EUROPEAN ORGANISATION
FOR THE SAFETY OF AIR NAVIGATION

EUROCONTROL

# EUROCONTROL EXPERIMENTAL CENTRE

# USER MANUAL FOR THE BASE OF AIRCRAFT DATA (BADA) REVISION 3.1

## EEC Note No. 25/98

Project SDV-D-E7

Issued: November 1998

## REPORT DOCUMENTATION PAGE

| **Reference:**<br>EEC Note No. 25/98 | **Security Classification:**<br>Unclassified |
|---|---|
| **Originator:**<br>EEC - APO<br>(**A**ircraft **P**erformance and **O**perations) | **Originator (Corporate Author) Name/Location:**<br>EUROCONTROL Experimental Centre<br>B.P.15<br>F - 91222 Brétigny-sur-Orge CEDEX<br>FRANCE<br>Telephone : +33 1 69 88 75 00 |
| **Sponsor:**<br>EEC | **Sponsor (Contract Authority) Name/Location:**<br>EUROCONTROL Agency<br>Rue de la Fusée, 96<br>B -1130 BRUXELLES<br>Telephone : +32 2 729 9011 |

**TITLE:**

**User Manual for the Base of Aircraft Data (BADA) - Revision 3.1**

| **Author** | **Date** | **Pages** | **Figures** | **Tables** | **Appendix** | **References** |
|---|---|---|---|---|---|---|
| P. Baulleret | 11/98 | xii + 62 | 0 | 1 | 4 | 10 |

| **EATCHIP Task Specification** | **Project SDV-D-E7** | **Task No. Sponsor** | **Period** |
|---|---|---|---|
| - | | | 3/98 to 11/98 |

**Distribution Statement:**
(a) Controlled by: Head of APO
(b) Special Limitations: None
(c) Copy to NTIS: YES / ~~NO~~

**Descriptors (keywords):**

aircraft model, total-energy model, BADA, user manual

**Abstract:**

The Base of Aircraft Data (BADA) provides a set of ASCII files containing performance and operating procedure coefficients for 151 different aircraft types. The coefficients include those used to calculate thrust, drag and fuel flow and those used to specify nominal cruise, climb and descent speeds. User Manual for Revision 3.1 of BADA provides definitions of each of the coefficients and then explains the file formats. Instructions for remotely accessing the files via Internet are also given.

# User Manual
# for the
# Base of Aircraft Data (BADA)
# Revision 3.1

Summary

The Base of Aircraft Data (BADA) provides a set of ASCII files containing performance and operating procedure coefficients for 151 different aircraft types. The coefficients include those used to calculate thrust, drag and fuel flow and those used to specify nominal cruise, climb and descent speeds. The User Manual for Revision 3.1 of BADA provides definitions of each of the coefficients and then explains the file formats. Instructions for remotely accessing the files via Internet are also given.

# User Manual Modification History

| Issue Number | Release Date | Comments |
|---|---|---|
| Revision 2.1<br>Issue 1.0 | 31.05.94 | First release of document |
| Revision 2.2<br>Issue 1.0 | 25.01.95 | Released with BADA Revision 2.2<br>- 8 new aircraft models<br>- 2 modified aircraft models<br>- 2 modified equivalences<br>- 6 removed equivalences<br>- 14 new equivalences<br>- modified file formats<br>- additional Synonym File<br>- corrections to formulas in previous version of document<br>- additional description of total-energy and standard atmosphere equations |
| Revision 2.3<br>Issue 1.0 | 08.06.95 | Released with BADA Revision 2.3<br>- document format modified to be consistent with EEC Technical Note standards<br>- new A/C models for B73V and D328<br>- MD11 changed from equivalence to direct support<br>- generic military fighter model, FGTR, replaces specific fighter models<br>- maximum payload parameter added to all OPF files<br>- Performance Tables Files (*.PTF) introduced<br>- ISA equations used for TAS/CAS conversions instead of approximations (Section 3.2)<br>- use only one formula for correction of speeds at mass values different from reference mass (Section 3.3)<br>- add specification of minimum speed as function of stall speed (Section 3.4)<br>- specification of transition altitude calculated added (Section 4.1)<br>- speed schedules modified for climb (Section 4.1) and descent (Section 4.3)<br>- modify Internet address for remote access and Eurocontrol contact person (Section 6)<br>- removed Section 7 (General Comments) |

# User Manual Modification History (cont'd)

| Issue Number | Release Date | Comments |
|---|---|---|
| Revision 2.4<br>Issue 1.0 | 04.01.96 | Released with BADA Revision 2.4<br>- new A/C model for FK70<br>- C421 changed from equivalence to directly supported<br>- 10 new equivalences<br>- 1 modified equivalence<br>- 3 re-developed models<br>- introduction of dynamic maximum altitude<br>- new temperature correction on thrust<br>- modified max.alt for 4 models<br>- modified minimum weight for 2 models<br>- modified temperature coefficients for 12 models<br>- esf calculation for constant CAS below tropopause changed from binomial approximation to exact formula<br>- cruise Mach numbers changed for 4 models<br>- change in altitude limit for descent speed |
| Revision 2.5<br>Issue 1.0 | 20.01.97 | - re-developed models: EA32, B737, B73S, AT42, B767, DC9, BA46, FK10, MD80.<br>- new model: CL65, DH83<br>- change of minimum speeds<br>- change of climb/descent speed schedules<br>- cruise fuel flow correction<br>- buffeting speed for jet a/c<br>- addition of BADA.GPF file<br>- definition of acceleration limits, bank angles and holding speeds<br>- 38 new equivalences added (SA4, SA5, SweDen 96)<br>- 1 modified equivalence (B74S)<br>- modified climb/cruise speeds (BE90, BE99, E120, PA42, FK50, B73F, B767,B747, B727, DA20)<br>- Format changes in OPF file<br>- Header changes in PTF file<br>- Temperature influence on thrust limitation changed<br>- Unit of Vstall in OPF file changed to KCAS<br>- Correction of typing errors<br>- Correction of APF file format explanation |

# User Manual Modification History (cont'd)

| Issue Number | Release Date | Comments |
|---|---|---|
| Revision 2.6<br>Issue 1.0 | 01.09.97 | - Added non-clean drag and thrust data for: EA32, B73S, MD80, B737, B747, FK10, AT42, B767 and CL65 models<br>- All models mentioned above were re-developed using new clean drag data.<br>- ND16, E120 and FK50 were re-modelled to correct the cruise speed capability.<br>- Change of speed schedule in the take-off / initial climb phase and approach / landing phase<br>- Change in descent thrust algorithm<br>- Use of exact formula for density below tropopause instead of approximation.<br>- Addition of formula for pressure above tropopause<br>- Change of buffeting limit to 1.2g (was 1.3g)<br>- Change of OPF file format<br>- Buffeting coefficients for B757 and MD80 were corrected.<br>- Hmo for B747 model was corrected to 45,000 ft<br>- Low altitude descent behaviour corrected for: SW3, PAYE, DA50, DA10, D328, C421, BE99, BE20 and BE90 models<br>- Correction of some minor typing errors<br>- dynamic maximum altitude coefficients changed for B747, B74F, C130 and EA30<br>- Saab 2000 (SB20) added as equivalent of D328<br>- Modified algorithm for lift coefficient |
| Revision 3.0<br>Issue 1.0 | 01.03.98 | - Climb speed law changed for jet aircraft<br>- Descent speed law changed for jet, turbo and piston<br>- Reduced power climbs<br>- B777, SB20 and B73X models were added<br>- DA01 model was removed<br>- Use of ICAO doc. 8643/25 standard, which resulted in the removal of 4 additional models<br>- B73F and B757 remodelled<br>- MD90 added as equivalenced model<br>- Cruise and descent speeds for several turboprops changed<br>- Climb thrust for several a/c changed<br>- Removal of $C_{m16}$ from drag expression |

# User Manual Modification History (cont'd)

| Issue Number | Release Date | Comments |
|---|---|---|
| Revision 3.1<br>Issue 1.0 | 01.10.98 | Released with BADA Revision 3.1<br>- Descent & cruise speeds for several jet aircraft changed : DC9, BA46, CL60<br>- Descent, cruise & climb speeds for several turboprops changed : D228, SH36<br>- Maximum Operating speed for several a/c changed : PA42<br>- Stalling speed for several a/c changed : DC8, T154<br>- Removed formula for air density calculation above tropopause<br>- Addition of Appendix D : Solutions for buffeting limit algtorithm<br>- Removed Section 3.7.2 : Maximum Take-Off Thrust<br>- Description for $C_{red}$ parameter added<br>- Correction of some minor typing errors<br>- Modified PTF File format (Flight Level): Section 6.6<br>- Cruise CAS schedule for jet & turbo aircrafts (Section 4.2) |

# Table of Contents

# 1. INTRODUCTION

## 1.1 Identification

This document is the User Manual for the Base of Aircraft Data (BADA) Revision 3.1. This manual replaces the previous User Manual for BADA Revision 3.0 [RD1].

## 1.2 Purpose

BADA is a collection of ASCII files which specifies operation performance parameters, airline procedure parameters and performance summary tables for 151 aircraft types. This information is designed for use in trajectory simulation and prediction algorithms within the domain of Air Traffic Management (ATM). All files are maintained within a configuration management system at the Eurocontrol Experimental Centre (EEC) in Brétigny-sur-Orge, France.

This document describes the mathematical models on which the data is based and specifies the format of the files which contain the data. In addition, this document describes how the files can be remotely accessed from the EEC.

## 1.3 Document Organisation

This document consists of seven sections including Section 1, the Introduction. A list of referenced documents along with a glossary of acronyms and symbols are included in this section.

Section 2, Revision Summary, provides a list of the aircraft types supported by BADA 3.1 and summarises the differences between BADA 3.1 and the previous revision BADA 3.0.

Section 3, Operation Performance Models, defines the set of equations, which are used to parameterise aircraft performance. This includes models of aerodynamic drag, engine thrust, and fuel consumption.

Section 4, Airline Procedure Models, defines the set of parameters which is used to characterise standard airline speed procedures for climb, cruise, and descent.

Section 5, Global Aircraft Parameters, defines the set of global aircraft parameters that are valid for all, or a group of, aircraft.

Section 6, File Structure, describes the files in which the BADA aircraft parameters are maintained. Five types of files are identified:

- Synonym Files listing the supported aircraft types;
- Operations Performance Files (OPF) containing the performance parameters for a specific aircraft type;
- Airline Procedures Files (APF) containing speed procedure parameters for a specific aircraft type;
- Performance Table Files (PTF) containing summary performance tables of true air speed. climb/descent rates and fuel consumption at various flight levels for a specific aircraft type;

- Global Parameters File (GPF) containing parameters that are valid for all aircraft or a group of aircraft for instance all turboprops or all military a/c.

Section 7, Remote File Access to BADA, provides instructions on how to remotely access BADA files from the EEC computing facilities over the Internet.

Four appendices are also provided with this document. Appendix A presents a summary list of all files contained in BADA Revision 3.1. A listing of the tar file contents available for remote data access is given in Appendix B. Appendix C gives an overview of all available aircraft models. Appendix D gives solutions for buffeting limit algorithm.

## 1.4 Referenced Documents

**RD1** User Manual for the Base of Aircraft Data (BADA) Revision 3.0; EEC Note No. 6/98; March 1998

**RD2** Aircraft Type Designators, ICAO Document 8643/25; January 1997

**RD3** Aircraft Modelling Standards for Future ATC Systems; Eurocontrol Division E1 Document No. 872003, July 1987

**RD4** Manual of the ICAO Standard Atmosphere; ICAO Document No. 7488, 2nd Edition, 1964.

**RD5** BADA Configuration Management Manual; Internal EEC Note 4/B2.3/1995; October 1995.

**RD6** Design and User Manual for BADA Excel Spreadsheets, Issue 2.0; EEC Note 13/98; May 1998.

**RD7** Memo on the Calculation of Energy Share Factor; EEC/FAS/BYR/95/50; 22 November 1995

**RD8** Revision Summary Document for the Base of Aircraft Data (BADA) Revision 3.1; EEC Note /98; October 1998.

**RD9** Aircraft Performance Summary Tables for the Base of Aircraft Data (BADA) Revision 3.1; EEC Note /98; October 1998.

**RD10** Aircraft Type Designators, ICAO Document 8643/23; January 1994

## 1.5 Glossary of Acronyms

| | |
|---|---|
| **AGL** | Above Ground Level |
| **APF** | Airlines Procedures File |
| **APO** | Centre for Aircraft Performance and Operations |
| **ASCII** | American Standard Code for the Interchange of Information |
| **ATM** | Air Traffic Management |
| **BADA** | Base of Aircraft Data |
| **CAS** | Calibrated Airspeed |
| **CRCO** | Central Route Charges Office |
| **EEC** | Eurocontrol Experimental Centre |
| **ESF** | Energy Share Factor |
| **IAS** | Indicated Airspeed |
| **ICAO** | International Civil Aviation Organisation |
| **ISA** | International Standard Atmosphere |
| **MASS** | Multi-Aircraft Simplified Simulator |
| **MLW** | Maximum Landing Weight |
| **MTOW** | Maximum Take-off Weight |
| **OPF** | Operations Performance File |
| **OWE** | Operational Weight Empty |
| **PTF** | Performance Table File |
| **RCS** | Revision Control System |
| **ROCD** | Rate of Climb or Descent |
| **TAS** | True Airspeed |
| **TEM** | Total-Energy Model |

## 1.6 Glossary of Symbols

A list of the symbols used in equations throughout this document is given below along with a description. Where appropriate, the engineering units typically associated with the symbol are also given.

| | | |
|---|---|---|
| a | speed of sound | [m/s] |
| d | distance | [nautical miles] |
| f | fuel flow | [kg/min] |
| g | gravitational acceleration | [m/s$^2$] |
| $\frac{dh}{dt}$ | rate of climb or descent | [m/s] or [ft/min] |
| h | altitude above sea level | [metres] or [ft] |
| C | general coefficient | |
| D | drag force | [Newtons] |
| m | aircraft mass | [tonnes] or [kg] |
| M | Mach number | |
| R | real gas constant for air | [m$^2$/Ks$^2$] |
| S | reference wing surface area | [m$^2$] |
| T | thrust<br>temperature | [N]<br>[Kelvin] |
| V | speed | [m/s] or [knots] |
| $\Delta$T | temperature difference | [Kelvin] |
| $\eta$ | thrust specific fuel flow | [kg/min/kN] |
| $\rho$ | air density | [kg/m$^3$] |

# 2. REVISION SUMMARY

This section summarises the aircraft types that are supported in BADA Revision 3.1 along with the updates that have been made from the previous release, BADA Revision 3.0.

## 2.1 Supported Aircraft

BADA 3.1 provides operations and procedures data for a total of 151 aircraft types. For 67 of these aircraft types, data is provided directly in files. These aircraft types are referred to as being directly supported. For the other 84 aircraft types, the data is specified to be the same as one of the directly supported 67 aircraft types. This second set of aircraft types is referred to as being supported through equivalence.

With one exception, each supported aircraft type is identified by a 4-character designation code assigned by the International Civil Aviation Organisation (ICAO) [RD2]. The exception is the model representing a generic military fighter, which uses the designator: FGTR.

The list of aircraft types supported by BADA 3.1 is given in Appendix C. In this Appendix the supported aircraft types are listed alphabetically by their designation code. For each aircraft type the aircraft name and type of BADA support (either direct or equivalence) is specified. Also, for each aircraft, which is supported through equivalence, the corresponding equivalent aircraft type is specified.

## 2.2 Updates for BADA Revision 3.1

Updates made to BADA Revision 3.1 from the previous revision 3.0 are listed below:

(a) Air Density calculation above tropopause (section 3.2)

(b) Addition of Appendix D: Solutions for Buffeting Limit Algorithm

(c) MaximumTake-Off Thrust (section)

(d) $C_{red}$ description (section 3.8)

(e) Descent Thrust (section 3.7)

(f) Cruise and descent speeds (__.APF files) were changed for several a/c (jet & turboprops)

(g) PTF file format modified (Flight Level)

(h) Cruise CAS schedule for jet and turboprop a/c

(i) Stalling speeds were changed for several a/c

A more complete overview of all changes can be found in [RD8].

# 3. OPERATIONS PERFORMANCE MODEL

This section defines the various equations and coefficients used by the BADA operations performance model.

The first two subsections describe the Total-Energy Model (TEM) equations and standard atmosphere equations respectively.

The remaining eight subsections define the aircraft model in terms of the eight categories listed below.

- aircraft type,
- mass,
- flight envelope,
- aerodynamics,
- engine thrust,
- reduced power,
- fuel consumption and
- ground movement

## 3.1 Total-Energy Model

The Total-Energy Model equates the rate of work done by forces acting on the aircraft to the rate of increase in potential and kinetic energy, that is:

$$(T - D)V_{TAS} = mg\frac{dh}{dt} + mV_{TAS}\frac{dV_{TAS}}{dt} \qquad (3.1\text{-}1)$$

The symbols are defined below with metric units specified:

| | | | |
|---|---|---|---|
| $T$ | - | thrust acting parallel to the aircraft velocity vector | [Newtons] |
| $D$ | - | aerodynamic drag | [Newtons] |
| $m$ | - | aircraft mass | [kilograms] |
| $h$ | - | altitude | [m] |
| $g$ | - | gravitational acceleration | [9.81 $m/s^2$] |
| $V_{TAS}$ | - | true airspeed | [m/s] |
| $\frac{d}{dt}$ | - | time derivative | [$s^{-1}$] |

Note that true airspeed is often calculated in knots and altitude calculated in feet thus requiring the appropriate conversion factors.

Without considering the use of devices such as spoilers, leading-edge slats or trailing-edge flaps, there are two independent control inputs available for affecting the aircraft trajectory in the vertical plane. These are the throttle and the elevator.

These inputs allow any two of the three variables of thrust, speed, or ROCD to be controlled. The other variable is then determined by equation 3.1-1. The three resulting control possibilities are elaborated on below.

(a) Speed and Throttle Controlled - Calculation of Rate of Climb or Descent

Assuming that velocity and thrust are independently controlled, then equation 3.1-1 is used to calculate the resulting rate of climb or descent (ROCD). This is a fairly common case for climbs and descents in which the throttle is set to some fixed position (maximum climb thrust or idle for descent) and the speed is maintained at some constant value of calibrated airspeed (CAS) or Mach number.

(b) ROCD and Throttle Controlled - Calculation of Speed

Assuming that the ROCD and thrust are independently controlled, then equation 3.1-1 is used to calculate the resulting speed.

(c) Speed and ROCD Controlled - Calculation of Thrust

Assuming that both ROCD and speed are controlled, then equation 3.1-1 can be used to calculate the necessary thrust. This thrust must be within the available limits for the desired ROCD and speed to be maintained.

Case (a), above, is the most common such that equation 3.1-1 is most often used to calculate the rate of climb or descent. To facilitate this calculation, equation 3.1-1 can be rearranged as follows:

$$(T - D)\,V_{TAS} = mg\frac{dh}{dt} + mV_{TAS}\left(\frac{dV_{TAS}}{dh}\right)\left(\frac{dh}{dt}\right) \qquad (3.1\text{-}2)$$

Isolating the rate of climb or descent on the left hand side gives:

$$\frac{dh}{dt} = \frac{(T - D)V_{TAS}}{mg}\left[1 + \left(\frac{V_{TAS}}{g}\right)\left(\frac{dV_{TAS}}{dh}\right)\right]^{-1} \qquad (3.1\text{-}3)$$

It has been shown by Renteux [RD3] that the last term can be replaced by an energy share factor as a function of Mach number, f{M}, as follows:

$$\frac{dh}{dt} = \left[\frac{(T - D)V_{TAS}}{mg}\right]f\{M\} \qquad (3.1\text{-}4)$$

This Energy Share Factor (ESF) specifies how much of the available power is allocated to climb as opposed to acceleration.

For several common flight conditions equation 3.1-4 can be rewritten as is done below. A more comprehensive description of this process can be found in RD7:

(a) Constant Mach number in stratosphere (i.e. above tropopause)

$$f\{M\} = 1.0 \qquad (3.1\text{-}5)$$

Note that above the tropopause (approximately 11000 metres under ISA conditions) the air temperature and the speed of sound are constant. Maintaining a constant Mach number therefore requires no acceleration and all available power can be allocated to a change in altitude.

(b) Constant Mach number below tropopause:

$$f_{share} = \left[1 + \frac{\gamma R k_T}{2g} M^2\right]^{-1} \qquad (3.1\text{-}6)$$

where,

| | |
|---|---|
| R | is the real gas constant for air, R = 287.04 $m^2/Ks^2$ |
| g | is the gravitational acceleration, g = 9.81 m/s2 |
| $k_T$ | is the ISA temperature gradient with altitude below the tropopause, $k_T$ = -0.0065 K/m |
| M | is the Mach number |
| γ | is the isentropic expansion coefficient for air, γ = 1.4 |

In this case, for a typical Mach number of 0.8 the energy share factor allocated to climb is 1.09.

This number is greater than 1 because below the tropopause, the temperature and thus speed of sound decreases with altitude. Maintaining a constant Mach number during climb thus means that the true air speed decreases with altitude. Thus, the rate of climb benefits from not only all the available power but also a transfer of kinetic energy to potential energy.

(c) Constant Calibrated Airspeed (CAS) below tropopause

$$f_{share} = \left\{1 + \frac{\gamma R k_T}{2g} M^2 + \left(1 + \frac{\gamma - 1}{2} M^2\right)^{\frac{-1}{\gamma - 1}} \left\{\left(1 + \frac{\gamma - 1}{2} M^2\right)^{\frac{\gamma}{\gamma - 1}} - 1\right\}\right\}^{-1} \qquad (3.1\text{-}7)$$

In this case the energy share factor is less than one. A Mach number of 0.6 for example yields an energy share factor of 0.85.

