ATLANTIC INTEROPERABILITY INITIATIVE TO REDUCE EMISSIONS

PERFORMANCE OF FLIGHT TRIALS VALIDATING SOLUTIONS FOR THE REDUCTION OF CO₂ EMISSIONS
Lot 4

A380 Transatlantic Green Flights

Deliverable Phase 2
A380-TGF/LC/0115-D2
EXECUTIVE SUMMARY

This document reflects the outcome of the ‘A380 Transatlantic Green Flights’ (A380-TGF) for which SJU awarded the contract SJU/LC/0115-CTR to a consortium composed of Airbus S.A.S. (coordinator), Air France (technical lead), NATS and NAV CANADA. FAA supported the trials in the frame of the general AIRE agreement with the European Commission. The Project was kicked-off on 25th August 2010, followed by a three months Definition Phase (see Phase 1 Report) and an eleven months Execution Phase ending with the Acceptance Review Meeting between SJU and project partners on 18-Oct-2011.

The project looked at two aspects of optimising the Air France transatlantic flights with A380 between New York and Paris: two-engine taxi-out for the ground movement phase of flight and optimised transatlantic trajectory for the enroute phase of flight.

Reduced engine taxi trials took place between Dec-2010 and Apr-2011 at New-York JFK airport with considerable support from FAA. The challenge was to put in place and optimise a new procedure which involved four stakeholders and provided to the flight crew an estimate of the taxi time, which served as decision criteria for reduced engine taxi.

Fifteen two-engine taxi-outs were performed with an average reduction of 360 kg in fuel burn (1.2 t of CO₂). Assuming one daily flight JFK – CDG and applying the “success” rate of 40% as experienced in the trials, this results in a potential yearly amount of 54 t of fuel (170 t CO₂) valued at 28 000 €.

The following remarkable observations were made:
- two engine taxi does not consume 50% but about 65% of four engine taxi due to higher sensitivity to acceleration;
- less breaking actions were observed thanks to easier taxi speed control;
- in average, one third of engine run time on ground was in the static phase at start-up point; this represents a further opportunity for optimisation.

To implement two-engine taxi on a regular basis a support tool is needed to improve the availability and reliability of taxi-time prediction. This tool shall ideally be a shared application in the frame of Airport Collaborative Decision Making (A-CDM) enabling operators to autonomously make the right decision without counting on tower controllers for efficiency/environment-related tasks.

In the period from December 2010 to April 2011, 34 flights were identified for transatlantic optimization. On four flights, the conventional North Atlantic Organized Track System was left within the airspace controlled by NAV CANADA and NATS. This was facilitated by the A380’s rather high cruise level at FL 390 and above, where less traffic is encountered allowing for such a flexible dynamic re-routing taking best advantage of the actual wind conditions. An average reduction of 600 kg in fuel burn (1.9 t of CO₂) was observed. Assuming that for 70 out of the 365 flights per year such an optimisation is successful, a yearly fuel saving of 42 t would be achievable (132 t CO₂) valued at 21 700 €.

It is remarkable that from an ATC point of view, the North Atlantic re-routing under the trial scenario was rather easy to handle with very little or no impact on workload. For NATS as the downstream air traffic service unit, the re-routings were transparent to controllers at Shanwick as they took place more than 30 minutes prior to data transfer from Gander to Shanwick area.

At airborne side an important observation was that flight plan syntax used by Airline Operational Communication (AOC) and ATC shall become compatible in order to get flight crew workload to an acceptable level when handling and transmitting the updated flight plan.
The A380-TGF project included also various communication activities, amongst others the production of a project video, which was published on SJU’s and project partners’ web-sites and which was shown in March 2011 at the occasions of ATC Global at Amsterdam and at Avionics Conference in Munich. Airbus covered the A380-TGF project through an article in the January 2011 issue of its FAST-magazine, which was distributed to Airbus customers worldwide. In October 2011, NAV CANADA organized a press briefing at Montreal on selected AIRE projects comprising A380-TGF.

In conclusion, the project partners judged the A380-TGF trials as successful with results being sufficiently significant to justify further studies aiming at a regular application of the trialed optimisations.

Link to project video:
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1. DESCRIPTION OF THE VALIDATION EXERCISE

1.1 OBJECTIVE

The AIRE A380 Transatlantic Green Flight project aimed at evaluating the possibilities to reduce emissions on New York JFK to Paris CDG routes performed by A380 revenue flights in ground operations and cruise operations. Possible axes of progress were identified by the project partners and potential fuel gains were assessed and listed in the Phase 1 Report.

The objective was to evaluate the fuel gains from each axis of progress identified by the project partners by adapting current procedures and determine whether they could be transferred into standard operations.

1.2 PREPARATION

Special attention during the preparation was given to proper coordination with the FAA, for, while FAA was not a consortium member, the agency agreed to support the ground part of the trials.

In 2009, FAA began discussions with the SJU to select potentially beneficial demonstration projects for 2010 (reference, SJU AIRE Phase II Document, 31 August, 2009). The FAA, NAV Canada, NATS UK, SJU and Airbus participated in the SJU AIRE Phase II Demonstration Kick-Off Meeting for the AIRE A380 TGF project in Toulouse in August, 2010. In September 2010, the FAA participated in the Partners Meeting at Air France Headquarters in Paris. AIRE Demonstration Procedures were documented and agreement reached by participants at the Meeting. Among other provisions, it was agreed that:

- no special priority was assigned to the demonstration flights, and
- the demonstrations would impose no adverse impacts on other flights

In October, 2010, the FAA hosted two days of Partner meetings at the New York Center (ZNY) and the JFK Air Traffic Control Tower (ATCT).

Participants included Air France, NAV Portugal, NATS, the French DSNA, ZNY and FAA Headquarters representatives. Air France explained the objective of the A380 Transatlantic Green Flights (TGF) was to demonstrate the potential benefits of optimized procedures on the ground and in oceanic airspace.

Air France explained that reduced engine A380 taxi, for example, could save considerable fuel and reduce engine emissions. Air France proposed for the demonstrations at JFK that prior to the A380’s engine start, the dispatcher would contact the ATCT for an estimate of the taxi time to take off. If estimated taxi time exceeded 20 minutes, the A380 flight crew would taxi to the departure runway using 2 engines rather than four. Estimated savings were significant.

FAA management explained JFK airport operations, including:

- Frequent runway configuration changes throughout the day to cater for changing arrival/ departure flows
- Runway configuration is changed approximately every 8 hours for environmental reasons
- Taxi time is a function of the runway configuration
- Airport layout requires frequent runway crossings
- The Taxi metering system, introduced to minimize the aircraft in queue as a result of construction on runway 13R
- Interdependence of JFK and La Guardia airport operations
- Different organizations are involved in the ground movement process, including
2. VALIDATION OF SURFACE MOVEMENT OPTIMIZATION

2.1 DESCRIPTION OF THE EXPERIMENTAL CONCEPT

The surface movement part of the A380 TGF project relied on reducing taxi fuel in a dense ground operations environment, at JFK airport. To do so, it was decided to evaluate the possibility to optimize 2 engine taxi-out on a 4 engine aircraft, the A380, by reinforcing coordination between all actors: ground control, ground operations and flight crew. Potential fuel savings were estimated at around 200 kg per flight (refer to project Phase 1 Report for details).

2.1.1 General Process

The process was defined during the workshop organized at FAA’s office at JFK airport on October 21st 2010, gathering all project stakeholders related to the surface optimization: FAA, Air France and Airbus.

In order to optimize 2-engine taxi-out, the flight crew needs to determine how long the aircraft is going to taxi before taking off. For this purpose, the flight crew needs to know which runway the aircraft will taxi to (which is a mandatory known operational data) and how many aircraft will be queuing before them and force them to wait additional time.

The trial concept consisted in FAA ATC estimating the taxi duration and forwarding it to the crew so that they could assess at engine start up time whether they could perform 2-engine taxi-out.

2.1.2 Pre Requisits and Constraints

2.1.2.1 JFK Ground Control Specificities

Ramp operations (engines off) and ground operations (engines on) are handled separately at JFK airport. Each terminal organizes its ramp activities through private subcontractors.

For Air France terminal (T1) : ASIG for push back, TOGA for ramp control, PASSUR for slot management.

FAA ATC takes over (for ground and runway control) once the aircraft exits the ramp at engine start up point.
Figure 1: New York JFK A380 Taxi Chart Departure

Figure 1: Air France operates from Terminal 1

Note: The A380 is restricted to gates 1, 5, 7 and 8.
2.1.2.2 ATCT Estimation Method

Departure taxi optimization alternatives for JFK were evaluated by Air France and the FAA during discussions at the JFK ATCT meeting on October 21, 2010.

A procedure was tested for the A380 flight the evening of October 21. The FAA ATCT supervisor provided a taxi time estimate which was relayed by Ramp Control to the A380 crew by ACARS. This estimate was sufficiently accurate to support the correct engine start up decision by the Air France crew. With the understanding that the AIRE demonstrations would be conducted approximately twice a week, FAA agreed to provide the estimate of taxi out times in accordance with the observed procedures.

The following constraint has to be taken into account: FAA Air Traffic Control Tower (ATCT) clears aircraft to taxi-out and then take off once outside the ramp. They are not aware of how many or exactly when aircraft exit the ramps of the different terminals in advance, but only at the moment of engine start up, when they request taxi-out clearance.

2.1.2.3 Air France Tool to estimate Taxi Time

Air France ground station is equipped with Aerobahn which allows:

- Dynamic queue monitoring
- Filtering possible for taxi-time between two specific points (e.g. runway crossing point, ...)
- Situations replay (history)
- Runway occupancy time calculation

Aerobahn is not used by FAA ATCT.

Aerobahn was consulted by Air France station agents during the flight preparation phase to transmit to the crew a first estimation of the taxi-out time, by identifying the rank of AF007 and counting an average spacing of 90 seconds between 2 take-offs. This was given for information only and would enable the crew to get a first idea of how long they should expect later on for the actual taxi time estimate.
2.1.2.4 A380 Two Engine Start

Amongst other innovative performances it features, the A380 offers the possibility to taxi on two engines (inner or outer) without impact on hydraulic or electrical systems. Four engine taxi is however necessary under some specific operational conditions (e.g. uphill slopes and high gross weight).

The procedure is clearly described in the Air France standard operations procedures.

![Airbus A380 engines](image)

Figure 3: Airbus A380 engines

The main important safety requirement for applying this procedure is to maintain the possibility to identify an engine fire. Therefore, the Air France 2 engine taxi procedure indicates the following, in case engines 1 and 4 are started first:

```
CAUTION
Start engines 2 and 3 at least 5 minutes before takeoff.
Make sure that the aircraft is visible from the tower, or that following aircraft are in a position to see the engines and warn the flight crew in case of an engine tail pipe fire.
```

A 5 minute stabilization elapse time is required before take off.

Flight crews are also advised that they need to take into account the fact that due to higher thrust per engine that may be required for taxiing, the jet blast and the risk of Foreign Object Damage (FOD) by ingestion will be higher than during a standard taxi.

2.1.2.5 Ground Communications

This information is listed in the JFK airport chart (see annex 8.1).

2.1.2.5.1 Between Air France Station / T1 Ramp Control and JFK Tower

As part of an experimental trial and in order not to disrupt JFK traffic ground communications, it was decided that all AIRE related communications would be performed via telephone only.
2.1.2.5.2 Between the Aircraft and Air France station

Once on board, the flight crew can communicate with Air France station via ACARS text messages or via the airline frequency.

2.1.2.5.3 Between the Aircraft and T1 Ramp Control

Once on board, the flight crew can communicate with Terminal 1 Ramp control via Ramp control frequency.

2.1.3 Procedure Details

The AIRE surface trial process relies on the close coordination between FAA ATCT and Air France. It takes into account the operational requirements of any JFK taxi-out procedure (refer to annex 8.1 for details).

2.1.3.1 Initial Process

The initial process involved an extra task for TOGA, the Terminal 1 ramp control, in charge of clearing the aircraft to push back until the engine start up point. T1 ramp activities are managed through private subcontractors, as mentioned in 2.1.2.1. They agreed to support the A380 TGF project. Their initial role was to relay the taxi time information from JFK ATCT to AIR FRANCE crew.

