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EUROCONTROL EXPERIMENTAL CENTRE

DESIGN AND USER MANUAL FOR BADA EXCEL SPREADSHEETS

Issue 1.1

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DESIGN AND USER MANUAL FOR BADA EXCEL SPREADSHEETS Issue 1.1

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Abstract:

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

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Design and User Manual
for
BADA Excel Spreadsheets
Issue 1.1

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 and recommended procedures for use.

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).

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 2.4 in January 1996 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 2.4 [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 2.4; EEC Note 5/96, February 19986

RD2 MASS Modélisation par Excel, Centre Expérimental Eurocontrol B3.2 Document, 25 juin 1993.

RD3 Aircraft Type Designators; ICAO Document 8643, 24th Edition; January 1994.

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 CAPO Document Number BADA/CMM/01

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

RD9 Technical Note on Maximum Altitude; EEC APO Document Number BADA/TN/95/05; December 1995

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	ICAO 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

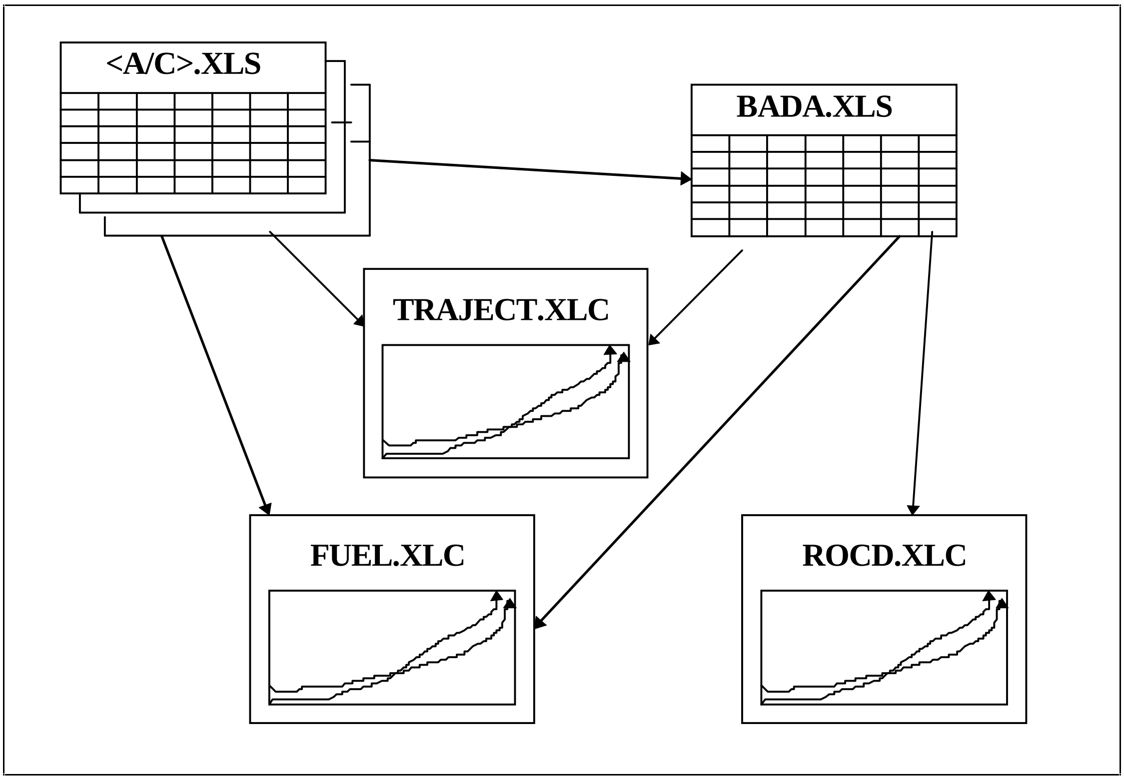
2.1 Spreadsheet Organisation

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 B73S.XLS or EA34.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.XLC	This is an Excel chart which compares the calculated trajectory for an aircraft with the corresponding reference trajectory.
ROCD.XLC	This is an Excel chart which displays the calculated rate of climb or descent for a calculated trajectory.
FUEL.XLC	This is an Excel chart which compares the calculated fuel consumption with the reference fuel consumption.

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. B73S.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. A number of various different 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.XLC and FUEL.XLC 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.XLC and FUEL.XLC charts. The ROCD.XLC chart is also used to observe the calculated rates of climb and descent.

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.

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) Separate Files for Each Aircraft Type

One Excel spreadsheet file, <A/C>.XLS, is created and maintained for each aircraft type supported by BADA. This file contains all the reference profile information for the aircraft as well as its BADA performance (OPF) and procedure (APF) parameters.

Each of these files are named after the ICAO designator for the aircraft type [RD3], for example

	B73S.XLS	(Boeing 737-300)
or	EA34.XLS	(Airbus A340)

In the previous version, information relevant to any one aircraft type was maintained in four separate files, that is:

OPF.XLS	for performance parameters
REFDAT1.XLS	for climb and descent reference profiles
SPEEDCLI.XLS	for speed profiles corresponding to reference climbs
SPEEDDES.XLS	for speed profiles corresponding to reference descents

This reorganisation was done for two reasons as explained below.

(i) The isolation of all information pertinent to an aircraft in one file facilitates configuration management. This way, the modification of any one aircraft model results in modifying only the one file associated with that aircraft model.

(ii) Separation of reference profiles into separate files for different aircraft prevents the files from growing unmanageably large as more reference profiles are used. Indeed, one of the main objectives with the new spreadsheets is to perform calculations of BADA coefficients several reference profiles. Only one climb and one descent profile had been used in the past.

(b) Removal of Speed Envelopes

Functions for the calculation and plotting of speed envelopes were removed from the spreadsheets since these functions are not used as part of the process of calculating the BADA coefficients.

The main advantage of this has been the simplification and reduction in size of the main spreadsheet, BADA.XLS, to 48 columns from 81 columns (called ATMREF.XLS in previous version).

(c) Labelling and Arrangement

The labelling and arrangement of the spreadsheets was improved to enable them to be better understood by users.

In particular, the BADA.XLS spreadsheet is now divided into a number of blocks with each block separated by bold outlines.

Colour shading is also standardised across spreadsheets, that is:

blue	- to indicate values that require input from the user
yellow	- to indicate values that are read from another spreadsheet

(d) Automatic Generation of Reference Speed Values

An automatic generation of the reference speed as a function of altitude in climb and descent was added. These values were specified to match those used in BADA/MASS where speed is a function of aircraft type, altitude and the stall speed.

In the previous version, a constant speed at all altitudes was assumed. Variable speed profiles had to then be entered in manually in the few times where they were used.

(e) Variable Mass due to Fuel Consumption

The values used for aircraft mass were modified to use the fuel consumption figures supplied for the reference trajectory.

In the previous version, accounting for a change in mass due to fuel consumption was done through an iterative solution using the BADA fuel coefficients. This made the calculation of coefficients more complex since an extra check step was need to first calculation the coefficients using fixed mass, then calculate the fuel coefficients, then iterate the process using variable mass. As a result of this added complexity, variable mass was rarely used.

(f) Adjustment of Thrust due to Temperature Deviations

The effect of temperature on thrust was added to the calculations.

This effect was not present in the previous version of the spreadsheets and thus temperature coefficients were not calculated for recent aircraft models.

(g) Specification of Initial Values

The profile calculation was modified to allow for the specification of an initial flight level.

The previous version of the spreadsheets always started profile calculations at sea level. In many cases, however, reference profiles are specified in terms of distance to climb to or descent from a level such as 1500 ft or 3000 ft.

In the new version, the initial condition for the calculations can be made to match the initial version of the reference profile.

(h) Account for Acceleration/Deceleration in Rate of Climb/Descent Calculations

There previous version of the spreadsheets assumed that the rate of climb or descent could be calculated based on a constant CAS or constant Mach between flight levels. No accounting for energy used to accelerate or decelerate between flight levels was done.

The new version calculates the time need to climb or descend between flight levels while including the effects of any power diverted to acceleration or power gained from acceleration when CAS or Mach is not constant.

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 [bytes]
BADA.XLS	08/12/95	17:34:18	246494
TRAJECT.XLC	08/12/95	12:52:32	11089
FUEL.XLC	08/12/95	12:52:32	6864
ROCD.XLC	08/12/95	12:52:32	4235

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 contents 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,
as an example, the cell B5 in BADA.XLS has the name:
tropopause altitude

units: This is the engineering units 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 2.4 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 which 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 48 columns (A to AV). It is organised into 8 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
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
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 which 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.

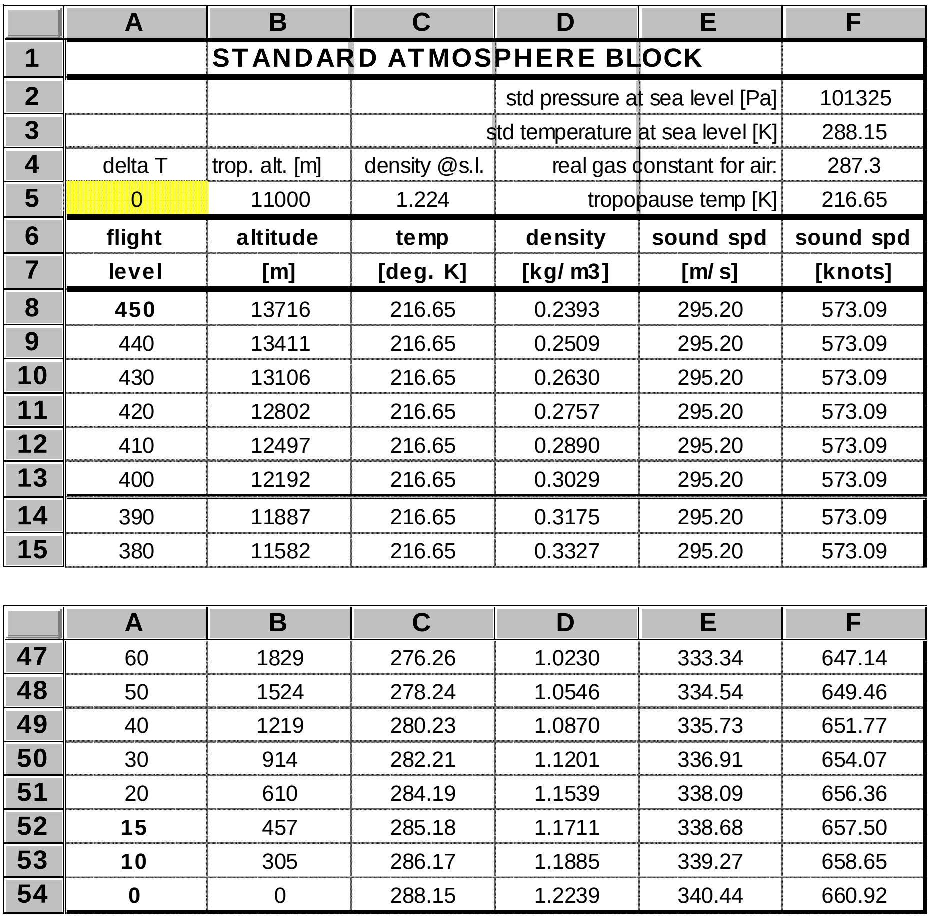
The design of each of the eight blocks is described in detail in the subsections below.

