EUROPEAN ORGANISATION
FOR THE SAFETY OF AIR NAVIGATION

EUROCONTROL

EUROCONTROL EXPERIMENTAL CENTRE

DESIGN AND USER MANUAL
FOR
BADA EXCEL SPREADSHEETS
Issue 2.0

EEC Note No. 13/98

EEC Task D09
EATCHIP Task SDV-D-E7

Issued: May 1998

REPORT DOCUMENTATION PAGE

Reference: EEC Note 13/98	**Security Classification:** Unclassified
Originator: EEC - APO (**A**ircraft **P**erformance and **O**perations)	**Originator (Corporate Author) Name/Location:** EUROCONTROL Experimental Centre B.P.15 F - 91222 Brétigny-sur-Orge CEDEX FRANCE Telephone : +33 1 69 88 75 00
Sponsor: EEC	**Sponsor (Contract Authority) Name/Location:** EUROCONTROL Agency Rue de la Fusée, 96 B -1130 BRUXELLES Telephone : +32 2 729 9011

TITLE:

DESIGN AND USER MANUAL FOR BADA EXCEL SPREADSHEETS Issue 2.0

Author	Date	Pages	Figures	Tables	Appendix	References
A.Bos	5/98	vi + 117	18	14	1	10

EATCHIP Task Specification	EEC Task No.	Task No. Sponsor	Period
SDV-D-E7	D09		8/96 to 5/98

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

Descriptors (keywords):

Base of Aircraft Data, BADA, aircraft modelling, total-energy model

Abstract:

A set of Microsoft Excel spreadsheets that are used to generate aircraft models for EUROCONTROL simulations are described in terms of the spreadsheet design and recommended procedures for use.

Design and User Manual
for
BADA Excel Spreadsheets
Issue 2.0

EUROCONTROL Experimental Centre

Summary

A set of Microsoft Excel spreadsheets which are used to generate aircraft models for EUROCONTROL simulations are described in terms of the spreadsheet design, while recommended procedures for use are also given.

Modification History

Issue Number	Release Date	Comments
1.0	19.07.95	First release of document
1.1	27.08.96	Released with BADA Revision 2.4 - Minor typing errors - Introduction of dynamic maximum altitude parameters. - New correction for temperature on thrust. - binomial approximation for esf modified to exact algorithm. - Change in altitude for descent speed limit at 11,000 ft(=> 10,999 ft).
2.0	01.05.98	Released with BADA Revision 3.0 - Ported to EXCEL 5.0 environment - Introduction of automated environment - Introduction of FUEL_CRZ.XLS - Addition of non-clean data - Addition of ground movement parameters - Reduced power expressions - Change climb/descent speed schedule - Introduction of stall/law option - Change in descent thrust algorithm - Change in description of procedures - Value of R corrected (287.3 => 287.04)

Table of Contents

1. INTRODUCTION

1.1 Identification and Purpose

This document describes the design and use of the set of BADA Excel Spreadsheets.

BADA, the Base of Aircraft Data, is a collection of ASCII files which specifies performance parameters and operating procedure parameters for different aircraft types. This information is designed for use in trajectory simulation and prediction algorithms within the domain of Air Traffic Management (ATM). The files are maintained by the Eurocontrol Experimental Centre (EEC) at Brétigny-sur-Orge, France. In the last release of BADA, Revision 3.0 in April 1998, files were provided for 67 different aircraft types.

The set of Excel spreadsheets described in this document is used at the EEC for maintaining A/C reference profile data and for calculating BADA coefficients from the reference profiles. These spreadsheets replace a previous version described in RD2. This new version of the spreadsheets is compatible with the BADA model as described in the User Manual for BADA Revision 3.0 [RD1].

Both design and user information is contained in this one document since the spreadsheets have been designed under the assumption that the same individual will be responsible for both using and maintaining the spreadsheets.

1.2 Document Organisation

This document is presented in five sections including Section 1, the Introduction. A list of reference documents along with a glossary of acronyms is included in this section.

Section 2, Overview, explains the organisation of the spreadsheets, that is, identifying and describing the separate spreadsheets and charts that are used. This section also summarises the new features in the spreadsheets that distinguishes them from the previous version [RD2].

Section 3, Design, presents a detailed description of each of the Excel spreadsheets and charts. In particular, an explanation of the Excel definitions placed in each spreadsheet cell is provided.

Section 4, Procedures for Use, describes how the spreadsheets are used to prepare a BADA aircraft model.

Section 5, Configuration Management, provides a description of the procedures for testing and maintaining the spreadsheets. Examples of maintenance logs are then provided as appendices.

1.3 Referenced Documents

RD1 User Manual for the Base of Aircraft Data (BADA) Revision 3.0; EEC Note 6/98, March 1998

RD2 Design and User Manual for BADA Excel Spreadsheets Issue 1.1; EEC Note 16/96, August 1996.

RD3 Aircraft Type Designators; ICAO Document 8643, 25th Edition; January 1997.

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

RD5 BADA Modelling Report for B73V Aircraft (Boeing 737-500); EEC CAPO Document Number BADA/AC/B73V/01; 14 April 1995.

RD6 BADA Modelling Report for D328 Aircraft (Dornier 328); EEC CAPO Document Number BADA/AC/D328/01; 17 February 1995.

RD7 BADA Configuration Management Manual; EEC Internal Note 1/APO/1998; April 1998

RD8 Test Report for BADA Excel Spreadsheets; EEC CAPO Document Number BADA/TN/95/03; May 1995.

RD9 Technical Note on a Low Speed Buffeting Algorithm for BADA Jet Aircraft; EEC APO Document Number TN/96/01; August 1996

RD10 Technical Note on an automated BADA coefficient optimization environment; EEC APO Number TN/97/01; July 1997

1.4 Glossary of Acronyms

A/C	Aircraft
APF	Airline Procedures File
APO	Centre for Aircraft Performance and Operations
ASCII	American Standard Code for the Interchange of Information
ATM	Air Traffic Management
BADA	Base of Aircraft Data
CAS	Calibrated Airspeed
CM	Configuration Management
EEC	Eurocontrol Experimental Centre
ESF	Energy Share Factor
FL	Flight Level
ICAO	International Civil Aviation Organisation
ISA	International Standard Atmosphere
MASS	Multi-Aircraft Simplified Simulator
OPF	Operations Procedures File
rms	root-mean-square
ROCD	Rate of Climb or Descent
TAS	True Air Speed
TEM	Total Energy Model
TSFC	Thrust Specific Fuel Consumption

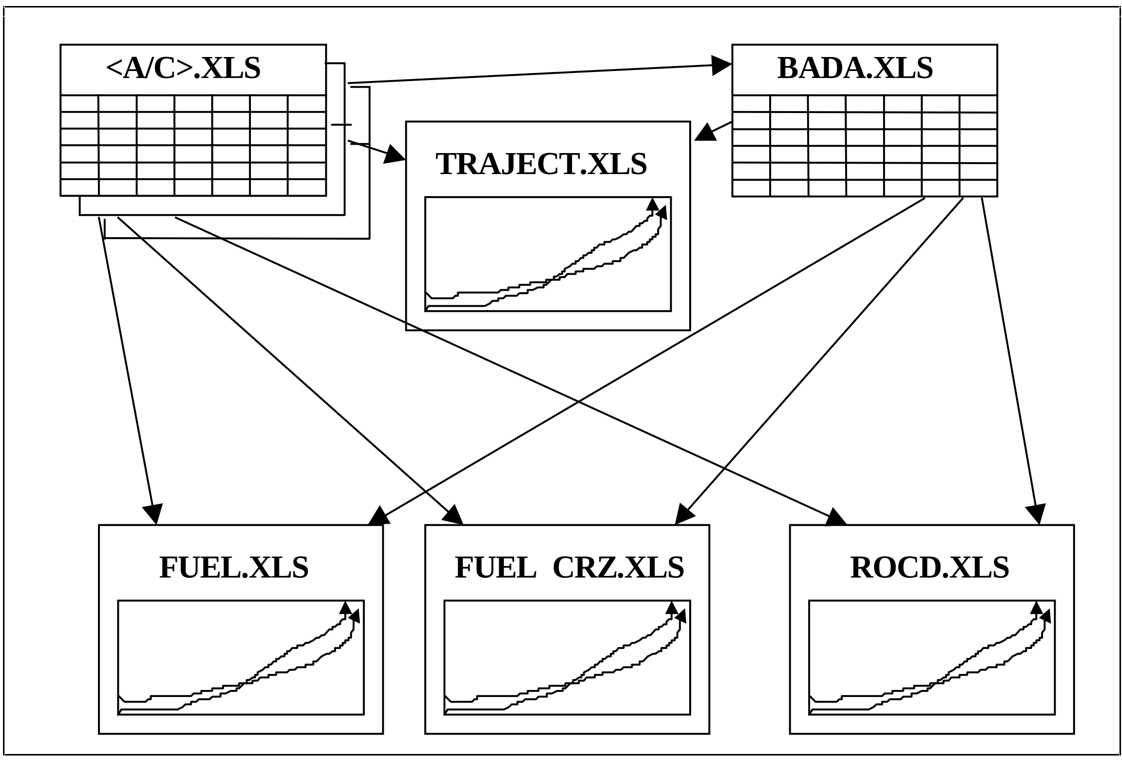
2. OVERVIEW

2.1 Spreadsheet Organisation

The BADA Excel spreadsheets consist of one main spreadsheet for calculations, a series of spreadsheets dedicated to each aircraft type and three charts. These are listed below with the relationships between them shown in Figure 2.1-1.

<A/C>.XLS	This refers to a series of spreadsheets, one for each aircraft type modelled by BADA. Each spreadsheet is named after the aircraft type such as B73C.XLS or A340.XLS. The spreadsheet contains the reference trajectory information and BADA coefficients for the aircraft type.
BADA.XLS	This spreadsheet performs all trajectory calculations based on the BADA Total-Energy Model (TEM).
TRAJECT.XLS	This is an Excel chart which compares the calculated trajectory for an aircraft with the corresponding reference trajectory.
ROCD.XLS	This is an Excel chart which displays the calculated rate of climb or descent for a calculated trajectory.
FUEL.XLS	This is an Excel chart which compares the calculated fuel consumption with the reference fuel consumption.
FUEL_CRZ.XLS	This is an Excel chart which compares the calculated fuel consumption for the cruise phase with the reference fuel consumption for the cruise phase.

Figure 2.1-1: Organisation of BADA Spreadsheets



The general use of these spreadsheets for the generation of a BADA aircraft model is described below.

(a) For each aircraft type to be modelled, a new instance of the <A/C>.XLS spreadsheet is created. This spreadsheet is named after the ICAO designator [RD3] for the aircraft type under consideration (e.g. B73C.XLS for Boeing 737-300).

(b) Reference data on the aircraft type (e.g. mass, maximum speeds, dimensions) are entered into the <A/C>.XLS spreadsheet along with reference data for climb and descent trajectories. The reference trajectory data consists of values for distances, times and fuel to climb to or descent from different flight levels with ROCD being an optional entry. A number of various trajectories (typically on the order of 10) are entered corresponding to different mass, speed or temperature conditions. Each reference trajectory is associated with a string identifier (e.g. CL1, CL2, DES1, etc.)

(c) Initial values of BADA coefficients are entered into the <A/C>.XLS spreadsheet. These initial values are based on either standard default values or values corresponding to similar aircraft types previously modelled.

(d) The BADA.XLS spreadsheet is updated to have an external link set to the new <A/C>.XLS spreadsheet. This results in the BADA.XLS spreadsheet importing BADA coefficients and reference trajectory information from this spreadsheet.

(e) The TRAJECT.XLS, FUEL.XLS, FUEL_CRZ.XLS and ROCD.XLS charts are updated to have their external links set to the new <A/C>.XLS spreadsheet. This allows for reference information to be imported from the <A/C>.XLS spreadsheet for plotting.

(f) The values of the BADA coefficients are varied in order to obtain a good as match as possible between the calculated trajectories and the reference trajectories. The BADA.XLS spreadsheet performs all calculations. Comparisons between calculated and reference trajectories are observed on the TRAJECT.XLS, FUEL.XLS, FUEL_CRZ.XLS charts. The ROCD.XLS chart is also used to observe the calculated rates of climb and descent. Note that the addition of ROCD data in the <A/C>.XLS spreadsheet is optional which means that a comparison between reference data and calculated data. The inclusion of ROCD data in the <A/C>.XLS spreadsheet is recommended whenever this data is available.

The selection of the BADA coefficients is done with the aim of obtaining the best possible match between the calculated and reference trajectories. For this, typically one descent trajectory and several climb trajectories are used. Cruise data is also entered in the alst column of the <A/C>.XLS file. This only concerns fuel flow data as a function of altitude.

The descent trajectory represents nominal mass, speed and temperature (ISA) conditions.

The climb trajectories cover a range of mass, speed and temperature conditions. Typically, three mass conditions are used (nominal, minimum, maximum), two speed conditions (nominal and one alternative speed) and three temperature conditions (ISA, ISA+10 and ISA+20).

For each trajectory, the goodness-of-fit between the calculation and the reference is measured by a figure-of-merit, F_M . This figure-of-merit is defined as follows:

$$F_M = [\,(\Delta X)^*_{max} + (\Delta X)^*_{rms} + (\Delta h)^*_{max} + (\Delta h)^*_{rms}\,] / 4 \qquad (2.1\text{-}1)$$

where

$(\Delta X)^*_{max}$ is the maximum distance error between the calculated and the reference trajectory, normalized with respect to the maximum distance at the top of climb/descent;

$(\Delta X)^*_{rms}$ is the root-mean-square distance error between the calculated and the reference trajectory, normalized with respect to the maximum distance at the top of climb/descent;

$(\Delta h)^*_{max}$ is the maximum altitude error between the calculated and the reference trajectory, normalized with respect to the maximum altitude at the top of climb/descent; and,

$(\Delta h)^*_{rms}$ is the root-mean-square altitude error between the calculated and the reference trajectory, normalized with respect to the maximum altitude at the top of climb/descent;

Figure-of-Merit includes measures of accuracy in both distance and altitude since accuracy in both these variable are considered to be equally important. Maximum error terms are included since these are generally the main specification for a trajectory prediction efficiency. Root-mean-square error terms are included because it is believed that this improves the robustness of the selected coefficients for prediction trajectories at conditions other than the reference conditions used.

For a good match between a calculated and reference trajectory, the value of F_M should be as small as possible. Generally, it is difficult for any trajectory to obtain values of F_M less than 1.0. Values less than 2.0 considered acceptable for a single trajectory.

The selection of the BADA coefficients is done in a heuristic manner with the aim of obtaining a low average value of F_M over a variety of trajectories. Values of F_M on the order of 3.0 are considered acceptable for an average over several trajectories at different conditions.

More detailed instructions on the use of the spreadsheets for aircraft model generation is given in Section 4 while design information on the spreadsheets is provided in Section 3.

2.2 New and Modified Features

The main differences between this version and the previous version of the BADA Excel spreadsheets [RD2] are summarised below.

(a) Ported to Excel 5.0/Excel 97 environment

All old .XLC files have been replaced by .XLS files (Excel 5.0). The charts are now imbedded in standard spreadsheets.

(b) Introduction of automated environment

The SOLV.XLS spreadsheet has been created, containing several Visual Basic modules, which can be used to find the optimum values of BADA thrust, drag and fuel flow parameters in an automated way.

(c) Introduction of FUEL_CRZ.XLS

The FUEL_CRZ.XLS spreadsheet was added in order to help find the optimum value for the Cf,cr coefficient.

(d) Addition of non-clean data

Non clean data has been added to BADA. This data concerns drag and thrust information for the approach and landing configurations.

(e) Addition of ground movement parameters

Ground movement parameters were added to help the simulation of airport movements. The parameters are all directly defined from reference data without the intervention of a calculation process.

(f) Reduced power expressions

The reduced power expression is introduced to allow the simulation of reduced power climbs. The reduction of power is calculated automatically and is a function of the aircraft mass. The choice between reduced power ***yes*** or ***no*** is given to the user. The option ***yes*** should be used at all times during the modelling process. Only after the process is finished one can chose the option ***no*** to investigate the influence of this option on the climb profiles

(g) Change climb/descent speed schedule

Several changes have been made to the climb and descent speed schedules for all aircraft types. Details on these changes can be found in RD1.

(h) Introduction of stall/law option

The stall/law option gives the user the possibility to use either the speed law used by the reference data (***law***) or the speedschedule defined by BADA based on the stallspeeds (***stall***). This has only effect at altitudes below 10,000 ft. Above 10,000 ft the option has no influence. During modelling the option should be set to ***law*** in order to simulate the reference data as close as possible. The option ***stall*** can be used afterwards, particularly when assessing the ROCD at lower altitudes.

(i) Change in descent thrust algorithm

The thrust algorithm has been simplified. The algorithm no longer uses a correction for mass or speed. The precise definition can be found in RD1.

(j) Change in description of procedures

Several procedures in the modelling process have been modified. These modified procedures are described in Section 4

(k) Value of R corrected

The gas constant R was defined as having the value 287.3. This has been corrected to the proper value of 287.04.

3. DESIGN

This section provides design information on each of the five BADA Excel spreadsheets and charts in five separate subsections. Table 3.0-1 below lists these spreadsheets and charts along with the last modification date and file size for the most recent versions upon which this manual is based. The various instances of the <A/C>.XLS spreadsheet are not shown in Table 3.0-1 since these files are produced at different times for each aircraft type.

Table 3.0-1: Spreadsheet/Chart Versions

File Name	Last Modification Date	Last Modification Time	File Size [kbytes]
BADA.XLS	01/05/98	2:11pm	164
TRAJECT.XLS	01/05/98	2:11pm	28
FUEL_CRZ.XLS	01/05/98	2:11pm	29
FUEL.XLS	01/05/98	11:14am	34
ROCD.XLS	01/05/98	2:11pm	22

The design information provided in this section explains the contents of each of the cells in the spreadsheets. In many cases, columns of data are defined in a similar manner, so the content of the column is described instead of its individual cells. For both cells and columns, the description consists of five parts as explained below:

name: This is a short descriptive name for the cell or column, for example, the cell B5 in BADA.XLS has the name: tropopause altitude

units: This is the engineering unit represented by the values in the cell or column.

symbol: This is the mathematical symbols which is used when referring to the contents of the cell or column, for example V_{TAS} or z_{trop}. Note that the symbols used in this document match those used in the BADA 3.0 User Manual [RD1].

description: this is a short description of the cell contents including where appropriate a mathematical representation,
example: $z_{trop} = 11000 + 100\ \Delta T / 6.5$
In some cases a reference to the BADA User Manual is included.

Excel definition: this is the Excel code that is written into the cell or column
example: B5 = 11000 + 1000*$A$5/6.5

At this point, it is worth noting two items concerning Excel syntax:

(a) All Excel cells are defined by a column letter (A, B, C, ...) and a row number (1, 2, 3, ...). Code placed in a cell can refer to the contents of other cells using either relative or absolute addressing where the dollar symbols "$" is used to indicate an absolute address.

(b) Values are imported from external spreadsheets using the notation:

<spreadsheet_name>!<cell_address>

Some special notation is used for describing the Excel code placed in columns, that is, the symbol {n} is used to refer to a row number the same as the current row number.

As an example, cells in the column M can be defined as functions of the cells in the same row but column K as follows:

M{n} = K{n}*.5151

Similarly a cell in column AO can be defined to be a function of the cell below it in the same column:

AO{n} = AO{n+1} + $AG{n}/60

3.1 BADA.XLS

The BADA.XLS spreadsheet is responsible for calculating a climb or descent trajectory based on the total-energy model and the BADA coefficients for a particular aircraft.

The spreadsheet has one external link to the spreadsheet containing the aircraft specific information (i.e. BADA coefficients and reference profiles). This link can be set to any one of the <A/C_code>.XLS spreadsheets in order to calculate trajectories for one of the supported aircraft types.

The spreadsheet contains 54 rows (1 to 54) and 52 columns (A to AZ). It is organised into 9 separate blocks as shown in Figure 3.1-1 below, each block consisting of several adjacent columns.

Figure 3.1-1: Layout of BADA.XLS Spreadsheet

Standard Atmosphere Block	Speed Block	Mass Block	Engine Thrust Block	Drag Block	Total Energy Block	Trajectory Block	Fuel Consumption Block	Cruise Fuel Consumption Block
block header	block header	block header	block header	block header	block header	block header	Block Header	block header
column labels	column labels	column labels	column labels	column labels	column labels	column labels	Column Labels	column labels
flight level data	flight level data	flight level data	flight level data	flight level data	flight level data	flight level data	Flight Level Data	flight level data

In general, each column of BADA.XLS represents a different parameter whereas each row represents the parameter value at a different flight level. The organisation of each block is similar and described below.

(a) The first row, row 1, contains the block titles.

(b) Rows 2 through 5 contain block header data which is common to the entire block. This data is typically BADA coefficients that are imported from the specified aircraft spreadsheets <A/C_code>.XLS.

(c) Rows 6 and 7 contain column labels for the block. As an example, the Standard Atmosphere Block contains columns for values of air density and temperature. The Aerodynamics Block contains columns for lift coefficient and drag force.

(d) Rows 8 through 54 contain column data. Each row specifies values at a different flight level with increments of 1000 ft or 10 flight levels between each row. Row 8 corresponds to FL 450 while row 54 corresponds to FL0. There is one exception to the standard increment of 10 FL with an extra row inserted for FL15. This extra row is inserted since several reference manuals using FL15 as the initial flight level for specifying climb or descent performance.

The design of each of the nine blocks is described in detail in the subsections below.

3.1.1 Standard Atmosphere Block

The Standard Atmosphere Block calculates atmosphere conditions at each flight level, in particular, the temperature, air density and the speed of sound. The speed of sound is needed to determine the Mach number. The air density is needed in order to calculate lift and drag coefficients.

The Standard Atmosphere Block consists of six columns of the BADA.XLS spreadsheet (columns A through F) and is shown in Figure 3.1.1-1 below.

Figure 3.1.1-1: Standard Atmosphere Block

	A	B	C	D	E	F
1		STANDARD ATMOSPHERE BLOCK				
2				std pressure at sea level [Pa]		101325
3				std temperature at sea level [K]		288.15
4	delta T	trop. alt. [m]	density @s.l.	real gas constant for air:		287.04
5	20	14077	1.146	tropopause temp [K]		216.65
6	**flight**	**altitude**	**temp**	**density**	**sound spd**	**sound spd**
7	**level**	**[m]**	**[deg. K]**	**[kg/m3]**	**[m/s]**	**[knots]**
8	**450**	13716	219.00	0.2678	296.66	575.92
9	440	13411	220.98	0.2782	297.99	578.52
10	430	13106	222.96	0.2890	299.33	581.11
11	420	12802	224.94	0.3001	300.65	583.68
12	410	12497	226.92	0.3115	301.98	586.25
13	400	12192	228.90	0.3232	303.29	588.80
14	390	11887	230.88	0.3353	304.60	591.34
15	380	11582	232.86	0.3477	305.91	593.88

	A	B	C	D	E	F
46	70	2134	294.28	0.9417	343.89	667.61
47	60	1829	296.26	0.9689	345.04	669.86
48	50	1524	298.24	0.9968	346.20	672.09
49	40	1219	300.23	1.0253	347.34	674.32
50	30	914	302.21	1.0544	348.49	676.54
51	20	610	304.19	1.0842	349.63	678.76
52	**15**	457	305.18	1.0993	350.20	679.86
53	**10**	305	306.17	1.1145	350.76	680.96
54	**0**	0	308.15	1.1455	351.90	683.16

Individual cells in header of the Standard Atmosphere Block are defined below.

