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BASE OF AIRCRAFT DATA (BADA) PRODUCT MANAGEMENT DOCUMENT

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BASE OF AIRCRAFT DATA (BADA) PRODUCT MANAGEMENT DOCUMENT

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Abstract:

This document is the Base of Aircraft Data (BADA) Product Management document.

The central part of the BADA Product is the BADA Aircraft Performance Model (APM), intended for use in aircraft trajectory simulation and prediction algorithms within the domain of Air Traffic Management. BADA APM has been developed by EUROCONTROL over the past decades in cooperation with aircraft manufacturers, airlines and ANSPs. It is used internally at EUROCONTROL, but also provided to the international aviation community comprising research institutions, universities, ANSPs, ATM suppliers, airlines and aircraft manufacturers. Use of BADA APM is governed by a licence agreement. Other complementary Support Tools and Support Services accompany BADA APM to facilitate its access and use. The present document provides details about each component of the BADA Product: (1) the BADA Aircraft Performance Model (APM), (2) Support Tools and (3) Support Services.

It also describes the legal aspects and licensing. It provides details about change and configuration management practices, processes for maintenance, development and release cycles. All actors and their roles and responsibilities are also defined and presented in the document.

The present document refers to the BADA family 3, BADA family 4, BADA family H and is applicable to the BADA release versions 3.15, BADA 4.2, BADA H1.0 and onwards.

REVISION HISTORY

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1.1	May 2019	Updates related to: - BADA Family 4 and Family H - New BADA User Interface web application - Licencing process - BADA release schedules	Angela Nuic Carol Sheehan Vincent Mouillet

EXECUTIVE SUMMARY

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GLOSSARY OF ACRONYMS

ANSP	**A**ir **N**avigation **S**ervice **P**rovider
APM	**A**ircraft **P**erformance **M**odel
APC	**A**ircraft **P**erformance **C**alculation
ATC	**A**ir **T**raffic **C**ontrol
ATM	**A**ir **T**raffic **M**anagement
BADA	**B**ase of **A**ircraft **Da**ta (BADA)
BR	**B**oard **R**eviewer
BUI	**B**ADA **U**ser **I**nterface
BSA	**B**ADA **S**upport **A**pplication
CCB	**C**hange **C**ontrol **B**oard
CM	**C**hange **M**anagement
ECAC	**E**uropean Civil Aviation Conference
EEC	**E**UROCONTROL **E**xperimental **C**entre
FDPS	**F**light **D**ata **P**rocessing **S**ystem
FP	Focal Point
ICAO	International Civil Aviation Organization
ISA	**I**nternational **S**tandard **A**tmosphere
LM	**L**icence **M**anager
MET	**Met**eorological Data
NMOC	**N**etwork **M**anager **O**perations **C**entre
PM	**P**roject **M**anager
RSD	**R**evision **S**ummary **D**ocument
TC	**T**echnica**l** **C**ontact
TEM	**T**otal **E**nergy **M**odel
TO	**T**echnical **O**fficer
TP	**T**rajectory **P**rediction
TSR	**T**echnical **S**upport **R**equest
UCG	**U**ser **C**onsultation **G**roup
UM	**U**ser **M**anual

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1. INTRODUCTION

EUROCONTROL (the European Organisation for the Safety of Air Navigation) is an intergovernmental organisation, committed to building, together with its partners, a Single European Sky that will deliver the air traffic management (ATM) performance required for the twenty-first century and beyond. EUROCONTROL's mission is to harmonise and integrate air navigation services in Europe, with the aim of creating a uniform ATM system for civil and military users, in order to achieve the safe, secure, orderly, expeditious and economic flow of traffic throughout Europe, while minimising adverse environmental impact (http://www.eurocontrol.int).

Efficient air traffic operations rely on the capability of ATM systems to predict aircraft trajectories. Likewise, ATM research and development activities require modelling and simulation tools capable of replicating real-life operations and aircraft performances as perfectly as possible.

To enable the high fidelity modelling and simulation of aircraft trajectories in support of various ATM research and operational applications, every aircraft in operation needs to have a corresponding Aircraft Performance Model (APM).

This is why EUROCONTROL has developed an Aircraft Performance Model referred to as BADA (Base of Aircraft Data). Over the past decades, EUROCONTROL has been dedicated in perfecting aircraft performance modelling skills, acquiring reference data and developing aircraft models that would meet the evolving requirements of both operational and Research & Development (R&D) ATM applications.

Aircraft performance reference data is a critical enabler for APM development. Aircraft models can be developed from various data sources with different levels of quality; the models' quality, however, is directly related to the quality of the reference data.

Building partnerships and working together with aircraft manufacturers, airlines, ANSPs, universities and BADA users greatly contributed to populating the BADA aircraft performance database with models for nearly all the aircraft in operation today.

BADA is used internally at EUROCONTROL, but also provided to the international aviation community comprising research institutions, universities, ANSPs, ATM suppliers, airlines and aircraft manufacturers.

Nowadays, BADA is considered a standard in aircraft performance modelling and a critical enabler for various ATM-related activities, including:

- R&D, mostly for the evaluation and validation of new operational concepts;
- Operational ATC purposes such as the management of traffic flows, there being a direct relationship between the accuracy of aircraft trajectory prediction and the efficiency of flight operations, with an impact on cost;
- Environment-related activities (such as global emission studies);
- Education (e.g. Air Traffic Controller's training, aeronautical engineers, etc.).

In the context of developments relating to the Single European Sky and its implementation across Europe, EUROCONTROL is committed to continuing to maintain and provide BADA for the benefit of the international aviation community and all its actors.

2. BADA PRODUCT COMPONENTS

The BADA product is made of three main components that are detailed in the following sub-sections: (1) BADA Aircraft Performance Model, (2) Support Tools and (3) Support Services.

