Performance
ATR Training & Flight Operations Services

For ultra flight safety & operational efficiency

Edition 2009

An AleniaAeronautica and EADS joint venture
Important notice

This guide is intended to provide general information regarding Performance. In no case it is intended to replace the operational and flight manuals for ATR aircraft. In all events, the information contained in the Aircraft Flight Manual shall prevail over the content of this guide.
Introduction

The safety of air transportation is a joint effort, with Government regulations on one hand, and manufacturers and airlines enactment on the other hand. The State is responsible for the supervision of civil aviation, to ensure that high safety standards are maintained throughout aircraft operations. Their primary means of enforcement is via the establishment of written regulations.

Every country has its own regulations, but the international aspect of air transportation takes into account the worldwide application of common rules. The International Civil Aviation Organization (ICAO) was therefore created in 1948, to provide a supranational council, to assist with an international definition of minimum recommended standards. The Chicago Convention was signed on December 7, 1944, and has become the legal foundation for civil aviation worldwide. Those standards are then integrated into national regulations. In this guide, only the European Aviation Safety Agency (EASA) and the US Federal Aviation Administration (FAA) regulations are developed.

The regulations concern all activities; aircraft design and certification, maintenance activities, licensing… Regarding more specifically aircraft initial airworthiness and air operations, the regulations to be applied are the following:

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<th>EASA</th>
<th>FAA</th>
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(1) Federal Aviation Regulations

Airworthiness and operations regulations

Airworthiness

This relates to all matters linked to the aircraft design and demonstrated by the manufacturer for the aircraft certification. The operational reference manual is the ATR produced Aircraft Flight Manual (AFM), specific for each aircraft, produced by ATR, and certified by the Authorities.
Air operations

This relates to all matters linked to operating rules and demonstrates by every airline in order to obtain its Air Operators Certificate (AOC). The reference manual is the Operations Manual (OM) produced by the airline. To help airlines with this task, the Flight Crew Operating Manual (FCOM) published by ATR, is of great assistance in the process of producing part B - Aeroplane Operating Matters of the OM.

European Regulation

EASA, created in 2003, took directly over the functions of aircraft Airworthiness previously performed by the Joint Aviation Authorities (JAA), with the publication of the Implementing Rules IR 21. This is the applicable regulation for initial airworthiness, while CS 25, part of in them, is the certification basis to which a manufacturer of large aircraft must demonstrate compliance.

EASA is working on the Implementing Rules for Air Operations, IR-OPS planned not latter than 2012. Meanwhile, the applicable regulation for Air Operations is EU-OPS published by the European Commission in 2008, a temporary text pending the EASA publication. While EU-OPS only concerns commercial air transport, the IR-OPS will cover any type of operations.

This guide is designed to address three different aspects of aircraft performance:

- The physical aspect, with numerous reminders on flight mechanics, aerodynamics, altimetry and influence of external parameters on aircraft performance.

- The regulatory aspect, with the description of the main EASA and FAA certification and operating rules, leading to the establishment of limitations.

- The operational aspect, with the description of aircraft navigation systems, operational procedures and pilot’s actions.

This guide is the revised version of and replaces our previous ‘Performance’ publication dated 2004. It incorporates features of the ATR-600 aircraft type due for entry into service by 2011.
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A. General
1. The international standard atmosphere (ISA)

1.1. Standard Atmosphere Modeling

The atmosphere is a gaseous envelope surrounding the earth. Its characteristics are different throughout the world. For this reason, it is necessary to adopt an average set of conditions called the International Standard Atmosphere (ISA).

1.1.1. Temperature Modeling

The following diagram illustrates the temperature variations in the standard atmosphere:

![ISA temperature model](image)

The international reference is based on the following standard assumptions at sea level:

- A temperature of 15°C
- A pressure of 1013.25 hPa (29.92 in Hg)
- An air density of 1.225 kg/m³.

Temperature decreases with altitude at a constant rate of -6.5°C/1000m or -1.98°C/1000ft up to the tropopause. The standard tropopause altitude is 11,000 m or 36,089 feet. From the tropopause upward, the temperature remains at a constant value of -56.5°C. The air, which is considered as a perfect gas in the ISA model, presents the following characteristics:

- **At Mean Sea Level (MSL):**

  \[
  \text{ISA temperature} = T_0 = +15^\circ C = 288.15 \text{ K} \\
  \left( 0^\circ C = 273.15 \text{ K} \right)
  \]

- **Above MSL and below the tropopause (36,089 feet):**

  \[
  \text{ISA temperature} \left( ^\circ C \right) = T_0 - 1.98 \times \text{Alt(feet)}/1000
  \]
For a quick determination of the standard temperature at a given altitude, the following approximate formula can be used:

\[
\text{ISA temperature (°C)} = 15 - 2 \times \frac{\text{Alt(feet)}}{1000}
\]

- **Above the tropopause (36,089 feet):**

  \[
  \text{ISA temperature} = -56.5°C = 216.65 \text{ K}
  \]

This ISA model is used as a reference to compare real atmospheric conditions and the corresponding engine/aircraft performance. The atmospheric conditions will therefore be expressed as \(\text{ISA} \pm \Delta \text{ISA}\) at a given flight level.

**Example:**
Let us consider a flight in the following conditions:
- Altitude = 33,000 feet
- Actual Temperature = –41°C

The standard temperature at 33,000 feet is 15 – (2 × 33) = –51°C, whereas the actual temperature is –41°C, i.e. 10°C above the standard.

**Conclusion:** The flight is operated in \(\text{ISA} + 10\) conditions.

### 1.1.2. Pressure Modeling

To calculate the standard pressure \(P\) at a given altitude, the following assumptions are made:
- Temperature is standard, versus altitude.
- Air is a perfect gas.

The altitude obtained from the measurement of the pressure is called **Pressure Altitude** (PA), and a standard (ISA) table can be set up.

<table>
<thead>
<tr>
<th>Pressure (hPa)</th>
<th>Pressure Altitude (PA) (feet)</th>
<th>FL= PA/100</th>
</tr>
</thead>
<tbody>
<tr>
<td>360</td>
<td>26000</td>
<td>7925</td>
</tr>
<tr>
<td>500</td>
<td>18287</td>
<td>5574</td>
</tr>
<tr>
<td>850</td>
<td>4813</td>
<td>1467</td>
</tr>
<tr>
<td>1013</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

*Table A1: Example of Tabulated Pressure Altitude Value (generally used with weather charts)*

![](Figure A2: Pressure Altitude versus Pressure)
Assuming a volume of air in static equilibrium, the aerostatics equation gives:
\[ \text{dP} = -\rho g dh \]

With
- \( \rho \) = air density
- \( g \) = gravity acceleration
- \( dh \) = height of the volume unit
- \( dP \) = pressure variation on \( dh \)

The perfect gas equation gives:
\[ \frac{P}{\rho} = RT \]

With
- \( R \) = universal gas constant

Consequently:

- **At Mean Sea Level (MSL):**
  \[ P_0 = 1013.25 \text{ hPa} \]

- **Above MSL and below the tropopause (36,089 feet):**
  \[ P = P_0 \left(1 - \frac{\alpha}{T_0} h\right) \frac{g_0}{R} \]

  With
  - \( P_0 = 1013.25 \text{ hPa} \) (standard pressure at sea level)
  - \( T_0 = 288.15 \text{ K} \) (standard temperature at sea level)
  - \( \alpha = 0.0065 ^\circ\text{C/m} \) (standard temperature gradient)
  - \( g_0 = 9.80665 \text{ m/s}^2 \) (gravity acceleration at sea level)
  - \( R = 287.053 \text{ J/kg/K} \)
  - \( h = \text{Altitude (m)} \)

  **NOTE:** For low altitudes, a reduction of 1 hPa in the pressure approximately corresponds to a Pressure Altitude increase of 28 feet.

- **Above the tropopause (36,089 feet):**
  \[ P = P_1 e^{-\frac{g_0 (h-h_1)}{RT_1}} \]

  With
  - \( P_1 = 226.32 \text{ hPa} \) (standard pressure at 11,000 m)
  - \( T_1 = 216.65 \text{ K} \) (standard temperature at 11,000 m)
  - \( h_1 = 11,000 \text{ m} \)
  - \( g_0 = 9.80665 \text{ m/s}^2 \)
  - \( R = 287.053 \text{ J/kg/K} \)
  - \( h = \text{Altitude (m)} \)

1.1.3. Density Modeling

To calculate the standard density \( \rho \) at a given altitude, the air is assumed to be a perfect gas. Therefore, at a given altitude, the standard density \( \rho \) (kg/m\(^3\)) can be obtained as follows:

\[ \rho = \frac{P}{RT} \]

With
- \( R \) = universal gas constant (287.053 J/kg/K)
- \( P \) in Pascal
- \( T \) in Kelvin
At Mean Sea Level (MSL):

\[ \rho_0 = 1.225 \, \text{kg/m}^3 \]

1.2. International Standard Atmosphere (ISA) Table

The International Standard Atmosphere parameters (temperature, pressure, and density) can be provided as a function of the altitude under a tabulated form.

<table>
<thead>
<tr>
<th>ALTITUDE (Feet)</th>
<th>TEMP. (°C)</th>
<th>PRESSURE</th>
<th>PRESSURE RATIO ( \delta = \frac{P}{P_0} )</th>
<th>DENSITY ( \sigma = \frac{\rho}{\rho_0} )</th>
<th>Speed of sound (kt)</th>
<th>ALTITUDE (meters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>25 000</td>
<td>-34.5</td>
<td>376</td>
<td>11.10</td>
<td>0.3711</td>
<td>0.4481</td>
<td>602</td>
</tr>
<tr>
<td>24 000</td>
<td>-32.5</td>
<td>393</td>
<td>11.60</td>
<td>0.3876</td>
<td>0.4642</td>
<td>604</td>
</tr>
<tr>
<td>23 000</td>
<td>-30.6</td>
<td>410</td>
<td>12.11</td>
<td>0.4046</td>
<td>0.4806</td>
<td>607</td>
</tr>
<tr>
<td>22 000</td>
<td>-28.6</td>
<td>428</td>
<td>12.64</td>
<td>0.4223</td>
<td>0.4976</td>
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</table>

*Table A2: International Standard Atmosphere (ISA)*
2. Altimetry Principles

2.1. General

An altimeter is a manometer, which is calibrated following standard pressure and temperature laws. The ambient atmospheric pressure is the only input parameter used by the altimeter.

Assuming the conditions are standard, the Indicated Altitude (IA) is the vertical distance between the following two pressure surfaces:

- The pressure surface at which the ambient pressure is measured (current aircraft location), and
- The reference pressure surface, corresponding to the pressure selected by the pilot through the altimeter's pressure setting knob.

\[
IA = f(P_{amb}) - f(P_{set})
\]

\[
IA = PA_{amb} - PA_{set}
\]
2.2. Definitions

The aim of altimetry is to ensure relevant margins, above ground and between aircraft. For that purpose, different operational pressure settings can be selected through the altimeter’s pressure setting knob:

- **QFE** is the pressure at the airport reference point. With the QFE setting, the altimeter indicates the height above the airport reference point (if the temperature is standard).

- **QNH** is the Mean Sea Level pressure. The QNH is calculated through the measurement of the pressure at the airport reference point moved to Mean Sea Level, assuming the standard pressure law. With the QNH setting, the altimeter indicates the altitude above Mean Sea Level (if temperature is standard). Consequently, at the airport level, the altimeter indicates the topographic altitude of the terrain.

- **Standard** corresponds to 1013 hPa. With the standard setting, the altimeter indicates the altitude above the 1013 hPa isobaric surface (if temperature is standard). The aim is to provide a vertical separation between aircraft while getting rid of the local pressure variations throughout the flight. After takeoff, crossing a given altitude referred to as Transition Altitude, the standard setting is selected.

The **Flight Level** corresponds to the Indicated Altitude in feet divided by 100, according to the standard setting selected.

- The Transition Altitude is the indicated altitude above which the standard setting must be selected by the crew.
- The Transition Level is the first available flight level above the transition altitude.
- The change between the QNH setting and Standard setting occurs at the latest crossing transition altitude when climbing, and at transition level when descending.

![Figure A6: QNH and Pressure Altitude](image-url)
2.3. Effects of Altimeter Setting and Temperature

The true altitude (or geometrical altitude) of an aircraft is rarely the same as the indicated altitude, when the altimeter setting is 1013 hPa. This is mainly due to the fact that the pressure at sea level is generally different from 1013 hPa, and/or that the temperature is different from ISA.

2.3.1. Altimeter Setting Correction

In case of ISA temperature conditions, and a standard altimetric setting, the aircraft true altitude can be obtained from the indicated altitude provided by the local QNH if known.

\[
\text{True altitude} = \text{Indicated altitude} + 28 \times (\text{QNH}_{\text{hPa}} - 1013)
\]

**Example:** An airport with an elevation of 1000ft and a current QNH of 1005 hPa, has a pressure altitude of \(1000 - 28 \times (1005 - 1013)\) = 1224 ft.

**Note:** The pressure setting and the indicated altitude move in the same direction: any increase in the pressure setting leads to an increase in the corresponding indicated altitude (IA). For instance, increasing the QNH setting by 10 hPa will increase the indicated altitude by 10 \(\times 28 = 280\) ft.
For that purpose, the following figure is proposed in the FCOM 3.01.04, Operating Data.

Example:
In QNH 1020 hPa conditions, a True altitude of 3000ft, corresponds to an Indicated pressure altitude of 2800ft.

Table A3: Geometrical Altitude versus Pressure altitude and QNH
2.3.2. Temperature Correction

Flying at a given indicated altitude, the true altitude increases with the temperature. The relationship between true altitude and indicated altitude can be approximated as follows:

\[ TA = IA + \frac{T}{T_{ISA}} \]

With
- \( TA \) = True altitude
- \( IA \) = Indicated altitude
- \( T \) = Actual temperature (in Kelvin)
- \( T_{ISA} \) = Standard temperature (in Kelvin)

An example is provided in Appendix 1, Altimetry – Temperature effect.

If the temperature is higher, you fly higher.
If the temperature is lower, you fly lower.
Temperature correction is important when flying a departure or arrival procedure in very low temperature conditions. For that purpose, the following table is proposed in the FCOM 3.01.04, Operating Data.

**Example:**
In ISA +10°C conditions, for an indicated pressure altitude of 15000ft, the True geometrical altitude is 15500ft.

*Table A4: Geometrical Altitude Correction versus Temperature*
3. Operating speeds

Different speed types are used to operate an aircraft. Some of them enable the crew to manage the flight while maintaining some margins from critical areas, whereas others are mainly used for navigational and performance optimisation purposes. This is why the following sections aim to review the different speed types that are used in aeronautics.

3.1. Calibrated Air Speed (CAS)

The Calibrated Air Speed (CAS) is obtained from the difference between the total pressure ($P_t$) and the static pressure ($P_s$). This difference is called dynamic pressure ($q$). As the dynamic pressure cannot be measured directly, it is obtained thanks to two probes.

$$q = P_t - P_s$$

To obtain the total pressure $P_t$, airflow is stopped by means of a forward-facing tube, called the Pitot tube, which measures the impact pressure. This pressure measurement accounts for the ambient pressure (static aspect) at the given flight altitude plus the aircraft motion (dynamic aspect).

The static pressure $P_s$ is measured by means of a series of symmetrical static probes perpendicular to the airflow. This measurement represents the ambient pressure at the given flight altitude (static aspect).

$$\text{CAS} = f(P_t - P_s) = f(q)$$
3.2. Indicated Air Speed (IAS)

The Indicated Air Speed (IAS) is the speed indicated by the airspeed indicator. Whatever the flight conditions, if the pressure measurements were accurate, then the IAS would ideally be equal to the CAS. Nevertheless, depending on the aircraft angle of attack, the flaps configuration, the ground proximity (ground effect or not), the wind direction and other influential parameters, some measurement errors are introduced, mainly on the static pressure. This leads to a small difference between the CAS and the IAS values. This difference is called instrumental correction or antenna error (Ki).

\[ \text{IAS} = \text{CAS} + \text{Ki} \]

3.3. True Air Speed (TAS)

An aircraft in flight moves in an air mass, which is itself in motion compared to the earth. The True Air Speed represents the aircraft speed in a moving reference system linked to this air mass, or simply the aircraft speed in the airflow. It can be obtained from the CAS, using the air density \( \rho \) and a compressibility correction \( K \).

\[ \text{TAS} = \sqrt{\frac{\rho}{\rho_0}} \cdot K \cdot \text{CAS} \]

With \( \rho_0 \) = MSL density
\( p = \text{Level altitude density} \)

TAS is a function of the pressure altitude.

3.4. Ground Speed (GS)

The ground speed (GS) represents the aircraft speed in a fixed ground reference system. It is the sum of the TAS and the wind component.

\[ \text{Ground Speed} = \text{TAS} + \text{Wind Component} \]
3.5. Mach Number

The Mach Number is a comparison between the TAS and the speed of sound.

\[ M = \frac{\text{TAS}}{a} \]

With \( \text{TAS} = \text{True Air Speed} \)
\( a = \text{speed of sound} \)

The speed of sound in knots is:

\[ a(\text{kt}) = 39\sqrt{\text{SAT}(\text{K})} \]

With \( \text{SAT} = \text{Static Air Temperature in Kelvin} \)

The **speed of sound is solely dependent on temperature**. Consequently, the Mach number can be expressed as follows:

\[ M = \frac{\text{TAS (kt)}}{39\sqrt{273+\text{SAT(°C)}}} \]

At a given Mach number, when the pressure altitude increases, the SAT decreases and thus the True Air Speed (TAS).

At a given Mach number, higher means slower

\( P_t \) and \( P_s \), respectively measured by the aircraft pitot tube and static probes, are also used to compute the Mach number. Therefore,

\[ M = f\left(\frac{P_t - P_s}{P_s}\right) = f\left(\frac{\rho}{P_s}\right) \]
The TAS indicated on the navigation display of modern aircraft is then obtained from the Mach number:

\[ \text{TAS(Kt)} = 39M \sqrt{\text{SAT(°C)}} \]

4. Flight mechanics

4.1. Angles definition

The Angle of Attack \( \alpha \) is the angle between the flight path and the aircraft longitudinal axis. The Flight Path Angle \( \gamma \) is the angle between the horizontal axis and the flight path. The aircraft attitude or pitch angle \( \theta \) is the angle between the horizontal axis and the longitudinal axis.

4.2. Forces diagram

There are four forces that act on an aircraft in flight:

- **Weight**, applied on the center of gravity of the aircraft, directly proportional to the mass of the aircraft
  \[ \text{Weight} = mg \]

- **Lift** and **drag** are aerodynamic forces that depend on the shape of the aircraft.
  
  Lift is directed perpendicular to the flight path and applied on the center of pressure of the aircraft.
  \[ \text{Lift} = \frac{1}{2} \rho S (\text{TAS})^2 C_L \]

  Drag is directed along the flight path.
  \[ \text{Drag} = \frac{1}{2} \rho S (\text{TAS})^2 C_D \]

  the **thrust** is determined by the engine type and the power setting selected by the pilot, and is directed in the aircraft axis.

With

- \( m = \) aircraft mass
- \( \rho = \) air density
- \( S = \) wing surface
- \( \text{TAS} = \) True Air Speed
- \( C_L = \) lift coefficient
- \( C_D = \) drag coefficient
A. General

NOTE: The lift and drag coefficients depend on the Angle of Attack (\( \alpha \)), the aircraft aerodynamics (mainly flaps and landing gears configuration) and the True Air Speed.

Along the flight path, the balance is expressed as:

\[
\text{Lift + Thrust} \cdot \sin \alpha = \text{weight} \cdot \cos \alpha
\]

and

\[
\text{Thrust} \cdot \cos \alpha = \text{drag} + \text{weight} \cdot \sin \gamma
\]

The motion of the aircraft through the air depends on the relative magnitude and direction of the various forces:
- For a flight at constant speed and in level flight, the drag force balances the engine thrust. And the lift balances the weight.
- When engine thrust is higher than drag, the aircraft can use the excess thrust to accelerate and/or climb.
- On the opposite, when the thrust is insufficient to balance the drag, the aircraft is forced to decelerate and/or descent.

4.3. Load factor

During a turn, an aircraft is not only subjected to its weight (W), but also to a horizontal acceleration force (Fa) directed towards the center of the turn to counteract the centrifugal force. The resulting force is called apparent weight (Wa), and its magnitude is equal to the load factor times the weight.
The load factor can be expressed versus the bank angle:

\[ n_z = \frac{1}{\cos \phi} \]

During a balance turn, the lift equals the apparent weight.

### 4.4. Lift-to-drag ratio

Because lift and drag are both aerodynamic forces, the ratio of lift to drag is an indication of the aerodynamic efficiency of the aeroplane. The **lift-to-drag ratio** \( L/D \) is the amount of lift generated by a wing, divided by the drag it creates by moving through the air.

A higher or more favorable lift-to-drag ratio is typically one of the major goals in aircraft design; since a particular aircraft required lift is set by its weight, delivering that lift with lower drag leads directly to better fuel economy and performance.
5. Turboprop engine

5.1. Engine description

The turboprop is a gas turbine engine where all the energy is transmitted by means of a shaft from the turbine and through a reduction gearbox to the propeller. The residual thrust in the exhaust nozzle is very low, contrary to the jet engine. The gas generator works at very high RPM incompatible with average propeller speeds: a reduction gear box is thus installed. Disconnecting the propeller from the gas generator by means of a specific shaft and a turbine allows more flexible control of propulsion. The Pratt and Whitney engine fitted on ATR aircraft is composed of two gas generator spools the gases of which are directed towards the two free turbines which provide rotational force to the propeller through a reduction gearbox.

![Pratt & Whitney turboprop engine](image)

**Figure A17:** Pratt & Whitney turboprop engine

5.2. Propeller

A propeller blade is a rotating wing which is submitted to a resulting air flow due to the aircraft motion and the propeller rotation: each blade section is an airfoil for which the angle of attack depends on the resulting blade motion.

![Propeller blade motion](image)

**Figure A18:** Propeller blade motion

For a given aircraft motion, the blade is accelerated from the hub to the blade tip. The blade is twisted strongly from the hub to the blade tip to decrease the blade angle $\beta$ and in this way counteract the increasing advance angle $\Phi$: the angle of attack $\alpha$ is thus kept at a convenient value.
The pitch is the distance covered by the blade during one rotation.

\[ \text{pitch} = 2\pi r \cdot \tan \beta \]

**5.3. Pitch control**

On PW127M engine, the propeller speed (Np) is fixed to 86% or 100%\(^{(1)}\), depending on the power management selection, and the blade speed is adjusted through the control of the pitch or equally the blade angle \(\beta\). This adjustment is made electronically and is not discernable by the pilot. The PW127M variation range is:

\[ -19^\circ \text{ (reverse)} \leq \beta \leq 78.5^\circ \text{ (feather)} \]

\(^{(1)}\) Np 100% represents 1200 RPM.

The blade angle setting depends on the aircraft speed, the engine power delivered and the propeller rotation speed.

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<td>engine power (TQ)</td>
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<tr>
<td>propeller speed (Np)</td>
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</tr>
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</table>

**5.4. Available and required power**

The thrust is the result of the force developed on the engine shaft by the efficiency of the propeller, which depends notably on the blade pitch angle.

The available power delivered by the engine is the thrust multiplied by the True Air Speed of the aircraft.

\[ P_a = \text{Thrust} \cdot \text{TAS} \]

The available power is determined by the atmospheric conditions (pressure altitude, OAT) and has a mechanical and a thermodynamic limit. In the Pratt and Whitney documentation, the power is expressed in Shaft Horse Power.

\[ 1 \text{ SHp} = 745 \text{ Watts} \]
The **Equivalent Shaft Horse Power** is commonly used in the Pratt and Whitney documentation. This parameter considers the jet thrust provided by the propeller.

\[
ESHP = SHP + \frac{\text{jet Thrust}}{2.5}
\]

Example: For the PW 120, \( SHP = 2000 \) SHP and, \( \text{jet thrust} = 250 \text{ lbs} \), which leads to a total ESHP of 2100SHP.

The shaft power delivered by the engine is assessed with the torque (TQ) and the propeller speed (Np).

\[
P_a = TQ \cdot Np
\]

The **power required** is the drag multiplied by the True Air Speed.

\[
P_r = \text{Drag} \cdot \text{TAS}
\]

\[
P_r = \frac{1}{2} \rho \cdot \text{TAS}^3 \cdot C_D
\]

With the assumption that \( \text{TAS} = \sqrt{\frac{2 \cdot \text{weight}}{\rho \cdot S \cdot C_L}} \)

\[
P_r = \sqrt{\frac{2}{\rho S}} \left( \frac{\text{weight}}{C_L} \right)^{3/2} C_D
\]

The power required is minimum when the ratio \( \frac{C_L^3}{C_D^2} \) is maximum.

---

**Figure A21:** Power required versus TAS
B. Aircraft Limitations

FCOM 2.01
1. Flight Limitations

During aircraft operation, the airframe must endure the forces generated by engines, aerodynamic loads, and inertial forces. In still air, when maneuvering of the aircraft, or during flight turbulence, load factors appear and thereby increase loads on the aircraft. This leads to the establishment of maximum weights and maximum speeds.

1.1. Limit Load Factors

**CS / FAR 25.301 Loads**

(a) Strength requirements are specified in terms of limit loads (the maximum loads to be expected in service) and ultimate loads (limit loads multiplied by prescribed factors of safety). Unless otherwise provided, prescribed loads are limit loads.

**CS / FAR 25.321 Flight Loads**

(a) Flight Load Factors represent the ratio of the aerodynamic force component (acting normal to the assumed longitudinal axis of the aeroplane) to the weight of the aeroplane. A positive load factor is one in which the aerodynamic force acts upward with respect to the aeroplane.

\[ n_z = \frac{\text{Lift}}{\text{Weight}} \]

Except when the lift force is equal to the weight and \( n_z = 1 \) (for instance in straight and level flight), the aircraft apparent weight is different from its real weight (mg):

\[ \text{Apparent weight} = n_z \cdot m \cdot g = \text{Lift} \]

In some cases, the load factor is greater than 1 (turn, resource, turbulence). In other cases, it may be less than 1 (rough air). The aircraft structure is obviously designed to resist to such load factors, up to the limits imposed by regulations. Consequently, load factor limits are defined so that an aircraft can operate within these limits without suffering permanent distortion of its structure. The ultimate loads, leading to rupture, are generally 1.5 times the load factor limits.

**CS / FAR 25.1531 Manoeuvring flight load factors**

Load factor limitations, not exceeding the positive limit load factors determined from the manoeuvring diagram in section 25.333 (b).

For all ATR types, the flight manoeuvring load acceleration limits are established as follows:

- Clean configuration .................. \(-1g \leq n \leq +2.5g\)
- Flaps extended ...................... \(0g \leq n \leq +2g\)
The selected design airspeeds are equivalent airspeeds (EAS).

- $V_A$: design manoeuvring airspeed
- $V_F$: design wing-flap speed
- $V_C$: design cruising speed
- $V_D$: design dive speed

**NOTE:** Equivalent airspeed is equal to calibrated airspeed in standard atmosphere at sea level.

### 1.2. Maximum Speeds

The maximum certified speeds are detailed in the FCOM 2.01.03, *Airspeed and operational parameters*.

#### 1.2.1. Maximum Operating limit speed: $V_{MO}$

**CS / FAR 25.1505 Maximum operating limit speed**

The maximum operating limit speed ($V_{MO}/M_{MO}$ airspeed or Mach number whichever is critical at a particular altitude) is a speed that may not be deliberately exceeded in any regime of flight (climb, cruise or descent).

**Example:** On ATR aircraft, $V_{MO} = 250$ kt and $M_{MO} = 0.55$.

#### 1.2.2. Flap extended speeds: $V_{FE}$

**CS / FAR 25.1511 Flap extended speed**

The flap extended speed $V_{FE}$ must be established so that it does not exceed the design flap speed chosen for the corresponding wing-flap position and engine powers.

**Example:** On ATR 72, $V_{FE}$ (flaps $15^\circ$) = 185 kt and $V_{FE}$ (flaps $30^\circ$) = 150 kt.

#### 1.2.3. Landing gear speeds: $V_{LO} / V_{LE}$

**CS / FAR 25.1515 Landing gear speeds**

(a) The landing gear operating speeds, $V_{LO}$, may not exceed the speed at which it is safe both to extend and to retract the landing gear. If the extension speed is not the same as the retraction speed, the two speeds must be designated as $V_{LO}$ and $V_{LERO}$, respectively.

(b) The landing gear extended speed, $V_{LE}$, may not exceed the speed at which it is safe to fly with the landing gear secured in the fully extended position.
Example: On ATR 72, \( V_{\text{LIM EXT}} = 160 \text{ kt} \), \( V_{\text{LIM EXT}} = 170 \text{ kt} \) and \( V_{\text{LIM}} = 180 \text{ kt} \).

NOTE: The speeds given are IAS speeds.

1.2.4. Maximum Brake Energy Speed: \( V_{\text{MBE}} \)

Brakes have a maximum absorption capacity, known as maximum brake energy. For certification purposes, this absorption capacity must be demonstrated with worn brakes (amendment post 42-300).