F2	name:	ISA air pressure at sea level
	units:	Pascals
	symbol:	$(P_0)_{ISA}$
	description:	a constant specified by the ICAO Standard Atmosphere (ISA) [RD4]
		$(P_0)_{ISA} = 101325$
	Excel definition:	F2 = 101325
F3	name:	ISA air temperature at sea level
	units:	degrees Kelvin [K]
	symbol:	$(T_0)_{ISA}$
	description:	a constant specified by the ICAO Standard Atmosphere (ISA) [RD4]
		$(T_0)_{ISA} = 288.15$
	Excel definition	F3 = 288.15
F4	name:	real gas constant for air
	units:	$m^2 / (Ks^2)$
	symbol:	R
	description:	a constant specified by the ICAO Standard Atmosphere (ISA) [RD4]
		$R = 287.04$
	Excel definition:	F4 = 287.04
F5	name:	air temperature above the tropopause
	units:	degrees Kelvin [K]
	symbol:	T_{trop}
	description:	a constant specified by the ICAO Standard Atmosphere (ISA) [RD4]
		$T_{trop} = 216.65$
	Excel definition:	F5 = 216.65

A5	name:	temperature deviation from ISA
	units:	degrees Kelvin [K]
	symbol:	ΔT
	description:	a constant associated with the selected reference profile, imported from the <A/C>.XLS spreadsheet
	Excel definition:	A5 = <A/C>.XLS!$G$2

B5	name:	altitude of tropopause
	units:	m
	symbol:	z_{trop}
	description:	calculated based on ICAO Standard Atmosphere (ISA) [RD4]
		$z_{trop} = 11000 + 1000\ \Delta T/6.5$
	Excel definition:	B5 = 11000 + 1000*$A$5/6.5

C5	name:	air density at sea level
	units:	kg/m^3
	symbol	ρ_0
	description:	calculated based on ICAO Standard Atmosphere (ISA) [RD4]
		$\rho_0 = (P_0)_{ISA}\ /\ R\ [\ (T_0)_{ISA} + \Delta T\ ]$
	Excel definition:	C5 = $F$2/$F$4/($F$3+$A$5)

Columns of flight level data (rows 8 through 54) contained in the Standard Atmosphere Block are defined below:

A	name:	flight level
	units:	100 feet
	symbol:	h_{FL}
	description:	independent variable for trajectory calculation varies from 0 to 450 with increment of 10 (46 values) additional value for h_{FL} =15 (total of 47 values)
	Excel definition:	A8 = 450 for 9 ≥ n ≥ 51 A{n}= A{n-1} -10 A52 = 15 A53 = 10 A54 = 0
	Note:	Fields A8, A52, A54 and A54 are highlighted in bold since these fields do not have the same definition as the other fields in the column.
B	name:	altitude above sea level
	units:	m
	symbol:	z
	description:	conversion of flight level to metric units $z = 30.48\ h_{FL}$
	Excel definition:	B{n} = 30.48*A{n}
C	name:	air temperature
	units:	degrees Kelvin [K]
	symbol:	T
	description:	calculated based in ICAO Standard Atmosphere (ISA) [RD4] if $z < z_{trop}$ then $T = (T_0)_{ISA} - 0.0065z + \Delta T$ else $T = T_{trop}$
	Excel definition:	C{n} = IF ($B{n} < $B$5, $F$3 - 0.0065*$B{n} + $A$5, $F$5)

D

name: air density
units: kg/m^3
symbol: ρ

description: calculated based on approximation to ICAO Standard Atmosphere (ISA) [RD1, Section 3.2]

if $z < z_{trop}$
then $\rho = \rho_0 \{ T / [(T_0)_{ISA} + \Delta T]\}^{4.255876}$
else $\rho = 0.36392\{(37000\text{-}z)/(15000+z)\}^2$

Excel definition: D{n} = IF ($B{n} < $B$5,
$C$5*($C{n}/($F$3+$A$5))^4.255876,
.36392*((37000-$B{n})/
(15000+$B{n}))^2)

E

name: speed of sound
units: m/s
symbol: a

description: calculated based on ICAO Standard Atmosphere (ISA) [RD4]

$a = [\gamma RT]^{1/2}$

where $\gamma = 1.4$ (isentropic constant)

Excel definition: E{n} = SQRT(1.4*$F$4*$C{n})

F

name: speed of sound (knots)
units: knots
symbol: a_{kts}

description: conversion of speed of sound to imperial units

$a_{kts} = a / .5151$

Excel definition: F{n} = $E{n}/ .5151

3.1.2 Speed Block

The Speed Block calculates the True Air Speed (TAS) and Mach number at each flight level.

The speed at each altitude is determined from the speed law associated with the selected reference profile. The speed law itself is specified by a constant Calibrated Air Speed (CAS) with a Mach number limit. For altitudes below FL60, the speed is in some cases limited to a function of the stall speed in accordance with the BADA model [RD1, sections 4.1 and 4.3].

The Speed Block consists of eight columns of the BADA.XLS spreadsheet (columns G through N) and is shown in Figure 3.1.2-1 below.

Figure 3.1.2-1: Speed Block

	G	H	I	J	K	L	M	N
1			SPEED BLOCK					
2	Vset app	speed law		stall speeds				
3	197.38	nax CAS<FL100	280.00	(corrected for mass)		ref descent speeds		stall/law
4	Vset Ind	nax CAS>FL100	280.00	(Vstall)TO	129.5	des CAS	280.00	law
5	172.94	max Mach	0.74	(Vstall)LD	112.8	des Mach	0.70	
6	flight	ref. CAS	TAS of CAS	TAS(maxM)	TAS	CAS	TAS	Mach
7	level	[knots]	[knots]	[knots]	[knots]	[knots]	[m/s]	
8	450	**280.0**	548.3	426.2	426.2	210.5	219.5	0.740
9	440	**280.0**	540.1	428.1	428.1	215.4	220.5	0.740
10	430	**280.0**	532.1	430.0	430.0	220.4	221.5	0.740
11	420	**280.0**	524.2	431.9	431.9	225.4	222.5	0.740
12	410	**280.0**	516.4	433.8	433.8	230.5	223.5	0.740
13	400	**280.0**	508.7	435.7	435.7	235.7	224.4	0.740
14	390	**280.0**	501.1	437.6	437.6	240.9	225.4	0.740
15	380	**280.0**	493.7	439.5	439.5	246.2	226.4	0.740

	G	H	I	J	K	L	M	N
46	70	**280.0**	317.5	494.0	317.5	280.0	163.6	0.476
47	60	**280.0**	313.3	495.7	313.3	280.0	161.4	0.468
48	50	**280.0**	309.2	497.3	309.2	280.0	159.3	0.460
49	40	**280.0**	305.1	499.0	305.1	280.0	157.2	0.452
50	30	**280.0**	301.1	500.6	301.1	280.0	155.1	0.445
51	20	**280.0**	297.2	502.3	297.2	280.0	153.1	0.438
52	15	**280.0**	295.3	503.1	295.3	280.0	152.1	0.434
53	10	**280.0**	293.3	503.9	293.3	280.0	151.1	0.431
54	0	**280.0**	289.6	505.5	289.6	280.0	149.1	0.424

Individual cells in header of the Speed Block are defined below.

G3

name: threshold speed for Approach configuration
units: knots
symbol: $V_{SET, approach}$

description: The minimum speed for the clean/cruise configuration. This speed is defined as being the 1.3 * Vstall for cruise + 10 knots. Once the speed falls below this value the configuration is automatically changed to Approach.

Excel definition: G3 = 1.3*<A/C>.XLS!$C$37*SQRT($Q$5/$Q$4)+10

G5

name: threshold speed for Landing configuration
units: knots
symbol: $V_{SET, landing}$

description: The minimum speed for the clean/cruise configuration. This speed is defined as being the 1.3 * Vstall for approach + 10 knots. Once the speed falls below this value the configuration is automatically changed to Landing.

Excel definition: G5 = 1.3*<A/C>.XLS!$C$40*SQRT($Q$5/$Q$4)+10

I3

name: constant CAS for speed law below 10,000 ft
units: knots
symbol: $(V_{CAS})_{<FL100}$

description: a constant associated with the selected reference profile; imported from the <A/C>.XLS spreadsheet

Excel definition: I4 = <A/C>.XLS!$G$4

I4

name: constant CAS for speed law above 10,000 ft
units: knots
symbol: $(V_{CAS})_{>FL100}$

description: a constant associated with the selected reference profile; imported from the <A/C>.XLS spreadsheet

Excel definition: I3 = <A/C>.XLS!$H$4

I5

name: maximum Mach number for speed law
units: dimensionless
symbol: M_{max}

description: a constant associated with the selected reference profile; imported from the <A/C>.XLS spreadsheet

Excel definition: I5 = <A/C>.XLS!$G$5

K4

name: mass corrected take-off stall speed;
units: knots
symbol: $(V_{stall})^*_{TO}$

description: calculated from the take-off stall speed specified for the aircraft in the <A/C>.XLS spreadsheet taking into account the difference in mass from the BADA reference mass [RD1, Section 3.4]

$$(V_{stall})^*_{TO} = (V_{stall})_{TO} \; [m/m_{ref}]^{0.5}$$

Excel definition: K4 = <A/C>.XLS!$C$39 *SQRT($Q$5/$Q$4)

K5

name: mass corrected landing stall speed
units: knots
symbol: $(V_{stall})^*_{LD}$

description: calculated from the landing stall speed specified for the aircraft in the <A/C>.XLS spreadsheet taking into account the difference in mass from the BADA reference mass [RD1, Section 3.4]

$$(V_{stall})^*_{LD} = (V_{stall})_{LD} \; [(m/m_{ref}]^{0.5}$$

Excel definition: K5 = <A/C>.XLS!$C$41 *SQRT($Q$5/$Q$4)

M4

name: reference descent speed (CAS)
units: knots
symbol: $V_{des,ref}$

description: a constant associated with each aircraft type which was used to correct the descent thrust. This parameter is not used for the moment, but left in for possible future use.

Excel definition: M4 = <A/C>.XLS!$C$29

M5	name:	reference descent Mach number
	units:	dimensionless
	symbol:	$M_{des,ref}$
	description:	a constant associated with each aircraft type which was used to correct the descent thrust. This parameter is not used for the moment, but left in for possible future use.
	Excel definition:	M5 = <A/C>.XLS!$C$30
N4	name:	law / stall option switch
	units:	dimensionless
	symbol:	law/stall
	description:	The law/stall option is used to select the speedschedule that is to be applied. The law option makes the spreadsheet use the value of $(V_{CAS})_{<FL100}$ from FL0 onwards. This option should be used when modelling the aircraft performance. The stall option makes the spreadsheet use the BADA defined speedschedule.
	Excel definition:	N4 = <A/C>.XLS!$C$42

Columns of flight level data (rows 8 through 54) contained in the Speed Block are defined below:

G	name:	flight level
	units:	100 feet
	symbol:	h_{FL}
	description:	independent variable for profile calculation varies from 0 to 450; copied from first column (A) to improve readability of the Speed Block
	Excel definition:	G{n} = A{n}
H	name:	reference Calibrated Air Speed (CAS)
	units:	knots
	symbol:	$(V_{CAS})_{ref}$
	description:	For altitudes above FL100, this is the same as the constant CAS values specified for the selected reference profile. At FL100 and below, however, this is either the constant CAS value or a function of the mass corrected stall speed. Note that the reference CAS is also a function of the profile type

(climb or descent) and engine type (jet, turboprop or piston). [RD1, Sections 4.1, 4.3]

for jet aircraft in climb:

for $h_{FL} < 15$
$(V_{CAS})_{ref} = 1.3\ (V_{stall})^{*}_{TO} + 5$
for $15 \leq h_{FL} < 30$
$(V_{CAS})_{ref} = 1.3\ (V_{stall})^{*}_{TO} + 10$
for $30 \leq h_{FL} < 40$
$(V_{CAS})_{ref} = 1.3\ (V_{stall})^{*}_{TO} + 30$
for $40 \leq h_{FL} < 50$
$(V_{CAS})_{ref} = 1.3\ (V_{stall})^{*}_{TO} + 60$
for $50 \leq h_{FL} < 60$
$(V_{CAS})_{ref} = 1.3\ (V_{stall})^{*}_{TO} + 80$
for $60 \leq h_{FL} < 100$
$(V_{CAS})_{ref} = \text{minimum}[250,(V_{CAS})_{<FL100}]$
for $100 \geq h_{FL}$
$(V_{CAS})_{ref} = (V_{CAS})_{>FL100}$

for turboprop and piston aircraft in climb:

for $h_{FL} < 5$
$(V_{CAS})_{ref} = 1.3\ (V_{stall})^{*}_{TO} + 20$
for $5 \leq h_{FL} < 10$
$(V_{CAS})_{ref} = 1.3\ (V_{stall})^{*}_{TO} + 30$
for $10 \leq h_{FL} < 15$
$(V_{CAS})_{ref} = 1.3\ (V_{stall})^{*}_{TO} + 35$
for $15 \leq h_{FL} < 100$
$(V_{CAS})_{ref} = \text{minimum}[250,(V_{CAS})_{<FL100}]$
for $100 \geq h_{FL}$
$(V_{CAS})_{ref} = (V_{CAS})_{>FL100}$

for jets and turboprops in descent:

for $h_{FL} < 10$
$(V_{CAS})_{ref} = 1.3\ (V_{stall})^{*}_{LD} + 5$
for $10 \leq h_{FL} < 15$
$(V_{CAS})_{ref} = 1.3\ (V_{stall})^{*}_{LD} + 10$
for $15 \leq h_{FL} < 20$
$(V_{CAS})_{ref} = 1.3\ (V_{stall})^{*}_{LD} + 20$
for $20 \leq h_{FL} < 30$
$(V_{CAS})_{ref} = 1.3\ (V_{stall})^{*}_{LD} + 50$

for $30 \leq h_{FL} < 60$
$(V_{CAS})_{ref} = \text{minimum}[220,(V_{CAS})_{<FL100}]$
for $60 \leq h_{FL} < 100$
$(V_{CAS})_{ref} = \text{minimum}[250,(V_{CAS})_{<FL100}]$
for $100 \geq h_{FL}$
$(V_{CAS})_{ref} = (V_{CAS})_{>FL100}$

for pistons in descent:

for $h_{FL} < 5$
$(V_{CAS})_{ref} = 1.3\ (V_{stall})^{*}_{LD} + 5$
for $5 \leq h_{FL} < 10$
$(V_{CAS})_{ref} = 1.3\ (V_{stall})^{*}_{LD} + 10$
for $10 \leq h_{FL} < 15$
$(V_{CAS})_{ref} = 1.3\ (V_{stall})^{*}_{LD} + 20$
for $15 \leq h_{FL} < 100$
$(V_{CAS})_{ref} = \text{minimum}[250,(V_{CAS})_{<FL100}]$
for $100 \geq h_{FL}$
$(V_{CAS})_{ref} = (V_{CAS})_{>FL100}$

Excel definition:

for $8 \leq n \leq 42$ [i.e. $110 \leq h_{FL} \leq 450$]
`$H{n} = $I$4`

for $43 \leq n \leq 45$ [i.e. $80 \leq h_{FL} < 100$]
`$H{n} = IF($N$4="law",$I$3,MIN(250,$I$3))`

for $46 \leq n \leq 47$ [i.e. $60 \leq h_{FL} \leq 70$]
```
H{n}    = IF($N$4="law",$I$3,
          MIN(250,IF($AL$2="climb",$I$3,
          IF($T$2="piston",$I$3,MIN(250,$I$3)))))
```

for n=48 [i.e. $h_{FL} = 50$]
```
H{n}    =IF($N$4="law",$I$3,
          MIN(250,IF($AL$2="climb",
          IF($T$2="jet",1.3*$K$4+80,$I$3),
          IF($T$2="piston",$I$3,MIN(220,$I$3)))))
```

for n=49 [i.e. $h_{FL} = 40$]
```
H{n}    =IF($N$4="law",$I$3,
          MIN(250,IF($AL$2="climb",
          IF($T$2="jet",1.3*$K$4+60,$I$3),
          IF($T$2="piston",$I$3,MIN(220,$I$3)))))
```

for n=50 [i.e. $h_{FL} = 30$]
```
H{n}    = IF($N$4="law",$I$3,
```

MIN(250,IF($AL$2="climb",
IF($T$2="jet",1.3*$K$4+30,$I$3),
IF($T$2="piston",$I$3,MIN(220,$I$3)))))

for n=51 [i.e. h_{FL} = 20]
H{n} =IF($N$4="law",$I$3,
MIN(250,IF($AL$2="climb",
IF($T$2="jet",1.3*$K$4+10,$I$3),
IF($T$2="piston",$I$3,1.3*$K$5+50))))

for n=52 [i.e. h_{FL} = 15]
H{n} =IF($N$4="law",$I$3,
MIN(250,IF($AL$2="climb",
IF($T$2="jet",1.3*$K$4+10,1.3*$K$4+35),
IF($T$2="piston",1.3*$K$5+20,1.3*$K$5+20))))

for n=53 [i.e. h_{FL} = 10]
H{n} =IF($N$4="law",$I$3,
MIN(250,IF($AL$2="climb",
IF($T$2="jet",1.3*$K$4+5,1.3*$K$4+30),
IF($T$2="piston",1.3*$K$5+10,1.3*$K$5+10))))

for n=54 [i.e. h_{FL} = 0]
H{n} =IF($N$4="law",$I$3,
MIN(250,IF($AL$2="climb",
IF($T$2="jet",1.3*$K$4+5,1.3*$K$4+20),
IF($T$2="piston",1.3*$K$5+5,1.3*$K$5+5))))

I

name: True Air Speed (TAS) corresponding to reference CAS
units: knots
symbol: $(V_{TAS})_{ref}$

description: calculated from the reference CAS and flight level [RD1, Section 3.2]:

$$(V_{TAS})_{ref} = V_{ref} /.5151$$

$$V_{ref}^2 = 7RT[(1+\{[1+ V_{CAS,m}^2 / 7R(T_0)_{ISA}]^{3.5} -1 \}/\delta)^{1/3.5}-1]$$

$$V_{CAS,m} = .5151\ V_{CAS,ref}$$

$$\delta = P/(P_0)_{ISA} = \rho RT/(P_0)_{ISA}$$

Excel definition: I{n} = SQRT(7*$F$4*$C{n}*((1+((1+
(.5151*$H{n})^2/7/$F$3/$F$4)^3.5-1)
*$F$2/$F$4/$C{n}/$D{n})^(1/3.5)
-1))/.5151

J

name: True Air Speed (TAS) corresponding to Mach limit
units: knots
symbol: $(V_{TAS})_M$

description: calculated as the product of the Mach number limit and the speed of sound:

$$(V_{TAS})_M = a\ M_{max}$$

Excel definition: J{n} = $F{n}*$I$5

K

name: True Air Speed (TAS)
units: knots
symbol: V_{TAS}

description: set equal to either the TAS corresponding to the reference CAS or the TAS corresponding to the Mach number limit, which ever is less

Excel definition: K{n} = MIN($J{n},$I{n})

L

name: Calibrated Air Speed (CAS)
units: knots
symbol: V_{CAS}

description: calculated from the True Air Speed [RD1, Section 3.2]:

$$V_{CAS} = V_{CAS,m} /.5151$$

$$V_{CAS,m}^{\ 2} = 7R(T_0)_{ISA} [(1+\{[1+ V^2 / 7RT]^{3.5}-1 \}\delta)^{1/3.5} -1]$$

$$V = .5151\ V_{TAS}$$

$$\delta = P/(P_0)_{ISA} = \rho RT/(P_0)_{ISA}$$

Excel definition: L{n} = SQRT(7*$F$4*$F$3*((1+((1+(.5151*$K{n})^2/7/$C{n}/$F$4)^3.5-1)*($F$4*$C{n}*$D{n}/$F$2))^(1/3.5)-1))/.5151

M

name: metric True Air Speed (TAS)
units: m/s
symbol: V

	description:	conversion of true airspeed to metric units
		$V = 0.5151\ V_{TAS}$
	Excel definition:	M{n} = K{n}*.5151
N	name:	Mach number
	units:	dimensionless
	symbol:	M
	description:	calculated as ratio of true air speed to speed of sound
		$M = V_{TAS} / a_{kts}$
	Excel definition:	N{n} = $K{n}/$F{n}

3.1.3 Aircraft Mass Block

The Aircraft Mass Block calculates the aircraft mass at each flight level, taking into account the fuel consumed.

The fuel consumed at each flight level is taken from the reference profile data in the <A/C>.XLS spreadsheet. For flight levels for which no reference data is supplied, the fuel consumed is calculated through linear interpolation.

The Aircraft Mass Block consists of four columns of the BADA.XLS spreadsheet (columns O through R) and is shown in Figure 3.1.3-1 below.

Figure 3.1.3-1: Aircraft Mass Block

	O	P	Q	R
1	AIRCRAFT MASS BLOCK			
2				
3		mass in tonnes		
4		reference	280.00	
5	selected trajectory (initial)		240.00	
6	flight	fuel (ref.)	fuel (fltr)	A/C mass
7	level	[kg]	[kg]	[kg]
8	450			
9	440			
10	430			
11	420			
12	410			
13	400	465.00	465.0	240000
14	390		460.0	239995
15	380		455.0	239990

	O	P	Q	R
46	70		132.0	239667
47	60		116.0	239651
48	50	100.00	100.0	239635
49	40		71.4	239606
50	30		42.9	239578
51	20		14.3	239549
52	15	0.00	0.0	239535
53	10		0.0	239535
54	0		**0.0**	239535

Individual cells in header of the Aircraft Mass Block are defined below.

Q4

name:	BADA reference mass
units:	tonnes
symbol:	m_{ref}
description:	a constant associated for each aircraft type, it indicates a reference mass used for calculating other A/C attributes such as stall speed; imported from <A/C>.XLS spreadsheet
Excel definition:	Q4 = <A/C>.XLS!$C$3

Q5

name:	initial trajectory mass
units:	tonnes
symbol:	m_{traj}
description:	a constant associated with the selected reference trajectory indicating the mass of the aircraft at the beginning of the trajectory; imported from the <A/C>.XLS spreadsheet
Excel definition:	Q5 = <A/C>.XLS!$G$3

Columns of flight level data (rows 8 through 54) contained in the Aircraft Mass Block are defined below:

O

name:	flight level
units:	100 feet
symbol:	h_{FL}
description:	independent variable for profile calculation varies from 0 to 450; copied from first column (A) to improve readability of the Speed Block
Excel definition:	O{n} = A{n}

P

name: consumed fuel (reference)
units: kg
symbol: $(m_{fuel})_{ref}$

description: values of fuel consumed per flight level are imported from the <A/C>.XLS spreadsheet

Excel definition:

```
P{n}    = IF(  ISNA(<A/C>.XLS!$H{n},
               " ",
               <A/C>.XLS!$H{n})
```

Q

name: fuel
units: kg
symbol: $(m_{fuel})_{fltr}$

description: fuel consumed to climb to or descend from each flight level; calculated using linear interpolation from those values which are available; calculated only for those flight levels less than or equal to the maximum trajectory flight level

Excel definition: for 8 ≤ n ≤ 53

```
Q{n}    = IF( A{n} > $AK$4,
          " ",
          IF(P{n} = " ",
             IF(ISNA(MATCH(0,$P$8:$P{n},-1),
                MAX($P$8:$P$54),
                Q{n+1} +
($A{n}-$A{n-1})*    (INDEX($P$8:$P{n},MATCH(0,$P$8:$P{n},-1))-  Q{n+1})
                  / (INDEX(A$8:A${n}, MATCH(0,$P$8:$P{n},-1))-$A{n+1})
             P{n} ))
```

for n=54

```
Q{n} = 0.0
```

Note: Cell Q54 is highlighted in bold since its definition is different from the other cells in the column.

