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## CONCEPT OF OPERATIONS OF AN ATC TOOL FOR TRAJECTORY OPTIMISATION

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ZFW zero fuel weight  
ZFWCG zero fuel weight centre of gravity

### Abstract

*In this paper, a detailed Concept of Operations (Con-Ops) associated with a trajectory optimisation tool is presented. Operational scenarios are included for both climb and descent phases. The paper also includes a description of the tests used to assess the Con-Ops and the ATC tool. Finally, an overview of the safety assessment procedure to be carried out for the Con-Ops is provided.*

### Nomenclature

|         |                                                            |
|---------|------------------------------------------------------------|
| ACARS   | aircraft communications<br>addressing and reporting system |
| AFTN    | aeronautical fixed<br>telecommunication network            |
| ANSP    | air navigation service provider                            |
| AOC     | air operators certificate                                  |
| ATC     | air traffic control                                        |
| ATCO    | air traffic control officer                                |
| ATM     | air traffic management                                     |
| CFOA    | clean flight optimisation application                      |
| Con-Ops | concept of operations                                      |
| COTS    | commercial off-the-shelf                                   |
| FDO     | flight dispatch officer                                    |
| FL      | flight level                                               |
| FMS     | flight management system                                   |
| LCO     | load control officer                                       |
| OCC     | operations control centre                                  |
| PF      | pilot flying                                               |
| PM      | pilot monitoring                                           |
| SID     | standard instrument departure                              |
| SOP     | standard operating procedures                              |
| STAR    | standard terminal arrival route                            |
| TBO     | trajectory based operations                                |
| TOW     | take-off weight                                            |
| UML     | unified modelling language                                 |
| VHF     | very high frequency                                        |

### 1 Introduction

With a drive towards greener aircraft operations by the aviation industry, trajectory optimisation tools are being introduced into the air traffic management system. In this respect, a quasi-real-time ground-based trajectory optimisation tool was presented in [1]. The tool is intended to be used a few minutes before a climb or descent taking into consideration the latest operational conditions, including ATC and weather constraints. The quasi-real-time tool is able to generate optimal aircraft-specific 4D trajectories (speed-altitude schedules) for a given Standard Instrument Departure (SID), Standard Terminal Arrival Route (STAR) or approach procedure. At the core of the tool lies a fast optimiser employing pseudo-spectral techniques that enables optimisation suitable for Trajectory Based Operations (TBO) [2]. In this context, trajectories are generated for minimum flight time, minimum fuel burn or a combination of both through the Cost Index associated with a particular flight. This paper presents the Concept of Operations (Con-Ops) associated with integrating the tool in the ATC system, while minimising the impact on the workload of the Air Traffic Control Officer (ATCO).

The Con-Ops describes a list of standard operating procedures that shall be adhered to by all the relevant parties, including the information that needs to be exchanged between them. It is defined using Unified Modelling Language (UML) use-case and activity diagrams, the latter of which have been included

