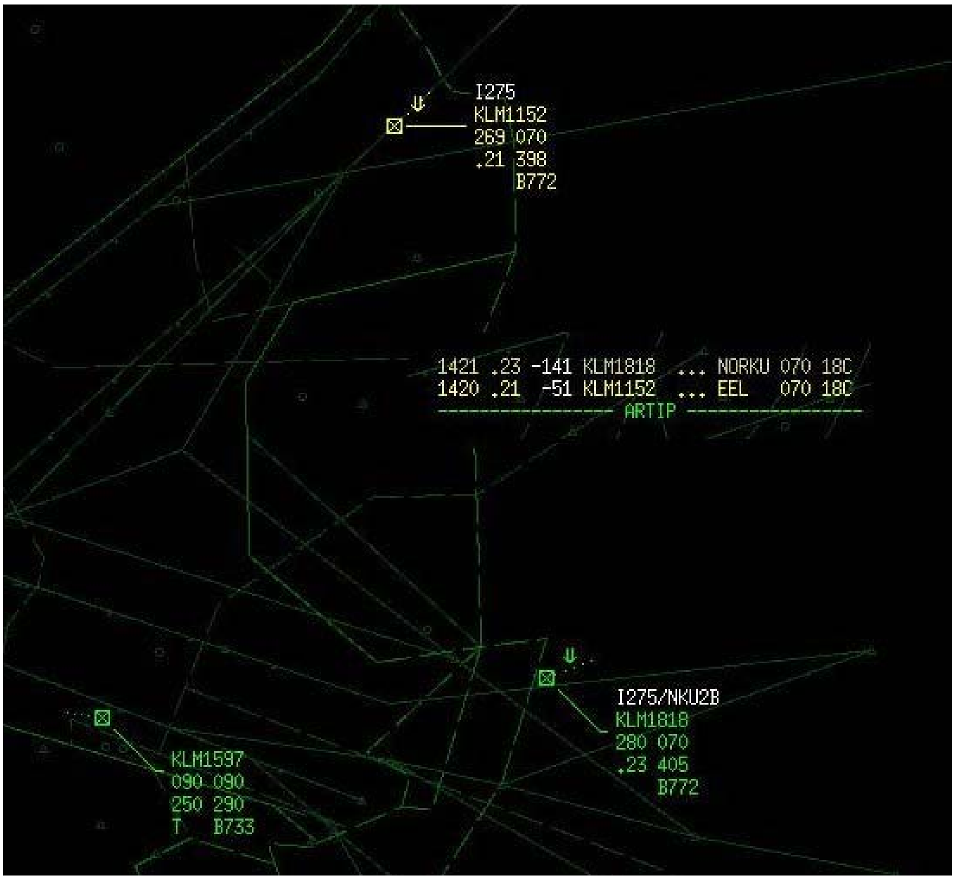
Concept of Operations (CONOPS)

Speed And Route Advisor (SARA)



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Summary

Current Situation and Rationale for Change

For inbound traffic to Amsterdam Schiphol Airport LVNL currently employs a system of inbound planning which provides controllers with the Expected Approach Time (EAT) at which traffic should be delivered at the Initial Approach Fix (IAF). Current transfer agreements between Amsterdam Area Control (ACC) and Schiphol Approach Control (APP) require a delivery accuracy of plus or minus 2 minutes at the IAF. APP uses radar vectoring in the Schiphol Terminal Control Area (TMA) to absorb the remaining inaccuracies.

LVNL plans to introduce fixed arrival routes in the Schiphol TMA for environmental and predictability reasons. The resulting reduction in complexity could yield a higher total capacity (movements/hour) of the TMA. While beneficial in other ways, this change is expected to reduce the control flexibility available to APP controllers to manage traffic in their airspace. As a result, traffic must be delivered at the IAF more accurately.

To be able to deliver traffic at the IAF with a higher degree of accuracy, LVNL is planning to support controllers by introducing a Speed And Route Advisor (SARA). It will be designed to support the controllers in delivering inbound traffic at the IAF to a degree of accuracy that enables the use of the aforementioned fixed routes in the Schiphol TMA. In the LVNL ATM System Strategy a margin of less than plus or minus 30 seconds instead of the present day margin of plus or minus 2 minutes is suggested.

Concepts for SARA

SARA will provide a speed change and, if required, a route deviation for each individual flight. In order to compute a speed and/or route, SARA requires the EAT and the expected flight trajectory that is used to calculate the estimated time over IAF. The EAT is supplied by the function ‘inbound planning’ (IBP) and the expected flight trajectory by the function ‘trajectory prediction’ (TP). The results of these calculations are presented to the controller via the user interface. Speed and route proposals will be passed to the flight as instructions; conformance with the instructions will cause the flight to meet the EAT within required accuracy bounds. SARA will monitor the flight and give a new advice if required.

Starting from a given basic concept, three operational concepts have been defined:

- Concept 1 - Speed only
- Concept 2 - Speed and, if required, static route
- Concept 3 - Conflict-free speed and, if required, dynamic route

The distinguishing feature between the concepts is the type of advice generated by SARA. The first concept – speed only – elaborates on the current working method. The second concept adds the possibility to delay or advance the flight by using an alternative – pre-determined and published – route segment. The third concept is the most advanced concept. In addition to a speed, SARA could issue a dynamic route segment, i.e. a tactically determined route segment within a strategically determined airspace block. For this concept the availability of a conflict management tool is required, as is the use of data link to communicate the instructions to the aircraft.

For all concepts the moment from which SARA will start generating advisories for a flight is determined by the SARA Horizon. The location of the SARA Horizon influences the amount of deviation from the inbound planning that can be absorbed using the advisories. For SARA to be able to generate an accurate advisory, a stable EAT has to be known for a flight so the IBP (and therefore also TP) should be active before the SARA Horizon.

Use of a SARA Horizon that is located before Top of Descent (TOD) of a flight is preferred for reason of predictability, stability, “control power” and related accuracy, together with environmental and economical benefits. With the limited airspace that is available in Amsterdam FIR, having the SARA Horizon before TOD, this automatically results in the involvement of adjacent centres.

Controllers are not obliged to comply with SARA advisories; however, in normal operations it is expected that controllers will issue clearances and instructions based on the advisories as and when they are displayed. Initially, SARA advisories will be given by radiotelephony to the flight. SARA advisories may be presented to the flight crew via data link communication, something that is required for the implementation of concept 3.

Benefits

All concepts of SARA are expected to enhance the predictability of the ATM system by assisting the controller in delivering traffic at the IAF with a higher degree of accuracy than in today’s operation.

The SARA concepts are also expected to decrease overall controller workload by reducing the number of tactical interventions. SARA should also enhance flight efficiency by allowing aircraft systems to calculate descent trajectories prior to TOD, trajectories that can then be executed accurately and economically. These efficient trajectories will also lead to less emissions and lower noise impact. An additional advantage for airlines and air passengers is the increased predictability that SARA will deliver.

Conclusions and Recommendations

Concept 3 (Conflict-free speed and, if required, dynamic route) is expected to have the best capabilities to absorb deviations from the planning. Moreover, delivery at the IAF is likely the most accurate, and the concept is estimated to have the largest positive impact on the workload of the controller. Concept 3 would therefore the most promising concept to develop further for direct implementation.

However, implementation of SARA also requires changes to the controllers’ expertise (the human factor), technical systems and procedures (with all three developed concepts). The complexity of implementation for concept 3 is significant making it impossible to enable operational use in near term. Although concept 3 is expected to give the best performance results, if implementation of SARA is required in the near future, using concepts 1 (speed only) and 2 (speed and, if required static route) to create a stepwise implementation is more suitable.

Therefore, a stepwise implementation of SARA is recommended. This approach will also allow for the required technological developments to take place stepwise. The results of planned real-time experiments and the operational trial should be used to decide on the first implementation step of SARA. Meanwhile preparations for the future implementation of concept 3 should be started.

Controllers can adapt to the new working procedures more gradually while already producing more predictable and stable traffic flows. Lessons learned from practical experience can be used in the next implementation step.

Contents

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1 Introduction

1.1 The project

1.1.1 Assignment

This concept of operations (CONOPS) is produced as part of LVNL's project 1557 'Speed And Route Advisor' (SARA). The SARA project – a study phase – has been initiated by LVNL and defined in project plan P1557 'Speed And Route Advisor (SARA)'. [Project Plan]

The project is being carried out under the flag of the Knowledge and Development Centre (KDC) in a collaborative effort of LVNL and KLM (both participating in the KDC), Eurocontrol's Maastricht Upper Area Control Centre (MUAC) and the Boeing Company.

The LVNL Strategy Co-ordination Team (Stratcor) commissioned the KDC to execute a study phase and produce a decision document aiming at the implementation of a Speed And Route Advisor (SARA) as an integral part of LVNL's AAA-system in the medium term.

The idea of the SARA-function is to realize – for traffic inbound to Amsterdam Airport Schiphol – greater accuracy of the planned expected approach times (EAT) at the initial approach fixes (IAF) by issuing timely advice on speed and/or route to (upper) area controllers. Also, it implicitly realizes a greater accuracy at the runway threshold.

The results of the SARA development are reported in various documents:

- A CONOPS describing the required functionality and performance of SARA. See for details section 1.2.
- A report on the effects of SARA-embedded operation with regard to safety, efficiency and environmental impact, including an indication of the feasibility and benefits of SARA implementation and an assessment of the acceptance risks (acceptance by controllers). The Dutch term used inside LVNL for such a report is VEMER (VEM-effectenrapportage).
- An analysis of the legal consequences of working with SARA (e.g. of inter-centre co-ordination). The Dutch term used inside LVNL for such a report is JER (juridische-effectenrapportage).
- A plan for the development and implementation of an operational version of SARA in the AAA-system. (The implementation itself falls outside the scope of this project.)

Considering the innovative character of the SARA development, the CONOPS is validated by means of prototype development and testing.

Outside the scope of the SARA project are the supporting functions needed by SARA to function: improved trajectory prediction (TP), improved inbound planning (IBP) and conflict management (CM). The SARA project will limit itself to the definition of SARA-specific requirements for the development of these functions.

1.1.2 Background

Throughout Europe ANSP's have difficulty in satisfying new requirements in the areas of increased airline efficiency and reduced environmental impact. The SESAR project has been defined by the European Commission to migrate to a new European ATM concept based on predictability of flight operations and optimization of airline operations.

Even without the new efficiency and environmental requirements European ANSP's have difficulty training sufficient new controllers for the current operations. More predictable operation of flights therefore is called for by ANSP's as a means of reducing controller workload and to make for a stable ATM environment.

LVNL has adopted an ATM System Strategy to structure and plan the required implementation activities. The guiding principles behind this strategy are that the future ATM system should be simple, stable and predictable. These guiding principles, which are completely in line with the European SESAR Concept of Operations, have been detailed in the Strategy in evolutionary building blocks to develop the ATM system within a scope of approximately seven years.

One of the areas where the current variability of flight operation is strongly felt is in Schiphol's busy terminal control area (TMA). Today aircraft do not operate on the basis of accurate time constraints. Therefore area controllers and approach controllers have to manage poorly timed inbound traffic streams into accurately timed traffic sequences to Schiphol's runways. One of the main development steps in LVNL's strategy is the transition to metered traffic streams by influencing traffic further out to meet an accurate pre-planned arrival time. A metered traffic stream will contribute to the achievement of stability, predictability and simplicity. This will allow a step-wise introduction of conflict-free fixed routes in the terminal area (reducing environmental impact by concentrating the noise), and will in the end also facilitate the use of low noise and low emissions operations.

The implementation of fixed arrival routes in the terminal area is a particular challenge which LVNL faces in the upcoming years. On the one hand these routes are necessary in the transition to the SESAR concept, where it is forecasted aircraft will need to know the number of track miles to be flown down to the runway in order to plan an optimized and predictable descent. For the growth of Schiphol however it is also necessary to define arrival routes as part of the strategy to minimize annoyance to the surrounding communities. Fixed arrival routes, however are not only a solution, they also have the side-effect that they limit the controller's ability to manage disturbances. Thus fixed arrival routes, which are needed to make inbound traffic more predictable, in themselves impose requirements on the timing accuracy and predictability of inbound traffic.

The challenge for LVNL is to develop means to increase the timing accuracy and predictability of inbound traffic independent of the implementation of fixed arrival routes. SARA has been defined as the implementation step that will increase the timing accuracy and predictability of inbound traffic at Schiphol within the System Strategy timeframe.

The SARA solution as described in LVNL's ATM System Strategy is, in fact, similar to NASA's En-route Descent Advisor (EDA), a function set which has been demonstrated at San Francisco, and is consistent with Boeing's concept of tailored arrivals. [EDA] LVNL has chosen to further develop an existing, EDA-like, function. As such the goal of the project is really to make a translation of the concepts underlying EDA and tailored arrivals to the Dutch situation and to demonstrate the feasibility thereof.

1.1.3 The challenge of SARA

The introduction of fixed arrival routes in the terminal area will reduce the flexibility that is intrinsic to current day operations. This flexibility relies rely on the use of radar vectoring and is needed to cope with bunches in traffic flows. To overcome this lack of flexibility in the terminal area, Amsterdam ACC will be required to deliver traffic to the Schiphol TMA more accurately, at pre-planned times. In the LVNL ATM System Strategy a margin smaller than plus or minus 30 seconds instead of the present day margin of plus or minus 2 minutes is suggested. Research in the area of defining timing accuracy required to enable the implementation of fixed arrival routes in the TMA is not yet complete. However, the SARA project is using the 30 second accuracy proposal from the strategy as a timing performance requirements baseline.

To meet the objective stated above, LVNL's ATM System Strategy identifies the need for a speed and/or route advisor (SARA), a AAA-system function, generating advice on speed and/or route to be flown by the aircraft for the controller. The SARA-generated advice shall assist area controllers in causing inbound flights to meet planned arrival times at the IAF (at the boundary of the TMA) accurately. Note that although the foreseen introduction of fixed arrival routes in the TMA was an initiator for the SARA project, the presence of these fixed arrival routes is not a requirement for the introduction of SARA.

To deliver flights to the terminal control area at preplanned times accurately it will be necessary to start planning and influencing traffic flows further upstream. This means that SARA must be able to provide advisories for aircraft both within and outside the Amsterdam FIR. Ideally, from the airline perspective, the SARA advice to meet a particular arrival time would be issued well before the aircraft reaches its top of descent (TOD). The starting point of the scope is based on the assumption that speed and/or route instructions should be given to pilots well before the descent starts in order to give the onboard flight management system (FMS) adequate time to finish descent path calculations. This foreseen scope of the SARA function implies required co-ordination with adjacent centers.

The ambition for a full-functional SARA would be to enable optimized descent profiles into Schiphol (continuous descent approaches) for better flight efficiency (and low emission) and to enable low noise approaches that reduce environmental impact for the communities around Schiphol.

1.1.4 Operational context

In general, inbound Schiphol traffic flows from the area of responsibility (AoR) of an adjacent centre via an Amsterdam ACC-controlled area (sector) to the Schiphol APP-controlled Schiphol TMA. The ACC controllers transfer inbound traffic to the Schiphol APP controller at the initial approach fix (IAF) located near the boundary between the ACC sector and the Schiphol TMA.

Figure 1.1 Traffic flow diagram

In figure 1.1, the traffic flows from left to right. The planning of the inbound flows, however, is from right to left. The inbound flow is planned by assigning a flight to a particular runway and building a landing sequence based on the landing interval per runway. From this landing slot for each flight a time is calculated at which the flight is expected to enter the terminal area at the IAF. This expected approach time (EAT) is calculated 12 minutes before the flight is expected to arrive over the IAF. The EAT is used by Amsterdam ACC as a target time to deliver inbound traffic to the Schiphol TMA. Current procedures require ACC to deliver an inbound flight to Schiphol within ± 2 minutes of the EAT. In addition there are restrictions at the IAF on flight level (below flight level 100, descending to flight level 70) and speed (maximum 250 knots indicated) for flights that are transferred from ACC to APP.

1.1.5 Related initiatives and concepts

The SARA project is concerned with the tactical cross-border planning, co-ordination and execution of inbound flights. As such, the SARA project is related to a number of initiatives and projects such as Traffic Management, Arrival Management Info Sharing, BridgeT and Optimal. But it can also be linked to the European ATM target concept SESAR and Global ATM initiatives. Establishing time-based control is a step towards implementation of the SESAR concept.

1.2 This CONOPS

The CONOPS is a major source of information for the decision document; it addresses systems, human factors and procedures.

During prototype development and testing, real-time simulations (RTS) and an operational trial, new insights may lead to necessary changes to the SARA CONOPS. As a result, the SARA CONOPS will remain a living document.

1.2.1 Purpose

The SARA CONOPS serves the following purposes:

- The CONOPS describes the operational use of the SARA function in the ATM system to a level of detail that allows investigation of the effects of the proposed changes on safety, efficiency and environmental impact.
- The CONOPS enables all operational personnel (controllers, pilots, etc) affected by the proposed changes to understand the impact on their work, and to judge the feasibility and acceptability of the proposed changes.
- The CONOPS describes the proposed changes and the requirements for these changes in sufficient detail to allow the detailed design and implementation of the proposed changes in later phases of development.
- The CONOPS serves as a basis for prototype development.

1.2.2 Structure

The SARA CONOPS is subdivided in six chapters.

Chapters

In chapter 1, 'Introduction', an outline is given of the SARA project and the SARA CONOPS.

In chapter 2, 'Starting point', the VEM requirements, the basic SARA concept and the concept element options are presented. The requirements and the basic concept are based mainly on the assignment (in which a solution is given) and the objective.

Chapter 3, 'Evaluation of concept element options', gives an evaluation of a number of concept element options. The approved options will be used in chapter 4 as building blocks for the developed concepts.

In chapter 4, 'Operational concepts', a general description is given of the concepts of operations based on the solutions described in chapter 3. These concepts are then elaborated on in required changes to procedures, systems, controller skills and interfaces with external systems and examined in the context of several nominal and non-nominal scenarios.

Chapter 5 'Evaluation' presents an evaluation of the three concepts based on the requirements identified in chapter 2

Chapter 6 ‘Conclusions and recommendations’ presents the conclusions based on the evaluation, and recommendations with regard to the SARA project itself and the follow-up based on the conclusions.

Underlying method

The method underlying the structure of this CONOPS is depicted in the illustration below:

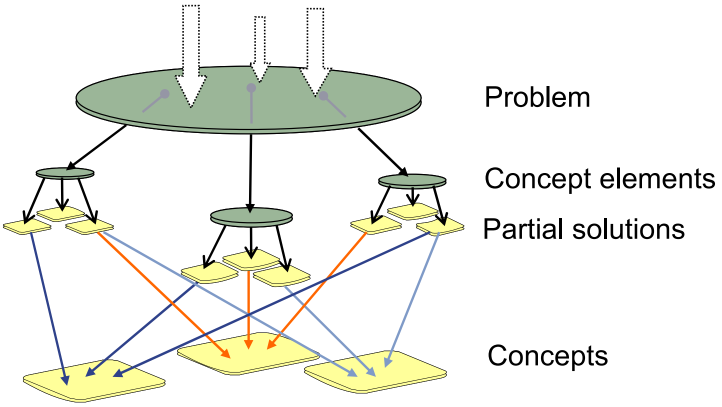

Figure 1.2 CONOPS method

The first step is to define the problem in terms of requirements and concept elements (chapter 2). The second step is to evaluate solutions for the identified concept elements (chapter 3). The third step is to integrate the selected (partial) solutions into operational concepts (chapter 4). Thereafter the operational concepts are evaluated (chapter 5). With all information available, conclusions and recommendations can be given in chapter 6.

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2 Starting point

In the Schiphol TMA, flights inbound Schiphol are currently vectored onto the final approach. This procedure has reached its limits in the framework of safety, efficiency and environment (VEM). The envisaged method of working – based on fixed arrival routes in the Schiphol TMA – requires flights to be delivered at the IAF (TMA entry point) on time (close to the planned EAT).

As stated in chapter 1, the given (conceptual) solution for this requirement is a Speed And Route Advisor (SARA), a AAA-function providing speed and/or route advice to the controllers involved in handling inbound Schiphol flights before the IAF. The SARA-generated speed and/or route advice should assist the controllers in making a flight comply with the EAT more accurately.

In this chapter the starting points for composing operational SARA concepts are outlined. In this context three considerations have been made:

- Which requirements must be met by SARA concepts?
- What exactly is the basic concept underlying the given solution?
- How to arrive at more developed concepts?

2.1 SARA concept requirements

SARA-related requirements can be deduced from the assignment and/or the objective, from the ATM system vision and strategy, and from relevant shortcomings of the current ATM-system.

Assignment and objective

From the assignment [Assignment] and the objective performance-related requirements can be deduced.

SARA should assist the controller in delivering flights at the IAF more accurately than in the current ATM-system. In the current ATM system and with the current working methods a margin of ± 2 minutes is tolerated in delivering inbound traffic at the IAF. The requirement has been specified in the assignment: in establishing time-based control, the future ATM system requires a delivery accuracy of less than 30 seconds from the EAT at the IAF for 99% of inbound traffic.

With regard to the other efficiency parameters (e.g. capacity) and the performance criteria safety and environmental impact, the impact of SARA based operations shall be neutral or better.

ATM system vision and strategy

Any change to LVNL's ATM system should contribute to the realization of the ATM system strategy (time horizon up to five years from now) and the ATM system vision (beyond five years). The principle underlying LVNL's ATM system vision and strategy is that the ATM system should be simplified, particularly because workload of controllers is at its limits. From this fact two more requirements can be deduced:

- the workload of the controllers shall not increase;
- SARA shall support the controller in creating a more predictable and stable traffic flow.