R

name: aircraft mass
units: kg
symbol: m

description: for climb profiles, the aircraft mass at a flight level is the initial trajectory mass (i.e. take-off mass) minus the fuel consumed to climb to that level

for descent profiles, the aircraft mass at a flight level is the initial trajectory mass (i.e. mass at the beginning of descent) minus the fuel consumed to descend to that level

the mass is only calculated for flight levels less than or equal to the maximum trajectory flight level

if $h_{FL} > (h_{FL})_{max}$
  undefined
else
  if climb trajectory
    $m = m_{prof} - (m_{fuel})_{fltr}$
  else if descent trajectory
    $m = m_{prof} - [\max\{(m_{fuel})_{fltr}\} - (m_{fuel})_{fltr}]$

Excel definition:

```
R{n}   = IF(A{n} > $AK$4,
            " ",
            IF($AL$2="climb",
               $Q$5*1000 - $Q{n},
               $Q$5*1000 - MAX($P$8:$P$54)+$Q{n}))
```

3.1.4 Engine Thrust Block

The Engine Thrust Block calculates the thrust available at each flight level.

The block includes calculation of thrust for jet, turboprop and piston type engines. The block also includes calculations to correct the thrust for temperatures greater than ISA and also to correct descent thrust conditions when the descent speed is different from the reference descent speed.

The Engine Thrust Block consists of seven columns of the BADA.XLS spreadsheet (columns S through Y) and is shown in Figure 3.1.4-1 below.

Figure 3.1.4-1: Engine Thrust Block

	S	T	U	V	W	X	Y
1			ENGINE THRUST BLOCK				
2	type	jet	descent FL	20000		hi des thrust	0.080
3	Tcl,1	568288				lo des thrust	0.090
4	Tcl,2	59488	Tcl,4	1.61		app des thrust	0.171
5	Tcl,3	0.00E+00	Tcl,5	0.0027		lnd des thrust	0.351
6	flight	jet	turbo	piston	selected	temp.corr	des. corr
7	level	[N]	[N]	[N]	[N]	[N]	[kN]
8	450	138404	288	138404	138404	138404	11.07
9	440	147957	307	147957	147957	147957	11.84
10	430	157510	327	157510	157510	157510	12.60
11	420	167063	347	167063	167063	167063	13.37
12	410	176616	367	176616	176616	176616	14.13
13	400	186169	387	186169	186169	186169	14.89
14	390	195722	407	195722	195722	195722	15.66
15	380	205275	427	205275	205275	205275	16.42
16	370	214828	446	214828	214828	214828	17.19
17	360	224381	466	224381	224381	224381	17.95
18	350	233934	484	233934	233934	233934	18.71
19	340	243486	501	243486	243486	243486	19.48

	S	T	U	V	W	X	Y
46	70	501417	1815	501417	501417	501417	45.13
47	60	510970	1877	510970	510970	510970	45.99
48	50	520523	2202	520523	520523	520523	89.23
49	40	530076	2275	530076	530076	530076	90.87
50	30	539629	2350	539629	539629	539629	92.51
51	20	549182	2745	549182	549182	549182	94.15
52	15	553959	3297	553959	553959	553959	194.68
53	10	558735	3566	558735	558735	558735	196.36
54	0	568288	3803	568288	568288	568288	199.71

Individual cells in header of the Engine Thrust Block are defined below.

T2

name: engine type
units: string, either “jet”, “turbo” or “piston”
symbol: none

description: a constant associated with with each aircraft type; imported from A/C spreadsheet

Excel definition: T2 = <A/C>.XLS!$C$16

T3

name: first climb thrust coefficient
units: Newtons (jet/piston)
knot-Newton (turbo)
symbol: $C_{Tc,1}$

description: a constant associated with with each aircraft type; used to calculate maximum climb thrust as a function of speed and altitude; imported from A/C spreadsheet [RD1, Section 3.7.1]

Excel definition: T3 = <A/C>.XLS!$C$19

T4

name: second climb thrust coefficient
units: feet
symbol: $C_{Tc,2}$

description: a constant associated with with each aircraft type; used to calculate maximum climb thrust as a function of speed and altitude; imported from A/C spreadsheet [RD1, Section 3.7.1]

Excel definition: T4 = <A/C>.XLS!$C$20

T5

name: third climb thrust coefficient

units: $feet^{-2}$ (jet)
Newton (turboprop)
knot-Newton (piston)

symbol: $C_{Tc,3}$

description: a constant associated with with each aircraft type; used to calculate maximum climb thrust as a function of speed and altitude; imported from A/C spreadsheet
[RD1, Section 3.7.1]

Excel definition: T5 = <A/C>.XLS!$C$21

V2

name: descent thrust transition altitude

units: feet

symbol: h_{des}

description: a constant associated with with each aircraft type; used to determine descent thrust from maximum climb thrust; imported from A/C spreadsheet
[RD1, Section 3.7.4]

Excel definition: V2 = <A/C>.XLS!$C$28

V4

name: first thrust temperature coefficient

units: degrees Celsius

symbol: $C_{Tc,4}$

description: a constant associated with with each aircraft type; used to correct maximum climb thrust for temperature deviations from ISA; imported from A/C spreadsheet
[RD1, Section 3.7.1]

Excel definition: V4 = <A/C>.XLS!$C$22

V5

name: second thrust temperature coefficient
units: dimensionless
symbol: $C_{Tc,5}$

description: a constant associated with with each aircraft type; used to correct maximum climb thrust for temperature deviations from ISA; imported from A/C spreadsheet
[RD1, Section 3.7.1]

Excel definition: V5 = <A/C>.XLS!$C$23

Y2

name: descent thrust coefficient at high altitude
units: dimensionless
symbol: $C*_{Tdes,high}$

description: specifies percentage of maximum climb thrust used in descent at high altitudes (i.e, when $h > h_{des}$);
[RD1, Section 3.7.4]

Excel definition: Y2 = <A/C>.XLS!$C$27

Y3

name: descent thrust coefficient at low altitude
units: dimensionless
symbol: $C*_{Tdes,low}$

description: specifies percentage of maximum climb thrust used in descent at high altitudes (i.e, when $h < h_{des}$); calculated as mass correction to constant imported from A/C spreadsheet
[RD1, Section 3.7.4]

Excel definition: Y3 = <A/C>.XLS!$C$26

Y4

name: descent thrust coefficient for approach
units: dimensionless
symbol: $C*_{Tdes,app}$

description: specifies percentage of maximum climb thrust used in descent at low altitudes (i.e, when h < 8000 ft). The percentage is corrected for weight.
[RD1, Section 3.7.4]

Excel definition: Y4 = <A/C>.XLS!$C$62*$Q$5/$Q$4

Y5

name:	descent thrust coefficient for landing
units:	dimensionless
symbol:	$C^*_{Tdes,land}$
description:	specifies percentage of maximum climb thrust used in descent at high altitudes (i.e, when h < 3000 ft). The percentage is corrected for weight. [RD1, Section 3.7.4]
Excel definition:	Y5 = <A/C>.XLS!$C$63*$Q$5/Q$4

Columns of flight level data (rows 8 through 54) contained in the Engine Thrust Block are defined below:

S

name:	flight level
units:	100 feet
symbol:	h_{FL}
description:	independent variable for profile calculation varies from 0 to 450; copied from first column (A) to improve readability of the Engine Thrust Block
Excel definition:	S{n} = A{n}

T

name:	maximum climb thrust for jet engine (ISA conditions)
units:	Newtons
symbol:	$(T_{max\ climb})_{ISA}$
description:	calculated as a function of altitude and three thrust coefficients [RD1, Section 3.7.1]

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

Excel definition: T{n} = $T$3*(1.0-$A{n}*100/$T$4 +10000*$A{n}*$A{n}*$T$5)

U

name: maximum climb thrust for turboprop engine (ISA conditions)

units: Newtons

symbol: $(T_{max\ climb})_{ISA}$

description: calculated as a function of altitude, TAS and three thrust coefficients
[RD1, Section 3.7.1]

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

Excel definition: U{n} = $T$3*(1.0-$A{n}*100/$T$4)/$K{n}
+$T$5

V

name: maximum climb thrust for piston engine (ISA conditions)

units: Newtons

symbol: $(T_{max\ climb})_{ISA}$

description: calculated as a function of altitude, TAS and three thrust coefficients
[RD1, Section 3.7.1]

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

Excel definition: V{n} = $T$3*(1.0-$A{n}*100/$T$4)
+$T$5/K{n}

W

name: maximum climb thrust for selected engine type (ISA conditions)

units: Newtons

symbol: $(T_{max\ climb})_{ISA}$

description: selects appropriate calculation of maximum climb thrust (ISA conditions) from jet, turboprop and piston alternatives depending upon the engine type

Excel definition:

```
W{n}   =   IF($T$2="jet",
               $T(n},
               IF($T$2="turbo",
                   $U{n},
                   $V{n})  )
```

X

name: maximum climb thrust corrected for temperature conditions

units: Newtons

symbol: $T_{max\ climb}$

description: calculated from the maximum climb thrust at ISA conditions using two thrust temperature coefficients [RD1, Section 3.7.1]

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

$(\Delta T_{ISA})_{eff} = (\Delta T_{ISA} - C_{tc,4})$

with: $0 \leq (\Delta T_{ISA})_{eff} * C_{Tc,5} \leq 0.4$

and: $C_{Tc,5} \geq 0$

Excel definition:

```
X{n}   =$W{n}(1-MIN(0.4,(MAX(0,V$5*($A$5-$V$4)))))
```

Y

name: net thrust

units: kN

symbol: T_{net}

description: for climb trajectories, this is simply the maximum climb thrust divided by 1000 for a value in kiloNewtons;
for descent trajectories, this is the maximum climb thrust divided by 1000 and then multiplied by the appropriate correction.
[RD1, Section 3.7.4]

if climb trajectory

$T_{net} = T_{max\ climb} / 1000$

else if descent trajectory

if $h > h_{des}$

$T_{net} = (T_{max\ climb} / 1000)\ C_{Tdes,high}$

else if $h < h_{des}$ and $(V_{CAS}) \geq (V_{SET})_{approach}$

$T_{net} = (T_{max\ climb} / 1000)\ C_{Tdes,low}$

else if $h <$ 8,000 ft and $(V_{CAS}) < (V_{SET})_{approach}$

$T_{net} = (T_{max\ climb} / 1000) * m/m_{ref} * C_{Tdes,\ approach}$

else if $h <$ 3,000 ft and $(V_{CAS}) < (V_{SET})_{landing}$

$T_{net} = (T_{max\ climb} / 1000) * m/m_{ref} * C_{Tdes,\ landing}$

Excel definition:

```
Y{n}   = $X{n}* (IF($AL$2="climb",1,
              IF(($A{n}*100)<$V$2,
              IF(AND($L{n}<$G$3,$L{n}>$G$5),
              $Y$4,IF($L{n}<$G$5,$Y$5,$Y$3)),
              $Y$2)))/1000
```

3.1.5 Drag Block

The Drag Block calculates the aerodynamic drag at each flight level.

The Drag Block consists of four columns of the BADA.XLS spreadsheet (columns Z through AC) and is shown in Figure 3.1.5-1 below.

Figure 3.1.5-1: Drag Block

	Z	AA	AB	AC
1		DRAG BLOCK		
2	drag polar	CD0	CD2	Conf.
3	coefficients	0.0185	0.0656	Clean
4	ref. area (S)	0.0350	0.0590	Approach
5	512.00	0.0800	0.0600	Lndg + gear !
6	flight	lift coeff.	drag coeff.	drag
7	level			[kN]
8	450			
9	440			
10	430			
11	420			
12	410			
13	400	0.494	0.0345	164.46
14	390	0.472	0.0331	165.19
15	380	0.450	0.0318	166.29
16	370	0.429	0.0306	167.75
17	360	0.410	0.0295	169.59

	Z	AA	AB	AC
46	70	0.457	0.0322	165.68
47	60	0.456	0.0321	165.71
48	50	0.587	0.0553	221.60
49	40	0.586	0.0553	221.65
50	30	0.585	0.0552	221.69
51	20	0.748	0.0680	213.67
52	15	1.045	0.1456	327.21
53	10	1.185	0.1642	325.71
54	0	1.265	0.1760	326.95

Individual cells in header of the Drag Block are defined below.

AA3

name: parasitic drag coefficient for clean configuration
units: dimensionless
symbol: $C_{D0, CR}$

description: a constant associated with with each aircraft type; used to calculate the aerodynamic drag as a function of air density and velocity; imported from A/C spreadsheet
[RD1, Section 3.6]

Excel definition: AA3 = <A/C>.XLS!$C$11

AB3

name: induced drag coefficient for clean configuration
units: dimensionless
symbol: $C_{D2, CR}$

description: a constant associated with with each aircraft type; used to calculate the aerodynamic drag as a function of aircraft mass, air density, and velocity; imported from A/C spreadsheet
[RD1, Section 3.6]

Excel definition: AB3 = <A/C>.XLS!$C$12

AA4

name: parasitic drag coefficient for approach configuration
units: dimensionless
symbol: $C_{D0, AP}$

description: a constant associated with with each aircraft type; used to calculate the aerodynamic drag as a function of air density and velocity; imported from A/C spreadsheet
[RD1, Section 3.6]

Excel definition: AA4 = <A/C>.XLS!$C$64

AB4

name: induced drag coefficient for approach configuration
units: dimensionless
symbol: $C_{D2, AP}$

description: a constant associated with with each aircraft type; used to calculate the aerodynamic drag as a function of aircraft mass, air density, and velocity; imported from A/C spreadsheet
[RD1, Section 3.6]

	Excel definition:	AB4 = <A/C>.XLS!$C$65
AA5	name:	parasitic drag coefficient for landing configuration (includes drag for landing gear)
	units:	dimensionless
	symbol:	$C_{D0,LD}$
	description:	a constant associated with with each aircraft type; used to calculate the aerodynamic drag as a function of air density and velocity; imported from A/C spreadsheet [RD1, Section 3.6]
	Excel definition:	AA5 = <A/C>.XLS!$C$66
AB5	name:	induced drag coefficient for landing configuration
	units:	dimensionless
	symbol:	$C_{D2,LD}$
	description:	a constant associated with with each aircraft type; used to calculate the aerodynamic drag as a function of aircraft mass, air density, and velocity; imported from A/C spreadsheet [RD1, Section 3.6]
	Excel definition:	AB5 = <A/C>.XLS!$C$67
Z5	name:	reference aerodynamic surface area
	units:	m^2
	symbol:	S
	description:	a constant associated with with each aircraft type; imported from A/C spreadsheet [RD1, Section 3.6.1]
	Excel definition:	Z5 = <A/C>.XLS!$C$10

Columns of flight level data (rows 8 through 54) contained in the Drag Block are defined below:

Z

name: flight level
units: 100 feet
symbol: h_{FL}

description: independent variable for profile calculation
varies from 0 to 450; copied from first column (A)
to improve readability of the Drag Block

Excel definition: Z{n} = A{n}

AA

name: lift coefficient
units: dimensionless
symbol: C_L

description: calculated assuming that lift is equal to weight
[RD1, Section 3.6]
the value is only calculated for flight levels less than or equal to the maximum flight level of the selected reference trajectory

if $h_{FL} > (h_{FL})_{max}$
undefined
else
$C_L = mg / [\rho \, (V_{TAS})_m^{\;2} \, S/2]$

Excel definition:

```
AA{n} =  IF($A{n}>$AK$4,
           " ",
          $R{n}*9.81/
            (0.5*$D{n}*$M{n}^2*$Z$5))
```

AB

name: drag coefficient
units: dimensionless
symbol: C_D

description: total drag coefficient calculated as a function of the parasitic drag coefficient, induced drag coefficient and the lift coefficient for the relevant configuration [RD1, Section 3.6]. The value is only calculated for flight levels less than or equal to the maximum flight level of the selected reference profile

if $h_{FL} > (h_{FL})_{max}$
  undefined
if phase = "climb"
$$C_D = C_{D0,CR} + C_{D2,CR}\, C_L^2$$
else if h > 8,000 ft
$$C_D = C_{D0,CR} + C_{D2,CR}\, C_L^2$$
else if h < 8,000 ft and $(V_{CAS}) < (V_{SET})_{approach}$
$$C_D = C_{D0,AP} + C_{D2,AP}\, C_L^2$$
else if h < 3,000 ft and $(V_{CAS}) < (V_{SET})_{landing}$
$$C_D = C_{D0,LD} + C_{D2,LD}\, C_L^2$$

Excel definition:

```
AB{n}  =IF($A{n}>$AK$4,"
        ",IF($AL$2="climb",$AA$3+$AB$3*$AA{n}^2,
        IF($L{n}>$G$3,$AA$3+$AB$3*$AA{n}^2,
        IF(AND($L{n}<$G$3,$L{n}>$G$5),
        $AA$4+$AB$4*$AA{n}^2,
        $AA$5+$AB$5*$AA{n}^2))))
```

AC

name: aerodynamic drag
units: kN
symbol: D

description: calculated from drag coefficient, reference aerodynamic surface area and dynamic pressure;
[RD1, Section 3.6]
the value is only calculated for flight levels less than or equal to the maximum flight level of the selected reference profile;

if $h_{FL} > (h_{FL})_{max}$
  undefined
else
$$D = [\, C_D\, \rho\, (V_{TAS})_m^2\, S/2\,] / 1000$$

Excel definition:

```
AC{n} =  IF($A{n}>$AK$4,
         " ",
         $AB{n}*$D${n}*$M{n}^2*$Z$5/2/1000 )
```

3.1.6 Total-Energy Block

The Total-Energy Block calculates the rate of climb or descent at each flight level based on the total-energy model.

The Total-Energy Block consists of six columns of the BADA.XLS spreadsheet (columns AD through AI) and is shown in Figure 3.1.6-1 below.

Figure 3.1.6-1: Total-Energy Model Block

	AD	AE	AF	AG	AH	AI
1			TOTAL ENERGY BLOCK			
2						
3						
4	max pow. red.		power reduction			
5	0.150		1.000			
6	flight	energy	avl. power	time step	esf	ROCD
7	level	[MJ]	[kW]	[sec]		[fpm]
8	450					
9	440					
10	430					
11	420					
12	410					
13	400	36077	-37071	19.4	1.000	3099
14	390	35358	-37063	19.4	1.000	3099
15	380	34640	-37145	19.3	1.000	3106
16	370	33922	-37318	19.0	1.000	3120
17	360	33209	-37600	17.2	1.104	3470
18	350	32558	-38141	16.9	1.104	3520
19	340	31908	-38778	16.6	1.104	3578
20	330	31257	-39509	24.2	1.104	3646

	AD	AE	AF	AG	AH	AI
46	70	7443	-17156	46.3	0.910	1307
47	60	6657	-16793	78.9	0.913	1284
48	50	5359	-16116	48.3	0.933	1259
49	40	4591	-15693	49.5	0.935	1229
50	30	3825	-15280	81.2	0.937	1199
51	20	2705	-12318	61.6	0.951	982
52	15	1971	-11471	43.4	0.965	927
53	10	1496	-10439	77.8	0.969	848
54	0	710	-9794	**0.0**	0.972	798

Individual cells in header of the Total-Energy Block are defined below

AD5

name: maximum power reduction
units: dimensionless
symbol: C_{RED}

description: variable that indicates the maximum amount of power reduction that can be applied during the climb phases. Value is a function of engine type. [RD1, Section 3.8]

if (type=jet)
$C_{RED} = 0.15$
else if (type=turbo)
$C_{RED} = 0.25$
else $C_{RED} = 0.0$

Excel definition: AD5 =IF($T$2="jet",0.15,IF($T$2="turbo",0.25,0))

AF5

name: power reduction
units: dimensionless
symbol: $C_{POW, RED}$

description: variable that indicates the amount of power reduction that is applied during the climb phase [RD1, Section 3.8]

if (phase = climb && reduced climb = “y”)
$C_{pow, red} = 1 – C_{red} *\{(m_{max} – m_{act}) / (m_{max} – m_{min})\}$
else
$C_{pow, red} = 1$

Excel definition: AF5 = IF(AND($AL$2="climb",
<A/C>.XLS!$C$24="y"),
1-$AD$5*(<A/C>.XLS!$C$4 - $Q$5)/
(<A/C>.XLS!$C$4 - <A/C>.XLS!$C$5), 1)

Columns in the Total-Energy Block are defined below

AD

name: flight level
units: 100 feet
symbol: h_{FL}

description: independent variable for profile calculation varies from 0 to 450; copied from first column (A) to improve readability of the Total-Energy Block

Excel definition: AD{n} = $A{n}

AE

name: total energy
units: MJ
symbol: E

description: sum of potential and kinetic energy of the aircraft; calculated as a function of altitude, mass and true air speed [RD1, Section 3.1].
The value is only calculated for flight levels less than or equal to the maximum flight level of the selected reference trajectory

if $h_{FL} > (h_{FL})_{max}$
undefined
else
$E = [mgz + mV^2/2]/1000000$

Excel definition:

```
AE{n} = IF($A{n}>$AK$4,
           " ",
          ($R{n}*9.81*$B{n} +
           $R{n}*($M{n}^2) /2 ) / 1000000 )
```

AF

name: available power
units: kW
symbol: P_{avl}

description: power available for either climb/descent or acceleration/deceleration; calculated as difference of thrust and drag times the true air speed
[RD1, Section 3.1]
the value is only calculated for flight levels less than or equal to the maximum flight level of the selected reference profile

if $h_{FL} > (h_{FL})_{max}$
undefined
else
$P_{avl} = (T_{net}\text{-}D) * V * C_{pow, red}$

Excel definition:

```
AF{n} = IF($A{n}>$AK$4,
           " ",
           ($Y{n}-$AC{n})*$M{n}*$AF$5 )
```

AG

name: time step
units: seconds
symbol: Δt

description: time taken to climb or descend between flight levels; calculated from energy difference between flight levels divided by the average available power between flight levels; the value is only calculated for flight levels less than or equal to the maximum flight level of the selected reference profile; the value at sea level (FL=0) is set to zero;

if $h_{FL} = 0$
  $\Delta t = 0$
else
  if $h_{FL} > (h_{FL})_{max}$
    undefined
  else
    $\Delta t|_k = 1000(E|_k - E|_{k-1})/((P_{avl}|_k + P_{avl}|_{k-1})/2)$

where subscript k refers to flight level

Excel definition: for $8 \le n \le 53$

```
AG{n} =  IF($A{n}>$AK$5,
            " ",
            ($AE{n}-$AE{n+1})*1000 /
            (($AF{n}+$AF{n+1})/2)  )
AG54  =  0.0
```

AH

name: energy share factor
units: dimensionless
symbol: f

description: the amount of energy that can be applied to a change in altitude while holding a constant speed; this is 1 for a constant Mach flight above the tropopause; below the tropopause it is a function of Mach number which differs depending upon whether the speed law is constant CAS or constant Mach; the value is only calculated for flight levels less than or equal to the maximum flight level of the selected reference profile

if $h_{FL} > (h_{FL})_{max}$
  undefined
else
  if $T \leq T_{tro}$ f = 1
  else
    if $(V_{TAS})_{ref} < (V_{TAS})_M$
      $f = \{1-.133\, M^2+(1+.2\, M^2)^{-2.5}[(1+.2\, M^2)^{3.5}-1]\}^{-1}$
    else
      $f = [1 - .133\, M^2\,]^{-1}$

Excel definition:

```
AH{n} =  IF($A{n}>$AK$4,
              " ",
              IF($C{n} ≤ $F$5,
                  1,
                  IF($I{n}<$J{n},
                     1/(1-.133*$N{n}+ (1+0.2 $N{n}^2)
                          ^-2.5 * ((1+0.2$N{n}^2)^3.5 -1)) ,
                     1/(1-.133*$N{n}^2  ) ) )
```

AI

name: rate of climb or descent
units: feet/minute (fpm)
symbol: $(V_z)_{csc}$

description: rate of climb or descent assuming constant CAS or Mach is maintained; calculated from available power and the energy share factor; the value is only calculated for flight levels less than or equal to the maximum flight level of the selected reference profile;

if $h_{FL} > (h_{FL})_{max}$
  undefined
else
  $(V_z)_{csc} = (60/.3048)\ 1000\ P_{avl}\ f / mg$

where $g = 9.81\ m/s^2$

Excel definition:

```
AI{n}  =  IF($A{n}>$AK$4,
             " ",
              60000*$AF{n}*$AH{n}/$R{n}/9.81/.3048
```

3.1.7 Trajectory Block

The Trajectory Block calculates a trajectory in terms of the time and distance to climb or descent at each flight level. This block also calculates the error between the calculated trajectory and the reference trajectory.