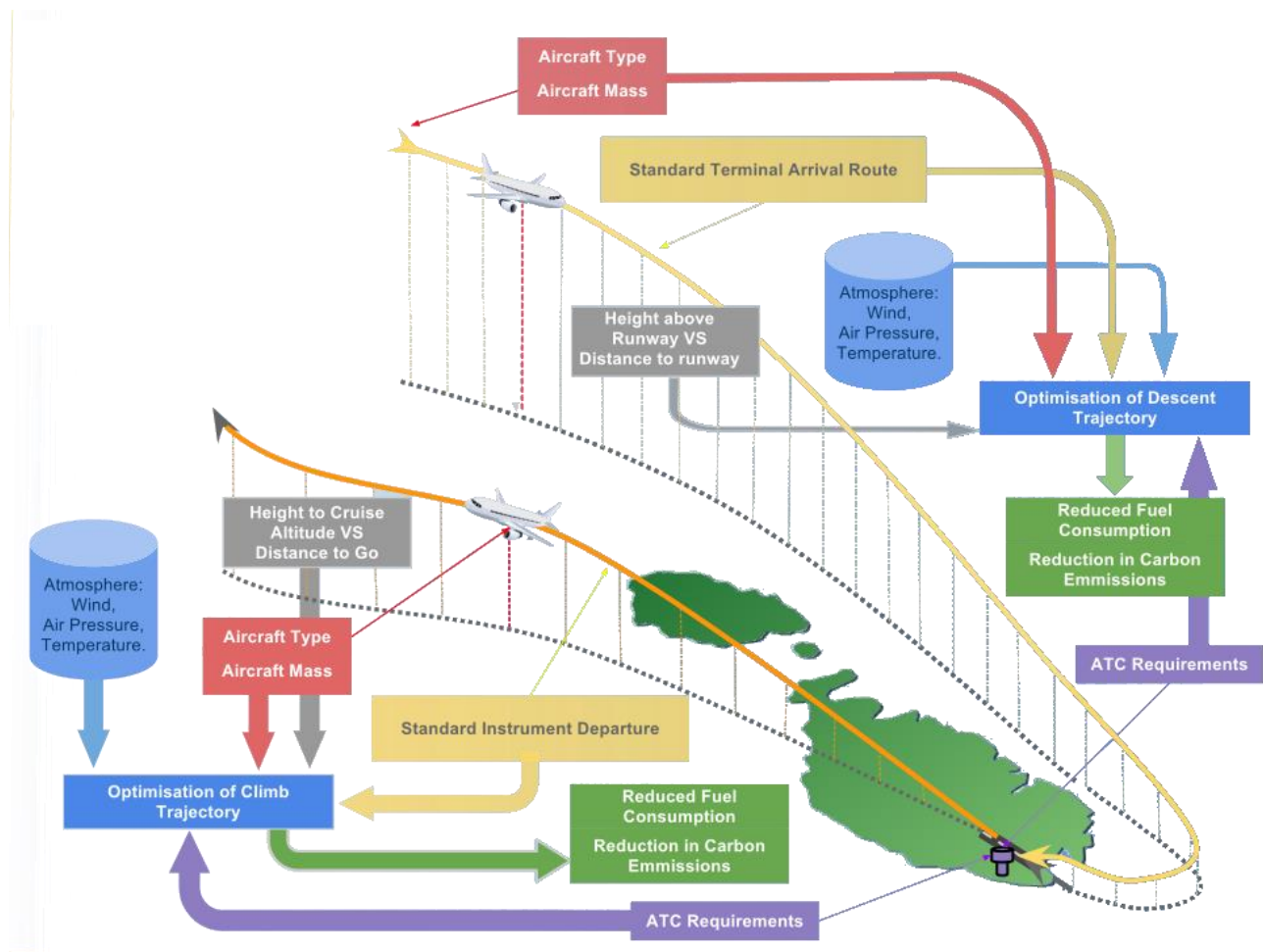


Fig. 1. CFO Process System Overview

in this paper to provide a visual description of the operational procedures.

## 2 Aims

The Con-Ops mentioned in this paper is primarily intended for low to medium air traffic density airspace. The Con-Ops recognises two possible owners of the ATC tool, designated as Clean Flight Optimisation Application (CFOA) within the document. These owners can be either the Airline Operators Certificate (AOC) or the Air Navigation Service Provider (ANSP).

In scenarios where AOC has ownership, the Operations Control Centre (OCC) Flight Dispatch Officer (FDO) controls the optimisation tool. On the other hand, in scenarios where ANSP has ownership, the ATCO has control of the optimisation tool. The

idea is that AOC ownership will promote internal fleet management within an airline, whereas ANSP ownership targets universal traffic management.

This paper however, will only cover scenarios in which the ANSP has ownership of the CFOA. In this paper, the CFOA is installed on a Commercial Off-The-Shelf (COTS) laptop, placed in the ATC operations room.

