BENEFIT ASSESSMENT OF USING CONTINUOUS DESCENT APPROACHES AT ATLANTA

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Abstract

The use of Continuous Descent Approaches (CDAs) has been discussed numerous times in recent years and has even seen limited demonstrations and implementations in the US and Europe. Even though almost all CDA discussion thus far has been focused on the benefits associated with reduction in noise and emissions, there are huge potential savings for airlines if CDAs were to be implemented. This research outlines a simple approach at quantifying the benefits of CDAs using TAAM Fast-Time simulation. As the results from this research show, allowing non altitude restricted STARs which have the 2D track freedom to fly direct to the base-leg following the IAF can save airlines approximately 1 minute of flight-time per operations and up to $30 million in fuel annually. All of these savings can be realized without increasing the Air Traffic Controller de-confliction workload, potentially even reducing counts of proximities observed.

Introduction

The pressure on airports to reduce noise has resulted in considerable attention being given to Continuous Descent Approaches (CDAs) [1–4]. It is anticipated that the potential for the adverse impact of noise and gaseous emissions will play increasingly larger roles in airport capacity constraints in the future [5]. There is now a considerable body of research on CDA, primarily with the intent to reduce noise and emissions on approach [5-6]. For example, Standard Terminal Arrival Routes (STARs) can be amended to require aircraft to join the glide path at 7000 feet, which allows the aircraft to maintain its velocity without requiring an increase in power and engine noise. This reduces the noise footprint in comparison to the aircraft maintaining level flight at say 3000 feet in a vectoring area, with flap and gear down. CDAs of this kind require the aircraft to follow a 'noise abatement pattern' that requires the aircraft to follow a STAR.

Similarly, aircraft on departure are expected to follow a noise abatement procedure which normally consists of a stylized and relatively extreme 'noise abatement' climb followed by a low power climb till above the noise abatement limit; normally 5,000–7,000 feet. As with the STARs the Standard Departures (SDs) also follow a precisely defined 3 dimensional path.

The design of both the SDs and STARs above are based on small alterations to the current airspace designs, however, all the forthcoming Concepts of Operations are moving toward the use of 4 Dimensional Air Traffic Management (4D ATM). Aircraft are now being equipped with Precision aRea NAVigation (pRNAV) systems that allow them to fly extremely accurately without the need to over-fly ground navigation beacons. Thus, an aircraft with modern avionics can be expected to fly a 4D trajectory accurately be within 0.1 NM and 5 seconds at all points on the pre-planned trajectory. Procedures are now being developed for airports to make use of these pRNAV capabilities using standard tools such as the Terminal Area Route Generation Evaluation and Traffic Simulation (TARGETS) tool [7].

However, the currently accepted technique in use for generation of pRNAV procedures is to define a single 3-dimensional route that follows the mean of the paths of aircraft in the vectoring area for the airport; both arriving and departing. This mirrors the noise abatement procedures above which also define a precise 3 dimensional route.

In this paper we highlight the shortcomings of this 'precision-3D' concept and by use of relatively simple fast time simulations demonstrate the extreme savings to the airlines that would accrue even by moving a little way toward 4 dimensional approaches at a major US Hub, Atlanta Hartsfield.

Background

The current IFR airspace structure is based on 3 dimensional airspace reservations in which aircraft are required to fly a precise 2 dimensional route while complying with altitude restrictions. The only areas where this is relaxed is in so called ‘vectoring areas’ around airports where controllers may vary routes to assist in (re)sequencing and spacing aircraft to make the best use of the runway and relevant separation criteria. The generic procedures used are the ‘Fan’ and the ‘Trombone’. Both are based on extending or reducing the distance flown by the aircraft with the intention of delaying or expediting the arrival of the aircraft. However, the new CDA approaches make this type of variance extremely difficult as the aircraft is attempting to intercept a normal approach path and speed at some point between 10 and 3 NM from touchdown. [8]

3D Precision Approaches

The current concept for implementation of pRNAV approaches is to capture the historic tracks of aircraft in the vectoring area(s) around an airport and then generate pRNAV routes that follow the median of those vectored routes. Since these approaches can be directly uploaded into the aircrafts’ Flight Management Systems (FMSs), this allows the aircraft to automatically fly the approach without requirement for controller intervention and adjust their speed to achieve the correct touchdown time and separation at the threshold. Figure 1 shows this methodology being defined at Seattle Tacoma.

