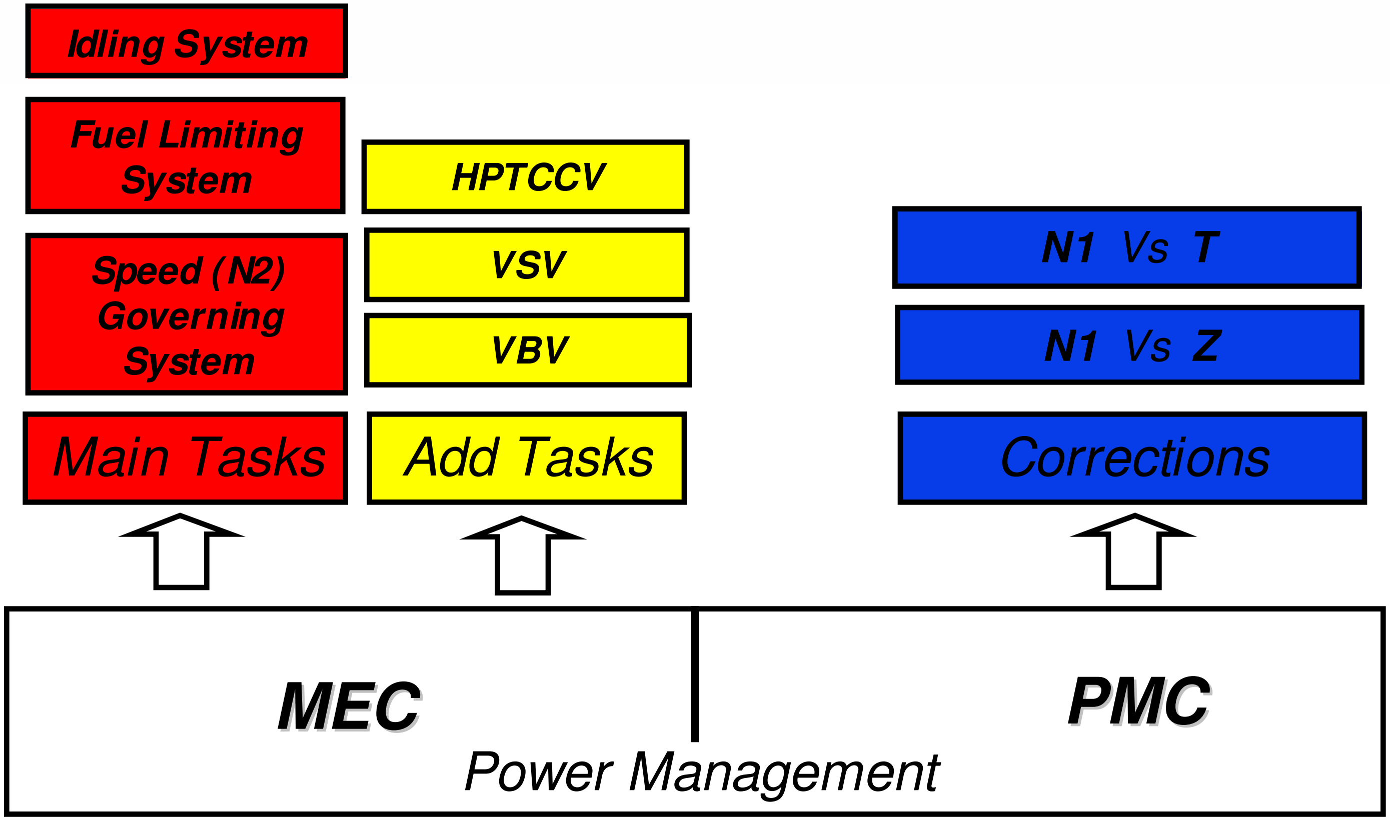
Engine Control System

Engine Power Management

The **CFM56-3** engine control system consists of both:

- Hydromechanical Unit, MEC (Main Engine Control)

- Electronic Unit, PMC (Power Management Control)



Engine Control System

Hydromechanical Unit

MEC ⇨ Main Engine Control

Automatically schedules:

- **WF** (Fuel Flow) N2
- **VBV** (Variable Bleed Valve)
- **VSV** (Variable Stator Vane)
- **HPTCCV** (High Pressure Turbine Clearance Control Valve)

Electronic Unit

PMC ⇨ Power Management Control

– Adjust FAN speed scheduling N1

Engine Control System

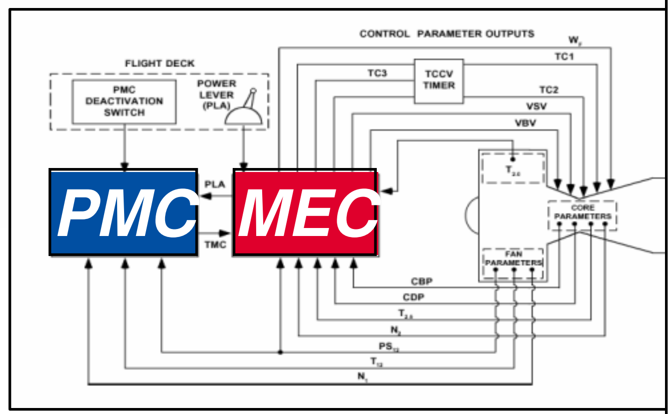
Control System Schematic

Main Engine Control (MEC)

N2

- ***Function***
  - Schedules a **core speed** as a function of altitude, temperature and thrust lever position
  - Schedules variable geometry (VSV/VBV)
  - Regulates turbine clearance control (TCC) position
  - Provides metered fuel flow to the combustor

- ***Inputs***
  - Core speed (N_2)
  - Fan inlet static pressure (PS_{12})
  - Compressor inlet temperature (T_{25})
  - Power lever angle (PLA)
  - Torque motor current (TMC)
  - Compressor discharge pressure (CDP/PS_3)
  - VSV feedback
  - VBV feedback
  - Fan inlet temperature (T_2)



N1	Fan Speed
N2	Core Speed
WF	Fuel Flow
TMC	Torque Motor Current
PS12	Fan Inlet Static Air Pressure
PS3	Compressor Discharge Pressure
CBP	Compressor Bleed Pressure
T12	Fan Inlet Total Air Temperature
T2.5	HPC Inlet Air Temperature
T2	Fan Inlet Temperature
TC1	Turbine Clearance Control (5Th Stage)
TC2	Turbine Clearance Control (9Th Stage)
TC3	Turbine Clearance Control (Timer Signal)

Power Management Control (PMC)

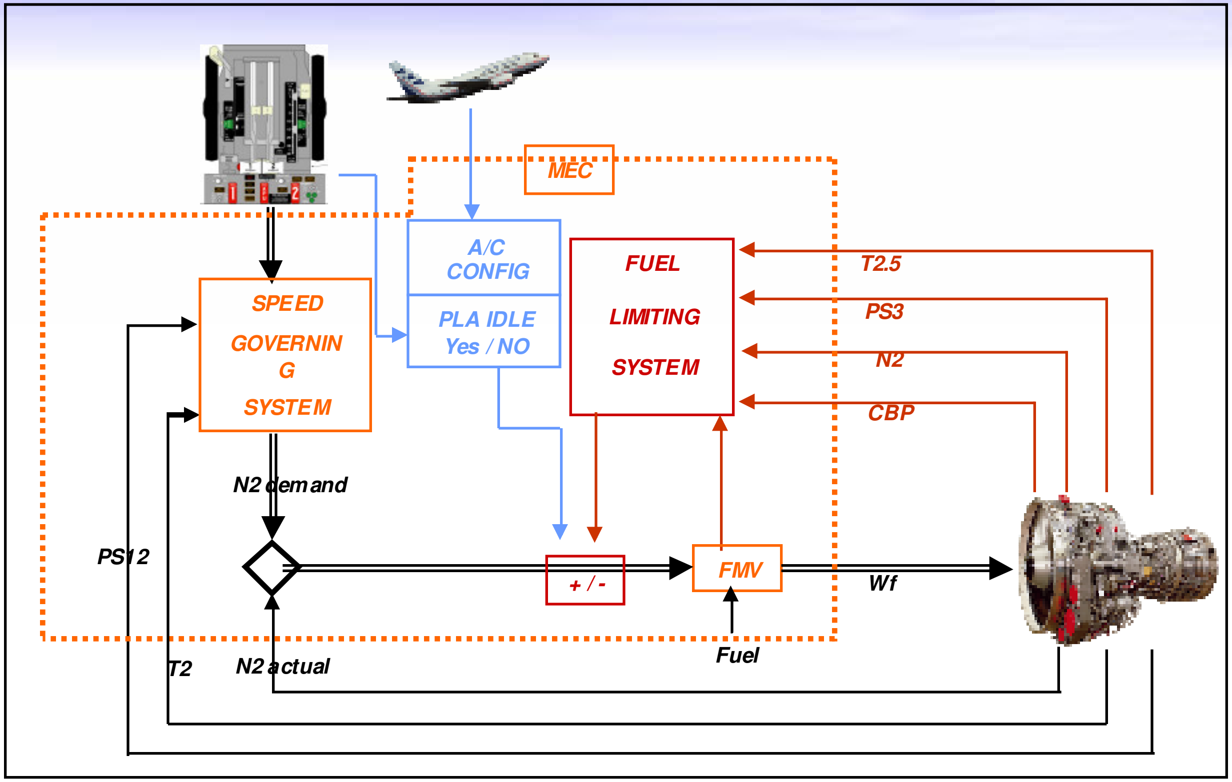
N1

- ***Function***
  - Schedules a **fan speed** as a function of altitude, temperature and power lever angle. Provides a "fine trim" signal to the MEC to obtain the desired fan speed.

- ***Inputs***
  - Power lever angle (PLA)
  - Fan inlet static pressure (PS_{12})
  - Fan inlet temperature (T_{12})
  - Actual fan speed (N_1)

Engine Control System

MEC



HIGH IDLE:

- Used only when anti-icing is selected or if a flying aircraft has flaps configuration > 15°.
- It is optimised to provide rapid recovery of takeoff thrust if required.

LOW IDLE:

- Ground idle:

Provide adequate taxi thrust while minimising noise, fuel consumption and braking effort

- Flight idle:

Scheduled to minimise fuel consumption.

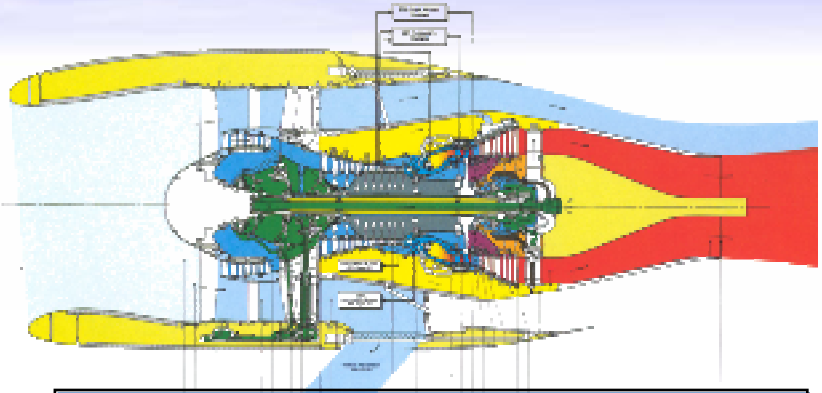
FUEL LIMITING SYSTEM

- During transient operation, the speed governing system could change the fuel flow beyond the safe limits.
- The purpose of the fuel limiting system is to define and impose correct engine fuel flow limits during rapid transients: ACCELERATIONS, DECELERATIONS, STARTS

Engine Control System

PMC purpose

- *In a high bypass engine, total thrust is more accurately controlled by controlling N1 speed.*
- *The accurate **N1** speed is achieved by varying **N2** speed*



FAN is 80% of the POWER !

PMC operation

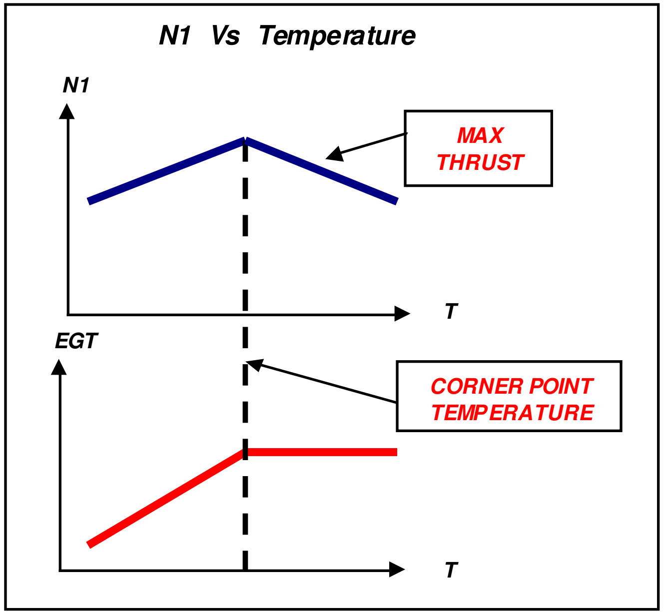
- ***PMC** efficiency start at **50% N1** and is fully efficient at or above **70% N1**.*
- ***PMC trims MEC** to maintain the commanded thrust*
- ***Schedule N1 is compared to actual N1**.The error signal generates from the PMC an Output Current (TMC) to a torque motor mounted on the MEC. The torque motor changes **Fuel Flow** (Wf).*
  - *N2 and N1 change.*

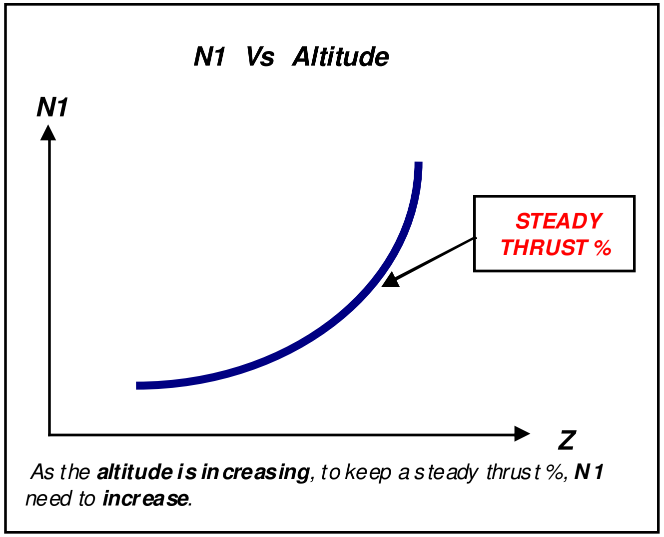
Power Management

PMC operation

The main goal of the PMC is to make **pilot's job more comfortable.**

PMC correct N1





PMC ON
PMC is limiting **N1**

PMC OFF
The **PILOT** must limit **N1**

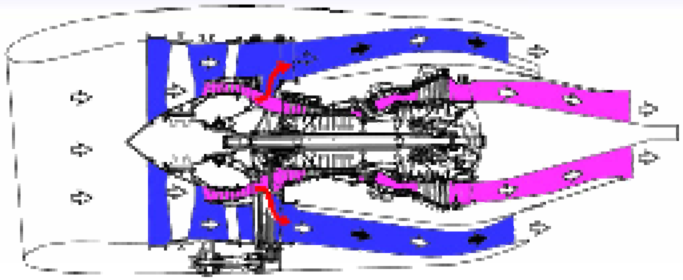
PMC ON
PMC increase N1

PMC OFF
The PILOT must increase N1

Air Control System

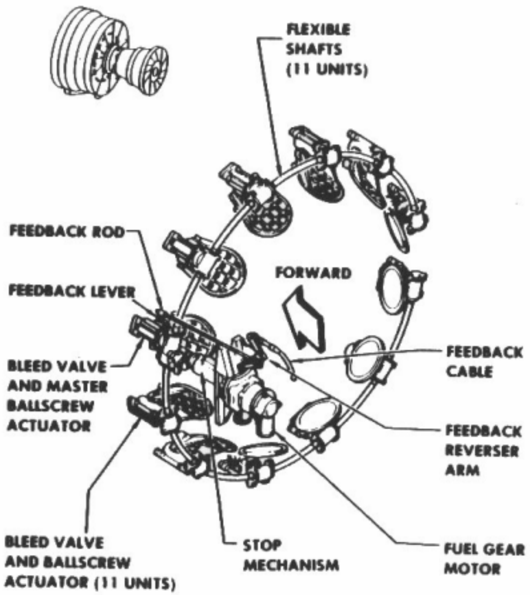
THE POWER OF FLIGHT

VBV (Variable Bleed Valve System)



CFM56-3

- VBV system positions 12 valves by hydraulic pressure acting upon a fuel gear motor.
- The fuel pressure is scheduled by the MEC.
- VBV feedback cable is positioned to provide the MEC with a current VBV position to compare with the desired position.



Air Control System

THE POWER OF FLIGHT

VBV Purpose

As the **Compressor is optimised for ratings close to maximum power** engine operation has to be protected during deceleration or at low speed:

Without VBV installed:

At Deceleration or Low speed

⇒ Booster Outlet Airflow ↓↓ much more than Booster Pressure Ratio

⇒ ***LPC stall margin reduced***

To re-establish a suitable mass flow **VBV** are installed on the contour of the primary airflow stream between booster and HPC to download booster exit.

With VBV installed:

At *Deceleration or Low speed*

⇒ VBV fully open

⇒ Booster Pressure Ratio ↓↓ but same Booster Outlet Airflow

⇒ ***Plenty of LPC stall margin***

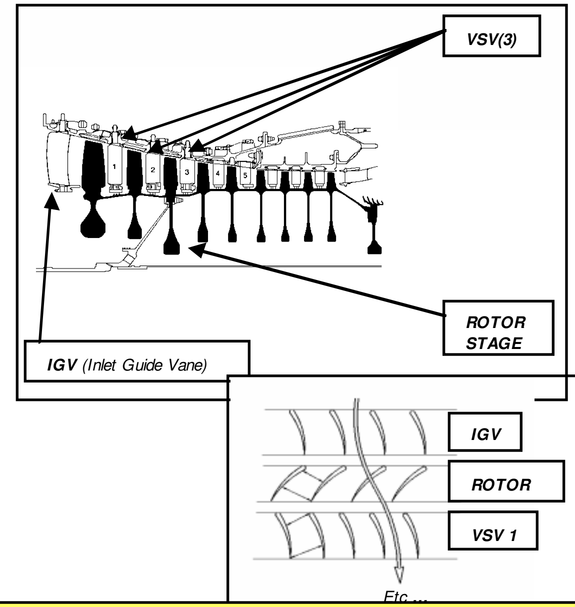
Air Control System

THE POWER OF FLIGHT

VSV (Variable Stator Vanes)

CFM56-3

- *The **Compressor is optimised for ratings close to maximum power.***
- *Engine operation has to be protected during **deceleration** or at **low speed**.*
- ***VSV** system position HPC Stator Vanes to the **appropriate angle of incidence**.*



- ***VSV optimise HPC efficiency.***
- ***VSV improve stall margin** for transient engine operations.*

Clearance Control System

THE POWER OF FLIGHT

Clearance Control CFM56-3

Operating **tip clearance** in the core engine are of primary importance. They determine:

Steady state efficiencies:

⇒ **Fuel consumption**

Transient engine performance:

⇒ **Peak gas temperature**

⇒ **Compressor stall margin**

Clearance Control in the CFM56 engine is accomplished by a combination of 3 mechanical designs:

Passive control:

⇒Using materials in the compressor aft case with low coefficient of thermal expansion.

Forced cooling:

⇒Using Low Pressure Booster discharge cooling air for compressor and turbine.

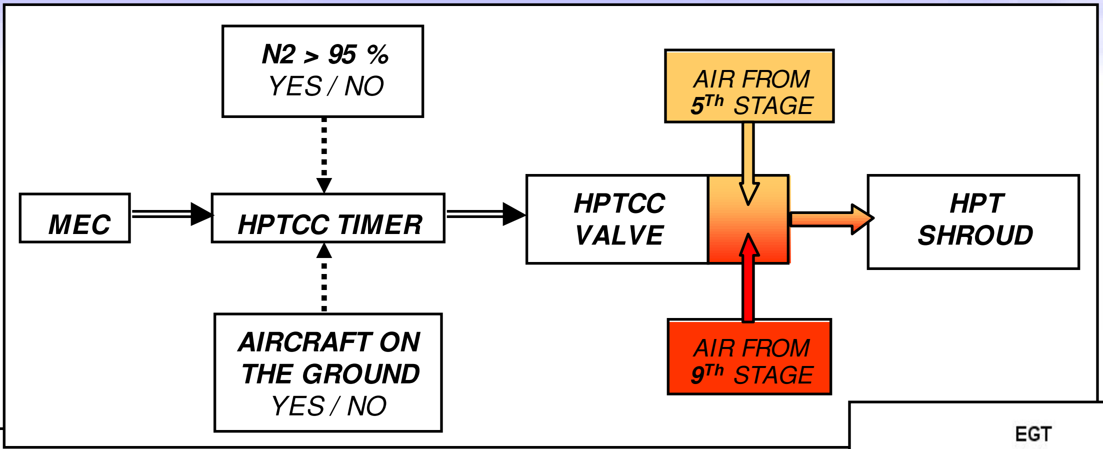
Automatic control:

⇒ HPTCC VALVE and HPTCC TIMER are used to control the tip clearance between HPT blades and stationary tip shrouds.