CS / FAR 25.109 Accelerate-stop distance

(i) A flight test demonstration of the maximum brake kinetic energy accelerate-stop distance must be conducted with no more than 10\% of the allowable brake wear range remaining on each of the aeroplane wheel brakes.

1.2.5. Maximum Tyre Speed: \( V_{\text{TYRE}} \)

The tyre manufacturer specifies the maximum ground speed that can be reached, in order to limit the centrifugal forces and the heat elevation that may damage the tyre structure.

Example: For ATR aircraft \( V_{\text{TYRE}} = 165 \text{ kt} \) (Ground Speed).

1.3. Minimum Speeds

The following speeds are defined in FCOM 2.02.01 Operating speeds, and their values are available in 2.01.03 Airspeed and operational parameters.

1.3.1. Minimum Control Speed on the Ground: \( V_{\text{MCG}} \)

CS / FAR 25.149 Minimum control speed

\( V_{\text{MCG}} \), the minimum control speed on the ground, is the calibrated airspeed during the take-off run, at which, when the critical engine is suddenly made inoperative, it is possible to maintain control of the aeroplane with the use of the primary aerodynamic controls alone (without the use of nose-wheel steering) to enable the take-off to be safely continued using normal piloting skill. In the determination of \( V_{\text{MCG}} \) assuming that the path of the aeroplane accelerating with all engines operating is along the centreline of the runway, its path from the point at which the critical engine is made inoperative to the point at which recovery to a direction parallel to the centreline is completed, may not deviate more than 30 ft laterally from the centreline at any point. \( V_{\text{MCG}} \) must be established, with:

(1) The aeroplane in each take-off configuration or, at the option of the applicant, in the most critical take-off configuration;
(2) Maximum available take-off power or thrust on the operating engines;
(3) The most unfavorable center of gravity;
(4) The aeroplane trimmed for take-off; and
(5) The most unfavorable weight in the range of take-off weights.

Figure B2: Minimum Control speed on the Ground: \( V_{\text{MCG}} \)

\( V_{\text{MCG}} \) is increased in case of narrow runway. ATR aircraft are certified to operate normally on runways whose widths are at least 30m (98ft). However a specific modification allows to operate on runways down to 14-meter (46ft) wide, please refer to AFM 7.01.09 or FCOM 3.11.10, Operations on narrow runways. In this case, the \( V_{\text{MCG}} \) is increased, and as a consequence \( V_{\text{1}} \) (please refer to Paragraph C.2.2.2, Decision Speed).

Example: For ATR 72-500, when the runway width is down to 14m, \( V_{\text{1}} \) is increased by 5 kt.
NOTE: The $V_{mcg}$ of the ATR 72-500 are lower than the ATR 42-500, because they are both equipped with the same engine PW127M, but as the ATR 42 is smaller, in case of engine failure, for the same power, the dissymmetry will be more important, and a higher speed is needed to control the aircraft.

Example: Considering a Pressure Altitude of 0ft, at 20°C, $V_{mcg}$ (72-500) = 88 kt, and $V_{mcg}$ (42-500) = 93 kt.

1.3.2. Minimum Control Speed in the Air: $V_{MCA}$

CS / FAR 25.149 Minimum control speed

(b) $V_{mca}$ is the calibrated airspeed, at which, when the critical engine is suddenly made inoperative, it is possible to maintain control of the aeroplane with that engine still inoperative, and maintain straight flight with an angle of bank of not more than 5 degrees.

(c) $V_{mca}$ may not exceed 1.13 $V_{s}$ with

1. Maximum available take-off power or thrust on the engines;
2. The most unfavorable center of gravity;
3. The aeroplane trimmed for take-off;
4. The maximum sea-level take-off weight
5. The aeroplane in the most critical take-off configuration existing along the flight path after the aeroplane becomes airborne, except with the landing gear retracted; and
6. The aeroplane airborne and the ground effect negligible

(d) During recovery, the aeroplane may not assume any dangerous attitude or require exceptional piloting skill, alertness, or strength to prevent a heading change of more than 20 degrees.

Figure B3: Minimum Control speed in the Air: $V_{MCA}$

1.3.3. Minimum Control Speed during Approach and Landing: $V_{MCL}$

CS / FAR 25.149 Minimum control speed

(f) $V_{mcl}$, the minimum control speed during approach and landing with all engines operating, is the calibrated airspeed at which, when the critical engine is suddenly made inoperative, it is possible to maintain control of the aeroplane with that engine still inoperative, and maintain straight flight with an angle of bank of not more than 5º. $V_{mcl}$ must be established with:

1. The aeroplane in the most critical configuration (or, at the option of the applicant, each configuration) for approach and landing with all engines operating;
2. The most unfavorable center of gravity;
3. The aeroplane trimmed for approach with all engines operating;
4. The most unfavorable weight, or, at the option of the applicant, as a function of weight (...)
5. Go-around thrust setting on the operating engines

(h) In demonstrations of $V_{mcl}$ (...)

3. Lateral control must be sufficient to roll the aeroplane from an initial condition of steady straight flight, through an angle of 20 degrees in the direction necessary to initiate a turn away from the inoperative engine(s) in not more than 5 seconds.
B. Aircraft Limitations

1.3.4. Minimum Unstick Speed: $V_{MU}$

CS / FAR 25.107 Take-off speeds

(d) $V_{MU}$ is the calibrated airspeed at and above which the aeroplane can safely lift off the ground, and continue the take-off...

During the flight test demonstration, at a low speed, the pilot pulls the control stick to the limit of the aerodynamic efficiency of the control surfaces. The aircraft accomplishes a slow rotation to an angle of attack at which the maximum lift coefficient is reached, or, for geometrically limited aircraft, until the tail strikes the runway. The pitch is maintained until lift-off and the corresponding speed is reported.

The flight test is also conducted with one-engine inoperative, and the minimum speed that ensures a safe lateral control, i.e. that prevents the engine or the wing from striking, is reported. That is the way the two minimum unstick speeds are determined and validated by flight tests.

- with all engines operative: $V_{MU(N)}$
- with one engine inoperative: $V_{MU(N-1)}$

$V_{MU(N)} \leq V_{MU(N-1)}$

It appears that:

ATR 42 is aerodynamically limited, i.e. $V_{MU}$ is limited by the minimum speed necessary to lift off the nose landing gear. And ATR 72 geometrically, i.e. $V_{MU}$ is limited by the speed at which the limiting angle of attack -when the tail strikes the ground while the main landing gear is still on ground- is reached, the maximum lift coefficient being not reached yet.

1.3.5. Stall Speed: $V_S$

An increase of the angle of attack implies an acceleration of the airflow over the wing, which means a decrease of the air pressure and an increase of the lift coefficient.

\[
\text{Angle of Attack} \Rightarrow \text{Air velocity over the wing} \Rightarrow \begin{cases} \text{Air pressure} \uparrow \\ \text{Lift coefficient} C_L \uparrow \end{cases}
\]

During a stabilised level flight, when the lift counteracts the weight and is assumed to be constant, a lower speed requires a higher lift coefficient.

\[
\text{Lift} = \frac{1}{2} \rho S (TAS)^2 C_L
\]

At a given Lift, TAS $\Rightarrow$ lift coefficient $C_L$

The lift coefficient reaches an optimum as the angle of attack is increasing. At a higher angle of attack, the airflow over the wing starts to separate from the airfoil and the lift coefficient suddenly decreases. This phenomenon is called stalling, and occurs at stalling speed. The aircraft cannot fly below this speed.
Two speeds are identified:

- \( V_{S1g} \), which corresponds to the maximum lift coefficient, just before the lift starts decreasing. At that moment, the load factor is still equal to one (CS 25 reference stall speed).
- \( V_{S} \), which corresponds to the conventional stall, when the lift suddenly collapses. At that moment, the load factor is always less than one (FAR 25 reference stall speed).

**CS 25.103 Stall speed**

(a) The reference stall speed \( V_{SR} \) is a calibrated airspeed defined by the applicant. \( V_{SR} \) may not be less than a 1g stall speed. \( V_{SR} \) is expressed as:

\[
V_{SR} = \frac{V_{CLMAX}}{\sqrt{n_{zw}}}
\]

Where:
- \( V_{CLMAX} \) = speed of maximum lift coefficient, i.e. \( V_{S1g} \)
- \( n_{zw} \) = Load factor normal to the flight path at \( V_{CLMAX} \)

**NOTE:** Change 15 of JAR 25 (October 2000) introduced this notion of **reference stall speed \( V_{SR} \)**, which is the same as \( V_{S1g} \). In the previous version of JAR 25, a direct relationship between \( V_{S} \) and \( V_{S1g} \) was provided, in order to ensure the continuity between aircraft models certified at \( V_{S} \), and aircraft models certified at \( V_{S1g} \).

For JAR, this rapport between \( V_{S} \) and \( V_{S1g} \) is:

\[
V_{S} = 0.94 \cdot V_{S1g}
\]

ATR 42-300 are the only ATR aircraft type that are certified with the \( V_{S} \).
B. Aircraft Limitations

Example: (please refer to Paragraph C.2.2.5, Take-Off Climb Speed for the \( V_{\text{\(L_{\text{min}}\)}} \) definition.)

For ATR 42-300, \( V_{\text{\(L_{\text{min}}\)}} = 1.2 \, V_{s} \)

For all other ATR, \( V_{\text{\(L_{\text{min}}\)}} = 1.13 \, V_{\text{s1g}} \)

IMPORTANT: For ATR 42-300, \( V_{s} \) is used as a reference, whereas for all the other ATR types, \( V_{\text{s1g}} \) is used as a reference. In this guide, which covers all ATR types, unless clearly mentioned, \( V_{s} \) refers to \( V_{s} \) or \( V_{\text{s1g}} \) depending on the aircraft type.

FAR 25.103 Stalling speed

(a) \( V_{s} \) is the calibrated stalling speed, or the minimum steady flight speed, in knots, at which the aeroplane is controllable, with Zero thrust at the stalling speed, or (...) with engines idling.

FAR 25 does not make any reference to the \( 1g \) stall speed requirement. Nevertheless ATR aircraft have been approved by the FAA, under special conditions and similarly to JAA approval, with \( V_{\text{s1g}} \) as the reference stall speed.

2. Limiting structural weights

2.1. Maximum weights

CS / FAR 25.25 Weight Limits

(a) Maximum weights. Maximum weights corresponding to the aeroplane operating conditions (such as ramp, ground taxy, take-off, en-route and landing) environmental conditions (such as altitude and temperature), and loading conditions (such as zero fuel weight, centre of gravity position and weight distribution) must be established so that they are not more than

(1) The highest weight selected by the applicant for the particular conditions; or

(2) The highest weight at which compliance with each applicable structural loading and flight requirement is shown.

(3) The highest weight at which compliance is shown with the noise certification requirement.

2.1.1. Maximum Structural Take-Off Weight (MTOW)

The Maximum structural Take-Off Weight (MTOW) is determined in accordance with in-flight structure resistance criteria, and landing gear and structure resistance criteria demonstrated during a landing impact with a vertical speed equal to -1.83 m/s (-360 feet/min). TOW must never exceed MTOW.

CS / FAR 25.473 Landing load conditions and assumptions

(a) (...) the aeroplane is assumed to contact the ground: (...) 

(3) With a limit descent velocity of \( 1.83 \) m/sec (6 fps) at the design take-off weight (the maximum weight for landing conditions at a reduced descent velocity).

2.1.2. Maximum Structural Landing Weight (MLW)

The Maximum structural Landing Weight (LW) is determined in accordance with landing gear and structure resistance criteria demonstrated during a landing impact with a vertical speed equal to -3.05 m/s (-600 feet/min). LW must never exceed MLW, and comply with the following formulae:

\[
\text{actual LW} = \text{TOW} - \text{Trip Fuel} \leq \text{MLW} \\
\text{or} \\
\text{actual TOW} \leq \text{MLW} + \text{Trip Fuel}
\]

CS / FAR 25.473 Landing load conditions and assumptions

(a) (...) the aeroplane is assumed to contact the ground: (...) 

(2) With a limit descent velocity of \( 3.05 \) m/sec (10 fps) at the design landing weight (the maximum weight for landing conditions at maximum descent velocity).
2.1.3. Maximum Structural Zero Fuel Weight (MZFW)

Bending moments due to the lift apply at the wing root and are maximum when the quantity of fuel in the wings is minimum. During flight, the quantity of fuel located in the wings decreases. As a consequence, it is necessary to limit the weight when there is no fuel in the tanks. This limit value is called Maximum Zero Fuel Weight (MZFW).

Therefore, the limitation is defined by:

\[
\text{actual ZFW} \leq MZFW \\
\text{or} \\
\text{actual TOW} \leq MZFW + \text{Take-off Fuel}
\]

2.1.4. Maximum structural Taxi Weight (MTW)

The Maximum Taxi Weight (MTW) is limited by the stresses on shock absorbers and potential bending of landing gear during turns on the ground. MTW is generally not a limiting factor as it is much higher than the MTOW.

2.2. Minimum weight

CS / FAR 25.25 Weight Limits

(b) Minimum weight. The minimum weight (...) must be established so that it is not less than –

(1) The lowest weight selected by the applicant;
(2) The design minimum weight (the lowest weight at which compliance with each structural loading condition of this CS/ FAR–25 is shown); or
(3) The lowest weight at which compliance with each applicable flight requirement is shown.

NOTE: The gusts and turbulence loads are usually among the criteria considered to determine the minimum weight.

3. Environmental envelope

CS / FAR 25.1527 Ambient air temperature and operating altitude

The extremes of the ambient air temperature and operating altitude for which operation is allowed, as limited by flight, structural, powerplant, functional, or equipment characteristics, must be established.

The result is the environmental envelope, which features the Pressure Altitude and temperature limits. Performance of aircraft and systems functioning are certified for operations inside the envelope.

Example: ATR 42-500 environmental envelope
4. Engine limitations

4.1. Power Setting

CS / FAR 25.1521 Powerplant limitations

(c) Operating limitations relating to the following must be established for turbine engine installations:

1) Horsepower, torque or thrust, rpm, gas, temperature and time for
   (i) maximum continuous power or thrust
   (ii) Take-off power or thrust

The engine limitations depends on the power setting. The different available power settings are:

- **Take-off rating.** It corresponds to the normal, derated take-off power. Its use is normally limited to 5 minutes. The power management knob is set to TO.

- **Maximum Climb rating.** It corresponds to the maximum power approved for normal climb operation. The power management knob is set to CLB.

- **Maximum Cruise rating.** It corresponds to the maximum power approved for normal cruise operation. The power management knob is set to CRZ.

- **Reserve take-off rating.** It corresponds to the maximum power certified for take-off. It is automatically selected by the ATPCS system in case of engine failure. Its use is limited to 10 minutes under EASA regulations and 5 minutes under FAA. The power management knob is set to TO.

- **Maximum Continuous rating.** It corresponds to the maximum power certified for continuous use to ensure safe flight in case of emergency, particularly engine failure. There is no time limitation for this rating. The power management knob is set to MCT.

**Example:** PW127M engine limiting parameters

---

Figure B8: ATR 42-500 Environmental Envelope
Figure B9: Engine Limitations

### 4.2. Power Limitations

The maximum power depends on the Outside Air Temperature and the Pressure Altitude.

- At a given Pressure Altitude, below the reference temperature ($T_{\text{ref}}$), the temperature has little influence on take-off power. Above $T_{\text{ref}}$, a higher temperature means lower available take-off power.
- At a given temperature, a higher Pressure Altitude means lower available take-off power.

The limitation can either be **mechanical**, because of torque limit, or **thermodynamical**, because of ITT limit.
The PW127M engine has improved possibilities to increase the maximum available power. It is particularly interesting to improve the take-off or en-route limitations. These options are currently only developed for ATR 72-500 and 72-600.

- **Full RTO.** This option is used at take-off, it allows to use the maximum power setting (100% RTO), thus retarding the mechanical limit. This is particularly interesting in case of short take-off runways, as the full power is delivered from the brake release. In case of engine failure, the delivered power is not increased more.
  
  To activate this option, the power levers are advanced to the ramp, and the power management set to TO.

- **Boost.** This option is used at take-off or en-route in case of limiting atmospheric conditions (hot temperature or high Pressure Altitude). It retards the thermodynamical limit, i.e. above $T_{\text{REF}}$, the power delivered is maintained (and not reduced).

  To activate this option, the power levers are in the notch, and the boost push button depressed.

**NOTE:** The two options can be combined at take-off to have the best engine performance.

Full RTO and boost power selections have obviously an impact on the engine, as the temperature in the engine will be momentarily increased. When selected, more engine life cycles are counted than during normal operations, thus impacting engine on-wing life.

Please refer to Paragraph C.8, Improvement of the take-off weight limitation, and F.4.4.2, Boost option for numerical examples.

**Figure B10:** PW127M Take-off power versus OAT, for PA=1000ft

### 4.3. Automatic Take-off Power Control System (ATPCS)

The propulsion unit includes an ATPCS which orders the uptrim of the take-off power on the remaining engine and the automatic feathering of the failed engine in case of an engine failure during take-off.

This system enables to reduce the power normally used for take-off by 10% below the power certified by Pratt&Whitney.

This is favorable for the engine/propeller life, without affecting the take-off performance in case of an engine failure.

Full ATPCS, i.e. uptrim and autofeather, is only available for take-off. Further details are available in FCOM 1.16.40, Power plant – Controls.
C. Take-off

FCOM 3.03
1. Introduction

The take-off is one of the most critical phase of the flight and the occurrence of an engine failure must always be considered.

It is divided into three main phases: the ground acceleration, the rotation and the airborne acceleration.

At the end of the ground acceleration phase, the pilot pulls back the controls to start the rotation. During this phase, acceleration is maintained and the angle of attack is increased in order to achieve a higher lift. The ground reactions progressively decrease until lift-off.

The take-off performance, assuming an engine failure during the ground acceleration phase must be determined. This may lead to take-off weight and speed limitations that can be due to the available runway length, the minimum required climb gradients, the obstacles to clear or the external conditions to cope with. The different limitations, which are detailed in this chapter, must be calculated, compared to each other and the most penalising one must be considered.

For EASA/FAA certified aircraft, the failure of the most critical engine must be considered.

On ATR aircraft, the critical engine is the left one, due to the propeller clockwise rotation. Indeed, the descending blade creates more traction than the ascending one (due to the difference in angle of attack); and the deflected airflow generates a left yawing moment, which is even more amplified when the left engine turns inoperative.

2. Take-off speeds

2.1. Certified speeds

The limiting certified speeds $V_{sp}$, $V_{MCG}$, $V_{MCA}$, $V_{Mn}$, $V_{MBE}$ and $V_{VYRE}$ are described in Paragraph B.1, Flight Limitations.

2.2. Operational take-off speeds

2.2.1. Engine Failure Speed: $V_{EF}$

2.2.2. Decision Speed: $V_{1}$

$V_{1}$ is the maximum speed at which the crew can decide to reject the take-off, and is ensured to stop the aircraft within the limits of the runway.

NOTE: $V_{1}$ is not a flying operating speed. $V_{1}$ is a means of decision for immediate action.
CS / FAR 25.107 Take-off speeds

(a) \( V_1 \), in terms of calibrated airspeed, is selected by the applicant; however, \( V_1 \) may not be less than \( V_{EF} \) plus the speed gained with the critical engine inoperative during the time interval between the instant at which the critical engine is failed, and the instant at which the pilot recognises and reacts to the engine failure, as indicated by the pilot’s initiation of the first action (e.g. applying brakes, reducing thrust, deploying speed brakes) to stop the aeroplane during accelerate-stop tests.

\( V_1 \) can be selected by the applicant, assuming that an engine failure has occurred at \( V_{EF} \). The time which is considered between the critical engine failure at \( V_{EF} \), and the pilot recognition at \( V_1 \), is 1 second. The following relation is thus verified:

\[
V_{MCG} \leq V_{EF} \leq V_1
\]

2.2.3. Rotation Speed: \( V_R \)

\( V_R \) is the speed at which the pilot initiates the rotation, at the appropriate rate of about 3° per second, to reach \( V_2 \) not latter than 35 ft.

2.2.4. Lift-off Speed: \( V_{LOF} \)

It is the speed at which the lift overcomes the weight.

2.2.5. Take-off Climb Speed: \( V_c \)

\( V_c \) is the minimum climb speed that must be reached at a height of 35 feet above the runway surface, in case of an engine failure. Reaching this speed ensures a minimum regulatory 2.4% gradient of climb, after take-off.

Figure C2: Decision Speed, \( V_1 \)
CS / FAR 25.107 Take-off speeds

(b) \( V_{2\text{min}} \), in terms of calibrated airspeed, may not be less than:

1. \( 1.13 \ V_{SR} \) [EASA] or \( 1.2 \ V_{S} \) [FAA] for two-engined turbo-propeller powered aeroplanes
2. \( 1.1 \ VMCA \)

(c) \( V_{2} \), in terms of calibrated airspeed, must be selected by the applicant to provide at least the gradient of climb required by CS / FAR 25.121(b) but may not be less than:

1. \( V_{2\text{MIN}} \) and
2. \( V_{R} \) plus the speed increment attained before reaching a height of 35 ft above the take-off surface.

\(^{1}\) 1.2 \( V_{S} \) limit is considered for ATR 42-300 and 1.13 \( V_{SR} \) for all other ATR.

\(^{2}\) 2.4\% climb gradient in the take-off configuration with the landing gear fully retracted.

\( V_{2\text{min}} \)

\( V_{2\text{MIN}} \) versus aircraft mass

\( V_{2\text{MIN}} \) depends on the OAT and Pressure altitude of the departure airport, whereas \( V_{g} \) depends only on the aircraft mass. At low weights, \( V_{MC} \) is generally more limiting.

2.2.6. ATR minimum manoeuver speed: \( V_{mLB}/V_{mHB} \)

Once the acceleration altitude is reached the aircraft is accelerated to reach speeds that allow safe manoeuvering. In the ATR operational documentation those speeds are identified as minimum manoeuver speed, Low Bank (\( V_{mLB} \)) when the bank angle is limited to 15\° or High Bank (\( V_{mHB} \)) when limited to 30\°.

Those speeds are defined by a minimum ratio to the appropriate stall speed in order to provide sufficient margin against stall. The ratio values are given in FCOM 2.02.01, Operating speeds. They vary with:

- normal or icing conditions
- flaps configuration
- type of manoeuver (high or low bank angle)
- flight phase (in icing conditions only, to take into account the accumulation of ice on the wing along the flight)

**NOTE:** \( V_{mLB}^{0\°} \) is the best climb gradient speed.
2.3. Summary

The following figure illustrates the relationships and the regulatory margins between the certified speeds (\(V_{S\ast}\), \(V_{STD}\), \(V_{MC\ast}\), \(V_{MCA}\), \(V_{MBE}\), \(V_{TYRE}\)), and the takeoff operating speeds chosen by the applicant (\(V_{EF}\), \(V_{1}\), \(V_{R}\), \(V_{LOF}\), \(V_{2}\)).

![Figure C4: Take-off speeds](image)

2.4. Cockpit speed display

On classic ATR aircraft, the take-off speeds are manually set by the flight crew on the Airspeed Indicator. On the latest ATR -600, the take-off speeds are automatically calculated by the FMS; and are written in the Performance initiation page of the Multi Function Display (MFD).

\(V_{1}\), \(V_{R}\), \(V_{2}\) must be acknowledged by the flight crew prior to take-off. The values computed only take into account the aircraft weight, and are thus only applicable to **Non Limiting runways**. The flight crew can modify their values to take into account the take-off limitations via the Take-Off performance page of the Multi Control Display Unit (MCDU).

The take-off speeds appear on the airspeed scale of the Primary Flight Display (PFD). \(V_{1}\), \(V_{R}\), \(V_{2}\) are only displayed at take-off whereas \(V_{MLB0}^\circ\) normal or icing are always displayed. The “F” is only displayed when the flaps are extended; this is to indicate the minimum speed to retract them.

**NOTE:** \(V_{MLBF}\) is not normally displayed on the PFD. It is displayed with the managed speed bug only in case of engine failure at take-off in icing conditions.

![Figure C5: Take-off speeds on classic ATR flight instruments, and on ATR -600 avionics](image)
3. Runway

The characteristics of the runway and its immediate surroundings as well as the aircraft take-off lengths need to be considered and compared to assess the resulting runway limitation.

3.1. Airport available take-off lengths

The surface considered as available take-off lengths at an airport is the runway, eventually extended by the clearway or the stopway.

3.1.1. Take-Off Run Available (TORA)

EU-OPS 1.480 Terminology

(a)(9) Take-Off Run Available (TORA): The length of runway which is declared available by the appropriate authority and suitable for the ground run of an aeroplane taking off.

TORA is either equal to the runway length, or to the distance from the runway entry point (intersecting taxiway) to the end of the runway.

3.1.2. Take-Off Distance Available (TODA)

The runway may be extended by an area called the clearway.

CS-Definitions / FAR 1.1 General Definitions

‘Clearway’ means, for turbine engine powered aeroplanes (..), an area beyond the runway, not less than 500 ft wide, centrally located about the extended centraline of the runway (...). The clearway is expressed in terms of a clearway plane, extending from the end of the runway with an upward slope not exceeding 1.25%, above which no object or terrain protrudes. However, threshold lights may protrude above the plane if their height above the end of the runway is 0.66 m (26 ins) or less and if they are located to each side of the runway.

EU-OPS 1.480 Terminology

(a)(7) Take-Off Distance Available (TODA): The length of the take-off run available plus the length of the clearway available.

\[ \text{TODA} = \text{TORA} + \text{CWY} \]
3.1.3. Accelerate-Stop Distance Available (ASDA)

The runway may be extended by an area called the **stopway**.

**CS-Definitions / FAR 1.1 General Definitions**

*Stopway* means an area beyond the take-off runway, no less wide than the runway and centred upon the extended centreline of the runway, able to support the aeroplane during an abortive take-off, without causing structural damage to the aeroplane, and designated by the airport authorities for use in decelerating the aeroplane during an abortive take-off.

**EU-OPS 1.480 Terminology**

(a)(1) **Accelerate-Stop Distance Available (ASDA):** The length of the take-off run available plus the length of the stopway

\[
\text{ASDA} = \text{TORA} + \text{SWY}
\]

**EU-OPS 1.490 Take-off**

(c)(6) An operator must take account of the loss, if any, of runway length due to alignment of the aeroplane prior to take-off.

Runways with displaced take-off thresholds, or ample turning aprons, should not need further adjustment. But lineup corrections should be made when computing take-off performance, anytime runway access does not permit positioning the aeroplane at the threshold.

For the take-off distance / take-off run (TOD / TOR) adjustments, the distance from the beginning of the runway to the **main gear** is considered -since the screen height is measured from the main gear- whereas for the accelerate-stop distance (ASD) adjustment, the distance to the **nose gear** is considered.

**Figure C8:** Acceleration-Stop Distance Available

**Figure C9:** Lineup Corrections
For ATR aircraft, the values considered for alignments corrections, depending on how the beginning of the runway is reached, are the following:

<table>
<thead>
<tr>
<th></th>
<th>90° taxiway entry</th>
<th>180° turnaround on the runway</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATR 42</td>
<td>Adjustment to TOD</td>
<td>11 m / 36 ft</td>
</tr>
<tr>
<td></td>
<td>Adjustment to ASD</td>
<td>20 m / 66 ft</td>
</tr>
<tr>
<td>ATR 72</td>
<td>Adjustment to TOD</td>
<td>12 m / 39 ft</td>
</tr>
<tr>
<td></td>
<td>Adjustment to ASD</td>
<td>23 m / 75 ft</td>
</tr>
</tbody>
</table>

### 3.2. Aircraft take-off lengths

#### 3.2.1. Take-Off Distance (TOD)

**CS / FAR 25.113 Take-off distance and take-off run**

(a) The take-off distance on a dry runway is the greater of:

1. The horizontal distance (...) from the start of the take-off to the point at which the aeroplane is 35 ft above the take-off surface, for a dry runway (assuming failure of the critical engine occurs at $V_{EF}$ and is recognised at $V_1$); or
2. 115% of the horizontal distance (..), with all engines operating, from the start of the take-off to the point at which the aeroplane is 35 ft above the take-off surface.

$$TOD_{dry} = \max \{TOD_{N-1 \ dry}, 1.15 \ TOD_{N}\}$$

(b) The take-off distance on a wet runway is the greater of:

1. The take-off distance on a dry runway ; or
2. The horizontal distance(...) from the start of the take-off to the point at which the aeroplane is 15 ft above the take-off surface, (...) for a wet runway.

$$TOD_{wet} = \max \{TOD_{dry}, TOD_{N-1 \ wet}\}$$

![Figure C10: Take-Off Distances](image)
3.2.2. Take-off Runs (TOR)

CS / FAR 25.113 Take-off distance and take-off run

(c) If the take-off distance does not include a clearway, the take-off run is equal to the take-off distance.