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:		287.3
5	0	11000	1.224	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	216.65	0.2393	295.20	573.09
9	440	13411	216.65	0.2509	295.20	573.09
10	430	13106	216.65	0.2630	295.20	573.09
11	420	12802	216.65	0.2757	295.20	573.09
12	410	12497	216.65	0.2890	295.20	573.09
13	400	12192	216.65	0.3029	295.20	573.09
14	390	11887	216.65	0.3175	295.20	573.09
15	380	11582	216.65	0.3327	295.20	573.09

	A	B	C	D	E	F
47	60	1829	276.26	1.0230	333.34	647.14
48	50	1524	278.24	1.0546	334.54	649.46
49	40	1219	280.23	1.0870	335.73	651.77
50	30	914	282.21	1.1201	336.91	654.07
51	20	610	284.19	1.1539	338.09	656.36
52	**15**	457	285.18	1.1711	338.68	657.50
53	**10**	305	286.17	1.1885	339.27	658.65
54	**0**	0	288.15	1.2239	340.44	660.92

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]

$R = 287.3$

Excel definition: F4 = 287.3

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 $9 \geq n \geq 51$
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 $\rho = 0.36392\{(37000-z)/(15000+z)\}^2$

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]

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

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`

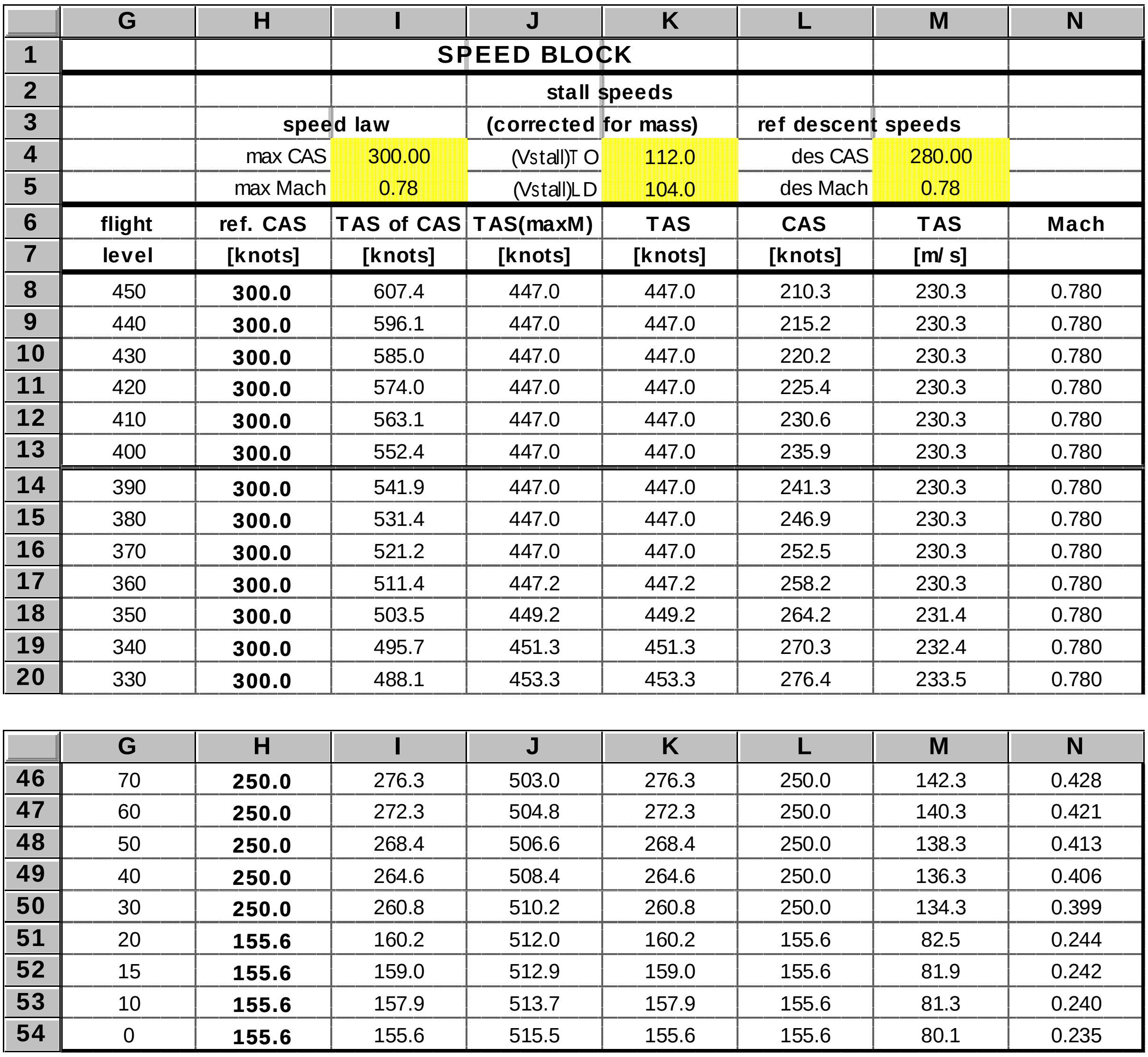
3.1.2 Speed Block

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 FL110, the speed is 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				stall speeds				
3		speed law		(corrected for mass)		ref descent speeds		
4		max CAS	300.00	(Vstall)TO	112.0	des CAS	280.00	
5		max Mach	0.78	(Vstall)LD	104.0	des Mach	0.78	
6	flight	ref. CAS	TAS of CAS	TAS(maxM)	TAS	CAS	TAS	Mach
7	level	[knots]	[knots]	[knots]	[knots]	[knots]	[m/s]	
8	450	300.0	607.4	447.0	447.0	210.3	230.3	0.780
9	440	300.0	596.1	447.0	447.0	215.2	230.3	0.780
10	430	300.0	585.0	447.0	447.0	220.2	230.3	0.780
11	420	300.0	574.0	447.0	447.0	225.4	230.3	0.780
12	410	300.0	563.1	447.0	447.0	230.6	230.3	0.780
13	400	300.0	552.4	447.0	447.0	235.9	230.3	0.780
14	390	300.0	541.9	447.0	447.0	241.3	230.3	0.780
15	380	300.0	531.4	447.0	447.0	246.9	230.3	0.780
16	370	300.0	521.2	447.0	447.0	252.5	230.3	0.780
17	360	300.0	511.4	447.2	447.2	258.2	230.3	0.780
18	350	300.0	503.5	449.2	449.2	264.2	231.4	0.780
19	340	300.0	495.7	451.3	451.3	270.3	232.4	0.780
20	330	300.0	488.1	453.3	453.3	276.4	233.5	0.780

	G	H	I	J	K	L	M	N
46	70	250.0	276.3	503.0	276.3	250.0	142.3	0.428
47	60	250.0	272.3	504.8	272.3	250.0	140.3	0.421
48	50	250.0	268.4	506.6	268.4	250.0	138.3	0.413
49	40	250.0	264.6	508.4	264.6	250.0	136.3	0.406
50	30	250.0	260.8	510.2	260.8	250.0	134.3	0.399
51	20	155.6	160.2	512.0	160.2	155.6	82.5	0.244
52	15	155.6	159.0	512.9	159.0	155.6	81.9	0.242
53	10	155.6	157.9	513.7	157.9	155.6	81.3	0.240
54	0	155.6	155.6	515.5	155.6	155.6	80.1	0.235

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

I4

name: constant CAS for speed law
units: knots
symbol: $(V_{CAS})_{const}$

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

Excel definition: I4 = <A/C>.XLS!$G$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 and used to correct descent thrust for speeds different from the reference speed [RD1, Section 3.7.4]; it is imported from the <A/C>.XLS spreadsheet

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 and used to correct descent thrust for speeds different from the reference speed [RD1, Section 3.7.4]; imported from the <A/C>.XLS spreadsheet

Excel definition: M5 = <A/C>.XLS!$C$30

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 FL110, this is the same as the constant CAS values specified for the selected reference profile. At FL110 and below, however, this is a function of the mass corrected stall speed as well as 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 $h_{FL} < 30$
$(V_{CAS})_{ref} = 1.3\ (V_{stall})^{*}_{TO} + 10$
for $30 \leq h_{FL} \leq 100$
$(V_{CAS})_{ref} = \text{minimum}[250,(V_{CAS})_{const}]$
for $100 < h_{FL}$
$(V_{CAS})_{ref} = (V_{CAS})_{const}$

for turboprop and piston aircraft in climb:

for $h_{FL} < 20$
$(V_{CAS})_{ref} = 1.3\ (V_{stall})^{*}_{TO} + 10$
for $20 \leq h_{FL} \leq 100$
$(V_{CAS})_{ref} = \text{minimum}[250,(V_{CAS})_{const}]$
for $100 < h_{FL}$
$(V_{CAS})_{ref} = (V_{CAS})_{const}$

for jets and turboprops in descent:

for $h_{FL} < 15$

$(V_{CAS})_{ref} = 1.3\,(V_{stall})^{*}_{LD} + 5$

for $15 \leq h_{FL} < 20$

$(V_{CAS})_{ref} = 1.3\,(V_{stall})^{*}_{LD} + 20$

for $20 \leq h_{FL} < 30$

$(V_{CAS})_{ref} = 1.3\,(V_{stall})^{*}_{LD} + 60$

for $30 \leq h_{FL} < 40$

$(V_{CAS})_{ref} = 1.3\,(V_{stall})^{*}_{LD} + 80$

for $40 \leq h_{FL} < 60$

$(V_{CAS})_{ref} = 1.3\,(V_{stall})^{*}_{LD} + 100$

for $60 \leq h_{FL} \leq 110$

$(V_{CAS})_{ref} = \text{minimum}[250,(V_{CAS})_{const}]$

for $110 < h_{FL}$

$(V_{CAS})_{ref} = (V_{CAS})_{const}$

for pistons in descent:

for $h_{FL} \leq 4$

$(V_{CAS})_{ref} = 1.3\,(V_{stall})^{*}_{LD} + 5$

for $4 < h_{FL} \leq 40$

$(V_{CAS})_{ref} = 1.3\,(V_{stall})^{*}_{LD} + 20$

for $40 < h_{FL}$

$(V_{CAS})_{ref} = (V_{CAS})_{const}$

Excel definition:

for $8 \leq n \leq 42$ [i.e. $110 \leq h_{FL} \leq 450$]

```
$H{n}  =  $I$4
```

for n = 43 [i.e. $h_{FL} = 100$]

```
H{n}    = IF(    $AL$2 =“climb”,
                 $I$4,
                 MIN($I$4,250) )
```

for $44 \leq n \leq 47$ [i.e. $60 \leq h_{FL} < 100$]

```
$H{n}  =  MIN($I$4,250)
```

