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Experiment design for the ATC simulation

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Summary

This document contains the experimental plan for the SII Real Time Simulation (RTS) for the ground side in NARSIM. It describes the aims and objectives of the experiment, the independent variables (i.e., experimental conditions), the dependent variables (i.e., the measurements to be taken). It also describes the assignment of traffic scenarios to experimental conditions. Furthermore, the simulation environment (simulated airspace and working positions) and the conduct of the experiment (i.e., participants and time schedule) is outlined.

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1. Introduction

1.1. Purpose

The objective of this document is to present the experimental plan for the SII Real Time Simulation (RTS) for the ground side in NARSIM.

1.2. Background

The new air traffic management (ATM) concept which the Sourdine II project intends to address is to improve the impact of aircraft noise and emissions around most airports by the definition of new approach and departure procedures, and by modifying or optimising the operations and traffic flow of aircraft around the airport (trying to maintain safety and capacity).

Before new procedures can be implemented, it needs to be demonstrated that they do indeed solve the ATM problem they were designed to solve in a satisfactory way. After this, an accepted implementation plan will be studied within the project to provide information and improve acceptance in Europe.

Sourdine II will use Validation to ensure the quality and suitability of the new air navigation procedures that Sourdine II proposes to solve part of current problems in European ATM. Validation is the process which an ATM concept undergoes throughout its lifecycle in order to ensure that it addresses the ATM problem for which it was designed and that it achieves its stated aims.

Homogeneity of experiment results has been ensured through the elaboration of a validation plan and the set up of a suitable validation management structure. The validation plan is based on existing ATM validation frameworks (MAEVA) and emphasises exercises to build confidence in the airport approach and departure procedures developed within Sourdine II.

A programme of validation exercise has also been defined, using the most suitable validation techniques and sequencing for each lifecycle phase, to establish objectively the performance benefits that Sourdine II can deliver.

1.3. Document Structure

This document contains four sections and one appendix that includes additional information:

- Section 1 presents a brief introduction that includes the document purpose, the project background, the document structure, as well as the definition of the terms and the description of the referenced documents used in this document.
- Section 2 contains the main objectives of the Sourdine II Real-Time Simulation (RTS).
- Section 3 describes both the independent variables that will be manipulated in the SII ground RTS and the data that will be collected.
- Section 4 presents a brief description of the experimental environment including the airspace and the approach procedures simulated in the SII RTS, the controller roles and the operational procedures related to them, the controller tools, the traffic scenarios and the NARSIM Layout during the SII experiment.
- Section 5 contains the participants and the time schedule of the experiment in outline.

Finally, the appendix includes the draft of the questionnaires that will be used during RTS in order to collect the necessary data.

1.4. Glossary

Term	Description
AFE	Above Field Elevation
APP	Approach
ARR	Arrival Controller
ATC	Air Traffic Control
ATCo	Air Traffic Controller
ATM	Air Traffic Management
ATS	Air Traffic Services
CAS	Calibrated Air Speed
CBA	Cost Benefit Analysis
CDA	Continuous Descend Approach
CWP	Controller Working Position
DCO	Departure Controller
FAS	Final Approach Speed
FDR	Feeder
FL	Flight Level
FPA	Flight Path Angle
FTS	Fast Time Simulations
HMI	Human-Machine Interface
IAF	Initial Approach Fix
ICAO	International Civil Aviation Organization
IFS	Intermediate Flap Speed
ILS	Instrument Landing System
ISA	International Standard Atmosphere
ISA	Instantaneous Self Assessment
KTS	Knots
MONA	Monitoring Aids
NAP	Noise Abatement Procedure
RC	Runway Controller
RNAV	Area Navigation
R/T	Radio Telephony
RTS	Real Time Simulation
RWY	Runway
OEI	One Engine Inoperative

Term	Description
OM	Outer Marker
SII	Sourdine II
SA	Situation Awareness
SART	Situation Awareness Rating Technique
STCA	Short Term Conflict Alert
TMA	Terminal Manoeuvring Area
TOGA	Take-off Go Around
TWR	Tower

1.5. Reference documents

LIST OF REFERENCE DOCUMENTS	
Short Reference	**Description**
[TA]	SII Technical Annex.
[D2-1]	D2-1: Validation Methodology Report, version 0.9
[D3-1-2]	Updated Definition of New Noise Abatement Procedures
[D3-2]	Requirements document for the pilot and controller tools
[D6-1]	D6-1: Prototyping results ATC simulator
[D6-2]	D6-2: Prototyping results flight simulator
[D6-5]	D6-5: Experiment design for the flight simulation
[D6-6]	D6-6: Concept of operation for Schiphol airport simulations

2. Aims and objectives of the SII RTS for the ground side

2.1. General Aim

The general aim of the SII Real Time Simulation (RTS) for the ground side is

- to present controllers with the new noise abatement procedures (NAPs) and controller tools,
- to investigate the feasibility and acceptance of the proposed NAPs,
- to investigate the usability and acceptance of the proposed controller tools, and
- to assess and the impact of the proposed NAPs and controller tools on noise, safety, capacity, airline costs as well as controller workload and situational awareness.

2.2. Evaluation Objectives

The general aim of the SII RTS for the ground side as described above was further detailed in a number of evaluation objectives. These are listed below.

Objective 1: Evaluate whether the proposed Noise Abatement Procedures (NAPs) yield a reduction in the noise level as compared with current procedures.

Within Objective 1, the following questions will be investigated:

1. Are there any significant differences in noise between the baseline condition and the NAPs (as implemented by the controllers)?
2. Are there any significant differences in noise between the two proposed NAPs (as implemented by the controllers)?

Objective 2: Evaluate the impact of the NAPs on airline costs.

Within Objective 2, the following questions will be investigated:

1. Is there any difference in the average trajectory per aircraft in the TMA between the three different approach procedures?
2. Is there any difference in the estimated fuel consumption between the three different approach procedures?

Objective 3: Evaluate whether the proposed NAPs and controller tools change the level of safety as compared with current procedures and tools.

Within Objective 3, the following questions will be investigated:

1. Is there any difference in the number of STCAs between the different approach procedures and tool sets?
2. Is there any difference in the number of losses of separation between the different approach procedures and tool sets?
3. Is there any difference in the experienced safety level between the different approach procedures and tool sets?

Objective 4: Evaluate whether the proposed NAPs and controller tools affect the capacity as compared with current procedures and tools.

Within Objective 4, the following questions will be investigated:

1. Is there any difference in the landing interval (number of aircraft landing per time unit) between the different approach procedures and tool sets?
2. Is there any difference in the average delay for aircraft between the different approach procedures and tool sets?