If TOD calculated without clearway, TOR = TOD

If the take-off distance includes a clearway –

(1) The take-off run on a dry runway is the greater of:
   (i) The horizontal distance (...) from the start of the take-off to a point equidistant between the point at which $V_{LOF}$ is reached and the point at which the aeroplane is 35 ft above the take-off surface, for a dry runway [assuming failure of the critical engine occurs at $V_{EF}$ and is recognised at $V_1$]; or
   (ii) 115% of the horizontal distance (...), with all engines operating, from the start of the take-off to a point equidistant between the point at which $V_{LOF}$ is reached and the point at which the aeroplane is 35 ft above the take-off surface.

$$TOR_{dry} = \max \{TOR_{n-1 \, dry}, 1.15 \, TOR_n\}$$

(2) The take-off run on a wet runway is the greater of:
   (i) the horizontal distance (...) from the start of the take-off to the point at which the aeroplane is 15 ft above the take-off surface (...) for a wet runway [assuming failure of the critical engine occurs at $V_{EF}$ and is recognised at $V_1$]; or
   (ii) 115% of the horizontal distance (...), with all engines operating, from the start of the take-off to a point equidistant between the point at which $V_{LOF}$ is reached and the point at which the aeroplane is 35 ft above the take-off surface.

$$TOR_{wet} = \max \{TOR_{n-1 \, wet}, 1.15 \, TOR_n\}$$

Figure C11: Take-Off Runs with a Clearway
3.2.3. Accelerate-Stop Distance (ASD)

CS / FAR 25.109 Accelerate-stop distance

(a) The accelerate-stop distance on a dry runway is the greater of the following distances:

1. The sum of the distances necessary to:
   i. Accelerate the aeroplane (...) with all engines operating to VEF ...
   ii. Allow the aeroplane to accelerate from VEF to the highest speed reached during the rejected take-off, assuming the critical engine fails at VEF and that the pilot takes the first action to reject the take-off at V1 ...
   iii. Come to a full stop ...
   iv. A distance equivalent to 2 seconds at the V1 ...

2. The sum of the distances necessary to:
   i. Accelerate the aeroplane (...) with all engines operating to the highest speed reached during the rejected take-off, assuming that the pilot takes the first action to reject take-off at V1 ...
   ii. With all engines still operating, come to a full stop ...
   iv. A distance equivalent to 2 seconds at the V1 ...

\[ \text{ASD}_{\text{dry}} = \max \{ \text{ASD}_{\text{N-1 dry}}, \text{ASD}_{\text{N dry}} \} \]

(b) The accelerate-stop distance on a wet runway is the greater of the following distances:

1. The accelerate-stop distance on a dry runway; or
2. The accelerate-stop distance determined in accordance with sub-paragraph (a) except that the runway is wet and the corresponding wet runway values of VEF and V1 are used.

\[ \text{ASD}_{\text{wet}} = \max \{ \text{ASD}_{\text{dry}}, \text{ASD}_{\text{N-1 wet}}, \text{ASD}_{\text{N wet}} \} \]

The ASD are determined with the following assumptions:

- The effects of reverse thrust must not be included as an additional means of deceleration when determining the accelerate-stop distance on a dry runway but may be on a wet runway, provided it is safe and reliable, as stated in CS / FAR 25.109 (f).
- The aircraft wheel brake assemblies are at the fully worn limit of their allowable wear range, as stated in CS / FAR 25.101(i), General.

**Figure C12:** Acceleration-Stop Distances

**NOTE:** ASD definition on a contaminated runway is the same as on a wet runway. The values of the ASD on contaminated runways are given as advisory materials in the AFM 7.03.01, Non dry runways, and are demonstrated with the use of reversers. Additional information on the correction to apply when decelerating without reverse is available too.
IMPORTANT: The TOR, TOD and ASD requirements differ between dry runways on one side, and wet & contaminated on the other side. For instance, the screen height for wet and contaminated runways is decreased to 15 ft, when determining the TOR and TOD. Or the use of reverse thrust is allowed when determining the ASD on wet and contaminated runways, whereas it is forbidden on dry runways. However in no case the take-off limitation shall be less penalising on wet and contaminated runways than on dry runways.

EU-OPS 1.490 Take-off

(b) (5) On a wet or contaminated runway, the take-off mass must not exceed that permitted for a take-off on a dry runway under the same conditions.

3.3. Runway limitations

3.3.1. Regulations requirements

The restrictions due to the runway characteristics are stated in the operational regulations.

EU-OPS 1.490 Take-off / FAR 121.189(c) Take-off limitations

(b) 1. The accelerate-stop distance must not exceed the accelerate-stop distance available.

\[ \text{ASD} \leq \text{ASDA} \]

2. The take-off distance must not exceed the take-off distance available, with a clearway distance not exceeding half of the take-off run available.

\[ \text{TOD} \leq \text{TODA} \]

3. The take-off run must not exceed the take-off run available.

\[ \text{TOR} \leq \text{TORA} \]

Those limitations then lead to the determination of a runway-limited take-off weight.

3.3.2. Optimisation of the runway limited take-off weight

The runway limitation can be optimised by acting on the decision speed \( V_1 \) at take-off.

For a given take-off weight, any increase in \( V_1 \) leads to a reduction in both \( \text{TOD}_{n-1} \) and \( \text{TOR}_{n-1} \). Indeed, a higher \( V_1 \) induces a longer all engines acceleration phase and, in case of an engine failure occurring at \( V_{EF} \), the same \( V_2 \) speed can be reached at 35 feet at a shorter distance.

However, any change in \( V_1 \) has no impact on \( \text{TOD}_n \) and \( \text{TOR}_n \) as there is no engine failure, and thus no consequence on the acceleration phase and the necessary distance to reach 35 feet.

For a given take-off weight, any increase in \( V_1 \) leads to an increase in both \( \text{ASD}_{n-1} \) and \( \text{ASD}_n \). Indeed, with a higher \( V_1 \) speed, the acceleration segment from brake release to \( V_1 \) is longer, the deceleration segment from \( V_1 \) to the complete stop is longer, and the 2 seconds segment at constant \( V_1 \) speed is longer.

In the following graph, the take-off and rejected take-off distances are plotted as a function of \( V_1 \). It shows that an optimum is reached at a particular \( V_1 \) speed, for which the distance required to complete the take-off with a failed engine equals the distance required to reject the takeoff. In this case, we talk about a balanced field take-off and the associated take-off weight limitation is the highest possible for the available runway.
For a given TOW distance, the Balanced V1 field is shown in Figure C13: Impact of V1 on take-off distances. The needed take-off distances have a direct link with the take-off weight limitations, and a similar graph can be plotted with the take-off weight limitation.

In this case for which the take-off weight is limited by TOD_N due to the TCDA, there is a corresponding V1 range to remain within to comply with the TOD_N+1 and ASD limits. By selecting a low V1, priority is given to take-off, thereby avoiding the accelerate-stop procedure; this is particularly useful in case of slippery runways or tyre problems, for instance. By selecting a high V1, priority is given to acceleration-stop, thereby avoiding take-off; this is particularly useful when there are obstacles in the take-off funnel.

NOTE: The take-off weight optimisation process is detailed in Appendix 2, Take-off optimisation principle.
4. Take-off path & flight path

4.1. Definitions

CS / FAR 25.111 Take-off path

(a) The take-off path extends from a standing start to a point in the take-off at which the aeroplane is 1500 ft above the take-off surface, or at which the transition from the take-off to the en-route configuration\(^{(1)}\) is completed and the final take-off speed\(^{(2)}\) is reached, whichever point is higher.

\(^{(1)}\) Maximum Continuous Thrust (MCT) setting and flaps 0° in atmospheric normal conditions or 15° in icing.

\(^{(2)}\) \(V_{mLB}\) in atmospheric normal conditions and \(V_{mLB15}\) in icing.

**NOTE:** Atmospheric icing conditions exist when OAT on ground and for take-off is at or below 5° or when TAT in flight is at or below 7°C and visible moisture in the air in any form is noticeable (such as clouds, fog with visibility of one mile or less, rain, snow, sleet and ice crystals).

CS / FAR 25.115 Take-off flight path

(a) The take-off flight path must be considered to begin 35 ft above the take-off surface at the end of the take-off distance.

The take-off path and flight path regulatory definitions assume that the aircraft is accelerated on the ground to \(V_{EF}\), at which point the critical engine is made inoperative and remains inoperative for the rest of the take-off.

4.2. Take-off flight path segments

The one engine out take-off flight path is divided in four different segments: first, second, third and final segment. Each segment begins when change is made either in the aircraft configuration, power or speed. For each segment, specific requirements apply, and must be fulfilled during the whole flight of the segment, i.e. at the most critical point – due to weight, configuration, power... – prevailing on the segment.

**NOTE:** The flight path must be based on the performance of the aircraft without ground effect. As a general rule, the aircraft is considered out of the ground effect, when it reaches a height equal to its wing span.

**IMPORTANT:** Remember that these requirements must always be met so that a minimum level of climb gradient is available, whatever the obstacle clearance problem may be (generally more restrictive).

![Diagram](image.png)

**Figure C15:** One engine out Take-off Path
4.2.1. Climb requirements
After an engine failure at $V_{EF}$, the aircraft must fulfill minimum climb gradients, on 1st, 2nd and final segment as required by the regulation.

**First segment**
CS / FAR 25.121 Climb: one-engine-inoperative
(a) In the critical take-off configuration existing along the flight path (between the points at which the aeroplane reaches $V_{LOF}$ and at which the landing gear is fully retracted) (...) the steady gradient of climb must be positive.

**Second segment**
CS / FAR 25.121 Climb: one-engine-inoperative
(b) In the take-off configuration existing at the point of the flight path at which the landing gear is fully retracted (...) the steady gradient of climb may not be less than 2.4%.

The 2nd segment requirement is generally the most limiting of the climb requirements at take-off and leads to Take-Off Weight limitation especially in hot and high altitudes runways.

**Final segment**
CS / FAR 25.121 Climb: one-engine-inoperative
(c) Final take-off. In the en-route configuration at the end of the take-off path (...) the steady gradient of climb may not be less than 1.2%.

4.2.2. Acceleration Height requirements
The acceleration performed during the 3rd segment must be done in a regulated height range.

**Minimum Acceleration Height**
CS / FAR 25.111 Take-off path
(c)(2) The aeroplane must reach $V_2$ before it is 35 ft above the take-off surface and must continue at a speed not less than $V_2$ until it is 400 ft above the take-off surface.
(3) At each point along the take-off flight path, starting at the point at which the aeroplane reaches 400 ft above the take-off surface, the available gradient of climb may not be less than 1.2%.

Below 400 feet, the speed must be maintained constant to a minimum of $V_2$, with a 2.4% minimum climb gradient, and above 400 feet, a 1.2% minimum climb gradient is required. The regulatory minimum acceleration height is 400 feet above the take-off surface. The aircraft can accelerate in level flight at 400ft.

**Maximum Acceleration Height**
The Reserve Take-Off (RTO) power is certified for use for a maximum of 10 minutes in EASA regulation, and 5 minutes in FAA. The Maximum Continuous Thrust (MCT), which is not time-limited, can only be selected once the en-route configuration is achieved. As a result, **the en-route configuration (end of the 3rd segment) must be achieved within a maximum of 10 / 5 minutes after take-off**, thus restricting the maximum acceleration height.

4.2.3. Optimisation of the climb limited take-off weight
The climb limitation can be optimised by acting on the **climb speed $V_c$**. Please refer to Appendix 2, Take-off optimisation principle for more details.
4.3. Take-off path summary

All the regulation requirements, power setting, associated speed, flaps and landing gear configurations are reminded here.

<table>
<thead>
<tr>
<th>Starts when</th>
<th>1st segment</th>
<th>2nd segment</th>
<th>3rd segment</th>
<th>Final segment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remaining engine power setting</td>
<td>Reserve Take-Off (RTO)</td>
<td>Gear fully retracted</td>
<td>Acceleration height reached</td>
<td>En-route configuration achieved</td>
</tr>
<tr>
<td>Minimum climb gradient (one engine out)</td>
<td>0%</td>
<td>2.4%</td>
<td>-</td>
<td>1.2%</td>
</tr>
<tr>
<td>Flaps configuration</td>
<td>15°</td>
<td>15°</td>
<td>Normal: clean</td>
<td>Icing: 15°</td>
</tr>
<tr>
<td>Landing gear</td>
<td>Retraction</td>
<td>Retracted</td>
<td>Retracted</td>
<td>Retracted</td>
</tr>
<tr>
<td>Speed reference</td>
<td>V_{LOF}</td>
<td>V_{2}</td>
<td>Normal: V_{MLB0°}</td>
<td>Icing: V_{MLB15°}</td>
</tr>
<tr>
<td>Weight reference</td>
<td>Weight at start of segment</td>
<td>Start of segment</td>
<td>Start of segment</td>
<td>End of segment</td>
</tr>
<tr>
<td>Ground effect</td>
<td>Without</td>
<td>Without</td>
<td>Without</td>
<td>Without</td>
</tr>
</tbody>
</table>

4.4. Take-off Turn Procedure

Airports surrounded by restricting noise areas or penalising obstacles may necessitate the application of a turn take-off procedure to avoid them. Turn departures are subject to specific restrictions. The turn conditions differ between the EASA and the FAA regulations, and is dealt with separately in the following paragraph.

EU-OPS 1.495 Take-off obstacle clearance
(c)(1) Track changes shall not be allowed up to the point at which the net take-off flight path has achieved a height equal to one half the wingspan but not less than 50 ft above the elevation of the end of the take-off run available.

For ATR aircraft, as the semi-wingspan is less than 50 ft, a turn shall not be initiated before 50ft.

EU-OPS 1.495 Take-off obstacle clearance
(c)(1) Thereafter, up to a height of 400 ft it is assumed that the aeroplane is banked by no more than 15°. Above 400 ft height bank angles greater than 15°, but not more than 25° may be scheduled.
(3) An operator must use special procedures, subject to the approval of the Authority, to apply increased bank angles of not more than 20° between 200 ft and 400 ft, or not more than 30° above 400 ft.

<table>
<thead>
<tr>
<th>Standard procedure</th>
<th>Specific approval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Below 200 ft</td>
<td>15°</td>
</tr>
<tr>
<td>Between 200 ft and 400 ft</td>
<td>15°</td>
</tr>
<tr>
<td>Above 400 ft</td>
<td>25°</td>
</tr>
</tbody>
</table>

Table C5: Maximum bank angle during a turn departure (EASA)

FAR 121.189 Take-off limitations
(f) For the purposes of this section, it is assumed that the aeroplane is not banked before reaching a height of 50ft, (...) and thereafter that the maximum bank is not more than 15 degrees.
5. Obstacles

Runways are most of the time surrounded by obstacles. If the obstacles cannot be avoided, by a turn procedure for instance, and that they are located in the take-off funnel, vertical margins have to be considered between the aircraft flight path and the obstacles to clear them. In this case, this can lead to take-off weight limitations.

5.1. Gross and net take-off flight paths

The vertical margin to consider above the obstacles is related to the aircraft net flight path. The net flight path is the gross flight path minus a mandatory climb reduction. Ideally the aircraft should be able to maintain the gross flight path, but the climb performance is reduced to conservatively account for aircraft performance degradation and pilot average skills.

The gross flight path is the flight path actually flown by the aircraft after an engine failure.

**CS / FAR 25.115 Take-off flight path**

(b) The net take-off flight path data must be determined so that they represent the actual [gross] take-off flight paths reduced at each point by a gradient equal to 0.8% for two-engined aeroplanes.

\[
\text{Net Flight Path} = \text{Gross Flight Path} - \text{Gradient Penalty}
\]

The 0.8% gradient penalty between the net and the gross flight path must be taken into account during all the take-off flight path.

**NOTE:** The gradient penalty applies on air gradient.

5.2. Obstacle lateral clearance

The take-off funnel represents an area surrounding the take-off flight path, within which all obstacles must be cleared with a regulatory margin. The contours of this area, also called departure sector, differ between the EASA and the FAA regulations, and is dealt with separately in the following paragraph.

5.2.1. EASA regulation

**EU-OPS 1.495 Take-off obstacle clearance**

(a) An operator shall ensure that the net take-off flight path clears all obstacles (…) by a horizontal distance of at least 90 m plus 0.125 x D, where D is the horizontal distance the aeroplane has traveled from the end of the take-off distance available or the end of the take-off distance if a turn is scheduled before the end of the take-off distance available. For aeroplanes with a wingspan of less than 60 m a horizontal obstacle clearance of half the aeroplane wingspan plus 60 m plus 0.125 x D may be used.

For ATR aircraft whose wingspans are less than 60m, the semi-width at the start of the departure sector are:

- ATR 42: \( \frac{1}{2} E_0 = 60m + \frac{1}{2} \times 25m = 73 m \) (238 ft)
- ATR 72: \( \frac{1}{2} E_0 = 60m + \frac{1}{2} \times 27m = 74 m \) (242 ft)

**EU-OPS 1.495 Take-off obstacle clearance**

(d) For those cases where the intended flight path does not require track changes of more than 15°, an operator need not consider those obstacles which have a lateral distance greater than:

1. 300 m, if the pilot is able to maintain the required navigational accuracy through the obstacle accountability area, or
2. 600 m, for flights under all other conditions.

**EU-OPS 1.495 Take-off obstacle clearance**

(e) For those cases where the intended flight path does require track changes of more than 15°, an operator need not consider those obstacles which have a lateral distance greater than:

1. 600 m, if the pilot is able to maintain the required navigational accuracy through the obstacle accountability area, or
2. 900 m for flights under all other conditions.
½ E₀ = 60 m + ½ wingspan
½ E = ½ E₀ + 0.125xD
½ E = 300 m with sufficient navaid accuracy, 600 m otherwise

Start of the take-off flight path
Start of the departure sector

TOD
TORA
TODA

D 1 2 3
½ E
1 ½ E₀ = 60 m + ½ wingspan
2 ½ E = ½ E₀ + 0.125xD
3 ½ E = 300 m with sufficient navaid accuracy, 600 m otherwise

Figure C15: EU-OPS departure sector (track change <15°)

NOTE: The ICAO annex 6 recommendations for the departure sector are the same as the EU-OPS definitions.

5.2.2. FAA regulation

FAR 121.189 Take-off limitations

(d)(2) No person operating a turbine engine powered transport category aeroplane may take off that aeroplane at a weight greater than that listed in the Airplane Flight Manual (…) that allows a net take-off flight path that clears all obstacles (…) by at least 200 feet horizontally within the airport boundaries and by at least 300 feet horizontally after passing the boundaries.

Start of the take-off flight path
Start of the departure sector

TOD
TORA
TODA

Airport boundary

½ E = 300 ft
½ E = 200 ft

Figure C17: FAR Departure Sector
5.3. Obstacle vertical clearance

5.3.1. During a straight take-off

EU-OPS 1.495 Take-off obstacle clearance / FAR 121.189 Take-off limitations

(a) An operator shall ensure that the net take-off flight path clears all obstacles by a vertical distance of at least 35 ft.

This requirement may have an impact on the 2nd and final segment climb gradient or on the minimum acceleration altitude and lead to take-off weight limitations.

Indeed, as the net flight path must clear any obstacle by at least 35 ft this may require the second segment gross climb gradient to be greater than 2.4% or the acceleration altitude to be not below a specific height.

Specificity of the wet runway

On a wet or contaminated runway, the screen height is 15 ft in case of engine failure, i.e. the gross take-off flight path starts 15 ft above the take-off surface. Whereas the net take-off flight path starts at 35 ft in any runway condition. The start of the gross and the net flight path are thus different in case of wet or contaminated runway.
While the net flight path clears the obstacles by 35 feet all along the take-off flight path, the gross flight path can initially be lower than 35 feet above close-in obstacles.

5.3.2. During a turn take-off

The obstacle clearance margins during a turn differ between EASA and FAA regulations. The FAA regulation does not consider any additional vertical margin during a turn, as the bank angle is limited to 15º. The following rule is then purely related to EU-OPS.

EU-OPS 1.495 Take-off obstacle clearance

(c) 2. Any part of the net take-off flight path in which the aeroplane is banked by more than 15° must clear the obstacles (...) by a vertical distance of at least 50 ft.

6. Influence of the external conditions

The determination of the take-off limitations must be done considering the current external conditions. The take-off weight can thus be significantly limited and vary considerably from one day to another.

EU-OPS 1.490 Take-off / FAR 121.189 (e) Take-off limitations

(c) an operator must take account of the following [when determining the maximum take-off mass]:
1. The Pressure Altitude at the aerodrome;
2. The ambient temperature at the aerodrome;
3. The runway surface condition and the type of runway surface,
4. The runway slope in the direction of take-off;
5. Not more than 50% of the reported head-wind component or not less than 150% of the reported tailwind component.

6.1. Atmospheric external conditions

6.1.1. Wind

The wind component along the runway axis significantly influences the take-off performance. Indeed, it affects the take-off ground speed and, therefore, the take-off distances, which are reduced in case of headwind and increased in case of tailwind.

The take-off weight limitations must be determined considering 50% of the actual headwind component, or 150% of the actual tailwind component. This condition is part of all the ATR operational documentation, the operator just need consider the actual wind component for the determination of the limitation.

CS / FAR 25.237 Wind velocities

(a) (1) A 90º cross component of wind velocity, demonstrated to be safe for take-off and landing, must be established for dry runways and must be at least 20 knots or 0.2 \( V_{S0} \), whichever is greater, except that it need not exceed 25 knots.

\( V_{S0} \) is the reference stall speed in clean configuration.

The crosswind component does not affect take-off performance. Nevertheless, it is necessary to demonstrate the safety of take-off and landing up to 25 knots of crosswind. The maximum demonstrated value must be published in the Aircraft Flight Manual. It is available in AFM 6.01.04, Cross wind.
6.1.2. Pressure Altitude and Temperature

The Pressure Altitude and the temperature have an influence on both the aerodynamics and the engine performance.

**Effect on take-off distances**

Increase in Pressure Altitude or Outside Air Temperature (OAT) induce a reduction in static air density. To lift-off the aircraft the lift must balance the aircraft weight, to verify the following equation:

\[
\text{Weight} = mg = \frac{1}{2} \rho S (TAS)^2 C_L
\]

The air density (\(\rho\)) is lower and the True Air Speed (TAS) needs to be increased to balance the weight. The take-off distance is thus increased.

**Effect on climb gradient**

Increase in Pressure Altitude or OAT induce a reduction in available take-off power. The take-off distances are thus longer and the take-off climb gradients are reduced.

**NOTE:** To obtain optimum efficiency from the engines, the air conditioning could be switched off during the take-off phase.

6.2. Runway characteristics

6.2.1. Runway slope

ATR aircraft are all basically certified for take-off on runways whose slopes are between –2% and +2%\(^{(1)}\). Nevertheless there is a dedicated modification that allows operating on runway with slope down to –4.5% (–4% for ATR 42-300).

Concerning the performance, an upward slope degrades the aircraft's acceleration capability and, consequently, increases the take-off distance. On the other hand, the stop distance is shortened in case of a rejected take-off. Depending on the runway limitation, an upward slope may improve the take-off weight limitation or degrade it. The performance modifications for runway slope beyond 2% are given in the AFM 7.01.10, Runway slope beyond 2%.

\[(1)\] A slope is expressed in percentage, preceded with a plus sign when it is upward, or a minus when it is downward.

6.2.2. Runway surface conditions

The runway contaminants significantly affect the take-off performance. The following section gives the definition of the different runway states and their related influence.

**Definitions**

EU-OPS 1.480 Terminology

4. **Dry runway:** A dry runway is one which is neither wet nor contaminated, and includes those paved runways which have been specially prepared with grooves or porous pavement and maintained to retain 'effectively dry' braking action even when moisture is present.

3. **Damp runway:** A runway is considered damp when the surface is not dry, but when the moisture on it does not give it a shiny appearance.

**NOTE:** The FAA does not make any reference to damp runways, which are considered as wet, whereas EU-OPS 1.475(d), *General*, states that a damp runway is equivalent to a dry one in terms of take-off performance.
EU-OPS 1.480 Terminology

(a) 10. Wet runway: A runway is considered wet when the runway surface is covered with water or equivalent, [with a depth less than or equal to 3 mm], or when there is a sufficient moisture on the runway surface to cause it to appear reflective, but without significant areas of standing water.

In other words, a runway is considered to be wet, as soon as it has a shiny appearance, but without risk of hydroplaning due to standing water on one part of its surface. The water depth is assumed to be less than 3 mm.

EU-OPS 1.480 Terminology

(a) 2. Contaminated runway: A runway is considered to be contaminated when more than 25% of the runway surface area within the required length and width being used is covered by the following:

(i) surface water more than 3 mm (0.125 in) deep, or by slush, or loose snow, equivalent to more than 3 mm (0.125 in) of water;
(ii) snow which has been compressed into a solid mass which resists further compression and will hold together or break into lumps if picked up (compacted snow); or
(iii) ice, including wet ice.

The following terminology is used in the ATR documentation:

- **Standing water:** Caused by heavy rainfall and/or insufficient runway drainage with a depth of more than 3 mm (0.125 in).
- **Slush:** Water saturated with snow, which spatters when stepping firmly on it. It is encountered at temperature around 5° C, and its density is approximately 0.85 kg/liter (7.1 lb / US GAL).
- **Wet snow:** If compacted by hand, snow will stick together and tend to form a snowball. Its density is approximately 0.4 kg/liter (3.35 lb / US GAL).
- **Dry snow:** Snow can be blown if loose, or if compacted by hand, will fall apart again upon release. Its density is approximately 0.2 kg/liter (1.7 lb / US GAL).
- **Compacted snow:** Snow has been compressed (a typical friction coefficient is 0.2).
- **Ice:** The friction coefficient is 0.05 or below.

**Effect on Performance**

There is a clear distinction of the effect of contaminants on aircraft performance. Contaminants can be divided into hard and fluid contaminants.

- Hard contaminants are: Compacted snow and ice. They reduce friction forces.
- Fluid contaminants are: Water, slush, and loose snow. They reduce friction forces, and cause precipitation drag and aquaplaning.

**Reduction of Friction Forces**

The friction forces on a dry runway vary with aircraft speed. Flight tests help to establish the direct relation between the aircraft's friction coefficient $\mu$ and the ground speed.

![Figure C21: $\mu_{dry}$ versus aircraft's speed](image)

The friction coefficient $\mu$ is the ratio of maximum available tyre friction force and vertical load acting on a tyre.

Until recently, regulations stated that, for a wet runway and for a runway covered with standing water or slush, the aircraft friction coefficient could be deduced from the one obtained on a dry runway, as follows:

$$\mu_{wet} = \mu_{dry}/2 \text{ (limited to 0.4)}$$
C. Take-off

\[ \mu_{\text{conta}} = \frac{\mu_{\text{dry}}}{4} \]

This concerns all ATR models.

As of today, a new method, known as ESDU, has been developed and introduced in CS / FAR 25.109. The proposed calculation method of the \( \mu_{\text{conta}} \) accounts for the tyre pressure, the tyre wear state, the type of runway and the anti-skid efficiency demonstrated through flight tests. The \( \mu_{\text{conta}} \) (water and slush) are demonstrated during flight tests too.

For snow-covered or icy runways, the following values are considered, whatever the aircraft type:

\[ \mu_{\text{snow}} = 0.2 \]
\[ \mu_{\text{icy}} = 0.05 \]

Effective \( \mu \) and Reported \( \mu \)

Airport authorities publish contaminated runway information in a document called SNOWTAM, which contains:

- The type of contaminant
- The mean depth for each third of total runway length
- The reported \( \mu \) or braking action.

The reported \( \mu \) is measured by such friction-measuring vehicles, as: Skidometer, Saab Friction Tester (SFT), MU-Meter, James Brake Decelerometer (JBD), Tapley meter, Diagonal Braked Vehicle (DBV). ICAO Airport Services Manual Part 2 provides information on these measuring vehicles.

The main problem is that the resulting friction forces of an aircraft (interaction tyre/runway) depend on its weight, tyre wear, tyre pressure, anti-skid system efficiency and… ground speed. The only way to obtain the effective aircraft \( \mu \) would be to use the aircraft itself in the same takeoff conditions, which is of course not realistic in daily operations.

Another solution is to use one of the above-mentioned vehicles, but these vehicles operate at much lower speeds and weights than an aircraft. Then comes the problem of correlating the figures obtained from these measuring vehicles (reported \( \mu \)), and the actual braking performance of an aircraft (effective \( \mu \)).

To date, scientists have been unsuccessful in providing the industry with reliable and universal values. But tests and studies are still in progress. This is why ATR publishes contaminated runway information as a function of the type of contaminant and depth of contaminant, and not as a function of actual aircraft \( \mu \). Regulation states that:

IEM OPS 1.485 Wet and contaminated runway data

\[(b) \text{ If the performance data has been determined on the basis of measured runway friction coefficient, the operator should use a procedure correlating the measured runway friction coefficient and the effective braking coefficient of friction of the aeroplane type over the required speed range for the existing runway conditions.}\]

Precipitation Drag

Precipitation drag is composed of:

- **Displacement drag**: Produced by the displacement of the contaminant fluid from the path of the tyre.
- **Spray impingement drag**: Produced by the spray thrown up by the wheels (mainly those of the nose gear) onto the fuselage.

