

EUROPEAN ORGANISATION  
FOR THE SAFETY OF AIR NAVIGATION



**EUROCONTROL EXPERIMENTAL CENTRE**

**USER MANUAL FOR THE BASE OF Aircraft DATA (BADA) REVISION 3.8**

**EEC Technical/Scientific Report No. 2010-003**

Project BADA

**Public**

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## SUMMARY

The Base of Aircraft Data (BADA) provides a set of ASCII files containing performance and operating procedure coefficients for 318 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 3.8 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.

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## USER MANUAL MODIFICATION HISTORY

Issue Number	Release Date	Comments
Revision 2.1 Issue 1.0	31.05.94	First release of document
Revision 2.2 Issue 1.0	25.01.95	Released with BADA Revision 2.2 <ul style="list-style-type: none"> <li>- 8 new aircraft models</li> <li>- 2 modified aircraft models</li> <li>- 2 modified equivalences</li> <li>- 6 removed equivalences</li> <li>- 14 new equivalences</li> <li>- modified file formats</li> <li>- additional Synonym File</li> <li>- corrections to formulas in previous version of document</li> <li>- additional description of total-energy and standard atmosphere equations</li> </ul>
Revision 2.3 Issue 1.0	08.06.95	Released with BADA Revision 2.3 <ul style="list-style-type: none"> <li>- document format modified to be consistent with EEC Technical Note standards</li> <li>- new A/C models for B73V and D328</li> <li>- MD11 changed from equivalence to direct support</li> <li>- generic military fighter model, FGTR, replaces specific fighter models</li> <li>- maximum payload parameter added to all OPF files</li> <li>- Performance Tables Files (*.PTF) introduced</li> <li>- ISA equations used for TAS/CAS conversions instead of approximations (Section 3.2)</li> <li>- use only one formula for correction of speeds at mass values different from reference mass (Section 3.3)</li> <li>- add specification of minimum speed as function of stall speed (Section 3.4)</li> <li>- specification of transition altitude calculated added (Section 4.1)</li> <li>- speed schedules modified for climb (Section 4.1) and descent (Section 4.3)</li> <li>- modify Internet address for remote access and EUROCONTROL contact person (Section 6)</li> <li>- removed Section 7 (General Comments)</li> </ul>
Revision 2.4	04.01.96	Released with BADA Revision 2.4

Issue Number	Release Date	Comments
Issue 1.0		<ul style="list-style-type: none"> <li>- new A/C model for FK70</li> <li>- C421 changed from equivalence to directly supported</li> <li>- 10 new equivalences</li> <li>- 1 modified equivalence</li> <li>- 3 re-developed models</li> <li>- introduction of dynamic maximum altitude</li> <li>- new temperature correction on thrust</li> <li>- modified max.alt for 4 models</li> <li>- modified minimum weight for 2 models</li> <li>- modified temperature coefficients for 12 models</li> <li>- esf calculation for constant CAS below tropopause changed from binomial approximation to exact formula</li> <li>- cruise Mach numbers changed for 4 models</li> <li>- change in altitude limit for descent speed</li> </ul>
Revision 2.5 Issue 1.0	20.01.97	<ul style="list-style-type: none"> <li>- re-developed models: EA32, B737, B73S, AT42, B767, DC9, BA46, FK10, MD80.</li> <li>- new model: CL65, DH83</li> <li>- change of minimum speeds</li> <li>- change of climb/descent speed schedules</li> <li>- cruise fuel flow correction</li> <li>- buffeting speed for jet a/c</li> <li>- addition of BADA.GPF file</li> <li>- definition of acceleration limits, bank angles and holding speeds</li> <li>- 38 new equivalences added (SA4, SA5, SweDen 96)</li> <li>- 1 modified equivalence (B74S)</li> <li>- modified climb/cruise speeds (BE90, BE99, E120, PA42, FK50, B73F, B767, B747, B727, DA20)</li> <li>- Format changes in OPF file</li> <li>- Header changes in PTF file</li> <li>- Temperature influence on thrust limitation changed</li> <li>- Unit of Vstall in OPF file changed to KCAS</li> <li>- Correction of typing errors</li> <li>- Correction of APF file format explanation</li> </ul>
Revision 2.6 Issue 1.0	01.09.97	<ul style="list-style-type: none"> <li>- Added non-clean drag and thrust data for: EA32, B73S, MD80, B737, B747, FK10, AT42, B767 and CL65 models</li> <li>- All models mentioned above were re-developed using new clean drag data.</li> <li>- ND16, E120 and FK50 were re-modelled to correct the cruise speed capability.</li> <li>- Change of speed schedule in the take-off / initial climb phase and approach / landing phase</li> <li>- Change in descent thrust algorithm</li> </ul>

Issue Number	Release Date	Comments
		<ul style="list-style-type: none"> <li>- Use of exact formula for density below tropopause instead of approximation.</li> <li>- Addition of formula for pressure above tropopause</li> <li>- Change of buffeting limit to 1.2g (was 1.3g)</li> <li>- Change of OPF file format</li> <li>- Buffeting coefficients for B757 and MD80 were corrected.</li> <li>- Hmo for B747 model was corrected to 45,000 ft</li> <li>- Low altitude descent behaviour corrected for: SW3, PAYE, DA50, DA10, D328, C421, BE99, BE20 and BE90 models</li> <li>- Correction of some minor typing errors</li> <li>- dynamic maximum altitude coefficients changed for B747, B74F, C130 and EA30</li> <li>- Saab 2000 (SB20) added as equivalent of D328</li> <li>- Modified algorithm for lift coefficient</li> </ul>
Revision 3.0 Issue 1.0	01.03.98	<ul style="list-style-type: none"> <li>- Climb speed law changed for jet aircraft</li> <li>- Descent speed law changed for jet, turbo and piston</li> <li>- Reduced power climbs</li> <li>- B777, SB20 and B73X models were added</li> <li>- DA01 model was removed</li> <li>- Use of ICAO doc. 8643/25 standard, which resulted in the removal of 4 additional models</li> <li>- B73F and B757 remodelled</li> <li>- MD90 added as equivalence model</li> <li>- Cruise and descent speeds for several turboprops changed</li> <li>- Climb thrust for several a/c changed</li> <li>- Removal of <math>C_{m16}</math> from drag expression</li> </ul>
Revision 3.1 Issue 1.0	01.10.98	<p>Released with BADA Revision 3.1</p> <ul style="list-style-type: none"> <li>- Descent &amp; cruise speeds for several jet aircraft changed: DC9, BA46, CL60</li> <li>- Descent, cruise &amp; climb speeds for several turboprops changed: D228, SH36</li> <li>- Maximum Operating speed for several a/c changed: PA42</li> <li>- Stalling speed for several a/c changed : DC8, T154</li> <li>- Removed formula for air density calculation above tropopause</li> <li>- Addition of Appendix D : Solutions for buffeting limit algorithm</li> <li>- Removed Section 3.7.2 : Maximum Take-Off Thrust</li> <li>- Description for Cred parameter added</li> <li>- Correction of some minor typing errors</li> <li>- Modified PTF File format (Flight Level): Section 6.6</li> <li>- Cruise CAS schedule for jet &amp; turbo aircraft (Section</li> </ul>

Issue Number	Release Date	Comments
		4.2)
Revision 3.3 Issue 1.0		<p>Released with BADA Revision 3.3</p> <ul style="list-style-type: none"> <li>- Standard atmosphere explanation added</li> <li>- Correction of some typing errors, minor changes in the layout and equations presentation.</li> <li>- Several aircraft types have changed ICAO's designator according to the ICAO doc.8643/27. Aircraft types affected by the RD3 are as follows: A300, ATR, B707, B727, B73A, B73B, B73C, B74A, B74B, B757, B767, B777, CARJ, DC8, DHC8, JSTA, JSTB, P31T, PA28, PA42. That resulted in: modification of the name of the OPF and APF files, addition of new models as synonyms, modification of Synonym.NEW and Synonym.LST files.</li> <li>- B73A, B757, MD80, B73B, F100, B727, CARJ, FA20, FA50, D228, T154 aircraft models have been re-modelled</li> <li>- A319, A321, A306, AT72 models have been added</li> <li>- Climb, cruise and descent speeds changed for several models.</li> <li>- Ground TOL for B73C has been modified.</li> <li>- MD80: Cd0 and Cd2 for IC and TO added, maximum altitude at MTOW, ISA weight gradient on maximum altitude Gw and temperature gradient Gt on maximum altitude have been changed</li> <li>- BA46 maximum altitude at MTOW, ISA weight gradient on maximum altitude Gw have been changed</li> <li>- E145 was added as equivalent of CRJ1</li> <li>- A478 was added as equivalent of AT72</li> </ul>
Revision 3.4 Issue 1.0	June 2002	<p>Released with BADA Revision 3.4</p> <ul style="list-style-type: none"> <li>- correction of some typing errors</li> <li>- in chapter 3.5 configuration threshold altitude values replaced with <math>H_{max,i}</math>, while the corresponding numbers are listed in chapter 5.6</li> <li>- Appendix B: a new column is added to the table; providing the information on maximum altitude that an aircraft can reach at MTOW (<math>h_{max}</math>)</li> <li>- FGTN aircraft model added</li> <li>- FGTH aircraft model added</li> <li>- FGTL aircraft model added</li> <li>- FGTR aircraft model removed</li> <li>- DC-9 aircraft model re-modelled</li> <li>- D228 cruise and descent speed modified</li> </ul>

Issue Number	Release Date	Comments
		<ul style="list-style-type: none"> <li>- SH36 cruise and descent speed modified</li> <li>- B738 maximum operational altitude modified</li> <li>- AT72 cruise speed corrected</li> <li>- PA34 minimum mass modified</li> <li>- B734 aircraft model added</li> <li>- B735 aircraft model added</li> <li>- E145 aircraft model added</li> <li>- B737 aircraft model added</li> <li>- AT45 aircraft model added</li> <li>- B762 aircraft model added</li> <li>- B743 aircraft model added</li> <li>- Removal of several existing OPF and APF files due to the change of ICAO aircraft designators according to RD3: A330, A340, BA46, DC9, MD80</li> <li>- Addition of several new OPF and APF files due to the change of ICAO aircraft designators according to RD3: A333, A343, B461, DC94, MD83</li> <li>- Addition of new equivalence aircraft types: A332, A342, A345, A346, B461, B462, B463, DC91, DC92, DC93, DC95, MD81, MD82, MD87, MD88, A124, AC80, AC90, AC95, AJET, AMX, AN72, ATLA, B1, B350, B739, B74D, BDOG, BE10, BE40, BE76, BER4, C17, C72R, C77R, C82R, C210, C212, C337, C526, C56X, CRJ7, E135, EUFI, F1, FT2H, F104, G222, GLF5, HAWK, H25A, H25C, IL96, JS1, JS3, JS20, LJ24, M20T, M20P, K35R, N262, P28T, P28B, PA32, PAY4, P68, PA44, SB05, T204, TBM7</li> <li>- Modification of the value for Maximum bank angles for civil flight during HOLD in BADA.GPF file</li> <li>- Configuration Management of BADA files have been changed; files have been migrated from RCS to Continuous Configuration Management System. That resulted in the modification of the "identification" part of all BADA files given in the header.</li> </ul>
<p>Revision 3.5 Issue 1.0</p>	<p>July 2003</p>	<p>Released with BADA Revision 3.5</p> <ul style="list-style-type: none"> <li>- correction of some typing errors</li> <li>- B712 aircraft model added</li> <li>- LJ45 aircraft model added</li> <li>- C750 aircraft model added</li> <li>- RJ85 aircraft model added</li> <li>- B736 aircraft model added</li> <li>- B753 aircraft model added</li> <li>- A332 aircraft model added</li> </ul>

Issue Number	Release Date	Comments
		<ul style="list-style-type: none"> <li>- B772 re-modelled</li> <li>- B738 re-modelled</li> <li>- B763 re-modelled</li> <li>- B703 WTC modified</li> <li>- JS41 WTC modified</li> <li>- Addition of new syn. aircraft types: P180, GLEX, C30J, J328, A7, B52, ETAR, F117, L159</li> <li>- Modification of BADA models for existing synonym aircraft types: C17, GLF3, GLF3, GLF4, GLF5</li> <li>- SYNONYM_ALL.LST file added.</li> </ul>
<p>Revision 3.6 Issue 1.0</p>	<p>July 2004</p>	<p>Released with BADA Revision 3.6</p> <p>The following models of aircraft added in BADA 3.6:</p> <ul style="list-style-type: none"> <li>- Dash 8-100: <b>DH8A</b></li> <li>- Boeing MD82: <b>MD82</b></li> <li>- Boeing B767-400: <b>B764</b></li> <li>- Boeing B777-300: <b>B773</b></li> <li>- BAE 146-200: <b>B462</b></li> </ul> <p>The following models of aircraft have been re-modelled in BADA 3.6:</p> <ul style="list-style-type: none"> <li>- Airbus A300B4-203: <b>A30B</b></li> <li>- Airbus A310: <b>A310</b></li> <li>- Airbus A319: <b>A319</b></li> <li>- Airbus A320: <b>A320</b></li> <li>- Airbus A321: <b>A321</b></li> <li>- Airbus A330-301: <b>A333</b></li> <li>- Airbus A340-313: <b>A343</b></li> <li>- Boeing B737-200: <b>B732</b></li> <li>- Boeing B737-300: <b>B733</b></li> <li>- Boeing B747-200: <b>B742</b></li> <li>- Boeing B747-400: <b>B744</b></li> <li>- Boeing B757-200: <b>B752</b></li> </ul> <p>Addition of new synonym aircraft types:</p> <p>A3ST, ASTR, B701, C441, GALX, J728, K35A, K35E, L29B, LJ25, LJ60, NIM, PC12, R135, RJ1H, RJ70, P32R, C208, AA5, S76, DC3, BLAS, AEST, EC35, PAY1, PA18, BE55, C170, B461.</p> <p>Correction of syntax errors in BADA files:</p> <ul style="list-style-type: none"> <li>- Boeing B777-200: <b>B772</b></li> <li>- ATR42-500: <b>AT45</b></li> </ul>
<p>Revision 3.7 Issue 1.0</p>	<p>March 2009</p>	<p>Released with BADA Revision 3.7</p> <ul style="list-style-type: none"> <li>- Modification of the values for constants g and R</li> </ul>

Issue Number	Release Date	Comments
		<p>in Section 3.</p> <ul style="list-style-type: none"> <li>- New description of formula 3.1-8 to match its actual use in some models.</li> <li>- Coefficient CV<sub>min</sub>, TO is no longer used in climb speed schedule, only in flight envelope determination.</li> <li>- Numbering of several equations changed due to reorganisation of related sections.</li> <li>- Change of descent thrust computation when CT<sub>des,app</sub> and CT<sub>des,ld</sub> are null in Section 3.7.3.</li> <li>- Clarification of descent fuel flow computation in Section 3.9.</li> <li>- Additional information on climb and descent speed schedules in Section 4.</li> <li>- Update of some Fortran format descriptions in Section 6.</li> <li>- Additional reasons for ROCD discontinuities added in Section 6.6.</li> <li>- Introduction of new PTD file format.</li> <li>- Update of Section 7 to describe the new means of access to the BADA files.</li> <li>- Remodelling of 71 a/c types from BADA 3.6 - more details in [RD8].</li> <li>- Addition of 12 new a/c models for following a/c types: A346, A388, BE58, C510, CRJ2, CRJ9, DA42, DH8D, E135, E170, E190, EA50.</li> <li>- All synonym aircraft have been re-evaluated and some reassigned – more details in [RD12] reassigned.</li> </ul>
<p>Revision 3.8 Issue 1.0</p>	<p>April 2010</p>	<p>Released with BADA Revision 3.8</p> <ul style="list-style-type: none"> <li>- Introduction of new revised atmosphere model and relevant corresponding updates throughout the User Manual document</li> <li>- Harmonisation of acronyms for physical constants with the EEC Technical Report No. 2010-001, February 2010 “Revision of Atmosphere Model in BADA Aircraft Performance Model”</li> <li>- Clarification of descent fuel flow computation in Section 3.9.</li> <li>- Information added on whether some BADA model coefficients may or may not be negative.</li> <li>- Missing information about speed schedule in cruise for piston aircraft added (section 4.2)</li> <li>- Additional clarifications provided on use of altitudes in Section 4.</li> <li>- Additional explanatory note provided on data presented in the PTF file.</li> <li>- Correction of error in the solution for buffeting limit algorithm.</li> </ul>

Issue Number	Release Date	Comments
		<ul style="list-style-type: none"><li>- Remodelling of 5 a/c types from BADA 3.7: B763, FA50, F900, RJ85, TRIN</li><li>- Addition of 8 new a/c models : A318, A3ST, A345, B739, B77L, B77W, F2TH, FA7X.</li><li>- 23 new synonym aircraft added – more details in [RD12].</li><li>- Regeneration of all PTF/PTD files</li></ul>

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## 1. INTRODUCTION

### 1.1. IDENTIFICATION

This document is the User Manual for the Base of Aircraft Data (BADA) Revision 3.8. This manual replaces the previous User Manual for BADA Revision 3.7 [RD1].

### 1.2. PURPOSE

BADA is a collection of ASCII files which specifies operation performance parameters, airline procedure parameters and performance summary tables for 318 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 Validation Infrastructure Centre of Expertise located 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.

### 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, summarises the differences between BADA 3.8 and the previous revision BADA 3.7.

**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. An atmosphere model is also provided.

**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. Six 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;
- Performance Table Data (PTD) containing detailed performance data 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 aircraft.

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

Two appendices are also provided with this document. **Appendix A** provides a list of the aircraft types supported by BADA 3.8 and **Appendix B** gives solutions for a buffeting limit algorithm.