Clearance Control System

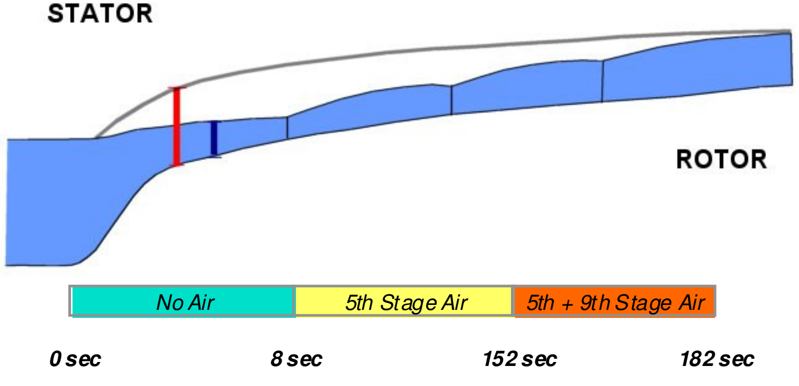
Clearance Control CFM56-3

HPTCCV Actuation

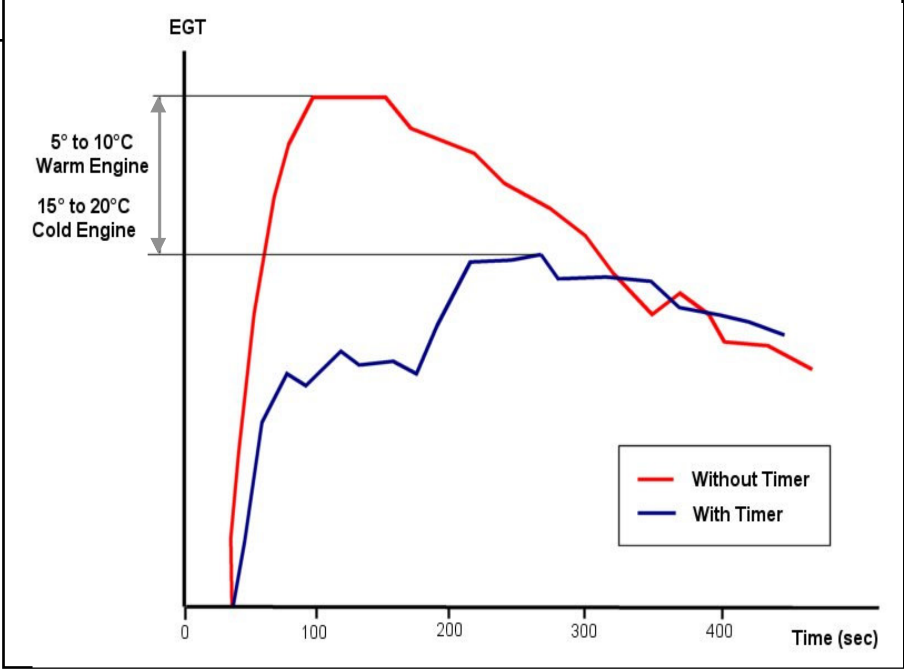


Automatic Control is using Bleed Air from 5Th and 9Th stages of HPC to either cool or heat the HPT shroud.

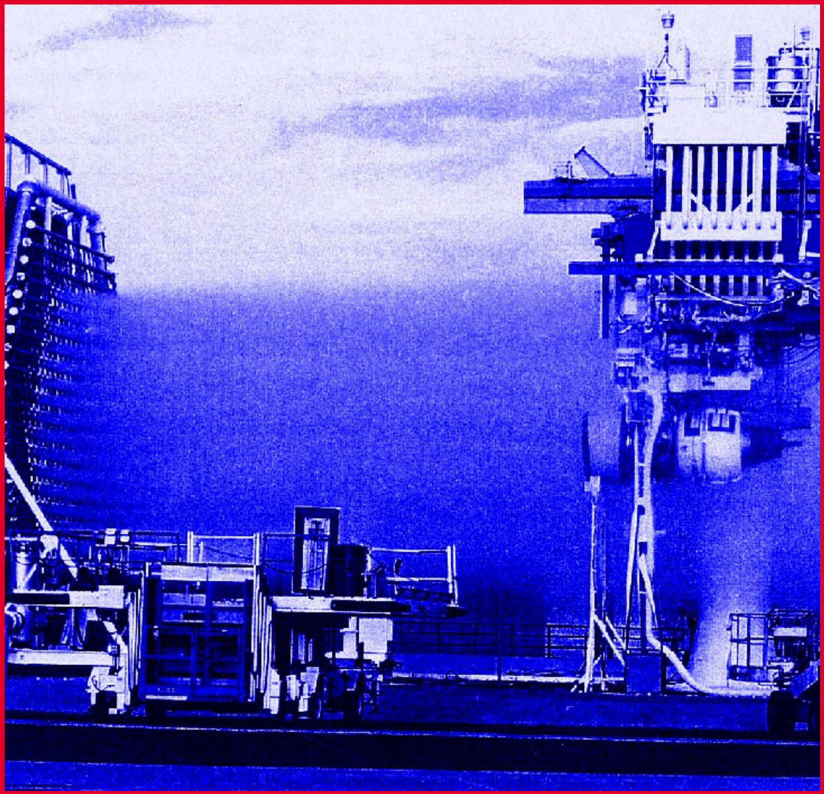
The Timer sequence



Starting Reference Point is when the engine reach **95 % N2**.



Engine Certification & Testing



- Block test
- Vibration test
- Blade containment
- Ingestion tests
  - Water
  - Hail
  - Ice slab
  - Hail stone
  - Birds (medium & large)
  - Mixed sand & gravel
- Induction system icing test
- Overtemperature test

Engine Certification

Blade containment test

Test Objectives

- *Demonstrate fan blade containment inside casing*
- *No fire accepted*
- *Engine mounting attachments must not fail*
- *Engine shut-down capacity within 15 sec.*

Main goal is to show no hazard to the aircraft

Test description

- *Engine running at or above maximum allowed fan speed*
- *1 fan blade released : explosive in shank of released blade.*

Engine Certification

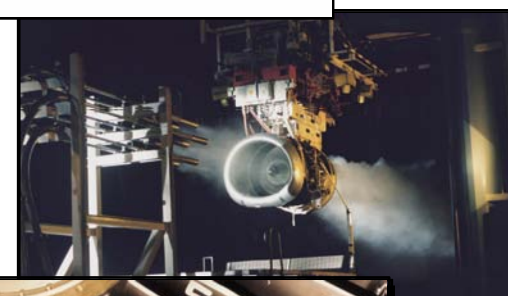
Ingestion tests

To demonstrate the capability of the engine to operate satisfactorily while ingesting simulated foreign object.

• <u>with no substantial thrust loss</u>
- water : 4% (in weight) of total airflow
- hailstones : 25 x 2 ” + 25 x 1” stones within 5 seconds
- ice from inlet : 2 x (1”x4”x6”) slabs

• <u>with less than 25% thrust loss</u>
- medium birds : 3 x 1.5 lb. +1 x 2.5 lb.
(core) in volley within 1 second and operate for a 20 minutes period
- mixed sand and gravel : 1 ounce for each 100 in. of inlet area

• <u>with no hazard to the aircraft</u>
- large bird : 1 x 6 lb. at most critical fan blade location.



Engine Certification

Overtemperature test

Demonstrate, by engine test, the ability to operate for 5 minutes at 42°C / 75°F above declared limit (N1, N2 at red line) with post-test inspection showing engines parts within serviceable limits.

Boeing 737 600-700-800 QRH NNC.7.12

ENGINE LIMIT/SURGE/STALL

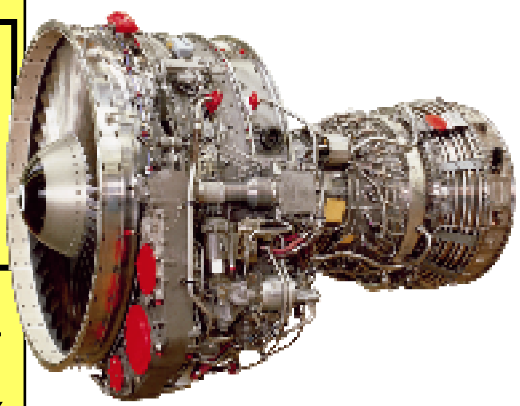
Condition: **One or more of the following conditions:**

- Engine RPM or EGT indications are abnormal, approaching or exceeding limits
- No response to thrust lever movement
- Abnormal engine noises

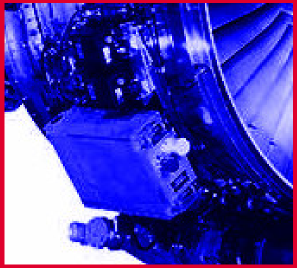
AUTOTHROTTLE (if engaged).. DISENGAGE
[Allows thrust lever to remain where manually positioned.]

THRUST LEVERS... RETARD
Retard until indications remain within appropriate limits or the thrust lever is closed.

If indications are abnormal or EGT continues to increase:
ENGINE START LEVER.......................... ....CUTOFF
XXXXXXXXX...XXXXXX
XXXXXXXXX...XXXXXX



Flight Ops Support



CFM56 General

Technical Features

Engine Certification & Testing

Operational Characteristcs

EGTMargin, OATL

Reduced TakeOff Thrust

Normal Operating Considerations

Flight phases, ops recommendations

cfm

THE POWER OF FLIGHT

Power Management

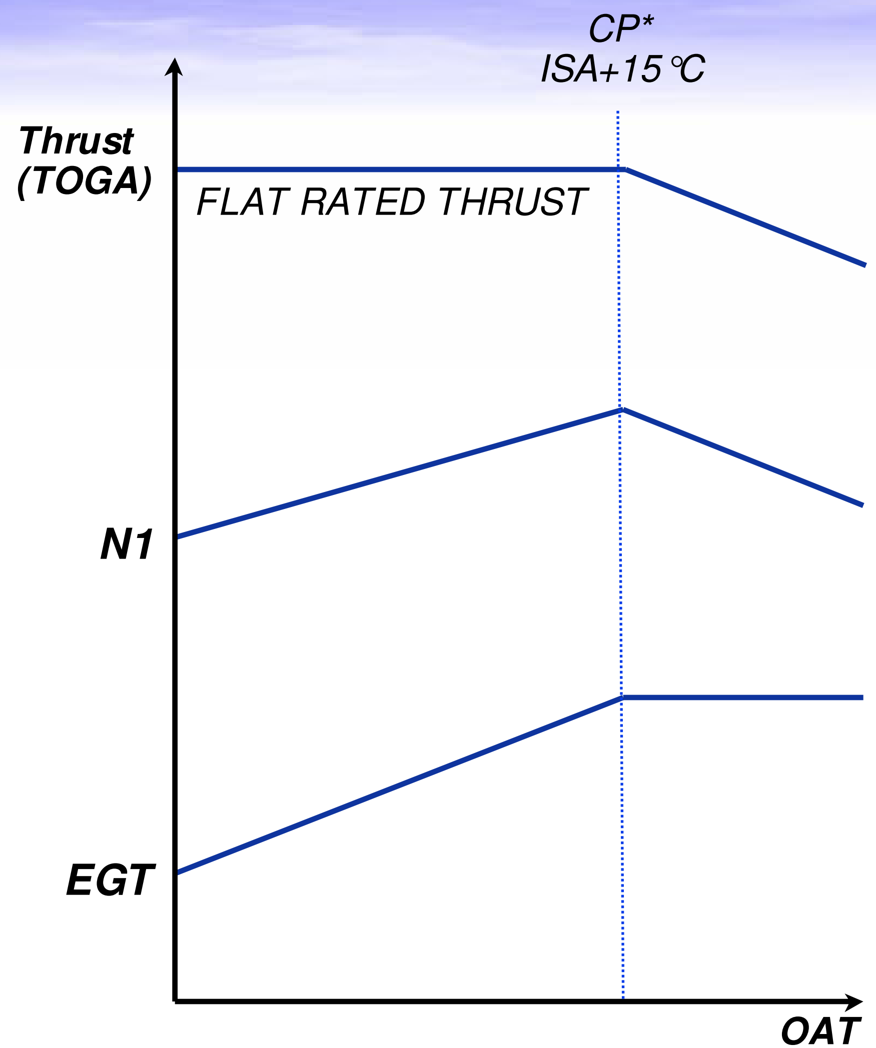
Flat Rate Concept

1. To meet aircraft performance requirements, the engine is designed to provide a given thrust level to some "Flat Rate" Temperature (FRT).

2. N_1 for takeoff power management schedule increases with OAT (up to FRT) to maintain constant thrust. After FRT, power management N_1 (and thrust) decreases.

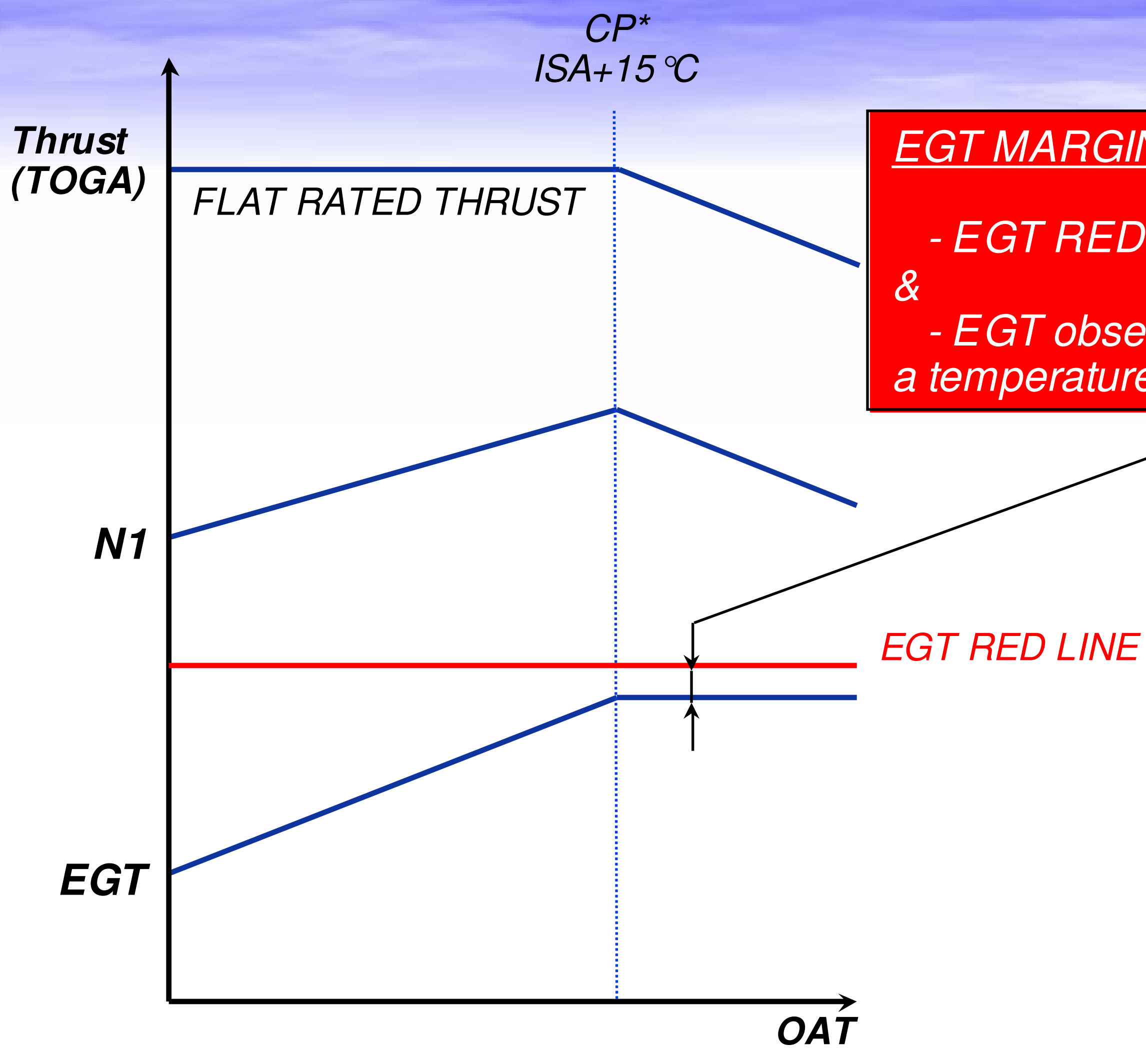
3. EGT increases with OAT to FRT, then remains constant.

At a given OAT, 1%N, is equivalent to approximately 10°C of EGT.



* CP: Corner Point or Flat Rated Temperature

EGTMargin & OATL



EGT MARGIN is the difference between:

- EGT RED LINE

&

- EGT observed on an engine at TOGA with a temperature ≥ CORNER POINT OAT

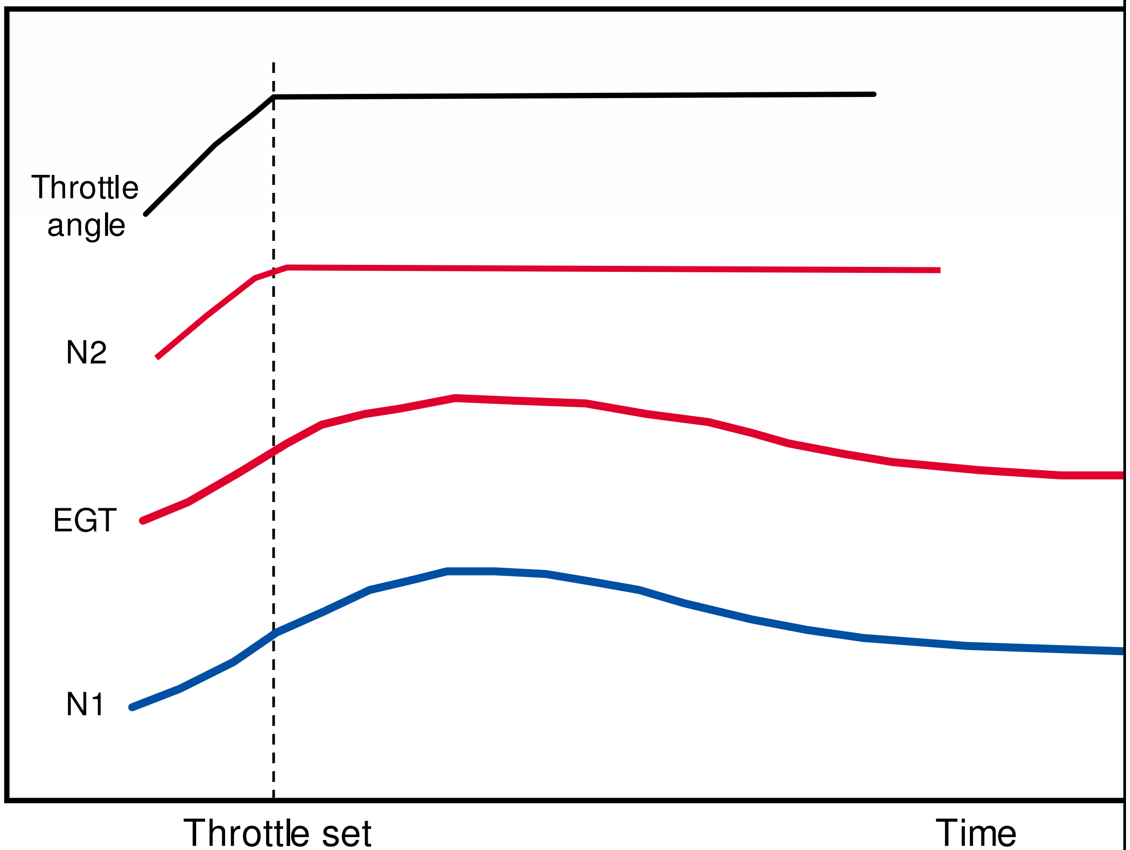
EGT MARGIN
CFM 56-3 New Engine

23.500 lbs ⇨ 53°
22.000 lbs ⇨ 73°
20.000 lbs ⇨ 117°
18.500 lbs ⇨ 142°

* CP: Corner Point or Flat Rated Temperature

Power Management

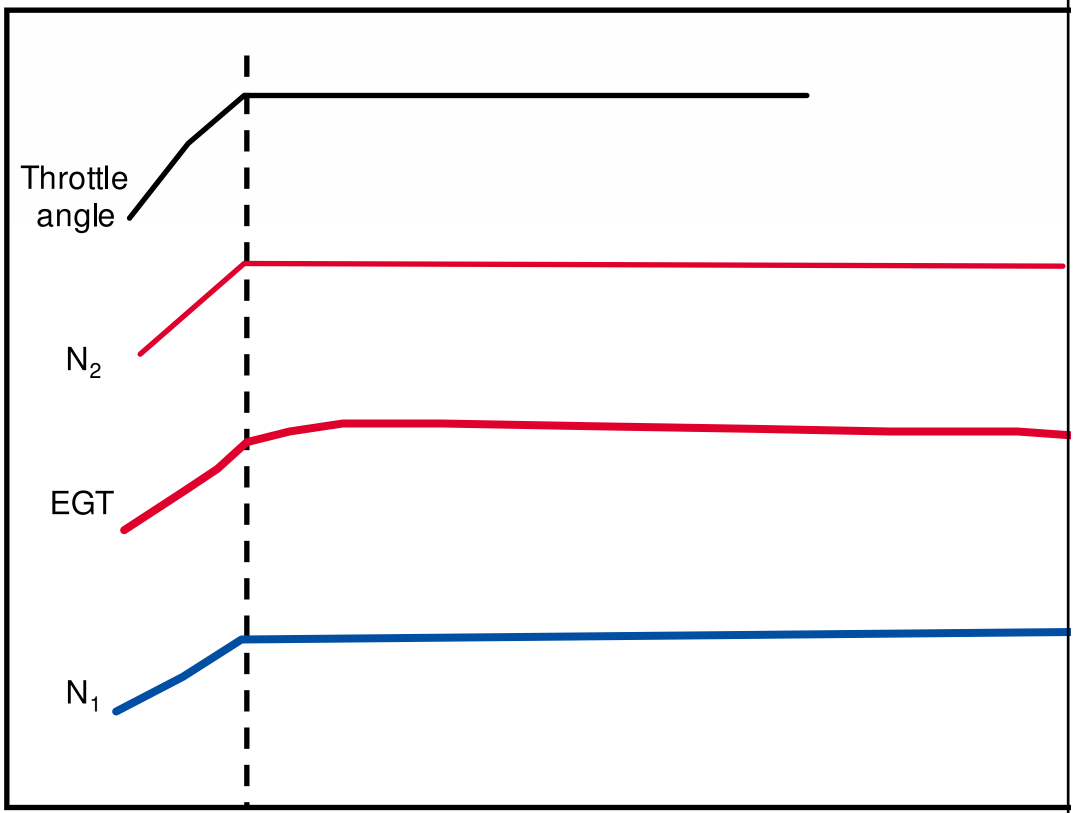
Transient Characteristics (Hydromechanical Control)



Throttles are advanced until target N1 is achieved. After throttle set, The Main Engine Control maintains the N2 corresponding to that throttle position. Because of different thermal characteristics of the core engine static and rotating components, the core becomes less efficient and a higher fuel flow and EGT is required to maintain N2. The increased energy available at the LPT causes N1 to increase: thus EGT and N1 "bloom". As the thermal growth of core components stabilize, the core becomes more efficient and EGT and N1 will decrease ("droop").