The effect of these additional drags is to:

- Improve the deceleration rate: Positive effect, in case of a rejected take-off.
- Worsen the acceleration rate: Negative effect for take-off.

The negative effect on the acceleration rate leads to limit the depth of a fluid contaminant to a maximum value. On the other hand, with a hard contaminant covering the runway surface, only the friction coefficient (effective \( \mu \)) is affected, and the depth of contaminant therefore has no influence on take-off performance.

Aquaplaning Phenomenon

The presence of water on the runway creates an intervening water film between the tyre and the runway, leading to a reduction of the dry area. This phenomenon becomes more critical at higher speeds, where the water cannot be
squeezed out from between the tyre and the runway. Aquaplaning (or hydroplaning) is a situation where the tyres of the aircraft are, to a large extent, separated from the runway surface by a thin fluid film. Under these conditions, tyre traction drops to almost negligible values along with aircraft wheels’ braking; wheel steering for directional control is, therefore, virtually ineffective.

Aquaplaning speed depends on tyre pressure, and on the specific gravity of the contaminant (i.e. how dense the contaminant is).

\[
V_{\text{AQUAPLANING}} \,(\text{kt}) = 34 \left( \frac{P_t}{\sigma} \right)^{0.5}
\]

With \( P_t \) = tyre pressure (kg/cm²) \\
\( \sigma \) = specific gravity of the contaminant.

In other words, the aquaplaning speed is a threshold at which friction forces are severely diminished. Performance calculations on contaminated runways take into account the penalising effect of hydroplaning.

**Aircraft Manufacturer Data**

The aircraft manufacturer has to provide relevant data for operations on runways contaminated by one of the above contaminants, as quoted below:

CS / FAR 25.1591 Performance information for Operations with contaminated runway surface conditions

(a) Supplementary performance information applicable to aeroplanes operated on runways contaminated with standing water, slush, snow or ice must be furnished at the discretion of the applicant.

ATR provides guidance material for the following runway contaminants and maximum depths, in the AFM 7.03.01, *Non dry runways*. Take-off is not recommended when conditions are worse than the ones listed.

<table>
<thead>
<tr>
<th>Contaminant</th>
<th>Wet runway or equivalent</th>
<th>Contaminated runway</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water (fluid)</td>
<td>&lt; 3 mm (0.12 in)</td>
<td>3 to 12.7 mm (0.5 in)</td>
</tr>
<tr>
<td>Slush (fluid)</td>
<td>–</td>
<td>3 to 12.7 mm (0.5 in)</td>
</tr>
<tr>
<td>Compacted snow (hard)</td>
<td>–</td>
<td>No depth limit</td>
</tr>
<tr>
<td>Ice (hard)</td>
<td>–</td>
<td>No depth limit</td>
</tr>
</tbody>
</table>

*Table C9: Wet and Contaminated Runways*
7. Determination of the take-off weight limitation

7.1. FCOM

The Regulatory Take-Off Weight is the lowest of the:
- Maximum structural take-off weight
- Runway limiting take-off weight
- Climb gradient limiting weight
- Obstacle limiting weight

The Take-Off weight limitation is always associated with the take-off speeds \( V_1, V_R, V_2 \). Changing the speeds may have an impact on the weight limitation.

To calculate the take-off weight limitation and the associated take-off speeds, the take-off methodology detailed in FCOM 3.03.02, Methodology, should be followed. The methodology gives the guidelines to assess the different limitations. Several limiting weights are calculated and the most penalising one is finally chosen. The different weights introduced are:

- **Weight A**: for the calculation of the runway and climb gradients limitations.
  The general policy for this weight assessment is to act on the take-off distances, and to determine at the end solely the corresponding weight limitation. One starts with the runway length available and increases or decreases fictitiously this length to take into account the different limiting parameters (air conditioning, slope, wind...). A limitation decreases fictitiously the length available.
  The most important step when determining weight A is the NL (Non-Limiting) chart which determines if the runway or the 2nd segment requirements induces a limitation of the Maximum Structural Take-Off weight, depending on the actual OAT.

- **Weight B**: for the calculation of the runway limitation in case of tailwind, accounting for the maximum brake energy absorption capacity. Depending on the velocity of the tailwind, the corresponding limiting take-off weight and the corresponding take-off speeds are directly read.

- **Weight C**: for the calculation of the obstacle limitation.
  One starts by assessing the limiting weight to follow the 2nd segment 2.4% climb gradient, depending on the OAT and Pressure Altitude. And then depending on the location and height of the obstacles, the climb gradient is corrected, and the corresponding weight reduction is assessed.
  There are two charts depending if the obstacles are closely or remotely located from the runway.

- **Weight D**: for the calculation of the go-around limitation, in case of unsuccessful return to the departure airport.
  This limitation is only applicable to the ATR 42-500 because the flaps configuration for take-off and go-around are not the same, thus inducing different climb gradients. Depending on the OAT, the Pressure Altitude and the minimum go-around climb gradient required at the airport, the corresponding limiting weight is directly read.

Let us consider the example of an ATR 42-500, where the departure airport has a TORA of 1600m and a minimum climb gradient of 3.5% to avoid a hill in the vicinity of the airport. The aircraft is dispatched under EASA regulations. The conditions at the departure airport are:
- Wet runway
- No slope
- 5kt tailwind
- \( Z_p=1000 \) ft
- OAT=30°C
- Obstacle 400m from end of TORA, 40ft height
- Normal atmospheric conditions.
The below methodology is followed.

**Figure C23:** FCOM 3.03.02 p.3, Take-Off - Methodology

**Figure C24:** FCOM 3.03.05 p.1, Take-off speeds values

Speeds are defined following those requirements.

The determination of the take-off speeds is done in relation with the TOW determined in 3.03.02 page 3.

- If TOW maxi = structural TOW (NL), speeds are read in the table 3.03.05 p2 or in QRH. Read the speeds corresponding to the actual TOW.
- If Wa limitation: speeds are read in the QRT 3.03.04, with the day conditions (Zp, OAT, corrected runway length). Take the speeds corresponding to the take-off weight indicated in the tables, even if the actual TOW is lower.
- If Wb limitation: speeds are read in the brakes energy tables 3.03.03 p6/7, with the day conditions (Zp, OAT). Take the speeds corresponding to the take-off weight indicated in the tables, even if the actual TOW is lower.
- If Wc or Wd limitation:
  - Without tailwind, speeds are read in the table 3.03.05 p2 or in QRH. Read the speeds corresponding to the actual TOW.
  - In case of tailwind, compare the previous speeds with the brake energy limitation speeds 3.03.03 p6/7 and take the lowest ones.
Maximum structural take-off weight

<table>
<thead>
<tr>
<th>DESIGN WEIGHT LIMITATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAXIMUM WEIGHT</td>
</tr>
<tr>
<td>RAMP</td>
</tr>
<tr>
<td>TAKE-OFF</td>
</tr>
<tr>
<td>LANDING</td>
</tr>
<tr>
<td>ZERO FUEL</td>
</tr>
</tbody>
</table>

Figure C25: FCOM 2.01.02 p1, Limitations - Weight and loading

Weight A assessment

The runway length is 1600m:  \( L=1600 \) m

The air conditioning is maintained off:  \( L_1=L \)

3 - Non dry runways corrections for FCOM computation

According to the previous assumptions, decrease the runway length by the following values to take into account the runway contamination:

<table>
<thead>
<tr>
<th>RUNWAY CONTAMINATION</th>
<th>CORRECTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wet</td>
<td>150 m (490 ft)</td>
</tr>
<tr>
<td>Water or slush between 3 mm (1/8 in) and 6.3 mm (1/4 in)</td>
<td>350 m (1150 ft)</td>
</tr>
<tr>
<td>Water or slush between 6.3 mm (1/4 in) and 12.7 mm (1/2 in)</td>
<td>450 m (1480 ft)</td>
</tr>
<tr>
<td>Compact snow</td>
<td>180 m (590 ft)</td>
</tr>
<tr>
<td>Ice</td>
<td>450 m (1480 ft)</td>
</tr>
</tbody>
</table>

Figure C26: FCOM 3.03.03 p2A, Take-off - Corrections

The runway is wet, the runway length is now \( L_2=1600-150=1450 \) m

<table>
<thead>
<tr>
<th>RUNWAY SLOPE</th>
</tr>
</thead>
</table>
| R • Runway slope between - 2 % and + 2 %
  Decrease the runway length by 700 m (2300 ft) for 1 % uphill slope.
  For a better accuracy, use the chart given in 3.03.02 page 5 or 6.

<table>
<thead>
<tr>
<th>WIND</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decrease the runway length by 500 m (1640 ft) for 10 kt tailwind.</td>
</tr>
</tbody>
</table>

Figure C27: FCOM 3.03.03 p2, Take-off - Corrections

There is 5kt tailwind, the runway length is now \( L_3=1450 - \frac{500}{2} = 1200 \) m

The important step now is to determine whether the runway and 2nd segment are limiting are not, through the NL chart.

NOTE: For a given Pressure Altitude, the runway limit increases as its length increases, until a certain point above which no matter the runway length, the 2nd segment climb gradient is limiting.
The OAT is 30°C, the conditions are thus limiting.

In the QRT (Quick Reference Table), the limiting weight and the associated speeds are read. The limitation code 3 indicates that this is a runway limitation.
WEIGHT A = 17482 Kg and $V_1 = V_2 = 105$ kt, $V_2 = 111$ kt

- In case of limiting runway, a maximum take-off weight and the associated speeds are provided in the chart.

The limitation is indicated under a specific code form:
1 = structure
2 = 2nd segment
3 = runway
4 = obstacle
5 = tyre speed
6 = brakes energy
7 = runway 2 engines
8 = final take-off

**Weight B assessment**

<table>
<thead>
<tr>
<th>R</th>
<th>USE FOR ANY TAILWIND UP TO 15 KT</th>
</tr>
</thead>
<tbody>
<tr>
<td>HP</td>
<td>ZP</td>
</tr>
<tr>
<td>0</td>
<td>16586</td>
</tr>
<tr>
<td>0</td>
<td>108</td>
</tr>
<tr>
<td>10</td>
<td>18261</td>
</tr>
<tr>
<td>10</td>
<td>107</td>
</tr>
<tr>
<td>20</td>
<td>17943</td>
</tr>
<tr>
<td>20</td>
<td>106</td>
</tr>
<tr>
<td>30</td>
<td>17666</td>
</tr>
<tr>
<td>30</td>
<td>105</td>
</tr>
<tr>
<td>40</td>
<td>17386</td>
</tr>
<tr>
<td>40</td>
<td>104</td>
</tr>
<tr>
<td>50</td>
<td>17137</td>
</tr>
<tr>
<td>50</td>
<td>104</td>
</tr>
</tbody>
</table>

In the brake energy limitations table, the limiting weight and the associated speeds are directly read.

WEIGHT B = 17379 Kg and $V_1 = V_2 = 104$ kt, $V_2 = 111$ kt

**Weight C assessment**

<table>
<thead>
<tr>
<th>WAT (WEIGHT ALTITUDE TEMPERATURE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum weight to face 2nd segment requirement.</td>
</tr>
<tr>
<td>Apply if necessary the weight decrements due to obstacles or abnormal configurations.</td>
</tr>
</tbody>
</table>

**NORMAL CONDITIONS**

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>AIRPORT PRESSURE ALTITUDE (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>20815 kg (45885 lb)</td>
</tr>
<tr>
<td>10</td>
<td>20565 kg (45335 lb)</td>
</tr>
<tr>
<td>20</td>
<td>20335 kg (44830 lb)</td>
</tr>
<tr>
<td>25</td>
<td>20230 kg (44595 lb)</td>
</tr>
<tr>
<td>30</td>
<td>20120 kg (44355 lb)</td>
</tr>
<tr>
<td>35</td>
<td>20015 kg (44120 lb)</td>
</tr>
<tr>
<td>40</td>
<td>19920 kg (43915 lb)</td>
</tr>
<tr>
<td>45</td>
<td>19780 kg (43605 lb)</td>
</tr>
<tr>
<td>50</td>
<td>19670 kg (41820 lb)</td>
</tr>
</tbody>
</table>

Figure C30: FCOM 3.03.02 p2, Take-off - Methodology
Figure C31: FCOM 3.03.03 p6, Take-off - Corrections
Figure C32: FCOM 3.03.03 p3, Take-off - Corrections
Considering the actual conditions, the 2nd segment limiting weight is \( W = 19890 \text{ Kg} \)

The weight decrement to take into account the obstacle is 3700 Kg. \( W_1 = 19890 - 3700 = 16190 \text{ Kg} \)

There is no MMEL item, so \( \text{WEIGHT C} = 16190 \text{ Kg} \).

The associated speeds for this specific TOW are directly read in the FCOM or QRH.

The speeds are \( V_1 = V_r = 105 \text{ kt}, \ V_2 = 112 \text{ kt} \). As there is tailwind, they are compared to the ones of \( \text{WEIGHT B} \). As the latter are lower, they are the ones taken into account.

\( \text{WEIGHT C} = 16190 \text{ Kg} \) and \( V_r = V_r = 104 \text{ kt}, \ V_2 = 111 \text{ kt} \).
Weight D assessment

The associated speed are the same that for WEIGHT C.

\[
\text{WEIGHT D} = 17400\text{Kg} \quad \text{and} \quad V_1 = V_{\text{f}} = 104\text{ kt}, \quad V_2 = 111\text{ kt}
\]

CONCLUSION:

\[
\text{RTOW} = \min (\text{Structural MTOW, WEIGHT A, WEIGHT B, WEIGHT C, WEIGHT D}) = \text{WEIGHT C}
\]

The regulatory take-off weight 16190 Kg is limited by the obstacle, and the associated speeds are \( V_1 = V_{\text{f}} = 104\text{kt}, \quad V_2 = 111\text{kt} \).
7.2. FOS

The performance calculations can be performed by the FOS software. The resulting airport take-off chart is the following:

For the actual conditions, the maximum Take-Off Weight computed by the FOS is 18291 Kg and the associated take-off speeds $V_1 = V_R = 106$ kt, $V_2 = 113$ kt; the limitation code is 4, which corresponds to an obstacle limitation.

MTOW$_{FOS} = 18291$ Kg and $V_1 = V_R = 106$ kt, $V_2 = 113$ kt

The FOS computations give an increased obstacle limitation TOW, compared to the FCOM (WEIGHT C). The FOS performs non conservative calculations and enables to maximise the payload by choosing notably optimised take-off speeds.

However, the FOS software does not compute the go-around climb gradient limitation. The latter is calculated with the FCOM and compared to the FOS calculation. WEIGHT D is more limitating, (please refer to Paragraph C.7.1. FCOM), the Regulatory Take-Off Weight is thus reduced. The take-off speeds however do not change.

CONCLUSION:

The Regulatory Take-Off Weight is 17400 Kg, limited by the go-around climb gradient, and the associated take-off speeds are $V_1 = V_R = 106$ kt, $V_2 = 113$ kt.

C - Take-off | p. 71
8. Improvement of the take-off weight limitation

In order to improve the take-off limitation, ATR has developed two options on the PW127M engine. This engine now replaces the PW127E/F on -500 and is standard on -600 series.

The **full RTO** option improves the take-off performance in case of limiting runways; both engines are set to RTO power from brakes release, thus improving the ground acceleration. The **boost** is beneficial in case of limiting atmospheric conditions; high Pressure Altitude or high OAT.

If necessary, both options can be combined to have optimum engine performance. Please refer to Paragraph B.4.2, *Power limitations* for details on engine limitations.

**NOTE:** The use of *boost* and for **full RTO** functions will impact life-limited engine components. It should therefore only be used when enhanced performance is required due to limiting conditions.

### 8.1. Full RTO option

The full RTO increases the available take-off power. Performance gains are thus done in case of limitations due to *runway length*.

**Example:** Let us consider a 1200 m length runway, in standard atmospheric conditions.

![Take-off runway conditions](image)

**Figure C37:** Take-off runway conditions

**Example:** The take-off weight limitation in normal take-off power is RTOW = 21639 kg / 47705 lbs. Whereas in full RTO power it is RTOW = 22094 kgs / 48709 lbs.

The **payload gain** is thus +455 kg /1000 lbs.

### 8.2. Boost option

The boost displaces the thermodynamic limitation. Performance gains are thus done in case of limitations due to *high temperature* or *high altitude* conditions, on the 2nd segment performance.

**Example:** Let us consider an airport located at 4000 ft high. In case of high take-off temperatures, the payload gain is around 500kg / +1100 lbs.

![Payload gain due to the boost](image)

**Figure C38:** Payload gain due to the boost
D. Climb
FCOM 3.04
1. Flight Mechanics

Please refer to Paragraph A.4, Flight mechanics, for further information on the general flight mechanics.

1.1. Lift and drag equations

During climb at constant speed, the flight mechanics equations that apply to the aircraft are(1):

\[
\text{lift} = \text{weight}
\]

\[
\text{thrust} = \text{drag} + \gamma \cdot \text{weight}
\]

(1) the Angle of Attack \( \alpha \) is considered negligible and the Flight Path Angle \( \gamma \) is very small, so \( \sin \gamma \approx \gamma \) (in radian) and \( \cos \gamma \approx 1 \).

1.2. Climb gradient (\( \gamma \))

During climb, the Flight Path Angle \( \gamma \) is also called climb gradient, and is expressed in degrees.

**NOTE:** The climb gradient is expressed in radians in the following formulae.

\[
\gamma = \frac{\text{thrust} - \text{drag}}{\text{weight}} = \frac{\text{thrust}}{\text{weight}} - \frac{\text{drag}}{\text{lift}} \quad \text{(in rad)}
\]

\[
\gamma = \frac{\text{thrust}}{\text{weight}} - \frac{1}{\text{L/D}} \quad \text{(in rad)}
\]

\[
\gamma = 100 \cdot \left( \frac{\text{thrust}}{\text{weight}} - \frac{1}{\text{L/D}} \right) \quad \text{(in %)}
\]

During a stabilised climb, the aircraft mass and engine rating are approximatively constant (weight and thrust are fixed), so the climb gradient is maximum, when the lift-to-drag ratio is maximum. The maximum climb gradient allows to climb to a given altitude over the shortest distance possible.

With ATR, the best lift-to-drag ratio, or maximum climb gradient speed is \( V_{\text{mLB}} \). This is the airspeed that is reached for climb in case of one engine inoperative to maximise the aircraft aerodynamic efficiency.
1.3. Rate of Climb (RC)

The Rate of Climb (RC) corresponds to the aircraft vertical speed, and is expressed in ft/mn.

\[
RC = TAS \sin \gamma \approx TAS \gamma
\]

\[
RC = TAS \cdot \frac{\text{Thrust} - \text{Drag}}{\text{Weight}} = \frac{P_{\text{available}} - P_{\text{required}}}{\text{Weight}}
\]

Climb is only possible when there is an excess of power, i.e. when the available power is higher than the required one. During a stabilised climb, the aircraft mass is approximatively constant (weight is fixed) so the rate of climb is maximum, when \(P_{\text{available}} - P_{\text{required}}\) is maximum, or for a given engine power, when \(P_{\text{required}}\) is minimum. The maximum rate of climb allows to climb to a given altitude in the shortest time.

With ATR, the best rate of climb speed is \(V_{\text{mHB0°}}\). (please refer to Paragraph C.2.2.6, ATR minimum manœuvre speed, for its definition.)
1.4. Influence of external conditions

1.4.1. Wind

A constant horizontal wind component changes the flight path but has no change on the rate of climb.

![Figure D4: Influence of headwind on flight path angle and Rate of Climb](image)

The air climb gradient ($\gamma_a$) remains unchanged, whatever the wind component. The fuel and time to the Top Of Climb (T/C) remain unchanged.

<table>
<thead>
<tr>
<th></th>
<th>Headwind</th>
<th>Tailwind</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rate of climb</td>
<td>$\rightarrow$</td>
<td>$\rightarrow$</td>
</tr>
<tr>
<td>Fuel and time to T/C</td>
<td>$\rightarrow$</td>
<td>$\rightarrow$</td>
</tr>
<tr>
<td>Flight path angle ($\gamma_g$)</td>
<td>$\uparrow$</td>
<td>$\downarrow$</td>
</tr>
<tr>
<td>Ground distance to T/C</td>
<td>$\downarrow$</td>
<td>$\uparrow$</td>
</tr>
</tbody>
</table>

1.4.2. Pressure Altitude and Temperature

An increase in the Pressure Altitude or the temperature induces a reduction in the air density, thus leading to a decrease in thrust and power. The climb gradient and rate of climb are thus degraded.

Temperature or PA $\uparrow$ \{ Climb gradients $\downarrow$, Rate of climb $\downarrow$ \}

1.4.3. Weight

At a given engine rating, altitude, and climb speed (TAS), any increase in weight leads to a decrease in the climb gradient and rate of climb.

Weight $\rightarrow$ \{ Climb gradients $\downarrow$, Rate of climb $\downarrow$ \}
2. FCOM climb performance table

Climb performance tables for standard climb with two-engines are provided in the FCOM 3.04, Climb. For each aircraft mass, climb parameters are shown, depending on the level off FL, on ISA deviation and atmospheric conditions. The standard climb IAS are 160 kt for the ATR 42 and 170 kt for the ATR 72. The climb performance tables are also given for a climb at 190 kt for both aircraft types.

### Table D1: ATR 72-500 climb performance table.

<table>
<thead>
<tr>
<th>FL</th>
<th>18</th>
<th>19</th>
<th>20</th>
<th>21</th>
<th>22.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>250</td>
<td>23 296</td>
<td>23 299</td>
<td>23 297</td>
<td>23 298</td>
<td>24 319</td>
</tr>
<tr>
<td>240</td>
<td>23 296</td>
<td>23 299</td>
<td>23 297</td>
<td>23 298</td>
<td>24 319</td>
</tr>
<tr>
<td>230</td>
<td>23 296</td>
<td>23 299</td>
<td>23 297</td>
<td>23 298</td>
<td>24 319</td>
</tr>
<tr>
<td>220</td>
<td>23 296</td>
<td>23 299</td>
<td>23 297</td>
<td>23 298</td>
<td>24 319</td>
</tr>
<tr>
<td>210</td>
<td>23 296</td>
<td>23 299</td>
<td>23 297</td>
<td>23 298</td>
<td>24 319</td>
</tr>
</tbody>
</table>

**Example:** Assuming an aircraft mass of 19t at start of climb, climbing at 170 kt to FL 210, ISA and normal conditions, the climb will be performed in 18 min, within 60 Nm, 238 Kg of fuel will be burnt and the mean TAS will be 206 kt.

**NOTE:** Blank boxes mean that the climb with a minimum rate of climb of 300 ft/min (100 ft/min in icing conditions) cannot be sustained. In the previous case, the maximum FL that can be reached is FL 230, in ISA conditions. In other than ISA conditions, please use the graph Twin-engine ceiling – normal conditions in the previous page.
E. Cruise
FCOM 3.05
The main objective of the previous chapters was to comply with airworthiness and air operations requirements. This chapter deals with another objective, that of optimising cruise parameters, speed and Flight Levels. A technical brochure dealing specifically with Fuel Saving is available on the ATR website.

1. Flight mechanics

Please refer to Paragraph A.4, Flight mechanics, for further information on the general flight mechanics.

1.1. Lift and drag equations

During cruise in level flight at constant speed, the flight mechanics equations that apply to the aircraft are:

\[
\text{Weight} = \text{Lift} = \frac{1}{2} \rho S (TAS)^2 C_L
\]

\[
\text{Thrust} = \text{Drag} = \frac{1}{2} \rho S (TAS)^2 C_D \quad \text{so}, \quad P_a = P_r
\]

\(^{1)}\) the Angle of Attack is negligible (\(\alpha \approx 0\)) and the Flight Path Angle \(\gamma=0\).

In level cruise, the lift-to-drag ratio is

\[
\frac{L}{D} = \frac{C_L}{C_D}
\]

1.2. Specific Range

The Specific Range (SR) is the ground or air distance covered per fuel unit, it is expressed in Nm/kg.

\[
\text{SR (ground)} = \frac{\text{Ground Speed}}{\text{Fuel consumption per hour (FF)}}
\]

\[
\text{SR (air)} = \frac{\text{True Air Speed (TAS)}}{\text{Fuel consumption per hour (FF)}}
\]

The Specific Range depends on the aerodynamic features of the aircraft – expressed by the lift-to-drag ratio –, the engine performance – expressed by the Specific Fuel Consumption, and the aircraft mass.

The engine Specific Fuel Consumption represents the fuel consumption for the shaft power delivered.

\[
\text{SFC} = \frac{\text{FF}}{P_a} \quad \text{(in Kg/kW/hr)}
\]

Example: For the PW127M engine, the Specific Fuel Consumption at max cruise power setting is 0.30 Kg/kW/hr, assuming an OAT of 22.8°C.

\[
\text{SR} = \frac{TAS}{FF} = \frac{TAS}{\text{SFC} \cdot P_a} = \frac{TAS}{\text{SFC} \cdot \text{Thrust} \cdot TAS} = \frac{1}{L/D} \cdot \frac{\text{weight}}{L/D}
\]
The SR of an aircraft can thus be optimised by minimising the mass of the aircraft, or by maximising the L/D ratio, i.e. selecting the appropriate speed, or angle of attack. The flight regime corresponding to the maximum SR is called Maxi Range.

2. Cruise speed

2.1 Maximum Range speed

When cruising at the Maximum Range speed $V_{MR}$, fuel consumption for a given distance is at its minimum: it corresponds to the maximum distance an aircraft can fly with a given fuel quantity.

\[
V_{LR} > V_{MR} \\
SR_{long\ range} = 0.99 \cdot SR_{max\ range}
\]

2.2. Long-Range speed

The Maximum Range speed is quite low, and generally, the operator will prefer to fly at a higher speed, even if it means slightly degrading the SR. When cruising at the Long Range speed $V_{LR}$, the SR is 99% of the maximum SR and the speed is higher.
2.3 Maximum Cruise speed

The maximum cruise speed corresponds to the highest speed that can be reached during the cruise, considering the engine performance. This speed depends on the atmospheric conditions, and the mass of the aircraft.

**Example:** Considering an ATR 42-500, 17t, at FL 150, the different cruise speeds are:

<table>
<thead>
<tr>
<th></th>
<th>Maxi Range</th>
<th>Long Range</th>
<th>Maxi Cruise</th>
</tr>
</thead>
<tbody>
<tr>
<td>TAS (kt)</td>
<td>211</td>
<td>230</td>
<td>297</td>
</tr>
<tr>
<td>SR (Nm/Kg)</td>
<td>0.451</td>
<td>0.447</td>
<td>0.370</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>For a 100 Nm trip</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuel burnt (Kg)</td>
<td>222</td>
<td>224</td>
<td>270</td>
</tr>
<tr>
<td>Flight Time (min)</td>
<td>28</td>
<td>26</td>
<td>20</td>
</tr>
</tbody>
</table>

*Table E1: Cruise Performance*

Selecting different cruise speeds has a significant impact on fuel consumption and flight time. The cruise speed must be adjusted in accordance with airline policy.
3. Cruise altitude

The higher the cruise altitude, the less dense is the air, and the less power is required to propel the aircraft, for a same resulting TAS: it is generally more beneficial to cruise at the highest FL to optimise the fuel consumption. There is however a limitation on the engines as their performance is decreased, as and when Pressure Altitude increases. The maximum cruise altitude is defined for a given mass, as the maximum altitude the aircraft can maintain at maximum cruise power.

![Figure E5: Maximum cruise altitude](image)

4. FCOM Cruise performance table

Cruise performance tables for maxi cruise power setting are provided in the FCOM 3.05, Cruise. For each aircraft mass, cruise parameters are shown, depending on the FL, on ISA deviation and atmospheric conditions.
### Table E2: 72-500 Cruise Performance.