0. Air France station uses Aerobahn to give a first estimate of the taxi time to the crew at the flight preparation phase (face to face)
1. After push back clearance delivery, the flight crew contacts T1 ramp control via radio and asks for taxi time estimate
2. Ramp control contacts JFK ATCT via phone for taxi out estimate
3. JFK ATCT relays taxi out estimate to Ramp control via phone
4. Ramp control relays it to the crew via radio
5. Based on the taxi out duration estimate, the flight crew decides to perform 2 engine taxi out or not once at start up point
6. Flight crew contacts ramp control via radio once 2 (or 4) engines are on and ready to taxi
7. If 2 engine taxi out is performed, at least 5 minutes before take off, the flight crew starts the 2 remaining engines.

2.1.3.2 Process Updates

2.1.3.2.1 Optimization through Air France Station Reactivity

After the first trials it became obvious that the process was not robust enough. In most cases, ramp control did not inform the flight crew of the updated estimate, leading to the crew deciding to perform 4 engine taxi-out by lack of usable information.

In order to reinforce the AIRE procedure, it was decided to limit the participants only to the project stakeholders and enhance the role of Air France station.

Air France station would monitor the push back clearance request on the frequency and contact by phone JFK ATCT after reception of clearance to get their taxi estimate. They would then relay it to the crew via ACARS.

0. Air France station uses Aerobahn to give a first estimate of the taxi time to the crew at the flight preparation phase (face to face)
   - Monitors frequency for push back clearance delivery
1. After push back clearance received by AF007, Air France station contacts JFK ATCT via phone
2. JFK ATCT relays taxi out time estimate to Air France station via phone
3. Air France station relays it to the crew via ACARS as soon as possible
4. Based on the taxi out time estimate, the flight crew decides to perform 2 engine taxi out or not once at start up point
5. Flight crew contacts ramp control once 2 (or 4) engines are on and ready to taxi
6. If 2 engine taxi out is performed, at least 5 minutes before take-off, the flight crew starts the 2 remaining engines

2.1.3.2.2 Optimizing the FAA Taxi Time Estimate

As explained in 2.1.2.2., ATCT is not aware in advance neither of the quantity of aircraft leaving the ramp nor about the exact time when they leave.
Therefore, the later the taxi-out time estimate is requested, the more accurate. Furthermore, once the A380 leaves the gate, as its primary route is to turn left on taxiway -A-, opposite of the flow of traffic (clockwise), there can be a significant amount of time before engine start up and ramp exit, which cannot be predicted in advance. Or, on the contrary, this time can be rather limited, leaving no time for the station to request the estimate and send it to the crew via ACARS.

Therefore, crew were under the impression that the estimate given by ATCT was not easily usable. To mitigate this, a different approach was followed.

Instead of waiting for the taxi estimate to decide whether or not they would start 2 or 4 engines, dedicated crews were instructed, for the AIRE trials only, to systematically consider 2 engine start and wait for the start of taxi to get the most updated estimate. If the estimate is sufficiently long (over 20 minutes), then crew would go along taxiing with 2 engines off until the preferential remaining engine start spot listed in the procedure. Otherwise, or in case the estimate is not received by the time they exit the ramp, they would immediately start the 2 remaining engines.

Note: All JFK runways accessible by the A380 are beyond 5 minute taxi of T1 ramp, leaving enough time for stabilization.

0. Air France station uses Aerobahn to give a first estimate of the taxi time to the crew at the flight preparation phase (face to face)

   Monitors push back clearance delivery frequency

1. Flight crew considers 2 engine taxi-out from start up point

2. Flight crew contacts ramp control for expected taxi slot time and advise when ready to taxi

3. Air France station monitors taxi clearance delivery frequency

4. When aircraft is cleared to taxi, AF station contacts FAA supervisor to get taxi duration

5. JFK ATCT relays taxi-out time estimate to Air France station via phone

6. Air France station relays it to the crew via ACARS as soon as possible

7. Based on the taxi-out time estimate, the flight crew decides to continue 2 engine taxi-out or start up the 2 remaining engines at their discretion.

8. If 2 engine taxi-out is performed, at least 5 minutes before take off, the flight crew starts the 2 remaining engines.
2.1.4 Dissemination to the Trial Participants

An important aspect of the flight trials preparation was the information of the operational participants. A special attention was paid to the drafting of the procedures, in order to limit misinterpretations and be as straightforward as possible.

The A380 captains who performed the trials were selected among management and instructors in order to enable better communication with them. They were briefed in advance by telephone or face to face by the head of the A380 flight crew technical office, in order to familiarize them with the concept and objectives of the trial and clarify all questions.

Air France station agents were verbally informed of the objectives and conduction of the trial.

FAA JFK ATCT Operations Manager participated in the discussions during the project meeting on October 21st, 2010. No other JFK air traffic controllers participated in these demonstrations.

2.1.5 Data Collection Process

The data collection process was performed as follows:

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<th>Performance Indicator</th>
<th>Measurement</th>
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<td>Fuel savings</td>
<td>AFR, Flight crew feedback</td>
</tr>
<tr>
<td>Operational</td>
<td>Impact on ATCO Workload</td>
<td>ATC, ATCO feedback</td>
</tr>
<tr>
<td>Economical</td>
<td>Environmental benefits expressed in €</td>
<td>Other traffic, Calculated</td>
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A questionnaire was handed out to flight crews at flight preparation (refer to annex 8.2) in order to collect:
- The taxi-out time estimate
- In case 2 engine start was performed, the taxi-out elapse time with 2 engines
- The actual taxi time
- Any additional information/feedback

This information was used by the crew primarily to evaluate if there were fuel savings to be made by performing 2 engine start but will also be used for the purpose of this analysis.

2.2 SAFETY ANALYSIS

In order to ensure safe operations during the AIRE TGF flight trials, the concept of the trial was defined in close collaboration with the « Bureau Information Technique », or A380 Flight crew technical office, responsible for ensuring that the process matched Air France standard operational procedures and safety requirements.

The AIRE procedure is based on an approved procedure from Air France Flight Crew Operating Manual, based on an Airbus procedure.

The main hazards are clearly listed in the procedure (refer to 2.1.2.4) and are as follows:
- the lack of available thrust in case of heavy aircraft or difficult airport configurations (steep turns and uphills)
the possible damage to surrounding facilities / aircrafts / vehicles / persons due to the increased jetblast necessary to maneuver

Dedicated crews were chosen to ensure a good knowledge of JFK airport ramp operations and taxiways.

Also, in order to facilitate the identification of the most optimized location to start up the two remaining engines, preferential spots were identified in collaboration with FAA for each runway, to ensure at least 5 minute stabilization before take off.

Note: the preferential spots were only suggested to the crew, the decision to start the two remaining engines remained at their discretion.

Another concern was to limit crew disturbance and especially avoid any task interruption within the demanding phase of aircraft push back and taxi in the busy environment of JFK airport. To do so, it was decided that the taxi duration message would be sent via ACARs and not by voice.

Finally, this message was sent by Air France station and not directly by ATCT in order to avoid any misunderstanding amongst the surrounding traffic, as this trial procedure was not known by the other crews/airlines.

In the JFK ATCT, only the Operations Manager participated in the demonstrations. Standard air traffic control procedures were observed by all the operational controllers in the ATCT throughout the demonstration period.

2.3 TRIAL EXECUTION

2.3.1 Overall Conduction of the Trial

The JFK surface trial was initially planned to take place over one month between December and January, though the overall planning of the project allowed some flexibility and possible extension of the trial period.

Due to weather constraints (heavy snow storms from December to February), many trial flights had to be cancelled and postponed to March.

Furthermore, the tuning of the process (see 2.1.3) required to extend the trial period up to April 22nd, with no negative impact on the project overall schedule since final results were supposed to be delivered by September 2011 at the latest.

2.3.2 Trial Schedule

The surface trial lasted 4 months and a total of 38 candidate flights were identified:

<table>
<thead>
<tr>
<th>Dec-2010</th>
<th>Jan-2011</th>
<th>Feb-2011</th>
<th>Mar-2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>24/12/10</td>
<td>AF007</td>
<td>08/01/11</td>
<td>AF007</td>
</tr>
<tr>
<td>25/12/10</td>
<td>AF007</td>
<td>10/01/11</td>
<td>AF007</td>
</tr>
<tr>
<td>27/12/10</td>
<td>AF007</td>
<td>15/01/11</td>
<td>AF007</td>
</tr>
<tr>
<td>28/12/10</td>
<td>AF007</td>
<td>13/02/11</td>
<td>AF007</td>
</tr>
<tr>
<td>24/01/11</td>
<td>AF007</td>
<td>14/02/11</td>
<td>AF007</td>
</tr>
<tr>
<td>29/01/11</td>
<td>AF007</td>
<td>28/02/11</td>
<td>AF007</td>
</tr>
<tr>
<td>21/03/11</td>
<td>AF007</td>
<td>10/04/11</td>
<td>AF007</td>
</tr>
<tr>
<td>26/03/11</td>
<td>AF007</td>
<td>11/04/11</td>
<td>AF007</td>
</tr>
<tr>
<td>27/03/11</td>
<td>AF007</td>
<td>12/04/11</td>
<td>AF007</td>
</tr>
<tr>
<td>28/03/11</td>
<td>AF007</td>
<td>15/04/11</td>
<td>AF011</td>
</tr>
<tr>
<td>22/04/11</td>
<td>AF011</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
2.4 TRIAL RESULTS

2.4.1 Qualitative Analysis – Feedback

2.4.1.1 Feedback from Flight Crew

During the first phase of the trial, as explained in 2.1.3.1, the process involved ramp control as a liaison between the crew and ATCT, leading to excessive exchanges between trial participants and to the taxi estimate not being received in time for engine start up on most trials. The process could not be evaluated and had to be changed.

As of January 29th, an updated process with a direct communication link between Air France station and ATCT was implemented. Crew acknowledged the improved coordination but unfortunately, as described in 2.1.2.2.1, they found that the taxi estimates that they received were unrealistically short, mostly between 10 to 15 minutes. Indeed, during the preparation meeting held in October 2010 between the project stakeholders at JFK, the unimpeded taxi time given by FAA was 17 minutes.

As of April 2nd, the process was tuned to mitigate this problem (AIRE trial flights performed systematic 2 engine start after push back and received the taxi estimate when cleared to taxi), with significant improvement. Most crews found that the ACARS message arrived at an appropriate time, leading to taking the decision of 2 engine taxi-out more easily.

The AIRE procedure suffered at first from the reluctance of pilots to start only 2 engines while taxiing, with no visual confirmation other than from the surrounding traffic and the distant ATCT. This concept was quite new at Air France and implemented mainly on modern aircrafts, such as the A380.

Once they had been briefed and performed it a couple of times, verbal feedback became positive and the potential gain immediately identifiable on the Fuel System Display in the cockpit reinforced the pilots adherence.

Another positive feedback from applying the 2 engine taxi-out procedure was the benefits on the brakes temperature management: 2 engine taxi allows better control, less braking actions and thus less temperature increases. This prevents overheat before take off, which can lead the aircraft to have to delay to cool down.

Note: As per airline procedure, crew must delay take off until the brake temperature is below 290° (refer to annex 8.3 for brake cooling time). Refer to annex 8.4 for crew feedback transcripts.

2.4.1.2 Feedback from Air France Station

No negative feedback was reported by Air France station regarding the conduction of the trial.

2.4.1.3 Feedback from ATC

Procedures for the surface trials were modified after trials began. The revised procedures allowed taxi times to be estimated just prior to aircraft taxi rather than, as first implemented, at the start of push-back. It is noted that, not surprisingly, the later an estimate is requested the more satisfactory the result.

2.4.2 Operational Results - Data Analysis

For analysis using FDR extracted data, flights will be rendered anonymous to respect Air France flight safety management policy.
2.4.2.1 General Data and Methodology

Out of the 38 candidate flights for the surface optimization, 28 crew questionnaires were received and 15 applied the surface trial procedure and decided to perform 2 engine start up.