#### 1.4. REFERENCED DOCUMENTS

- RD1** User Manual for the Base of Aircraft Data (BADA) Revision 3.7; EEC Technical Report No. 2009/03, March 2009.
- RD2** Aircraft Type Designators, ICAO Document 8643/37, 2009 edition, <http://www.icao.int/anb/ais/8643/>
- 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 Product Management Document; EEC Technical Report No. 2009-008, April 2009.
- RD6** Base of Aircraft Data (BADA) Aircraft Performance Modelling Manual: EEC Technical Report No. 2009-009, April 2009.
- 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 3.8; EEC Technical Note 2010/004; April 2010.
- RD9** Aircraft Performance Summary Tables for the Base of Aircraft Data (BADA) Revision 3.8; EEC Technical Note 2010/005; April 2010.
- RD10** Aircraft Type Designators, ICAO Document 8643, Version 24-37.
- RD11** BADA User Support Tool – User Guide, April 2009.
- RD12** Synonym Aircraft Report for the Base of Aircraft Data (BADA) - Revision 3.8: EEC Technical Report No. 2010-007, April 2010.
- RD13** Model Accuracy Summary Report for the Base of Aircraft Data (BADA) - Revision 3.8: EEC Technical Report No. 2010-006, April 2010.
- RD14** Revision of Atmosphere Model in BADA Aircraft Performance Model: EEC Technical Report No. 2010-001, February 2010.

## 1.5. GLOSSARY OF ACRONYMS

<b>AGL</b>	<b>A</b> bove <b>G</b> round <b>L</b> evel
<b>APF</b>	<b>A</b> irlines <b>P</b> rocedures <b>F</b> ile
<b>ASCII</b>	<b>A</b> merican <b>S</b> tandard <b>C</b> ode for the <b>I</b> nterchange of <b>I</b> nformation
<b>ATM</b>	<b>A</b> ir <b>T</b> raffic <b>M</b> anagement
<b>BADA</b>	<b>B</b> ase of <b>A</b> ircraft <b>D</b> ata
<b>CAS</b>	<b>C</b> alibrated <b>A</b> irspeed
<b>EEC</b>	<b>E</b> UROCONTROL <b>E</b> xperimental <b>C</b> entre
<b>ESF</b>	<b>E</b> nergy <b>S</b> hare <b>F</b> actor
<b>ICAO</b>	<b>I</b> nternational <b>C</b> ivil <b>A</b> viation <b>O</b> rganisation
<b>ISA</b>	<b>I</b> nternational <b>S</b> tandard <b>A</b> tmosphere
<b>MASS</b>	<b>M</b> ulti- <b>A</b> ircraft <b>S</b> implified <b>S</b> imulator
<b>MLW</b>	<b>M</b> aximum <b>L</b> anding <b>W</b> eight
<b>MSL</b>	<b>M</b> ean <b>S</b> ea <b>L</b> evel
<b>MTOW</b>	<b>M</b> aximum <b>T</b> ake- <b>o</b> ff <b>W</b> eight
<b>OPF</b>	<b>O</b> perations <b>P</b> erformance <b>F</b> ile
<b>PTD</b>	<b>P</b> erformance <b>T</b> able <b>D</b> ata
<b>PTF</b>	<b>P</b> erformance <b>T</b> able <b>F</b> ile
<b>RCS</b>	<b>R</b> evision <b>C</b> ontrol <b>S</b> ystem
<b>ROCD</b>	<b>R</b> ate of <b>C</b> limb or <b>D</b> escent
<b>TAS</b>	<b>T</b> rue <b>A</b> irspeed
<b>TEM</b>	<b>T</b> otal- <b>E</b> nergy <b>M</b> odel

## 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]
$g_0$	gravitational acceleration	[m/s <sup>2</sup> ]
$\frac{dh}{dt}$	vertical speed	[m/s] or [ft/min]
h	geodetic altitude	[metres] or [ft]
H	geopotential altitude	[metres] or [ft]
$H_p$	geopotential pressure altitude	[metres] or [ft]
C	general coefficient	
D	drag force	[Newtons]
m	aircraft mass	[tonnes] or [kg]
M	Mach number	
MSL	Mean Sea Level	
$p$	Actual pressure	[Pa]
$p_0$	Standard pressure at MSL	[Pa]
R	real gas constant for air	[m <sup>2</sup> /Ks <sup>2</sup> ]
ROCD	Rate of Climb or Descent	[m/s] or [ft/min]
S	reference wing surface area	[m <sup>2</sup> ]
T	temperature	[Kelvin]
$T_{HR}$	thrust	[N]
V	speed	[m/s] or [knots]
$\Delta T$	temperature difference	[Kelvin]
W	weight	[N]
$\eta$	thrust specific fuel flow	[kg/(min*kN)]
$\rho$	air density	[kg/m <sup>3</sup> ]

## 2. REVISION SUMMARY

This section summarises the aircraft types that are supported in BADA Revision 3.8 along with the updates that have been made from the previous release, BADA Revision 3.7.

### 2.1. SUPPORTED AIRCRAFT

BADA 3.8 provides operations and procedures data for a total of 318 aircraft types. For 111 of these aircraft types, data is provided directly in files. These aircraft types are referred to as being directly supported and referred to as aircraft original models. The way they have been identified is described in [RD6]. For the other 207 aircraft types, the data is specified to be the same as one of the directly supported 111 aircraft types. These aircraft types have been identified as being 'equivalent' to original aircraft models. They are referred to as synonym aircraft. More details on the way they have been identified is given in [RD12].

With three exceptions, each supported aircraft type is identified by a 4-character designation code assigned by the International Civil Aviation Organisation (ICAO) [RD2]. The exceptions are the models representing generic military fighters, which use the designators: FGTH, FGTL, FGTN.

The list of aircraft types supported by BADA 3.8 is given in Appendix A. 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 original or synonym) is specified. Also, for each synonym aircraft, which is supported through equivalence, the corresponding equivalent aircraft type is specified.

### 2.2. UPDATES FOR BADA REVISION 3.8

Updates made to BADA Revision 3.8 from the previous revision 3.7 are listed below:

- (a) Introduction of new atmosphere model.
- (b) Updates of existing documentation.
- (c) Re-modelling of 5 aircraft models.
- (d) Addition of 8 new aircraft models.
- (e) Regeneration of all PTF and PTD files.
- (f) Addition of new synonym aircraft.
- (g) Implementation of new ICAO aircraft designators according to the ICAO doc. 8643/37.

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

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### 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 equations for atmospheric properties and the Total-Energy Model (TEM) 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. ATMOSPHERE MODEL

This section provides expressions for the atmospheric properties (pressure, temperature, density and speed of sound) as a function of altitude which are required for calculation of aircraft performances and movements<sup>1</sup>. Conversions from CAS to TAS and Mach number also require the determination of several atmospheric properties as a function of altitude.

The most important equations for atmospheric properties used by BADA and CAS/TAS conversion are summarised in this chapter, while other expressions and more details are provided in the RD14.

##### 3.1.1. Definitions

Mean Sea Level (MSL) Standard atmosphere conditions are those that occur in the International Standard Atmosphere (ISA) at the point where the geopotential pressure altitude  $H_p^2$  is zero. They are denoted as  $T_0$ ,  $p_0$ ,  $\rho_0$  and  $a_0$  with the values listed below:

Standard atmospheric temperature at MSL :	$T_0$	=	288.15	[°K]
Standard atmospheric pressure at MSL :	$p_0$	=	101325	[Pa]
Standard atmospheric density at MSL :	$\rho_0$	=	1.225	[kg/m <sup>3</sup> ]
Speed of sound :	$a_0$	=	340.294	[m/s]

<sup>1</sup> These equations are based on the International Standard Atmosphere (ISA) [RD4].

<sup>2</sup> Geopotential pressure altitude  $H_p$  is the geopotential altitude  $H$  that occurs in the ISA atmospheric conditions [RD14].

Mean Sea Level (MSL) atmosphere conditions are those that occur in a non-ISA atmosphere. They are identified by the sub index MSL and differ from  $(T_0, p_0, \rho_0, a_0)$  in non-ISA conditions.

Non-ISA atmospheres are those that follow the same hypotheses as the ISA atmosphere but differ from it in that one or both of the following parameters is not zero:

1.  **$\Delta T$** . Temperature differential at MSL. It is the difference in atmospheric temperature between a given non standard atmosphere and ISA at MSL.
2.  **$\Delta p$** . Pressure differential at MSL. It is the difference in atmospheric pressure at MSL between a given atmosphere and ISA.

The values of these two parameters uniquely identify any non ISA atmosphere. Thus, a non ISA atmosphere provides expressions for the atmospheric pressure, temperature and density as functions of the geopotential altitude  $H^3$  and its two differentials. RD14 provides more details on the corresponding analytical expressions.

### 3.1.2. Expressions

The relationships linking the atmospheric pressure  $p$ , temperature  $T$ , geopotential pressure altitude  $H_p$  and geopotential altitude  $H$  for any ISA<sup>4</sup> and non ISA atmosphere are provided below.

Physical constants which are used throughout this chapter are listed below:

$$\text{Adiabatic index of air : } \kappa = 1.4$$

$$\text{Real gas constant for air : } R = 287.05287 \text{ [m}^2/\text{Ks}^2\text{]}$$

$$\text{Gravitational acceleration : } g_0 = 9.80665 \text{ [m/s}^2\text{]}$$

$$\begin{array}{l} \text{ISA temperature gradient with altitude} \\ \text{below the tropopause : } \beta_{T,<} = -0.0065 \text{ [}^\circ\text{K/m]} \end{array}$$

Note that subindex  $<$  denotes values below and equal to the tropopause and subindex  $>$  denotes values above the tropopause (as defined by 3.1-11).

#### Standard Mean Sea Level (subindex $H_p = 0$ )

The temperature differential  $\Delta T$  sets the value of the real temperature  $T$  in non standard atmospheres.

$$H_{P,HP=0} = 0 \tag{3.1-1}$$

<sup>3</sup> Geopotential altitude  $H$  is that which under the standard constant gravitational field provides the same differential work performed by the standard acceleration of free fall when displacing the unit of mass a distance  $dH$  along the line of force, as that performed by the geopotential acceleration when displacing the unit of mass a geodetic distance  $dh$  [RD14].

<sup>4</sup> By replacing  $\Delta T$  and  $\Delta p$  parameters with zeros the expressions are made applicable to the case of the standard atmosphere.

$$T_{ISA,HP=0} = T_0 \quad (3.1-2)$$

$$\rho_{HP=0} = \rho_0 \quad (3.1-3)$$

$$T_{HP=0} = T_0 + \Delta T \quad (3.1-4)$$

$$H_{HP=0} = 1/\beta_{T,<} (T_0 - T_{ISA,MSL} + \Delta T \ln (T_0 / T_{ISA,MSL})) \quad (3.1-5)$$

Where  $T_{ISA}$  is the standard atmospheric temperature that occurs in the ISA atmosphere. It is a function of the geopotential pressure altitude  $H_P$ .

### Mean Sea Level (subindex MSL)

The pressure differential  $\Delta p$  sets the value of the atmospheric pressure  $p$ .

$$H_{MSL}^5 = 0 \quad (3.1-6)$$

$$\rho_{MSL} = \rho_0 + \Delta p \quad (3.1-7)$$

$$H_{P,MSL} = \frac{T_0}{\beta_{T,<}} \left[ \left( \frac{p_{MSL}}{p_0} \right)^{\frac{\beta_{T,<R}}{g_0}} - 1 \right] \quad (3.1-8)$$

$$T_{ISA,MSL} = T_0 + \beta_{T,<} H_{P,MSL} \quad (3.1-9)$$

$$T_{MSL} = T_0 + \Delta T + \beta_{T,<} H_{P,MSL} \quad (3.1-10)$$

### Tropopause

Tropopause is the separation between two different layers: the troposphere, which stands below it, and the stratosphere, which is placed above. Its altitude  $H_{P,trop}$  is constant when expressed in terms of geopotential pressure altitude:

$$H_{p,trop} = 11000 \text{ [m]} \quad (3.1-11)$$

---

<sup>5</sup> In order to simplify the expressions, this document assumes that the geopotential altitude at mean sea level is always zero.

a) Determination of Temperature

$$T = f(H_P, \Delta T) \quad (3.1-12)$$

$$T_{<} = T_0 + \Delta T + \beta_{T,<} H_{P,<} \quad (3.1-13)$$

$$T_{trop} = T_0 + \Delta T + \beta_{T,<} H_{P,trop} \quad (3.1-14)$$

$$T_{>} = T_{trop} \quad (3.1-15)$$

 b) Determination of Air Pressure

$$\rho = f(T, \Delta T) \quad (3.1-16)$$

$$p_{<} = p_0 \left( \frac{T_{<} - \Delta T}{T_0} \right)^{-\frac{g}{\beta_{T,<} R}} \quad (3.1-17)$$

$$p_{trop} = p_0 \left( \frac{T_{trop} - \Delta T}{T_0} \right)^{-\frac{g}{\beta_{T,<} R}} \quad (3.1-18)$$

$$-\frac{g}{k_T \cdot R} \approx 5.25583 \quad (3.1-19)$$

$T_{>} = T_{trop}$ , so  $p_{>}$  does not directly depend on temperature  $T_{>}$ .

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

$$p_{>} = p_{trop} \exp \left[ -\frac{g}{RT_{ISA,trop}} (H_{P,>} - H_{P,trop}) \right] \quad (3.1-20)$$

where altitudes  $H_{P,>}$  and  $H_{P,trop}$  are expressed in metres.

 c) Determination of Air Density

The Air Density,  $\rho$ , in kg/m<sup>3</sup>, is calculated from the pressure  $p$  and the temperature  $T$  at altitude using the perfect gas law:

$$\rho = \frac{P}{RT} \quad (3.1-21)$$

d) Determination of Speed of Sound

The speed of sound, a, is the speed at which the pressure waves travel through a fluid and it is given by the expression:

$$a = \sqrt{\kappa R T} \quad (3.1-22)$$

e) CAS/TAS Conversion

The true air speed, VTAS, is calculated as a function of the calibrated air speed, VCAS, as follows:

$$V_{TAS} = \left[ \frac{2 p}{\mu \rho} \left\{ \left( 1 + \frac{p_0}{p} \left[ \left( 1 + \frac{\mu \rho_0}{2 p_0} V_{CAS}^2 \right)^{1/\mu} - 1 \right] \right)^\mu - 1 \right\} \right]^{1/2} \quad (3.1-23)$$

Similarly, VCAS is calculated as a function of VTAS as follows:

$$V_{CAS} = \left[ \frac{2 p_0}{\mu \rho_0} \left\{ \left( 1 + \frac{p}{p_0} \left[ \left( 1 + \frac{\mu \rho}{2 p} V_{TAS}^2 \right)^{1/\mu} - 1 \right] \right)^\mu - 1 \right\} \right]^{1/2} \quad (3.1-24)$$

where symbols not previously defined are explained below:

$$\mu = \frac{(\kappa - 1)}{\kappa} \quad (\mu = 1 / 3.5 \text{ if } \kappa = 1.4) \quad (3.1-25)$$

Also note that for these conversion formulas above, the speeds VTAS and VCAS must be specified in m/s.

f) Mach/TAS conversion

$$V_{TAS} = M \times \sqrt{\kappa \cdot R \cdot T} \quad (3.1-26)$$

g) Mach/CAS transition altitude

The transition altitude (also called crossover altitude),  $H_{p,trans}$  (feet), between a given CAS, VCAS [m/s] and a Mach number,  $M$ , is defined to be the geopotential pressure altitude at which VCAS and  $M$  represent the same TAS value, and can be calculated as follows:

$$H_{p,trans} = \left( \frac{1000}{(.3048) \cdot (6.5)} \right) \cdot [(T_0 + \Delta T) \cdot (1 - \theta_{trans})] \quad (3.1-27)$$

where,

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

$$\theta_{trans} = (\delta_{trans})^{\frac{\beta_{T,c} R}{s}} \quad (3.1-28)$$

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

$$\delta_{trans} = \frac{\left[ 1 + \left( \frac{\kappa - 1}{2} \right) \left( \frac{V_{CAS}}{a_0} \right)^2 \right]^{\frac{\kappa}{\kappa - 1}} - 1}{\left[ 1 + \frac{\kappa - 1}{2} M^2 \right]^{\frac{\kappa}{\kappa - 1}} - 1} \quad (3.1-29)$$

where  $a_0$  is the ISA speed of sound at sea level = 340.29 m.s-1

### 3.2. 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:

$$(T_{HR} - D) V_{TAS} = mg_0 \frac{dh}{dt} + mV_{TAS} \frac{dV_{TAS}}{dt} \quad (3.2-1)$$

The symbols are defined below with metric units specified:

$T_{HR}$	-	thrust acting parallel to the aircraft velocity vector	[Newtons]
$D$	-	aerodynamic drag	[Newtons]
$m$	-	aircraft mass	[kilograms]
$h$	-	geodetic altitude	[m]
$g_0$	-	gravitational acceleration	[9.80665 m/s <sup>2</sup> ]
$V_{TAS}$	-	true airspeed	[m/s]
$\frac{d}{dt}$	-	time derivative	[s <sup>-1</sup> ]

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 rate of climb or descent (ROCD) to be controlled. The other variable is then determined by equation 3.2-1. 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 3.2-1 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 3.2-1 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 3.2-1 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 3.2-1 is most often used to calculate the rate of climb or descent. To facilitate this calculation, equation 3.2-1 can be rearranged as follows:

$$(T_{HR} - D) \times V_{TAS} = mg_0 \frac{dh}{dt} + m V_{TAS} \left( \frac{dV_{TAS}}{dh} \right) \left( \frac{dh}{dt} \right) \quad (3.2-2)$$

Isolating the vertical speed on the left hand side gives:

$$\frac{dh}{dt} = \frac{(T_{HR} - D)V_{TAS}}{mg_0} \left[ 1 + \left( \frac{V_{TAS}}{g_0} \right) \left( \frac{dV_{TAS}}{dh} \right) \right]^{-1} \quad (3.2-3)$$

Vertical speed is defined as the variation with time of the aircraft geodetic altitude  $h$ . The assumption of a standard constant gravity field derives in identical geodetic and geopotential altitudes  $H$  [RD14].

The ROCD is defined as the variation with time of the aircraft geopotential pressure altitude  $H_p$ . It is the preferred way of presenting the performances of an aircraft as it eliminates possible variations caused by the atmospheric conditions:

$$ROCD = \frac{dH_p}{dt} = \frac{T - \Delta T}{T} \frac{(T_{HR} - D)V_{TAS}}{mg_0} \left[ 1 + \left( \frac{V_{TAS}}{g_0} \right) \left( \frac{dV_{TAS}}{dh} \right) \right]^{-1} \quad (3.2-4)$$

where :

- $T$  - atmosphere temperature, [°K];
- $\Delta T$  - temperature differential, [°K].