<table>
<thead>
<tr>
<th>FLIGHT LEVEL</th>
<th>MINIMUM TIME</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DELTA ISA</td>
</tr>
<tr>
<td></td>
<td>-10</td>
</tr>
<tr>
<td>60</td>
<td>94.5</td>
</tr>
<tr>
<td></td>
<td>467</td>
</tr>
<tr>
<td></td>
<td>251</td>
</tr>
<tr>
<td></td>
<td>266</td>
</tr>
<tr>
<td>80</td>
<td>94.5</td>
</tr>
<tr>
<td></td>
<td>459</td>
</tr>
<tr>
<td></td>
<td>248</td>
</tr>
<tr>
<td></td>
<td>271</td>
</tr>
<tr>
<td>100</td>
<td>95.2</td>
</tr>
<tr>
<td></td>
<td>453</td>
</tr>
<tr>
<td></td>
<td>246</td>
</tr>
<tr>
<td></td>
<td>277</td>
</tr>
<tr>
<td>120</td>
<td>93.6</td>
</tr>
<tr>
<td></td>
<td>446</td>
</tr>
<tr>
<td></td>
<td>243</td>
</tr>
<tr>
<td></td>
<td>281</td>
</tr>
<tr>
<td>140</td>
<td>94.7</td>
</tr>
<tr>
<td></td>
<td>427</td>
</tr>
<tr>
<td></td>
<td>235</td>
</tr>
<tr>
<td></td>
<td>281</td>
</tr>
<tr>
<td>160</td>
<td>95.2</td>
</tr>
<tr>
<td></td>
<td>406</td>
</tr>
<tr>
<td></td>
<td>228</td>
</tr>
<tr>
<td></td>
<td>280</td>
</tr>
<tr>
<td>180</td>
<td>96.2</td>
</tr>
<tr>
<td></td>
<td>381</td>
</tr>
<tr>
<td></td>
<td>219</td>
</tr>
<tr>
<td></td>
<td>278</td>
</tr>
<tr>
<td>200</td>
<td>96.5</td>
</tr>
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<td></td>
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<td>208</td>
</tr>
<tr>
<td></td>
<td>273</td>
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<tr>
<td>220</td>
<td>97.8</td>
</tr>
<tr>
<td></td>
<td>338</td>
</tr>
<tr>
<td></td>
<td>197</td>
</tr>
<tr>
<td></td>
<td>266</td>
</tr>
<tr>
<td>240</td>
<td>98.2</td>
</tr>
<tr>
<td></td>
<td>303</td>
</tr>
<tr>
<td></td>
<td>185</td>
</tr>
<tr>
<td></td>
<td>260</td>
</tr>
<tr>
<td>250</td>
<td>98.5</td>
</tr>
<tr>
<td></td>
<td>290</td>
</tr>
<tr>
<td></td>
<td>178</td>
</tr>
<tr>
<td></td>
<td>254</td>
</tr>
</tbody>
</table>

Letter: E - Cruise

| P1 0  | 83 |

Example:

Assuming an aircraft cruise mass of 22t, FL 150, ISA +10 the cruise parameters will be:

\[
\text{TQ} = \frac{76.4 + 72.4}{2} = 73.7\%
\]

\[
\text{Fuel consumption} = \frac{374 + 357}{2} = 365.5 \text{ kg/hr}
\]

\[
\text{IAS} = \frac{215 + 208}{2} = 211.5 \text{ kt}
\]

\[
\text{TAS} = 267 \text{ kt}
\]

Blank boxes mean that the FL cannot be maintained in cruising mode. With the previous assumptions, the maximum FL that can be flown is FL 240.
F. En-route limitations

FCOM 3.09
1. Introduction

In flight, engine or pressurisation failures are potential problems, which must be carefully studied before operating a new route. Their occurrence seriously impacts flight altitudes and therefore become very constraining over mountainous areas.

In case of engine failure during flight, the remaining thrust is no longer sufficient to balance the drag force and to maintain an adequate cruise speed. The power required to fly at the initial altitude suddenly becomes greater than the available power delivered by the engines. The only solution is then to descend to a more appropriate flight altitude, where the available power can equal the required power, thus allowing the aircraft to level off.

In case of an in-flight cabin pressurisation loss, descent is also necessary. It is not dictated by a performance constraint, but by the oxygen system constraint. Indeed, at the initial cruise altitude, the rate of oxygen in the air is insufficient to allow crew members and passengers to breathe normally. This is why the installation of an oxygen system is required. As the necessary oxygen quantity must be quite significant to supply the entire cabin, its flow rate is limited to a maximum duration. A new flight altitude, where oxygen is no longer required must be reached, before a certain time limit.

The descent cannot always be operated in the same conditions, since, aircraft are sometimes flying over mountainous areas. This is why, in these particular cases, a route study is necessary to evaluate whether or not an acceptable escape procedure is possible when a failure occurs at the worst moment during flight. If possible, it must be clearly defined and indicated to the pilots. If not possible, a new route must be found.

Any route study must be done in accordance with the following airworthiness requirements.

2. Engine failure

2.1. Gross and net flight paths

Regulations require that the flight paths are determined as stated below:

CS / FAR 25.123 En-route flight paths

(a) For the en-route configuration, the flight paths must be determined at each weight, altitude, and ambient temperature (…). The variation of the weight along the flight path, accounting for the progressive consumption of fuel (…) by the operating engines, may be included in the computation. The flight paths must be determined (…) with:

1. The most unfavorable center of gravity
2. The critical engine inoperative
3. The remaining engine at the available maximum continuous power (…)

(b) The one-engine-inoperative net flight path data must represent the actual climb performance diminished by a gradient of climb of 1.1% for two-engined aeroplanes.

\[
\text{Net flight path} = \text{gross flight path} - \text{gradient penalty}
\]

The gross flight path is the flight path actually flown by the aircraft after an engine failure.

The net flight path is the gross flight path minus a mandatory climb reduction. Ideally the aircraft should be able to maintain the gross flight path, but the climb performance is reduced to conservatively account for aircraft performance degradation and pilot average skills.

NOTE: The gradient penalty applies on air gradient.

Figure F1: Gross and net flight paths (climb and descent)
2.2. Following engine failure procedure

In any case, the maximum continuous power (MCT) is set to the remaining engine.

• If no obstacle limitation (condition 1)

If the engine failure occurs during the **cruise**, a 200 kt descent is performed until a vertical speed of 500 ft/mn is reached.

If the engine failure occurs during **climb**, climb is continued at \( V_{MLB0°} \) or \( V_{MLB15°} \) depending on the atmospheric conditions, until the single engine ceiling.

• If obstacle limitation (condition 2)

If the engine failure occurs during cruise, over a mountainous or a restricted area, the **drift-down procedure** is followed.

The minimum manoeuvre speed in flight is \( V_{MLB} \) flaps 0° in normal conditions and \( V_{MLB} \) flaps 15° in icing conditions. This speed ensures the highest altitude versus the distance in climb, and the best lift-to-drag ratio speed during descent. This speed is selected when an engine failure occurs in flight and that the vertical profile has to be optimised. This procedure consists in:
- deciding at the decision point whether to continue, divert or return.
- then decelerating to \( V_{MLB0°} \) or \( V_{MLB15°} \) depending on the atmospheric conditions, called in this case **drift-down speed**, and descending to the gross ceiling, where, if the obstacle is cleared, a single engine cruise is initiated.

**NOTE:** Procedures are detailed in the FCOM 3.09.03, *One engine inoperative procedure - in flight*.

![Figure F2: Drift-down procedure](image_url)

2.3. Obstacle Clearance

2.3.1. Lateral Clearance

Obstacle clearance must be ensured throughout the route, in case of an engine failure. The problem is to clearly identify which obstacles must be cleared. Regulations indicate which obstacles must be taken into account.

**EU-OPS 1.500 En-route - One engine inoperative**

(c) The net flight path must permit the aeroplane to continue flight from the cruising altitude to an aerodrome where landing can be made (…) clearing (…) all terrain and obstructions along the route within 9.3 km (5 nm) on either side of the intended track

(d) (…) an operator must increase the widths margins (…) to 18.5 km (10 nm) if the navigational accuracy does not meet the 95% containment level.

**NOTE:** The FAA regulation (FAR 121.191 *En-route limitations: One engine inoperative*) is quite similar, except that it requires a lateral margin of 5 statute miles on each side of the intended track.
2.3.2. Vertical Clearance

Vertical clearance shall always be understood as a margin between the net flight path and the obstructions. The en-route net flight path shall be determined from the Aircraft Flight Manual, and must take into account the meteorological conditions (wind and temperature) prevailing in the area of operations. Moreover, if icing conditions can be expected at the diversion level, the effect of the anti/de-ice system must be considered on the net flight path.

Any route study should be conducted by checking one of the following two vertical clearance conditions. When Condition 1 cannot be met, or when it appears to be too penalising in terms of weight, a detailed study must then be carried out to fulfil Condition 2.

**Condition 1: 1,000 feet clearance margin**

**EU-OPS 1.500 / FAR 121.191 En-route - One engine inoperative**

(b) The gradient of the net flight path must be positive at at least 1,000 ft above all terrain and obstructions along the route within 5 Nm on either side of the intended track.

**Condition 2: 2,000 feet clearance margin**

Condition 2 concerns the case of an engine failure during the cruise phase. When Condition 1 is not met, or when it is too limiting in terms of weight, a drift-down procedure should be studied, as detailed below.

**EU-OPS 1.500 / FAR 121.191 En-route - One engine inoperative**

(c) The net flight path must permit the aeroplane to continue flight from cruising altitude to an aerodrome where a landing can be made, (...) clearing vertically, by at least 2,000 ft all terrain and obstructions along the route.
F. En-route limitations

Fulfilling condition 2 implies determining critical points along the route. Those are the points at which, if an engine failure occurs and if the aircraft initiates a drift-down, the net flight path will clear the most penalising obstacle by the minimum required 2,000 ft margin. A critical point can be a:

- **no-return point**: Point after which it is not possible to turn back, otherwise the 2,000 feet obstacle clearance margin on the net flight path would not be met.
- **continuing point**: Point after which it is possible to continue on the route because the 2,000 feet obstacle clearance margin on the net flight path is ensured.

If the no-return point is obtained after the continuing point, the route is suitable, and if an engine failure occurs in-between a decision must be taken to return or continue.

If the no-return point is obtained before the continuing point, the route is not suitable, and if an engine failure occurs in-between the aircraft must divert to another airport.
2.4. Methodology for engine failure study

2.4.1. In climb
From a topographic map, select in the regulatory corridor, all the constraining obstacles that must be cleared during the climb phase. Plot these obstacles on a graph, with their distance from the intended route (horizontal axis) and their height (vertical axis).
From the AFM, determine the climb net flight path for a conservative weight (for instance, use the maximum certified take-off weight), and for conservative meteorological conditions. Plot it on the previous graph.
If the net flight path clears each obstacle with a margin of at least 1,000 feet, the route study is finished and obstacle clearance is ensured at any moment during climb.
If the net flight path does not clear at least one of the obstacles by 1,000 feet, reduce the take-off weight and recalculate the net flight path until the previous condition is checked. If it is not possible, establish a diversion procedure.

2.4.2. In cruise
From a topographic map, determine the highest obstacle in the regulatory corridor and add 1,000 feet to obtain a height \( H_1 \).
From the AFM, determine the net ceiling (\( H_2 \)) at a conservative weight. For instance, choose the heaviest possible aircraft weight at the entrance of the constraining area.
If \( H_2 \) is higher than \( H_1 \), the route study is completed and the obstacle clearance is ensured at any moment.
If \( H_2 \) is lower than \( H_1 \), then a more detailed study based on Condition 2 shall be conducted, or a weight limitation at take-off established, or a new route found.

2.4.3. Determination of En-route limitation
Let us consider a route flown with an ATR 72-500, which goes over a mountain with a height of 14,000 feet. Let us determine the different en-route limitations, in ISA conditions and in still air.

Condition 1 → weight limitation
The single engine net ceiling must be 1000 ft above the more constraining obstacle of the route, 15,000 feet in this case.
The corresponding en-route limiting weight is read in the single engine net ceiling table below: to have a single engine net ceiling equals to 15,000 feet, the weight along the route must not exceed 18,800 Kg.
The fuel burnt to reach this obstacle is added. Let us assume the fuel to go is 700 kg, the TOW limited by the en-route obstacle is thus 19,500 Kg.

If this limitation is too constraining for the dispatch, the other calculation based on condition 2 is carried on.

**Condition 2 → critical point**

More payload is loaded, and the TOW is finally 22,350 Kg. The weight at start of cruise is 22,000 Kg. The single engine net ceiling for this weight is read in the previous graph, and is 10,200 feet. The cruise FL chosen is FL210. The critical point determination is done with the drift-down descent profile drawn below; this profile represents the real flight path flown by the aircraft during a drift-down. The drift-down starts at 10,800 ft (=21,000-10,200) above the single engine ceiling and crosses 20,000 ft above obstacle, 30 Nm further. The critical decision point of whether to continue or to divert is located 30 Nm before the obstacle.
3. Cabin pressurisation failure

3.1. Oxygen Systems

EU-OPS 1.770 / FAR 121.329 Supplemental oxygen - pressurised aeroplanes

(a) 1. An operator shall not operate a pressurised aeroplane at Pressure Altitudes above 10,000 ft unless supplemental oxygen equipment (…) is provided.

On ATR, the oxygen system consists of a main system supplying the cockpit crew and the passengers, and a portable unit for the cabin attendant.
3.2 Oxygen Requirement

EU-OPS 1.770 Supplemental oxygen - pressurised aeroplanes

(b) 2. (v) The oxygen supply requirements (...) for aeroplanes not certificated to fly above 25 000 ft, may be reduced to the entire flight time between 10 000 ft and 13 000 ft cabin Pressure Altitudes for all required cabin crew members and for at least 10% of the passengers if, at all points along the route to be flown, the aeroplane is able to descend safely within 4 minutes to a cabin Pressure Altitude of 13 000 ft.

NOTE: FAR 121.331(c)(1) requires a minimum oxygen quantity to provide 10% of the passengers for 30 minutes at 14000ft.

To help operators determine their needs in terms of supplementary oxygen, regulations provide the minimum required oxygen quantity. This information is given for flight crew members, cabin crew members, as well as for passengers. Oxygen reserves for crew members are usually much more important than the ones for passengers.

As a consequence, the passenger oxygen system reserves generally induce limitation to the remaining time to fly after a pressurisation failure.

The oxygen limitation chart is available in the FCOM 2.01.05, Limitations - systems.

3.3. Methodology for cabin pressurisation failure study

During the flight preparation, the flight profile following a cabin pressurisation failure must be studied, considering the oxygen system and the performance limitations. For a given initial weight and flight level, the oxygen profile, function of the time, is transformed into a performance profile, function of the distance. The performance profile must always remain below the oxygen profile.

**Oxygen system limitation**

Following a cabin pressurisation failure, it is always assumed that the cabin Pressure Altitude is the same as the aircraft Pressure Altitude. The flight profile is established considering the above-mentioned oxygen requirements.

This flight profile represents the maximum level that can be flown with respect to the oxygen system’s capability.

**Performance limitation**

The oxygen descent profile only depends on the oxygen system’s capability, and not on the aircraft performance capability.

Nevertheless, this does not mean that the aircraft is always able to follow the oxygen profile. The performance profile must be established, based on the following assumptions:

- **Descent phase**: Emergency descent at V_{NO}. Maxi RPM can be selected to increase the rate of descent, if necessary.
- **Cruise phase**: Cruise at maximum speed (limited to V_{MO}).

NOTE: A net flight path is not required when determining the performance limitation after a cabin pressurisation failure. Indeed, the net flight path shall be understood as a safety margin, when there is a risk that the aircraft cannot maintain the expected descent performance in case of an engine failure. In the event of a cabin depressurisation, any altitude below the initial flight altitude can be flown without any problem when all engines are running.

4. Route study

4.1. Methodology

As a general rule, failures (engine or pressurisation) must always be expected to occur at the most critical points of the intended route. Nevertheless, as descent profiles differ, critical points may differ between two failure cases. It is important to notice that regulations do not require to consider performance to cope with both failures simultaneously, except for ETOPS.

When both failure cases are dealt with separately, the number of critical points and the specific escape routes also increase. As a result, the complexity may engender a supplementary workload for flight crews and a subsequent risk of error.
This is why, whenever possible, it must be preferred to define the same critical points and the same escape routes, whatever the failure case. Thus, reaction times and mistake risks are reduced. In that case, the route study should be based on the most penalising descent profile.

4.2. Diversion airport

In case of an event encountered during the flight, the captain may decide to divert from the initial route. A diversion airport must respect the following rules:

EU-OPS 1.500 / FAR 121.191 En-route - One engine inoperative

(a) The net flight path must have a positive gradient at 1,500 ft above the aerodrome where the landing is assumed to be made after an engine failure.

(c) The aerodrome where the aeroplane is assumed to land after engine failure must meet the following criteria:

(i) The performance requirements at the expected landing mass are met.

(ii) Weather reports or forecasts, or any combination thereof, and field condition reports indicate that a safe landing can be accomplished at the estimated time of landing.

The route study must indicate the different possible en-route diversion airfields associated with the various diversion procedures. The prescribed weather minimums for the approach category must be met, if not, the associated diversion procedures are no longer possible.

4.3. Minimum flight altitudes

To assist EASA operators in their choice, guidance material is provided in IEM OPS 1.250, where the most common definitions of published minimum flight altitudes are recalled:

- **MOCA** (Minimum Obstacle Clearance Altitude) and **MORA** (Minimum Off-Route Altitude). They correspond to the maximum terrain or obstacle elevation, plus:
  - 1,000 ft for elevation up to and including 5,000 ft for Jeppesen or 6,000 feet for KSS charts.
  - 2,000 ft for elevation exceeding 5,000 ft for Jeppesen or 6,000 ft for KSS charts rounded up to the next 100 ft.

- **MEA** (Minimum Safe En route Altitude) and **MGA** (Minimum Safe Grid Altitude). They correspond to the maximum terrain or obstacle elevation, plus:
  - 1,500 ft for elevation up to and including 5,000 ft.
  - 2,000 ft for elevation above 5,000 ft and below 10,000 ft.
  - 10% of the elevation plus 1,000 ft above 10,000 ft.

When studying the route, consider than the minimum flight altitudes given on the charts may already take into account the 1,000 ft or 2,000 ft safety margin.
4.4. Optimisation of the route

4.4.1. Extended range operations for two-engined aeroplanes (ETOPS)

EU-OPS 1.245 Maximum distance from an adequate aerodrome for two-engined aeroplanes without an ETOPS approval / FAR 121.161 Airplane limitations: type of route

(a) Unless specifically approved by the Authority (…), an operator shall not operate a two-engined aeroplane over a route which contains a point further from an adequate aerodrome than the distance flown in 60 minutes at the [approved] one-engine-inoperative cruise speed.

When at least one point of the route sector is located at more than 60 minutes from a diversion airfield, the airline needs specific approval, called ETOPS.

The ETOPS concept aims to settle and support the operations of two-engined aircraft on long distances. It allows airlines to operate on routes containing points further than 60 minutes flying time from an adequate airport with one engine inoperative. This authorisation is associated to a maximum time from an alternate airport. All ATR aircraft except 42-300 are certified ETOPS 120 min. Please refer to AFM 7.01.08 or FCOM 3.11.09, ETOPS for further information on ATR aircraft capability.

4.4.2. Boost option

In order to improve the en-route limitation, ATR has developed a specific option on the PW127M engine. This engine now replaces the PW127E/F on -500 and is standard on -600 series.

The boost option can be selected in flight in case of an engine failure in order to recover at a higher ceiling. The expected gain is around 1000 ft which is particularly interesting when flying over mountainous environment, or in hot atmospheric conditions.
G. Descent / holding

FCOM 3.06 / 3.07
1. Flight Mechanics

1.1. Lift and drag equations

During descent at constant speed, the flight mechanics equations that apply to the aircraft are\(^1\):

\[
\text{lift} = \text{weight}
\]
\[
\text{thrust} = \text{drag} + \alpha \cdot \text{weight}
\]

\(^1\) the Angle of Attack \(\alpha\) is considered negligible and the Flight Path Angle. \(\gamma\) is very small, so \(\sin \gamma \approx \gamma\) (in radian) and \(\cos \gamma \approx 1\).

1.2. Descent Gradient (\(\gamma\))

During descent, the Flight Path Angle is also called descent gradient, and is expressed in degree.

**NOTE:** The descent gradient is expressed in radians in the following formulae.

\[
\gamma = \frac{\text{Thrust} - \text{Drag}}{\text{Weight}} \quad \text{(in rad)}
\]

As the descent is generally performed at a very low thrust, it is negligible compared to drag, so:

\[
\gamma = -\frac{\text{Drag}}{\text{Weight}} \quad \text{(in rad)}
\]

and

\[
\gamma = -\frac{1}{L/D} \quad \text{(in radians)}
\]

\[
\gamma = -\frac{100}{L/D} \quad \text{(in %)}
\]

**NOTE:** The descent gradient, as well as the rate of descent are negative values.

The descent gradient is minimum, when the **lift-to-drag ratio is maximum**. The maximum descent gradient allows the **highest possible altitude** to be maintained over the **longest distance**.

With ATR, the best lift-to-drag ratio, or minimum descent angle speed is \(V_{\text{LDB}}\). A \(V_{\text{LDB}}\) descent is of no interest in normal operations, as it requires too much time. On the other hand, it is of great use in case of an engine failure during cruise over a mountainous area, since it offers more escape solutions than any other speed. A \(V_{\text{LDB}}\) 0° descent with one inoperative engine is called a **drift-down** procedure (please refer to Paragraph F.2.2, *Following engine failure procedure.*)
1.3. Rate of Descent (RD)

The Rate of Descent (RD) corresponds to the vertical speed of the aircraft, and is expressed in ft/mn.

\[ RD = \text{TAS} \sin \gamma \approx \text{TAS} \gamma \]

(since \( \gamma \) is small)

Hence:

\[ RD = -\text{TAS} \cdot \frac{\text{Drag}}{\text{Weight}} \]

At a given aircraft weight, the rate of descent is maximum, when \( \text{TAS} \cdot \text{Drag} \) is minimum. On ATR, descent is operated at a constant Indicated Air Speed (IAS), generally 240 kt, i.e. \( V_{\text{MO}}-10 \) at high altitude.

While climb is due to an excess of thrust, descent is, on the other hand, caused by a lack of thrust.

---

**NOTE:** When an emergency descent needs to be performed, the highest rate of descent must be reached. For this reason, \( V_{\text{MO}} \) is the best speed schedule, as it enables the quickest possible rate of descent. This rate can even be increased by selecting max RPM, if needed.
1.4. Influence of external conditions

1.4.1. Wind Effect
A constant horizontal wind component changes the flight path but has no change on the rate of descent.

The air descent gradient \( \gamma_a \) remains unchanged, whatever the wind component. Fuel and time from the Top Of Descent (T/D) remain unchanged.

### Figure G4: Influence of headwind on flight path angle and Rate of descent

<table>
<thead>
<tr>
<th>Headwind</th>
<th>Tailwind</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rate of descent</td>
<td>➔</td>
</tr>
<tr>
<td>Fuel and time from T/D</td>
<td>➔</td>
</tr>
<tr>
<td>Flight path angle ( \gamma_a )</td>
<td>➔</td>
</tr>
<tr>
<td>Ground distance from T/D</td>
<td>➔</td>
</tr>
</tbody>
</table>

1.4.2. Pressure Altitude and Temperature
Increase in Pressure Altitude or Outside Air Temperature (OAT) induce a reduction in air density. So that, for a given aircraft weight and a given True Air Speed, there is a decrease in the drag force and, as a result, a decrease in the magnitude of the descent gradient and rate of descent.

Nevertheless, descent is never performed at a given TAS, but at a given IAS, and as the TAS increases with Temperature and Pressure Altitude (for a given IAS), this counterbalances drag reduction.

This is why descent variations versus temperature are not really significant. Unlike the climb phase, it is difficult to assess descent parameters (gradient and rate), as they are fully dependent on drag, not on thrust.

1.4.3. Weight
A higher weight means that a higher lift coefficient \( (C_l) \) is needed to maintain the balance of forces. This is achieved by increasing the angle of attack \( (\alpha) \) and thus reducing the descent gradient \( (\gamma_a) \), and as a consequence the Rate of Descent.

As a conclusion, in the standard descent speed range:

<table>
<thead>
<tr>
<th>Weight</th>
<th>Descent gradient</th>
<th>Rate of descent</th>
</tr>
</thead>
<tbody>
<tr>
<td>➔</td>
<td>➔</td>
<td>➔</td>
</tr>
</tbody>
</table>

A descent performed at higher weight has no impact on the time and distance from the T/D, but requires less fuel.
## 2. FCOM Descent performance table

Descent performance tables for standard descent at given IAS are provided in the FCOM 3.07, Descent. The descent parameters are given, depending on the Rate of Descent or descent gradient and the atmospheric conditions.

### Table G1: ATR 72-500 descent performance table.

<table>
<thead>
<tr>
<th>FL</th>
<th>200 KT IAS</th>
<th>220 KT IAS</th>
<th>240 KT IAS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1500 ft/min</td>
<td>2000 ft/min</td>
<td>1500 ft/min</td>
</tr>
<tr>
<td>250</td>
<td>19 119</td>
<td>15 81</td>
<td>19 145</td>
</tr>
<tr>
<td></td>
<td>63 47</td>
<td>70 52</td>
<td>76 52</td>
</tr>
<tr>
<td>240</td>
<td>18 115</td>
<td>14 79</td>
<td>18 40</td>
</tr>
<tr>
<td></td>
<td>60 45</td>
<td>66 49</td>
<td>72 54</td>
</tr>
<tr>
<td>230</td>
<td>17 112</td>
<td>14 77</td>
<td>17 36</td>
</tr>
<tr>
<td></td>
<td>57 43</td>
<td>63 47</td>
<td>68 51</td>
</tr>
<tr>
<td>220</td>
<td>17 108</td>
<td>13 75</td>
<td>17 31</td>
</tr>
<tr>
<td></td>
<td>54 40</td>
<td>59 44</td>
<td>65 48</td>
</tr>
<tr>
<td>210</td>
<td>16 105</td>
<td>13 73</td>
<td>16 126</td>
</tr>
<tr>
<td></td>
<td>51 38</td>
<td>56 42</td>
<td>61 46</td>
</tr>
<tr>
<td>200</td>
<td>15 101</td>
<td>12 71</td>
<td>15 21</td>
</tr>
<tr>
<td></td>
<td>48 36</td>
<td>53 39</td>
<td>57 43</td>
</tr>
<tr>
<td>180</td>
<td>14 94</td>
<td>11 67</td>
<td>14 12</td>
</tr>
<tr>
<td></td>
<td>42 31</td>
<td>46 35</td>
<td>50 38</td>
</tr>
<tr>
<td>160</td>
<td>13 87</td>
<td>10 63</td>
<td>13 62</td>
</tr>
<tr>
<td></td>
<td>36 27</td>
<td>40 30</td>
<td>44 33</td>
</tr>
<tr>
<td>140</td>
<td>11 79</td>
<td>9 59</td>
<td>11 92</td>
</tr>
<tr>
<td></td>
<td>31 23</td>
<td>34 25</td>
<td>37 28</td>
</tr>
<tr>
<td>120</td>
<td>10 72</td>
<td>8 54</td>
<td>10 83</td>
</tr>
<tr>
<td></td>
<td>25 19</td>
<td>28 21</td>
<td>31 23</td>
</tr>
<tr>
<td>100</td>
<td>9 65</td>
<td>7 50</td>
<td>9 73</td>
</tr>
<tr>
<td></td>
<td>20 15</td>
<td>22 17</td>
<td>24 18</td>
</tr>
<tr>
<td>80</td>
<td>7 57</td>
<td>6 45</td>
<td>7 63</td>
</tr>
<tr>
<td></td>
<td>15 11</td>
<td>17 13</td>
<td>18 14</td>
</tr>
<tr>
<td>60</td>
<td>6 49</td>
<td>5 40</td>
<td>6 53</td>
</tr>
<tr>
<td></td>
<td>10 8</td>
<td>11 9</td>
<td>13 10</td>
</tr>
<tr>
<td>40</td>
<td>5 41</td>
<td>4 36</td>
<td>5 33</td>
</tr>
<tr>
<td></td>
<td>6 4</td>
<td>6 5</td>
<td>7 6</td>
</tr>
<tr>
<td>15</td>
<td>3 30</td>
<td>3 30</td>
<td>3 30</td>
</tr>
</tbody>
</table>

**FROM START OF DESCENT TIME (MN)**

**FROM START OF DESCENT DIST (NM)**

**FUEL (KG)**

**Eng.: PW127F / PW127M BOOST OFF**
**Example:** Assuming an aircraft mass of 19 t at start of descent, descending at 220 kt and RD=1500 ft/mn from FL 210 to the start of the approach procedure (FL 15), in normal conditions, the descent will be performed:
- in 16-3 = 13 min,
- within 56 Nm, and
- 126-30 = 96 Kg of fuel will be burnt.

**NOTE:** The FCOM tables are computed for an aircraft mass of 15t. If the actual aircraft mass is higher, the descent parameter values are not updated. Indeed, for a higher weight, the time and distance remain unchanged, only the fuel consumption is reduced. As FCOM values are conservative, fuel consumption is not corrected.

### 3. Holding

#### 3.1. Holding speed

During Holding, the important point is to minimise fuel consumption versus time as much as possible, to ensure maximum endurance. As the aircraft is turning around, the distance covered is not the primary objective.

The power required should be as low as possible.

In level Holding the lift and drag equations are the same as for cruise (please refer to E.1.1, *Lift and drag equations*), the power required is:

\[
P_r = \text{TAS} \cdot \text{drag} = \frac{1}{2} \frac{\rho \cdot S \cdot \text{TAS}^3 \cdot C_D}{C_L}
\]

\[
\text{TAS} = \sqrt{\frac{2 \cdot \text{weight}}{\rho \cdot S \cdot C_L}}
\]

\[
P_r = \sqrt{\frac{2 \cdot \text{weight}^2}{\rho \cdot S \cdot C_L^2}}
\]

The power required is minimum when \(C_L^2/C_D^2\) is maximum.

On ATR aircraft the chosen holding speed equals the \(V_{\text{forco}}\) speed of icing conditions. This manoeuvering speed covers the whole flight envelope in normal and in icing conditions without an appreciable increase in consumption.

**NOTE:** ATR is a cat B aircraft. Therefore the maximum approach speed that ensures every protections on published approach charts is 180 kt.

