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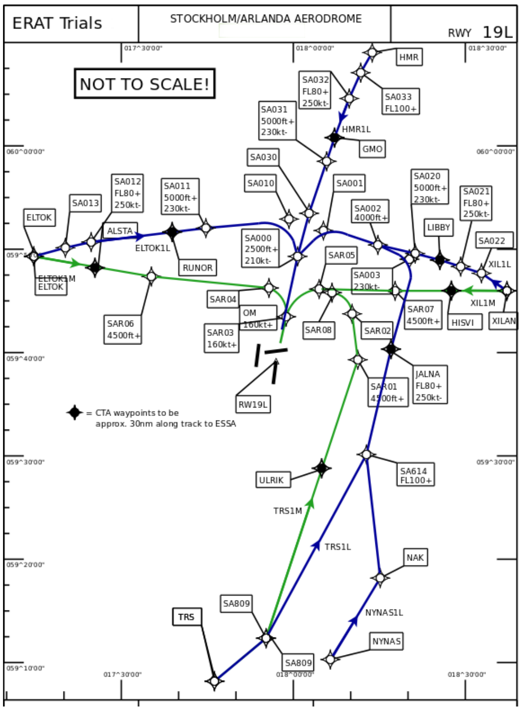
Executive summary

Real Time ATC simulation of Time Based CDA operations



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Introduction
The expected future growth in aviation requires more efficient and environmentally sustained operations. The present paper presents the results of a concept evaluation in a real-time ATC simulation to increase the rate of Continuous Descent Approaches. This work was carried out within the frame of the EU sponsored 6FW project ERAT (Environmentally Responsible Air Transport). The project facilitates in enhanced climb and descent services as defined by SESAR and aims for operational improvements for implementation in 2015. The concept of operation attempts to achieve medium to high density CDA operations applying time based operations. It is based on an advanced arrival management (AMAN) system that supports Controlled Time of Arrival (CTA) operations.

Results and conclusions
After extensive preparations and prototyping sessions, in total two weeks of real time ATC simulations were carried out in 2010 on the NARSIM platforms at LFV in

This report is based on a presentation held at the 3rd CEAS Air & Space Conference, Venice (Italy), 24-28 October 2011.

Malmö and NLR in Amsterdam. Each evaluation session involved 6 active ATC controllers and 5-7 pseudo pilots.
The obtained ATC simulation results clearly showed that the time based CDA concept is well feasible with the offered medium traffic flow density of on average 32 landings per hour, including higher traffic peaks. About 20% more PRNAV based CDA's were observed when using the time based concept and support tools, compared to conventional procedures.
Initial results with operating shorter RNP based approaches may give additional efficiency benefits, although this part of the evaluation had a limited scope.

Applicability
The experiences gained with the real-time ATC simulations have considerably supported the validation of a time based CDA concept at Stockholm Arlanda and improved the concept as well as supporting technology. The obtained experiences will be applied in follow-on projects, at Arlanda and other European airports, and within the SESAR programme.

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Real Time ATC simulation of Time Based CDA operations

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Abstract

The expected future growth in aviation requires more efficient and environmentally sustained operations. The present paper presents the results of a concept evaluation to increase the rate of Continuous Descent Approaches. This work was carried out within the frame of the EU sponsored 6FW project ERAT (Environmentally Responsible Air Transport). The project facilitates in enhanced climb and descent services as defined by SESAR and aims for operational improvements for implementation in 2015. The concept of operation attempts to achieve medium to high density CDA operations applying time based operations. It is based on an advanced arrival management (AMAN) system that supports Controlled Time of Arrival (CTA) operations.

1 Introduction

Continuous efforts are made worldwide to achieve a sustainable growth of the air transport industry with an acceptable burden to society. As such, it is necessary that improvements are made, both by introducing more economic and silent aircraft, but also by a more efficient and environmentally friendly operation of the entire air traffic system.