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,  $f \{M\}$ .

$$f \{M\} = \left[ 1 + \left( \frac{V_{TAS}}{g_0} \right) \cdot \left( \frac{dV_{TAS}}{dh} \right) \right]^{-1} \quad (3.2-5)$$

This leads to:

$$\frac{dh}{dt} = \left[ \frac{(T_{HR} - D)V_{TAS}}{mg_0} \right] f \{M\} \quad (3.2-6)$$

$$ROCD = \frac{dH_p}{dt} = \frac{T - \Delta T}{T} \left[ \frac{(T_{HR} - D)V_{TAS}}{mg_0} \right] f \{M\} \quad (3.2-7)$$

This energy share factor  $f \{M\}$  specifies how much of the available power is allocated to climb as opposed to acceleration while following a selected speed profile during climb.

For several common flight conditions equation 3.2-5 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)

$$f \{M\} = 1.0 \quad (3.2-8)$$

Note that above the tropopause 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:

$$f \{M\} = \left[ 1 + \frac{\kappa R \beta_{T,<}}{2 g_0} M^2 \frac{T - \Delta T}{T} \right]^{-1} \quad (3.2-9)$$

where,

- R is the real gas constant for air,  $R = 287.05287 \text{ [m}^2/\text{Ks}^2]$
- $g_0$  is the gravitational acceleration,  $g = 9.80665 \text{ [m/s}^2]$
- $\beta_{T,<}$  is the ISA temperature gradient  
with altitude below the tropopause,  $\beta_{T,<} = -0.0065 \text{ [}^\circ\text{K/m]}$
- M is the Mach number
- $\kappa$  is the adiabatic index of air,  $\kappa = 1.4$

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. Consequently, 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

$$f \{M\} = \left\{ 1 + \frac{\kappa R \beta_{T,<}}{2 g_0} M^2 \frac{T - \Delta T}{T} + \left( 1 + \frac{\kappa - 1}{2} M^2 \right)^{\frac{-1}{\kappa - 1}} \left\{ \left( 1 + \frac{\kappa - 1}{2} M^2 \right)^{\frac{\kappa}{\kappa - 1}} - 1 \right\} \right\}^{-1} \quad (3.2-10)$$

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.

$$f\{M\} = \left\{ 1 + \left( 1 + \frac{\kappa-1}{2} M^2 \right)^{\frac{-1}{\kappa-1}} \left\{ \left( 1 + \frac{\kappa-1}{2} M^2 \right)^{\frac{\kappa}{\kappa-1}} - 1 \right\} \right\}^{-1} \quad (3.2-11)$$

This formula is identical to (3.2-10), except that  $\beta_{T,<}$  is null since we are above the tropopause.

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 neither constant Mach number nor constant CAS is maintained, the following energy share factors are used.

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 1 since the change of altitude benefits from a transfer of kinetic energy.

### 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 ICAO associates a wake category with each aircraft type designator [RD2].

### 3.4. MASS

Four mass values are specified for each aircraft in tonnes:

- $m_{\min}$  - minimum mass
- $m_{\max}$  - maximum mass
- $m_{\text{ref}}$  - reference mass
- $m_{\text{pyld}}$  - maximum payload mass

Note that the specified mass limits are taken from aircraft performance reference data which is available in the BADA library. In function of specific aircraft certified limitations, a particular aircraft version of a given aircraft type (model) may have different limits. More details on the way the mass limits are selected in BADA is provided in [RD6].

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

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

In this formula, the aircraft reference speed  $V_{\text{ref}}$  is given for the reference mass  $m_{\text{ref}}$ . 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,  $V_{\text{stall}}$ .

### 3.5. FLIGHT ENVELOPE

#### (a) Maximum Speed and Altitude

The maximum speed and altitude for an aircraft are 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 operating altitude, in feet, above standard MSL
$h_{max}$	-	maximum altitude, in feet, above standard MSL at MTOW under ISA conditions (allowing about 300 fpm of residual Rate Of Climb), in feet
$G_w$	-	mass gradient on $h_{max}$ , in feet/kg
$G_t$	-	temperature gradient on $h_{max}$ in feet/degree Celsius

The maximum altitude for any given mass is:

$$h_{max/act} = \text{MIN} [ h_{MO}, h_{max} + G_t \times (\Delta T - C_{Tc,4}) + G_w \times (m_{max} - m_{act}) ] \quad (3.5-1)$$

with:  $G_w \geq 0$ ;

$G_t \leq 0$ ;

if  $(\Delta T - C_{Tc,4}) < 0$ , then :  $(\Delta T - C_{Tc,4}) = 0$ ;

with  $\Delta T$  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  $h_{MO}$ .

Note that the given speed and altitude limits are taken from available reference data: depending upon specific certifications, a particular aircraft of a given type may present different limits.

#### (b) Minimum Speed

The minimum speed for the aircraft is in function of aircraft stall speed and specified as follows:

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

$$V_{min} = C_{vmin} \times V_{stall} \quad \text{otherwise} \quad (3.5-3)$$

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  $[(V_{stall})_i]$  and configuration threshold altitude  $[H_{max, i}]$  given for each:

TO - take-off configuration (in climb up to $H_{max, TO}$ AGL)	$(V_{stall})_{TO}$
IC - initial climb configuration (in climb between $H_{max, TO}$ and $H_{max, IC}$ AGL)	$(V_{stall})_{IC}$
CR - cruise (clean) configuration (in climb above $H_{max, IC}$ AGL, in descent above $H_{max, AP}$ AGL, in descent below $H_{max, AP}$ AGL as long as $V \geq V_{minCruise} + 10$ kts )	$(V_{stall})_{CR}$
AP - approach configuration (in descent between $H_{max, AP}$ AGL and $H_{max, LD}$ AGL when $V < V_{minCruise} + 10$ kts, in descent below $H_{max, LD}$ AGL as long as $V \geq V_{minApproach} + 10$ kts)	$(V_{stall})_{AP}$
LD - landing configuration (in descent below $H_{max, LD}$ AGL when $V < V_{minApproach} + 10$ kts )	$(V_{stall})_{LD}$

The threshold altitudes are expressed in terms of geopotential pressure altitude. However, in this case when aircraft operations close to the ground are considered one has to account for airport/runway elevation<sup>6</sup>. The pressure altitude thresholds provided above correspond to geopotential pressure altitude Above Ground Level (AGL).

The 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:

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

The configuration specific values are listed in Section 5.6. The speeds  $[V]$  used during the descent, approach and landing phases are defined in Section 4.3.

<sup>6</sup> Measured from Mean Sea Level (MSL).

### 3.6. AERODYNAMICS

#### 3.6.1. Aerodynamic Drag

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

$$C_L = \frac{2 \cdot m \cdot g_0}{\rho \cdot V_{TAS}^2 \cdot S \cdot \cos \phi} \quad (3.6-1)$$

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

$$C_D = C_{D0,CR} + C_{D2,CR} \times (C_L)^2 \quad (3.6-2)$$

Formula 3.6-2 is valid for all situations except for the approach and landing where other drag coefficients are to be used.

In the approach configuration (as defined in Section 3.5) a different flap setting is used, and formula 3.6-3 should be applied:

$$C_D = C_{D0,AP} + C_{D2,AP} \times (C_L)^2 \quad (3.6-3)$$

In the landing configuration (as defined in Section 3.5) a different flap setting is used, and formula 3.6-4 should be applied:

$$C_D = C_{D0,LDG} + C_{D0,\Delta LDG} + C_{D2,LDG} \times (C_L)^2 \quad (3.6-4)$$

The value of  $C_{D0, \Delta LDG}$  represents drag increase due to the landing gear. The values of  $C_{D0, LD}$  in the 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:

$$D = \frac{C_D \cdot \rho \cdot V_{TAS}^2 \cdot S}{2} \quad (3.6-5)$$

Where :

$\rho$  is the air density ( $\text{kg/m}^3$ )

$S$  is the wing reference area ( $\text{m}^2$ )

$V_{TAS}$  is the true airspeed (m/s).

Note that the air density is a function of altitude as described in subsection 3.2.

The above equations thus result in eight coefficients for the specification of drag:

$$\begin{array}{l}
 S \\
 C_{D0,CR} \qquad C_{D2,CR} \\
 C_{D0,AP} \qquad C_{D2,AP} \\
 C_{D0,LD} \qquad C_{D2,LD} \\
 C_{D0,\Delta LDG}
 \end{array}$$

In case the  $C_{D0,AP}$  ,  $C_{D2,AP}$  ,  $C_{D0,LD}$  ,  $C_{D2,LD}$  and  $C_{D0,\Delta LDG}$  coefficients (referred to as “non-clean” data in this document) are set to 0 (zero) in the OPF file, expression 3.6-2 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:

$$k \times M^3 - C_{Lbo(M=0)} \times M^2 + \frac{W}{S \cdot p \cdot 0.583} = 0 \quad (3.6-6)$$

where:

k is lift coefficient gradient

$C_{Lbo(M=0)}$  is initial buffet onset lift coefficient for M=0

p is actual pressure (Pa)

M is Mach number

S is the wing reference area (m<sup>2</sup>)

W is aircraft weight (N)

Note that the factor of 0.583 gives a 0.2 g margin.

The k and  $C_{Lbo(M=0)}$  parameters have been determined for nearly all jet aircraft in BADA 3.8. If the k and  $C_{Lbo(M=0)}$  parameters in the OPF file are set to 0 (zero), the minimum speed is given by expressions 3.5-2 and 3.5-3. Otherwise, the solution for M in Formula 3.6-6 can be obtained using the method given in Appendix B. The buffeting limit should be applied as a minimum speed in the following way:

- If (Hp > 15,000 ft) then:  $V_{min} = \text{MAX}(V_{min, stall}, M_b)$

- If (Hp < 15,000 ft) then:  $V_{min} = V_{min, stall}$

where: Hp is geopotential pressure altitude

$M_b$  is the lowest positive solution of expression 3.6-6,

$V_{min, stall}$  is given by expressions 3.5-2 and 3.5-3

Note that the units of the two values ( $V_{min, stall}$  and  $M_b$ ) inside the MAX() expression should be the same.

### 3.7. ENGINE THRUST

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

- maximum climb and 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 thrust conditions.

#### 3.7.1. Maximum Climb and Take-Off Thrust

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

- engine type: either Jet, Turboprop or Piston;
- geopotential pressure altitude,  $H_P$ , in feet;
- true air speed,  $V_{TAS}$ , in knots;
- temperature deviation from standard atmosphere,  $\Delta T$ , in degrees Celsius.

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

$$\text{Jet: } (T_{\max \text{ climb}})_{\text{ISA}} = C_{Tc,1} \times \left( 1 - \frac{H_P}{C_{Tc,2}} + C_{Tc,3} \times H_P^2 \right) \quad (3.7-1)$$

$$\text{Turboprop: } (T_{\max \text{ climb}})_{\text{ISA}} = C_{Tc,1} \times \left( 1 - \frac{H_P}{C_{Tc,2}} \right) / V_{TAS} + C_{Tc,3} \quad (3.7-2)$$

$$\text{Piston: } (T_{\max \text{ climb}})_{\text{ISA}} = C_{Tc,1} \times \left( 1 - \frac{H_P}{C_{Tc,2}} \right) + \frac{C_{Tc,3}}{V_{TAS}} \quad (3.7-3)$$

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

$$T_{\max \text{ climb}} = (T_{\max \text{ climb}})_{\text{ISA}} \times \left( 1 - C_{Tc,5} \cdot (\Delta T)_{\text{eff}} \right) \quad (3.7-4)$$

Where:

$$\Delta T_{\text{eff}} = \Delta T - C_{Tc,4} \quad (3.7-5)$$

with the limits:

$$0.0 \leq \Delta T_{\text{eff}} \times C_{Tc,5} \leq 0.4 \quad (3.7-6)$$

and:

$$C_{Tc,5} \geq 0.0 \quad (3.7-7)$$

This maximum climb thrust is used for both take-off and climb phases.

### 3.7.2. Maximum Cruise Thrust

The normal cruise thrust is by definition set equal to drag ( $T_{HR} = D$ ). However, the maximum amount of thrust available in cruise situation is limited. The maximum cruise thrust is calculated as a ratio of the maximum climb thrust given by expression 3.7-4, that is:

$$(T_{\text{cruise}})_{\text{MAX}} = C_{T_{\text{cr}}} \times T_{\text{max climb}} \quad (3.7-8)$$

The coefficient  $C_{T_{\text{cr}}}$  is currently uniformly set for all aircraft (see Global Aircraft Parameters section 5.5).

### 3.7.3. Descent Thrust

Descent thrust is calculated as a ratio of the maximum climb thrust given by expression 3.7-4, with different correction factors used for high and low altitudes, and approach and landing configurations (see Section 3.5), that is:

if  $H_p > H_{p,\text{des}}$ :

$$T_{\text{des,high}} = C_{T_{\text{des,high}}} \times T_{\text{max climb}} \quad (3.7-9)$$

if  $H_p > H_{p,\text{des}}$ :

Cruise configuration:

$$T_{\text{des,low}} = C_{T_{\text{des,low}}} \times T_{\text{max climb}} \quad (3.7-10)$$

Approach configuration:

$$T_{\text{des,app}} = C_{T_{\text{des,app}}} \times T_{\text{max climb}} \quad (3.7-11)$$

Landing configuration:

$$T_{\text{des,ld}} = C_{T_{\text{des,ld}}} \times T_{\text{max climb}} \quad (3.7-12)$$

Note that for those models where “non-clean” data (see Section 3.6.1) is available,  $H_{p,\text{des}}$  cannot be below  $H_{\text{max, AP}}$ .

### 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.

$$C_{pow,red} = 1 - C_{red} \times \frac{m_{max} - m_{act}}{m_{max} - m_{min}} \quad (3.8-1)$$

The value of  $C_{red}$  is a function of the aircraft type and is given in Section 5.11.

Nevertheless:

If  $H_p < (0.8 \cdot h_{max})$ :

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

Else

$$C_{red} = 0 \quad [\text{dimensionless}]$$

where  $h_{max}$  is given by expression 3.5-1.

The power reduction  $C_{pow,red}$  is to be applied during the climb phase in expression 3.1-6, which becomes:

$$ROCD = \frac{dH_p}{dt} = \frac{T - \Delta T}{T} \frac{(T_{max,climb} - D)V_{TAS} C_{pow,red}}{mg_0} f\{M\} \quad (\text{in climb}) \quad (3.8-2)$$

### 3.9. FUEL CONSUMPTION

#### 3.9.1. Jet and Turboprop Engines

For the jet and turboprop engines, the thrust specific fuel consumption,  $\eta$  (kg/(min\*kN)), is specified as a function of true airspeed,  $V_{TAS}$  (knots):

$$\text{jet:} \quad \eta = C_{f1} \times \left( 1 + \frac{V_{TAS}}{C_{f2}} \right) \quad (3.9-1)$$

$$\text{turboprop:} \quad \eta = C_{f1} \times \left( 1 - \frac{V_{TAS}}{C_{f2}} \right) \times (V_{TAS} / 1000) \quad (3.9-2)$$

The nominal fuel flow,  $f_{nom}$  (kg/min), can then be calculated using the thrust,  $T_{HR}$ :

$$\text{jet/turboprop:} \quad f_{nom} = \eta \times T_{HR} \quad (3.9-3)$$

These expressions are used in all flight phases except during idle descent and cruise, where the following expressions are to be used.

Minimum fuel flow,  $f_{min}$  (kg/min), corresponding to idle thrust descent conditions for both jet and turboprop engines, is specified as a function of geopotential pressure altitude,  $H_p$  (ft), that is:

$$\text{jet/turboprop:} \quad f_{min} = C_{f3} \left( 1 - \frac{H_p}{C_{f4}} \right) \quad (3.9-4)$$

Note that for both jet and turboprop engines, the idle thrust part of the descent stops when the aircraft switches to approach and landing configuration (see Section 3.5), at which point thrust is generally increased. Hence, the calculation of fuel flow during approach and landing phases shall be based on the nominal fuel flow (expressions 3.7-11, 3.7-12 and 3.9-3), and limited to the minimum fuel flow (expression 3.9-4) if necessary:

$$\text{Jet/turboprop:} \quad f_{ap/ld} = \text{MAX}(f_{nom}, f_{min}) \quad (3.9-5)$$

Cruise fuel flow,  $f_{cr}$  (kg/min), is calculated using the thrust specific fuel consumption  $\eta$ , the thrust  $T_h$ , and a cruise fuel flow factor,  $C_{fcr}$ :

$$\text{jet/turboprop:} \quad f_{cr} = \eta \times T_{HR} \times C_{fcr} \quad (3.9-6)$$

For the moment the cruise fuel flow correction factor has been established for a number of aircraft types whenever the reference data for cruise fuel consumption is available. This factor has been set to 1 (one) for all the other aircraft models.

### 3.9.2. Piston Engines

For piston engines, the nominal fuel flow,  $f_{\text{nom}}$  (kg/min), is specified to be a constant, that is:

$$f_{\text{nom}} = C_{\text{fl}} \quad (3.9-7)$$

This expression is used in all flight phases except during descent and cruise, where the following expressions are to be used.

Minimum fuel flow,  $f_{\text{min}}$  (kg/min), corresponding to descent conditions for piston engines, is specified to be a constant:

$$f_{\text{min}} = C_{\text{f3}} \quad (3.9-8)$$

Cruise fuel flow,  $f_{\text{cr}}$  (kg/min), is calculated using a cruise fuel flow factor,  $C_{\text{fcr}}$ :

$$f_{\text{cr}} = C_{\text{fl}} \times C_{\text{fcr}} \quad (3.9-9)$$

For the moment the cruise fuel flow correction factor has been established for a number of aircraft types whenever the reference data for cruise fuel consumption is available. 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 provided in BADA. Apart from these model specific parameters, there are also a number of ground speeds defined as general parameters in 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.