Relevant shortcomings of the current ATM system

Relevant shortcomings can be derived by comparing, within the scope of this project, the current and desired ATM system. The result of this shortcoming analyses will be a number of SARA-related ATM system requirements. The shortcoming analysis and the resulting requirements are, however, not given in this chapter but in chapter 4, 'Operational concepts' (in the 'Required changes' sections). The reasons are:

- Shortcomings may differ per concept.
- Only from a concept in which some detail is included significant shortcomings can be deduced.

- The resulting requirements are mainly design requirements for systems, procedures and human factors.

Overview of VEM requirements

Efficiency requirements

- SARA-generated advice shall lead to a delivery accuracy at the IAF of less than EAT plus or minus 30 seconds (for 99% of the inbound traffic).
- Working with SARA shall not increase the workload of the controllers (although it may be slightly redistributed).
- SARA shall support the controller in creating a more predictable and stable traffic flow.
- The introduction of SARA shall not lead to a reduction in capacity.

Safety requirements

- The introduction of the envisaged changes to the operation must not lead to risks that are unacceptable or risks that normally require mitigation before operational introduction.[1]

Environmental requirements

- The introduction of SARA shall not increase the noise and emission impact of flight operations.

Conclusion

In conclusion it can be said that here, with only an assignment, an objective and a directive ATM system vision available, the number of requirements is (for the time being) limited to a number of VEM requirements.

In this CONOPS additional design requirements will emerge from the evaluation of concept element options in chapter 3 and from the determination of the developed operational concepts in chapter 4.

[1] The introduction of SARA is an enabler for the theme “Working according to plan (*Planmatiger werken*)” as described in the Masterplan [Masterplan]. The VEM objectives for SARA contribute to the VEM objectives for the theme. As such SARA is not envisaged to have an explicit safety improvement for LVNL’s ACC operations.

2.2 Basic SARA concept

SARA calculates for a particular flight a speed and/or route which the flight must utilize if it is to cross the IAF at the EAT. In order to compute a speed and/or route, SARA requires the EAT and the expected flight trajectory. Within the SARA context, a trajectory is considered to be a time sequenced series of 3D points. The EAT is supplied by the AAA-function 'inbound planning' (IBP) and the expected flight trajectory by the AAA-function 'trajectory prediction' (TP).[2]

The output of SARA, a speed and/or a route for a particular flight, must be conveyed to the controller responsible for the flight (and whose duty it is to issue instructions and clearances to pilots).

In the basic SARA concept a significant number of (functional) requirements have been implicitly incorporated.

Basic concept framework

The framework of any SARA concept – the basic SARA concept – is presented in the table below.

Actor	Input	Action	Output	Feedback
IBP (AAA)	Arriving traffic data	Feed SARA	Expected approach time (EAT)	
TP (AAA)	Aircraft state data Weather data	Feed SARA	Expected trajectory	To IBP
SARA (AAA)	EAT Expected trajectory	Generate speed and/or route	Speed and/or route	To TP
Interface SARA - controller	Speed and/or route	Convey speed and/or route	Speed and/or route	Not applicable
Controller	SARA-generated speed and/or route	Observe SARA-generated speed and/or route Instruct pilot	Instruction to pilot	To SARA
Interface controller - pilot	Instruction	Transfer instruction	Instruction	Not applicable
Pilot	Route and/or speed instruction	Confirm instruction Obey instruction	Aircraft system instruction	To controller
Aircraft	Aircraft system instruction	Act upon input	Changed speed an/or route	To TP (via SUR-systems)

Table 2.1 Basic SARA concept

Supplementary aspects of the basic SARA concept

- SARA starts calculating speeds and/or route for a particular flight when the flight is planned by IBP and is positioned within the SARA Horizon.
- The limits of the SARA Horizon will be examined in chapter 3.

[2] The trajectory prediction AAA-function predicts the future progress of an individual aircraft on the basis of the current aircraft state, expected weather conditions and models of aircraft performance and procedures. The TP is fed directly from sensors providing information on the aircraft state and weather information.

- SARA issues (new) speed and/or route advice to the controller when the gap between EAT and ETO is 30 seconds or more.[3]
- SARA stops issuing speed and/or route advice for a particular flight at a certain distance before the IAF.
- The controller utilizing SARA could be a controller at Amsterdam ACC and/or a controller at an adjacent centre.
- If the controller utilizing SARA is a controller of an adjacent centre, Amsterdam ACC will be informed about the proposal and the controller's decision.

Basic concept diagram

This basic concept presented in table 2.1 can also be presented in a diagram; see figure 2.1 below.

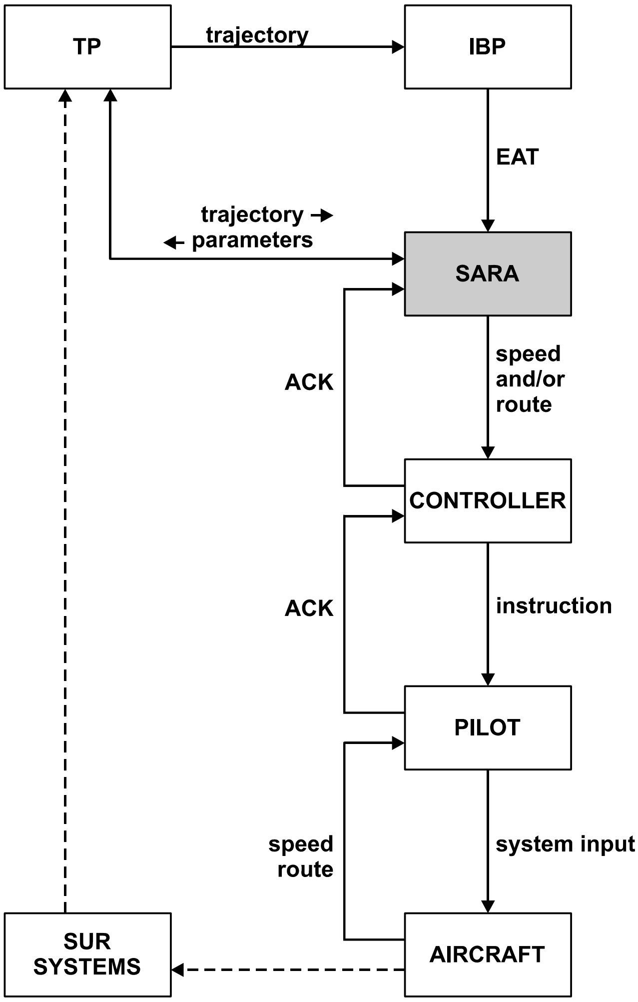

Figure 2.1 Basic SARA concept

[3] This value may be adjusted as a result of trials.

2.3 From basic SARA concept to developed SARA concepts

The basic SARA concept is a starting point for composing one or more developed SARA concepts of operation. To make developed concepts, building blocks must be defined. Building blocks are concept elements for which more than one conceptual solution can be devised.

In the table below, based on the basic concept, the concept elements which qualify for building blocks are listed per actor. For each concept element the options are given in the last column. These options are evaluated in chapter 3 of this CONOPS. The resulting concepts are discussed in chapter 4.

Actor	Concept element	Options
Speed and/or route advisor (SARA)	• First generation moment	after TOD before TOD
	• Speed output	to be executed immediately to be executed from a waypoint forward required time of arrival (RTA)
	• Route output	static routes dynamic routes
	• Speed & route output	conflict free not checked for possible conflicts
Interface between SARA and controller	• Passing the advisory to an adjacent centre	voice on-line data interchange (OLDI) internet
	Presenting the speed and/or route	stand alone HMI radar screen integrated HMI
Controller	Complying with the advice	without any assessment at controller's discretion
	Giving feedback to SARA	no feedback manually by the controller automatically
Interface between controller and pilot	Passing the instructing to the pilot	radiotelephony (RTF) data link

Table 3.2 Building blocks

Note: Possible conceptual solutions for IBP and TP fall outside the scope of this project.

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3 Evaluation of concept element options

In this chapter, the concept element options that were presented in chapter 2 are evaluated. An option can be judged positively ('possible') or negatively ('rejected'). The possible options are used as building blocks for the concepts to be composed in chapter 4.

Concept elements

Figure 3.1, depicts the generation and communication of SARA advisories schematically. In this diagram, three groups of concept elements can be identified:

- Calculating the SARA advisory
- Communicating and presenting the SARA advisory to the responsible controller
- Handling of the advisory by the responsible controller

For the calculation of the SARA advisory, the SARA function can make use of different speed and route options. If a conflict management tool is in place, the calculated advisories can be automatically de-conflicted.

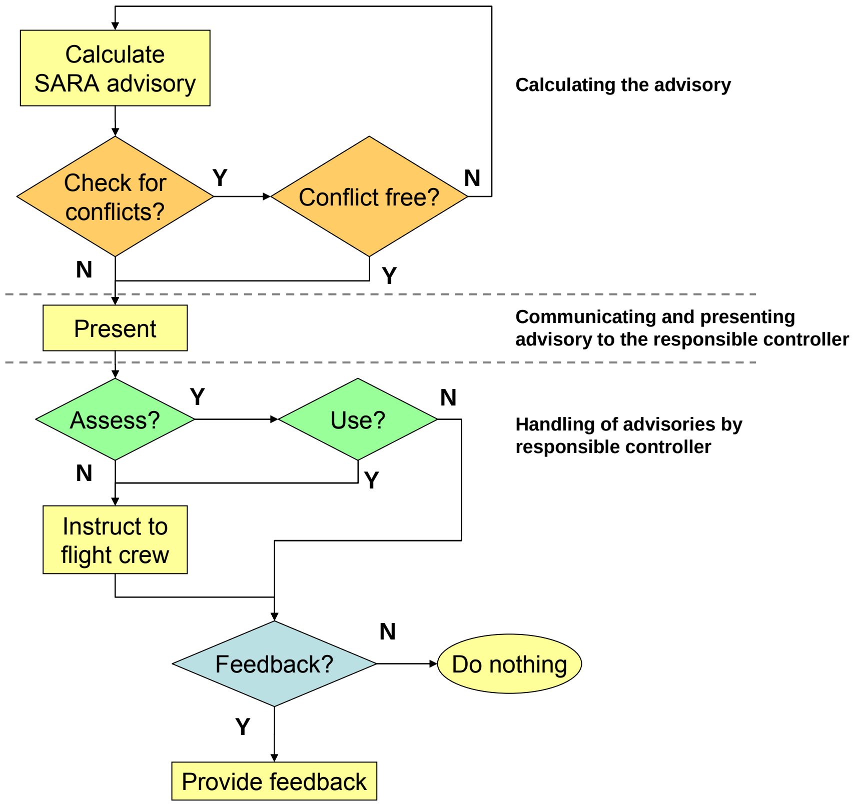

Figure 3.1 Schematic presentation of the generation, communication and handling of SARA advisories. The flow of information is sketched. In this schema, the three groups of concept elements that will be discussed in the following sections are marked.

Once generated, the advisory should be communicated and presented to the responsible controller, i.e. the controller that is responsible for instructing the flight crew with the SARA advisory. This will be the executive controller in most cases, but could be the planner controller if controller/pilot data link communication is in place. Within Amsterdam ACC, the advisory will be communicated using available system infrastructure. For communication of the advisory to the responsible controller of an adjacent centre, different options will be discussed. Next, the options for the presentation of the advisory to the responsible controller from Amsterdam ACC or an adjacent centre are evaluated.

Once presented, the controller will be able to assess the advice before instructing the flight crew. After possible assessment, he will comply with the advice, use alternative tactical means and instruct the flight accordingly, or do nothing. In all cases, feedback of the controller's actions might be given to the SARA function. Different options for providing this feedback will be discussed.

In the following sections, possible partial solutions for the different concept elements are presented and discussed.

3.1 Calculating the SARA advisory

In the inbound planning, a flight is planned to pass over the initial approach fix (IAF) at the expected approach time (EAT). A ground-based trajectory predictor (TP) is used to calculate the estimated time over IAF (ETO) using the planned route and present speed schedule as inputs. If the ETO differs from the assigned EAT, the same TP provides information to the SARA function to calculate an advisory. In this section, we discuss different options for the calculation of this SARA advisory.

A SARA advisory may consist of speed advice or a combination of speed and route. The advisory aims to absorb a certain predicted deviation (positive or negative) from the EAT. The amount of deviation that can be absorbed by a speed-only SARA advisory is a function of the remaining flight time before IAF and the available speed change. If this is not sufficient to adjust the ETO to meet the EAT, SARA will generate a route advisory that is always accompanied by a speed[4] advisory. When no route options are made available to SARA, advisories will always be speed-only.

SARA advisories are calculated for a specific flight only when a set of conditions are satisfied. The following conditions will be considered by SARA, and each can be made a variable parameter during the development phase:

- SARA Horizon: the maximum time or distance from IAF an inbound flight is located, in order to be selected for evaluating the deviation from EAT.
- Minimum deviation from EAT: only flights whose ETO's differ by more than this minimum deviation from the planned time over IAF will trigger the presentation of a SARA advisory.
- Frequency of updating advice: the frequency at which the EAT adherence of a flight is probed and evaluated for possible advice generation.
- Minimum distance from IAF: flights that are close to IAF will be excluded from the selection and no longer receive new advice. This prevents the generation of last-minute advisories that could introduce undesirable large changes in speed or route.

The value to which these parameters are set will influence the functioning of SARA. Especially the location of the SARA Horizon can have a large influence on the functionality and operation of SARA and on the available modes of operation in the aircraft. Different possibilities will be considered in the section 3.1.1 and used as a concept element in the creation of the concept.

The values that are used for the other conditional parameters should be determined based on results of e.g. real-time simulations. They should be chosen such that they create a balance in the number and frequency of the advisories generated and presented for a flight and the time accuracy that is required. Results of prototyping and operational trials could be used in determining the preferred settings.

[4] In fact a speed-only SARA advisory is also always accompanied by a route, namely the planned route of the flight for which the advisory is calculated. Since this route information will not need adjustment in these cases, only the speed is communicated as an advisory.

Besides the automatic selection of aircraft for which SARA will generate an advisory at set intervals, the controller will have the option to request an immediate advisory for a specific inbound flight. In addition, it should be possible for the controller to turn off the generation of SARA advisories for individual flights, and turn them back on if desired. Possible reasons for this might be e.g. emergencies or severe weather conditions. This setting will be valid only for the period that the selecting controller has the flight under control. This means that if a controller of an adjacent centre has turned off the generation (or displaying) of SARA advisories for a specific flight, it will be automatically turned on again when the flight comes under control of Amsterdam ACC.

Prioritizing speed and route options

The order in which speed and route options (if both are available) are used for the generation of SARA advisories is a choice that is driven by different factors. For example, if minimization of the total flown track miles is considered a basis for prioritization, speed options should be exhausted both within Amsterdam ACC and in the involved adjacent centres before using route options. If, however, it is decided that SARA should provide advisories that should be handled by Amsterdam ACC first, before involving adjacent centres, a different order will be used by SARA. The decision on how to prioritize and combine should be made and further evaluated before implementation.

Options considered for the calculation and generation of Speed And Route Advisories by SARA will be presented in the next sections after discussing the options for the SARA Horizon.

3.1.1 The location of the SARA Horizon

The location of the SARA Horizon influences the functional behaviour of SARA (the types of advisories generated) and the amount of deviation from the inbound planning that can be absorbed using the advisories. In general, for SARA to be able to generate an accurate advisory, a stable (and possibly fixed) EAT has to be known for a flight. Therefore the location of the SARA Horizon sets requirements for the IBP function; the IBP function should be active and stable before the SARA Horizon[5].

If the SARA Horizon is located far from the IAF (e.g. further than 150 NM), SARA will be able to start generating advisories relatively early for an inbound flight to Schiphol. Since the time over which the advisories can influence the flight would then be relatively long, larger deviations from the EAT could be corrected using advisories that only differ slightly from the planned speed and route schedule. It is expected that such an approach would minimize the need for using route advisories. Moreover, if the SARA Horizon lies well before TOD of an aircraft, it will allow the flight crew to enter the advisory into the FMS, thereby enabling the use of their FMS to optimize and predictably execute the flight path. This would also allow minimization of fuel burn. The predictable execution of the flight would in turn result in more accurate SARA advisories requiring less adjustments or updates. See Figure 3.2 for a schematic representation of the relationship between the SARA Horizon, stable IBP and TOD.

[5] This reasoning could just as well be used to limit the location of the SARA Horizon by using the location of the stable IBP horizon as a restrictive condition for the SARA Horizon. This would make the initial implementation of SARA less dependent on the availability of a matching IBP function but might limit the effectiveness of SARA.

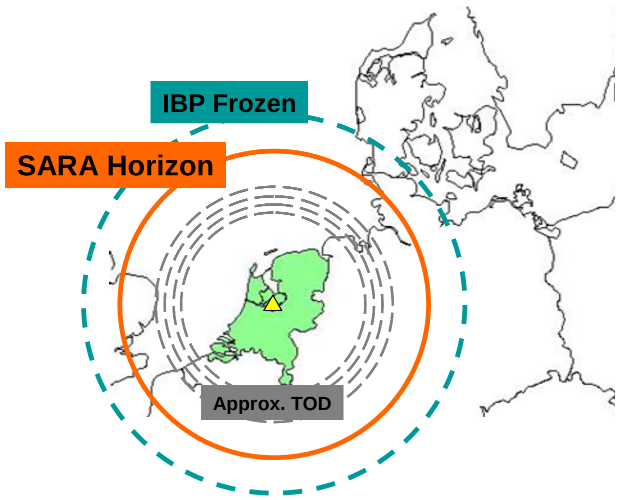

Figure 3.2 Relationship between the SARA Horizon, the location where the IBP should be frozen and the approximate location of TOD. Note that for implementation these locations do not need to be concentric circles but can be of any shape as long as the IBP is stable when the SARA Horizon begins.

Several considerations will influence the final position of the SARA Horizon. However, for use as a concept element, we will consider the position of the SARA Horizon relative to the TOD. There are two partial solutions for this concept element: the SARA Horizon located before TOD or the SARA Horizon located after TOD. Although TOD is not the same for all flights, we interpret these solutions as located before and after for all considered flights.

Conclusion

From the discussion above, it can be concluded that for the creation of a concept for the operation of SARA, both proposed solutions are possible. Use of a SARA Horizon that is located before TOD is preferred for reasons of predictability, stability and related accuracy, together with environmental and economical benefits. This solution will therefore be used in the construction of the concepts in chapter 4. With the limited airspace that is available in Amsterdam FIR, having the SARA Horizon before TOD automatically results in the involvement of adjacent centres.

In chapters 5 and 6 we will discuss the factors that might restrict the location of the SARA Horizon and the implications this has on the developed concepts.

3.1.2 Speed options

Speed advisories issued by SARA should be realistic, i.e. an aircraft has to be able to execute them. This restricts the speed instructions that can be used by SARA to the flight envelope of the specific aircraft. Moreover, the speeds that are instructed to the aircraft should also be usable by the ground-based TP to predict the ETO. For this, the TP should be able to predict the speed profile of a flight based on the intended speed instruction.

Types of speed instructions that have been considered for use with SARA are:
1. A speed that is instructed[6] by the controller and executed by the aircraft immediately.
2. A speed instructed by the controller that should be used from a waypoint on forward.
3. A speed that is calculated by the FMS of the aircraft using a Required Time of Arrival (RTA) at a certain waypoint that is instructed by the controller.

[6] The way the instruction is passed on to the flight crew is discussed in section 3.3.3

The above listed types of speed instructions are discussed, and an indication of the implications they have on predictability of the execution by the aircraft is given. This in turn has an impact on the usability of SARA in calculating an accurate advisory that allows the aircraft to meet the required EAT.

The first type of speed instruction considered is one that will be executed by the aircraft immediately after receiving the instruction. This largely enhances the predictability of the speeds that will be flown by the aircraft resulting in accurate time over IAF. Also, this type of speed instruction can be executed by all modern aircraft in all phases of the flight. It is therefore a type of speed instruction that is suitable for use with SARA. The predictable moment of execution by the aircraft will not have a negative impact on the situational awareness of the executive controller.

When instructing the flight crew to fly a certain speed from a waypoint forward, the predictability of the actual flown speeds is limited. Speeds flown prior to the constrained waypoint may be different from what SARA assumes. Different aircraft, having different technologies on board, will execute the instruction differently. Also, since a waypoint is needed for this type of speed instruction, the number of possible variations is limited. Depending on the location of the available waypoints, the time that the SARA advisory is able "to do its work" may be limited. Or there might not be enough waypoints to let SARA generate intermediate advisories that are needed to meet the required ETA.

For the last option, RTA, the difference in capabilities of the FMS's that are present in today's aircraft strongly limit the predictability of this type of speed instruction. Moreover, not all FMS are capable of providing speed guidance to meet a RTA after top of decent. This makes it impossible to use RTA in calculating the SARA advisory for all aircraft, in all phases of the flight. Moreover, these differences represent significant reasons for requiring a single tool in the ground system that handles all aircraft in the same way.

Conclusions for speed options

For the generation of SARA advisories, the speed instruction that is executed immediately is preferred due to the high level of predictability for the ground-based TP. This will lead to more accurate SARA advisories that enable EAT compliance. Both of the remaining options have been rejected since they do not lead to the level of predictable aircraft behaviour that is required for the generation of accurate SARA advisories. The predictable moment of execution by the aircraft of this type of speed instruction is also expected to result in improved situational awareness for the executive controller as compared to the other two options.

Which speed reference should be used?

The speed at which an aircraft is flying can be expressed using different reference units. But not all references can be used in the generation of SARA advisories. For example, the use of true air speed or ground speed for communication is not considered a viable option since the flight crew is not able to control the aircraft actively with reference to these data.

Speed references that can be used by SARA are Mach number and Calibrated Air Speed (CAS – often referred to in pilot/controller communication as 'Indicated Airspeed'). Advisories based on these speed references can be calculated accurately, the controller is able to communicate the advisory to the flight crew and the flight crew is able to execute the instruction predictably.