The Trajectory Block consists of seven columns of the BADA.XLS spreadsheet (columns AJ through AP) and is shown in Figure 3.1.7-1 below.

Figure 3.1.7-1: Trajectory Block

	AJ	AK	AL	AM	AN	AO	AP
1			TRAJECTORY BLOCK				
2	B747	DES1	descent	dist. [n.m]	dist[%TOCD]	alt. [ft]	alt.[%TOCD]
3	min FL	15	max error	12.0	10.3	5078	12.7
4	max FL	400	rms error	10.1	8.6	3539	8.8
5	max dist.	117	figure of merit	10.1			
6	flight	allowed	gnd speed	distance	time	dist. error	alt.error
7	level	FL	[knots]	[n. miles]	[min]	[n. miles]	[ft]
8	450	#N/A					
9	440	#N/A					
10	430	#N/A					
11	420	#N/A					
12	410	#N/A					
13	400	400	480.20	128.17	22.07	11.2	4327
14	390	390	480.20	125.59	21.75		
15	380	380	480.20	123.00	21.42		
16	370	370	480.19	120.43	21.10		
17	360	360	480.15	117.90	20.79		
18	350	350	482.31	115.60	20.50	11.6	5078
19	340	340	484.46	113.33	20.22		
20	330	330	486.59	111.08	19.94		

	AJ	AK	AL	AM	AN	AO	AP
46	70	70	275.97	23.40	6.10		
47	60	60	272.00	19.87	5.32		
48	50	50	236.04	14.30	4.01	0.8	257
49	40	40	232.64	11.16	3.20		
50	30	30	229.32	7.99	2.38		
51	20	20	199.85	3.15	1.03		
52	15	15	167.77	0.00	0.00		
53	10	10	156.45	0.00	0.00		
54	0	0	149.22	0.00	0.00		

Individual cells in header of the Trajectory Block are defined below.

AJ2	name:	aircraft type identifier
	units:	string
	symbol:	not applicable
	description:	a string constant associated with each aircraft type and used to identify each aircraft type; imported from A/C spreadsheet;
	Excel definition:	AJ2 = <A/C> .XLS!$C$1
AK2	name:	profile identifier
	units:	string
	symbol:	not applicable
	description:	a string constant associated with with each reference profile and used to identify the profile currently selected as the reference; imported from the A/C spreadsheet;
	Excel definition:	AK2 = <A/C> .XLS!$C$2
AL2	name:	profile type
	units:	string
	symbol:	not applicable
	description:	a string constant, either “climb” or “descent” associated with each reference profile; imported from the A/C spreadsheet;
	Excel definition:	AL2 = <A/C>.XLS!$H$1
AK3	name:	minimum flight level
	units:	100 feet
	symbol:	$(h_{FL})_{min}$
	description:	initial flight level associated with a reference climb profile or final flight level associated with a reference descent profile; imported from the A/C spreadsheet;
	Excel definition:	AK3 = <A/C>.XLS!$E$3

AK4

name: maximum flight level
units: 100 feet
symbol: $(h_{FL})_{max}$

description: final flight level associated with a reference climb profile or initial flight level associate with a reference descent profile; imported form the A/C spreadsheet;

Excel definition: AK4 = <A/C>.XLS!$E$5

AK5

name: maximum distance
units: nautical miles
symbol: d_{max}
description: maximum distance at the end of the reference climb or end of reference descent; imported form the A/C spreadsheet;

Excel definition: AK5 = <A/C>.XLS!$E$4

AM3

name: maximum distance error
units: nautical miles
symbol: $(\Delta d)_{max}$

description: maximum of the distance errors at each flight level between the calculated and reference profiles;

Excel definition: AM3 = MAX($AO$8:$AO$54)

AM4

name: root-mean-square distance error
units: nautical miles
symbol: $(\Delta d)_{rms}$

description: root-mean-square of the distance errors at each flight level between calculated and reference profiles;

Excel definition: AM4 = SQRT((SUMPRODUCT($AO$8:$AO$54, $AO$8:$AO$54)/COUNT($AO$8:$AO$54))

AN3

name: normalised maximum distance error
units: percent
symbol: $(\Delta d)^{*}_{max}$

description: maximum distance error divided by the maximum profile distance and expressed as a percentage;

$$(\Delta d)^{*}_{max} = 100\,(\Delta d)_{max} / d_{max}$$

Excel definition: AN3 = 100*$AM$3/$AK$5

AN4

name: normalised root-mean-square distance error
units: percent
symbol: $(\Delta d)^{*}_{rms}$

description: root-mean-square distance error divided by the maximum profile distance and expressed as a percentage;

$$(\Delta d)^{*}_{rms} = 100\,(\Delta d)_{rms} / d_{max}$$

Excel definition: AN4 = 100*$AM$4/$AK$5

AO3

name: maximum altitude error
units: feet
symbol: $(\Delta h)_{max}$

description: maximum of the altitude errors at each flight level between the calculated and reference profiles;

Excel definition: AO3 = MAX($AP$8:$AP$54)

AO4

name: root-mean-square altitude error
units: feet
symbol: $(\Delta h)_{rms}$

description: root-mean-square of the altitude errors at each flight level between calculated and reference profiles;

Excel definition: AO4 = SQRT((SUMPRODUCT($AP$8:$AP$54, $AP$8:$AP$54)/COUNT($AP$8:$AP$54))

AP3

name: normalised maximum altitude error

units: percent

symbol: $(\Delta h)^*_{max}$

description: maximum altitude error divided by the maximum profile altitude and expressed as a percentage;

$$(\Delta h)^*_{max} = (\Delta h)_{max} / (h_{FL})_{max}$$

Excel definition: AP3 = $AO$3/$AK$4

AP4

name: normalised root-mean-square altitude error

units: percent

symbol: $(\Delta h)^*_{rms}$

description: root-mean-square altitude error divided by the maximum profile altitude and expressed as a percentage;

$$(\Delta h)^*_{rms} = (\Delta h)_{rms} / (h_{FL})_{max}$$

Excel definition: AP4 = $AO$4/$AK$4

AM5

name: figure-of-merit

units: dimensionless

symbol: f_M

description: measure of the goodness of fit between the calculated trajectory and the reference trajectory; calculated as the average of the maximum and rms distance errors (normalised) and the maximum and rms altitude errors (normalised);

$$f_M = [\ (\Delta d)^*_{rms} + (\Delta d)^*_{max} + (\Delta h)^*_{rms} + (\Delta h)^*_{max}\ ] /4$$

Excel definition: AM5 = ($AN$4+$AN$3+$AP$4+$AP$3)/4

Columns in the Trajectory Block are defined below

AJ	name:	flight level
	units:	100 feet
	symbol:	h_{FL}
	description:	independent variable for profile calculation varies from 0 to 450; copied from first column (A) to improve readability of the Trajectory Block
	Excel definition:	AJ{n} = $A{n}

AK	name:	allowed flight level
	units:	100 feet
	symbol:	$h_{FL,allowed}$
	description:	same as flight level, but flagged as "not available" for flight levels greater than the maximum flight level of the reference trajectory; this is used as the independent variable for Excel plots where the "not available" flag results in the suppression of data points at flight levels above the maximum
	Excel definition:	AK{n} = IF($A{n}>$AK$4, NA( ), $A{n})

AL	name:	ground speed
	units:	knots
	symbol:	V_x
	description:	calculated using pythagorean theorem from true air speed and vertical speed; the value is only calculated for flight levels less than or equal to the maximum flight level of the selected reference profile;

if $h_{FL} > (h_{FL})_{max}$
undefined
else

$$V_x = [V_{TAS}^2 - .000975V_z^2]^{0.5}$$

Excel definition:

```
AL{n} =  IF($A{n}>$AK$4,
            " ",
            SQRT($K{n}^2-.000975*$AI{n}^2)
```

AM

name: distance to climb or descent
units: nautical miles
symbol: X

description: distance taken to climb to or descend from a specific flight level; calculated by integrating ground speeds at each flight level; the value is only calculated for flight levels less than or equal to the maximum flight level of the selected reference profile;

if $h_{FL} > (h_{FL})_{max}$
 undefined
else
 $X|_k = X|_{k-1} + \Delta t|_k * (V_x|_k + V_x|_{k-1})/2/3600$

where the subscript k indicates the flight level

Excel definition:

```
AM{n}=  IF($A{n}>$AK$4,
          " ",
          $AM{n+1} +
          ($AL{n}+$AL{n+1})*$AG{n}/2/3600
```

AN

name: time to climb or descend
units: minutes
symbol: t

description: time taken to climb to or descend from a specific flight level; calculated by adding the time steps associated with each flight level; the value is only calculated for flight levels less than or equal to the maximum flight level of the selected reference profile;

if $h_{FL} > (h_{FL})_{max}$
 undefined
else
 $t|_k = t|_{k-1} + \Delta t|_k/60$

where the subscript k indicates the flight level

Excel definition:

```
AN{n} =  IF($A{n}>$AK$4,
          " ",
          $AN{n+1} + $AG{n}/60
```

AO

name: distance error
units: nautical miles
symbol: ΔX

description: absolute distance between the calculated time to climb or descent and the reference profile; the value is only calculated for flight levels for which reference distances are available and if the distance to climb/descent is greater than 5% of the distance at the top of climb/descent; this latter criterion rejects large relative errors that can occur at the low altitudes

if reference distance not available or $X < 0.05 d_{max}$
  undefined
else
  $\Delta X = | X_{ref} - X |$

Excel definition:

```
AO{n} = IF(ISNA(<AC>.XLS!$F{n}),
          " ",
          IF($AM{n}<0.05*$AK$5
             " ",
             ABS(<AC> .XLS!$F{n}-$AM{n}))
```

AP

name: equivalent altitude error
units: feet
symbol: Δh

description: equivalent altitude error at each flight level; calculated from distance error using ratio of ground and vertical speeds; the value is only calculated for flight levels for which distance errors are available;

if ΔX not available
  undefined
else
  $\Delta h = 60 \, \Delta X \, (V_z / V_x)$

Excel definition:

```
AP{n} = IF($AO{n}=" ",
          " ",
          60*$AO{n}*$AI{n}/$AL{n} )
```

3.1.8 Fuel Consumption Block

The Fuel Consumption Block calculates the fuel used in climb or descent based on the BADA fuel coefficients. The block also determines the difference between the calculcated fuel consumption and the reference fuel consumption.

The Fuel Consumption Block consists of five columns of the BADA.XLS spreadsheet (columns AQ through AV) and is shown in Figure 3.1.8-1 below.

Figure 3.1.8-1: Fuel Consumption Block

	AQ	AR	AS	AT	AU	AV
1	FUEL CONSUMPTION BLOCK					
2	thrust specific		descent (minimum)		max. err. kg	164
3	fuel flow coefficients		fuel flow coefficients		rms err. kg	135
4	Cf1	0.91	Cf3	38.55	max err. %	26.2
5	Cf2	5324	Cf4	6.10E+04	rms err %	21.5
6	flight	climb flow	des. flow	fuel used	error	error
7	level	[kg/sec]	[kg/sec]	[kg]	[kg]	[%]
8	450					
9	440					
10	430					
11	420					
12	410					
13	400	0.2454	0.2213	627.4	162.4	25.9
14	390	0.2580	0.2318	623.0		
15	380	0.2706	0.2424	618.4		
16	370	0.2832	0.2529	613.7		
17	360	0.2958	0.2634	608.8		
18	350	0.3085	0.2740	604.1	164.1	26.2
19	340	0.3212	0.2845	599.4		
20	330	0.3340	0.2950	594.6		

	AQ	AR	AS	AT	AU	AV
46	70	0.7174	0.5688	219.9		
47	60	0.7306	0.5794	193.3		
48	50	1.4085	0.5899	147.2	47.2	7.5
49	40	1.4334	0.6004	118.5		
50	30	1.4584	0.6110	88.5		
51	20	1.4763	0.6215	38.5		
52	15	3.0350	0.6268	0.0	0.0	0.0
53	10	3.0549	0.6320	0.0		
54	0	3.1030	0.6426	0.0		

Individual cells in header of the Fuel Consumption Block are defined below.

AR4

name: first thrust specific fuel consumption coefficient

units: kg/min/kN (jet)
kg/min/kN/knot (turboprop)
kg/min (piston)

symbol: C_{f1}

description: a constant associated with each aircraft type; used to calculate thrust specific fuel consumption as a function of true airspeed; imported from A/C spreadsheet;
[RD1, Section 3.9]

Excel definition: AR4 = <A/C>.XLS!$C$32

AR5

name: second thrust specific fuel consumption coefficient

units: knots

symbol: C_{f2}

description: a constant associated with each aircraft type; used to calculate thrust specific fuel consumption as a function of true airspeed; imported from A/C spreadsheet;
[RD1, Section 3.9]

Excel definition: AR5 = <A/C>.XLS!$C$33

AT4

name: first minimum fuel flow coefficient

units: kg/min

symbol: C_{f3}

description: a constant associated with each aircraft type; used to calculate minimum fuel flow as a function of altitude; imported from A/C spreadsheet;
[RD1, Section 3.9]

Excel definition: AT4 = <A/C>.XLS!$C$34

AT5	name:	second thrust specific fuel consumption coefficients
	units:	feet
	symbol:	C_{f4}
	description:	a constant associated with each aircraft type; used to calculate minimum fuel flow as a function of altitude; imported from A/C spreadsheet; [RD1, Section 3.9]
	Excel definition:	AT5 = <A/C>.XLS!$C$35

AV2	name:	maximum fuel consumption error
	units:	kg
	symbol:	$(\Delta w)_{max}$
	description:	maximum error between calculated fuel consumption and reference fuel consumption
	Excel definition:	AV2 = MAX($AU$8:$AU$54)

AV3	name:	root-mean-square fuel consumption error
	units:	kg
	symbol:	$(\Delta w)_{rms}$
	description:	root-mean-square error between calculated fuel consumption and reference fuel consumption
	Excel definition:	AV3 = SQRT(SUMPRODUCT($AU$8:$AU$54, $AU$8:$AU$54)/COUNT($AU$8:$AU$54))

AV4	name:	normalized maximum fuel consumption error
	units:	percent
	symbol:	$(\Delta w)^{*}_{max}$
	description:	maximum of normalized error between calculated fuel consumption and reference fuel consumption
	Excel definition:	AV4 = MAX($AV$8:$AV$54)

AV5

name: normalized root-mean-square fuel consumption error
units: percent
symbol: $(\Delta w)^{*}_{rms}$

description: root-mean-square of normalized error between calculated fuel consumption and reference fuel consumption

Excel definition: AV5 = SQRT(SUMPRODUCT($AV$8:$AV$54, $AV$8:$AV$54)/COUNT($AV$8:$AV$54))

Columns in the Fuel Consumption Block are defined below

AQ

name: flight level
units: 100 feet
symbol: h_{FL}

description: independent variable for profile calculation
varies from 0 to 450; copied from first column (A)
to improve readability of the Fuel Consumption Block

Excel definition: AQ{n} = $A{n}

AR

name: climb fuel flow
units: kg/sec
symbol: f_{cl}

description: fuel flow during climb trajectory, calculated as product of thrust times the thrust specific fuel consumption;
[RD1, Section 3.9]
the value is only calculated for flight levels less than or equal to the maximum flight level of the selected reference profile

if $h_{FL} > (h_{FL})_{max}$ then
  f_{cl} is undefined
else
  if engine type is jet then
    $f_{cl} = C_{f1} (1+V_{TAS}/C_{f2})T/ 60$
  else if engine type is turboprop then
    $f_{cl} = C_{f1} (1-V_{TAS}/C_{f2}) T (V_{TAS}/1000) /60$
  else engine type is piston then
    $f_{cl} = C_{f1} /60$

Excel definition:

```
AR{n} = IF($A{n}>$AK$4,
          " ",
          IF($T$2 = "jet"
             $AR$4*(1+$K{n}/$AR$5)*$Y{n}/60,
             IF$T$2 = "turbo",
                $AR$4*(1-$K{n}/$AR$5)
                      *$Y{n}*($K{n}/1000)/60,
                $AR$4 / 60 ) ) )
```

AS

name: descent fuel flow

units: kg/sec

symbol: f_{des}

description: fuel flow during descent trajectory calculated the same as minimum fuel flow;
[RD1, Section 3.9]
the value is only calculated for flight levels less than or equal to the maximum flight level of the selected reference profile

if $h_{FL} > (h_{FL})_{max}$ then
  f_{cl} is undefined
else
  if engine type is jet or turboprop then
    $f_{cl} = C_{f3}\,(1\text{-}100h_{FL}/C_{f4}) / 60$
  else engine type is piston then
    $f_{cl} = C_{f4}/60$

Excel definition:

```
AS{n} = IF($A{n}>$AK$4,
          " ",
          IF($T$2 = "jet"
             $AT$4*(1-$A{n}/$AT$5)/60,
             IF$T$2 = "turbo",
                $AT$4*(1-$A{n}/$AT$5)/60,
                $AT$4 / 60 ) ) )
```

AT

name: fuel to climb or descent

units: kg

symbol: w

description: fuel needed to climb to or descend from a specific flight level; calculated by integrating either the climb fuel flow or descent fuel flow as appropriate; for flight levels less than the minimum flight level the fuel needed is set to zero; the value is only calculated for flight levels less than or equal to the maximum flight level of the selected reference profile

if $h_{FL} > (h_{FL})_{max}$ then
  $w|_k$ is undefined
else
  if $h_{FL} \le (h_{FL})_{min}$
    $w|_k = 0$
  else
    if profile type is "climb" then
      $w|_k = w|_{k-1} + \Delta t|_k*(f_{cl}|_k + f_{cl}|_{k-1})/2$
    else if profile type is "descent" then
      $w|_k = w|_{k-1} + \Delta t|_k*(f_{des}|_k + f_{des}|_{k-1})/2$

Excel definition:

```
AT{n} =  IF($A{n}>$AK$4,
              " ",
              IF($A{n}≤$AK$3,
                 0,
                 IF($AL$2 = "climb"
                    $AT{n+1} +
                    $AG{n}*($AR{n}+$AR{n+1})/2/60,
                    $AT{n+1} +
                    $AG{n}*($AS{n}+$AS{n+1})/2/60) )
```

AU

name: fuel error
units: kg
symbol: Δw

description: calculated as the absolute difference between the calculated fuel to climb or descend and the reference value, w_{ref}; this value is only calculated for flight levels for which a reference value is available;

if w_{ref} is not available then
  Δw is undefined
else
  $\Delta w = |w - w_{ref}|$

Excel definition:

```
AU{n} =  IF($P{n}= "  "
            " ",
            ABS($AT{n}-$P{n})  )
```

AV	name:	normalised fuel error
	units:	percent
	symbol:	Δw^*
	description:	calculated as the fuel error divided by the maximum fuel used to climb or descend; this value is only calculated for those flight levels where a fuel error has been calculated;

if Δw is not available then
  Δw^* is undefined
else
  $\Delta w^* = \Delta w / (w)_{max}$

Excel definition:

```
AV{n}      =  IF($AU{n} = " ",
                 " ",
                 100*$AU{n}
                 / MAX($AT$8:$AT$54) )
```

3.1.9 Cruise Fuel Block

The Cruise Fuel Block calculates the fuel used in the cruise phase based on the BADA fuel coefficients. The block also determines the difference between the calculcated fuel consumption and the reference fuel consumption.

The Cruise Fuel Block consists of 5 columns of the BADA.XLS spreadsheet (columns AW through BA) and is shown in Figure 3.1.9-1 below.

Figure 3.1.9-1: Cruise Fuel Block

	AW	AX	AY	AZ	BA
1		CRUISE FUEL BLOCK			
2				max. err. kg	619
3		**cruise fuel consumption**		rms err. kg	321
4		**correction factor**		max err. %	5.4
5		Cfcr	0.946335	rms err %	2.8
6	**flight**	**cruise flow**	**fuel data**	**error**	**error**
7	**level**	**[kg/hr]**	**[kg/hr]**	**[kg/hr]**	**[%]**
8	450				
9	440				
10	430				
11	420				
12	410				
13	400				
14	390				
15	380	10744.93	11364	619.1	5.4
16	370	10762.58			
17	360	10804.43	10948	143.6	1.3
18	350	10875.20			
19	340	10969.93	11056	86.1	0.8
20	330	11088.21			
21	320	11229.68	11368	138.3	1.2
22	310	11394.04			
23	300	11581.04	11852	271.0	2.3
24	290	11790.50			
25	280	11891.64	12000	108.4	0.9
26	270	11908.47			
27	260	11924.66	11836	88.7	0.7
28	250	11940.21			
29	240	11955.12	11816	139.1	1.2
30	230	11969.40			
31	220	11983.06	11364	619.1	5.4

Note that the data in the Cruise Fuel Block is only relevant when a Cruise Trajectory (e.g. CRZ1) has been selected in the <A/C>.XLS. Furthermore the cruise data below 10,000 ft is usually not entered in the <A/C>.XLS, so all data below 10,000 ft is ignored.

Individual cells in header of the Fuel Consumption Block are defined below.

AY5	name:	cruise fuel flow factor
	units:	dimensionless
	symbol:	C_{fcr}
	description:	factor used as a correction to the thrust specific fuel consumption in order to calculate the cruise fuel flow [RD1, Section 3.9]
	Excel definition:	AY5 = <A/C>.XLS!$C$60

BA2	name:	maximum cruise fuel consumption error
	units:	kg
	symbol:	$(\Delta w)_{max}$
	description:	maximum error between calculated cruise fuel consumption and reference cruise fuel consumption
	Excel definition:	BA2 = MAX($AZ$8:$AZ$53)

BA3	name:	root-mean-square cruise fuel consumption error
	units:	kg
	symbol:	$(\Delta w)_{rms}$
	description:	root-mean-square error between calculated cruise fuel consumption and reference cruise fuel consumption
	Excel definition:	BA3 = SQRT(SUMPRODUCT($AZ$8:$AZ$53, $AZ$8:$AZ$53)/COUNT($AZ$8:$AZ$53))

BA4

name: normalized maximum cruise fuel consumption error
units: percent
symbol: $(\Delta w)^*_{max}$

description: maximum of normalized error between calculated cruise fuel consumption and reference cruise fuel consumption

Excel definition: BA4 = MAX($BA$8:$BA$53)

BA5

name: normalized root-mean-square cruise fuel consumption error
units: percent
symbol: $(\Delta w)^*_{rms}$

description: root-mean-square of normalized error between calculated cruise fuel consumption and reference cruise fuel consumption

Excel definition: BA5 = SQRT(SUMPRODUCT($BA$8:$BA$53, $BA$8:$BA$53)/COUNT($BA$8:$BA$53))

Columns in the Cruise Fuel Block are defined below

AW

name: flight level
units: 100 feet
symbol: h_{FL}

description: independent variable for profile calculation
varies from 0 to 450; copied from first column (A)
to improve readability of the Fuel Consumption Block

Excel definition: AW{n}= $A{n}

AX

name: cruise fuel flow
units: kg/hr
symbol: f_{cr}

description: fuel flow during cruise, calculated as product of thrust times the thrust specific fuel consumption time the cruise fuel flow factor
[RD1, Section 3.9]
the value is only calculated for flight levels less than or equal to the maximum flight level of the selected reference profile

if $h_{FL} > (h_{FL})_{max}$ then
  f_{cl} is undefined
else
  if engine type is jet then
    $f_{cl} = C_{fcr} * 3600 * C_{f1} * (1 + V_{TAS}/C_{f2}) T / 60$
  else if engine type is turboprop then
    $f_{cl} = C_{fcr} * 3600 * C_{f1} * (1 - V_{TAS}/C_{f2}) T (V_{TAS}/1000) / 60$
  else engine type is piston then
    $f_{cl} = C_{fcr} * 3600 * C_{f1} / 60$

Excel definition: AX{n} = =IF($A{n}>$AK$4," ",IF($T$2="jet", $AY$5*3600*$AR$4*(1+$K{n}/$AR$5)*$AC{n}/60, IF($T$2="turbo",$AY$5*3600*$AR$4* (1-$K{n}/$AR$5)*$AC{n}*($K{n}/1000)/60, $AY$5*3600*$AR$4/60)))

AY
name: cruise fuel reference data
units: kg/hr
symbol: $(f_{cr})_{ref}$

description: reference data with regard to cruise fuel consumption taken from the <A/C>.XLS spreadsheet

Excel definition: AY{n} =IF(ISNA(<A/C>.XLS!$F{n})," ", <A/C>.XLS!$F{n})

AZ
name: cruise fuel error
units: kg
symbol: Δw

description: calculated as the absolute difference between the calculated cruise fuel and the reference value, $(f_{cr})_{ref}$ this value is only calculated for flight levels for which a reference value is available;

if $(f_{cr})_{ref}$ is not available then
  Δw is undefined
else
  $\Delta w = | f_{cr} - (f_{cr})_{ref} |$

Excel definition: AZ{n} =IF($AY{n}=" "," ",ABS(AY{n}-AX{n}))

BA
name: normalised fuel error
units: percent

symbol:	Δw^*

description:	calculated as the fuel error divided by the maximum cruise fuel; this value is only calculated for those flight levels where a fuel error has been calculated;
	
	if Δw is not available then
	Δw^* is undefined
	else
	$\Delta w^* = \Delta w / (f_{cr})_{max}$

Excel definition:	BA{n} = IF($AY{n}=" "," ",ABS((($AX{n}-$AY{n})/$AY{n})*100))

3.2 <A/C>.XLS

The purpose of the <A/C>.XLS spreadsheet is to store all the reference information and BADA coefficients that are associated with a specific aircraft type.

