Operational validation of the OPTAIN-SA Tool
Supporting optimized profile descent approach sequencing into Palma TMA

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Abstract— Air Navigation Service Providers (ANSPs) around the world as well as International Programmes are facing the conflict between increasing pressures from the general public to reduce the environmental impact while allowing for steady growth in traffic volume.

In order to offer a solution to this dilemma a Spanish initiative started a study whose objectives were the development of a methodology, design and validation of optimised descent procedures (OPD) and Air Traffic Controller’s (ATCo) supporting tool into Palma’s Terminal Manoeuvring Area (TMA).

This paper contains the main results of the operational validation performed on an ATCo tool called OPTAIN-SA, which was developed ad-hoc during the initiative to support the efficient introduction of OPD procedures. Likewise, it covers the subjacent operational concept as well as live flight trial exercises. The tool supports ATCo on their daily tasks promoting the use of CDOs (Continuous Descent Operations) in particular Optimised Descent Operations (OPD) as an environmental short term solution; while requiring no substantial upgrade to the ground systems and any to the on-board avionics.

The ATCo tool showed good potentials for the introduction of OPDs in PMI. ATCo feedback and sequencing results underscored the benefits to the Controller while highlighting the operational lines of improvement. Two consecutive projects provide the core information to the paper and are evidence of the validation cycle performed: the OPTA (Optimised Profile Descent Approaches) project and the OPTA-IN (OPTA – Implementing Windows).

Keywords—CDO; Sequencing; Merging; Speed Advisory; OPDs; Automation; ATM; ATCo support tool; Arrivals; TIE point; Demonstration Activities; Traffic flows; Predictability; Arrivals.

I. INTRODUCTION

For decades now, it has well been known that Continuous Descent Operations [1] deliver both reduction in noise [2][3]. Error! Reference source not found. and emissions together with interesting savings in fuel [6][7]. These benefits are key assets for the short and long term business of the air transport system and the related customers.

International Programme activities [8][9][10][11], together with ANSP initiatives which ended with successful flight trials and published CDO procedures [12][13], have provided evidence of relevant environmental and economic benefits coming from these particular operations. However, clear evidence has also highlighted the operational limits inherent in achieving a full implementation in medium to high density traffic conditions [15]; thus restricting the use to only low density or night-time operations [15] or the implementation of mid solutions as OPDs [16]. Which takes into account both the a/c’s optimum descent profile and the complexity of the airspace [1].

One of the main difficulties identified with the use of CDOs is the fact that the ATM System needs further advanced sequencing and monitoring tools to support the ATCo in their daily work. These advanced tools are on the main delivery list of major ATM system modernization initiatives [17] and programmes such as NextGen [18] and SESAR [19], but are currently not available.

In the midst of the previous context, the activities described in the following sections relate the evolution, following the E-OCVM [20] maturity cycle, of the OPD [21] concept proposed as a mid-term solution tailored to the airspace of PMI. This evolution started from a previous project called OPTA-OCVM (2009)[22], which identified the major limitations and the foreseeable lines of development. These were received and tackled by the OPTA-IN (2011) [23] project which further developed the concept, proposed and prototyped the supporting ATCo tool and tested it, through live demo flights, its validity and feasibility.

The paper is structured in such a way that it mimics the steps taken: the reader will be introduced to the major concepts and previous activities supporting the final work; it will thus describe the design; the live demo testing and operational validation of both concept and ATCo supporting tool. Finally it will deliver the results obtained as compared to the success indicators foreseen. A final section is dedicated to the steps...
forward, reflecting the fact that still changes and improvements have to be made to date.

II. PREVIOUS PROJECTS AND CONCEPTS

A. OPDs
The Optimized Profile Descent [1] is one method promoted by the FAA to solve the CDO caveats by ensuring an optimal balance is made between: a/c performance (a main parameter); delivery of environmental benefits and air traffic control requirements; maintenance or even increase in safety levels. OPD procedures in fact, allow ATC to sequence and maintain the required spacing of the traffic while allowing for a continuous descent: this extends the availability and use of this procedure to medium traffic scenarios.