This number is less than 1 because as density decreases with altitude, maintaining a constant CAS during climb requires maintaining a continual increase in true air speed. Thus, some of the available power needs to be allocated to acceleration leaving the remainder for climb.

(d) Constant Calibrated Airspeed (CAS) above tropopause

$$f_{share} = \left\{1 + \left(1 + \frac{\gamma - 1}{2} M^2\right)^{\frac{-1}{\gamma-1}} \left[\left(1 + \frac{\gamma - 1}{2} M^2\right)^{\frac{\gamma}{\gamma-1}} - 1\right]\right\}^{-1} \qquad (3.1\text{-}8)$$

This is a very uncommon situation that would only occur at very low temperatures (ISA -20 or below) and it is therefore not incorporated in BADA, but merely mentioned for the sake of completeness.

The energy share factors given above apply equally well to descent as to climb. The difference being that the available power is negative for descent.

In cases where a constant Mach number or constant CAS is not maintained, the following energy share factors is specified by the BADA model.

| | |
|---|---|
| acceleration in climb | f{M} = 0.3 |
| deceleration in descent | f{M} = 0.3 |
| | |
| deceleration in climb | f{M} = 1.7 |
| acceleration in descent | f{M} = 1.7 |

Note for the cases of acceleration in climb or deceleration in descent, the majority of the available power is devoted to a change in speed.

For the cases of deceleration in climb or acceleration in descent, the energy share factor is greater than one since the change of altitude benefits from a transfer of kinetic energy.

## 3.2 Standard Atmosphere

Calculations for lift, drag, and conversions from CAS to TAS and Mach number require the determination of several atmospheric properties as a function of altitude.

The equations used by BADA for the standard atmosphere and CAS/TAS conversion are summarised below. These equations are based on the International Standard Atmosphere (ISA) [RD4].

(a) Determination of the Tropopause

$$h_{trop} = 11000 + 1000\ \Delta T_{ISA} / 6.5 \qquad (3.2\text{-}1)$$

Here the tropopause altitude, $h_{trop}$, is specified in metres.

$\Delta T_{ISA}$ is the temperature difference from the International Standard Atmosphere (ISA). That is, the temperature at sea level, $T_0$ , would be:

$$T_0 = (T_0)_{ISA} + \Delta T_{ISA} \qquad (3.2\text{-}2)$$

$$(T_0)_{ISA} = 288.15\ K \qquad (3.2\text{-}3)$$

For standard atmosphere conditions, ($\Delta T_{ISA} = 0$) the tropopause is at 11000 metres altitude.

(b) Determination of Temperature

Above the tropopause, the temperature is a constant, that is,

$$T_{trop} = 216.65\ K \qquad (3.2\text{-}4)$$

Below the tropopause, the temperature is calculated as a function of altitude as follows:

$$T = T_0 - 6.5*h/1000 \qquad (3.2\text{-}5)$$

Here the altitude, h, is specified in metres.

(c) Determination of Air Density

Below the tropopause, the air density, $\rho$ , in kg/$m^3$ is calculated as function of temperature as follows:

$$\rho = \rho_0\ [T/T_0]^{4.25611} \qquad (3.2\text{-}6)$$

Here $\rho_0$ is the air density at sea level:

$$\rho_0 = (\rho_0)_{ISA}\,(T_0)_{ISA} / T_0 \qquad (3.2\text{-}7)$$

and $(\rho_0)_{ISA}$ is the standard atmosphere air density at sea level:

$$(\rho_0)_{ISA} = 1.225\ \text{kg/m}^3 \qquad (3.2\text{-}8)$$

Above the tropopause, the air density, ρ, in kg/m³ is calculated as follows [RD4]:

$$\rho = \rho_{Trop}\, e^{-\left(\frac{g}{R \cdot T_{Trop}}\right)\cdot(h - 11000)} \qquad (3.2\text{-}9)$$

Here h represents the altitude in meters.

(d) Determination of Sound Speed

Above the tropopause the speed of sound, a , is a constant:

$$a_{trop} = 295.07\ \text{m/s} \qquad (3.2\text{-}10)$$

Below the tropopause, the speed of sound is calculated as a function of temperature:

$$a = 340.29\sqrt{\frac{T}{(T_0)_{ISA}}} \qquad (3.2\text{-}11)$$

(e) CAS/TAS Conversion

The true air speed, $V_{TAS}$, is calculated as a function of the calibrated air speed, $V_{CAS}$, as follows:

$$V_{TAS} = \left[\frac{2}{\mu}\frac{P}{\rho}\left\{\left(1+\frac{(P_0)_{ISA}}{P}\left[\left(1+\frac{\mu}{2}\frac{(\rho_0)_{ISA}}{(P_0)_{ISA}}V_{CAS}{}^2\right)^{1/\mu}-1\right]\right)^{\mu}-1\right\}\right]^{1/2} \qquad (3.2\text{-}12)$$

Similarly, $V_{CAS}$ is calculated as a function of $V_{TAS}$ as follows:

$$V_{CAS} = \left[\frac{2}{\mu}\frac{(P_0)_{ISA}}{(\rho_0)_{ISA}}\left\{\left(1+\frac{P}{(P_0)_{ISA}}\left[\left(1+\frac{\mu}{2}\frac{\rho}{P}V_{TAS}^{\ 2}\right)^{1/\mu}-1\right]\right)^{\mu}-1\right\}\right]^{1/2} \quad (3.2\text{-}13)$$

where symbols not previously defined are explained below:

$$\mu = \frac{(\gamma - 1)}{\gamma} \quad (3.2\text{-}14)$$

$\gamma$ is the isentropic expansion coefficient for air = 1.4 [dimensionless]

P is the pressure at altitude [Pa]

$(P_0)_{ISA}$ is the ISA pressure at sea level = 101325 Pa

Also note that for these conversion formulas above, the speeds $V_{TAS}$ and $V_{CAS}$ must be specified in m/s.

The pressure at altitude, P, can be determined from the temperature at altitude, T, by the following formula, which is valid for altitudes below the tropopause:

$$P = (P_0)_{ISA} \cdot \left(\frac{T}{T_0}\right)^{5.25611} \quad (3.2\text{-}15)$$

For altitudes above the tropopause, the following formula should be used:

$$P = P_{Trop} \cdot e^{-\left(\frac{g}{R \cdot T_{Trop}}\right) \cdot (h - 11000)} \quad (3.2\text{-}16)$$

Where h is the altitude in meters.

(f) Mach/TAS conversion

$$V_{TAS} = M\sqrt{\gamma \cdot R \cdot T} \quad (3.2\text{-}17)$$

where,

- M is the Mach number,
- T is the local temperature at altitude,
- R is the universal gas constant for air = 287.04 [$m^2/Ks^2$], and
- $\gamma$ is the isentropic expansion coefficient for air = 1.4

## 3.3 Aircraft Type

Three values are specified for aircraft type, these being the number of engines, $n_{eng}$ , the engine type and the wake category.

The engine type can be one of three values:

- Jet,
- Turboprop, or,
- Piston.

The wake category can also be one of three values:

H - heavy
M - medium
L - light

Note that the ICAO associates a wake category with each aircraft type designator [RD2].

## 3.4 Mass

Four mass values are specified for each aircraft in tonnes:

| | | |
|---|---|---|
| $m_{ref}$ | - reference mass | |
| $m_{min}$ | - minimum mass | (operational weight empty) |
| $m_{max}$ | - maximum mass | (maximum take-off weight) |
| $m_{pyld}$ | - maximum payload mass | |

The reference mass is the mass for which other BADA performance coefficients are calculated.

Aircraft operating speeds vary with the aircraft mass. This variation is calculated according to the formula below:

$$V = V_{ref}\sqrt{\frac{m}{m_{ref}}} \qquad (3.4\text{-}1)$$

In this formula, the aircraft reference speed $V_{ref}$ is given for the reference mass $m_{ref}$. The speed at another mass, m, is then calculated as V.

An example of an aircraft speed, which can be calculated via this formula is the stall speed, $V_{stall}$.

## 3.5 Flight Envelope

The maximum speed and altitude for the aircraft is expressed in terms of the following six parameters:

| | |
|---|---|
| $V_{MO}$ | - maximum operating speed (CAS), in knots |
| $M_{MO}$ | - maximum operational Mach number |
| $h_{MO}$ | - maximum operational height, in feet above sea level |
| $h_{max}$ | - maximum altitude (300 fpm) at MTOW under ISA conditions |
| $G_w$ | - mass gradient on maximum altitude |
| $G_t$ | - temperature gradient on maximum altitude |

where the maximum altitude for any given mass is:

$$h_{max/act} = \text{MIN}(h_{MO}\ ,\ h_{max} + G_t * (\Delta T_{ISA} - C_{Tc4}) + G_w *( m_{max} - m_{act})\ ) \qquad (3.5\text{-}1)$$

with: $G_w \geq 0$;
$G_t \leq 0$;
if $(\Delta T_{ISA} - C_{tc4}) < 0$, then : $(\Delta T_{ISA} - C_{tc4}) = 0$;

with $\Delta T_{ISA}$ being the temperature deviation from ISA and $m_{act}$ being the actual aircraft mass (kg). Formula 3.5-1 should not be executed when the $h_{max}$ value in the .OPF file is set to 0 (zero). In that case the maximum altitude is always $h_{MO}$.

The minimum speed for the aircraft is specified as follows:

$$V_{min} = C_{Vmin,\,TO} * V_{stall} \quad \text{if in take-off} \qquad (3.5\text{-}2)$$

$$V_{min} = C_{Vmin} * V_{stall} \quad \text{otherwise} \qquad (3.5\text{-}3)$$

Note: See 3.6.2 for minimum speed at high altitude for jet aircraft and Section 5.7 for the values of the minimum speed coefficients.

Here the speeds are specified in terms of CAS. The stall speed depends upon the configuration. Specifically, five different configurations are specified with a stall speed given for each:

| | | |
|---|---|---|
| TO | - take-off configuration (up to 400 ft AGL) | $(V_{stall})_{TO}$ |
| IC | - initial climb configuration ( between 400 and 3000 ft AGL) | $(V_{stall})_{IC}$ |

CR - cruise (clean) configuration $(V_{stall})_{CR}$
(above 2000 ft AGL in climb,
in descent above 8,000 ft and,
in descent below 8,000 ft as long as $V > Vmin_{Cruise} + 10$ kts )

AP - approach configuration $(V_{stall})_{AP}$
(in descent below 8,000 ft when $V < Vmin_{Cruise} + 10$ kts )

LD - landing configuration $(V_{stall})_{LD}$
(in descent below 3,000 ft when $V < Vmin_{Approach} + 10$ kts )

Note that these stall speeds correspond to a minimum stall speed and not a 1-g stall speed. Also, the BADA model assumes that for any aircraft these stall speeds have the following relationship:

$$(V_{stall})_{CR} \geq (V_{stall})_{IC} \geq (V_{stall})_{TO} \geq (V_{stall})_{AP} \geq (V_{stall})_{LD}$$

# 3.6 Aerodynamics

## 3.6.1 Aerodynamic Drag

Under nominal conditions, the drag coefficient, $C_D$ is specified as a function of the lift coefficient $C_L$ as follows:

$$C_D = ( C_{D0,\,CR} + C_{D2,\,CR}\, C_L^2 ) \qquad (3.6\text{-}1)$$

Formula 3.6-1 is valid for all situations except for the approach and landing where other drag coefficients are to be used.

In the approach phase a different flap setting is used. Formula 3.6-2 should be applied below 8,000 ft when the aircraft descends and the speed falls below $Vmin_{Cruise}$ + 10 kts for the clean configuration (corrected for aircraft mass). Note that $Vmin_{Cruise} = 1.3 * Vstall_{Cruise}$.

$$C_D = ( C_{D0,\,AP} + C_{D2,\,AP}\, C_L^2 ) \qquad (3.6\text{-}2)$$

In the landing phase Formula 3.6-3 is used. This formula is applied below 3,000 ft when the aircraft descends and as soon as the speed falls below $Vmin_{Approach}$ + 10 kts, where $Vmin_{Approach} = 1.3 * Vstall_{Approach}$ .

$$C_D = ( C_{D0,\,LD} + C_{D0,\,\Delta LDG} + C_{D2,\,LD}\, C_L^2 ) \qquad (3.6\text{-}3)$$

The value of $C_{D0,\,\Delta LDG}$ is a function of the flap setting. The values of $C_{D0,\,\Delta LDG}$ in the <A/C>__.OPF files were all determined for the landing flap setting mentioned in the OPF file. The drag force in Newtons is then determined from the drag coefficient in the standard manner:

$$D = \frac{C_D \cdot \rho \cdot V_{TAS}^{\;2} \cdot S}{2} \qquad (3.6\text{-}4)$$

where ρ is the air density (kg/$m^3$ ), S is the wing reference area ($m^2$), and $V_{TAS}$ is the true airspeed (m/s). Note that the air density is a function of altitude as described in subsection 3.2.

The lift coefficient, $C_L$ , is determined assuming that the flight path angle is zero, however a correction for bank angle is made:

$$C_L = \frac{2 \cdot m \cdot g}{\rho \cdot V_{TAS}^{\;2} \cdot S \cdot \cos\phi} \qquad (3.6\text{-}5)$$

The above equations thus result in nine coefficients for the specification of drag: S, $C_{D0,CR}$ , $C_{D2,CR}$ , $C_{D0,AP}$ , $C_{D2,AP}$ , $C_{D0,LD}$ , $C_{D2,LD}$ , $C_{D0,\Delta LDG}$ and $C_{M16}$. In case the $C_{D0,AP}$ , $C_{D2,AP}$ , $C_{D0,LD}$ , $C_{D2,LD}$ and $C_{D0,\Delta LDG}$ coefficients are set to 0 (zero) in the OPF file, expression 3.6-1 will be used in all cases.

### 3.6.2 Low Speed Buffeting Limit (jet aircraft only)

For jet aircraft a low speed buffeting limit has been introduced. This buffeting limit is expressed as a Mach number and can be determined using the following equation:

$$k*M^3 - C_{Lbo\,(M=0)}*M^2 + (W/S) / (0.583*P) = 0 \qquad (3.6\text{-}6)$$

Note that the factor of 0.583 gives a 0.2g margin. The W, S and P parameters are already known in BADA. The k and $C_{Lbo\,(M=0)}$ parameters have been determined for nearly all jet aircraft in BADA 3.1. The solution for M in Formula 3.6-6 can be obtained using the method given in Appendix D. The buffeting limit should be applied as a minimum speed in the following way:

If (Altitude > 15,000 ft) then: $V_{min}$= MAX(1.3* $V_{stall}$, $M_b$ )
If (Altitude < 15,000 ft) then: $V_{min}$= expressions 3.5-2, 3.5-3

where $M_b$ is the lowest positive solution of expression 3.6-6. Note that the units of the two values inside the MAX() expression should be the same .

If the k and $C_{Lbo\,(M=0)}$ parameters in the OPF file are set to 0 (zero), the minimum speed above 15,000 ft is 1.3*$V_{stall}$.

## 3.7 Engine Thrust

The BADA model provides coefficients that allow the calculation of the following thrust levels:

- maximum climb
- nominal climb
- maximum take-off
- maximum cruise
- descent

The thrust is calculated in Newtons and includes the contribution from all engines. The subsections below provide the equations for each of the four thrust conditions.

### 3.7.1 Maximum Climb and Take-Off Thrust

The maximum climb thrust at standard atmosphere conditions, $(T_{max\ climb})_{ISA}$ , is calculated in Newtons as a function of the following:

- engine type: either Jet, Turboprop or Piston;
- altitude above sea level, h, in feet;
- true air speed, $V_{TAS}$ , in knots;
- temperature deviation from standard atmosphere, $\Delta T_{ISA}$, in degrees Celsius.

The equations corresponding to the three engine types are given below.

Jet: $$(T_{max\ climb})_{ISA} = C_{Tc,1}\,(1 - h/C_{Tc,2} + C_{Tc,3}\,h^2) \qquad (3.7\text{-}1)$$

Turboprop: $$(T_{max\ climb})_{ISA} = C_{Tc,1}\,(1 - h/C_{Tc,2})/V_{TAS} + C_{Tc,3} \qquad (3.7\text{-}2)$$

Piston: $$(T_{max\ climb})_{ISA} = C_{Tc,1}\,(1 - h/C_{Tc,2}) + C_{Tc,3}/V_{TAS} \qquad (3.7\text{-}3)$$

For all engine types, the maximum climb thrust is corrected for temperature deviations from standard atmosphere, $\Delta T_{ISA}$ , in the following manner:

$$T_{max\ climb} = (T_{max\ climb})_{ISA}\,[1 - C_{Tc,5}\,(\Delta T_{ISA})_{eff}] \qquad (3.7\text{-}4)$$

where $$(\Delta T_{ISA})_{eff} = \Delta T_{ISA} - C_{Tc,4} \qquad (3.7\text{-}5)$$

with the limit: $$0.0 \leq (\Delta T_{ISA})_{eff} * C_{Tc,5} \leq 0.4 \qquad (3.7\text{-}6)$$

and: $$C_{Tc,5} \geq 0.0 \qquad (3.7\text{-}7)$$

### 3.7.2 Maximum Cruise Thrust

The normal cruise thrust is by definition set equal to drag (T = D). However, the amount of thrust that is available in cruise situations is limited. The maximum cruise thrust is calculated as a ratio of the maximum climb thrust given in section 3.7.1, that is:

$$(T_{cruise})_{max} = C_{Tcr} * T_{max\ climb} \quad (3.7\text{-}9)$$

The coefficient $C_{Tcr}$ is currently uniformly set to 0.95 for all aircraft.

### 3.7.3 Descent Thrust

Descent thrust is calculated similarly than cruise thrust with different correction factors used for high and low altitude and approach and landing configurations, that is:

if $h > h_{des}$

$$T_{des,\ high} = C_{Tdes,high} * T_{max\ climb} \quad (3.7\text{-}10)$$

if $h < h_{des}$

$$T_{des,low} = C_{Tdes,low} * T_{max\ climb} \quad (3.7\text{-}11)$$

Once the aircraft has descended below 8,000 ft it changes configuration as soon as the airspeed falls below a certain threshold (Section 3.5). At the same time the thrust setting is changed as well as detailed below:

if $h < 8{,}000$ ft and $V < Vmin_{Cruise} + 10$ kts

$$T_{des,app} = C_{Tdes,app} * T_{max\ climb} \quad (3.7\text{-}12)$$

if $h < 3{,}000$ ft and $V < Vmin_{Approach} + 10$ kts

$$T_{des,ld} = C_{Tdes,\ ld} * T_{max\ climb} \quad (3.7\text{-}13)$$

In case the $C_{Tdes,app}$ and $C_{Tdes,\ ld}$ are set to 0 (zero) in the OPF file, expression 3.7-11 must be used in all cases where $h < h_{des}$. For those models where non-clean data is available, $h_{des}$ cannot be below 8,000 ft. Note that the speeds (V) used during the descent, approach and landing phase are defined in Section 4.3.

## 3.8 Reduced Climb Power

The reduced climb power has been introduced to allow the simulation of climbs using less than the maximum climb setting. In day-to-day operations, many aircraft use a reduced setting during climb in order to extend engine life and save cost. The correction factors that are used to calculate the reduction in power have been obtained in an empirical way and have been validated with the help of air traffic controllers.

In BADA, climbs that are performed using the full climb power will result in profiles that match the reference data that is found in the Flight Manual of the aircraft. Climbs with reduced power will give a realistic profile.

$$C_{pow,\,red} = 1 - C_{red} * \{(m_{max} - m_{act}) / (m_{max} - m_{min})\} \quad (3.8\text{-}1)$$

The value of $C_{red}$ is a function of the aircraft type and is given in the BADA.GPF file (see Section 5.11).

Nevertheless:

If $h < (0.8*h_{max})$

$C_{red} = f$ (aircraft type) see Section 5.11

Else

$C_{red} = 1.0$ [dimensionless]

$C_{pow,\,red}$ is to be used in the following expression:

$$P = (T_{max,climb} - D) * V * C_{pow,\,red} \quad (3.8\text{-}2)$$

The power reduction is to be applied in the Initial Climb and Climb phases.

## 3.9 Fuel Consumption

The thrust specific fuel consumption, $\eta$ , in kg/minute/kN is specified as a function of true airspeed, $V_{TAS}$ (knots) for the jet and turboprop engines. The nominal fuel flow, $f_{nom}$ (kg/minute), can then be calculated using the thrust, T:

jet: $\eta = C_{f1} \, ( 1 + V_{TAS} / C_{f2} )$ (3.9-1)

with:

$f_{nom} = \eta * T$ (3.9-2)

turboprop: $\eta = C_{f1} \, (1 - V_{TAS} / C_{f2} )( V_{TAS} /1000)$ (3.9-3)

with:

$f_{nom} = \eta * T$ (3.9-4)

These expressions are used in all flight phases except during cruise and for descent/idle conditions.

Minimum fuel flow, $f_{min}$ , corresponding to idle thrust or descent conditions for both jets and turboprop engines is specified in kg/minute as a function of altitude above sea level, h (ft), that is:

jet/turboprop: $f_{min} = C_{f3} \, ( 1 - h / C_{f4} )$ (3.9-5)

Cruise fuel flow, $f_{cr}$ , is calculated using the thrust specific fuel consumption and a cruise fuel flow factor:

jet/turboprop: $f_{cr} = \eta * T * C_{fcr}$ (3.9-6)

For piston engines the fuel flow, f , in kg/minutes is specified to be a constant, that is,

piston: $f_{cr} = C_{f1} * C_{fcr}$ (cruise) (3.9-7)

$f_{min} = C_{f3}$ (idle/descent) (3.9-8)

$f_{nom} = C_{f1}$ (all other phases) (3.9-9)

For the moment the cruise fuel flow correction factor has been established for a number of aircraft. This factor has been set to 1 (one) for all the other aircraft models.