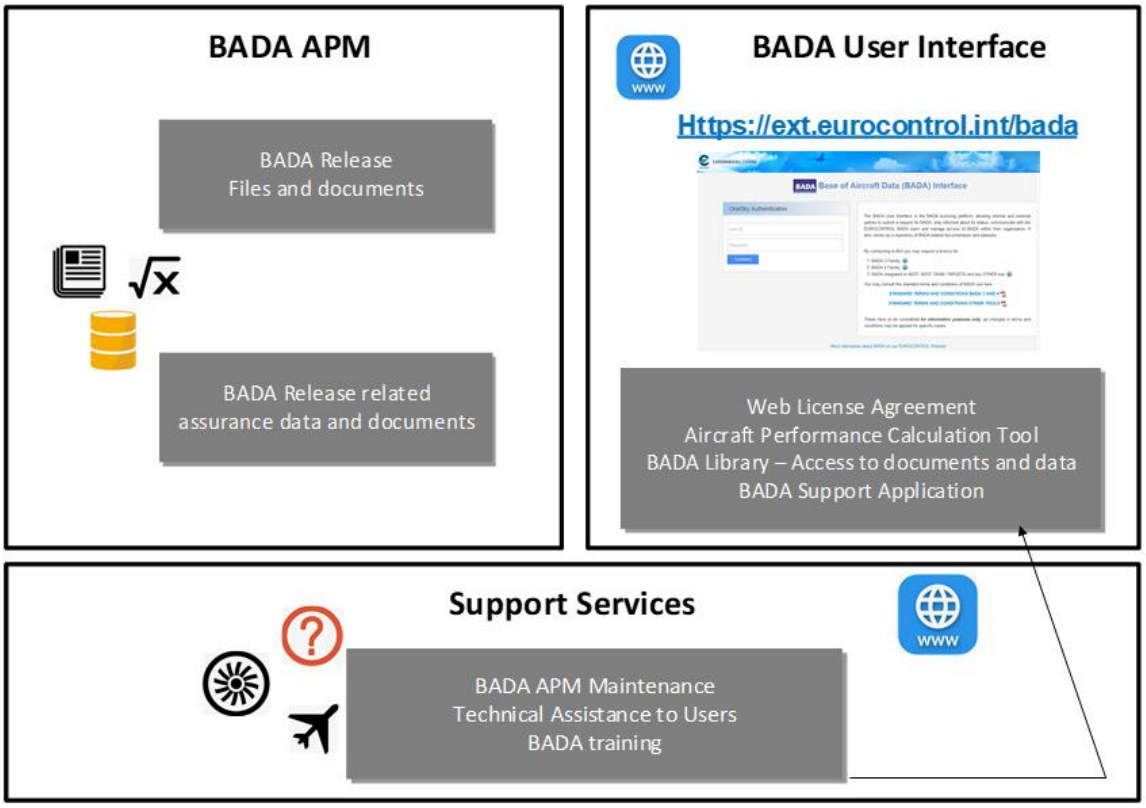

Figure 2-1: BADA product components

2.1. BADA AIRCRAFT PERFORMANCE MODEL (APM)

BADA APM is not a software product. It is a mathematical model that enables calculation of aircraft performances. It is made of:

1. **Model specifications:** theoretical models used to calculate aircraft performance parameters, described and provided in a document called BADA User Manual;
2. **Data sets:** aircraft-specific coefficients needed to make calculations, provided in form of ASCII or XML files.

There are three co-existing variants of the BADA APM, referred to as **BADA Families**:

1. **BADA Family 3:** Today's standard for aircraft performance modelling with almost 100% coverage of aircraft types in the European Civil Aviation Conference (ECAC) area. Its objectives are to model aircraft behaviour over the nominal part of the flight envelope and to meet today's requirements for aircraft performance modelling and simulation.
2. **BADA Family 4:** This newly developed model family covers 80% of aircraft types operated in the ECAC area. It provides increased levels of precision in aircraft performances parameters over the entire flight envelope to enable modelling and simulation of advanced systems and future concepts.
3. **BADA Family H:** An extension of the BADA aircraft performance model in order to provide modelling and trajectory calculation capabilities for helicopter aircraft types.

2.1.1. BADA Delivery Package

Delivery package for each BADA APM Family is made of a set of documents and data files that are referred to as BADA Release.

2.1.1.1. Documents

Release specific documents available to licenced users (see Appendix A for more insight into the main purpose and content):

- BADA Family 3:
  - User Manual
  - Revision Summary Document
  - Aircraft Performance Summary Tables
  - Synonym Aircraft Report
  - Model Accuracy Summary Report
- BADA Family 4:
  - User Manual
  - Release Note
  - Compatibility Matrix
- BADA Family H:
  - User Manual
  - Release Note

Supporting documents publicly available:

- BADA Product Management document

Supporting documents available on request:

- BADA APM Development Manual
- Coverage of European Air Traffic for BADA

2.1.1.2. Data Files

There are several types of data files:

- Aircraft-specific data files,
- Generic data files applicable to all aircraft models.

2.2. BADA SUPPORT TOOLS

BADA User Interface (BUI) offers a number of web-based functionalities to facilitate the use of BADA. The BUI can be accessed by both internal and external users, provided the user holds a EUROCONTROL OneSky Online (extranet) account (see section 3.4.2).

The BUI provides the following functions:

1. Web Licensing and BADA APM Access Rights Management
2. Repository for Documents and Data files
3. Aircraft Performance Calculation tool
4. Aircraft Synonym Search tool
5. BADA User Support Application (BSA)

2.2.1. Web Licencing and BADA APM Access Rights Management

Licence requests and user access rights management is handled using dedicated interfaces of the BUI accessible via the 'Licence' section.

The following functions are provided there to:

- allow external and internal requestors to request a BADA licence or approval to use a tool where BADA is integrated;
- follow the update and status of their request(s) on-line;
- facilitate requestor exchanges directly with the BADA review members (BADA Licence Agreement Board) regarding their request(s);
- allow a licenced user to manage access rights within the user's organisation by providing access to BUI to the project team members.

2.2.2. Repository for Documents and Data files

The majority of the BADA Documents and Data files are made available for download via the 'BADA Libraries' section of the BUI. Access rights are divided into two distinct categories:

- public: documents and files which are accessible to all licenced users, regardless of model family and release version(s) for which a licence has been granted.
- private: documents and files of a specific BADA model family and release for which a licence has been granted.

2.2.3. Aircraft Performance Calculation Tool

The Aircraft Performance Calculation (APC) tool allows the calculation of aircraft performances based on the BADA APM for climb, cruise and descent phases (including flight envelope) under various conditions. The input parameters are chosen by the user. Calculations may be carried out either by single aircraft type (with reference to a particular BADA version) or by selecting several aircraft types (multi aircraft calculation). The calculation results are made available to the users in two ways: displayed on the screen, and provided in a text file that can be downloaded for further use. In addition to the APC function, there are other functionalities such as:

- speed conversions (TAS/CAS/Mach) at different pressure altitudes;
- transition altitude calculation between predefined CAS and Mach;
- atmospheric properties according to International Standard Atmosphere (ISA).

The APC functionality is provided only for BADA Family 3.

2.2.4. Aircraft Synonym Search Tool

The BADA data files provide performance and operating procedure data for a set of aircraft known as BADA aircraft original models. A further set of aircraft types is identified as being 'equivalent' to these original aircraft models. They are referred to as synonym aircraft.

For each BADA Family 3 release, a list of synonym aircraft types is provided based on a pre-defined set of criteria. However, users may change the importance and weighing of the search criteria and customise the choice according to their needs and application type.

A synonym search function in BUI assists the user to identify an aircraft model in BADA that meets the user specific selected criteria. A user document "Guidelines for BADA Synonym Search Tool" is available under the documentation section of the BUI.

