LEAP-1B Engine Starting

6 July 2017

Overview

This presentation provides an overview of the following topics related to starting LEAP-1B engines:

- Bowed rotor motoring

- Ground start
  - Engine start simulation (Video)

- SAV manual override start

- Ground cart engine starting

- Extended motoring situations after maintenance action

Bowed Rotor Motoring

Difference in engine architecture drives difference in ground starting procedure between CFM56-7B and LEAP-1B

- LEAP-1B has a longer and narrower core relative to CFM56-7B which causes it have a bowed rotor mode below idle speed

Bowed rotor is transient condition caused by the thermal gradient created after shutdown which causes thermal expansion of the core components

Results of unmitigated thermally bowed rotors are:

- Rubbing of compressor blades and CDP seal leading to performance impact

- Start stalls due to more open clearances on one side of the rotor

- Vibratory issues with external components

Hot Air

HPC   HPT
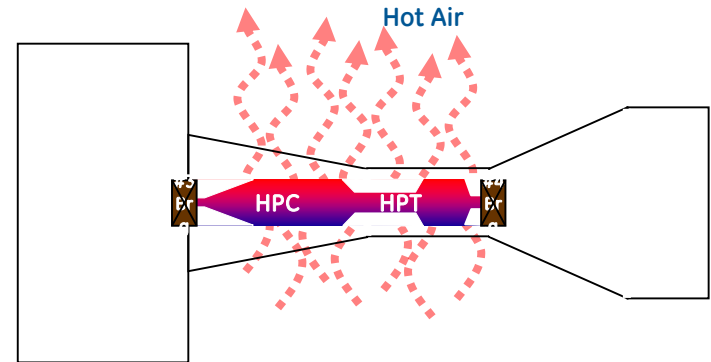
Following Engine Shutdown, hot air rises to the top of the engine, unevenly cooling the core rotor shaft
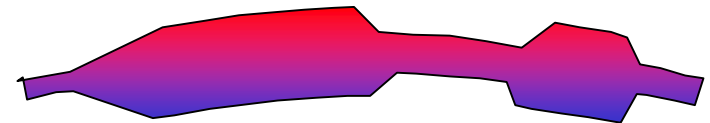
Uneven cooling of the rotor results in the top of the shaft being longer than the bottom, creating a "bow"

Necessary to eliminate bowed rotor before reaching max motoring speed

Normal Engine Start Procedure

Start times may be affected by ambient temperature, altitude, & starter duct air pressure.

- Does not include scenarios involving no light-off, & hot/hung starts – Repeat start attempt

Bowed rotor motoring (BRM) time based on ISA conditions & engine off time

- Min 6 sec BRM & core vibration check at 23% N2
- Bowed rotor condition may increase motoring time between 0 – 80 sec

If EGT>120°C at the end of calculated BRM, EECs will continue motoring until EGT<120°C, up to 90 sec total BRM time

- Reduces hot start potential in high elevation, hot day, high residual EGT conditions

LEAP-1B
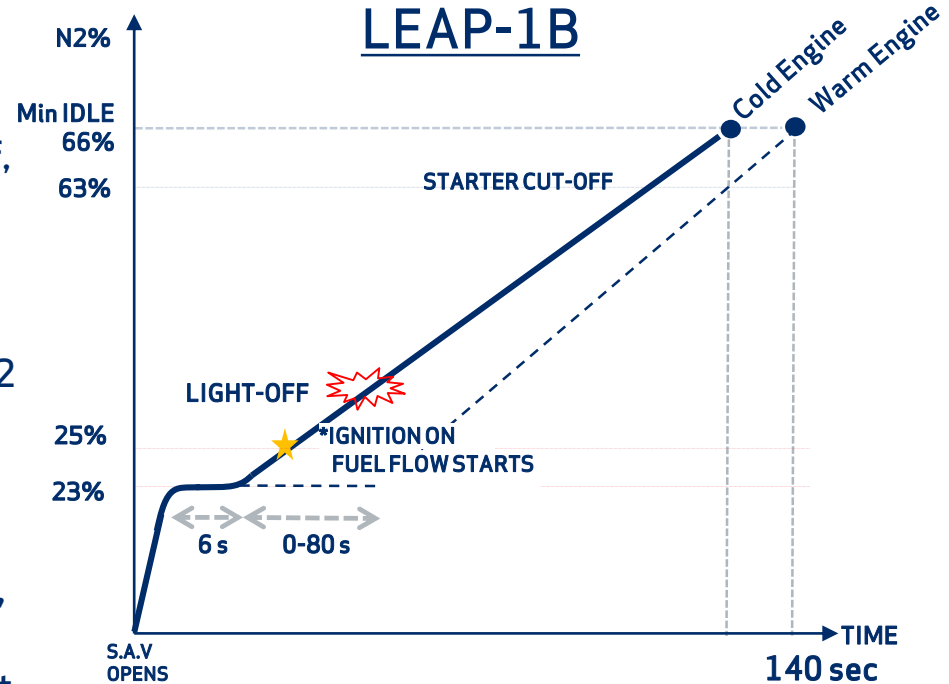
Starter Duct Air Source	BRM N2 Speed Management Method
APU	APU IGV Schedule, VSV Schedule, & SAV Pulse-Width Modulation (PWM)
Cross-bleed or Ground Start Cart	VSV Schedule & SAV Pulse-Width Modulation (PWM)
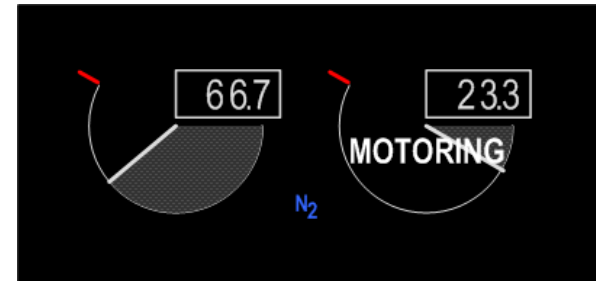
'MOTORING' indication on N2 dial during BRM