When flying above the crossover altitude[7], the speed of an aircraft is normally expressed in Mach numbers; below the crossover altitude, CAS is used to refer to the speed. Depending on the phase

[7] At the crossover altitude, CAS and Mach values represent the same True Air Speed value. The curves for constant CAS and constant Mach as a function of altitude intersect at this point. Above this altitude the Mach number is used to reference speeds, below this altitude CAS is used.

a flight is in at the moment SARA calculates, the resulting advisory may contain a combination of Mach and CAS. However, since the end point of the route over which SARA calculates advisories (i.e. the IAF) is located below the crossover altitude, the advisory will always contain a CAS component. A SARA advisory will therefore never contain a single Mach-only speed. More specifically:

1. For a flight that is in cruise above the crossover altitude; SARA advisory will be based on a combination of cruise Mach and descent Mach/CAS schedule
2. For a flight that is in descent above the crossover altitude; SARA advisory will be based on a descent Mach/CAS schedule
3. For a flight that is in cruise or descent below the crossover level; SARA advisory will be based on CAS

In communicating the advisories, the controllers and flight crew will use the terminology Indicated Air Speed (IAS), or 'Indicated', for CAS. The flight crew will enter the received instruction as a CAS in the automation functions of the aircraft.

For implementation, there might be reasons not to allow all possible types of advisories. Combining Mach for cruise and Mach/CAS for descent in one instruction, together with possible level constraints, might result in an undesired practise for both controllers and flight crews. Moreover, the effect a Mach-speed advisory in cruise has on the adherence to the EAT might be minimal compared to a Mach/CAS or CAS that is given in descent. This should be further evaluated in the implementation phase of SARA, aiming for a uniform solution for all involved adjacent centres.

3.1.3 Route options

For the calculation of a route advisory, SARA also calculates the associated speed needed to adjust for the deviation from EAT. This required speed will always be issued together with the route advisory.

Route advisories can only be defined within the airspace that is available to SARA. SARA should always be able to take into account airspace available, i.e. in periods of reduced as well as non-reduced coordination, in order to make optimal use of the available airspace when applicable.

Two categories of route adjustments to be used in a route advice are envisaged:
- Static route adjustments
- Dynamic route adjustments

Partial solutions for both categories will be discussed in the next sections.

Static route adjustments

A static route adjustment is a pre-defined route adjustment in the form of published routes and/or published waypoints. In normal practise, use of a static route allows easy reference by aircrew and controllers when requesting, assigning, and confirming complex or lengthy route clearances with e.g. multiple lateral points and altitude and speed constraints. Formal descriptions of the routes, along with short names for rapid reference, are defined and published by ANSP's in the AIP. These descriptions and names are then generally stored in airborne and ground based navigational databases for reference by aircrew and controllers respectively, and by their supporting automation systems.

Such static route definitions are used to help ensure that both the aircraft and the ground systems are using the same route intent. For SARA, the routes provide the ground-based TP with an accurate track length from which the ETO for a flight can be calculated to determine deviation from the assigned EAT.

The static route definitions are used as a "solution set" of pre-defined arrival routes, or arrival route segments. SARA uses one or more of the route segments from the static solution set to adjust the flight's ETO at the IAF. As long as an integrated data link between the airborne and ground systems is not present for all aircraft, these solution sets need to be available in both the airborne and ground systems.

If an integrated air/ground data link is available, only the ground system needs to have a stored representation of the static route(s). As long as the ground system knows the static route, it can uplink that definition of the route to data-link-equipped aircraft rather than referring to a stored name and definition. This technique can reduce the pressure on airborne navigational databases and allow ground systems to adjust the static route descriptions in their system based on lessons learned and on new operational needs without being required to go through a formal publication process.

Independent of the availability of an integrated air/ground data link, different types of static route adjustments are possible for use by SARA. They will be discussed below.

A: Default route and one direct route

This type of static route adjustment consists of one default route and one direct route (see Figure 3.3). Waypoints are published points and the routes are named.

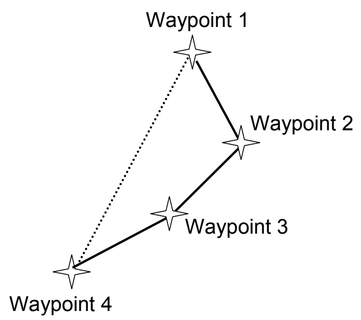

Figure 3.3 Sketch of a default (solid line) and alternative direct route (dotted line)

A disadvantage of this option is that there is only a possibility to accelerate and not to delay a flight compared to the default route. It also requires additional space in the FMS database, space which is not always available.

B: Default route is direct and one delay option

This solution consists of one direct route, which is a default route, and one optional route with extra track miles (see Figure 3.4). Waypoints are published points and default and alternate routes are named.

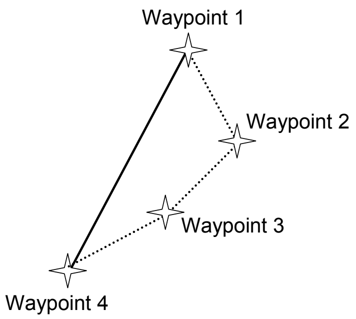

Figure 3.4 Direct route is a default route (solid line) and one delay option (dotted line).

The advantage of this solution, compared to previous option, is that there is a route option to delay flights. During inbound peaks, it is expected that delaying flights will be needed more often than the option to accelerate them.

A disadvantage is that it is only possible to delay a flight with this solution and not to accelerate.

C: Default route including extra miles, one delay option and one direct route

This type of static route adjustment consists of one default route that requires some extra track miles compared to a direct route, and two optional routes: one direct route and one delayed route with more track miles than the default (see Figure 3.5). Waypoints are published points and default and alternate routes are named.

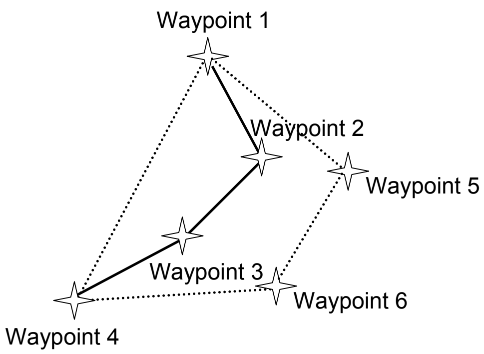

Figure 3.5 Default route (solid line) includes some extra track miles. The delay route and a direct one (both dotted lines) can be used as an alternative.

This solution gives the flexibility to both accelerate and to delay.

The disadvantage is that these extra routes need to be loaded into the FMS and, since they cannot be communicated to the flight crew verbally, they must be in the FMS database, taking up space which may not always be available.

D: Turn-back point

For this static route adjustment option, doglegs are defined by single turn-back points. The turn-back point needs to be published. See Figure 3.6.

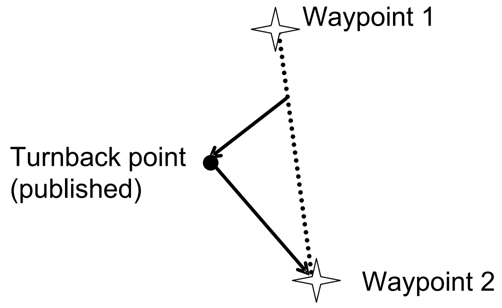

Figure 3.6 A route (dotted line) with a published turn-back point.

From any point on a route, an aircraft can be directed towards the published turn-back point. After reaching this point, the aircraft will return to the next waypoint on the route it was flying previously and continue on it. This allows a variable amount of extra track miles to be added to the planned route. Also, this option can make flexible use of military airspace if it becomes available without the need for published routes.

Since only a single point needs to be published and loaded into the FMS, this requires little space in the FMS database. The turn-back point may even be an existing waypoint requiring no additional database storage.

The disadvantage is that executive controllers from both LVNL and the adjacent centres have little experience with the use of published turn-back points. It is not common practice and would require training to prevent confusion and extra RTF load if used.

Dynamic route adjustments

A dynamic route adjustment will be dynamically defined during the calculation of the advisory based on all the available information on conflicts, flight status and weather conditions, as well as constraints imposed by airspace restrictions and letters of agreement with adjacent centres.

SARA calculates the route advice in a pre-defined area between two waypoints. The route is defined by one or more additional (latitude-longitude) coordinates (see Figure 3.7).

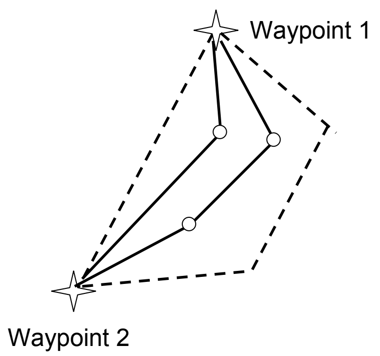

Figure 3.7 Dynamic route options. The dotted lines indicate the available airspace for the creation of dynamic route adjustments.

The dynamic route adjustment does not require pre-defined route segments that need to be stored in FMS databases. It allows ground-based automation to identify the best route adjustment solution for an arriving flight including lateral, vertical, and speed constraints. While the dynamic route solutions are created within the available airspace, taking into account procedural and other constraints in the airspace, they do not need to be limited to a set of pre-defined paths or points in either the air or ground systems. Rather, they can take full advantage of the airspace available in deriving optimal routing solutions.

However, since use of dynamic route solutions results in the need to communicate non-static portions of a route modification without relying on pre-defined static route segments, the use of integrated data link is required.

Dynamic routes might lead to a situation where it is no longer possible for a controller to evaluate the proposed route on possible conflicts with other flights. This is expected to happen when many flights receive dynamic routes as an advice. Conflict management will be required in this situation. Section 3.1.4 will address this more detail.

Conclusions for route options

Static route adjustments do not require the availability of data link. They can therefore be used by all aircraft in current-day operations. From the described options, option C provides the most flexibility for SARA in using routes for both delaying and advancing aircraft. Options A and B are considered possible alternatives for implementation, providing less flexibility to SARA in generating optimal route adjustments than would option C. Although not commonly used at present, the use of turn-back points (option D) offers a flexible way to add a variable number of track miles to a planned route, requiring little FMS database capacity, making it a viable option also. However, constraints on required training for both controllers and pilots to prevent confusion and related increased RTF-load, might limit the possibilities to use this option.

The static route option that is chosen for implementation of SARA will most probably be a combination of two or more of the proposed options. In designing route options for use with SARA, a balance between extra track miles and the delays expected to be absorbed, together with the speed ranges available, need to be considered. This must result in a set of routes that is capable of absorbing expected deviations from the EAT. Setting speed constraints on default routes will not only enhance the predictability, but also allow the use of speed increase on flights that need to be advanced.

Dynamic routes give SARA the maximum flexibility in calculating optimal routing that ensures correct metering over IAF. Data link is needed for communication of this information to the aircraft. Since it is expected to be difficult for controllers to check dynamic routes for conflicts with other aircraft route intentions, conflict management should be in place when introducing dynamic route options.

In theory, static routes and dynamic routes can be used together in an operational environment. For aircraft that are data link equipped, SARA could generate advisories based on dynamic routes while issuing advisories using static routes for non-data-link-equipped aircraft.

3.1.4 Check advisories for conflicts

When an advisory is calculated by SARA, the result of this advice should be checked with other flight intents for conflicts. This can be done either by an executive controller or by an automated function called conflict management (CM)[8]. CM for calculated advisories is optional when using speed-only or speed/static route advisories. The controller is expected to be able to determine if the advisories are conflict free.

If dynamic routes are used in generating SARA advisories, CM is required; the controller will have too little opportunity to test the advisories for possible conflicts with other flights. In section 3.3.1 we will discuss the possibilities for the controller to either comply with or decline an advisory. If dynamic routes and CM are used in the generation of the advisories, not accepting an advice might force the CM function to reconsider flights already flying on a SARA advisory in order to maintain a conflict-free situation. This might result in an unstable and undesirable situation.

3.2 Communicating and presenting the SARA advisory to the controller

The concept phase in between the generation of the advisory by SARA and the handling of the advisory by the responsible controller implies two concept elements:
- communicating the advisory to the controller;
- presenting the advice.

An advisory that is generated by SARA should be communicated to the responsible controller in order to be presented. For advisories that are meant for the responsible controller at Amsterdam ACC, available ATM system infrastructure will be used. For communication of the advisory to an adjacent centre, different partial solutions will be evaluated in this subchapter.

The level of integrity of a generated SARA advisory should be such that there is no need for individual validation on usability of the advisory. It should be sound; i.e. usable in terms of aircraft identification (correct), speed and/or route (performable) and resulting EAT (unique).

The next subchapter deals with the way in which the advice could be handled by the responsible controller.

3.2.1 Communicating the advisory to an adjacent centre

If the SARA Horizon is such that adjacent centres are involved, SARA will generate advisories that should be communicated to the flight crew by the responsible controller[9] at an adjacent centre. The SARA-generated information to be passed on to the adjacent centre must include the aircraft identification and the contents of the advisory.

There are several ways to pass on the required SARA-generated information to the responsible controller at the adjacent centre:
- voice communication;
- on-line data interchange (OLDI);
- internet.

Voice communication

Voice communication is a common procedure for communication between Amsterdam ACC and adjacent centres. It is available for use with all adjacent centres. The amount of information that

[8] Research and development activities for implementation of a conflict management tool are outside the scope of this project.

[9] This might be an executive controller but could be e.g. the planner controller if data link is in place and used for communication of the advisory to the airplane. See section 3.3.3.

can be communicated is limited. It will not be possible to communicate advisories that contain dynamic routes using voice communication. Communication of larger amounts of SARA advisories, containing speed and static route information for multiple flights, in addition to the information that is already communicated by voice, is not expected to be possible for longer periods. Since SARA will be operated for longer periods, this option for passing the advisory to an adjacent centre is rejected.[10]

On-line data interchange (OLDI)

The information that needs to be shared with the adjacent centre can be sent by an OLDI protocol. The advantage of OLDI is that the information can be presented on the radar screen of the responsible controller at the adjacent centre without the need to enter the data manually. The type of messages to be sent by OLDI, however, are specified by Eurocontrol, and the inclusion of a speed and/or route advice requires the protocol to be adapted.

Internet

The advisories could be displayed on a secure internet page. The time between generation of the advisory and display of the advisory on the screen is low and there is no standard protocol needed for the data exchange. However, this solution requires an additional HMI at the adjacent centre and LVNL, which is not desirable; see section 3.2.2.

Conclusion

OLDI is the best means to transfer SARA-generated advice since the information can be presented directly on the radar screen (without any manual inputs). Furthermore, the amount of information that can be transferred in one message and the number of advisories that can be communicated per unit of time is expected to be sufficient to communicate the SARA advisories, including during periods of high traffic demand. The protocol will require adaptation to allow inclusion of Speed And Route Advisories. This is planned for the next release of OLDI, i.e. version 4.0.

3.2.2 Presenting the advice

This section addresses the question of how SARA advice should be presented to the responsible controller at Amsterdam ACC and at an adjacent centre.

The advice should be presented in a predictable manner, i.e. in such a way that the controller knows what to expect when SARA generates advice, when to expect it, where to expect it to be displayed and in what manner.

Two options can be distinguished for presentation. The advice can be presented:

- on a screen dedicated to SARA advisories (a stand-alone HMI);
- on the radar screen (an integrated HMI).

Stand-alone HMI

The stand-alone HMI comprises a display and an input device dedicated to SARA. The stand-alone HMI should be located close to the controller's radar screen, as the controller must interrelate the SARA-generated data displayed on the stand-alone screen with the track information on the radar screen.

The advantage of the stand-alone option is that the display of the advisories need not be integrated with the ATC-system HMI and hence, probably, is easier to implement.

[10] This option might be used in operational trials.

A disadvantage of this option, even when both screens are placed close together, is that the controller has to monitor both the SARA display and the radar screen, and make inputs in two separate systems.

There is neither a direct psychological link nor a physical link between the data presented on the stand-alone screen and the data on the radar screen. As a result, the relationship between the information presented on the screens may not be immediately obvious. Furthermore, having a separate screen increases the scanning time of the controller. Overall, this may increase reaction time and promote errors. The likely result is an increased workload. Working with two screens may therefore impair safety.

Another disadvantage is that the introduction of a stand-alone HMI is not in line with the design philosophy of the main ATC-system, i.e. a system in which all flight-data-related functionalities should be integrated.[11]

Integrated HMI

This solution integrates the SARA HMI into the main ATC system. Integration has an advantage: the controller is used to the ATC system HMI.

For the display of the advisories, there are two options:

- The advice is displayed in the track's label;
- The advice is not displayed in the track's label, but in a table or a specific area.

The disadvantage of both options is that integrating the advisories on the ATC system HMI may cost more than presenting the advisories on a stand-alone HMI and may take longer to implement.

The advantage of presenting the SARA advice in the track label is that the advice is presented as part of the most relevant track data. To grab the attention quickly, an attention getter (e.g. flashing, another colour) might still be necessary. When presented in the track label with an attention getter, it might reduce the reaction time of the controller and reduce the risk of errors.

Presenting the SARA advice somewhere else on the screen, e.g. in the stack list, would require extra attention of the controller and would possibly increase the workload. In fact this is just a form of stand-alone display with little or no advantage over a separate screen.

Conclusion

A stand-alone HMI has no functional advantages and increases workload. Therefore an integrated HMI is preferred. Presenting the SARA advice in the track label seems the best option, since it is in line with the standard working methods.

[11] Again this option might be used in operational trials

3.3 Handling of the advisory by the responsible controller

The concept phase 'Handling of the advisory by the responsible controller' implies the following concept elements:

- complying with the advisory;
- giving feedback;
- instructing the flight crew.

3.3.1 Complying with the advice

Two options can be devised:

- comply with the SARA advisory without any assessment;
- comply with the SARA advisory at controller's discretion.

Comply with the SARA advisory without any assessment

If the controller complies with the SARA advisory without any assessment of its consequences, he/she must be sure that the advice is sound and, when acted upon, will not result in conflicts. In other words, the conflict management function (detecting and preventing) supporting SARA must be an advanced function, taking into account all traffic in the Amsterdam ACC sectors and the adjacent centres.

If the controller complies with advice without assessment, he/she will only intervene when required and the role of the controller changes from controlling to monitoring inbounds Schiphol.

Changing the role of the controller from controlling to monitoring is a big step. It requires training and possibly modification of procedures. Negative influence on the situational awareness of the controller is expected, especially if dynamic routes are used in the advisories. Together it might contribute to reluctance to accept the change, and therefore this option requires a managed implementation.

It is however important to realize that the controller currently is, and remains, legally responsible for all instructions and clearances he/she gives to the flight crew. This means that the controller should always be aware of the actual and upcoming traffic situation, even when his/her role is changed to a monitoring function and he/she does not assess the advice before passing it on (as an instruction or a clearance) to the flight crew. This means that the controller should always have the technical means to cancel advisories, or stop SARA advising.

Comply with the SARA advice at controller's discretion

In this option, the responsible controller assesses the effects of the advisory before passing it on (as an instruction or a clearance) to the flight crew. This means that the controller determines whether he/she will accept or decline the advice. Conflict management by the system is welcome but not required if no dynamic route options are used.

The major difference from the first option is that the controller's role does not change. Advice is strictly no more than advice. There is no role change, so the transition to an environment with SARA-generated advisories has less impact than with the previous solution.

A disadvantage of this option compared to the first option is that assessing SARA-generated advice is an additional task, increasing the workload. Another disadvantage is that, when a substantial number of advisories is not accepted, advice will not be optimized, and aircraft will more likely be delivered at the IAF outside the planned EAT window. Moreover, if dynamic routes and CM are used in the generation of the advisories, not accepting advice might force the CM function to reconsider flights already flying on a SARA advisory in order to maintain a conflict-free situation. This might result in an unstable and undesirable situation.

Conclusion

None of the options is rejected. Their impact on the current working methods and workload of the controller will be different and should be carefully evaluated. Option one – no assessment of the advice – is preferred because the workload of the controller is reduced. A precondition is that conflict management is performed by the system in the areas of responsibility of Amsterdam ACC and the adjacent centres. When dynamic routes are involved, the traffic situation might become so complex that the controller is no longer able to evaluate the impact of an advisory. Option two – comply at controller's discretion – cannot be used in this situation.

The current legal position of the controller is such that he/she is legally responsible for all instructions and clearances he/she gives to the flight crew. Therefore the controller should always have the means to decline advisories. How to combine this requirement with the impact a non-comply of advice has in complex traffic situations with dynamic routes involved, is further discussed in chapter 4.

3.3.2 Giving feedback

The question to be answered is whether the system (SARA and its supporting function trajectory prediction) should know if the advice has been acted upon and, if feedback is required, how it is accomplished.

Three options have been considered:
- feedback is not given;
- feedback is given by the responsible controller;
- feedback is given automatically.

Feedback is not given

If feedback is not given, the system – in particular the trajectory prediction function – does not know whether the advice has been complied with. This will lead to unreliable trajectory prediction (because the TP will not know what path length to use) and hence to inaccurate ETO's.

Not giving feedback at all also implies that the advisory information that is presented to the controller cannot be automatically removed.

Feedback is given by the responsible controller

The responsible controller – at Amsterdam ACC and at an adjacent centre – could let the system know whether the advisory has been acted upon or not. The advantage is that SARA and the supporting trajectory prediction function can be informed and use the updated information for future calculation of advisories. Also the presented advisory information can be removed automatically.

An underlying question is whether positive feedback should be given before or after confirmation by the pilot.

This option also applies when the controller does not assess the advice (see above). Even when the controller does not assess the advice, he/she could decline the advice. That means that the system cannot take it for granted that all advices are complied with.

The disadvantage is that the controller has to make a system input – accept or decline – upon each advice. However, if this feedback can be combined with the already existing required inputs for speed and route instructions, this will have no (or only limited) impact on the workload of the controller.