for n=48 [i.e. $h_{FL} = 50$]

```
H{n}    = IF(    $AL$2 = “climb”,
                 MIN($I$4,250),
                 IF(      $T$2 = “piston”,
                          MIN($I$4,250),
                          MIN($I$4,1.3*$K$5+100,250)))
```

```
for n=49                                [i.e. $h_{FL}$ = 40]
H49       = IF(     $AL$2 = “climb”,
                    MIN($I$4,250),
                    IF(       $T$2 = “piston”,
                              1.3*$K$5+20,
                              MIN($I$4,1.3*$K$5+100,250)))

for n=50                                [i.e. $h_{FL}$ = 30]
H{n}      = IF(     $AL$2 = “climb”,
                    MIN($I$4,250),
                    IF(       $T$2 = “piston”,
                              1.3*$K$5+20,
                              MIN($I$4,1.3*$K$5+80,250)))

for n=51                                [i.e. $h_{FL}$ = 20]
H{n}      = IF(     $AL$2 = “climb”,
                    IF(       $T$2=“jet”,
                              1.3*$K$4+10,
                              MIN($I$4,250)),
                    IF(       $T$2=“piston”,
                              1.3*$K$5+20,
                              MIN($I$4,1.3*$K$5+60,250)))


for n=52                                [i.e. $h_{FL}$ = 15]
H{n}      = IF(     $AL$2 = “climb”,
                    1.3*$K$4+10,
                    1.3*$K$5+20 )

for n=53                                [i.e. $h_{FL}$ = 10]
H{n}      = IF(     $AL$2 = “climb”,
                    1.3*$K$4+10,
                    IF(       $T$2 = “piston”,
                              1.3*$K$5+20,
                              1.3*$K$5+5))

for n=54                                [i.e. $h_{FL}$ = 0]
H{n}      = IF(     $AL$2 = “climb”,
                    1.3*$K$4+10,
                    1.3*$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}

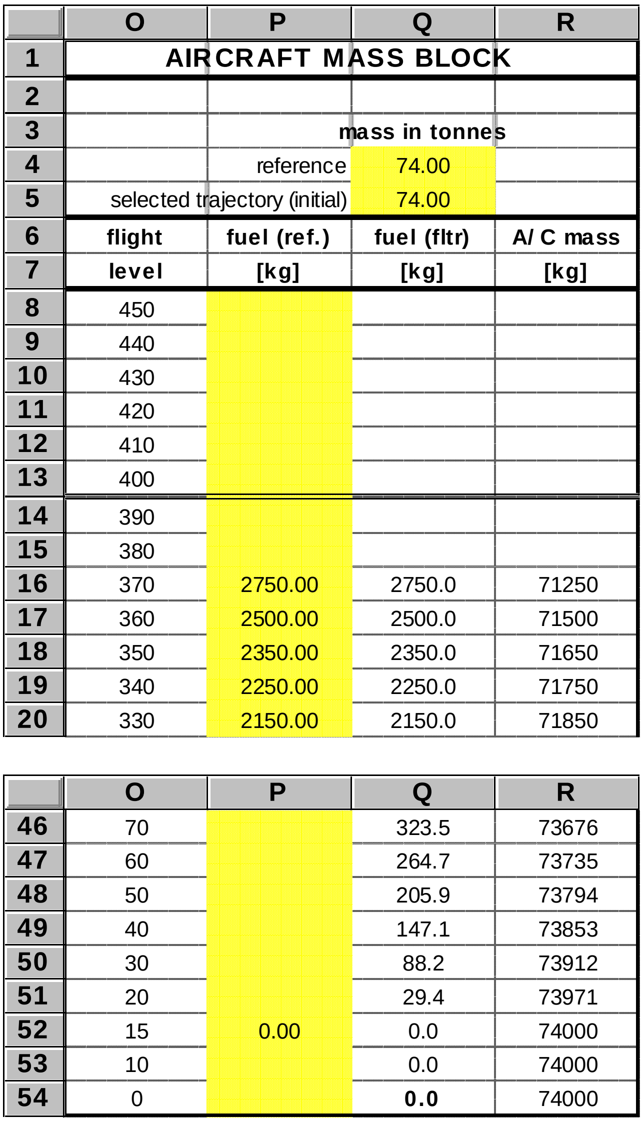
3.1.3 Aircraft Mass Block

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	74.00	
5		selected trajectory (initial)	74.00	
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			
14	390			
15	380			
16	370	2750.00	2750.0	71250
17	360	2500.00	2500.0	71500
18	350	2350.00	2350.0	71650
19	340	2250.00	2250.0	71750
20	330	2150.00	2150.0	71850

	O	P	Q	R
46	70		323.5	73676
47	60		264.7	73735
48	50		205.9	73794
49	40		147.1	73853
50	30		88.2	73912
51	20		29.4	73971
52	15	0.00	0.0	74000
53	10		0.0	74000
54	0		**0.0**	74000

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}))
```

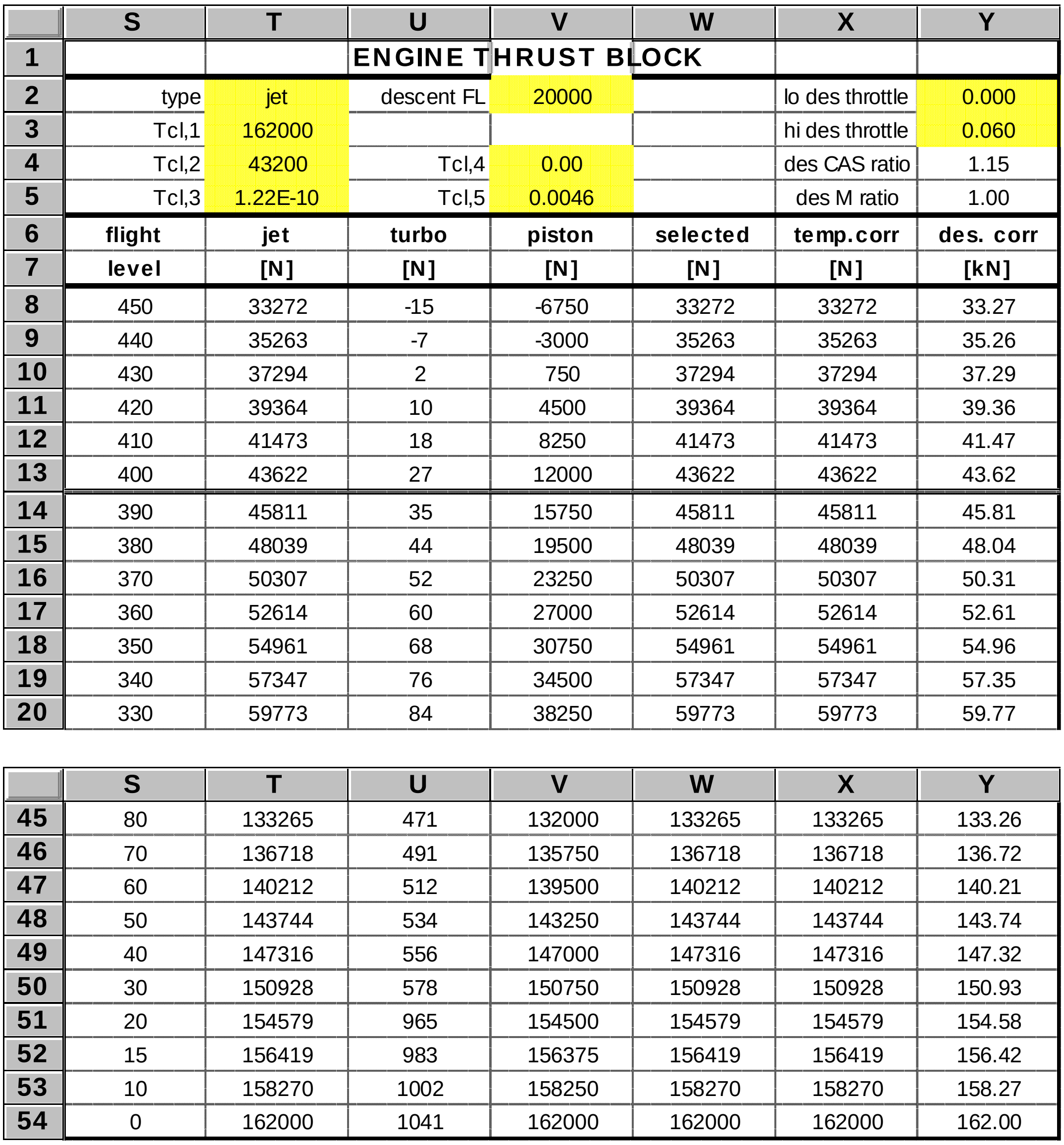
3.1.4 Engine Thrust Block

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 3.2.4-1 below.

Figure 3.2.4-1: Engine Thrust Block



	S	T	U	V	W	X	Y
1			ENGINE THRUST BLOCK				
2	type	jet	descent FL	20000		lo des throttle	0.000
3	Tcl,1	162000				hi des throttle	0.060
4	Tcl,2	43200	Tcl,4	0.00		des CAS ratio	1.15
5	Tcl,3	1.22E-10	Tcl,5	0.0046		des M ratio	1.00
6	**flight**	**jet**	**turbo**	**piston**	**selected**	**temp.corr**	**des. corr**
7	**level**	**[N]**	**[N]**	**[N]**	**[N]**	**[N]**	**[kN]**
8	450	33272	-15	-6750	33272	33272	33.27
9	440	35263	-7	-3000	35263	35263	35.26
10	430	37294	2	750	37294	37294	37.29
11	420	39364	10	4500	39364	39364	39.36
12	410	41473	18	8250	41473	41473	41.47
13	400	43622	27	12000	43622	43622	43.62
14	390	45811	35	15750	45811	45811	45.81
15	380	48039	44	19500	48039	48039	48.04
16	370	50307	52	23250	50307	50307	50.31
17	360	52614	60	27000	52614	52614	52.61
18	350	54961	68	30750	54961	54961	54.96
19	340	57347	76	34500	57347	57347	57.35
20	330	59773	84	38250	59773	59773	59.77

	S	T	U	V	W	X	Y
45	80	133265	471	132000	133265	133265	133.26
46	70	136718	491	135750	136718	136718	136.72
47	60	140212	512	139500	140212	140212	140.21
48	50	143744	534	143250	143744	143744	143.74
49	40	147316	556	147000	147316	147316	147.32
50	30	150928	578	150750	150928	150928	150.93
51	20	154579	965	154500	154579	154579	154.58
52	15	156419	983	156375	156419	156419	156.42
53	10	158270	1002	158250	158270	158270	158.27
54	0	162000	1041	162000	162000	162000	162.00

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 low altitude
units: dimensionless
symbol: $C^*_{Tdes,low}$

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

$$C^*_{Tdes,low} = C_{Tdes,low}\ (m/m_{ref})^{0.5}$$

Excel definition: Y2 = <A/C>.XLS!$C$26*SQRT($Q$5/$Q$4)