The average fuel consumption for a 4 engine taxi given by Airbus is 48 kg per minute. This estimate is confirmed when analyzing actual non candidate A380 flights (performed over the same period as the AIRE trial flights):

<table>
<thead>
<tr>
<th>Collected data for non AIRE flights</th>
<th>Flight_01</th>
<th>Flight_02</th>
<th>Flight_03</th>
<th>Flight_04</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average fuel cons (kg/min)</td>
<td>49</td>
<td>48</td>
<td>48</td>
<td>49</td>
<td>48</td>
</tr>
</tbody>
</table>

Note: Accelerations have little impact on the A380 four engine on fuel consumption as shown in the graphs in annex 8.5

Calculations in section 2.4.2.2 are based on the actual 2 engine taxi-out time recorded by the aircraft FDR compared with the average fuel consumption during 4 engine taxi (48kg/min).

Calculations in section 2.4.2.3 are based on the actual 2 engine taxi-out time recorded by the crew in flight multiplied by the average fuel savings for 2 engine taxi-out, calculated in 2.4.2.2.

2.4.2.2 Post Flight Data Analysis

The data extracted from the aircraft Flight Data Recorder (FDR) were analyzed for an accurate fuel savings assessment: 6 flights were extracted.

Refer to annex 8.6 for corresponding charts.

First of all, these data confirm that the total taxi out time can vary greatly from one flight to another, even when departing the same runway (see flights 05, with 57 minutes; and flight 11, with 19 minutes), making the possible 2 engine taxi-out time difficult to estimate by the flight crew without any assistance.
Once engines are on, the average time before starting to taxi is 13 minutes, representing about one third of the overall time when engines are running on ground; this on its own would represent significant fuel savings (about 200 kg per flight) taking into account that usually four engines are started right from the beginning on.

After having left the start-up point, almost half of the taxi time could be made on 2 engines (11 min corresponding to 44%).

Two flight crews decided to start the two remaining engines while taxiing: no difficulty was reported on these trial flights.

All flights performed outer engines start first, to allow more momentum for airport manoeuvres. The average fuel savings per flight from data analysis is 360 kg per flight.

When compared to non candidate A380 flights (see annex 8.5 and 8.6), ground accelerations on candidate flights seem to have more impact when only 2 engines are on than when 4 are on. More fuel flow peaks can be identified whenever ground speed increases on candidate flights than on non candidate flights, leading to the average fuel consumption with 2 engines on being higher than expected: 31 kg/min instead of 24 kg/min (assuming that 2 GTR and 4 GTR fuel consumption are proportional) i.e. average two engine taxi fuel flow was observed to be about 65% compared with four-engine taxi.

Furthermore, non candidate flights fuel flows are consistent throughout the taxi phase.

For AIRE flights, we can see that fuel savings are only achieved when 2 engines are on (-426 kg per flight). As soon as the 2 remaining engines are started, the general fuel consumption is slightly greater than average (53 kg/min).

The overall balance remains beneficial for flights performing optimized taxi (39 kg/min instead of 48 kg/min i.e. about 20% less).

### 2.4.2.3 Flight Crew collected Data and their Analysis

For each trial flights, crews were asked to fill in a questionnaire: 15 ground optimized flights were recorded.
As calculated in 2.4.2.2, the average fuel consumption when performing two engine taxi is 31 kg/min; this is 17 kg/min less compared to the 48 kg/min at four engine taxi. The table below uses this difference to calculate the fuel savings resulting from the actual two-engine taxi time and the fuel saving potential if two-engine taxi duration would have been optimized.

Note: Taxi duration in this graph does not include stand by time
When blank, the data was not recorded by crew.

The average fuel saving is **370 kg** per two-engine taxi out (based on data collected by flight crew).

The column titled ‘Margin’ indicates the difference between the actual taxi time and the taxi duration estimate, which was given before taxi start. As we can see, this margin was significantly higher at the beginning of the trial period and was reduced once the process was improved.

The A380 AIRE project aimed at evaluating the taxi-out fuel benefits thanks to the transmission to the crew of the taxi duration estimate to decide whether to perform 2 engine taxi or not.

Assuming that the estimate had been perfectly accurate and given a 10 minute stabilization time required before take off to include a safety margin of 5 minutes, we can see in the last column of the tab that the maximum potential fuel savings \(^{(1)}\) were even higher than evaluated on the trial flights: 435 kg per flight.

These encouraging data motivate the project stakeholders of the surface optimization trial for the next phase of transition into standard operations to collaboratively work on improving this estimate.

\[(1) = (\text{actual taxi time} – 10 \text{ minutes})*(48-31 \text{ kg/min})\]

Note: The data collected by the crew (370 kg of fuel saved per flight) is very similar to the data extracted from the aircraft flight data recorder (360 kg of fuel saved per flight), proving the strength of these results.

<table>
<thead>
<tr>
<th>Flight id</th>
<th>Taxi time given to crew?</th>
<th>Taxi duration estimate* (1)</th>
<th>Engine start</th>
<th>Actual taxi time* (2)</th>
<th>2 GTR actual taxi time*</th>
<th>Margin (2)-(1)</th>
<th>Calculated fuel savings**</th>
<th>Max pot fuel savings**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flight01</td>
<td>Y</td>
<td>15</td>
<td>2GTR</td>
<td>28</td>
<td>13</td>
<td>306</td>
<td></td>
<td>306</td>
</tr>
<tr>
<td>Flight02</td>
<td>Y</td>
<td>25-30</td>
<td>2GTR</td>
<td>60</td>
<td>30</td>
<td>850</td>
<td></td>
<td>850</td>
</tr>
<tr>
<td>Flight03</td>
<td>Y</td>
<td>25</td>
<td>2GTR</td>
<td>15</td>
<td>255</td>
<td>255</td>
<td></td>
<td>255</td>
</tr>
<tr>
<td>Flight04</td>
<td>Y</td>
<td>15</td>
<td>2GTR</td>
<td>30</td>
<td>15</td>
<td>255</td>
<td>340</td>
<td>340</td>
</tr>
<tr>
<td>Flight05</td>
<td>Y</td>
<td>25-30</td>
<td>2GTR</td>
<td>25</td>
<td>425</td>
<td>425</td>
<td></td>
<td>425</td>
</tr>
<tr>
<td>Flight06</td>
<td>Y</td>
<td>15</td>
<td>2GTR</td>
<td>35</td>
<td>20</td>
<td>425</td>
<td>629</td>
<td>629</td>
</tr>
<tr>
<td>Flight07</td>
<td>Y</td>
<td>10</td>
<td>2GTR</td>
<td>47</td>
<td>37</td>
<td>510</td>
<td>629</td>
<td>629</td>
</tr>
<tr>
<td>Flight08</td>
<td>Y</td>
<td>10</td>
<td>2GTR</td>
<td>20</td>
<td>14</td>
<td>238</td>
<td>238</td>
<td>238</td>
</tr>
<tr>
<td>Flight09</td>
<td>Y</td>
<td>30</td>
<td>2GTR</td>
<td>45</td>
<td>15</td>
<td>595</td>
<td></td>
<td>595</td>
</tr>
<tr>
<td>Flight10</td>
<td>Y</td>
<td>20</td>
<td>2GTR</td>
<td>29</td>
<td>9</td>
<td>340</td>
<td>340</td>
<td>340</td>
</tr>
<tr>
<td>Flight11</td>
<td>Y</td>
<td>20</td>
<td>2GTR</td>
<td>25</td>
<td>5</td>
<td>255</td>
<td>255</td>
<td>255</td>
</tr>
<tr>
<td>Flight12</td>
<td>Y</td>
<td>30</td>
<td>2GTR</td>
<td>20</td>
<td>-10</td>
<td>255</td>
<td>255</td>
<td>255</td>
</tr>
<tr>
<td>Flight13</td>
<td>Y</td>
<td>40</td>
<td>2GTR</td>
<td>42</td>
<td>2</td>
<td>595</td>
<td>595</td>
<td>595</td>
</tr>
<tr>
<td>Flight14</td>
<td>Y</td>
<td>15</td>
<td>2GTR</td>
<td>42</td>
<td>-10</td>
<td>714</td>
<td>714</td>
<td>714</td>
</tr>
<tr>
<td>Flight15</td>
<td>Y</td>
<td>25</td>
<td>2GTR</td>
<td>20</td>
<td>5</td>
<td>170</td>
<td>170</td>
<td>170</td>
</tr>
</tbody>
</table>

* minutes ** kgs

Average 370 435

Note: Taxi duration in this graph does not include stand by time
When blank, the data was not recorded by crew.

Refer to annex 8.4 for details on data analysis and crew feedback.
2.4.3 Environmental Benefits

Environmental benefits are calculated from fuel savings applying a conversion factor of 3.16 t of CO$_2$ for 1t of fuel.

For the AIRE A380 TGF surface trial, the average CO$_2$ emissions reduction is 1.2 t per two-engine taxi out.

3. DEPLOYMENT SCENARIOS FOR SURFACE MOVEMENT OPERATIONS

3.1 TECHNICAL AND OPERATIONAL FEASIBILITY ASSESSMENT

Significant fuel savings were demonstrated by applying the ground optimization procedure, thanks to the close collaboration mainly between the key stakeholders FAA and Air France. The positive outcome of this flight trial can only encourage us to maintain our efforts so as to strengthen the process and broaden it to more operational situations, to create more interest and more adherence to the concept.

Therefore, with the transition into standard operations in mind, areas for improvement were identified throughout the project.

3.1.1 Consolidate the Taxi Duration Estimation and Transmission to the Crew

For the trial flights (final process), the crews were asked to systematically start with 2 engines only and once the taxi-out time estimate was received, before taxi clearance, decide whether or not to start the 2 remaining engines straight away or perform 2 engine taxi-out until a spot at their discretion.

In a first step, this process could be implemented with the dedicated crews chosen to perform the flights, thanks to their good knowledge of JFK airport configuration and taxi constraints. However, for standard operations with regular crews not as familiar with the procedure, receiving an accurate taxi estimate before engine start is a requirement. This is all the more important if the next steps of the transition into standard operations involve more aircraft of the Air France fleet and then more airlines.

A discussion was lead amongst the ground optimisation stakeholders on the origin of the information on taxi time. In the frame of the A380-TGF trial, this information originated from the ATC Tower supervisor based on experience.

Taking into account the outstanding role of tower controllers in the ground operation safety chain, activities related to efficiency improvements maybe more suitably initiated on the level of airline operators as long as no automatic calculation and transmission tool is at their disposal. Enabling the airlines to autonomously make the right decision related to reduced engine taxi through Airport Information Management (AIM) presents an option to be further investigated.

Decision support tools are needed to improve the availability and reliability of the taxi-time prediction. Such tools may be shared by the various stakeholders becoming the technical enabler to avoid dependence from ATCT for information, which can be obtained elsewhere.

For information, at Paris CDG an estimate is provided to the flight crew of the taxi time duration (taking into account runway congestion) together with the TSAT message (Target Start-up Approval Time). TSAT is transmitted by ACARS in the Clearance Delivery message sent by the ATC Departure Management (DMAN) system.

With the A380-TGF trial procedure it was not possible to fully optimize the duration of two-engine taxi, but for future support tools it may be considered to provide the flight crew with an update of the estimate on remaining taxi-time to avoid a too early start of the remaining engines.
engines. These are typical Airport Collaborative Decision Making (A-CDM) aspects, which is the subject of SESAR WP 6.06 (A-CDM).

The magnitude of the fuel savings and engine emission reductions observed during the A380- TFG trials at JFK suggest the possible extension of the reduced engine taxi practices described in this report.

A collaborative approach to airport surface traffic optimization offers the potential not only of fuel savings and emission reductions for departing traffic, but also airport traffic delay reduction, and the overall optimization of airport ground resources. This option may also be an appropriate subject for further research.

3.1.2 Ensure the highest Confidence in the Process

Should the taxi-out time estimate become available to the flight crew as standard operations, many crews would be likely to perform optimized taxi-out. As already mentioned, the concept of 2-engine taxi-out is not a common practice as it has potential risks (jet blast, foreign object damage...).

To do so, internal discussions within Air France will be implemented as of the last trimester to determine whether 2-engine start should be integrated into pilot training and/or simulator sessions, and if so, how.

Furthermore, for each airport where the AIRE procedure will be considered (JFK to start with, but CDG is also a good candidate considering the long taxi times and the availability of the taxi duration information), a complete precise analysis will be carried out for:

- airport environment
- aircraft configurations
- thrust requirements
- impact of operational constraints / hazards (last minute runway change, slippery taxiways,...)

This information will have to be made available to the crews, in airport charts for instance.

Although 2 engine taxi-in was not evaluated during the trial, it also represents an interesting lead to reduce CO₂ emissions : the same recommendations as above would apply.