Feedback is given automatically

Automatic feedback should be based on the assumption that the advice will be complied with if the controller does not decline the advice. That means that the responsible controller still has to make a system input if he does not accept the advice. Automatic feedback should thus be read as 'partial automatic feedback' or 'automatic positive feedback'.

Automatic positive feedback requires a time window in which the controller could decline the advice. If the defined period of time expires, the system will automatically assume that the advice is acted upon. The problem is that such a period of time cannot be defined unambiguously. The traffic situation might be such that the controller would be unable to pay attention to the advice within the set period of time. Possibilities to interpret changes in heading or groundspeed as feedback from the aircraft and use them as feedback from the controller's actions to SARA suffer the same problem.

Another disadvantage of this option is that a confirmation by the pilot using RTF cannot be taken into account. Where data link is used for this confirmation, the function might be automated. But still, if the controller decides not to make use of an advisory, this will not be automatically known by SARA this way.

Conclusion

Not giving any feedback results in a situation where the trajectory prediction function does not know if the advisory is complied with or not. This will lead to unreliable trajectory prediction and hence to inaccurate ETO's, a situation that is undesirable when using SARA.

Automatic feedback is not considered a feasible option. It is unknown how to feed back the information that a controller has <u>not</u> instructed the advice to the flight crew automatically.

The remaining option is feedback given by the responsible controller. Whether the controller assesses the advice or not, he/she should let the system know if the advice has been acted upon.

3.3.3 Instructing the flight crew

SARA-generated advice, if accepted, must be communicated to the flight crew in the form of an instruction or a clearance, which must be clear and unambiguous. The options for passing SARA-advice-based instructions or clearances to the flight crew are radiotelephony (RTF) and data link.

Radiotelephony (RTF)

RTF is a standard method of passing information from controller to flight crew (and vice versa). A disadvantage is that errors can occur due to the misunderstanding and misinterpretation of the RTF messages. Congested frequencies and impact on workload for controller and flight crew promotes limited usage of RTF. With the introduction of SARA, the number of instructions that is communicated to the flight crew is expected to decrease. This would have a positive effect on the aforementioned issues.

As discussed in section 3.1.3, use of RTF excludes the possibility to use dynamic route options in the SARA advice.

Data link

Sending SARA-advice-based instructions or clearances by data link to the aircraft could be linked to the acknowledge input to be made by the responsible controller. As such, it would not become an additional task for the controller. If the acknowledge input is also used for feedback, the confirmation by the pilot should be also automatically incorporated in this message.

The advantages of a data link between ATC and aircraft are: 1) the amount of information that can be exchanged is almost unlimited, 2) the chance of errors is much reduced, and 3) the workload of the controller is reduced because less voice communication is needed.[12]

Another advantage is that the flight crew will be able to load route clearance and perhaps speed instruction data contained in the message directly into the FMC.

Safety loops to ensure that the message has been delivered to the cockpit, and feedback from the flight deck that the crew has seen the instruction, will need to be provided by the data link technology that is used. Like with all instructions, feedback on execution of the instruction (based on the SARA advisory) to the controller will need to be provided either using the data link capabilities (if possible) or using RTF.

Data link technology, on the other hand, is an expensive technology with different implementation varieties of the standards and not many aircraft are yet equipped with it. Many of those aircraft currently equipped with data link are not capable of loading uplinked data into the FMC without crew manual input.

Conclusion

For SARA, it is desirable to use data link with the possibility to load ATC messages directly into the FMC. This will contribute to efficiency, reduce errors and workload, and increase safety. It will also allow the use of dynamic routes in the generation of the SARA advisory. The problem however is the limited percentage of equipped aircraft in combination with different implementation varieties of the standards.

Data link and RTF are means of communication that can be used simultaneously. Therefore it is advised to use data link with aircraft offering this technology and voice communication with aircraft without data link technology.

3.4 Summary

In this chapter, concept elements have been identified and partial solutions for them derived and discussed. Some partial solutions have been rejected for use in concepts of operations, while others have been identified as possible or preferred. In Table 3.1, a list of the discussed partial solutions is shown, including the conclusion from the discussion in this chapter.

Only the partial solutions that have been considered possible in this chapter will be used in the next chapter for the construction of the different concepts of operation.

[12] Assuming the data-link HMI has no negative impact on the workload

Table 3.1 List of discussed partial solutions. In the last column the conclusion from this chapter for the partial solutions is given.

Partial solutions			Conclusion
Calculating the SARA advisory			
Location of SARA Horizon			
	Before Top of Descent		√
	After Top of Descent		√
Speed options			
	Speed that is executed immediately		√
	Speed that is executed from a waypoint forward		×
	Requested Time of Arrival (RTA)		×
Route options			
	Static route adjustments		√
	Dynamic route adjustments		√
Check advisories for conflicts			
	Use Conflict Management Tool		√
	No automated conflict resolution for advisories		√
Communicating and presenting the SARA advisory on to the controller			
Communicating the advisory to an adjacent centre			
	Voice communication		×
	On-line data interchange		√
	Exchanging information through internet page		×
Presenting the advisory			
	Stand alone HMI		×
	Integrated HMI		
		SARA advisory presented in a table or an area	×
		SARA advisory presented in the track label	√
Handling of the advisory by the responsible controller			
Complying with the advice			
	Comply with the advisory without any assessment		√
	Comply with the advisory at controller's discretion		√
Giving feedback			
	Feedback is not given		×
	Feedback is given by the responsible controller		√
	Feedback is given automatically		×
Instructing the flight crew			
	Radiotelephony (RTF)		√
	Data link		√

√ = possible × = rejected

4 Operational concepts

In this chapter, operational concepts are composed and outlined. First the three operational concepts are introduced. Thereafter each operational concept is illustrated from three perspectives:

- a general functional description in chronological order;
- the behaviour of the concept in a number of particular nominal and non-nominal situations;
- required (high level) changes in procedures, systems and controllers' competencies.[13]

4.1 Introduction

Starting from the basic concept outlined in chapter 2 and the accepted solutions for concept elements as found in chapter 3, three operational concepts have been defined:

- Concept 1 - Speed only
- Concept 2 - Speed and, if required, a static route
- Concept 3 - Conflict-free speed and, if required, a dynamic route

As can be concluded form the concept titles, the distinguishing feature among the concepts is the type of advice generated by SARA. The first concept – speed only – implies that the time gap between ETO and EAT is stopped with speed corrections only. The second concept adds the possibility to delay or advance the flight by using an alternative – strategically determined – route segment. The third concept is the most advanced concept. In addition to a speed, SARA could issue a dynamic arrival route, i.e. a tactically determined route within a strategically determined airspace block.

Table 4.1 gives an overview of the possible building blocks that are used in the concepts 1, 2 and 3.

Concept element	Possible solution	Concept		
		1	2	3
SARA Horizon	After TOD	×	×	×
	Before TOD	✓	✓	✓
Speed options	Speed that is executed immediately	✓	✓	✓
Route options	Static route adjustments	×	✓	×
	Dynamic route adjustments	×	×	✓
Conflict management	No conflict resolution	✓	✓	×
	Automated conflict resolution	×	×	✓
Interface with adj. centre	On-line data interchange	✓	✓	✓
Presenting the output	In the track label	✓	✓	✓
Complying with the advice	At controller's discretion	✓	✓	×
	Without assessment	×	×	✓
Giving feedback	By the controller	✓	✓	✓
Instructing the pilot	Radiotelephony (RTF)	✓	✓	×
	Data link	✓	✓	✓

Table 4.1

As can be seen in the table, the use of route changes is the distinguishing factor among the three concepts: in concept 1 no route changes are used, in concept 2 static route changes are used and in concept 3 dynamic route changes are used. The other differences are the result of having dynamic routes in concept 3. The use of dynamic routes requires the system to detect and resolve conflicts, and the controller to comply with the advice without assessment and to instruct the pilot

[13] The section on required changes is restricted to required changes to LVNL's ATM system (and to aircraft equipment). Changes to the systems, procedures and human factors of adjacent centres have not been addressed, though some of the changes to the LVNL system could also be applicable to the ATM system of an adjacent centre.

via data link. In concept 1 and 2 there is no conflict detection and resolution; the controller regards the output of SARA as a proposal and the pilot can be instructed via RTF. Note that only one possible solution is not incorporated in any of the operational concepts: SARA Horizon after TOD. In chapters 5 and 6, however, this option is taken into consideration again.

4.2 Concept 1: Speed only

SARA will calculate the speed an aircraft must and can fly to meet the EAT over the IAF.

4.2.1 Functional description

A flight becomes active in inbound planning (IBP) before TOD.[14] When a flight becomes active in IBP, the EAT is calculated for the flight. The calculation takes the assigned landing runway into account. Further downstream, but still before TOD, IBP should be stable. This moment is the so-called SARA Horizon.[15]

When a flight (active in IBP) passes the SARA Horizon, SARA starts calculating whether a speed change is required to meet the EAT. SARA issues a required speed only if the gap between ETO and EAT is 30 seconds or more (this value may be adjusted as a result of trials). The route SARA uses for the speed calculation is the route in the system flight plan.

The route in the system flight plan should be flown because the EAT and a possible speed proposal are based on this route. If the controller gives a route instruction departing from the flight plan route, TP will assume an alternative route, possibly a direct route to the IAF.

If SARA calculates that a speed correction is required, the controller responsible for the flight will be a controller at an adjacent centre. The speed proposal is forwarded to this controller via OLDI and presented in the flight's label.

Upon receiving the speed proposal, the controller – instructed to comply with the proposal whenever possible – assesses the safety effects. If the controller decides to comply with the proposal, he/she instructs the flight crew – by RTF or data link – and gives feedback about his/her decision via OLDI to SARA and to Amsterdam ACC (e.g. the PLC). The controller gives also feedback when he/she decides not to comply with the proposal.

The speed instructed to the flight crew has to be executed immediately. Through the AIP, the flight crew is encouraged to fly the descent in the VNAV and LNAV modes.

Between the SARA Horizon and the IAF, SARA calculates continuously whether a gap of 30 seconds or more between EAT and expected arrival time at the IAF exists.[16]

When the flight is under control of an Amsterdam ACC controller and SARA calculates that a speed change is required, the speed is presented in the track label on the executive controller's radar screen.

Upon receiving the speed proposal, the ACC controller – instructed to comply with the proposal whenever possible – assesses the safety effects. If the controller decides to comply with the proposal, he/she instructs the flight crew by RTF and gives feedback to SARA. The controller gives feedback also when he/she decides not to comply with the proposal.

The expected result of all the activity described above is that the flight passes the IAF within 30 seconds from the EAT and is welcomed by a pleased approach controller.

[14] A flight may become active in IBP about 150-200 NM before TOD.
[15] The SARA Horizon could be 50 NM before TOD.
[16] SARA could stop calculating at about 10 NM before the IAF.

4.2.2 Particular situations

In addition to the functional description given above, the following nominal and non-nominal situations are discussed below:

- Manual changes to IBP;
- Pop-up traffic;
- Reduced co-ordination;
- SARA failures;
- Communication failures;
- The controller does not comply with the speed proposal;
- Deviations from the predicted trajectory;
- Aircraft in an abnormal or an emergency situation.

Manual changes to IBP

Situation

Aircraft proceeding to meet the EAT. A manual change is made in IBP.
Possible reasons to make a change are:

- change in runway assignment;
- manual landing slot (MSL), e.g. due to correction of the planning;
- weather, e.g. low visibility with lot of changes in RVRs and inbound traffic;
- change in landing interval, followed by an NPT input (results in a series of EAT changes).

Result

A manual IBP change results in revised EAT(s) and hence in a revised SARA speed proposal(s).

If the required speed can not be presented (e.g. because the calculated speed cannot be flown), SARA presents either the minimum aircraft related speed (if the flight should be delayed) or the maximum aircraft type related speed (if the flight should be speeded up). Both speed proposals are accompanied with a time (in seconds), indicating the time gap between ETO and EAT.

Note: If needed, the holdings can still be used to delay flights.

Pop-up traffic

Situation

Pop-up traffic is inbound traffic to Schiphol within the SARA Horizon (for instance from Düsseldorf airport). Pop-up traffic must be merged with the inbound flows.

When the EAT over the IAF for a pop-up flight is calculated, the inbound planning could be filled up with flights with approximately the same ETO.

Result

A pop-up flight will be introduced in IBP and SARA will calculate a speed for it. As a result, new proposals may be generated for other flights as well.

Pop-up flights could make IBP less stable. This effect could be significant, because SARA starts calculating at the SARA Horizon a number of originating airports lies within the SARA Horizon.

Reduced co-ordination

Situation

In periods of reduced co-ordination, more airspace is available.

Result

During periods of reduced co-ordination the controller could instruct a flight to depart from the flight plan route and fly a (shorter) direct route or a (longer) dogleg-type route. SARA will recalculate taking into account an alternative route. This route assumption is made by TP and could be a direct route to the IAF.

If the required speed can not be presented (e.g. because the calculated speed cannot be flown), SARA presents either the minimum aircraft related speed (if the flight should be delayed) or the maximum aircraft type related speed (if the flight should be speeded up). Both speed proposals are accompanied with a time (in seconds), indicating the time gap between ETO and EAT.

SARA failures

Situation

SARA fails completely or does not receive input from IBP and/or TP.

Result

SARA is out of order. The controller should be notified and has to comply with the relevant backup procedure. Actual approach time over IAF might be 30 seconds or more.

Communication failures

Situation

Different communication failures can be identified:
- Ground to ground (G/G) OLDI failure;
- Ground to air (G/A) and/or air to ground (A/G) RTF or data link failure.

Results

If OLDI fails, SARA cannot communicate with an adjacent centre. In other words, a speed proposal can not be forwarded to an adjacent centre and feedback cannot be given by the adjacent centre. The controller of and adjacent centre will proceed in the conventional way. The executive controller at ACC could expect more speed proposals.

In case of a G/A/G communication failure, the pilot will act in accordance with the communication failure procedure published in the AIP. Within the Amsterdam FIR the pilot will select SSR code 7600, hold on to speed and heading for 7 minutes, and proceed conform flight plan. The controller will instruct SARA to stop issuing speed proposals for this flight. For other flights, SARA may be used as long as separation – e.g. with the 7600 flight – can be guaranteed.

The controller does not comply with the speed proposal

Situation

The controller does not issue the SARA proposal to the ACFT. Possible reasons are:
- the controller considers the advised speed to result in a conflict;
- the controller is busy with handling other traffic and ignores the speed proposal.

Result

If time is available, the controller gives input to SARA that speed is not instructed.
SARA monitors the flight's trajectory and issues a new proposal.

Deviations from the predicted trajectory

Situation

A flight is instructed to fly a SARA-generated speed. This speed is based on a predicted trajectory taking into account weather conditions ahead of the flight. In most cases the predicted trajectory and actual trajectory should be the same. There are however situations where flights deviate - intended or unintended - from the predicted trajectory.

Intended deviations of the route occur when a controller or pilot intervenes, for example to avoid unexpected weather. This deviation can either be in the horizontal or the vertical plane. In the horizontal plane flights may want to circumnavigate CB cells. In the vertical plane flights may encounter turbulence and wish to level off or, for example, maintain altitude to avoid unexpected strong winds.

Unintended deviations may result from a variety of reasons. The trajectory prediction might be inaccurate (e.g. because of weather inaccuracies) causing a difference between the actual and predicted situation. Another reason is when a crew reacts late on an instruction or misunderstands an instruction.

Result

The EAT and a possible speed proposal are based on the SFPL. If the controller gives a route instruction departing from the flight plan route, TP will assume an alternative route, possibly a direct route to the IAF.

Based on the latest trajectory prediction, SARA monitors the difference between ETO and EAT and issues a new speed when the difference is 30 seconds or more.

If the required speed can not be presented (e.g. because the calculated speed cannot be flown), SARA presents either the minimum aircraft related speed (if the flight should be delayed) or the maximum aircraft type related speed (if the flight should be speeded up). Both speed proposals are accompanied with a time (in seconds), indicating the time gap between ETO and EAT.

Note: If needed, the holdings can still be used to delay flights.

Major disturbances of the inbound planning

Situation

Due to, for example, a contingency situation at Schiphol airport, the overall inbound planning is upset.

Result

The ACC SUP will stop SARA generating advice.

Depending on the cause of the disturbance, aircraft may be directed into a holding or diverted.

Aircraft in an abnormal or an emergency situation

Situation

The pilot is confronted with an abnormal or an emergency situation. Emergency situations could be the result of electrical problems, engine failure or fire, fuel problems, hydraulic problems, radio communication problems. Emergency situations also includes a bomb warning, an emergency descent, a security flight, a lightning strike. Abnormal situations include problems with aircraft systems which do not result in an emergency situation.

Result

In case of an abnormal situation onboard, the pilot may decide not to comply. In case of an emergency situation, and the ATC controller is aware of the emergency situation, the pilot should not troubled with a speed instruction (to meet the EAT) at all. In both cases the ATC controller commands SARA to stop generating speeds for this flight. SARA will remain generating speeds for other flights.

4.2.3 Required changes to procedures

Introduction

'Procedures' should be understood as the development, design and publication of:

- air traffic services procedures (tasks and responsibilities, normal procedures, backup procedures);
- flight procedures;
- airspace structure and routes.

Procedural changes will be drafted and justified in a procedure design document (POD).

Procedural changes will be published in:

- AIP Netherlands, the aeronautical information publication designed for users of the Amsterdam FIR (pilots and aircraft operators);
- LVNL regulations for ATC controllers (VDV);
- LVNL's quick reference handbooks for ATC controllers (QRH);
- Letters of agreement between Amsterdam ACC and adjacent centres (LoA).

Tasks and responsibilities

An additional task for the controller is that he/she has to deal with the presented output of SARA (in concept 1 a speed only).

The controller remains responsible for the instructions and clearances he/she gives to the flight crew. Hence no changes is responsibilities are required.

- Dealing with the presented SARA output shall be added to the tasks of the involved controllers.

Normal procedures

Approach inbound planner (APLN)

The APP planner is responsible for inbound (EAT) planning. The APLN, supported by an improved IBP function, should:

- plan earlier (looking further ahead);
- plan better (find a balance between the dynamics of traffic flows in the TMA and the stability of the planning for operations with SARA)

The degree of complexity of the new procedures depends on the position of the SARA Horizon.

- Inbound planning procedures for the APLN shall be drawn up.

Executive controller ACC (EC)

A speed proposal may be presented to the executive controller (EC) at Amsterdam ACC. If a speed proposal is presented, the controller must know how to deal with it.

- Speed proposal handling procedures shall be drawn up for the ACC EC.

Planning controller ACC (PLC)

The planning controller (PLC) at Amsterdam ACC may be informed about instructions affecting the trajectories of inbound flights.

- Relevant procedures for the ACC PLC shall be drawn up.

Supervisor

Major disturbances of the inbound planning, for example due to a contingency situation at Schiphol, could require the supervisor to halt working with SARA for all inbound flights.

- Relevant guidelines for the SUP shall be drawn up.

Backup procedures

The SARA function could fail. Two failure modes can be thought of: SARA degraded and SARA unserviceable. A failure mode of SARA could also be the result of a failing supporting system. The failure modes must be given by LVNL's system engineering department. If SARA degrades or becomes unserviceable, the controller must know what to do.

- Backup procedures 'SARA degraded' and 'SARA U/S' shall be drawn up.

Agreements with adjacent centres

The SARA Horizon lies outside the area of responsibility (AoR) of Amsterdam ACC. Hence, a speed proposal could be given to a controller in an adjacent centre. The involved controller should be informed about the flight and know how to handle the speed proposal.

Adjacent centres of Amsterdam ACC are: Bremen ACC, Brussels ACC, Copenhagen ACC, Langen ACC, London AC (Swanwick), London TC (Swanwick), Maastricht UAC, Scottish ACC. However, an flight inbound to Amsterdam could even descent through the AoR of a centre (e.g. in the north of France), which is not adjacent and with which no LoA has been drafted. The adjacent centres, with the exclusion of MUAC, have not been consulted about the SARA concept of operations during the study phase.

- Agreements shall be made with (adjacent) involved centres with regard to data transfer and procedures associated with the issued speed proposal.

Flight procedures

The SARA based instructions given to the pilot should be treated as components of the arrival procedure clearance and be flown as accurately as possible. Predictability is best achieved when flying in the LNAV and VNAV mode. In the LNAV mode the aircraft laterally follows the active FMS flight plan. In the VNAV mode the vertical path of the aircraft is controlled by thrust and pitch commands from the FMS.

- The descent to Schiphol shall preferably be flown in the LNAV and VNAV mode.

4.2.4 Required changes to technical systems

Introduction

The technical systems discussed in all sections entitled 'Required changes to technical systems' comprise:

- trajectory predicting;
- inbound planning;
- conflict management;
- Speed And Route Advisor – input data, generation moments, output data;
- fall-back SARA;
- human machine interface;
- interface with adjacent centre;
- data link with aircraft.

Trajectory prediction (TP)

To plan an inbound flight, an accurate prediction for the flight trajectory is needed. The trajectory prediction AAA-function predicts the future progress of individual aircraft. The TP function is currently activated by the ACT message 8 minutes before a flight reaches the entry COP. This might be too late.

- Predictions are made using input from the system flight plan, actual position, aircraft performance and wind data. The accuracy of the predictions, however, is hindered by inaccuracies in the input data. Another shortcoming is that TP does not take reduced co-ordination into account.TP for a particular flight shall be activated before the flight crosses the SARA Horizon.
- TP shall use more and more accurate data to improve its accuracy.
- Deviations from the SFPL shall not lead to inaccurately predicted trajectories.

Inbound planning (IBP)

SARA makes use of the IBP function of AAA. IBP plans a landing sequence. The output of IBP is the expected approach time (EAT) at the IAF.