The current version of the Con-Ops document addresses single-aircraft optimisation only, despite the ATC tool being designed to support multi-aircraft optimisation as well. As a result, the Con-Ops will eventually need to be further developed to accommodate multi-aircraft optimisation scenarios.

### 3 System Overview

The optimisation process (termed Clean Flight Optimisation (CFO) process) as a system is considerably complex and encompasses several subsystems both within the organisations involved (i.e. AOC and ANSP) as well as externally. Fig. 1 illustrates a high-level system overview of the entire process during both the climb and the descent.

The AOC is the primary user of the process since it operates the aircraft. The main system involved in the process is the aircraft itself and the flight crew operating the aircraft. Subsystems supporting the process include the OCC and the FDO allocated to support the process as well as the Load Control Officer (LCO) assigned to the particular aircraft at the time.

The ANSP is the secondary user and monitors the CFO process through Approach ATC and Area ATC officers and using the required equipment.

A subsystem external to the organisations involved is the weather dataset service provider. Communication with this service provider is performed within the CFOA itself and is thus invisible to all organisations and other subsystems.

The main interactions between the different subsystems are shown in Fig. 4, Fig. 5 and Fig. 6.

### 4 The Optimisation Cycle

Optimisation of the climb and descent phases requires a pre-calculated speed profile to be followed by the aircraft performing the optimised climb or descent. It is also important that Continuous Climb Operations [3][4] and Continuous Descent Operations [5][6] are exercised at all times.

The optimisation cycle starts 24 hours before the AOC provides the ANSP with a list of flights which will intend to perform climb or

descent optimisation. The cycle itself follows a distinct set of two phases, namely the preparation phase and the optimisation phase.

In the preparation phase, all the required optimisation data is collected and decisions are taken on whether to proceed with the optimisation or not. Ultimately, the optimised climb or descent speed schedule is generated and transmitted to the Flight Crew.

During the optimisation phase, the Flight Crew flies and monitors the progress of the optimised climb/descent, constantly ensuring that the aircraft is able to continue safely on the optimised profile. In the meantime, ATC also monitors the progress of the optimised climb/descent, always ensuring that the required safe clearances are maintained from other aircraft. If at any time either the Flight Crew or ATC realises that safety may be compromised or some kind of doubt regarding the continuation of the optimised profile exists, the optimisation process can be aborted such that normal operations are performed instead. Fig. 2 shows the climb optimisation cycle, while Fig. 3 depicts the descent optimisation cycle. Each phase consists of a predetermined order of a sequence of events.