Detailed information on how these parameters have been obtained during the process of BADA aircraft model identification using the aircraft performance reference documents is provided in [RD6].

**Important notice:** Parameters listed in bold in the Table 3-1 below should not be modified by the user as such modifications may impact the validity of the data provided in [RD13].

Table 3-1: BADA Operations Performance Parameter Summary

Model Category	Symbols	Units	Description
aircraft type (3 values)	<b>n<sub>eng</sub></b> <b>engine type</b> <b>wake category</b>	dimensionless string string	<b>number of engines</b> <b>either Jet, Turboprop or Piston</b> <b>either H (heavy), M (medium) or L (light)</b>
mass (4 values)  see def. P25	<b>m<sub>ref</sub></b> <b>m<sub>min</sub></b> <b>m<sub>max</sub></b> <b>m<sub>pyld</sub></b>	tonnes tonnes tonnes tonnes	<b>reference mass</b> <b>minimum mass</b> <b>maximum mass</b> <b>maximum payload mass</b>
flight envelope (6 values)	<b>V<sub>MO</sub></b> <b>M<sub>MO</sub></b> <b>h<sub>MO</sub></b> <b>h<sub>max</sub></b> <b>G<sub>w</sub></b> <b>G<sub>t</sub></b>	knots (CAS) dimensionless feet feet feet/kg feet/C	<b>maximum operating speed</b> <b>maximum operating Mach number</b> <b>maximum operating altitude</b> <b>max. altitude at MTOW and ISA</b> <b>weight gradient on max. altitude</b> <b>temperature gradient on max. altitude</b>
Aerodynamics (14 values)  (16 values for jet aircraft )	<b>S</b> <b>C<sub>D0,CR</sub></b> <b>C<sub>D2,CR</sub></b> <b>C<sub>D0,AP</sub></b> <b>C<sub>D2,AP</sub></b> <b>C<sub>D0,LD</sub></b> <b>C<sub>D2,LD</sub></b> <b>C<sub>D0,ΔLDG</sub></b> <b>(V<sub>stall</sub>)<sub>i</sub></b> <b>C<sub>Lbo(M=0)</sub></b>	m2 dimensionless dimensionless dimensionless dimensionless dimensionless dimensionless dimensionless knots (CAS) dimensionless	<b>reference wing surface area</b> <b>parasitic drag coefficient (cruise)</b> <b>induced drag coefficient (cruise)</b> <b>parasitic drag coefficient (approach)</b> <b>induced drag coefficient (approach)</b> <b>parasitic drag coefficient (landing)</b> <b>induced drag coefficient (landing)</b> <b>parasite drag coef. (landing gear)</b> <b>stall speed [TO, IC, CR, AP, LD]</b> <b>Buffet onset lift coef. (jet only)</b>

Model Category	Symbols	Units	Description
	<b>K</b>	[1/M]	<b>Buffeting gradient (jet only)</b>
engine thrust (12 values)	<b>C<sub>Tc,1</sub></b>	Newton (jet/piston) knot-Newton (turboprop)	<b>1st max. climb thrust coefficient</b>
	<b>C<sub>Tc,2</sub></b>	feet	<b>2nd max climb thrust coefficient</b>
	<b>C<sub>Tc,3</sub></b>	1/feet <sup>2</sup> (jet) Newton (turboprop) knot-Newton (piston)	<b>3rd max. climb thrust coefficient</b>
	<b>C<sub>Tc,4</sub></b>	deg. C	<b>1st thrust temperature coefficient</b>
	<b>C<sub>Tc,5</sub></b>	1/ deg. C	<b>2nd thrust temperature coefficient</b>
	<b>C<sub>Tdes,low</sub></b>	dimensionless	<b>low altitude descent thrust coefficient</b>
	<b>C<sub>Tdes,high</sub></b>	dimensionless	<b>high altitude descent thrust coefficient</b>
	<b>H<sub>p,des</sub></b>	feet	<b>transition altitude for calculation of descent thrust</b>
	<b>C<sub>Tdes, app</sub></b>	dimensionless	<b>approach thrust coefficient</b>
	<b>C<sub>Tdes,ld</sub></b>	dimensionless	<b>landing thrust coefficient</b>
	<b>V<sub>des,ref</sub></b>	knots	reference descent speed (CAS)
<b>M<sub>des,ref</sub></b>	dimensionless	reference descent Mach number	
fuel flow (5 values)	<b>C<sub>f1</sub></b>	kg/(min*kN) (jet) kg/(min*kN*knot) (turboprop) kg/min (piston)	<b>1st thrust specific fuel consumption coefficient</b>
	<b>C<sub>f2</sub></b>	knots	<b>2nd thrust specific fuel consumption coefficient</b>
	<b>C<sub>f3</sub></b>	kg/min	<b>1st descent fuel flow coefficient</b>
	<b>C<sub>f4</sub></b>	feet	<b>2nd descent fuel flow coefficient</b>
	<b>C<sub>fcr</sub></b>	dimensionless	<b>Cruise fuel flow correction coefficient</b>
Ground movement (4 values)	TOL	m	take-off length
	LDL	m	landing length
	span	m	wingspan
	length	m	Length

*Note:*

*The following coefficient can have negative values: K, G<sub>t</sub>, C<sub>Tc,2</sub>, C<sub>Tc,3</sub>, C<sub>Tdes,low</sub>, C<sub>Tdes,high</sub>, C<sub>f2</sub>, C<sub>f4</sub>.*

## 4. AIRLINE PROCEDURE MODELS

This section defines the standard airline procedures, which are parameterised by the BADA airline procedure models. Definition of the standard airline procedures in BADA is driven by a requirement to provide means of simulating standard or nominal aircraft operations using different simulation and modelling tools for various ATM applications.

The BADA airline procedure model is provided for three separate flight phases: climb, cruise and descent. For each of these phases and each aircraft model, the BADA airline procedure model requires the following information to determine aircraft speed schedule:

1. BADA airline procedure default speeds provided in Airline Procedure File (APF):

$V_1$  - standard CAS (knots) below 10,000 ft;

$V_2$  - standard CAS (knots) between 10,000 ft and Mach transition altitude;

M - standard Mach number above Mach transition altitude;

where the Mach transition altitude is defined in Section 3.1 (g).

2. Stall speeds for take-off and landing configurations provided in Operations Performance File (OPF)
3. Coefficients provided in the Section 5.7 and 5.8

The process of definition of the BADA airline procedure default speeds and choice of aircraft configurations in function of flight phase is described in [RD6]. The airline procedure model below 10,000 ft with corresponding coefficients (mentioned under item 3 above) have been defined taking into account aircraft manufacturer's performance reference data and aircraft operational data available at EUROCONTROL.

The fact that the way aircraft is operated varies significantly in function of specific airspace procedures and operating policies of locally dominant airlines is widely recognised. It is for that reason that the resulting speed schedules of the BADA standard airline procedure model may differ from a geographical location or of an aerospace's specific aircraft operation.

To account for the local aircraft operation characteristics and improve conformance of the simulated aircraft behaviour with real operations, the user of BADA is given a possibility to modify the BADA default speeds (as provided in APF file). The change of speed related APF parameters should be done in accordance with the BADA modelling procedure described in the Chapter 2.2.3 of [RD6].

However, the stall speeds (as provided in OPF file) and coefficients detailed in Section 5.7 and 5.8 are not subject to modification. The BADA User should not modify them.

The altitude levels, used for determination of CAS speed schedules and provided in the following chapters, are expressed in terms of geopotential pressure altitude. However, different reference datums for altitude measurement <sup>7</sup> may be applied in function of the user application and its functional design choices.

The BADA Airline Procedure Model only identifies the possibility to introduce notion of different altitude altimetry for calculation of the CAS speed schedules in the user application. The implementation decision is left to the application owner.

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<sup>7</sup>Such as use of standard operational pressure settings used in aviation: QNH for MSL pressure, QFE for pressure at the airport reference point or QNE corresponding to standard MSL1013 hPa. These can be selected through the altimeter's pressure setting knob in the aircraft.

#### 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 Mach transition altitude.

Note that the climb speed schedule shall determine an increasing speed from takeoff to  $V_{cl,1}$ . To ensure that monotony, it is recommended to determine the speed schedule from the highest altitude to the lowest one, and to use at each step the speed of the higher altitude range as a ceiling value for the lower altitude range.

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

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

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

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

The take-off stall speed,  $(V_{stall})_{TO}$ , must be corrected for the difference in aircraft mass from the reference mass using formula 3.4-1. The values for  $V_{dCL,i}$  can be found in Section 5.

## 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 ft
- $V_{cr,2}$  - standard cruise CAS (knots) between 10,000 ft and Mach transition altitude
- $M_{cr}$  - standard cruise Mach number above Mach transition altitude

- For jet aircraft the following CAS schedule is assumed:

from 0 to 2,999 ft	170 kt
from 3,000 to 5,999 ft	$\min (V_{cr,1} , 220 \text{ kt})$
from 6,000 to 13,999 ft	$\min (V_{cr,1} , 250 \text{ kt})$
from 14,000 ft to Mach transition altitude	$V_{cr,2}$
above Mach transition altitude	$M_{cr}$

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

from 0 to 2,999 ft	150 kt
from 3,000 to 5,999 ft	$\min ( V_{cr,1} , 180 \text{ kt} )$
from 6,000 to 9,999 ft	$\min ( V_{cr,1} , 250 \text{ kt} )$
from 10,000 ft to Mach transition altitude	$V_{cr,2}$
above Mach transition altitude	$M_{cr}$

### 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) between 10,000 ft and Mach transition altitude.
- $M_{des}$  - standard descent Mach number above Mach transition altitude.

Note that the descent speed schedule shall determine a decreasing speed from  $V_{des,1}$  to landing. To ensure that monotony, it is recommended to evaluate the speed schedule from the highest altitude to the lowest one, and to use at each step the speed of the higher altitude range as a ceiling value for the lower altitude range.

- 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	$C_{Vmin} * (V_{stall})_{LD} + V_{dDES, 1}$	(4.3-1)
from 1,000 to 1,499 ft	$C_{Vmin} * (V_{stall})_{LD} + V_{dDES, 2}$	(4.3-2)
from 1,500 to 1,999 ft	$C_{Vmin} * (V_{stall})_{LD} + V_{dDES, 3}$	(4.3-3)
from 2,000 to 2,999 ft	$C_{Vmin} * (V_{stall})_{LD} + V_{dDES, 4}$	(4.3-4)
from 3,000 to 5,999 ft	$\min (V_{des,1} , 220 )$	
from 6,000 to 9,999 ft	$\min (V_{des,1} , 250 )$	
from 10,000 ft to Mach transition altitude	$V_{des,2}$	
above Mach transition altitude	$M_{des}$	

- For piston aircraft the following CAS schedule is assumed:

from 0 to 499 ft	$C_{Vmin} * (V_{stall})_{LD} + V_{dDES, 5}$	(4.3-5)
from 500 to 999 ft	$C_{Vmin} * (V_{stall})_{LD} + V_{dDES, 6}$	(4.3-6)
from 1000 to 1,499 ft	$C_{Vmin} * (V_{stall})_{LD} + V_{dDES, 7}$	(4.3-7)
from 1,500 to 9,999 ft	$V_{des,1}$	
from 10,000 ft to Mach transition altitude	$V_{des,2}$	
above Mach transition altitude	$M_{des}$	

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  $V_{dDES,i}$  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 which have general use, have been put in the Global 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 <sup>2</sup> ]:
$a_{l, \max (civ)}$	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:  $|V_k - V_{k-1}| \leq a_{l, \max (civ)} \Delta t$  (5.2-1)

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

where,

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

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	35
$\phi_{max, civ (OTHERS)}$	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 (  $\dot{\phi}$  ) is calculated as a function of bank angle:

$$\dot{\phi} = \frac{g_0}{V_{TAS}} \times \tan(\phi) \quad (5.3-1)$$

### 5.4. EXPEDITED DESCENT

The expedited descent factor is to be used as a drag multiplication factor during expedited descents in order to simulate use of spoilers:

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

The drag during an expedited descent is calculated using the nominal drag (see 3.6.1):

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

### 5.5. THRUST FACTORS

Maximum take-off and maximum cruise thrust factors have been specified. The  $C_{Th,TO}$  factor is no longer used since BADA 3.0. The  $C_{Tcr}$  factor is to be used in expression 3.7-8.

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

## 5.6. CONFIGURATION ALTITUDE THRESHOLD

For 4 configurations, altitude thresholds have been specified in BADA: take-off (TO), initial climb (IC), approach (AP) and landing (LD). Note that the selection of the take-off and initial climb configurations is defined only with the altitude. The selection of the approach and landing configurations is done through the use of air speed and altitude (see Section 3.5), while the altitudes at which the configuration change takes place should not be higher than the ones given below. The altitude values are expressed in terms of geopotential pressure altitude.

<b>Name:</b>	<b>Description:</b>	<b>Value [ ft ]:</b>
$H_{max, TO}$	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 (for  $C_{Vmin}$  only) in Section 4.1 and 4.3:

<b>Name:</b>	<b>Description:</b>	<b>Value [ - ]:</b>
$C_{Vmin, TO}$	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 applicable below FL100 for climb and descent are based on a factored stall speed plus increment valid for a specified altitude range. The altitude values are expressed in terms of geopotential pressure altitude.

<b>Name:</b>	<b>Description:</b>	<b>Value[KCAS]:</b>
$V_{dCL, 1}$	Climb speed increment below 1500 ft (jet)	5
$V_{dCL, 2}$	Climb speed increment below 3000 ft (jet)	10
$V_{dCL, 3}$	Climb speed increment below 4000 ft (jet)	30
$V_{dCL, 4}$	Climb speed increment below 5000 ft (jet)	60
$V_{dCL, 5}$	Climb speed increment below 6000 ft (jet)	80
$V_{dCL, 6}$	Climb speed increment below 500 ft (turbo/piston)	20
$V_{dCL, 7}$	Climb speed increment below 1000 ft (turbo/piston)	30
$V_{dCL, 8}$	Climb speed increment below 1500 ft (turbo/piston)	35
$V_{dDES, 1}$	Descent speed increment below 1000 ft (jet/turboprop)	5
$V_{dDES, 2}$	Descent speed increment below 1500 ft (jet/turboprop)	10
$V_{dDES, 3}$	Descent speed increment below 2000 ft (jet/turboprop)	20
$V_{dDES, 4}$	Descent speed increment below 3000 ft (jet/turboprop)	50
$V_{dDES, 5}$	Descent speed increment below 500 ft (piston)	5

$V_{DES, 6}$	Descent speed increment below 1000 ft (piston)	10
$V_{DES, 7}$	Descent speed increment below 1500 ft (piston)	20

These values are to be used in the expressions in Section 4.1 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:

<b>Name:</b>	<b>Description:</b>	<b>Value[KCAS]:</b>
$V_{hold, 1}$	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:

<b>Name:</b>	<b>Description:</b>	<b>Value[KCAS]:</b>
$V_{backtrack}$	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 manoeuvring between the gate position and the apron.

## 5.11. REDUCED POWER COEFFICIENT

The reduced power coefficients are defined for the three different engine types. It is stressed that the values given below were found in an empirical way and have been validated with the help of air traffic controllers:

<b>Name:</b>	<b>Description:</b>	<b>Value[- ]:</b>
$C_{red,turbo}$	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 3.8 is organised into six types of files:

- three Synonym Files,
  - a set of Operations Performance Files,
  - a set of Airline Procedure Files,
  - a set of Performance Table Files,
  - a set of Performance Table Data,
  - a Global Parameter File.
- Three Synonym Files have the names:

SYNONYM.LST  
SYNONYM.NEW  
SYNONYM\_ALL.LST

The 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). In addition to that, SYNONYM\_ALL.LST file provides the information on history and evolution of the ICAO aircraft designators over the years. The format of the files is 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 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.
- There is one Performance Table Data (PTD) file for each directly supported aircraft type. This file contains a detailed table of computed performance values at various flight levels. Details on the format of the PTD file are given in Section 6.7.
- 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, PTF and PTD files are based on the ICAO designation code for the aircraft type. With only the exception of the generic military fighter aircraft types (FGTH, FGTL, FGTN), 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
Performance Table Data name:	<ICAO_code>__.PTD

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. F50) and thus require more underscore characters. For example, an Airbus 310 which has the ICAO code of A310 is represented in BADA 3.7 by the following files:

Operations Performance File:	A310__.OPF
Airline Procedures File:	A310__.APF
Performance Table File:	A310__.PTF
Performance Table Data:	A310__.PTD

The Fokker F50, which has the ICAO code of F50, is represented in BADA 3.7 by the following files:

Operations Performance File:	F50____.OPF
Airline Procedures File:	F50____.APF
Performance Table File:	F50____.PTF
Performance Table Data:	F50____.PTD

All files belonging to BADA Revision 3.8, that is the Synonym Files, the GPF file and all APF, OPF, PTF and PTD files are controlled within a configuration management system. This system is described in Section 6.2.

## 6.2. FILE CONFIGURATION MANAGEMENT

Starting with the BADA 3.4 release, the BADA Synonym Files, GPF and all APF, OPF, PTF and PTD files are placed and managed under the Change Management Synergy (CM Synergy) tool at EUROCONTROL.

This section briefly describes some of the CM Synergy features that will be used for the management of the BADA files.

CM Synergy provides a complete change management environment in which development and management of the files can be done easily, quickly, and securely. It maintains control of file versions and allows management of project releases with some of the benefits listed below:

- workflow management, which enables easy identification of the files modified to implement the change, and review of the reason for a change,

- project reproducibility by accurately creating baseline configurations,
- role-based security,
- Distributed Change Management (DCM) which allows files sharing among any number of CM Synergy databases. With DCM transfer of an entire database or a subset of a database can be done, either automatically or manually.

The CM Synergy automated migration facilities feature complete version history migration from RCS system archives. This has enabled to bring successfully all the BADA files with their history under the CM Synergy control. A CM Synergy database is created for BADA project. Such a database represents a data repository that stores all controlled data, including data files, their properties and relationships to one another.

The following BADA files are placed in the CM Synergy database:

- the Synonym Files
- the GPF file
- all APF, OPF, PTF and PTD files

Within the CM Synergy, different methodologies in the way the files are managed are used. For BADA database, the task-based methodology is chosen which enables the tracking of the changes by using tasks, rather than individual files, as the basic unit of work.