## 3.10 Ground Movement

Four values are specified that can be of use when simulating ground movements. These parameters are:

- TOL: - FAR Take-Off Length with MTOW on a dry, hard, level runway under ISA conditions and no wind [m].
- LDL: - FAR Landing Length with MLW on a dry, hard, level runway under ISA conditions and no wind [m].
- span: - Aircraft wingspan [m]
- length: - Aircraft length [m]

Note that currently the value of the MLW is not defined in BADA. Apart from these model specific parameters, there are also a number of groundspeeds defined as general parameters in the BADA.GPF file, see Section 5.10.

## 3.11 Summary of Operations Performance Parameters

A summary of the parameters specified by the BADA operations performance model is supplied in Table 3.11-1 below. This table excludes those parameters that have been set to zero.

**Table 3.11-1: BADA Operations Performance Parameter Summary**

| Model Category | Symbols | Units | Description |
|---|---|---|---|
| aircraft type (3 values) | $n_{eng}$<br>engine type<br>wake category | dimensionless<br>string<br>string | number of engines<br>either Jet, Turboprop or Piston<br>either H (heavy), M (medium) or L (light) |
| mass (4 values) | $m_{ref}$<br>$m_{min}$<br>$m_{max}$<br>$m_{pyld}$ | tonnes<br>tonnes<br>tonnes<br>tonnes | reference mass<br>minimum mass<br>maximum mass<br>maximum payload mass |
| flight envelope (6 values) | $V_{MO}$<br>$M_{MO}$<br>$h_{MO}$<br>$h_{max}$<br>$G_w$<br>$G_t$ | knots (CAS)<br>dimensionless<br>feet<br>feet<br>feet/kg<br>feet/C | maximum operating speed<br>maximum operating Mach number<br>maximum operating altitude<br>maximum altitude at MTOW and ISA weight gradient on maximum altitude temperature gradient on maximum altitude |
| Aerodynamics (14 values)<br>(16 values for jet aircraft ) | S<br>$C_{D0,CR}$<br>$C_{D2,CR}$<br>$C_{D0,AP}$<br>$C_{D2,AP}$<br>$C_{D0,LD}$<br>$C_{D2,LD}$<br>$C_{D0,\Delta LDG}$<br>$C_{M16}$<br>$(V_{stall})_i$<br>$C_{Lbo(M=0)}$<br>K | $m^2$<br>dimensionless<br>dimensionless<br>dimensionless<br>dimensionless<br>dimensionless<br>dimensionless<br>dimensionless<br>dimensionless<br>knots (CAS)<br>dimensionless<br>[1/M] | reference wing surface area<br>parasitic drag coefficient (cruise)<br>induced drag coefficient (cruise)<br>parasitic drag coefficient (approach)<br>induced drag coefficient (approach)<br>parasitic drag coefficient (landing)<br>induced drag coefficient (landing)<br>parasite drag coef. (landing gear)<br>Mach drag coefficient<br>stall speed [TO, IC, CR, AP, LD]<br>Buffet onset lift coef. (jet only)<br>Buffeting gradient (jet only) |

**Table 3.11-1: BADA Operations Performance Parameter Summary (continued)**

| Model Category | Symbols | Units | Description |
|---|---|---|---|
| engine thrust (12 values) | $C_{Tc,1}$ | Newton (jet/piston)<br>knot-Newton (turboprop) | 1st max. climb thrust coefficient |
| | $C_{Tc,2}$ | feet | 2nd max climb thrust coefficient |
| | $C_{Tc3,}$ | 1/feet$^2$ (jet)<br>Newton (turboprop)<br>knot-Newton (piston) | 3rd max. climb thrust coefficient |
| | $C_{Tc,4}$ | deg. C | 1st thrust temperature coefficient |
| | $C_{Tc,5}$ | 1/ deg. C | 2nd thrust temperature coefficient |
| | $C_{Tdes,low}$ | dimensionless | low altitude descent thrust coefficient |
| | $C_{Tdes,high}$ | dimensionless | high altitude descent thrust coefficient |
| | $h_{des}$ | feet | transition altitude for calculation of descent thrust |
| | $C_{Tdes, app}$ | dimensionless | approach thrust coefficient |
| | $C_{Tdes,ld}$ | dimensionless | landing thrust coefficient |
| | $V_{des,ref}$ | knots | reference descent speed (CAS) |
| | $M_{des,ref}$ | dimensionless | reference descent Mach number |
| fuel flow (5 values) | $C_{f1}$ | kg/min/kN (jet)<br>kg/min/kN/knot (turboprop)<br>kg/min (piston) | 1st thrust specific fuel consumption coefficient |
| | $C_{f2}$ | knots | 2nd thrust specific fuel consumption coefficient |
| | $C_{f3}$ | kg/min | 1st descent fuel flow coefficient |
| | $C_{f4}$ | feet | 2nd descent fuel flow coefficient |
| | $C_{fcr}$ | dimensionless | Cruise fuel flow correction coefficient |

**Table 3.11-1: BADA Operations Performance Parameter Summary (continued)**

| | | | |
|---|---|---|---|
| ground movement (4 values) | TOL | m | take-off length |
| | LDL | m | landing length |
| | span | m | wingspan |
| | length | m | length |

The total number of BADA performance coefficients summarised in the above table is 51.

# 4. AIRLINE PROCEDURE MODELS

This section defines the standard airline procedures, which are parameterised by the BADA procedure models. Three separate flight phases are considered:

- climb
- cruise
- descent

Each of these phases is described in the subsections below. Note that $C_{Vmin}$ in the sections below always has the value of 1.3 unless the aircraft is in the take-off phase (below 400 ft) in which case the value is 1.2 (see also Section 5.7).

## 4.1 Climb

The following parameters are defined for each aircraft type to characterise the climb phase:

$V_{cl,1}$ - standard climb CAS (knots) between 1,500 / 6,000 and 10,000 ft

$V_{cl,2}$ - standard climb CAS (knots) between 10,000 ft and Mach transition altitude

$M_{cl}$ - standard climb Mach number above transition altitude

Note that the Mach transition altitude is defined to be the altitude where a CAS value corresponding to $V_{cl,2}$ results in a Mach number of $M_{cl}$. That is, $M_{cl}$ imposes an upper limit on the Mach number during climb.

For jet aircraft the following CAS schedule is assumed, based on the parameters metioned above and the take-off stall speed:

| | | |
|---|---|---|
| from 0 to 1,499 ft | $C_{Vmin}*(V_{stall})_{TO} + Vd_{CL,1}$ | (4.1-1) |
| from 1,500 to 2,999 ft | $C_{Vmin}*(V_{stall})_{TO} + Vd_{CL,2}$ | (4.1-2) |
| from 3,000 to 3,999 ft | $C_{Vmin}*(V_{stall})_{TO} + Vd_{CL,3}$ | (4.1-3) |
| from 4,000 to 4,999 ft | $C_{Vmin}*(V_{stall})_{TO} + Vd_{CL,4}$ | (4.1-4) |
| from 5,000 to 5,999 ft | $C_{Vmin}*(V_{stall})_{TO} + Vd_{CL,5}$ | (4.1-5) |
| from 6,000 to 9,999 ft | $\min(V_{cl,1}, 250\text{ kt})$ | |
| from 10,000 ft to transition | $V_{cl,2}$ | |
| above transition | $M_{cl}$ | |

For turboprop and piston aircraft the following CAS schedule is assumed:

| | | |
|---|---|---|
| from 0 to 499 ft | $C_{Vmin} * (V_{stall})_{TO} + Vd_{CL,6}$ | (4.1-6) |
| from 500 to 999 ft | $C_{Vmin} * (V_{stall})_{TO} + Vd_{CL,7}$ | (4.1-7) |
| from 1,000 to 1,499 ft | $C_{Vmin} * (V_{stall})_{TO} + Vd_{CL,8}$ | (4.1-8) |
| from 1,500 to 9,999 ft | min ( $V_{cl,1}$ , 250 kt ) | |
| from 10,000 ft to transition | $V_{cl,2}$ | |
| above transition | $M_{cl}$ | |

The take-off stall speed, $(V_{stall})_{TO}$ , must be corrected for the difference in aircraft mass from the reference mass using the formula as described in Section 3.4. The values for $Vd_{CL}$ can be found in Section 5.

Also, the transition altitude, $h_{trans}$, in feet for a given $V_{CAS}$ (in m/s), and Mach number, M, can be calculated as follows:

$$h_{trans} = \left(\frac{1000}{(.3048)\cdot(6.5)}\right)\cdot\left[T_0\cdot\left(1-\theta_{trans}\right)\right] \qquad (4.1\text{-}9)$$

where,

$T_0$ is the temperature at sea level in Kelvin,

$(T_0)_{ISA}$ is the ISA temperature at sea level = 288.15 K,

$\theta_{trans}$ is the temperature ratio at the transition altitude,

$$\theta_{trans} = (\delta_{trans})^{0.1903} \qquad (4.1\text{-}10)$$

$\delta_{trans}$ is the pressure ratio at the transition altitude,

$$\delta_{trans} = \frac{\left[1+\left(\frac{\gamma-1}{2}\right)\left(\frac{V_{CAS}}{(a_0)_{ISA}}\right)^2\right]^{\frac{\gamma}{\gamma-1}}-1}{\left[1+\frac{\gamma-1}{2}M^2\right]^{\frac{\gamma}{\gamma-1}}-1} \qquad (4.1\text{-}11)$$

$(a_0)_{ISA}$ is the ISA speed of sound at sea level = 340.29 $m.s^{-1}$

## 4.2 Cruise

The following parameters are defined for each aircraft type to characterise the cruise phase:

$V_{cr,1}$ - standard cruise CAS (knots) between 3,000 and 10,000 feet

$V_{cr,2}$ - standard cruise CAS (knots) above 10,000 ft until Mach transition altitude

$M_{cr}$ - standard cruise Mach number above transition altitude

For jet aircraft the following CAS schedule is assumed:

| | |
|---|---|
| from 0 to 3,000 ft | 170 kt |
| from 3,000 to 6,000 ft | min ( $V_{cr1}$ , 220 kt ) |
| from 6,000 to 14,000 ft | min ( $V_{cr1}$ , 250 kt ) |
| from 14,000 to transition | $V_{cr2}$ |
| above transition | $M_{cr}$ |

For turboprop aircraft the following CAS schedule is assumed:

| | |
|---|---|
| from 0 to 3,000 ft | 150 kt |
| from 3,000 to 6,000 ft | min ( $V_{cr1}$ , 180 ft ) |
| from 6,000 to 10,000 ft | min ( $V_{cr1}$ , 250 kt ) |
| from 10,000 to transition | $V_{cr2}$ |
| above transition | $M_{cr}$ |

## 4.3 Descent

The following parameters are defined for each aircraft type to characterise the descent phase:

$V_{des,1}$ - standard descent CAS (knots) between 3,000 / 6,000 and 10,000 ft

$V_{des,2}$ - standard descent CAS (knots) above 10,000 ft until Mach transition

$M_{des}$ - standard descent Mach number above transition altitude

For jet and turboprop aircraft the following CAS schedule is assumed, based on the above parameters and the landing stall speed:

| | | |
|---|---|---|
| from 0 to 999 ft | $C_{Vmin}*(V_{stall})_{LD} + Vd_{DES,1}$ | (4.3-1) |
| from 1,000 to 1,499 ft | $C_{Vmin}*(V_{stall})_{LD} + Vd_{DES,2}$ | (4.3-2) |
| from 1,500 to 1,999 ft | $C_{Vmin}*(V_{stall})_{LD} + Vd_{DES,3}$ | (4.3-3) |
| from 2,000 to 2,999 ft | $C_{Vmin}*(V_{stall})_{LD} + Vd_{DES,4}$ | (4.3-4) |
| from 3,000 to 5,999 ft | MIN ($V_{des,1}$ , 220) | (4.3-5) |
| from 6,000 to 9,999 ft | MIN ($V_{des,1}$ , 250) | (4.3-6) |
| above 10,000 ft to transition | $V_{des,2}$ | |
| above transition | $M_{des}$ | |

For piston aircraft the following CAS schedule is assumed:

| | | |
|---|---|---|
| from 0 to 499 ft | $C_{Vmin}*(V_{stall})_{LD} + Vd_{DES,7}$ | (4.3-7) |
| from 500 to 999 ft | $C_{Vmin}*(V_{stall})_{LD} + Vd_{DES,8}$ | (4.3-8) |
| from 1000 to 1,499 ft | $C_{Vmin}*(V_{stall})_{LD} + Vd_{DES,9}$ | (4.3-9) |
| above 1,500 ft to 9,999 ft | $V_{des,1}$ | |
| above 10,000 ft to transition | $V_{des,2}$ | |
| above transition | $M_{des}$ | |

The landing stall speed, $(V_{stall})_{LD}$ , must be corrected for the difference in aircraft mass from the reference mass using formula 3.4-1. The values for $Vd_{DES,}$ can be found in Section 5.

# 5 GLOBAL AIRCRAFT PARAMETERS

## 5.1 Introduction

A number of parameters that have been described in Section 3 (Operations Performance Model) and Section 4 (Airline Procedure Model) have values that are independent of the aircraft type or model for which they are used. The values of these and other parameters that up to BADA 2.4 were hard-coded in the aircraft navigator (MASS at the EEC), have been put in the General Parameters File (BADA.GPF). This increases the flexibility and allows an easier evaluation of the values that are used.

The next section gives an overview of the parameters that are defined in the Global Parameters File. If relevant, it also indicates the formula in which the parameter should be used.

## 5.2 Maximum Acceleration

Maximum acceleration parameters are used to limit the increment in TAS (longitudinal) or ROCD (normal). 2 parameters are defined:

| **Name:** | **Description:** | **Value [fps$^2$]:** |
|---|---|---|
| $a_{l,\ max\ (civ)}$ | maximum longitudinal acceleration for civil flights | 2.0 |
| $a_{n,\ max\ (civ)}$ | maximum normal acceleration for civil flights | 5.0 |

The two acceleration limits are to be used in the following way:

longitudinal acceleration: $$| V_k - V_{k-1} | \leq a_{l\ max\ (civ)} \Delta t \qquad (5.2\text{-}1)$$

normal acceleration: $$| \gamma_k - \gamma_{k-1} | \leq \frac{a_{n\ max\ (civ)} \Delta t}{V} \qquad (5.2\text{-}2)$$

where,

$$\gamma = \sin^{-1}\left(\frac{\dot{h}}{V}\right) \qquad (5.2\text{-}3)$$

and,

| | |
|---|---|
| $\gamma$ | is the climb/descent angle, |
| V | is the True Air Speed, |
| k, k-1 | indicates values at update intervals k and k-1,and, |
| $\Delta t$ | is the time interval between k and k-1 |

The values for $a_{l,\ max\ (mil)}$ (maximum longitudinal acceleration for military flights) and $a_{n,\ max\ (mil)}$ (maximum normal acceleration for military flights) are currently undefined.

## 5.3 Bank Angles

Nominal and maximum bank angles are defined separately for military and civil flights. These bank angles can be used to calculate nominal and maximum rate of turns.

| Name: | Description: | Value [degr.]: |
|---|---|---|
| $\phi_{nom, civ (TO, LD)}$ | Nominal bank angles for civil flight during TO and LD | 15 |
| $\phi_{nom, civ (OTHERS)}$ | Nominal bank angles for civil flight during all other phases | 35 |
| $\phi_{nom, mil}$ | Nominal bank angles for military flight (all phases) | 50 |
| $\phi_{max, civ (TO, LD)}$ | Maximum bank angles for civil flight during TO and LD | 25 |
| $\phi_{max, civ (HOLD)}$ | Maximum bank angles for civil flight during HOLD | 30 |
| $\phi_{max, civ (OTHERS)}$ | Maximum bank angles for civil flight during all other phases | 45 |
| $\phi_{max, mil}$ | Maximum bank angles for military flight (all phases) | 70 |

The rate of turn ( $\dot{\varphi}$ ) is calculated as a function of bank angle: $\dot{\varphi} = (g / V_{TAS})*\tan(\phi)$ (5.3-1)

## 5.4 Expedited Descent

The expedited descent factor is to be used as a drag increment during expedited descents:

| Name: | Description: | Value [ - ]: |
|---|---|---|
| $C_{des, exp}$ | Expedited descent factor | 1.6 |

The drag during an expedited descent is calculated using the nominal drag (see 3.6-2):

$$D_{des, exp} = C_{des, exp} * D_{nom} \quad (5.4\text{-}1)$$

## 5.5 Thrust Factors

Maximum take-off and maximum cruise thrust factors have been specified. These factors are to be used in expressions 3.7-8 and 3.7-9, respectively:

| Name: | Description: | Value [ - ]: |
|---|---|---|
| $C_{Th , to}$ | Take-off thrust coefficient | 1.2 |
| $C_{Th , cr}$ | Maximum cruise thrust coefficient | 0.95 |

## 5.6 Configuration Altitude Threshold

For 4 configurations, altitude thresholds have been specified in BADA: take-off (TO) and initial climb (IC). Note that the selection of the approach and landing configurations is done through the use of air speed (see Section 3.5) but the altitudes at which this takes place should not be higher than the ones mentioned below.

| **Name:** | **Description:** | **Value [ ft ]:** |
|---|---|---|
| $H_{max, TO}$ | Maximum altitude threshold for take-off | 400 |
| $H_{max, IC}$ | Maximum altitude threshold for initial climb | 2,000 |
| $H_{max, AP}$ | Maximum altitude threshold for approach | 8,000 |
| $H_{max, LD}$ | Maximum altitude threshold for landing | 3,000 |

## 5.7 Minimum Speed Coefficients

Two minimum speed coefficients are specified, which are to be used in expressions 3.5-2 and 3.5-3 and in Section 4.1, 4.2 and 4.3:

| **Name:** | **Description:** | **Value [ - ]:** |
|---|---|---|
| $C_{Vmin, TO}$ | Minimum speed coefficient for take-off | 1.2 |
| $C_{Vmin}$ | Minimum speed coefficient (all other phases) | 1.3 |

## 5.8 Speed Schedules

The speed schedules for climb and descent are based on a factored stall speed plus increment valid for a specified altitude range:

| **Name:** | **Description:** | **Value[KCAS]:** |
|---|---|---|
| $Vd_{CL, 1}$ | Climb speed increment below 1500 ft (jet) | 5 |
| $Vd_{CL, 2}$ | Climb speed increment below 3000 ft (jet) | 10 |
| $Vd_{CL, 3}$ | Climb speed increment below 4000 ft (jet) | 30 |
| $Vd_{CL, 4}$ | Climb speed increment below 5000 ft (jet) | 60 |
| $Vd_{CL, 5}$ | Climb speed increment below 6000 ft (jet) | 80 |
| $Vd_{CL, 6}$ | Climb speed increment below 500 ft (turbo/piston) | 20 |
| $Vd_{CL, 7}$ | Climb speed increment below 1000 ft (turbo/piston) | 30 |
| $Vd_{CL, 8}$ | Climb speed increment below 1500 ft (turbo/piston) | 35 |
| $Vd_{DES, 1}$ | Descent speed increment below 1000 ft (jet/turboprop) | 5 |
| $Vd_{DES, 2}$ | Descent speed increment below 1500 ft (jet/turboprop) | 10 |
| $Vd_{DES, 3}$ | Descent speed increment below 2000 ft (jet/turboprop) | 20 |
| $Vd_{DES, 4}$ | Descent speed increment below 3000 ft (jet/turboprop) | 50 |
| $Vd_{DES, 5}$ | Descent speed increment below 500 ft (piston) | 5 |
| $Vd_{DES, 6}$ | Descent speed increment below 1000 ft (piston) | 10 |
| $Vd_{DES, 7}$ | Descent speed increment below 1500 ft (piston) | 20 |

These values are to be used in the expressions in Section 4.1, 4.2 and 4.3

## 5.9 Holding Speeds

The holding speeds that are to be used to calculate holding areas are defined according to the ICAO standards:

| **Name:** | **Description:** | **Value[KCAS]:** |
|---|---|---|
| $V_{hold, 1}$ | Holding speed below FL140 | 230 |
| $V_{hold, 2}$ | Holding speed between FL140 and FL200 | 240 |
| $V_{hold, 3}$ | Holding speed between FL200 and FL340 | 265 |
| $V_{hold, 4}$ | Holding speed above FL340 [ Mach] | 0.83 |

Note that the holding speeds that are used by individual aircraft may vary between types.

## 5.10 Ground Speeds

A number of ground speeds are defined for the simulation of ground movement. For the moment, no distinction between aircraft type or engine type is made. The following speeds have been defined:

| **Name:** | **Description:** | **Value[KCAS]:** |
|---|---|---|
| $V_{backtrack}$ | Runway backtrack speed | 35 |
| $V_{taxi}$ | Taxi speed | 15 |
| $V_{apron}$ | Apron speed | 10 |
| $V_{gate}$ | Gate speed | 5 |

The runway backtrack speed is the speed the aircraft will maintain when it backtracks across the runway. The taxi speed is used anywhere between the runway and the apron area. The apron speed is used in the apron area while the gate speed is used for all manouevering between the gate position and the apron.