OPD with RNAV are designed to reduce fuel consumption, emissions, and noise during descent [22] by allowing pilots to set a/c engines near idle throttle while using the capabilities of the a/c Flight Management System (FMS) to fly a continuous descending path without level segments [25]. By definition, an OPD is a method which enables operation of a semi best CDO without requiring further substantial upgrades to the ATM System, while none to the current new generation of a/c.

OPDs are constructed taking into account: the published STAR; the window of best performance of the fleet servicing the Airport; the airspace and the ATC needs; the environmental limitations; the use of speed adjustments by ATCo rather than vectoring; and the use of equidistant Tie Points (ad-hoc speed adjustment triggering points). This concept was proved beneficial and is currently in use in TRACONs such as LAX [26].

B. Optimised Profile Descent Approaches (OPTA)
The aim of the OPTA project was to provide a control technique and a procedure design with which it enabled ATCos to support the reduction of emissions and the optimization of fuel consumption in TMA, through the use of Optimal Descent Approaches from Top of Descent (ToD).

The OPTA [27][28] project based on the work performed by the FAA in LAX, was promoted by ENAIRE–Spanish ANSP (former Aena) – to provide CDOs during daytime and at an airport which had the perfect mix of small-medium density traffic due to the tourist season. During the development of the project the OPD concept was applied and tailored into the Palma TMA environment and specifically to the western STARs to PMI (see Figure 1).

The project included various assessments (Business, Human Performance, Safety and Environmental) and was validated by tools such as FTS (Fast Time Simulation) and RTS (Real Time Simulation), coupled with commercial flights provided by AirEuropa (AEA) through its 738 fleet of a/c.

1) The OPTA concept
The OPTA [27] procedure differs from the current procedures mainly on the descent profile, which resembles the best performance of an a/c in descent. From the ATCo point of view, it requires mainly the use of speed adjustments, enabling the a/c to fly its optimal path through pre-defined speed-altitude windows keeping its predictability.

2) Specific Characteristics of the OPTA procedure
This procedure is based on a group of specific characteristics that have to be covered in order to ensure a successful performance of the procedure:

- TMA entry speed (280 kts).
- Definition of reference points “TIE points” equidistant 31 NM to the Initial Approach Fix (IAF) in each arrival flow.
- Speed Limitations: Speed Limit Points (SLPs) (250 kts) and at the IAF (220 kts).
- Speed Reduction Advisory Tables (SRAT [31]) in order to provide an a/c sequence fulfilling the required 5/10 NM separation at the IAF when required, through speed adjustments (see TABLE 1).

<table>
<thead>
<tr>
<th>Distance offset [NM]</th>
<th>IAS [kts]</th>
<th>Distance offset [NM]</th>
<th>IAS [kts]</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 7.6</td>
<td>280</td>
<td>&gt; 16.0</td>
<td>280</td>
</tr>
<tr>
<td>7.3 — 7.6</td>
<td>270</td>
<td>15.2 — 16.0</td>
<td>270</td>
</tr>
</tbody>
</table>

1 Separation required by the Final APP sector to sequence traffic coming from different IAFs.
A sequence of actions - to be followed by crews and ATCos was created to allow the generation of a queue of a/c at the IAF, while obtaining the proper spacing depending on ATC needs (see TABLE I. and Figure 2).

Once AC1 had reached its TIE Point (T1) the ATCo would manually check on the Controller Working Position (CWP) the distance between AC2 and its own TIE point (T2). At this point ATCo would check the SRAT table (see TABLE I.) and, depending on the separation required at the IAF, communicate the speed adjustment to AC2.

The result of the complete set of actions carried out, delivered a safe sequence of a/c, arriving at the same IAF with the required spacing.

4) Main Outcomes of OPTA [27]

ATCos, were able to estimate spacing between a pair of a/c (coming from the same or different flows) and predict the right separation at the merging point creating a safe sequence at the IAF. Further results included: enhanced flight predictability; fuel burn reduction; a positive business and environmental case.

On the other hand, although proving its objectives, the project underscored the following issues:

- A minimum spacing among flights is required in order to build the sequence before entering the TMA (En-Route pre coordination);
- Designation of AC1 and AC2 a/c can be cumbersome without training;
- Measurement of distance between flights when AC1 on TIE point should be automated;
- Visualization and knowledge of required SRAT table should be improved;
- Designation of speed to distance and required separation should be enhanced.