IBP aims to regulate all IFR flights entering the Schiphol TMA with destination EHAM. The planning process is triggered by an ACT message which is sent from an upstream centre 8 minutes before the flight reaches the co-ordination point. 12 minutes before the estimated time over (ETO) the IAF (just before the FIR boundary), the inbound process has generated a planning. IBP, therefore, has only a limited span of control. An inbound flight needs to be planned by IBP before it passes the SARA Horizon.

IBP takes the landing runway threshold as a starting point for its calculations. As a result, non-unique EATs for an IAF could be issued (e.g. as a result of aircraft performance differences or if one IAF is feeding two runways). That means that two or more flights could be planned to fly over the same IAF at the same time (thereby potentially violating separation criteria).

IBP uses the runway configuration that is in use at the time it calculates the landing sequence. A new EAT is assigned to a flight when a change in landing runway configuration occurs, resulting in the flight's being planned for another runway.

EATs can be manually adjusted by the approach planner (APLN). The APLN uses this feature to balance the traffic load on the runways.

Pop-up traffic also causes instability of the IBP. Pop-ups are flights that originate from an airport with a flying time of less than 12 minutes to the IAF. Pop-up traffic generally suffers from an inaccurate and inconsistent activation process due to the large departure slot interval. When the EAT over the IAF for a pop-up flight is calculated, the inbound planning has already assigned slots to flights with approximately the same ETO. Usually, the pop-up flight will have to be squeezed in, making inbound planning less stable. If inbound planning were to be finalised earlier than 12 minutes before ETO IAF, the issue of pop-up traffic would increase, because more originating airports would lie within the span of the planning.

EAT updates due to, for example, runway configuration changes, manual adjustments and pop-up traffic, causes IBP instability and could trigger SARA to start calculating again. Too many EAT updates resulting in new speed corrections and/or route deviations are undesirable because it increases workload and reduces the predictability.

- The EAT for a particular flight shall be determined before the flight crosses the SARA Horizon.
- The EAT for a particular flight shall be as stable as possible; i.e. EAT updates due to e.g. pop-up flights and landing runway changes shall be avoided.
- Pop-up traffic shall be avoided by using early flight data from, for example, aircraft operators and other ATC units (a use of CDM).
- Landing runway changes shall be avoided by realizing and using a stable runway configuration plan.
- The EAT determined for a particular flight shall be unique for an IAF; i.e. IBP shall observe the separation criteria (over the IAF) in calculating EATs.

Conflict management (CM)

Concept 1 does not require conflict detection and resolution by a CM tool.

Speed And Route Advisor (SARA)

Function

- SARA shall calculate whether the flight is predicted to cross the IAF at less than 30 seconds from the EAT and, if this target time cannot be met, issue a speed proposal to meet the EAT.

Input data

The following input is required:
- EAT; see IBP above;
- Trajectory prediction; see TP above.

Generation moments

Airborne arrival planning in the FMS should be completed before TOD to optimise the descent path (in terms of fuel efficiency) and increase the predictability. The position of the TOD, however, depends on the route to be flown, including all speed and altitude constraints. Therefore, the pilot should know all the tactically issued constraints – among them any instructions or clearances based on SARA-generated advice – well before the TOD (calculated by the FMS also using its navigation database) is reached.

- The moment SARA starts calculating – i.e. when passing the SARA Horizon – shall be far before a flight reaches its planned TOD.

Beyond the SARA Horizon, the aircraft ETO may deviate from the EAT for various reasons, for example weather. To avoid deviations at the IAF larger than the required maximum, SARA should recalculate the difference between ETO and EAT frequently and issue, when necessary, a new speed.

- SARA shall recalculate as often as necessary to avoid deviations at the IAF of 30 seconds or more.

Frequent recalculations, however, may result in several successive speed proposals. This is an undesired situation because the workload of the controller would increase and the predictability of the trajectory could be consequently impaired.

- Recalculations shall not result in excessive numbers of speed proposals per flight (see also IBP requirements).

Output data

To adjust the time gap between ETO and EAT over the IAF, SARA should be able to generate speeds which do accelerate or decelerate the aircraft. However, different aircraft types have different cruise and descent speeds and different ranges of achievable speeds. Sara should take these differences into account.

- The SARA-generated speed to which an aircraft is instructed to accelerate or decelerate shall be within the flight envelope of the type of aircraft for which it is generated.
- If the calculated speed cannot be flown by a particular aircraft, SARA shall present either the minimum aircraft-type-related speed (if the flight should be delayed) or the maximum aircraft-type-related speed (if the flight should be speeded up). Both speed proposals shall be accompanied with a time (in seconds), indicating the time gap between ETO and EAT.

Fall-back SARA

As yet, a fall-back SARA is not required; backup procedures will be in place. However, if the use of SARA is established and controllers routine is adapted to having SARA available, a fall-back SARA might be considered.

- A fall-back SARA shall be considered when controllers routine is expected to become SARA dependent.

Human machine interface (HMI)

The SARA-generated speed is presented in the flight's track label. The controller needs a control interface with SARA, for example to accept or reject the speed proposal, and to stop and start calculating for one or all flights.

- The SARA-generated speed for a flight shall be presented in the flight's track label.
- The controller shall have all the required SARA controls available.

Interface with adjacent centres

SARA-generated data (speed) and other relevant flight data should be transferred to adjacent centres via OLDI protocol.

The adjacent centres will transfer back to LVNL e.g. ACFT IDENT, a (non)compliance message, and other relevant data.

- Means to transfer SARA-relevant data to and from adjacent centres in a timely manner via OLDI shall be developed.

Data link with aircraft

No requirements.

4.2.5 Required changes to controllers' competencies

Controllers are used to a certain way of working. Becoming used to the working method required by SARA will likely need some training. Also with the prolonged use of Concept 1 training may be necessary in order for the controllers to maintain their basic controller skills should it be required. In other words, in the short-term SARA can make the task easier, but in order to stay current with more traditional methods, more training may be required for the duration of concept 1.

Overall workload may be reduced because SARA takes away some of the complexity of the task.

On the other hand, having to double check every SARA-generated proposal for potential conflicts may increase workload. Also, an increased dependency on SARA advisories could influence the controller's Situation Awareness. Hence, it is as yet unclear which changes are expected with the introduction of concept 1 in terms of controller workload and SA, and how much the training has to change. Until changes in acquisition of Situational Awareness and workload are understood, it should be assumed that the required competences for new controllers are not likely to substantially change with the first iteration of SARA. Further research in the form of desk research, the real-time simulation and the operational trial is needed to clarify these issues.

- The controllers shall be instructed in the way SARA works and in the related procedures.
- The controllers shall be kept competent in working without SARA.

4.3 Concept 2: Speed and, if required, a static route

SARA will calculate the speed and, if required, the strategically-determined route deviation an aircraft must fly to meet the EAT.

4.3.1 Functional description

A flight becomes active in IBP before TOD.[17] When a flight becomes active in IBP, the EAT is calculated for the flight. The calculation takes the assigned landing runway into account. Further downstream, but still before TOD, IBP should be stable. This moment is the so-called SARA Horizon.[18]

When a flight (active in IBP) passes the SARA Horizon, SARA starts calculating whether a speed change is required and sufficient to meet the EAT. If a speed change only is predicted to be insufficient to fly over the IAF within the required margin of the EAT, SARA recalculates again now also considering route deviation options. To minimize track miles, priority will be given to the shortest route deviation. The result is a proposal consisting of a new route and a corresponding speed.

The available route options have been strategically determined and published.

When SARA calculates that a speed and route correction is required, the controller responsible for the flight will be a controller at an adjacent centre. The proposal is forwarded to this controller via OLDI and presented in the flight's label.

Upon receiving the proposal, the controller – instructed to comply with the proposal whenever possible – assesses the safety effects. If the controller decides to comply with the proposal, he/she instructs the flight crew – by RTF or data link – and gives feedback about his/her decision via OLDI to SARA and to Amsterdam ACC (e.g. the PLC). The controller gives feedback also when he/she decides not to comply with the proposal.

The speed instructed to the flight crew has to be executed immediately. Through the AIP, the flight crew is also encouraged to fly the descent in the VNAV and LNAV modes.

Between the SARA Horizon and the IAF, SARA calculates continuously whether a gap of 30 seconds or more between ETO and EAT exists.[19] Is so, a new proposal is issued.

When the flight is under control of an Amsterdam ACC controller and SARA calculates that a speed and/or route change is required, the speed and/or route is presented in the track label on the executive controller's radar screen.

Upon receiving the proposal, the ACC controller – instructed to comply with the proposal whenever possible – assesses the safety effects. If the controller decides to comply with the proposal, he/she instructs the flight crew by RTF and gives feedback to SARA. The controller gives feedback also when he/she decides not to comply with the proposal.

The expected result of the activity described above is that the flight passes the IAF within 30 seconds from the EAT and is welcomed by a pleased approach controller.

[17] A flight could become active in IBP about 150-200 NM before TOD.
[18] The SARA Horizon could be 50 NM before TOD.
[19] To draw a picture, SARA could stop calculating at about 10 NM before the IAF.

4.3.2 Particular situations

Manual changes to IBP

See concept 1.

Pop-up traffic

See concept 1.

Reduced co-ordination

See concept 1. Additionally, SARA may use predetermined static route deviations through the AoR of MilATCC.

SARA failures

See concept 1.

Communication failures

See concept 1.

The controller does not comply with the SARA-generated proposal

See concept 1.

Deviations from the predicted trajectory

See concept 1.

Major disturbances of the inbound planning

See concept 1.

Aircraft in an abnormal or an emergency situation.

See concept 1.

4.3.3 Required changes to procedures

For a general introduction to procedures see concept 1.

Tasks and responsibilities

See concept 1.

Normal procedures

See concept 1. The difference is that the SARA-generated proposal could comprise of both a speed and a static route.

Backup procedures

See concept 1.

Airspace and routes

In concept 2 static deviations from the (current) inbound routes are used to advance or delay the flight. For optimal design freedom, these deviations from the current ATS-routes and STARs should be RNAV designed route segments.

- Static route deviations from the (current) inbound routes shall be developed (as RNAV-1 routes) and published.

The last requirement assumes the normal areas of responsibility (AoR) of Amsterdam ACC and its adjacent centres. The AoR of the Amsterdam ACC sectors in particular, are relatively small. So the airspace available to design significant (in terms of ETO adjustment capability) static route deviations is limited. However, when airspace controlled by MilATCC is inactive, parts of that airspace are used by ACC and/or MUAC. These so called periods of 'reduced co-ordination' happen both at predictable (e.g. weekends, public holidays) and unpredictable times. Inbound traffic might then be instructed to fly a shorter direct route or a longer route through the extended sector airspace.

- Supplementary or extended static route deviations from the (current) inbound routes shall be developed and published for use during periods of reduced co-ordination.

Agreements with adjacent centres

See concept 1.

A difference with concept 1 is that static route deviations could be (partially) positioned within the AoR of the adjacent centre.

Another difference concerns the predictability of the periods of reduced co-ordination. Better predictability (without reduction in availability) is preferred.

- Route deviations within the AoR of an adjacent centre – to be used during periods of reduced coordination – shall be agreed on with the adjacent centre.
- The predictability of the availability of military airspace shall be aimed at.

Flight procedures

See concept 1.

Additionally, the static routes must be published in order to allow the navigation database suppliers to add these routes to the databases.

The static routes are RNAV routes. To fly these routes and to fly them accurately enough, aircraft should be RNAV-1 equipped.

- Route deviations from ATS routes and STARs shall be published.
- Flights inbound for Schiphol shall be RNAV-1 equipped.

4.3.4 Required changes to technical systems

Introduction

See concept 1.

Trajectory prediction (TP)

See concept 1.

- TP shall take the newly developed static routes into account.

Inbound planning (IBP)

See concept 1.

- IBP shall take the newly developed static routes into account.

Conflict management (CM)

Concept 2 does not require conflict detection and resolution by a CM tool.

Speed And Route Advisor (SARA)

Input data

See concept 1. Because static routes will be developed in airspace which becomes available during periods of reduced co-ordination (see required changes to procedures), SARA must know when this airspace is available.

- SARA shall be informed when, during reduced co-ordination, additional airspace becomes available in order to take route deviations through this airspace into account.

Generation moments

See concept 1.

Output data

See concept 1. In addition to a speed, SARA could output a static route deviation (within a predetermined block of airspace).

- If required to comply with the EAT, SARA shall generate – in addition to a speed – a static route deviation.

Fall-back SARA

As yet, a fall-back SARA is not required; backup procedures will be in place. However, if the use of SARA is established and controllers routine is adapted to having SARA available, a fall-back SARA might be considered.

- A fall-back SARA shall be considered when controllers routine is expected to become SARA dependent.

Human machine interface (HMI)

See concept 1.

Interface with adjacent centres

See concept 1.
The proposal passed to an adjacent centre may include a static route deviation.

Data link with aircraft

See concept 1 (no requirements).

4.3.5 Required changes to controllers' competencies

See concept 1.

4.4 Concept 3: Conflict-free speed and, if required, a dynamic route

SARA will calculate the speed and, if required, the tactically-determined route deviation an aircraft must fly to meet the planned time over the IAF.

4.4.1 Functional description

A flight becomes active in IBP before TOD.[20] When a flight becomes active in IBP, the EAT is calculated for the flight. The calculation takes the assigned landing runway into account. Further downstream, but still before TOD, IBP should be stable. This moment is the so-called SARA Horizon.[21]

When a flight (active in IBP) passes the SARA Horizon, SARA starts calculating whether a speed change is required and sufficient to meet the EAT. If a speed change only is predicted to be insufficient to fly over the IAF within the required margin of the EAT, SARA calculates again now also using the route deviation options. The result will be a proposal consisting of a route (deviation) and a corresponding speed.

The route deviation is tactically determined by SARA within a strategically determined (and published) block of airspace. The entry and exit points are located on one or more ATS routes and/or STARs.

The trajectory resulting from the calculations can be flown free of conflicts with other flights and will avoid severe weather. In other words, a speed and/or route will not be issued if the resulting trajectory causes a conflict with another flight.

When SARA calculates that a speed and possibly a route correction is required, the controller who has the flight UCO will be a controller at an adjacent centre. The speed and/or route is forwarded via OLDI and presented on the radar screen.

Upon receiving the speed and/or route, the controller complies with it without assessing the safety effects. Assessing the proposal is difficult because of the complexity of the tactically-determined trajectories and not needed due the fact that the resulting trajectory is free of conflicts based on then-current knowledge of the intent of all other flights.

The controller instructs the flight crew via data link and gives feedback to SARA and to Amsterdam ACC (e.g. the PLC).

The speed instructed to the flight crew has to be executed immediately. Through the AIP, the flight crew is also advised to fly the descent in the VNAV and LNAV modes.

Between the SARA Horizon and the IAF, SARA calculates continuously whether a gap 30 seconds or more between EAT and ETO at the IAF exists.[22]

When the flight is under control of an Amsterdam ACC controller, and SARA calculates that a speed and/or route change is required, the speed and/or route is presented on the executive controllers' radar screen. The controller instructs the flight crew via data link without assessing the 'proposal' and gives feedback to SARA.

The expected result of the activity described above is that the flight passes the IAF within 30 seconds from the EAT and is welcomed by a pleased approach controller.

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[20] A flight could become active in IBP about 150-200 NM before TOD.
[21] The SARA Horizon could be 50 NM before TOD.
[22] SARA could stop calculating at about 10 NM before the IAF.

4.4.2 Particular situations

Manual changes to IBP

See concept 1.

Pop-up traffic

See concept 1.

Reduced co-ordination

See concept 1. Additionally, SARA may use a predetermined block of airspace in the AoR of MilATCC.

SARA failures

Situation

SARA fails completely or does not receive input from IBP, TP and/or CM.

Result

A fall-back SARA takes over the tasks of the failed SARA.

Communication failures

See concept 1.

The controller does not comply with the SARA-generated speed and route

Situation

The controller does not issue the SARA speed and route to the ACFT because the controller is busy with handling other traffic or the controller is compelled to handle a flight at his/her discretion, for example due to an aircraft emergency or extreme weather conditions.

Result

The controller shall be warned to instruct the aircraft with the SARA-generated speed and route immediately (before the flight enters the block of airspace in which separation is assured by the system).

If the controller did not issue the SARA-generated speed and route on purpose, the controller shall stop SARA issuing speeds and/or routes for this flight.

Deviations from the predicted trajectory

See concept 1.

Major disturbances of the inbound planning

See concept 1.

Aircraft in an abnormal or an emergency situation

See concept 1.

4.4.3 Required changes to procedures

For a general introduction to procedures see concept 1.

Tasks and responsibilities

In concept 3 the controller does not assess the speed and route generated by SARA.

- Tasks and responsibilities of the ACC controller shall be adapted to the new mode of operation within the predetermined block of airspace.

Normal procedures

See concept 1. The difference is that the SARA-generated proposal could comprise of both a speed and a dynamic route.

Backup procedures

See concept 1.

Airspace and routes

In concept 3 dynamic deviations from the inbound routes are used to advance or delay the flight. These deviations are routes dynamically determined by SARA within a predetermined block of airspace.

- Blocks of airspace within which route deviations can be dynamically calculated by SARA shall be developed and published.
- Supplementary or extended blocks of airspace shall be developed and published to be used during periods of reduced co-ordination.
- The entry and exit points shall be located on an ATS route and/or a STAR.
- In case of a cross-border block of airspace, the location of the COP shall be flexible.

Agreements with adjacent centres

See concept 2.

Tthe airspace block within which dynamic routes are generated could be (partially) positioned within the AoR of the adjacent centre.

Flight procedures

See concept 1.

Additionally, the blocks of airspace within which dynamic routes should be flown must be published. The status of these airspace blocks should be investigated. Is traffic without an dynamic route instruction allowed to enter this airspace?

- The location o the blocks of airspace within which dynamic routes should be flown shall be published.
- The status of these block of airspace shall be determined an dpublished.

4.4.4 Required changes to technical systems

Introduction

See concept 1.

Trajectory prediction (TP)

See concept 1.

Inbound planning (IBP)

See concept 1.

Conflict management (CM)

The route deviations in concept 3 are dynamically determined by SARA. With such an operating method, it will be very difficult for a controller to gain situational awareness of the calculated 4D-trajectories within the dynamic route airspace block. Because one objective of SARA is to avoid increasing controller workload, the trajectories defined by SARA in concept 3 must be free of conflicts. Within the airspace block, conflict detection, resolution and prevention for all known traffic must provide continued separation assurance.

In the current ATM system there is no conflict management function in place other than for short-term conflicts and medium-term conflicts for en-route traffic. Conflict management is mainly performed by the controller manually. Traffic intent information is not shared between centres before the ACT is sent since it is not needed to achieve sequencing objectives or for a conflict management function. In short, there is no medium-term CM function in place in the AAA system for inbound (or outbound) EHAM traffic and no intent information is available to perform conflict management.

- A CM function shall be in place for SARA to be able to issue conflict-free advice (to adjacent centres and Amsterdam ACC).

Speed And Route Advisor (SARA)

Input data

See concept 1.

Additionally, CM data is required.

Because dynamic routes will be developed in airspace which becomes available during periods of reduced co-ordination (see required changes to procedures), SARA must know when this airspace is available and its three-dimensional bounds.

- SARA shall be informed when, during reduced co-ordination, additional airspace becomes available and what airspace is available in order to take into account the extended block of airspace within which dynamic route deviations could be generated.

Generation moments

See concept 1.

Output data

See concept 1. In addition to a speed, SARA could generate a dynamically-determined route deviation (within a predetermined block of airspace).

Because separation within the block of airspace is initially assured by the system, the controller must instruct all flights about to enter the airspace block with the SARA generated speed and route.

- If required to comply with the EAT, SARA shall generate – in addition to a speed – a dynamic route deviation (within a predetermined block of airspace).
- The SARA-generated speed and route shall be free of conflicts.
- If the controller does not instruct the flight timely, i.e. well before the flight enters the airspace block, he/she shall be warned to instruct the flight.

Fall-back SARA

The controllers' working method will change due to the fact that – within a predetermined block of airspace – the system will provide advice that is initially free of conflict. The question is whether the controller is capable of reverting to conventional procedures if SARA fails.

- A thorough analysis shall be made of (required) controllers' competencies in order to determine whether a fall-back SARA is required or not.

Human machine interface (HMI)

The SARA-generated speed can be presented, as in concept 1 and 2, in the flight's track label. The route segment however, possibly consisting of a number of co-ordinates, may be too large for display in the track label. A possible solution is to present the abbreviation DYN in the track label (behind the advised speed) in combination with an on-request graphical display of the dynamic route on the map.

- An alternative solution shall be found for presenting the SARA-generated dynamic route on the radar screen.

Interface with adjacent centres

See concept 1.

Data link with aircraft

A dynamically-determined route could consist of a number of positional co-ordinates perhaps with altitude constraints detached. A route instruction of this kind cannot be passed to the pilot by radiotelephony. Hence data link is required to pass these route instructions.

- Data link equipment shall be available at all relevant controller positions.
- Data link equipment shall be available in all aircraft flying IFR to Schiphol.

4.4.5 Required changes to controllers' competencies

In concept 3 conflict management is introduced. This likely makes this version very different from the first two concepts in terms of attaining situation awareness and managing workload. Because

SARA-generated speeds and routes are presented conflict free, there may be less need for the level of situational awareness that is required nowadays. Therefore, the controller may not to have to build up his/her mental picture as much as in concepts 1 and 2. The same is true for decision making and problem solving. As a result, this makes the task of the controller less complex and is likely to reduce workload.

Concept 3 is seen as a further progression from the controller being an active problem solver to being a more passive monitor of traffic or a traffic flow manager. Furthermore, the controller is required to adhere to the speed and route presented in order not to disrupt SARA's 'plan' and send these to the aircraft via data link. Therefore in the progression from concept 1 to concept 3 the controller will likely have a decreased ability to fall back on basic controller skills when required.