The name of each spreadsheet is based on the ICAO code of the aircraft type. Thus, the spreadsheet for the Boeing 737-300 is named B73S.XLS. Similarly, the spreadsheet for the McDonnell-Douglas DC-9 is named DC9.XLS. Note that most of the <A/C>.XLS files were created using the old ICAO designator standard. Each <A/C>.XLS spreadsheet has the same structure, consisting of a BADA Coefficient Block, a Selected Trajectory Block and a variable number of Reference Trajectories Block. Each block is 54 rows in length. This organisation is shown in Figure 3.2.0-1 below.

Figure 3.2.0-1: Organisation of <A/C>.XLS Spreadsheet

BADA Coefficient Block	Selected Trajectory Block	Reference Trajectory Climb/Des Block Number 1	Reference Trajectory Climb/Des Block Number 2	... ...	Reference Trajectory Climb/Des Block Number N	Reference Trajectory Cruise Block Number 1

The BADA Coefficient Block contains all BADA coefficients that are to be placed in the OPF and APF files. Some of these coefficients such as reference surface area (S) and maximum operating altitude (h_{MO}) are determined from reference manuals. Other coefficients such as the drag coefficients (C_{D0} and C_{D2}) need to be calculated as described in Section 4.

The BADA.XLS spreadsheet imports the coefficient values from the BADA Coefficient Block when calculating climb and descent trajectories. Each of the Reference Trajectory Blocks specifies a climb or descent trajectory in terms of distance, time and fuel needed to climb to or descent from a flight level, or a provides cruise fuel flow data as a function of altitude (always the last block). Values for flight levels from 450 to 0 are placed in rows 8 to 54, compatible with the BADA.XLS spreadsheet. Each of the reference trajectories represents different conditions in terms of climb/descent, aircraft mass, speed or temperature deviation from ISA. Each of the reference trajectories is given an identifier (eg. CL1, CL2, DES1, CRZ1) to distinguish it from the other trajectories. Note that the cruise trajectory (CRZx) has a different format and will be described seperately.

The Selected Trajectory Block is similar in structure to a Reference Trajectory Block. It is used as a working area and contains the values corresponding to the reference trajectory which is currently selected as a basis for calculations. The BADA.XLS spreadsheet, as well as the TRAJECT.XLS, FUEL_CRZ.XLS, ROCD.XLS and FUEL.XLS charts import the reference trajectory specifications from the Selected Trajectory Block.

Further information on all of the four types of blocks in the <A/C>.XLS spreadsheet are given in the subsections below.

3.2.1 BADA Coefficient Block

The BADA Coefficient Block contains all BADA coefficients that are to be placed in the Operations Performance File (OPF) and (Airline Performance File) APF files. This block consists of three columns, A through C, of each <A/C>.XLS spreadsheet and is shown in Figure 3.2.1-1.

All coefficient values are placed in row C with labels placed in rows A and B. All values that are to be entered by the user are shaded in light blue. This comprises all values except the minimum drag speed, which is automatically calculated from the mass and drag coefficients.

The values in row C can be divided into the following categories:

(a) Input from A/C Reference Manuals

These are values such as aircraft mass and stall speeds, which are looked up in A/C reference manuals or Jane's and entered directly into the spreadsheet. Once these values are entered they need not be changed. A special case of this type is cell C1, which specifies the aircraft identifier. This corresponds to the ICAO identifier for the aircraft type and must be the same as the name of the spreadsheet, for example, B727 for the B727.XLS spreadsheet. Some input is not directly available but needs to be extracted from data in the Flight Manual. Expamples are the maximum dynamic altitude parameters. These parameters are not directly available but need to be determined using maximum altitude graphs.

(b) Optimised Coefficients

These are values that are calculated in order to obtain the best match between BADA calculated trajectories and the reference trajectories. This includes the drag coefficients, thrust coefficients and fuel flow coefficients.

(c) Automatic Calculation Parameters

There is only on value of this type. This is the minimum drag speed in cell C14 which is automatically calculated as a function of the mass and drag coefficients.

(d) Profile Selection Parameter

There is only one value of this type. This is the profile identifier in cell C2. This cell can be set to any one of the profile identifiers associated with a Reference Trajectory Block in the spreadsheet. This causes the Selected Trajectory Block to be updated to contain the selected profile data.

A detailed description of each of the coefficients in the block is given in Table 3.2.1-1.

Figure 3.2.1-1 : Coefficient Block

	A	B	C
1	**Aircraft Type**		**B747**
2	**Selected Trajectory**		**DES1**
3	**A/C**	m(ref)	280
4	**mass**	m(max)	380
5		m(min)	173.0
6		m(payload)	64.6
7	**speed**	Vmo	375
8	**limits**	Mmo	0.92
9	**ceiling**	hmo	45100
10	**drag**	S	512
11	**coeff.**	CD0	0.0185
12		CD2	0.0656
13		CM16	0
14	**min drag speed**		249
15			
16	**engine**	type	jet
17		number	4
18			
19	**climb**	C Tc,1	568288
20	**thrust**	C Tc,2	59488
21	**coeff.**	C Tc,3	0.00E+00
22	**temp.**	C Tc,4	1.6100
23	**coeff**	C Tc,5	0.0027
24	**reduced power [y/n]**		n
25	**cruise**	C Tcr	0.95
26	**descent**	C Tdes,lo	0.0900
27	**thrust**	C Tdes,hi	0.0800
28	**coeff.**	hdes	20000
29	**reference**	V des,ref	300
30	**descent**	Mdes,ref	0.84
31			
32	**TSFC**	Cf1	0.9068
33		Cf2	5324
34	**minimum**	Cf3	38.5540
35	**fuel flow**	Cf4	61014
36			
37	**stall**	(Vstall)CR	179
38	**speeds**	(Vstall)IC	132
39		(Vstall)TO	130
40		(Vstall)AP	130
41		(Vstall)LD	120
42	**spd.sched.[law/stall]**		**law**
43	**nominal**	V cl,1	340
44	**climb**	V cl,2	340
45	**speeds**	M cl	0.82
46			
47	**nominal**	V cr,1	340
48	**cruise**	V cr,2	340
49	**speeds**	M cr	0.82
50			
51	**nominal**	V des,1	300
52	**descent**	V des,2	300
53	**speeds**	M des	0.84

Figure 3.2.1-1 : Coefficient Block (continued)

	A	B	C
55	**dynamic**	Hmax	3.15E+04
56	**maximum**	Gw	0.07
57	**altitude**	Gt	-1.90E+02
58			
59	**cruise fuel cons.**		
60	**correction**	Cfcr	0.9463
61			
62	**non clean**	C T des,app	0.2
63	**data**	C Tdes,ld	0.41
64	flap 10	CD0, app	0.035
65	flap 10	CD2,app	0.059
66	flap 25	CD0, ld	0.08
67	flap 25	CD2, ld	0.06

Table 3.2.1-1: Coefficient Block Cells

Cell	Name	Symbol	Units	Source
C1	aircraft type	n/a	string	ICAO listing [RD3]
C2	profile identifier	n/a	string	user input
C3	reference mass	m_{ref}	tonnes	A/C reference manuals
C4	maximum mass	m_{max}	tonnes	A/C reference manuals (maximum take-off)
C5	minimum mass	m_{min}	tonnes	A/C reference manuals (minimum ops empty)
C6	payload max	m_{pld}	tonnes	A/C reference manuals (maximum payload)
C7	maximum operating speed (CAS)	V_{MO}	knots	A/C reference manuals
C8	maximum operating Mach number	M_{MO}	dimensionless	A/C reference manuals
C9	maximum operating altitude	h_{MO}	feet	A/C reference manuals (300 fpm climb)
C10	reference aerodynamic surface area	S	m^2	A/C reference manuals
C11	parasitic drag coefficient (clean configuration)	C_{D0}	dimensionless	calculated as described in Section 4
C12	induced drag coefficient (clean configuration)	C_{D2}	dimensionless	calculated as described in Section 4
C13	Mach drag coefficient	C_{M16}	dimensionless	nominally set to zero
C14	minimum drag speed	$V_{min,drag}$	knots (CAS)	calculated from mass and drag coefficients (note 1)

note 1: $V_{min,drag} = 1.941 [2 (C_{D2} / C_{D0})^{0.5} (1000\ m_{ref}\ g)/ S(\rho_0)_{ISA}]^{0.5}$

where: $g = 9.81\ m/s^2$ i.e. gravitational acceleration
and $(\rho_0)_{ISA} = 1.225\ kg/m^3$ i.e. ISA air density at sea level

Excel definition: C16 = 1.941*SQRT(2*SQRT(C12/C11)*(1000*C3*9.81)/(C10* 1.225))

Table 3.2.1-1: Coefficient Block Cells (continued)

Cell	Name	Symbol	Units	Source
C16	engine type	n/a	"jet", "turbo" or "piston"	A/C reference manuals
C17	number of engines	n_{eng}	dimensionless	A/C reference manuals
C19	1st maximum climb thrust coefficient	$C_{Tc,1}$	N (jet/turbo) knot-N (piston)	calculated as described in Section 4
C20	2nd maximum climb thrust coefficient	$C_{Tc,2}$	feet	calculated as described in Section 4
C21	3rd maximum climb thrust coefficient	$C_{Tc,3}$	$1/ft^2$ (jet) N (turbo) knot-N (piston)	calculated as described in Section 4
C22	1st thrust temperature coefficient	$C_{Tc,4}$	deg. C	calculated as described in Section 4
C23	2nd thrust temperature coefficient	$C_{Tc,5}$	dimensionless	calculated as described in Section 4
C25	cruise thrust coefficient	C_{Tcr}	dimensionless	set to 0.95
C26	low altitude descent thrust coefficient	$C_{Tdes,lo}$	dimensionless	calculated as described in Section 4
C27	high altitude descent thrust coefficient	$C_{Tdes,hi}$	dimensionless	calculated as described in Section 4
C28	descent thrust transition altitude	h_{des}	feet	calculated as described in Section 4
C29	reference descent speed	$V_{des,ref}$	knots (CAS)	calculated as described in Section 4
C30	reference descent Mach number	$M_{des,ref}$	dimensionless	calculated as described in Section 4

Table 3.2.1-1: Coefficient Block Cells (continued)

Cell	Name	Symbol	Units	Source
C32	1st thrust specific fuel consumption coefficient	C_{f1}	kg/min/kN (jet) kg/min/kN/knot (turbo) kg/min (piston)	calculated as described in Section 4
C33	2nd thrust specific fuel consumption coefficient	C_{f2}	knots	calculated as described in Section 4
C34	1st minimum fuel flow coefficient	C_{f3}	kg/min	calculated as described in Section 4
C35	2nd minimum fuel flow coefficient	C_{f4}	feet	calculated as described in Section 4
C37	cruise stall speed	$(V_{stall})_{CR}$	knots (CAS)	A/C reference manuals
C38	initial climb stall speed	$(V_{stall})_{IC}$	knots (CAS)	A/C reference manuals
C39	take-off stall speed	$(V_{stall})_{TO}$	knots (CAS)	A/C reference manuals
C40	approach stall speed	$(V_{stall})_{AP}$	knots (CAS)	A/C reference manuals
C41	landing stall speed	$(V_{stall})_{LD}$	knots (CAS)	A/C reference manuals
C43	low altitude climb speed	$V_{cl,1}$	knots (CAS)	A/C reference manuals
C44	high altitude climb speed	$V_{cl,2}$	knots (CAS)	A/C reference manuals
C45	Mach limit for climb	M_{cl}	dimensionless	A/C reference manuals
C47	low altitude cruise speed	$V_{cr,1}$	knots (CAS)	A/C reference manuals
C48	high altitude cruise speed	$V_{cr,2}$	knots (CAS)	A/C reference manuals
C49	Mach limit for cruise	M_{cr}	dimensionless	A/C reference manuals
C51	low altitude descent speed	$V_{des,1}$	knots (CAS)	A/C reference manuals
C52	high altitude descent speed	$V_{des,2}$	knots (CAS)	A/C reference manuals
C53	Mach limit for descent	M_{des}	dimensionless	A/C reference manuals

Table 3.2.1-1: Coefficient Block Cells (continued)

Cell	Name	Symbol	Units	Source
C55	Maximum altitude at MTOW and ISA	Hmax	feet	A/C reference manuals
C56	Weight gradient for maximum altitude	G_w	feet/kg	A/C reference manuals
C57	Temperature gradient for maximum altitude	G_t	feet/deg. C	A/C reference manuals
C60	Cruise fuel correction factor	C_{fcr}	dimensionless	calculated as described in Section 4
C62	Approach thrust correction factor	$C_{Tdes, app}$	dimensionless	calculated as described in Section 4
C63	Landing thrust correction factor	$C_{Tdes, ld}$	dimensionless	calculated as described in Section 4
C64	parasitic drag coefficient, approach configuration	$C_{D0, AP}$	dimensionless	calculated as described in Section 4
C65	induced drag coefficient, approach configuration	$C_{D2, AP}$	dimensionless	calculated as described in Section 4
C66	parasitic drag coefficient, landing configuration	$C_{D0, LD}$	dimensionless	calculated as described in Section 4
C67	induced drag coefficient, landing configuration	$C_{D2, LD}$	dimensionless	calculated as described in Section 4

3.2.2 Selected Trajectory Block

The Selected Trajectory Block holds the data corresponding to the selected reference trajectory. The data is copied from the particularly Reference Trajectory Block that corresponds to the profile selected by the user in cell C2. This allows for the BADA.XLS spreadsheet and the charts to have a constant link point when importing reference profile information.

The Selected Trajectory Block consists of five columns of the <A/C>.XLS spreadsheet (columns D through I) and is shown in Figure 3.2.2-1 below. Rows 1 through 7 contain header information that applies globally to the profile. Rows 8 through 54 contain distance, time, fuel and ROCD data as a function of flight level.

Figure 3.2.2-1: Selected Trajectory Block

	D	E	F	G	H	I
1			**selected trajectory**	**CL1**	climb	
2			delta T	0.00	C	
3	min FL:	15	mass	190.00	tonnes	
4	max dist:	114	max spd KCAS	310	310	
5	max FL:	440		0.820	Mach	
6	**REF.**	**FLIGHT**	**DIST**	**TIME**	**FUEL**	**ROCD**
7	**LEVEL**	**LEVEL**	**[n. miles]**	**[min]**	**[kg]**	**[fpm]**
8		**450**	#N/A	#N/A	#N/A	#N/A
9	440	440	114.00	16.00	4500.00	#N/A
10		430	#N/A	#N/A	#N/A	#N/A
11	420	420	97.00	13.00	4150.00	#N/A
12		410	#N/A	#N/A	#N/A	#N/A
13	400	400	84.00	12.00	3850.00	#N/A
14		390	#N/A	#N/A	#N/A	#N/A
15	380	380	75.00	11.00	3600.00	#N/A
16		370	#N/A	#N/A	#N/A	#N/A
17	360	360	67.00	10.00	3400.00	#N/A
18		350	#N/A	#N/A	#N/A	#N/A

	D	E	F	G	H	I
46		70	#N/A	#N/A	#N/A	#N/A
47		60	#N/A	#N/A	#N/A	#N/A
48		50	#N/A	#N/A	#N/A	#N/A
49		40	#N/A	#N/A	#N/A	#N/A
50		30	#N/A	#N/A	#N/A	#N/A
51		20	#N/A	#N/A	#N/A	#N/A
52	15	**15**	0.00	0.00	0.00	#N/A
53		**10**	#N/A	#N/A	#N/A	#N/A
54		**0**	#N/A	#N/A	#N/A	#N/A

Individual cells in header of the Selected Trajectory Block are defined below.

E3	name:	minimum flight level
	units:	100 feet
	symbol:	$(h_{FL})_{min}$
	description:	a constant associated with each reference trajectory; it indicates the flight level corresponding to the beginning of climb or the bottom of descent; it is copied from the Reference Trajectory Block
	Excel definition:	E3 = INDEX($J$5:$FN$5, MATCH($G$1,$J$2:$FN2,0)))
E4	name:	maximum distance
	units:	nautical miles
	symbol:	X_{max}
	description:	the maximum distance at the top of climb or top of descent of the reference profile; it is copied from the Reference Trajectory Block for the selected trajectory and the row corresponding to the maximum flight level. This field is empty when a cruise trajectory is selected
	Excel definition:	E4 =IF($H$1="cruise"," ", INDEX($F8:$F54,MATCH(MAX($D8:$D54), $D$8:$D$54,0)))
E5	name:	maximum flight level
	units:	100 feet
	symbol:	$(h_{FL})_{max}$
	description:	the maximum flight level at the top of climb or top of descent;
	Excel definition:	E5 = MAX($D$8:$D$54)
G1	name:	trajectory identifier
	units:	string
	symbol:	not applicable
	description:	a strong constant associated with each reference trajectory and used to identify the reference trajectory; it is copied from the Coefficient Block where it is input by the user
	Excel definition:	G1 = $C$2

G2	name:	temperature deviation from ISA	
	units:	K	
	symbol:	ΔT	
	description:	a constant associated with each reference trajectory; it is copied from the selected Reference Trajectory Block	
	Excel definition:	G2	=INDEX($J$2:$FN$2, MATCH($G$1,$J$2:$FN$2,0)-2)
H1	name:	trajectory type	
	units:	string	
	symbol:	not applicable	
	description:	a string constant, either “climb”, “descent” or “cruise” associated with each reference trajectory; it is copied from the selected Reference Trajectory Block	
	Excel definition:	H1	= INDEX($J$3:$FN$3, MATCH($G$1,$J$2:$FN$2,0)-2)
G3	name:	initial trajectory mass	
	units:	tonnes	
	symbol:	m_{traj}	
	description:	a constant associated with each reference trajectory, it represents the aircraft mass at the beginning of the climb or descent; it is copied from the selected Reference Trajectory Block	
	Excel definition:	G3	=INDEX($J$3:$FN$3, MATCH($G$1,$J$2:$FN$2,0)-2)
G4	name:	constant CAS for speed law below 10,000 ft	
	units:	knots	
	symbol:	$(V_{CAS})_{< FL100}$	
	description:	a constant associated with each reference trajectory, it represents the value of CAS maintained during the climb or descent below 10,000 ft; it is copied from the selected Reference Trajectory Block	
	Excel definition:	G4	=INDEX($J$4:$FN$4, MATCH($G$1,$J$2:$FN$2,0)-2)

H4	name:	constant CAS for speed law above 10,000 ft
	units:	knots
	symbol:	$(V_{CAS})_{> FL100}$
	description:	a constant associated with each reference trajectory, it represents the value of CAS maintained during the climb or descent above 10,000 ft; it is copied from the selected Reference Trajectory Block
	Excel definition:	H4 =INDEX($J$4:$FN$4, MATCH($G$1,$J$2:$FN$2,0)-1)
G5	name:	maximum Mach number
	units:	dimensionless
	symbol:	M_{max}
	description:	a constant associated with each reference trajectory, it represents the maximum Mach number during climb or descent; it is copied from the selected Reference Trajectory Block
	Excel definition:	G5 =INDEX($J$5:$FN$5, MATCH($G$1,$J$2:$FN$2,0)-2)

Columns in the Selected Trajectory Block are defined below

D	name:	reference flight level
	units:	100 feet
	symbol:	h_{FL}
	description:	shows the flight levels where there is reference information available;
	Excel definition:	D{n} = IF(ISNA(F{n}, " ", E{n})
E	name:	flight level
	units:	100 feet
	symbol:	h_{FL}
	description:	independent variable for profile calculation varies from 0 to 450;

	Excel definition:	E8 = 450 for 9 ≤n ≤51 E{n} = E{n-1}-10 E52 = 15 E53 = 10 E54 = 0
F	name:	reference distance to climb/descend
	units:	nautical miles
	symbol:	X_{ref}
	description:	value copied from the Reference Trajectory Block for the selected reference trajectory; the value is explicitly set to zero for the initial flight level and is set to the Excel “not available” value for those flight levels for which reference information is not available
	Excel definition:	F{n} =IF($E9=$E$3,0, IF(INDEX($K9:$FN9, MATCH($G$1,$K$2:$FN$2,0))=0, NA(),INDEX($K9:$FN9, MATCH($G$1,$K$2:$FN$2,0)-2)))
G	name:	reference time to climb/descend
	units:	min
	symbol:	t_{erf}
	description:	value copied from Reference Trajectory Block for the selected reference trajectory; value is explicitly set to zero for the initial flight level and is set to the Excel “not available” for those flight levels for which reference information is not available
	Excel definition:	G{n} =IF($E9=$E$3,0, IF(INDEX($K9:$FN9, MATCH($G$1,$K$2:$FN$2,0))=0, NA(),INDEX($K9:$FN9, MATCH($G$1,$K$2:$FN$2,0)-1)))
H	name:	reference fuel to climb/descend
	units:	kg
	symbol:	w_{ref}
	description:	value copied from Reference Trajectory Block for the selected reference trajectory; value is explicitly set to zero for the initial flight level and is set to the Excel “not available” for those flight levels for which reference information is not available

Excel definition: H{n} =IF($E9=$E$3,0,
IF(INDEX($K9:$FN9,
MATCH($G$1,$K$2:$FN$2,0))=0,NA(),
INDEX($K9:$FN9,
MATCH($G$1,$K$2:$FN$2,0))))

I

name: reference ROCD
units: fpm
symbol: dh/dt
description: value copied from Reference Trajectory Block for the selected reference trajectory; value is explicitly set to the Excel "not available" for those flight levels for which reference information is not available

Excel definition: I{n} =IF(INDEX($K9:$FN9,
MATCH($G$1,$K$2:$FN$2,0)+1)=0,
NA(),INDEX($K9:$FN9,
MATCH($G$1,$K$2:$FN$2,0)+1))

3.2.3 Reference Trajectory Blocks for Climb and Descent Profiles

A Reference Trajectory Block holds the data corresponding to a reference climb ,cruise or descent trajectory. There are several such blocks in each <A/C>.XLS spreadsheet corresponding to profiles for different conditions of mass, speed and temperature. For the cruise data, only one block (the last one) is available. This profile has a different format and will be described in Section 3.2.4.

Each Reference Trajectory Block consists of four columns of the <A/C>.XLS spreadsheet. An example is shown in Figure 3.2.3-1 below. Rows 1 through 7 contain header information that applies globally to the profile. Rows 8 through 54 contain distance, time, fuel and ROCD data as a function of flight level.