The Synonym Search function:

- provides a means of searching the BADA original aircraft model data parameters using

predefined search criteria,

- proposes the BADA original aircraft models that fit the search criteria,
- allows the comparison of a set of aircraft operational parameters against the BADA original aircraft models by providing a difference metric.

Note that the Synonym Search Tool functionality is provided only for BADA Family 3.

2.2.5. BADA User Support application (BSA)

The primary objective of this function is to allow users to report and track problems, request a change and ask questions related to BADA model implementation and its application.

To request support the user must hold a valid BUI user account.

A user can access this tool via the 'BADA Support Application' (BSA) section of the BUI. A user may either report an issue under the 'Report an Issue' option where a report form is proposed; or may track the progress of an already reported issue.

2.3. SUPPORT SERVICES

The purpose of the support service activity is to cater for user-customised needs that are outside of the scope of the BADA core product management (BADA APM). The support services could refer to:

- technical support request (TSR) for expert assistance in the BADA APM related domain,
- provision of training on BADA APM,
- assistance with the installation and configuration of the BADA Support Tools,
- modelling study definition and execution,
- new tool developments,
- etc.

The way in which the support services are managed is described in section 6.

3. LICENCE AGREEMENT

The use of BADA is governed by a licence agreement. The licence is granted for a specific intended use as long as the intended use falls into one of the permitted domains of application.

3.1. PERMITTED USE OF BADA

BADA may be used as a source for aircraft performance models and data for the following areas of application:

- Research and Development activities in the domain of ATM;
- Non-safety-critical operational ATM applications and systems[1];
- Flight profile calculations in support to preliminary design, analysis, and operational assessment of procedures and airspace. All procedures must still go through a separate and independent validation, safety, and certification process;
- Education and training in the domain of ATM;
- Environmental assessments;
- Flight efficiency studies, cost benefit analysis and similar.

3.2. PROHIBITED USE OF BADA

- All safety-critical ATM applications and systems;
- Any comparisons of any kind between aircraft types (from the same or different aircraft manufacturers) where the intent of such a comparison is to identify a direct relationship between aircraft performances. However, general (system-wide) comparisons of aircraft performance of different aircraft types for research purposes to assess ATM system performances may be allowed;
- Aircraft flight planning and flight dispatch purposes;
- In commercial tools which are not related to the ATM domain.

3.3. USE OF BADA IN COMMERCIAL CONTEXT

- It is not permitted to sell BADA or BADA data as such;
- It is permitted to develop a commercial tool with “BADA inside” provided that the client of the tool obtains a BADA licence and access to data sets directly from EUROCONTROL;
- It is permitted to use BADA where the results/deliverables are in principle of a commercial nature, but for this purpose, not considered as commercial use.

3.4. LICENCING PROCESS

The BADA licence agreement is web-based and the corresponding process is explained in this sub-section.

[1] *Non-safety-critical applications and systems are those intended to improve the ATM system or facilitate ATM operations, through provision of awareness or relevant information to make decisions, whenever it can be guaranteed that the ATM application shall never create a safety breach in any part of the system. For an ATM application or system to be considered as non-safety-critical, it has to be proven that the application outcomes do not produce a direct effect on the system, but through a further agent (human or system) that holds the responsibility for safety. Thus, the responsibility to make decisions or take actions that might impact safety needs to reside in such further agent that shall, among others, validate the input provided by the ATM application or system considered.*

3.4.1. Who is entitled to submit a request?

Licence agreement requests may be submitted by any authorised representative of a legal entity who has or has been delegated the authority to place a request on behalf of their organisation and to bind the company with respect to licence agreements with other organisations.

When a requestor is a person who has been delegated the authority, a proof (attestation) of such legal authority delegation must be provided when submitting a request.

For licencing purposes, BADA refers to an organisation's legal authority as the organisation 'representative' whereas the BADA contact person within the organisation is referred to as BADA Focal Point (FP); see section 4.1 for further explanation.

In the case of educational establishments, only requests which have been formally submitted on behalf of the educational establishment by an authorised employee are accepted for review. Students shall obtain access to BADA only via official channels at the educational establishment.

In no case will a licence be granted to a private individual.

3.4.2. Steps in the Licencing process

1. **Register to the OneSky Online portal** on the EUROCONTROL Extranet https://ext.eurocontrol.int/
2. Once registered and logged on to OneSky, **click on "BADA User Interface"** listed under "My services" which will automatically direct you to the BADA User Interface with a logged-on status.
3. **Fill and submit the on-line registration form** corresponding to the licence type required (BADA 3, BADA 4, BADA H or other tools where BADA is integrated). Through the use of the user request form, the requestors are obliged to fill mandatory data thus providing valuable information regarding the nature of the requestor (e.g. ANSP, Research organism, University etc.) and detailed information on the intended use of BADA.
4. **BADA Licence Agreement Board reviewers analyse and assess requests** in view to providing BADA access. Should clarifications be further required, this may be done directly through the BUI where reviewers may exchange directly with the requestor (discussion function) or request more detailed information in addition to the data provided initially in the request form. The content of information provided by the requestor is then transferred to the formal BADA use description outlined in the BADA user licence agreement.
5. **A draft version of BADA Licence is prepared and sent** to the requestor for information and review before final acceptance.
6. **Review of BADA Licence by the requestor.** After having carefully reviewed the terms and conditions, the requestor has the option to accept or refuse.
    a. In the case where the requestor accepts the proposed BADA licence, the BADA Licence Manager issues a final licence that includes the date of acceptance, which is considered as the licence start date.
    b. In the case where the requestor refuses the proposed Terms and Conditions of the draft agreement, the BADA Board may either accept the refusal and terminate the request as such; or the Board may place the request in a "Re-submitted" state in order to re-evaluate the refusal cause.
7. **Creation of a user access in BUI**:
    a. The BADA requestor (Focal Point) obtains access to BUI.
    b. The Focal Point is entitled to provide access to BUI to his team project members (see section 4.1). These accesses must use the same e-mail "domain name" as the Focal Point and require a prior OneSky account login.

c. In the event of a breach of a licence, the licence suspension or licence cancellation processes may be applied, removing access to the BADA libraries either temporarily or permanently.

Specific case:

For the case of BADA approval for integrated tools, the tool owner organisations and requestors receive a copy of the confirmation licence of approval to use BADA in relation to the requested tool. No data or tools access is provided to the requestor.

3.4.3. **Licence Request Processing Time**

The target processing time for a licence request is set to 3 to 5 working days[2]. It greatly depends on the completeness of information provided in the licence request form. The level of information provided is paramount for the BADA board reviewers to assess that the request respects the permitted uses of BADA. A lack of key information or imprecise details will unavoidably slow down the review phase.