LEAP-1B Engine Start Example

Engine Start 90F Day, Warm Engine
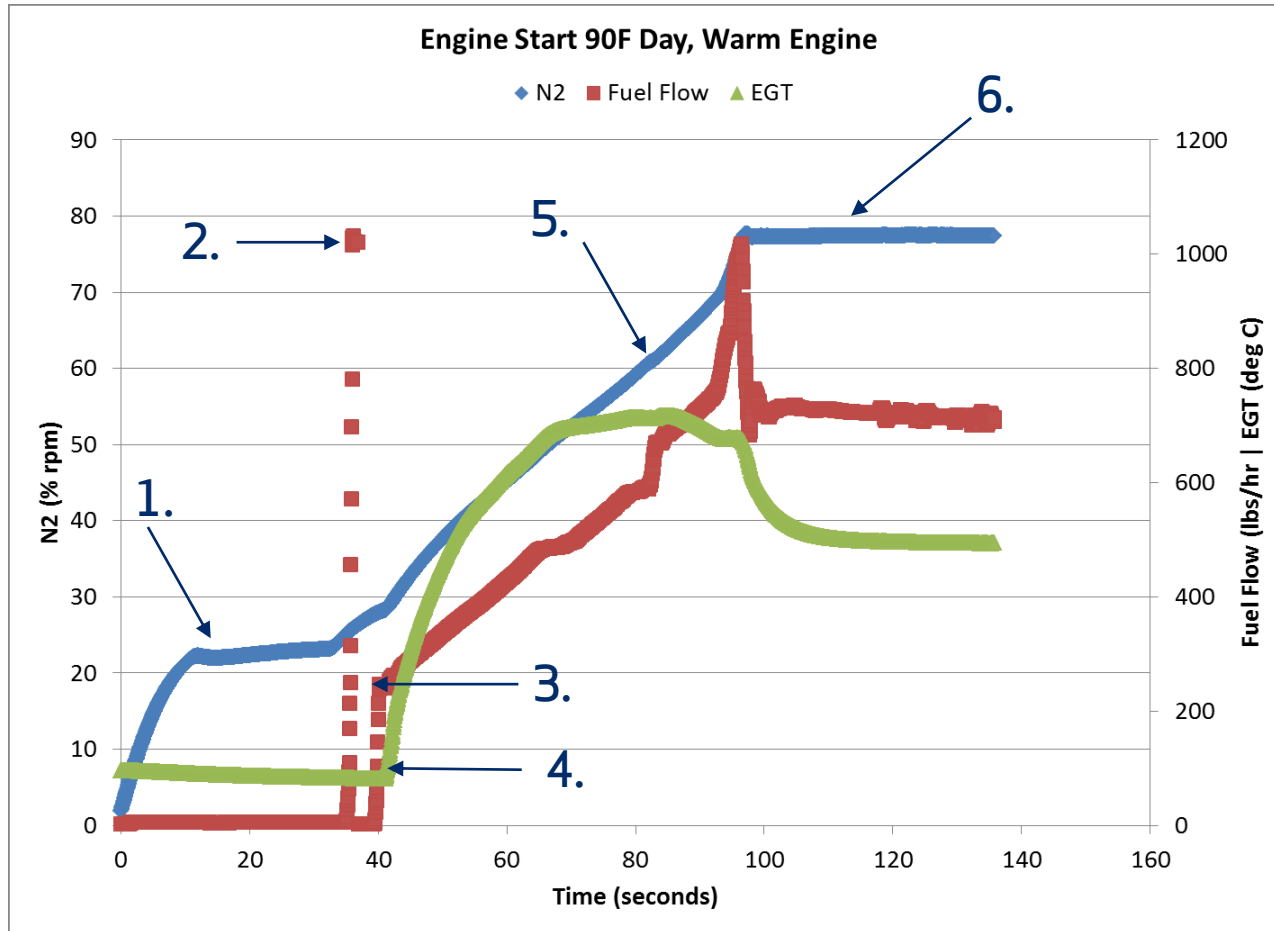
1. Bowed Rotor Motoring
2. Prefill, EOS/TCMA
3. Fuel On
4. Lightoff
5. Starter cutout
6. Idle