All fields that require data entry by the user are shown in blue on the screen.

Figure 3.2.3-1: Reference Trajectory Block (Climb and Descent)

	J	K	L	M	N
1	trajectory:	nom. spd/min mass/ISA		B747	
2	delta T	0	deg. C	CL1	
3	mass	190	tonnes	climb	
4	max CAS	310	310	knots	
5	max Mach	0.820	minimum FL	15	
6	LEVEL	DIST	TIME	FUEL	ROCD
7		[n. miles]	[min]	[kg]	[fpm]
8	450				
9	440	114.0	16.0	4500	
10	430				
11	420	97.0	13.0	4150	
12	410				
13	400	84.0	12.0	3850	
14	390				
15	380	75.0	11.0	3600	
16	370				
17	360	67.0	10.0	3400	
18	350				
19	340	61.0	9.0	3200	
20	330				

Individual cells in header of the Reference Trajectory Block are defined below. Note that the Column letter is valid only for the example shown in Figure 3.2.3-1.

K1	name:	trajectory name
	units:	string
	symbol:	not applicable
	description:	free text used to describe the trajectory;
	Excel definition:	user input

K2	name:	temperature deviation from ISA
	units:	K
	symbol:	ΔT
	description:	a constant associated with each reference trajectory; it is input by the user;
	Excel definition:	user input

K3	name:	initial trajectory mass
	units:	tonnes
	symbol:	m_{traj}
	description:	a constant associated with each reference trajectory, it represents the aircraft mass at the beginning of the climb or descent; it is input by the user;
	Excel definition:	user input

K4	name:	constant CAS for speed law below 10,000 ft
	units:	knots
	symbol:	$(V_{CAS})_{< FL100}$
	description:	a constant associated with each reference trajectory, it represents the value of CAS maintained during the climb or descent below 10,000 ft; it is input by the users;
	Excel definition:	user input

K5	name:	maximum Mach number
	units:	dimensionless
	symbol:	M_{max}
	description:	a constant associated with each reference trajectory, it represents the maximum Mach number during climb or descent; it is input by the users;
	Excel definition:	user input
L4	name:	constant CAS for speed law above 10,000 ft
	units:	knots
	symbol:	$(V_{CAS})_{> FL100}$
	description:	a constant associated with each reference trajectory, it represents the value of CAS maintained during the climb or descent above 10,000 ft; it is input by the users;
	Excel definition:	user input
M1	name:	aircraft type identifier
	units:	string
	symbol:	not applicable
	description:	a string constant associated with each aircraft; it is copied from the Coefficient Block where it is input by the user;
	Excel definition:	M1 = $C$1
M2	name:	trajectory identifier
	units:	string
	symbol:	not applicable
	description:	a string constant associated with each reference trajectory and used to identify the reference profile; it is input by the user;
	Excel definition:	user input

M3	name:	trajectory type
	units:	string
	symbol:	not applicable
	description:	a string constant, either "climb", "descent" or "cruise" associated with each reference trajectory; it is input by the user;
	Excel definition:	user input

M5	name:	minimum flight level
	units:	100 feet
	symbol:	$(h_{FL})_{min}$
	description:	a constant associated with each reference trajectory; it indicates the flight level corresponding to the beginning of climb or the bottom of descent; it is input by the user;
	Excel definition:	user input

Columns in the Reference Trajectory Block are defined below:

J	name:	flight level
	units:	100 feet
	symbol:	h_{FL}
	description:	independent variable for trajectory calculation that varies from 0 to 450; it is copied from the Selected Trajectory Block
	Excel definition:	J{n} = $E{n}

K	name:	reference distance to climb/descend
	units:	nautical miles
	symbol:	X_{ref}
	description:	reference values input by user;
	Excel definition:	user input

L	name:	reference time to climb/descend
	units:	min
	symbol:	t_{ref}
	description:	reference values input by user;
	Excel definition:	user input
M	name:	reference fuel to climb/descend
	units:	kg
	symbol:	w_{ref}
	description:	reference values input by user;
	Excel definition:	user input
N	name:	reference ROCD
	units:	fpm
	symbol:	dh/dt
	description:	reference values input by user. This value is optional. It should be entered whenever data is available, but it is not essential for the modelling process.
	Excel definition:	user input

3.2.4 Reference Trajectory Blocks for Cruise Profiles

The Cruise Reference Trajectory Block holds the data corresponding to a reference cruise trajectory. There is usually only one block in each <A/C>.XLS spreadsheet corresponding to a profile for nominal mass, nominal speed and ISA.

The Cruise Reference Trajectory Block consists of three columns of the <A/C>.XLS spreadsheet. An example is shown in Figure 3.2.4-1 below. Rows 1 through 7 contain header information that applies globally to the profile. Rows 8 through 54 contain distance, time, fuel and ROCD data as a function of flight level.

All fields that require data entry by the user are shown in blue on the screen.

Figure 3.2.4-1: Reference Trajectory Block (Climb and Descent)

	CG	CH	CI	CJ
1	**trajectory:**	**cruise**		**B73S**
2	**delta T**	**0**	**deg. C**	**CRZ1**
3	**mass**	**54**	**tonnes**	**cruise**
4	**max CAS**	**300**	**300**	**knots**
5	**max Mach**	**0.74**	**minimum FL**	**0**
6	**LEVEL**	**FUEL CONS.**	***	***
7		**[kg/hr]**	***	***
8	450			
9	440			
10	430			
11	420			
12	410			
13	400			
14	390			
15	380			
16	370			
17	360	2274	1	1
18	350			
19	340	2290	1	1
20	330			
21	320	2354	1	1

Individual cells in header of the Reference Trajectory Block are defined below. Note that the Column letter is valid only for the example shown in Figure 3.2.4-1.

CH1	name:	trajectory name
	units:	string
	symbol:	not applicable
	description:	free text used to describe the trajectory;
	Excel definition:	user input

CH2	name:	temperature deviation from ISA
	units:	K
	symbol:	ΔT
	description:	a constant associated with each reference trajectory; it is input by the user;
	Excel definition:	user input

CH3	name:	trajectory mass
	units:	tonnes
	symbol:	m_{traj}
	description:	a constant associated with each reference trajectory
	Excel definition:	user input

CH4	name:	constant CAS for speed law below 10,000 ft
	units:	knots
	symbol:	$(V_{CAS})_{< FL100}$
	description:	a constant associated with each reference trajectory, it represents the value of CAS maintained below 10,000 ft; it is input by the users;
	Excel definition:	user input

CH5	name:	maximum Mach number
	units:	dimensionless
	symbol:	M_{max}
	description:	a constant associated with each reference trajectory, it represents the maximum Mach number; it is input by the users;
	Excel definition:	user input

CI4	name:	constant CAS for speed law above 10,000 ft
	units:	knots
	symbol:	$(V_{CAS})_{> FL100}$
	description:	a constant associated with each reference trajectory, it represents the value of CAS maintained above 10,000 ft; it is input by the users;
	Excel definition:	user input
CJ1	name:	aircraft type identifier
	units:	string
	symbol:	not applicable
	description:	a string constant associated with each aircraft; it is copied from the Coefficient Block where it is input by the user;
	Excel definition:	CJ1 = $C$1
CJ2	name:	trajectory identifier
	units:	string
	symbol:	not applicable
	description:	a string constant associated with each reference trajectory and used to identify the reference profile; it is input by the user;
	Excel definition:	user input
CJ3	name:	trajectory type
	units:	string
	symbol:	not applicable
	description:	a string constant, must be set to “cruise”
	Excel definition:	user input
CJ5	name:	minimum flight level
	units:	100 feet
	symbol:	$(h_{FL})_{min}$
	description:	a constant set to 0 (zero)
	Excel definition:	user input

Columns in the Reference Trajectory Block are defined below:

CG	name:	flight level
	units:	100 feet
	symbol:	h_{FL}
	description:	independent variable for trajectory calculation that varies from 0 to 450; it is copied from the Selected Trajectory Block
	Excel definition:	J{n} = $E{n}

CH	name:	fuel consumption
	units:	kg/hr
	symbol:	f_{cruise}
	description:	reference values input by user;
	Excel definition:	user input

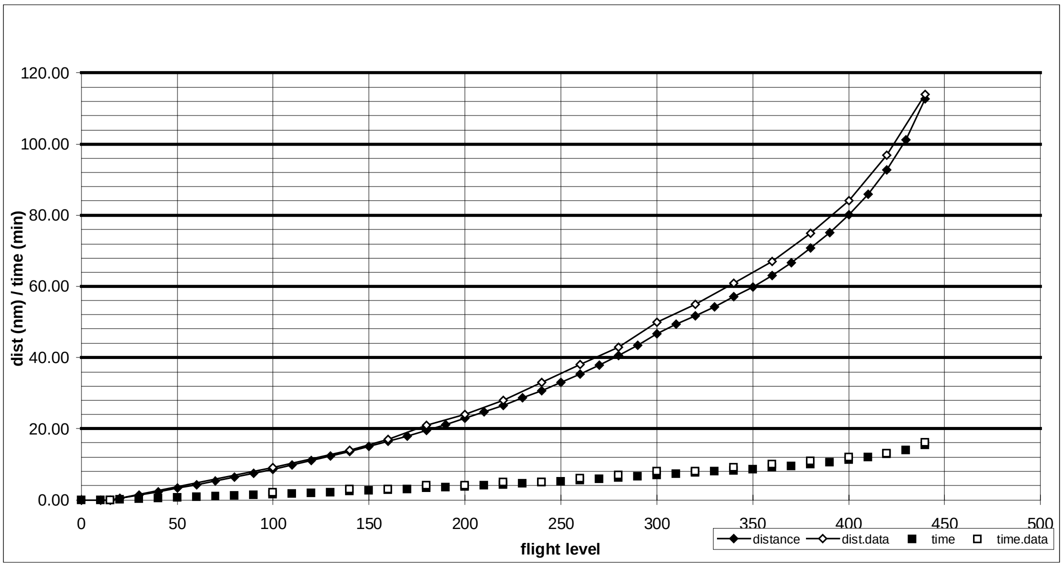
The columns **CI** and **CJ** are not empty. Behind every value entered in the **CH** column, a 1 (one) is entered in the corresponding rows in the **CI** and **CJ** columns. This has to be done for compatibility reasons. Note again that the column identifiers are only given for the example in Figure 3.2.4-1.

3.3 TRAJECT.XLS

The TRAJECT.XLS spreadsheet has an embedded chart that shows a plot of the predicted climb or descent trajectory in comparison with the corresponding reference trajectory. An example is shown in Figure 3.3-1 below.

Figure 3.3-1: TRAJECT.XLS Spreadsheet

speeds	**law**	**B747**		errors	dist[nm]	dist[%]	alt[ft]	alt[%]			
310	knots			max	**4.3**	**3.8**	**1376**	**3.1**	mass	**190**	tonnes
310	knots	Trajectory:	**CL1**	rms	**2.8**	**2.4**	**855**	**1.9**	ISA	**0**	deg.C
0.82	Mach		**climb**				Figure of Merit:	**2.8**			



The x-axis of the plot is the flight level while the y-axis is used for both the distance to climb/descend in nautical miles and the time to climb/descend in minutes.

The predicted trajectory data points are shown using the solid black symbols while the reference trajectory is depicted using the solid symbols.

Labels at the top left of the plot indicate the aircraft type (B747), trajectory identifier (CL1) and trajectory type (climb). Also are indicated the speed law parameters for the trajectory, in this case a constant CAS of 310 knots below 10,000 ft, a constant CAS of 310 knots above 10,000 ft with a Mach limit of 0.78. Labels at the top right indicate the assumed aircraft mass at the beginning of the trajectory (190 tonnes) and the atmospheric conditions (ISA+0).

Measurements of the error between the calculated and reference trajectories are summarised at the top (middle). The maximum and root-mean-square (rms) errors in both distance and altitude are given. These errors are expressed in both absolute terms and normalised with respect to the maximum distance or maximum altitude. In addition, the figure-of-merit for the fit of the prediction profile to the reference trajectory is specified. This figure-of-merit is the average of the four normalised error terms.

The TRAJECT.XLS chart has two external links. One of these links is to the BADA.XLS spreadsheet, which is used for importing the trajectory identifiers, the predicted trajectory data points, the trajectory conditions (e.g. speed, mass) and the error values. The other link is to the appropriate <A/C>.XLS spreadsheet which is used for importing the reference trajectory data points.

The use of the links for defining the four plotted data series is summarised in Table 3.3-1 below. Table 3.3-2 summarises the links used for the various labels.

Table 3.3-1: Data Series Definitions for TRAJECT.XLS

Series Number	Legend Label	Description	Excel Definition
1	distance	predicted distance to climb or descend in nautical miles	x values: BADA.XLS!$AK$8:$AK$54 y values: BADA.XLS!$AM$8:$AM$54
2	dist. data	reference distance to climb or descent in nautical miles	x values: BADA.XLS!$AK$8:$AK$54 y values: <A/C>.XLS!$F$8:$F$54
3	time	predicted time to climb or descent in minutes	x values: BADA.XLS!$AK$8:$AK$54 y values: BADA.XLS!$AN$8:$AN$54
4	time data	reference time to climb or descent in minutes	x values: BADA.XLS!$AK$8:$AK$54 y values: <A/C>.XLS!$G$8:$G$54

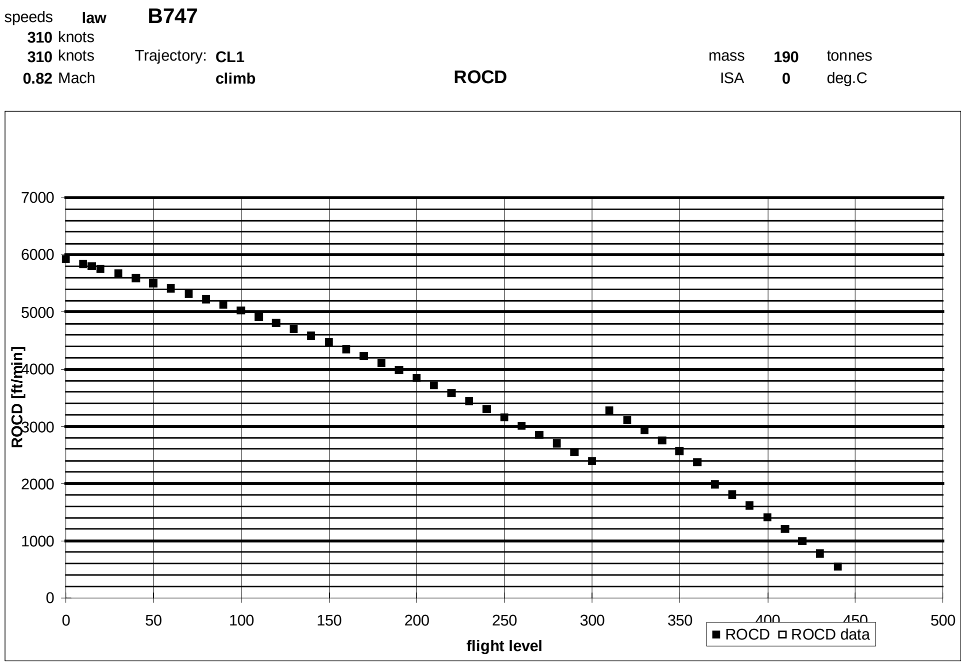
Table 3.3-2: Label Definitions for TRAJECT.XLS

Description	Location	Value in Figure 3.3-1	Excel Definition
aircraft type identifier	$C$1	B747	BADA.XLS!$AJ$2
trajectory identifier	$D$3	CL1	BADA.XLS!$AK$2
trajectory type	$D$4	climb	BADA.XLS!$AL$2
speed law CAS < FL100 [knots]	$A$2	310	BADA.XLS!$I$3
speed law CAS > FL100 [knots]	$A$3	310	BADA.XLS!$I$4
maximum Mach number [-]	$A$4	.82	BADA.XLS!$I$5
initial mass [tonnes]	$L$2	190	BADA.XLS!$Q$5
temperature difference from ISA [deg. C]	$L$3	0	BADA.XLS!$A$5
maximum distance error [nautical miles]	$G$2	4.3	BADA.XLS!$AM$3
normalized maximum distance error [%]	$H$2	3.8	BADA.XLS!$AN$3
maximum altitude error [ft]	$I$2	1376	BADA.XLS!$AO$3
normalised maximum altitude error [%]	$J$2	3.1	BADA.XLS!$AP$3
root-mean-square distance error [nautical miles]	$G$3	2.8	BADA.XLS!$AM$4
normalised root-mean-square distance error [%]	$H$3	2.4	BADA.XLS!$AN$4
root-mean-square altitude error [ft]	$I$3	855	BADA.XLS!$AO$4
normalised root-mean-square altitude error [%]	$J$3	1.9	BADA.XLS!$AP$4
Figure-of-Merit	$K$4	2.8	BADA.XLS!$AM$5

3.4 ROCD.XLS

The ROCD.XLS spreadsheet contains a chart that shows a plot of the predicted rate of climb or descent and the reference rate of climb or descent if available. The reference rate of climb or descent is an optional field in the trajectory block and usually only available when the reference data comes from an aircraft performance program instead of a flight Manual. An example of an ROCD.XLS spreadsheet is shown in Figure 3.4-1 below.

Figure 3.4-1: ROCD.XLS Chart



The x-axis of the plot is the flight level while the y-axis is used for the rate of climb or descent in feet per minute [fpm]. The predicted data points are shown using the solid black symbols. The reference data points (if available) are shown in white

Labels at the top left of the plot indicate the aircraft type (B747), trajectory identifier (CL1) and trajectory type (climb). Also indicated are the speed law parameters for the trajectory, in this case a constant CAS of 310 knots (both below and above 10,000 ft) with a Mach limit of 0.82. Labels at the top right indicate the assumed aircraft mass at the beginning of the trajectory (190 tonnes) and the atmospheric conditions (ISA+0). The ROCD.XLs chart has two external links. One link is to the BADA.XLS spreadsheet, which is used for importing the trajectory identifiers, the predicted rate of climb/descent data points, and the trajectory conditions (e.g. speed, mass). The other link is to the <A/C>.XLS, which is used for importing the ROCD reference data.

Table 3.4-1: Data Series Definitions for ROCD.XLS

Series Number	Legend Label	Description	Excel Definition
1	ROCD	predicted ROCD in fpm	x values: BADA.XLS!$AK$8:$AK$54 y values: BADA.XLS!$AI$8:$AI$54
2	ROCD data.	reference ROCD in fpm	x values: BADA.XLS!$AK$8:$AK$54 y values: <A/C>.XLS!$I$8:$I$54

It is important to note that the rate of climb/descent plotted is that calculated using the constant speed coefficient method. It thus represents the rate of climb or descent achieved under conditions of either constant CAS or constant Mach number.

Table 3.4-2 summarises the links used for the various labels.

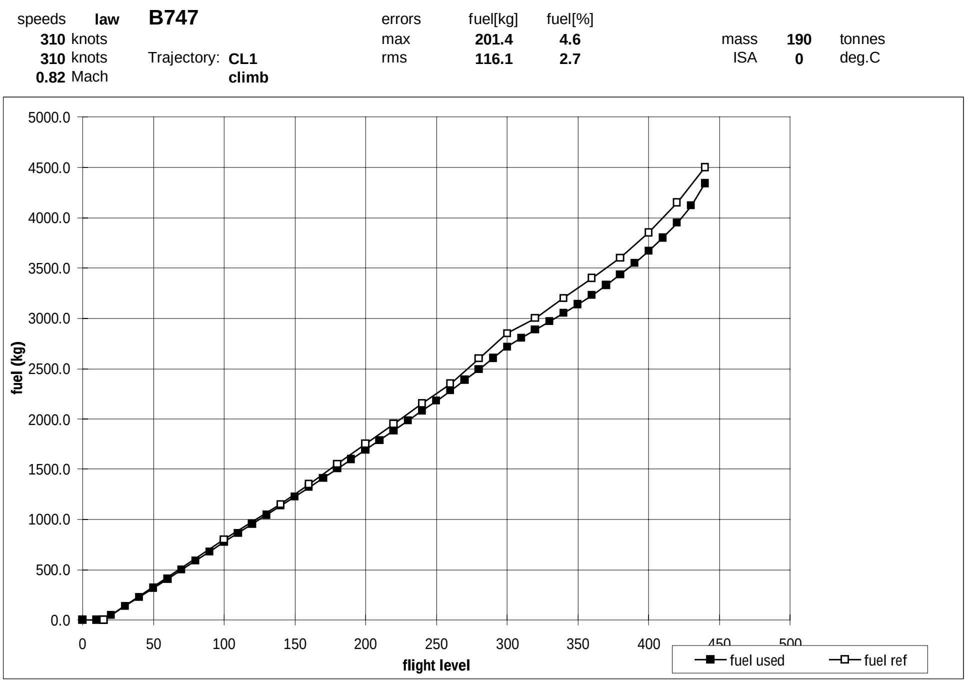
Table 3.4-2: Label Definitions for ROCD.XLS

Description	Location	Value in Figure 3.4-1	Excel Definition
aircraft type identifier	$D$1	B747	BADA.XLS!$AJ$2
trajectory identifier	$E$3	CL1	BADA.XLS!$AK$2
trajectory type	$E$4	climb	BADA.XLS!$AL$2
speed law CAS < FL100 [knots]	$B$2	310	BADA.XLS!$I$3
speed law CAS > FL100 [knots]	$B$3	310	BADA.XLS!$I$4
maximum Mach number	$B$4	.82	BADA.XLS!$I$5
initial mass [tonnes]	$L$3	190	BADA.XLS!$Q$5
temperature difference from ISA [deg. C]	$L$4	0	BADA.XLS!$A$5

3.5 FUEL.XLS

The FUEL.XLS spreadsheet has an embedded chart that shows a plot of the predicted fuel consumption in climb or descent in comparison with the corresponding reference fuel consumption. An example is shown in Figure 3.5-1 below.

Figure 3.5-1: FUEL.XLS Chart



The x-axis of the plot is the flight level while the y-axis is used for both the predicted and reference fuel consumption.

The predicted profile data points are shown using the solid black symbols while the reference trajectory is depicted using the hollow symbols.

Labels at the top centre of the plot indicate the aircraft type (B747), trajectory identifier (CL1) and trajectory type (climb).

Labels at the bottom left indicate the speed law parameters for the profile, in this case a constant CAS of 310 knots (below and above FL 100) with a Mach limit of 0.82. Further labels at the bottom left indicate the assumed aircraft mass at the beginning of the profile (190 tonnes) and the atmospheric conditions (ISA+0).

Measurements of the error between the calculated and reference fuel are summarised at the top right. The maximum and root-mean-square (rms) errors are given in both absolute terms (kg) and normalised with respect to the total reference fuel consumption.

The FUEL.XLS chart has two external links. One of these links is to the BADA.XLS spreadsheet, which is used for importing the trajectory identifiers, the predicted trajectory fuel consumption, the trajectory conditions (e.g. speed, mass) and the error values. The other link is to the appropriate <A/C>.XLS spreadsheet which is used for importing the reference fuel consumption.

The use of the links for defining the two plotted data series is summarised in Table 3.5-1 below. Table 3.5-2 summarises the links used for the various labels.