Y3

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 $h > h_{des}$); calculated as mass correction to constant imported from A/C spreadsheet
[RD1, Section 3.7.4]

$$C^*_{Tdes,low} = C_{Tdes,low}\ (m/m_{ref})^{0.5}$$

Excel definition: Y3 = <A/C>.XLS!$C$27*SQRT($Q$5/$Q$4)

Y4

name: descent speed ratio correction coefficient
units: dimensionless
symbol: C_{Vdes}

description: square of ratio of descent speed to BADA reference descent speed; used to correct descent thrust coefficients for speeds other than BADA reference value
[RD1, Section 3.7.4]

$$C_{Vdes} = (V_{CAS} / V_{des,ref})^{2}$$

Excel definition: Y4 = ($I$4/$M$4)^2

Y5

name: descent Mach ratio correction coefficient
units: dimensionless
symbol: C_{Mdes}

description: square of ratio of descent Mach number to BADA reference descent Mach number; used to correct descent thrust coefficients for Mach numbers other than BADA reference value
[RD1, Section 3.7.4]

$$C_{Mdes} = (M_{max} / M_{des,ref})^{2}$$

Excel definition: Y5 = ($I$5/$M$5)^2

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

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

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

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

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

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

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

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: $T_{\text{max climb}}$

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

$$T_{\text{max climb}} = (T_{\text{max climb}})_{ISA}\ [1 - C_{Tc,5}\ (\Delta T_{ISA})_{eff}\ ]$$
$$(\Delta T_{ISA})_{eff} = (\Delta T_{ISA} - C_{tc,4})$$
$$\text{with:}\quad 0 \leq (\Delta T_{ISA})_{eff} * C_{Tc,5} \leq 0.3$$
$$\text{and:}\quad C_{Tc,5} \geq 0$$

Excel definition:

```
X{n}   =$W8(1-MIN(0.3,(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 two factors: the first being a descent thrust coefficient dependent upon altitude, the second being a descent speed ratio
[RD1, Section 3.7.4]

```
if climb trajectory
    $T_{net} = T_{max\ climb} / 1000$
else if descent trajectory
    if  $h < h_{des}$ and $(V_{TAS})_M < (V_{TAS})_{ref}$
        $T_{net} = (T_{max\ climb} / 1000)\ C^*_{Tdes,low}\ C_{Mdes}$
    else if  $h < h_{des}$ and $(V_{TAS})_M \geq (V_{TAS})_{ref}$
        $T_{net} = (T_{max\ climb} / 1000)\ C^*_{Tdes,low}\ C_{Vdes}$
    else if  $h \geq h_{des}$ and $(V_{TAS})_M < (V_{TAS})_{ref}$
        $T_{net} = (T_{max\ climb} / 1000)\ C^*_{Tdes,high}\ C_{Mdes}$
    else if  $h \geq h_{des}$ and $(V_{TAS})_M \geq (V_{TAS})_{ref}$
        $T_{net} = (T_{max\ climb} / 1000)\ C^*_{Tdes,high}\ C_{Vdes}$
```

Excel definition:

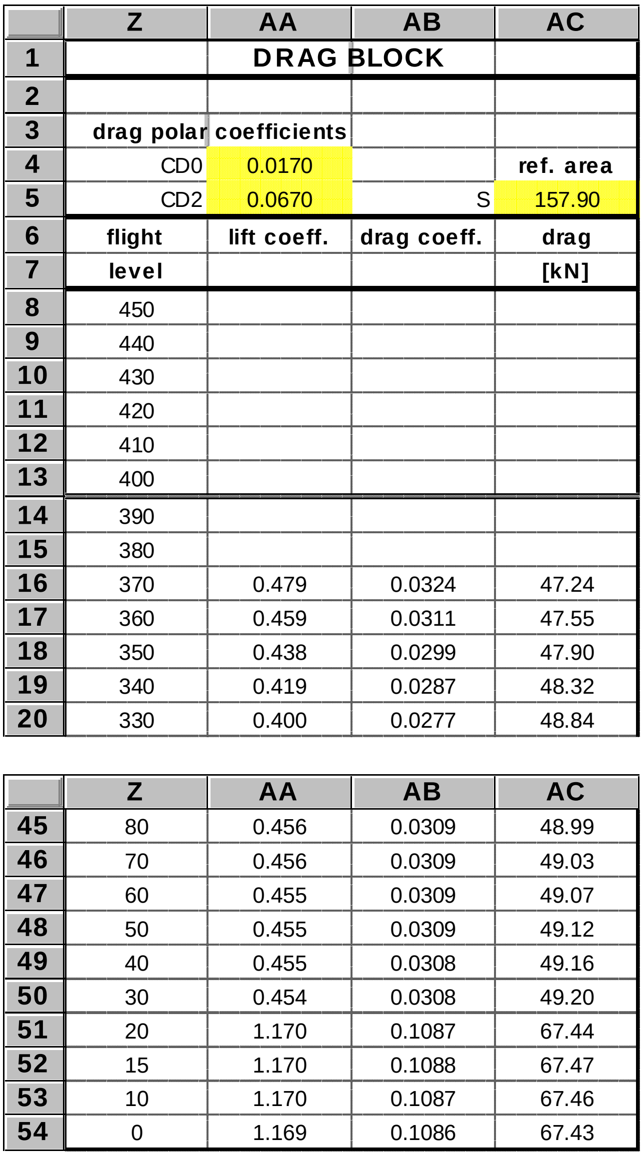
```
Y{n}   =  $X{n}/1000
          *IF($AL$2="climb",
              1,  IF(($A{n}*100)<$V$2,$Y$2,$Y$3))
          *IF($AL$2="climb",
              1,IF(($J{n}<$I{n},$Y$5,$Y$4))
```

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				
3	drag polar	coefficients		
4	CD0	0.0170		ref. area
5	CD2	0.0670	S	157.90
6	flight	lift coeff.	drag coeff.	drag
7	level			[kN]
8	450			
9	440			
10	430			
11	420			
12	410			
13	400			
14	390			
15	380			
16	370	0.479	0.0324	47.24
17	360	0.459	0.0311	47.55
18	350	0.438	0.0299	47.90
19	340	0.419	0.0287	48.32
20	330	0.400	0.0277	48.84

	Z	AA	AB	AC
45	80	0.456	0.0309	48.99
46	70	0.456	0.0309	49.03
47	60	0.455	0.0309	49.07
48	50	0.455	0.0309	49.12
49	40	0.455	0.0308	49.16
50	30	0.454	0.0308	49.20
51	20	1.170	0.1087	67.44
52	15	1.170	0.1088	67.47
53	10	1.170	0.1087	67.46
54	0	1.169	0.1086	67.43

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

AA4	name:	parasitic drag coefficient
	units:	dimensionless
	symbol:	C_{D0}
	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$11
AA5	name:	induced drag coefficient
	units:	dimensionless
	symbol:	C_{D2}
	description:	a constant associated with with each aircraft type; used to calculate the aerodynamic drag as a function of aircraft mass, air density, and velocity; imported from A/C spreadsheet [RD1, Section 3.6]
	Excel definition:	AA5 = <A/C>.XLS!$C$12
AC5	name:	reference aerodynamic surface area
	units:	m^2
	symbol:	S
	description:	a constant associated with with each aircraft type; imported from A/C spreadsheet [RD1, Section 3.6.1]
	Excel definition:	S4 = <A/C>.XLS!$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}*$M{n}^2*$AC$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; differs from BADA 2.3 in that the Mach number is ignored;
[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
$C_D = C_{D0} + C_{D2}\, C_L^{\,2}$

Excel definition:

```
AB{n} =  IF($A{n}>$AK$4,
             “ “,
             $AA$4 + $AA$5*$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:

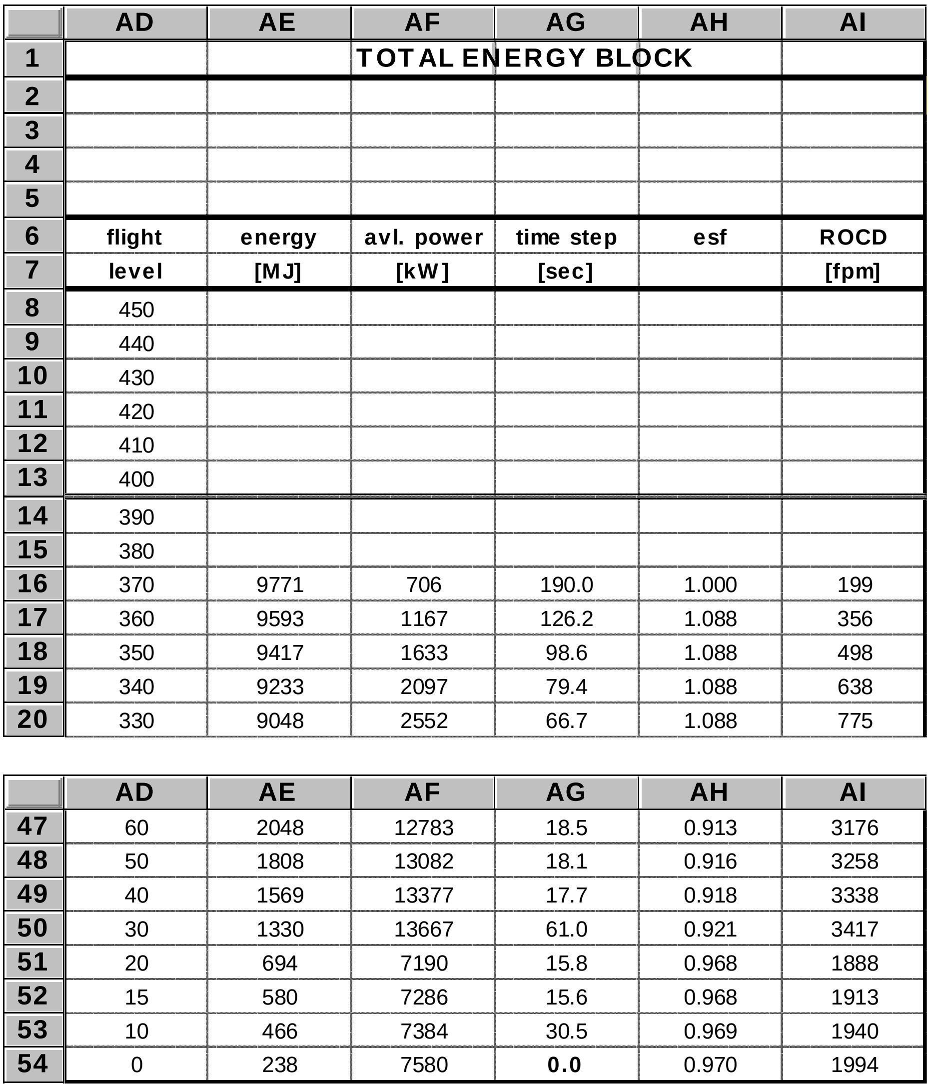
```
AC{n} = IF($A{n}>$AK$4,
           “ “,
           $AB{n}*$D${n}*$M{n}^2*$AC$5/2/1000 )
```

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						
5						
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					
14	390					
15	380					
16	370	9771	706	190.0	1.000	199
17	360	9593	1167	126.2	1.088	356
18	350	9417	1633	98.6	1.088	498
19	340	9233	2097	79.4	1.088	638
20	330	9048	2552	66.7	1.088	775

	AD	AE	AF	AG	AH	AI
47	60	2048	12783	18.5	0.913	3176
48	50	1808	13082	18.1	0.916	3258
49	40	1569	13377	17.7	0.918	3338
50	30	1330	13667	61.0	0.921	3417
51	20	694	7190	15.8	0.968	1888
52	15	580	7286	15.6	0.968	1913
53	10	466	7384	30.5	0.969	1940
54	0	238	7580	**0.0**	0.970	1994

There are no header cells in the Total-Energy Block.