To reduce the environmental burden to communities around airports and to improve the economic and environmental efficiency during the initial and final phases of flight, many countries have already invested in researching and introducing improved departure and arrivals operations.

At present, the frequent use of CDAs, flown from top-of-descent to final approach, is not yet feasible during daytime operations at major airports. Such Continuous Descent Approaches are currently too unpredictable for existing air traffic management systems, which means it is difficult for air traffic controllers to merge them within the tightly orchestrated arrival flow around busy airports. On the other hand, with respect to departing traffic, there is also the goal to provide for continuous climbing departure profiles, as any restriction made to departing traffic due to the facilitation of continuous descents may easily offset any benefit gained on the arrival side.

Within the EU sponsored FP6 project ERAT (Environmentally Responsible Air Transport), the project partners teamed up to prepare and validate the operational context for enhanced climb and descent services as defined in SESAR for two major airports. As part of this project, Sweden's Air Navigation Service provider LFV, with the aid of DLR, NLR and the other project partners, have developed and validated an operational concept, controller tools and procedures for the implementation of Continuous Descent Approach operations under higher traffic conditions.

Based on previous experiences for operating timed (CDA) approaches in other projects, such as CASSIS [1], TMA2010+ [2,3,4], SARA, OPTIMAL [5], and Sourdine II [6], work was continued to further develop and validate a suitable operational concept for time based continuous descent approaches under medium-high traffic conditions at Stockholm Arlanda airport. The main elements of the concept are described in the following section.

Furthermore, prototypes of essential concept elements, such as a suitable integrated controller working environment and air traffic management tools capable for time based arrivals needed to be developed.

The concept, system support and associated operational procedures were evaluated under realistic simulated air traffic conditions during real-time ATC simulations of Stockholm Arlanda airport, as described in section 3. These simulations and results are described in the final sections.

2 ERAT Operational Concept for Arlanda

The concept of time based CDA operations, applied to the Stockholm Arlanda airport and airspace environment, applies the assignment of Controlled Times of Arrival (CTA) to arriving aircraft in order to achieve accurate sequencing for the final approach. The CTA control point is a dedicated waypoint on the arrival route for the inbound arriving aircraft.

Earlier projects already gained considerable experience with the application of different CTA waypoint locations, e.g. TMA entry, around 20-40 NM or on the runway. Based on the obtained feedback, it was regarded most optimal to use a CTA distance to the runway of 30NM with the present state of technology.

An overview of the operational concept for a typical flight is indicated in fig. 1. The CTA time constraint to be achieved by the inbound aircraft is determined by the ground based arrival management system (AMAN), which determines the landing sequence. For such a nominal arrival the sequence of events is the following.

Once within planning range, arriving aircraft for Arlanda airport are taken into account in the AMAN landing sequence planning. The aircraft are issued a standard arrival route (STAR) to the landing runway in use. Approximately 30-35 minutes prior to estimated runway touchdown, the AMAN system finalises the planned landing sequence. The scope of this concept applied to Stockholm Arlanda has been visualised on the map in fig. 2.

Based on the frozen runway arrival time in the landing sequence planning, the estimated time over the 30NM control waypoint on the assigned arrival route can be provided as a 4D time constraint for the arriving aircraft.

The en-route (ACC) ATC controller is notified and may then issue this time constraint as a CTA clearance to the aircraft. The flight crew verifies and reprograms the active flight plan in the onboard Flight Management System (FMS) with the assigned CTA time.

Once confirmed by the flight crew, the aircraft now will try to achieve passing the CTA waypoint with ±30 sec accuracy using guidance provided by the 4D capable FMS. In addition, the ACC controller will mark the CTA controlled flight in the system, indicated by a special 🕒 symbol with the aircraft flight label on the radar screen.