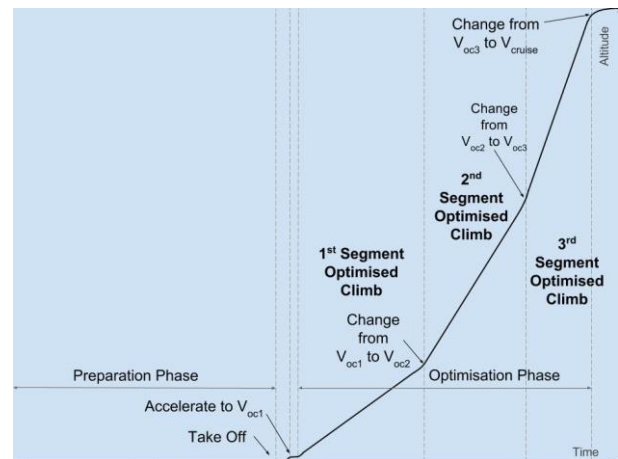


Fig. 2. Climb Optimisation Cycle

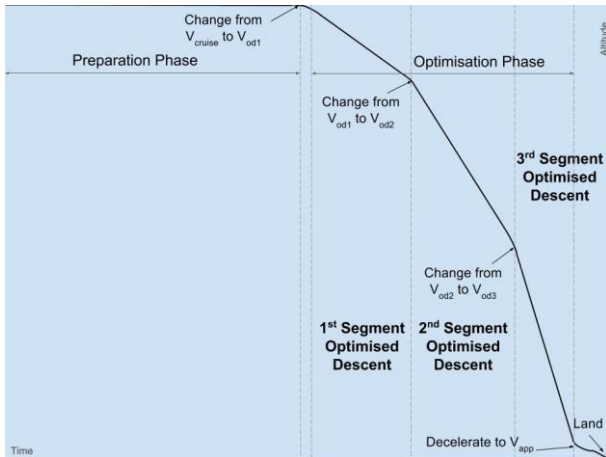


Fig. 3. Descent Optimisation Cycle

## 5 Operational Scenarios

As described in Section 4, the optimisation cycle can be either a climb or descent, consisting of a preparation phase and an optimisation (flight) phase in both cases. Each preparation phase has the following functional requirements:

- initial aircraft mass
- initial aircraft altitude
- initial aircraft speed
- start of optimisation time
- start of optimisation distance
- final aircraft altitude
- final aircraft speed

The initial parameters refer to their respective parameter value at the start of the optimisation process, while the final parameters refer to their respective parameter value at the end of optimisation.

The Con-Ops procedures have been written such that all supporting subsystems have the ability to abort the optimisation process at any time. In case of an abort request, the optimisation process is immediately terminated and normal operations are resumed.

### 5.1 Climb Preparation Phase

A few minutes after the crew boards the aircraft, the Pilot Flying (PF) and the Pilot Monitoring (PM) check the aircraft status and weather conditions. In case of favourable conditions, the optimisation process can proceed. The First Officer contacts Ground ATC for the flight plan, slot confirmation and optimisation request via Very High Frequency (VHF). Ground ATC then advises Approach ATC and Area ATC of the optimisation request, both of which then decide whether to accept or reject the request. This decision is then communicated back to the Flight Crew by Ground via VHF, together with the flight plan and slot confirmation. Regardless of whether the optimisation process has been accepted or not, the LCO then receives the final weight figures, prepares the load sheet and sends it to the aircraft via Aircraft Communications Address and Reporting System (ACARS).

Upon receiving the load sheet, the PF enters the zero fuel weight (ZFW) and the zero fuel weight centre of gravity (ZFWCG) into the Flight Management System (FMS), cross checks the fuel and takes note of the take-off weight (TOW). The PF and PM then perform take-off calculations separately, based on the TOW. In case of any disagreement, these calculations are revised and, if necessary, the load sheet is requested again.

After agreeing on the take-off calculations, the PF checks the initial and final states of the climb on the FMS flight plan and sends the data via ACARS to the OCC FDO, who relays the data to Approach ATC via Aeronautical Fixed Telecommunication Network (AFTN). At this point, the Approach ATCO enters the data into