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 $P_{avl} = (T_{net}-D)\ V$
	Excel definition:	AF{n} = IF($A{n}>$AK$4, “ “, ($Y{n}-$AC{n})*$M{n})

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 $8 \leq n \leq 53$

```
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 $T \le T_{tro}$    $f = 1$
    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:

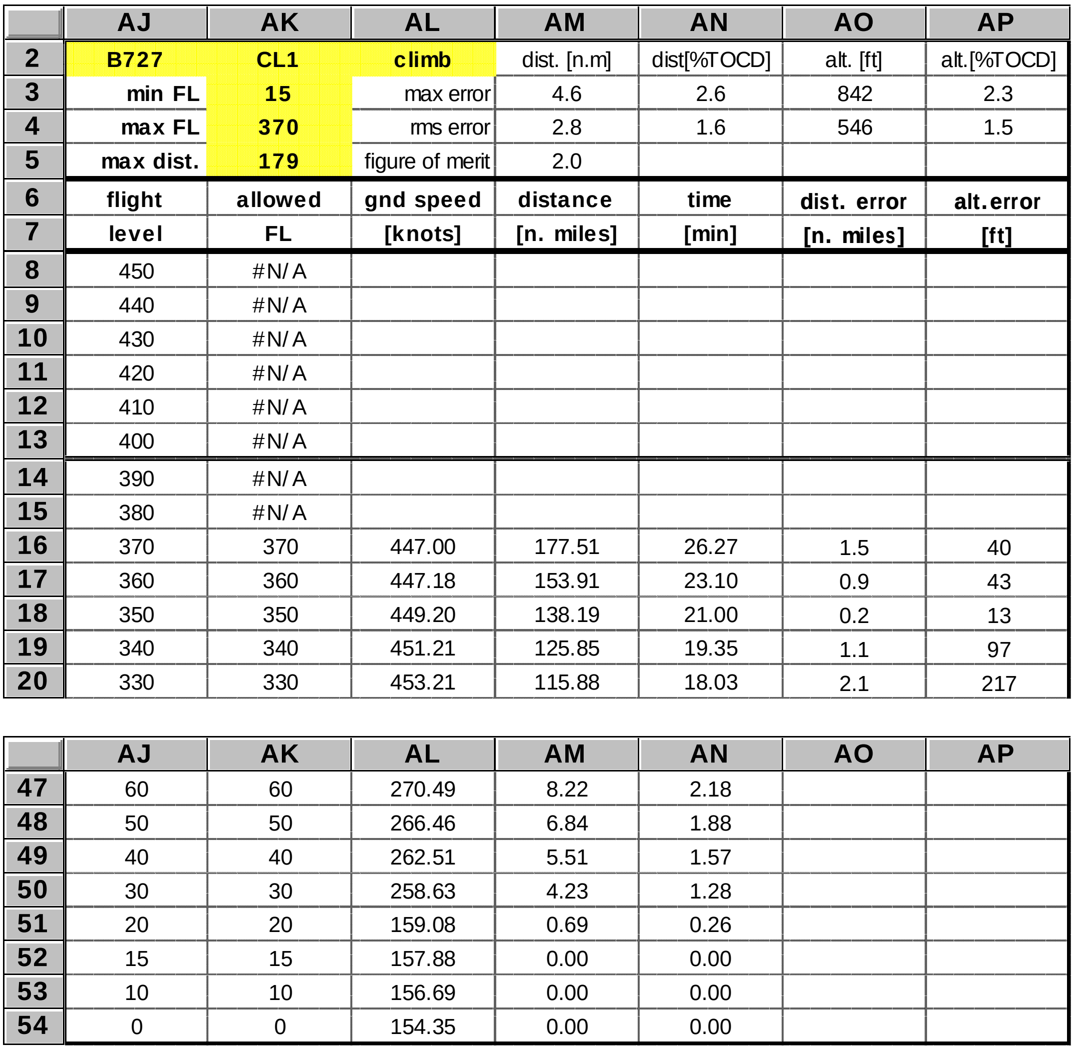
```
AI{n}  =  IF($A{n}>$AK$4,
               " ",
               60000*$AF{n}*$AH{n}/$R{n}/9.81/.3048
```

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
2	**B727**	**CL1**	**climb**	dist. [n.m]	dist[%TOCD]	alt. [ft]	alt.[%TOCD]
3	**min FL**	**15**	max error	4.6	2.6	842	2.3
4	**max FL**	**370**	rms error	2.8	1.6	546	1.5
5	**max dist.**	**179**	figure of merit	2.0			
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	#N/A					
14	390	#N/A					
15	380	#N/A					
16	370	370	447.00	177.51	26.27	1.5	40
17	360	360	447.18	153.91	23.10	0.9	43
18	350	350	449.20	138.19	21.00	0.2	13
19	340	340	451.21	125.85	19.35	1.1	97
20	330	330	453.21	115.88	18.03	2.1	217

	AJ	AK	AL	AM	AN	AO	AP
47	60	60	270.49	8.22	2.18		
48	50	50	266.46	6.84	1.88		
49	40	40	262.51	5.51	1.57		
50	30	30	258.63	4.23	1.28		
51	20	20	159.08	0.69	0.26		
52	15	15	157.88	0.00	0.00		
53	10	10	156.69	0.00	0.00		
54	0	0	154.35	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 $X < 0.05d_{max}$
    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 $\Delta X$ not available
    undefined
else
    $\Delta h = 60 \Delta X (V_z / V_x)$
```

Excel definition:

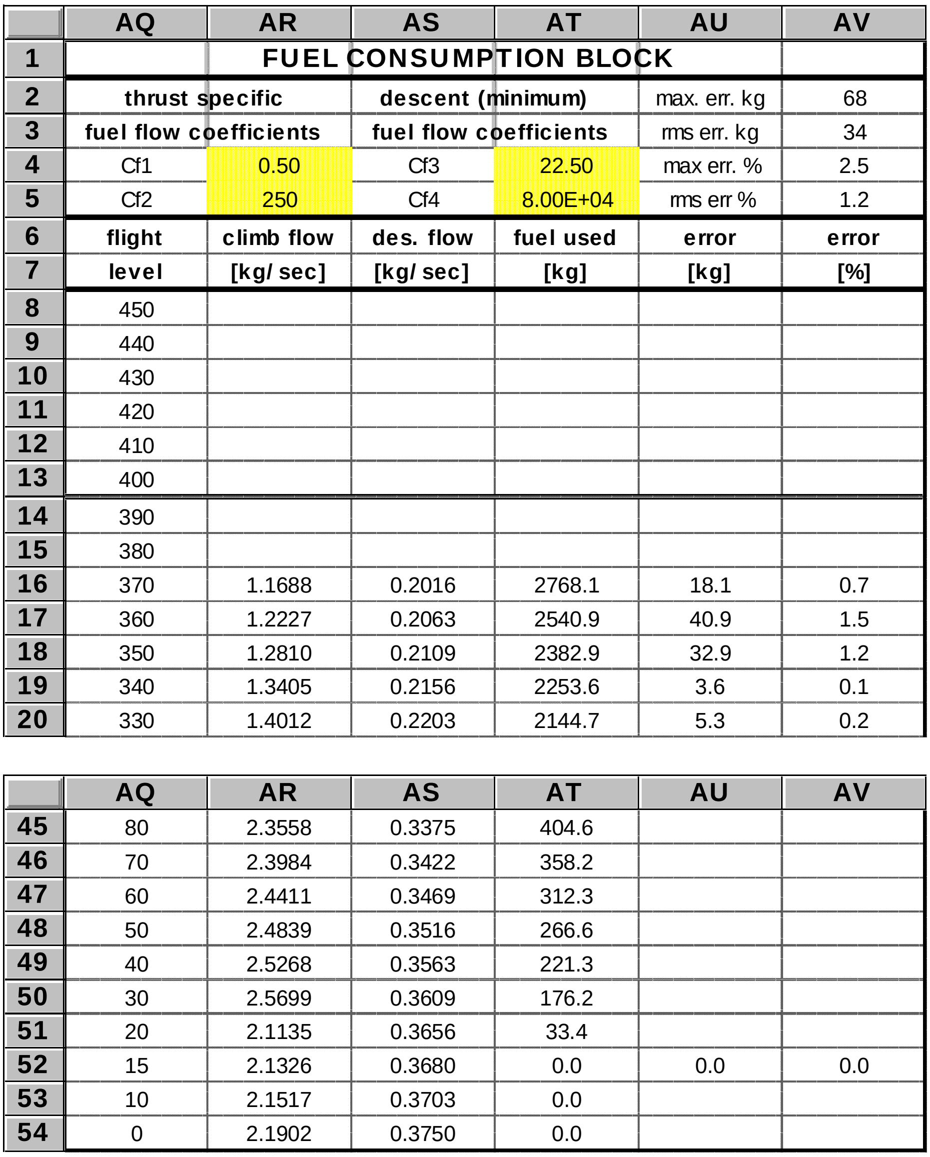
```
AP{n} = IF($AO{n}=” “,
               “ “,
               60*$AO{n}*$AI{n}/$AL{n} )
```

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	68
3	fuel flow coefficients		fuel flow coefficients		rms err. kg	34
4	Cf1	0.50	Cf3	22.50	max err. %	2.5
5	Cf2	250	Cf4	8.00E+04	rms err %	1.2
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					
14	390					
15	380					
16	370	1.1688	0.2016	2768.1	18.1	0.7
17	360	1.2227	0.2063	2540.9	40.9	1.5
18	350	1.2810	0.2109	2382.9	32.9	1.2
19	340	1.3405	0.2156	2253.6	3.6	0.1
20	330	1.4012	0.2203	2144.7	5.3	0.2

	AQ	AR	AS	AT	AU	AV
45	80	2.3558	0.3375	404.6		
46	70	2.3984	0.3422	358.2		
47	60	2.4411	0.3469	312.3		
48	50	2.4839	0.3516	266.6		
49	40	2.5268	0.3563	221.3		
50	30	2.5699	0.3609	176.2		
51	20	2.1135	0.3656	33.4		
52	15	2.1326	0.3680	0.0	0.0	0.0
53	10	2.1517	0.3703	0.0		
54	0	2.1902	0.3750	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 3.8]

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 3.8]

Excel definition: AR4 = <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 3.8]