The specific procedures used for configuration management are specified in the BADA Configuration Management Manual [RD5].

### 6.2.1. File Identification

Any file managed in a CM Synergy database is uniquely identified by the following attributes: *name*, *version*, *type*, and *instance*. By default, the four-part name (also called full name) is written like this: *name-version:type:instanc* .

A file name can be up to 151 characters long, and the version can be any 32-character combination. The type can be any of the default types (e.g., *csrc*, *ascii*, etc.), or any BADA type that is created (APF, OPF, PTF, PTD, GPF).

The name, version, and type are designated by the user, but the instance is calculated by CM Synergy.

The version of a file corresponds to the evolution of the file in time. By default, CM Synergy creates version numbers, starting with 1, for each file that is created in the CM Synergy database. Each time the object is modified, CM Synergy increments the version.

The instance is used to distinguish between multiple objects with the same name and type, but that are not versions of each other.

It is important to notice that, following the CM Synergy approach of the file identification, no information on the file version is provided in the BADA file itself.

A new layout of the header of BADA files has been developed and it will be described in more details in the following sections.

### **6.2.2. History**

The history of a file shows all the existing versions and the relationships between the versions. By history, CM Synergy means all of the file versions created before the current file version (called predecessors) and all of the file versions created after the current file version (called successors). This functionality allows for the tracking of all modifications to a file.

### **6.2.3. Release**

The release is a label that indicates the version of the project, in this case the release of BADA files. BADA Releases are usually identified by a two digit number, e.g. 3.3 or 3.4. However, the name of release in CM Synergy can be made out of any combination of alphabetic and numerical characters.

Like in the case of the file version, no information on the current BADA release is given in the BADA files.

### 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).

```

CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC SYNONYM.LST CCCCCCCCCCCCCC/
CC                                                                    /
CC              BADA SYNONYM FILE                                     /
CC                                                                    /
CC                                                                    /
CC      File_name: SYNONYM.LST                                       /
CC                                                                    /
CC      Creation_date: Mar 26 2002                                   /
CC                                                                    /
CC      Modification_date: Mar 26 2002                               /
CC                                                                    /
CC                                                                    /
CC===== Aircraft List =====/
CC                                                                    /
CC  A/C      NAME OR MODEL      FILE              SYNONYMS          /
CC  CODE                                           /
CC                                                                    /
- A306__ AIRBUS A300B4-600    A306__           A306              /
- A30B__ AIRBUS A300B4-200    A30B__           A30B  IL76        /
- A310__ AIRBUS A310          A310__           A310              /
- A319__ AIRBUS A319          A319__           A319              /
- A320__ AIRBUS A320          A320__           A320  C17         /
- A321__ AIRBUS A321          A321__           A321              /
- A333__ AIRBUS A330-300      A333__           A333  A332           /
- A343__ AIRBUS A340-300      A343__           A343  A342  A345       /
                                           A346           /
- AT43__ ATR ATR 42-300        AT43__           AT43  CN35  CVLT       /
                                           AT44           /
- AT45__ ATR ATR 42-500      AT45__           AT45              /
- AT72__ ATR ATR 72          AT72__           AT72  A748           /
- ATP__  ADVANCED TURBOPROP  ATP__           ATP   G222           /
- B461__ BAE 146-100/RJ       B461__           B461  B462  B463           /
                                           YK42           /
- B703__ BOEING 707-300      B703__           B703  B720  K35R          /
                                           E3TF  E3CF  C135          /
                                           VC10  IL62           /
- B722__ BOEING 727-100      B722__           B722  B721  BER4           /
- B732__ BOEING 737-228      B732__           B732  B731  A124           /
- B733__ BOEING 737-300      B733__           B733              /
- B734__ BOEING 737-400      B734__           B734              /
- B735__ BOEING 737-500      B735__           B735  B736           /
- B737__ BOEING 737-700      B737__           B737              /

```

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 two blocks separated by a comment line consisting of the block name and 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, creation and modification date. The block consists of 12 comment lines.

```

CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC SYNONYM.LST CCCCCCCCCCCCCC/
CC                                                                /
CC          BADA SYNONYM FILE                                     /
CC                                                                /
CC          File_name: SYNONYM.LST                               /
CC                                                                /
CC          Creation_date: Mar 26 2002                           /
CC                                                                /
CC          Modification_date: Mar 26 2002                        /

```

The comment lines specify the file name along with the creation and the modification date. The creation date indicates the date when the file was created for the first time. The modification date indicates when the contents of the file were last modified.

### 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                                                                /
- A306__ AIRBUS A300B4-600    A306__             A306
- A30B__ AIRBUS A300B4-200    A30B__             A30B   IL76
- A310__ AIRBUS A310          A310__             A310
- A319__ AIRBUS A319          A319__             A319
- A320__ AIRBUS A320          A320__             A320   C17
- A321__ AIRBUS A321          A321__             A321
- A333__ AIRBUS A330-300      A333__             A333   A332
- A343__ AIRBUS A340-300      A343__             A343   A342
- AT43__ ATR ATR 42-300        AT43__             AT43   CN35   CVLT
                                     AT44
- AT45__ ATR ATR 42-500        AT45__             AT45
- AT72__ ATR ATR 72            AT72__             AT72   A748
- ATP___ ADVANCED TURBOPROP    ATP___             ATP    G222
- B461__ BAE 146-100/RJ        B461__             B461   B462   B463
                                     YK42
- B703__ BOEING 707-300        B703__             B703   B720   K35R
                                     E3TF   E3CF   C135
                                     VC10   IL62
- B722__ BOEING 727-100        B722__             B722   B721   BER4
- B732__ BOEING 737-228        B732__             B732   B731   A124
- B733__ BOEING 737-300        B733__             B733
- B734__ BOEING 737-400        B734__             B734
- B735__ BOEING 737-500        B735__             B735   B736
- B737__ BOEING 737-700        B737__             B737

```

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, PTF or PTD 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 B703 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).

```

CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC SYNONYM.NEW CCCCCCCCCCCCCCCC/
CC /
CC          BADA SYNONYM FILE /
CC /
CC /
CC          File_name: SYNONYM.NEW /
CC /
CC          Creation_date: Mar 26 2002 /
CC /
CC          Modification_date: Mar 26 2002 /
CC /
CC /
CC===== Aircraft List =====/
CC /
CC  A/C      MANUFACTURER      NAME OR MODEL      FILE      OLD /
CC  CODE /
CC /
CD * A10    FAIRCHILD          THUNDERBOLT II    FGTN__  A10A /
CD * A124   ANTONOV                    ANTONOV AN-124    B732__  AN4R /
CD - A306   AIRBUS                      A300B4-600        A306__  A306 /
CD - A30B   AIRBUS                      A300B4-200        A30B__  A300 /
CD - A310   AIRBUS                      A310               A310__  A310 /
CD - A319   AIRBUS                      A319               A319__  A319 /
CD - A320   AIRBUS                      A320               A320__  EA32 /
CD - A321   AIRBUS                      A321               A321__  A321 /
CD * A332   AIRBUS                      A330-200           A333__  A332 /
CD - A333   AIRBUS                      A330-300           A333__  A330 /
CD * A342   AIRBUS                      A340-200           A343__  A342 /
CD - A343   AIRBUS                      A340-300           A343__  A340 /
CD * A345   AIRBUS                      A340-500           A343__  A345 /
CD * A346   AIRBUS                      A340-600           A343__  A346 /
CD * A4     MCDONNELL-DOUGLAS         SKYHAWK            FGTN__  A4 /
CD * A6     GRUMMAN                    INTRUDER           FGTN__  EA6B /
CD * A748   BAE                        BAE 748            AT72__  HN74 /
CD * AC80   ROCKWELL                   TURBO COMMANDER    BE20__  AC6T /
CD * AC90   ROCKWELL                   TURBO COMMANDER    BE20__  AC90 /
CD * AC95   ROCKWELL                   TURBO COMMANDER    BE20__  AC95 /
CD * AJET   DASSAULT                   ALPHA JET          FGTN__  AJET /
CD * AMX    EMBRAER                    AMX                FGTN__  AMX /
CD * AN12   ANTONOV                    AN-12              C130__  AN12 /
CD * AN24   ANTONOV                    AN-124             F27___  AN24 /
CD * AN26   ANTONOV                    AN-26              F27___  AN26 /

```

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 two blocks separated by a comment line consisting of the block name and 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, creation and modification date. The block consists of 12 comment lines as shown below.

```
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC SYNONYM.NEW CCCCCCCCCCCCCCCC/  
CC /  
CC          BADA SYNONYM FILE /  
CC /  
CC /  
CC          File_name: SYNONYM.NEW /  
CC /  
CC          Creation_date: Mar 26 2002 /  
CC /  
CC          Modification_date: Mar 26 2002 /  
CC /  
CC /
```

The comment lines specify the file name along with the creation and last modification date. The creation date indicates the date when the file was created for the first time. The modification date indicates 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 * A10    FAIRCHILD      THUNDERBOLT II      FG1N__ A10A /  
CD * A124   ANTONOV        ANTONOV AN-124      B732__ AN4R /  
CD - A306   AIRBUS         A300B4-600          A306__ A306 /  
CD - A30B   AIRBUS         A300B4-200          A30B__ A300 /
```

Each data line consists of 6 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, PTF or PTD 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 A333 will be A333\_\_\_. This indicates an OPF file A333\_\_\_.OPF, an APF file A333\_\_\_.APF, a PTF file A333\_\_\_.PTF and a PTD file A333\_\_\_.PTD. For the Fokker F-27 with an ICAO code of F27, the file names include three underscore characters, that is, F27\_\_\_.OPF, F27\_\_\_.APF, F27\_\_\_.PTF and F27\_\_\_.PTD.

For an aircraft type which is supported through 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 equivalent to the Lockheed C-130 Hercules (C130). Thus the files C130\_\_\_.OPF, C130\_\_\_.APF, C130\_\_\_.PTF and C130\_\_\_.PTD should be used.

## (f) Old Code field

The old code field gives the name of the aircraft that refers to the formerly known aircraft designator as published in one of the previous editions of the ICAO document 8643 [RD10]. This allows the BADA 3.8 user to continue to use the old ICAO standard and to establish a link between the old and the new aircraft designators.

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

### 6.3.3. SYNONYM\_ALL.LST File

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

```

CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC SYNONYM_ALL.LST CCCCCCCCCCCCCC/
CC                                          /
CC          BADA SYNONYM_ALL FILE                      /
CC                                          /
CC          File_name: SYNONYM_ALL.LST                /
CC                                          /
CC          Creation_date: May 22 2003                /
CC                                          /
CC          Modification_date: May 22 2003            /
CC                                          /
CC          =====/
CC          /
CC          /
CC          ICAO      ICAO      ICAO      ICAO      ICAO      ICAO      ICAO
CC          CODE     CODE     CODE     CODE     CODE     CODE     CODE
CC          BADA 3.5  V24      V25      V26      V27      V28      V29      V30
CD * A10    THUNDERBOLT II    FAIRCHILD  FGTN__    A10A     A10      A10      A10      A10      A10      A10      A10
CD * A124   ANTONOV AN-124    ANTONOV   B732__    AN4R     A124     A124     A124     A124     A124     A124     A124
CD - A306   A300B4-600        AIRBUS    A306__    A306     A306     A306     A306     A306     A306     A306
CD - A30B   A300B4-200          AIRBUS    A30B__    EA30     A300     A30B     A30B     A30B     A30B     A30B
CD - A310   A310              AIRBUS    A310__    EA31     A310     A310     A310     A310     A310     A310
CD * A318   A318              AIRBUS    A319__    A318     A318     A318     A318     A318     A318     A318
CD - A319   A319              AIRBUS    A319__    A319     A319     A319     A319     A319     A319     A319
CD - A320   A320              AIRBUS    A320__    EA32     A320     A320     A320     A320     A320     A320
CD - A321   A321              AIRBUS    A321__    A321     A321     A321     A321     A321     A321     A321
CD - A332   A330-200          AIRBUS    A332__    A332     A332     A332     A332     A332     A332     A332
CD - A333   A330-300          AIRBUS    A333__    EA33     EA33     A330     A333     A333     A333     A333
CD * A342   A340-200          AIRBUS    A343__    A342     A342     A342     A342     A342     A342     A342
CD - A343   A340-300          AIRBUS    A343__    EA34     EA34     A340     A343     A343     A343     A343
CD * A345   A340-500          AIRBUS    A343__    A345     A345     A345     A345     A345     A345     A345
CD * A346   A340-600          AIRBUS    A343__    A346     A346     A346     A346     A346     A346     A346

```

There are three types of lines in the SYNONYM\_ALL.LST 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 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.

### 6.3.3.1. File Identification Block

The file identification block provides information on the file name, creation and modification date. The block consists of 13 comment lines as shown below.

```

CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC SYNONYM_ALL.LST CCCCCCCCCCCCCCCC/
CC /
CC          BADA SYNONYM_ALL FILE /
CC /
CC /
CC      File_name: SYNONYM.NEW /
CC /
CC      Creation_date: May 22 2003 /
CC /
CC      Modification_date: May 22 2003 /
CC /

```

The comment lines specify the file name along with the creation and last modification date. The creation date indicates the date when the file was created for the first time. The modification date indicates when the contents of the file were last modified.

### 6.3.3.2. Aircraft Listing Block

The aircraft listing block consists of 7 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.

* A10	THUNDERBOLT II	FAIRCHILD	FGTN__	A10A	A10	A10	A10	A10	A10	A10
* A124	ANTONOV AN-124	ANTONOV	B732__	AN4R	A124	A124	A124	A124	A124	A124
- A306	A300B4-600	AIRBUS	A306__	A306	A306	A306	A306	A306	A306	A306
- A30B	A300B4-200	AIRBUS	A30B__	EA30	A300	A30B	A30B	A30B	A30B	A30B

Each data line consists of 5 fields describing the aircraft type and number of additional fields providing the history of ICAO aircraft type designators. Detailed description is given 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, PTF or PTD 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 A333 will be A333\_\_\_. This indicates an OPF file A333\_\_\_.OPF, an APF file A333\_\_\_.APF, a PTF file A333\_\_\_.PTF and a PTD file A333\_\_\_.PTD. For the Fokker F-27 with an ICAO code of F27, the file names include three underscore characters, that is, F27\_\_\_.OPF, F27\_\_\_.APF, F27\_\_\_.PTF and F27\_\_\_.PTD.

For an aircraft type which is supported through 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 equivalent to the Lockheed C-130 Hercules (C130). Thus the files C130\_\_\_.OPF, C130\_\_\_.APF, C130\_\_\_.PTF and C130\_\_\_.PTD should be used.

(f) Old Code fields

The old code fields give the name of the aircraft that refers to the formerly known aircraft designator as published in one of the previous editions (versions, i.e. V24 to V37) of the ICAO document 8643 [RD10]. This allows the BADA 3.8 user to continue to use the old ICAO standard and to establish a link between the old and the new aircraft designators, as well as the corresponding aircraft file name from the most recent BADA release. If the specific aircraft model version did not have assigned designator in the past editions of the ICAO document or the information was not available to BADA team, then the most recent designator is used throughout the all versions.

### 6.4. OPF FILE FORMAT

The Operations Performance File (OPF) is an ASCII file, which for a particular aircraft type specifies the operations performance parameters described in Section 3. An example of an OPF file for the A306 (Airbus 300B4-600) aircraft is shown below.

```

CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC A306__.OPF CCCCCCCCCCCCCC/
CC                                                                                               /
CC              AIRCRAFT PERFORMANCE OPERATIONAL FILE                                           /
CC                                                                                               /
CC              File_name: A306__.OPF                                                            /
CC                                                                                               /
CC              Creation_date: Mar 26 2002                                                       /
CC                                                                                               /
CC              Modification_date: Mar 26 2002                                                  /
CC                                                                                               /
CC              /                                                                                /
CC==== Actype =====/
CD A306__      2 engines      Jet      H /
CD Airbus A300-B4-622 with PW4158 engines      wake /
CC                                                                                               /
CC==== Mass (t) =====/
CC reference      minimum      maximum      max payload      mass grad /
CD .14000E+03     .87000E+02     .17170E+03     .39000E+02     .14100E+00 /
CC==== Flight envelope =====/
CC VMO(KCAS)      MMO      Max.Alt      Hmax      temp grad /
CD .33500E+03     .82000E+00     .41000E+05     .31600E+05     -.67000E+02 /
CC==== Aerodynamics =====/
CC Wing Area and Buffet coefficients (SIM) /
CCndrst Surf(m2)  Clbo(M=0)      k      CM16 /
CD 5 .26000E+03   .15300E+01   .10290E+01   .00000E+00 /
CC Configuration characteristics /
CC n Phase Name  Vstall(KCAS)      CD0      CD2      unused /
CD 1 CR Clean   .15100E+03   .19000E-01   .53000E-01   .00000E+00 /
CD 2 IC S15F00  .11700E+03   .33057E-01   .45362E-01   .00000E+00 /
CD 3 TO S15F00  .11700E+03   .33057E-01   .45362E-01   .00000E+00 /
CD 4 AP S15F15  .10900E+03   .38031E-01   .44932E-01   .00000E+00 /
CD 5 LD S30F40  .97000E+02   .78935E-01   .44822E-01   .00000E+00 /
CC Spoiler /
CD 1 RET /
CD 2 EXT      .00000E+00   .00000E+00 /
CC Gear /
CD 1 UP /
CD 2 DOWN     .22500E-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 .30400E+06   .44800E+05   .11600E-09   .67500E+01   .42600E-02 /
CC Desc(low)   Desc(high)   Desc level   Desc(app)   Desc(ld) /
CD .73000E-02   .20600E-01   .80000E+04   .12000E+00   .36000E+00 /
CC Desc CAS   Desc Mach   unused      unused      unused /
CD .28000E+03   .79000E+00   .00000E+00   .00000E+00   .00000E+00 /
CC==== Fuel Consumption =====/
CC Thrust Specific Fuel Consumption Coefficients /
CD .88100E+00   .16900E+05 /
CC Descent Fuel Flow Coefficients /
CD .26805E+02   .45700E+05 /
CC Cruise Corr.   unused      unused      unused      unused /
CD .10380E+01   .00000E+00   .00000E+00   .00000E+00   .00000E+00 /
CC==== Ground =====/
CC TOL      LDL      span      length      unused /
CD .23620E+04   .15550E+04   .44840E+02   .54080E+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, creation date and modification date. The block consists of 11 comment lines. An example of the file identification block for the A306\_\_.OPF file is shown below.