[2] *Due to the restricted uses of BADA Family 4 data sets (in comparison to BADA Family 3), requests require to be strongly justified in order to receive approval from both EUROCONTROL and the source data providers (aircraft manufacturers). Licence for granting access to the BADA Family 4 model specification is processed within 3-5 days. However, as a result of requiring an external approval, the provision of BADA Family 4 data sets may take from several weeks (3-6 weeks) to, in some extreme cases (holiday periods), up to 2 months.*

4. ACTORS, ROLES AND RESPONSIBILITIES

The management of the BADA Product is a shared responsibility between:

- BADA Focal Point (FP)
- BADA Licence Manager (LM)
- BADA Board Reviewers (BR)
- BADA Project Manager (PM)
- BADA Technical Officer (TO)
- BADA Change Control Board (CCB)
- BADA User Consultation Group (UCG)

4.1. BADA FOCAL POINT

A BADA Focal Point is a person who submits a request for BADA and commits to the BADA licence agreement terms and conditions on behalf of his/her organisation. This person needs to have a legal authority or have it delegated to them by the person in the organisation who holds it. The Focal Point is responsible for granting and managing access accounts to so-called Technical Contacts (TC) within their organisation for the sole use stipulated in their approved licence agreement. These accesses must use the same email “domain name” as the Focal Point and require a prior OneSky account login.

4.2. BADA LICENCE MANAGER AND LICENCE BOARD REVIEWERS

The BADA LM is responsible for management and administration of licence requests and interacts directly with BADA Board Reviewers (BR). The BR is an internal EUROCONTROL body who has the responsibility to examine requests for BADA in order to decide if the access to BADA shall be granted or not.

4.3. BADA PROJECT MANAGER

The BADA PM is the person in charge of the BADA project, who is responsible for supervision and coordination activities. BADA PM chairs the UCG and CCB meetings. The PM coordinates any changes to the Licence Agreement with legal and regulatory experts at EUROCONTROL.

4.4. BADA TECHNICAL OFFICER

The BADA Technical Officer is the primary person responsible for maintenance and development of the BADA APM and management of the supporting tools.

In particular, the BADA TO is responsible for the following tasks:

- development of aircraft performance models;
- updates of BADA documentation;
- configuration management of BADA data files and documents at EUROCONTROL;
- analysis and evaluation of User requests;
- definition and execution of corrective measures;
- liaising with users on technical matters;
- provision of technical support;
- preparation of agendas and minutes for meetings,
- etc.

4.5. BADA CHANGE CONTROL BOARD (CCB)

The CCB is a EUROCONTROL internal body. The members of the CCB can vary, but will always include the BADA PM, TO and representatives from other EUROCONTROL sections/divisions who have interest in the BADA applications and development.

The role of the CCB is to provide a central control mechanism to ensure that user requests are properly considered, coordinated and prioritized. The CCB takes into consideration the advice from the UCG and makes decisions related to the BADA development strategy. EUROCONTROL is the only sponsor and development is funded through a budgetary envelope. Priorities have to be decided in order to fit within the limits of this envelope.

The CCB attendees must guarantee their ability to understand the completeness of requirements and to be empowered to come to an agreement on BADA prioritisation of changes. The CCB formally meets twice a year. Between the formal meetings of the CCB, members may still be called periodically in case of urgent needs.

4.6. BADA USER CONSULTATION GROUP

The BADA User Consultation Group (UCG) is formed of the BADA User Focal Points (or delegated contact persons) who wish to actively participate in the BADA product and strategy development.

The UCG is an advisory body to EUROCONTROL, while EUROCONTROL keeps design authority for BADA developments. The UCG meets periodically (once every year and a half) with the aim to discuss, define and prioritize requirements to be proposed for implementation in the new BADA releases.

5. BADA APM MANAGEMENT

This section describes different aspects of the BADA APM management. It defines the scope of maintenance and support by detailing provided services and defining corresponding processes. The way user requests are dealt with, together with supporting tools for change and configuration management are mentioned. The BADA release management and corresponding lifecycles are also presented.

5.1. MAINTENANCE AND SUPPORT

Maintenance refers to corrective and perfective change management of the BADA APM components (ranging from the BADA model algorithms to the aircraft models and corresponding parameters). The support refers to the provision of the first-level support to the BADA users in implementing and using the BADA APM.

The BADA Support Application (BSA) enables efficient communication and support management of various user requests by ensuring traceability and transparency. Brief information on how to access the BSA is given in section 2.2.5.

5.1.1. User request management

There are four main categories of user requests with respect to the BADA APM maintenance and support:

- **Question**: first-level support;
- **Problem Report**: corrective maintenance;
- **Model/Synonym Request**: perfective maintenance of the aircraft database;
- **Evolution Request**: perfective maintenance of the model specifications.

All user requests follow the same lifecycle, implemented in BSA and presented in Figure 5-1.

The following sections provide details on how the user can determine the request category that corresponds to his/her request, and on the associated process.

5.1.1.1. Question

Scope: The **Question** category of user requests refers to questions and clarification inquiries related to different aspects of the BADA model, from its theoretical foundations to implementation and application.

Process: The user submits a Question via the BSA. The TO analyses the request and responds to the user.