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 3.8]

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:	$(\Delta w)^{*}_{\mathrm{max}}$
	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:	$(\Delta w)^{*}_{\mathrm{rms}}$
	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 3.8]
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 3.8]
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
      $f_{cl} = C_{f3} (1-100h_{FL}/C_{f4}) / 60$
   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 $h_{FL} \leq (h_{FL})_{min}$
        $w|_k = 0$
    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
  $\Delta w$ 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 $\Delta w$ is not available then
  $\Delta w^*$ is undefined
else
  $\Delta w^* = \Delta w / (w)_{max}$
```

Excel definition:

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

3.2 <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.

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 Block Number 1	Reference Trajectory Block Number 2	... ...	Reference Trajectory Block Number N

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 spreadsheets 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. 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) to distinguish it from the other trajectories.

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.XLC and FUEL.XLC charts import the reference trajectory specifications from the Selected Trajectory Block.

Further information on all of the three 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 rows, 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 which 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.

(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

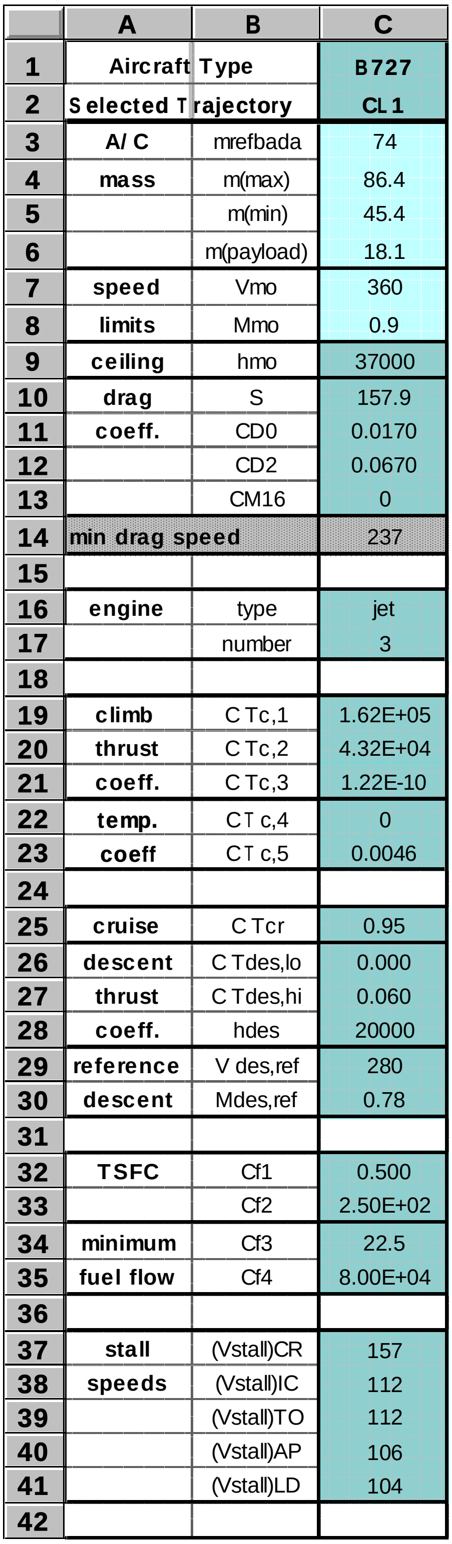
There is only on value of this type. This is the minimum drag speed in cell C14 which is automatically calculated as a function of the mass and drag coefficients.

(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.

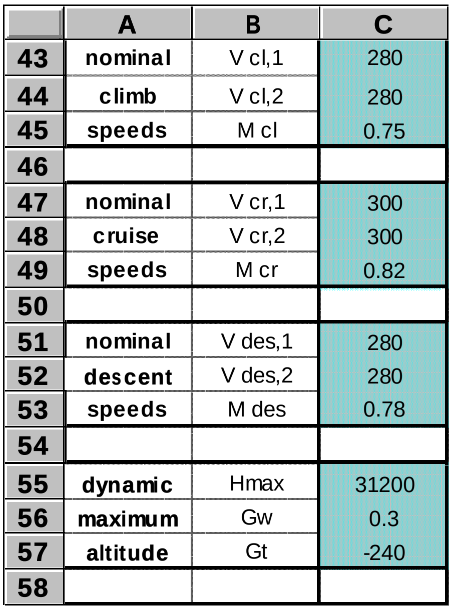
A detailed description of each of the coefficients in the block is given in Table 3.2.1-1.

Figure 3.2,1-1 : Coefficient Block



	A	B	C
1	Aircraft Type		B727
2	Selected Trajectory		CL1
3	A/ C	mrefbada	74
4	mass	m(max)	86.4
5		m(min)	45.4
6		m(payload)	18.1
7	speed	Vmo	360
8	limits	Mmo	0.9
9	ceiling	hmo	37000
10	drag	S	157.9
11	coeff.	CD0	0.0170
12		CD2	0.0670
13		CM16	0
14	min drag speed		237
15			
16	engine	type	jet
17		number	3
18			
19	climb	C Tc,1	1.62E+05
20	thrust	C Tc,2	4.32E+04
21	coeff.	C Tc,3	1.22E-10
22	temp.	CT c,4	0
23	coeff	CT c,5	0.0046
24			
25	cruise	C Tcr	0.95
26	descent	C Tdes,lo	0.000
27	thrust	C Tdes,hi	0.060
28	coeff.	hdes	20000
29	reference	V des,ref	280
30	descent	Mdes,ref	0.78
31			
32	TSFC	Cf1	0.500
33		Cf2	2.50E+02
34	minimum	Cf3	22.5
35	fuel flow	Cf4	8.00E+04
36			
37	stall	(Vstall)CR	157
38	speeds	(Vstall)IC	112
39		(Vstall)TO	112
40		(Vstall)AP	106
41		(Vstall)LD	104
42			

Figure 3.2.1-1: Coefficient Block (continued)



	A	B	C
43	nominal	V cl,1	280
44	climb	V cl,2	280
45	speeds	M cl	0.75
46			
47	nominal	V cr,1	300
48	cruise	V cr,2	300
49	speeds	M cr	0.82
50			
51	nominal	V des,1	280
52	descent	V des,2	280
53	speeds	M des	0.78
54			
55	dynamic	Hmax	31200
56	maximum	Gw	0.3
57	altitude	Gt	-240
58			

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	C_{D0}	dimensionless	calculated as described in Section 4
C12	induced drag coefficient	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: $g = 9.81 \text{ m/s}^2$ i.e. gravitational acceleration
and $(\rho_0)_{ISA} = 1.225 \text{ kg/m}^3$ 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)

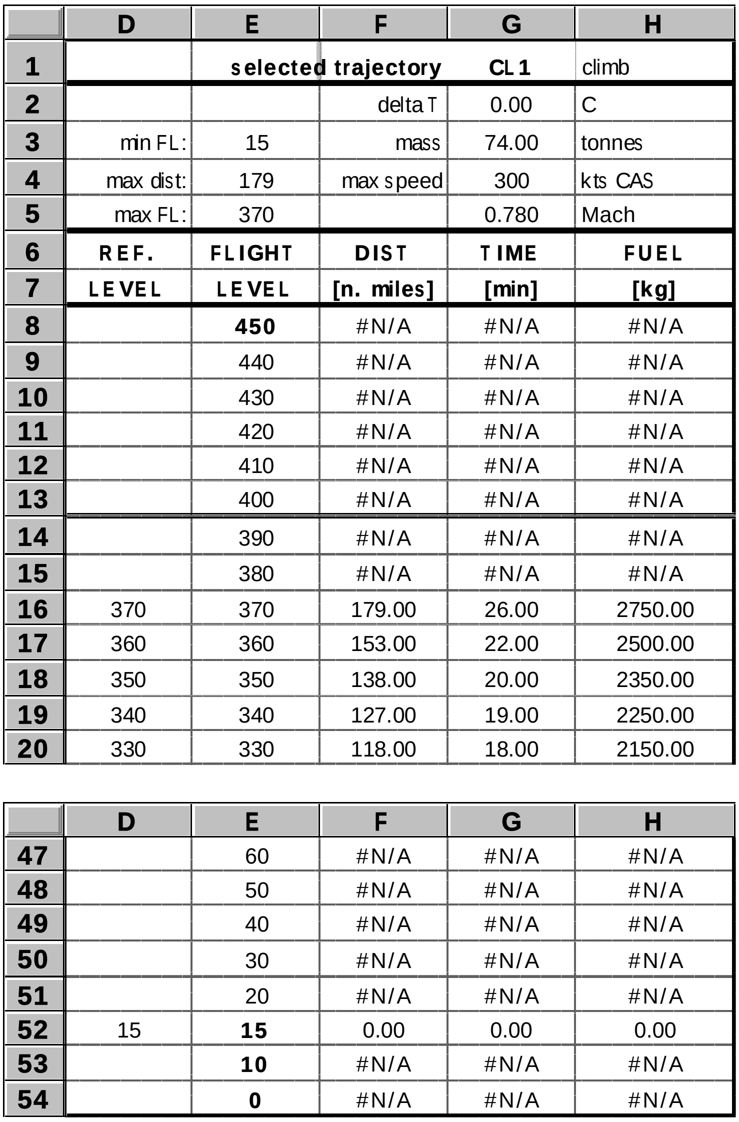
Cell	**Name**	**Symbol**	**Units**	**Source**
C55	Maximum altitude at MTOW and ISA	Hmax	feet	A/C reference manuals
C56	Weight gradient for maximum altitude	G_w	feet/kg	A/C reference manuals
C57	Temperature gradient for maximum altitude	G_t	feet/deg. C	A/C reference manuals

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 H) 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 and fuel data as a function of flight level.

Figure 3.2.2-1: Selected Trajectory Block



	D	E	F	G	H
1		selected trajectory		CL1	climb
2			delta T	0.00	C
3	min FL:	15	mass	74.00	tonnes
4	max dist:	179	max speed	300	kts CAS
5	max FL:	370		0.780	Mach
6	REF.	FLIGHT	DIST	TIME	FUEL
7	LEVEL	LEVEL	[n. miles]	[min]	[kg]
8		450	#N/A	#N/A	#N/A
9		440	#N/A	#N/A	#N/A
10		430	#N/A	#N/A	#N/A
11		420	#N/A	#N/A	#N/A
12		410	#N/A	#N/A	#N/A
13		400	#N/A	#N/A	#N/A
14		390	#N/A	#N/A	#N/A
15		380	#N/A	#N/A	#N/A
16	370	370	179.00	26.00	2750.00
17	360	360	153.00	22.00	2500.00
18	350	350	138.00	20.00	2350.00
19	340	340	127.00	19.00	2250.00
20	330	330	118.00	18.00	2150.00

	D	E	F	G	H
47		60	#N/A	#N/A	#N/A
48		50	#N/A	#N/A	#N/A
49		40	#N/A	#N/A	#N/A
50		30	#N/A	#N/A	#N/A
51		20	#N/A	#N/A	#N/A
52	15	15	0.00	0.00	0.00
53		10	#N/A	#N/A	#N/A
54		0	#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($I$5:$DF$5,
MATCH($G$1,$J$2:$DZ2,0)))

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

Excel definition: E4 = INDEX($F$8:$F$54,

MATCH(MAX($D$8:$D$54),$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$2
H1	name:	trajectory type
	units:	string
	symbol:	not applicable
	description:	a string constant, either “climb” or “descent” associated with each reference trajectory; it is copied from the selected Reference Trajectory Block
	Excel definition:	G2 = INDEX($I$3:$DZ$3 MATCH($G$1,$I$2:$DZ2,0))
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(I2$DZ$2 MATCH($G$1,$I$2:$DZ2,0)-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($I$3$:DZ$3 MATCH($G$1,$I$2:$DZ2,0)-2)`

G4

name: constant CAS for speed law
units: knots
symbol: $(V_{CAS})_{const}$

description: a constant associated with each reference trajectory, it represents the value of CAS maintained during the climb or descent; it is copied from the selected Reference Trajectory Block

Excel definition: `G4 = INDEX($I$4:$DZ$4 MATCH($G$1,$I$2:$DZ2,0)-2)`

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($I$5:$DZ$5 MATCH($G$1,$I$2:$DZ2,0)-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($E{n}=$E$3,
            0,
            IF(INDEX($J{n}:$DZ{n},
               MATCH($G$1,$J$2:$DZ2,0))=0,
                  NA(),
                  INDEX($J{n}:$DZ{n},
                  MATCH($G$1,$J$2:$DZ2,0)-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:

```
H{n}    = IF($E{n}=$E$3,
              0,
              IF(INDEX($J{n}:$DZ{n},
                  MATCH($G$1,$J$2:$DZ2,0))=0,
                     NA(),
                     INDEX($J{n}:$DZ{n},
                     MATCH($G$1,$J$2:$DZ2,0)-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($E{n}=$E$3,
              0,
              IF(INDEX($J{n}:$DZ{n},
                  MATCH($G$1,$J$2:$DZ2,0))=0,
                     NA(),
                     INDEX($J{n}:$DZ{n},
                     MATCH($G$1,$J$2:$DZ2,0))))
```

3.2.3 Reference Trajectory Blocks

A Reference Trajectory Block holds the data corresponding to a reference climb 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.

Each Reference Trajectory Block consists of four columns of the <A/C>.XLS spreadsheet. An example is shown in Figure 3.3.3-1 below. Rows 1 through 7 contain header information that applies globally to the profile. Rows 8 through 54 contain distance, time and fuel data as a function of flight level.

All fields that require data entry by the user are shown in blue on the screen but are shown as shaded in Figure 3.2.3-1.

Figure 3.2.3-1: Reference Trajectory Block

	I	J	K	L
1	trajectory:	nom. spd/min mass/ISA		B727
2	delta T	0	deg. C	CL1
3	mass	74	tonnes	climb
4	max CAS	300	knots	
5	max Mach	0.780	minimum FL	15
6	LEVEL	DIST	TIME	FUEL
7		[n. miles]	[min]	[kg]
8	450			
9	440			
10	430			
11	420			
12	410			
13	400			
14	390			
15	380			
16	370	179.0	26.0	2750
17	360	153.0	22.0	2500
18	350	138.0	20.0	2350
19	340	127.0	19.0	2250
20	330	118.0	18.0	2150

	I	J	K	L
47	60			
48	50			
49	40			
50	30			
51	20			
52	15	0.0	0.0	0
53	10			
54	0			

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.

L1 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: L1 = $C$1

L2 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

L3 name: trajectory type
units: string
symbol: not applicable

description: a string constant, either “climb” or “descent” associated with each reference trajectory; it is input by the user;

Excel definition: user input

J2 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

J3 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

J4 name: constant CAS for speed law
units: knots
symbol: $(V_{CAS})_{const}$

description: a constant associated with each reference trajectory, it represents the value of CAS maintained during the climb or descent; it is input by the users;

Excel definition: user input

J5 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

L5 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

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

description: independent variable for trajectory calculation varies from 0 to 450; it is copied from the Selected Trajectory Block

Excel definition: I{n} = $E{n}

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

Excel definition: user input

K name: reference time to climb/descend
units: min
symbol: t_{ref}
description: reference values input by user;

Excel definition: user input

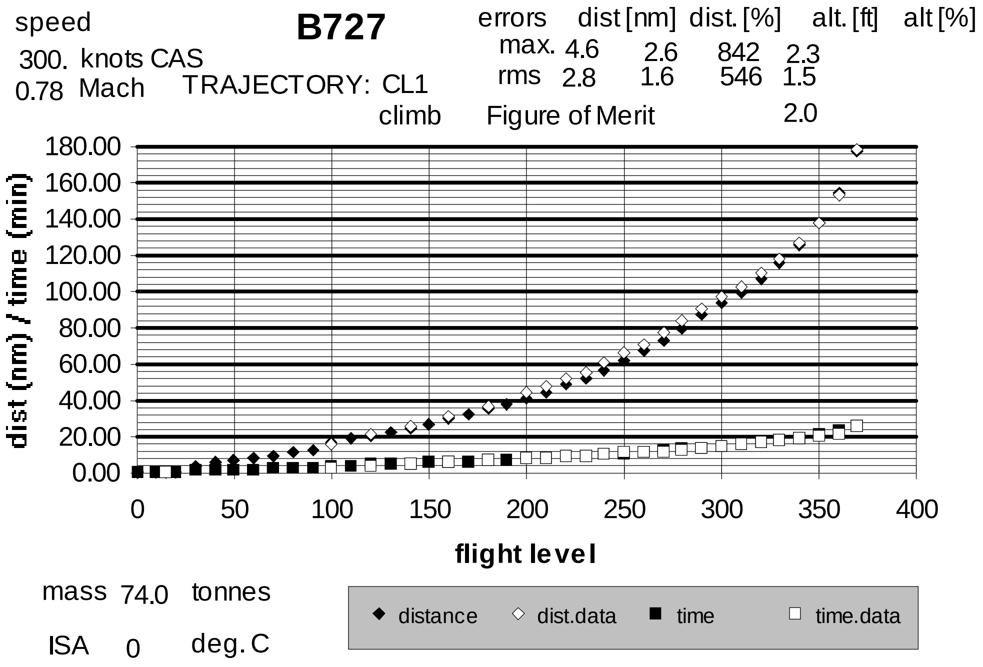
L name: reference fuel to climb/descend
units: kg
symbol: w_{ref}
description: reference values input by user;

Excel definition: user input

3.3 TRAJECT.XLC

The TRAJECT.XLC chart 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.XLC Chart



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 centre of the plot indicate the aircraft type (B727), trajectory identifier (CL1) and trajectory type (climb).

Labels at the top left indicate the speed law parameters for the trajectory, in this case a constant CAS of 300 knots with a Mach limit of 0.78. Labels at the bottom left indicate the assumed aircraft mass at the beginning of the trajectory (74 tonnes) and the atmospheric conditions (ISA+0).

Measurements of the error between the calculated and reference trajectories are summarised at the top right. 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.XLC 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 3.4-1 below. Table 3.4-2 summarises the links used for the various labels.

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

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

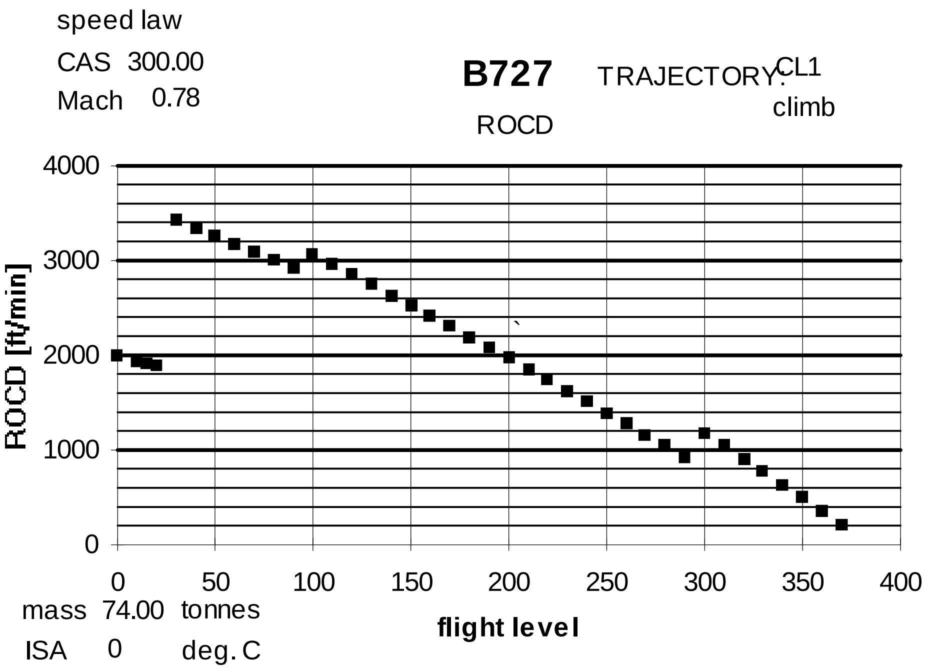
Table 3.3-2: Label Definitions for TRAJECT.XLC

Description	Location	Value in Figure 3.4-1	Excel Definition
aircraft type identifier	top-centre	B727	BADA.XLS!$AJ$2
trajectory identifier	top-centre	CL1	BADA.XLS!$AK$2
trajectory type	top-centre	climb	BADA.XLS!$AL$2
speed law CAS [knots]	top-left	300	BADA.XLS!$I$4
maximum Mach number	top-left	.78	BADA.XLS!$I$5
initial mass [tonnes]	bottom-left	74.0	BADA.XLS!$Q$5
temperature difference from ISA [deg. C]	bottom-left	0	BADA.XLS!$A$5
maximum distance error [nautical miles]	top-right	4.6	BADA.XLS!$AM$3
normalized maximum distance error [%]	top-right	2.6	BADA.XLS!$AN$3
maximum altitude error [ft]	top-right	975	BADA.XLS!$AO$3
normalised maximum altitude error [%]	top-right	2.6	BADA.XLS!$AP$3
root-mean-square distance error [nautical miles]	top-right	2.8	BADA.XLS!$AM$4
normalised root-mean-square distance error [%]	top-right	1.6	BADA.XLS!$AN$4
root-mean-square altitude error [ft]	top-right	577	BADA.XLS!$AO$4
normalised root-mean-square altitude error {%]	top-right	1.6	BADA.XLS!$AP$4
Figure-of-Merit	top-right	2.1	BADA.XLS!$AM$5

3.4 ROCD.XLC

The ROCD.XLC chart shows a plot of the predicted rate of climb or descent. An example is shown in Figure 3.4-1 below.

Figure 3.4-1: ROCD.XLC 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.

Labels at the top centre of the plot indicate the aircraft type (B727), trajectory identifier (CL1) and trajectory type (climb).

Labels at the top left indicate the speed law parameters for the trajectory, in this case a constant CAS of 300 knots with a Mach limit of 0.78. Labels at the bottom left indicate the assumed aircraft mass at the beginning of the trajectory (74 tonnes) and the atmospheric conditions (ISA+0). The ROCD.XLC chart has just one external link. This 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 x and y values for the plotted data points are imported from BADA.XLS as follows:

x value: BADA.XLS!$AK$8:$AK$54

y values: BADA.XLS!$AI$8:$AI$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 3.4-1 summarises the links used for the various labels.

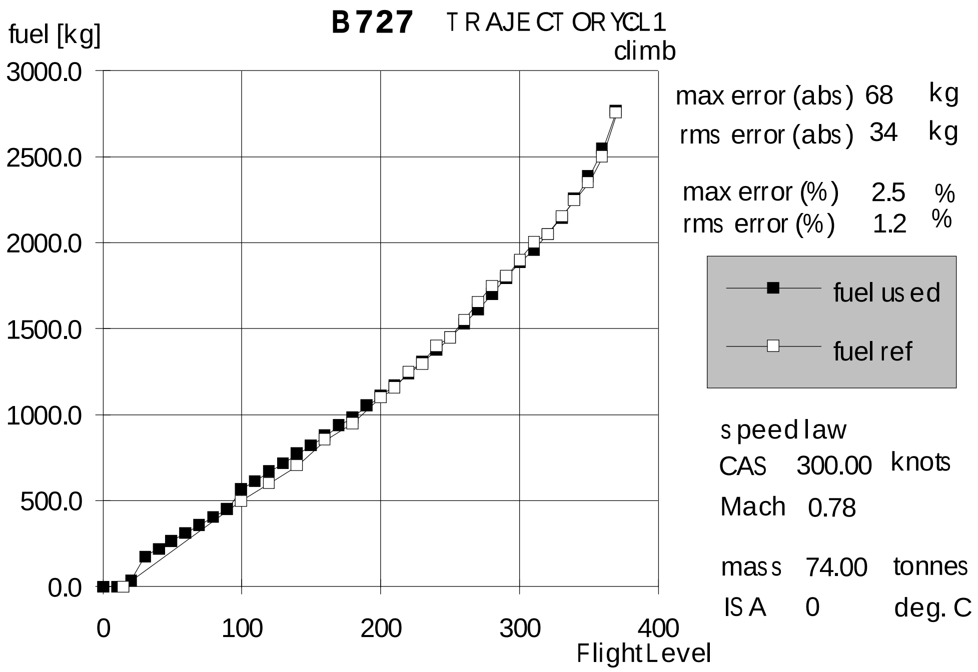
Table 3.4-1: Label Definitions for ROCD.XLC

Description	Location	Value in Figure 3.5-1	Excel Definition
aircraft type identifier	top-centre	B727	BADA.XLS!$AJ$2
trajectory identifier	top-centre	CL1	BADA.XLS!$AK$2
trajectory type	top-centre	climb	BADA.XLS!$AL$2
speed law CAS [knots]	top-left	300	BADA.XLS!$I$4
maximum Mach number	top-left	.78	BADA.XLS!$I$5
initial mass [tonnes]	bottom-left	74.0	BADA.XLS!$Q$5
temperature difference from ISA [deg. C]	bottom-left	0	BADA.XLS!$A$5

3.5 FUEL.XLC

The FUEL.XLC chart 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.XLC 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 (B727), 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 300 knots with a Mach limit of 0.78. Further labels at the bottom left indicate the assumed aircraft mass at the beginning of the profile (74 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.XLC 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 FULE.XLC

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.XLC

Description	Location	Value in Figure 3.6-1	Excel Definition
aircraft type identifier	top-centre	B727	BADA.XLS!$AJ$2
trajectory identifier	top-centre	CL1	BADA.XLS!$AK$2
trajectory type	top-centre	climb	BADA.XLS!$AL$2
speed law CAS [knots]	bottom-right	300	BADA.XLS!$I$4
maximum Mach number	bottom-right	.78	BADA.XLS!$I$5
initial mass [tonnes]	bottom-right	74.0	BADA.XLS!$Q$5
temperature difference from ISA [deg. C]	bottom-right	0	BADA.XLS!$A$5
maximum fuel error [kg]	top-right	70	BADA.XLS!$AV$2
root-mean-square fuel error [kg]	top-right	31	BADA.XLS!$AV$3
normalised maximum fuel error [%]	top-right	2.5	BADA.XLS!$AV$4