These transient characteristics are taken into account when determining power management N1 required to achieve aircraft performance. They are also taken into account when establishing operating limits for the engine.

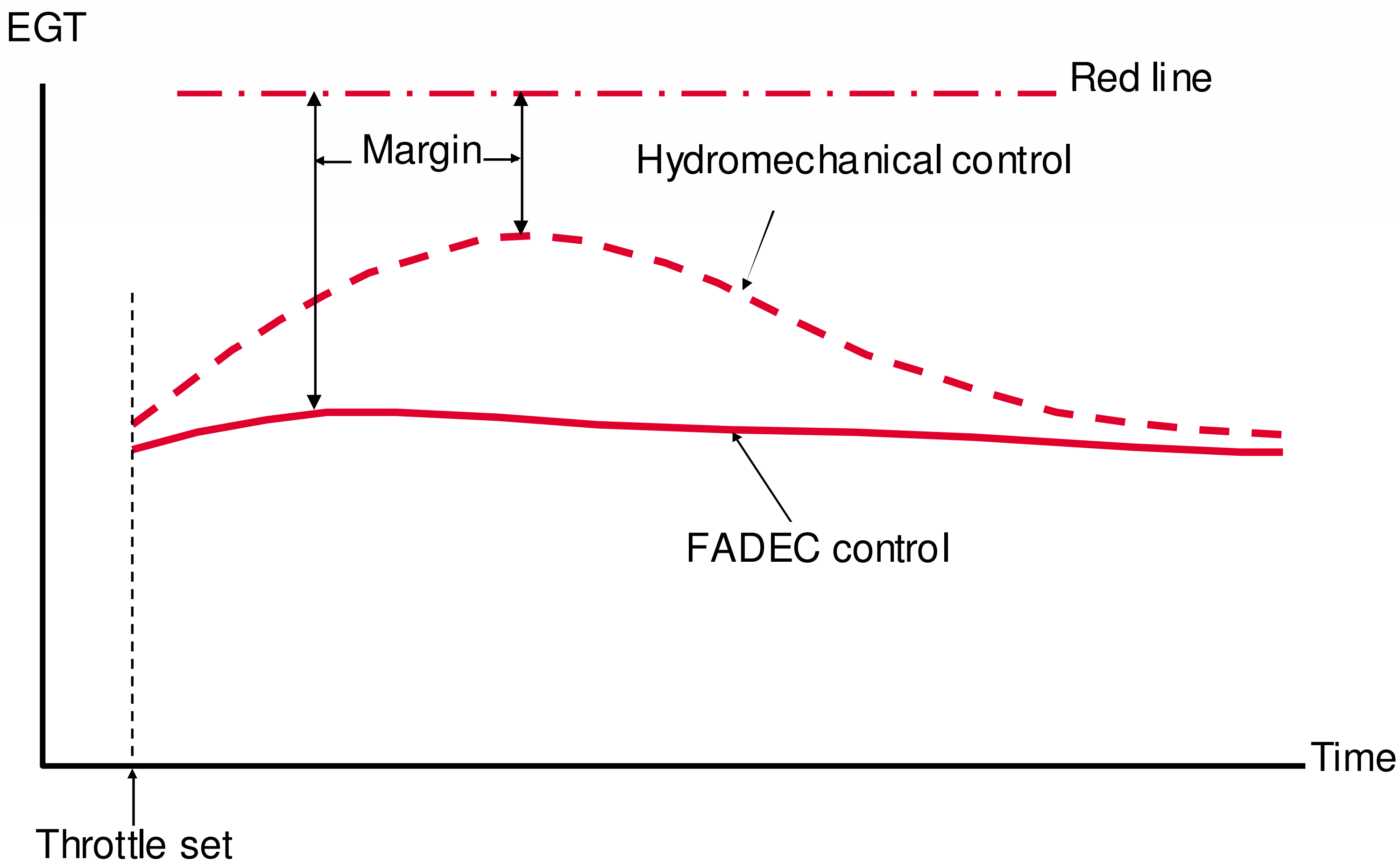
CFM56 PMC or FADEC Transient Characteristics



The power management function on the CFM56 PMC and FADEC engines consists of controlling N_1 (rather than N_2) to produce thrust requested by the throttle position. The PMC and FADEC use the ambient conditions (total air temperature, total pressure and ambient pressure) and engine bleed requirements to calculate N_1 based on a throttle position. Additionally, FADEC modulates the variable bleed valves, variable stator vanes, bore cooling valves and HPT and LPT active clearance control valves to maximize engine efficiency during transient and steady state operations. As a result of this increased efficiency, the EGT bloom and droop are reduced.

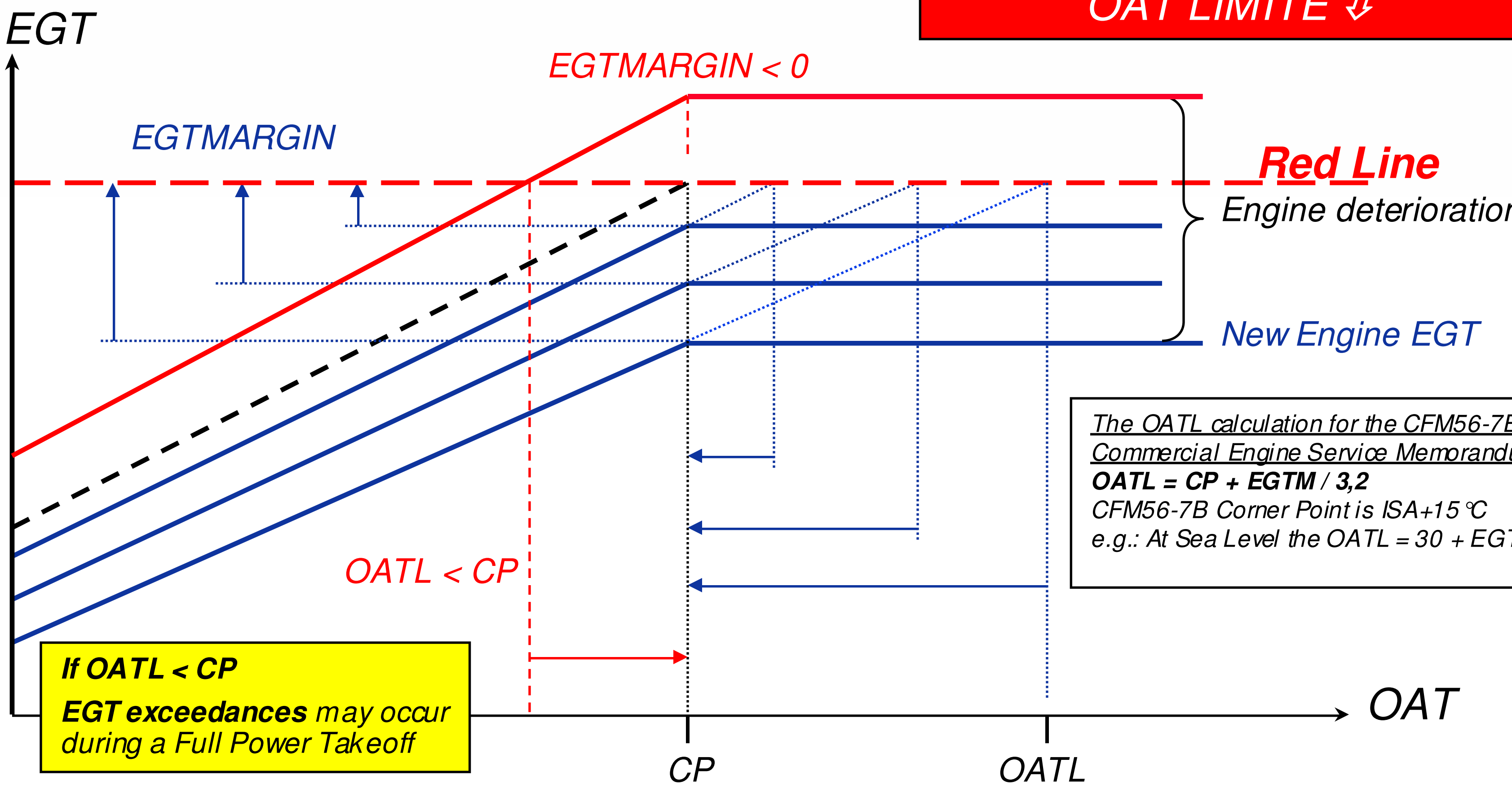
Power Management

EGT Transient



EGTMargin & OATL

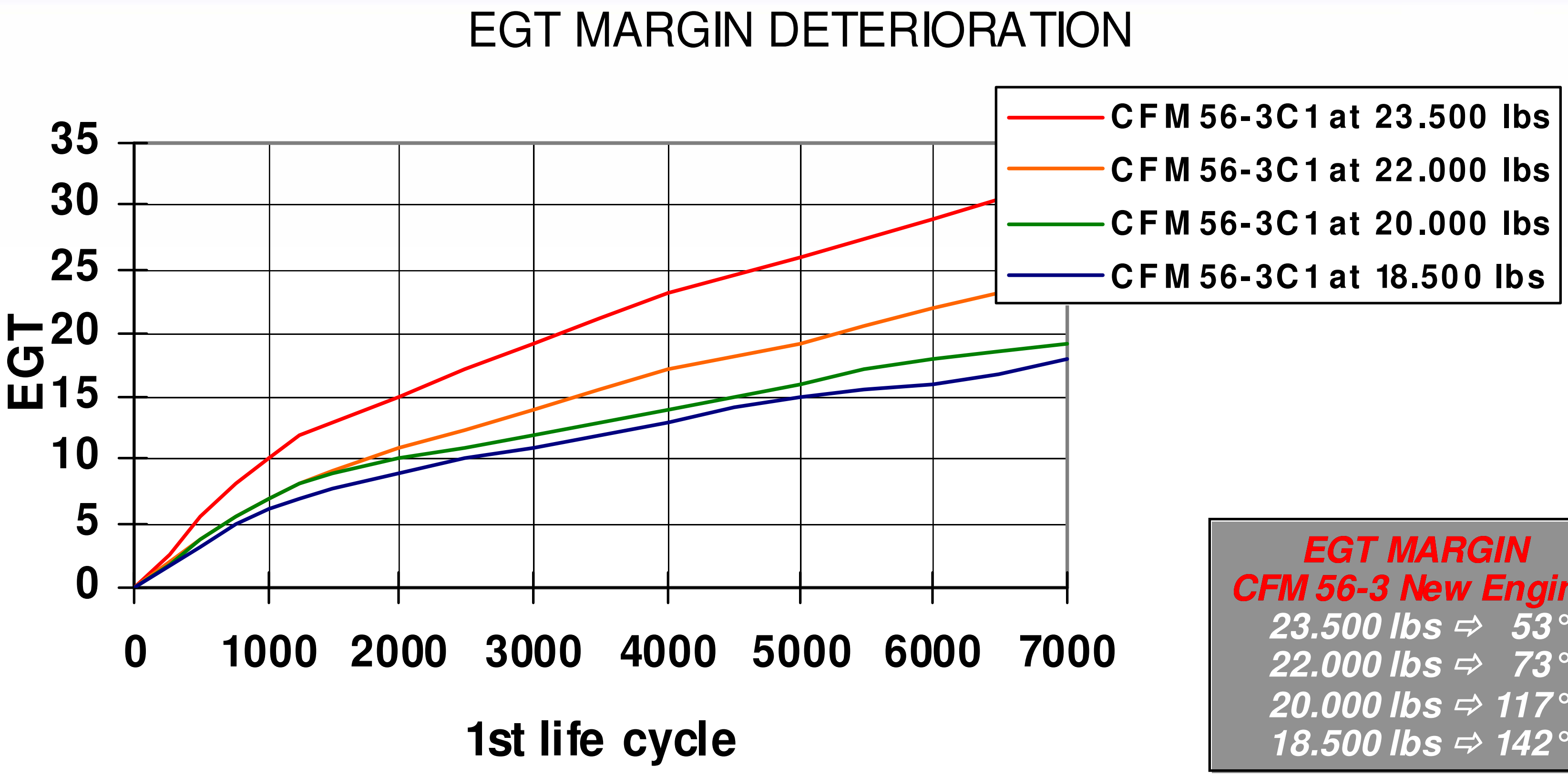
ENGINE DETERIORATION ⇧
EGT MARGIN ⇩
OAT LIMITE ⇩



The OATL calculation for the CFM56-7B:(see Commercial Engine Service Memorandum)
OATL = CP + EGTM / 3,2
CFM56-7B Corner Point is ISA+15 °C
e.g.: At Sea Level the OATL = 30 + EGTM / 3,2

1 °C OAT or Assumed Temperature = 3,2 °C EGT

EGTMargin & OATL



EGT MARGIN
CFM 56-3 New Engine
23.500 lbs ⇨ 53°
22.000 lbs ⇨ 73°
20.000 lbs ⇨ 117°
18.500 lbs ⇨ 142°

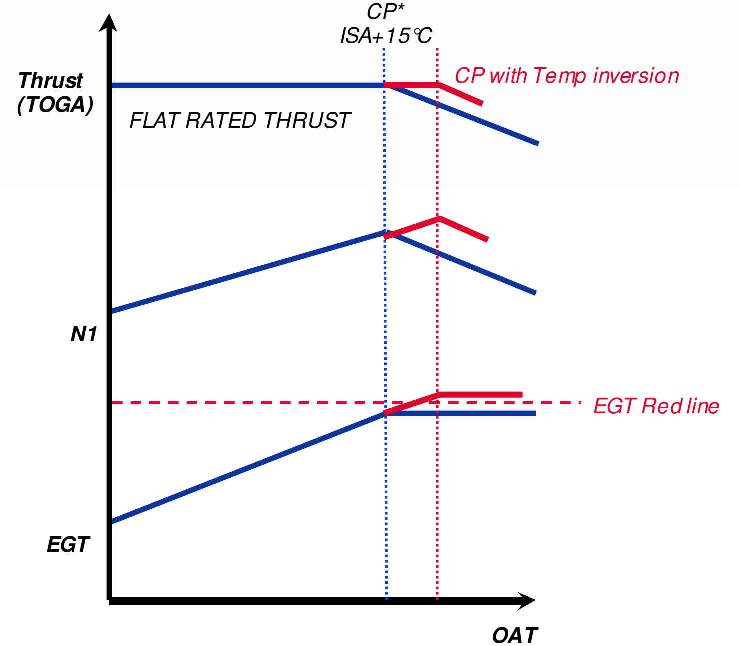
CFM56-3 FLEET AVERAGE

Causes of EGT exceedances

- Temperature inversion
- Warm-up time
- Dirty compressor airfoils
- Engine deterioration
- Too much bleed air on the engine
- FOD
- Engine system malfunction

  (e.g. VBV actuation)
- Engine hardware malfunction

Temperature invertion



* CP: Corner Point or Flat Rated Temperature

If temperature goes up (inversion) after takeoff it requires a higher gage N1 to maintain a constant corrected N1 (N1K). This also causes EGT to continue to increase, possibly resulting in an EGT exceedance.

EGTMargin & OATL

KEEP IN MIND

- ***Stick to your Flight Manual Procedures***

- ***Certified thrust will indeed remain available even in case of EGT Exceedance***

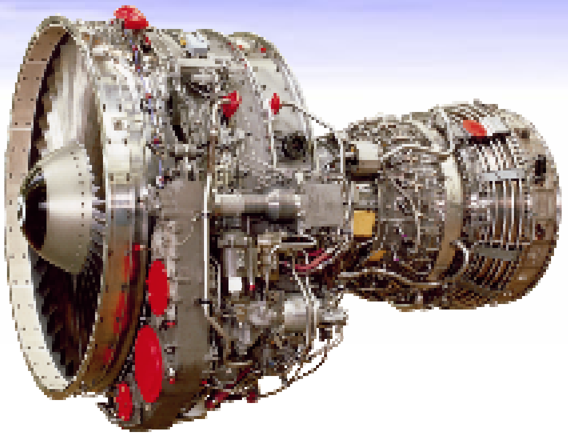
- *At TOGA, ENG OVERTEMPERATURE may occur when:*
OAT ≥ OATL ***and*** *the OATL ≤ CP (ISA+15°C)*

- *No EGT exceedances for performance deterioration as long as the OATL > CP (ISA+15°C)*

- *1°C OAT or Assumed Temperature = 3,2°C EGT (CFM56-3)*

- *OATL data helps the crew to assess potential EGT exceedances*

Performance Deteriation



ENGINES *contribute...*

... ~ ?66 %

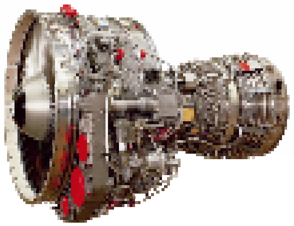
***... to AIRCRAFT** performance deterioration*