## 5.11 Reduced Power Coefficient

The reduced power coefficients are defined for the three different engine types. Within the jet engines a further distinction is made between MTOWs. It is stressed that the values given below where found in an empirical way and have been validated with the help of air traffic controllers:

| **Name:** | **Description:** | **Value[ - ]:** |
|---|---|---|
| $C_{red,turbo}$ | Maximum reduction in power for turboprops | 0.25 |
| $C_{red,piston}$ | Maximum reduction in power for pistons | 0.0 |
| $C_{red,jet}$ | Maximum reduction in power for jets | 0.15 |

The coefficients should be used in Formula 3.8-1.

# 6. FILE STRUCTURE

## 6.1 File Types

All data provided by BADA Revision 3.1 is organised into five types of files:

- two Synonym Files,
- a set of Operations Performance Files,
- a set of Airline Procedure Files,
- a set of Performance Table Files, and,
- a Global Parameter File

The two Synonym Files have the names:

SYNONYM.LST
SYNONYM.NEW

Both files provide a list of all the aircraft types which are supported by BADA and indicate whether the aircraft type is supported directly (through provision of parameters in other files) or supported by equivalence (through indicating an equivalent aircraft type that is supported directly). The only difference between these two files is their formats, which are described in Section 6.3.

There is one Operations Performance File (OPF) provided for each aircraft type which is directly supported. This file specifies parameter values for the mass, flight envelope, drag, engine thrust and fuel consumption that are described in Section 3. Details on the format of the OPF file are given in Section 6.4.

There is one Airline Procedures File (APF) for each directly supported aircraft type. This file specifies the nominal manoeuvre speeds that are described in Section 4. Details on the format of the APF file are given in Section 6.5.

There is also one Performance Table File (PTF) for each directly supported aircraft type. This file contains a summary table of speeds, climb/descent rates and fuel consumption at various flight levels. Details on the format of the PTF file are given in Section 6.6.

Finally there is one Global Parameter File which is named BADA.GPF. This file contains parameters that are described in Section 5 and are valid for all aircraft or a group of aircraft (for instance all civil flights or all jet aircraft). Details on the format of the GPF file are given in Section 6.7.

The names of the OPF, APF and PTF files are based on the ICAO designation code for the aircraft type. With the one exception of the generic military fighter aircraft type (FGTR), this code is the same as the International Civil Aviation Organisation (ICAO) designator code for the aircraft type [RD2]. That is:

Operations Performance File name: <ICAO_code>__.OPF

Airline Procedures File name: <ICAO_code>__.APF

Performance Table File name: <ICAO_code>__.PTF

Note that there are at least two underscore characters between the ICAO code and the file extension such that the length of the file name without the extension is six characters. Most ICAO codes are four characters in length and thus have two underscore characters. Some ICAO codes, however, can be shorter (e.g. DC9) and thus require more underscore characters. For example, an Airbus 310 which has the ICAO code of A310 is represented in BADA 3.1 by the following files:

Operations Performance File: A310__.OPF

Airline Procedures File: A310__.APF

Performance Table File: A310__.PTF

The McDonnell-Douglas DC-9, which has the ICAO code of DC9 is represented in BADA 3.1 by the following files:

Operations Performance File: DC9___.OPF

Airline Procedures File: DC9___.APF

Performance Table File: DC9___.PTF

All files belonging to BADA Revision 3.1, that is the Synonym Files, the GPF file and all APF and OPF files are controlled within a configuration management system. This system is described in Section 6.2.

## 6.2 File Configuration Management

The BADA Synonym File and all APF and OPF files are placed under configuration management at the EEC using the UNIX-based Revision Control System (RCS). The specific procedures used for configuration management are specified in the BADA Configuration Management Manual [RD5].

The PTF files are not placed under the Revision Control System since these files are generated automatically from the OPF and APF files. The file version numbers of the OPF and APF file that were used for the calculation being are in the PTF file. Integrity of the PTF files is however traced through the recording of checksums.

Under the BADA configuration management system, users have access to the following files:

- a Revision Summary File listing all APF, OPF and PTF files contained in the revision
- the two Synonym Files
- the GPF file
- all APF, OPF and PTF files
- all RCS files corresponding to the APF and OPF files.

Detailed instructions for remote access of the files is given in Section 7.

### 6.2.1 Revision Summary File

The Revision Summary File provides a list of all files provided as part of the BADA Revision. The name of the Revision Summary File is simply:

revisionSummary

A copy of the Revision Summary file for BADA Revision 3.1 is included in this document as Appendix A.

The Revision Summary File lists for each file the last modification date, size in bytes and checksum.

The checksum provides a useful means to ensure that a file has not been inadvertently modified. To verify a checksum, the UNIX command **cksum** is used on the file. The first number returned is the checksum and should match the value specified in the Revision Summary File.

### 6.2.2 Revision Numbers

All BADA Revisions are identified by a two digit number, e.g. 2.0 or 2.1. All files belonging to the BADA Revision have a file revision number, which is the same as the BADA revision number.

Between releases of successive BADA Revisions, the contents of various files may be updated due to correction of coefficients, removal of excess information or addition of new information. In this case the modified file revision number is updated to a four digital number, for example:

2.1.1.3

The first two digits of the modified file revision number are the same as the last BADA Revision number in which the file was released. The third digit is always 1. The fourth digit is incremented by 1 for each successive modification of a file. It is recognised that the third digit is not necessary. This digit, however, is included for consistency with RCS numbering conventions.

Thus, if a file is modified twice between revision 2.1 and 2.2, the file revision number will undergo the following evolution:

| | |
|---|---|
| 2.1 | - initial file revision in BADA Revision 2.1 |
| 2.1.1.1 | - first modification |
| 2.1.1.2 | - second modification |
| 2.2 | - file released in BADA Revision 2.2, identical to 2.1.1.2. |

In the Revision Summary File, the last modification date will then reflect the date on which revision 2.1.1.2 was made.

### 6.2.3 RCS Files

RCS files are files organised in a format internal to RCS which allows for the tracking of all modifications to a file.

The RCS files corresponding to the Synonym Files, GPF files or each APF or OPF file are named with a ",v" extension. For example the RCS files corresponding to B74A__.OPF is:

B74A__.OPF,v

These files are provided to BADA users for information purposes. The use of standard UNIX/RCS utilities such as **rlog** and **co** on these files allows for information on the file modifications to be recovered along with previous file revisions. Instructions on the use of **rlog** and **co** can be obtained from UNIX manuals.

## 6.3 Synonym File Format

### 6.3.1 SYNONYM.LST File

The SYNONYM.LST file is an ASCII file which lists all aircraft types which are supported by the BADA revision. An example of the SYNONYM.LST file is given below (partial listing).

```
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC SYNONYM.LST CCCCCCCCCCCC/
CC                                                                  /
CC                BADA SYNONYM FILE                                 /
CC                                                                  /
CC     BADA RCS File Id                                             /
CC    File Name        Current Revision      Last Modification      /
CC                     revision    date      revision     date      /
CC    SYNONYM.LST          3.1 98/09/14    3.0.1.2    98/06/12      /
CC                                                                  /
CC   BADA Revision:                                                 /
CC                                                                  /
CD   Rev  3.1                                                       /
CC====== Aircraft List =============================================/
CC                                                                  /
CC   A/C    NAME OR MODEL        FILE                SYNONYMS       /
CC   CODE                                                           /
CC                                                                  /
 - A300__  AIRBUS A300          A300__              A300   IL76
 - A310__  AIRBUS A310          A310__              A310
 - A320__  AIRBUS A320          A320__              A320
 - A330__  AIRBUS A330          A330__              A330
 - A340__  AIRBUS A340          A340__              A340
 - ATP___  BAE ADVANCED         ATP___              ATP
           TURBOPROP
 - ATR___  ATR 42/72            ATR___              ATR    CN35   CVLT
 - B707__  BOEING 707-300/400   B707__              B707   C135   E3
           SERIES                                   IL62   VC10
                                                    B720
 - B727__  BOEING 727,ALL SE-   B727__              B727
           RIES
```

There are three types of lines in the SYNONYM.LST file with the line type identified by the first two characters in the line. These line types with their associated leading characters are listed below.

| | |
|---|---|
| CC | comment line |
| CD | data line |
| - | synonym line |

The data is organised into a two blocks separated by a comment line consisting of equal signs "=":

- file identification block

- aircraft list block

Each of these blocks is described in the subsections below.

### 6.3.1.1 File Identification Block

The file identification block provides information on the file name, revision number and modification date. The block consists of 11 comment lines and one data line.

```
        CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC SYNONYM.LST CCCCCCCCCCCC/
        CC                                                                  /
        CC                BADA SYNONYM FILE                                 /
        CC                                                                  /
        CC     BADA RCS File Id                                             /
        CC    File Name        Current Revision      Last Modification      /
        CC                     revision    date      revision     date      /
        CC    SYNONYM.LST          3.1 98/09/14    3.0.1.2    98/06/12    /
        CC                                                                  /
        CC   BADA Revision:                                                 /
        CC                                                                  /
1 ->    CD   Rev  3.1                                                       /
```

The comment lines specify the file name along with the RCS current revision and last modification revision. For all released files, the current revision number and date will be the same as the number and date of the BADA Revision. The last modification revision number and date indicate when the contents of the file were last modified.

The data line gives the BADA Revision Id to which the file belongs. This value is specified in the following fixed format (Fortran notation):

‘CD’, 8X, F3.1

### 6.3.1.2 Aircraft Listing Block

The aircraft listing block consists of 5 comment lines with additional synonym lines for each aircraft supported by the BADA Revision. A partial listing of this block is shown below.

```
        CC====== Aircraft List ==============================================/
        CC                                                                   /
        CC   A/C    NAME OR MODEL        FILE              SYNONYMS          /
        CC   CODE                                                            /
        CC                                                                   /
1 ->     - A300__  AIRBUS A300          A300__              A300   IL76
         - A310__  AIRBUS A310          A310__              A310
         - A320__  AIRBUS A320          A320__              A320
         - A330__  AIRBUS A330          A330__              A330
         - A340__  AIRBUS A340          A340__              A340
         - ATP___  BAE ADVANCED         ATP___              ATP
                   TURBOPROP
         - ATR___  ATR 42/72            ATR___              ATR    CN35   CVLT
         - B707__  BOEING 707-300/400   B707__              B707   C135   E3
                   SERIES                                   IL62   VC10
                                                            B720
```

There is one synonym line for each of the directly supported aircraft within the BADA release. Each such line consists of 4 fields as described below:

(a) Aircraft Code Field

This field identifies the aircraft type. It consists of a three or four-character ICAO code followed by two or more underscore characters.

(b) Name or Model Field

This field identifies the manufacturer and model of the aircraft.

(c) File Name Field

This field identifies the file name for the APF, OPF or PTF files associated with the aircraft (minus the file extension). For each aircraft this is the same as the A/C code.

(d) Equivalence Field

This field lists any equivalences associated with the aircraft. By default, each aircraft has at least one equivalence to itself.

Note that in some cases the name or model or equivalence fields may be continued onto the next line as it is the case with the B707 model.

### 6.3.2 SYNONYM.NEW File

The SYNONYM.NEW file is an ASCII file, which lists all aircraft types, which are supported by the BADA revision. Its format differs from the SYNONYM.LST file in that all supported aircraft are listed alphabetically in the file whether they are supported directly or by equivalence. An example of the SYNONYM.NEW file is given below (partial listing).

```
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC SYNONYM.NEW CCCCCCCCCCCC/
CC                                                                    /
CC                BADA SYNONYM FILE                                   /
CC                                                                    /
CC     BADA RCS File Id                                               /
CC     File Name        Current Revision      Last Modification       /
CC                      revision    date      revision     date       /
CC     SYNONYM.NEW          3.1   98/09/14    3.0.1.2    98/06/12     /
CC                                                                    /
CC   BADA Revision:                                                   /
CC                                                                    /
CD   Rev  3.1                                                         /
CC====== Aircraft List ===============================================/
CC                                                                    /
CC   A/C    MANUFACTURER        NAME OR MODEL             FILE   OLD  /
CC   CODE                                                        CODE /
CC                                                                    /
CD * A10    FAIRCHILD          THUNDERBOLT II           FGTR__  A10A /
CD - A300   AIRBUS             A300                     A300__  EA30 /
CD - A310   AIRBUS             A310                     A310__  EA31 /
CD - A320   AIRBUS             A320                     A320__  EA32 /
CD - A330   AIRBUS             A330                     A330__  EA33 /
CD - A340   AIRBUS             A340                     A340__  EA34 /
CD * A4     MCDONNELL-DOUGLAS  SKYHAWK                  FGTR__  A4   /
CD * A6     GRUMMAN            INTRUDER                 FGTR__  A6   /
CD * AC6T   ROCKWELL           TURBO COMMANDER          BE20__  AC6T /
CD * AN12   ANTONOV            AN-12                    C130__  AN12 /
CD * AN24   ANTONOV            AN-24                    F27___  AN24 /
CD * AN26   ANTONOV            AN-26                    F27___  AN26 /
CD - ATP    BAE                ADVANCED TURBOPROP       ATP___  BATP /
CD - ATR    ATR                ATR 42/72                ATR___  AT42 /
CD - ATR    ATR                ATR 42/72                ATR___  AT72 /
CD - B707   BOEING             707-300/400              B707__  B707 /
CD * B720   BOEING             720B                     B707__  B72S /
CD - B727   BOEING             727, ALL SERIES          B727__  B727 /
```

There are three types of lines in the SYNONYM.NEW file with the line type identified by the first two characters in the line. These line types with their associated two leading characters are listed below.

CC comment line

CD data line

FI end-of-file line

The data is organised into a two blocks separated by a comment line consisting of equal signs "=":

- file identification block
- aircraft list block

Each of these blocks is described in the subsections below.

#### 6.3.2.1 File Identification Block

The file identification block provides information on the file name, revision number and modification date. The block consists of 1 data line with 11 comment lines for a total of 12 lines as shown below.

```
        CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC SYNONYM.NEW CCCCCCCCCCCC/
        CC                                                                  /
        CC                BADA SYNONYM FILE                                 /
        CC                                                                  /
        CC     BADA RCS File Id                                             /
        CC    File Name        Current Revision      Last Modification      /
        CC                     revision    date      revision     date      /
        CC    SYNONYM.NEW          3.1   98/09/14    3.0.1.2    98/06/12    /
        CC                                                                  /
        CC   BADA Revision:                                                 /
        CC                                                                  /
1 ->    CD   Rev  3.1                                                       /
```

The only data line gives the BADA Revision Id to which the file belongs. This value is specified in the following fixed format (Fortran notation):

'CD', 8X, F3.1

The comment lines specify the file name along with the RCS current revision and last modification revision. For all released files, the current revision number and date will be the same as the number and date of the BADA Revision. The last modification revision number and date indicate when the contents of the file were last modified.

#### 6.3.2.2 Aircraft Listing Block

The aircraft listing block consists of 5 comment lines and at least one data line for each aircraft supported by the BADA Revision. Some aircraft have more than one data line, see under (f). A partial listing of this block is shown below.

```
CD - A330   AIRBUS             A330                      A330__  EA33 /
CD - A340   AIRBUS             A340                      A340__  EA34 /
CD * A4     MCDONNELL-DOUGLAS  SKYHAWK                   FGTR__  A4   /
CD * A6     GRUMMAN            INTRUDER                  FGTR__  A6   /
```

Each data line consists of 5 fields as described below:

(a) Support Type Field

This field is one character in length being one of the following two values:

"-" to indicate an aircraft type directly supported, and,
"*" to indicate an aircraft type supported by equivalence with another directly supported aircraft

(b) Aircraft Code Field

This field identifies the aircraft type. It consists of a three or four-character ICAO code.

(c) Manufacturer Field

This field identifies the manufacturer of the aircraft. Examples are Boeing, Airbus or Fokker.

(d) Name or Model Field

This field identifies the name or model for the aircraft type. Examples are the 747-400 series or Learjet 35.

(e) File Field

This field indicates the name of the OPF, APF or PTF file, which contains the parameters for the aircraft type (minus the file extension).

For an aircraft type which is directly supported this file name will be the same as the ICAO code with an additional two or more underscore characters to form a string of six characters in length. For example, the file name corresponding to the B707 will be B707__. This indicates an OPF file B707__.OPF, an APF file B707__.APF and a PTF file B707__.PTF. For the Fokker F-27 with an ICAO code of F27, the file names include three underscore characters, that is, F27___.OPF, F27___.APF and F27___.PTF.

For an aircraft type which is supported through an equivalence the file name will indicate the file for the equivalent aircraft type which should be used. As an example, the Antonov 12 (AN12) is equivalenced to the Lockheed C-130 Hercules (C130). Thus the files C130__.OPF, C130__.APF and C130__.PTF should be used.

(f) Old Code field

The old code field gives the name of the aircraft under the old ICAO standard (doc. 8643/24) [RD10]. This allows the BADA 3.1 user to continue to use the old standard and to establish a link between the old and the new aircraft designators. For this reason some aircraft types now appear more than once (ATR, B73B and DHC8) because under the old standard these aircraft were covered by more than one designator (e.g. ATR used to be AT42 and AT72).

The above fields are specified in the following fixed format (Fortran notation):

'CD', 1X, A1, 1X, A4, 3X, A18, 1X, A25, 1X, A6, 2X, A4

## 6.4 OPF File Format

The Operations Performance File (OPF) is an ASCII fil, which for a particular aircraft type specifies the operations performance parameters described in Section 3. An example of an OPF file for the A320 (Airbus 320) aircraft is shown below.

```
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC A320__.OPF CCCCCCCCCCCCCC/
CC                                                                      /
CC                AIRCRAFT PERFORMANCE                                  /
CC                operational    files                                  /
CC                                                                      /
CC      BADA RCS File Id                                                /
CC     File Name        Current Revision      Last Modification         /
CC                      revision    date      revision     date         /
CC     A320__.OPF       3.1.1.4   98/09/23    3.1.1.4    98/09/23       /
CC                                                                      /
CC    BADA Revision:                                                    /
CD    Rev  3.1                                                          /
CC====== Actype =======================================================/
CD    A320__          2 engines    Jet                      M           /
CC    Airbus A320-111 with CFM56_5_A1 engines              wake         /
CC                 (source: AIR FRANCE OPS manual)                      /
CC====== Mass (t) =====================================================/
CC     reference      minimum      maximum     max payload  mass grad   /
CD      .62000E+02   .41800E+02   .73500E+02   .19220E+02   .32000E+00  /
CC====== Flight envelope ==============================================/
CC      VMO(KCAS)       MMO        Max.Alt       Hmax       temp grad   /
CD      .35000E+03   .82000E+00   .39000E+05   .36500E+05  -.40000E+02  /
CC====== Aerodynamics =================================================/
CC Wing Area and Buffet coefficients (SIM)                              /
CCndrst Surf(m2)     Clbo(M=0)       k           CM16                   /
CD 5    .12240E+03   .12100E+01   .47000E+00   .00000E+00               /
CC    Configuration characteristics                                     /
CC n Phase  Name    Vstall(KCAS)    CD0          CD2        unused      /
CD 1 CR   Clean      .15400E+03   .28465E-01   .40000E-01   .00000E+00  /
CD 2 IC   Clean      .15400E+03   .28465E-01   .40000E-01   .00000E+00  /
CD 3 TO   1+F        .12300E+03   .39000E-01   .34000E-01   .00000E+00  /
CD 4 AP   2          .11600E+03   .42000E-01   .34000E-01   .00000E+00  /
CD 5 LD   FULL       .11000E+03   .98000E-01   .35000E-01   .00000E+00  /
CC    Spoiler                                                           /
CD 1      RET                                                           /
CD 2      EXT                                  .00000E+00   .00000E+00  /
CC    Gear                                                              /
CD 1      UP                                                            /
CD 2      DOWN                    .24000E-01   .00000E+00   .00000E+00  /
CC    Brakes                                                            /
CD 1      OFF                                                           /
CD 2      ON                                   .00000E+00   .00000E+00  /
CC====== Engine Thrust ================================================/
CC          Max climb thrust coefficients (SIM)                         /
CD      .14565E+06   .53660E+05   .40600E-10   .11060E+01   .31100E-04  /
CC       Desc(low)    Desc(high)   Desc level   Desc(app)    Desc(ld)   /
CD      .11107E+00   .10711E+00   .20000E+05   .14500E+00   .27000E+00  /
CC       Desc CAS     Desc Mach    unused       unused       unused     /
CD      .30000E+03   .78000E+00   .00000E+00   .00000E+00   .00000E+00  /
CC====== Fuel Consumption =============================================/
CC    Thrust Specific Fuel Consumption Coefficients                     /
CD      .81827E+00   .95608E+04                                         /
CC    Descent Fuel Flow Coefficients                                    /
CD      .91335E+01   .10636E+06                                         /
CC    Cruise Corr.    unused       unused       unused       unused     /
CD      .97685E+00   .00000E+00   .00000E+00   .00000E+00   .00000E+00  /
CC====== Ground =======================================================/
CC         TOL          LDL        span         length       unused     /
CD      .21900E+04   .14400E+04   .34100E+02   .37570E+02   .00000E+00  /
CC=====================================================================/
FI                                                                      /
```

There are three types of lines in the OPF file with the line type identified by the first two characters in the line. These line types with their associated two leading characters are listed below.

CC comment line

CD data line

FI end-of-file line

The comment lines are provided solely for the purpose of improving the readability of the file. All coefficients are contained within the CD lines in a fixed format. The end-of-file line is included as the last line in the file in order to facilitate the reading of the file in certain computing environments.

The data is organised into a total of eight blocks with each block separated by a comment line containing the block name and equal signs "=". These blocks are listed below and are described in further detail in the subsections below.