Taking into account other en-route traffic, the ACC controller provides progressive descent clearances to allow the continued execution of the timed based idle descent. Once approaching the TMA boundary, the descending aircraft is then transferred to the next approach (APP) controller. Further on, once passing the 30NM control waypoint with sufficient accuracy, the aircraft will continue on the idle optimum descent with further time constraints monitored by the approach controller and/or final director.

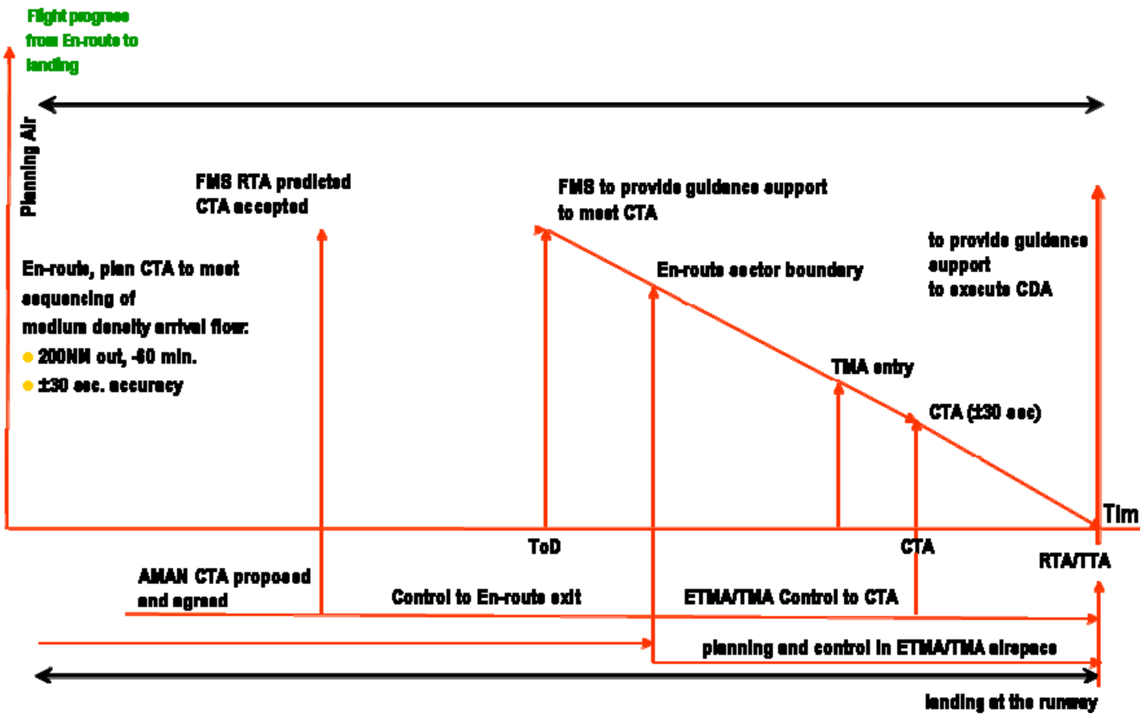

Fig. 1 Overview of operational concept

It should be noted that any controller may issue speed, heading or altitude instructions at all times to achieve a safe operation of flight.

In addition to the nominal flights operating on a CTA clearance, the operational concept and support tools also considered handling of other traffic not operating on a time constraint on their own for various reasons. In addition, the concept and system should also be robust to disturbances in the traffic flow.