3.1.3 Generic Deployment Scenario

Today there are already some tools available which can be used for taxi-time prediction e.g. Aerobahn, DMAN (by Aeroport de Paris) or Airtop, but it remains to be assessed whether they fully fit the purpose or if they need further developments. It is recommended, for the benefit of all airports, to develop e.g. in the frame of SESAR, generic requirements for such a support tool. Available tools on the market should be assessed with respect to such requirements. The taxi-duration prediction function may typically be integrated in a module within a wider application for overall airport surface movement and departure management. In line with the principles of System Wide Information Management and Collaborative Decision Making, the architecture of such a support tool should allow all stakeholders (ATC, operators, ramp control, handling agents, etc.) to inject relevant up-to-date information of which they are owner in a manner that the quality of the taxi-time prediction would be kept on a high level.

Where to obtain and how to transmit the taxi-time information would depend on the complexity and individual characteristics of each airport. To allow a flexible solution, it would be certainly worthwhile to study the feasibility to include a related message type in the standard of the future Taxi-Clearance via Data Link (D-TAXI), a subject dealt with in SESAR WPs 6.7.2 and 9.13.

As part of a deployment scenario, airports of various complexity (hub as well as regional) could be chosen for trial purpose.
In a first step it could be envisaged to use the taxi-time prediction tool in a shadow-mode, i.e. without interfering with controller or flight crew. The predictions obtained from the tool would be observed and compared with the taxi times encountered under real conditions. If the quality of the predictions would not be sufficient for the purpose of trials with controller and/or flight crew in the loop, then the factors causing the deviations would have to be identified as well as the corresponding type of information needed, which eventually would improve the predictions when taken into account by the system. Several design loops may be necessary integrating lessons learned in the field in order to improve the reliability and availability of the predictions.

In a second step, when acceptable quality of the taxi-time prediction would be reached, the information could be systematically provided to airlines participating to trials. Depending on the operational characteristics of the airport the information may be transmitted to flight crew by ATC via D-TAXI or by any other suitable stakeholder (e.g. ramp control or airline station) through ACARS. Progressively, more and more crews of the participating airlines would apply reduced engine taxi, thanks to training measures and the quality of the predictions, which allows building-up confidence in their reliability.

In a third step, the trial airport may choose that taxi-time information is systematically provided to all operators and may inform so through AIP. It would remain to the discretion of each flight crew how to take advantage of this additional information service. After an adequate period of observation, a survey amongst operators at the trial airport could be made allowing to quantify the benefits of the provided taxi-time information.

In case the obtained benefits would be convincing, it might be considered in a forth step that taxi-duration would become a standard information at any airport as part of the taxi-clearance or provided through the most appropriate stakeholder. In any case, a corresponding message type within D-TAXI shall be defined as placeholder already by now as the standardisation of this datalink service is currently underway.

As an accompanying deployment measure, awareness material could be produced on European level, which would cover all safety and operational aspects related to reduced engine taxi. Further, a generic business case model could be developed, which would identify all the factors which would influence the investment decision of the airport stakeholder community for such a support tool.

3.2 ECONOMICAL AND ENVIRONMENTAL IMPACT ANALYSIS

During the AIRE A380 TGF ground trials, 15 taxi-outs were optimized out of 38 candidate trial flights, representing an optimization “success” rate of 40%. With the operation of one Air France A380 daily flight from JFK to CDG, assuming that the optimization procedure would be applied today, with the same success rate as those of the trial, the yearly potential for emission reduction would represent 170 t of CO₂ less, equivalent to 54 tonnes of fuel with a value of 28 k€ (at a rate of 518 € per tonne).

With the improvements identified in the §3.1.1, this success rate could increase and more aircraft and / or airlines could be concerned, leading to even greater savings.
4. VALIDATION OF TRANSATLANTIC OPTIMIZATION

4.1 DESCRIPTION OF EXPERIMENTAL CONCEPT

The oceanic part of the A380 TGF project relied on optimizing the lateral profile of A380 JFK to CDG flights once within the oceanic airspace, by taking advantage of the A380 high performance to fly above the OTS and request random routing once FL400 is reached.

![Figure 5: Representation of the A380 entering the OTS](image)

Potential fuel savings were estimated at around 500 kg per flight (refer to project Deliverable 1 document for details).

4.1.1 General Process

The process was defined during the workshop organized at Air France headquarters in CDG airport on September 2nd 2010, gathering NATS, Nav Canada and Air France.

4.1.1.1 Prerequisites and Constraints

4.1.1.1.1 Automatic Route Upload / Download

The Air France fleets were upgraded from December 2010 to March 2011 so that the FMS could support automatic upload of the route from the Airline Operations Center to the aircraft. An internal note was issued to inform flight crews of the process.

4.1.1.2 Transfer to ATC

The A380 offers the possibility to transfer a secondary flight plan received by the aircraft directly to the ATC, without having to retype it, by using the “XFER to mailbox” function.
However during the trial preparation phase of this project, it was discovered that the downlink from the aircraft to the ATC centre could not be understood by the controller. The latitude/longitude format, ARINC 424, used by the AOC is not compatible with the one required by the ATC and would be received as unreadable (“NxxxxWxxxxx” instead of “N2000W05000” for instance). No modification could be planned within the AIRE trial timeframe. Therefore, for the AIRE trials, flight crews had to re-type manually the entire new route received from the AOC in the re route request sent to the ATC observing the format requested by ATC.

4.1.1.2 North Atlantic Organized Track System (NAT OTS)

The NAT OTS represents trans-Atlantic routes that stretch from the northeast of North America to western Europe across the Atlantic Ocean. They ensure aircraft are separated over the ocean, where there is little radar coverage while maximizing traffic capacity. Westbound and eastbound routes change daily, depending on the forecast preferred routes sent by the airlines the day before, to accommodate the preference of the majority of the airspace users.

Therefore they are designed based on what the airlines intend to fly the next day, to follow their most optimized routes.

The Gander planner will use several tools in determining the eastbound North Atlantic tracks.

- The airline requested routings (Preferred Route Messages), determined by the dispatchers using the predicted jet stream for that evening.
- A tool called the minimum time tracks, or MTTs. The MTTs are produced daily, and will give the routing across the ocean that will result in the shortest time between two airports, taking into account the actual jet streams.
Not all airports are included, but the planner knows that any eastern seaboard traffic can be represented by New York, any midwestern by Toronto or Chicago, any northern Europe represented by Frankfurt, Central Europe represented by London, and so on.

- The planner will also check to see if any military activity that will restrict his routings exist, or if there is severe weather that will also affect them. In the fall of course, the tropical storms and hurricanes can affect it greatly.

![Figure 7: Example of eastbound OTS (track U to Z from north to south)](image)

Using all this information, the oceanic planner will determine where he wants the aircraft to fly. The sheer volume of aircraft restricts the capacity that any one routing, or track, can handle, so the planner will try and spread the track systems throughout the airspace. The normal set of eastbound tracks usually consists of 5, with additions sometimes from New York center to accommodate any traffic that is routing out south of the main flow.

4.1.1.3 CDG Arrivals

The two western Initial Approach Fixes (IAF) of CDG airport are:

- MERUE in the northern quadrant
- BALOD in the southern quadrant

MERUE gets congested in the morning due to the early arrivals from the US and flights to/from England. Therefore, to avoid this busy airspace, it was decided to take advantage of the closure of the military airspace TSA 8A/8B until 09:30AM local time, to fly a southern route via LATGO through BALOD*. Although this planned route (LATGO-GONEK-ROMLO-BALOD) is longer by 20 NM, the actual flown route (shortcut from LATGO to ROMLO) is only approximately 10NM longer, it is less congested and offers increased arrival efficiency via reduced holding time and ATM delay for other traffic.

AF007 is an eligible flight for this southern routing, which also offers a reduced taxi-in time from the southern CDG runways to terminal S3 (refer to annex 8.7 for details).

* This optimisation was implemented independently from the A380-TGF project.
Therefore, filing a flight at departure with a southern route can lead to an increased calculated fuel burn but results in fuel savings during flight execution.

For the AIRE trial flights, the same arrival will have to be kept for the initial and optimized flight plan in order to assess fuel savings from flying a random route over the oceanic airspace. This can limit the possibilities to find an optimized route, especially if more favourable winds are found north of the original route.

### 4.1.1.3.1 Air France Dispatch Organization Change

Air France dispatch is currently being re-engineered to improve their work methods and gain efficiency. As part of a two year deployment plan, the “North American Lab” was being evaluated during the AIRE trial phase for all flights to / from the US and Canada.

This lab aimed at assessing a possible future organization of dispatch: instead of taking over the flight upon departure after being prepared by a technician, following up to 30 airborne flights, the dispatcher would follow an entire flight from preparation to landing (within working hours range limits), with only 10 flights at a time.

Although this was foreseen as an opportunity for the AIRE A380 TGF project during phase 1, the fact that this lab was still in a tuning phase during the trial execution phase did not allow the dispatchers to be fully available for the AIRE optimization.

### 4.1.1.4 Procedure Details

#### 4.1.1.4.1 Trial Specifications

In order not to impact negatively the surrounding traffic, it was decided to give no special priority to the trial flight (subject to current traffic). Also, no airspace reservation, neither block
of altitude nor variable Mach was performed for the trial flights. Standard procedures were applied.

### 4.1.1.4.2 A380 TGF Oceanic Trial Procedure

The A380 TGF oceanic trial relied on a strong coordination between Gander OCA, Shanwick OCA, Air France dispatch and flight crew.

1. Once Top of Climb (TOC) is reached and prior to requesting oceanic clearance to Gander oceanic control center, the flight crew requests an updated flight plan (providing to dispatch updated operational information: gross operating weight, speed and FL on the next waypoint to dispatch)
2. The dispatcher calculates 2 new flight plans based on:
   - the original route as filed to the ATC at the flight preparation phase updated with the operational data sent by the crew (mentioned further in this document as “original revised”)
   - the best random and European routes once the flight cruises at or above FL400 resulting from his latest research using the operational data (“optimized revised”)
3. The dispatcher provides via ACARS time and fuel burn information for each flight plan (original revised and optimum revised)
4. The flight crew compares and considers the new route if acceptable
5. Upon crew request, the dispatcher sends the optimum flight plan:
   - to the crew for upload as a secondary flight plan
   - to Gander for advanced notice if agreed by crew
6. Gander coordinates with Shanwick prior to approval
7. Once in contact with Gander, the crew requests route change via CDPLC, using freetext, specifying “AIRE TGF trial”
8. If acceptable, Gander sends new route clearance
   If unable, Gander rejects request via HF
9. The flight crew informs dispatch if the new route is granted or rejected

### 4.1.2 Baseline

For each flight, the original route is established depending on current operational and weather conditions during the flight preparation phase. This route can differ from the actual route flown,
given the possible adjustments of operational data (e.g. change in Estimated Time of Arrival or take off weight,…), air traffic restrictions and unforecast weather phenomena.

No global baseline per se could be established for the AIRE A380 TGF oceanic trial, but an alternative solution was found to determine fuel gains (refer to 4.4.2.1 for methodology details).

4.1.3 Dissemination to the Trial Participants

4.1.3.1 Dissemination to Air France Flight Crew

The captains who performed the trials were selected among management and instructors to enable better communication with them.

They were briefed in advance by the A380 flight crew technical expert, to explain the concept and objectives of the trial and ensure a good appropriation of the project.

4.1.3.2 Dissemination to Air France Dispatch

The dispatchers were informed in advance by the dispatch manager of the conduction of the trial.