- file identification block
- aircraft type block
- mass block
- flight envelope block
- aerodynamics block
- engine thrust block,
- fuel consumption block
- ground movements block

### 6.4.1 File Identification Block

The file identification block provides information on the file name, revision number and modification date. The block consists of 1 data line with 11 comment lines for a total of 12 lines. An example of the file identification block for the A320__.OPF file is shown below.

```
       CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC A320__.OPF CCCCCCCCCCCCCC/
       CC                                                                  /
       CC                AIRCRAFT PERFORMANCE                              /
       CC                operational    files                              /
       CC                                                                  /
       CC     BADA RCS File Id                                             /
       CC    File Name        Current Revision      Last Modification      /
       CC                     revision    date      revision     date      /
       CC    A320__.OPF       3.1.1.4   98/09/23    3.1.1.4    98/09/23    /
       CC                                                                  /
       CC   BADA Revision:                                                 /
1 ->   CD   Rev  3.1                                                       /
```

The only data line gives the BADA Revision Id to which the file belongs. This value is specified in the following fixed format (Fortran notation):

'CD', 8X, F3.1

The comment lines specify the file name along with the RCS current revision and last modification revision. For all released files, the current revision number and date will be the same as the number and date of the BADA Revision. The last modification revision number and date indicate when the contents of the file were last modified.

### 6.4.2 Aircraft Type Block

The OPF aircraft type block consists of 1 data line with 3 comments lines for a total of 4 lines. An example of the aircraft type block is given below.

```
       CC====== Actype ======================================================/
1 ->   CD   A320__        2 engines    Jet                       M          /
       CC   Airbus A320-111 with CFM56_5_A1 engines             wake        /
       CC                 (source: AIR FRANCE OPS manual)                   /
```

The data line specifies the following aircraft type parameters:

- ICAO aircraft code
(followed by 2 or more underscore characters as required to form a six character string),
- number of engines, $n_{eng}$ ,
- engine type, and,
- wake category

The engine type can be one of the following three values: Jet, Turboprop or Piston. The wake category can be one of the three values H (heavy), M (medium) or L (light).

The four values are specified in the following fixed format (Fortran notation)

'CD', 2X, A6, 10X, I1, 12X, A9, 17X , A1

The comment lines typically indicate the engine manufacturer's designation and the source of the performance coefficients.

### 6.4.3 Mass Block

The OPF mass block consists of 1 data line with 2 comment lines for a total of 3 lines.
An example of the mass block is given below.

```
       CC====== Mass (t) ====================================================/
       CC    reference      minimum      maximum     max payload  mass grad  /
1 ->   CD     .62000E+02   .41800E+02   .73500E+02   .19220E+02   .32000E+00 /
```

The data line specifies the following BADA mass model parameters (in tonnes):

$m_{ref}$ $m_{min}$ $m_{max}$ $m_{pyld}$ $G_W$

These parameters are specified in the following fixed format (Fortran notation)

'CD', 2X, 5( 3X, E10.5)

### 6.4.4 Flight Envelope Block

The OPF flight envelope block consists of 1 data line with 2 comment lines for a total of 3 lines. An example of the flight envelope block is given below.

```
        CC====== Flight envelope =============================================/
        CC     VMO(KCAS)      MMO        Max.Alt       Hmax       temp grad  /
1 ->    CD     .35000E+03   .82000E+00   .39000E+05   .36500E+05  -.40000E+02 /
```

The date line specifies the following BADA speed envelope parameters:

$V_{MO}$ $M_{MO}$ $h_{MO}$ $h_{max}$ $G_t$

Note that all altitudes are expressed in feet.

These parameters are specified in the following fixed format (Fortran notation):

'CD', 2X, 5( 3X, E10.5 )

### 6.4.5 Aerodynamics Block

The OPF aerodynamics block consists of 12 data lines and 8 comment lines for a total of 20 lines. An example of the aerodynamics block is given below.

```
        CC====== Aerodynamics ================================================/
        CC Wing Area and Buffet coefficients (SIM)                            /
        CCndrst Surf(m2)     Clbo(M=0)       k           CM16                 /
1 ->    CD 5   .12240E+03   .12100E+01   .47000E+00   .00000E+00              /
        CC   Configuration characteristics                                    /
        CC n Phase  Name    Vstall(KCAS)    CD0          CD2        unused    /
2 ->    CD 1 CR   Clean     .15400E+03   .28465E-01   .40000E-01   .00000E+00 /
3 ->    CD 2 IC   Clean     .15400E+03   .28465E-01   .40000E-01   .00000E+00 /
4 ->    CD 3 TO   1+F       .12300E+03   .39000E-01   .34000E-01   .00000E+00 /
5 ->    CD 4 AP   2         .11600E+03   .42000E-01   .34000E-01   .00000E+00 /
6 ->    CD 5 LD   FULL      .11000E+03   .98000E-01   .35000E-01   .00000E+00 /
        CC   Spoiler                                                          /
7 ->    CD 1      RET                                                         /
8 ->    CD 2      EXT                                  .00000E+00   .00000E+00 /
        CC   Gear                                                             /
9 ->    CD 1      UP                                                          /
10 ->   CD 2      DOWN                    .24000E-01   .00000E+00   .00000E+00 /
        CC   Brakes                                                           /
12 ->   CD 1      OFF                                                         /
13 ->   CD 2      ON                                   .00000E+00   .00000E+00 /
```

The first data line specifies the following BADA aerodynamic model parameters:

S Clbo(M=0) k $C_{M16}$

These parameters are specified in the following fixed format (Fortran notation):

'CD', 2X, 4 (3X, E10.5)

Note that the "5" under the header "ndrst" stands for the five drag settings. Currently this is not used but is left in for compatibility requirements.

The next line holds besides the stall speed and flap setting for cruise as well as the values for the two drag coefficients for this configuration:

$(V_{stall})_{CR}$ $C_{D0}$ $C_{D2}$

These parameters are specified in the following fixed format (Fortran notation):

'CD', 15X, 3 (3X, E10.5)

The next four data lines have the same format and correspond to the other configurations. The configurations are specified in the following order, corresponding to a semi-monotonically decreasing stall speed:

| | |
|---|---|
| IC | initial climb |
| TO | take-off |
| AP | approach |
| LD | landing |

The stall speed, $(V_{stall})_{i}$, is specified for each configuration and $C_{D0}$ and $C_{D2}$ are given if available in the following fixed format (Fortran notation): $C_{D0}$ and $C_{D2}$

'CD', 15X, 3 (3X, E10.5)

In case the IC configuration is equal to the CR configuration, the values for $C_{D0}$ and $C_{D2}$ are mentioned only in the CR dataline. Note that in BADA 3.1 only 9 models have values for the $C_{D0}$ and $C_{D2}$ coefficients for approach and landing and that dragsettings for take-off and initial climb are not used at all.

The data lines 7 through 9 are not used but are included for the reason of compatibility with previous versions.

Dataline 10 holds the drag increment for landing gear down:

$C_{D0\ \Delta LDG}$

The format of this line is:

'CD', 32X, E10.5

Datalines 11 and 12 are not used but are included for the reason of compatibility with previous versions.

### 6.4.6 Engine Thrust Block

The OPF engine thrust block consists of 3 data lines with 4 comment lines for a total of 7 lines. An example of the engine thrust block is given below.

```
       CC====== Engine Thrust =============================================/
       CC         Max climb thrust coefficients (SIM)                       /
1 ->   CD     .14565E+06   .53660E+05   .40600E-10   .11060E+01   .31100E-04 /
       CC      Desc(low)    Desc(high)   Desc level   Desc(app)    Desc(ld)  /
2 ->   CD     .11107E+00   .10711E+00   .20000E+05   .14500E+00   .27000E+00 /
       CC      Desc CAS     Desc Mach    unused       unused       unused    /
3 ->   CD     .30000E+03   .78000E+00   .00000E+00   .00000E+00   .00000E+00 /
```

The first data line specifies the following BADA parameters used to calculate the maximum climb thrust, that is:

$C_{Tc,1}$ $C_{Tc,2}$ $C_{Tc,3}$ $C_{Tc,4}$ $C_{Tc,5}$

These parameters are specified in the following fixed format (Fortran notation):

'CD', 2X, 5 (3X, E10.5)

The second data line specifies the following BADA parameters used to calculate cruise and descent thrust, that is:

$C_{Tdes,low}$ $C_{Tdes,high}$ $h_{des}$ $C_{Tdes,app}$ $C_{Tdes,ld}$

These parameters are specified in the following fixed format (Fortran notation):

'CD', 2X, 5 (3X, E10.5)

The third data line specifies the reference speed during descent, that is:

$V_{des,ref}$ $M_{des,ref}$

These parameters are specified in the following fixed format (Fortran notation):

'CD', 2X, 2 (3X, E10.5)

Note that these two coefficients are no longer used in BADA 3.1. For the moment they are left in place until it is clear if they will be of use for the new descent thrust algorithm, to be developed for a future release of BADA.

The zero values in the data lines are not used but are included in the file due to compatibility requirements with previous versions.

### 6.4.7 Fuel Consumption Block

The OPF fuel consumption block consists of 3 data lines with 4 comment lines for a total of 7 lines. An example of a fuel consumption block is shown below.

```
        CC====== Fuel Consumption ==========================================/
        CC   Thrust Specific Fuel Consumption Coefficients                  /
1 ->    CD     .81827E+00   .95608E+04                                      /
        CC   Descent Fuel Flow Coefficients                                 /
2 ->    CD     .91335E+01   .10636E+06                                      /
        CC   Cruise Corr.    unused       unused       unused       unused  /
3 ->    CD     .97685E+00   .00000E+00   .00000E+00   .00000E+00   .00000E+00 /
```

The first data line specifies the following BADA parameters for thrust specific fuel consumption.

$C_{f1}$ $C_{f2}$

These parameters are specified in the following fixed format (Fortran notation):

'CD', 2X, 2 (3X , E10.5)

The second data line specifies the following BADA parameters for descent fuel flow.

$C_{f3}$ $C_{f4}$

These parameters are specified in the following fixed format (Fortran notation):

'CD', 2X, 2 (3X, E10.5)

The third data line specifies the cruise fuel flow correction factor.

$C_{fcr}$

The parameter is specified in the following fixed format (Fortran notation):

'CD', 5X, E10.5

### 6.4.8 Ground Movement Block

The OPF ground movement block consists of 1 data line with 3 comment lines for a total of 4 lines. An example of a ground movement block is shown below. The ground movement block is the last block in the OPF file and is thus followed by the end-of-file line as shown below.

```
        CC====== Ground ====================================================/
        CC        TOL          LDL        span         length       unused  /
1 ->    CD     .21900E+04   .14400E+04   .34100E+02   .37570E+02   .00000E+00 /
        CC==================================================================/
        FI                                                                  /
```

The dataline specifies the following BADA parameters for ground movements:

TOL LDL span length

These parameters are specified in the following fixed format (Fortran notation):

'CD', 2X, 4 (3X, E10.5)

## 6.5 APF File Format

The Airlines Procedures File (APF) is an ASCII file which, for a particular aircraft type, specifies recommended speed procedures for climb, cruise, and descent conditions. An example of an APF file for the Airbus A320 aircraft is shown below.

```
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC A320__.APF CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC/
CC                                                                                                  /
CC                AIRLINES PROCEDURES FILE                                                          /
CC                                                                                                  /
CC    File Name        Current Revision            Last Modification                                /
CC                     revision    date            revision     date                                /
CC    A320__.APF       3.1.1.3   98/09/18          3.1.1.3    98/09/18                              /
CC                                                                                                  /
CC   BADA Revision:                                                                                 /
CD   Rev  3.1                                                                                       /
CC                                                                                                  /
CC   LO= 41.80 to --.--  /  AV= --.-- to --.--  /  HI= --.-- to 73.50                               /
CC                                                                                                  /
CC==================================================================================================/
CC  COM CO    Company name ------climb-------  --cruise--  -----descent------  --approach-  model- /
CC                     mass  lo  hi              lo  hi         hi  lo           (unused)         /
CC    version engines  ma  cas cas mc xxxx xx  cas cas mc  mc cas cas xxxx xx  xxx xxx xxx  opf___ /
CC===:=======:=======::==::===:===:==:====:==::===:===:==::==:===:===:====:==::===:===:===::======:/
CD  *** **    Default Company                                                                       /
CD    111     CFM565A  LO  250 300 78          250 300 78  78 300 250            0   0   0  A320__ /
CD    111     CFM565A  AV  250 300 78          250 300 78  78 300 250            0   0   0  A320__ /
CD    111     CFM565A  HI  250 300 78          250 300 78  78 300 250            0   0   0  A320__ /
CC===:=======:=======::==::===:===:==:====:==::===:===:==::==:===:===:====:==::===:===:===::======:/
CC////////////////////////////////////  THE END   //////////////////////////////////////////////////
```

There are two types of lines in the APF file with the line type identified by the first two characters in the line. These line types with their associated two leading characters are listed below:

CC - comment line
CD - data line

The last line in the file, as shown above, is also a comment line.

The comment lines are provided solely for the purpose of improving the readability of the file. All coefficients are contained within the CD lines in a fixed format.

The data is organised into 2 blocks separated by a comment line containing a string of equal signs, "=":

- file identification block
- speed procedures block

Each of the two blocks is described further in the subsections below.

### 6.5.1 File Identification Block

The file identification block provides information on the file name, revision number and modification date. The block consists of 1 data line with 12 comment lines for a total of 13 lines. An example of a file identification block is shown below.

```
        CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC A320__.APF CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC/
        CC                                                                                                /
        CC                 AIRLINES PROCEDURES FILE                                                       /
        CC                                                                                                /
        CC    File Name        Current Revision            Last Modification                              /
        CC                     revision    date            revision     date                              /
        CC    A320__.APF       3.1.1.3   98/09/18          3.1.1.3    98/09/18                            /
        CC                                                                                                /
        CC   BADA Revision:                                                                               /
1 ->    CD   Rev  3.1                                                                                     /
        CC                                                                                                /
        CC   LO= 41.80 to --.--  /  AV= --.-- to --.--  /  HI= --.-- to 73.50                             /
        CC                                                                                                /
```

The only data line gives the BADA Revision Id to which the file belongs. This value is specified in the following fixed format.

’CD’, 8X, F3.1

The comment lines provide background information on the file contents. In addition, the comment lines specify the file name along with the RCS current revision and last modification. For all released files, the current revision number and date are the same as the number and date of the BADA revision. The last modification revision number and date indicate when the contents of the file were last modified.

The second last comment line in the identification block specifies three mass ranges for the aircraft in tonnes. That is, a low range (LO), average range (AV) and high range (HI). The definition of these ranges is used for interpreting the information presented below in the procedures specification block. In the example given above, all three ranges are assumed equivalent.

### 6.5.2 Procedures Specification Block

The APF procedures specification block consists of 4 data lines with 7 comment lines for a total of 11 lines. An example of a procedures specification block is shown below.

```
        CC================================================================================================/
        CC  COM CO    Company name ------climb-------  --cruise--  -----descent------  --approach-  model- /
        CC                    mass  lo  hi              lo  hi          hi  lo          (unused)          /
        CC    version engines  ma  cas cas mc xxxx xx  cas cas mc  mc cas cas xxxx xx  xxx xxx xxx  opf___ /
        CC===:=======:=======::==::===:===:==:====:==::===:===:==::==:===:===:====:==::===:===:===::======:/
1 ->    CD  *** **    Default Company                                                                     /
2 ->    CD    111     CFM565A  LO  250 300 78          250 300 78  78 300 250            0   0   0  A320__ /
3 ->    CD    111     CFM565A  AV  250 300 78          250 300 78  78 300 250            0   0   0  A320__ /
4 ->    CD    111     CFM565A  HI  250 300 78          250 300 78  78 300 250            0   0   0  A320__ /
        CC===:=======:=======::==::===:===:==:====:==::===:===:==::==:===:===:====:==::===:===:===::======:/
        CC////////////////////////////////////  THE END   ////////////////////////////////////////////////////
```

The first data line specifies the company name for which the next three datalines are valid. The company can be identified by its 3 and 2 letter code plus the company name. The dataline fomat is:

’CD’, 2X, 3A, 1X, 2A, 4X, 15A

As it is, within BADA 3.1 all APF files specify procedures for only one "default" company.

The next three data lines specify the following parameters corresponding to climb, cruise and descent

$V_{cl,1}$ $V_{cl,2}$ $M_{cl}$ $V_{cr,1}$ $V_{cr,2}$ $M_{cr}$ $M_{des}$ $V_{des,1}$ $V_{des,2}$

Note that all Mach numbers values are also multiplied by a value of 100. For example, the 78 indicated for $M_{cl}$ above corresponds to a Mach number of 0.78.

The three lines specify parameters for mass ranges of Low (LO), Average (AV) and High (HI) respectively. These parameters are specified in the following fixed format (Fortran notation):

'CD', 25X, 2(I3, 1X), I2, 10X, 2(I3, 1X), I2, 2X, I2, 2(1X, I3)

Note that approach values are set to zero. These values are not used but are included in the file due to compatibility requirements with previous versions.

Also each line specifies an aircraft version number, engine, and operational model. The operational model is always the same as the file name. The version number may provide some additional information on the aircraft version covered by the file while the engine states which engine is used by the aircraft.

The file format is designed such that the four data lines can be repeated for the different companies which operate the aircraft and which may have different standard procedures. If data were to be provided for more than one company then the version, engine and operational model fields may be useful since different companies could operate different versions of the aircraft with different engines and thus different associated operational models.

## 6.6 PTF File Format

The Performance Table File (PTF) is an ASCII file, which for a particular aircraft type specifies cruise, climb and descent performance at different flight levels. An example of a PTF file for the Airbus A320 aircraft (A320) is shown below.

```
BADA PERFORMANCE FILE              98/09/28

AC/Type: A320__              Last BADA Revision:  3.1
                             Source OPF File:     3.1.1.4    98/09/23
                             Source APF file:     3.1.1.3    98/09/18

 Speeds:   CAS(LO/HI)  Mach   Mass Levels [kg]         Temperature:   ISA
 climb   - 250/300     0.78   low     -  50160
 cruise  - 250/300     0.78   nominal -  62000         Max Alt. [ft]:  39000
 descent - 250/300     0.78   high    -  73500
```

| FL | CRUISE TAS | CRUISE fuel lo | CRUISE fuel nom | CRUISE fuel hi | CLIMB TAS | CLIMB ROCD lo | CLIMB ROCD nom | CLIMB ROCD hi | CLIMB fuel nom | DESCENT TAS | DESCENT ROCD nom | DESCENT fuel nom |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | [kts] | [kg/min] | [kg/min] | [kg/min] | [kts] | [fpm] | [fpm] | [fpm] | [kg/min] | [kts] | [fpm] | [kg/min] |
| 0 | | | | | 165 | 2650 | 2580 | 2290 | 121.2 | 148 | 720 | 13.4 |
| 5 | | | | | 166 | 2640 | 2560 | 2270 | 120.1 | 149 | 730 | 13.3 |
| 10 | | | | | 167 | 2620 | 2550 | 2260 | 119.0 | 155 | 730 | 13.2 |
| 15 | | | | | 174 | 2730 | 2620 | 2310 | 118.0 | 167 | 730 | 13.1 |
| 20 | | | | | 175 | 2710 | 2600 | 2290 | 116.9 | 199 | 800 | 13.0 |
| 30 | 230 | 30.6 | 35.0 | 40.1 | 198 | 3100 | 2870 | 2510 | 114.9 | 230 | 980 | 12.8 |
| 40 | 233 | 30.6 | 35.0 | 40.1 | 233 | 3550 | 3160 | 2740 | 113.1 | 233 | 1010 | 12.6 |
| 60 | 272 | 35.3 | 38.7 | 42.7 | 272 | 3950 | 3230 | 2710 | 109.0 | 240 | 1050 | 12.1 |
| 80 | 280 | 35.2 | 38.6 | 42.7 | 280 | 3800 | 3100 | 2590 | 104.7 | 280 | 1400 | 11.6 |
| 100 | 289 | 35.2 | 38.6 | 42.6 | 289 | 3640 | 2960 | 2460 | 100.4 | 289 | 1460 | 11.2 |
| 120 | 297 | 35.1 | 38.6 | 42.6 | 356 | 3300 | 2690 | 2250 | 96.7 | 356 | 2310 | 10.7 |
| 140 | 306 | 35.0 | 38.5 | 42.6 | 366 | 3080 | 2510 | 2080 | 92.4 | 366 | 2370 | 10.3 |
| 160 | 377 | 45.3 | 47.8 | 50.7 | 377 | 2860 | 2310 | 1910 | 88.2 | 377 | 2430 | 9.8 |
| 180 | 388 | 45.1 | 47.6 | 50.5 | 388 | 2640 | 2120 | 1730 | 84.1 | 388 | 2490 | 9.3 |
| 200 | 400 | 44.9 | 47.4 | 50.4 | 400 | 2410 | 1910 | 1540 | 79.9 | 400 | 2580 | 8.6 |
| 220 | 412 | 44.6 | 47.2 | 50.2 | 412 | 2170 | 1700 | 1350 | 75.8 | 412 | 2630 | 8.1 |
| 240 | 425 | 44.4 | 47.0 | 50.0 | 425 | 1920 | 1490 | 1160 | 71.7 | 425 | 2690 | 7.7 |
| 260 | 438 | 44.1 | 46.7 | 49.8 | 438 | 1670 | 1270 | 960 | 67.7 | 438 | 2750 | 7.2 |
| 280 | 452 | 43.8 | 46.4 | 49.5 | 452 | 1420 | 1050 | 750 | 63.7 | 452 | 2800 | 6.8 |
| 290 | 459 | 43.7 | 46.3 | 49.4 | 459 | 1290 | 930 | 650 | 61.7 | 459 | 2820 | 6.6 |
| 310 | 458 | 41.1 | 44.0 | 47.3 | 458 | 1650 | 1150 | 750 | 57.6 | 458 | 3760 | 6.5 |
| 330 | 454 | 38.5 | 41.6 | 45.3 | 454 | 1500 | 1000 | 580 | 53.6 | 454 | 3530 | 6.3 |
| 350 | 450 | 36.1 | 39.6 | 43.6 | 450 | 1320 | 820 | 400 | 49.6 | 450 | 3350 | 6.1 |
| 370 | 447 | 34.1 | 37.9 | 42.3 | 447 | 1030 | 570 | 170 | 45.7 | 447 | 2950 | 6.0 |
| 390 | 447 | 32.4 | 36.5 | 38.8 | 447 | 830 | 360 | 0 | 41.8 | 447 | 2860 | 5.8 |

The OPF and APF files are generated as a result of a modelling process using Excel spreadsheets [RD6]. Once these two files are generated, the PTF can be automatically generated. A brief summary of the format of these files is given below.