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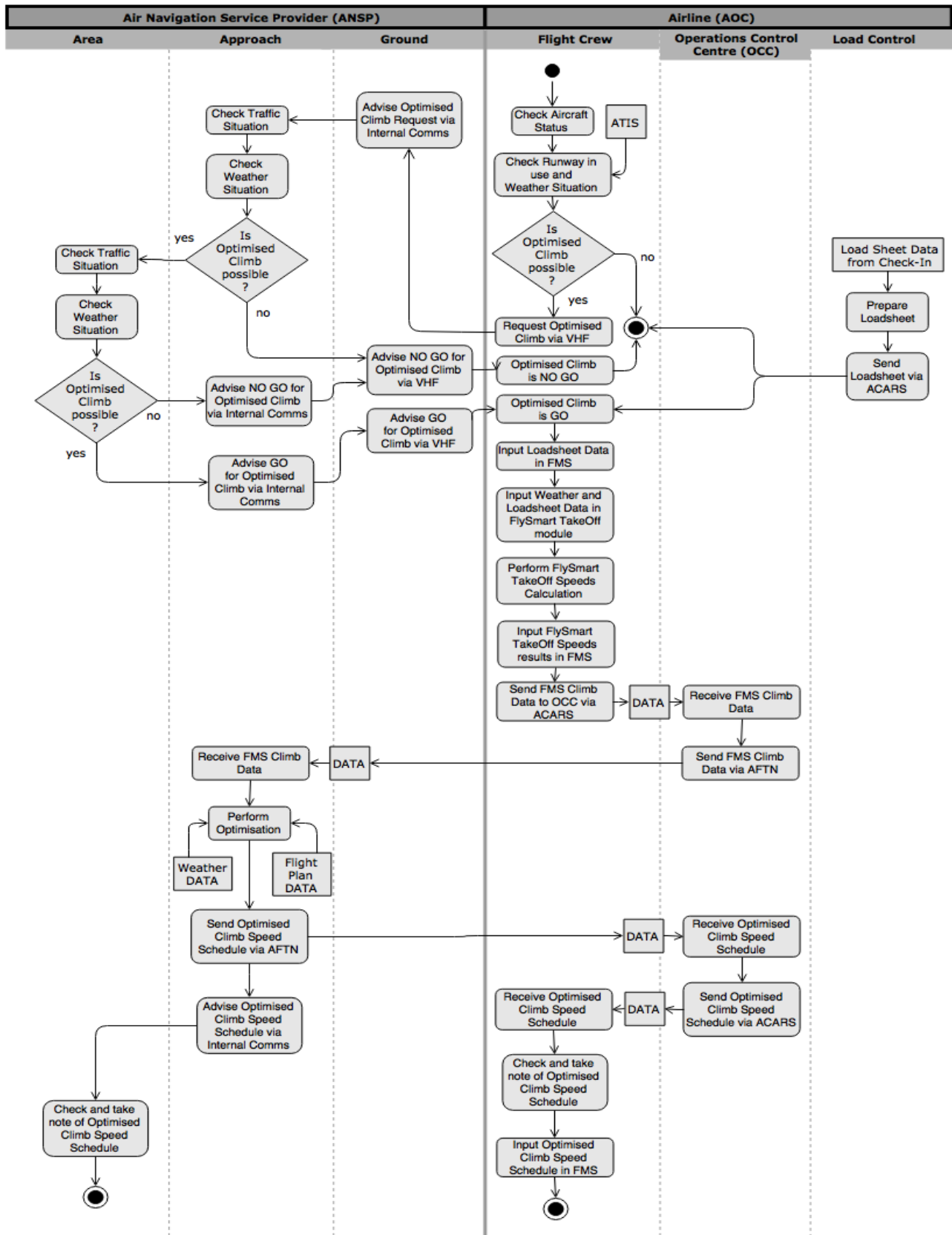