C. Optimised Profile Descent Approaches – Implementing Windows (OPTA-IN)

The OPTA-IN project [29][30], sponsored by the SJU inside the Integrated Flight Trials and Demonstration Activities framework, and based on the OPTA project and its results, was developed with the aim to be the demonstration platform and therefore the subsequent validation step for the implementation of the OPTA concept as a short term solution.

In summary, the core of the project was to demonstrate by means of real live traffic: the OPTA concept; the ATC-control techniques together with assurance and verification of the procedure; the operational requirements from [27]and Acceptance/testing of the support tool which would aid the Air Traffic Controllers.

In fact, during the demonstrations the OPTA-IN support tool developed by INDRA based on requirements that had come from [27] and feedback from ATCos and Pilots was trialled.

The designated airspace was the Palma’s TMA situated in the FIR BCN (SP), where the OPTA concept was simulated and the traffic density conditions allowed for the OPTA-IN project to be adequately demonstrated thanks to the seasonality of the traffic.

Three STARs were used for the demonstrations (as shown in Figure 2.) with their starting points: TOLSO, LORES, KENAS (the KENAS flow was not assessed by OPTA).

The demonstration flights were conducted by two airlines with base in PMI: AirBerlin (BER) and AEA. The demonstration campaign included more than 101 flights: these were performed with a mixed fleet of ERJ190’s, A320/1s and B738s. The total number of couples monitored and sequenced by applying the OPTA-IN procedure with the support of OPTA-IN-SA (Speed Adjustment) ATCo tool was 24, of which at least 6 were performed in a triplet formation (see Sec. IV. E for more details).

1) Method of Operations - OPTA-IN procedure sequence

Hereafter the sequence of steps followed by the main actors involved in the OPTA-IN procedure:

a) Based on the aforementioned entry points (LORES/TOLSO/KENAS) the a/c enter at 280 KIAS and proceed to the IAF (POS) (see Figure 2.).

b) The crew has already planned in their FMS the CDO through the defined entry point.

c) The ATCo, responsible for the management of this traffic/area, performs, as part of his activities of continuous monitoring, the detection of flights which are closing-in to the TIE Points.

d) Once a/c number one (AC1) reaches TIE Point 1 (TIE1), the tool will support the ATCos’ operation with visual indications, including speed advisories (depending on the desired spacing at IAF) based on the distance (d) between a/c number two (AC2) and its own TIE Point 2 (TIE2).

<table>
<thead>
<tr>
<th>Speed Reduction Advisory Tables</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 [NM]</td>
</tr>
<tr>
<td>Distance offset (NM)</td>
</tr>
<tr>
<td>6.3 — 7.3</td>
</tr>
<tr>
<td>5.6 — 6.3</td>
</tr>
<tr>
<td>4.7 — 5.6</td>
</tr>
<tr>
<td>3.8 — 4.7</td>
</tr>
<tr>
<td>3.0 — 3.8</td>
</tr>
</tbody>
</table>
Simultaneously the ATCo provides a/c number two (AC2) with a proposed speed adjustment provided by the tool.

The action undertaken upon AC2 provides the separation - either 5 or 10NM as required by the operation - necessary for the arrivals to merge at the IAF (POS).

The crew follows the speed instruction confirming and adjusting its own speed (as far as possible) in the swiftest possible way.

AC1, will continue its procedure without making any change to its manoeuvre, reaching the 250 kts SLP (complying thus with the restrictions in place by the conventional procedures) and later the IAF (POS).

In the meantime AC2, which had received the speed adjustment, will reach its SLP respecting the conditions assigned by the ATCo and following those, will reach the IAF (POS) with the adequate separation.

As a result the a/c are sequenced at the IAF with the required 5/10 NM separation, performing both simultaneously a CDO (or quasi) as planned by the crew.

The cornerstone of the OPTA-IN procedure is the SRAT. These tables were designed in order to assist ATCos in sequencing traffic at the same IAF.

However, the work to be performed by the ATCos without the support of automated tools did not prove to be very efficient: in fact previously, in OPTA, the SRATs were available printed on a paper sheet and the distance between the a/c and its TIE point had to be measured on the CWP. Hence there was a clear necessity to create a tool which would assist the ATCos in applying the OPTA-IN procedure. Indra (with the support of the OPTA-IN consortium members CRIDA, INECO and ENAIRE) was able to identify the proposed operational needs and tailored a prototype that perfectly fit the operational requirements and technical specifications.