```
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC A306__.OPF CCCCCCCCCCCCCC/  
CC                                                                                               /  
CC              AIRCRAFT PERFORMANCE OPERATIONAL FILE                                         /  
CC                                                                                               /  
CC                                                                                               /  
CC      File_name: A306__.OPF                                                                    /  
CC                                                                                               /  
CC      Creation_date: Mar 26 2002                                                                /  
CC                                                                                               /  
CC      Modification_date: Mar 26 2002                                                            /  
CC                                                                                               /
```

The comment lines specify the file name along with the creation date and last modification date. The creation date indicates the date when the file was created for the first time. The modification date indicates 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 comment lines for a total of 4 lines. An example of the aircraft type block is given below.

```
CC===== Actype =====/   
1 -> CD  A306__          2 engines   Jet                H                /   
CC  Airbus A300-B4-622 with PW4158 engines             wake                /   
CC                                                                                               /
```

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   .14000E+03  .87000E+02  .17170E+03  .39000E+02  .14100E+00 /

```

The data line specifies the following BADA mass model parameters:

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

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   .33500E+03  .82000E+00  .41000E+05  .31600E+05  -.67000E+02 /

```

The data 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 .26000E+03 .15300E+01 .10290E+01 .00000E+00 /
CC Configuration characteristics /
CC n Phase Name Vstall(KCAS) CD0 CD2 unused /
2 -> CD 1 CR Clean .15100E+03 .19000E-01 .53000E-01 .00000E+00 /
3 -> CD 2 IC S15F00 .11700E+03 .33057E-01 .45362E-01 .00000E+00 /
4 -> CD 3 TO S15F00 .11700E+03 .33057E-01 .45362E-01 .00000E+00 /
5 -> CD 4 AP S15F15 .10900E+03 .38031E-01 .44932E-01 .00000E+00 /
6 -> CD 5 LD S30F40 .97000E+02 .78935E-01 .44822E-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 .2250E-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<sub>M16</sub>

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<sub>stall</sub>)<sub>CR</sub>                      C<sub>D0</sub>                      C<sub>D2</sub>

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<sub>stall</sub>)<sub>i</sub>, is specified for each configuration, and C<sub>D0</sub> and C<sub>D2</sub> are given if available in the following fixed format (Fortran notation):

'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  $C_{D0}$  and  $C_{D2}$  coefficients for IC and TO configurations are not used but are included for the reason of compatibility with previous versions.

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:

$$'CD', 31X, E10.5$$

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      .30400E+06  .44800E+05  .11600E-09  .67500E+01  .42600E-02 /
CC      Desc(low)   Desc(high)  Desc level  Desc(app)   Desc(ld) /
2 -> CD      .73000E-02  .20600E-01  .80000E+04  .12000E+00  .36000E+00 /
CC      Desc CAS    Desc Mach   unused      unused      unused /
3 -> CD      .28000E+03  .79000E+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:

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

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:

$$C_{Tdes,low} \quad C_{Tdes,high} \quad H_{p,des} \quad C_{Tdes,app} \quad C_{Tdes,ld}$$

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

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

Note that the  $C_{Tdes,app}$  and  $C_{Tdes,ld}$  coefficients are determined in order to obtain a 3° descent gradient during approach and landing.

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

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

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

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

Note that these two parameters are no longer used in BADA model implementation, but are left in place only to provide information on one of the reference speeds during descent used during the model identification.

The zero values at the end of this data line 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 .88100E+00 .16900E+05 /
CC Descent Fuel Flow Coefficients /
2 -> CD .26805E+02 .45700E+05 /
CC Cruise Corr. unused unused unused /
3 -> CD .10380E+01 .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      .23620E+04 .15550E+04 .44840E+02 .54080E+02 .00000E+00 /
CC===== /
FI /

```

The data line 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 A306 aircraft is shown below.

```

CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC A306__.APF CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC /
CC /
CC      AIRLINES PROCEDURES FILE /
CC /
CC      File_name: A306__.APF /
CC /
CC      Creation_date: Mar 26 2002 /
CC /
CC      Modification_date: Mar 26 2002 /
CC /
CC /
CC /
CC /
CC      LO= 087.00 to ---.-- / AV= ---.-- to ---.-- / HI= ---.-- to 171.70 /
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      B4_622 PW4158 LO 250 300 79          250 310 79 79 280 250          0 0 0 A306__ /
CD      B4_622 PW4158 AV 250 300 79          250 310 79 79 280 250          0 0 0 A306__ /
CD      B4_622 PW4158C HI 250 300 79          250 310 79 79 280 250          0 0 0 A306__ /
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, creation date and modification date. The block consists of 14 comment lines. An example of a file identification block is shown below.

```

CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC A306__.APF CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC/
CC                                                                                                                                           /
CC           AIRLINES PROCEDURES FILE                                                                                                       /
CC                                                                                                                                           /
CC   File_name: A306__.APF                                                                                                                 /
CC                                                                                                                                           /
CC   Creation_date: Mar 26 2002                                                                                                           /
CC                                                                                                                                           /
CC   Modification_date: Mar 26 2002                                                                                                       /
CC                                                                                                                                           /
CC                                                                                                                                           /
CC                                                                                                                                           /
CC   LO= 087.00 to ---.--- / AV= ---.--- to ---.--- / HI= ---.--- to 171.70                                                                 /
CC                                                                                                                                           /

```

The comment lines provide background information on the file contents. In addition, the comment lines specify the file name along with the creation and last modification date. The creation date indicates the date when the file was created for the first time. The modification date indicates 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   B4_622 PW4158  LO  250 300 79          250 310 79  79 280 250          0 0 0  A306___ /
3 -> CD   B4_622 PW4158  AV  250 300 79          250 310 79  79 280 250          0 0 0  A306___ /
4 -> CD   B4_622 PW4158C HI  250 300 79          250 310 79  79 280 250          0 0 0  A306___ /
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 format is:

'CD', 2X, A3, 1X, A2, 4X, A15

As it is, within BADA 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:

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

Note that all Mach number 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 A306 aircraft is shown below.

```

BADA PERFORMANCE FILE                               Apr 23 2002

AC/Type: A306

Source OPF File:           Mar 26 2002
Source APF file:           Mar 26 2002

Speeds:  CAS(LO/HI) Mach  Mass Levels [kg]           Temperature:  ISA
climb   - 250/300   0.79  low    - 104400
cruise  - 250/310   0.79  nominal - 140000           Max Alt. [ft]: 41000
descent  - 250/280   0.79  high   - 171700
=====
FL |          CRUISE          |          CLIMB          |          DESCENT          |
  | TAS      fuel           | TAS      ROCD          fuel | TAS  ROCD  fuel         |
  | [kts]    [kg/min]      | [kts]    [fpm]        [kg/min] | [kts] [fpm] [kg/min]    |
  |   lo    nom   hi      |   lo  nom   hi      |   nom  nom              |
=====
0 |          | 157 2210 1990 1620 270.3 | 131 760 97.2 |
5 |          | 158 2190 1970 1600 267.3 | 132 780 96.1 |
10 |         | 159 2170 1950 1570 264.3 | 138 800 95.0 |
15 |         | 166 2290 2030 1650 261.5 | 149 850 94.0 |
20 |         | 167 2270 2010 1620 258.5 | 181 1020 31.0 |
30 | 230 61.2 81.4 104.3 | 190 2750 2360 1920 253.0 | 230 1360 25.0 |
40 | 233 61.2 81.4 104.4 | 225 3350 2780 2270 247.7 | 233 1380 24.5 |
60 | 272 65.9 81.7 99.6  | 272 4210 3070 2370 236.8 | 240 1410 23.3 |
80 | 280 65.8 81.7 99.7  | 280 4040 2930 2230 225.7 | 280 1550 22.1 |
100 | 289 65.8 81.7 99.8 | 289 3860 2780 2090 214.8 | 289 1590 20.9 |
120 | 297 65.7 81.7 99.8 | 356 3820 2800 2170 204.8 | 332 1880 19.8 |
140 | 306 65.6 81.7 99.9 | 366 3590 2610 2000 194.3 | 342 1920 18.6 |
160 | 389 82.4 93.1 105.3 | 377 3360 2410 1820 184.1 | 353 1960 17.4 |
180 | 401 82.1 92.9 105.1 | 388 3120 2220 1650 174.2 | 363 2000 16.2 |
200 | 413 81.7 92.6 104.9 | 400 2880 2020 1470 164.5 | 375 2040 15.1 |
220 | 425 81.3 92.3 104.7 | 412 2630 1810 1290 155.0 | 386 2080 13.9 |
240 | 438 80.9 91.9 104.5 | 425 2380 1610 1100 145.8 | 398 2120 12.7 |
260 | 452 80.4 91.6 104.3 | 438 2130 1400 920 136.9  | 411 2160 11.6 |
280 | 466 79.9 91.2 104.1 | 452 1880 1200 730 128.1  | 424 2200 10.4 |
290 | 468 78.4 90.1 103.4 | 459 1760 1090 640 123.9  | 431 2220 9.8  |
310 | 464 74.3 87.0 101.5 | 464 2200 1290 660 115.4  | 444 2250 8.6  |
330 | 459 70.6 84.7 100.6 | 459 1950 1050 420 107.2  | 459 2290 7.4  |
350 | 455 67.6 83.0 97.9  | 455 1700 810 170 99.2    | 455 3150 6.3  |
370 | 453 65.1 82.0 90.3  | 453 1320 510 0 91.6     | 453 2850 5.1  |
390 | 453 63.2 81.9 83.0  | 453 1080 260 0 84.1     | 453 2850 3.9  |
410 | 453 61.9 75.9 75.9  | 453 830 10 0 77.0      | 453 2880 2.8  |
=====

```

The OPF and APF files are generated as a result of a modelling process using MatLab [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.

source file dates: The last modification 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	$m_{max}$

Note that the low mass is not the Minimum Mass but 1.2 times the minimum mass.

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 (nominal mass) in kg/min
Column 11	descent TAS (nominal mass) in knots
Column 12	rate of descent (nominal mass) in fpm
Column 13	descent fuel consumption (nominal mass) in kg/min

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

I3, 4X, I3, 2X, 3(1X, F5.1), 5X, I3, 2X, 3(1X, I5), 3X, F5.1, 5X, I3, 2X, I5, 3X, 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),
  - end of the application scope for reduced climb power (at 80% of  $h_{max}$ ).
- (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 to approach or landing aerodynamic configuration,
  - change in speed between flight levels (e.g. application of 250 knot limit below FL100).
- (i) The PTF files are made with "non-clean" configuration data for approach and landing when such data is available (see Section 3.6.1).
- (j) The performance data presented in the table are computed by using 'point type' calculation, that is without performing integration over time: aircraft weight is constant and does not account for consumed fuel, and speed changes take place immediately.
- (k) The flight envelope limitations are not taken into account for calculation of performance parameters<sup>8</sup>

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

---

<sup>8</sup> Example: cruise fuel flow is calculated without checking for given aircraft weight, speed and FL whether aircraft drag is lower than maximum available cruise thrust.

**6.7. PTD FILE FORMAT**

In addition to the data provided in the PTF file, more detailed climb and descent performance data are presented in the PTD file. An example of a PTD file for the Airbus A306 aircraft is shown below (partial listing):

```

BADA PERFORMANCE DATA                               Feb 16 2009

AC/Type: A306

Source OPF File:           Sep 05 2008
Source APF file:           Sep 05 2008

Speeds:  CAS(LO/HI)  Mach  Mass Levels [kg]      Temperature:  ISA
climb   - 250/300    0.79  low      - 104400
cruise  - 250/310    0.79  nominal - 140000      Max Alt. [ft]: 41000
descent - 250/280    0.79  high    - 171700

Low mass CLIMBS
=====

FL[-] T[K] p[Pa] rho[kg/m3] a[m/s] TAS[kt] CAS[kt] M[-] mass[kg] Thrust[N] Drag[N] Fuel[kgm] ESF[-] ROC[fpm] TDC[N] PWC[-]
0 288 101325 1.225 340 136.35 136.35 0.21 104400 297160 85670 215.8 0.98 2452 186284 0.88
5 287 99508 1.207 340 137.34 136.35 0.21 104400 294268 85680 213.9 0.98 2435 183727 0.88
10 286 97717 1.190 339 138.34 136.35 0.21 104400 291385 85691 212.0 0.98 2417 181179 0.88
15 285 95952 1.172 339 144.45 141.35 0.22 104400 288510 82072 211.0 0.97 2527 181833 0.88
20 284 94213 1.155 338 145.51 141.35 0.22 104400 285643 82082 209.1 0.97 2509 179299 0.88
30 282 90812 1.121 337 168.52 161.35 0.26 104400 279935 72295 209.0 0.96 2937 182892 0.88
40 280 87511 1.088 336 202.72 191.35 0.31 104400 274260 67093 210.7 0.95 3470 182476 0.88
60 276 81200 1.024 333 272.30 250.00 0.42 104400 263011 74643 213.7 0.91 4075 165917 0.88
80 272 75262 0.963 331 280.34 250.00 0.44 104400 251895 74535 206.0 0.91 3925 156222 0.88
100 268 69682 0.905 328 345.37 300.00 0.54 104400 240914 91120 207.0 0.87 3905 131941 0.88
120 264 64441 0.849 326 355.51 300.00 0.56 104400 230066 90785 199.1 0.86 3703 122681 0.88
140 260 59524 0.796 324 366.04 300.00 0.58 104400 219352 90425 191.3 0.85 3495 113561 0.88
160 256 54915 0.746 321 376.97 300.00 0.60 104400 208772 90038 183.6 0.84 3281 104583 0.88
180 252 50600 0.698 319 388.32 300.00 0.63 104400 198326 89622 175.8 0.83 3060 95748 0.88
200 249 46563 0.653 316 400.10 300.00 0.65 104400 188013 89175 168.1 0.82 2834 87059 0.88
220 245 42791 0.610 314 412.32 300.00 0.68 104400 177835 88694 160.4 0.81 2601 78516 0.88
240 241 39271 0.569 311 425.00 300.00 0.70 104400 167790 88179 152.7 0.80 2364 70123 0.88
260 237 35989 0.530 308 438.16 300.00 0.73 104400 157879 87627 145.0 0.79 2122 61879 0.88
280 233 32932 0.493 306 451.80 300.00 0.76 104400 148102 87036 137.3 0.78 1875 53788 0.88
290 231 31485 0.475 304 458.81 300.00 0.78 104400 143263 86725 133.4 0.78 1749 49800 0.88
310 227 28745 0.442 302 463.54 293.28 0.79 104400 133687 83916 124.9 1.09 2184 43839 0.88
330 223 26201 0.410 299 459.48 280.58 0.79 104400 124245 79587 115.8 1.09 2205 44658 1.00
350 219 23842 0.380 297 455.37 268.17 0.79 104400 114936 75881 106.8 1.09 1911 39055 1.00
370 217 21663 0.348 295 453.12 256.08 0.79 104400 105761 72808 98.1 1.00 1470 32953 1.00
390 217 19677 0.316 295 453.12 244.46 0.79 104400 96720 70398 89.7 1.00 1174 26322 1.00
410 217 17874 0.287 295 453.12 233.34 0.79 104400 87813 68640 81.5 1.00 855 19173 1.00
    
```

The performance values presented in the PTF file. They are generated in the same conditions as the corresponding PTF file: same aircraft, same source OPF and APF files, same speed laws, same mass levels, same temperature and same flight levels. The purpose of this file is mainly to provide the user with a greater number of computed parameters, especially intermediate parameters used to compute the final TAS and ROCD, which may be useful to validate an implementation of the BADA model.

The files consists of a header, conforming to the same format as the PTF file header described in Section 6.6, followed by performance data consisting of 4 sections:

- low mass climb performance
- nominal mass climb performance
- high mass climb performance
- nominal mass descent performance

Each section contains a table that presents, for several flight levels, a set of performance parameters spread across 16 columns. Each of these columns is described below:

Column 1	Flight level [FL]
Column 2	Temperature [K]
Column 3	Pressure [Pa]
Column 4	Air density [ $\text{kg/m}^3$ ]
Column 5	Speed of sound [m/s]
Column 6	TAS [kt]
Column 7	CAS [kt]
Column 8	Mach [dimensionless]
Column 9	Mass [kg]
Column 10	Thrust [N]
Column 11	Drag [N]
Column 12	Fuel flow [kg/min]
Column 13	Energy share factor [dimensionless]
Column 14	Rate of climb/descent [ft/min]
Column 15	$(T - D) * C_{\text{pow,red}}$ [kg/min] (see section 3.8)
Column 16	- climb tables: Power reduction coefficient $C_{\text{pow,red}}$ [dimensionless] - descent table: Descent gradient [degree]

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

Climb tables:

I6, 1X, I3, 1X, I6, 1X, F7.3, 1X, I7, 2(1X, F8.2), 1X, F7.2, 1X, I6, 2(1X, I9), 1X, F7.1, 1X, F7.2, 1X, I7, 1X, I8, 1X, F7.2

Descent tables:

I6, 1X, I3, 1X, I6, 1X, F7.3, 1X, I7, 2(1X, F8.2), 1X, F7.2, 1X, I6, 2(1X, I9), 1X, F7.1, 1X, F7.2, 1X, I7, 1X, I8, 1X, F8.2



```

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]                /
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 three blocks separated by a comment line consisting of the block name and equal signs "=":

- file identification block
- class block
- parameter block

Each of these blocks is described in the subsections below.



### 6.8.3. 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 /
1 -> 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] /
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 identifies 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

The files associated with BADA Revision 3.8 are accessible through the BADA Support Application (BSA). The BSA is a Web application that provides BADA users with the ability to exchange requests, as well as data files and documents, with the BADA team members. It is also used for data repository of the BADA release files and documents.