The way of working enabled by concept 3 is expected to require less situational awareness and make decision making and planning easier. The result is a reduced complexity of the task. As a result, this makes training new controllers easier and less training is expected to keep the controller current. However, concept 3 should be seen from a different perspective.

This most advanced SARA concept is likely to fundamentally change the role and competencies of the controller. Therefore, the criteria that are currently used for making training impact assessments are less applicable than with the first two concepts.

By having a system that provides the pilot via data link with a conflict-free speed and route, the controller's role changes from an active problem solver to a traffic flow manager. Therefore, it can not be expected that future controllers will be able to maintain the competency level of present-day controllers or that present day competencies will still be relevant for concept 3. As a result, it can be expected that controllers will not yet be solely responsible for traffic handling, at least not for inbound traffic. Therefore, a fall-back system shall be in place that will continue to support the controller should system degradation occur. This requires a system with a high degree of accuracy and reliability and will likely require some degree of certification. This is a discussion that goes beyond the current project but is one that should be carefully considered inside the project and outside.

- The controller's new competencies shall be analysed profoundly to be able to estimate impacts on selection and training.
- The controllers shall be instructed in the way SARA works and in the related procedures.

5 Evaluation

In this chapter, the concepts that were described in the previous chapter will be evaluated. First, the aspects on which the concepts will be evaluated are determined. The results of the evaluation will lead to initial conclusions that will be discussed in the next chapter together with recommendations for initial implementation and required developments.

5.1 Evaluation of the SARA concepts

In chapter 2, requirements for the basic SARA concept were deduced. All concepts that are described in chapter 4 should comply with these requirements. However, it is not possible at this stage to evaluate if all requirements can be met by the concepts. The Safety, Efficiency and Environmental impact report (VEMER) will validate the different concepts on their compliance to the VEM requirements set. The planned real-time experiments and operational trial will contribute to this evaluation.

The main performance requirement for SARA was set on the accuracy of delivering the traffic at the IAF. This requirement is driven by the need for predictability in traffic flows in the TMA. Since the only reference at present for this requirement is stated in the LVNL Master Plan [Master Plan], the requirement that is stated there was used in this document. It is set to less than 30 seconds from the EAT for 99% of the traffic. It is, however, not possible at this stage to quantitatively evaluate if this requirement is met by the developed concepts. Therefore a relative qualitative evaluation of the different concepts will be performed in this chapter. A similarly qualitative assessment will also be carried out on the amount of adjustment in the actual time over the IAF that SARA can achieve. The impact of the location of the SARA Horizon on the expected performance of SARA will be discussed in this evaluation.

Note: The level of accuracy for the metering at IAF that is required to enable the envisaged way of creating a predictable time-based operation is something that has to be determined in more detail in the future. The foreseen introduction of P-RNAV routes in the TMA is expected to create a more detailed and operations-based requirement.

Other requirements derived in chapter 2 from the LVNL’s ATM System vision and strategy are based on the desire for “simplicity”. These requirements are related to the impact of SARA on controller task complexity and workload. We will qualitatively compare the impact of the developed concepts on task complexity and expected workload.

In addition, it was stated in chapter 2 that the introduction of SARA should not result in the need for extensive additional initial and refresher training. It should also support the controller in creating a more predictable traffic flow. The level to which the different concepts comply with these other requirements will need further evaluation. The results of the planned real-time simulations are expected to provide valuable input for this.

The functional requirements that were derived in chapter 4 should be considered in the upcoming design and realisation phase. These are requirements that are set by the developed concepts (e.g. for functions supporting SARA or the involvement of adjacent centres) and not requirements to which the concepts should conform. Evaluation of these requirements will be realized in the design phase.

Both the described human factor aspects (change in task complexity and required training) and consequences of derived functional requirements (necessary supporting functions and required involvement of adjacent centres) influence the complexity of implementation for the concepts. This is further evaluated in the next chapter.

In summary, the following sections qualitatively evaluate and mutually compare the concepts in the following areas:

- Ability (of the concepts) to absorb deviations from EAT
- Accuracy of metering at IAF
- Impact on workload for responsible controllers

5.1.1 Ability to absorb deviations from EAT

The expected capability of SARA advisories to absorb a certain deviation from the EAT in the different concepts cannot be quantified in this stage of the development. Results of real-time simulations and operational trials are needed for this. A qualitative comparison can however be made.

The amount of deviation from the planning that can be absorbed by an appropriate SARA advisory is dependent on:

- Speed window: the range of speeds available. The speed window can be defined as being the range between the minimum and maximum speed an aircraft of a certain type is able to fly on the planned route.
- SARA Horizon: the maximum time or distance from IAF an inbound flight is located, in order to be selected for evaluating the deviation from EAT.
- Available static or dynamic routes that can be used in SARA advice.

Speed window and SARA Horizon are factors that influence the capability of SARA advisories in all concepts. Routes are only influential in concepts 2 and 3.

Speed window

The possibilities to advance or delay a flight using a speed change are limited by the minimum and maximum speed an aircraft can fly on the planned route. The speed range will be different for different types of aircraft. The amount of deviation that can be absorbed using a speed instruction is thus a function of the current and default planned speeds and the remaining distance to the IAF on the planned route.

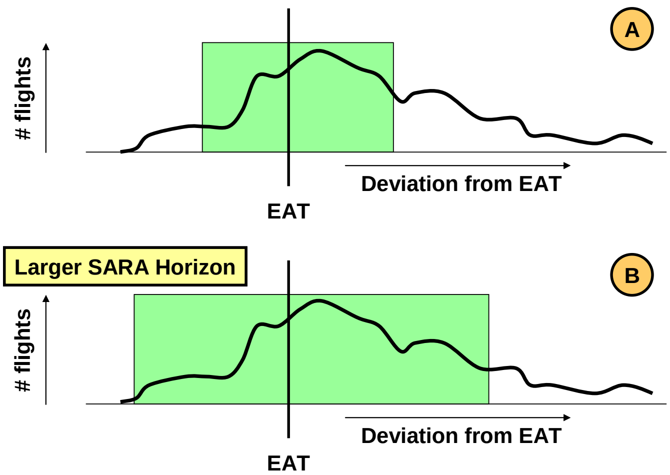

Figure 5.1 The amount of deviation from EAT that can be absorbed by a SARA advisory is dependent on the speed range within which a speed can be selected by SARA, and on the SARA Horizon. The speed range is determined by the capabilities of an aircraft and is fixed for SARA. With all factors considered constant, the possibilities to absorb a certain deviation are determined by he difference from the current speed and the minimum and maximum speed possible for the type of aircraft. This is depicted in the top figure (A). Increasing the SARA Horizon enables the generation of advisories earlier. Having the same speed window available this results in a larger deviation that can be absorbed. This is indicated in the bottom figure (B).

In Figure 5.1, an arbitrary deviation distribution for flights inbound Schiphol is presented by the curved line. This curve is not based on actual data and should be interpreted as an example. Flights that need to be advanced to meet their ETO are located left from the EAT-line. Flights that need delay are located right from this line. The bigger the distance from the EAT-line, the bigger the deviation that has to be absorbed is.

In the upper figure (A) the coloured area indicates the range of deviations that can be absorbed using a speed-only instruction. The left side of this area is limited by the maximum speed and aircraft can fly, the right side is limited by the minimum speed.

If the deviation from EAT for a flight is located outside the coloured area, this means that the most extreme SARA advice (speed-only) available does not delay or advance a flight enough to meet the planned EAT. In case of a needed delay the controller may still use executive measures, like vectoring of the flight, to enable correct metering. For advancing a flight more than possible with a SARA advisory, fewer alternatives will be available to the controller, especially if the flight is already on a direct route to the IAF.

SARA Horizon

When SARA can start calculating advisories earlier, i.e. the SARA Horizon is located further from the IAF, the amount of deviation that can be absorbed by issuing speed advice in the same speed window will increase. This is schematically depicted in Figure 5.1 (B).

The SARA Horizon can be controlled in all three concepts to a certain degree. In the description of the concepts in chapter 4, the SARA Horizon was envisaged to be located well before TOD for reasons of improved predictability, stability and related accuracy, together with environmental and economical benefits. Having the SARA Horizon located far from the IAF allows SARA to start generating advisories early. Since the time the advisories can influence the flight is relatively long, the advisories used to meet the EAT will require relatively small changes to the flight status. Moreover, because the SARA Horizon lies well before TOD of an aircraft, it will allow the flight crew to enter the advisory into the FMS, thereby enabling the FMS to optimize and predictably execute the flight path. This in turn will result in better adherence to the EAT requiring less adjustments or updates.

However, the maximum SARA Horizon is also limited due to other factors that need to be considered:

a) The IBP should be active and stable at the moment SARA starts generating advisories for a flight. In other words, the EAT for a flight should be known and fixed at the moment SARA starts generating advice. Thus, the SARA Horizon can only be located within the IBP Horizon. Note: For the IBP to work the TP should also be active. As discussed in chapter 4, active TP for a flight requires the presence of an ACT message in AAA. Absence of an ACT message will therefore limit the IBP Horizon.
b) Changes to the IBP, resulting in last minute adjustments for flights to meet their EAT, should be avoided. Pop-up traffic could introduce the need for such changes in the IBP. Having the SARA Horizon located further away will increase the amount of pop-up traffic, resulting in a possible disturbance of the IBP and associated increases in the need to update SARA advisories. Since the number of these extra updates due to changes in the IBP should be limited, it limits the location of the SARA Horizon.
c) Involvement of ATC centres: it might be that not all adjacent centres for all sectors are both willing and able to be involved in the use of SARA. This will influence the possible location of the SARA Horizon.

So from the point of view of SARA's span of control and related performance possibilities, the SARA Horizon should be located as far from IAF as possible (see Figure 5.1). Its extent will however be limited by the availability of a stable plan from IBP and required involvement of adjacent centres.

Having the SARA Horizon located outside the Amsterdam FIR implies the need for involvement of adjacent centres to pass the SARA advisories to the aircraft that are in their airspace. This in turn requires the availability of means to pass the SARA advisories to the adjacent centre and receive feedback from their actions. Although this enables the absorption of larger deviations from the EAT, it will increase the complexity of implementation.

Use of route options

With the speed window and the SARA Horizon considered fixed, the introduction of route options in the SARA advisories will increase the amount of deviation from the planning that can be absorbed by SARA. This is schematically presented in Figure 5.2.

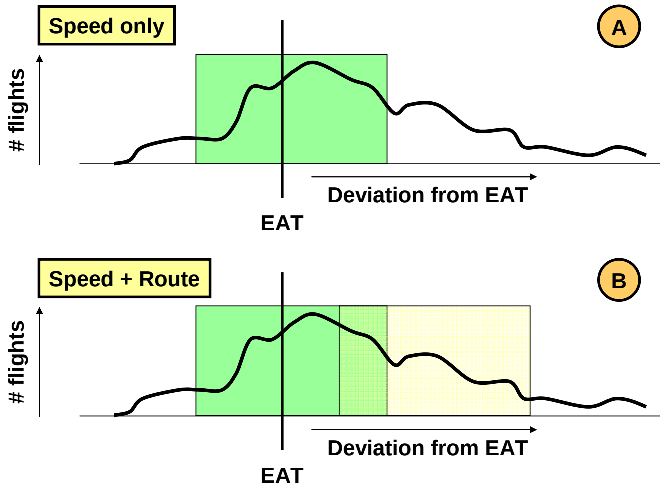

Figure 5.2 Use of route options will enlarge the amount of deviation from the planning that can be absorbed.

The coloured area in the upper part of the figure (A) shows an indication of the deviation that can be absorbed with a SARA speed-only advisory (concept 1). In the lower part of the figure (B) the effect of also having a route option available is shown: additional deviations can be absorbed by an appropriate SARA speed + route advisory. It will thereby enlarge the total range of deviation that can be handled by SARA advisories.

In Figure 5.2, a certain overlap between the deviations that can be absorbed by two different routes (the default and one alternative) is shown. This is merely indicative and will depend on the route design and aircraft type. Having an overlap however, will be practical and prevent the situation that, due to a small disturbance, neither a default route with minimum speed, nor an alternative with maximum speed can accurately absorb the deviation for a specific flight.

Route options are introduced in concepts 2 and 3. Depending on the configuration of the default route and the available airspace, the route option could contain extra or fewer track miles compared to the default route.

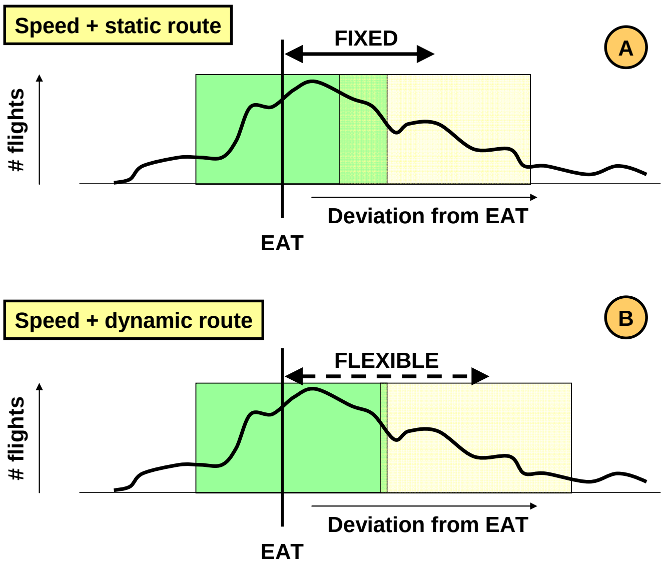

Figure 5.3 Difference between static and dynamic routes in relation to the deviation that can be absorbed by the advisory. The main difference is that the shift in deviations that can be absorbed is fixed for static routes while it is flexible for dynamic routes.

The difference between the use of static routes (concept 2) and dynamic routes (concept 3) is depicted in Figure 5.3. Static routes need to be published. The shift in deviations that can be absorbed using this route is therefore fixed as indicated in the top figure (A). Because the static route options are determined strategically, there is no possibility to adapt to unanticipated changes in the distribution of deviations from EAT of the inbound traffic. This might result in a situation where certain larger deviations that need the flight to be delayed cannot be absorbed with a SARA advisory. Other measures need to be used by the executive controller if correct metering at the IAF is still to be met. Depending on the traffic situation, this might not be desired or even possible.

For dynamic routes that are used in concept 3, the shift in deviations that can be absorbed is flexible. It can therefore be adapted to the needs of an individual flight. See the bottom figure (B) in Figure 5.3. It is expected that a flight, under normal conditions, can be delayed as much as needed with a SARA advisory containing a dynamic route and related speed. Thus, the advisory can be adapted flexibly to the requirements of the situation. Still, it will not be desirable from an operational point of view to also handle exceptional large required delays this way. These situations will most probably be dealt with separately.

If a flight needs to be advanced more than is possible with a direct route and maximum speed possible for that particular aircraft, this is still not possible with advisories as developed for concept 3. Therefore the IBP must calculate a realistic and achievable EAT for every flight.

Conclusion

In conclusion, with the same SARA Horizon assumed for all three concepts, the amount of deviation from the planning that can be absorbed by SARA advisories is the smallest for concept 1, is larger but fixed for concept 2 and flexibly adjustable in concept 3.

In all concepts, there might be deviations from the planning that are too big to be absorbed by a SARA advisory. These are flights that need to be advanced more than is possible using maximum speed and direct routing to the IAF. For concept 1 and 2, these may also be flights that need to be delayed more than possible with a speed-only or speed & static route advisory, or exceptionally large delays for concept 3. As discussed in chapter 4, the controller should be informed if SARA is unable to provide an advisory that will result in the flight's meeting its EAT within required performance bounds.

Moving the SARA Horizon further out will positively influence the amount of deviation that can be absorbed for all concepts. However, the benefit will be limited by the need for a fixed and stable IBP. Moreover, extending the SARA Horizon beyond the Amsterdam FIR has technical implications and will generate bi-lateral agreement requirements due to the need for involvement of adjacent centres. Both will increase the complexity of implementation.

5.1.2 Accuracy of metering at IAF

The previous section qualitatively evaluated the possibilities that the different concepts offer in absorbing deviation from the EAT. Here we want to qualitatively evaluate the possible differences in metering accuracy. Quantitative evaluation of the accuracy for the different concepts should be done using results of real-time experiments.

Considering accuracy for a single flight

At first observation, there is no obvious reason for having a difference in the accuracy that can be achieved between the different concepts for a single flight. For every flight, the deviation from EAT is predicted and a suitable SARA advisory generated to absorb the predicted deviation. If the amount of deviation is such that the SARA advice can absorb it (see the discussion in the previous section) then, in theory, this will lead to adherence to the planned EAT.

Factors that influence the accuracy of metering at IAF for a single flight are:

- deviation from the predicted flight path due to executive measures needed to resolve conflicts or avoid severe weather;
- deviation from the predicted flight path and cleared speed by flight crews;
- inaccuracies in the TP;
- changes in the IBP due to pop-up traffic; relation with the SARA Horizon;
- changes in the IBP due to aircraft not adhering to their planned EAT;
- resolution of SARA advice; speed can be given in e.g. 5 knots or 1 knot increments. Instructing the speed advisory in 5 knot increments can result in an inaccuracy at IAF.[23]

So it is the expected difference in stability of the planning and predictability of the flight execution among the different concepts that might result in different accuracy that is to be expected for the concepts. Also, the flexibility to adjust a flight that already received SARA advice might be of influence on the accuracy of a single flight. Since the use of conflict free dynamic routes in concept 3 gives the most flexibility, it is expected that changes in the planning can be handled better than in concept 1 and 2.

Considering accuracy for all flights

The accuracy of metering at IAF for all flights that is expected for the different concepts is the result of both the amount of deviation that can be absorbed and the accuracy for a single flight. Having more flights for which SARA cannot generate appropriate advice will lead to more flights that will not meet their EAT. Since concept 3 is expected to have the best possibilities to absorb deviations and the most flexibility for intermediate adjustments, it is also expected to have the best overall accuracy.

In the above reasoning, executive measures that the controller will use for flights that are not expected to meet their EAT are not considered. In concept 1 and 2, the controller will still have the

[23] Assuming an average speed of about 250 knots IAS, a maximum difference between calculated and instructed of 2.5 knots, the deviation will be 1/100 of the remaining flight time to IAF after the SARA instruction is executed. For a flight time of 12 minutes, this results in a maximum of 7 seconds inaccuracy resulting from the resolution of the advisory. For longer flight times it will increase. At the moment that the ETO is differing more than the set maximum from the planned EAT, SARA will update the advice if possible. Such an update will only be provided if the flight is outside the minimum distance from IAF to generate a new advisory.

ability to use executive measures to try to meet the EAT “by hand”. For concept 3, this is not expected to be needed. Moreover, in concept 3, executive measures might lead to undesired updates of flight paths for other flights that are needed to maintain a conflict-free operation.

Conclusion

Concept 3 is expected to result in the best overall accuracy for metering over IAF. Concept 1 is expected to produce less accurate results than concept 2. Depending on the location of the SARA Horizon and the stability and accuracy of the SARA supporting functions IBP and TP, the absolute difference in accuracy that is produced may vary among the concepts. Which concept is able to meet the performance target of less than 30 seconds from EAT in practise, using which configuration of SARA Horizon and supporting functions, should be evaluated using real-time experiments.

5.1.3 Impact on workload for the responsible controller

In chapter 4, the consequences for the workload of the controller working with the SARA advisories were estimated for the different concepts. Although the change in workload as compared to current-day operation is difficult to assess on only a theoretical basis and is dependent to an extent on the implementation design, a qualitative comparison between the different concepts is possible. Results of the planned real-time experiments are expected to provide a more quantitative comparison.

SARA advisories in concept 1 are limited to speed-only; in concept 2, static routes can be part of the advisory. For both concepts, it is envisaged that the number of SARA advisories will be limited. In fact, SARA will intend to issue one single advice that is expected to result in correct metering over IAF. However, the advisories are not checked for potential conflicts along the flight path. This is the main difference with today’s way of controlling the aircraft; the controller now tries to create instructions that meet the EAT, but will issue instructions from which he knows (to what point) they will be conflict free. This might result in more instructions needed to meet the required time at IAF, but implicitly helps the controller maintain situation awareness.

Therefore it is expected that the number of instructions that need to be communicated to the flight crew in order to meet the planned EAT decreases with the introduction of concept 1 or 2 when compared to today’s operation. However, maintaining situation awareness will require additional effort. This effect is expected to be higher for concept 2 due to the involvement of static routes.

For concept 3, the advisories will be conflict free, making the controller’s task less complex, requiring less situation awareness and likely reducing the workload compared to concepts 1 and 2.

Conclusion

From the three concepts that have been developed, concept 3 is likely to have the greatest reduction in workload. Concept 1 is expected to have the least impact on situation awareness. Assuming that the workload reduction due to a decreased RTF load is similar for concept 1 and 2 and an equal percentage of flights over which tactical control needs to be maintained for both concepts, this would lead to more reduction in workload for concept 1. However, since the percentage of flights that require additional tactical control is expected to be higher in concept 1, the overall workload reduction for concept 2 is most probably larger.

Note that the required change in working procedures and the expected movement towards monitoring instead of actively solving problems are not taken into consideration in this qualitative evaluation. The effect on the overall workload of the introduction of SARA, will need to be investigated further.

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6 Conclusions and recommendations

In the previous chapter, qualitative evaluations of the expected performance of the SARA concepts and their estimated impact on the workload of the controller have been made. Based on these results, an overall conclusion is made in this chapter. In addition, an assessment of the complexity for implementation of the different concepts is performed. This will lead to recommendations that are given in the next sub-chapter.