When EGTMargin decrease,
Fuel Burn increase.
+ 10° EGT = + 0.7% SFC

Performance Deteriation

THERMAL Loads

CENTRIFUGAL Loads

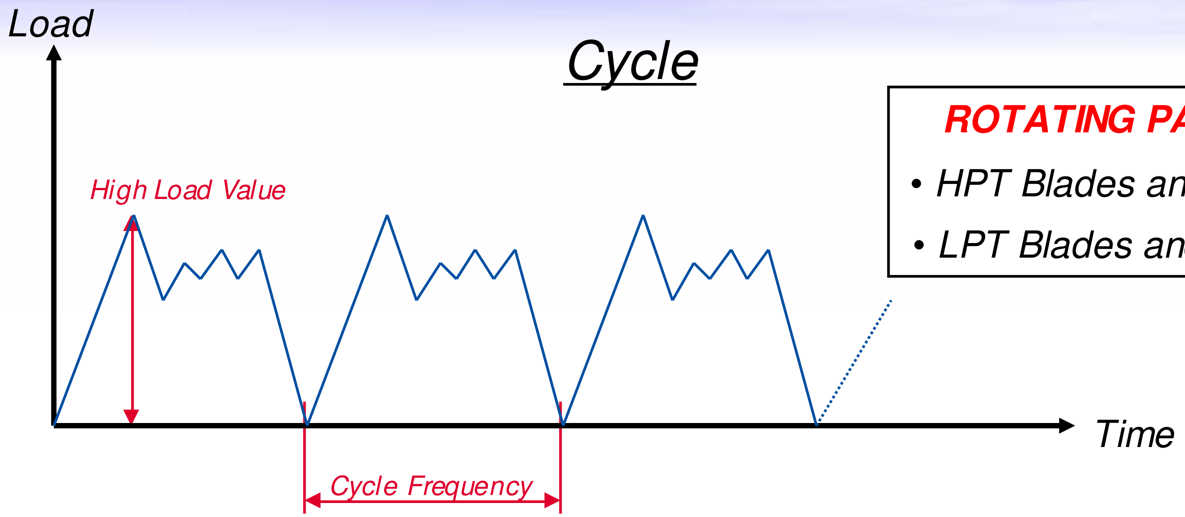


ENGINE
performance
deterioration

PRESSURE & AERODYNAMIC Loads

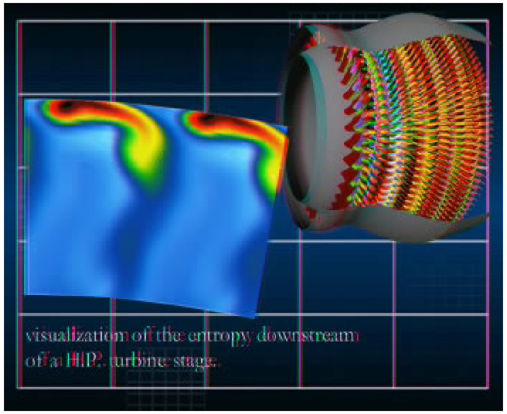
Performance Deteriation

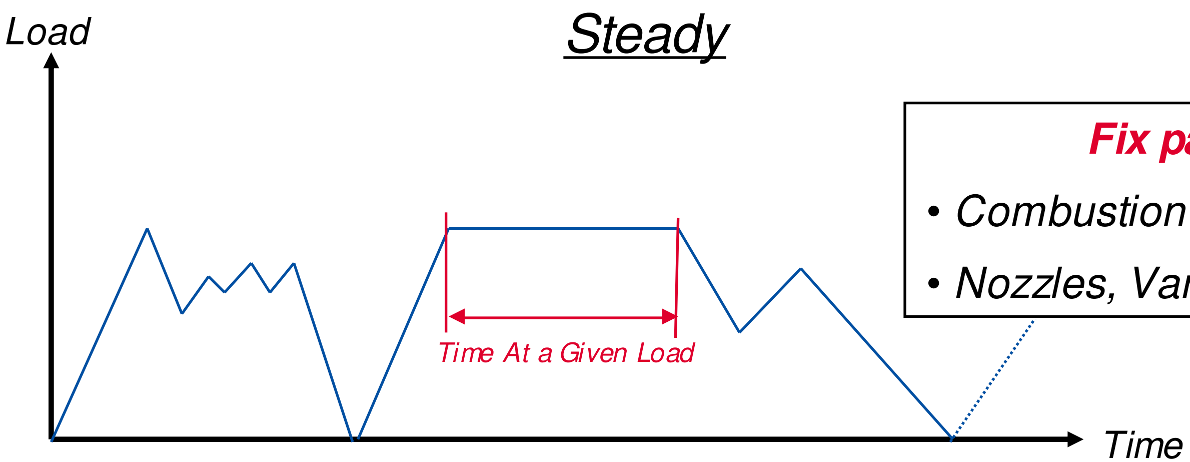
FATIGUES



ROTATING PARTS

- *HPT Blades and Disks*
- *LPT Blades and Disks*

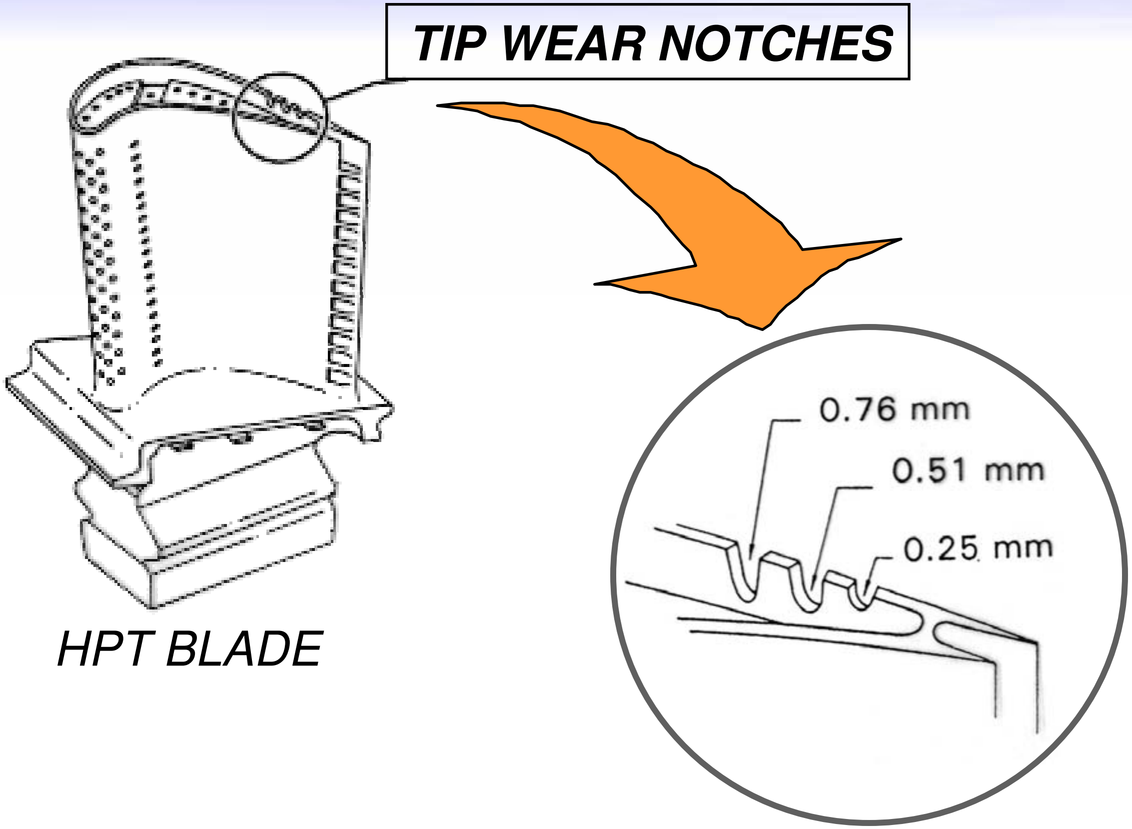




Fix parts

- *Combustion Chamber*
- *Nozzles, Vanes, Valves*

Performance Deteriation



1 Notch = 10° EGT margin loss

Performance Deteriation

BLADES / CASING CLEARANCES → **ENGINE WEAR**

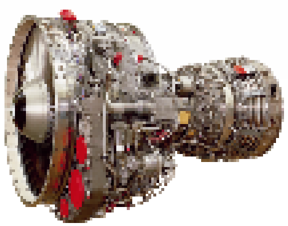
LEADS TO A DETERIORATION OF THE ENGINE EFFICIENCY →

Fuel consumption increase

whith possible EGT overlimit

↓

+ 10° EGT = + 0.7% SFC



ENGINE performance deterioration

- 1% leakage, 9Th stage **HPTCC bleed** ➔ **+ 0.5% SFC**
- 1% leakage, 5Th stage **CUSTOMER bleed** ➔ **+ 1.6% SFC**
- **VBV leakage**, open 10° ➔ **+ 0.7% SFC**

BLEED AIR → **AIR LEAKAGES** → *Customer Bleeds Valves VBV, HPTCC...*

Performance Deteriation

TAKE CARE OF YOUR ENGINES…

… YOU WILL SAVE MONEY…

… AND KEEP YOUR AIRCRAFT SAFE !!!

THE POWER OF FLIGHT

Reduced TakeOff Thrust

Reduced TakeOff Thrust

THE POWER OF FLIGHT

Technical terms

RATED TAKE OFF THRUST *(FAA AC 25-13)*

The approved Engine Thrust (Name Plate)

TAKE OFF THRUST *(FAA AC 25-13)*

The Engine Rated Take Off Thrust or corrected

Derated Takeoff Thrust

Level less than the max. takeoff thrust. The value is considered a normal take off operating limit.

Reduced Takeoff Thrust (Assumed Temp)

Level less than the max. takeoff or Derated Take Off thrust. The thrust setting parameter is not considered a takeoff operating limit.

Is at least 75% of the max. takeoff or Derated Take Off thrust.

RERATING

Is a manufacturer action changing the approved engine thrust (Name Plate)

Reduced TakeOff Thrust

Reduced Thrust Versus Derate

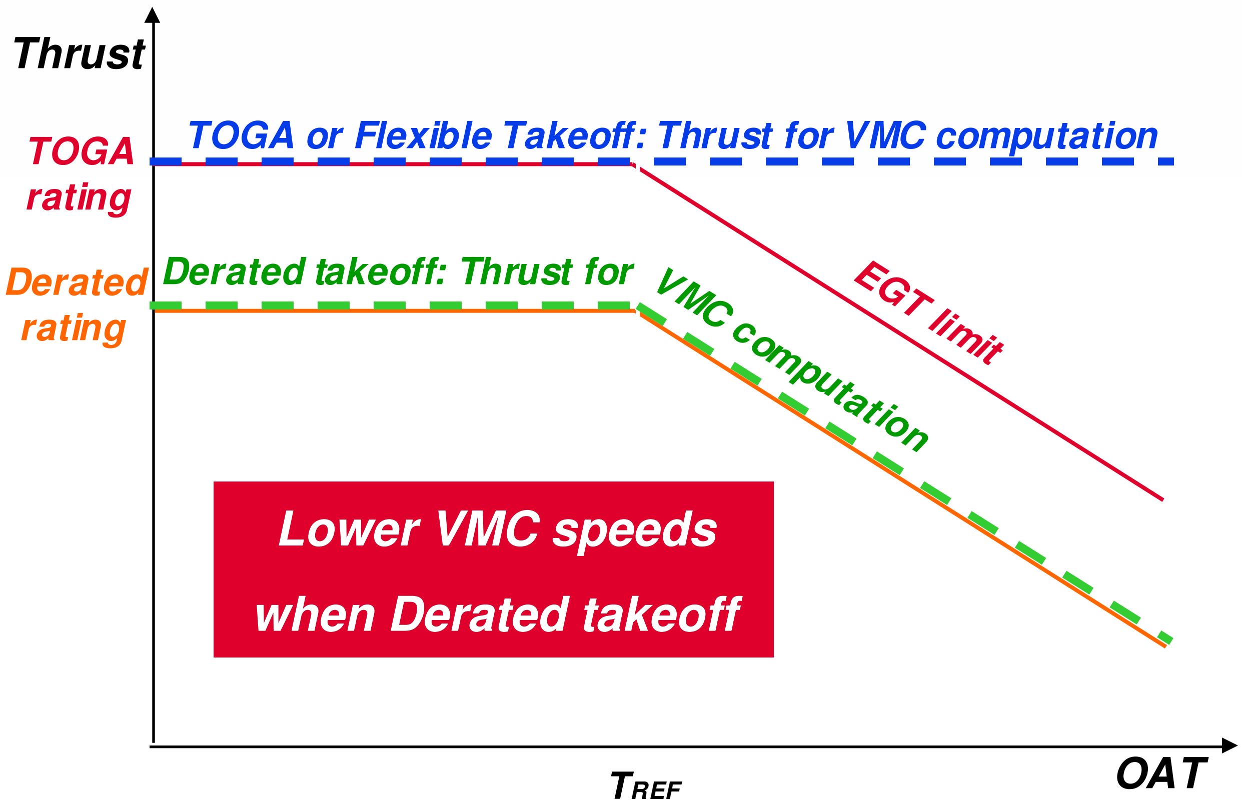
- ***Reduced thrust takeoff (Assumed Temp)***
  - *V-speeds used protect minimum control speeds* ***(VMCG, VMCA) for full thrust***
  - *Reduced thrust setting is not a limitation for the takeoff, I.e., full thrust may be selected at any time during the takeoff*

- ***Derated takeoff***
  - *Takeoff at a thrust level less than maximum takeoff for which separate limitations and performance data exist in the AFM. Corresponds to an “alternate” thrust rating*
  - *V-speeds used protect minimum control speeds* ***(VMCG, VMCA) for the derated thrust . . . not original maximum takeoff thrust***
  - *The derated thrust setting becomes an operating limitation for the takeoff*

- *On some installations derated thrust and reduced thrust can be used together, e.g., a derated thrust can be selected and thrust further reduced using the assumed temperature method*

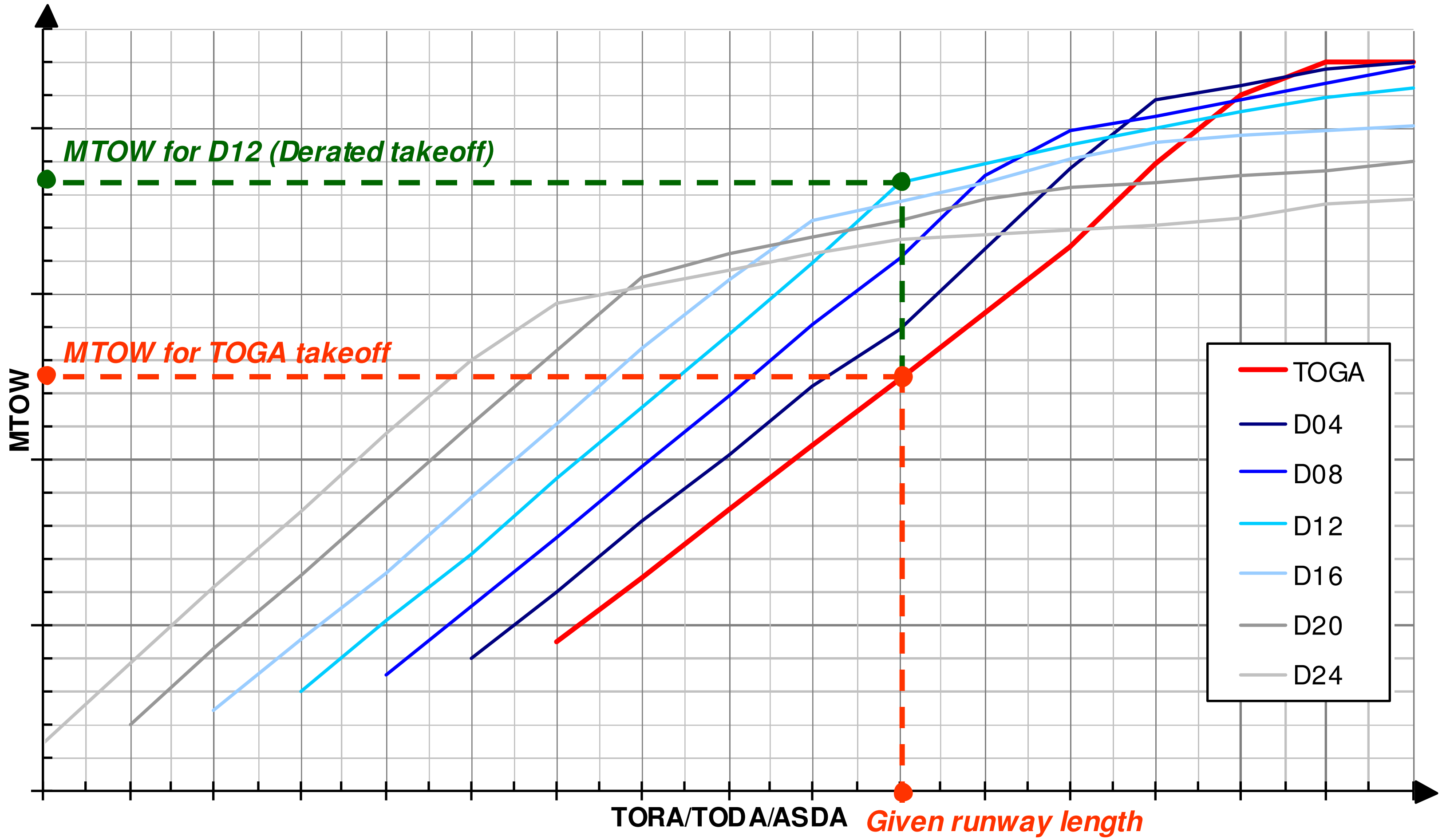
Reduced TakeOff Thrust

Thrust for VMC speeds determination



Reduced TakeOff Thrust

MTOW with Derated takeoff



Reduced thrust takeoffs restrictions

- ***On contaminated runways***
  - *"More than 25 % of the required field length, within the width being used, is covered by standing water or slush more than .125 inch deep or has an accumulation of snow or ice."*

- ***If anti-skid system is inoperative***

- ***These restrictions do not apply to "derated" takeoffs***

- *Any other restrictions on reduced thrust or derated thrust are imposed by the aircraft manufacturer or operator; not by AC 25-13*

Typical Additional Restriction applied by individual operators on Reduced Thrust Takeoffs

- *Possible windshear*
- *Brakes deactivated*
- *Other MMEL items inoperative*
- *De-icing performed*
- *Anti-ice used for takeoff*
- *Takeoff with tailwind*
- *Wet runway*
- *Performance demo "required"*

Reduced TakeOff Thrust

THE POWER OF FLIGHT

Periodic Takeoff Demonstrations

AC 25-13 Restrictions

A periodic takeoff demonstration must be conducted using full takeoff thrust. An approved maintenance procedure or engine condition monitoring program may be used to extend the time interval between takeoff demonstrations

- ***Operator methods vary e.g.***
  - *Every tenth takeoff*
  - *Every Friday*
  - ***Never make dedicated full thrust T/O for performance verification***
    - ***Take credit for ECM and full thrust T/O's performed for operational reasons***
- ***Less reduced thrust benefits acrue when unnecessary full thrust takeoffs are performed***
- ***Full thrust takeoffs meaningful only when takeoff is performed at the flat rate temperature****; otherwise the takeoff data must be extrapolated to flat rate temperature*
  - *Reduced thrust takeoffs can be extrapolated as well*
  - *Cruise ECM data can also be used to predict EGT margin*
- ***Negotiate with regulatory agency to extend interval between dedicated performance verification takeoffs***
  - *Take credit for ECM programs (T/O or Cruise)*
  - *Take credit for full thrust takeoffs performed for operational requirements*
  - *Extrapolate data obtained during reduced thrust as well as full thrust takeoffs*

Reduced TakeOff Thrust

TakeOff thrust is reduced when REAL GW < MAX LIMITING GW

- Max Thrust is not any more necessary!

Benefits of Reduced Thrust/Derated

- Lower Takeoff EGT

- Fewer operational events due to high EGT

- Lower fuel burn over on-wing life of engine

- Lower maintenance costs

EGTMargin decrease slowly ⇒ SFC kept at low rate

Better Engine performance retention ⇒ - Longer engine life on wing
- Shop Visit rate decrease

- Improved flight safety

For a given TakeOff, engine stress decreasing,
probability of engine failure decrease on that TakeOff.

Reduced TakeOff Thrust

Three engine ***parameters that determine the degree of engine severity are rotor speeds, internal temperature and internal pressure****. Operating an engine at a lower thrust rating or at reduced thrust reduces the magnitude of these parameters, thus reducing engine severity.*

Less severe operation tends to lower EGT deterioration*. Since lack of EGT margin is one cause of scheduled engine removals, lowering the EGT deterioration rate can increase the time on wing between shop visits.*

Fuel flow deterioration rate varies directly with EGT deterioration rate*, thus decreasing with the use of reduced thrust.*

Maintenance costs are reduced because of the longer time between shop visits and the lower labor and material costs of the shop visit *to restore the engine to a specified condition.*

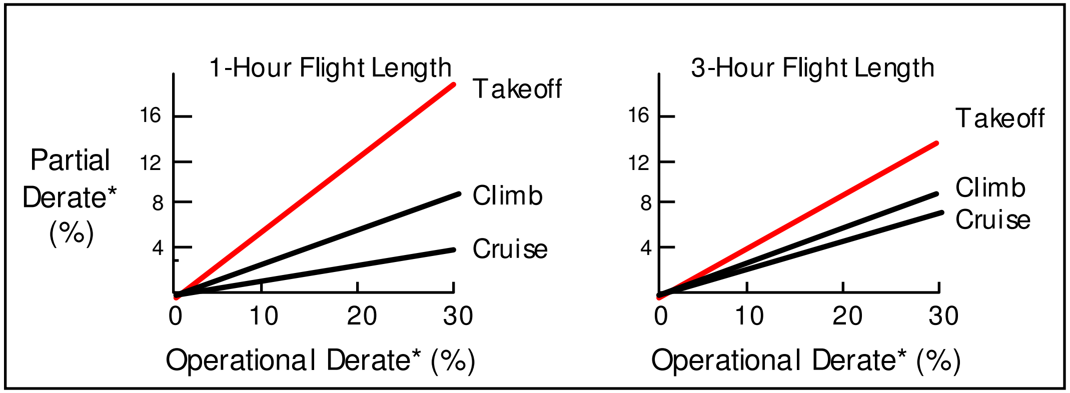
Finally, reduced thrust on a given takeoff reduces stress level *and likelihood of an engine failure on that takeoff.*

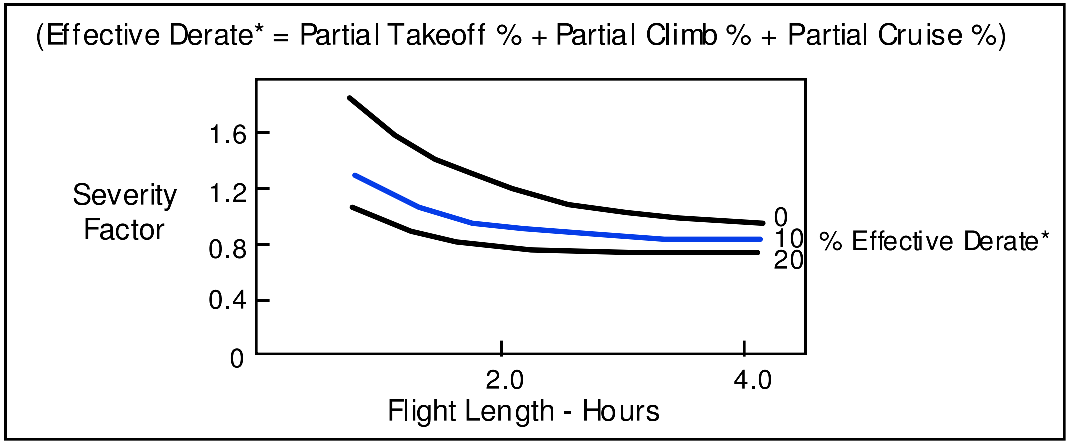
Reduced TakeOff Thrust

Severity Analysis

A means of quantifying and predicting mission severity based on how the engine is used

- *Severity of operation is a function of flight length and "effective derate*" which is a composite of takeoff, climb and cruise reduced thrust/derate.*
- *T/O is weighted heavier on shorter flights; climb and cruise derate are weighted heavier (relative to takeoff) on long flights.*
- *This visualization is not used in the pricing of maintenance service contracts.*