The header of each PTF file contains information as described below.

file creation date: This is in the first line, at the top-right corner

aircraft type: This is in the third line.

last BADA revision: This is in the 3rd line and indicates the last BADA revision which has been released as of the file creation date.

source file revisions: The RCS revision numbers and dates of the OPF and APF files which were used to create the PTF file are given in the 4th and 5th lines respectively.

speeds: The speed laws for climb, cruise and descent are specified in lines 8, 9 and 10, that is:

| | | |
|---|---|---|
| climb | $V_{cl,1}$ / $V_{cl,2}$ | $M_{cl}$ |
| cruise | $V_{cr.1}$ / $V_{cr.2}$ | $M_{cr}$ |
| descent | $V_{des,1}$ / $V_{des.2}$ | $M_{des}$ |

mass Levels: The performance tables provide data for three different mass levels in lines 8, 9 and 10 that is:

| | |
|---|---|
| low | 1.2 $m_{min}$ |
| nominal | $m_{ref}$ |
| high | $m_{max}$ |

temperature: data The temperature is mentioned in line 7. All PTF files currently only provide for ISA conditions.

maximum altitude: The maximum altitude as specified in the OPF file, $h_{MO}$ , is given in line 9.

The table of performance data within the file consists of 13 columns. Each of these columns is described below:

| | |
|---|---|
| Column 1 | FL |
| Column 2 | cruise TAS (nominal mass) in knots |
| Column 3 | cruise fuel consumption (low mass) in kg/min |
| Column 4 | cruise fuel consumption (nominal mass) in kg/min |
| Column 5 | cruise fuel consumption (high mass) in kg/min |
| Column 6 | climb TAS (nominal mass) in knots |
| Column 7 | rate of climb with reduced power (low mass) in fpm |
| Column 8 | rate of climb with reduced power (nominal mass) in fpm |
| Column 9 | rate of climb with reduced power (high mass) in fpm |
| Column 10 | climb fuel consumption in kg/min |
| Column 11 | descent TAS (nominal mass) in knots |
| Column 12 | rate of descent (nominal mass) in fpm |
| Column 13 | descent fuel (nominal mass) consumption in fpm |

The format for data presented in each line of the table is as follows (Fortran notation)

I3, 4X, I3, 2X, 3(2X, F4.1), 5X, I3, 2X, 3(1X,I4), 4X, F4.1, 5X, I3, 2X, I4, 4X, F4.1

Further explanatory notes on the data presented in the performance tables are given below:

(a) Cruise data is only specified for flight levels greater than or equal to 30.

(b) Performance data is specified up to a maximum flight level of 510 or to highest level for which a positive rate of climb can be achieved at the low mass.

(c) True Air Speed for climb, cruise and descent is determined based on the speed schedules specified in Sections 4.1, 4.2 and 4.3 respectively.

(d) Rates of climb are calculated at each flight level assuming the energy share factors associated with constant CAS or constant Mach speed laws and using the reduced power correction as given in Section 3.8.

(e) The fuel consumption in climb is independent of the aircraft mass and thus only one value is given. There are three different climb rates however corresponding to low, nominal and high mass conditions.

(f) The rate of descent and fuel consumption in descent is calculated assuming the nominal mass. Values for other mass conditions are not given.

(g) Discontinuities in climb rate can occur for the following reasons:

- change in speed between flight levels (e.g. removal of 250 knot restriction above FL100)
- transition from constant CAS to constant Mach (typically around FL300)
- transition through the tropopause (FL360 for ISA)

(h) Discontinuities in descent rate can occur for the following reasons:

- transition through tropopause (FL360 for ISA)
- transition from constant Mach to constant CAS
- change in assumed descent thrust (specified by the BADA $h_{des}$ parameter)
- change in speed between flight levels (e.g. application of 250 knot limit below FL100)

(i) The PTF files are made with "clean" configuration data only.

Note that all PTF files are available in document form in [RD9].

## 6.7 BADA.GPF File Format

The BADA.GPF file is an ASCII file which specifies the values of the global aircraft parameters (see Section 5). The complete BADA.GPF file is shown below:

```
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC BADA.GPF CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC/
CC                                                                                   /
CC                  GLOBAL PARAMETERS FILE                                           /
CC                                                                                   /
CC      BADA RCS File Id                                                             /
CC     File Name        Current Revision      Last Modification                      /
CC                      revision    date      revision     date                      /
CC        BADA.GPF      3.0.1.1   98/03/13    3.0.1.1    98/03/13                    /
CC                                                                                   /
CC    BADA Revision:                                                                 /
CC                                                                                   /
CD    Rev  3.1                                                                       /
CC======== Class ====================================================================/
CC                                                                                   /
CC Flight = civ,mil                                                                  /
CC Engine = jet,turbo,piston                                                         /
CC Phase  = to,ic,cl,cr,des,hold,app,lnd,gnd                                         /
CC                                                                                   /
CC======== Parameters List ==========================================================/
CC                                                                                   /
CC Name             Unit                                                             /
CC Parameter       Flight  Engine           Phase                         Value      /
CC                                                                                   /
CC max. long. acc.  [fps2]                                                           /
CD acc_long_max    civ     jet,turbo,piston to,ic,cl,cr,des,hold,app,lnd  .20000E+01 /
CC max. norm. acc.  [fps2]                                                           /
CD acc_norm_max    civ     jet,turbo,piston to,ic,cl,cr,des,hold,app,lnd  .50000E+01 /
CC nom. bank angle  [deg]                                                            /
CD ang_bank_nom    civ     jet,turbo,piston to,lnd                        .15000E+02 /
CC nom. bank angle  [deg]                                                            /
CD ang_bank_nom    civ     jet,turbo,piston ic,cl,cr,des,hold,app         .35000E+02 /
CC nom. bank angle  [deg]                                                            /
CD ang_bank_nom    mil     jet,turbo,piston to,ic,cl,cr,des,hold,app,lnd  .50000E+02 /
CC max. bank angle  [deg]                                                            /
CD ang_bank_max    civ     jet,turbo,piston to,lnd                        .25000E+02 /
CC max. bank angle  [deg]                                                            /
CD ang_bank_max    civ     jet,turbo,piston hold                          .30000E+02 /
CC max. bank angle  [deg]                                                            /
CD ang_bank_max    civ     jet,turbo,piston ic,cl,cr,des,app              .45000E+02 /
CC max. bank angle  [deg]                                                            /
CD ang_bank_max    mil     jet,turbo,piston to,ic,cl,cr,des,hold,app,lnd  .70000E+02 /
CC exp. desc. fact. [-]                                                              /
CD C_des_exp       civ,mil jet,turbo,piston des                           .16000E+01 /
CC to thrust factor [-]                                                              /
CD C_th_to         mil,civ jet,turbo,piston to                            .12000E+01 /
CC cr thrust factor [-]                                                              /
CD C_th_cr         mil,civ jet,turbo,piston cr                            .95000E+00 /
CC max alt for to  [ft]                                                              /
CD H_max_to        mil,civ jet,turbo,piston to                            .40000E+03 /
CC max alt for ic  [ft]                                                              /
CD H_max_ic        mil,civ jet,turbo,piston ic                            .20000E+04 /
CC max alt for app  [ft]                                                             /
CD H_max_app       mil,civ jet,turbo,piston app                           .80000E+04 /
CC max alt for ld  [ft]                                                              /
CD H_max_ld        mil,civ jet,turbo,piston lnd                           .30000E+04 /
CC min speed coef.  [-]                                                              /
CD C_v_min         mil,civ jet,turbo,piston cr,ic,cl,des,hold,app,lnd     .13000E+01 /
CC min speed coef.  [-]                                                              /
CD C_v_min_to      mil,civ jet,turbo,piston to                            .12000E+01 /
CC spd incr FL < 15 [KCAS]                                                           /
CD V_cl_1          mil,civ jet              cl                            .50000E+01 /
CC spd incr FL < 30 [KCAS]                                                           /
CD V_cl_2          mil,civ jet              cl                            .10000E+02 /
CC spd incr FL < 40 [KCAS]                                                           /
CD V_cl_3          mil,civ jet              cl                            .30000E+02 /
CC spd incr FL < 50 [KCAS]                                                           /
CD V_cl_4          mil,civ jet              cl                            .60000E+02 /
CC spd incr FL < 60 [KCAS]                                                           /
CD V_cl_5          mil,civ jet              cl                            .80000E+02 /
CC spd incr FL < 5  [KCAS]                                                           /
CD V_cl_6          mil,civ turbo,piston     cl                            .20000E+02 /
CC spd incr FL < 10 [KCAS]                                                           /
CD V_cl_7          mil,civ turbo,piston     cl                            .30000E+02 /
CC spd incr FL < 15 [KCAS]                                                           /
CD V_cl_8          mil,civ turbo,piston     cl                            .35000E+02 /
CC spd incr FL < 10 [KCAS]                                                           /
```

(BADA.GPF continued)

```
CD V_des_1         mil,civ jet,turbo        des                              .50000E+01 /
CC spd incr FL < 15 [KCAS]                                                              /
CD V_des_2         mil,civ jet,turbo        des                              .10000E+02 /
CC spd incr FL < 20 [KCAS]                                                              /
CD V_des_3         mil,civ jet,turbo        des                              .20000E+02 /
CC spd incr FL < 30 [KCAS]                                                              /
CD V_des_4         mil,civ jet,turbo        des                              .50000E+02 /
CC spd incr FL < 5  [KCAS]                                                              /
CD V_des_5         mil,civ piston           des                              .50000E+01 /
CC spd incr FL < 10 [KCAS]                                                              /
CD V_des_6         mil,civ piston           des                              .10000E+02 /
CC spd incr FL < 15 [KCAS]                                                              /
CD V_des_7         mil,civ piston           des                              .20000E+02 /
CC hold. spd FL < 140 [KCAS]                                                            /
CD V_hold_1        mil,civ jet,turbo,piston hold                             .23000E+03 /
CC hold. spd FL < 200 [KCAS]                                                            /
CD V_hold_2        mil,civ jet,turbo,piston hold                             .24000E+03 /
CC hold. spd FL < 340 [KCAS]                                                            /
CD V_hold_3        mil,civ jet,turbo,piston hold                             .26500E+03 /
CC hold. spd FL > 340 [M]                                                               /
CD V_hold_4        mil,civ jet,turbo,piston hold                             .83000E+00 /
CC backtrack spd    [KCAS]                                                              /
CD V_backtrack     mil,civ jet,turbo,piston gnd                              .35000E+02 /
CC taxi spd         [KCAS]                                                              /
CD V_taxi          mil,civ jet,turbo,piston gnd                              .15000E+02 /
CC apron spd        [KCAS]                                                              /
CD V_apron         mil,civ jet,turbo,piston gnd                              .10000E+02 /
CC gate spd         [KCAS]                                                              /
CD V_gate          mil,civ jet,turbo,piston gnd                              .50000E+01 /
CC Piston pow. red. [-]                                                                 /
CD C_red_piston    mil,civ piston           ic,cl                            .000000+00 /
CC Turbo pow. red.  [-]                                                                 /
CD C_red_turbo     mil,civ turbo            ic,cl                            .250000+00 /
CC Jet power red.   [-]                                                                 /
CD C_red_jet       mil,civ jet              ic,cl                            .150000+00 /
FI=====================================================================================/
CC//////////////////////////////  THE END  ////////////////////////////////////////////
```

There are three types of lines in the BADA.GPF file with the line type identified by the first two characters in the line. These line types with their associated two leading characters are listed below.

CC comment line

CD data line

FI end-of-file line

The data is organised into a three blocks separated by a comment line consisting of equal signs "=":

- file identification block
- class block
- parameter block

Each of these blocks is described in the subsections below.

### 6.7.1 File Identification Block

The file identification block provides information on the file name, revision number and modification date. The block consists of 11 comment lines and one data line.

```
       CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC BADA.GPF CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC/
       CC                                                                                   /
       CC              GLOBAL PARAMETERS FILE                                               /
       CC                                                                                   /
       CC    BADA RCS File Id                                                               /
       CC   File Name       Current Revision     Last Modification                          /
       CC                   revision    date     revision     date                          /
       CC      BADA.GPF     3.0.1.1   98/03/13   3.0.1.1    98/03/13                        /
       CC                                                                                   /
       CC  BADA Revision:                                                                   /
       CC                                                                                   /
1 ->   CD  Rev  3.1                                                                         /
```

The data line gives the BADA Revision Id to which the file belongs. This value is specified in the following fixed format (Fortran notation):

'CD', 8X, F3.1

The comment lines specify the file name along with the RCS current revision and last modification revision. For all released files, the current revision number and date will be the same as the number and date of the BADA Revision. The last modification revision number and date indicate when the contents of the file were last modified.

### 6.7.2 Class Block

The class block consists of 6 comment lines and defines the three classes (Flight, Engine and Phase) and their instances that are used in the BADA.GPF file.

```
CC======== Class ===================================================================/
CC                                                                                 /
CC Flight = civ,mil                                                                /
CC Engine = jet,turbo,piston                                                       /
CC Phase  = to,ic,cl,cr,des,hold,app,lnd,gnd                                       /
CC                                                                                 /
```

| | | | |
|---|---|---|---|
| With: | civ | = | civil flight |
| | mil | = | military flight |
| | jet | = | jet engine |
| | turbo | = | turboprop engine |
| | piston | = | piston engine |
| | to | = | take off |
| | ic | = | initial climb |
| | cl | = | climb |
| | cr | = | cruise |
| | des | = | descent |
| | hold | = | holding |
| | app | = | approach |
| | lnd | = | landing |
| | gnd | = | ground |

### 6.7.3 Parameter Block

The parameter block contains the values of the global aircraft parameters. This block has 5 comment lines plus a comment line and a dataline for each parameter.

```
       CC======== Parameters List ========================================================/
       CC                                                                                  /
       CC Name              Unit                                                           /
       CC Parameter        Flight  Engine           Phase                         Value     /
       CC                                                                                  /
       CC max. long. acc.  [fps2]                                                          /
1 ->   CD acc_long_max     civ     jet,turbo,piston to,ic,cl,cr,des,hold,app,lnd  .20000E+01 /
       CC max. norm. acc.  [fps2]                                                          /
2 ->   CD acc_norm_max     civ     jet,turbo,piston to,ic,cl,cr,des,hold,app,lnd  .50000E+01 /
       CC nom. bank angle  [deg]                                                           /
3 ->   CD ang_bank_nom     civ     jet,turbo,piston to,lnd                        .15000E+02 /
```

The parameter comment line contains the parameter name and its unit.

The parameter data line contains five fields:

(a) Parameter Field: This field identifies the parameter.

(b) Flight Field: This field identified whether the parameter is valid for a civil flight, a military flight or both.

(c) Engine Field: This field identifies the engine type (jet, turboprop or piston) for which the parameter is valid.

(d) Phase Field: This field identifies for which flight phase the parameter is valid. 8 different flight phases are currently defined

(e) Value Field: The value field gives the value of the parameter.

The fields above are specified in the following fixed format (Fortran notation):

'CD', 1X, A15, 1X, A7, 1X, A16, 1X, A29, 1X, E10.5

The parameter list continues until 'FI' (end of file) is reached.

# 7. REMOTE FILE ACCESS

All files associated with BADA Revision 3.1 are placed within a compressed tar file located on the EEC computing facilities.

This file can be accessed from a remote system using **ftp** over Internet in the following manner:

**Outside the EEC:**

(a) Initiate an **ftp** session to the Internet address: **bada.eurocontrol.fr** using the **anonymous** account. No password is needed for this account, however, to allow for tracing of access to the account it is requested that your E-mail address is used as the password, that is:

**name@machine.domain.country**

(b) Change the working directory to bada/3.1:

**cd bada/3.1**

(c) Copy the following file to your local system using the ftp **get** command:

**get bada/3.1/badaRevision3.1.tar.Z**

(d) Uncompress the file, that is:

**uncompress badaRevision3.1.tar.Z**

(e) Restore from the tar archive file, that is:

**tar xf badaRevision3.1.tar bada3.1**

This will restore the following files:

| | |
|---|---|
| bada3.1/revisionSummary | |
| bada3.1/SYNONYM.LST | bada3.1/RCS/SYNONYM.LST,v |
| bada3.1/SYNONYM.NEW | bada3.1/RCS/SYNONYM.NEW,v |
| bada3.1/BADA.GPF | bada3.1/RCS/BADA.GPF,v |
| bada3.1/*.OPF | bada3.1/RCS/*.OPF,v |
| bada3.1/*.APF | bada3.1/RCS/*.APF,v |
| bada3.1/*.PTF | |

Note that the *.OPF, *.APF, *.PTF, BADA.GPF, SYNONYM.* and revisionSummary files are also located in the directory and can be copied individually. A summary list of the files to be restored as obtained by using the **tar -tvf** command is provided as Appendix B.

**Inside the EEC:**

**from UNIX:**

(a) Initiate an **ftp** session to the Internet address: **ftp.eurocontrol.fr** using the **anonymous** account. No password is needed for this account, however, to allow for tracing of access to the account it is requested that your E-mail address is used as the password, that is:

**name@eurocontrol.fr**

From here onwards you may follow the same procedure as for those outside the EEC.

**from PC:**

(a) Click on the "EEC Network" icon and then click on "Wftp". Fill in:

Remote Host Name: **bada.uneec.eurocontrol.fr**
User Name: **anonymous**
Password: ***your own e-mail address***

From here onwards you may follow the same procedure as for those outside the EEC.