The OPTAIN-SA tool (SA - Speed Adjustment) is able to generate the required sequence of a/c to a certain point by suggesting to the ATCo the necessary speed adjustments. This allows the a/c to perform the descent to the runway at near idle thrust.

The HMI of the tool has the appearance of a tabular interface, where flights are listed with useful information to properly perform the procedure. ATCos, during the validation exercises, were able to interact with the tool tailored to the local operational needs (as described in Sec. II. B. 2)

Ideally, the OPTAIN-SA tool should be integrated in the Flight Data Processing (FDP) system (SACTA), on the other hand the final decision was to develop an external tool: a laptop PC (shown in Figure 3. with access restricted only to the ATCos involved in the validation activity, and the support team.

A. OPTAIN-SA architecture

The architecture of the OPTAIN-SA is shown in Figure 3.

There are two main components: the server and the client. The OPTA-IN server was connected to the Palma ACC Centre network. It mainly obtains information from two different subsystems: SIS (Surveillance Information Supply) and GIPV (Flight Plan Information Management). The first one provides the radar track information, and the second, the flight plan information. All this data is updated periodically and it is stored in a database.

OPTAIN-SA’s HMI runs on the client’s internet browser (Internet Explorer). More than one client can be connected to the OPTA-IN server through the internal network, which provides all the necessary data (flight plan and radar track information). The idea is to have, at least, one client available per CWP.
B. OPTAIN-SA HMI

In the OPTA-IN window, the arrival flight sequence to PMI, going through IAF (POS), is available to the controller. This sequence does not make distinction in the different arrivals paths (TOLSO, LORES or KENAS).

The flights to be shown in the sequence must comply with the following requirements:

- The destination airport (PMI);
- The flight is inside the defined geographical area (Figure 4);
- IAF (POS) is one of the waypoints in the flight plan (initial or tactically modified);

The flights are shown 18NM before the TIE point. Once this point is overflown, the flight will be highlighted until 2 NM after the TIE point, to then disappear.

![Figure 4. OPTAIN-SA tool appearance](image)

The information available for the controller for each flight is: Call Sign, Ground Speed, STAR entry point, distance to the TIE Point and a suggested speed, which is calculated for the separation of 5 NM or 10 NM with the previous a/c in the sequence. Furthermore, the air traffic controllers are able to check the status of each flight in the arrival sequence. Each status is highlighted with a different colour of the label:

- Candidate (yellow): when a flight is able to be involved in an OPTA-IN procedure;
- Execution (green): flight involved in an OPTA-IN procedure;
- Excluded (red): when a flight is not able to be involved in an OPTA-IN procedure. There are two reasons for this to occur:
  - the flight is too close to its predecessor and it is impossible to get the separation of 5 and 10NM;
  - or because the ATCo decides to exclude the flight manually due to operational circumstances.

OPTAIN-SA tool also informs the ATCOS with a visual alert, when the speed clearance must be transmitted to the pilot.

C. OPTAIN-SA functionalities

The main functionalities of the OPTAIN-SA tool can be summarized as follow:

1) **OPTA-IN procedure activation**: An OPTA-IN procedure is activated the moment the ATCo selects the appropriate speed. The ATCo is able to accept the default speed (the speed value showed in the OPTA-IN window, calculated by the tool) or to modify it manually by a more suitable speed.

2) **Exclude/Include**: OPTAIN-SA allows the ATCo to manually exclude or include flights in the sequence.

   By default, OPTAIN-SA makes pairs of candidate flights with consecutive a/c in the sequence, but sometimes an ATCo is interested in pairing two non-consecutive a/c. In order to do that, all the flights between them must be excluded. This is the main utility of this function.

3) **OPTA-IN procedure cancellation**: There is no direct action to cancel an OPTA-IN procedure. But, if an ATCo wants to cancel it, the OPTAIN-SA tool allows doing so in two different ways. The first option is excluding one of the flights involved in the procedure (as it is explained in previous item). The second one, it is including a flight (initially excluded) between two flights involved in a procedure.