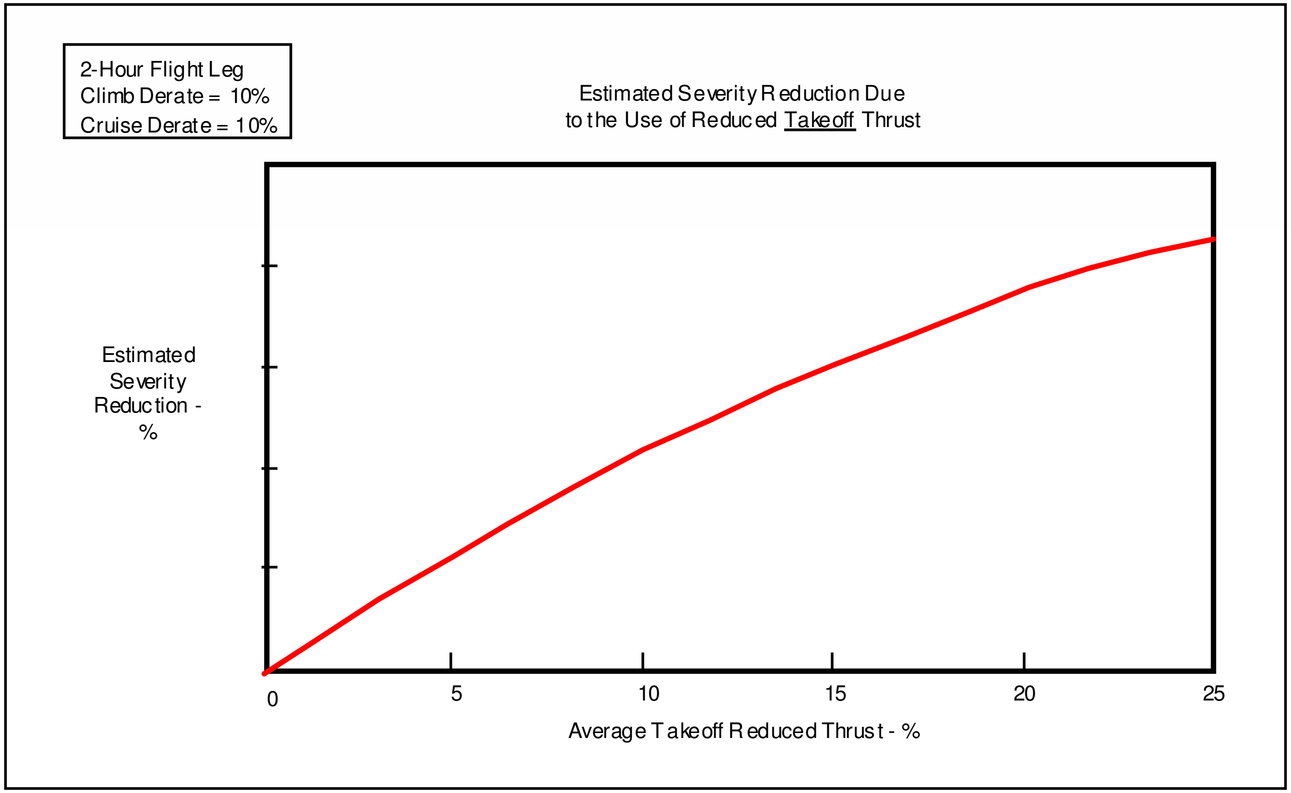
**Reduced Thrust*

Reduced TakeOff Thrust

Severity Analysis

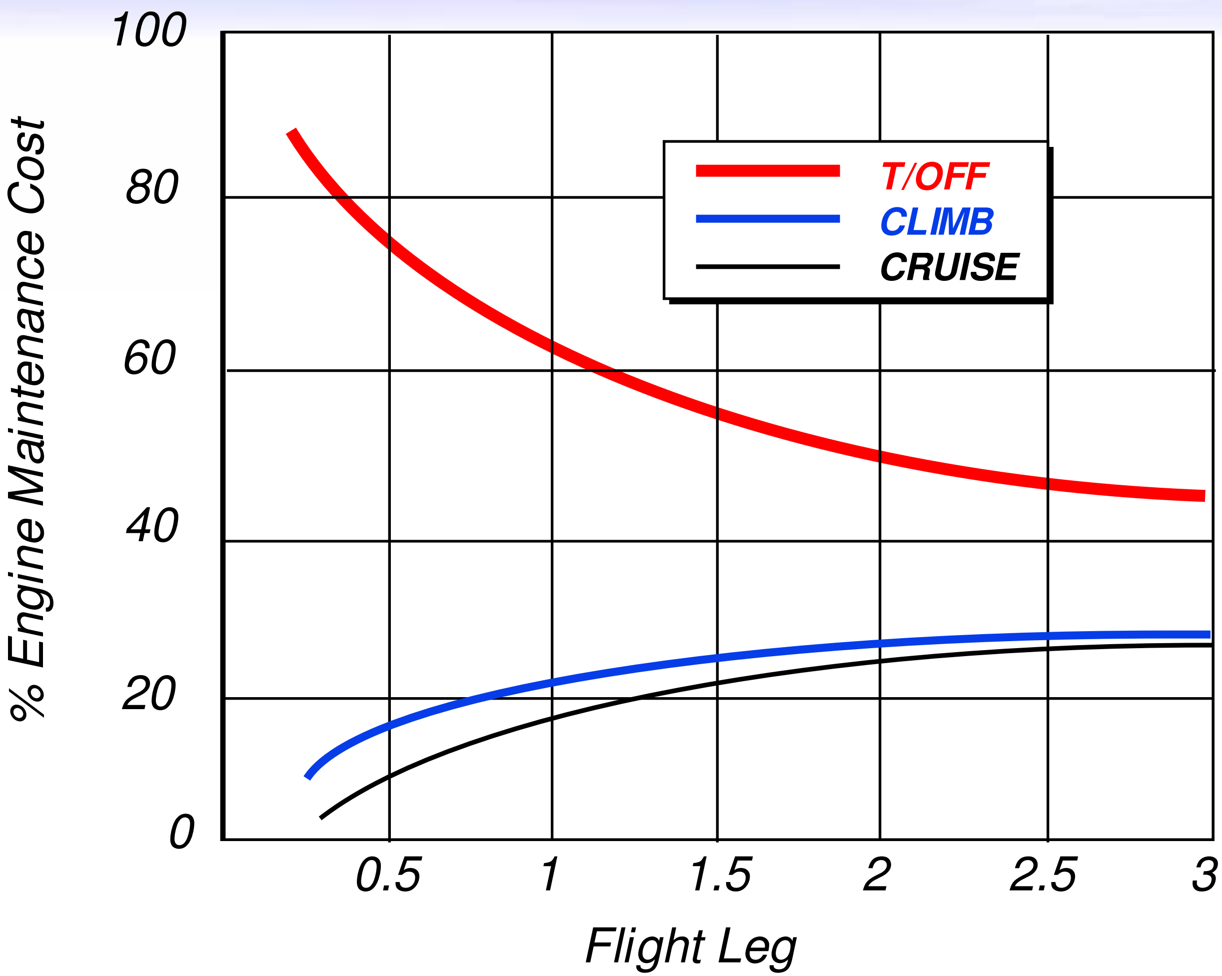
This chart represents the relative impact of reduced thrust increments on severity.

This shows that the first increment of thrust reduction is the most important but that thrust reduction even at the higher increments is important.



Reduced TakeOff Thrust

Lower maintenance costs



1 minute of takeoff has a responsibility of at least 45% at least on the engine maintenance cost

Reduced TakeOff Thrust

Improved flight safety

- No data on Thrust Reduction versus engine failures

- Following data is for takeoff phase Vs climb phase, showing significantly higher chance of engine failure at higher thrust settings associated with takeoff

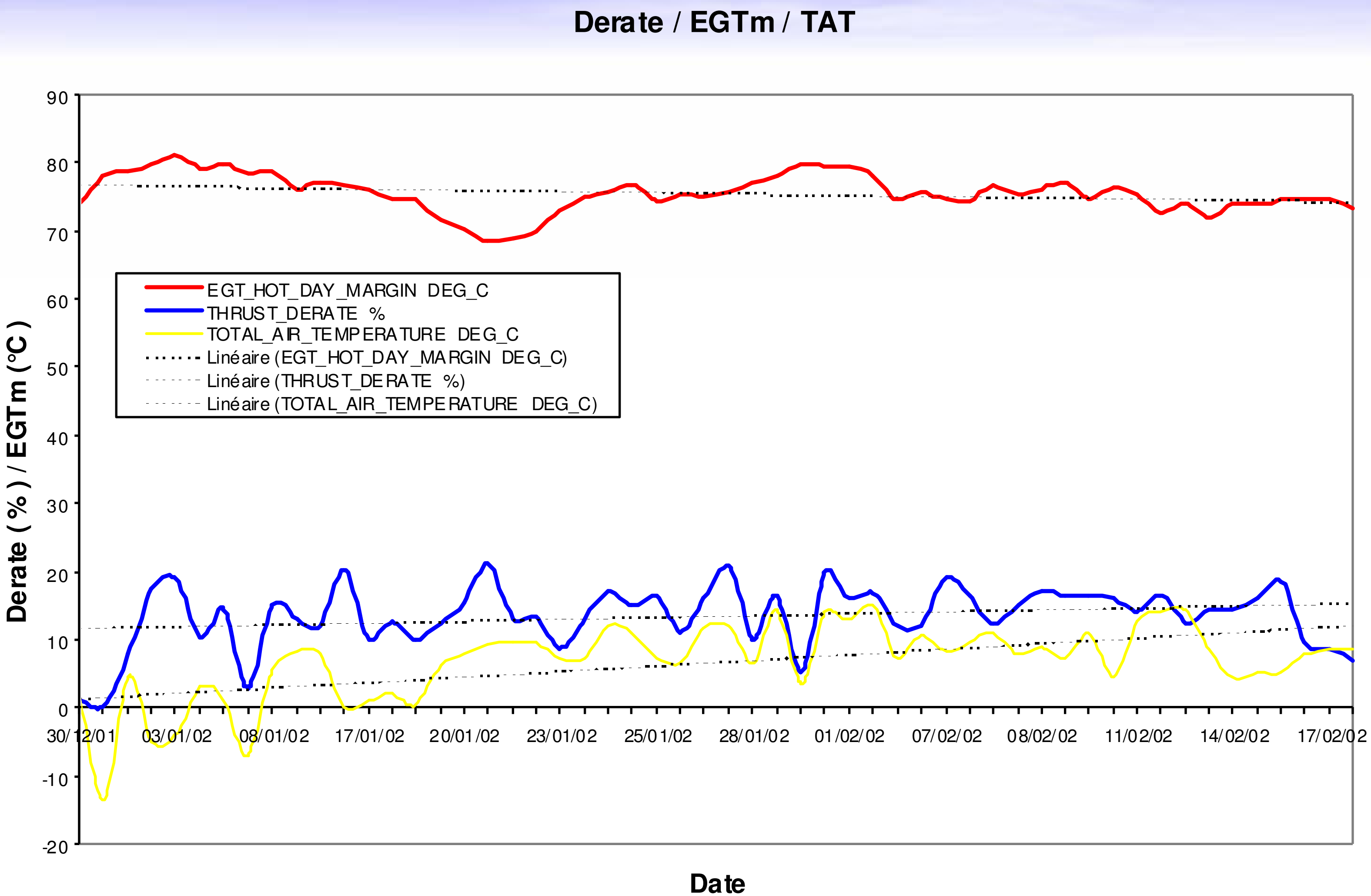
Phase	Exposure Time	% IFSD	IFSD Factor	% Major Failures	Major Factor	% Fires	Fire Factor	% Component Separation	Separation Factor	% All Engine Power Loss	Power Loss Factor
Takeoff	1	4	4	43	43	12	12	23	23	8	8
Climb	14	31	2	30	2	42	3	34	2,5	22	1,6
Takeoff Vs Climb factor			2		21,5		4		9		5

Note: - Data for entire high-bypass engine-powered commercial transport fleet
- Source: « Propulsion Safety Analysis Methodology for Commercial Transport Aircraft », 1998

Example: For an average high bypass turbofan mission (approximately 2 hours) 43% of the uncontained engine failures occur in the 1% of the time spent in the takeoff phase. This yields an "uncontained factor" of 43÷1 = 43 versus the "uncontained factor" for climb which is 30÷14 ~ 2. Thus, on uncontained failure is 21.5 times more likely to occur in the takeoff (higher thrust) phase than the climb (lower thrust) phase of flight. To make the point that an engine failure is less likely at reduced thrust, one can think of the takeoff phase as a "full thrust" takeoff and the climb phase as "reduced thrust." Thus, the data would show a significantly higher chance of engine failure at full thrust than reduced thrust.

Reduced TakeOff Thrust

THE POWER OF FLIGHT



Reduced TakeOff Thrust

THE POWER OF FLIGHT

For

- RUNWAY (Length, Altitude, slope…)
- TEMPERATURE, QNH, wind,…
- FLAPS SETTING
- OBSTACLES HEIGHT & DISTANCE
- AIRPLANE CONDITION
- RUNWAY CONDITION

At

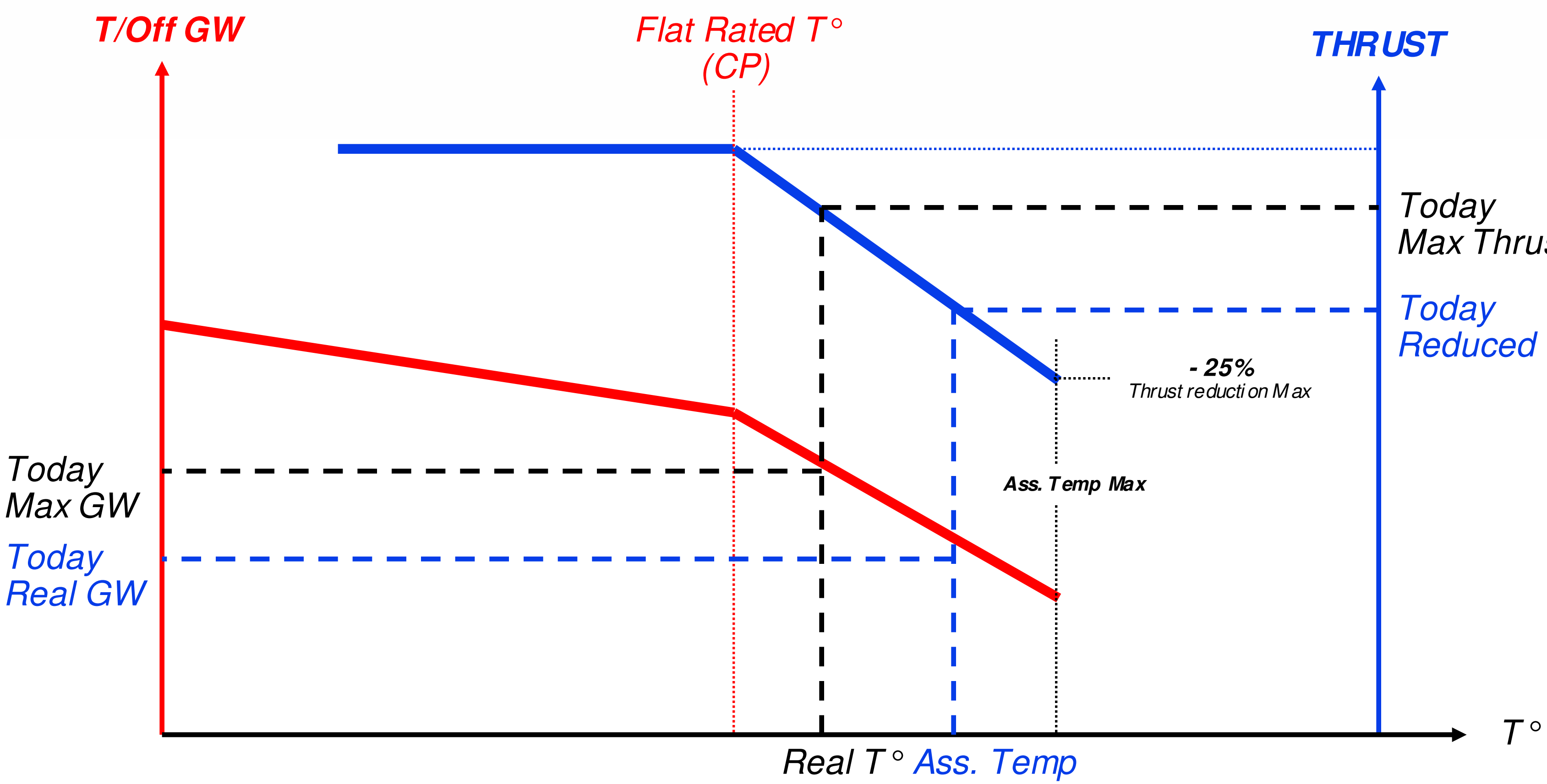
- MAX TAKEOFF THRUST SETTING

There is

1 LIMITING GW

Reduced TakeOff Thrust

***IF REAL GW < MAX LIMITING GW**, a T° called "**Assumed**" can be computed that would limit the airplane performance to the real GW.*

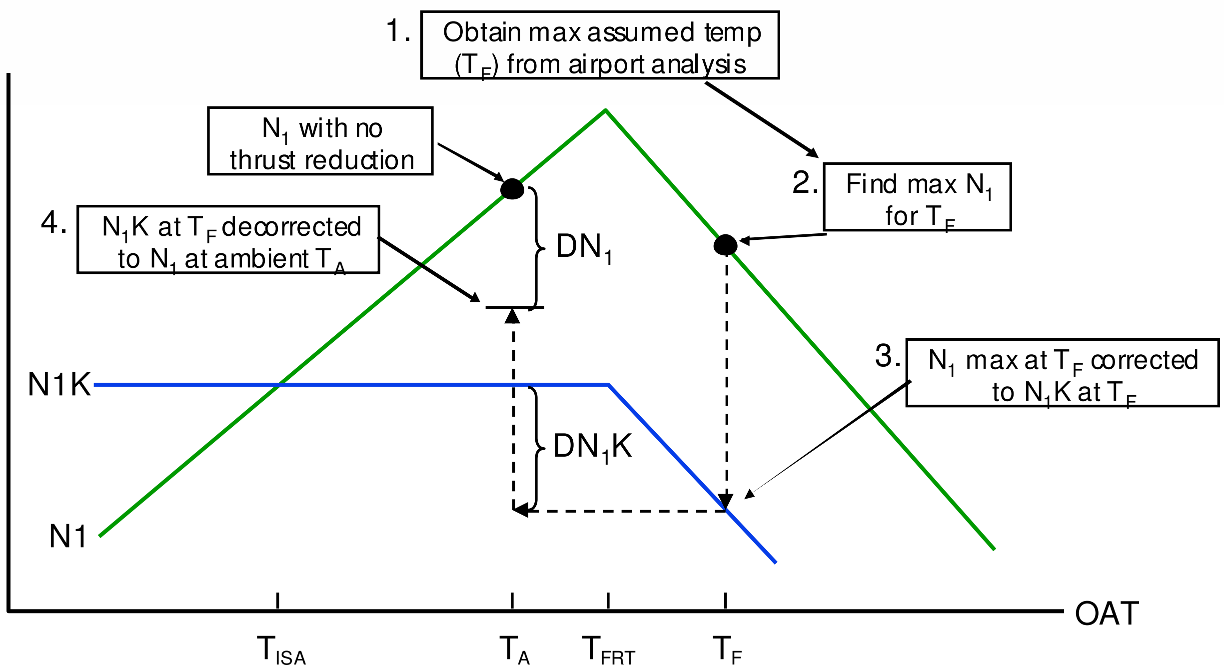


Performance Aspects

Logic for calculating reduced takeoff N1 with the Flex/assumed Temperature method:

Note: this logic is incorporated in your FCOM/Operations Manual procedures and FMS– not a manual crew calculation

- *1. Find allowable assumed temperature using takeoff analysis chart*
- *2. Find gage N1 (maximum) corresponding to assumed temperature*
- *3. Convert the gage N1 (maximum) for the assumed temperature to a value of corrected N1 using the assumed temperature*
    - *This represents the thrust required if actual temperature was equal to assumed temperature value*
- *4. Convert this corrected N1 back to the gage N1 using the <u>actual</u> temperature*
    - *This gage N1 value will yield a corrected N1 (and thrust) equivalent to that achieved in Step 3*



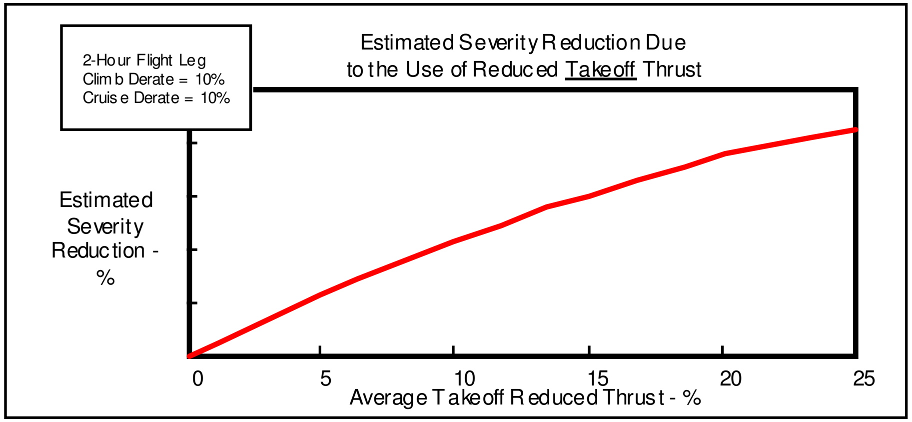
N_1 = Physical (gage) N_1
N_1K = N_1 corrected for temperature

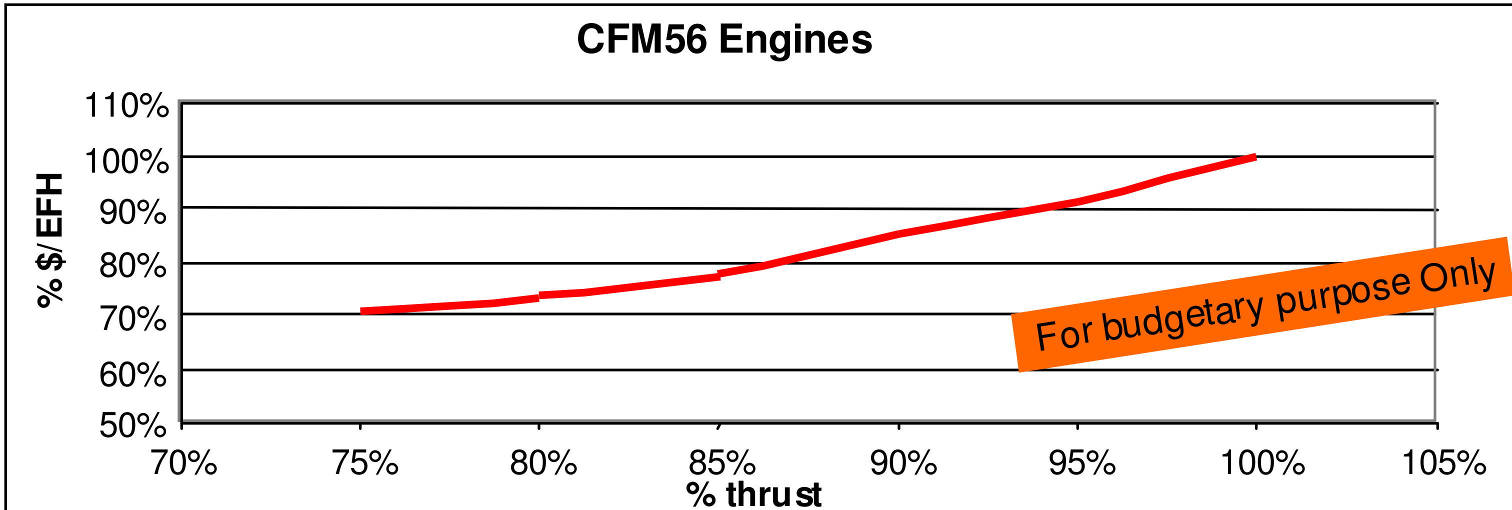
Reduced TakeOff Thrust

Severity Analysis
Reduced Thrust effect on CFM56 Engines

This chart represents the relative impact of reduced thrust increments on severity.