Fig. 4. Activity Diagram of Optimised Climb Preparation Phase

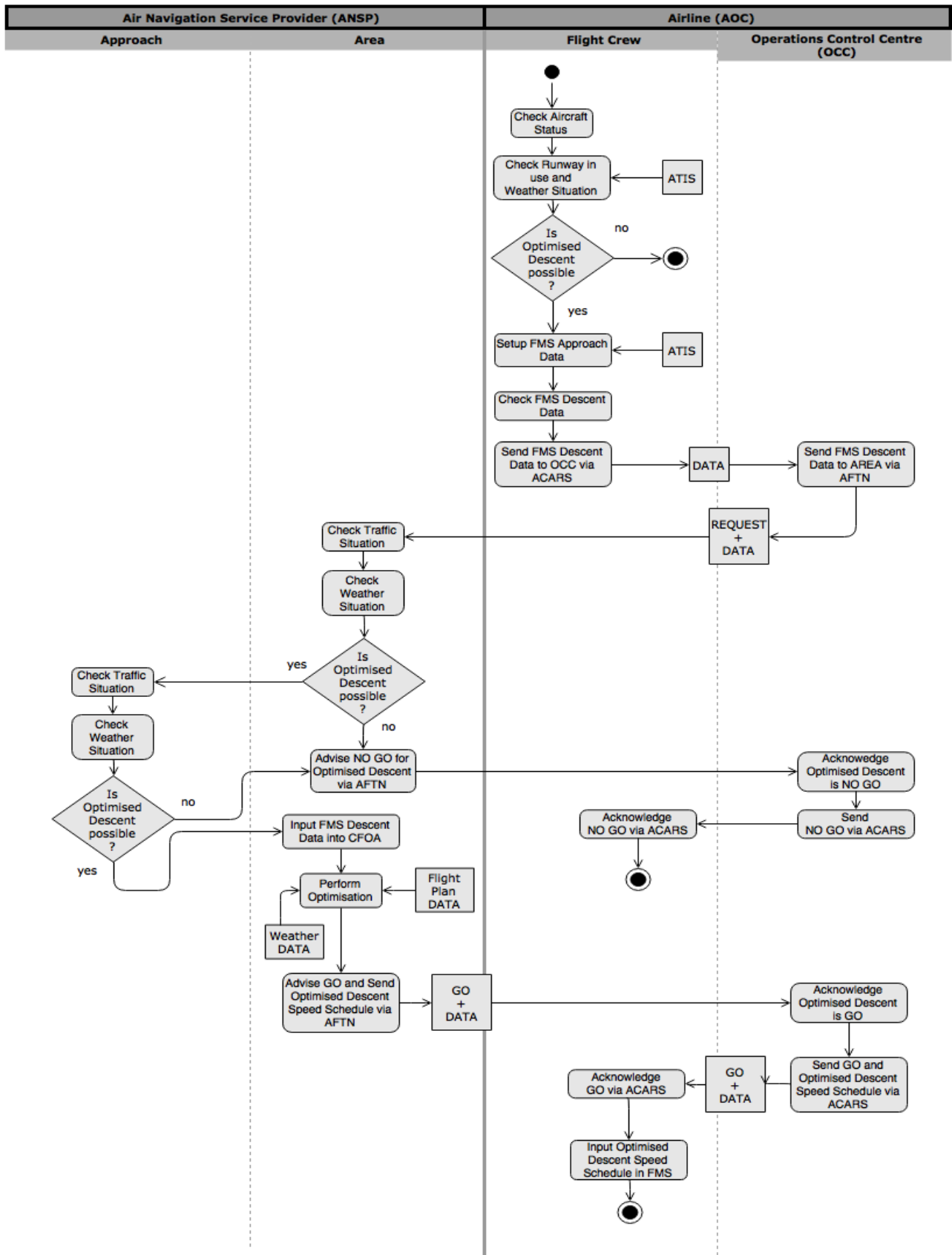


Fig. 5. Activity Diagram of Optimised Descent Preparation Phase

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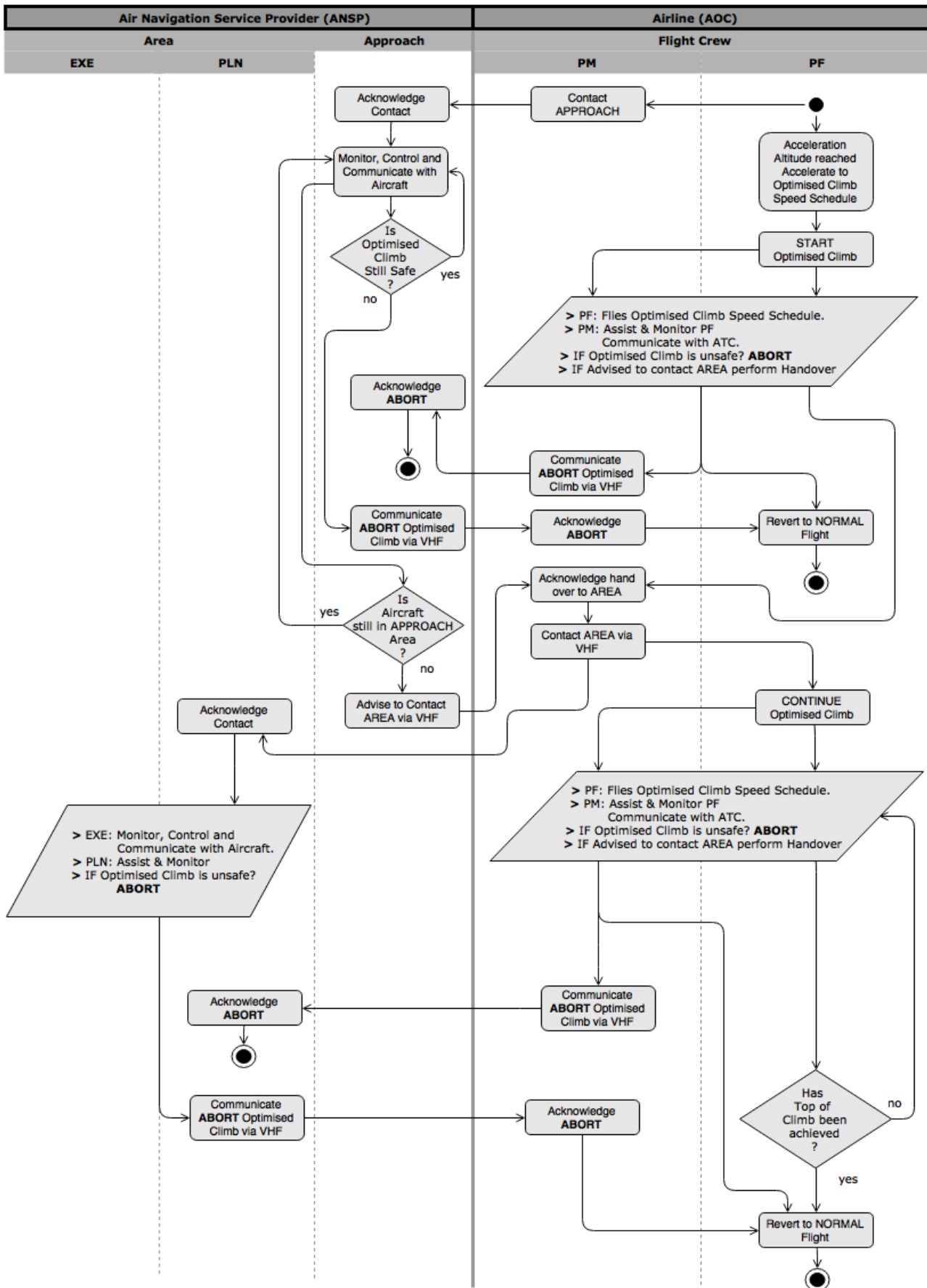


Fig. 6. Activity Diagram of Optimised Flight (Climb)

the ATC tool to perform the optimisation. If a solution is found, the Approach ATCO advises Area of the optimised speed schedule, which is also sent to the OCC FDO via AFTN. Upon receiving this schedule, the OCC FDO sends it to the Flight Crew via ACARS.

At this point, which is the final step in the climb preparation phase, the PF enters the optimised speed schedule into the FMS, which is also cross checked by the PM. Fig. 4 shows the activity diagram of the optimised climb preparation phase.

## 5.2 Descent Preparation Phase

The optimisation process for a descent starts roughly 20 minutes before the planned top of descent. At this point, the PF checks the initial and final parameters of the closest waypoint on the FMS flight plan and sends the data via ACARS to the OCC FDO and in turn to Area ATC via AFTN. Area ATC then communicates the optimisation request to Approach ATC and both decide whether to accept or reject this request. If both accept, the Area ATC performs the optimisation using the ATC tool and sends the descent speed schedule via AFTN to the OCC FDO if a solution is found. The outcome (and speed schedule) of the optimisation is then sent to the Flight Crew via ACARS.