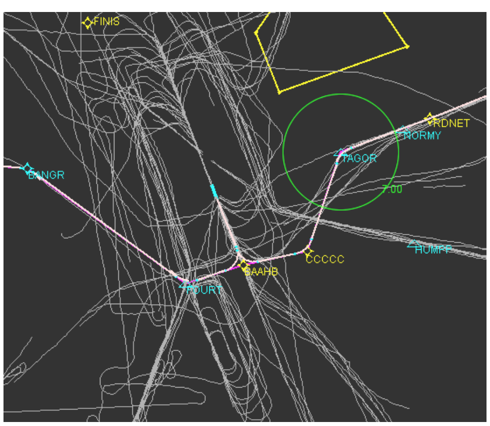

Figure 1. pRNAV-RNP Route Generation at Seattle Tacoma using TARGETS

The concept of pRNAV equipped aircraft following a precisely defined STAR that can be flown automatically is not new. It has been trialled in the Programme for Harmonized ATM Research in EUROCONTROL (PHARE) [9]. In PHARE Demonstration 2 (PD/2) simulating Frankfurt, 3 different scenarios were run. The first Organisation 0, was a standard control baseline with controllers vectoring the aircraft into Frankfurt’s runway 25. From Figure 2 the vectoring strategies of the controllers can be seen with fanning and trombone being used and the alteration of the intercept of the downwind traffic from the southerly and northerly flows to a 90 degree offset that is easier for the controllers to estimate.

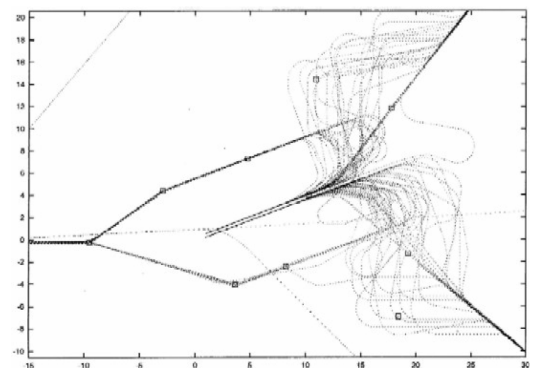

Figure 2. PHARE Demonstration 2 Manual Vectoring into Frankfurt 25L and 25R

Figure 3 shows the recording of a scenario with 70% of the aircraft equipped with pRNAV and data-link and the remainder vectored using ground based trajectory generation with advisories passed by the controllers.

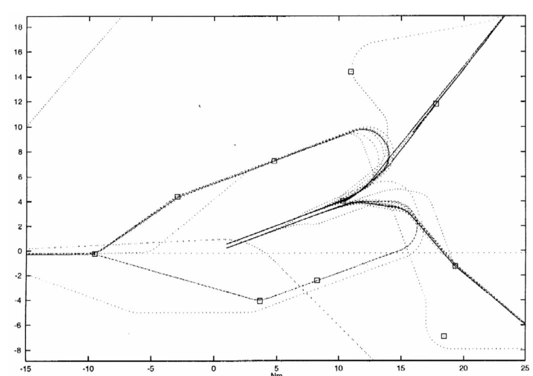

Figure 3. PHARE Demonstration 2

It can be seen that the pRNAV approaches being generated for Seattle and the procedures generated in PHARE are almost identical in their methodology. However, they also suffer from the same major drawback. Approach and departure procedures that are ‘generic’ must be designed to be flyable by all aircraft. Indeed, the Seattle approaches are simulated by tools that check that the procedures can be flown by all aircraft types, from heavy B777 to a light ATR42. This means that the turns and size of the procedure are wide enough for the heavy aircraft while the light aircraft are required to fly the same – and for them – extremely extended pattern. Similarly, a fast aircraft must be considerably separated from a slow aircraft at the start of the procedure such that it only catches up to the separation minima when on very short finals. (This is also alluded to in [5]).

This is a fundamental problem with all 3 dimensional procedures. By enforcing the single generic route at low level where aircraft would normally be vectored by controllers, the system is made less efficient, even though the aircraft are now flying the final parts of the STAR on their internal navigation systems.

Altitude Profiles

Aside from requirements for all aircraft to fly the same 2D paths, altitude restrictions are also included in the procedures, forcing aircraft to perform stepped descents to cleared altitude levels along their descent paths as directed by the air traffic controller. This not only creates the need for aircraft to continuously adjust turbine thrust and flaps, but also forces aircraft to fly at lower altitudes and speeds than optimally preferred. Figure 4 shows historically recorded descent paths into Atlanta Hartsfield-Jackson International Airport generated from ASDI data for a busy day of the week (Thursday) in November 2004.