Objective 5: Evaluate the acceptance of the NAPs and controller tools.

Within Objective 5, the following questions will be investigated:

1. Are controllers willing to accept the new working methods that follow from the use of NAPs?
2. Which advantages/disadvantages of the NAPs do controllers see?
3. To which extent do controllers follow the new approach procedures (deviation from the approach routes)?
4. Do controllers see any benefit in the new controller tools?
5. To which extent do controllers make use of the new controller tools?

Objective 6: Evaluate the impact of the proposed NAPs and controller tools on workload.

Within Objective 6, the following questions will be investigated:

1. Is there any difference in the subjectively experienced level of workload (ISA, NASA TLX) between the three different approach procedures?
2. Is there any difference in the task load (total R/T time, number of instructions, number of CFL and heading inputs) between the three different approach procedures?

Objective 7: Evaluate the impact of the NAPs and controller tools on situational awareness.

Within Objective 7, the following questions will be investigated:

1. Is there any difference in the experienced level of situation awareness (situation awareness rating technique SASHA) between the different approach procedures and tool sets?

See also the Low Level Objectives (LLO) as described in the Validation Methodology [D2-1].

3. Experimental Design

3.1. Experimental factors

The following experimental factors will be manipulated in the SII ground RTS: (1) Approach procedures, (2) ATC tools, and (4) controller role.

3.1.1. Approach procedures

The main manipulation in the experiment concerns the different approach procedures. Three different approach procedures will be used in the experiment:

- **Approach procedure I (baseline)**
- **Approach procedure II (CDA with fixed flight path angle, without speed constraints**
- **Approach procedure II-A (CDA with fixed flight path angle, with speed constraints)**
- **Approach procedure V (CDA with variable path segment)**

Approach Procedures II and II-A differ in that II-A (but not II) includes fixed speed constraints at certain waypoints. In this way, "speed constraints" could be considered a further experimental variable. However, "speed constraints" (with/without) are not fully combined with Approach procedure I (which does not include fixed speed constraints) and Approach procedure V (which does include some constraints). Therefore, it cannot be considered an independent experimental factor.

The approach procedures are described in more detail in Chapter 3.2.

3.1.2. ATC tools

The following tools will be used in the experiment: Ghosting (i.e., projection of aircraft radar targets from the TMA entry point SUGOL on the RIVER route), and the MONA tools. It is suggested not to treat ATC tools as a further experimental variable that will be included in the experimental design. The reasons are as follows: Ghosting is only sensible with the new approach procedures, but not in the baseline condition. MONA tools were not considered as useful in the prototyping session, therefore, the effect of MONA can be expected to be very limited. It is suggested to use ATC tools only with the experimental conditions and not with the baseline condition.

3.1.3. Controller role

Two controller roles in the Schiphol TMA will be realised:

- The Feeder/Departure Controller (FDR/DCO) for either the TMA East or the TMA West, and
- The Arrival Controller (ARR).

Note that the variable "controller role" does not increase the number of trials needed to realise a complete design. The reason is that, in every simulation run, there is a FDR/DCO and an ARR anyway. Treating controller role as an experimental variable, however, is important because the proposed procedures may affect the two roles differently. For instance, a certain procedure might include a shift of tasks from the FDR/DCO to the ARR, which means that workload decreases for the FDR/DCO but increases for the ARR.

A detailed description of the two controller roles can be found in Chapter 3.3.

3.2. Measurements

The data collected in the experiment pertain to the following topics: Airline costs, safety, capacity, acceptance, controller workload and situational awareness.

3.2.1. Airline costs

Airline costs will be measured in terms of the average trajectory length in the TMA and the calculated fuel consumption. Any other costs such as investment costs or operational costs associated with the implementation of the SII procedures cannot be measured in the simulation, and thus, are outside the scope of the simulation. Thus, the following metrics will be used:

- average trajectory length per aircraft in the TMA,
- average flying time in the TMA per aircraft,

Average trajectory length and flying time will be compared for the baseline condition and the proposed SII procedures.

3.2.2. Safety

The following measurements will be collected that are related to the concept of safety:

- the number of STCAs in the simulations runs,
- the number of separation losses in the simulation runs, and
- the *experienced safety* level in the simulations runs.

The number of STCAs and losses of separation will be recorded on the basis of NARSIM. The experienced level of safety is a subjective assessment made by the participating controllers on how safe in their opinion the control of traffic in the simulation was. The experienced level of safety will be measured on the basis of a rating scale used as part of a questionnaire.

All metrics pertaining to safety (i.e., number of STCAs, losses of separation, and experienced level of safety) will be compared between the baseline condition and the proposed SII procedures and tools.

3.2.3. Capacity

Capacity was measured on the basis of the following metric:

- the landing interval (i.e., number of aircraft landing per time unit), and
- the perceived capacity and efficiency level in the simulation.

The landing interval is based on NARSIM recordings. Landing intervals are compared for the baseline condition and the proposed SII procedures and tools.

3.2.4. Acceptance

Controllers' acceptance will be measured on the basis of controllers' feedback with respect to the following issues:

- The degree to which controller are willing to accept the SII procedures,
- advantages/disadvantages of the SII procedures,
- advantages/disadvantages of the SII tools, and
- reported use of the new SII tools.

The subjective measurements will be obtained on the basis of interviews and de-briefings. The data will not be quantitative, but qualitative, and therefore will be analysed with the method of content analysis rather than statistically.

3.2.5. Situational Awareness

Situational Awareness refers to the “the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future” (cf. Endsley, [1, 2]).

Situational Awareness was measured on the basis of

- A questionnaire item on the experienced level of Situation Awareness during the simulation.

Self-ratings of situational awareness are compared for the baseline condition and the SII procedures.

3.2.6. Workload

Workload will be measured on the basis of objective and subjective (i.e., self-assessment) measurements. With respect to objective measurements, the following metrics will be used:

- total R/T time,
- number of instructions,
- number of instructions (EFL, heading, speed).

All of these metrics will be recorded with NARSIM. With respect to subjective measurements, the following metric will be used:

- Instantaneous Self-Assessment Technique (ISA), to be measured continuously during a simulation run, and

Objective and subjective measurements of taskload and workload will be compared for the baseline condition and the SII procedures.

3.3. Combinations of experimental factors

The table below shows an experimental design with the factors procedures, tools, and ATC roles independently manipulated. In this design, speed constraints will be held constant, that is, the Approach Procedures II-A and V will always incorporate speed restrictions.

Note that the numbering of the experimental runs in the table do not refer to the presentation order of runs. Rather, the numbering is only used as an identifier for a specific run. The presentation order of runs will be balanced or random in order to avoid confounds of training effects with experimental manipulations. The presentation order of experimental runs will be discussed in more detail below.