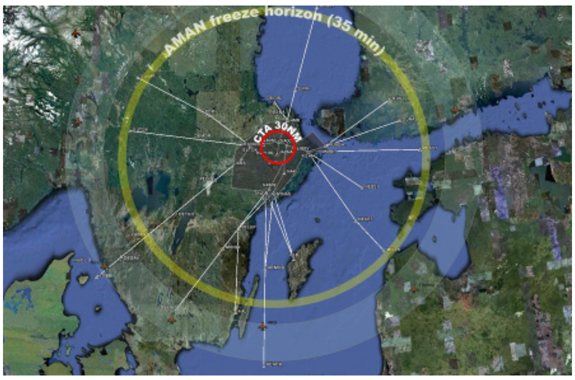

Fig. 2 Scope of arrival management at Arlanda airport

2.1 Non-CTA based arrivals

In reality there will always be a percentage of the inbound traffic that will not be able to comply with a CTA clearance, e.q. due to onboard equipment limitations or due to aircraft performance (too early/late to achieve). In such cases, the ACC controller will continue to give conventional instructions to achieve the target time over the CTA waypoint. However, to support the controller in achieving the planned time over the CTA point with increased accuracy, additional system support is provided by means of time to loose or gain for that flight.

2.2 Short flights

Ideally, the landing sequence planning will be scheduled with all inbound flights becoming active in the AMAN planning system at cruise altitude. However, in reality special handling will be necessary for short flights with flight times at or around the AMAN planning horizon.

The en-route and arrival times of such flights can only be determined with sufficient accuracy after becoming airborne. This uncertainty will also affect final sequence planning of those arrivals just before or after these flights.

Within the developed concept, short flights are taken into the planning before take-off with a provisional arrival time slot, which is used to coordinate a target take-off time before departure.

3 Concept evaluation

To evaluate the feasibility and performance of the concept on the various operational aspects a series of real time simulations were prepared. Following extensive preparations and testing, ATC simulator evaluations were carried out during two weeks in Malmö and Amsterdam in 2010 with the participation of active controllers from Stockholm ATC. For the ATC evaluations, the NARSIM ATC simulation platform was used configured with en-route and terminal airspace around Stockholm Arlanda airport. The DLR developed TrafficSim was used to generate air traffic able to accurately fly time-based CDA approaches.

3.1 Airspace and routes

The scope of the arrival management process was already indicated in fig. 2. In reality this scope surpasses multiple ATC en-route sectors, in particular to the East with the neighboring Finnish airspace. For the assignment of arrival time constraints this will normally require coordination. However for evaluation of the concept this was not regarded essential and not taken into account. The simulated en-route control sectors were therefore enlarged to encompass the entire CTA allocation process.

A single landing runway configuration was simulated at Stockholm Arlanda, resulting in using runway 19L for arriving traffic and 19R for departures. In addition, for traffic in and out of nearby Bromma airport, the runway in use for both take-off and landing was runway 12. The standard instrument departure (SID) routes were used as officially published, although with a modification to the initial SID altitude.

Draft P-RNAV and RNP based standard arrival routes to runway 19L were designed for the present concept evaluation, since at present no published RNAV arrival routes exist for this runway. In addition, the special CTA control waypoints at 30NM were added to the procedure. Fig. 3 provides an overview of the final version of the arrival routes. Note that either the P-RNAV or RNP based arrival routes were used, not simultaneously.

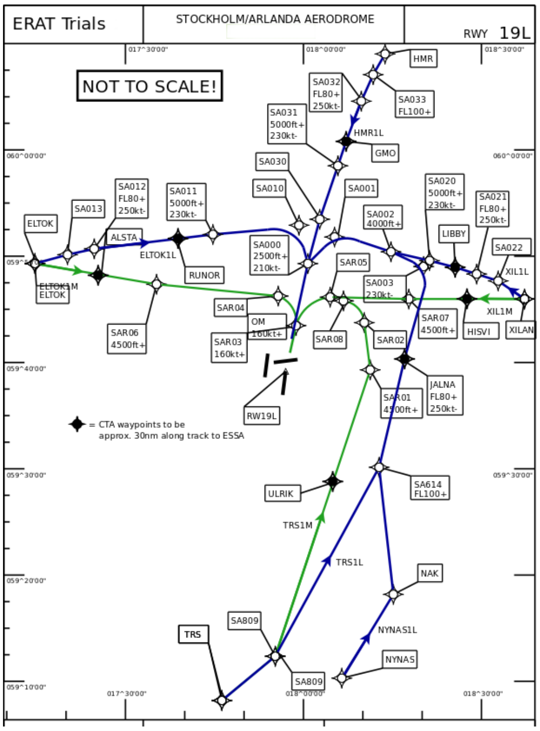

Fig. 3 Overview of P-RNAV and RNP arrival procedures in the Stockholm Arlanda terminal area

No alternations were made to the route structure outside the Stockholm terminal area for accommodating the RNAV STARs.