4.1.3.3 Dissemination to ATC

All NAV CANADA control staff was given a mandatory briefing including the following:

- AFR007 A380 KJFK – LFPG, will file a flight plan indicating TGF (TRANSATLANTIC GREEN FLIGHT) Trial Flight
- After departure, Air France dispatch will advise the flight crew if a route other than the original flight plan would be more fuel efficient.
- The aircraft’s objective is to climb to FL410 and (if required) request a routing change via HF in Oceanic Airspace
- Gander and Shanwick will attempt to accommodate this request, however no restrictions are to be placed on other traffic to achieve this
- The trial is based totally around a flexible track/random route request and does not include elements of speed or altitude.
- Gander indicated to Air France that a routing change may in fact be available at a lower flight level than FL410, traffic permitting

NATS edited a Temporary Operating Instruction (TOI) comprising the following:

- If a laterally optimised flight profile was requested crossing 030W, or after data transfer from Gander to Shanwick had occurred, Gander would co-ordinate this profile with Shanwick before issuing the new clearance to the flight.
- Normal Oceanic procedures require every 10° line of longitude to be crossed at a whole degree of latitude, but for the purposes of this trial it was accepted that a laterally optimised route may take the flight across several 10° lines of longitude at non-whole degrees of latitude. In such an event an exact position report was still required at each 10° line of longitude for the purposes of surveillance and separation assurance.
- All optimised routes were required to cross the eastern Shanwick FIR boundary at a named Oceanic Exit Point (e.g. LIMRI).
- Shanwick’s procedures do not permit the issuing of a route clearance via CPDLC. All clearances on to a more optimised route would be issued on HF radio. To avoid any confusion, all optimisation requests were to be made on HF. This included route, level and speed change requests.
- To allow for time delays in the HF communication loop, and to establish an exact point from which to assure conflict-free clearances were available, the pilot was to identify an exact position in latitude and longitude at least 10 minutes ahead of the flight’s present
position. This intermediate waypoint would form the start point of the new optimised route.

- To assess the possible wider impact of the A380-TGF trial flight on other flights, controllers at Shanwick were required to log details of any aircraft adversely affected by the A380 TGF. No adverse effects were noted.

### 4.1.4 Data Collection Process

The data collection process was performed as follows:

<table>
<thead>
<tr>
<th>Performance Area</th>
<th>Performance Indicator</th>
<th>Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environmental</td>
<td>Fuel savings</td>
<td>AFR Crew feedback</td>
</tr>
<tr>
<td></td>
<td></td>
<td>AFR Post flight analysis database</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ATC ATCO feedback</td>
</tr>
<tr>
<td>Economical</td>
<td>Environmental benefits expressed in €</td>
<td>Other traffic Calculated</td>
</tr>
</tbody>
</table>

Flight crews were handed out at flight preparation a questionnaire (refer to annex 8.8) to fill in in order to record the data sent by dispatch in flight: starting at the same waypoint with the same conditions (aircraft weight, FL) transmitted by the crew, the original track flight plan (OCTAVE) data updated with the revised current operational conditions and the optimized random route flight plan data with revised conditions.

Other relevant information was also collected, such as the filed OTS track and filed / actual Flight Level.

This information was used by the crew primarily to evaluate if there were fuel savings to be made by requesting a revised flight plan but will also be used for the purpose of this analysis.

### 4.2 SAFETY ANALYSIS

#### 4.2.1 Air France Safety Aspects

In order to ensure safe operations during the AIRE TGF flight trials, the concept of the trial was defined in close collaboration with the « Bureau Information Technique », or flight crew technical experts, responsible for ensuring that the process matched Air France standard operational procedures and safety requirements.

The lateral optimization process involves numerous tasks and verifications intervening in an operational context. To limit the risk of mistakes that might result from the repetition of demanding actions, it was decided that only one re-route request would be performed per trial flight.

#### 4.2.2 ANSP Safety Aspects

**NATS**

Special procedures were written for ATC staff at Shanwick for the A380 trial. In principle, the issuing of reroutes is a standard ATC procedure. However, in practice it is not usual for flights to receive reroutes in the NAT region, especially when these reroutes might involve clearing a flight across more than one 10° line of longitude at a non-whole degree of latitude. These procedures were given a full hazard analysis before being promulgated to all control staff in Shanwick ahead of the start of the trial.
No additional safety procedures were required for this trial as this method is incorporated into today’s environment and is available for all aircraft. All requests are performed on a tactical basis limited to NAT traffic.

4.3 TRIAL EXECUTION

4.3.1 Overall Conduction of the Trial

The oceanic trial was initially planned to take place over 2 months between mid December 2010 and January 2011, though the overall planning of the project allowed some flexibility and possible extension of the trial period. The flight trials were extended to April, until sufficient results were found to perform the data analysis.

4.3.2 Trial Schedule

The oceanic trial lasted 5 months and a total of 34 candidate flights were identified:

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>24/12/10</td>
<td>AF007</td>
<td>08/01/11</td>
<td>AF007</td>
<td>05/02/11</td>
</tr>
<tr>
<td>25/12/10</td>
<td>AF007</td>
<td>10/01/11</td>
<td>AF007</td>
<td>06/02/11</td>
</tr>
<tr>
<td>27/12/10</td>
<td>AF007</td>
<td>15/01/11</td>
<td>AF007</td>
<td>13/02/11</td>
</tr>
<tr>
<td>28/12/10</td>
<td>AF007</td>
<td>22/01/11</td>
<td>AF007</td>
<td>14/02/11</td>
</tr>
<tr>
<td>24/01/11</td>
<td>AF007</td>
<td>15/02/11</td>
<td>AF007</td>
<td>14/03/11</td>
</tr>
<tr>
<td>29/01/11</td>
<td>AF007</td>
<td>28/02/11</td>
<td>AF007</td>
<td>17/03/11</td>
</tr>
<tr>
<td>21/03/11</td>
<td>AF007</td>
<td>11/04/11</td>
<td>AF007</td>
<td></td>
</tr>
<tr>
<td>26/03/11</td>
<td>AF007</td>
<td>15/04/11</td>
<td>AF011</td>
<td></td>
</tr>
<tr>
<td>27/03/11</td>
<td>AF007</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>28/03/11</td>
<td>AF007</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4.4 TRIAL RESULTS

4.4.1 Qualitative Analysis

4.4.1.1 Feedback from Air France Flight Crew and Dispatch

Opportunities to optimize the cruise across the North Atlantic airspace is often perceived as limited: pilots tend to think there is no need to try and request a FL or route change, it will most likely be rejected by ATC due to traffic. Therefore, the concept of the trial was very well received by the crews, who were eager to participate in the trial flights.

It takes from 1h30 to 2h to enter Gander oceanic airspace from JFK airport, which left enough time to search for an optimized route before requesting the oceanic clearance. Pilots did not report being rushed or any extra workload.

The main difficulty laid on the identification of the potential savings on the new route calculated by the dispatcher. For most candidate flights, the planned track was already the most optimized route, as described in 4.4.2, meaning that no further optimization was possible.

In other cases, an optimized route was found but with a different arrival at CDG, leading to the crew not being able to identify whether fuel gains were thanks to the arrival change or the oceanic random route.

As explained in 4.1.1.3.1, Air France dispatch was undergoing structural changes at the time of the AIRE A380 TGF flight trials. However, their workload was still important ; at the time flight AF007 departs, a dozen other eastbound flights leave North America and require the dispatcher’s attention for all mandatory or urgent requests. This left little availability to tune
their optimization research beyond what the Air France Flight Planning Processing System could suggest as a random route.

Note: in case a calculated random route is close to the OTS, OCTAVE will select automatically the organized track.

Air France dispatch also highlighted the precision of the weather data when crossing the north Atlantic oceanic airspace, due to the important traffic flow of aircraft allowing to collect accurate data for weather update in order to fine tune the specialists forecasts.

### 4.4.1.2 Feedback from ANSPs

**NATS**

Controllers at Shanwick had some reservations about the trial because of potentially adverse effects on other flights in the OCA. Reassurances were given that these trials would not lead to any reduction in the level of service delivery to other NAT customers.

No concerns were expressed about any increase in workload as a result of the trial, although the fact that the trial procedures themselves presented a slight departure from normal operating practices would cause some extra work for controllers. A degree of additional monitoring would be required for any flight given a direct route which resulted in its crossing a 10° line of longitude at a non-whole degree of latitude. There would also be some additional work involved in identifying a point from which any reclearance would begin and in coordinating a non-standard Oceanic exit point with the receiving Domestic sector. However, this additional workload was considered acceptable.

The anticipated additional workload did not happen. It appears that any optimisation requested occurred around the 50W longitude or before. Flight data transfer from Gander to Shanwick occurs approximately 30 minutes before the aircraft’s estimate for 40W. Consequently, the optimisations appear to have been requested and issued before the estimate message was sent from Gander to Shanwick and the optimisation was therefore transparent to the Shanwick controllers. Any resulting increase in workload for Shanwick caused by this trial was minimal.

**NAV CANADA**

NAV CANADA did not experience any notable increase in workload. Adhoc route requests are handled on a tactical basis within the NAT. All requests are handled on a timely basis, however, as with any flight profile requests, approval time will vary as all NAT flight profiles require a conflict free profile from oceanic entry point to oceanic exit point. Approvals may be subject, but not limited, to multiple adjacent inter-unit coordination and approvals, controller workload and delivery of clearance to aircraft if verbal clearance required.

### 4.4.2 Operational Results – Quantitative Data Analysis

#### 4.4.2.1 General Data and Methodology

Out of the 34 candidate flights for the oceanic optimization, 22 applied the AIRE trial procedure: 4 optimized routes were found and requested to Gander ATC. As described in 4.1.2, no global baseline per se could be established.

To assess the reduction of emissions, two methods were used:

- comparison between the Flight Planning Processing System (FPPS) calculated data from the original revised flight plan and the optimized revised flight plan (in flight collected data)
- comparison between the original revised flight plan and the actual data, from rerouting waypoint to CDG (post flight analysis)
Note: for the original revised flight plan, only limited data were recoverable as recorded in flight (no details per waypoint).

### 4.4.2.2 Data Analysis

#### 4.4.2.2.1 In Flight Collected Data

The results of the optimized flights are presented below (refer to annex 8.10 for details).

<table>
<thead>
<tr>
<th>Date (local)</th>
<th>Flight n°</th>
<th>TOW (t)</th>
<th>WPT</th>
<th>Track OTS</th>
<th>Calculated gain (t)</th>
<th>Random from FL</th>
<th>WPT</th>
</tr>
</thead>
<tbody>
<tr>
<td>4-Feb-11</td>
<td>AF007</td>
<td>//</td>
<td>RONPO</td>
<td>W</td>
<td>0,3</td>
<td>410</td>
<td>RONPO</td>
</tr>
<tr>
<td>11-Mar-11</td>
<td>AF007</td>
<td>441</td>
<td>HECKK</td>
<td>W</td>
<td>0,25</td>
<td>400</td>
<td>ABYAY</td>
</tr>
<tr>
<td>28-Mar-11</td>
<td>AF007</td>
<td>422</td>
<td>VODDK</td>
<td>Y</td>
<td>1,88</td>
<td>410</td>
<td>45N50W</td>
</tr>
<tr>
<td>12-Apr-11</td>
<td>AF007</td>
<td>//</td>
<td>NOVEP</td>
<td>//</td>
<td>1,1</td>
<td>//</td>
<td>//</td>
</tr>
</tbody>
</table>

// : unknown data

In flight calculations estimating fuel savings varied greatly from one optimized flight to another: between 0,25 and 1,88 t; with an average fuel gain per flight of 0,88 t.