Table 1: Experimental Design with factors "procedures", "ATCO role" crossed

	Baseline Without tools	Procedure II With tools	Procedure II-A With tools	Procedure V With tools
FDR/DCO	Run1	Run2	Run3	Run4
ARR	Run1	Run2	Run3	Run4
FDR/DCO	Run5	Run6	Run7	Run8
ARR	Run5	Run6	Run7	Run8

In a single experimental run, two cells of the above experimental plan can be realised. The reason is that two participants will be measured at the same time, and one will act as the ARR and the other one as the FDR/DCO. This means that a complete design would only require 4 runs.

According to the experimental planning (which will be outlined below), a total of 8 experimental runs (plus a couple of training runs at the beginning of the experiment) can be carried out in three days experimentation.

4. Approach Procedures, Operational Concept and Tools

4.1. The reference procedure

The reference procedure reflects current working procedures. That is, there are no fixed routes used in the TMA, but aircraft are given radar vectors to intercept the ILS. Furthermore, there are no fixed speed constraints as part of the approach procedure. The approach procedure that is used in the reference scenario is outlined below.

Approach procedure I: Reference with level deceleration at 3000ft

Condition	Parameter values
7000 ft *[at IAF]* (Fixed height)	– Speed 250 KTS calibrated air speed (CAS) – Level flight – Clean configuration – Landing Gear up
	– Constant CAS descent
3000 FT *[AT ILS INTERCEPT]* (Fixed height)	– Level flight – Decelerate and change to intermediate configuration – Decelerate to intermediate flap speed (IFS)
	– Fixed descent angle of 3°
	– Landing gear down – Decelerate and change to landing configuration – Decelerate to final approach speed (FAS)
Landing configuration and speed reached (Resulting height, minimum 1000ft)	– Adapted Thrust for descent at 3° – Constant speed (FAS) descent to 50ft

4.2. Approach Procedure II and II-A

The Approach Procedure II is characterised by an RNAV approach and a certain noise abatement procedure. There are two variants of approach Procedure II, one without speed constraints and one with speed constraints (II-A). These are outlined below.

4.2.1. RNAV approaches

The following RNAV transitions and approaches are used in the experiment:

- RIVER 1B TRANSITION (RNAV route RIVER TO RWY 18R)
- SUGOL 1B TRANSITION (RNAV route SUGOL TO RWY 18R)
- REGSU 1 APPROACH (RNAV route ARTIP TO RWY 18C)

Figure 1 shows the new RNAV approaches and transitions. The merging point EH606 is slightly displaced and now called MICOL. This was necessary because traffic from RIVER starts their CDA at FL80 instead of FL70. Therefore traffic between SUGOL and RIVER is always vertically separated at the merging point. Traffic will start their descend along the CDA vertical path after this merging point. Points NIRSI, EH607 and EH608 are also slightly displaced and now called NARSI, EH707 and EH708 respectively. This was necessary to comply with the PANS-OPS requirements for parallel approaches.

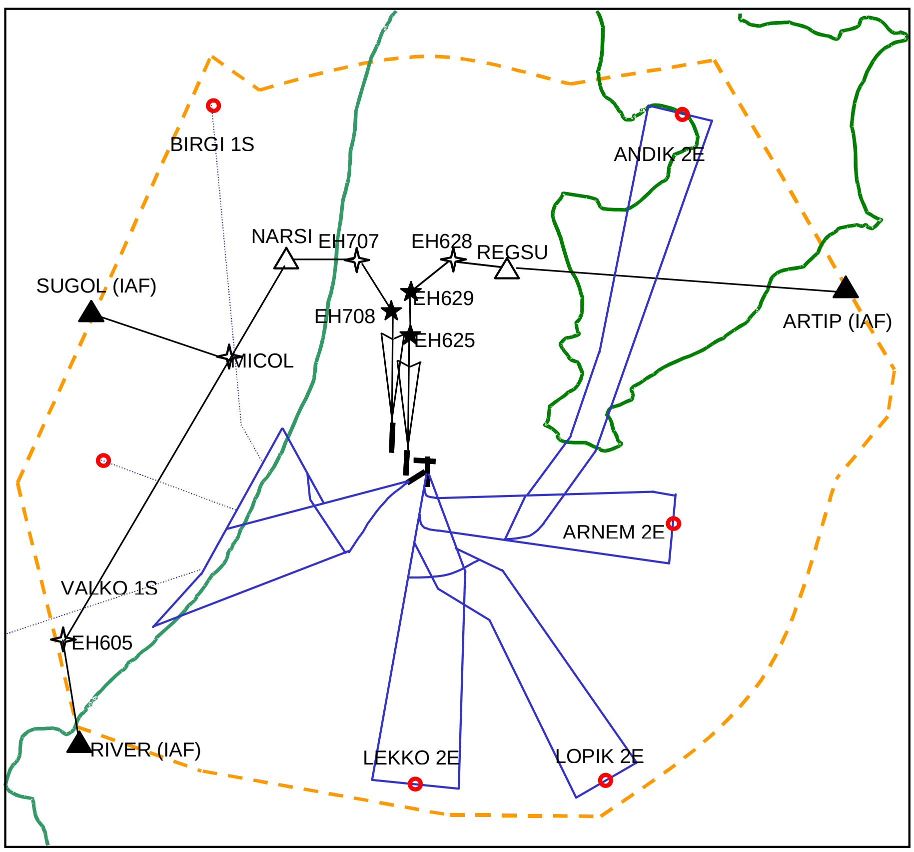

Figure 1: RNAV transitions and approaches in the experiment.

4.2.2. *Noise abatement procedure II: Basic CDA with 2°initial FPA*

Condition	Parameter values
7000 ft *[at SUGOL]*, 8000 ft *[at RIVER}* (Fixed height)	– Speed 250 KTS calibrated air speed (CAS) – Level flight – Clean configuration – Landing Gear up
Start of CDA *[between MICOL and NARSI]*	– Fixed 2° Flight Path Angle (FPA) – Adapted thrust for 2° FPA
3000 ft *[at ILS intercept]* (Fixed height)	– Fixed 3° Flight Path Angle. – Landing gear down
	– Decelerate and change to landing configuration – Decelerate to final approach speed (FAS)
Landing configuration and speed reached (Resulting height, minimum 1000ft)	– Adapted thrust for descent at 3° – Constant speed (FAS) descent to 50ft

4.2.3. *Speed constraints (Approach Procedure II-A only)*

Approach Procedure II will be used in two variants: One without speed constraints (i.e. procedure II), and one with speed constraints (i.e., procedure II-A). Figure 2 shows the constraints for the along the RNAV route for Approach Procedure II-A.