#### 3.2. FCOM holding performance table

Holding performance tables are provided in the FCOM 3.06, *Holding*. IAS, torque setting and fuel consumption are shown for each FL, aircraft weight and atmospheric conditions.
### Table G2: ATR 72-500 holding performance table

<table>
<thead>
<tr>
<th>WEIGHT (1000KG)</th>
<th>FLIGHT LEVEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>50 100 150 200</td>
</tr>
<tr>
<td>13</td>
<td>21.8 21.5 23.4 24.6 26.1</td>
</tr>
<tr>
<td></td>
<td>218 215 232 232 232</td>
</tr>
<tr>
<td></td>
<td>131 131 132 132 132</td>
</tr>
<tr>
<td>14</td>
<td>23.8 25.6 26.9 28.8</td>
</tr>
<tr>
<td></td>
<td>226 232 237 237 237</td>
</tr>
<tr>
<td></td>
<td>139 141 132 132 132</td>
</tr>
<tr>
<td>15</td>
<td>25.8 27.8 29.3 31.4</td>
</tr>
<tr>
<td></td>
<td>234 239 233 233 233</td>
</tr>
<tr>
<td></td>
<td>141 141 141 141 141</td>
</tr>
<tr>
<td>16</td>
<td>27.8 30.1 32.0 34.3</td>
</tr>
<tr>
<td></td>
<td>241 247 243 243 243</td>
</tr>
<tr>
<td></td>
<td>146 146 146 146 146</td>
</tr>
<tr>
<td>17</td>
<td>29.9 32.4 34.7 37.3</td>
</tr>
<tr>
<td></td>
<td>248 254 251 251 251</td>
</tr>
<tr>
<td></td>
<td>150 151 151 151 151</td>
</tr>
<tr>
<td>18</td>
<td>32.1 34.9 37.3 40.4</td>
</tr>
<tr>
<td></td>
<td>256 262 258 258 258</td>
</tr>
<tr>
<td></td>
<td>155 155 155 155 155</td>
</tr>
<tr>
<td>19</td>
<td>34.3 37.6 40.1 43.6</td>
</tr>
<tr>
<td></td>
<td>264 270 266 266 266</td>
</tr>
<tr>
<td></td>
<td>159 159 159 159 159</td>
</tr>
<tr>
<td>20</td>
<td>36.6 40.2 43.0 46.8</td>
</tr>
<tr>
<td></td>
<td>272 264 255 243 243</td>
</tr>
<tr>
<td></td>
<td>163 163 163 163 163</td>
</tr>
<tr>
<td>21</td>
<td>38.9 42.9 46.2 50.1</td>
</tr>
<tr>
<td></td>
<td>282 275 264 255 255</td>
</tr>
<tr>
<td></td>
<td>167 167 167 167 167</td>
</tr>
<tr>
<td>22</td>
<td>41.3 45.6 49.5 53.4</td>
</tr>
<tr>
<td></td>
<td>292 286 272 267 268</td>
</tr>
<tr>
<td></td>
<td>171 171 171 172 172</td>
</tr>
</tbody>
</table>

**Example:** Assuming an aircraft mass of 20t, holding at FL 50 in normal conditions
- the recommended IAS is 163 kt
- the hour fuel consumption is 264x2 = 528 kg/hr

**NOTE:** The fuel consumption is given for ONE engine. Multiply by two when Holding is performed with both engines.
H. Landing
FCOM 3.08
1. Introduction

Landing performance has to be assessed prior to take-off and if any change, re-assessed in flight, considering the
different potential limitations that may exist on landing. Those may be due to available runway lengths, to minimum
required climb gradients for go-around, to external conditions or system failures.
In normal operations, these limitations are not very constraining and, most of the time authorize dispatch at the maxi-

mum structural landing weight. However, landing performance can be drastically penalised in case of inoperative items,
adverse external conditions, or contaminated runways. Flight preparation is, therefore, of the utmost importance, to
ensure a safe flight.
The different limitations, which are detailed in this chapter, must be calculated, compared to each other and the most
penalising ones must be considered.

2. Landing Speeds

2.1. Reference Speed: \( V_{\text{REF}} \)

\( V_{\text{REF}} \) is the calibrated airspeed that is considered in stabilised final approach during flight tests for the determination of
the certified landing distances, the aircraft being assumed in landing flaps configuration.

\[
V_{\text{REF}} = \max \{ V_{\text{MHB}}^{(1)}, V_{\text{MCL}}^{(2)} \}
\]

\( V_{\text{MHB}}^{(1)} \) in landing flaps configuration. For the definition of this speed, please refer to Paragraph C.2.2.6, ATR minimum
manoeuver speed.

\( V_{\text{MCL}}^{(2)} \) For the definition of this speed, please refer to Paragraph B.1.3.3, Minimum Control Speed during Approach and
Landing.

In case of a system failure affecting landing performance, ATR operational documentation indicates the correction to
be applied to \( V_{\text{REF}} \) to take into account the failure.

2.2. Operational landing speeds

The operational landing speeds are defined in the FCOM 2.02.01, Operating speeds.

2.2.1. Approach Speed: \( V_{\text{APP}} \)

\( V_{\text{APP}} \) is the operational speed during landing, determined with the flaps in landing configuration and the landing gears
extended.

\[ V_{\text{APP}} = V_{\text{REF}} + \text{wind factor} \]

The wind factor is the highest of:
- 1/3 of the head wind velocity
- the full gust
but may not exceed 15 kt.

EXAMPLE: If the wind recorded is 15kt/gust 25kt, the wind factor is the highest between 15/3=5 and 25-15=10, i.e. 10 kt.
2.2.2. Go-around speed: $V_{GA}$

The go-around speed is the High Bank minimum manoeuvre speed increased by 5 kt, and must not be less than 1.1 $V_{MCA}$.

$$V_{GA} = \max \left\{ V_{MHB}^{(1)} + 5 \text{kt}, 1.1 \ V_{MCA}^{(2)} \right\}$$

$^{(1)}$ In landing flaps configuration. For the definition of this speed, please refer to Paragraph C.2.2.6, ATR minimum manoeuvre speed.

$^{(2)}$ For the definition of this speed, please refer to Paragraph B.1.3.2, Minimum Control Speed in the Air.

2.3. Cockpit speed display

On classic ATR aircraft, the approach speeds are manually set by the flight crew on the Airspeed Indicator.

On the latest ATR -600, the approach speeds are automatically calculated by the FMS and cannot be modified. $V_{REF}$ and $V_{APP}$ in normal and icing conditions are written in the Performance initiation page of the MFD and in the Approach performance page of the MCDU in normal or icing, depending on the outside conditions.

The managed speed bug on the airspeed scale of the PFD indicates $V_{APP}$ when the landing flaps are selected and $V_{GA}$ when the go-around pushbutton on the power levers is activated. $V_{REF}$ has a dedicated green bug.

**NOTE:** $V_{REF}$ is identified as $V_{MHB \ FULL}$ in the FMS.

![Figure H1: Approach speeds on classic ATR flight instruments, and on ATR-600 avionics](image)

3. Runway

3.1 Landing Distance Available (LDA)

EU-OPS 1.480 Terminology

(a) (5) **Landing distance available (LDA):** The length of the runway which is declared available by the appropriate authority and suitable for the ground run of an aeroplane landing.

Landing Distance Available is the runway length (TORA). The stopway cannot be used for landing calculation.

![Figure H2: Landing Distance Available](image)

The Landing Distance Available may be shortened, due to the presence of obstacles under the landing path. ICAO Doc 8168. Vol II *Construction of visual and instrument flight procedures*, specifies the dimension of the protection surfaces for the approach.
When there is no obstacle within the approach funnel, it is possible to use the full runway length available to land. When there is an obstacle, the threshold of the runway is displaced, and the LDA shortened.

### 3.2 Actual Landing Distance (ALD)

CS / FAR 25.125 Landing

(a) The horizontal distance necessary to land and to come to a complete stop from a point 50 ft above the landing surface must be determined (for standard temperatures, at each weight, altitude and wind [...]).

(b) In determining the [landing] distance:

1. The aeroplane must be in the landing configuration.
2. A stabilised approach, with a calibrated airspeed of not less than $V_{REF}$, must be maintained down to the 50 ft height. (…)
3. The landing must be made without excessive vertical acceleration, tendency to bounce, nose over or ground loop.
4. The landings may not require exceptional piloting skill or alertness.

(c) The landing distance must be determined on a level, smooth, dry hard-surfaces runway. In addition:

1. The pressures on the wheel braking systems may not exceed those specified by the brake manufacturer; (…)
2. Means other than wheel brakes\(^{(1)}\) may be used if that means is safe and reliable (…)

\(^{(1)}\) Braking means other than the wheel brakes are reversers on ATR aircraft.
Actual Landing Distances are certified on dry runways for all ATR aircraft, and published (for information) for wet and contaminated runways. They are given for normal conditions in AFM 6.05, Landing, for icing conditions in 6.06, Atmospheric icing conditions and for contaminated runways in 7.03.01, Non dry runways; and in the FCOM 3.08.03, Landing distances.

Distances are demonstrated during flight tests in normal and icing conditions, without the use of reverse. The effects of reverse are however quantified in the ATR documentation.

Landing distances are also certified with degraded braking means (spoiler inoperative, one brake inoperative...) and the values are given in the AFM 7.02, Supplements.

**3.3 Required Landing Distance (RLD)**

Before departure, operators must check that the Landing Distance Available (LDA) at destination is at least equal to the Required Landing Distance (RLD) for the forecasted landing weight and conditions.

The RLD, based on certified landing performance (ALD), has been introduced to assist operators in defining the minimum distance required at destination, and allow flight dispatch. In all cases, the requirement is:

\[ \text{RLD} \leq \text{LDA} \]

EASA and FAA regulations differ on the definition of RLD, the FAA one being on the whole more restrictive. EASA definitions change depending on the runway conditions and the FAA ones depending on destination or alternate airport.

**NOTE:** In the event of an aircraft system failure, known prior to dispatch and affecting the landing distance, the available runway length and consequently the required landing distance must be updated with the degradation coefficient given in the AFM 7.02, Supplements, or in the FCOM 3.11, Special Operations. In an exceptional in-flight failure event, please refer to Paragraph H.6.1, In-flight failure.

**3.3.1 EASA regulation**

**Dry runway**

EU-OPS 1.515 Landing - dry runways

(a) An operator shall ensure that the landing mass of the aeroplane for the estimated time of landing at the destination aerodrome and at any alternate aerodrome allows a full stop landing (...)

2. For turbo-propeller powered aeroplanes, within 70 % of the landing distance available.

![Figure H6: EASA Required Landing Distance on dry runway](image-url)

\[ \text{RLD}_{\text{dry}} = \frac{\text{ALD}_{\text{dry}}}{0.7} \quad (\text{EASA}) \]
Wet runway

EU-OPS 1.520 Landing - wet and contaminated runways

(a) An operator shall ensure that when (...) the runway at the estimated time of arrival may be wet, the landing distance available is at least 115% of the required landing distance, determined on a dry runway.

\[ \text{RLD}_{\text{wet}} = 1.15 \times \text{RLD}_{\text{dry}} \quad \text{(EASA)} \]

Contaminated Runways

EU-OPS 1.520 Landing - wet and contaminated runways

(b) An operator shall ensure that when (...) the runway at the estimated time of arrival may be contaminated, the landing distance available must be at least the landing distance determined on a wet runway or at least 115% of the landing distance determined in accordance with approved contaminated landing distance (…), whichever is greater.

\[ \text{RLD}_{\text{contaminated}} = \max \left\{ 1.15 \times \text{ALD} \right\} \]

3.3.2. FAA regulation

Destination airport

FAR 121.195 Landing limitations: destination airports

(b) No person operating a turbine engine powered aeroplane may take-off that aeroplane unless its weight on arrival, allowing for normal consumption of fuel and oil in flight (…), would allow a full stop landing at the intended destination airport within 60 percent of the effective length of each runway (…).

\[ \text{RLD}_{\text{destination}} = \frac{\text{ALD}}{0.6} \quad \text{(FAA)} \]

Alternate airport

FAR 121.197 Landing limitations: alternate airports

No person may list an airport as an alternate airport in a dispatch for a turbine engine powered aeroplane unless that aeroplane at the weight anticipated at the time of arrival can be brought to a full stop landing within 70 percent of the effective length of the runway for turbopropeller powered aeroplanes (…).

\[ \text{RLD}_{\text{alternate}} = \frac{\text{ALD}}{0.7} \quad \text{(FAA)} \]

3.4. Optimisation of the runway-limited landing weight

The ATR 42-500 and the 72-500 are certified for steep slope approach, i.e. they have the capability to perform an approach with a slope higher than 4.5° but not exceeding 5.5°. When performing a steep slope approach, the screen height (from where the landing distance is calculated) above the runway threshold is decreased to 35ft.

EU-OPS 1.515 Landing - dry runways

(a) For steep approach procedures the Authority may approve the use of landing distance data (…), based on a screen height of less than 50ft, but not less than 35ft.

For the 42-500, providing specific limitations, this may improve the performance, with a gain on landing distance of up to 114 m. On the 72-500, there is no expected gain on performance, due to the length of the airframe which requires a long distance for the flare. The steep slope approach is approved for operations under specific limitations. The operator must actually have the specific modification on the aircraft, and receive local authority approval for it. For instance, ATR aircraft are certified to operate at London City airport with its slope approach being 5.5°.
4. Go-Around

When determining landing limitations, the occurrence of a go-around must be considered. Minimum air climb gradients must be observed when performing a go-around.

4.1. Approach Climb

4.1.1. Certification requirement

CS / FAR 25.121 Climb: one-engine-inoperative

Approach: In a configuration corresponding to the normal all-engines-operating procedure (…):

(1) The steady gradient of climb may not be less than 2.1% for two-engined aeroplanes with –

(i) The critical engine inoperative, the remaining engines at the go-around power;

(ii) The maximum landing weight;

(iii) A climb speed established in connection with normal landing procedures, but not more than 1.4 \( V_{S} \); and

(iv) Landing gear retracted.

This is the climb capability that must be demonstrated for the aircraft certification, assuming that one engine is inoperative.

The approach climb wording comes from the fact that go-around performance is based on approach configuration.

4.1.2. Operational requirement

When the aircraft is operated by airlines, operational regulations must be applied. The minimum climb gradient required by the operational regulation is generally 2.5% for instrument approaches.

The go-around climb gradient considered for the design of the procedure is 2.5%, as stated in the ICAO Doc 8168 Vol II Construction of visual and instrument flight procedures. Besides, for airports with restricting obstacles on the go-around path, a more stringent climb gradient may be required and is necessarily indicated on the airport approach chart.

EU-OPS 1.510 Landing - Destination and alternate aerodromes
(c) For instrument approaches with decision heights below 200 ft, an operator must verify that the expected landing mass of the aeroplane allows a missed approach gradient of climb, with the critical engine failed and with the speed and configuration used for go-around of at least 2.5%, or the published gradient, whichever is the greater.

4.2. Landing Climb

CS / FAR 25.119 Landing climb: all-engines-operating

In the landing configuration, the steady gradient of climb may not be less than 3.2%, with the engines at the power that is available 8 seconds after initiation of movement of the power controls from the minimum flight idle to the go-around power setting.

The objective of this constraint is to ensure aircraft climb capability, in case of a missed approach with all engines operating. The landing climb wording comes from the fact that go-around performance is based on landing configuration. This requirement never leads to landing weight limitations for the ATR aircraft. Therefore, in its operational documentation, ATR does not publish the limitations due to landing climb gradients.
5. Influence of external conditions

5.1. Atmospheric external conditions

5.1.1. Wind
The wind component along the runway axis significantly influences the landing performance. Indeed, it affects the ground speed and, therefore, the landing distances, which are reduced in case of headwind and increased in case of tailwind.

CS / FAR 25.125 Landing

(f) The landing distance data must include correction factors for not more than 50% of the nominal wind components along the landing path opposite to the direction of landing, and not less than 150% of the nominal wind components along the landing path in the direction of landing.

This condition is part of all the ATR operational documentation, the operator needs to consider just the actual wind component to determine the limitation.

5.1.2. Pressure Altitude and Temperature
Pressure Altitude and Temperature have an influence on the aerodynamics and the engine performance.

Effect on landing distances
Increase in Pressure Altitude or Outside Air Temperature (OAT) induce a reduction in static air density.

To lift-off the aircraft the lift must balance the aircraft weight, to verify the following equation:

\[ \text{Weight} = mg = \frac{1}{2} \rho S (\text{TAS})^2 C_L \]

The air density is lower and the True Air Speed (TAS) needs to be increased to balance the weight. The landing distance is thus increased.

Effect on climb gradient
Increase in Pressure Altitude or OAT induce a reduction in available go-around power. The go-around climb gradients are thus reduced.

\[ \text{PA or OAT} \rightarrow \text{landing distance} \rightarrow \text{climb gradients} \rightarrow \]

NOTE: To obtain optimum efficiency from the engines, the air conditioning could be switched off during the go-around phase.
5.2. Runway characteristics

5.2.1. Runway slope

ATR aircraft are all basically certified for landing on runways where slopes are between \(-2\%\) and \(+2\%\)\(^\text{(1)}\). A runway slope within this range is not considered for the determination of landing limitations.

\[\text{EU-OPS 1.515 Landing - dry runways}\]

For the determination of the Required Landing Distance

(b) (...) an operator must take account of the following: (...) 3. the runway slope in the direction of landing if greater than \(\pm 2\%\).

Nevertheless there is a dedicated modification that allows operating on runway with slopes down to \(-4.5\%\) (\(-4\%\) for ATR 42-300) and up to \(+4.5\%\) (\(+4\%\) for ATR 42-300). Regarding performance, an upward slope improves the aircraft stopping capability, and, consequently, decreases the landing distance. Performance modifications for runway slopes beyond \(2\%\) are given in the AFM 7.01.10, Runway slope beyond \(2\%\).

\[\text{Slope} \uparrow, \text{Landing distance} \downarrow\]

\(^{(1)}\) A slope is expressed in percentage, preceded with a plus sign when it is upward, or a minus when it is downward.

5.2.2. Runway surface conditions

The definition of runway conditions is the same as for take-off (please refer to Paragraph C.6.2.2, Runway surface conditions). When the runway is contaminated, landing performance is affected by the runway friction coefficient, and the precipitation drag due to contaminants.

\[\text{Friction coefficient} \uparrow, \text{Landing distance} \uparrow\]

\[\text{Precipitation drag} \uparrow, \text{Landing distance} \uparrow\]

5.3. Aircraft

Flaps setting

An increase in flaps deflection implies an increase in the lift coefficient \((C_L)\), and in the wing surface. It is then possible to reduce the speed such that the aircraft will need a shorter distance to land. When wing flap deflection increases, landing distance decreases. However, when flap deflection increases, drag increases thus penalising the climb performance of the aircraft.

\[\text{Wing Flap Deflection} \uparrow, \text{Landing distance} \uparrow\]

\[\text{Air Climb gradients} \uparrow\]

\textbf{NOTE:} When landing at a high altitude airport with a long runway, it might be better to decrease the flap setting in order to increase the go-around air climb gradient.

6. In-flight requirements

6.1. In-Flight Failure

\[\text{EU-OPS 1.400 Approach and landing conditions}\]

Before commencing an approach to land, the commander must satisfy himself that, according to the information available to him, the weather at the aerodrome and the condition of the runway intended to be used should not prevent a safe approach, landing or missed approach, having regard to the performance information contained in the Operations Manual.
In the event of an aircraft system failure occurring in flight, and affecting landing performance, the runway length to be considered for landing is the actual landing distance without failure, multiplied by the landing distance coefficient associated to the failure. These coefficients, as well as the ALDs for each runway state, are published in ATR’s operational documentation.

**NOTE:** The required landing distance concept no longer applies and the margins retained for alternate airport selection are at the captain’s discretion.

\[
\text{ALD}_{\text{with failure}} \leq \text{LDA} \quad \text{(EASA)}
\]

Additionally, the FAA regulation recommends that a 15% margin be considered, unless in emergency situation, as assessed by the flight crew.

\[
1.15 \text{ALD}_{\text{with failure}} \leq \text{LDA} \quad \text{(FAA)}
\]

**NOTE:** Refer to Safety Alert for Operators (SAFO 06012) dated 8/31/06 for more information on the FAA landing performance assessment at time of arrival.

### 6.2. Overweight Landing

In exceptional conditions (in-flight turn-back or diversion), an immediate landing at a weight above the Maximum Landing weight is permitted.

The aircraft structural resistance is protected for a landing at Maximum structural Take-off Weight (MTOW), with a rate of descent of -360 feet per minute (please refer to Paragraph B.2.2, *Maximum Structural Take-Off Weight*).

Nevertheless, the minimum required air climb gradients, in the case of a go-around, must be satisfied. This is the case for ATR 42-300 and all ATR 72 series, as the flaps setting for take-off and go-around is the same (flaps 15°). For ATR 42-500 and 42-600, the flaps setting is different for take-off (flaps 15°) and go-around (flaps 25°). This induces an additional limitation at take-off to satisfy the go-around air climb gradient.

**NOTE:** MOD 4450 on ATR 42-500 allows to land in flaps 25° configuration. In this case, take-off and go-around are both performed with flaps 15° and the climb gradients are thus equivalent.

### 7. Landing performance calculation

#### 7.1 FCOM

The Regulatory Landing Weight is the lowest of:
- Maximum structural landing weight
- Runway limiting landing weight
- Climb gradient limiting weight

Let us consider the example of an ATR 72-500, whose destination airport has a LDA of 1500m and a minimum climb gradient of 3.5% to avoid a hill in the vicinity of the airport. The aircraft is dispatched under EASA regulations. The conditions at the destination airport are:
  - Wet runway
  - 5kt headwind
  - Zp=1000 ft
  - OAT=30°C
  - Normal atmospheric conditions
Maximum structural landing weight

### DESIGN WEIGHT LIMITATIONS

<table>
<thead>
<tr>
<th>MAXIMUM WEIGHT</th>
<th>KG</th>
<th>LB</th>
</tr>
</thead>
<tbody>
<tr>
<td>TAXI</td>
<td>22 670</td>
<td>49 978</td>
</tr>
<tr>
<td>TAKE OFF</td>
<td>22 500</td>
<td>49 603</td>
</tr>
<tr>
<td>LANDING</td>
<td>22 350</td>
<td>49 273</td>
</tr>
<tr>
<td>ZERO FUEL</td>
<td>20 300</td>
<td>44 753</td>
</tr>
</tbody>
</table>

[Figure H8: FCOM 2.01.02 p1, Limitations - Weight and loading]

Runway limiting landing weight

The landing weight limited by the runway is obtained when LDA=RLD. Let us calculate the corresponding landing weight.

\[
LDA = RLD_{\text{dry}} = 1.15 RLD_{\text{wet}} = 1.15 \cdot \left( \frac{ALD_{\text{dry}}}{0.7} \right)
\]

\[
ALD_{\text{dry}} = \frac{0.7 \cdot LDA}{1.15} = 913\text{m}
\]

The relation between ALD and the corresponding landing weight given in the FCOM is done in cases of no wind and with the airport Zp=0ft.

The 1st step is to convert the ALD with the above conditions, to ALD with no wind and Zp=0ft conditions.

The corrections to go from ALD no wind & Zp=0ft to ALD are the following:

-2% for 5kt headwind and +3% for 1000ft, i.e. a total of +1%.

### Figure H9: FCOM 3.08.03 p2, Approach landing - Landing distances

In the current case, we want to go from ALD with the actual conditions to ALD determined with no wind & Zp=0ft. To have the ALD in case of no wind and Zp=0ft, 1% must be retrieved.

\[
ALD_{\text{dry_{noWinds2p0ft}}} = ALD_{\text{dry}} - 1\% = 904\text{m}
\]
The corresponding landing weight for $\text{ALD}_{\text{dry/zero wind & 2m/h}}$ longer than 650m is 22.5t.

$$\text{LW}_{\text{runway limited}} = 22500\text{Kg}$$
Climb gradient limiting weight

The limiting weight depending on the OAT, Zp, the approach speed and the required climb gradient is given in the FCOM.

Figure H11: FCOM 3.08.01 p2, Approach landing - Approach climb limiting weight

Under the conditions of this example, the climb gradient limiting weight is 21.7t.

\[ LW_{\text{climb gradient limited}} = 21700 \text{Kg} \]

CONCLUSION:

\[ RLW = \min \{LW_{\text{runway limited}}, LW_{\text{climb gradient limited}}\} \]

The regulatory landing weight is 21700 Kg, limited by the climb gradient.
### 7.2 FOS

The performance calculations can be performed by the FOS software. The resulting airport landing chart is the following:

**CONCLUSION:** For the actual conditions, the Regulatory Landing Weight is 21684 Kg; the limitation code is 3, which corresponds to an **approach climb gradient** limitation.

The FOS computations give a result more accurate than the FCOM.
I. Fuel policy

FCOM 3.10
1. Introduction

Fuel policy regulations are detailed in the EU-OPS and FAR 121. The FAA fuel policy regulation differs depending on the type of flight, whether it is domestic, flag or supplemental. It is important to note that when referring to turbine engine aircraft, the FAA fuel policy regulation, shows a number of specific instructions for turbo-propeller-powered aircraft.

EASA and FAA regulations on flag and supplemental operations are very similar.

**NOTE:** The definitions of domestic, flag and supplemental operations are detailed in FAR 119(3), Definitions. In summary, domestic flights are operated within the United States territory, flag flights have at least a departure or an arrival out of the US territory, and supplemental operations encompass all cargo flights.

2. Fuel planning

The fuel quantity required for a safe trip along the planned route is calculated for each flight. Each operator has its own fuel policy. This policy is based on the loading of minimum regulatory fuel quantities developed in the EU-OPS and FAR 121 regulations.

**NOTE:** The applicable regulations are EU-OPS 1.255 and FAR 121.639 for domestic, 121.641 for flag and 121.643 for supplemental operations.

---

**EU-OPS 1.255 Fuel policy**

(a) An operator must establish a fuel policy for the purpose of flight planning and in-flight re-planning to ensure that every flight carries sufficient fuel for the planned operation and reserves to cover deviations from the planned operation.

2.1. Standard fuel quantity

A standard flight is composed of different phases, for each of which a minimum fuel quantity is required. Additionally, some more fuel is planned to cope with unexpected flight conditions.

**EU-OPS 1.255 Fuel policy**

(b) An operator shall ensure that the planning of flights is at least based upon (...)

2. The operating conditions under which the flight is to be conducted including:

(i) realistic aeroplane fuel consumption data;
(ii) anticipated masses;
(iii) expected meteorological conditions; and
(iv) air navigation services provider(s) procedures and restrictions.

---

![Figure 1: Fuel quantities](image-url)
EU-OPS 1.255 Fuel policy

(c) An operator shall ensure that the pre-flight calculation of usable fuel required for a flight includes:

1. Taxi fuel; and
2. Trip fuel; and
3. Reserve fuel consisting of:
   (i) contingency fuel (see OPS 1.192); and
   (ii) alternate fuel, if a destination alternate aerodrome is required. (This does not preclude selection of the departure aerodrome as the destination alternate aerodrome); and
   (iii) final reserve fuel; and
   (iv) additional fuel, if required by the type of operation (e.g. ETOPS); and
4. extra fuel if required by the commander.

![Diagram showing fuel planning and management](image)

### 2.1.1. Taxi fuel

**EASA**

Appendix 1 to EU-OPS 1.255 Fuel policy

1.1. **Taxi fuel**, which shall not be less than the amount, expected to be used prior to take-off. Local conditions at the departure aerodrome and APU consumption shall be taken into account.

**FAA**

FAA regulation does not clearly state a minimum **taxi fuel** quantity.

The standard **taxi fuel** quantity considered in the FCOM is equal to 14 kg (30 lb), which corresponds to an average 2-minute taxiing. The operator may need to adjust it to fit its own operational requirements at departure airport. The APU is replaced by the ATR Hotel mode function; the fuel used at the ramp in Hotel mode should be added to the taxi fuel quantity.

**Example:** The fuel consumption in hotel mode of the PW127M engine is 110 kg/hr.

**NOTE:** The taxi-in fuel is not considered in the minimum taxi fuel required. Indeed, once landed, the aircraft is assumed to be safe, and the Taxi to the ramp is performed with the remaining fuel.
2.1.2. Trip fuel

EASA

Appendix 1 to EU-OPS 1.255 Fuel policy

1.2. Trip fuel, which shall include:
(a) fuel for take-off and climb from aerodrome elevation to initial cruising level/altitude, taking into account the expected departure routing; and
(b) fuel from top of climb to top of descent, including any step climb/descent; and
(c) fuel from top of descent to the point where the approach is initiated, taking into account the expected arrival procedure; and
(d) fuel for approach and landing at the destination aerodrome.

FAA

The FAA trip fuel quantity required is the same for domestic, flag and supplemental operations.

FAR 121.639 Fuel supply: all domestic operations

No person may dispatch or take off an aeroplane unless it has enough fuel—
(a) To fly to the airport to which it is dispatched.