As can be expected from current STAR definitions at Atlanta, aircraft level off at 12,000 ft – this depends on the aircraft type and the specific procedure used and might vary some up or down – as they pass the IAF (awaiting clearance into the TRACON), and again between 4,000 ft and 5,000 ft when nearing the Final Approach Fix. Figure 4 also shows an optimal descent path if CDAs were implemented.

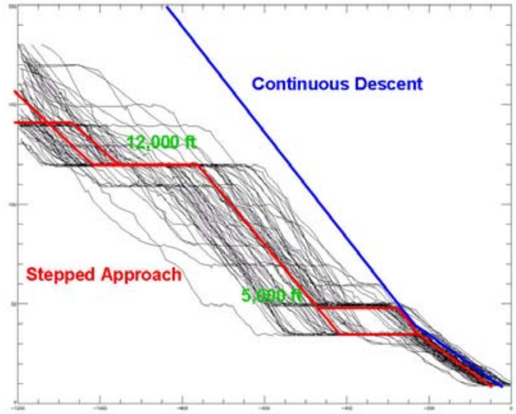

Figure 4. Descent Profiles into ATL

Whereas STARs may exhibit a fairly large difference between actual and optimized descent paths, departures show a much more comparable altitude profile. As Figure 5 shows, departures are only forced to interrupt their climb at about 10,000 ft, which is where they contact En-route ARTCC’s for further climb instructions.

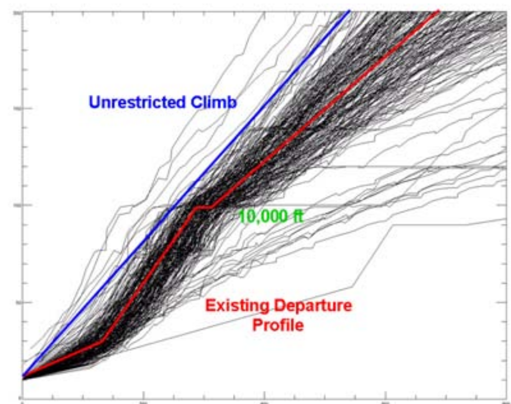

Figure 5. Climb Profiles Out of ATL

4-D ATM

The majority of future Concepts of Operation for the NAS are all biased toward the use of 4D ATM or ‘trajectory control’. Ideally the user will be able to fly a user preferred trajectory to the destination, which allows freedom vis-à-vis 2D-tracks as well as altitudes and speeds. This will not only satisfy environmental concerns in terms of noise and emissions, but also increases profitability from an airline point of view as approaches can be flown almost entirely on low engine thrust settings, thereby reducing fuel burn. As aircraft may also remain at higher altitudes for longer periods of time before reaching the Top of Descent (TOD) points on the approach, higher speeds are also possibly, which reduces total air time.

One of the effects that was also reported in PHARE and in other studies, was that if aircraft are allowed more freedom in routing the number of potential conflicts reduces markedly[1].

Issue Researched

The feasibility of 4D ATM inside the TRACON has clearly been demonstrated in both the PHARE project demonstrations of 4 dimensional approaches at Schiphol airport and during UPS trials organized by MIT at Louisville airport [10].

In an attempt to quantify the benefits and disadvantages of 4D approaches beyond those of noise and emissions, the processed cited in this research used TAAM fast-time simulations to assess effects on airlines if CDAs were to be implemented. In particular, this researched asked the question: if aircraft were given free routing within a TRACON but only from the IAFs of a major hub in the United States, what would the savings and costs be.

Research efforts were focused on benefits exhibited during arrivals (on STARs), as this is where preliminary research showed the highest potential for savings.

Scenarios

The fast-time simulation software used for the analysis portions of this research study was TAAM. TAAM is a widely accepted simulation and modelling tool that is capable of high-fidelity airspace and airport studies. The airport chosen was Atlanta Hartsfield-Jackson International Airport, which routinely vies with Chicago O'Hare for the busiest airport in the United States.