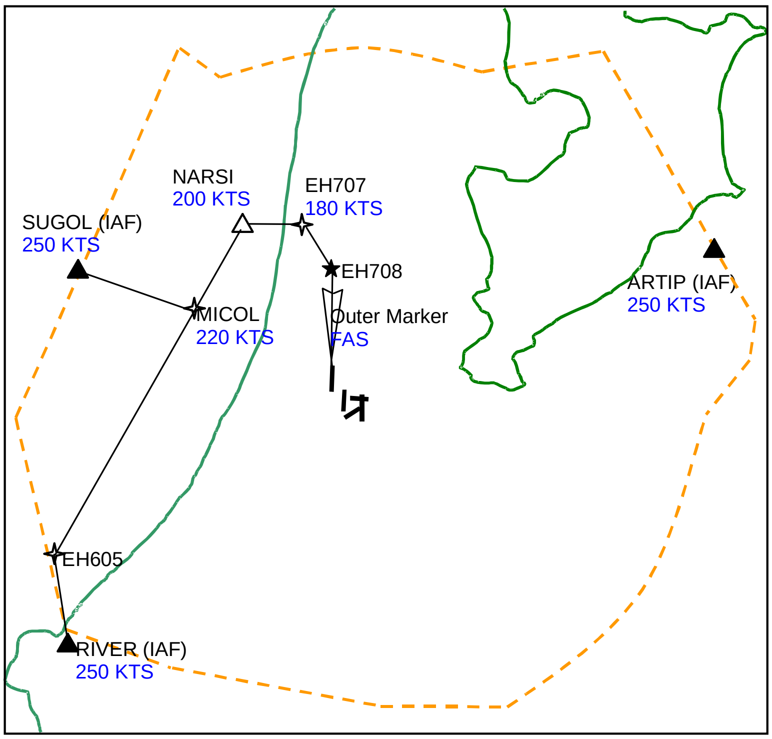

Figure 2: Arrival Procedure II-B with speed constraints

4.3. Approach Procedure V

The Approach Procedure V is characterised by an RNAV approach, a certain noise abatement procedure and the speed constraints along the route. These are outlined below.

4.3.1. RNAV approaches

The RNAV approaches and transitions used with Approach Procedure V are identical to the ones used with the Approach Procedure II. For this reason, information can be taken from Chapter 3.2.1.

4.3.2. Noise abatement procedure V

Approach procedure V: CDA with variable FPA segment at intermediate configuration, with speed constraints

Condition	Parameter values
7000 ft *[at SUGOL],* 8000 ft *[at RIVER}* (Fixed height)	– Speed 250 KTS CAS – Level flight – Clean configuration – Landing Gear up
	– Idle thrust – Decelerate and change to intermediate configuration – Decelerate to intermediate flap speed (IFS[1])
Intermediate configuration reached (Resulting FPA)	– Descend at constant speed (IFS) to 3000ft – Idle thrust
3000 ft *[at ILS]* (Fixed height)	– Fixed descent angle of 3°. – Adapted thrust for descent at 3°
	– Landing gear down – Decelerate and change to landing configuration – Decelerate to final approach speed (FAS)
Landing configuration and speed reached (Resulting height, minimum 1000ft)	– Constant speed (FAS) descent to 50ft

[1] IFS is FAS plus approx. 40 kts.

4.3.3. Speed constraints

In order to prevent aircraft running into each other because of differences in speed reductions associated with the descend, procedure V will include speed restrictions. These are, in addition to the 250 kts at the IAF, 220 kts at MICOL. Aircraft will be at intermediate flap speed (IFS) at CDA initiation point, and at final approach speed (FAS) at 4NM final.

Figure 3 shows the constraints for the along the RNAV route for Approach Procedure V.

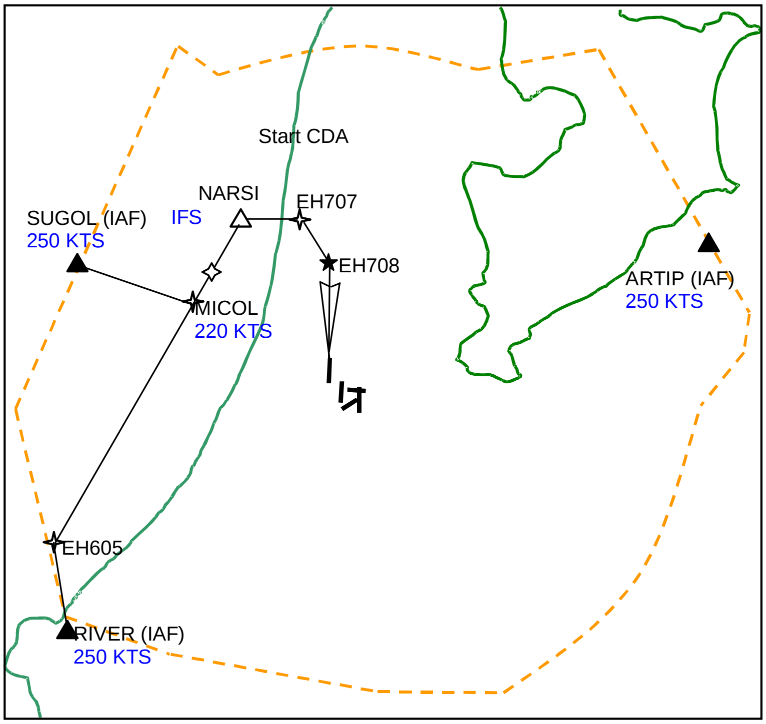

Figure 3: Arrival procedure V with speed constraints

Note: As the flight path angle for this procedure depends on aircraft type, the CDA initiation point will vary as well and will lie somewhere on the MICOL-NARSI leg. Therefore also the location of the point where the aircraft will be at IFS, varies significantly. Furthermore, as each aircraft has its own deceleration rate, the moment of reducing to IFS varies significantly.

4.4. Operational procedures for the different approach procedures

4.4.1. Reference Procedure

The present-day ATC organisation applies arrival procedure I and departure procedure I (ICAO-A), which are the baseline conditions for the present study.

Inbound traffic is usually transferred from ACC Executive controller to FDR/DCO at or before the IAFs RIVER, ARTIP and SUGOL. Minimum flight level is then FL70 and maximum speed 250 KTS IAS. FDR/DCO will use radar instructions to vector the aircraft to the downwind leg; ARR will guide the aircraft to the ILS of the runway in use. On final, the aircraft will contact TWR. The Approach Planner (APLN) function is often combined with the Approach Supervisor position. The APLN will decide among others on the active runway combination and the landing interval (LIV). In some cases and only during night-time, fixed routes, so called transitions are used.