Note that any enquiries can be addressed to the current BADA Configuration Manager at the EEC:

E-mail: bada@eurocontrol.fr

Fax: + 33 1 69 88 73 33

BADA web page: http://www.eurocontrol.fr/projects/bada/

# APPENDIX A

# BADA 3.1 - REVISION SUMMARY FILE

BADA Status Summary File
Summary Date: 98/09/29

Last BADA Revision: 3.1
Number of Files: 204 Page 1 / 6

| File Name | Revision Number | Revision Date | New | Size (bytes) | Checksum |
|---|---|---|---|---|---|
| A300__.APF | 3.1.1.1 | 98/09/17 | ... | 2424 | 2402466271 |
| A300__.OPF | 3.1.1.2 | 98/09/17 | ... | 4392 | 1079324128 |
| A300__.PTF | | 98/09/29 | | 6613 | 966483125 |
| A310__.APF | 3.1.1.1 | 98/09/17 | ... | 2424 | 2320721976 |
| A310__.OPF | 3.1.1.1 | 98/09/17 | ... | 4392 | 3340171678 |
| A310__.PTF | | 98/09/29 | | 6611 | 1605730951 |
| A320__.APF | 3.1.1.3 | 98/09/18 | ... | 2424 | 3643989116 |
| A320__.OPF | 3.1.1.4 | 98/09/23 | ... | 4392 | 2740253716 |
| A320__.PTF | | 98/09/29 | | 6613 | 1926292718 |
| A330__.APF | 3.1.1.1 | 98/09/17 | ... | 2424 | 3930034524 |
| A330__.OPF | 3.1.1.1 | 98/09/17 | ... | 4392 | 3436246341 |
| A330__.PTF | | 98/09/29 | | 6611 | 3090522326 |
| A340__.APF | 3.1.1.1 | 98/09/17 | ... | 2424 | 819928345 |
| A340__.OPF | 3.1.1.1 | 98/09/17 | ... | 4392 | 3614284317 |
| A340__.PTF | | 98/09/29 | | 6611 | 3489781152 |
| ATP___.APF | 3.1 | 98/09/11 | ... | 2424 | 3938831240 |
| ATP___.OPF | 3.1 | 98/09/11 | ... | 4392 | 3728115980 |
| ATP___.PTF | | 98/09/29 | | 6629 | 3012056807 |
| ATR___.APF | 3.1 | 98/09/11 | ... | 2424 | 2184801674 |
| ATR___.OPF | 3.1 | 98/09/11 | ... | 4392 | 1906342733 |
| ATR___.PTF | | 98/09/29 | | 6629 | 3959712654 |
| B707__.APF | 3.1 | 98/09/11 | ... | 2424 | 2121494469 |
| B707__.OPF | 3.1 | 98/09/11 | ... | 4392 | 4036297123 |
| B707__.PTF | | 98/09/29 | | 6611 | 528109107 |
| B727__.APF | 3.1 | 98/09/11 | ... | 2424 | 2234016588 |
| B727__.OPF | 3.1 | 98/09/11 | ... | 4392 | 771700228 |
| B727__.PTF | | 98/09/29 | | 6615 | 284159780 |
| B73A__.APF | 3.1 | 98/09/11 | ... | 2424 | 3005273040 |
| B73A__.OPF | 3.1 | 98/09/11 | ... | 4392 | 1157354747 |
| B73A__.PTF | | 98/09/29 | | 6615 | 4133231356 |
| B73B__.APF | 3.1 | 98/09/11 | ... | 2424 | 1145642309 |
| B73B__.OPF | 3.1 | 98/09/11 | ... | 4392 | 2404373627 |
| B73B__.PTF | | 98/09/29 | | 6615 | 3770941107 |
| B73C__.APF | 3.1 | 98/09/11 | ... | 2424 | 939726555 |
| B73C__.OPF | 3.1 | 98/09/11 | ... | 4392 | 699078617 |
| B73C__.PTF | | 98/09/29 | | 6607 | 3567431980 |
| B74A__.APF | 3.1 | 98/09/11 | ... | 2424 | 4052889346 |
| B74A__.OPF | 3.1 | 98/09/11 | ... | 4392 | 2469696040 |
| B74A__.PTF | | 98/09/29 | | 6587 | 3728262560 |
| B74B__.APF | 3.1 | 98/09/11 | ... | 2424 | 776320315 |

BADA Status Summary File
Summary Date: 98/09/29

Last BADA Revision: 3.1
Number of Files: 204



| File Name | Revision Number | Revision Date | New | Size (bytes) | Checksum |
|---|---|---|---|---|---|
| B74B__.OPF | 3.1 | 98/09/11 | ... | 4392 | 1999100852 |
| B74B__.PTF | | 98/09/29 | | 6607 | 6671166 |
| B757__.APF | 3.1 | 98/09/11 | ... | 2424 | 2052919635 |
| B757__.OPF | 3.1 | 98/09/11 | ... | 4392 | 2297467854 |
| B757__.PTF | | 98/09/29 | | 6611 | 237215350 |
| B767__.APF | 3.1 | 98/09/11 | ... | 2424 | 730503177 |
| B767__.OPF | 3.1 | 98/09/11 | ... | 4392 | 3417626437 |
| B767__.PTF | | 98/09/29 | | 6609 | 2024078377 |
| B777__.APF | 3.1 | 98/09/11 | ... | 2424 | 1306007711 |
| B777__.OPF | 3.1 | 98/09/11 | ... | 4392 | 3262935250 |
| B777__.PTF | | 98/09/29 | | 6609 | 94368737 |
| BA11__.APF | 3.1 | 98/09/11 | ... | 2424 | 1891806417 |
| BA11__.OPF | 3.1 | 98/09/11 | ... | 4392 | 1955428171 |
| BA11__.PTF | | 98/09/29 | | 6617 | 80778528 |
| BA46__.APF | 3.1 | 98/09/11 | ... | 2424 | 1491193809 |
| BA46__.OPF | 3.1 | 98/09/11 | ... | 4392 | 3622468884 |
| BA46__.PTF | | 98/09/29 | | 6621 | 2049516772 |
| BADA.GPF | ... | 9828 | 2002601091 | | |
| BE20__.APF | 3.1 | 98/09/11 | ... | 2424 | 1967059947 |
| BE20__.OPF | 3.1 | 98/09/11 | ... | 4392 | 3976772971 |
| BE20__.PTF | | 98/09/29 | | 6621 | 59131108 |
| BE99__.APF | 3.1 | 98/09/11 | ... | 2424 | 2291691715 |
| BE99__.OPF | 3.1 | 98/09/11 | ... | 4392 | 1917977017 |
| BE99__.PTF | | 98/09/29 | | 6639 | 665603622 |
| BE9L__.APF | 3.1 | 98/09/11 | ... | 2424 | 2670101977 |
| BE9L__.OPF | 3.1 | 98/09/11 | ... | 4392 | 969383479 |
| BE9L__.PTF | | 98/09/29 | | 6621 | 3234671174 |
| C130__.APF | 3.1 | 98/09/11 | ... | 2424 | 3640841743 |
| C130__.OPF | 3.1 | 98/09/11 | ... | 4392 | 2915286552 |
| C130__.PTF | | 98/09/29 | | 6613 | 625516511 |
| C160__.APF | 3.1 | 98/09/11 | ... | 2424 | 4088391282 |
| C160__.OPF | 3.1 | 98/09/11 | ... | 4392 | 203243625 |
| C160__.PTF | | 98/09/29 | | 6623 | 2061094263 |
| C421__.APF | 3.1 | 98/09/11 | ... | 2424 | 3261265188 |
| C421__.OPF | 3.1 | 98/09/11 | ... | 4392 | 410352080 |
| C421__.PTF | | 98/09/29 | | 6631 | 2103768831 |
| C550__.APF | 3.1 | 98/09/11 | ... | 2424 | 2782051080 |
| C550__.OPF | 3.1 | 98/09/11 | ... | 4392 | 2289204181 |
| C550__.PTF | | 98/09/29 | | 6609 | 3028430578 |
| C560__.APF | 3.1 | 98/09/11 | ... | 2424 | 3898316051 |

```
BADA Status Summary File
Summary Date:  98/09/29

Last BADA Revision:  3.1
Number of Files:     204                Page 3 / 6
```

| File Name | Revision Number | Revision Date | New | Size (bytes) | Checksum |
|---|---|---|---|---|---|
| C560__.OPF | 3.1 | 98/09/11 | ... | 4392 | 265591091 |
| C560__.PTF | | 98/09/29 | | 6607 | 866792712 |
| CARJ__.APF | 3.1 | 98/09/11 | ... | 2424 | 2554437208 |
| CARJ__.OPF | 3.1 | 98/09/11 | ... | 4392 | 2711349337 |
| CARJ__.PTF | | 98/09/29 | | 6611 | 845943290 |
| CL60__.APF | 3.1 | 98/09/11 | ... | 2424 | 3077365812 |
| CL60__.OPF | 3.1 | 98/09/11 | ... | 4392 | 270835273 |
| CL60__.PTF | | 98/09/29 | | 6611 | 3742869293 |
| D228__.APF | 3.1.1.1 | 98/09/17 | ... | 2424 | 1597363537 |
| D228__.OPF | 3.1 | 98/09/11 | ... | 4392 | 52470958 |
| D228__.PTF | | 98/09/29 | | 6623 | 2484071920 |
| D328__.APF | 3.1 | 98/09/11 | ... | 2424 | 2056303119 |
| D328__.OPF | 3.1 | 98/09/11 | ... | 4392 | 364596414 |
| D328__.PTF | | 98/09/29 | | 6621 | 786771307 |
| DC10__.APF | 3.1 | 98/09/11 | ... | 2424 | 1524471418 |
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| T134__.OPF | 3.1 | 98/09/11 | ... | 4392 | 710921954 |
| T134__.PTF | | 98/09/29 | | 6613 | 2899634837 |
| T154__.APF | 3.1 | 98/09/11 | ... | 2424 | 1137746663 |
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# APPENDIX B

# BADA 3.1 - TAR FILE CONTENTS

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r--r--r-- 206/201   9121 Sep 14 10:16 1998 bada3.1/RCS/SW3___.APF,v
r--r--r-- 206/201  19310 Sep 14 10:16 1998 bada3.1/RCS/SW3___.OPF,v
r--r--r-- 206/201   3328 Sep 14 10:16 1998 bada3.1/RCS/T134__.APF,v
r--r--r-- 206/201   5213 Sep 14 10:16 1998 bada3.1/RCS/T134__.OPF,v
r--r--r-- 206/201   3328 Sep 14 10:16 1998 bada3.1/RCS/T154__.APF,v
r--r--r-- 206/201   5214 Sep 14 10:16 1998 bada3.1/RCS/T154__.OPF,v
r--r--r-- 206/201   3328 Sep 14 10:17 1998 bada3.1/RCS/TRIN__.APF,v
r--r--r-- 206/201   5213 Sep 14 10:17 1998 bada3.1/RCS/TRIN__.OPF,v
r--rw-r-- 206/201  17668 Sep 14 10:17 1998 bada3.1/revisionSummary
r--r--r-- 206/201   9139 Sep 14 10:01 1998 bada3.1/SYNONYM.LST
r--r--r-- 206/201  12613 Sep 14 10:01 1998 bada3.1/SYNONYM.NEW
r--r--r-- 206/201   2424 Sep 14 10:01 1998 bada3.1/A300__.APF
r--r--r-- 206/201   4392 Sep 14 10:02 1998 bada3.1/A300__.OPF
r--r--r-- 206/201   5456 Sep 14 15:03 1998 bada3.1/A300__.PTF
r--r--r-- 206/201   2424 Sep 14 10:02 1998 bada3.1/A310__.APF
r--r--r-- 206/201   4392 Sep 14 10:02 1998 bada3.1/A310__.OPF
r--r--r-- 206/201   5456 Sep 14 15:03 1998 bada3.1/A310__.PTF
r--r--r-- 206/201   2424 Sep 14 10:02 1998 bada3.1/A320__.APF
r--r--r-- 206/201   4392 Sep 14 10:02 1998 bada3.1/A320__.OPF
r--r--r-- 206/201   5456 Sep 14 15:03 1998 bada3.1/A320__.PTF
r--r--r-- 206/201   2424 Sep 14 10:02 1998 bada3.1/A330__.APF
r--r--r-- 206/201   4392 Sep 14 10:02 1998 bada3.1/A330__.OPF
r--r--r-- 206/201   5456 Sep 14 15:03 1998 bada3.1/A330__.PTF
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r--r--r-- 206/201   2424 Sep 14 10:02 1998 bada3.1/A340__.APF
r--r--r-- 206/201   4392 Sep 14 10:02 1998 bada3.1/A340__.OPF
r--r--r-- 206/201   5456 Sep 14 15:03 1998 bada3.1/A340__.PTF
r--r--r-- 206/201   2424 Sep 14 10:02 1998 bada3.1/ATP___.APF
r--r--r-- 206/201   4392 Sep 14 10:02 1998 bada3.1/ATP___.OPF
r--r--r-- 206/201   5316 Sep 14 15:03 1998 bada3.1/ATP___.PTF
r--r--r-- 206/201   2424 Sep 14 10:02 1998 bada3.1/ATR___.APF
r--r--r-- 206/201   4392 Sep 14 10:03 1998 bada3.1/ATR___.OPF
r--r--r-- 206/201   5456 Sep 14 15:03 1998 bada3.1/ATR___.PTF
r--r--r-- 206/201   2424 Sep 14 10:03 1998 bada3.1/B707__.APF
r--r--r-- 206/201   4392 Sep 14 10:03 1998 bada3.1/B707__.OPF
r--r--r-- 206/201   5456 Sep 14 15:03 1998 bada3.1/B707__.PTF
r--r--r-- 206/201   2424 Sep 14 10:03 1998 bada3.1/B727__.APF
r--r--r-- 206/201   4392 Sep 14 10:03 1998 bada3.1/B727__.OPF
r--r--r-- 206/201   5456 Sep 14 15:03 1998 bada3.1/B727__.PTF
r--r--r-- 206/201   2424 Sep 14 10:03 1998 bada3.1/B73A__.APF
r--r--r-- 206/201   4392 Sep 14 10:03 1998 bada3.1/B73A__.OPF
r--r--r-- 206/201   5456 Sep 14 15:03 1998 bada3.1/B73A__.PTF
r--r--r-- 206/201   2424 Sep 14 10:03 1998 bada3.1/B73B__.APF
r--r--r-- 206/201   4392 Sep 14 10:04 1998 bada3.1/B73B__.OPF
r--r--r-- 206/201   5456 Sep 14 15:03 1998 bada3.1/B73B__.PTF
r--r--r-- 206/201   2424 Sep 14 10:04 1998 bada3.1/B73C__.APF
r--r--r-- 206/201   4392 Sep 14 10:04 1998 bada3.1/B73C__.OPF
r--r--r-- 206/201   5456 Sep 14 15:03 1998 bada3.1/B73C__.PTF
r--r--r-- 206/201   2424 Sep 14 10:04 1998 bada3.1/B74A__.APF
r--r--r-- 206/201   4392 Sep 14 10:04 1998 bada3.1/B74A__.OPF
r--r--r-- 206/201   5456 Sep 14 15:03 1998 bada3.1/B74A__.PTF
r--r--r-- 206/201   2424 Sep 14 10:04 1998 bada3.1/B74B__.APF
r--r--r-- 206/201   4392 Sep 14 10:04 1998 bada3.1/B74B__.OPF
r--r--r-- 206/201   5456 Sep 14 15:03 1998 bada3.1/B74B__.PTF
r--r--r-- 206/201   2424 Sep 14 10:04 1998 bada3.1/B757__.APF
r--r--r-- 206/201   4392 Sep 14 10:04 1998 bada3.1/B757__.OPF
r--r--r-- 206/201   5456 Sep 14 15:03 1998 bada3.1/B757__.PTF
r--r--r-- 206/201   2424 Sep 14 10:04 1998 bada3.1/B767__.APF
r--r--r-- 206/201   4392 Sep 14 10:05 1998 bada3.1/B767__.OPF
r--r--r-- 206/201   5456 Sep 14 15:03 1998 bada3.1/B767__.PTF
r--r--r-- 206/201   2424 Sep 14 10:05 1998 bada3.1/B777__.APF
r--r--r-- 206/201   4392 Sep 14 10:05 1998 bada3.1/B777__.OPF
r--r--r-- 206/201   5456 Sep 14 15:03 1998 bada3.1/B777__.PTF
r--r--r-- 206/201   2424 Sep 14 10:05 1998 bada3.1/BA11__.APF
r--r--r-- 206/201   4392 Sep 14 10:05 1998 bada3.1/BA11__.OPF
r--r--r-- 206/201   5456 Sep 14 15:03 1998 bada3.1/BA11__.PTF
r--r--r-- 206/201   2424 Sep 14 10:05 1998 bada3.1/BA46__.APF
r--r--r-- 206/201   4392 Sep 14 10:05 1998 bada3.1/BA46__.OPF
r--r--r-- 206/201   5456 Sep 14 15:03 1998 bada3.1/BA46__.PTF
r--r--r-- 206/201  10350 Sep 14 10:06 1998 bada3.1/BADA.GPF
r--r--r-- 206/201   2424 Sep 14 10:06 1998 bada3.1/BE20__.APF
r--r--r-- 206/201   4392 Sep 14 10:06 1998 bada3.1/BE20__.OPF
r--r--r-- 206/201   5456 Sep 14 15:03 1998 bada3.1/BE20__.PTF
r--r--r-- 206/201   2424 Sep 14 10:06 1998 bada3.1/BE99__.APF
r--r--r-- 206/201   4392 Sep 14 10:06 1998 bada3.1/BE99__.OPF
r--r--r-- 206/201   5456 Sep 14 15:03 1998 bada3.1/BE99__.PTF
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r--r--r-- 206/201   2424 Sep 14 10:06 1998 bada3.1/BE9L__.APF
r--r--r-- 206/201   4392 Sep 14 10:06 1998 bada3.1/BE9L__.OPF
r--r--r-- 206/201   5436 Sep 14 15:03 1998 bada3.1/BE9L__.PTF
r--r--r-- 206/201   2424 Sep 14 10:06 1998 bada3.1/C130__.APF
r--r--r-- 206/201   4392 Sep 14 10:07 1998 bada3.1/C130__.OPF
r--r--r-- 206/201   5456 Sep 14 15:03 1998 bada3.1/C130__.PTF
r--r--r-- 206/201   2424 Sep 14 10:07 1998 bada3.1/C160__.APF
r--r--r-- 206/201   4392 Sep 14 10:07 1998 bada3.1/C160__.OPF
r--r--r-- 206/201   5416 Sep 14 15:03 1998 bada3.1/C160__.PTF
r--r--r-- 206/201   2424 Sep 14 10:07 1998 bada3.1/C421__.APF
r--r--r-- 206/201   4392 Sep 14 10:07 1998 bada3.1/C421__.OPF
r--r--r-- 206/201   5416 Sep 14 15:03 1998 bada3.1/C421__.PTF
r--r--r-- 206/201   2424 Sep 14 10:07 1998 bada3.1/C550__.APF
r--r--r-- 206/201   4392 Sep 14 10:07 1998 bada3.1/C550__.OPF
r--r--r-- 206/201   5456 Sep 14 15:03 1998 bada3.1/C550__.PTF
r--r--r-- 206/201   2424 Sep 14 10:07 1998 bada3.1/C560__.APF
r--r--r-- 206/201   4392 Sep 14 10:08 1998 bada3.1/C560__.OPF
r--r--r-- 206/201   5456 Sep 14 15:03 1998 bada3.1/C560__.PTF
r--r--r-- 206/201   2424 Sep 14 10:08 1998 bada3.1/CARJ__.APF
r--r--r-- 206/201   4392 Sep 14 10:08 1998 bada3.1/CARJ__.OPF
r--r--r-- 206/201   5456 Sep 14 15:03 1998 bada3.1/CARJ__.PTF
r--r--r-- 206/201   2424 Sep 14 10:08 1998 bada3.1/CL60__.APF
r--r--r-- 206/201   4392 Sep 14 10:08 1998 bada3.1/CL60__.OPF
r--r--r-- 206/201   5456 Sep 14 15:03 1998 bada3.1/CL60__.PTF
r--r--r-- 206/201   2424 Sep 14 10:08 1998 bada3.1/D228__.APF
r--r--r-- 206/201   4392 Sep 14 10:08 1998 bada3.1/D228__.OPF
r--r--r-- 206/201   5456 Sep 14 15:03 1998 bada3.1/D228__.PTF
r--r--r-- 206/201   2424 Sep 14 10:08 1998 bada3.1/D328__.APF
r--r--r-- 206/201   4392 Sep 14 10:09 1998 bada3.1/D328__.OPF
r--r--r-- 206/201   5456 Sep 14 15:03 1998 bada3.1/D328__.PTF
r--r--r-- 206/201   2424 Sep 14 10:09 1998 bada3.1/DC10__.APF
r--r--r-- 206/201   4392 Sep 14 10:09 1998 bada3.1/DC10__.OPF
r--r--r-- 206/201   5456 Sep 14 15:03 1998 bada3.1/DC10__.PTF
r--r--r-- 206/201   2424 Sep 14 10:09 1998 bada3.1/DC8___.APF
r--r--r-- 206/201   4392 Sep 14 10:09 1998 bada3.1/DC8___.OPF
r--r--r-- 206/201   5456 Sep 14 15:03 1998 bada3.1/DC8___.PTF
r--r--r-- 206/201   2424 Sep 14 10:09 1998 bada3.1/DC9___.APF
r--r--r-- 206/201   4392 Sep 14 10:09 1998 bada3.1/DC9___.OPF
r--r--r-- 206/201   5456 Sep 14 15:03 1998 bada3.1/DC9___.PTF
r--r--r-- 206/201   2424 Sep 14 10:09 1998 bada3.1/DHC8__.APF
r--r--r-- 206/201   4392 Sep 14 10:09 1998 bada3.1/DHC8__.OPF
r--r--r-- 206/201   5396 Sep 14 15:03 1998 bada3.1/DHC8__.PTF
r--r--r-- 206/201   2424 Sep 14 10:10 1998 bada3.1/E120__.APF
r--r--r-- 206/201   4392 Sep 14 10:10 1998 bada3.1/E120__.OPF
r--r--r-- 206/201   5376 Sep 14 15:03 1998 bada3.1/E120__.PTF
r--r--r-- 206/201   2424 Sep 14 10:10 1998 bada3.1/F100__.APF
r--r--r-- 206/201   4392 Sep 14 10:10 1998 bada3.1/F100__.OPF
r--r--r-- 206/201   5456 Sep 14 15:03 1998 bada3.1/F100__.PTF
r--r--r-- 206/201   2424 Sep 14 10:10 1998 bada3.1/F27___.APF
r--r--r-- 206/201   4392 Sep 14 10:10 1998 bada3.1/F27___.OPF
r--r--r-- 206/201   5356 Sep 14 15:03 1998 bada3.1/F27___.PTF
r--r--r-- 206/201   2424 Sep 14 10:10 1998 bada3.1/F28___.APF
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r--r--r-- 206/201   4392 Sep 14 10:10 1998 bada3.1/F28___.OPF
r--r--r-- 206/201   5456 Sep 14 15:03 1998 bada3.1/F28___.PTF
r--r--r-- 206/201   2424 Sep 14 10:10 1998 bada3.1/F50___.APF
r--r--r-- 206/201   4392 Sep 14 10:10 1998 bada3.1/F50___.OPF
r--r--r-- 206/201   5356 Sep 14 15:03 1998 bada3.1/F50___.PTF
r--r--r-- 206/201   2424 Sep 14 10:11 1998 bada3.1/F70___.APF
r--r--r-- 206/201   4392 Sep 14 10:11 1998 bada3.1/F70___.OPF
r--r--r-- 206/201   5456 Sep 14 15:03 1998 bada3.1/F70___.PTF
r--r--r-- 206/201   2424 Sep 14 10:11 1998 bada3.1/F900__.APF
r--r--r-- 206/201   4392 Sep 14 10:11 1998 bada3.1/F900__.OPF
r--r--r-- 206/201   5456 Sep 14 15:03 1998 bada3.1/F900__.PTF
r--r--r-- 206/201   2424 Sep 14 10:11 1998 bada3.1/FA10__.APF
r--r--r-- 206/201   4392 Sep 14 10:11 1998 bada3.1/FA10__.OPF
r--r--r-- 206/201   5456 Sep 14 15:03 1998 bada3.1/FA10__.PTF
r--r--r-- 206/201   2424 Sep 14 10:11 1998 bada3.1/FA20__.APF
r--r--r-- 206/201   4392 Sep 14 10:11 1998 bada3.1/FA20__.OPF
r--r--r-- 206/201   5456 Sep 14 15:03 1998 bada3.1/FA20__.PTF
r--r--r-- 206/201   2424 Sep 14 10:11 1998 bada3.1/FA50__.APF
r--r--r-- 206/201   4392 Sep 14 10:11 1998 bada3.1/FA50__.OPF
r--r--r-- 206/201   5456 Sep 14 15:03 1998 bada3.1/FA50__.PTF
r--r--r-- 206/201   2424 Sep 14 10:11 1998 bada3.1/FGTR__.APF
r--r--r-- 206/201   4392 Sep 14 10:11 1998 bada3.1/FGTR__.OPF
r--r--r-- 206/201   5456 Sep 14 15:03 1998 bada3.1/FGTR__.PTF
r--r--r-- 206/201   2424 Sep 14 10:12 1998 bada3.1/H25B__.APF
r--r--r-- 206/201   4392 Sep 14 10:12 1998 bada3.1/H25B__.OPF
r--r--r-- 206/201   5456 Sep 14 15:03 1998 bada3.1/H25B__.PTF
r--r--r-- 206/201   2424 Sep 14 10:12 1998 bada3.1/JSTA__.APF
r--r--r-- 206/201   4392 Sep 14 10:12 1998 bada3.1/JSTA__.OPF
r--r--r-- 206/201   5376 Sep 14 15:03 1998 bada3.1/JSTA__.PTF
r--r--r-- 206/201   2424 Sep 14 10:12 1998 bada3.1/JSTB__.APF
r--r--r-- 206/201   4392 Sep 14 10:12 1998 bada3.1/JSTB__.OPF
r--r--r-- 206/201   5376 Sep 14 15:03 1998 bada3.1/JSTB__.PTF
r--r--r-- 206/201   2424 Sep 14 10:12 1998 bada3.1/L101__.APF
r--r--r-- 206/201   4392 Sep 14 10:12 1998 bada3.1/L101__.OPF
r--r--r-- 206/201   5456 Sep 14 15:03 1998 bada3.1/L101__.PTF
r--r--r-- 206/201   2424 Sep 14 10:12 1998 bada3.1/LJ35__.APF
r--r--r-- 206/201   4392 Sep 14 10:12 1998 bada3.1/LJ35__.OPF
r--r--r-- 206/201   5456 Sep 14 15:03 1998 bada3.1/LJ35__.PTF
r--r--r-- 206/201   2424 Sep 14 10:13 1998 bada3.1/MD11__.APF
r--r--r-- 206/201   4392 Sep 14 10:13 1998 bada3.1/MD11__.OPF
r--r--r-- 206/201   5456 Sep 14 15:03 1998 bada3.1/MD11__.PTF
r--r--r-- 206/201   2424 Sep 14 10:13 1998 bada3.1/MD80__.APF
r--r--r-- 206/201   4392 Sep 14 10:13 1998 bada3.1/MD80__.OPF
r--r--r-- 206/201   5456 Sep 14 15:03 1998 bada3.1/MD80__.PTF
r--r--r-- 206/201   2424 Sep 14 10:13 1998 bada3.1/MU2___.APF
r--r--r-- 206/201   4392 Sep 14 10:14 1998 bada3.1/MU2___.OPF
r--r--r-- 206/201   5456 Sep 14 15:03 1998 bada3.1/MU2___.PTF
r--r--r-- 206/201   2424 Sep 14 10:14 1998 bada3.1/P31T__.APF
r--r--r-- 206/201   4392 Sep 14 10:14 1998 bada3.1/P31T__.OPF
r--r--r-- 206/201   5456 Sep 14 15:03 1998 bada3.1/P31T__.PTF
r--r--r-- 206/201   2424 Sep 14 10:14 1998 bada3.1/PA27__.APF
r--r--r-- 206/201   4392 Sep 14 10:14 1998 bada3.1/PA27__.OPF
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r--r--r-- 206/201   5296 Sep 14 15:03 1998 bada3.1/PA27__.PTF
r--r--r-- 206/201   2424 Sep 14 10:14 1998 bada3.1/PA28__.APF
r--r--r-- 206/201   4392 Sep 14 10:14 1998 bada3.1/PA28__.OPF
r--r--r-- 206/201   5216 Sep 14 15:03 1998 bada3.1/PA28__.PTF
r--r--r-- 206/201   2424 Sep 14 10:14 1998 bada3.1/PA31__.APF
r--r--r-- 206/201   4392 Sep 14 10:15 1998 bada3.1/PA31__.OPF
r--r--r-- 206/201   5356 Sep 14 15:03 1998 bada3.1/PA31__.PTF
r--r--r-- 206/201   2424 Sep 14 10:15 1998 bada3.1/PA34__.APF
r--r--r-- 206/201   4392 Sep 14 10:15 1998 bada3.1/PA34__.OPF
r--r--r-- 206/201   5236 Sep 14 15:03 1998 bada3.1/PA34__.PTF
r--r--r-- 206/201   2424 Sep 14 10:15 1998 bada3.1/PA42__.APF
r--r--r-- 206/201   4392 Sep 14 10:15 1998 bada3.1/PA42__.OPF
r--r--r-- 206/201   5456 Sep 14 15:03 1998 bada3.1/PA42__.PTF
r--r--r-- 206/201   2424 Sep 14 10:15 1998 bada3.1/SB20__.APF
r--r--r-- 206/201   4392 Sep 14 10:15 1998 bada3.1/SB20__.OPF
r--r--r-- 206/201   5456 Sep 14 15:03 1998 bada3.1/SB20__.PTF
r--r--r-- 206/201   2424 Sep 14 10:15 1998 bada3.1/SF34__.APF
r--r--r-- 206/201   4392 Sep 14 10:16 1998 bada3.1/SF34__.OPF
r--r--r-- 206/201   5456 Sep 14 15:03 1998 bada3.1/SF34__.PTF
r--r--r-- 206/201   2424 Sep 14 10:16 1998 bada3.1/SH36__.APF
r--r--r-- 206/201   4392 Sep 14 10:16 1998 bada3.1/SH36__.OPF
r--r--r-- 206/201   5356 Sep 14 15:03 1998 bada3.1/SH36__.PTF
r--r--r-- 206/201   2424 Sep 14 10:16 1998 bada3.1/SW3___.APF
r--r--r-- 206/201   4392 Sep 14 10:16 1998 bada3.1/SW3___.OPF
r--r--r-- 206/201   5456 Sep 14 15:03 1998 bada3.1/SW3___.PTF
r--r--r-- 206/201   2424 Sep 14 10:16 1998 bada3.1/T134__.APF
r--r--r-- 206/201   4392 Sep 14 10:16 1998 bada3.1/T134__.OPF
r--r--r-- 206/201   5456 Sep 14 15:03 1998 bada3.1/T134__.PTF
r--r--r-- 206/201   2424 Sep 14 10:16 1998 bada3.1/T154__.APF
r--r--r-- 206/201   4392 Sep 14 10:16 1998 bada3.1/T154__.OPF
r--r--r-- 206/201   5456 Sep 14 15:03 1998 bada3.1/T154__.PTF
r--r--r-- 206/201   2424 Sep 14 10:17 1998 bada3.1/TRIN__.APF
r--r--r-- 206/201   4392 Sep 14 10:17 1998 bada3.1/TRIN__.OPF
r--r--r-- 206/201   5216 Sep 14 15:03 1998 bada3.1/TRIN__.PTF
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# APPENDIX C