6.1 Conclusions

From the evaluation in chapter 5, it is concluded that concept 3 is expected to have the best capabilities to absorb deviations from the planning. Moreover, delivery at the IAF is likely the most accurate, and the concept is estimated to have the largest positive impact on the workload of the controller. It is therefore the most promising concept to develop further for direct implementation.

However, implementation of SARA also needs changes to the controllers´ expertise (the human factor), the technical systems and procedures (with all three developed concepts). The required changes in these areas for the different concepts have been discussed in chapter 4. The complexity of implementation of a concept significantly affects the effort and time needed to meet these requirements. In the next section, the complexity of implementation for the different concepts is discussed using LVNL's Mens/Machine/Procedures (MMP) terminology.

6.1.1 Complexity of implementation

The level of required change in MMP-terms for the three developed concepts is different. Supporting technology (Machine), expected changes to the controllers' working procedures (Mens), and the involvement of adjacent centres (Procedures) are all expected to have significant impact on the complexity associated with implementation of the concepts. These elements will be compared for all three concepts.

Mens

The changes to the controller's working practices are also the largest for concept 3. Here the task of the controller will change from problem solving to monitoring, impacting situation awareness the most. For concept 1 and 2, the impact is smaller with concept 2 causing the slightly larger impact of the two due to the introduction of static routes.

In addition, the implementation of SARA will introduce changes in the inbound planning process, thereby affecting the working methods of the approach planner (see also section 4.2.4). These changes are expected to be present for all concepts and will be dependent on the changes to IBP.

Machine

All concepts require improvement of the current IBP and TP for the generation of accurate SARA advisories. Concept 2 requires more technological changes compared with concept 1 due to the introduction of static routes. Concept 3 also requires conflict-free dynamic routes. Dynamic, conflict-free route clearances will require the general availability of data link communication and the incorporation of a proven and accepted Conflict Management tool. This represents a significant change in technology that is expected to require a large amount of effort and time.

Procedures

Assuming the involvement of adjacent centres in the developed concepts (i.e. assuming the SARA Horizon to be located beyond the Amsterdam FIR), concept 3 is considered to require significantly more change to the current working methods with adjacent centres. Introduction of dynamic routes and conflict management will involve time and effort as well as costly legal matters. For concept 1 and 2, this will be much less. Since concept 2 requires definition of static routes and related additional COP's with adjacent centres, this impact is larger than for concept 1.

The conclusions in this section have been summarized in Table 6.1. The resulting relative complexity of implementation is much larger for concept 3 than it is for concept 1 and 2, and larger for concept 2 than for concept 1.

Table 6.1 Indication of the order of magnitude of the required changes in MMP terms per concept resulting in an indication for the relative complexity of implementation.

Required changes	**Concept**		
	1	**2**	**3**
Mens	Small	Some	Significant
Machine	Small	Some	Significant
Procedures	Small	Some	Significant
Complexity of implementation	**Smallest**	**Intermediate**	**Largest**

Although concept 3 is expected to give the best performance results, if implementation of SARA is required in the near future, concepts 1 and 2 are more suitable. The complexity of implementation for concept 3 is too large to enable operational usage in the near term.

In sub-chapter 6.2 recommendations for further research, development and implementation of SARA have been drawn up based on the evaluations and conclusions in the last two chapters.

6.1.2 Combining concepts

Throughout this document, the developed concepts have been described completely separately. However, implementation of SARA does not need to be limited to a single concept. Combinations of different concepts are an option and should be considered if possible. Also the SARA Horizon does not have to be restricted to a single value for all sectors. A variable horizon would allow the optimum usage of SARA in an operation where, for example, data link is not available in all arriving aircraft, or not all adjacent centres are willing (or able) to cooperate with Amsterdam ACC.

This is reasoned from a theoretical point of view, with the knowledge available. New insights or practical reasons might complicate the implementation of concept combinations or use of a variable SARA Horizon. However, at this stage it is concluded that:

Implementation of SARA does not need to be limited to a single concept nor does the SARA Horizon need to be equal for all sectors involved

6.2 Recommendations

Based on the conclusions drawn, implementation of concept 3 is the preferred concept for use in operations. Due to the complexity of implementation however, it will require significant change, resources and time before it can be operational deployable.

Concept 1 and 2 will also increase the accuracy of metering over the IAF. To let the operation benefit from SARA sooner, a stepwise implementation is recommended. This approach will also allow the required technological developments to take place stepwise. Controllers can adapt to the new working procedures more gradually while already producing more predictable and stable traffic flows. Lessons learned from practical experience can be used in the next implementation step.

Improvement of TP and IBP is required for all concepts; projects should be started parallel to the development of the first implementation step of SARA.

In the meantime, preparations for the complex implementation of concept 3 should be started. Projects should be planned for the development of CM and data link. The concept of use of dynamic routes and its impact on the expected competencies of the controller and required training should be further investigated.

To enable an informed choice of which concept (1, 2 or a combination of 1 and 2) to implement first, practical experience is of added value to the theoretical insights so far. It is therefore planned to:

- **Prototype concepts 1 and 2 and perform real-time simulations**
  Based on the results of hands-on evaluations of the prototype, real-time simulator sessions will be prepared. The NLR ATM Research Simulator (NARSIM) will be used for these sessions. From the RTS experiments, it will be possible to (quantitatively) measure e.g. controller workload, metering over the IAF including statistical distribution, changes to average flown track miles and related fuel burn. Also coordination with adjacent centres can be simulated, enabling the validation of proposed hand-over procedures, suggested RTF phraseology etc. In addition, it will be possible to measure the performance of the concepts with different configuration settings of, for example, SARA Horizon, SARA advisory update frequency etc.
- **Prepare and conduct an operational trial using concept 1**
  An operational trial can be planned to involve a large portion of the controllers. It enables feedback on workability of the concept and gives reliable insight into controller acceptance. It will give insight into practical issues that need further investigation and might give an indication on the required training. Moreover, an operational trial requires the involvement of aircraft and flight crews, enabling the collection of feedback on SARA from this party, and the assessment of real-world operating effects. To limit the changes required for the operational trial, use of concept 1 is expected to be most suitable.

In summary: the results of the RTS experiments and the operational trial should be used to decide on the first implementation step of SARA and will provide valuable data to be used in the detailed design of SARA and the supporting functions. Implementation should be made possible in the near future. Meanwhile, preparations for the future implementation of concept 3 should be started.

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Bibliography

AADT	Research Report Advanced Arrival Techniques – Using aircraft capabilities for improving arrivals. D/R&D 05/026 version 2.0 dated July 31, 2006.
Assignment	Project assignment "*Verzoek definiëren AT Concept Element SARA*" (in Dutch). SCT/2007/018 dated 10 April 2007.
EDA	Coppenbarger, Richard A., Richard Lanier, Doug Sweet, and Susan Dorsky, *Design and Development of the En Route Descent Advisor (EDA) for Conflict-Free Arrival Metering,* AIAA 2004-4875, AIAA Guidance, Navigation, and Control Conference, Providence, RI, August 16-19, 2004.
Hopkin, D.	(1995). *Human Factors in Air Traffic Control.* London; Taylor & Francis Ltd.
Masterplan	Masterplan LVNL ATM Vision & Strategy (in Dutch). LVNL document D/R&D 07/009 version 1.0, November 2007.
Method CONOPS	LVNL, afdeling MS Research, *Methode Ontwikkeling CONOPS* (in Dutch). *Proces Veranderen ATM Systeem*, versie 2.0, 1 augustus 2003.
Oprins, E. & Schuver, M.	(2003). Competentiegericht opleiden en beoordelen bij LVNL. *HUFAG nieuwsbrief, 6,* p.2-4.
OTA	ATM Operational Concept Document Tailored Arrivals. OCDTA-P2-001, 20 April 2006.
Project plan	Project plan P1557 "Speed And Route Advisor (SARA)". Doc. Nr. KDC-2007-0040 version 1.0 dated 11 May, 2007.
VEMPS 2007/2008	VEM Performance Standard Winter 2007/2008. Doc D/R&D 07/002 version 1.0, 10 April 2007.

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List of abbreviations & acronyms

A/G	air to ground
AAA	Amsterdam advanced ATC system
AC	area control
ACC	area control centre
ACFT	aircraft
ACK	acknowledge
ACT	activation
AIP	aeronautical information publication
AMA	arrival management message
AMAN	arrival manager
ANSP	air navigation service provider
AoI	area of interest
AoR	area of responsibility
APLN	approach planner
APP	approach (unit)
ATC	air traffic control
ATCO	air traffic controller
ATM	air traffic management
ATS	air traffic services
CAS	calibrated airspeed
CB	cumulus nimbus
CDM	collaborative decision making
CM	conflict management
CONOPS	concept of operations
COP	co-ordination point
EAT	expected approach time
EC	executive controller
Econ	economic(al)
EDA	en-route descent advisor
EHAM	Europa Holland Amsterdam
ETO	estimated time over (IAF)
FIR	flight information region
FMC	flight management computer
FMS	flight management system
G/A	ground to air
G/A/G	ground to air and air to ground
G/G	ground to ground
HMI	human machine interface
IAF	initial approach fix
IAS	indicated airspeed
IBP	inbound planning
IDENT	identification
IFR	instrument flight rules
JER	juridische-effectenrapportage
LIV	landing interval
LNAV	lateral navigation
LoA	letter of agreement
LVNL	Luchtverkeersleiding Nederland (Air Traffic Control the Netherlands)
MADAP	Maastricht automated data processing and display system

MCP	mode control panel
MilATCC	military ATC centre
MSL	manual slot
MUAC	Maastricht Upper Area Control Centre
N	no
NARSIM	NLR ATM research simulator
NDB	navigation database
NLR	Nationaal Lucht- en Ruimtevaartlaboratorium
NM	nautical mile
NPT	new planning time
OLDI	on-line data interchange
PLC	planning controller
POD	procedure-ontwerpdocument (procedure design document)
P-RNAV	precision area navigation
QRC	quick reference card
QRH	quick reference handbook
RTA	required time of arrival
RTF	radiotelephony
RTS	real-time simulations
RWY	runway
SARA	Speed And Route Advisor
SDM	supplementary data message
SES	Single European Sky
SESAR	SES ATM Research
SFPL	system flight plan
STAR	standard arrival route
SUP	supervisor
SUR	surveillance
TC	terminal control
TLS	target level of safety
TMA	terminal control area
TOD	top of descent
TP	trajectory prediction
U/S	unserviceable
UCO	under control
VCS	voice communications system
VDV	Voorschriften Dienst Verkeersleiding
VEM	veiligheid, efficiency, milieu
VEMER	VEM-effectenrapportage
VNAV	vertical navigation
Y	yes

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Annex A - An outline of the current ATM-system

A.1 Introduction

Inbound traffic is normally coming in the direction of Schiphol via the airway structure. From an airway the traffic is proceeding on a Standard Arrival Route (STAR) to a Initial Approach Fix (IAF). From there the traffic is radar vectored to the landing runway.

Figure A1 shows the side view of a flight approaching SPL. The aircraft proceeds through the Upper Control Area (UTA) and descends through the Control Area (CTA) and Terminal Control Area (TMA) to be handed over to the tower and land.

The CTA, UAC and TMA areas are not presented in detail to reduce the complexity of the figure. The blue area represents the area where the flight is still outside MUAC AoR. The green area corresponds to the ToD and the region when the aircraft is still outside of the Amsterdam FIR, grey area denotes the area where the aircraft is assigned to the Amsterdam ACC and yellow area corresponds to the area where the aircraft is taken over by the APP. All these areas as well as the corresponding distances, timeframes and events shown below will be described later in the text.

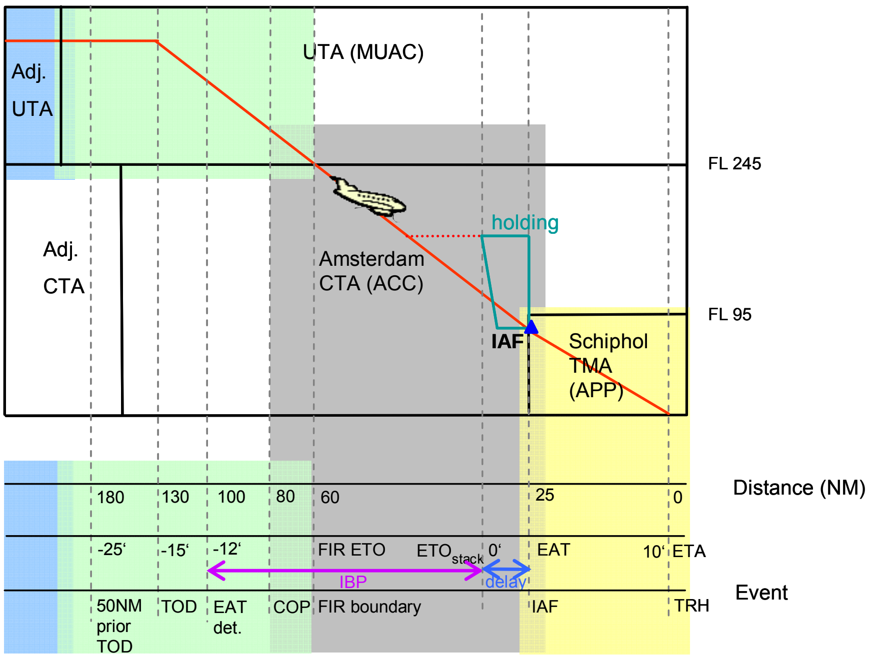

Figure A1 Simplified side view of a flight approaching SPL.

Inbound traffic to Schiphol usually starts its descent 200-100 NM prior to Schiphol. This means that the ToD is always outside the Amsterdam FIR. In this area the traffic is complex because there is not only inbound traffic to Schiphol, but also crossing traffic and traffic to and from other main airports in the neighbouring countries. (e.g. London, Brussels and Frankfurt.)

Moreover, the flight passes through several blocks of airspace in the Netherlands as well as outside of the Amsterdam FIR. As an example an inbound flight to Schiphol from the south works with six different ATC units before landing at Schiphol as shown in Figure A2.

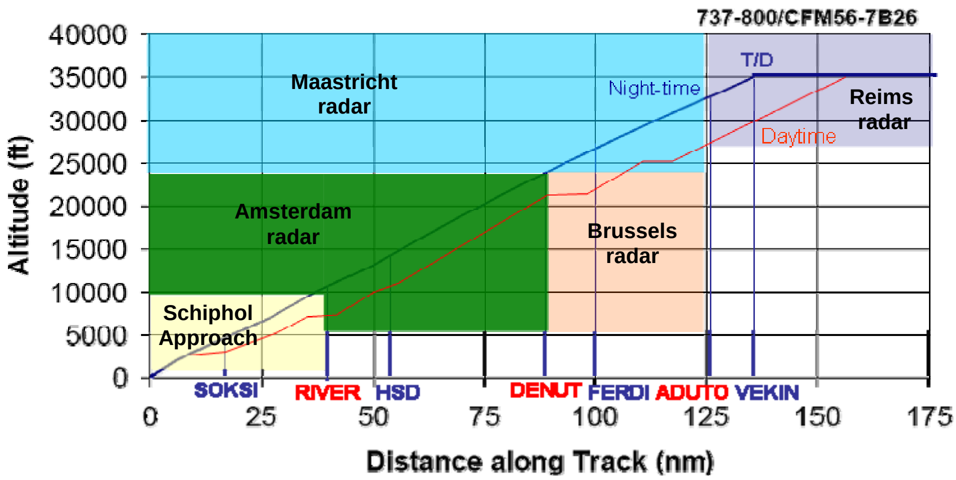

Figure A2. ATC units involved with a B737-800 descent from FL350 to Schiphol runway 06 during day and night time

The Amsterdam FIR is adjacent to several foreign FIRs. Each FIR is divided in lower and upper airspace. For instance the upper airspace above the Benelux and a large part of Germany is controlled by Maastricht UAC. Other upper airspaces that are adjacent to Maastricht UAC are London UAC, Scottish UAC and Reims UAC. Depending on the origin of inbound traffic several of these airspaces will be crossed. In the description below only Maastricht UAC is considered.

The Dutch ATC centre takes over the flights from the neighbouring ATC centres: London, Bremen, Langen, Brussels, Scottish and Dutch military.

Outside of the Amsterdam FIR the inbound flight to Schiphol flies mainly the standard routes (depending on the coordination with the military) filed in the flight plan. During the flight the rerouting is possible due to the restrictions on specific ATS route points or segments in both the upper and lower airspace.

The paragraphs below describe the inbound traffic process in more detail.

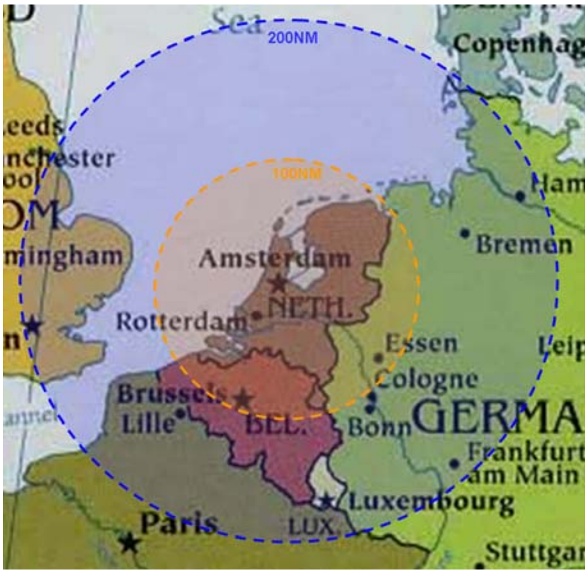

Figure A3. Area where the aircraft begins its descent (200-100 NM prior to SPL).

A.2 Approaching the Maastricht AoR

The phase of the flight that is described in this paragraph, is depicted by the blue area in Figure A2.

MUAC Planning of inbound traffic

Eighty minutes prior to the estimated entry in to the airspace under the responsibility Maastricht Upper Area Control Centre (MUAC) the Initial Flight Plan Processing System (IFPS) of the Central Flight Management Unit (CFMU) sends MUAC the most up to date version of the flight plan. Reception of the flight plan from IFPS results in the creation of an inactive flight plan, no events are scheduled when a flight plan is in this state. It remains dormant in the system until activated. Change or delay messages received via the IFPS will be automatically associate with the flight plan and the inactive plan modified accordingly.

Via the Online Data Interchange system (OLDI) Advance Boundary Information is received from the upstream sector approximately 30 minutes prior to the UAC entry this is associated with the inactive flight plan and checked for coherency. Activation occurs when an Activation Message (ACT) is received from the previous Centre. This typically occurs 20 to 15 minutes before entering Maastricht UAC's Area of Responsibility (AoR). Upon Activation, an SSR Code is allocated to the flight and all events related to the flight plan, like the Correlation Process, Flight Plan Progress Monitoring and STCA processing, are calculated, scheduled and ultimately executed when the scheduled time arrives.

Internal Data Distribution Events ensure that the relevant flight data is made available to the right controller at the right time while External Data Distribution Events will ensure that the relevant flight data is made available to the downstream external Centre at the right time. The Controllers need to know which flights are to be controlled by them at any time, in order to do so, the expected sequence of sectors is to be determined by the System.

The route filed contains information which allows the calculation of a 4-dimensional path for the flight, the route gives the path in the horizontal plane and processing the different Flight Levels in use at MUAC (Requested, Entry and eXit Flight Levels) adds the vertical aspect of the flight path. This is done taking into account the aircraft performance parameters (based on generic type specific data). Two main principles are used to determine the Vertical profile: An aircraft will climb as early as possible (to reach its RFL as soon as possible) and an aircraft will descend as late as possible (to keep its RFL as long as possible). Using the estimated time information of the ACT message and the continuous recalculation as the flight progresses, the expected timing over significant points can be added.

A flight plan is presented to the sectors responsible to the flight for a set time prior to entry to that sector. First planning information, concentrating on coordination for both up and downstream are displayed to the control team, and shortly after tactical information is made available. This is displayed in textual form in windows which the controllers may view however most of the information is also available via the label associated with the radar track.

Approaching the Amsterdam FIR through Maastricht AoR

The phase of the flight described underneath, is depicted in Figure A3 in the green area.

MUAC Working Method

When the aircraft is transferred to MUAC and has called in on the frequency the Executive controller "Assumes" the flight, this indicates to the system that the flight is now under the responsibility of MUACand initiates further events that have been scheduled.

Control teams at MUAC are generally made up of a Coordinating Controller and an Executive Controller: The Co-ordinating Controller (CC) establishes the overall plan for the entry and exit of the traffic and for the flow of that traffic through and, whenever possible, beyond their sector's AoR. They are responsible for the co-ordination with adjacent and subjacent sectors or ATM-Units, and assist the Executive Controller in their tasks.

The Executive Controller (EC) carries out the overall plan established by the Co-ordinating Controller and is responsible for the direct control of the aircraft assigned to them. It is the EC who assumes responsibility for a flight, they are in radio or datalink contact with the cockpit crew and issue ATC instructions to them to ensure that the minimum separation standards are maintained, and that a safe and efficient flow of traffic is maintained.

A.3 LVNL Planning of inbound traffic

The Amsterdam Advanced ATC system (AAA) is the main supporting system for Air Traffic Controllers at LVNL. It provides several functions which support the Approach Planner (APLN) and Executive Controllers (EC) in planning inbound traffic.

Up to five hours before traffic is estimated to enter the FIR, the AAA system receives the Flight Plan (FPL) from the Integrated Initial Flight Plan Processing System (IFPS) in Brussels, to which AAA is directly linked. Two hours before entering the FIR, the route is extracted from the received flight plan and transformed to a System Flight Plan (SFPL). The SFPL starts with a reporting point (RP) outside the Amsterdam FIR, adding following known RP's along the extracted route and ending with the DEST. Also an entry co-ordination point / change-over point (COP) is determined for all IFR inbound traffic. The COP is the point where the handover of traffic between adjacent centres takes place.