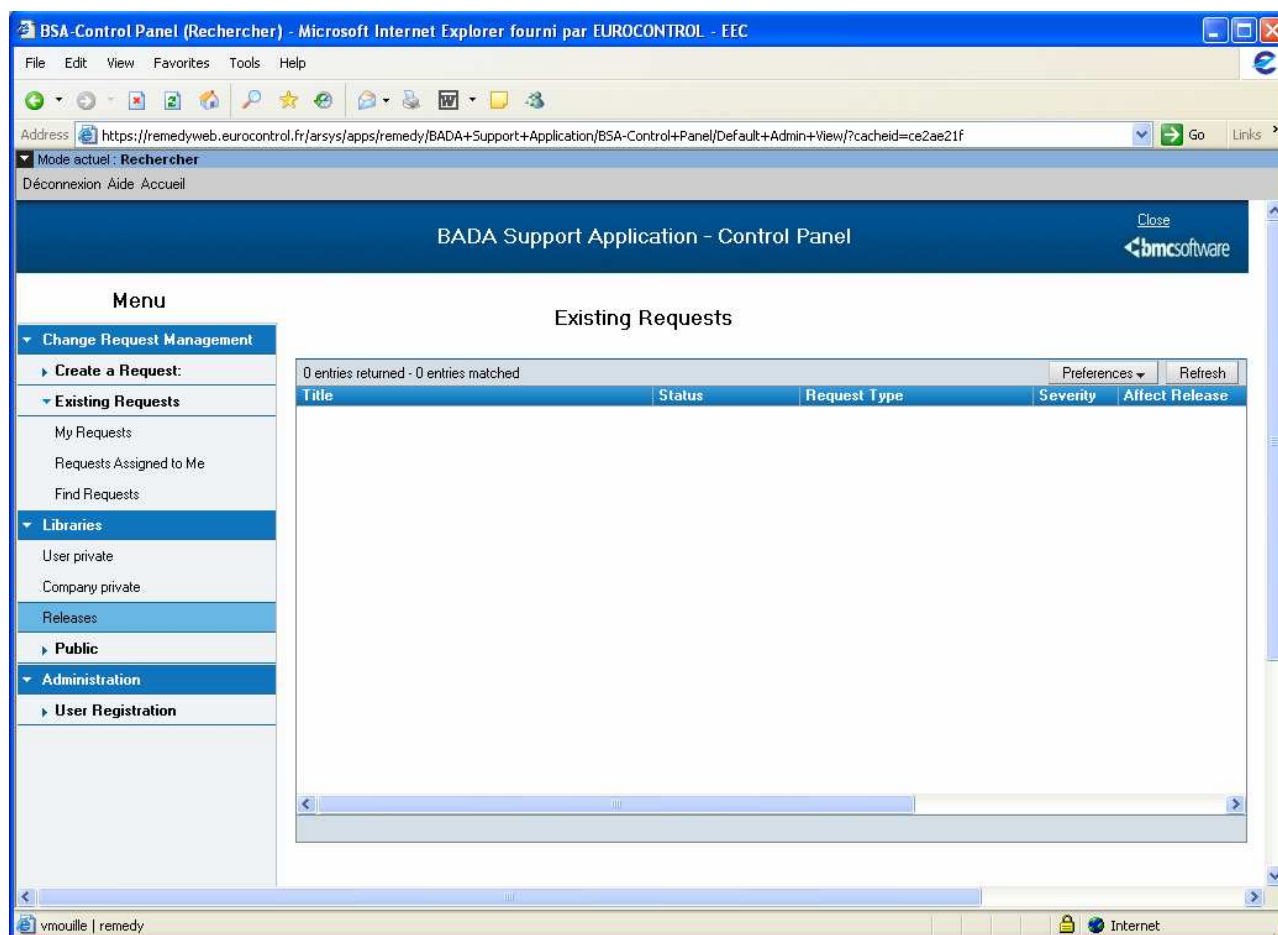
The right to use the BSA is granted to the licensed user of BADA. The application can be accessed by using a dedicated login and password as provided by the BADA team.

Once granted the access right to BSA, the user can access the application at this address:

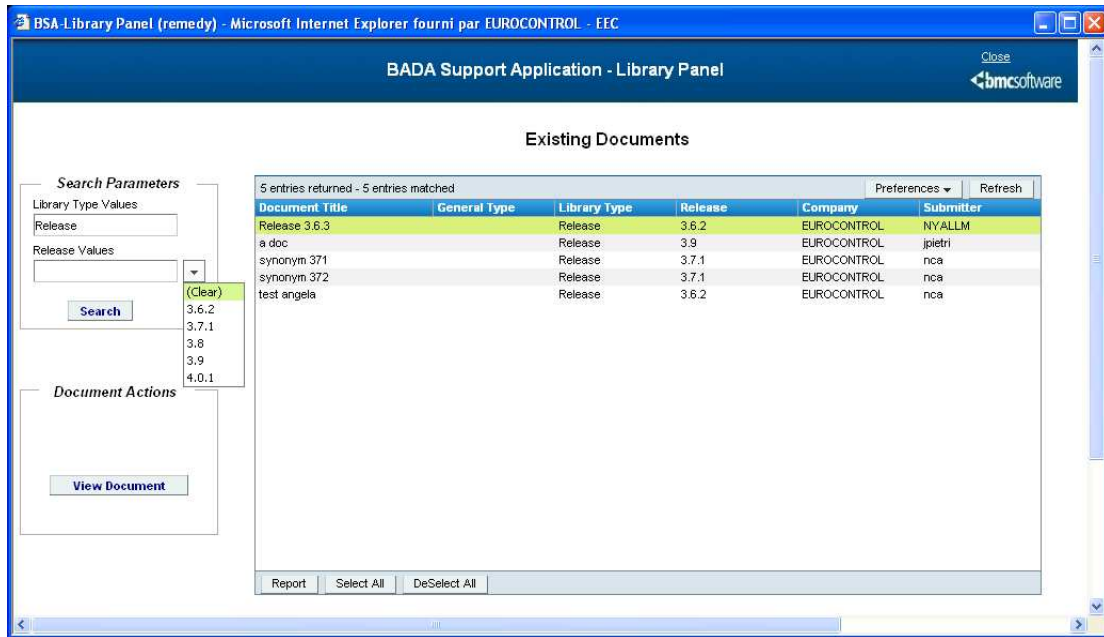
<https://remedyweb.eurocontrol.fr>

by using the [BADA Support Application](#) link and logging in with the provided login/password.

Once logged in, the user can access BADA releases through the **Librairies**→**Releases** item located in the main menu:



Then the release library page opens up, from where the user can download the BADA release files:



This process, as well as the general usage of the BSA application, is described in detail in [RD11].

Note that enquiries can be addressed to the following addresses:

E-mail: [eec.bada@eurocontrol.int](mailto:eec.bada@eurocontrol.int)

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BADA web page: [http://www.eurocontrol.int/eec/public/standard\\_page/proj\\_BADA.html](http://www.eurocontrol.int/eec/public/standard_page/proj_BADA.html)

## **APPENDIX A**

### **BADA 3.8 – LIST OF AVAILABLE AIRCRAFT MODELS**

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Table 7-1: List of Aircraft Types Supported by BADA 3.8

A/C Code	Model Type	Aircraft manufacturer	Aircraft model	Synonym aircraft	h <sub>MO</sub> [ft]	h <sub>max</sub> [ft]	WTC
A10	equiv.	FAIRCHILD	THUNDERBOLT II	FGTN	50000		M
A124	equiv.	ANTONOV	AN-124 RUSLAN	A345	41450	32862	H
A306	direct	AIRBUS	A300B4-600	A306	41000	32378	H
A30B	direct	AIRBUS	A300B4-200	A30B	39000	31967	H
A310	direct	AIRBUS	A310	A310	41000	35719	H
A318	direct	AIRBUS	A318	A318	39800	37606	M
A319	direct	AIRBUS	A319	A319	39000	36365	M
A320	direct	AIRBUS	A320	A320	39000	33965	M
A321	direct	AIRBUS	A321	A321	39100	35396	M
A332	direct	AIRBUS	A330-200	A332	41000	36211	H
A333	direct	AIRBUS	A330-300	A333	41000	36392	H
A342	equiv.	AIRBUS	A340-200	A343	41000	32325	H
A343	direct	AIRBUS	A340-300	A343	41000	32325	H
A345	direct	AIRBUS	A340-500	A345	41450	32862	H
A346	direct	AIRBUS	A340-600	A346	41500	33613	H
A388	direct	AIRBUS	A380-800	A388	43100	34330	H
A3ST	direct	AIRBUS	A-300ST Beluga	A3ST	35000		H
A4	equiv.	DOUGLAS	SUPER SKYHAWK	FGTN	50000		M
A6	equiv.	GRUMMAN	INTRUDER	FGTN	50000		M
A7	equiv.	VOUGHT	CORSAIR II A7	FGTN	50000		M
A748	equiv.	AVRO	AVRO 748	ATP	25000	21628	M
AA5	equiv.	GULFSTREAM AMERICAN	Cheetah AA-5	P28A	12000		L
AC90	equiv.	ROCKWELL	TURBO COMMANDER	PAY3	33000		L
AC95	equiv.	GULFSTREAM AEROSPACE	Jetprop Commander 980	PAY3	33000		L
AEST	equiv.	TED SMITH	AEROSTAR	MU2	28000		L

A/C Code	Model Type	Aircraft manufacturer	Aircraft model	Synonym aircraft	h <sub>MO</sub> [ft]	h <sub>max</sub> [ft]	WTC
AJET	equiv.	DASSAULT	ALPHA JET	FGTN	50000		M
AMX	equiv.	EMBRAER	AMX	FGTN	50000		M
AN12	equiv.	ANTONOV	AN-12	C130	32000	21892	M
AN24	equiv.	ANTONOV	AN-124	F27	25000	22778	M
AN26	equiv.	ANTONOV	AN-26	AT72	25000	20943	M
AN72	equiv.	ANTONOV	AN-72	F28	35000		M
ASTR	equiv.	IAI	1125 Astra	FA10	45000		M
AT43	direct	ATR	ATR 42-300	AT43	25000	22700	M
AT44	equiv.	ATR	ATR 42-400	AT45	25000	23592	M
AT45	direct	ATR	ATR 42-500	AT45	25000	23592	M
AT72	direct	ATR	ATR 72	AT72	25000	20943	M
ATLA	equiv.	DASSAULT	1150 ATLANTIC	E120	32000		M
ATP	direct	BAE	ADVANCED TURBOPROP	ATP	25000	21628	M
B1	equiv.	ROCKWELL	B1 LANCER	FGTL	41000		H
B190	equiv.	BEECH	1900	JS32	25000		L
B350	equiv.	BEECH	SUPER KING AIR 350	PAY3	33000		L
B461	equiv.	BAE	146-100/RJ	B462	31000	30350	M
B462	direct	BAE	146-200/RJ	B462	31000	30350	M
B463	equiv.	BAE	146-300/RJ	B462	31000	30350	M
B52	equiv.	BOEING	B-52 Stratofortress	FGTL	41000		H
B701	equiv.	BOEING	707-100	B752	42000	35478	M
B703	direct	BOEING	707-300	B703	42000		H
B712	direct	BOEING	717-200	B712	37000	35188	M
B720	equiv.	BOEING	B720B	B752	42000	35478	M
B721	equiv.	BOEING	727-100	B752	42000	35478	M

A/C Code	Model Type	Aircraft manufacturer	Aircraft model	Synonym aircraft	h <sub>MO</sub> [ft]	h <sub>max</sub> [ft]	WTC
B722	direct	BOEING	727-200	B722	37000	33845	M
B731	equiv.	BOEING	737-100	T134	39000	34765	M
B732	direct	BOEING	737-200	B732	37000	34508	M
B733	direct	BOEING	737-300	B733	37000	33637	M
B734	direct	BOEING	737-400	B734	37000	33448	M
B735	direct	BOEING	737-500	B735	37000	34340	M
B736	direct	BOEING	737-600	B736	41000	39276	M
B737	direct	BOEING	737-700	B737	41000	37333	M
B738	direct	BOEING	737-800	B738	41000	34983	M
B739	direct	BOEING	737-900	B739	41000	34683	M
B741	equiv.	BOEING	747-100	B743	45000	30944	H
B742	direct	BOEING	747-200	B742	45000	33180	H
B743	direct	BOEING	747-300	B743	45000	30944	H
B744	direct	BOEING	747-400	B744	45000	32727	H
B748	equiv.	BOEING	747-800	B743	45000	30944	H
B74D	equiv.	BOEING	747-400 DOMESTIC	B744	45000	32727	H
B74R	equiv.	BOEING	747SR	B743	45000	30944	H
B74S	equiv.	BOEING	747-SP	B742	45000	33180	H
B752	direct	BOEING	757-200	B752	42000	35478	M
B753	direct	BOEING	757-300	B753	43000	33340	M
B762	direct	BOEING	767-200	B762	43000	35861	H
B763	direct	BOEING	767-300	B763	43100	36502	H
B764	direct	BOEING	767-400	B764	45000	33210	H
B772	direct	BOEING	777-200 ER	B772	43100	34643	H
B773	direct	BOEING	777-300	B773	43100	31858	H
B77L	direct	BOEING	777-200 LRF	B77L	43100	35104	H

A/C Code	Model Type	Aircraft manufacturer	Aircraft model	Synonym aircraft	h <sub>MO</sub> [ft]	h <sub>max</sub> [ft]	WTC
B77W	direct	BOEING	777-300 ER	B77W	43100	34314	H
BA11	direct	BAE	111 ALL SERIES	BA11	35000		M
BDOG	equiv.	BAE	SA-3 BULLDOG	PA34	25000		L
BE10	equiv.	BEECH	KING AIR 100	D228	28000		L
BE20	direct	BEECH	SUPER KING AIR 200	BE20	32000		L
BE30	equiv.	BEECH	SUPER KING AIR 300	PAY3	33000		L
BE33	equiv.	BEECH	BONANZA 33	TRIN	20000		L
BE36	equiv.	BEECH	BONANZA 36	DA42	18000		L
BE40	equiv.	BEECH	BEECHJET 400	C560	45000	41083	M
BE55	equiv.	BEECH	BARON 55	BE58	20688		L
BE58	direct	BEECH	BARON 58	BE58	20688		L
BE60	equiv.	BEECH	DUKE 60	PA31	23000		L
BE76	equiv.	BEECH	DUCHESS 76	DA42	18000		L
BE95	equiv.	BEECH	TRAVEL AIR 95	TRIN	20000		L
BE99	direct	BEECH	AIRLINER C99	BE99	15000		L
BE9L	direct	BEECH	KING AIR 90	BE9L	31000		L
BE9T	equiv.	BEECH	KING AIR 90	BE9L	31000		L
BN2P	equiv.	BRITTEN NORMAN	BN-2A MARITIME DEFENDER	PA34	25000		L
C130	direct	LOCKHEED	HERCULES	C130	32000	21892	M
C135	equiv.	BOEING	STRATOLIFTER C-135C	B703	42000		H
C141	equiv.	LOCKHEED	STARLIFTER C-141	A310	41000	35719	H
C160	direct	TRANSALL	C160	C160	30000	25500	M
C17	equiv.	BOEING	GLOBEMASTER 3	B764	45000	33210	H
C170	equiv.	CESSNA	170	P28A	12000		L
C172	equiv.	CESSNA	SKYHAWK 172	P28A	12000		L

A/C Code	Model Type	Aircraft manufacturer	Aircraft model	Synonym aircraft	h <sub>MO</sub> [ft]	h <sub>max</sub> [ft]	WTC
C177	equiv.	CESSNA	CARDINAL 177	P28A	12000		L
C182	equiv.	CESSNA	SKYLANE 182	TRIN	20000		L
C208	equiv.	CESSNA	CARAVAN	PA27	20000		L
C210	equiv.	CESSNA	CENTURION	TRIN	20000		L
C212	equiv.	CASA	T-12 AVIOCAR	D228	28000		L
C25A	equiv.	CESSNA	525A Citation CJ2	C560	45000	41083	M
C25B	equiv.	CESSNA	525B Citation CJ3	C560	45000	41083	M
C303	equiv.	CESSNA	CRUSADER 303	PA31	23000		L
C30J	equiv.	LOCKHEED MARTIN	C130J HERCULES	C130	32000	21892	M
C310	equiv.	CESSNA	310	PA34	25000		L
C337	equiv.	CESSNA	SUPER SKYMASTER	PA27	20000		L
C340	equiv.	CESSNA	C-340/340A	PA31	23000		L
C402	equiv.	CESSNA	402	PA34	25000		L
C404	equiv.	CESSNA	TITAN	C421	23500		L
C414	equiv.	CESSNA	CHANCELLOR 414	PA31	23000		L
C421	direct	CESSNA	GOLDEN EAGLE 421	C421	23500		L
C425	equiv.	CESSNA	CORSAIR	PAY2	29000		L
C441	equiv.	CESSNA	Conquest	PAY3	33000		L
C5	equiv.	LOCKHEED	L-500 GALAXY	A346	41500	33613	H
C500	equiv.	CESSNA	CITATION 1	C550	43000		L
C501	equiv.	CESSNA	CITATION 1SP	C550	43000		L
C510	direct	CESSNA	CITATION MUSTANG	C510	41000		L
C525	equiv.	CESSNA	CITATION JET	C550	43000		L
C550	direct	CESSNA	CITATION II-S2	C550	43000		L
C551	equiv.	CESSNA	CITATION 2SP	C550	43000		L
C560	direct	CESSNA	CITATION V	C560	45000	41083	M