Outbound traffic will be transferred from TWR to FDR/DCO shortly after take-off. The standard maximum flight level is FL60 to prevent any conflict with inbound traffic entering at FL70. When the aircraft is clear of other traffic it will be cleared to continue their climb and transferred to ACC Executive controller. After that, the aircraft is transferred to an adjacent ATC centre.

4.4.2. Concept using CDA with fixed vertical path (II and II-A)

ACC controller

The present working method is to clear aircraft direct to the SPL VOR/DME and to transfer the aircraft to the FDR/DCO controller for further instructions. Within the Sourdine II concept the ACC executive controller provides clearance to the aircraft from the TMA entry fixes by providing them the RNAV transition route. For instance, for arrivals via RIVER, instead of issuing a "*After RIVER, proceed to SPL*", the phraseology changes to *"After RIVER, proceed on RIVER 1B transition to NARSI"*. This implies a clearance to proceed with an approach procedure via the RNAV transition route until interception of the ILS of runway 18R. At or before reaching the IAF, the aircraft is transferred to the frequency of the FDR/DCO controller.

An important pre-requisite for the Sourdine II concept is that aircraft arrive more timely at the IAF. This has to be achieved by the ACC and stack controller.

Note that the ACC controller will not be part of the simulation. However, changing in the operational procedures are described because they have an effect on the task of the Approach Controllers.

Feeder/departure controller

Lateral Control. The feeder/departure controller (FDR/DCO) receives the inbound aircraft from the ACC controller. Inbound aircraft have already received a clearance from the ACC executive controller for the appropriate Sourdine approach route (lateral RNAV route). At initial call, the pilot will report this cleared route to the FDR/DCO. In case the FDR/DCO wants the aircraft to proceed on the transition, he has to confirm the clearance again (e.g., *"proceed as cleared")*.

Traffic from the ARTIP IAF always uses a dedicated runway. This runway is 18C during Mode 2 flying a REGSU 1 Approach. Traffic from the RIVER IAF and the SUGOL IAF will use runway 18R. The ARTIP traffic will follow the same vertical procedure as traffic from SUGOL and RIVER.

There is only one RNAV route between MICOL and 18R, which means that traffic from RIVER and SUGOL IAF must be merged. In order to obtain some flexibility to do so, RNAV shortcuts can be given. These are direct to NARSI between SUGOL and MICOL or between RIVER and EH605. Extensions of the RNAV routes are also possible. For example a “maintain heading” for aircraft coming from RIVER can be issued when the aircraft has not passed EH605 yet. When the aircraft has passed EH605, the controller can issue a heading instruction to the west of the RNAV route (over sea). Once the controller estimates that enough separation has been gained he/she can issue a “direct MICOL/NARSI”, sending the aircraft back to it’s original routing.

The estimation of the separation between aircraft from SUGOL and RIVER is supported by the usage of ghost plots. Aircraft coming from SUGOL will be displayed on the RIVER 1B transition with a ghost plot.

Vertical profile and Speed Control. By receiving the clearance for a certain transition, aircraft are also cleared to descend following the approach procedure. The aircraft will initiate the CDA shortly after passing the merging point MICOL. Due to the fixed vertical profile of procedures II, the controller knows where the aircraft’s Top of Descent (TOD) lies. Altitude instructions should be avoided unless they are needed for safety reasons.

To increase the predictability of the aircraft behaviour, several speed constraints are applied in the arrival procedure II-A (not in II). These were described above. Speed control can also be applied in order to ensure separation or to optimise the sequence.

The arriving traffic is transferred to the ARR controller when the inbound traffic flows are merged and separated from the departing traffic.

Arrival controller

There will be one Arrival Controller (ARR) for 18R in the simulation. Traffic to 18C will be scripted. The Arrival controller receives the inbound traffic from the FDR/DCO between MICOL and NARSI.

The clearance for the transition is a clearance to follow the RNAV route until ILS interception. For aircraft on a Sourdine approach, the only means of control for the ARR controller is speed control. Lateral instructions and altitude instructions should be avoided unless they are needed for safety reasons.

4.4.3. Concept using CDA with variable vertical path (V)

The most important difference between this concept and the concept using the CDA with a fixed vertical path is the fact that the CDA initiation point, the flight path angle and speed during descend depend on the type of aircraft.

ACC controller

The ACC procedures are identical to those for the concept using CDA with fixed vertical path.

Feeder/departure controller

Lateral Control. Lateral control in procedure V with variable vertical path is identical to lateral control in procedure II (CDA with fixed vertical path).

The feeder/departure controller (FDR/DCO) receives the inbound aircraft from the ACC controller. Inbound aircraft have already received a clearance from the ACC executive controller for the appropriate Sourdine approach route (lateral RNAV route). In case the FDR/DCO wants the aircraft to proceed on the transition, he has to confirm the clearance again (e.g., *"proceed on RIVER 1B transition to NARSI")*. Short-cuts and extensions can be used in order to obtain flexibility in merging the inbound streams from RIVER and SUGOL.

The estimation of the separation between aircraft from SUGOL and RIVER is supported by the usage of ghost plots. Aircraft coming from SUGOL will be displayed on the RIVER 1B transition with a ghost plot.

The arriving traffic is transferred to the ARR controller when the inbound traffic flows are merged and separated from the departing traffic.

Vertical profile and Speed Control. By receiving the clearance for a certain transition, aircraft are also cleared to descend following the approach procedure. In procedure V, the flight path angle as well as the TOD depend on the type of aircraft. Altitude instructions should be avoided unless they are needed for safety reasons.

In order to prevent aircraft running into each other because of differences in speed reductions associated with the descend, procedure V will include speed restrictions. These are, in addition to the 250 kts at the IAF, 220 kts at MICOL. Aircraft will be at intermediate flap speed (IFS) at CDA initiation point, and at final approach speed (FAS) at 4NM final.

Arrival controller

A clearance for a certain transition means that the aircraft is cleared to follow the RNAV route until ILS interception. The ARR controller is responsible for the final sequencing in order to optimise the sequence. Since the aircraft is flying in intermediate configuration with its IFS along the entire CDA, there is not a lot of manoeuvrability for both the controller as well as the pilot during this part of the arrival.

Lateral instructions and altitude instructions should also be avoided unless they are needed for safety reasons.