3.2 ATC working positions

The Controller Working Positions for area and approach control resembled those currently used at Arlanda, however with specific adaptations for the concept evaluations. Six controller working positions were prepared for the following roles:

- APP West executive controller
- APP East executive controller
- APP final director
- Approach coordinator
- ACC executive controller sector 3 (W)
- ACC executive controller sector 1 (E)

A number of actual en-route airspace sectors were combined to reduce the number of controllers required for the simulation. While this could result in a higher workload than usual for these positions, this was compensated by using appropriate traffic samples for these sectors.

Rotation of the participating controllers was applied, when applicable, to collect opinions of the concept from different participants' view points. It was expected that familiarisation with the traffic samples would also be minimised as controllers were rotated.

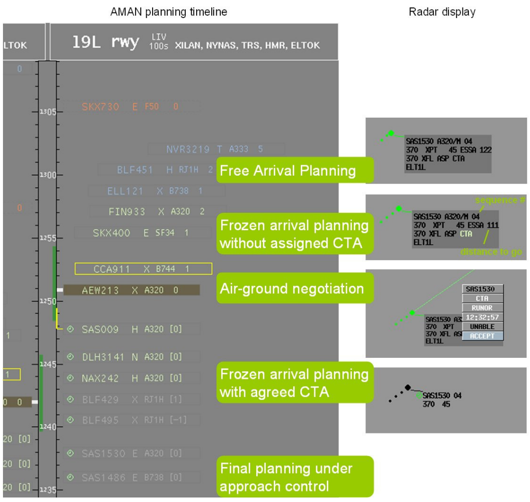

Fig. 4 Integrated Controller Working Position

In addition to the "normal" radar screens showing traffic for the relevant control sectors, an Arrival Sequence window was also available to the controllers. This presented the planned arrival sequence by means of a "time-line" with aircraft labels. In addition, this sequence and time information was also available on the radar screens in the aircraft label or on mouse-over as shown in fig. 4.

3.3 Experimental factors

To make a validated comparison between conventional and time based operations, the following conditions were compared:

- A baseline, reference condition reflecting present day operations
- Time based CDA concept with P-RNAV based arrival routes
- Time based CDA concept with shorter RNP based arrival routes

The time based CDA operations with CTA point at 30NM were supported by enhanced AMAN, and conventional speed control and vectoring as necessary.

The following factors were randomised over the different validation runs

- Traffic sample
- Wind condition
- Controller seating

The simulated traffic scenarios consisted of both inbound and outbound traffic for Arlanda including short flights, flights to/from nearby Bromma airport as well as overflying en-route traffic. The amount of traffic into Arlanda was set for a medium-high landing rate.

4 Results

During the two weeks of real time ATC simulations in total 27 measured evaluation runs were made. The first week of evaluation run (RTS1) was carried out at LFV Malmö in June 2010. A second week of extensive simulations (RTS2) was completed in September 2010 at NLR in Amsterdam. Feedback and comments received during the RTS1 sessions were incorporated in the overall simulation setup, support tools and traffic samples. In addition, the second series also included the evaluation of RNP arrival routes, which provided a further reduction in track miles compared to the P-RNAV based STARs which are more comparable to present day vectored tracks.

During and after each run subjective assessments, data logging and observations were recorded. Following each run direct feedback and comments were given by the participating controllers and pilots.