2.1.3. Contingency fuel

EASA

A fuel contingency quantity is required by the EASA regulation to cope with unexpected deviations with the trip fuel planned.

Appendix 1 to EU-OPS 1.255 Fuel policy

1.3. Contingency fuel, (…) shall be the higher of a. or b. below:
(a) Either:
   (i) 5 % of the planned trip fuel (…); or
   (ii) Not less than 3 % of the planned trip fuel (…), provided that an en-route alternate aerodrome is available (…); or
   (iii) An amount of fuel sufficient for 20 minutes flying time based upon the planned trip fuel consumption provided that the operator has established a fuel consumption monitoring programme for individual aeroplanes (…); or
   (iv) An amount of fuel based on a statistical method approved by the Authority which ensures an appropriate statistical coverage of the deviation from the planned to the actual trip fuel. (…)
(b) An amount to fly for five minutes at holding speed at 1 500 ft (450 m), above the destination aerodrome in standard conditions.

FAA

FAA regulation does not require any contingency fuel for turbo-propeller aircraft.

2.1.4. Alternate fuel

EASA

Appendix 1 to EU-OPS 1.255 Fuel policy

1.4. Alternate fuel which shall:
(a) include:
   (i) fuel for a missed approach from the applicable MDA/DH at the destination aerodrome to missed approach altitude, taking into account the complete missed approach procedure; and
(ii) fuel for climb from missed approach altitude to cruising level/altitude, taking into account the expected departure routing; and
(iii) fuel for cruise from top of climb to top of descent, taking into account the expected routing; and
(iv) fuel for descent from top of descent to the point where the approach is initiated, taking into account the expected arrival procedure;
(v) fuel for executing an approach and landing at the destination alternate aerodrome selected in accordance with OPS 1.295.

(b) where two destination alternate aerodromes are required in accordance with OPS 1.295(d), be sufficient to proceed to the alternate aerodrome which requires the greater amount of alternate fuel.

**FAA**

The FAA alternate fuel quantity required is the same for domestic, flag and supplemental operations:

```
FAA 121.639 Fuel supply: All domestic operations
No person may dispatch or take off an aeroplane unless it has enough fuel—
(b) Thereafter, to fly to and land at the most distant alternate airport (where required) for the airport to which dispatched.
```

**NOTE:** In some specific cases, no alternate airport is necessary; please refer to Paragraph I.2.2.1, Additional fuel when no alternate airport. In this case, a higher amount of additional fuel may be required.

### 2.1.5. Final reserve fuel

**EASA**

Appendix 1 to EU-OPS 1.255 Fuel policy

1.5. Final reserve fuel, which shall be: (…)

(b) for aeroplanes with turbine engines, fuel to fly for 30 minutes at holding speed at 1 500 ft (450 m) above aerodrome elevation in standard conditions, calculated with the estimated mass on arrival at the destination alternate aerodrome or the destination aerodrome, when no destination alternate aerodrome is required.

```
Final reserve fuel = 30 min holding at 1500 ft above alternate
```

(1) or destination if no alternate is required. Please refer to Paragraph I.2.2.1, Additional fuel when no alternate airport, to know the appropriate conditions for to dispatch when no alternate airport.

**FAA**

The FAA final fuel reserve quantity required is different for domestic and for flag operations. For supplemental operations, the final reserve fuel is equal to the domestic or to the flag quantity, depending on the type of flight.

```
FAA 121.639 Fuel supply: All domestic operations
No person may dispatch or take off an aeroplane unless it has enough fuel—
(c) Thereafter, to fly for 45 minutes at normal cruising fuel consumption or, (…) to fly for 30 minutes at normal cruising fuel consumption for day VFR operations.
```

```
Final reserve fuel = 45 min cruising
```

(FAA domestic)

```
FAA 121.641 Fuel supply: Nonturbine and turbo-propeller-powered aeroplanes: Flag operations
(a) No person may dispatch or take off a nonturbine or turbo-propeller-powered aeroplane unless, considering the wind and other weather conditions expected, it has enough fuel—
(3) Thereafter, to fly for 30 minutes plus 15 percent of the total time required to fly at normal cruising fuel consumption to the [destination and alternate] (…) or to fly for 90 minutes at normal cruising fuel consumption, whichever is less.
```

```
Final reserve fuel = min \{ 30 min cruising + 15% total trip time \hspace{1cm} \text{(FAA flag)}
```

90 min cruising
2.1.6. Additional fuel

**EASA**

An additional fuel quantity is required by the EASA regulation in two cases:

- when there is no alternate airport (please refer to Paragraph I.2.2.1, Additional fuel when no alternate airport.)
- when the amount of trip fuel and final reserve fuel is not enough to cope with unexpected en-route engine failure or loss of pressurisation.

---

**Appendix 1 to EU-OPS 1.255 Fuel policy**

1.6. The minimum additional fuel, which shall permit:

(a) the aeroplane to descend as necessary and proceed to an adequate alternate aerodrome in the event of engine failure or loss of pressurisation, whichever requires the greater amount of fuel based on the assumption that such a failure occurs at the most critical point along the route, and

(i) hold there for 15 minutes at 1 500 ft (450 m) above aerodrome elevation in standard conditions; and

(ii) make an approach and landing, except that additional fuel is only required, if the minimum amount of fuel calculated in accordance with subparagraphs 1.2. to 1.5. above is not sufficient for such an event, and

(b) Holding for 15 minutes at 1 500 ft (450 m) above destination aerodrome elevation in standard conditions, when a flight is operated without a destination alternate aerodrome.

<table>
<thead>
<tr>
<th>additional fuel (when no alternate) = 15 min holding at 1500ft above destination</th>
<th>(EASA)</th>
</tr>
</thead>
</table>

**FAA**

The FAA additional fuel is not required for domestic operations. It is the same for flag and supplemental operations, and only required in case there is no alternate airport (please refer to Paragraph I.2.2.1, Additional fuel when no alternate airport.)

---

**FAR 121.641 Fuel supply: Nonturbine and turbo-propeller-powered aeroplanes: Flag operations**

(b) No person may dispatch a (...) turbo-propeller-powered aeroplane to an airport for which an alternate is not specified, unless it has enough fuel, considering wind and forecast weather conditions, to fly to that airport and thereafter to fly for three hours at normal cruising fuel consumption.

<table>
<thead>
<tr>
<th>additional fuel (when no alternate) = 3 hrs cruise</th>
<th>(FAA)</th>
</tr>
</thead>
</table>

2.1.7. Extra fuel

**EASA**

<table>
<thead>
<tr>
<th>Appendix 1 to EU-OPS 1.255 Fuel policy</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.7. Extra fuel, which shall be at the discretion of the commander.</td>
</tr>
</tbody>
</table>

**FAA**

The FAA regulation does not clearly mention the extra fuel quantity.

---

2.2. Specific fuel quantity

2.2.1 Additional fuel when no alternate airport

**EASA**

The alternate airport at destination is not required by EASA regulations under the following circumstances:

---

**OPS 1.295 Selection of aerodromes**

(c) An operator must select at least one destination alternate for each IFR flight unless:

1. both:

   (i) the duration of the planned flight from take-off to landing (...) does not exceed six hours, and
(ii) two separate runways are available and usable at the destination aerodrome and the appropriate weather reports or forecasts for the destination aerodrome, (…) indicate that for the period from one hour before until one hour after the expected time of arrival at the destination aerodrome, the ceiling will be at least 2 000 ft or circling height + 500 ft, whichever is greater, and the visibility will be at least 5 km;

or

2. the destination aerodrome is isolated.

OPS 1.192 Terminology

(f) Isolated aerodrome. If acceptable to the Authority, the destination aerodrome can be considered as an isolated aerodrome, if the fuel required (diversion plus final) to the nearest adequate destination alternate aerodrome is more than: (…) For aeroplanes with turbine engines, fuel to fly for two hours at normal cruise consumption above the destination aerodrome, including final reserve fuel.

additional (when isolated destination airport) = 2 hrs (including final reserve for holding) (EASA)

FAA

The alternate airport at destination is not required by FAA regulations under the following circumstances which are different for domestic and flag operations. An alternate airport is required for supplemental operations.

FAR 121.619 Alternate airport for destination: IFR or over-the-top: Domestic operations

(a) No person may dispatch an aeroplane under IFR (…) unless he lists at least one alternate airport (…). When the weather conditions forecast for the destination and first alternate airport are marginal at least one additional alternate must be designated.

However, no alternate airport is required if for at least 1 hour before and 1 hour after the estimated time of arrival at the destination airport the appropriate weather reports or forecasts, (…) indicate—

1. The ceiling will be at least 2,000 feet above the airport elevation; and
2. Visibility will be at least 3 miles.

FAR 121.621 Alternate airport for destination: Flag operations

(a) No person may dispatch an aeroplane under IFR (…) unless he lists at least one alternate airport (…), unless—

1. The flight is scheduled for not more than 6 hours and, for at least 1 hour before and 1 hour after the estimated time of arrival at the destination airport, the appropriate weather reports or forecasts (…) indicate the ceiling will be:
   i. At least 1,500 feet above the lowest circling MDA, if a circling approach is required and authorized for that airport; or
   ii. At least 1,500 feet above the lowest published instrument approach minimum or 2,000 feet above the airport elevation, whichever is greater; and
   iii. The visibility at that airport will be at least 3 miles, or 2 miles more than the lowest applicable visibility minimums, whichever is greater, for the instrument approach procedures to be used at the destination airport; or

NOTE: For flag and supplemental operations, if the route is approved without available alternate and if the aircraft carries the minimum additional fuel required, no alternate is needed.

2.2.2 Reduced contingency fuel

EASA

With EASA regulation, there are three ways of reducing the contingency fuel quantity:

– By selecting an En-Route Alternate aerodrome, as defined in Appendix 2 to EU-OPS 1.255.
– By implementing a Reduced Contingency Fuel procedure, as defined in Appendix 1 to EU-OPS 1.255 (2).
– By implementing a Pre-determinated point procedure, as defined in Appendix 1 to EU-OPS 1.255 (3).

FAA

With FAA regulations, there is only one way of reducing the contingency fuel quantity, by implementing a redispatch procedure, as defined in FAR 121.631.

2.2.3. ETOPS route

For ETOPS flight, the standard fuel quantity required is different: it is compulsory to consider the event of a loss of pressurisation at the most critical point of the route.

Please refer to EU-OPS 1.255 or FAR 121.646 regulations for details.
3. Fuel management

EASA
The flight crew has to monitor the fuel consumption during the flight and make sure that the fuel burnt for the flight is not more than the planned trip and contingency quantities.
At the destination airport, the fuel reserves must be at least the final reserves and the alternate fuel, in the event there is an alternate airport.
An emergency must be declared when the actual fuel on board is less than the final fuel reserves.

EU-OPS 1.375 In-flight fuel management
An operator shall establish a procedure to ensure that in-flight fuel checks and fuel management are carried out according to the following criteria:
(a) in-flight fuel checks. (…)
(b) in-flight fuel management.
1. the flight must be conducted so that the expected usable fuel remaining on arrival at the destination aerodrome is not less than:
   (i) the required alternate fuel plus final reserve fuel, or
   (ii) the final reserve fuel if no alternate aerodrome is required; (…)
3. the commander shall declare an emergency when calculated usable fuel on landing, at the nearest adequate aerodrome where a safe landing can be performed, is less than final reserve fuel.

FAA
FAA regulations do not provide fuel management rules but the operating manual has to address appropriate procedures.

4. Determination of standard fuel quantity
Let us assess the standard take-off fuel required for a flight operated with a 42-500, under EASA regulations. Conditions are as follows:
– trip leg: 300Nm, FL200, 30kts tailwind
– alternate leg: 50Nm, FL100, no wind
– ZFW: 16000Kg
– ISA +10
Take-off fuel is the sum of taxi fuel, trip fuel, contingency fuel alternate fuel and final reserve fuel. In the FCOM, the taxi, the trip and a 5% contingency fuel quantities are grouped under “fuel to destination”. The quantities to determine are thus:
– fuel to destination
– fuel to alternate
– final reserve, or holding fuel

Approximation of the TOW
The 1st step is to have an approximation of the TOW which is a required input for the calculation: an approximation of the fuel necessary for the flight must be done. For that, we consider the following approximate fuel consumptions.
I. Fuel planning and management

<table>
<thead>
<tr>
<th>Flight phase</th>
<th>approximate fuel consumption (Kg / hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cruise</td>
<td></td>
</tr>
<tr>
<td>1st hour</td>
<td>600</td>
</tr>
<tr>
<td>Following hour</td>
<td>500</td>
</tr>
<tr>
<td>holding</td>
<td>400</td>
</tr>
<tr>
<td>Other aircraft</td>
<td></td>
</tr>
<tr>
<td>Cruise</td>
<td>700</td>
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<tr>
<td>Cruise</td>
<td>600</td>
</tr>
<tr>
<td>Cruise</td>
<td>500</td>
</tr>
</tbody>
</table>

Table I1: ATR approximate hourly fuel consumption

- Fuel to destination approximation:
  \[ \text{TAS is assumed equal to 250 kts, GS = 280 kts.} \]
  \[ \text{Time to destination} = \frac{300}{280} \approx 1h \]
  Fuel to destination = 700 Kg

- Fuel to alternate approximation:
  \[ \text{TAS} = 250 \text{ kts} \]
  \[ \text{Time to alternate} = \frac{50}{250} \approx 0.2h \]
  Fuel to alternate = 0.2 \cdot 600 = 120 Kg

- Final reserve fuel approximation:
  \[ \text{Time for holding: 30 min} \]
  \[ \text{Fuel for holding} = \frac{500}{2} = 250 \text{ Kg} \]

\[ \text{TOW=ZFW+TOF} \]
\[ \text{The approximate TOW is thus } 16000 + (700 + 120 + 250) \approx 17100 \text{ Kg.} \]

**Fuel to destination**

The fuel to destination reads **810 Kg**. This value is valid for a 17500 Kg as a reference TOW, and in ISA conditions.
Corrections:
- Weight: TOW = 17100 Kg which is considered very close to the reference TOW and the difference is thus negligible.
- ISA: we are in ISA +10 conditions; the correction is thus, \(-13 \text{ Kg} \cdot \frac{300 \text{ Nm}}{100 \text{ Nm}} = -39 \text{ Kg}\)

\[
\text{Fuel to destination} = 810 - 39 = 771 \text{ Kg}
\]

**Fuel to alternate**

The fuel to alternate reads **225 Kg**. This value is valid for a 16000Kg as a reference LW, and in ISA conditions.

Corrections:
- Weight: LW=TOW-fuel to destination \(\approx 17100 - 770 = 16330 \text{ Kg}\)
  which is considered very close to the reference LW and the difference is thus negligible.
- ISA: no correction

\[
\text{Fuel to alternate} = 225 \text{ Kg}
\]
The aircraft weight above the alternate airport is LW – fuel to alternate=16330 – 225 = 16000 Kg.

The fuel for holding is 248 Kg/hr/eng. For 30 minutes holding with both engines, the total fuel consumption is thus 248 kg.

**Fuel for holding = 248 Kg**

**CONCLUSION:**

The standard take-off fuel required for this flight is:

\[
\text{Take-off fuel = Fuel to destination + fuel to alternate + fuel for holding} = 771+225+248=1244 \text{ Kg}
\]

And the take-off weight is:

\[
\text{TOW = ZFW + TOF} = 16000 + 1244 = 17244 \text{ Kg}
\]
J. Weight & Balance

FCOM 2.06
Determining the weight & balance of an aircraft before each flight is an important step in the flight preparation. It ensures that the aircraft is operated within the weight & balance operational envelope, i.e. ensuring structure integrity and aircraft maneuverability and stability.

1. Weight

The limiting structural weights are defined in Paragraph B.2, Limiting structural weights.

1.1. Definitions

Some of the following weights are defined in the EU-OPS 1.607, Terminology, and in the AC 120-27 (appendix 1), Aircraft weight and balance control.

- **Manufacturer’s Empty Weight (MEW):** The weight of the structure, power plant, furnishings, systems and other items of equipment that are considered an integral part of the aircraft. It is essentially a “dry” weight, including only those fluids contained in closed systems (e.g. hydraulic fluid).
- **Operational Empty Weight (OEW):** The manufacturer’s weight empty plus the operator’s items, i.e. the flight and cabin crew and their baggage, unusable fuel, engine oil, emergency equipment, toilet chemicals and fluids, galley structure, catering equipment, seats, documents...
- **Dry Operating Weight (DOW):** The total weight of an aircraft ready for a specific type of operation excluding all usable fuel and traffic load. Operational Empty Weight plus items specific to the type of flight, i.e. catering, newspapers, pantry equipment...
- **Zero Fuel Weight (ZFW):** The weight obtained by addition of the total traffic load (payload including cargo loads, passengers and passenger’s bags) and the dry operating weight.
- **Payload (P/L):** sum of passengers, cargo and baggage weights.
- **Take-Off Weight (TOW):** The weight at takeoff at the departure airport. It is equal to the zero fuel weight plus the takeoff fuel (fuel needed at the brake release point including reserves).
- **Landing Weight (LW):** The weight at landing at the destination airport. It is equal to the Zero Fuel Weight plus the fuel reserves or the Take-Off Weight minus the trip fuel.

\[
\text{TOW} = \text{DOW} + \text{traffic load} + \text{fuel reserves} + \text{trip fuel} \\
\text{LW} = \text{DOW} + \text{traffic load} + \text{fuel reserves} \\
\text{ZFW} = \text{DOW} + \text{traffic load}
\]

**Figure J1:** Aircraft weights
1.2. Payload

The payload is the load of the aircraft that is profitable. Carrying more payload is more profitable, but it must always remain contained within the limits, and never exceed the maximum allowable for a given flight.

1.2.1. Payload range

The maximum payload that can be carried for a flight depends on the length of the flight. Indeed, for short-haul flight, the highest payload can be carried. As the flight lengthens, more fuel must be loaded, so the loadable payload is lower, to comply with MTOW limitations or maxi fuel tanks capacities.

![Figure J2: ATR 72-600 & ATR 72-500 payload range](image)

1.2.2. Maximum allowable payload

For a specific flight, particular limitations (take-off, landing, en-route) can reduce the loadable payload. Eventually the maximum allowable payload must comply with the following limitations:

\[
\text{max allowable P/L} = \min \{ \text{P/L}_{\text{structural}}, \text{P/L}_{\text{take-off}}, \text{P/L}_{\text{en-route}}, \text{P/L}_{\text{landing}} \}
\]

- **Structural limitation (please refer to Chapter B, Aircraft limitations)**

  \[
  \text{P/L}_{\text{structural}} \leq \text{MZFW} - \text{DOW}
  \]

  This is the maximum payload that can be carried for an aircraft. This is a structural limitation and is fixed for one aircraft (provided the DOW is the same for every flight).

- **Take-off weight limitation (please refer to Chapter C, Take-Off)**

  \[
  \text{P/L}_{\text{take-off}} \leq \text{RTOW} - (\text{TOF} + \text{DOW})
  \]

  This payload limitation includes the MTOW, and maxi fuel tanks payload limitations seen in Paragraph J.1.2.1, Payload range.

- **En-route limitation (please refer to Chapter F, En-route limitations)**

  \[
  \text{P/L}_{\text{en-route}} \leq \text{En-Route weight limitation} - \text{fuel to go} - (\text{TOF} + \text{DOW})
  \]
Landing limitation (please refer to Chapter H, Landing)

\[ P/L_{\text{landing}} \leq RLW - TF - (TOF + DOW) \]

2. Balance

Assessing and controlling the balance of the aircraft is of great importance to ensure the aircraft maneuverability and stability during the entire flight. The balance of the aircraft is expressed through the localisation of its Center of Gravity.

2.1. Definitions

2.1.1. Mean Aerodynamic Chord

The Mean Aerodynamic Chord (MAC) is the average width of the wing; it is a reference line used in the design of the wing.

**Example:** For ATR 42, the MAC is 2.285 m (89.960 in).

2.1.2. Center of gravity

The Center of Gravity, CG, is the point where the weight of the aircraft is applied. The CG position is commonly expressed:

- by its distance from the reference line ahead the nose of the aircraft. This distance is called Horizontal arm (H-arm).
- by its location on the Mean Aerodynamic Chord in percentage (%MAC).

**Example:** On ATR 42, CG located 11.937 m from ahead reference line means the same as located 22.41% MAC.

2.1.3. Moment

When a force is applied to an object, the resulting motion of the object depends on where the force is applied and how the object is confined.

If the object on which the force is applied is located at some distance from the center of gravity of the aircraft, it induces a rotation around the center of gravity. The details of the rotation, also called moment, depend on the intensity of the force, and the distance from the object to the center of gravity.

\[ \text{Moment} = \text{Force} \cdot \text{Distance} \]
**2.2. Stability**

The static stability of an object depends on its tendency to return to its initial position after being slightly moved. The aircraft CG position has an influence on the aircraft static longitudinal stability in steady flight and during maneuvers.

On an aircraft, there are two forces that mainly act on the longitudinal stability: the weight applied on the Center of Gravity and the lift applied on the Aerodynamic center. (please refer to Paragraph A.4, Flight Mechanics)

The Aerodynamic center remains nearly constant with angle of attack, and is approximately located at ¼ of the MAC on most low speed airfoils. On an aircraft, there are two lifting surfaces where the lift applies: the wing and the elevator. The global lift is applied on a point located between those two surfaces.

The Center of Gravity depends on the loading of the aircraft. Its position is generally contained on the main wing.

**Forward balanced aircraft: CG forward Aerodynamic Center**

When the aircraft is submitted to a gust, it is equivalent to an increase in angle of attack or to the creation of a pitch up moment. A lift increase is created at the aerodynamic center. If the CG is located forward of the aerodynamic center, the increase in lift creates a pitch down moment which reduces the incidence and brings the aircraft back to its initial conditions.

The aircraft is stable.
Aft balanced aircraft: CG aft Aerodynamic center

If the CG is located aft to the aerodynamic center, the increase in lift creates a pitch up moment which adds to the initial pitch up moment due to the gust. This brings the aircraft further away from its initial conditions.

The aircraft is unstable.

3. Certification envelope

The manufacturer certifies the weight and CG envelopes of the aircraft. The envelopes are available in the Weight and Balance Manual (WBM), part 1.70, Load and CG control.
3.1. Take-off and landing limit

The take-off and landing limit is demonstrated during the certification of the aircraft and complies with CS/ FAR 25 regulations.

CS / FAR 25.143 General

(a) The aeroplane must be safely controllable and manoeuvrable during
   (1) Take-off;
   (2) Climb;
   (3) Level flight;
   (4) Descent; and
   (5) Landing (…)

The forward limit is designed by the nose gear strength, the take-off rotation, the manoeuvrability in flight and the flaps extension. The aft limit is designed by the main gear strength, the take-off rotation (tail strike), the stability in flight and the go-around.

Remaining within the limits thus ensures structural integrity and good handling qualities.

3.2. Operational limit

The operational limit is the one used for the aircraft operations, and complies with the air operation regulation. This envelope is more restrictive than the take-off and landing envelope, to consider operational safety margins (e.g. weights and positions imprecision, in-flight crew movements …).

NOTE: This envelope should be designed by the airlines, ATR however suggests one.

Appendix 1 to OPS 1.605 Mass and Balance — General

(d) Centre of gravity limits

1. Operational CG envelope. (...) operational margins must be applied to the certificated centre of gravity envelope. In determining the CG margins, possible deviations from the assumed load distribution must be considered. (...) The CG margins and associated operational procedures, including assumptions with regard to passenger seating, must be acceptable to the Authority.

4. Load and Trim Sheet filling

The load and trim sheet is a graphical tool enabling to easily calculate the aircraft Center of Gravity position. It must be filled before each flight to ensure that the weight and center of gravity will remain within its certified limits throughout all the different flight phases.

Besides, another output of the load and trim sheet is the determination of the take-off CG, and the corresponding trim to set.

4.1. Index

To easily assess the influence of each object weight of the aircraft on the global balance, an index parameter is used; it represents the weight and the location of each object. It is a value with no unit.

The index is equivalent to the moment parameter (please refer to Paragraph J.2.1.3, Moment), because it combines both the weight and the position of the object but it is easier to manipulate.

On ATR, the index is 0 when located at 25% MAC. The index is negative, when located forward 25% MAC and positive when aft.
4.2. Example

An example of a load and trim sheet filling is done. Assumptions are as follows:

- ATR 42-300, DOW = 10750 Kg, CG: 18.1% MAC
- Loading:
  - Passengers: 10 men, 20 women, 2 children /
    - zone A: 4 pax, zone B: 16 pax, zone C: 12 pax
  - Cargo: 610 kg FWD, 330 kg AFT
  - 90Kg in the cockpit
  - This additional weight used by the pilots is part of the DOW. It is included to the weight deviation box, and to the basic index correction box.
- Take-Off fuel: 1500 Kg, Trip fuel: 500 Kg

The objective is to check that take-off & landing weights & balances are contained within the operational envelope. The 2nd objective is to determine the trim at take-off.

Dry Operating Weight and Index

\[
D = (C\% - 25) \times W(\text{kg}) \times 0.2285 \\
I = \frac{1000}{1000}
\]

\[
\text{DOW WT INDEX} = -16.9
\]

Actual Take-Off and Landing Weights

The 1st step is to calculate the passengers and cargo load. Take-off and Landing weights are then determined.
Dry Operating Weight and Index deviation

The loading of each zone and cargo area of the aircraft have an impact on the balance of the aircraft, expressed with the variation of the index parameter. The resulting indexes with for ZFW, Take-Off Weight (1500 Kg fuel loaded) and the Landing weight (1000 Kg fuel remaining) are determined.

Operational envelope

Once the index is determined, the line is extended to the operational envelope and crossed with the TOW line. The resulting take-off point is checked to be within the operational envelope.

The same operation must be done with the Zero Fuel and the Landing point and checked within the envelope.
**Take-Off trim**

The Take-Off CG is located 28.1% MAC. The corresponding trim setting is 0.6 down.
Appendices
Appendix 1. Altimetry - Temperature effect

Let us consider the case of Switzerland's Sion airport. During ILS approach on Runway 25, it is required to overfly given waypoints at given geometrical altitudes, whatever the temperature conditions. For example, at outer marker, D16 ISI, the aircraft must be at a true altitude of 9900 ft above Mean Sea Level, equivalent to a height of 8319 ft above the runway threshold. The transition level is FL 170 unless ATC states differently, and the transition altitude is 16,000 ft. The description of the instrument approach provides the indicated altitude values to maintain the required true altitude for different temperature conditions.

<table>
<thead>
<tr>
<th></th>
<th>ISA+10</th>
<th>ISA-10</th>
</tr>
</thead>
<tbody>
<tr>
<td>True Altitude</td>
<td>9900 ft</td>
<td>9900 ft</td>
</tr>
<tr>
<td>Indicated Altitude</td>
<td>9570 ft</td>
<td>10250 ft</td>
</tr>
<tr>
<td>Difference in altitude</td>
<td>-330 ft</td>
<td>+350 ft</td>
</tr>
</tbody>
</table>

Indicated Altitude versus True Altitude depending on ISA conditions.

When the temperature is lower than the ISA conditions, you fly lower than the Indicated Altitude.
SION airport Jeppesen approach chart
Appendix 2. Take-off optimisation principle

This section is specifically designed for a more in-depth explanation of the take-off optimisation principle. The optimisation objective is to obtain the highest possible performance-limited take-off weight, while fulfilling all airworthiness requirements.

For that purpose, it is necessary to determine what parameters influence take-off performance and offer a freedom of choice.

For instance, temperature is a parameter which influences take-off performance, but which cannot be chosen. This is a **sustained parameter**. Air conditioning is a parameter which influences the take-off performance and can be selected. This is a **free parameter**.

### Parameters impacting on take-off performance

- **Sustained parameters**
  - Length, clearway, stopway, elevation, slope, obstacles
  - Temperature, pressure, wind, runway condition

- **Free parameters**
  - Status (CDL, MMEL)
  - Air conditioning, take-off speeds ($V_1$, $V_2$)
  - Engine power (full RTO, boost)

### 1. Air Conditioning

Air conditioning, when switched on during take-off, decreases the available power and thus degrades the take-off performance. It is then advisable to switch it off during take-off, but this is not always possible as some constraints exist (high air temperature in the cabin or/and company policy).

### 2. Take-off Speeds

Take-off speeds represent the most important source of optimisation and TOW gain.

#### 2.1. Decision speed $V_1$

**2.1.1. $V_1/V_R$ Range**

The decision speed $V_1$ must not be higher than the rotation speed $V_R$. As $V_R$ depends on weight, the maximum $V_1$ value is not fixed, whereas the **maximum $V_1/V_R$ ratio is equal to one** (regulatory value).

Besides, it has been demonstrated that a $V_1$ speed less than 84% $V_R$ induces too long take-off distances and does not, therefore, present any take-off performance advantages. Consequently, the **minimum $V_1/V_R$ ratio is equal to 0.84** (manufacturer value).
The $V_1/V_R$ ratio parameter is used in the optimisation process, and varies:

$$0.84 \leq V_1/V_R \leq 1$$

**NOTE:** Any $V_1/V_R$ increase (resp. decrease) should be considered to have the same effect on take-off performance as a $V_1$ increase (resp. decrease).