# BADA 3.1 - LIST OF AVAILABLE AIRCRAFT MODELS

**List of Aircraft Types Supported by BADA 3.0**

| A/C Code | Model Type | Aircraft Name | Equiv. A/C | Max Alt [feet] | Wake Cat. |
|---|---|---|---|---|---|
| A10 | equiv | Thunderbolt II | FGTR | 50000 | M |
| A300 | direct | Airbus A300 | | 39000 | H |
| A310 | direct | Airbus A310 | | 41000 | H |
| A320 | direct | Airbus A320 | | 39000 | M |
| A330 | direct | Airbus A330 | | 41000 | H |
| A340 | direct | Airbus A340 | | 41000 | H |
| A4 | equiv | Skyhawk | FGTR | 50000 | M |
| A6 | equiv | Intruder | FGTR | 50000 | M |
| AC6T | equiv. | Rockwell Turbo Commander 690C | BE20 | 32000 | L |
| AN12 | equiv | Antonov AN-12 | C130 | 30000 | M |
| AN24 | equiv | Antonov AN-24 | F27 | 25000 | M |
| AN26 | equiv | Antonov AN-26 | F27 | 25000 | M |
| ATP | direct | BAe Advanced Turboprop | | 25000 | M |
| ATR | direct | ATR 42 / 72 | | 25000 | M |
| B190 | equiv | Beech 1900 | JSTA | 25000 | L |
| B707 | direct | Boeing 707-300/400 series | | 42000 | M |
| B720 | equiv | Boeing 720B | B707 | 42000 | M |
| B727 | direct | Boeing 727, all series | | 37000 | M |
| B73A | direct | Boeing 737-100/200 series | | 37000 | M |
| B73B | direct | Boeing 737-300/400/500 series | | 37000 | M |
| B73C | direct | Boeing 737-600/700/800 series | | 45000 | M |
| B74A | direct | Boeing 747-100/200/300 series | | 45000 | H |
| B74B | direct | Boeing 747-400 | | 45000 | H |
| B74S | equiv. | Boeing 747 SP | B74B | 45000 | H |
| B757 | direct | Boeing 757 all series | | 42000 | M |
| B767 | direct | Boeing 767 all series | | 42000 | H |
| B777 | direct | Boeing 777 all series | | 43100 | H |

| | | | | | |
|---|---|---|---|---|---|
| BA11 | direct | BAe 111, all series | | 35000 | M |
| BA46 | direct | BAe 146-100/200/300 | | 33000 | M |
| BE20 | direct | Beech Super King Air 200 / Huron | | 32000 | L |
| BE30 | equiv. | Beech Super King Air 300 | BE20 | 32000 | L |
| BE33 | equiv | Beech Bonanza 33 | PA34 | 15000 | L |
| BE36 | equiv | Beech Bonanza 36 | PA34 | 15000 | L |
| BE58 | equiv | Beech Baron 58 | PA27 | 20000 | L |
| BE60 | equiv | Beech Duke 60 | C421 | 23500 | L |
| BE95 | equiv. | Beech Travelair 95 | PA31 | 23000 | L |
| BE99 | direct | Beech Airliner C99 | | 15000 | L |
| BE9L | direct | Beech King Air 90 | | 31000 | L |
| BN2P | equiv. | Pilatus Islander BN2-A/B | PA31 | 23000 | L |
| C130 | direct | Lockheed Hercules | | 40000 | M |
| C135 | equiv. | Boeing Stratolifter 717 | B707 | 42000 | M |
| C141 | equiv | Lockheed Starlifter | DC8 | 42000 | H |
| C160 | direct | Aerospatiale Transall C160 | | 30000 | M |
| C172 | equiv. | Cessna Skyhawk 172 | PA28 | 12000 | L |
| C177 | equiv. | Cessna Cardinal 177 | PA28 | 12000 | L |
| C182 | equiv. | Cessna Skylane 182 | PA28 | 12000 | L |
| C303 | equiv | Cessna Crusader 303 | PA31 | 23500 | L |
| C310 | equiv | Cessna 310/310T | PA31 | 23000 | L |
| C340 | equiv. | Cessna 340/340A | PA31 | 23000 | L |
| C402 | equiv. | Cessna 402 | PA31 | 23000 | L |
| C414 | equiv | Cessna Chancellor 414 | C421 | 23500 | L |
| C421 | direct | Cessna Golden Eagle 421 | | 23500 | L |
| C425 | equiv | Cessna Corsair/Conquest | P31T | 29000 | L |
| C5 | equiv | Lockheed Galaxy | B74A | 40000 | H |
| C500 | equiv. | Cessna Citation | C550 | 43000 | L |
| C525 | equiv | Cessna Citationjet 525 | C550 | 43000 | L |
| C550 | direct | Cessna Citation II-S2 | | 43000 | L |
| C560 | direct | Cessna Citation V | | 45000 | M |

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|---|---|---|---|---|---|
| C650 | equiv. | Cessna Citation III | LJ35 | 43000 | M |
| CARJ | direct | Canadair Regional Jet | | 41000 | M |
| CL60 | direct | Canadair Challenger 600/601 | | 41000 | M |
| CN35 | equiv | Airtech (CASA/IPTN) CN-235 | ATR | 25000 | M |
| CONC | equiv | BAe-Aerospatiale Concorde | FGTR | 50000 | H |
| CVLT | equiv | Convair 580 | ATR | 25000 | M |
| D228 | direct | Dornier 228-100/200 | | 29600 | L |
| D28D | equiv. | Dornier DO 28 | PA31 | 23000 | L |
| D328 | direct | Dornier 328 | | 32800 | M |
| DC10 | direct | McDonnell-Douglas DC-10 | | 39000 | H |
| DC8 | equiv. | McDonnell-Douglas DC-8 all series | DC8 | 42000 | H |
| DC9 | direct | McDonnell-Douglas DC-9 | | 35000 | M |
| DHC8 | direct | De Havilland Dash 8 all series | | 25000 | M |
| E110 | equiv | Embrear Bandeirante | D228 | 29600 | L |
| E120 | direct | Embraer EMB-120 Brasilia | | 32000 | L |
| E3 | equiv | Boeing E-3A Sentry | B707 | 42000 | M |
| F100 | direct | Fokker 100 | | 35000 | M |
| F14 | equiv | Grumman F-14 Tomcat | FGTR | 50000 | M |
| F15 | equiv. | McDonnell-Douglas F15 Eagle | FGTR | 50000 | M |
| F16 | equiv | General Dynamics F16 Fighting Falcon | FGTR | 50000 | M |
| F18 | equiv. | McDonnell-Douglas F18 Hornet | FGTR | 50000 | M |
| F27 | direct | Fokker Friendship F27 | | 25000 | M |
| F28 | direct | Fokker Fellowship F28 | | 35000 | M |
| F4 | equiv | McDonnell-Douglas F4 Phantom | FGTR | 50000 | M |
| F50 | direct | Fokker 50 | | 25000 | M |
| F70 | direct | Fokker 70 | | 37000 | M |
| F900 | direct | Dassault Falcon 900 | | 49000 | M |
| FA10 | direct | Dassault Falcon 10 | | 45000 | M |
| FA20 | direct | Dassault Falcon 20 | | 42000 | M |
| FA50 | direct | Dassault Falcon 50 | | 43000 | M |
| FGTR | direct | Generic Military Fighter | | 50000 | M |

| | | | | | |
|---|---|---|---|---|---|
| GULF | equiv. | Gulfstream II, III, IV | CL60 | 41000 | M |
| H25B | direct | BAe Dominie | | 41000 | M |
| HAR | equiv. | BAe Harrier | FGTR | 50000 | M |
| IL18 | equiv. | Ilyushin IL-18 | C130 | 30000 | M |
| IL62 | equiv. | Ilyushin IL-62 | B707 | 42000 | M |
| IL76 | equiv. | Ilyushin IL-76 | A300 | 42000 | H |
| IL86 | equiv. | Ilyushin IL-86 | DC8 | 42000 | H |
| JAGR | equiv. | BAe Jaguar | FGTR | 50000 | M |
| JSTA | direct | BAe Jetstream 31 | | 25000 | L |
| JSTB | direct | BAe Jetstream 41 | | 26000 | L |
| L101 | direct | Lockheed L-1011 Tristar | | 42000 | H |
| L188 | equiv. | Lockheed Electra/Orion | C130 | 30000 | H |
| L29A | equiv | Lockheed Jetstar | CL60 | 41000 | M |
| L410 | equiv | LET 410 | D228 | 29600 | L |
| LJ31 | equiv | Gates Learjet 31 | LJ35 | 43000 | M |
| LJ35 | direct | Gates Learjet 35/36 | | 43000 | M |
| LR55 | equiv. | Gates Learjet 55 | LJ35 | 43000 | M |
| M20 | equiv | Mooney Mark 20 | TRIN | 12000 | L |
| MD11 | direct | McDonnell-Douglas MD-11 | | 43000 | H |
| MD80 | direct | McDonnell-Douglas MD-80 | | 37000 | M |
| MD90 | direct | McDonnell-Douglas MD-90 | MD80 | 37000 | M |
| MG21 | equiv | Mikoyan MiG 21 | FGTR | 50000 | M |
| MG23 | equiv | Mikoyan MiG 23 | FGTR | 50000 | M |
| MG25 | equiv | Mikoyan MiG 25 | FGTR | 50000 | M |
| MG29 | equiv | Mikoyan MiG 29 | FGTR | 50000 | M |
| MIR2 | equiv | Dassault-Breguet Mirage 2000 | FGTR | 50000 | M |
| MIR4 | equiv. | Dassault-Breguet Mirage IV | FGTR | 50000 | M |
| MRF1 | equiv | Dassault Mirage F1 | FGTR | 50000 | M |
| MU2 | direct | Mitsubishi Marquise/Solitaire | | 28000 | L |
| MU30 | equiv | Mitsubishi MU-300 | C550 | 43000 | L |
| P28R | equiv. | Piper Cherokee Arrow IV | TRIN | 12000 | L |

| | | | | | |
|---|---|---|---|---|---|
| P3 | equiv. | Lockheed Orion | C130 | 30000 | M |
| P31T | direct | Piper Cheyenne I/II | | 29000 | L |
| PA23 | equiv. | Piper Apache | PA27 | 20000 | L |
| PA27 | direct | Piper Aztec | | 20000 | L |
| PA28 | direct | Piper Cherokee Archer/Dakota | | 12000 | L |
| PA31 | direct | Piper Chieftain/Mojave/Navaho | | 23000 | L |
| PA34 | direct | PA34-200T Seneca-3 | | 15000 | L |
| PA42 | direct | Piper Cheyenne II/IV | | 33000 | L |
| S601 | equiv | Aerospatiale SN601 Corvette | C550 | 43000 | L |
| SB20 | direct | SAAB 2000 | | 31000 | M |
| SB32 | equiv | SAAB Lansen | FGTR | 50000 | M |
| SB35 | equiv | SAAB Draken | FGTR | 50000 | M |
| SB37 | equiv | SAAB Viggen | FGTR | 50000 | M |
| SB39 | equiv | SAAB Gripen | FGTR | 50000 | M |
| SBR1 | equiv | Rockwell Sabreliner 265 | FA20 | 42000 | M |
| SF34 | direct | SAAB Fairchild 340 | | 31000 | M |
| SH33 | equiv | Shorts 330 | SH36 | 20000 | M |
| SH36 | direct | Shorts 360 | | 20000 | M |
| SK60 | equiv | SAAB 105 | FGTR | 50000 | M |
| SW2 | equiv. | Fairchild Merlin IIA/B, IIIB/C, IVA | SW3 | 31000 | L |
| SW3 | direct | Fairchild Merlin IVC / Metro III | | 31000 | L |
| SW4 | equiv | Merlin II/A | SW3 | 31000 | L |
| T134 | direct | Tupolev TU-134 | | 39000 | M |
| T154 | direct | Tupolev TU-154 | | 41000 | M |
| TOBA | equiv. | Aerospatiale Tobago TB-10 | PA28 | 12000 | L |
| TOR | equiv. | Panavia Tornado | FGTR | 50000 | M |
| TRIN | direct | Aerospatiale Trinidad TB-20 | | 12000 | L |
| VC10 | equiv. | BAe VC10-1100 | B707 | 42000 | M |
| WW24 | equiv | IAI 1124 Westwind | H25B | 41000 | M |
| YK40 | equiv | Yakolev YK-40 | DHC8 | 25000 | M |
| YK42 | equiv | Yakolev YK-42 | BA46 | 33000 | M |

# APPENDIX D

# BADA 3.1 - SOLUTIONS FOR BUFFETING LIMIT ALGORITHM

A general solution for finding the roots of a cubic expression ( $X^3 + a_1 \cdot X^2 + a_2 \cdot X + a_3 = 0$ ) can be found in Ref. 1. If we take exprssion 3.6-6, we can rewrite it to:

$$M^3 - \frac{C_{Lbo(M=0)}}{k} \cdot M^2 + \frac{\frac{W}{S}}{0.538 \cdot P \cdot k} = 0$$

Therefore:

$$a_1 = \frac{C_{Lbo(M=0)}}{k}$$

$$a_2 = 0 \qquad a_3 = \frac{\frac{W}{S}}{0.538 \cdot P \cdot k}$$

Now let: $Q = \frac{(3 \cdot a_2 - a_1^2)}{9}$ and $R = \frac{(9 \cdot a_1 \cdot a_2 - 27 \cdot a_3 - 2 \cdot a_1^3)}{54}$

The discriminant D is equal to: $Q^3 + R^2$ . In our case D is always < 0 that means that all roots are unequal and real. A simplified computation method with the help of trigonometry is given below:

$$X_1 = 2 \cdot \sqrt{-Q} \cdot \cos\left(\frac{\theta}{3}\right) - \frac{a_1}{3}$$

$$X_2 = 2 \cdot \sqrt{-Q} \cdot \cos\left(\frac{\theta}{3} + 120^0\right) - \frac{a_1}{3}$$

$$X_3 = 2 \cdot \sqrt{-Q} \cdot \cos\left(\frac{\theta}{3} + 240^0\right) - \frac{a_1}{3}$$

With: $\cos\theta = \frac{R}{\sqrt{-Q^3}}$

The solutions x1, x2 and x3 now give the possible values of M. One solution (in our case usually x1) is always negative. The others are positive with the lower one (usually x2) being the low speed buffeting limit we are looking for.

**Ref. 1** Mathematical Handbook; M.R. Spiegel; 1968; McGraw-Hill book compagny