4.1 CDA arrival profiles flown

A direct indication of the feasibility of the developed concept is the number of successfully completed CDA approaches during the different experimental conditions.

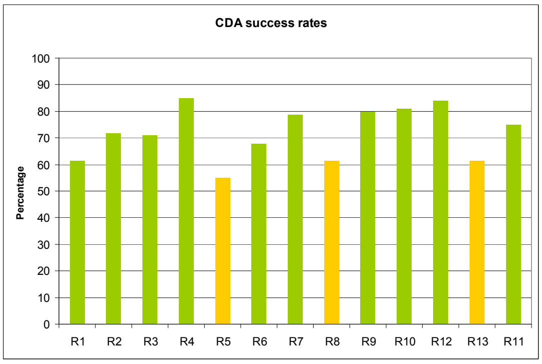

Fig. 5 comparing CDA success rate between baseline and time based concept

Fig. 5 provides an overview of successfully completed CDA's from top-of-descent to landing observed during the first week of evaluation sessions (RTS1). Clearly visible is the fact that the time based CDA concept (green) shows a marked improvement compared to the baseline situation, where already good score is achieved by the controllers using conventional operations (yellow).

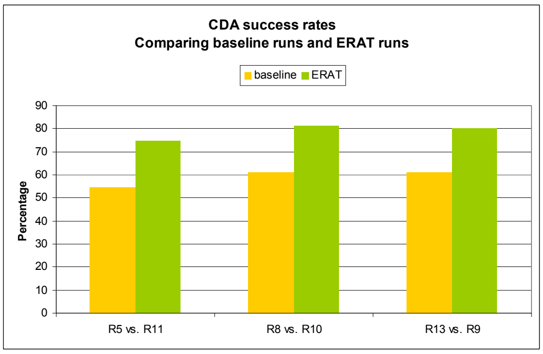

Fig. 6 comparing CDA success rate between baseline and ERAT time based concept (comparable runs)

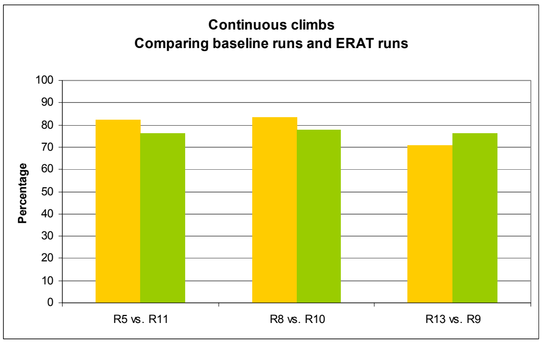

Fig. 7 Amount of continuous climb departures

Focusing within the overall results on true comparable runs with identical initial conditions in traffic and weather, the figures 6 and 7 show a clear increase in the amount of CDA's without significantly impacting the efficiency of aircraft departures.

4.2 Workload and Situation Awareness

While the definite increase in the amount of completed CDA profiles could be noted, the delegation of 4D trajectory control to arriving aircraft to achieve the target time did not appear to negatively affect the workload of the controllers. During the simulations, through a pop-up menu on a separate touch screen, controllers were asked every few minutes to give a self assessment of their current workload. Averaged results are indicated in figure 8 for the approach controllers. The comparison does not show significant differences with the baseline situation. Similar results were also obtained from the en-route controllers.

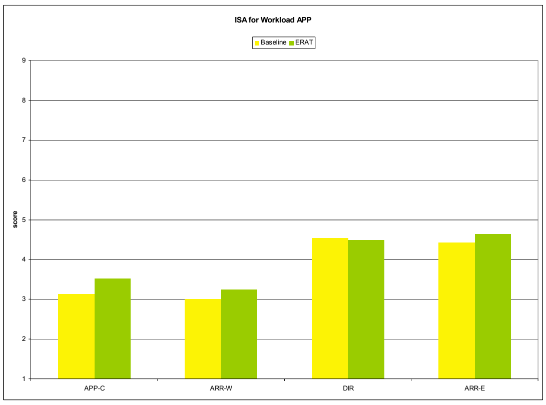

Fig. 8 Instantaneous Self Assessment of Workload experienced by APP Controllers

During the post-run questionnaires the ATC controllers were requested to provide feedback on the perceived situation awareness (SA), ref. [9]. The resulting SA scores are shown in figure 9, which do not show significant differences compared to the baseline situation (yellow).