A/C Code	Model Type	Aircraft manufacturer	Aircraft model	Synonym aircraft	h <sub>MO</sub> [ft]	h <sub>max</sub> [ft]	WTC
C56X	equiv.	CESSNA	CITATION Excel	C560	45000	41083	M
C650	equiv.	CESSNA	CITATION VII	H25A	40000		M
C680	equiv.	CESSNA	Citation Sovereign	F2TH	47000	41486	M
C72R	equiv.	CESSNA	CUTLASS RG	TRIN	20000		L
C750	direct	CESSNA	CITATION 10	C750	51000	45181	M
C77R	equiv.	CESSNA	CARDINAL 177RG	P28A	12000		L
C82R	equiv.	CESSNA	SKYLANE R182 RG	TRIN	20000		L
CL30	equiv.	BOMBARDIER	Challenger 300	F2TH	47000	41486	M
CL60	direct	CANADAIR	CHALLENGER 600/601	CL60	41000	39223	M
CN35	equiv.	CASA	CN-235	AT43	25000	22700	M
COL4	equiv.	CESSNA	COLUMBIA 400	TRIN	20000		L
CRJ1	direct	CANADAIR	REGIONAL JET CRJ-100	CRJ1	41000	34334	M
CRJ2	direct	CANADAIR	REGIONAL JET CRJ-200	CRJ2	41000	36856	M
CRJ7	equiv.	CANADAIR	REGIONAL JET CRJ-700	CRJ9	41000	36458	M
CRJ9	direct	CANADAIR	REGIONAL JET CRJ-900	CRJ9	41000	36458	M
CVLT	equiv.	CANADAIR	CC-109 COSMOPOLITAN	DH8C	25000	24805	L
D228	direct	DORNIER	228	D228	28000		L
D328	direct	DORNIER	328	D328	32800	29051	M
DA42	direct	DIAMOND	TWIN STAR	DA42	18000		L
DC10	direct	MCDONNELL DOUGLAS	DC-10	DC10	39000		H
DC3	equiv.	DOUGLAS	DC-3	C421	23500		L
DC85	equiv.	MCDONNELL DOUGLAS	DC-8-50	A310	41000	35719	H
DC86	equiv.	MCDONNELL DOUGLAS	DC-8-60	DC87	42000		H
DC87	direct	MCDONNELL DOUGLAS	DC-8-70	DC87	42000		H
DC91	equiv.	MCDONNELL DOUGLAS	DC-9-10	B712	37000	35188	M

A/C Code	Model Type	Aircraft manufacturer	Aircraft model	Synonym aircraft	h <sub>MO</sub> [ft]	h <sub>max</sub> [ft]	WTC
DC92	equiv.	MCDONNELL DOUGLAS	DC-9-20	DC94	35000		M
DC93	equiv.	MCDONNELL DOUGLAS	DC-9-30	DC94	35000		M
DC94	direct	MCDONNELL DOUGLAS	DC-9-40	DC94	35000		M
DC95	equiv.	MCDONNELL DOUGLAS	DC-9-50	DC94	35000		M
DH8A	direct	DE HAVILLAND	DASH 8-100	DH8A	25000	25000	M
DH8B	equiv.	DE HAVILLAND	DASH 8-200	DH8C	25000	24805	L
DH8C	direct	DE HAVILLAND	DASH 8-300	DH8C	25000	24805	L
DH8D	direct	DE HAVILLAND	DASH 8-400	DH8D	25000		M
E110	equiv.	EMBRAER	BANDEIRANTE	SW4	25000	25000	L
E120	direct	EMBRAER	EMB-120 BRASILIA	E120	32000		M
E121	equiv.	EMBRAER	Xingu	PAY2	29000		L
E135	direct	EMBRAER	EMB-135	E135	37000		M
E145	direct	EMBRAER	EMB-145	E145	37000		M
E170	direct	EMBRAER	EMB-175	E170	41000		M
E190	direct	EMBRAER	EMB-190	E190	41000		M
E3CF	equiv.	BOEING	E-3 SENTRY	B762	43000	35861	H
E3TF	equiv.	BOEING	E-3A SENTRY	B762	43000	35861	H
E50P	equiv.	EMBRAER	Phenom 100	C550	43000		L
E55P	equiv.	EMBRAER	Phenom 300	C560	45000	41083	M
EA50	direct	ECLIPSE	ECLIPSE 500	EA50	41000		L
ETAR	equiv.	DASSAULT	ETENDARD 4	FGTN	50000		M
EUFI	equiv.	EUROFIGHTER	2000	FGTN	50000		M
F1	equiv.	MITSUBISHI	F1	FGTN	50000		M
F100	direct	FOKKER	100	F100	35000	35000	M
F104	equiv.	LOCKHEED	STARFIGHTER	FGTN	50000		M
F117	equiv.	LOCKHEED	NIGHTHAWK	FGTN	50000		M

A/C Code	Model Type	Aircraft manufacturer	Aircraft model	Synonym aircraft	h <sub>MO</sub> [ft]	h <sub>max</sub> [ft]	WTC
F14	equiv.	GRUMMAN	TOMCAT	FGTN	50000		M
F15	equiv.	MCDONNELL DOUGLAS	EAGLE	FGTN	50000		M
F16	equiv.	GENERAL DYNAMICS	FIGHTING FALCON	FGTN	50000		M
F18	equiv.	MCDONNELL DOUGLAS	HORNET	FGTN	50000		M
F27	direct	FOKKER	FRIENDSHIP	F27	25000	22778	M
F28	direct	FOKKER	FOLLOWSHIP	F28	35000		M
F2TH	direct	DASSAULT	FALCON 2000	F2TH	47000	41486	M
F4	equiv.	MCDONNELL DOUGLAS	PHANTOM	FGTN	50000		M
F5	equiv.	NORTHROP	F-5	FGTN	50000		M
F50	direct	FOKKER	50	F50	25000	21331	M
F70	direct	FOKKER	70	F70	37000	36565	M
F900	direct	DASSAULT	FALCON 900	F900	51000	38187	M
FA10	direct	DASSAULT	FALCON 10	FA10	45000		M
FA20	direct	DASSAULT	FALCON 20	FA20	42000		M
FA50	direct	DASSAULT	FALCON 50	FA50	49000	41177	M
FA7X	direct	DASSAULT	FALCON 7X	FA7X	51000	39848	M
FGTH	direct	GENERIC	MIL FIGHTER HEAVY	FGTH	50000		M
FGTL	direct	GENERIC	MIL FIGHTER LIGHT	FGTL	41000		H
FGTN	direct	GENERIC	MIL FIGHTER NORMAL	FGTN	50000		M
G150	equiv.	IAI	Gulfstream G150	LJ35	45000	40288	M
G222	equiv.	ALENIA	SPARTAN C-27A	ATP	25000	21628	M
GALX	equiv.	IAI	1126 GALAXY	F2TH	47000	41486	M
GL5T	equiv.	BOMBARDIER	Global 5000	C750	51000	45181	M
GLAS	equiv.	STODDARD-HAMILTON	GLASAIR	BE58	20688		L
GLEX	equiv.	BOMBARDIER	BD-700 Global Express	C750	51000	45181	M

A/C Code	Model Type	Aircraft manufacturer	Aircraft model	Synonym aircraft	h <sub>MO</sub> [ft]	h <sub>max</sub> [ft]	WTC
GLF2	equiv.	GULFSTREAM	GULFSTREAM II	LJ35	45000	40288	M
GLF3	equiv.	GULFSTREAM	GULFSTREAM III	FA7X	51000	39848	M
GLF4	equiv.	GULFSTREAM	GULFSTREAM IV	FA7X	51000	39848	M
GLF5	equiv.	GULFSTREAM	GULFSTREAM V C37	FA7X	51000	39848	M
GLST	equiv.	GLASAIR	GlaStar	TRIN	20000		L
H25A	direct	HAWKER SIDDELEY	DOMINE HS 125	H25A	40000		M
H25B	equiv.	HAWKER SIDDELEY	HS 125-700/800	H25A	40000		M
H25C	equiv.	RAYTHEON	HAWKER 1000	FA20	42000		M
HAR	equiv.	HAWKER SIDDELEY	HARRIER	FGTN	50000		M
HAWK	equiv.	HAWKER SIDDELEY	HAWK	FGTN	50000		M
HELI	equiv.	GENERIC	HELICOPTER	P28A	12000		L
IL18	equiv.	ILYUSHIN	IL-18	C130	32000	21892	M
IL62	equiv.	ILYUSHIN	IL-62 /-62M / MK	A30B	39000	31967	H
IL76	equiv.	ILYUSHIN	IL-76	B764	45000	33210	H
IL86	equiv.	ILYUSHIN	IL-86	B763	43100	36502	H
IL96	equiv.	ILYUSHIN	IL-96	A343	41000	32325	H
J328	equiv.	FAIRCHILD DORNIER	328 Jet	E135	37000		M
JAGR	equiv.	SEPECAT	JAGUAR	FGTN	50000		M
JS1	equiv.	JETSTREAM	JETSTREAM 1	BE20	32000		L
JS20	equiv.	JETSTREAM	JETSTREAM 200	D228	28000		L
JS31	equiv.	BAE	JETSTREAM 31	JS32	25000		L
JS32	direct	JETSTREAM	JETSTREAM Super 31	JS32	25000		L
JS41	direct	JETSTREAM	JETSTREAM 41	JS41	26000	24685	M
K35A	equiv.	BOEING	STRATOTANKER KC-135A	B703	42000		H
K35E	equiv.	BOEING	STRATOTANKER KC-135D/E	B703	42000		H
K35R	equiv.	BOEING	STRATOTANKER K35R	B703	42000		H

A/C Code	Model Type	Aircraft manufacturer	Aircraft model	Synonym aircraft	h <sub>MO</sub> [ft]	h <sub>max</sub> [ft]	WTC
L101	direct	LOCKHEED	TRISTAR L-1011	L101	42000		H
L159	equiv.	AERO (2)	L-159	FGTN	50000		M
L188	equiv.	LOCKHEED	ELECTRA L-188	C160	30000	25500	M
L29A	equiv.	LOCKHEED	JETSTART	CL60	41000	39223	M
L29B	equiv.	LOCKHEED	L1329 JETSTAR	CL60	41000	39223	M
L410	equiv.	LET	TURBOLET 410	D228	28000		L
LJ24	equiv.	LEARJET	24	C560	45000	41083	M
LJ25	equiv.	LEARJET	25	LJ45	51000	44100	M
LJ31	equiv.	LEARJET	31	LJ45	51000	44100	M
LJ35	direct	LEARJET	35	LJ35	45000	40288	M
LJ40	equiv.	LEARJET	40	LJ45	51000	44100	M
LJ45	direct	LEARJET	45	LJ45	51000	44100	M
LJ55	equiv.	LEARJET	55	LJ45	51000	44100	M
LJ60	equiv.	LEARJET	60	LJ45	51000	44100	M
M20P	equiv.	MOONEY	MARK 201	TRIN	20000		L
M20T	equiv.	MOONEY	MARK 20T	TRIN	20000		L
MD11	direct	MCDONNELL DOUGLAS	MD-11	MD11	43000	31838	H
MD81	equiv.	MCDONNELL DOUGLAS	MD-81	MD82	37000	34448	M
MD82	direct	MCDONNELL DOUGLAS	MD-82	MD82	37000	34448	M
MD83	direct	MCDONNELL DOUGLAS	MD-83	MD83	37000	33513	M
MD87	equiv.	MCDONNELL DOUGLAS	MD-87	MD82	37000	34448	M
MD88	equiv.	MCDONNELL DOUGLAS	MD-88	MD82	37000	34448	M
MD90	equiv.	MCDONNELL DOUGLAS	MD-90	MD83	37000	33513	M
MG21	equiv.	MIKOYAN	MIG-21	FGTN	50000		M
MG23	equiv.	MIKOYAN	MIG-23	FGTN	50000		M

A/C Code	Model Type	Aircraft manufacturer	Aircraft model	Synonym aircraft	h <sub>MO</sub> [ft]	h <sub>max</sub> [ft]	WTC
MG25	equiv.	MIKOYAN	MIG-25	FGTN	50000		M
MG29	equiv.	MIKOYAN	MIG-29	FGTN	50000		M
MIR2	equiv.	DASSAULT	MIRAGE 2000	FGTN	50000		M
MIR4	equiv.	DASSAULT	MIRAGE IV	FGTN	50000		M
MRF1	equiv.	DASSAULT	MIRAGE F1	FGTN	50000		M
MU2	direct	MITSUBISHI	MARQUISE/SOLIT AIRE	MU2	28000		L
MU30	equiv.	MITSUBISHI	MU-300	C560	45000	41083	M
N262	equiv.	NORD	262	JS41	26000	24685	M
NIM	equiv.	HAWKER SIDDELEY	NIMROD	B738	41000	34983	M
P180	equiv.	PIAGGIO	P180 AVANTI	C550	43000		L
P28A	direct	PIPER	PA-28-140 CHEROKEE	P28A	12000		L
P28B	equiv.	PIPER	PA-28-236 DAKOTA	TRIN	20000		L
P28R	equiv.	PIPER	PA-28R-201 ARROW	DA42	18000		L
P28T	equiv.	PIPER	PA-28RT TURBO ARROW 4	DA42	18000		L
P3	equiv.	LOCKHEED	ORION P-3	C130	32000	21892	M
P32R	equiv.	PIPER	PA-32R-301 SARATOGA SP	TRIN	20000		L
P46T	equiv.	PIPER	Malibu Meridian	BE9L	31000		L
P68	equiv.	PARTENAVIA	P-68 Observer	PA27	20000		L
PA18	equiv.	PIPER	PA-18 SUPER CUB	PA34	25000		L
PA23	equiv.	PIPER	APACHE PA23-150/160	PA27	20000		L
PA27	direct	PIPER	AZTEC PA23-235/250	PA27	20000		L
PA30	equiv.	PIPER	Twin Comanche	TRIN	20000		L
PA31	direct	PIPER	CHIEFTAIN	PA31	23000		L
PA32	equiv.	PIPER	PA-32 CHEROKEE SIX	TRIN	20000		L
PA34	direct	PIPER	PA34-200T SENECA-III	PA34	25000		L
PA44	equiv.	PIPER	PA-44 SEMINOLE	TRIN	20000		L

A/C Code	Model Type	Aircraft manufacturer	Aircraft model	Synonym aircraft	h <sub>MO</sub> [ft]	h <sub>max</sub> [ft]	WTC
PAY1	equiv.	PIPER	PA-A-31T1-500 CHEYENNE I	PAY2	29000		L
PAY2	direct	PIPER	PA-31T-620 CHEYENNE II	PAY2	29000		L
PAY3	direct	PIPER	PA-42-720 CHEYENNE III	PAY3	33000		L
PAY4	equiv.	PIPER	PA-42-1000 CHEYENNE 400	C510	41000		L
PC12	equiv.	PILATUS	PC-12 SPECTRE	BE9L	31000		L
PRM1	equiv.	HAWKER BEECHCRAFT	390 Premier 1	C560	45000	41083	M
RFAL	equiv.	DASSAULT	RAFALE	FGTN	50000		M
RJ1H	equiv.	AI(R)	RJ-100 Avroliner	RJ85	35000	31355	M
RJ70	equiv.	AI(R)	RJ-70 Avroliner	RJ85	35000	31355	M
RJ85	direct	AI(R)	RJ-85 Avroliner	RJ85	35000	31355	M
S601	equiv.	AEROSPATIAL	SB 601 CORVETTE	C550	43000		L
SB05	equiv.	SAAB	SAAB 105	C510	41000		L
SB20	direct	SAAB	SAAB 2000	SB20	31000		M
SB32	equiv.	SAAB	LANSEN	FGTN	50000		M
SB35	equiv.	SAAB	DRAKEN	FGTN	50000		M
SB37	equiv.	SAAB	VIGGEN	FGTN	50000		M
SB39	equiv.	SAAB	GRIPEN	FGTN	50000		M
SBR1	equiv.	ROCKWELL	SABRELINER	FA10	45000		M
SF34	direct	SAAB	SF 340	SF34	25000	24369	M
SH33	equiv.	SHORTS	SH3-330	SH36	20000		M
SH36	direct	SHORTS	SH3-360	SH36	20000		M
SR22	equiv.	CIRRUS	SR-22	TRIN	20000		L
SW2	equiv.	SWEARINGEN	MERLIN II	SW4	25000	25000	L
SW3	equiv.	SWEARINGEN	MERLIN III	PAY3	33000		L
SW4	direct	SWEARINGEN	MERLIN IV	SW4	25000	25000	L

A/C Code	Model Type	Aircraft manufacturer	Aircraft model	Synonym aircraft	h <sub>MO</sub> [ft]	h <sub>max</sub> [ ft ]	WTC
T134	direct	TUPOLEV	TU134A-3	T134	39000	34765	M
T154	direct	TUPOLEV	TU154M	T154	41000	37285	M
T160	equiv.	TUPOLEV	TU160	B742	45000	33180	H
T204	equiv.	TUPOLEV	TU 204	T154	41000	37285	M
TBM7	equiv.	TBM	TBM-700	PAY3	33000		L
TBM8	equiv.	SOCATA	TBM-850	BE20	32000		L
TOBA	equiv.	SOCATA	TOBAGO TB-10	TRIN	20000		L
TOR	equiv.	PANAVIA	TORNADO	FGTN	50000		M
TRIN	direct	SOCATA	TRINIDAD TB-20	TRIN	20000		L
VC10	equiv.	VICKERS	VC10	B762	43000	35861	H
WW24	equiv.	IAI	1124 WESTWIND	FA10	45000		M
YK40	equiv.	YAKOLEV	YAK-40	AT43	25000	22700	M
YK42	equiv.	YAKOLEV	YAK-42	DC94	35000		M

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## **APPENDIX B**

### **BADA 3.8 – SOLUTIONS FOR BUFFETING LIMIT ALGORITHM**

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A general solution for finding the roots of a cubic expression can be found in Ref. 1. If we take expression 3.6-6, we can rewrite it to:

$$M^3 - \frac{C_{Lbo(M=0)}}{k} \cdot M^2 + \frac{\frac{W}{S}}{0.583 \cdot P \cdot k} = 0$$

Therefore:

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

$$a_2 = 0$$

$$a_3 = \frac{\frac{W}{S}}{0.583 \cdot P \cdot k}$$

$$Q = \frac{(3 \cdot a_2 - a_1^2)}{9}$$

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

Now let:

and

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:

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

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

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

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

With:

The solutions  $x_1$ ,  $x_2$  and  $x_3$  now give the possible values of M. One solution (in our case usually  $x_1$ ) is always negative. The others are positive with the lower one (usually  $x_2$ ) being the low speed buffeting limit we are looking for.

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

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