However, a post flight analysis could only be performed on the last three flights, with the following particularities:

- for the flight of March 11\textsuperscript{th}: the original flight plan was already filed with an arrival via DVL (see figure 8), therefore could be compared with the optimized revised flight plan that had also a DVL arrival
- for the flight of March 28\textsuperscript{th}: both flight plans had a common oceanic exit point via SOMAX, but with a different arrival at CDG (LATGO for the original revised and DVL for the optimized revised), leading to a margin in the results to consider (longer southern route)
- for the flight of April 12\textsuperscript{th}: the original revised and the optimized revised flight plan were both calculated with a LATGO arrival

The difficulty to identify comparable data resulted in having to use two different types of analysis to estimate fuel savings from the actual flight data.
4.4.2.2 Post Flight Data Analysis

The three trial flights with post flight analysis were compared from the start of re-routing waypoint until arrival at CDG:

<table>
<thead>
<tr>
<th></th>
<th>11/03/2011</th>
<th>28/03/2011</th>
<th>12/04/2011</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimized revised fuel cons. (kg)</td>
<td>57470</td>
<td>57718</td>
<td>44093</td>
<td></td>
</tr>
<tr>
<td>Original revised fuel cons. (kg)</td>
<td>59050</td>
<td>59330</td>
<td>45210</td>
<td></td>
</tr>
<tr>
<td>Fuel gain (kg)</td>
<td>-1674</td>
<td>.2112</td>
<td>-617</td>
<td>-1401</td>
</tr>
<tr>
<td>Optimized revised ground distance (Nm)</td>
<td>2798</td>
<td>2902</td>
<td>2179</td>
<td></td>
</tr>
<tr>
<td>Original revised ground distance (Nm)</td>
<td>2845</td>
<td>2943</td>
<td>2180</td>
<td></td>
</tr>
<tr>
<td>Ground distance gain (Nm)</td>
<td>-49</td>
<td>-41</td>
<td>-1</td>
<td>-30</td>
</tr>
<tr>
<td>Optimized revised air distance (Nm)</td>
<td>2563</td>
<td>2639</td>
<td>1967</td>
<td></td>
</tr>
<tr>
<td>Original revised air distance (Nm)</td>
<td>2687</td>
<td>2681</td>
<td>2017</td>
<td></td>
</tr>
<tr>
<td>Air distance gain (Nm)</td>
<td>-24</td>
<td>-42</td>
<td>-30</td>
<td>-32</td>
</tr>
</tbody>
</table>

From: EBCNY  WHALE  NOVEP
To:    CDG  CDG  CDG
Observations: Same arrival  Arrival change  Same arrival

Fuel savings range from 500 kg to 2,1t and are more beneficial than calculated by Air France PPS. Impacting factors such as the impact of the flown vertical profile, acceleration or deceleration of the flight due to the surrounding traffic or more beneficial winds than forecast can explain this great fluctuation. Therefore, it was decided not to consider these fuel savings data for the assessment.

However, lateral optimization can be confirmed by analyzing the air distance, which represents the routing distance taking into account the effect of the wind, independently of the vertical or speed profiles.

Note for flight of March 28th: Fuel savings could result from the arrival change at CDG, to an extent that could not be measured here. The ground distance gained from the arrival change was 28 NM (from SOMAX to CDG) with an air distance gain of 17 NM. Are presented below updated results withdrawing the impact of the arrival:

<table>
<thead>
<tr>
<th></th>
<th>11/03/2011</th>
<th>28/03/2011*</th>
<th>12/04/2011</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground distance gain (Nm)</td>
<td>-49</td>
<td>-19</td>
<td>-1</td>
<td>-21</td>
</tr>
<tr>
<td>Air distance gain (Nm)</td>
<td>-24</td>
<td>-25</td>
<td>-30</td>
<td>-26</td>
</tr>
</tbody>
</table>

AIRE trial flights have demonstrated the possibility to optimize the lateral profile of the A380 for JFK to CDG flights with an average gain of 26 NM per flight.

Given an average specific consumption of 22 kg/NM**, this represents an average potential of 600 kg of fuel saved per flight.

**calculated from the oceanic re routing point to destination on the three extracted trial flights.

4.4.3 Environmental Benefits of the Trial Flights

Environmental benefits are calculated from fuel savings given the fact that 1 t of fuel saved equals 3,16 t of CO₂ less.

For the AIRE A380 TGF oceanic project, the trial flights demonstrated an average reduction of CO₂ emissions by 1.9 t per flight.
5. DEPLOYMENT SCENARIOS FOR TRANSATLANTIC OPTIMISATION

The AIRE A380 TGF project demonstrated the possibility to save fuel by flying random routes outside North Atlantic organized track system, thanks to the close coordination and commitment of all project stakeholders.

However, the low rate of success of the experiment (four optimized flights out of 22 trial flights), can lead to two different conclusions:

- either the organized tracks designed daily are already the most efficient routes to be flown,
- or the procedure, organization and tools used for the trial flights could be improved for better results.

The second option poses more challenging consequences for this project. So, for the purposes of our report, we will presume the optimization procedures, organization and tools used for the trial flights could be improved. And we will, accordingly, attempt to identify useful improvements.

From an NAV CANADA and NATS perspective, these NAT re-routing procedures are now readily available for airline use. Procedures and technology are developed to accept this procedure in today’s environment. All approvals and/or denials would strictly be based on traffic scenario with-in the NAT.

5.1 TECHNICAL AND OPERATIONAL FEASIBILITY ASSESSMENT

5.1.1 Weather Forecast

The trial flights were performed over a period of 5 months, leading to the chances of success being of 20% optimized flights.

Weather was indeed a contributing factor to this experiment but was not assessed during the trial. A detailed analysis of weather forecasts over the North Atlantic region could help better understand if there are more beneficial periods throughout the year or even identify circumstances that would enable more favourable conditions for an optimization research.

Studies have been conducted regarding the possibility of constructing the OTS on the basis of flight schedules and the most recent weather forecast available at the time of the OTS publication. These studies are at early stage but have indicated that there may be fuel burn and workload benefits associated with this approach.

5.1.2 Resources at Dispatch

The lack of availability / resources at dispatch, in its current organization, did not allow them to fine tune their research of optimized route. Air France dispatch is currently undergoing a restructuring phase to improve and optimize their processes.

Within two years, dispatchers are to be specialized by region and will follow one flight from its preparation until its conduction, with no more than ten flights at a time. This will enable them to act more proactively and become more available for all pilots request, including optimization research.

Furthermore, as their training program is also being re-engineered, a “green optimization module” could be integrated in order to increase the dispatchers’ awareness to the stakes, benefits and concept of such an optimization.
5.1.3 Automatic Transmission of the Flight Plan

Flight trials were performed by dedicated captains which allowed to avoid potential safety problems due to the technical constraint of having to transfer the flight plan from the aircraft to the ATC manually (refer to 4.1.1.1.2). However, this cannot be envisaged for non dedicated flight crews, who need to have straight forward instructions that mitigate the possibilities of error to the greatest extent possible. This difficulty will have to be resolved so that transition into standard operations could be considered.

The issue of incompatibility between ARINC 424 message types used for Airline Operational Communication and the waypoint syntax used by ATC is known since long. Please refer to ICAO Global Operational Data Link Document (GOLD), where flight crews are invited to avoid the non-ICAO A424 format for downlink to ATC.

Remark : The A424 syntax allows only to define waypoints down to half degree precision, which may not satisfy expectations of future route optimization concepts.

In line with operational concepts promoted by SESAR and NextGen, dynamic re-routing shall become more frequent in future in order to allow more airspace users to follow the optimum trajectory. A technical pre-requisite for this is the quick and efficient exchange of routes via data link between AOC and flight crew and between flight crew and ATC. To overcome the shortfalls encountered in the A380-TGF trials (see 4.1.1.1.2) :

• either a common language has to be agreed on, which is recognized by systems within AOC, ATC and on board
• or systems within AOC, ATC and onboard become capable to convert one standard into another.

This issue has to be addressed in ATM upgrade programs like SESAR and NextGen. Airbus pro-actively took the initiative and will introduce in the next standard of the A380 flight management system a feature, which allows the automatic conversion of abbreviated A424 waypoints into full latitude-longitude coordinates, which is recognized by ATC. This will reduce considerably the workload for flight crews and the risk of entering wrong coordinates. An equivalent solution shall be easily implementable on ATC and AOC level, in order to facilitate re-routing of aircraft, which haven’t this capability.

5.1.4 Search for a Random Route as of the Flight Preparation Phase

For the AIRE trials, flights were prepared with the intent of flying a OTS track, therefore calculating the fuel on board to ensure this route and all mandatory reserves. Flights were then optimized in flight, with no possible action on the fuel already on board, which has an impact on the fuel burnt (as calculated in the transport coefficient). Considering the possibility to fly a random route as of FL 400 during the flight preparation could tune the quantity of fuel taken on board and therefore lead to less CO₂ emissions.

5.1.5 Generic Deployment Scenario

The A380-TGF North-Atlantic re-routing trials were specific to the environment of the North Atlantic Organized Track System, i.e. there are only two ANSPs, who are concerned: NAV CANADA and NATS. However, the conclusions drawn from the trials could also be of relevance to some degree to other remote regions (oceanic or continental) where Dynamic Airborne Reroute Planning (DARP) is already practiced today. Especially the recommendations given in 5.1.3 related to compatibility between AOC and ATC flight plan syntax are of global interest.

A further specificity of this trial was the performance of the A380, which has its most economic cruise level above the Atlantic Organized Track System. Therefore, deployment of the trialed procedure would be limited for the time being to operators of aircraft types with similar
performance characteristics. However, the conclusions drawn by Air France could also be of relevance to other operators who apply DARP in remote regions without organized track system, especially what concerns the improved definition of the flight-dispatchers’ responsibilities with regard to identifying more efficient routings.

This aspect may typically be treated in SESAR WP11, Flight/Wing Operation Centre. Of special interest would be the development of support tools, which would instantly alert the dispatcher when more efficient re-routing options are detected. The interface with the most recent weather information is crucial and would have to be taken into account when specifying such tools.

5.2 ECONOMICAL AND ENVIRONMENTAL IMPACT ANALYSIS

The Air France A380 operates daily from JFK to CDG airport. Taking an average optimization rate of about 20%, assuming chances of success do not vary within a year, we could infer that approximately 70 flights could be optimized per year, leading to a potential of 132 t of CO₂ less per year equivalent to 54 t of fuel with a value of 37 800 $ (at a rate of 518 € per t).

This reduction could be increased with the implementation of the axes of progress listed above. To push the concept further, the extension to other aircraft with similar performance and other airlines would lead to significant CO₂ emissions reduction providing it does not induce new congestion of the airspace located at FL400 or above.
6. COMMUNICATION ACTIVITIES

6.1 CONTRIBUTIONS TO COMMUNICATION ACTIVITIES INITIATED BY SJU

The project contributed through a presentation to the AIRE Technical Dissemination Workshop held at SJU in Brussels on 7th and 8th December 2010, in presence of numerous other AIRE projects stakeholders.

The project also contributed to the “European AIRE 2010/2011 Programme Results - Closure/Dissemination Workshop” in Marseille 28th October 2011. Main project results were presented focusing on lessons learnt, data analysis and implementation and information was shared among AIRE and SESAR projects.

Contributions were made to the “AIRE Call 2010 – Summary of Projects” fact sheet issued by SJU in September 2010.

The project shared experiences with other AIRE projects by using the secured web page, which was created on the SJU’s Extranet (https://extranet.sesarju.eu/aire/). Under A380-TGF, a folder ‘Communication’ was created, which contains project-related information.

6.2 PRESS RELEASES AND PUBLICATIONS BY PROJECT PARTNERS

Airbus issued a press release at project launch in August 2010. In January 2011 Airbus published an article in its bi-annual ‘FAST’ magazine distributed globally to airlines on the subject: ‘Demonstrating the green trajectory - Fuel efficient trajectory management trialed on revenue flights’; the A380-TGF project is covered in this publication. The A380-TGF project was also included in a paper and presentation by Airbus for the Avionics Europe Exhibition and Conference in Munich, 16th and 17th March 2011.

Air France issued a web article on 22-Jul-2010 covering A380-TGF, which received feedback amongst others by ‘Le Monde’ in an article on 26th October 2010.

6.3 PROJECT VIDEO

A project video was produced and shown at ATC Global, Amsterdam, 8th to 10th March, at the stands of SJU, EADS/Airbus, NATS and NAV CANADA. It was also projected at the same occasion during the Green ATM Workshop organized by SJU. An extended version of the video was also produced incorporating statements from SJU and project partners.

Air France presented the A380-TGF video at the Avionics Europe Exhibition and Conference in Munich, 16th and 17th March 2011. It was also displayed by French ANSP, DSNA, at its stand at Paris Air Show, 20th to 26th June 2011. The video was published on the project partners’ corporate websites and on SJU’s web-site.


6.4 INTERNAL COMMUNICATION

Airbus organized an two hours briefing on its involvement in AIRE in the context of SESAR and NextGen for the purpose of internal buy-in. This took place during the AIRE tender phase (17th June 2010) and more than 50 colleagues participated. The A380-TGF project was also covered in an article in Airbus’ staff magazine ‘ONE’.
Air France published an article in November 2010 to announce the launch of all AIRE projects involving Air France in the flight crews’ monthly magazine « Pilotes Info ». A section was dedicated to the AIRE A380 Transatlantic Green Flights. This document is still available on Air France flight operations intranet. Another article presenting the trial results is scheduled for the last quarter of 2011.