TAT = 32C
SAP = 23 psig
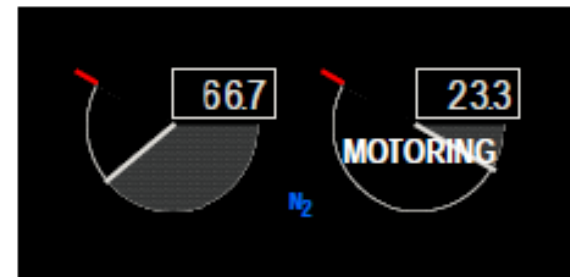
MOTORING indication will be displayed in cockpit during BRM
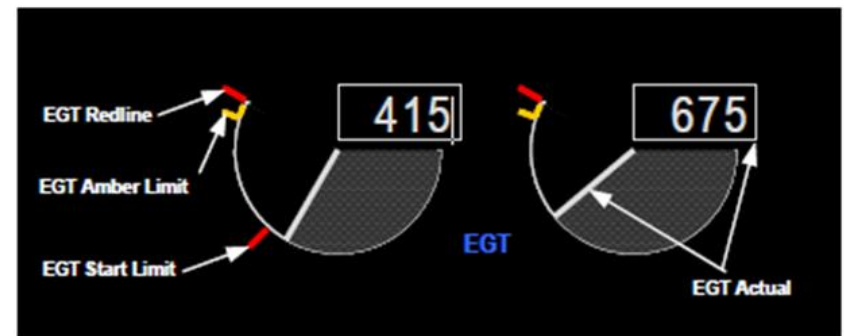
Normal Engine Start Procedure

Due to the larger EGT range on the LEAP-1B, EGT during start may appear to come close to the start EGT limit displayed on the center display panel.

- The ground start EGT limit is 753°C.

EEC logic adapts to the EGT during start by modulating TBV and fuel flow to protect the engine from reaching the start EGT limit.
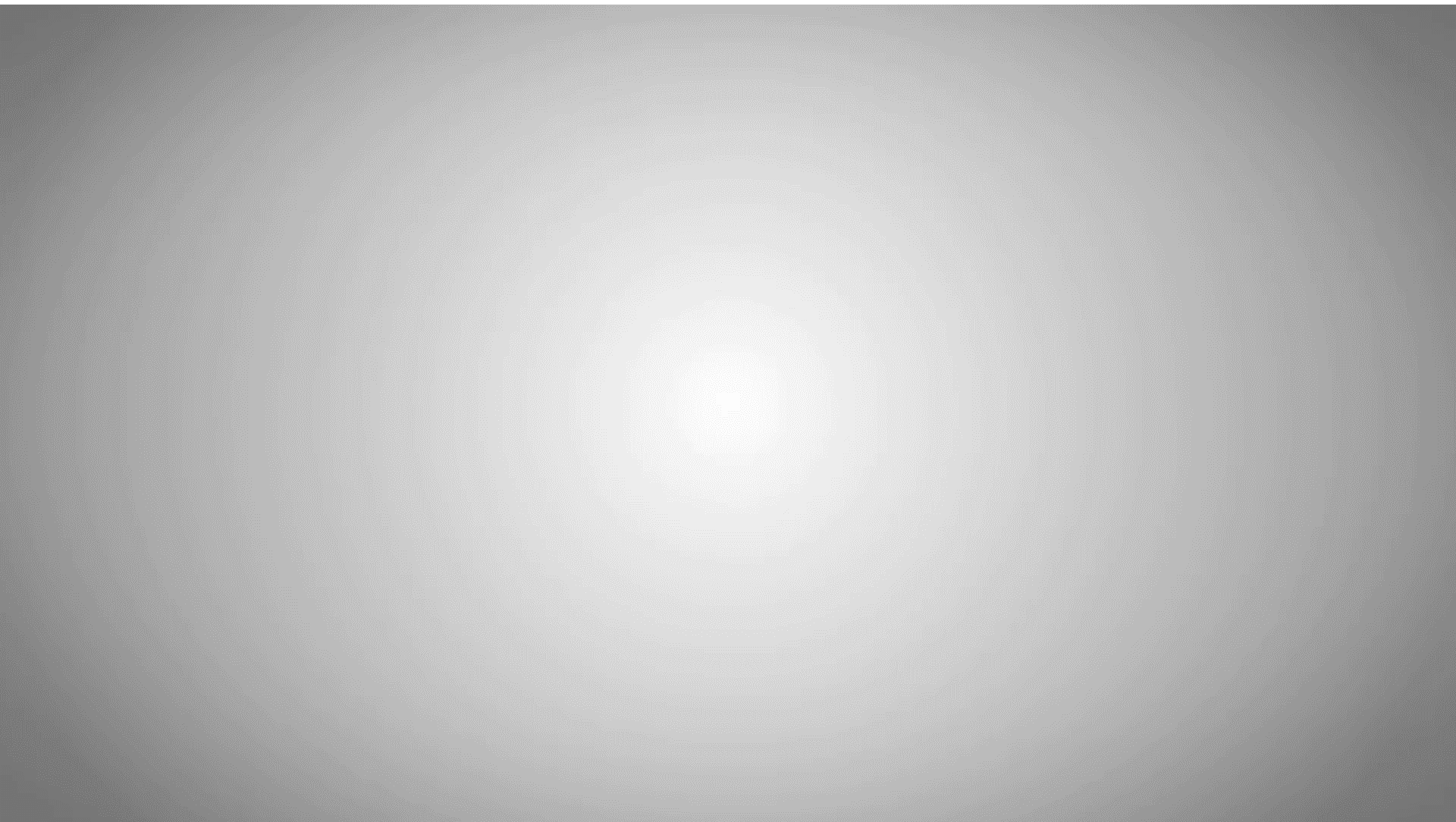
- This logic does not activate until the EGT is getting close to the limit.