normalised root-mean-square fuel error [%]	top-right	1.1	BADA.XLS!$AV$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) Update of APF and OPF Files

(viii) Completion of Aircraft Modelling Report

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.

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.

Currently, the reference information is obtained by members of EEC RTO CoE who maintain contacts with a number of operating airlines and national certification agencies. All reference manuals 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 HS25 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 which have 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 HS25 model for BADA Revision 2.3 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 Dornier 328 aircraft was initialised as a copy of the report for the previously modelled Dornier 228 aircraft. 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. More information on these gradients is available from RD9.

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 Pratt & Whitney Canada PW119B turboprop	[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)

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	Appr.
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	parasitic 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
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

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

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 many cases, only one CAS is specified and thus the same value is used for both. In some cases, the 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.

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	
trajectory type	[either “climb” or “descent”]
temperature difference from ISA	[deg. C]
mass	[tonnes]
CAS	[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.

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.XLC
ROCD.XLC
FUEL.XLC

The BADA.XLS spreadsheets and the TRAJECT.XLC and FUEL.XLC charts 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 File Menu.

Note that the update of the links are the only changes to these files which 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.XLC 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.XLC 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.XLC 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.XLC 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. 10000 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.

In some cases, also 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 5.0. 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.XLC chart.

Not too much time should be spent trying to optimise the two drag coefficients at this point. This is because they will later need to be adjusted 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.

(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.XLC 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>.XLC 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.XLC 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. The ROCDs obtained through this calculation should not deviate more than 20% from those calculated by BADA. Matching the ROCD below FL30 appears to be very difficult to achieve.

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 is 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 final BADA coefficients to be determined are the fuel coefficients.

There are two sets of fuel coefficients. The first set is the two coefficients, C_{f1} and C_{f2} , that specify the Thrust Specific Fuel Consumption (TSFC). The second set is the two coefficients, C_{f3} and C_{f4} , that specify the minimum fuel flow.

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.XLC 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 criteria 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 4% 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 3.8] 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.XLC 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. Only if it is not possible to obtain an acceptable fit it this manner should the C_{f4} coefficient be varied. Note that the C_{f4} term introduces a dependency of the minimum fuel flow on altitude [RD1, Section 3.8] for jets and turboprops but is ignored completely for piston aircraft.

4.7 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.

The format of the APF, OPF and SYNONYM files are described in Section 4 of the BADA User Manual [RD1]. Configuration management procedures for these files are specified in the BADA Configuration Management Manual [RD7].

4.8 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.

4.9 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.

5. CONFIGURATION MANAGEMENT

The BADA/Excel spreadsheet files are not controlled within any formal Configuration Management (CM) system. A formal CM system will 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 which perform the calculations (BADA.XLS, TRAJECT.XLC, ROCD.XLC, FUEL.XLC).

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.

APPENDIX A

Configuration Maintenance Logs

Excel Spreadsheet Modification Log

Aircraft Spreadsheet Log

Modification Log for BADA/Excel Spreadsheets

Date: 22.7.96
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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	237252	06/04/95	17:23:34	B727	Boeing 727	07.04.95
		TRAJECT.XLC	11185	06/04/95	17:23:34	B737	Boeing 737-500	14.04.95
		FUEL.XLC	6918	06/04/95	17:23:34	FK50	Fokker 50	17.07.95
		ROCD.XLC	4238	06/04/95	17:23:34	TU54	Tupolev Tu154	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	240757	13/04/95	12:52:32	MD11	McDonnell-Douglas MD-11	14.04.95
		TRAJECT.XLC	11274	13/04/95	12:52:32			
		FUEL.XLC	6963	13/04/95	12:52:32			
		ROCD.XLC	4266	13/04/95	12:52:32			
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	240925	21/04/95	14:30:50			
		TRAJECT.XLC	11274	13/04/95	12:52:32			
		FUEL.XLC	6963	13/04/95	12:52:32			
		ROCD.XLC	4266	13/04/95	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

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Date	Modification Description	File Specifications				Modelled Aircraft		
		Name	Size	Date	Time	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 TRAJECT.XLC FUEL.XLC ROCD.XLC	242320 11269 6960 4266	29/05/;95 29/05/95 29/05/95 13/04/95	13:26:52 13:26:52 13:26:52 12:52:32	TU34 FK70 C421	Tupolev Tu- 134 Fokker 70 Cessna 421 Golden Eagle	9.11.95 4.12.95 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 TRAJECT.XLC FUEL.XLC ROCD.XLC	246494 11089 6864 4235	08.12.95 08.12.95 08.12.95 08.12.95	15:10:12 15:10:20 15:10:18 15:10:24	MD80 DH83 EA32	McDonnell Douglas MD80 DeHavilland Dash 8-300 Airbus A-320	6.3.96 19.3.96 19.7.96

Aircraft Spreadsheet Log

Date: 22/7/96
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File Name	Aircraft Name	XLS File Specifications			Report Date
		Date	**Time**	**Size**	
B727.XLS	Boeing 727	24.04.95	11:42:42	164730	07.04.95
B73V.XLS	Boeing 737-500	11.04.95	15:04:51	193380	14.04.95
BA31.XLS	BAe Jetstream 31	03.04.95	17:44:32	118545	04.11.94
BA41.XLS	BAe Jetstream 41	03.04.95	17:44:58	128917	04.11.94
BATP.XLS	BAe Advanced Turboprop	03.04.95	17:45:26	164248	19.11.94
C421.XLS	Cessna 421 Golden Eagle	19.12.95	11:45:54	154906	8.12.95
D228.XLS	Dornier 228	03.04.95	17:40:48	144531	26.01.95
D328.XLS	Dornier 328	03.04.95	17:47:10	159982	17.02.95
DH83.XLS	DeHavilland Dash 8-300	19.03.96	15:21:54	163371	19.03.96
EA32.XLS	Airbus A-320	16.07.96	11:18:10	55296	19.07.96
FGTR.XLS	Generic Military Fighter	12.05.95	14:02:04	157611	12.05.95
FK50.XLS	Fokker 50	20.07.95	11:01:26	89443	17.07.95
FK70.XLS	Fokker 70	08.12.95	15:10:14	180387	04.14.95
MD80.XLS	McDonnell-Douglas MD-80	06.03.96	11:07:42	163574	06.03.96

Aircraft Spreadsheet Log

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MD11.XLS	McDonnell-Douglas MD-11	13.04.95 12:52:32 148206	14.04.95
SH36.XLS	Shorts 360	03.04.95 17:54:38 180527	23.11.94
TU34.XLS	Tupolev Tu-134	09.11.95 09:52:22 162048	09.11.95
TU54.XLS	Tupolev Tu-154	29.06.95 11:40:08 88767	27.06.95