Airborne data, such as information on actual routing and estimated times, can be used to update the SFPL. The CFMU maintains an overview on the overall flow of European Air Traffic. In the near future AAA could use Flight Update Messages (FUM) from CFMU. These messages provide an accurate estimated landing time which can be used to update the SFPL.

Control Coordination with adjacent centres makes it possible to exchange tactical flight plan data (coordination information) between AAA and systems of adjacent centres, without manual intervention. The exchange of tactical flight plan data with adjacent centres is based on System Supported Coordination (SYSCO) messages and procedures. Eight minutes before traffic reaches the COP an Activate message (ACT) is received from an adjacent centre. The purpose of this message is to update the SFPL with the latest information available (e.g. route information, estimates and SSR code).

As soon as the ACT is received, the correlation function is able to connect radar tracks to SFPL's and maintain a flight position for a SFPL. As soon as correlation between a System Flight Plan (SFPL) and a radar track is established, Trajectory Prediction (TP) updates the expected time of arrival at the FIR entry (FIR ETO), stack (ETO stack) and runway ETA. These calculations are made using the SFPL, actual position, aircraft performance and wind data. TP is used for inbound planning and is performed at least every minute.

Inbound planning (IBP) regulates flights entering the SPL TMA. The IBP function is used by the APLN, using the Electronic Data Display (EDD). When traffic is still outside the FIR the inbound process starts with the creation of a planning. The planning is divided in several steps and starts with the determination of the Schiphol inbound ATM configuration. A runway combination with corresponding capacity is determined under responsibility of the APP-SUP and TWR-SUP in consultation with KNMI and AAS. Depending on the time of the day there is either more traffic inbound than outbound, or vice versa. These periods are called peak periods, and there are several of these periods during the day. During the day (0600-2300) in peak periods most of the time three runways (e.g. two inbound and one outbound, or vice versa) are in use at the same time. At some moments it can be even four. Outside peak periods there are only two runways in use (one inbound, one outbound) and in special circumstances only one runway is in use (both for in- and outbound). There are a lot of different runway combinations, and during the day the combination in use is changed several times. These changes are the result of changing traffic demand and/or changing weather. During the night (2300-0600) there is only one runway for inbounds and one runway for outbounds. Normally only runway 06-24 and 36L/18R are used. Which runway combination will be used is primarily depending on weather, and secondary on environmental rules. The environmental rules are translated in a preferential runway system.

Next step is that the APLN determines a stack preference for each landing runway. Normally only one runway is allocated to a stack to avoid traffic from one stack going to different runways. The exception is the RIVER-stack, which will usually feed more runways, depending on the runway combination in use. The stack preference is depending on the runway combination. Then a Landing Interval (LIV) per runway is established which in fact determines the landing capacity.

Sixteen minutes before ETO stack, the flight is displayed in the EDD of the APLN. Twelve minutes before ETO stack IBP initially assigns landing runways to flights and plans a landing sequence based on the LIV, ETA (from SFPL), Wake Turbulence Category (WTC) and wind conditions.

The output of IBP is a calculated runway slot, an Expected Approach Time (EAT) at the Initial Approach Fix (IAF) and the delay for each flight. This EAT is not dynamic, but the sequence can be manually adjusted by the APLN when required. This process is called runway balancing. By planning in this way it is assured that the TMA is not overloaded.

Reserved slots are assigned to unplanned flights that have an ETA preceding a planned flight. These unplanned flights are called pop-up flights and need to be activated (ACT).

Actual times over and flight position are continuously monitored to see if there are any deviations from the route.

MUAC Coordination Procedures

During the initial processing of the flight plan certain adaptations are made to assist the control teams at MUAC. In particular for the inbounds to Amsterdam a Maastricht XFL is automatically inserted of FL260 – this being the agreed transfer flight level in the Letter of Agreement between the Maastricht and Amsterdam Centres. It is the responsibility of the coordinating controller to ensure that the coordination with Amsterdam ACC has been successfully effected via the OLDI link, or in the case of failure verbally; and it is the responsibility of the executive controller to ensure that the aircraft is at FL260 at the agreed transfer point.

Under standard conditions the controllers will direct the aircraft to the agreed transfer point however when military activity allows, and with prior agreement between Amsterdam and Maastricht direct routing to the initial approach fix may be given. This takes in to account the prevailing situation in both the civil sectors and the needs of the Dutch and German military partners. In exceptional circumstances, e.g. thunderstorms, and with prior coordination, controllers may deviate entirely from the standard route network and the anticipated vertical profile.

At a distance where the executive controller judges that the aircraft can meet the clearance to descend to FL260, he will issue this clearance and takes into account all other traffic in his sector. This can be done via voice or data-link communication and, when conditions allow, this task may be delegated to the coordinating controller (using data-link). Should more than one aircraft be inbound to Amsterdam at the same time the controller will endeavour to sequence the flights with a distance of ten miles between them. If this is not possible, then vertical separation will be used. Sectors will endeavour to sequence inbounds through their individual AoRs however sequencing of arrival streams between sectors is not done. To assist the controller in this task, the 'Verification of Separation' tool and Short Term Conflict Alert are used.

At or before the agreed transfer of control point the controller will instruct the pilot (via voice or data-link) to contact Amsterdam. Should there be any outstanding coordination, a warning is provided to the coordinating controller and the downstream unit is informed. When the flight plan is no longer of operational interest, i.e. after the flight has left Maastricht UACs AoR (detected by the flight plan progress monitoring process), the flight plan is deleted from the system, and all distribution of data for this flight will be stopped.

ACC Coordination Procedures

The flight inbound Schiphol is handed over to the LVNL ACC Executive Controller (EC) conform agreements laid down in Letters of Agreement (LoA). These agreements are different per sector and described in the VDV. They contain for instance the sectorisation of the adjacent unit, airspace structure, coordination agreements, coordination points, flight level allocation, radar coordination procedures and procedures for transfer of control and communication.

A.4 Guidance to the Schiphol TMA boundary

Airspace and routes

The inbound flight which enters the Amsterdam FIR and is below FL 245, is taken over by the Amsterdam ACC as is made clear by the green area in Figure A2.

Amsterdam ACC area is divided into 5 sectors: sector 1 until sector 5. The vertical boundaries of the Amsterdam ACC are from the FL 55/FL 65/(or FL95 during weekends/holidays) until FL 245.

The lateral route, which an inbound aircraft follows from the FIR boundary until IAF (i.e., within the ACC area) is fixed and called Standard Arrival Route (STAR) (Fig. A5). There are three TMA entry points (IAFs): SUGOL, RIVER and ARTIP. These points are also holding points. Additional holding point is NARSO (see Fig. A5). It is used only if the ARTIP holding does not have enough capacity.

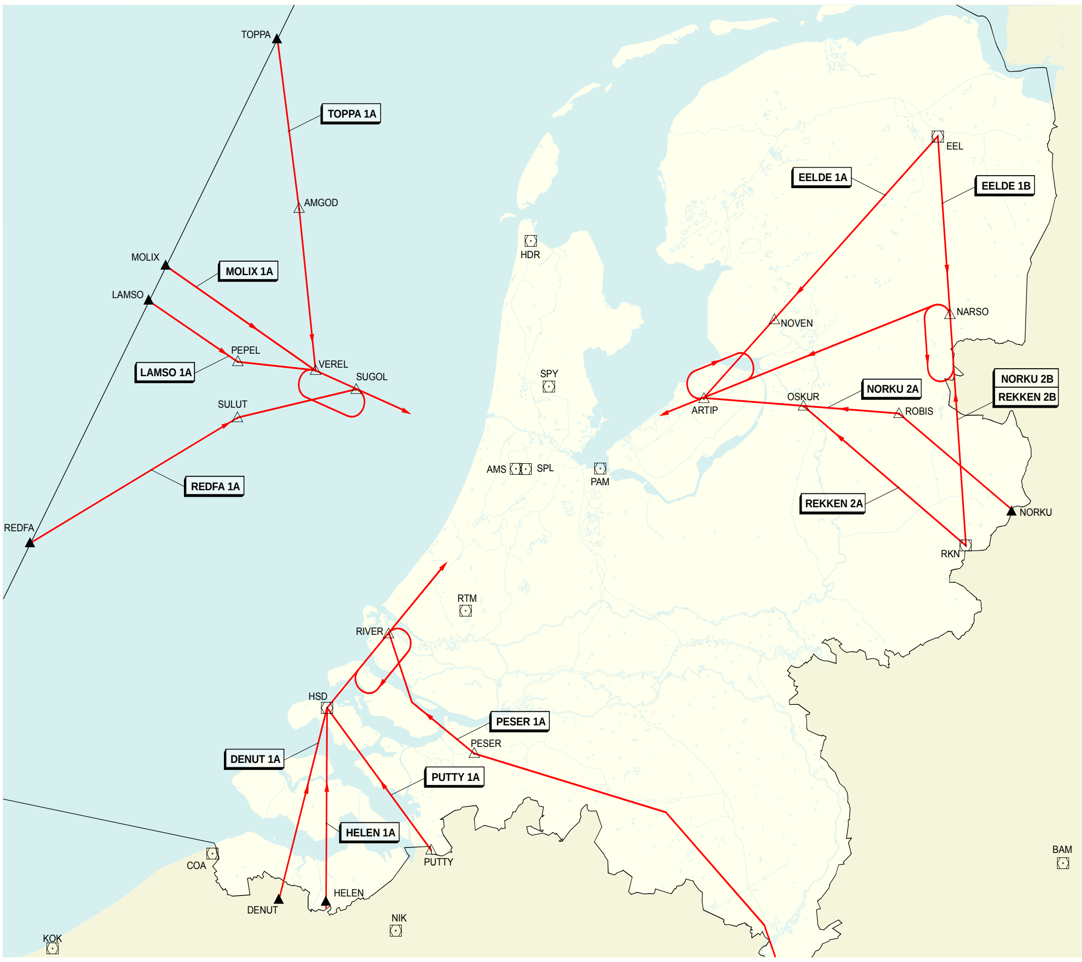

Figure A5. STARs and the 3 IAFs within the Amsterdam FIR.

ACC Working Method

The EC guides the inbound traffic to the IAF based on the EAT. The process starts before or at the entrance of the Amsterdam ACC sector when the arrival clearance, is issued. To guide the traffic to the TMA boundary the EC has to merge the inbound flows to the relevant IAF, and to keep the flight path of each aircraft free of other out-, inbound or crossing traffic. To resolve conflicts, to delay or expedite traffic the EC may deviate traffic from a STAR by issuing directs, vectors and/or speed control. Vectoring means issuing heading instructions. When reduced coordination is applicable (extension of the airspace when Dutch Military is inactive), inbound traffic is often instructed not to follow a STAR but a shorter direct route instead, which takes the traffic through the extended sector (military) airspace. Besides the inbound flows described above there is also pop-up traffic which shall be merged with the inbound flows. Pop-up traffic is traffic which is departing from nearby aerodromes inbound to Schiphol and popping up within 12 minutes before ETO stack.

The EC controls the flight taking in to account that the traffic shall pass the IAF at the EAT plus or minus two minutes.

To absorb small delays the EC can issue altitude, speed and various heading instructions. When the expected delay is more significant the flight may be instructed to enter a holding pattern. Currently there are no fixed criteria which define when a holding pattern should be activated. If a flight will be instructed to hold it depends on the amount of delay, the EC on duty, weather, operational conditions, etc. Holding in Amsterdam CTA is limited to FL245 and below (see Figure A2, grey area). The EC is responsible for control of the holding patterns, unless a Stack Controller (SC) is active. When traffic has to hold, the EAT is communicated to the pilots when they receive the arrival clearance. EAT's for traffic in a holding pattern may be swapped provided that they are planned for the same landing runway.

Flights which want to wait for weather improvement may also enter a holding pattern. In this case the EC makes a HOLD input in the system which deletes the landing slot and EAT. The flight becomes 'unplanned' and its position in the sequence is lost. When ACC makes a New Time Over (NTO) input to cancel the holding, the flight is planned automatically within 60 seconds.

The EC is supported by STCA. This Short Term Conflict Alert (STCA) function will detect current and future violations of allowed separation between all pairs of aircraft that are within a defined altitude range. A different set of vertical and horizontal separation allowances is maintained for different altitudes, for different areas and for aircraft in reduced separation and holding areas. Upon a detected violation, this capability will inform the controller about the conflicts. The conflict is signified on the radar screen by using a warning colour and a conflict symbol. Furthermore the flight is entered into the STCA table. This table contains the aircraft identities of the conflicting flights, time remaining until the predicted separation reduces to the separation limit expressed in seconds and the predicted minimum separation between tracks in nautical miles.

Transfer of communication between ACC and APP takes place well before passing the TMA boundary while the actual transfer of control between the ACC EC and TMA Feeder/Departure Controller (FDR/DCO) takes place at the boundary of the TMA (IAF). When the aircraft is transferred, then the following standard criteria should be met:

Day (0600-2300 LT)
- Altitude: 30 DME SPL below FL100, descending to FL 070;
- Speed: at 250 kt at SLP1 (30 DME SPL) (only jets);
- Clearance: cleared to SPL;
- Separation: longitudinal separation.

Night (2300-0600 LT)*
- Altitude: 30 DME SPL, at FL100; or when a block clearance till FL140 is issued: 30 DME SPL below FL150, descending to FL100**;
- Speed: minimum 220 kt, maximum 250 kt at SLP1 (30 DME SPL) (only jets);
- Clearance: on a transition to runway 06 or 18R***;
- Separation: longitudinal separation.

* When another runway is used (a runway without transition) than 06 or 18R the day criteria apply.
** A block clearance is a clearance issued by ACC for APP to be able to continue climb with outbound flights above the TMA boundary to maximum FL140 without prior coordination.

*** For (propeller) aircraft that do not fly transitions, ACC will coordinate with APP about the transfer.

In non-standard situations the PLC coordinates the route with the APLN, and the altitude at transfer and the clearance limit.

A.5 Guidance to the runway

Airspace and routes

The flight enters the TMA (yellow part in Figure A2). The TMA area could also be split into TMA-East and TMA-West. Within the TMA there are no fixed routes during daytime. The routes of the inbound traffic that enters the TMA can be stretched by means of radar vectors to ensure enough separation and to be sequenced for the landing. During night there are RNAV transitions, which should be flown between IAF and final approach. For the RWYs 06 and 18R the night transitions are defined.

APP Working Method

Within the TMA the traffic flows from the IAFs have to be merged to the landing runways and the inbound traffic shall be separated from outbound traffic.

During the period of the day (0600-2300lt) flights are guided to the point where the final approach is intercepted by means of radar vectors. When entering the TMA the flights normally are on a route inbound to SPL (see Figure A2, yellow part). When required the FDR/DCO provides additional instructions to optimise the inbound sequence, or to guarantee separation with other traffic. For noise abatement reasons the FDR/DCO should wait as long as possible with descending traffic below minimum IFR altitudes. Next step is that instructions for the approach are given to the specific flight (e.g. clearance, QNH, etc.).

When approaching the vector area of the landing runway concerned, the FDR/DCO transfers communication to the ARR. Transfer of control takes place at the boundary of the vector area. The FDR/DCO is responsible to maintain separation in such a way that the coordination required with ARR is limited to a minimum.

The task of the ARR is to optimally sequence the traffic on to the final approach by means of radar vectors and keep separation.

When the traffic is free of conflicts, the ARR issues a heading and altitude to intercept the final approach, together with the approach clearance. In case of a visual approach the ARR shall assure that the traffic is lined up for the correct runway before issuing the clearance.

The approach clearance contains:

- The approach procedure;
- Landing runway;
- Significant changes in weather.

During night time (2300-0600lt) special procedures apply for jet aircraft operating in the Schiphol TMA. Traffic above land shall enter the TMA at or above FL070, and traffic to runway 06 and 18R are instructed to fly a transition followed by a SOKSI-, NIRSI or NARIX-approach.

The ARR hands over flights to the Runway Controller (RC) in sequence of the approach as soon as a pilot mentions that he is ‘ILS established’, or in case of a non-precision approach or visual approach when the pilot mentions that the runway is in sight and that it is assured that the aircraft is approaching for the correct runway.

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Annex B - The ATC performance model

The ATC performance model describes the information processing, attitudes and actions that are required by the ATCO in order to provide proper traffic handling (Oprins and Schuver, 2003).

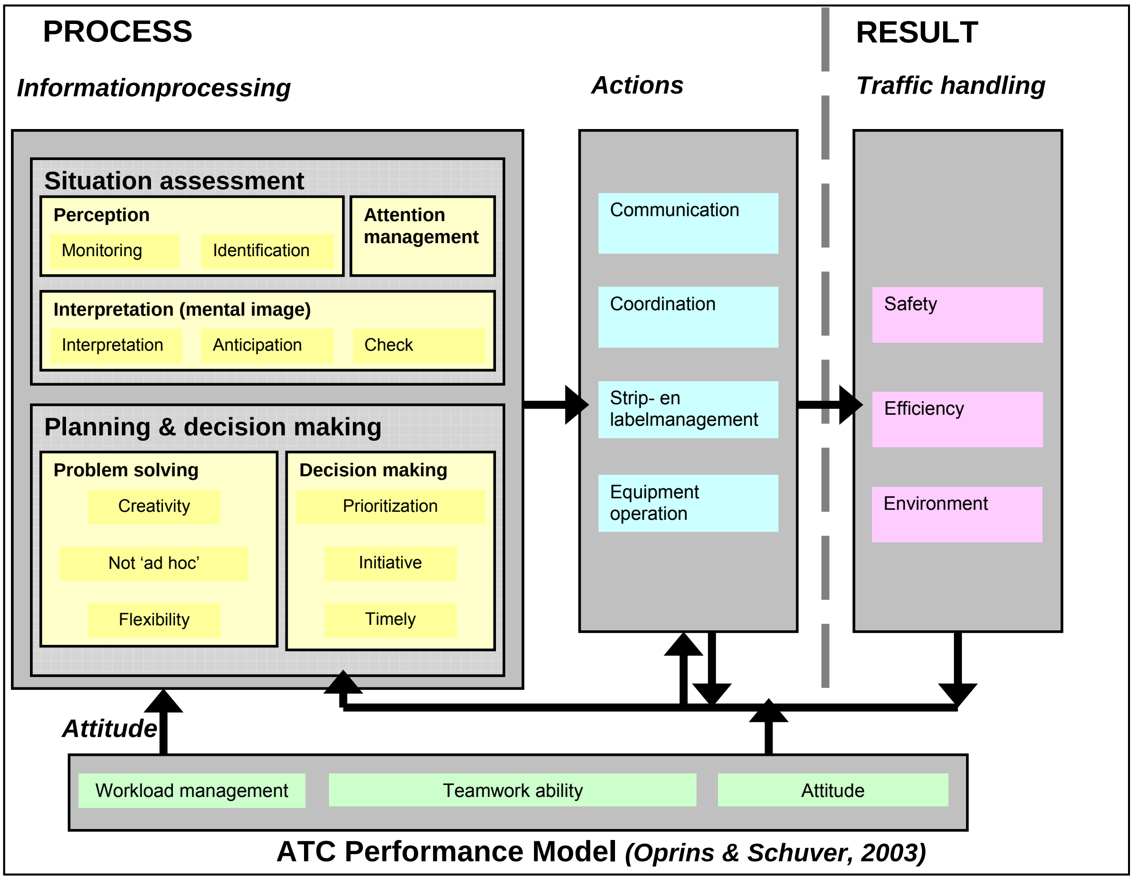

Figure 1. The ATC performance model (Oprins and Schuver, 2003).

The model is a framework for the development of trainings and assessments. The problem with Air Traffic Control is that the act of controlling traffic is largely a very complex cognitive task. Under normal circumstances the result of this cognitive processing is only manifested through correct traffic handling. In other words, only the outcome of the cognitive processes are able to be observed and not the internal processes inside the controller. This poses a problem for assessing operator performance and workload, especially when changes in the operational environment occur. The abovementioned framework is an aid to more accurately investigate such cognitive processes. Furthermore, it is an aid to assess the influences of changes that occur in the ATM environment on the competences of the controllers.

Situation Assessment

A major aspect of ATC is the controller's ability to create a mental picture of the situation. The controller is constantly busy with monitoring the situation and identifying the information presented on the screen. Attention is managed between viewing, listening, speaking etcetera. Based on these perceptions the situation is interpreted and a mental picture of the situation is created. This picture is subsequently used to anticipate future situations as well as to check for possible conflicts.

Planning & decision making

Based on the mental picture, the controller plans the sequencing of flights in a creative manner such that conflicts are resolved. As a result, decisions are made that take into account such actions that have the highest priority and are made in a timely manner.

Actions

The result of the interplay between the controller's SA, planning and decision making as well as external influences leads to actions. One of the most obvious actions performed by a controller is communication with the aircraft (RTF) and with adjacent centres. But also the ability to coordinate actions, deal with flight labels and the use of equipment are actions resulting from internal cognitive processes.

External factors

Cognitive processes are influenced by external factors such as the controller's ability to manage workload as well as the interaction with team members and personal attitudes. Such influences can affect the ability of the controller to effectively manage traffic. In a stimulating environment, such influences can enhance operator performance. Alternatively, in a noisy environment with poor interaction between team member performance is likely to be detrimental.

Results

The result is a safe and efficient traffic management taking into account the environmental restrictions. A feedback loop exists between the results and the cognitive processes. For example, the consequences of the controller's actions feedback to the cognitive processes and influence aspects such as monitoring behaviour and the prioritization of actions. These, in turn, result in an altered SA which leads to changes in communication which influences traffic handling, etc.

What is important to realize here is that efficient traffic management is the result of a very complex chain of processes which mostly occur inside the controller's head. Changing the operating environment, by introducing SARA for example, will have an influence on all processes and not only RTF. Below an overview is provided of the perceived influence of SARA on the controller according to the performance model.