Table 3.5-1: Data Series Definitions for FUEL.XLS

Series Number	Legend Label	Description	Excel Definition
1	fuel used	predicted fuel consumption to climb or descend in kg	x values: BADA.XLS!$AK$8:$AK$54 y values: BADA.XLS!$AT$8:$AT$54
2	fuel ref.	reference fuel consumption to climb or descent in kg	x values: BADA.XLS!$AK$8:$AK$54 y values: <A/C>.XLS!$H$8:$H$54

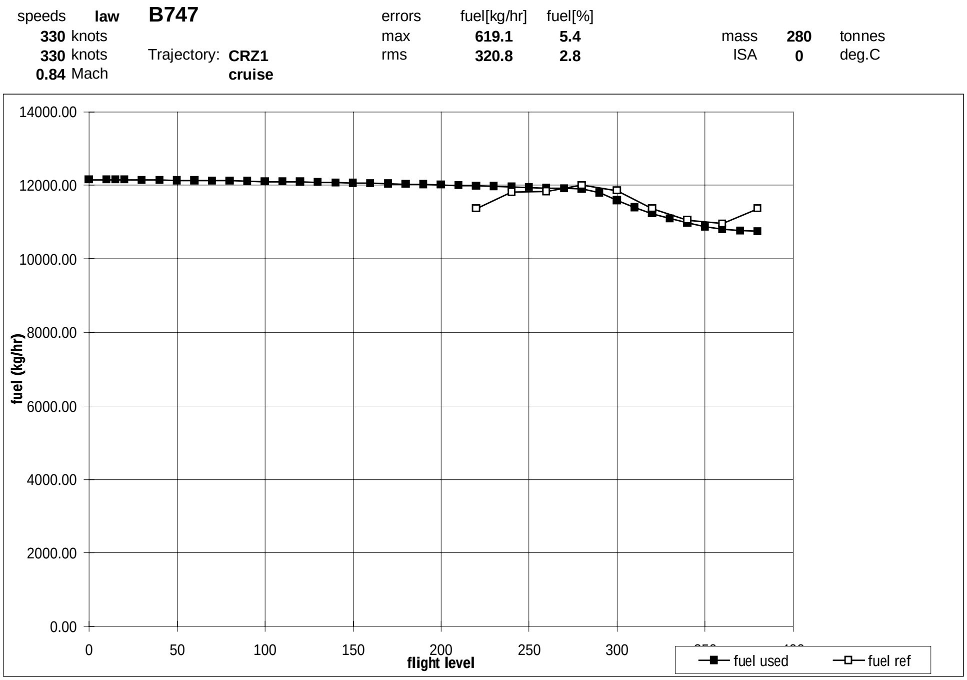
Table 3.5-2: Label Definitions for FUEL.XLS

Description	Location	Value in Figure 3.5-1	Excel Definition
aircraft type identifier	$D$1	B747	BADA.XLS!$AJ$2
trajectory identifier	$E$3	CL1	BADA.XLS!$AK$2
trajectory type	$E$4	climb	BADA.XLS!$AL$2
speed law CAS < FL100 [knots]	$B$2	310	BADA.XLS!$I$3
speed law CAS > FL100 [knots]	$B$3	310	BADA.XLS!$I$4
maximum Mach number [-]	$B$4	.82	BADA.XLS!$I$5
initial mass [tonnes]	$L$2	190.0	BADA.XLS!$Q$5
temperature difference from ISA [deg. C]	$L$3	0	BADA.XLS!$A$5
maximum fuel error [kg]	$H$2	201.4	BADA.XLS!$AV$2
root-mean-square fuel error [kg]	$H$3	116.1	BADA.XLS!$AV$3
normalised maximum fuel error [%]	$I$2	4.6	BADA.XLS!$AV$4
normalised root-mean-square fuel error [%]	$I$3	2.7	BADA.XLS!$AV$5

3.6 FUEL_CRZ.XLS

The FUEL_CRZ.XLS spreadsheet has an embedded chart that shows a plot of the predicted cruise fuel flow in comparison with the corresponding reference cruise fuel flow. An example is shown in Figure 3.6-1 below.

Figure 3.6-1: FUEL_CRZ.XLS Chart



The x-axis of the plot is the flight level while the y-axis is used for both the predicted and reference fuel flow.

The predicted profile data points are shown using the solid black symbols while the reference trajectory is depicted using the hollow symbols.

Labels at the top centre of the plot indicate the aircraft type (B747), trajectory identifier (CRZ1) and trajectory type (cruise). This chart only gives relevant information when a CRZ trajectory has been selected.

Labels at the bottom left indicate the speed law parameters for the profile, in this case a constant CAS of 330 knots (below and above FL 100) with a Mach limit of 0.84. Further labels at the bottom left indicate the assumed aircraft mass for the profile (280 tonnes) and the atmospheric conditions (ISA+0).

Measurements of the error between the calculated and reference fuel are summarised at the top right. The maximum and root-mean-square (rms) errors are given in both absolute terms (kg/hr) and normalised with respect to the total reference fuel flow.

The FUEL_CRZ.XLS chart has two external links. One of these links is to the BADA.XLS spreadsheet, which is used for importing the trajectory identifiers, the predicted trajectory fuel consumption, the trajectory conditions (e.g. speed, mass) and the error values. The other link is to the appropriate <A/C>.XLS spreadsheet which is used for importing the reference fuel flow.

The use of the links for defining the two plotted data series is summarised in Table 3.6-1 below. Table 3.6-2 summarises the links used for the various labels.

Table 3.6-1: Data Series Definitions for FUEL_CRZ.XLS

Series Number	Legend Label	Description	Excel Definition
1	fuel used	predicted cruise fuel flow in kg/hr	x values: BADA.XLS!$AK$8:$AK$54 y values: BADA.XLS!$AX$8:$AX$54
2	fuel ref.	reference cruise fuel flow in kg/hr	x values: BADA.XLS!$AK$8:$AK$54 y values: <A/C>.XLS!$F$8:$F$54

Table 3.6-2: Label Definitions for FUEL_CRZ.XLS

Description	Location	Value in Figure 3.6-1	Excel Definition
aircraft type identifier	$D$1	B747	BADA.XLS!$AJ$2
trajectory identifier	$E$3	CRZ1	BADA.XLS!$AK$2
trajectory type	$E$4	cruise	BADA.XLS!$AL$2
speed law CAS < FL100 [knots]	$B$2	330	BADA.XLS!$I$3
speed law CAS > FL100 [knots]	$B$3	330	BADA.XLS!$I$4
maximum Mach number	$B$4	.84	BADA.XLS!$I$5
mass [tonnes]	$L$2	280.0	BADA.XLS!$Q$5
temperature difference from ISA [deg. C]	$L$3	0	BADA.XLS!$A$5
maximum fuel error [kg/hr]	$H$2	201.4	BADA.XLS!$BA$2
root-mean-square fuel error [kg/hr]	$H$3	116.1	BADA.XLS!$BA$3
normalised maximum fuel error [%]	$I$2	4.6	BADA.XLS!$BA$4
normalised root-mean-square fuel error [%]	$I$3	2.7	BADA.XLS!$BA$5

4. PROCEDURES FOR USE

This section describes how the BADA Excel spreadsheets are used for the preparation of a BADA aircraft model. This preparation process consists of the following eight stages, each of which is separately described by a subsection below.

(i) Acquisition of Reference Information

(ii) Initialisation of Aircraft Modelling Report

(iii) Initialisation of a <A/C>.XLS Spreadsheet

(iv) Determination of Thrust and Drag Coefficients

(v) Determination of Thrust Temperature Coefficients

(vi) Determination of Fuel Flow Coefficients

(vii) Dynamic Maximum Altitude parameters

(viii) Buffeting Parameters

(ix) Update of APF and OPF Files

(x) Create PTF file

(xi) Completion of Aircraft Modelling Report

(xii) Use of SOLV.XLS spreadsheet

4.1 Acquisition of Reference Information

The first step in the preparation of a BADA aircraft model is the acquisition of reference information. The main source of information is A/C Operation Manuals as published by the manufacturer or by operating airlines. In particular, the A/C Operation Manuals contain a number of reference climb and descent profiles which specify, in either tabular or graphical form, the climb and descent performance of the aircraft at various mass, speed and temperature conditions. It is primarily these reference profiles which are used for the generation of the BADA thrust, drag and fuel coefficients. Other sources of information are the aircraft performance programs that are available to APO. Currently these progrmas are available for the Airbus family (PEP program) and ATR family (FOS program). These programs offer the user a level of flexibility and accuracy that cannot be matched by the Flight Manual. They also provide the user with a number of parameters that are normally not available (drag coefficients, thrust level, angle of attack etc.) Reference data from these programs should be used whenever available. User Manuals for both programs are available from the APO library.

It is possible to generate BADA coefficients using only one reference climb and one reference descent profile. However, in order to have coefficients that can robustly represent the aircraft behaviour over a variety of conditions the following number of profiles is recommended:

(a) one descent profile at ISA conditions for a nominal mass and speed;

(b) three climb profiles at ISA conditions for the nominal speed and representing minimum, nominal and maximum mass conditions;

(c) three climb profiles at ISA conditions for an alternative speed and representing minimum, nominal and maximum mass conditions;

(d) three climb profiles at ISA+10 conditions for the nominal speed and representing minimum, nominal and maximum mass conditions; and,

(e) one climb profile at ISA+20 conditions for the nominal speed and mass.

(f) one cruise profile for the nominal speed, nominal weight and ISA conditions.

Currently, the reference information is obtained by members of RTO and APO CoE through *adhoc* contacts with airlines and national certification agencies. All reference manuals that are obtained, are maintained by APO within an A/C Performance Library.

A secondary source of information is *Jane's All the World's Aircraft* which is published annually. Jane's is suitable for providing information such as maximum weights, dimensions, and maximum operating speeds but it does not provide reference climb or descent profiles. Copies of *Jane's All the World's Aircraft* for each year are also maintained by APO within an A/C Performance Library.

It is important to note that BADA provides just one aircraft model for each aircraft type as distinguished by an ICAO Aircraft Type Designator [RD3]. Each ICAO designator may be used for several series of aircraft. As an example, the H25B designator represents the following series of the Hawker Siddely 125 aircraft:

Series 1/1A/1B
Series 2
Series 3/3A/3B
Series 400A/B
Series 600A/B
Series 700A/B
Series 800A/B

Each of the different series will have different performance due to changes in the airframe (e.g. extended fuselage) or engines.

The first decision for the modelling process is thus to decide which aircraft series to base the BADA model upon. If possible, the selected series should be that which is most commonly used in the European airspace. Both *Jane's* and *Flight International* provide statistics on the number of different series of each aircraft that has been sold or continue to be operated. This information can be used when making a decision.

Unfortunately, most often the decision is limited by the availability of reference information. In this case, the choice which series to use as a basis is set to that series for which reference information has been obtained.

Regardless of why a particular model is chosen, it is important to note that all further decisions on BADA coefficients must be consistent with the chosen series.

It should also be noted that while it may be acceptable to produce a model based on whatever reference information is available, the model should be regenerated if more suitable reference information becomes available. As an example, the version of the H25B model for BADA Revision 3.0 is based on the HS-125/3B aircraft. This is an older version, which accounts for approximately 5% of the HS-125 aircraft in operation. When available, a revised model should be generated that is based on a series 700 or 800 aircraft which accounts for a much larger proportion of the HS-125 aircraft operating today.

4.2 Initialisation of Aircraft Modelling Report

The preparation of each BADA aircraft model is documented by a BADA Modelling Report. The purpose of this report is to record the source of all reference information used for the generation of the model and to record the decisions made during the modelling process.

All BADA Modelling Reports follow a standard format. Examples of this format can be found in the reports for the Boeing 737-500 or the Dornier 328 aircraft [RD5 and RD6]. Following standard Eurocontrol practice, the BADA Modelling Reports are written using Microsoft Word. Some earlier reports have been written using WordPerfect.

For a new aircraft model, the BADA Modelling Report is initialised as a copy of a report for another aircraft. For example, the report for the Fokker 70 aircraft was initialised as a copy of the report for the previously modelled Fokker 100. Once an initial copy of the report is made, a number of edits are done to change the report title, page headers, page footers and introductory sections as appropriate for the aircraft under consideration. Following this, summary tables of aircraft parameters and reference profiles are updated in Section 2 of the report.

An example of a Parameter Summary Table for the Dornier 328 is shown below as Table 4.2-1. This table would be Table 2-1 in the modelling report. Note that the references in this table refer to references of the A/C Modelling Report and not to references in this document. The Parameter Summary Table contains a list of parameters that must be extracted from the reference information for each aircraft to be modelled. For every parameter a reference including page number must be given. This ensures that all values can be traced back to the original source.

Some points to remember when extracting these parameters are given below.

(a) The BADA reference mass is typically chosen to be 70% of the way between the minimum (operational empty mass) and the maximum (maximum take-off) mass while corresponding to a mass value for which reference climb and descent profiles are available. This is thus typically a multiple of 1000 or 500 kg.

(b) The service ceiling should be specified while allowing for 300 fpm climb.

(c) Stall speeds refer to the minimum stall speed in a configuration and not the 1-g stall speed.

(d) The BADA reference descent speed must correspond to the speed for which the reference descent profile is available. This is typically but not necessarily the same as the nominal descent speed.

(e) The maximum altitude at MTOW and ISA can be the same as the (absolute) maximum altitude. This is normally the case for smaller aircraft. For the larger jet aircraft however there is usually a distinct difference between the two.

(f) The temperature and weight gradients can usually be found by examining the flight envelope given in the manuals. If G_w can not be determined using Flight Manual information than the following approximation may be used: G_w= 23500 / MTOW. G_t can not be approximated which means that it will be set to 0 (zero) if no temperature information is available. Note that the temperature and weight gradients are not used during the spreadsheet calculation and that they maybe entered at the end of the process.

Table 4.2-1: D328 Parameter Summary

Parameter	Value	Source Reference
manufacturer series	Series 100	[RD3] pg 01
number of engines and engine type	two 1380 kW turboprops Pratt & Whitney Canada PW119B	[RD2] pg 98
ICAO wake category	M (medium)	[RD1] pg 2-4
mass (kg)	maximum: 13640 (maximum take-off) minimum: 8810 (operating weight empty) maximum payload: 3450 reference: 12000	[RD3] pg 03-03 [RD3] pg 08-03 [RD3] pg 08-03
maximum operating speed	CAS (knots): 270 Mach: 0.59	[RD3] pg A1-01-02 [RD3] pg A1-01-02
maximum altitude (ft above sea level)	32800 service ceiling with 300 fpm climb	[RD3] pg A1-02-01
reference aerodynamic surface area (m^2)	40.0	[RD3] pg 06-01
stall speed (knots, CAS)	cruise: 109 climb: 109 take-off: 109 approach: 109 landing: 90	[RD3] pg A1-01-02
nominal climb speed	180 kts / 0.59 M	[RD3] pg A1-30-06
nominal cruise speed	270 kts / 0.59 M	[RD3] pg 03-05
nominal descent speed	250 kts /270 kts / 0.59 M	[RD3] pg A1-50-03

Table 4.2-1: D328 Parameter Summary (cont'd)

Parameter	Value	Source Reference
BADA reference descent speed	260 kts / 0.59 M	[RD3] pg A1-50-03
max. alt. at MTOW/ISA	30,000 ft	[RD3] pg A1-30-06
weight gradient	1.72 ft/kg	Approximated.
temp gradient	-200 ft/deg.C	[RD3] pg A1-30-06/07

An example of a Parameter Summary Table for the Dornier 328 is shown below as Table 4.2-2. This table would be Table 2-2 in the modelling report. Again note that the references in this table refer to references in the A/C Modelling Report and not to references in this document.

The Profile Summary Table contains a list of reference profiles available from the reference manuals and which are used for calculating the BADA coefficients. Recall that it is recommended to have at least 10 climb and 1 descent profiles. For every profile a reference including page number must be given. This ensures that all values can be traced back to the original source.

Table 4.2-2: D328 Profile Summary

Profile Id	Climb/ Descent	Mass (kg)	Speed Law (CAS/M)	Atm.	Comments	Reference Source
CL1	climb	12000	180/.59	ISA	ref. mass	[RD3] pg A1-30-06
CL2	climb	11000	180/.59	ISA	min. mass	[RD3] pg A1-30-06
CL3	climb	13640	180/.59	ISA	max. mass	[RD3] pg A1-30-06
CL4	climb	12000	180/.59	ISA+10	ref. mass	[RD3] pg A1-30-07
CL5	climb	11000	180/.59	ISA+10	min. mass	[RD3] pg A1-30-07
CL6	climb	13640	180/.59	ISA+10	max. mass	[RD3] pg A1-30-07
CL7	climb	12000	180/.59	ISA+20	ref. mass	[RD3] pg A1-30-08
CL8	climb	12000	155/.59	ISA	ref. mass	[RD3] pg A1-30-10
CL9	climb	11000	155/.59	ISA	min. mass	[RD3] pg. A1-30-10
CL10	climb	13600	155/.59	ISA	max. mass	[RD3] pg. A1-30-10
DES1	descent	12000	250/.59	ISA	ref. mass	[RD3] pg. A1-50-04
DES2	descent	11000	250/.59	ISA	min. mass	[RD3] pg. A1-50-04
DES3	descent	13000	250/.59	ISA	max. mass	[RD3] pg A1-50-04

4.3 Initialisation of <A/C>.XLS Spreadsheet

After the Parameter Summary Table and and Profile Summary Table have been completed in the Modelling Report, the next step is to create an initial version of the <A/C>.XLS spreadsheet. This is done by copying an existing spreadsheet. For example, for the Dornier 328 aircraft the D328.XLS file is created initially as a copy of the D228.XLS file (Dornier 228 aircraft).

When the file has been created through a copy, column C of the spreadsheet must be edited to fill in those parameters which have been already extracted from the reference information and documented in the Parameter Summary Table. Note that all the cells which require data entry are shaded in blue. A summary of data to be entered in column C is given below.

C1	aircraft type identifier	enter the ICAO identifier, e.g. D328
C2	trajectory identifier	enter a default value of CL1
C3	reference mass:	enter value from Parameter Summary Table
C4	maximum mass	enter value from Parameter Summary Table
C5	minimum mass	enter value from Parameter Summary Table
C6	maximum payload	enter value from Parameter Summary Table
C7	maximum operating speed	enter value from Parameter Summary Table
C8	maximum operating Mach	enter value from Parameter Summary Table
C9	maximum operating altitude	enter value from Parameter Summary Table
C10	aerodynamic surface area	enter value from Parameter Summary Table
C11	parasite drag coefficient	leave existing value as default value
C12	induced drag coefficient	leave existing value as default value
C13	Mach drag coefficient	enter 0.0 as default value
C16	engine type	enter “jet”, “turbo” or “piston” as appropriate
C17	number of engines	enter value from Parameter Summary Table
C19	1st thrust coefficient	leave existing value as default
C20	2nd thrust coefficient	leave existing value as default
C21	3rd climb thrust coefficient	leave existing value as default
C22	1st temperature coefficient	enter 0.0 as default value
C23	2nd temperature coefficient	enter 0.01 as default value
C24	reduced power option [y/n]	set at “n” during modelling
C25	cruise thrust coefficient	leave 0.95 as default value
C26	low altitude descent coefficient	enter 0.0 as default value
C27	high altitude descent coefficient	enter 0.0 as default value
C28	descent threshold altitude	enter 0.0 as default value
C29	reference descent CAS	enter value from Parameter Summary Table
C30	reference descent Mach	enter value from Parameter Summary Table
C32	1st TSFC coefficient	leave existing value as default value
C33	2nd TSFC coefficient	set to 1e9 as default value
C34	1st minimum fuel flow coefficient	leave existing value as default value
C35	2nd minimum fuel flow coefficient	set to 1e9 as default value

C37	cruise stall speed	enter value from Parameter Summary Table
C38	initial climb stall speed	enter value from Parameter Summary Table
C39	take-off stall speed	enter value from Parameter Summary Table
C40	approach stall speed	enter value from Parameter Summary Table
C41	landing stall speed	enter value from Parameter Summary Table
C42	speedschedule option [law/stall]	set at “law” during modelling
C43	low altitude, nominal climb CAS	enter value from Parameter Summary Table
C44	high altitude, nominal climb CAS	enter value from Parameter Summary Table
C45	nominal climb Mach limit	enter value from Parameter Summary Table
C47	low altitude, nominal cruise CAS	enter value from Parameter Summary Table
C48	high altitude, nominal cruise CAS	enter value from Parameter Summary Table
C49	nominal cruise Mach limit	enter value from Parameter Summary Table
C51	low altitude, nominal descent CAS	enter value from Parameter Summary Table
C52	high altitude, nominal descent CAS	enter value from Parameter Summary Table
C53	nominal descent Mach limit	enter value from Parameter Summary Table
C55	maximum altitude at MTOW/ISA	enter value from Parameter Summary Table
C56	weight gradient for max. alt.	enter value from Parameter Summary Table
C57	temperature gradient for max. alt.	enter value from Parameter Summary Table
C60	cruise fuel correction factor	set to 1.0 as default value
C62	approach thrust	copied from C26
C63	descent thrust	copied from C26
C64	parasite drag for approach conf.	filled in when known, else copied from C11
C65	induced drag for approach conf.	filled in when known, else copied from C12
C66	parasite drag for landing conf.	filled in when known, else copied from C11
C67	parasite drag for landing conf.	filled in when known, else copied from C12

Note that the nominal climb, cruise and descent speeds require both a low altitude CAS (below 10000 feet) and a high altitude CAS (above 10,000 ft). In some cases, only one CAS is specified and thus the same value is used for both. In other cases, the Flight/Operation Manuals will specify two values. Taking the example of the Dornier 328, separate values were specified for the descent speed, that is 250 knots CAS below 10,000 ft and 270 knots above 10,000 ft.

After the entries in column C are completed, the reference profile information must be entered. This is the most time-consumption part of the process. When the data comes from a Flight Manual, this process is completely manually. However when the results of the PEP or FOS programs are used, the data can be entered by using some “cut and paste” actions.

For each reference profile a separate Reference Trajectory Block as described in Section 3.3.3 must be created. In the block header the following cells must be filled in:

trajectory descriptor	
trajectory identifier	[CLn, DESn or CRZn]
trajectory type	[either "climb", "descent"or "cruise"]
temperature difference from ISA	[deg. C]
mass	[tonnes]
CAS < FL100	[knots]
CAS > FL100	[knots]
Mach number	
minimum flight level	

Recall from section 3.3.3 that the minimum flight level corresponds to the initial flight level for a reference climb (i.e. climb from) and a final flight level for a reference descent (i.e. descend to)

After the header values are specified, the values for the distance, time and fuel to climb/descent at each flight level must then be filled in. This can be especially time-consuming if the values must be read from graphs in the Operational Manual rather than tables. It is not necessary to fill in value for each flight level. A value for each 2000 feet is sufficient. For the cruise profile only fuel/flow data is required. The cruise profile is always the last profile in the <A/C>.XLS file.

Note that all of the fields in the Reference Trajectory Block that are to be filled in are shaded in blue.

4.4 Determination of Climb Thrust and Drag Coefficients

After the initial version of the <A/C>.XLS spreadsheet has been created, then the other spreadsheets can be used to calculate the BADA maximum climb thrust and drag coefficients.

This process is described in several steps below:

(a) Open Spreadsheets and Update Links

Assuming that the <A/C>.XLS spreadsheet is already opened for the operations described in Section 4.3 above, then the other Excel files must be opened. These are:

BADA.XLS
TRAJECT.XLS
ROCD.XLS
FUEL.XLS
FUEL_CRZ.XLS

All spreadsheets must have their links updated to import from the proper <A/C>.XLS spreadsheet. This is done using the Excel Links function, which is under the Edit Menu.

Note that the updates of the links are the only changes to these files that are necessary. All further updates are made to the <A/C> spreadsheet only.

(b) Set Drag Coefficients to Match Reference Descent

The first coefficients to be set are the drag coefficients C_{D0} and C_{D2}. The Mach drag coefficient, C_{M16} , is already initialised to zero. This coefficient can be kept at zero as it is not used for the calculation of drag.

The two drag coefficients are set by matching the descent performance to a reference descent trajectory. The trajectory chosen should be one that isolates the drag term as much as possible and thus should be a low-speed, low thrust descent. This is especially important with turboprop aircraft where high speed descents use a significant amount of thrust.

To select the reference profile, update the C3 field in the <A/C>.XLS spreadsheet to match the desired trajectory identifier. For example, to select the trajectory DES1, enter “DES1” in the C3 field.