Upon receiving the optimised speed schedule, the PF enters it into the FMS, while the PM cross-checks the schedule. Fig. 5 provides the UML activity diagram of the optimised descent preparation phase.

## 5.3 Optimised Flight Phase

In both climb and descent scenarios, the preparation phase is followed by the actual flight optimisation phase.

The climb preparation phase ends with the Flight Crew entering the optimised speed schedule into the FMS. The climb flight phase thus starts off with the Flight Crew requesting clearance and engine start, which is provided shortly afterwards by Ground ATC. After takeoff, the PF accelerates according to the

optimised flight speed schedule. The optimised climb process then terminates when the top of climb is reached. Fig. 6 shows the activity diagram of the optimised flight climb. The activity diagram for the optimised descent has not been included since it is very similar to Fig. 6.

The descent preparation phase also ends with the Flight Crew entering the optimised speed schedule into the FMS. The start of the descent flight phase occurs when the PM contacts Area ATC via VHF to request descent, while confirming or rejecting the optimised descent. In response, the Area ATC issues clearance to a descent Flight Level (FL) and confirms or rejects the optimised descent via VHF.

## 6 Flight Trials Campaign

In order to analyze and assess the performance of the ATC tool and of the Con-Ops, a number of tests have been designed.

### 6.1 Preparation

The first test package involves providing the ATC tool with historical data, that is, historical flight plans together with corresponding past weather data. The results generated by the optimiser, particularly flight time and fuel burn, are then compared with the actual track log of these flights. This comparison would verify the effectiveness of the ATC tool in finding a more efficient trajectory which could have been flown. It is important to note that this test package does not involve the Con-Ops.

### 6.2 Simulation

The second package includes performing flight simulations which involve both pilots and ATCOs. The main purpose behind this test package is to study the impact of using the Con-Ops procedures together with the ATC tool on all involved personnel.

### 6.3 Live Trials

The third test package is similar to test package B, with the difference that the scenarios are no

longer simulated, but are performed on actual flights. To ensure minimal impact on all other operations, these flight trials will be performed during off-peak hours, where air traffic is low.

For obvious reasons, both pilots and ATCOs involved in these trials will be briefed beforehand and provided with all the necessary information on the Con-Ops procedures. SOPs are also being written to provide detailed step-by-step instructions to involved personnel.

## **7 Safety Assessment**

Since the project involves air traffic, it is of utmost importance that both the Con-Ops and the ATC tool have the necessary safety assurance for this application. It is important to note at this point that the project is expected to be declared safe for aircraft and ANS operations. This means that the current level of operational safety will not decrease, but possibly increase. This will be achieved by performing the safety assessment commencing at worst case scenario to meet requirements of EC regulation EC 1035/2011.

The project will be managed according to proper planning, design principles and best practices as used in the industry. This implies that all supporting documents such as the Con-Ops document are required to describe all supporting activities in an orderly and safe implementation. The UK CAA document CAP760 [7] has been chosen as the safety standard for this safety assessment. The safety case will address all system elements and will be conducted such that the whole life cycle of the project is covered.

The testing, simulations, procedures and trials are expected to be acceptably safe for operations. As a result, testing shall be planned, brainstormed and coordinated with all stakeholders.

Safety will continue to be demonstrated throughout the entire life cycle by performing the necessary safety activities and applying

adequate monitoring to ensure integrity and consistency.

## **8 Conclusion**

In this paper, a detailed description of the developed Con-Ops of an ATC tool was given. A well-documented Con-Ops ensures that all involved personnel follow an orderly and safe set of procedures, with the option of aborting the process whenever any concerns exist. Since the ATC tool is meant as an advisory tool, aborting the optimisation process simply means that normal operations will take over instead.

With the required documentation in place, the Con-Ops together with the ATC tool will be put through a series of tests to assess different aspects of their performance. Furthermore, a safety assessment will be carried out to ensure that the whole optimisation process contains the necessary safety assurance.

## **Acknowledgements**

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