For the purpose of assessing airline benefits under CDAs, a baseline scenario was compared to two other scenarios which incrementally gave aircraft more freedom in their trajectories. The baseline scenario mirrored the current system, which is a standard 3 dimensional STARs from 4 corner post IAFs. All current speed and altitude restrictions were observed. The first alternative scenario removed any altitude restrictions on the STARs, essentially giving the simulation the freedom of allowing aircraft to fly aircraft at their optimal altitudes (usually their cruise altitudes) as long as possible, thereby achieving a CDA. The final alternative scenario further removed any pre-defined STAR path constraints and allowed aircraft to fly directly from their IAFs to the base-legs of their respective runway. It should be noted that even though no altitude restrictions were used in the alternative scenarios, TAAM still assumed a standard 3 degree glide slope to the runway from the Final Approach Fix on. Departures were modified in both alternative scenarios by essentially eliminating any altitude and speed restrictions on the climb, allowing aircraft to fee-climb to their cruising altitudes.

A simulation screenshot depicting the final scenario which allowed complete CDA track and altitude freedom is depicted in Figure 6.

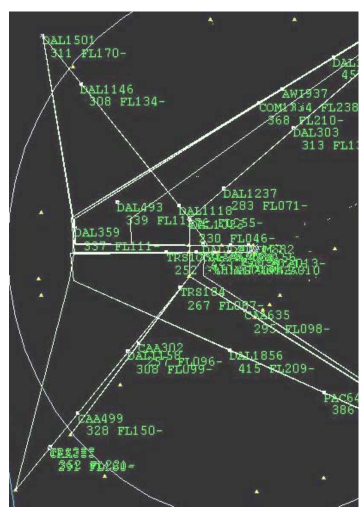

Figure 6. CDAs into ATL Direct from IAF to Base-Leg

All three scenarios were simulated using a representative timetable of actual operations at Atlanta airport on October 21, 2004. This timetable was obtained from filed flight plans recorded via the ASDI data stream and included ~2,800 flights.

[1] This is hardly surprising logically but does not have face validity for many people.

Simulation Results

Using TAAM's extensive reports generated from the three scenario simulations, results were extracted for both the airspace and airport sides.

Airspace

Airspace metrics gathered during the course of this research included the total air time, fuel burn, and flown distance for all flights in the timetable. In addition, airspace conflict counts were gathered for the TRACON and the surrounding En-Route airspace to gain some minor insight into potential controller de-confliction workloads. Table 1 presents a summary of time, distance, and fuel metrics for all simulation scenarios.

Table 1. Airspace Simulation Results

	Air Time	*Fuel ($)*	*Distance (nm)*
Baseline	2,145 hrs	$3.98 mil	870K
Altitude Freedom	2,135 hrs	$3.95 mil	870K
Track & Alt Freedom	2,100 hrs	$3.90 mil	861K

These results clearly show incremental savings in time, fuel and distance flown as first altitude and then track freedom is provided. The total flight time in the simulation decreases by 10 hours when aircraft are allowed to fly a CDA with the existing STAR paths and by 45 hours per day if direct paths are allowed direct to the base-legs from the IAFs. This equates to savings of an average of 1 minute per flights using the latter methodology. Total daily fuel savings are estimated to reach $80K, which equates to roughly $29mil annually. The result of allowing track freedom on the STARs results in a total of ~9,000nm savings in flown track distance, which equates to about 3nm per airplane

As these results indicate, not only do there exist tremendous potential fuel savings for airlines by using CDAs, savings in total flight time – and associated reductions in airspace delay – present just as powerful a proponent for using Continuous Descent Approaches. These flight time savings likely equal if not surpass fuel savings from an airline point of view.

From an airspace provider viewpoint, it is important that any new procedures show improvements – or at the very least no detrimental effects to – safety and workload as aircraft have to be sequenced and de-conflicted around an airport. To assess potential controller de-confliction actions using CDAs as outlined in this research, TAAM's sophisticated conflict detection mechanism was used to gather potential proximity counts in all scenarios in the TRACON as well as the immediately surrounding En-route airspace sectors.

Within the TRACON sector, proximities among arriving aircraft showed a minor increase by about 10% when comparing the last alternative with track and altitude freedom to the current baseline configuration. This is offset by a noted 25% decrease in proximities among departures, where the ability to free-climb without having to level-off at 10,000 ft while awaiting clearance to enter En-route airspace appeared to naturally separate aircraft by altitudes, eliminating the need for controller interventions.