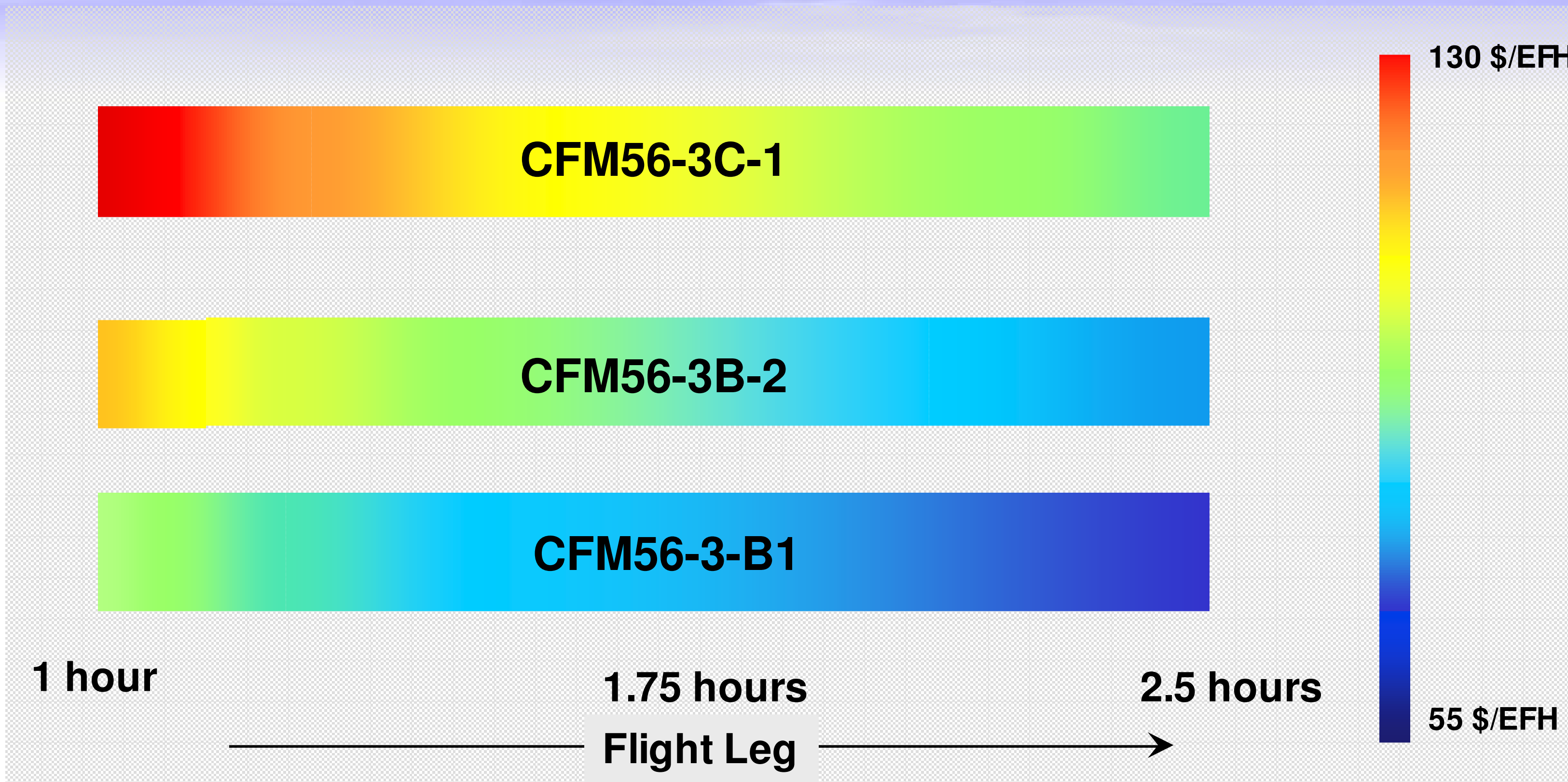
This shows that the first increment of thrust reduction is the most important but that thrust reduction even at the higher increments is important.





CFM56-3 Maintenance Costs

Line and shop cost estimates -10 year average



Bare engine cost excluding fees, transportation, life limited parts. $70 labor rate. $2002

LOW MAINTENANCE COST WITH ALL RATINGS AND UTILIZATION

For budgetary purpose Only

Reduced TakeOff Thrust

The accuracy of the OAT is essential to optimize

ENGINE TYPE	EGTM-SLOATL COEFFICIENT
CFM56-7B27	3,5
CFM56-7B26	3,5
CFM56-7B24	3,5
CFM56-7B22	3,5
CFM56-7B20	3,5
CFM56-7B18	3,5
CFM56-5C4	3,7
CFM56-5C3	3,7
CFM56-5C2	3,7
CFM56-5B6	3,27
CFM56-5B5	3,27
CFM56-5B4	3,28
CFM56-5B3	3,43
CFM56-5B2	3,43
CFM56-5B1	3,43
CFM56-5A5	3
CFM56-5A4	2,9
CFM56-5A3	3,1
CFM56-5-A1	3,1
CFM56-3C-1	3,2
CFM56-3B-2	3,2
CFM56-3-B1	3,2
CFM56-2-C1	3,2

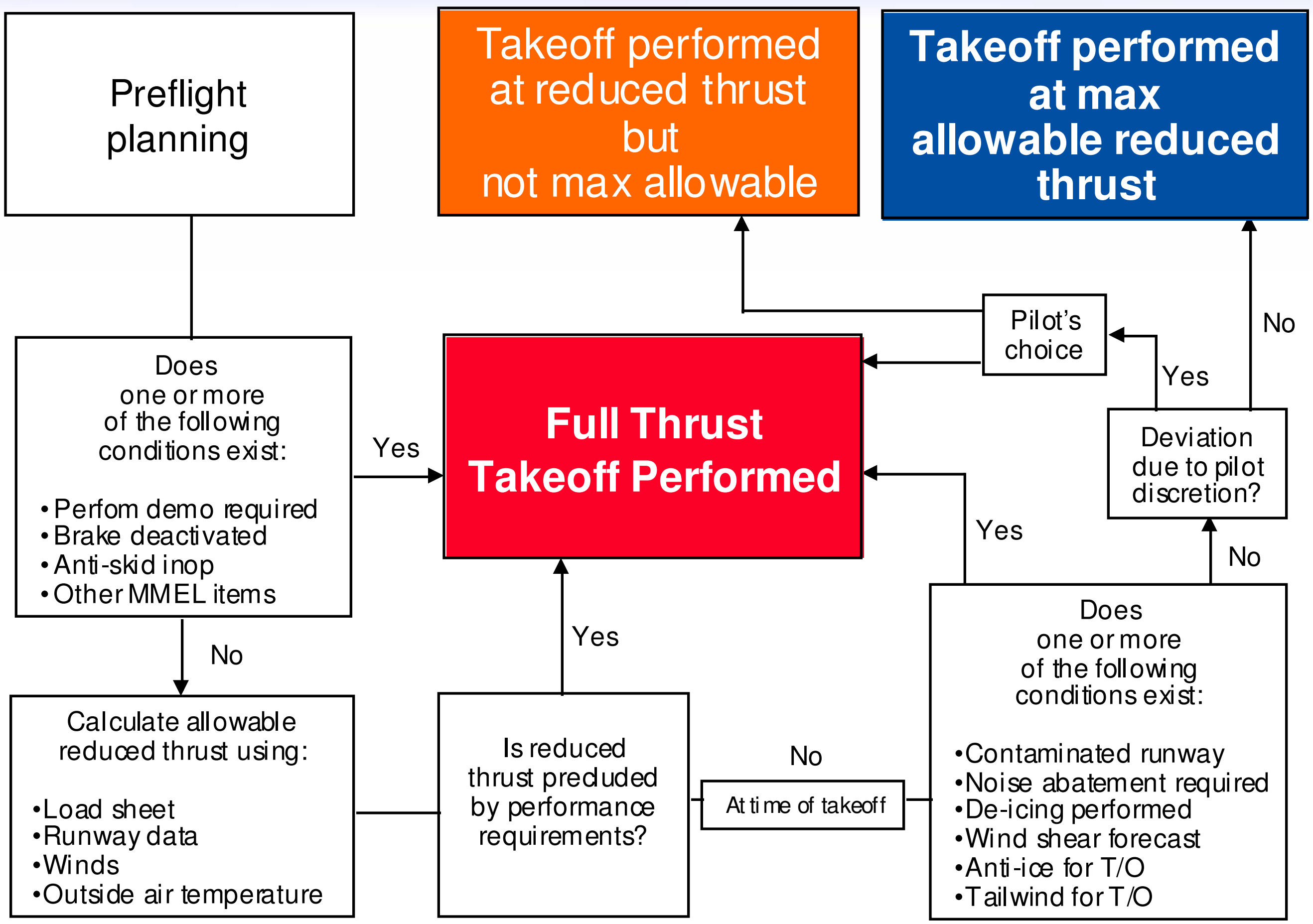
TAKEOFF GROSS WEIGHT

THRUST REDUCTION

1°C OAT or Assumed Temp = 3,2°C EGT

Reduced TakeOff Thrust

Tools to Analyze Reduced Thrust Programs
Process Map (Typical)



This is a process map for a typical operator with the typical company restrictions on reduced thrust discussed earlier in this presentation. Note that there are many hard decision rules and discretionary decisions on the part of the pilot that may result in full thrust takeoffs or takeoffs at less than maximum allowable reduced thrust.

Reduced TakeOff Thrust

THE POWER OF FLIGHT

THE ASSUMED T° METHOD ALWAYS CONSERVATIVE ON THE AIRCRAFT PERFORMANCES.

Example:

Assumed T° = 45°
&
V1 CAS = 140 Kts

⇨ TAS = 148.5 Kts

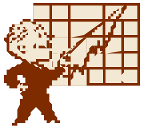
The Speed used to comply with the performance calculations!

Air T° = 10°
&
V1 CAS = 140 Kts

⇨ TAS = 138.5 Kts

The Speed you will have...

Due to lower ambient temperature and higher air density in the actual takeoff conditions, actual TAS is lower and actual thrust is higher



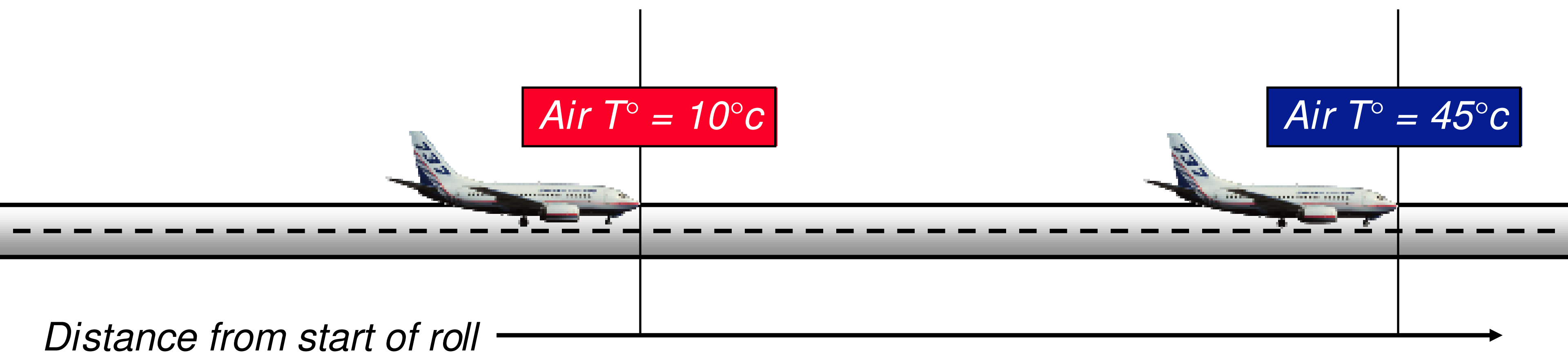
TAS = CAS +/- 1% ⇨ Δ5°C / Std (+ if T° > Std, - if T° < Std)

Reduced TakeOff Thrust

AIRCRAFT PERFORMANCE MARGIN WITH REDUCED TAKE OFF THRUST IS ALWAYS CONSERVATIVE.

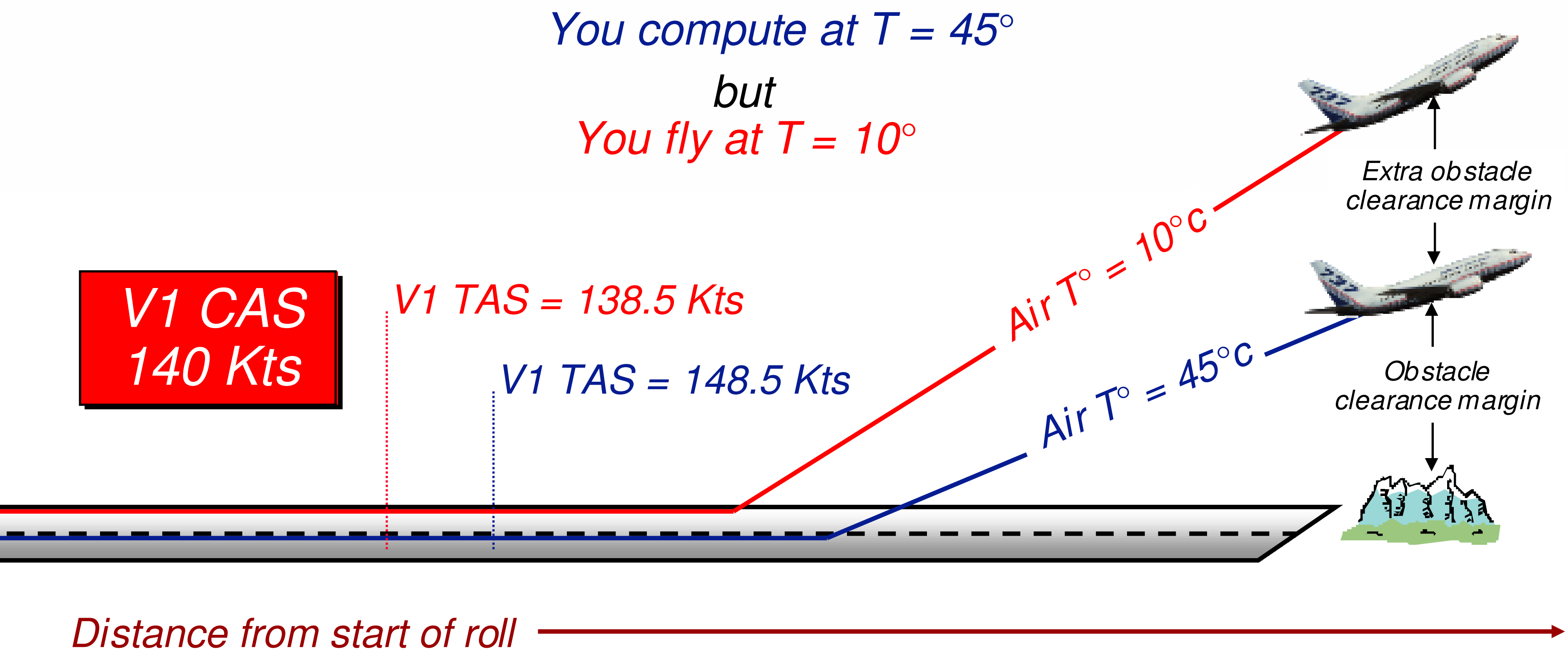
V1 CAS = 140 Kts
V1 TAS = 138.5 Kts

V1 CAS = 140 Kts
V1 TAS = 148.5 Kts



Reduced TakeOff Thrust

AIRCRAFT PERFORMANCE MARGIN WITH REDUCED TAKEOFF THRUST IS ALWAYS CONSERVATIVE.



- If performance is limited by the one engine inoperative minimum climb gradient requirements, the higher actual thrust will result in a higher climb gradient
- If performance is limited by obstacle clearance, the higher climb gradient combined with the shorter takeoff distance will result in extra clearance margin

Reduced TakeOff Thrust

AIRCRAFT PERFORMANCE MARGIN WITH REDUCED TAKE OFF THRUST IS ALWAYS CONSERVATIVE.