Flight crews may see EGT getting close to the limit, but the rate of EGT increase should slow as it approaches the limit.

EGT Limit Indications

Engine Start Simulation (Video)

SAV Manual Override (At EIS - EEC Software 4.5)

SAV manual override procedure varies based on bleed source:

APU Supplied Bleed Air

- Manually open SAV similar to 737NG

- EEC limits N2 speed during bowed rotor motoring by partially closing APU inlet guide vanes (IGVs), limiting ECS bleed air available to starter

Cross Bleed or Ground Cart

- Two step procedure:
  1. Use EEC Special Function for pre-start motoring for 4 minutes with ECS Pack on
     - Pack on to limit available bleed flow to starter, limiting N2 motoring speed
     - 4 minute motor to mitigate worst case bowed rotor
  2. Manually open SAV within 15 minutes of completing EEC Special Function and conduct engine start
     - EEC will bypass bowed rotor motoring on subsequent start if accomplished within 15 minutes
     - 15 minute limitation to prevent rotor bow from reforming

SAV Manual Override (Post EIS - EEC Software 5.1)

EEC software 5.1 will introduce improvements to eliminate the use of the EEC Special Function for cross bleed or ground cart starts

APU Supplied Bleed Air

- Unchanged (no pre-start motoring required; manually open SAV similar to 737NG)

Cross Bleed or Ground Cart

- Revise engine start logic to recognize 4-minute pre-start motoring with ECS Pack on was accomplished within 15 minutes without use of EEC Special Function

- Once EEC s/w updated to v5.1 on entire fleet, update DDG & AMM:

  - Revise DDG to include instructions which allow flight crews to motor engine for 4 minutes with ECS Pack on

  - Revise AMM to remove pre-start motoring procedure using EEC Special Function

> Revised procedures will permit manual SAV override with single mechanic on ground & flight crew in flight deck for all air sources

Ground Cart Engine Starting

LEAP-1B requires more airflow than the CFM56-7B to achieve fuel on speed

- Additional stage of HPC and second stage of HPT on LEAP-1B
- Higher pressure ratio engine

Low output (deteriorated) ground carts that worked on CFM56-7B may not work with LEAP-1B

- Refer to Boeing Maintenance Facility and Equipment Planning Document (MFEPD)

737 MAX | Start Cart Starting

Extended Motoring Situations After Maintenance Action

When the EEC detects a "New Engine", the EEC logic defaults to motoring time for worst case engine off time prior to start. This logic is active following:

- Engine Change

- New EEC installation or EEC swap between engines

- Engine Serial Number entry (ex. after software load)

- Change rating plug or plug pin settings

- Input of new Aircraft Tail Number

The motoring time may also be extended if vibration is detected, there are T12, T3 or TCF sensor faults, or if high residual EGT remains the end of bowed rotor motoring.

Motoring prior to start will not exceed 90 seconds