FAA hosted two days of partner meetings at the New York Center (ZNY) and the JFK Air Traffic Control Tower (ATCT). Participants included Air France, NATS, Airbus, the French DSNA, ZNY and FAA Headquarters representatives. It was noted that the objective of the A380 Transatlantic Green Flights (TGF) was to demonstrate the potential benefits of optimized procedures on the ground and in oceanic airspace; and, further, that reduced engine A380 taxi out from the JFK ramp could save considerable fuel and reduce engine emissions. Results of the Partner meetings were communicated to ZNY and JFK ATCT managers.

NATS put the A380-TGF trials on the agenda for the Shanwick Service Provision Improvement Group (SPIG) once the trial ATC procedures have been drafted. This group meets on a regular basis and comprises senior members of all Oceanic Watches. The remit of the SPIG is the delivery of service provision improvement to all NAT customers in the Shanwick OCA. After delivering a presentation on the A380 TGF trial to the SPIG, the finalised trial procedures were written and disseminated to all the Ocean Watches.

6.5 COVERAGE ON THE WEB

Numerous web hits are obtained under following key-words: A380 Transatlantic Green Flight, A380-TGF; some examples are listed here below:

http://www.emg.rs/en/emplus/131408.html
http://www.thaipr.net/nc/readnews.aspx?newsid=BFE50D810F7F1E7FD2D76BFF16A1B15C
http://www.energy-daily.com/reports/Airbus_Led_AIRE2_Trials_To_Spearhead_Green_Trajectories_With_A380_999.html
7. CONCLUSION

In combining two-engine taxi and enroute optimisation for a given A380 transatlantic flight from New York JFK to Paris CDG the trials revealed a fuel saving potential of 970 kg per flight (3 t CO₂). This corresponds to 1.3% of the trip fuel for a typical JFK - CDG flight.

Out of the 17 successful trial flights, two were combined ground-oceanic optimisations, 13 performed ground optimisation only and two oceanic optimisation only.

The average fuel saving for the ground optimisation was 370 kg, which equals to 20% of the 1870 kg for an average four-engine taxi-out.

The average fuel saving for the oceanic optimisation was 600 kg, which equals to 2% of the 29,6 t average fuel consumption for the oceanic cruise segment.

The project partners judge the A380-TGF trials as successful with results being sufficiently significant to justify further studies aiming at a regular application of the trialed optimisations.

For reduced engine taxi, the vector of progress will be mainly directed to investigations in shared support tools improving the availability and reliability of predicted taxi duration.

For the transatlantic optimisation, procedures are in place at the level of ATC to apply re-routing more frequently. The challenge here is

a) to reduce flight crew workload through compatibility between AOC and ATC flight plan syntax,

b) to improve procedures, organisation and tools in order to detect more systematically the cases where re-routing would bring savings.

The consortium members are prepared to work together in the identified domains of improvement with the aim to apply the optimisations on a regular basis.
8. ANNEX

8.1 AIR FRANCE AIRPORT CHART – JFK DEPARTURE INFO

DEPARTURE INFO

D- ATIS
128.725

START-UP PROCEDURES (INTL. TERMINAL 4 / TERMINAL 1)
1. Call CLU on 135.050 for clearance and/or delay information 20 minutes prior to pushback.
2. Prior to pushback, contact Ramp Control giving “off block” time.
   - 130.770 (for INTL Terminal 4) or
   - 130.275 (for Terminal 1)
3. Monitor Ramp Control frequency at all times while pushing back and advise Ramp Control when “ready to taxi”.

TAXI PROCEDURES (INTL. TERMINAL 4 / TERMINAL 1)
1. All movements of aircraft on international ramp will be accomplished at the discretion of the Carrier in accordance with FAA and PANYNJ (Port Authority of New York and New Jersey) ramp regulations. The Carrier will take whatever precautionary measures may be necessary.
2. After pushback call “Ground Control” 121.900 or 121.650 for taxi instructions.

Aircraft prohibited in the runup block areas at TWY Z. To be used for turn around only.
8.2 FLIGHT CREW QUESTIONNAIRE FOR SURFACE OPTIMIZATION (FINAL VERSION)

OPTIMISATION DU ROULAGE SUR 2 MOTEURS À JFK

Avez-vous décidé de débuter le roulage avec 2 moteurs ?
Oui  Non

Si oui, pour combien de temps ?  min jusqu'à ? min

Avez-vous reçu une estimation du temps de roulage du start up pilots au décrochage ?
Oui  Non

Si oui, indiquer la durée :  min. Oral fait il est réalisé ?  min.

L'estimation est-arrêtée :  Trop tard  Trop tôt  Au bon moment

Commentaires / remarques :

JFK 2 ENGINE TAXI OPTIMIZATION

A380 TAXI OUT PROCEDURE

1. Cell (C, R ou S) en 15,000 fot clearance 30 minutes prior push back time
2. Push to gate back, contact Ramp Control picking "off block" time
3. After clearance delivery, contact Ramp Control to get expected taxi time (clearance)
4. Start to Ramp Control: Confirm all times with push back and service Ramp Control: "mode off"?
5. Contact 2 engines and then start up point
6. Contact Ramp Control: confirm mode on
7. After push back, call General Control 121.500 or 124.600 for instructions
8. When aircraft is cleared taxi, TF ramp operating contact FAA imposition to get taxi duration, and operation duration to the flight crew via JFK AIS

JFK 2 ENGINE TAXI OPTIMIZATION

OPTIMIZED LOCATION TO START UP THE 2 REMAINING ENGINES

Free competition about: professional pilots to start up 2 remaining engines

Take-off from RLL: after crossing runway 180/180, on R
Take-off from 22L: (full length) between G and E
Take-off from 13R: (full length) between H and D
Take-off from 36R: (full length) crossing runway 36L, (full) consider 1 engine taxi out from start-up point

Free competition about: professional pilots to start up 2 remaining engines

A380-TGF/LC/0115-D2
### 8.3 A380 BRAKE COOLING TIME TABLE (EXERPT FROM AIR FRANCE FCOM)

<table>
<thead>
<tr>
<th>Current Hottest Brake Temp</th>
<th>300 °C</th>
<th>350 °C</th>
<th>400 °C</th>
<th>450 °C</th>
<th>500 °C</th>
<th>550 °C</th>
<th>600 °C</th>
<th>650 °C</th>
<th>700 °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temp. Target</td>
<td>SAT</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-54 °C</td>
<td>0</td>
<td>18</td>
<td>29</td>
<td>42</td>
<td>53</td>
<td>63</td>
<td>72</td>
<td>81</td>
<td>89</td>
</tr>
<tr>
<td>15 °C</td>
<td>0</td>
<td>19</td>
<td>35</td>
<td>50</td>
<td>63</td>
<td>74</td>
<td>85</td>
<td>94</td>
<td>103</td>
</tr>
<tr>
<td>55 °C</td>
<td>0</td>
<td>22</td>
<td>40</td>
<td>56</td>
<td>70</td>
<td>83</td>
<td>94</td>
<td>104</td>
<td>114</td>
</tr>
<tr>
<td>250 °C</td>
<td>-54 °C</td>
<td>18</td>
<td>33</td>
<td>47</td>
<td>59</td>
<td>71</td>
<td>81</td>
<td>90</td>
<td>99</td>
</tr>
<tr>
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<td>49</td>
<td>67</td>
<td>83</td>
<td>97</td>
<td>110</td>
<td>121</td>
<td>131</td>
<td>141</td>
</tr>
<tr>
<td>200 °C</td>
<td>-54 °C</td>
<td>39</td>
<td>55</td>
<td>68</td>
<td>81</td>
<td>92</td>
<td>102</td>
<td>111</td>
<td>120</td>
</tr>
<tr>
<td>15 °C</td>
<td>51</td>
<td>70</td>
<td>86</td>
<td>101</td>
<td>113</td>
<td>125</td>
<td>135</td>
<td>145</td>
<td>154</td>
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<tr>
<td>55 °C</td>
<td>62</td>
<td>84</td>
<td>102</td>
<td>118</td>
<td>132</td>
<td>144</td>
<td>156</td>
<td>166</td>
<td>176</td>
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<td>150 °C</td>
<td>-54 °C</td>
<td>65</td>
<td>80</td>
<td>94</td>
<td>106</td>
<td>118</td>
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<td>146</td>
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<td>15 °C</td>
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<td>123</td>
<td>138</td>
<td>150</td>
<td>162</td>
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<td>191</td>
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<tr>
<td>55 °C</td>
<td>111</td>
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<td>152</td>
<td>168</td>
<td>182</td>
<td>194</td>
<td>206</td>
<td>218</td>
<td>225</td>
</tr>
</tbody>
</table>
### 8.4 SURFACE TRIAL – IN FLIGHT DATA ANALYSIS AND CREW FEEDBACK