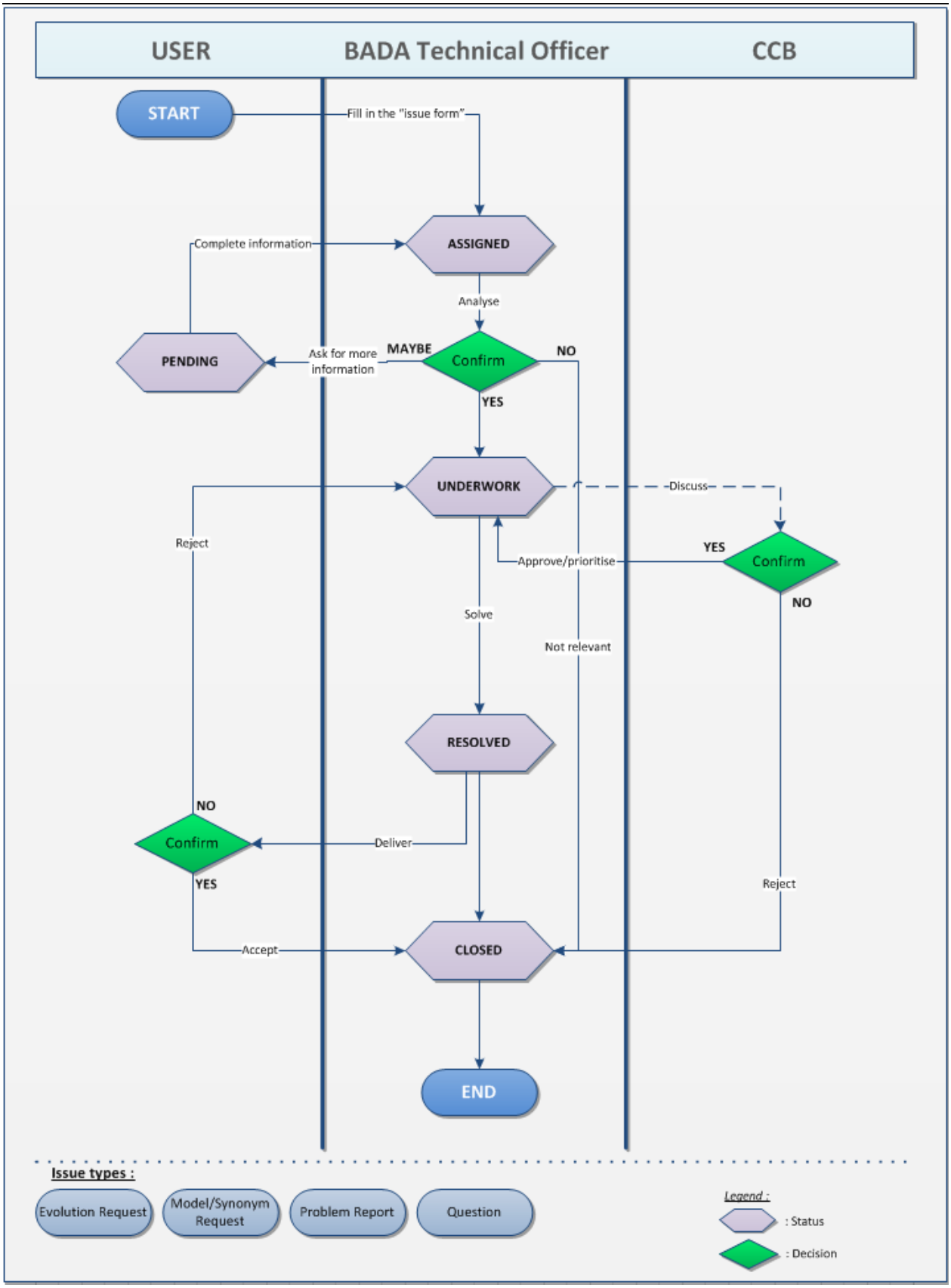

Figure 5-1: User Request workflow

5.1.1.2. Problem Report

Scope: A **Problem Report** can be submitted in the following cases:

- Problem with existing aircraft model
- Problem with existing synonym model
- Problem with a BADA support tool
- Generic problem report

Process: For all the above listed cases, the user submits a Problem Report via the BSA. At the time of creation, the user provides information as requested in the BSA templates. The user is requested to provide evidence and supporting data for problem analysis (as described in Appendices B and C).

The TO analyses the request and clarifies unclear issues with the user. Once the TO has all the relevant information and data, he/she deals with the PR.

In case of a reported problem with an existing model aircraft, the problem analysis is focused on the BADA model and its coefficients. This analysis can lead to the discovery of errors in the coefficient determination due to, for example, the use of inappropriate information from the aircraft performance reference data. If such errors are detected then the model can be corrected and the problem resolved.

In some cases, it may be verified that the BADA model correctly matches the reference information, but reference information is specific to an aircraft model or version of the aircraft type which is different from the aircraft versions in actual use. A corrective action in this case is more difficult. If the current model is based on an older version that is no longer widely used, then it is recommended practice to redevelop the model based on a more modern or widely used version.

The problem resolution may require the availability of additional aircraft performance reference data, such as aircraft manufacturer's data or operational data. The TO should try to acquire the data through contacts with the aircraft manufacturers and operating airlines. The user, through his/her organisation, may also assist in the process of finding the contacts and obtaining the required data. In case aircraft operational data (e.g. radar data) is required, then the user shall ensure access to this information to the TO.

A generic problem report can be related to an inherent limitation in the BADA models and algorithms. In these cases, it may happen that no immediate correction can be defined. Instead, long-term studies over a period of several weeks or months may be required to identify the best way to upgrade the model and then implement the upgrades for all aircraft types. This kind of problem report is then reclassified as an Evolution Request.

It may also be that the reported problem is due to a misinterpretation by users, wrong use of aircraft parameters or due to a known/unknown error in another piece of software such as the on-line trajectory prediction or trajectory generation software. For cases like these, the Problem Report for BADA is rejected with the recommendation that it has to be assigned to another component without any corrective action taken in BADA.

In a case where the TO resolves the problem, a correction patch may be sent to the user for validation and feedback. The approval process shall be based on data and facts to avoid conflicting and dead end situations. This aspect shall be further elaborated and discussed in the BADA workshops and UCG meetings. To avoid that requests stay pending approval indefinitely, either the system or a BADA team member may accept the correction in place of the user.

All the Problem Reports that have been registered since the last CCB meeting are presented at the CCB meeting. The TO explains the reported problems and corrective actions that were taken. In collaboration with the members of the CCB, a decision is made whether these modifications will be incorporated in the future BADA baseline release.

5.1.1.3. Model/Synonym Request

Scope: A **Model/Synonym Request** can be considered when the user needs aircraft performance data for an aircraft type that is not represented in BADA, neither through a native model nor a synonym.

Process: The user submits a Model/Synonym Request via the BSA. At the time of creation, the user provides information as requested in the BSA templates. The user shall explain how the addition of the requested model or synonym would benefit his/her work.

The provision of a new model/synonym may require the availability of additional aircraft performance reference data, such as aircraft manufacturer's data or operational data. The TO should try to acquire the data through contacts with the aircraft manufacturers and operating airlines. The user, through his/her organisation, may also assist in the process of finding the contacts and obtaining the required data.

All the Model/Synonym Requests which have been registered since the last CCB meeting are presented at the CCB meeting. In collaboration with the members of the CCB, a decision is made whether these models/synonyms will be incorporated in the future BADA baseline release.

5.1.1.4. Evolution Request

Scope: An Evolution Request can be submitted when a change is requested to the model algorithms, format of the release files or data in global aircraft parameters.

Process: The user submits an Evolution Request via the BSA. At the time of creation, the user provides information as requested in the BSA templates. The user is requested to provide information and supporting data to enable the analysis of the request. The TO analyses the request and clarifies unclear items with the user until obtaining all the relevant information that would enable the identification of required actions.

If the requested evolution consists in a new feature or performance parameter, a prerequisite to analysing, validating and implementing the change is the availability of the corresponding aircraft performance reference data, such as aircraft manufacturer's data or operational data. The TO should try to acquire the data through contacts with the aircraft manufacturers and operating airlines. The user, through his/her organisation, may also assist in the process of finding the contacts and obtaining the required data.

The TO may also propose changes that are deemed beneficial to the model.

All the evolutions requests are discussed at the UCG and CCB meetings. The TO explains the results of the analysis and identifies required resources (data and staff). In function of that and expressed user needs, the CCB decides on prioritisation and definition of the actions.

After development, the changes are implemented in one of the future BADA releases based on the release cycle (section 5.3) and BADA development roadmap.