4.5. Controller Tools

Ghosting

A ghosting tool projects the position of an aircraft onto another plane. For the Sourdine II prototyping sessions, the inbound aircraft from the SUGOL IAF are projected onto the RIVER arrival route. This provides the controller with information about the relative positions of the aircraft on the two inbound routes, prior to merging into a single stream.

The current version of the tool uses a basic ghosting algorithm that determines the distance to go (along track) to a projection-point on the route. This distance is then backtracked across a given path in order to determine the location of the ghost plot. This path can either be a straight line or a predefined route (e.g. RIVER arrival route). For the projection point the NIRSI position was configured, as all arrivals will have to be merged at this location, even those aircraft that were cleared to proceed direct from SUGOL to NIRSI, skipping the MICOL merging point.

The Figure below shows an example of a ghost plot.

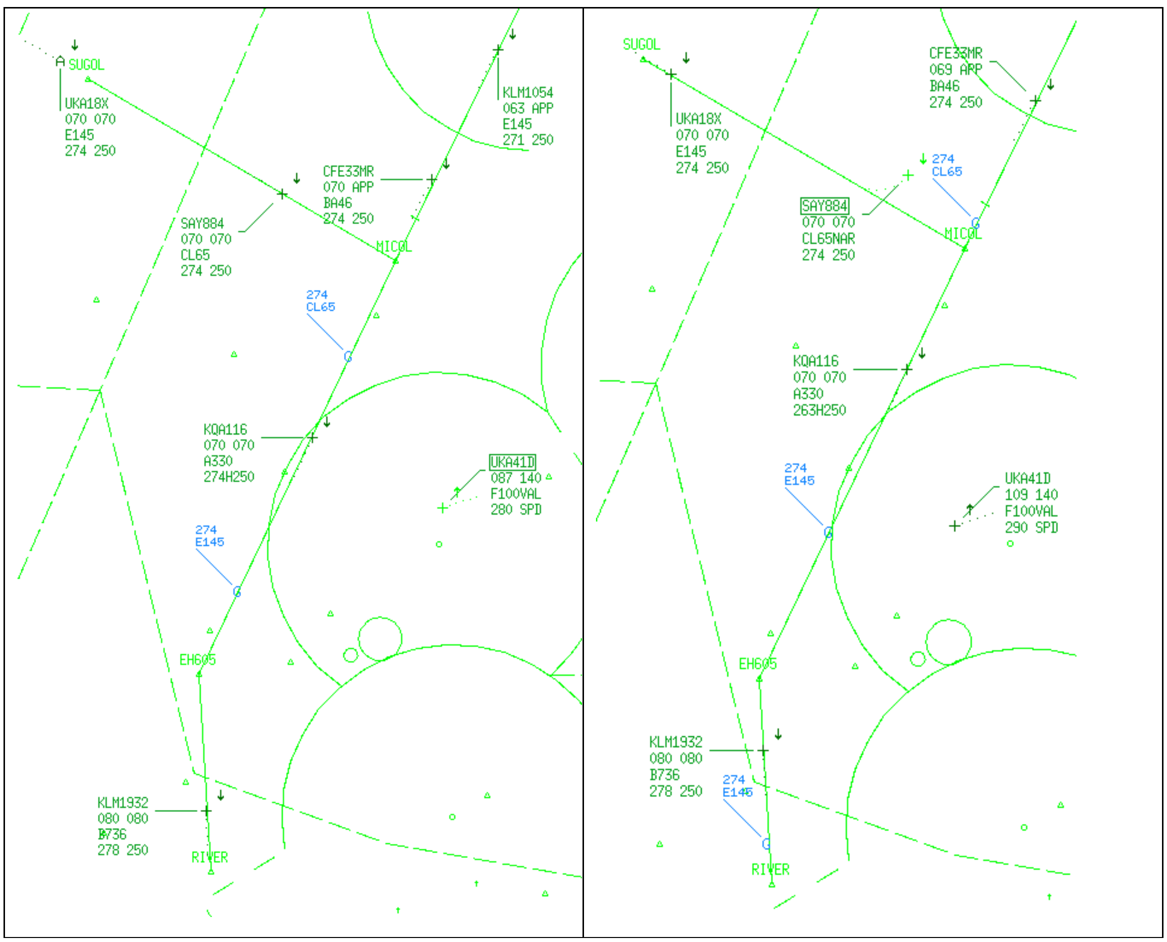

Figure 4: Example of a ghost plot

Monitoring Aids

Monitoring Aids (MONA) compare the current flight data with the system trajectory and detects any deviations from the cleared flight level or the cleared lat/lon route. In case, a deviation of the flight from the system trajectory is detected, a non-conformance warning (NCW) is issued. These NCWs are displayed in line 0 of the label and have the following meaning:

- FL DEV means that a deviation from the cleared flight level has been detected,
- FL Bust means that the cleared flight level has been busted,
- LAT DEV means that the deviation from the cleared route has been detected.

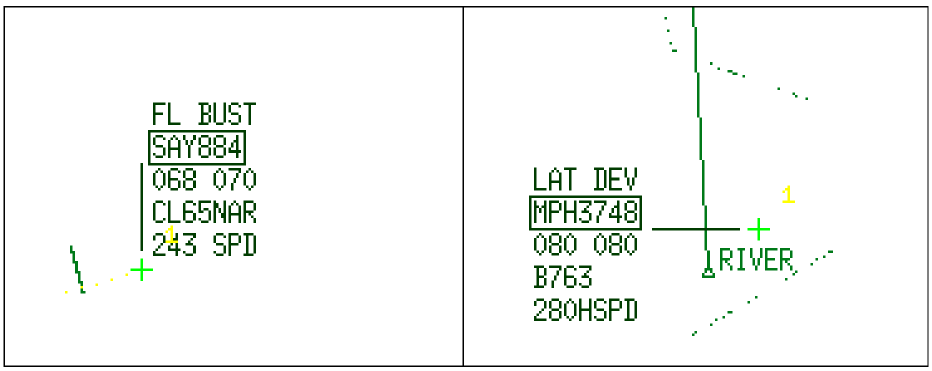

Figure 5: Example of a MONA alert

5. Experimental Environment

5.1. Airspace

The airspace simulated in the Experiment will be Schiphol Terminal Manoeuvring Area (TMA). A map of Schiphol TMA can be found in Chapter 3.2.

Note that because there will only be one Arrival Controller and one FDR/DCO, the simulation will be restricted to only half of the TMA (either TMA East or TMA West).

In addition, there will be feed sectors from which aircraft will be entering the TMA and to which they will be handed over. Feed sectors will not be measured in the simulation.

In the simulation, three different set of Approach Procedures will be used: Two new proposed procedures (the Sourdine procedures), and the reference procedure (which reflects the current way of working in the Schiphol TMA).