<table>
<thead>
<tr>
<th>Date</th>
<th>Flight or route</th>
<th>Taxi time spent to crew?</th>
<th>Taxi duration estimated?</th>
<th>Engine start</th>
<th>Actual taxi time</th>
<th>2 GTR actual taxi time</th>
<th>Start of remaining engines</th>
<th>Estimation found useful?</th>
<th>The estimation arrived (1)</th>
<th>Crew feedback</th>
</tr>
</thead>
<tbody>
<tr>
<td>25-Dec-19</td>
<td>AF007 A380</td>
<td>N</td>
<td>/</td>
<td>40 TR</td>
<td>14</td>
<td>0</td>
<td>/</td>
<td>//</td>
<td>//</td>
<td>Ramp control not aware of the trial</td>
</tr>
<tr>
<td>7-Jan-11</td>
<td>AF007 A380</td>
<td>Y</td>
<td>&lt;30</td>
<td>40 TR</td>
<td>30</td>
<td>0</td>
<td>Yes</td>
<td>//</td>
<td>//</td>
<td>Long wait at parking stand</td>
</tr>
<tr>
<td>9-Jan-11</td>
<td>AF007 A380</td>
<td>N</td>
<td>/</td>
<td>40 TR</td>
<td>30</td>
<td>0</td>
<td>Yes</td>
<td>//</td>
<td>//</td>
<td>Taxi duration estimated by AF, station of 40 min during flight preparation</td>
</tr>
<tr>
<td>10-Jan-11</td>
<td>AF007 A380</td>
<td>N</td>
<td>/</td>
<td>40 TR</td>
<td>15</td>
<td>0</td>
<td>//</td>
<td>//</td>
<td>//</td>
<td>Taxi estimate requested by VMH instead of sent by ACARS</td>
</tr>
<tr>
<td>12-Jan-11</td>
<td>AF007 A380</td>
<td>Y</td>
<td>20 TR</td>
<td>28</td>
<td>0</td>
<td>/</td>
<td>//</td>
<td>//</td>
<td>//</td>
<td>Taxi duration estimated by AF, station of 30 min during flight preparation</td>
</tr>
<tr>
<td>13-Jan-11</td>
<td>AF007 A380</td>
<td>Y</td>
<td>20 TR</td>
<td>60</td>
<td>0</td>
<td>No</td>
<td>No</td>
<td>//</td>
<td>//</td>
<td>Taxi duration estimated by AF, station of 40 min during flight preparation</td>
</tr>
<tr>
<td>15-Jan-11</td>
<td>AF007 A380</td>
<td>N</td>
<td>/</td>
<td>40 TR</td>
<td>15</td>
<td>0</td>
<td>//</td>
<td>//</td>
<td>//</td>
<td>Taxi duration estimated by AF, station of 40 min during flight preparation</td>
</tr>
<tr>
<td>22-Jan-11</td>
<td>AF007 A380</td>
<td>Y</td>
<td>20 TR</td>
<td>15</td>
<td>1</td>
<td>No</td>
<td>Yes</td>
<td>//</td>
<td>//</td>
<td>Taxi duration estimated by AF, station of 40 min during flight preparation</td>
</tr>
<tr>
<td>29-Jan-11</td>
<td>AF007 A380</td>
<td>Y</td>
<td>40 TR</td>
<td>20</td>
<td>0</td>
<td>Yes</td>
<td>//</td>
<td>//</td>
<td>//</td>
<td>Taxi duration estimated by AF, station of 40 min during flight preparation</td>
</tr>
<tr>
<td>4-Feb-11</td>
<td>AF007 A380</td>
<td>Y</td>
<td>40 TR</td>
<td>20</td>
<td>0</td>
<td>//</td>
<td>//</td>
<td>//</td>
<td>//</td>
<td>Taxi duration estimated by AF, station of 40 min during flight preparation</td>
</tr>
<tr>
<td>6-Feb-11</td>
<td>AF007 A380</td>
<td>Y</td>
<td>40 TR</td>
<td>30</td>
<td>0</td>
<td>//</td>
<td>Yes</td>
<td>//</td>
<td>//</td>
<td>Taxi duration estimated by AF, station of 40 min during flight preparation</td>
</tr>
<tr>
<td>12-Feb-11</td>
<td>AF007 A380</td>
<td>Y</td>
<td>20 TR</td>
<td>30</td>
<td>15</td>
<td>1</td>
<td>Yes</td>
<td>Yes</td>
<td>//</td>
<td>Taxi duration estimated by AF, station of 40 min during flight preparation</td>
</tr>
<tr>
<td>13-Feb-11</td>
<td>AF007 A380</td>
<td>Y</td>
<td>20 TR</td>
<td>60</td>
<td>26</td>
<td>1</td>
<td>No</td>
<td>//</td>
<td>//</td>
<td>Taxi duration estimated by AF, station of 40 min during flight preparation</td>
</tr>
<tr>
<td>1-Mar-11</td>
<td>AF007 A380</td>
<td>Y</td>
<td>40 TR</td>
<td>40</td>
<td>0</td>
<td>//</td>
<td>Yes</td>
<td>//</td>
<td>//</td>
<td>Taxi duration estimated by AF, station of 40 min during flight preparation</td>
</tr>
<tr>
<td>4-Mar-11</td>
<td>AF007 A380</td>
<td>Y</td>
<td>40 TR</td>
<td>10</td>
<td>0</td>
<td>//</td>
<td>Yes</td>
<td>//</td>
<td>//</td>
<td>Taxi duration estimated by AF, station of 40 min during flight preparation</td>
</tr>
<tr>
<td>11-Mar-11</td>
<td>AF007 A380</td>
<td>Y</td>
<td>20 TR</td>
<td>35</td>
<td>26</td>
<td>1</td>
<td>Yes</td>
<td>//</td>
<td>//</td>
<td>Taxi duration estimated by AF, station of 40 min during flight preparation</td>
</tr>
<tr>
<td>13-Mar-11</td>
<td>AF007 A380</td>
<td>Y</td>
<td>20 TR</td>
<td>47</td>
<td>30</td>
<td>1</td>
<td>No</td>
<td>//</td>
<td>//</td>
<td>Taxi duration estimated by AF, station of 40 min during flight preparation</td>
</tr>
<tr>
<td>21-Mar-11</td>
<td>AF007 A380</td>
<td>Y</td>
<td>20 TR</td>
<td>20</td>
<td>14</td>
<td>1</td>
<td>Yes</td>
<td>No</td>
<td>//</td>
<td>Taxi duration estimated by AF, station of 40 min during flight preparation</td>
</tr>
<tr>
<td>30-Mar-11</td>
<td>AF007 A380</td>
<td>Y</td>
<td>40 TR</td>
<td>50</td>
<td>0</td>
<td>//</td>
<td>Yes</td>
<td>Yes</td>
<td>//</td>
<td>Taxi duration estimated by AF, station of 40 min during flight preparation</td>
</tr>
<tr>
<td>27-Mar-11</td>
<td>AF007 A380</td>
<td>Y</td>
<td>20 TR</td>
<td>40</td>
<td>0</td>
<td>No</td>
<td>No</td>
<td>//</td>
<td>//</td>
<td>Taxi duration estimated by AF, station of 40 min during flight preparation</td>
</tr>
<tr>
<td>28-Mar-11</td>
<td>AF007 A380</td>
<td>Y</td>
<td>20 TR</td>
<td>50</td>
<td>30</td>
<td>1</td>
<td>Yes</td>
<td>Yes</td>
<td>//</td>
<td>Taxi duration estimated by AF, station of 40 min during flight preparation</td>
</tr>
<tr>
<td>2-Apr-11</td>
<td>AF007 A380</td>
<td>Y</td>
<td>20 TR</td>
<td>25</td>
<td>15</td>
<td>1</td>
<td>Yes</td>
<td>No</td>
<td>//</td>
<td>Taxi duration estimated by AF, station of 40 min during flight preparation</td>
</tr>
<tr>
<td>3-Apr-11</td>
<td>AF007 A380</td>
<td>Y</td>
<td>30 TR</td>
<td>20</td>
<td>15</td>
<td>1</td>
<td>Yes</td>
<td>No</td>
<td>//</td>
<td>Taxi duration estimated by AF, station of 40 min during flight preparation</td>
</tr>
<tr>
<td>4-Apr-11</td>
<td>AF007 A380</td>
<td>Y</td>
<td>40 TR</td>
<td>15</td>
<td>0</td>
<td>X</td>
<td>//</td>
<td>//</td>
<td>//</td>
<td>Taxi duration estimated by AF, station of 40 min during flight preparation</td>
</tr>
<tr>
<td>5-Apr-11</td>
<td>AF007 A380</td>
<td>Y</td>
<td>20 TR</td>
<td>42</td>
<td>35</td>
<td>X</td>
<td>//</td>
<td>//</td>
<td>//</td>
<td>Taxi duration estimated by AF, station of 40 min during flight preparation</td>
</tr>
<tr>
<td>15-Apr-11</td>
<td>AF007 A380</td>
<td>Y</td>
<td>20 TR</td>
<td>20</td>
<td>13</td>
<td>PA</td>
<td>//</td>
<td>//</td>
<td>//</td>
<td>Taxi duration estimated by AF, station of 40 min during flight preparation</td>
</tr>
<tr>
<td>12-Apr-11</td>
<td>AF007 A380</td>
<td>Y</td>
<td>20 TR</td>
<td>10</td>
<td>13</td>
<td>PA</td>
<td>//</td>
<td>//</td>
<td>//</td>
<td>Taxi duration estimated by AF, station of 40 min during flight preparation</td>
</tr>
<tr>
<td>13-Apr-11</td>
<td>AF007 A380</td>
<td>Y</td>
<td>20 TR</td>
<td>35</td>
<td>0</td>
<td>X</td>
<td>//</td>
<td>//</td>
<td>//</td>
<td>Taxi duration estimated by AF, station of 40 min during flight preparation</td>
</tr>
</tbody>
</table>

Note: // = Yes, // = No, X = No data available due to technical issues.
8.5 SURFACE TRIAL – POST FLIGHT ANALYSIS / EXAMPLE FOR AN A380 NON CANDIDATE FLIGHT

Fuel flow GTR 1
Fuel flow GTR 2
Fuel flow GTR 3
Fuel flow GTR 4
Ground speed

Average fuel consumption = 48 kg/min

Non AIRE Flight

00:13:25
00:13:57
00:14:30
00:15:02
00:15:34
00:16:06
00:16:38
00:17:10
00:17:42
00:18:14
00:18:46
00:19:18
00:19:50
00:20:22
00:20:54
00:21:26
00:21:58
00:22:30
00:23:02
00:23:34
00:24:06
00:24:38
00:25:10
00:25:42
00:26:14
00:26:46
00:27:18
00:27:50
00:28:22
00:28:54
00:29:26
00:29:58
00:30:30
00:31:02
00:31:34
00:32:06
00:32:38
Average fuel consumption = 48 kg/min

Taxi start

Non AIRE Flight

A380 Transatlantic Green Flights – Deliverable 2
8.6 SURFACE TRIAL – POST FLIGHT ANALYSIS / CHARTS PER AIRE FLIGHT

- Fuel flow GTR 1
- Fuel flow GTR 2
- Fuel flow GTR 3
- Fuel flow GTR 4
- Ground speed

![Graph showing fuel flow and ground speed over time.](image)
Flight 07

2 GTR on

4 GTR on

Taxi start

A380 Transatlantic Green Flights – Deliverable 2
8.8 FLIGHT CREW QUESTIONNAIRE FOR OCEANIC OPTIMIZATION (FINAL VERSION)
8.9 REPRESENTATION OF THE AIRE TRIAL FLIGHTS REROUTING

AF007 of February 4th, 2011

AF007 of March 28th, 2011
AF007 of March 11th, 2011

Initial route

Optimized route

AF007 of April 12th, 2011
### OCEANIC TRIAL – IN FLIGHT COLLECTED DATA

<table>
<thead>
<tr>
<th>Date (local)</th>
<th>Flight no</th>
<th>IOW (T)</th>
<th>WP1</th>
<th>Track OTE</th>
<th>FL</th>
<th>Mkt requested</th>
<th>FL</th>
<th>FL granted</th>
<th>FL granted?</th>
<th>Random granted?</th>
<th>Potential gain (T)</th>
<th>Actual gain (T)</th>
<th>Random frame</th>
<th>FL</th>
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<td>Random = planned track. Blocked at FL330 due to turbulence up to 40W.</td>
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<td>Numerous messages sent by DSP, difficulty to determine which route was more optimized.</td>
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<td>CDG arrival with initial route via LATGO but random route sent with arrival via DVL. Gain ~500 kg. Configuration with landing facing east given the estimated taxitime at CDG. Random route not chosen. Random route request via LATGO remained unanswered.</td>
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<td>No</td>
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<td>Random route not performed because new flight plan changed only after leaving the oceanic airspace.</td>
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<td>0.4</td>
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<td>Optimized route found but only with arrival change via DVL via LATGO. Request denied. Gander requested maintain FL370, due to traffic.</td>
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<td>2-Apr-11</td>
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<td>Oceanic entry via KZOVY, no random found. Only optimization possible with arrival via DVL via LATGO.</td>
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<td>4-Apr-11</td>
<td>A1011</td>
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<td>No</td>
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<td>Entry point 40 min after take-off, AKARS unavailable for 45 min and clearance requested by VHF to 410.</td>
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<tr>
<td>10-Apr-11</td>
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<td>Initial clearance at G272, first denied by Gander then granted 2nd clearance. 8 minute flight time savings. Aerial via DVL via LATGO.</td>
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</table>

- **FL**: Flight Level
- **WP1**: Waypoint
- **Mkt**: Market
- **Grant**: Grant
- **No**: Not granted
- **Yes**: Yes
- **//**: Unknown data
# 8.11 LIST OF ABBREVIATIONS

<table>
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<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tr>
<td>AAR</td>
<td>Airport Arrival Rate</td>
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<tr>
<td>ACARS</td>
<td>Aircraft Communications Addressing and Reporting System</td>
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<td>ADS-C</td>
<td>Automatic Dependent Surveillance - Contract</td>
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<td>AF</td>
<td>Air France</td>
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<tr>
<td>AFR</td>
<td>Air Navigation Service Provider</td>
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<td>ANSP</td>
<td>Air Navigation Service Provider</td>
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<td>AOC</td>
<td>Airline Operational Communication / Centre</td>
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<td>ARM</td>
<td>Acceptance Review Meeting</td>
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<td>ARR</td>
<td>Arrival</td>
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<td>ATCO</td>
<td>Air Traffic Controller</td>
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<td>ATCT</td>
<td>Air Traffic Control Tower</td>
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<td>CDG</td>
<td>Paris Charles de Gaulle airport</td>
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<tr>
<td>COM</td>
<td>Communication</td>
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<td>CPDLC</td>
<td>Controller Pilot Data Link Communication</td>
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<td>DEP</td>
<td>Departure</td>
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<td>DSP</td>
<td>Dispatch</td>
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<td>ETOPS</td>
<td>Extended Twin Engine Operations</td>
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<td>FDR</td>
<td>Flight Data Recorder</td>
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<td>Flight Management System</td>
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<td>Flight Planning Processing System</td>
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<td>JFK</td>
<td>New York John Fitzgerald Kennedy airport</td>
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<tr>
<td>MNPS</td>
<td>Minimum Navigation Performance Specification</td>
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<td>North Atlantic</td>
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<td>NAV</td>
<td>Navigation</td>
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<tr>
<td>NM</td>
<td>Nautical Mile</td>
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<td>Notice to Airmen</td>
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<td>Oceanic Control Area</td>
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<td>OTS</td>
<td>Organized Track Structure / System</td>
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<td>Runway</td>
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<td>SESAR Joint Undertaking</td>
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<td>SOP</td>
<td>Standard Operations Procedure</td>
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<td>Transatlantic Green Flights</td>
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<td>Tower</td>
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<td>New York Center</td>
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