5.1.2. Responsiveness

Responsiveness is defined as the response time within which a User Request is being dealt with and a response (not necessarily a solution) is provided back to the requestor.

Considering the nature of BADA APM-related User Requests (described in the previous sections), the resolution of the problem or implementation of a change strongly depends on the availability of the required data (aircraft performance or operational data). It is therefore impossible to precisely predict or define the total response time.

An acknowledgement and diagnosis period, including feedback to the User on the estimated delay before resolution, can in principle be better controlled. When taking into account the limited resources available to the BADA TO, however, EUROCONTROL cannot commit to a fixed period for response. EUROCONTROL shall endeavour to keep such a period as short as possible.

5.2. CHANGE AND CONFIGURATION MANAGEMENT

Change and configuration management is related to the version management of the BADA APM data files and documents.

A Change Management tool is used at EUROCONTROL for this purpose. This tool provides a complete change management environment in which development and management of the files and documents is done easily, quickly, and securely.

It maintains control of file versions and allows management of project releases with some of the benefits listed below:

- workflow management, which enables easy identification of the files modified to implement the change and to review the reason for a change,
- project reproducibility by accurately creating baseline configurations,
- role-based security.

5.3. RELEASE MANAGEMENT

There is a distinct release management for each BADA APM family. Overall, each new release brings updates to the BADA data sets and documentation as a result of Problem Reports, Model/Synonym Requests and Evolution Requests (introduced in section 5.1.1) coming from the BADA users.

The typical updates and release cycles per model family are described hereafter.

5.3.1. BADA Family 3

In general, there is one release of BADA 3 per year, usually issued in spring of a calendar year. The release is preceded by a Release note, published on average two months before the release date, with objective to provide preliminary information about all changes to the BADA APM that may be expected compared to the previous release.

Updates to Data Sets:

- New models to improve coverage and synonym mappings,
- Updated models to improve accuracy,
- New synonyms to improve coverage,
- Update of aircraft designators according to ICAO Doc 8643. Note that the frequency of such updates may increase in function of the frequency of updates published by ICAO. The updates are regularly published on BUI.

Updates to Model Specifications:

- Minor changes only,
- Back-compatibility is ensured.

5.3.2. BADA Family 4 and Family H

There is no strict schedule for BADA 4 and BADA H new releases. The main objective is to maintain and further evolve them in function of user requirements and resources available.

Updates to Data Sets:

- New models to improve coverage,
- Updated models following changes in specifications.

Updates to Model Specifications:

- Still open for evolutions from one release to another to further enhance different aspects of the model,
- No back-compatibility is ensured.

5.4. MAINTENANCE SERVICE APPLICABILITY

As stipulated in the BADA licence agreement, different maintenance and support levels will apply to different BADA licensees in function of the availability of the appropriate expert resources.

EUROCONTROL Member States or Air Navigation Service Providers of Member States will have priority when dealing with the user requests.

Corrective maintenance and support shall be applied to the latest BADA release identified as the one that is in use. Exceptionally, the corrective maintenance could be provided for the release N-1, provided that justification is made by the user for a need to keep the same release during the whole study life.

In order to benefit from the maintenance and support service, a user is obliged to use the latest BADA release and related intermediate release(s).

6. SUPPORT SERVICES MANAGEMENT

Provision of the support services introduced in Section 2.3 depends on the nature of the request and the cost/effort incurred. This section provides information on how the support service request is managed within the BADA product.

The BADA FP submits the Technical Support Request (TSR) by addressing an e-mail to eec.bada@eurocontrol.int. The TO registers and analyses the request. He/she reports the request to CCB who discusses and decides on its feasibility and priority. In case of a positive opinion, the TO prepares technical specifications and estimates the cost. This is used for coordination and planning with the request originator in order to plan schedules and agree on technical and contractual details.

The Figure 6-1 below depicts the process flow.

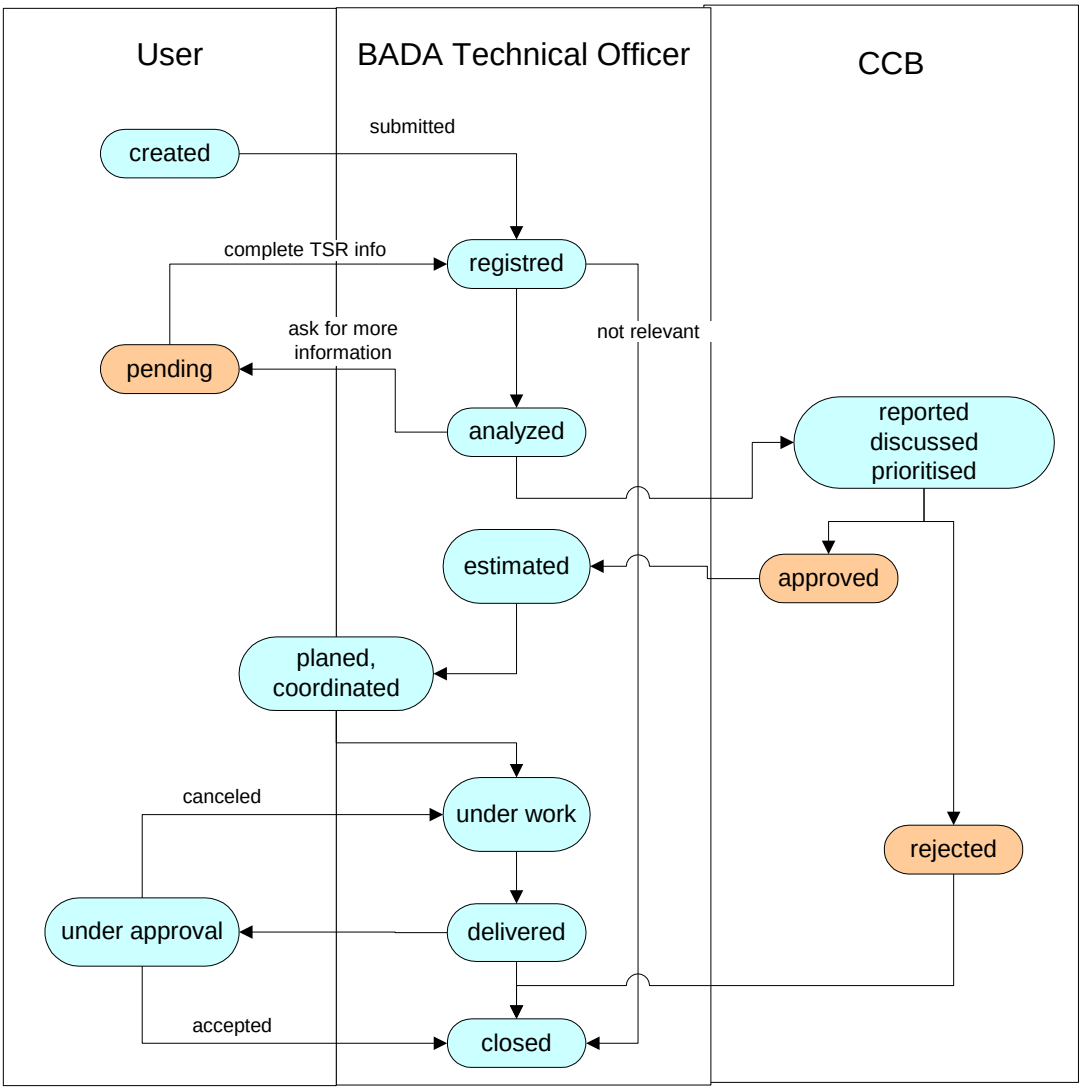

Figure 6-1: Support Service process flow

It is worth considering that the maximum effort for this activity is limited to the availability of the aircraft performance expert resources at EUROCONTROL. The User is likely to be asked to participate financially, while contractual and execution aspects shall be discussed and defined on a case-to-case basis.