Once the trajectory is selected, the match of the calculated trajectory with the reference trajectory can be seen by opening the TRAJECT.XLS chart. To improve the match, the values of C_{D0} and C_{D2} can be adjusted by entering in different values in the C11 and C12 cells of the <A/C> spreadsheet.

Typically it is convenient to size the TRAJECT.XLS chart and the <A/C> spreadsheet such that both can fit on the screen at the same time. In this way changes in the drag coefficients can be almost instantaneously evaluated.

In general, the fit of the calculated trajectory to the reference trajectory can be evaluated visually on the TRAJECT.XLS chart. Once a reasonable fit is obtained, however, small improvements are difficult to visualise. When this level has been reached the Figure-of-Merit which is displayed in the top-right corner of the TRAJECT.XLS chart should be used to indicate whether the fit is improved or not. The aim is to minimise this Figure-of-Merit which is an average of the normalised maximum and normalised rms errors in both altitude and distance. A value of 2.0 is considered acceptable.

In some cases, notably with turboprop aircraft, it will be difficult to match that profile at high altitudes. This is because some thrust is generally needed. If this is the case, set the descent thrust threshold, h_{des} (cell C27) and the high altitude descent thrust coefficient, $C_{Tdes,high}$ (cell C28) to some reasonable values (eg. 15,000 ft and 0.3 respectively) to obtain a better match. At this point it is not important that the thrust coefficients themselves have not been optimised.

Notably with turboprop aircraft, there can be extreme difficulty in obtaining a reasonable match for the descent. That is, it may be difficult to get the Figure-of-Merit below a value of 4.0. This often occurs because the reference descent trajectory is based on a constant rate of descent where the thrust is being continually adjusted. For these cases, it is often better to try to match the rate-of-descent to the constant value specified by using the ROCD.XLS spreadsheet.

Not too much time should be spent trying to optimise the two drag coefficients at this point. This is because they will need to be adjusted in a later stage in order to match reference climbs for different masses as described in step (e) below while the descent thrust coefficients will be used to fine-tune the descent performance as described in step (f). Thus, the drag coefficients determined at this stage are still a rough estimation.

In some cases however, the drag coefficients are known before the modelling process starts. This can be the case when an aircraft performance program is available for the particular aircraft type. In that case the values for the drag parameters should be kept fixed, and the modelling starts by setting the thrust coefficients (c).

(c) Set Thrust Coefficient to Match Reference Climb

Given the first estimate of the drag coefficients in step (b) above, the next step is to set the three maximum climb thrust coefficients, $C_{TC,1}$, $C_{TC,2}$, and $C_{TC,3}$ located in cells C19, C20 and C21 of the <A/C>.XLS spreadsheet.

The selected profile should be changed to the reference climb profile for conditions of nominal mass, nominal speed and ISA+0. When this is done the TRAJECT.XLS chart shows the match between the calculated climb profile and the reference.

Note that these three coefficients are used differently for jet, turboprop and piston engines. The equations that use these coefficients for determining thrust [RD1, Section 3.7] should be referred to as a guide for deciding how the coefficients should be varied to improve the fit.

The three coefficients should be varied to optimise the match and minimise the Figure-of-Merit. A value of 2.0 is generally acceptable. Further optimisation is not necessary since further adjustment must consider other profiles for alternative speeds and different mass values.

(d) Update Thrust Coefficients to Match Different Speeds

At this point there is now an initial estimate of the two drag coefficients and the three maximum climb thrust coefficients. This is, however, based on a consideration of only one climb profile and one descent profile.

The next step is to adjust the three thrust coefficients so that as good a match as possible is obtained for different speed conditions.

To compare the results for different trajectories, the trajectory identifier in the C3 cell of the <A/C>.XLS spreadsheet is changed. The trajectories to be considered should all use the reference mass with ISA+0 conditions. The climb speed, however should be different.

Again, the thrust equations in RD1, Section 3.7 should be used as a guide for deciding what coefficients to change. As an example, for turboprop aircraft the ratio of $C_{TC,1}$ to $C_{TC,3}$ should be varied (while keeping the sum constant) match the performance at different speeds.

The optimisation criteria is now that the average of the Figure-of-Merit over the different profiles be a minimum. It should still be possible to obtain a value of approximately 2.0.

(e) Update Thrust and Drag Coefficients to Match Different Mass

The next step is to adjust both the drag and thrust coefficients so that as good as match as possible is obtained for different mass conditions.

The number of climb profiles that are to be taken into consideration can be six or more. That is, three mass conditions at the nominal speed, three mass conditions at an alternative speed and possibly three mass conditions at a second alternative speed. All profiles are at ISA+0.

Generally, a divergence at minimum and maximum mass is corrected by adjusting the ration of C_{D2} to C_{D0}. That is, if the climb is too slow at maximum mass then this indicates that the C_{D2} term for induced drag is too large and so a small ratio of C_{D2} / C_{D0} would help. Conversely, if the climb is too fast at maximum mass then this indicates that the C_{D2} term for induced drag is not large enough and that the ratio of C_{D2} / C_{D0} should be increased.

Each time the drag coefficients are changed, the three thrust coefficients need to be adjusted.

The optimisation criteria is now that the average of the Figure-of-Merit over all the profiles be a minimum. It should be possible to obtain a value of approximately 3.0 with the nominal mass profiles remaining at a value around 2.0.

(f) Determination of Descent Thrust Coefficients

After the climb thrust and drag coefficients have been adjusted as described in (d) and (e) above the descent thrust coefficients must be finalised.

The descent thrust coefficients are set to match one and only one reference trajectory. This is the descent trajectory with nominal mass, speed and ISA conditions. There are three coefficients to be set, that is:

low altitude descent thrust coefficient	$C_{Tdes,low}$	(cell C26)
high altitude descent thrust coefficient	$C_{Tdes,high}$	(cell C27)
descent thrust transition altitude	h_{des}	(cell C28)

A Figure-of-Merit of 2.0 should be aimed for. This can often prove to be difficult for turboprop aircraft however that use significant amounts of thrust which varies continuously with altitude.

As a final check, other descent trajectories for different speed or mass conditions can be checked. It should be possible to match these trajectories with different descent thrust settings. If this cannot be done, then it may be necessary to increase or decrease the drag coefficients as required and re-iterate starting at step (c).

After completion of this process it is wise to check ROCD.XLS to verify the ROCD values predicted by BADA. These values can be checked by using the information in the Flight Manual regarding the time necessary to climb from one FL to the next FL or by using the ROCD reference information if available. The ROCDs obtained through this calculation should not deviate more than 20% from those calculated by BADA.

For some aircraft models, non-clean data may be available (fields C64-C67 in the <A/C>.XLS). In that case the approach and landing thrust coefficients need to be determined (C62 and C63). The most appropriate way is to set the *law/stall* option to *stall* and to analyse the ROCD.XLS spreadsheet. The landing thrust should be set first so that the resulting ROD gives (combined with the landing speeds) a gradient of about 3 degrees. Once this is set the approach thrust should be changed in order to have a smooth transition from the clean ROD at lower altitudes to the landing ROD. If only clean dat is available then the final values of C26 are copied into C62-C63.

At the end of this step the drag and climb thrust coefficients are finalised.

4.5 Determination of Thrust Temperature Coefficients

After the thrust and drag coefficients have been finalised as described in Section 4.4 above, the next step is to determine the thrust temperature coefficients. There are two such coefficients:

$C_{TC,4}$	1st thrust temperature coefficient	(cell C22)
$C_{TC,5}$	2nd thrust temperature coefficient	(cell C23)

The coefficient $C_{TC,4}$ is in units of degrees Celsius. Essentially this coefficient specifies the temperature threshold below which the thrust is assumed to be constant. For example, if $C_{TC,4}$ is set to 5, then this means that the thrust does not vary with temperatures below ISA+5.

The coefficient $C_{TC,5}$ specifies the rate at which the thrust is reduced for temperatures above the threshold specified by $C_{TC,4}$. For example, if $C_{TC,4}$ is set to 5 and $C_{TC,5}$ is set to 0.01 then this means that the thrust is reduced by 1 % for each degree Celsius above ISA+5.

Recall that default values for $C_{TC,4}$ and $C_{TC,5}$ are 0 and 0.01 respectively. These are typically very close to the final values for any aircraft.

Two climb trajectories, one at ISA+10 and the other at ISA+20 are used to determine these coefficients. Both of the profiles should represent conditions of the nominal mass and nominal climb speeds.

First the value of $C_{TC,5}$ is optimised for the climb trajectory at ISA+10. The results for the condition of ISA+20 are then checked.

If the calculated climb is too slow at ISA+20 then the value of $C_{TC,4}$ can be increased from 0 to some positive value while decreasing the value of $C_{TC,5}$. This should allow for the ISA+20 calculation to improve while retaining the same results for the ISA+10 condition.

If the calculated climb at ISA+20 is too fast then no adjustments are made. The reasons for this are as follows:

(i) The value of $C_{TC,5}$ is limited to be greater than 0; and,

(ii) It is more important to match the ISA+10 conditions than to improve the ISA+20 conditions.

4.6 Determination of Fuel Flow Coefficients

After the descent thrust coefficients have been determined, the next BADA coefficients to be determined are the fuel coefficients.

There are three kinds of fuel coefficients. The first kind are the two coefficients, C_{f1} and C_{f2} , that specify the Thrust Specific Fuel Consumption (TSFC). The second kind are the two coefficients, C_{f3} and C_{f4} , that specify the minimum fuel flow. The third is the cruise fuel correction factor C_{fcr}.

The TSFC coefficients are determined first using just one climb trajectory. This should be the climb trajectory under nominal mass, speed and ISA conditions. This trajectory is selected for calculation by entering the appropriate trajectory identifier in the C2 cell of the <A/C>.XLS spreadsheet.

The FUEL.XLS chart shows the match between the actual fuel consumption and the calculated value. The C_{f1} and C_{f2} coefficients are adjusted in cells C32 and C33 of the <A/C>.XLS spreadsheet to make this match as good as possible. The optimisation criterium for obtaining a good match is to minimise the sum of the normalised maximum error and normalised rms error in percent. These two figures are shown in the top-right corner of the chart. It is usually possible to obtain a minimum of 6% or less for this sum.

In general, an acceptable fit for the climb fuel consumption can be achieved using just the C_{f1} coefficient, that is, assuming that TSFC is a constant value. Indeed, this possibility should always be tried first with the C_{f2} coefficient set to a high value (eg. 1e9) so that its affect is negligible. Only if it is not possible to obtain an acceptable fit in this manner should the C_{f2} coefficient be varied. Note that the C_{f2} term introduces a dependency of the TSFC on true airspeed [RD1, Section 3.9] for jets and turboprops but is ignored completely for piston aircraft.

The minimum fuel flow coefficients, C_{f3} and C_{f4}, are determined next. Minimum fuel flow is determined by trying to match the fuel consumption to a descent trajectory. Similar to the TSFC coefficients, the FUEL.XLS chart is used while adjusting the C_{f3} and C_{f4} values in cells C34 and C35 of the <A/C>.XLS spreadsheet.

Also similar to the TSFC, an acceptable fit to the minimum fuel flow condition can be achieved by setting C_{f4} to a high value (e.g. 1e9) so that it is negligible and using only C_{f3}. This then assumes that the minimum fuel flow is a constant. The C_{f4} coefficient be varied only if it is not possible to obtain an acceptable fit in this manner. Note that the C_{f4} term introduces a dependency of the minimum fuel flow on altitude [RD1, Section 3.9] for jets and turboprops but is ignored completely for piston aircraft.

Finally the cruise fuel correction factor, C_{fcr}, is determined. For this the only cruise profile (CRZ1) is selected. The value of C_{fcr} should be modified in order to obtain the lowest maximum error. The default value of C_{fcr} is 1.0 and the end value is usually between 0.85 and 1.15.

4.7 Dynamic Maximum Altitude parameters

The dynamic maximum altitude parameters are determined directly from the Flight Manual without the intervention of the BADA spreadsheets. The data necessary to determine the values of Hmax, Gw and Gt is not always available though. What is needed is a graph or a table that shows the influence of weight and temperature on the maximum operational altitude. The maximum operational altitude is the altitude at which the aircraft is still capable of climbing with at least 300 fpm. Hmax is defined as the maximum operational altitude at MTOW/ISA condition. This value can usually be read directly from the graph. For Gw one needs to determine the gradient of the maximum altitude line that is given as a function of weight. Gw is expressed in ft/kg. For Gt the temperature gradient needs to be determined by analysing the difference between the maximu maltitude lines for ISA and ISA+10/20 condition. Gt is expressed in ft/C.

4.8 Buffeting parameters

Buffeting parameters are only determined for jet aircraft. The reference data needed to determine the two buffeting parameters is often diffcult to find. RD9 gives an explanation of the process that needs to be followed to determine the parameters k and $C_{Lbo\,(M=0)}$. The latest version of the spreadsheet that is to be used to determine the parameters is called Buffet4.XLS and is available in C:\BADA\BUFFET\. The fields Q9:S12 are used for entering the reference data. Fields R22 and R23 are used for the values of $C_{Lbo\,(M=0)}$ and k respectively. Field W22 should be minimised by changing the values of $C_{Lbo\,(M=0)}$ and k. The values of $C_{Lbo\,(M=0)}$ and k are, for the moment, directly entered in the .OPF files. They is no place reserved for these parameters in the <A/C>.XLS file, but this should be corrected in the near future.

4.9 Update of APF and OPF Files

Once the fuel coefficients are determined, then all BADA coefficients are known and the APF and OPF files can be constructed. For a new aircraft model, the SYNONYM files also need to be updated to add the new aircraft and the new files should be added to RCS. Configuration management procedures for these files are specified in the BADA Configuration Management Manual [RD7].

The format of the APF, OPF and SYNONYM files are described in Section 4 of the BADA User Manual [RD1].

4.10 Create PTF file

After the OPF and APF files have been produced, the PTF file can be created. This is done using the "badaMakePTF" command. This utility program creates a PTF file using the OPF and APF file and place the PTF file in the bada/current directory.

4.11 Completion of Aircraft Modelling Report

The last step for the preparation of an aircraft model is the completion of the BADA Aircraft Modelling Report.

The selection of the coefficient values must be written in Section 3 of this report describing the choices made and the reasoning behind the choices. In addition, summary tables must be filled in that show the errors and Figures-of-Merit of the calculated profiles compared to each reference profile. Hardcopies of the charts and reference material are included in the reports as appendices. Examples of this are shown in the reports for the Boeing 737-500 [RD5] and Dornier 328 [RD6] Modelling Reports.

4.12 Use of the SOLV.XLS spreadsheet

Sections 4.4 throught 4.6 have described how drag, thrust and fuel flow parameters are to be determined. This can be a lengthy task particularly with many reference trajectories. It is for this reason that an automated environment has been developed. This environment is based upon the SOLV.XLS spreadsheet, which is explained in RD10. The SOLV.XLS spreadsheet can find the optimum values for the drag, thrust and fuel flow parameters. Depending on the number of reference profiles, this process can take several hours. Tests have shown that the result is nearly always a better match than with the manual process. However, the initial values of the drag, thrust and fuel flow coefficients need to be at least in the same order as the final values. If the initial value is too far away from the optimal value, then the program will not be able to converge to a useful solution. This means that despite the fact that the process is automated, a fair amount of knowledge is necessary to determine the initial values of the parameters. It is suggested that any first modelling of a (new) aircraft is done “manually” and that any re-modelling, usually done when new or more reference data has become available, is done using the SOLV.XLS spreadsheet. Instructions on how to set up the SOLV.XLS environment are given in RD10.

5. CONFIGURATION MANAGEMENT

The BADA/Excel spreadsheet files are not controlled within any formal Configuration Management (CM) system. A formal CM system should be added in the near future.

Instead, any modifications to the BADA/Excel spreadsheets are recorded in log files. There is one log file, ACLOG.DOC for the aircraft spreadsheets and another log file, MNTLOG.DOC for the spreadsheets that perform the calculations (BADA.XLS, TRAJECT.XLS, ROCD.XLS, FUEL.XLS).

Copies of these log files are included in this document as Appendix A. In both log files the file modification date, time and size are used as identifiers for the file versions. However since the BADA environment has moved to a new PC, these dates no longer correspond to the dates of the files on the PC but only to those on the back-up diskettes.

APPENDIX A

Configuration Maintenance Logs

Excel Spreadsheet Modification Log

Aircraft Spreadsheet Log

Modification Log for BADA/Excel Spreadsheets

Date: 1.5.98

Date	Modification Description	File Specifications				Modelled Aircraft		
		Name	Size	Date	Time	Id	Name	Report Date
06.04.95	Initial version for recording modifications	BADA.XLS TRAJECT.XLC FUEL.XLC ROCD.XLC	237252 11185 6918 4238	06/04/95 06/04/95 06/04/95 06/04/95	17:23:34 17:23:34 17:23:34 17:23:34	B727 B737 FK50 TU54	Boeing 727 Boeing 737-500 Fokker 50 Tupolev Tu154	07.04.95 14.04.95 17.07.95 29.06.95
13.04.95	(a) Update BADA.XLS to calculate distance and altitude errors only for points corresponding to more than 5% of total distance to climb/descend (b) Minor formatting changes to charts	BADA.XLS TRAJECT.XLC FUEL.XLC ROCD.XLC	240757 11274 6963 4266	13/04/95 13/04/95 13/04/95 13/04/95	12:52:32 12:52:32 12:52:32 12:52:32	MD11	McDonnell-Douglas MD-11	14.04.95
19.04.95	Several modifications to BADA.XLS (a) update TAS/CAS conversion to account for ISA differences (b) use 1.3 factor for climb speeds instead of 1.2 (c) for jets, restrict climb speed to 1.3Vstall+10 at FL20 (previously set to Vcl,1 for FL20)	BADA.XLS TRAJECT.XLC FUEL.XLC ROCD.XLC	240925 11274 6963 4266	21/04/95 13/04/95 13/04/95 13/04/95	14:30:50 12:52:32 12:52:32 12:52:32			

Modification Log for BADA/Excel Spreadsheets

Date	Modification Description	File Specifications				Modelled Aircraft		
		Name	Size	Date	Time	Id	Name	Report Date
19.04.95 (cont'd)	(d) shift jet/turboprop descent speed schedule FL former value new value 15 1.3Vstall + 5 1.3Vstall + 20 20 1.3Vstall + 20 1.3Vstall + 60 30 1.3Vstall + 60 1.3Vstall + 80 40 1.3Vstall + 80 1.3Vstall +100 60 1.3Vstall + 100 Vdes,1							
02.05.95	Several modifications to BADA.XLS (a) modified TAS/CAS conversion to use exact isentropic equations instead of empirical approximations (b) simplified calculation of density (c) simplified calculation of sound speed to use real gas constant	BADA.XLS TRAJECT.XLC FUEL.XLC ROCD.XLC	241757 11274 6963 4266	04/05/95 13/04/95 13/04/95 13/04/95	18:20:54 12:52:32 12:52:32 12:52:32			
09.05.95	Modifications to BADA.XLS (a) correct definitions of Y4 and Y5 in engine thrust block, ratios were inversed	BADA.XLS TRAJECT.XLC FUEL.XLC ROCD.XLC	242324 11274 6963 4266	09/05/;95 13/04/95 13/04/95 13/04/95	17:34:18 12:52:32 12:52:32 12:52:32	FGTR	Generic Military Fighter	12.05.95

Modification Log for BADA/Excel Spreadsheets

Date	Modification Description	File Specifications Name Size Date Time	Modelled Aircraft Id Name Report Date
09.05.95 (cont'd)	(b) modify colour shading to improve quality of black and white printouts		
29.05.95	Change default link from FGTR.XLS to MD11.XLS in the following spreadsheets: BADA.XLS TRAJECT.XLC FUEL.XLC	BADA.XLS 242320 29/05/;95 13:26:52 TRAJECT.XLC 11269 29/05/95 13:26:52 FUEL.XLC 6960 29/05/95 13:26:52 ROCD.XLC 4266 13/04/95 12:52:32	TU34 Tupolev Tu- 134 9.11.95 FK70 Fokker 70 4.12.95 C421 Cessna 421 Golden Eagle 8.12.95
19.12.95	Modifications to BADA.XLS: (a) Correction of descent speeds altitude limit from 11,000 ft to 10,999 ft (b) binomial approximation for esf in constant CAS below tropopause changed to exact algorithm (c) new temperature correction on thrust introduced Modification to <A/C>. XLS (d) Addition of dynamic maximum altitude parameters	BADA.XLS 246494 08.12.95 15:10:12 TRAJECT.XLC 11089 08.12.95 15:10:20 FUEL.XLC 6864 08.12.95 15:10:18 ROCD.XLC 4235 08.12.95 15:10:24	MD80 McDonnell Douglas MD80 6.3.96 DH83 DeHavilland Dash 8-300 19.3.96 EA32 Airbus A-320 19.7.96 CL65 Canadair Reg. Jet 24/7/96 B737 Boeing 737-100/200 26/7/96 B73S Boeing 737-300 27/7/96 B767 Boeing 767 2/8/96 DC9 McDonnel Douglas DC-9 8/8/96 FK10 Fokker 100 25/9/96 BA46 BAe 146 2/10/96

Modification Log for BADA/Excel Spreadsheets

Date: 1.5.98

Date	Modification Description	File Specifications				Modelled Aircraft		
		Name	Size	Date	Time	Id	Name	Report Date
1.05.98	Modification to BADA spreadsheets: see Section 2.2	BADA.XLS	164kb	17/4/98	2:11pm	B747	Boeing 747	30/6/97
		TRAJECT.XLS	28kb	17/4/98	2:11pm	B777	Boeing 777	1/11/97
		ROCD.XLS	22kb	17/4/98	2:11pm	B73X	Boeing 737-800	1/11/97
		FUEL.XLS	34kb	17/12/97	11:14am	SB20	Saab 2000	27/10/97
		FUEL_CRZ.XLS	29kb	17/4/98	2:11am	B757	Boeing 757	11/9/97
						B73F	Boeing 737-400	16/12/97

Aircraft Spreadsheet Log

Date: 22/4/98

File Name	Aircraft Name	Report Date
B727.XLS	Boeing 727	07.04.95
B737.XLS	Boeing 737-100/200	26.07.96
B73F.XLS	Boeing 737-400	16.12.97
B73S.XLS	Boeing 737-400	27.07.96
B73V.XLS	Boeing 737-500	14.04.95
B73X.XLS	Boeing 737-800	01.11.97
B747.XLS	Boeing 747-100/200	30.06.97
B757.XLS	Boeing 757	11.09.97
B767.XLS	Boeing 767	2.8.96
B777.XLS	Boeing 777	2.11.97
BA31.XLS	BAe Jetstream 31	04.11.94
BA41.XLS	BAe Jetstream 41	04.11.94
BA46.XLS	BAe 146	02.10.96

Aircraft Spreadsheet Log

Date: 22/4/98

File Name	Aircraft Name	Report Date
BATP.XLS	BAe Advanced Turboprop	19.11.94
C421.XLS	Cessna 421 Golden Eagle	8.12.95
CL65.XLS	Canadair Regional Jet	24.07.96
D228.XLS	Dornier 228	26.01.95
D328.XLS	Dornier 328	17.02.95
DC9.XLS	McDonnell-Douglas DC-9	08.08.96
DH83.XLS	DeHavilland Dash 8-300	19.03.96
EA32.XLS	Airbus A-320	19.07.96
FGTR.XLS	Generic Military Fighter	12.05.95
FK10.XLS	Fokker 100	25.09.96
FK50.XLS	Fokker 50	17.07.95
FK70.XLS	Fokker 70	04.14.95
MD80.XLS	McDonnell-Douglas MD-80	06.03.96

Aircraft Spreadsheet Log

File Name	Aircraft Name	Report Date
MD11.XLS	McDonnell-Douglas MD-11	14.04.95
SB20.XLS	SAAB 2000	27/10/97
SH36.XLS	Shorts 360	23.11.94
TU34.XLS	Tupolev Tu-134	09.11.95
TU54.XLS	Tupolev Tu-154	27.06.95