737-800W WITH CFM56-7B27 ENGINES
PRESSURE ALTITUDE 0 FT
RUNWAY LENGTH 7000 FT, DRY
NO OBSTACLES
FLAPS 5, A/C AUTO, STANDARD TAKEOFF SPEEDS

MAXIMUM RATED THRUST (27K)				24K DERATE		
OAT (C)	MTOW (KG)	PERF LIM	V1 VR V2 (KT)	MTOW (KG)	PERF LIM	V1 VR V2 (KT)
60	60400	FLD	134 135 140	55900	FLD	131 131 13[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	57700	FLD	133 133 13[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	59700	FLD	134 135 13[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	61900	FLD	136 137 14[illegible]
40	69300	FLD	141 143 150	64100	FLD	138 139 14[illegible]
38	70300	FLD	142 144 151	65000	FLD	139 140 14[illegible]
36	71100	FLD	142 145 152	65800	FLD	139 141 14[illegible]
34	72000	FLD	143 145 153	66700	FLD	140 141 14[illegible]
32	72900	FLD	143 146 154	67700	FLD	141 142 14[illegible]
30	73700	FLD	144 147 15[illegible]	[illegible]	[illegible]	[illegible]
25	74300	FLD	144 147 15[illegible]	[illegible]	[illegible]	[illegible]0
20	75000	FLD	145 148 15[illegible]	[illegible]	[illegible]	[illegible]1
15	75600	FLD	146 149 157	70300	FLD	144 145 151
10	76200	FLD	146 149 157	71000	FLD	144 146 152

Maximum Allowable Assumed Temperature 38°C

27K, OAT 15°C
Takeoff Weight 70300 KG

Parameter	OAT 38°C	OAT 15°C assume 38°C	Extra margin
V1 (KIAS / KTAS)	142 / 148	142 / 142	6
VR (KIAS / KTAS)	144 / 150	144 / 144	6
V2 (KIAS / KTAS)	151 / 157	151 / 151	6
Thrust per engine at V1, lb	23855	24061	206
Thrust per engine at VR, lb	19833	20019	186
Thrust per engine at V2, lb	19857	20034	177
One engine inoperative takeoff distance, ft	7000	6507	493
Accelerate-stop distance, ft	7000	6507	493
115% all-engine takeoff distance, ft	6942	6464	478

Reduced TakeOff Thrust

**More the difference between OAT and Assumed Temperature is,
More Reduced TakeOff Thrust available...**

1 - TakeOff performance margin ⇗⇗

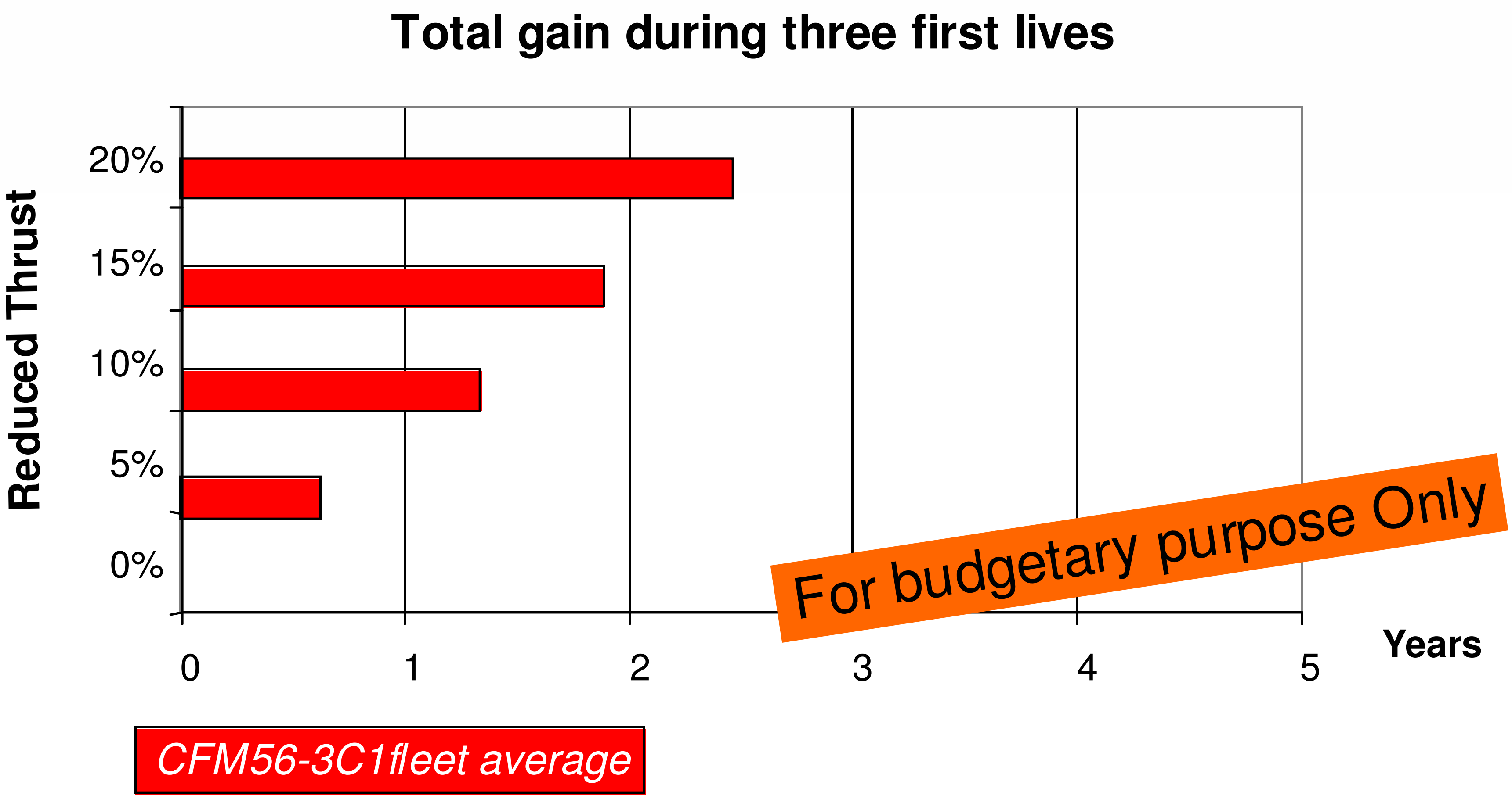
2 - Safety ⇗⇗

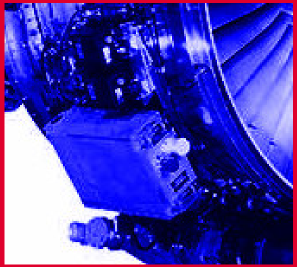
3 - Maintenance Cost ⇘⇘

Reduced TakeOff Thrust

Reduced Thrust effect on CFM56-3C 23.5K

3000 hours Flight Leg 1.6 / year /aircraft,





CFM56 General

Technical Features

Engine Certification & Testing

Opera

Reduc

- Review by flight phase of normal operating considerations
- If there are inconsistencies between this presentation and the Flight Crew Operating (FCOM) or the Aircraft Operating Manual (AOM) the FCOM and/or AOM take precedence

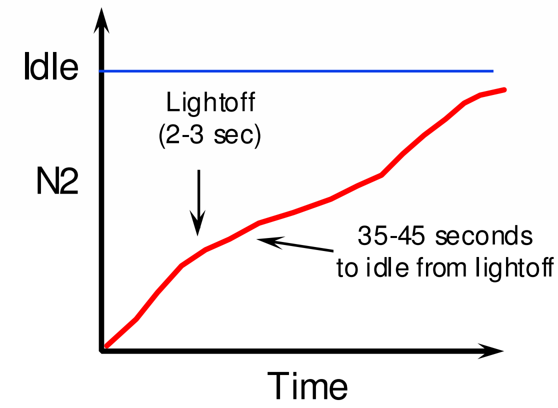
Normal Operating Considerations

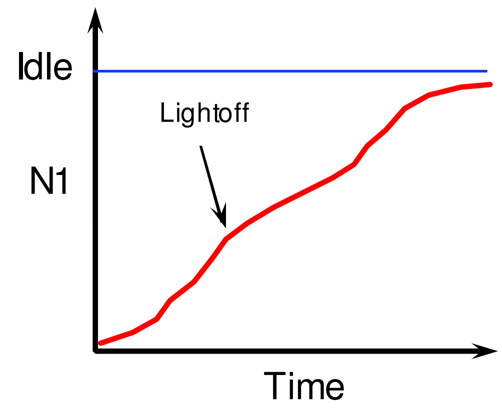
Flight phases, ops recommendations

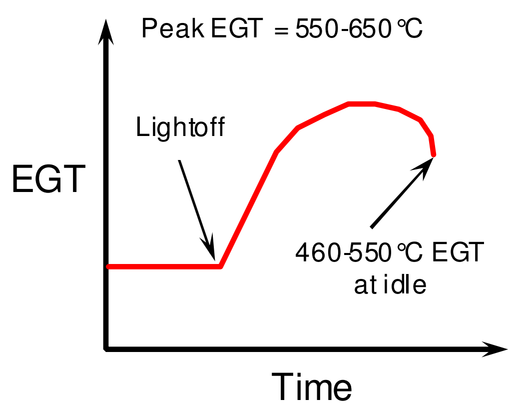
Starting Characteristics

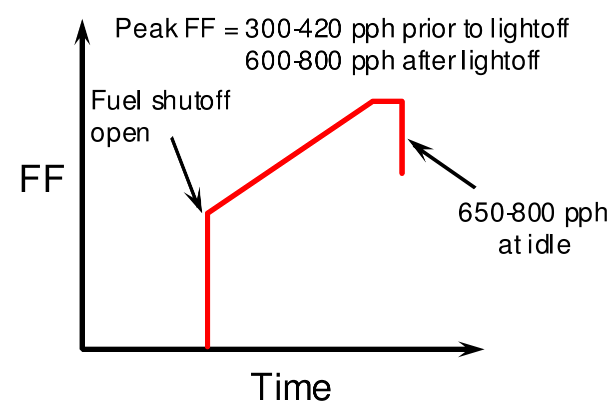
Normal Start (All Numerical Values Are "Typical" Not Limits)

- *Lightoff*
  - *Typically within 2-3 seconds*
- *EGT start limit*
  - ***725°C***
- *Idle*
  - *Indicated by EGT and fuel flow reduction*
  - *Typical start time: 45 to 60 seconds*

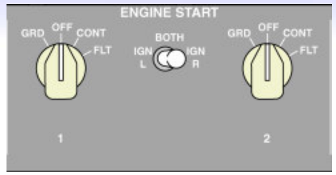








Common Start for CFM56-3 &-7B



❑Manual start

❑Starter air Pressure

- *25 psig desirable (start valve open)*
- *Warmer, slower starts with lower pressure . . . Be alert for stall or overtemperature*

❑Start valve

- *Opens when start switch placed to "Ground"*
- *Closes at approximately 50% N2*

❑Ignition

- *Turned on with fuel*
- *Crew manually selects igniters used*
- *Recommend alternating "L" and "R"*

❑Start lever

- *Select "Idle" when N1 rotation is verified and N2 rpm reaches 25% or, if 25% cannot be achieved, at maximum motoring N2 speed (minimum N2 20%)*

❑Fan rotation

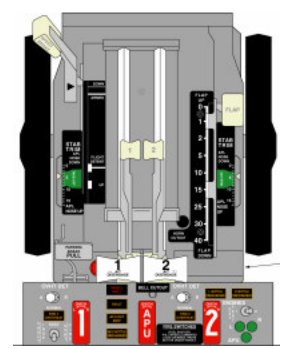
- *No restriction on opposite fan rotation (tailwind)*
  - *Initial N1 indication slower with a tailwind*

❑Tailwinds

- *Starts demonstrated with 53 knot tailwind*
- *Expect **warmer starts** with high residual EGT*

❑Crosswinds

- *No significant impact on start characteristics*



Normal Operation

THE POWER OF FLIGHT

Start *(Continued)*

CFM56-3

- **Lightoff**
  - *Typically 1-5 seconds after start lever to "idle"*
  - *Pilot must abort the start if there is no lightoff within 10 seconds (30 seconds for in-flight start)*

CFM56-7B

- **Lightoff**
  - *Typically 1-5 seconds after start lever to "idle"*
  - *Pilot must abort the start if there is no lightoff within 10 seconds (30 seconds for in-flight start)*
  - *During ground start, if lightoff is not detected within 15 seconds of start lever to idle (20 seconds - cold day), FADEC will terminate fuel and ignition*
  - *For in-flight starts, FADEC will not automatically terminate fuel and ignition for no lightoff*

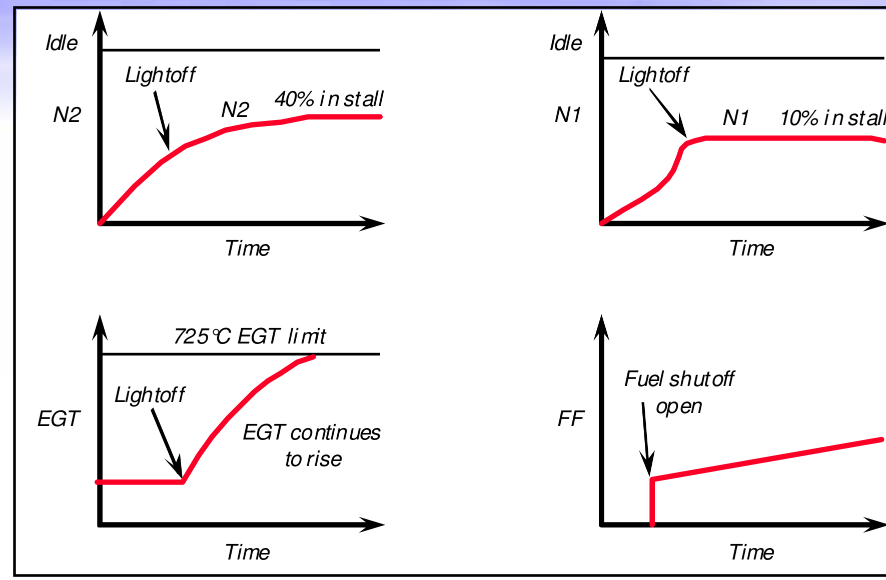
- **Oil pressure**
  - *Must be indication by ground idle*
  - *May be full-scale for a cold-soaked engine*
    - *Should come off full-scale after the required minimum 2-minute warm-up time prior to takeoff*
- **N1**
  - *Must have N1 indication prior to start lever to "idle"*

Normal Operation

Low Speed Stall Characteristics

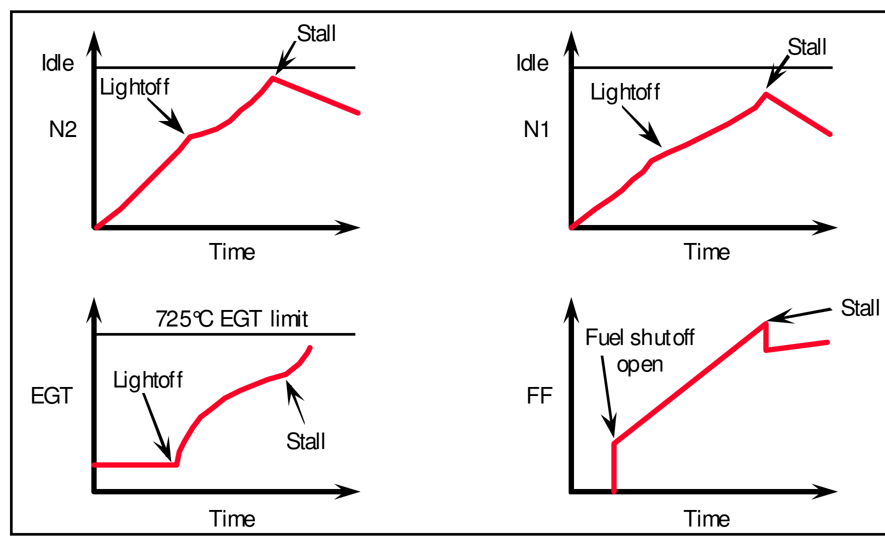
Lightoff Stall

- Engine speed stagnates immediately after lightoff
- EGT rises rapidly
- Not self-recovering
  - Recovery requires FADEC or flight crew intervention



High Sub-idle Stall

- Engine stalls just below idle
- EGT rises rapidly
- Not self-recovering
  - Recovery requires FADEC or flight crew intervention



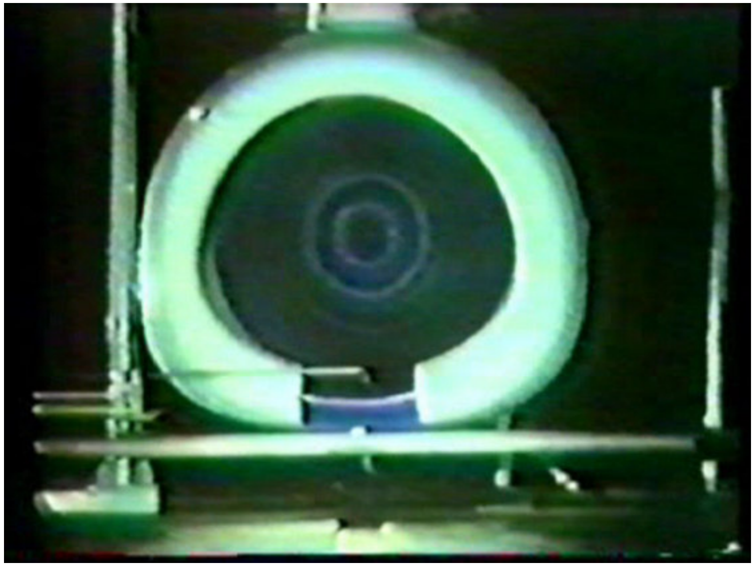
Normal Operation

Taxi

High FOD Potential Areas

- Desert Airports
- Coastal Airports
- Airports with: Construction activit, Deteriorated runways/ramps/taxiways, Narrow runways/taxiways, Ramps/taxiways sanded for winter operation, Plowed snow/sand beside runways/taxiways

Engine Vortices is a common cause of ingestion on ground



Engine Vortices

- Strength increases at high thrust, low airspeed
- High exposure
  - Thrust advance for breakaway from stop
  - Thrust advance for TakeOff
  - Reverse Thrust at low airspeed
  - 180° turn on runway
  - Power assurance runs
- Destroyed by Airspeed and/or Headwind

Normal Operation

Taxi

Not sensitive to ambient conditions

- *EGT unaffected by cross winds may be slightly higher with tail winds*
- *Constant idle thrust: N2 varies with OAT/PA to maintain constant thrust level*

Minimize breakaway thrust

- *Vortices is common cause of FOD ingestion on ground*
- *10 knots headwind/Airspeed will destroy vortices formed up to 40% N1*

10 knots

airspeed/headwind will destroy vortices formed up to ***40% N1***

30 knots

airspeed will destroy vortices formed at typical ***TakeOff thrust settings***

Normal Operation

Taxi

One Engine Taxi Out (Not recommended)

- *2 minutes minimum recommended before apply TakeOff thrust setting*
- *Crews have to consider no fire protection available from ground staff when starting the other engine away from the ramp.*
- *If mechanical problems occur during start up, departure time might be delayed due to a gate return.*
- *After frequent occurrences, possible increase of deterioration level versus the engine running first.*

Warm up 2 min mini prior to takeoff

*A cold engine is defined by shut-down of more than 6 hours. A 2 minutes minimum warm- up is recommended in the FCOM but CFM experience shows that warm-up times between **10** and **15 minutes** consistently reduces the takeoff EGT.*

Warm up impact on cold engine						
Engines Estimated idle time impact on TakeOff EGTMargin						
Idle time (min)	**2**	**5**	**10**	**15**	**20**	**25**
EGT (°C)	**ref ***	**ref - 4°C**	**ref - 9°C**	**ref - 12°C**	**ref - 14°C**	**ref - 15°C**

**** ref equal to TakeOff EGT with a 2 min warm up***

CFM REP 05/09/00 based on PSE information

Normal Operation

THE POWER OF FLIGHT

Taxi

- **Reverse thrust during taxi only in emergency**
- **Oil pressure varies with N2**
  - **Minimum 13 psi** (required ENG SHUT DOWN), May be full scale for cold soaked engine
- **Oil temperature**
  - No minimum
  - Rise must be noted prior to takeoff
  - Maximum 140°C continuous, 155°C for 15 minutes
- **Oil quantity:**
  - Varies inversely with engine speed
  - Should remain constant during steady-state operation
  - Oil gulping: after engine start, oil level decreases due to distribution within system (sumps, gearboxes and supply scavenge lines)
  - Increasing oil quantity or lack of gulping could indicate leak in fuel/oil heat exchanger

Gulping effect

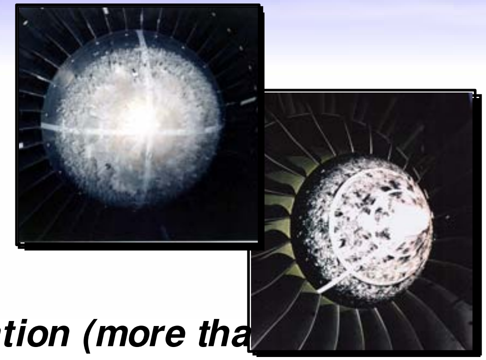
Flight Phase	Deviation From Pre-Start Quantity
Ground idle	4 quarts (20%)
Takeoff	6 quarts (30%)
Climb, cruise, descent	4-5 quarts (20%-25%)
After landing	4 quarts (20%)
Shutdown	0 quarts* (0%)

Note: These values are not limits . . . information only

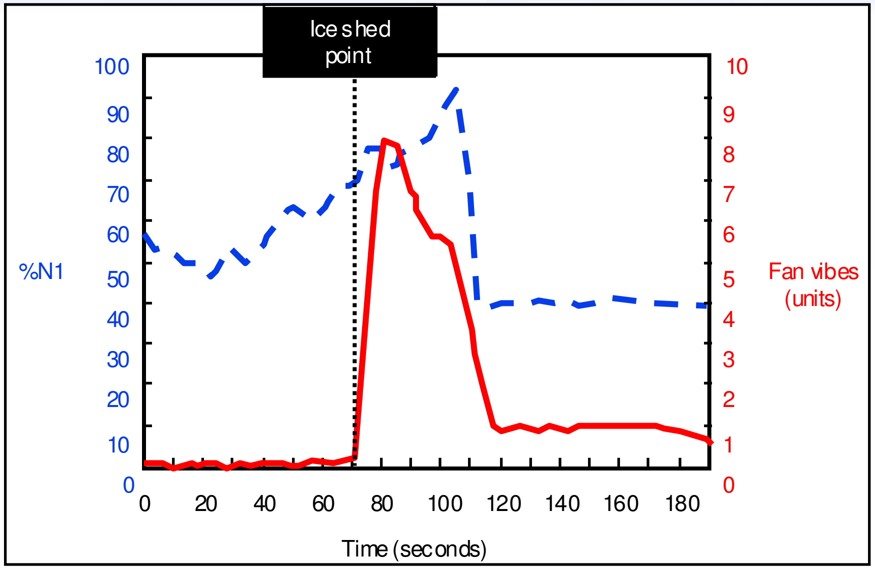
Normal Operation

Ground Operation in Icing Conditions

- ***ANTI-ICE ON***
  - *Anti-ices inlet lip*



- ***During extended operation (more tha minutes):***
  - ***Accelerates engines to 70% N1 and hold for 30 seconds** (or to an N1 and dwell time as high as practical, considering airport surface conditions and congestion)*
    - *Allows immediate shedding of fan blade and spinner ice*
    - *De-ices stationary vanes with combination of shed ice impact, pressure increase and temperature rise*



- ***Perform this procedure every 30 minutes and just prior to or in conjunction with the takeoff procedure**, with particular attention to engine parameters prior to final advance to takeoff thrust*

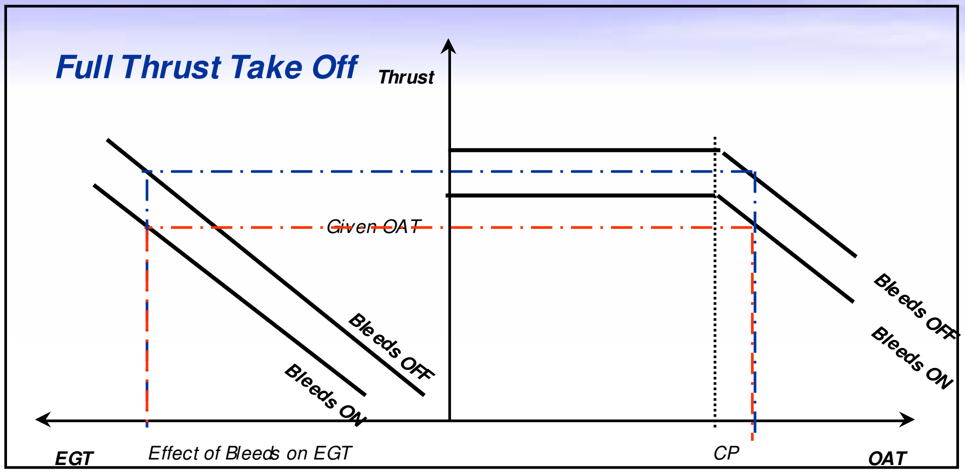
Normal Operation

Takeoff

- ***From an engine standpoint, rolling takeoff is preferred***
  - *Less FOD potential on contaminated runways*
  - *Inlet vortex likely if takeoff N1 set below 30 KIAS*
  - *Less potential for engine instability or stall during crosswind/tailwind conditions*
- ***N_1 thrust management***
  - *Engine control computes command N_1 for max or reduced thrust*
  - *Throttle "stand up" prior to full thrust (minimizes uneven acceleration)*
  - *Pilot sets throttle for full thrust or reduced thrust*
  - *Aircraft/engine controls maintain N_1 at command value*
- ***Ignition***
  - *Requirement specified by aircraft manufacturer*
  - *Engine certification tests completed without the use of ignition*
- ***Bleeds***
  - *ON/OFF depending on company policy/performance requirements*
  - *Effect on engine parameters*

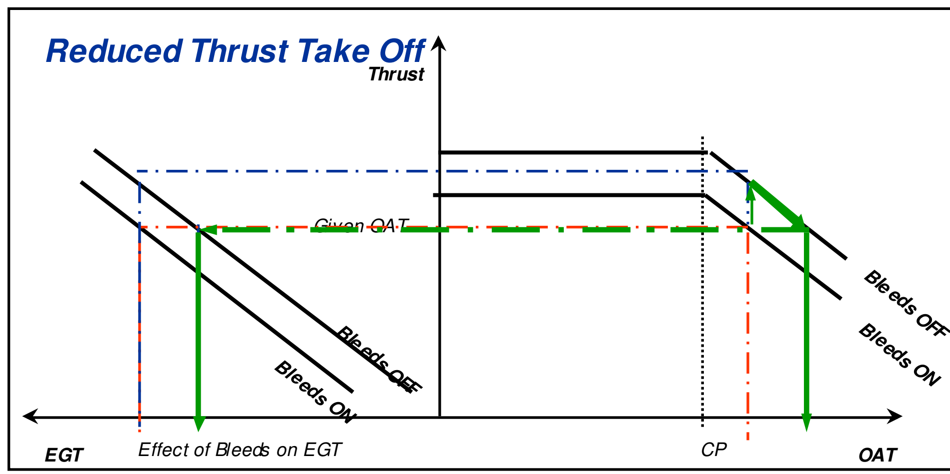
Normal Operation

Eng Bleeds effect at Takeoff



At full take off power, there is a thrust decrement when setting Eng Bleeds Off to Bleeds On when EGT remain the same. Only MTOW is impacted, higher with Bleeds Off than Bleeds On.