7. COMMUNICATION MEANS

The BADA web page (https://simulations.eurocontrol.int/solutions/bada-aircraft-performance-model/) provides an overview of the BADA product with instructions on how to make a request for BADA and contact the BADA project team (https://badaext.eurocontrol.fr/).

The BADA User Interface (BUI) accessible via https://ext.eurocontrol.int serves as a licensing platform, allowing internal and external parties to submit a request for BADA, stay informed about its status, communicate with the EUROCONTROL BADA team and manage access to BADA within their organisation.

The BADA Support Application (BSA), accessible from BUI, allows users to address a clarification inquiry to a BADA expert, and to report, track and follow up on problem reports related to the BADA aircraft performance model and aircraft data sets.

APPENDICES

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Appendix A: Content summary of BADA documents

A.1 User Manual for BADA

The BADA provides a set of files (ASCII or XML) containing performance and operating procedure coefficients for different aircraft types. The coefficients include those related to general, operating and aircraft configurations characteristics and those used to calculate thrust, drag, fuel flow, flight envelope and altitude capability. Information on speed schedules that specify nominal cruise, climb and descent operations are also provided.

The BADA User Manual (UM) describes the mathematical models on which the data is based, provides the definition of each coefficient, and specifies the format of the files which contain the data.

There is a separate User Manual document for each BADA model family: BADA 3, BADA 4 and BADA H.

The structure of the documents is similar and it consists of several sections covering the following aspects:

- Operation Performance Models: defines the set of equations and coefficients used by the BADA operations performance model. This includes models for *Actions (aerodynamic* - drag and lift, *propulsive* – thrust and related fuel consumption, *gravitational* – weight), *Motion (Total Energy Model)*, *Operations (*provides the features that are needed to bring actions and motion together thereby closing the mathematical problem to compute the resulting aircraft trajectory)*, Limitations* (restrict the aircraft behaviour in order to keep it between certain limits to safeguard the safe operation of the aircraft), *Aircraft Characteristics (e*ach aircraft is described with a set of coefficients which represent characteristics that are intrinsic to the aircraft), and *ground movements* (a number of values are specified that can be of use when simulating ground movements). Standard atmosphere (ISA) equations are also provided.
- Airline Procedure Models: defines the set of parameters that are used to characterize a default standard airline speed procedure for climb, cruise, and descent as provided in the aircraft manufacturers' documentation.
- Global Aircraft Parameters: defines the set of global aircraft parameters that are valid for all, or a group of, aircraft.
- File Structure: describes the files containing the BADA aircraft parameters.

The TO is responsible for the update of the UM which is done for each new BADA release.

A.2 Revision Summary Document

This Revision Summary Document (RSD) describes all the changes made to BADA files with respect to the previous release. Change and configuration management procedures for BADA trace all changes and the RSD thus presents a list of all changes implemented for a specific BADA release along with a description for each change.

For each implemented change, a description of the change, motivation for the change and a specification of the affected files is provided. Additional information might be provided to enable users' evaluation of the impact of a new release on their end system (software/files; major/minor changes).

A.3 BADA Aircraft Modelling and Accuracy Reports

Each time a new aircraft model is generated, the results obtained through the BADA modelling process are recorded and collected in an Aircraft Modelling and Accuracy Report. The purpose of this report is to:

- specify the reference sources used for model generation;
- document any assumptions made during model generation;
- summarise the results of the model generation, in particular the errors between trajectories calculated using BADA model coefficients and the reference trajectories (accuracy summary report).

Aircraft Modelling and Accuracy Reports are internal EUROCONTROL documents as they contain confidential information on reference aircraft performances.

A.4 Model Accuracy Summary Report for BADA

This document is an extraction of the Aircraft Modelling and Accuracy Reports that gives an overview of the accuracy of the BADA aircraft models. It is intended to provide the User with information on the trajectory and fuel consumption accuracy that can be expected from a particular model under the given conditions. The accuracy and range of the model validity is given in relation to the reference data that was used to identify the model.

The Modelling Accuracy Summary report is made available to the BADA licenced users.

A.5 Synonym Aircraft Report for BADA Family 3

BADA provides a set of files containing performance and operating procedure coefficients for different aircraft types, based on data provided by aircraft manufacturers. These are the so-called directly supported models.

To deal with aircraft for which no manufacturers' data were made available to EUROCONTROL, BADA provides additional models that were assessed to be relatively equivalent to one of the directly supported models.

This document presents an evaluation of aircraft equivalences by providing the summary results of a comparison between the attributes of the equivalence and reference aircraft, that is:

- wake vortex category,
- type of engines,
- maximum take-off weight,
- maximum operating altitude,
- maximum operating speed,
- normal operating speed in cruise.

It provides information on the source of reference data information and documents all the assumptions made. It also describes the criteria that are used for evaluating and selecting an aircraft equivalence, and provides error metrics for each individual attribute together with a global evaluation.

A.6 Aircraft Performance Summary Tables for BADA Family 3

This document is a collection of the aircraft performance table files for each aircraft type provided in the corresponding BADA Release. The performance tables specify the true air speed, rate of climb/descent and fuel flow for conditions of climb, cruise and descent at various flight levels and aircraft masses. The performance figures contained within the tables are calculated based on a total-energy model and the BADA aircraft model performance coefficients.

The motivation for providing the performance summary tables is that some ATM applications prefer the use of table-based performance data over TEM coefficients for determining aircraft performances.

A.7 Coverage of European Air Traffic for BADA

The air traffic statistics obtained from the NMOC for the ECAC airspace are used to determine the mix of aircraft types in the European air traffic. The BADA Coverage report then permits a statistical comparison of the available BADA models against that of the current representation of European traffic. This annual coverage report highlights the new aircraft models that would then be needed to achieve the BADA target of a 90% traffic coverage. In parallel, for BADA family 3, the coverage of the BADA synonym aircraft types is also shown.