### 2.1.2 $V_1/V_R$ Ratio Influence
To study the influence of $V_1/V_R$ ratio variations on take-off performance, all the other parameters listed in introduction are fixed, including the $V_2/V_S$ ratio. The effects on the runway, the climb and obstacles and the brake energy limitations are assessed in the following.

#### Runway Limitations
As seen in the take-off section of this brochure, any $V_1/V_R$ increase:
- increases the TOW limited by $TOD_{n-1}$, $TOR_{n-1}$, $ASD_{n-1}$ (or $n-1$)
- does not influence the TOW limited by $TOD_n$, $TOR_n$

![Influence of $V_1/V_R$ on runway limited TOW](image)

#### Climb and Obstacle Limitations
The $V_1$ speed (decision speed on ground) has no influence on climb gradients (first, second and final take-off segments). On the contrary, the obstacle-limited weight is improved with a higher $V_1$, as the take-off distance is reduced. Therefore, the start of the take-off flight path is obtained at a shorter distance, requiring a lower gradient to clear the obstacles.

![Influence of $V_1/V_R$ on climb and obstacle limited TOW](image)
Any $V_1/V_a$ increase:
- Increases the TOW limited by the obstacles
- Does not influence the TOW limited by the first segment, second segment, final take-off segment

**Brake Energy and Tyre Speed Limitations**

A maximum $V_1$ speed, limited by brake energy ($V_{MBE}$), exists for each TOW. To achieve a higher $V_1$ speed, it is necessary to reduce TOW.

On the contrary, the decision speed does not influence the tyre speed limit.

---

![Graph showing the influence of $V_1/V_a$ on brake energy and tyre speed limited TOW](image)

Any $V_1/V_a$ increase:
- Decreases the TOW limited by the brake energy
- Does not influence the TOW limited by the tyre speed

**Optimised $V_1$**

The following shows that the highest maximum take-off weight can be achieved at a given optimum $V_1/V_a$ ratio. This optimum point corresponds to the intersection between two limitation curves.

![Graph showing the determination of the optimum $V_1/V_a$ ratio](image)

The result of this optimisation process is, for a given $V_1/V_a$ ratio, an optimum RTOW and an associated optimum $V_1/V_a$ ratio.
2.2. Take-off climb speed $V_2$

2.2.1. $V_2/V_s$ Range

The minimum $V_2$ speed is defined by regulations, and limited by the stall speed ($V_s$) and the minimum control speed in the air ($V_{MCAS}$). The stall speed depends on the weight and the minimum $V_2/V_s$ ratio is known for a given aircraft type. The minimum control speed in the air depends on the atmospheric conditions (OAT and Pressure Altitude), and is generally limiting when the aircraft is light.

Above $(V_2/V_s)_{opt}$ where the maximum gradient is reached, there is no interest of increasing $V_2$ because the take-off distances are increased and the climb gradient decreased.

Example: For ATR 72-500, $V_{2opt} = 1.35 V_s$.

The $V_2/V_s$ ratio parameter is used in the optimisation process, and varies:

$$(V_2/V_s)_{min} \leq V_2/V_s \leq (V_2/V_s)_{opt}$$

@1 1.2 for ATR 42-300

2.2.2. $V_2/V_s$ Ratio Influence

To study the influence of $V_2/V_s$ ratio on take-off performance, all the other parameter listed in introduction are fixed. The effects on the runway, the climb and obstacles limitations are assessed in the following:

Runway Limitations

As a general rule, for a given $V_1/V_s$ ratio, any increase in the $V_2/V_s$ ratio leads to an increase in the one-engine out and the all-engine take-off distances. Indeed, it is necessary to acquire more energy on the runway, in order to achieve a higher $V_2$ speed at 35 ft. As a result, the acceleration phase is longer.

On the contrary, $V_2$ speed has no direct impact on the ASD. But a higher $V_2$ speed results in a higher $V_s$ speed and, therefore, for a given $V_1/V_s$ ratio, in a higher $V_1$ speed. Hence, the effect on ASD.
Influence of $V_2/VS$ on runway limited TOW

Any $V_2/VS$ increase:
- decreases the TOW limited by $TOD_{h-1}$ and $TOD_{h}$, $TOR_{h-1}$ and $TOR_{h}$, $ASD_{h-1}$ and $ASD_{h}

Climb and Obstacle Limitations

Any $V_2/VS$ increase until $(V_2/VS)_{opt}$ results in better climb gradients ($1^{st}$ and $2^{nd}$ segment) and, therefore, in better climb limited TOWs ($1^{st}$ segment, $2^{nd}$ segment, obstacle).

On the other hand, as the final take-off segment is flown at the climb speed, it is not influenced by $V_2$ speed variations.

Influence of $V_2/VS$ on climb and obstacle limited TOW

Any $V_2/VS$ increase:
- increases the TOW limited by the first segment, second segment, obstacles
- does not influence the TOW limited by the Final take-off segment

Brake Energy and Tyre Speed Limitation

$V_2$ speed does not directly impact brake energy limitation. Nevertheless, any $V_2$ increase results in a $V_1$ increase and, therefore, in a $V_2/V_1$ ratio. Hence, the effect on brake energy limited weight. The lift-off speed, $V_{LOF}$, is limited by the tyre speed ($V_{TYRE}$). As a result, $V_2$ is limited to a maximum value. Any $V_2/VS$ increase is then equivalent to a $V_2$ reduction, since $V_2$ is assumed to be fixed, and thus the tyre speed limited take-off weight is reduced.
2.3. Result of the Speed Optimisation Process

2.3.1. Optimisation of the Take-off Weight

The previous section shows how, for a given $V_2/V_S$ ratio, it is possible to find an optimum $R_{TOW}$ and its associated optimum $V_1/V_R$ ratio. For each $V_2/V_S$ ratio comprised between $(V_2/V_S)_{\text{min}}$ and $(V_2/V_S)_{\text{opt}}$, such a determination is carried out. In the end, the highest of all the optimum $R_{TOW}$s and associated optimum $V_1/V_R$ is retained. It therefore corresponds to an optimum $V_2/V_S$ ratio.

IMPORTANT: The optimisation process indicates that $R_{TOW}$ can only be taken off with a single set of take-off speeds ($V_1$, $V_R$ and $V_2$). The use of different speeds would result in an $R_{TOW}$ reduction.

Once the optimum speed ratios ($V_1/V_R$ and $V_2/V_S$) are obtained, the take-off speeds are obtained as follows:

\[
\begin{align*}
R_{TOW} & \rightarrow V_S \\
V_2/V_S & \rightarrow V_2 \\
V_1/V_R & \rightarrow V_1
\end{align*}
\]

2.3.2. Limitations codes

The nature of the take-off weight limitation is always indicated in the take-off charts ($R_{TOW}$ charts).

<table>
<thead>
<tr>
<th>LIMITATION CODES</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-DRY CHECK</td>
<td>1-STRUCTURE</td>
</tr>
<tr>
<td>1-STRUCTURE</td>
<td>2-2ND-SEGMENT</td>
</tr>
<tr>
<td>2-2ND-SEGMENT</td>
<td>3-RUNWAY</td>
</tr>
<tr>
<td>3-RUNWAY</td>
<td>4-OBSTACLE</td>
</tr>
<tr>
<td>4-OBSTACLE</td>
<td>5-TYRE SPEED</td>
</tr>
<tr>
<td>5-TYRE SPEED</td>
<td>6-BRAKE ENERGY</td>
</tr>
<tr>
<td>6-BRAKE ENERGY</td>
<td>7-RWY 2 ENGINES</td>
</tr>
<tr>
<td>7-RWY 2 ENGINES</td>
<td>8-FINAL T.O.</td>
</tr>
<tr>
<td>8-FINAL T.O.</td>
<td>9-VMC</td>
</tr>
</tbody>
</table>

Take-off charts limitation codes
## Limitation codes

<table>
<thead>
<tr>
<th>Limitation codes</th>
<th>Designation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Dry check</td>
<td>in case of wet/ contaminated runways only, the limitations must not be better than on dry runways.</td>
</tr>
<tr>
<td>1</td>
<td>Structure</td>
<td>Maximum structural Take-Off Weight</td>
</tr>
<tr>
<td>2</td>
<td>2nd segment</td>
<td>regulatory 2.4% air climb gradient</td>
</tr>
<tr>
<td>3</td>
<td>Runway</td>
<td>TORA, TODA, ASDA</td>
</tr>
<tr>
<td>4</td>
<td>Obstacle</td>
<td>obstacle clearance</td>
</tr>
<tr>
<td>5</td>
<td>Tyre speed</td>
<td>( V_{\text{LOF}} &lt; V_{\text{VRE}} )</td>
</tr>
<tr>
<td>6</td>
<td>Brake energy</td>
<td>( V_1 &lt; V_{\text{VNE}} )</td>
</tr>
<tr>
<td>7</td>
<td>Runway 2 engines</td>
<td>take-off length 2 engines</td>
</tr>
<tr>
<td>8</td>
<td>Final TO</td>
<td>regulatory 1.2% air climb gradient</td>
</tr>
<tr>
<td>9</td>
<td>( V_{\text{MC}} )</td>
<td>( V_1 &gt; V_{\text{MCG}} ) or ( V_2 &gt; 1.1 V_{\text{MCA}} )</td>
</tr>
</tbody>
</table>

### Limitation codes description

TOW limited by one limitation

In the following example, the take-off weight is limited only by obstacles. An RTOW chart would therefore indicate Limitation **Code 4-4**.
**TOW limited by two limitations**

Most of the time, RTOW is obtained at the intersection of two limitation curves. This is why the limitation codes are always indicated with two digits in a RTOW chart. In the following example, the take-off weight is limited by obstacles and by the Accelerate Stop Distance (ASD). An RTOW chart would indicate Limitation Code 3-4.

![Double Limitation Case](image)

**TOW limited by three limitations**

In the following example, a $V_1$ range exists. As a result, whatever the selected $V_1$ speed between a minimum $V_1$ and a maximum $V_1$, the RTOW remains the same while the nature of the limitation changes. In this case, the effective take-off $V_1$ speed remains at the operator’s discretion.

![Triple Limitation Case](image)

In the example, the nature of the limitation depends on the $V_1/V_r$ ratio:
- At $V_1/V_{r_{\text{min}}}$ (Point 1): The take-off weight is limited by both the TOD$_{D_{\text{r}}}$ and the 2nd segment (RTOW Code: 2-3).
- Between $V_1/V_{r_{\text{min}}}$ and $V_1/V_{r_{\text{max}}}$: The take-off weight is only limited by the 2nd segment (RTOW Code: 2-2).
- At $V_1/V_{r_{\text{max}}}$ (Point 2): The take-off weight is limited by the 2nd segment and the brake energy (RTOW Code: 2-6).
3. Engine power

If the RTOW resulting from the take-off speed optimisation process is not high enough, the operator can choose to select the full RTO, the boost power or a combination of them at take-off. The full RTO selection will mainly increase the RTOW on limiting runway, and the boost selection in case of high and hot atmospheric conditions. Please refer to Paragraph C.8, Improvement of the take-off weight limitation, for an example of the expected gain.

**NOTE:** Full RTO and boost power selections have a strong impact on the engine life cycle. They must not be systematically chosen, but only in case of specific limiting conditions.
Appendix 3. Flight Operations Software (FOS)

In addition to the FCOM, which contains all the basic performance data, ATR has developed a tool specifically designed to cover all the day-to-day operator needs for aircraft flight preparation.

This in-house software application is to be used on ground by airline engineers and flight dispatchers to compute performance data in a user-friendly way.

FOS is composed of five different modules:
- Module 1: Take-off and Landing Charts
- Module 2: In-Flight Performance
- Module 3: Flight Planning
- Module 4: En-Route Net Flight path
- Module 5: Cruise Performance Monitoring

FOS, which is based on databases and computation cases, covers all airline needs in performance calculations for their daily operations as well as for specific studies.

**FOS key benefits: Safety and Optimisation**

Computations are based on accurate performance data computed by the EADS design office and initially used to build the Aircraft Flight Manual. This data, coming directly from the Manufacturer, ensures a high level of integrity.

FOS provides optimised calculations, leading to maximum economic utilisation. The aircraft is thus operated with an optimal payload whilst maintaining safety conditions.

**Flight Operations Software-Databases**

**Fleet Database**
The Fleet Database Module allows the user to define all the ATR aircraft operated in his own fleet with their applicable specificities.

For each aircraft the user specifies the associated:
- Aircraft registration number
- Type
- Applicable regulation
- Weights...

**Airport Database**
The Airport Database allows the user to create several airport databases, which can be used for take-off and landing performance computation. An airport database contains detailed information on airports, runways and the surroundings.

The user can define the following airport characteristics:
- Runway lengths and elevation
- Slope
- Width
- Approach and climb gradients requirements
- Obstacle location under take-off flight path.

The user also has the possibility to import runways from:
- An existing airport file for FOS DOS version
- A SITA format airport file
- An Airbus PEP for Windows airport database
- Another FOS Windows airport database

**Route Database**
The Route Database Module allows the user to create several route databases, which can be used for Flight planning computation. The user can organise the network through country, city and airport and create the routes by manually entering the waypoints using a graphical tool. Waypoints can also be automatically imported from an existing navigation database (Arinc 424-9 Format).
Flight Operations Software-Modules

Take-off & Landing Charts Module
This module optimises take-off and landing calculations for improved performance and cost effectiveness. It computes maximum permissible take-off and landing weights and associated optimised speeds for all combinations of environmental conditions, airport characteristics and aircraft systems, quickly and precisely, thereby helping to:
- Maximise your payload
- Improve safety
- Reduce costs and saves time.

Take-off chart computation is done for a given QNH, but the user has the possibility to select up to two QNH deviations and compute the corresponding weight and speed corrections for each temperature and wind combination. This FOS Module is also available in SCAP version, at no additional charge.

In-Flight Performance Module
This module computes single and twin-engine performance data for all flight phases (climb, cruise, descent, holding...) except Take-off and Landing.
It has been used to compute the performance tables given in the FCOM and enables performance engineers to perform various performance studies. For instance, the FOS module 2 enables to edit Long-Range cruise performance charts.

Flight Planning Module
This module is a tool to compute navigation logs including accurate fuel calculations for flight conditions selected by the user. The program can optimise the flight level and / or speed according to the criteria chosen by the operator
- Minimum fuel / Long-range cruise
- Minimum time / Max cruise power
- Given IAS cruise.

This Module is proving valuable for aircraft daily operations, providing pilots with accurate information regarding fuel planning and flight management.

En-Route Net Flight Path Module
The En-Route Net Flight Path Module is dedicated to the calculation of regulatory performance in case of an engine failure during the cruise. It is particularly beneficial for airlines operating ATR aircraft on routes flying over mountaineous areas.

Computation results fall in two categories:
- Weight Limitation
  Calculation of the maximum take-off weight, which allows to fly over the obstacles, even in case of an engine failure.
- Decision Point Computation
  In case of an engine failure, the predetermination of decision points will help the pilot to decide whether to return or to continue, depending on obstacles or fuel remaining on board.

Cruise Performance Monitoring Module
The CPM module enables comparison of the aircraft actual cruise performance measured in flight with the theoretical data computed by the FOS. After the CPM analysis, computed deviations for torque, fuel flow and IAS are recorded in both ASCII text and Excel CSV format for post-processing by operators. A graphical output is also available to provide immediate trend curve deviations.

For aircraft fitted with the Multi Purpose Computer (MPC), the parameters are recorded automatically during the stabilised cruise phase and stored in the PCMCIA card of the MPC. The downloading of the Cruise report files in the FOS is then easily achieved by inserting the card in a laptop. For aircraft not equipped with MPC, a manual mode for data entry is available.
Appendix 4. Single-point Performance Software (SPS)

With the introduction of the EFB solution into ATR cockpit, ATR has developed a new tool dedicated to aircraft performance calculation. SPS can be installed on ATR EFB (CMC manufactured PilotView®) as well as on any other Class 1 (laptop) and Class 2 EFB. It can also be used on any standard PC for ground utilisation (operations centers, briefing rooms or despatch offices).

SPS allows to achieve fast and optimised, real-time take-off and landing parameter calculations. SPS offers enhanced outputs compared to FOS (Flight Operation Software). Displayed results, especially speeds, are shown with the fill-in weight and integrate all data required in a take-off or landing card (minimum manoeuvre speeds, approach speed, torque, etc.).

SPS is composed of two different modules:
- Take-off module: allows computing limitations and speeds for take-off.
- Landing module: allows computing limitations and speeds for landing.

A Weight & Balance module will soon be made available in a version that will allow aircraft weights and balance calculations.

An administration module allows the management of both aircraft and airport databases. It also allows the configuration of SPS (ergonomics, units, default values) to match airline-defined criteria.

SPS key benefits: Safety, Optimisation and Time Benefits

Calculations are based on aircraft manufacturer's performance calculators, as per the FOS ones. SPS is an invaluable tool for crew and operational staff. It easily allows the selection of MEL items or en-route failures and calculates the new relevant optimised limitations and parameters. Greater flexibility leads to greater accuracy which means greater payloads, yet with reduced workload for the crew and fewer flight delays due to manual calculations.

SPS User Modules

Take-off module
- Calculate maximum take-off weight.
- Calculate speeds (take-off and manoeuvre speeds) with the fill-in weight.
- Optimise performance calculation for the given conditions.
- Integrate MEL items.
- Integrate airport modification such as runway reductions and new obstacle.

Example: Aside is the same example as in Paragraph C.7.2, FOS.

Like the FOS performance chart, the SPS output displays the RTOW (=18404Kg) but the speeds are linked to the Actual TOW. Additionally the climb speed VmLB0° is displayed.
Landing module

- Calculate maximum landing weight.
- Calculate speeds (landing and maneuver speeds) with the fill-in weight.
- Optimize performance calculation for the given conditions.
- Integrate MEL items.
- Integrate En-Route Failures.
- Integrate airport modification such as runway reductions.

**Example:** Aside is the same example as in Paragraph H.7.2, FOS.

Like the FOS performance chart, the SPS output displays the RLW (21883Kg) but the approach and go-around speeds are linked to the Actual LW.
## Appendix 5. Abbreviations

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \alpha )</td>
<td>Angle of Attack</td>
</tr>
<tr>
<td>( \gamma )</td>
<td>Flight Path Angle</td>
</tr>
<tr>
<td>( \Delta )</td>
<td>Parameters variation (ex: ( \Delta \text{ISA}, \Delta P ))</td>
</tr>
<tr>
<td>( \phi )</td>
<td>Bank angle</td>
</tr>
<tr>
<td>( \mu )</td>
<td>Runway friction coefficient</td>
</tr>
<tr>
<td>( \theta )</td>
<td>Aircraft attitude</td>
</tr>
<tr>
<td>( \rho )</td>
<td>Air density</td>
</tr>
<tr>
<td>( a )</td>
<td>Sound velocity</td>
</tr>
<tr>
<td>AFM</td>
<td>Aircraft Flight Manual</td>
</tr>
<tr>
<td>ALD</td>
<td>Actual Landing Distance</td>
</tr>
<tr>
<td>AMC</td>
<td>Acceptable Means of Compliance (EASA)</td>
</tr>
<tr>
<td>ASD</td>
<td>Accelerate-Stop Distance</td>
</tr>
<tr>
<td>ATC</td>
<td>Air Traffic Control</td>
</tr>
<tr>
<td>ATPCS</td>
<td>Automatic Take-off Power Control System</td>
</tr>
<tr>
<td>( C_d )</td>
<td>Drag coefficient</td>
</tr>
<tr>
<td>( C_L )</td>
<td>Lift coefficient</td>
</tr>
<tr>
<td>CAS</td>
<td>Calibrated Air Speed</td>
</tr>
<tr>
<td>CDL</td>
<td>Configuration Deviation List</td>
</tr>
<tr>
<td>CWY</td>
<td>Cleanway</td>
</tr>
<tr>
<td>EASA</td>
<td>European Aviation Safety Agency</td>
</tr>
<tr>
<td>ETOPS</td>
<td>Extended range with Twin engine aircraft OPerationS</td>
</tr>
<tr>
<td>( f(\ ) )</td>
<td>Function of ( )</td>
</tr>
<tr>
<td>FAA</td>
<td>Federal Aviation Administration</td>
</tr>
<tr>
<td>FAR</td>
<td>Federal Aviation Regulation</td>
</tr>
<tr>
<td>FCOM</td>
<td>Flight Crew Operating Manual</td>
</tr>
<tr>
<td>FF</td>
<td>Fuel Flow (hourly consumption)</td>
</tr>
<tr>
<td>FL</td>
<td>Flight Level</td>
</tr>
<tr>
<td>FMS</td>
<td>Flight Management System</td>
</tr>
<tr>
<td>( g )</td>
<td>Gravitational acceleration</td>
</tr>
<tr>
<td>GS</td>
<td>Ground Speed</td>
</tr>
<tr>
<td>( h )</td>
<td>hecto Pascal</td>
</tr>
<tr>
<td>IA</td>
<td>Indicated Altitude</td>
</tr>
<tr>
<td>IAS</td>
<td>Indicated Air Speed</td>
</tr>
<tr>
<td>ICAO</td>
<td>International Civil Aviation Organization</td>
</tr>
<tr>
<td>IEM</td>
<td>Interpretative Explanatory Material</td>
</tr>
<tr>
<td>in Hg</td>
<td>Inches of mercury</td>
</tr>
<tr>
<td>ISA</td>
<td>International Standard Atmosphere</td>
</tr>
<tr>
<td>JAA</td>
<td>Joint Aviation Authority</td>
</tr>
<tr>
<td>JAR</td>
<td>Joint Aviation Requirements</td>
</tr>
<tr>
<td>K</td>
<td>Kelvin</td>
</tr>
<tr>
<td>LDA</td>
<td>Landing Distance Available</td>
</tr>
<tr>
<td>LW</td>
<td>Landing Weight</td>
</tr>
<tr>
<td>m</td>
<td>Aircraft’s mass</td>
</tr>
<tr>
<td>M</td>
<td>Mach number</td>
</tr>
<tr>
<td>( M_{\text{mo}} )</td>
<td>Maximum Operating Mach number</td>
</tr>
<tr>
<td>MCDU</td>
<td>Multi Control Display Unit</td>
</tr>
<tr>
<td>MCT</td>
<td>Maximum Continuous Thrust</td>
</tr>
<tr>
<td>MEA</td>
<td>Minimum safe En route Altitude</td>
</tr>
<tr>
<td>MEL</td>
<td>Minimum Equipment List</td>
</tr>
<tr>
<td>MFD</td>
<td>Multi Function Display</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Description</td>
</tr>
<tr>
<td>--------------</td>
<td>-------------------------------------------</td>
</tr>
<tr>
<td>MGA</td>
<td>Minimum safe Grid Altitude</td>
</tr>
<tr>
<td>MLW</td>
<td>Maximum Landing Weight</td>
</tr>
<tr>
<td>MOCA</td>
<td>Minimum Obstacle Clearance Altitude</td>
</tr>
<tr>
<td>MORA</td>
<td>Minimum Off Route Altitude</td>
</tr>
<tr>
<td>MSL</td>
<td>Mean Sea Level</td>
</tr>
<tr>
<td>MTOW</td>
<td>Maximum Take-Off Weight</td>
</tr>
<tr>
<td>MTW</td>
<td>Maximum Tax Weight</td>
</tr>
<tr>
<td>MZFW</td>
<td>Maximum Zero Fuel Weight</td>
</tr>
<tr>
<td>n</td>
<td>Load factor</td>
</tr>
<tr>
<td>n_z</td>
<td>Load factor component normal to the aircraft’s longitudinal axis</td>
</tr>
<tr>
<td>N</td>
<td>All engines operating</td>
</tr>
<tr>
<td>N-1</td>
<td>One engine inoperative</td>
</tr>
<tr>
<td>OAT</td>
<td>Outside Air Temperature</td>
</tr>
<tr>
<td>P</td>
<td>Pressure</td>
</tr>
<tr>
<td>P_a</td>
<td>Power available</td>
</tr>
<tr>
<td>P_r</td>
<td>Power required</td>
</tr>
<tr>
<td>P_0amb</td>
<td>Standard pressure at Mean Sea Level</td>
</tr>
<tr>
<td>P_amb</td>
<td>Ambient pressure at the flight altitude</td>
</tr>
<tr>
<td>P_s</td>
<td>Static pressure</td>
</tr>
<tr>
<td>P_t</td>
<td>Total pressure</td>
</tr>
<tr>
<td>PA</td>
<td>Pressure Altitude</td>
</tr>
<tr>
<td>PFD</td>
<td>Primary Flight Display</td>
</tr>
<tr>
<td>QFE</td>
<td>Pressure at the airport reference point</td>
</tr>
<tr>
<td>QNH</td>
<td>Mean Sea Level pressure</td>
</tr>
<tr>
<td>QRH</td>
<td>Quick Reference Handbook</td>
</tr>
<tr>
<td>R</td>
<td>Universal gas constant</td>
</tr>
<tr>
<td>RC</td>
<td>Rate of Climb</td>
</tr>
<tr>
<td>RD</td>
<td>Rate of Descent</td>
</tr>
<tr>
<td>RLD</td>
<td>Required Landing Distance</td>
</tr>
<tr>
<td>RLW</td>
<td>Regulatory Landing Weight</td>
</tr>
<tr>
<td>RTOW</td>
<td>Regulatory Take-Off Weight</td>
</tr>
<tr>
<td>S</td>
<td>Wing area</td>
</tr>
<tr>
<td>SAT</td>
<td>Static Air Temperature</td>
</tr>
<tr>
<td>SR</td>
<td>Specific Range</td>
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<tr>
<td>SWY</td>
<td>Stopway</td>
</tr>
<tr>
<td>T</td>
<td>Temperature</td>
</tr>
<tr>
<td>T_a</td>
<td>Standard temperature at Mean Seal Level</td>
</tr>
<tr>
<td>T_EA</td>
<td>Standard temperature</td>
</tr>
<tr>
<td>T/C</td>
<td>Top of Climb</td>
</tr>
<tr>
<td>T/D</td>
<td>Top of Descent</td>
</tr>
<tr>
<td>TA</td>
<td>True Altitude</td>
</tr>
<tr>
<td>TAS</td>
<td>True Air Speed</td>
</tr>
<tr>
<td>TAT</td>
<td>Total Air Temperature</td>
</tr>
<tr>
<td>TOD</td>
<td>Take-Off Distance</td>
</tr>
<tr>
<td>TOR</td>
<td>Take-Off Run</td>
</tr>
<tr>
<td>TOW</td>
<td>Take-Off Weight</td>
</tr>
<tr>
<td>V1</td>
<td>Take-off decision speed</td>
</tr>
<tr>
<td>V2</td>
<td>Take-off climb speed</td>
</tr>
<tr>
<td>V APP</td>
<td>Final approach speed</td>
</tr>
<tr>
<td>V EF</td>
<td>Engine Failure speed</td>
</tr>
<tr>
<td>V FE</td>
<td>Maximum Flap-Extended speed</td>
</tr>
<tr>
<td>V LE</td>
<td>Landing gear Extended speed</td>
</tr>
<tr>
<td>V LO</td>
<td>Landing gear Operating speed</td>
</tr>
<tr>
<td>Symbol</td>
<td>Description</td>
</tr>
<tr>
<td>--------</td>
<td>-------------</td>
</tr>
<tr>
<td>$V_{LOF}$</td>
<td>Lift-Off speed</td>
</tr>
<tr>
<td>$V_{MRE}$</td>
<td>Maximum Brake Energy speed</td>
</tr>
<tr>
<td>$V_{MCA}$</td>
<td>Minimum Control Speed in the Air</td>
</tr>
<tr>
<td>$V_{MIN}$</td>
<td>Minimum Control Speed on Ground</td>
</tr>
<tr>
<td>$V_{MCL}$</td>
<td>Minimum Control Speed during approach and Landing</td>
</tr>
<tr>
<td>$V_{MO}$</td>
<td>Maximum Operating speed</td>
</tr>
<tr>
<td>$V_{MU}$</td>
<td>Minimum Unstick speed</td>
</tr>
<tr>
<td>$V_{R}$</td>
<td>Rotation speed</td>
</tr>
<tr>
<td>$V_{REF}$</td>
<td>Reference landing speed</td>
</tr>
<tr>
<td>$V_{S}$</td>
<td>Stalling speed</td>
</tr>
<tr>
<td>$V_{STG}$</td>
<td>Stalling speed at one g</td>
</tr>
<tr>
<td>$V_{SREF}$</td>
<td>Reference stalling speed</td>
</tr>
<tr>
<td>$V_{MAX}$</td>
<td>Maximum tyre speed</td>
</tr>
<tr>
<td>$W$</td>
<td>Weight</td>
</tr>
<tr>
<td>$W_{a}$</td>
<td>Apparent weight</td>
</tr>
<tr>
<td>$Z_{g}$</td>
<td>Geometrical altitude</td>
</tr>
<tr>
<td>$Z_{p}$</td>
<td>Pressure Altitude</td>
</tr>
</tbody>
</table>
Dear Readers,

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Yours faithfully;

Your ATR Training and Flight Operations support team.