At reduced take off thrust, this is the same logic that full thrust. But as the TOW (Take Off Weight) is not maximum, in order to recover the same level of thrust Bleeds Off than Bleeds On, reduced thrust need to be increase, so EGT will decrease .



Redcued thrust Take Off with engine bleeds OFF increase engine live

Throttle "stand up" prior to full thrust (minimizes uneven acceleration)

Slow/Differential Engine Acceleration (CESM 031)

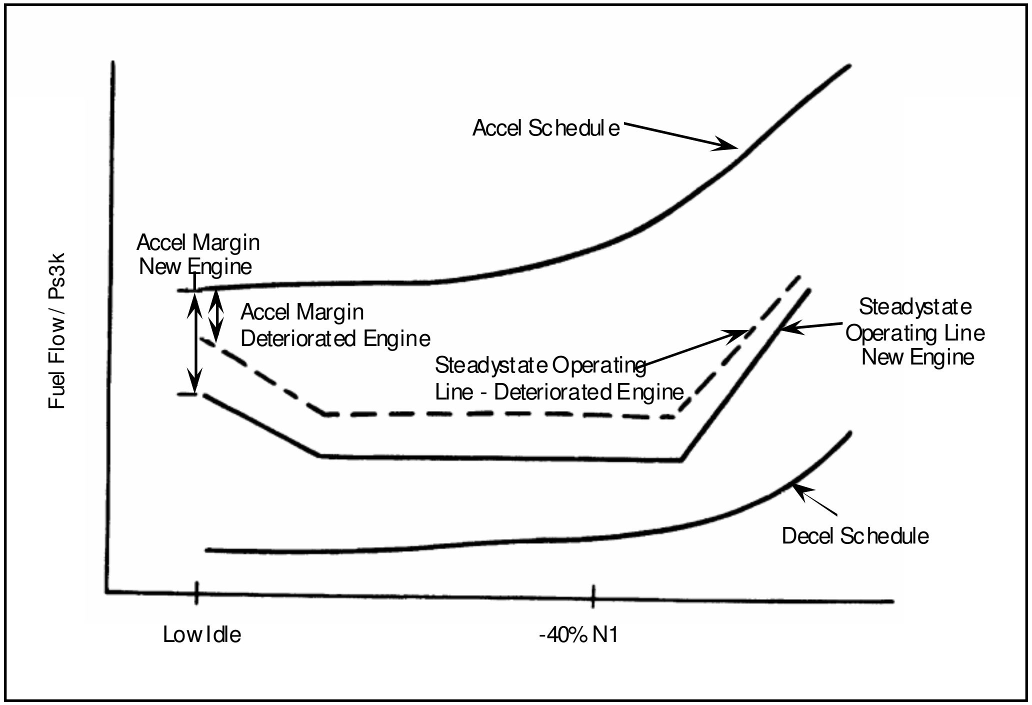
Background

- Field experience shows that CFM56-3 series engines can exhibit differential acceleration times from low Idle as time accumulates, which can affect takeoff operation)

- The opposite figure depicts the relationship between the engine operating line and the MEC acceleration schedule

- The operating line represents the fuel-to-air ratio required to maintain a steadystate speed and is not scheduled

- The engine's operating line is affected by
  - Basic engine health
  - Engine thermal condition
  - VSV tracking
  - Pneumatic bleed
  - etc…



- Slow accelerating engines exhibit an upward migration of the low-speed steadystate operating line This reduces the acceleration margin and causes engines to accelerate more slowly from low idle

Normal Operation

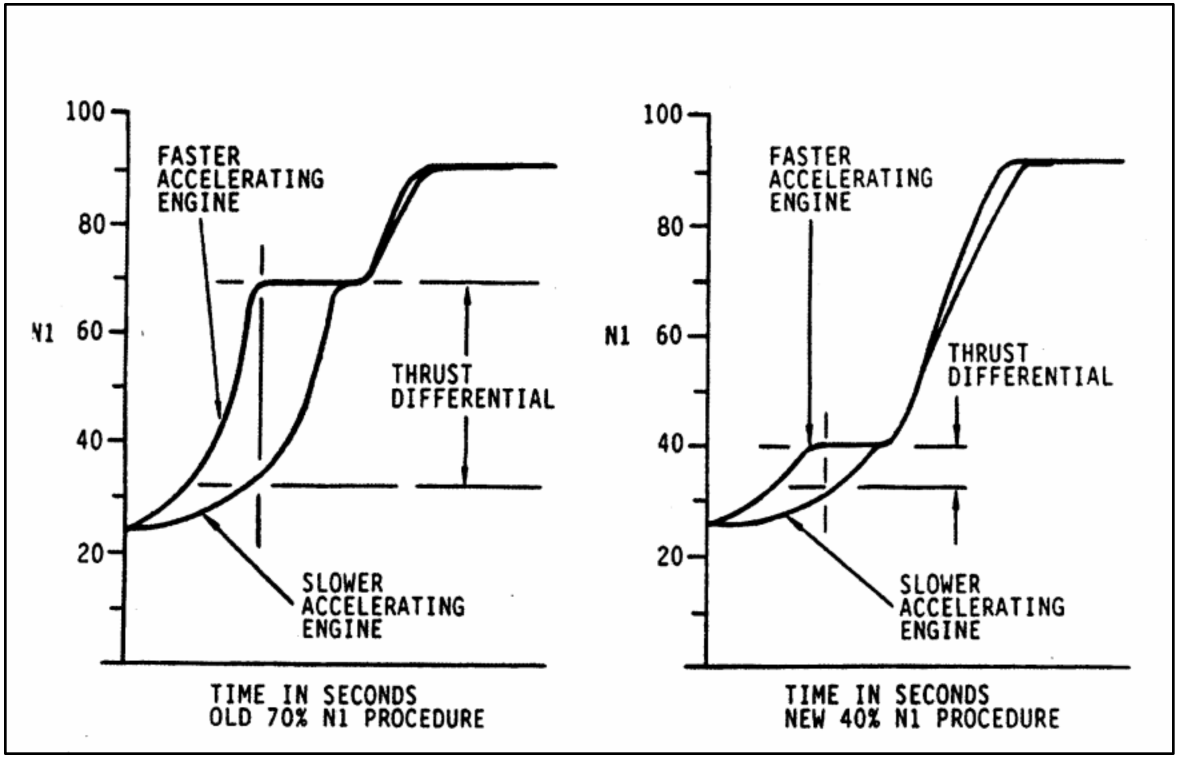
Slow/Differential Engine Acceleration (CESM 031)

Procedures & Programs

Several procedures have been implemented by CFM and Boeing to minimize and control differential acceleration from low idle.

Boeing Operations Manual

- *The Boeing Operations Manual was revised in May 1989 (OMB 737-300 89-3 and 737-400 89-4) to reflect a change in recommended take off thrust lever set procedure.*



Previously, the procedure called for a vertical throttles position (60%-70%) allowing the engine to stabilize prior to takeoff power setting.

The revised procedure recommends a pause at 40% N1, and provides a means to effectively control differential acceleration during the entire takeoff thrust lever set.

Normal Operation

Slow/Differential Engine Acceleration (CESM 031)

Procedures & Programs (contd)

VSV dynamic rigging

- *Opening the VSVs within limits significantly improves an engine's start and acceleration characteristics*
- *Minor tooling required to perform this procedure*
- *Improves accel times from low idle to 40% N1 by 4-5 seconds*

Idle speed adjustments

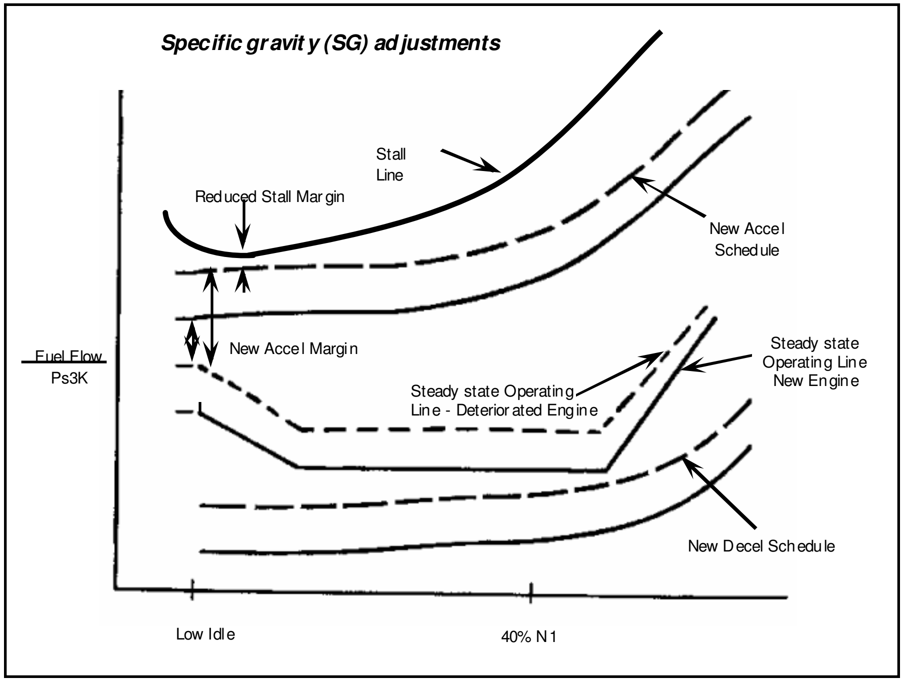
- *Adjusting low and high idle to the upper tolerance improves accel times*
- *Idle adjustments significantly improve accel times*

Specific gravity (SG) adjustments

- *Adjusting SG improves start and acceleration times*

HPT nozzle W-seal

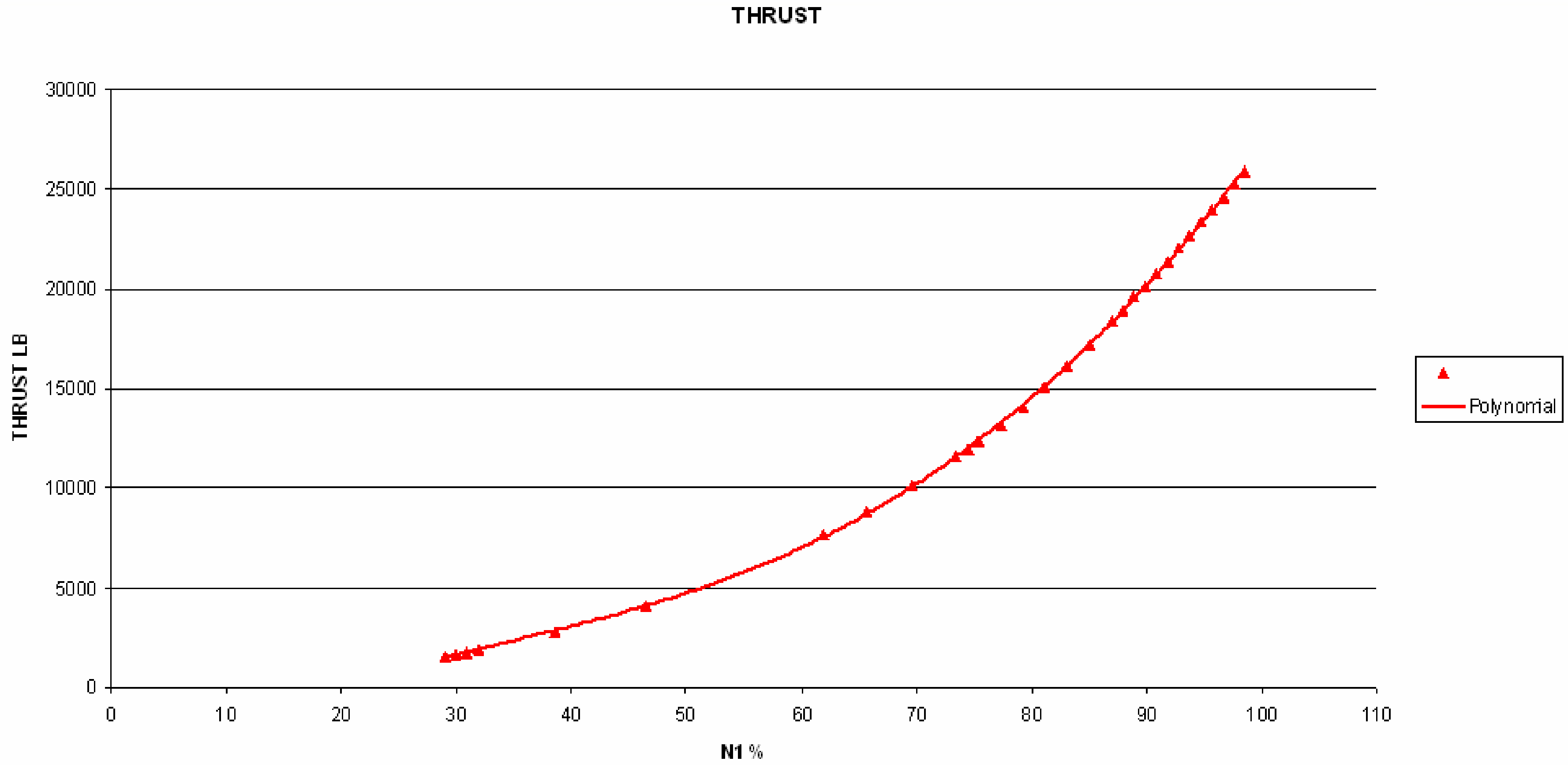
CFM identified than an excessive wear as a strong contributor to low speed operating line migration. New coated W-seal introduction (S/B 72-555 10/10/90)



Normal Operation

Slow/Differential Engine Acceleration (CESM 031)

Engine thrust versus FAN speed



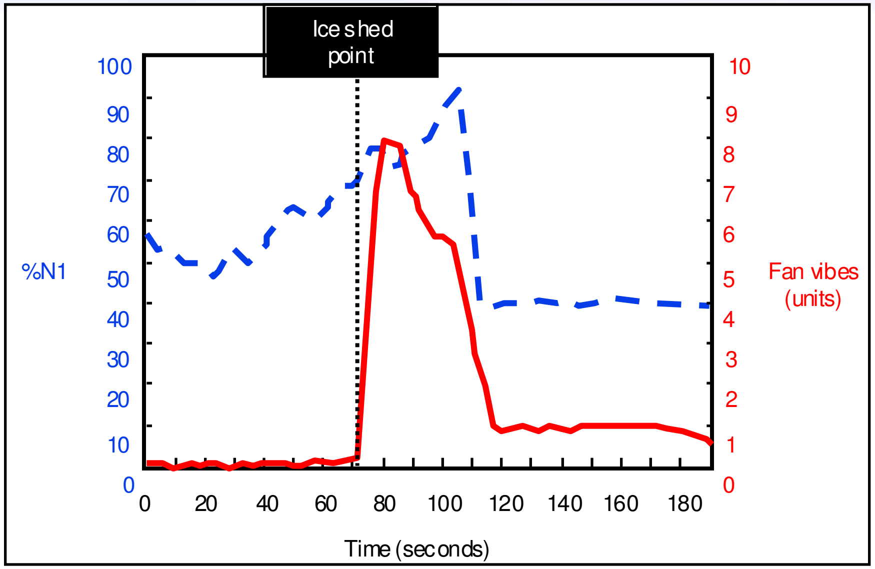
Normal Operation

Cruise

- ***Avoid <u>unnecessary</u> use of ignition***
  - *Conserves ignitor plug life*
- ***Trend monitoring***
  - *Per company policy*

<u>Operation in icing conditions</u>

- ***Only inlet cowl is anti-iced****:*
use ***ENG ANTI-ICE*** *per FCOM*



- ***Fan/spinner*** *ice manifested as vibration as ice partially sheds*
  - ***If vibration encountered in icing conditions or as a preventive measure when operating at 70% N1 or below in moderate to severe icing conditions, perform the following procedure (1 engine at a time):***
    - ***Reduce N1 to 45%***
    - ***Increase N1 to 80% minimum then reduce as required for flight conditions***
    - ***Repeat the procedure every 15 minutes***
  - *Centrifugal force, temperature rise, and pressure increase will remove ice*

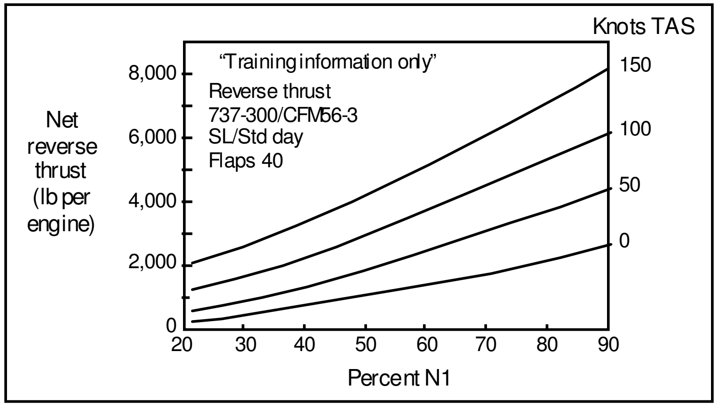
Normal Operation

Descent

- Smooth power reduction
- Idle most economical
- Engine control maintains appropriate idle speed
- Engine control maintains mini N1 required for operation in icing or rain/hail conditions

Landing/Reversing

- Reversers most effective at higher airspeed
- Modulate reverse if full thrust not needed
  - Less thermal stress and mechanical loads
  - Reduced FOD
- Reduce reverse thrust at 60 KIAS



Normal Operation

Shutdown

- ***3 minutes cooldown*** *after coming out of reverse*
  - *Includes taxi*

- ***One Engine Taxi In ?..*** *Operators have to keep in mind some specifics.*
  - *On well known airports to take benefit of this procedure by anticipating maneuvers*
  - *Caution to avoid jet blast and FOD*
  - *More thrust for breakaway and 180° turn*
  - *Turns on the operating engine may not be possible at high GW*

- ***Cool down not required for emergency shutdown***

Conference Summary

Airlines are fully involved for the engine choice, but crews are the main contributors for saving the engine

- *Pilots are the single most important influence on the engine operation*
- *99% of engine operating time is dedicated to the pilot*
- *Over the last 20 years, engine technology has deeply changed and determines pilots behaviour in terms of aircraft operations.*
- *New generations of engines being not any more handled as in the past, pilot should adapt to new managing.*

Pilots need to be fully informed and confident about either comprehensive overview of optimized engine operation and development of what is qualified as an Economical Reflex to ensure proper and longer Time On Wing.

Airlines are fully involved for the engine choice,...

...But crews are the main contributors for saving the engine...

cfm

THE POWER OF FLIGHT

Thanks for your attention!