Using a mock En-route sector which extended to an 80nm radius around Atlanta and from 12,000 ft up to FL500 presented an indication of the effect of CDAs on potential de-confliction actions in the Center. As expected, eliminating the need for arriving aircraft to funnel into IAFs at the same altitude levels eliminated many of the proximities observed in the Baseline scenario. In fact, the number of proximities observed among arriving aircraft was reduced by 50% when altitude restrictions were removed in the first alternative scenario. Allowing further track freedom in the second alternative did not show any effects on proximities.

Airport Throughput

In light of all potential savings associated with CDAs at Atlanta airport, it is important to show that neither alternative scenario had an appreciable effect on the overall airport throughput. Figure 7 presents 15 minute movements at ATL in the baseline as well as alternative scenarios.

The fact that visually there appears to be very little variability in movements across all scenarios is compounded by statistical tests which proved no appreciable variation/difference among any of the scenarios.

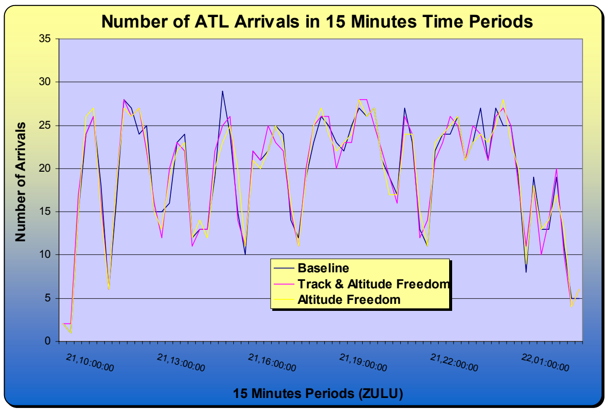

Figure 7. ATL Airport 15 Minute Movements

As a frame of reference for the throughput presented in the chart above, ATL airport historically as been capable of achieving an average of 100 arrivals per hour under VFR weather conditions [11].

CDA Benefits

The following is a summary of potential benefits observed in the process of this research:

- Each aircraft would descend at an economically ideal rate
- The environmentally damaging emissions from the engines at close to flight-idle are considerably reduced [9,12]
- The noise from the approach is considerably reduced as is the airport 'footprint'
- Flight times overall can be reduced to the minimum while flight at cruise altitude can be prolonged
- Fuel use is reduced considerably due to more engine-idle descents
- Climbing aircraft can maintain a standard power setting in the climb reducing engine maintenance requirements
- CDA benefits may be observed while potential airspace conflicts remain at base levels or are even reduced
- The use of CDAs shows valuable benefits to airlines and air traffic service providers alike

Future Work

To support the 4D control of aircraft in the TRACON it will be necessary to develop new Decision Support Tools for controllers at the centers and TRACONS. More detailed simulations will also be needed using the developed tools to demonstrate the safety and capacity of the new procedures. Work should be carried out with FMS manufacturers to confirm that current or future FMSs are capable of flying 4D trajectories to meet a constraint touchdown time and data-link that trajectory to the ground. Complete implementation of CDAs will not be possible unless air and ground systems are able to communicate. Current procedure development tools such as IAPA and TARGETS will also have to be modified to support future CDA implementations.

The current set of simulations all used a standard glide-slope path from the FAF to the runway. This essentially forces all aircraft to follow the same altitude profiles from the FAF to touchdown. If aircraft were allowed complete autonomy in deciding their altitude profiles, higher – or sometimes lower – rates of descent would likely be observed. Assuming that GPS approaches are in place to support these non-ILS approaches, and FMSs were certified to guarantee times at touchdown for sequencing purposes, separation requirements may be reduced from the current 3nm standard. Furthermore, wake turbulence separations may also be reduced as aircraft fly at different altitudes over the FAF.

Conclusions

At a time when all the major airlines have some degree of financial difficulty and when the concerns on the impact of aviation on the environment are at a high profile, it behoves the research community to investigate alternate methods of managing the flows of aircraft that could ameliorate both concerns without sacrificing safety or capacity.

This study shows that even a relatively small provision of 4 dimensional control can lead to quite noticeable savings in fuel, time, environmental impact and costs without impacting the airport acceptance rates or the number of conflicts. To achieve this capability the current procedures will need to be changed and agreed with the TRACON and ARTCCs. Additionally, it will be imperative that controllers in both locations have decision support tools that support CDA.

With simply fuel savings in excess of $29Million at a single hub airport (not to speak of airspace delay reductions which may equal or likely even exceed fuel savings), development of new procedures is surely worthwhile.

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