The proposed Approach Procedures include a combination of preferred routes and noise abatement procedures during take-off and landing. The idea of the preferred routes (SIDs and STARs) is to keep the aircraft away from sensitive (i.e., densely populated) areas. The noise abatement procedures during take-off and landing aim at reducing the global noise exposure on the ground to a minimum and assure safe operation of the aircraft. Furthermore, there will be speed constraints along the route.

Thus, the new approach procedures are characterised by:

- A lateral route i.e., the RNAV approach),
- A specific approach procedure (describing the aircraft setting and the vertical route), and
- In some cases, a set of speed constraints.

These aspects will be described in separate chapters. Before this, though, the reference (or baseline) situation will be described.

5.2. Controller Roles in the Experiment

5.2.1. General description

The SII exercises will always contain two arrival runways, one of which will be actively controlled and one which will be used for automatic landing aircraft. This allows for the investigation of parallel approaches on the workload of the arrival controller, without the use of an arrival controller for the adjacent runway. In line with current practices by Dutch ATC, each arrival runway requires one arrival controller. During peak hours (which SII will focus on) each arrival controller is paired with a feeder controller. The feeder controller is also responsible for the departing traffic. The feeder/DCO controller is responsible for the merging of the two inbound traffic flows, and the arrival controller will be responsible for sequencing the aircraft onto the ILS glide slope, where he/she will hand over control to the tower controllers.

The arrival and feeder/departure controller will both have a large screen (2k x 2k) Controller Working Position. Consequently, two NARSIM CWPs being used for one controlled runway.

Due to the pseudo-pilot's workload and aircraft frequencies each arrival and feeder controller will be communicating with one pseudo-pilot.

During the SII experiment, only feeder/DCO and arrival controller positions will be used. The inbound aircraft stream will be defined off-line, prior to the experiments.

5.2.2. Feeder/Departure Controller

Within the Schiphol TMAs and Schiphol CTR, the Feeder/Departure Controller (FDR/DCO) is responsible for the guidance of aircraft arriving and departing from Schiphol airport. In addition, the FDR/DCO is responsible for aircraft crossing the Schiphol TMAs and controlled VFR flights in the Schiphol TMAs.

The FDR/DCO:

- Carries out communication with aircraft under his responsibility;
- Ensures separation between flights under his responsibility, which concerns
- separating inbound traffic from outbound traffic, and
- separating different streams of inbound traffic.

The FDR/DCO's task is to deliver traffic in such a way to the ARR that co-ordination needs between FDR/FCO and ARR are minimised. This means that the FDR/DCO tries to deliver inbound traffic conflict-free to the ARR. In case of traffic from only one TMA entry point to a runway, no merging of traffic streams is required and the traffic delivered to the ARR already constitutes a first inbound sequence. In case of traffic from different TMA entry points to the same downwind, the FDR/DCO often already merges traffic streams in order to deliver traffic conflict-free to the Arrival Controller. However, at this point it is still possible that traffic from different TMA entry points is vertically separated. Hand-over of traffic to ARR has to take place before an aircraft starts the CDA procedure and is usually done before the merging point MICOL.

5.2.3. Arrival Controller

The FDR/DCO transfers the inbound aircraft to the Arrival controller (ARR) approximately when the aircraft have turned to downwind and the inbound aircraft have no conflicts with outbound aircraft. From this point on the ARR's main task is to guide the arriving aircraft by providing radar vectors to base-leg and thereafter to intercept the ILS. An important part of the job is to optimise the sequence of arriving traffic by taking advantage of vectoring and speed control to maximise the runway capacity. When aircraft are established on the ILS, the aircraft are transferred to the Runway Controller (RC).

The ARR:

- Carries out communication with flights under control,
- Ensures separation between aircraft under control
- Optimises the approach sequence
- Supports aircraft in carrying out a Surveillance Radar Approach (SRA).

For precision approaches (i.e. ILS approaches), the procedures are as follows. If a flight is free of conflicts, the ARR issues a heading with which the aircraft can intercept the ILS localizer. At the same time, the approach clearance is given. Intercepting the localizer usually occurs under the following conditions:

- An angle of 30 degrees with the runway centreline;
- In case of approaches at 2000ft with a distance of at least 8 NM from the runway threshold;
- In case of approaches at 3000 ft with a distance from at least 11 NM from the runway threshold;
- Below the ILS glide path (not lower than 2000ft and 3000ft respectively).

Once the pilot has reported to be established on the ILS, the ARR hands over the aircraft to the RC. Aircraft are handed-over to the RC in the approach order. After handing over a flight to the RC, the ARR is still responsible for ensuring separation between

- aircraft lined-up for one runway, and
- aircraft on parallel approaches.

At this point, the ARR can issue speed instructions to the aircraft via the RC. However, speed instructions can only be issued until the 4NM final[2] from which one the pilot will select the Final Approach Speed (FAS).

5.3. Traffic scenarios

For the SII ground experiment, four different traffic scenarios will be used (see Chapter 3.7 for the assignment of traffic scenarios to experimental conditions). A further traffic scenario will be used for training purposes. In all of these scenarios, 18R and 18C will be used for inbound traffic, and 24 will be used for outbound traffic.

The traffic scenarios will be based on recordings of real traffic in the Schiphol TMA, and will include a fairly high traffic load (as they will be based on recordings of peak hours). All scenarios to be used in the SII simulation will incorporate a substantial wind component, in order to increase the level of difficulty involved in realising the NAP.

In order to investigate whether the proposed NAPs are also feasible in non-standard situations, a number of non-nominal events will be realised in the traffic scenarios. A list of such non-nominal events is given below:

1 **Strong wind.** Due to a strong wind component, the heading and the track of the aircraft in the simulation will differ substantially.

2 **Pilot error**. The pilot of an aircraft might fail to comply with any of the following parameters issued by ATC: speed, route, and altitude.

3 **Disrupted sequence on the IAF**. The sequence of aircraft to be handed over to the FDR/DCO will deviate from the planned sequence (i.e., sequence of aircraft does not correspond to EATs).

Note that for the non-nominal events “pilot error” and “disrupted sequence on the IAF”, there will only be one event per traffic scenario. Strong wind, in contrast will refer to the whole or a significant part of the traffic scenario.

5.4. Assignment of traffic scenarios to experimental conditions

According to the current planning, there will be 8 experimental runs for every participant (plus additional training runs, if needed). It is suggested to have four qualitatively different traffic samples. “Qualitatively different” means that the traffic scenarios differ with respect to more aspects than just the callsigns of the aircraft in the TMA. Given four different traffic scenarios and 8 runs, this means that every controller sees every scenario twice.