4) **Report**: In order to facilitate the post implementation assessment and verify that the operation has been granted with the procedure, OPTAIN-SA also produces reports with the information of all the OPTA-IN procedures done. These reports were very useful for the analysis of the results coming from the validation activities.

IV. TECHNICAL AND OPERATIONAL VALIDATION

A. Validation Objectives

The necessary key validation areas, identified in [29], were established in order to reach operational and technical validation. The former required the verification of: the initial speed at the TMA entry; the restrictions to the vertical profiles; SRAT, etc. Situational Awareness of the ATCo need be maintained or improved. Over more the involved traffic was required to be correctly separated in accordance with operational needs during the continuous descent until the IAF.

- Just after the speed is selected and accepted, the colour of the candidate flights turns to green.
while not affecting traffic managed through standard procedures.

- From a technical point of view to validate the OPTAIN-SA tool operational and technical setup.

B. Validation Exercises – Demonstration Campaign

In order to cover the key validation areas, three main validation exercises were defined, with increasing maturity levels. The first one was a fast and real time simulation. This exercise and its aspects were the study and analysis of the OPTA project. The results were used entirely by OPTA-IN.

The second was a flight demonstration campaign through the Barcelona FIR. The traffic was analysed in transition from Barcelona ACC to Palma TMA and arriving at Palma de Mallorca Airport. Two scenarios were studied:

- ERJ190 flight campaign to calibrate the fuel performances of the a/c during optimum continuous descents.
- Analysis of flights performing the OPTA-IN procedure.

And the third validation exercise was a vertical and longitudinal separation assessment based on surveillance data collection and OPTAIN-SA data analysis. The first trial flights began on the 24th of February 2014 with BER followed in parallel a week later by AEA. The campaign ran until the end of April 2014.

Previously, ENAIRE made a few trials for coordination purposes to help adjusting all the steps of the OPTA-IN procedure (e.g. determine responsibility and priorities, phraseology, adaption of current procedures, etc…)

A total of two Palma TMA approach controllers, with full dedication to the validation exercises were granted, together with the collaboration of the daily shift from the Barcelona ACC.

C. Evaluation Results

A preliminary analysis of the flight schedules for BER and AEA was done in order to find the best opportunity windows where flights would coincide. During the performance of this analysis two scenarios were found:

- “Merge”, when traffic comes from different flows (different entry points).
- And “Sequence”, when the traffic is coming from the same flow (same entry point).

Once the potential flights were identified, the ATC controllers planed each day of the campaign theirs shifts to manage the potential OPTA-IN flights.

Likewise, this operational assessment served to record and processes surveillance data during the trials: pictured in Figure 5, the radar tracks of all the flights, separated with OPTA-IN during the demo flight campaign. Different colours identify the entry points. Orange colour is associated to flights coming from TOLSO, dark green for those coming from LORES; blue is related to those flights coming through KENAS. The light green line indicates the F1X sector boundary.

In Figure 6, below, the vertical profile of the flights is shown. Flights in orange mainly belong to AEA and they correspond to flights from the BCN-PMI city pair, performing pure CDO Flights in blue, mainly belong to BER and they correspond to optimised descent approaches by applying the OPTA-IN procedure.

The red rectangle in Figure 6 delimits the flight segments where the OPTA-IN procedure was tested: a range of heights starting around FL200 (Palma TMA entry point) and ending at FL70/80 IAF (POS). By definition the OPTA-IN procedure has been designed from the entry point to Palma TMA (FL 200-240) to IAF (POS), which means the optimised procedure finishes over 7000ft.

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3 Analysis required by the environmental objectives of the project [24], and not covered by this paper.

4 At least 30 ATCos were directly involved in the validation exercises.
D. **OPTA-IN Procedure Validation example**

The main objective of this section is to show the OPTA-IN procedure as followed by a pair of a/c, which are performing an optimised descent, through speed adjustments. The following example shows the performance of a procedure based on speed adjustments provided by OPTAIN-SA. This is an example usually designated as a “Merge” which means that flights come from different flows. Below in Figure 7, the AEA flight was designated to be the first a/c in sequence followed by the BER flight which was going to receive the speed adjustment at a certain point with the aim of having sequenced flights at the IAF (POS). The spacing required at the IAF, and dependent on operational needs, was at that specific time 10 NM. As shown in Figure 7, AEA6037 was coming through TOLSO while BER737M from LUNIK.