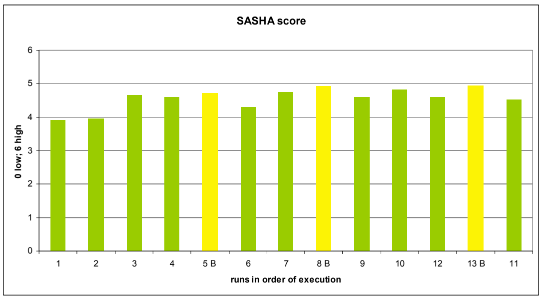

Fig. 9 Average SASHA score for each run (RTS1)

Nevertheless, the en-route controllers sometimes noted difficulty to maintain situation awareness of flights that received a CTA time clearance. It was sometimes difficult to estimate the applied FMS speed strategy, in particular in relation to surrounding other traffic.

4.3 Handling of short flights

Apart from evaluating the feasibility of the time based CDA concept, special interest went to developing procedures for better handling of short flights, with flight times of 25-40 minutes, which occur on a regular basis at Arlanda. The short flights are often operated by turboprop aircraft, which also adds an additional challenge in handling within the more homogeneous arrival flow of jet traffic.

Since take-offs will not be performed with the same accuracy as is achieved for CTA time constraints when already in flight, planning the final landing sequence around such a short flight required special coordination. The flights were sequenced in advance using preliminary arrival slots and target take-off times.

Although sequencing uncertainty remained until initial climb, the flexibility of the operation proved to be sufficient to deal with short flights and turboprop behaviour.

4.4 RNP based arrivals

Given the promising results obtained during RTS1 when operating on P-RNAV STARs that proved to be well compatible with vectoring, a step ahead was made to evaluate shorter RNP based STARs during the second evaluation in RTS2. While the P-RNAV STARs mixed very well with vectoring when necessary, these also required relatively long 10NM final approach. Use of RNP based STARs with a shorter 5NM final approach should bring additional efficiency due to reduced overall track miles to fly.

Results with the (limited) amount of runs with RNP approaches showed that the number of successful CDAs was lower compared to the more standard P-RNAV based CDA routes using the ERAT concept. Analysis showed that aircraft were vectored more often, in particular at lower altitudes. In hindsight, the amount of dedicated training of the RNP runs should have been more and a definite learning curve was visible during the trials. It is expected that better results are possible with further RNP STAR and SID route refinements as well as more operational experience of both pilots and controllers. Nevertheless, based on simulation results it was expected that a landing throughput of up to 30 per hour should be feasible when using RNP STARS, slightly lower compared to the regular P-RNAV STARs.

5 Concluding remarks

Results clearly indicated that the developed time based CDA concept with the CTA point at 30NM is well feasible with the offered medium traffic density of around 32 landings per hour with higher temporary peaks. About 20% more CDA's were flown using the P-RNAV arrivals with the time based concept compared to conventional operating procedures during the experiment baseline conditions.

In addition, the operation with RNP arrivals appears to yield additional efficiency in terms of fuel consumption. Given the limited amount of familiarisation, results are promising and the concept with shorter RNP routes is considered feasible in medium traffic density

The experiences gained with the real-time ATC simulations have considerably supported the validation of the time based CDA concept at Stockholm Arlanda and improved the concept as well as supporting technology. The knowledge and experience obtained will be applicable to other airports to profit from time-based CDAs in daily practice.

Acknowledgements

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