A.8 BADA Aircraft Performance Modelling Manual

The purpose of this document is to provide information on the BADA aircraft performance modelling environment to the BADA end users. The document is intended for both the beginner trying to obtain a general view of the modelling environment and the experienced user interested in understanding underlying assumptions.

The document includes information on the high-level design of the BADA modelling environment, and a description on its components (tools, databases), data exchange formats and information flow.

It describes the data preparation, the identification and the validation processes. The data preparation includes acquisition and pre-processing of aircraft performance reference data. In the identification process, the BADA Enhanced Approach to Modelling concept is introduced and the identification process itself is described in details. The validation process includes checking the behaviour of developed models with respect to input performance data, checking the syntax of release files, cross-validation of the BADA baseline implementation with other implementations, and validation of developed models with respect to real flight data.

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Appendix B: Guidelines for validation of BADA implementation

B.1 Introduction and scope

There are two common ways in which the BADA APM is used in the simulation tools:

1. Full implementation of the BADA TEM using APF and OPF files.
2. Use of the tabular aircraft performance data from the BADA PTF/PTD files.

Regardless of the way the BADA data is used in a simulation application, there is first a need to ensure that the aircraft performance model algorithms, parameters and data are used correctly. Only then will it be possible to troubleshoot and analyse a reported problem related to a BADA APM.

Therefore, such a validation activity is considered a pre-requisite for provision of maintenance and support to the users of BADA.

B.2 Baseline implementation

The software implementation of the BADA APM algorithms within the BADA Modelling environment developed in MatLab by EUROCONTROL, described in [8], is considered the baseline for the purpose of this validation. The BADA PTF and PTD files are obtained using the flight profile calculator function of this implementation. The correctness of this application is cross-checked and validated against other existing implementations of BADA at EUROCONTROL, such as the BADA web calculation application, and use of both air and ground components of the ESCAPE simulator.

B.3 Validation objectives

The main objectives of the validation activity are to ensure that:

- BADA APM algorithms are correctly implemented.
- BADA coefficients and data parameters are correctly read from the BADA release files.
- Calculation results of aircraft performance parameters under different conditions are identical to those obtained with the BADA baseline implementation.

B.4 Validation enablers and process

Each BADA user (owner of simulation tool) is responsible for the preparation and provision of a text file, produced by using their simulator application specific tools (so-called flight profile generator or similar), that contains recordings of the flight profile parameters across several scenarios. The parameters to record, the basic principles to apply and the step-by-step process to follow are described hereafter.

B.4.1 Required parameters

Table 1 presents the list of parameters that shall be recorded by the user to provide a sufficient level of details to perform an analysis of the implementation.

Table 1: Parameters required to validate an implementation of BADA

Description	Type	Units
Aircraft Type	Text	-
Sequence Number or Time stamp	Number	hh:mm:ss
Altitude	Number	ft
Air Temperature	Number	Degree Kelvin
Density	Number	kg/m^3
Pressure	Number	Pa
Configuration (take off, climb, cruise, descent, approach, landing, initial climb)	Text	-
Speed Domain (CAS or Mach)	Text	-
CAS	Number	kt
MACH	Number	-
TAS	Number	kt
Aircraft Mass	Number	kg
Max Climb Thrust	Number	N
Available Thrust (CRZ or DESC)	Number	N
Lift Coefficient	Number	-
Drag coefficient	Number	-
Drag	Number	N
Available Power	Number	W
Power Coefficient	Number	-
ESF	Number	-
Rate of Climb or Descent	Number	ft/min
Flight Path Angle	Number	degree
Fuel Flow	Number	kg/min
Acceleration	Number	m/s^2

B.4.2 Basic principles

The profile preparation process shall be based on the following principles:

- Use of a set of different aircraft types to cover all engine types, with a minimum of 3 aircraft models per type of engine, covering if possible different sizes and technologies
- Use of 'point type' calculation for aircraft performance parameters, that is without performing integration over time:
    - aircraft weight is constant and does not account for consumed fuel
    - speed changes take place immediately and do not account for acceleration

  This principle allows legitimate comparisons between implementations, without relying on particular integration algorithms.
- Use of aircraft default speed schedules as defined in the Airline Procedure Model section of the BADA User Manual
- Flight profiles in climb, cruise and descent without imposing any constraint
- Take-off and landing occur at sea level
- Use of ISA and ISA+20, no wind weather conditions
- Calculation step shall be defined in terms of pressure altitude. Altitude step should not be greater than 1000 ft.

B.4.3 Step-by-step process

Taking into account the above listed principles, the following steps shall be performed:

1. Generate climb profiles at 3 different aircraft masses: BADA low, nominal and high (as provided in the BADA PTF file)
2. Generate descent profile at BADA nominal mass
3. Generate cruise profile at BADA nominal mass at several FLs to account for different types of speed (CAS or Mach)
4. Print results of the calculations for following parameters: FL, T [K], p [Pa], rho [kg/m^3], a [m/s^2], TAS [kt], CAS [kt], Mach, mass [kg], Thrust [N], Drag [N], Fuel flow [kg/min], ESF, Rate of Climb or Descent [ft/min], PWC (power reduction coefficient)
5. Compare obtained results per aircraft parameter type with the figures provided in the BADA PTD file
6. Present results of comparison in the most suitable form (numerical comparison with reporting of the error per parameter, graphically presented results, etc.)
7. Report findings to the BADA team

B.5 Analysis of the results

If differences in aircraft performance parameters appear, then the source of the problem shall be troubleshot. Here a “top-down’ approach can be taken using the most used formulation of the TEM:

$$ROCD = \frac{dH_p}{dt} = \frac{T - \Delta T}{T} \frac{(Thr_{max\ climb} - D) \cdot V_{TAS} \cdot C_{pow,red}}{m \cdot g_0} \cdot ESF$$

If the ROCD is incorrect, then one has to go deeper and analyse the underlying parameters. If for example Drag is not correct, then the error may come from incorrect speed, drag coefficient, lift coefficient, air density, etc.

The error can be caused by the use of a wrong coefficient (possible format problem), different interpretations of the BADA algorithms or errors in implementation.

In any case, this validation shall become one of the important means of validating and cross-checking different implementations of BADA, hence improving its use and reducing risk of misuse. Furthermore, the established recording and reporting means will be used in the future for dealing with the problem reports.

Appendix C: Supporting data for problem analysis

For the purpose of analysis and evaluation of the Problem Reports, the User is invited to provide supporting information and data. The type of data is related to the nature of the problem, but as a minimum, the User has to provide:

- Report and assurance data demonstrating that the BADA APM is implemented and used in a correct way;
- Copies of locally used BADA release files;
- Information on any modification in BADA release files and reason for such a change;
- Any other supporting data as requested by BADA TO which is required to timely and efficiently troubleshoot the problem.