The AEA flight was thus designated as AC1 in the sequence (see sec II.C.1). The flights proceeded until the action point. As previously explained, when AEA6037 reached its TIE point (TIETO), according to the distance between BER737M and its TIE point, automatically measured by OPTAIN-SA, the same tool suggested a speed adjustment which was applied to BER737M (reduction to 240 kts).

After giving the suggested speed-indication to the pilot of the BER flight, the situation evolved by itself with no more indications. A/c kept flying their optimised approaches until the Merging point. On the right, in Figure 8, it is possible to appreciate the separation reached when AEA6037 was flying over IAF (POS).

A dashed red line shows the distance between the flights, this corresponds to 11 NM.

It is shown below that the separation is maintained after the traffic’s evolution (see Figure 9). Vertical profiles from the flights were crosschecked through analysis of performance data coming from the Flight Data Recorder to establish if there were performing an OPD.

![Figure 7. OPTAIN Technique: AEA6037 & BER737M](image1)

**E. Results**

The number of flights performing the optimised descent, during the demonstration calendar, as described in the previous section consisted of a total number of 44 flights. TABLE II, below, shows the number of Optimised descents divided into doublets/triplets.

<table>
<thead>
<tr>
<th>GROUPS</th>
<th>Nº. in groups</th>
<th>Nº. of flights</th>
</tr>
</thead>
<tbody>
<tr>
<td>DOUBLETS</td>
<td>24</td>
<td>44</td>
</tr>
<tr>
<td>TRIPLETS</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>TOTAL⁵</td>
<td>53</td>
<td></td>
</tr>
</tbody>
</table>

The OPTA-IN concept covered only the pairing of flights, the fact that three consecutive a/c were found to be supported with the aid of OPTAIN-SA was a surprise for the project opening the possibility for further analysis or extension of the concept.

V. **Main Conclusions**

With a demonstration calendar of nearly three months and more than 100 valid flights performed, the project

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⁵ Note that the TOTAL figure includes the triplets since they have been accounted for as two consecutive couples.
demonstrated the potential of the procedure as a short-term solution into medium traffic densities for the application of OPDs and the robustness of the OPTAIN-SA tool.

The operational side of the project showed the following:

- The validation activity proved that all the functionalities developed in the OPTAIN-SA tool worked properly. The tool provided valid support to the concept and the ATCos, opening further lines of development and integration into the ATM system.

- The feedback provided by ATCos and Crew, on the OPTAIN-SA tool and the procedure, showed that the workload associated to CDOs was acceptable for both. In fact, ATCos involved in the validation activities, highlighted the easy adaptation to the OPTAIN-SA tool and the simple learning process.

- Initially defined for pairs of flights, it was found that OPTAIN-SA had the potential to be used with triplets.

- OPTAIN-SA was developed to be used in Palma TMA, nonetheless it can be tailored to other scenarios in a seamless manner by including: new location data and SRATs; and easily integrated into the CWP.

VI. FUTURE WORK

Two parallel foreseen paths are envisaged for the future evolution of the OPTAIN-SA tool:

- Hand in hand with a potential implementation of the OPTA-IN concept through easy update of the SRATs considering the scenario’s fleet mix. And the tailoring of the tool to the local operational constrains and requirements (e.g. winds, traffic density, etc.)

- Further development of the tool functions including: the potential for supporting three consecutive flights and future integration into the CWP.

The tool and the concept will certainly benefit from new SESAR solutions and/or to-be- implemented technology (e.g. Mode-S²/ADS-B). This technology could be a key technical improvement which would support the deployment of procedures like OPTA-IN where the speed adjustment is the only technique to be used to separate the traffic.

ACKNOWLEDGMENT

The Authors wish to thank the crews of BER and AEA for the support given during the demonstration activities. Special thanks to the Palma TMA personnel, especially to the two dedicated ATCos who provided daily feedback on the validation of the tool and participated in the definition of the requirements. The data post analysis would not have been possible without the support of CRIDA and the data provided from the AEA Flight Data Dept, and ENAIRE. The authors would also like to underscore the support given by the SJU inside the AIRE framework in making the demonstration possible.

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⁴Mode-S provides a/c IAS to CWP.