In addition to the traffic scenarios for the experimental runs, a further traffic scenario is needed for the two training runs at the beginning of the experiment (see Table 4).

The table below shows how the four traffic scenarios could be assigned to the different experimental conditions and participants. The assignment of scenarios to experimental conditions is completely balanced which means that every scenario is used equally often with every experimental condition.

[2] Runway 18R is not equiped with outermarker , therefore the 4NM final distance is used.

Table 2: Assignment of traffic scenarios to experimental conditions (S1…S4 denote traffic scenarios)

ATCo	Role	Baseline (without tools)	Procedure II (with tools)	Procedure II-A (with tools)	Procedure V (with tools)
1	**FDR/DCO**	S1	S4	S3	S2
2	**ARR**				
1	**ARR**	S2	S1	S4	S3
2	**FDR/DCO**				

Note that in the above design

- All traffic scenarios are used once with all experimental conditions
- All traffic scenarios are used equally often with participant group 1 and group 2.

5.5. NARSIM Layout

For NARSIM two controller working positions (CWPs) will be used, one for the Arrival controller position and one for the Feeder/Departure controller (FDR/DCO). Both controllers have a dedicated R/T connection with one or two pseudo-pilots. De experiment supervisor position is between the CWPs and the pseudo-pilots.

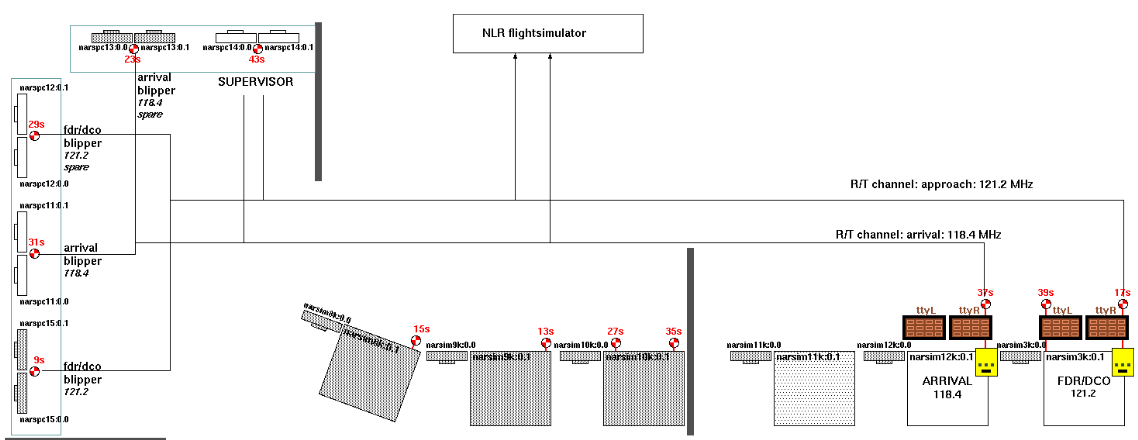

Figure 6: NARSIM layout during the SII experiment

6. Conduct of the experiment

6.1. Participants

It is assumed that four Approach controllers from LVNL and two controllers from another ANSP will participate in the experiment. The controllers will participate in two groups with two controllers each.

6.2. Duration of the experiment

Three controller groups will participate for two or three (depending on the required training) days each.

6.3. Pre-experimental information and training

Probably all participants in the simulation were previously involved in the usability testing for the SII procedures and tools. For this reason, no extensive training is foreseen before the start of the experiment.

However, there will be a briefing guide send to the experimental participants before the experiment. This briefing guide should cover:

- Information on the experiment (research questions, experimental manipulations, number of runs)
- Controller roles and tasks in the experiment
- A description of the SII NAPs,
- A description of the new controller tools (i.e., ghosting and MONA).

Furthermore, the morning of the first day of the experiment will be used for familiarisation with the SII procedures and tools. It is planned to have two training runs, one with each of the two new approach procedures. If possible, participants should swap positions (Arrival Controller and Feeder/DCO) during the two training runs.

6.4. Time schedule for the simulation

Each simulation run will last 1:15 minutes. The first 15 minutes of a run will be used for building up traffic, and will not be measured. Thus, the measured time in each simulation run will be 1hrs 00mins.

Table 3: Proposed time schedule for the simulation

Day 1		Day 2	
08.30- 09.00	Welcome and Briefing	**08.30- 09.30**	Simulation Run 6 (baseline)
09.00-10.00	Simulation Run 1 (Baseline)	**09.30-09.45**	Coffee Break
10.00-10.15	Coffee Break	**9.45-10.45**	Simulation Run 7 (II-A)
10.15-11.15	Simulation Run 2 (II)	**10.45-11.00**	Coffee Break
11.15-11.30	Coffee Break	**11.15-12.15**	Simulation Run 8 (II-A)
11.30-12.30	Simulation Run 3 (II)	**12.15-12.45**	Post-run De-briefing
12.30-13.00	Post-run Debriefing	**12.45-13.45**	Lunch
13.00-14.00	Lunch	**13.45-15.00**	General De-briefing
14.00-15.00	Simulation Run 4 (V)		
15.00-15.15	Coffee Break		
15.15-16.15	Simulation Run 5 (V)		
16.15-16.45	Post-run De-briefing		
16.45-17.00	Wrap-up		

Optionally the experiments can be preceded with a additional training of half a day. During these runs, the crew is familiarised with the system, airspace, procedures and tools. The recordings of these runs will not be analysed.

Dependent on controller needs, these runs can be shortened, lengthened or multiple shorter runs can be performed.

	Training day
9.00-9.15	Briefing
9.15-10.30	Training Run 1
10.30-10.40	De-briefing
10.40-10.55	Coffee Break
10.55-12.10	Training Run 2
12.10-12.20	De-briefing

Annex A: Questionnaires

Participant ID:	**Date:**

Biographical Questionnaire

The questions below serve to give us some background information on you. Please note that all personal information will be treated confidently and can not be traced back to any particular person.

Personal information

Age: ☐female ☐male

Native Language:

Professional training and experience:

Current or Last Employer:

If retired or not active any more, since when:

Licences/ Ratings:

Professional Experience (in years):

Previous involvement in research:

Have you previously participated in any Sourdine research activities? If so, please specify.

Post-run questionnaire

Participant:	Date:	Trial:
Role:	Time:	

Please assess the statements on the previous simulation run by ticking one of the boxes.

- **In my opinion, the level of safety was high throughout the simulation.**

	Completely disagree	*Mostly disagree*	*Slightly disagree*	*Slightly agree*	*Mostly agree*	*Completely agree*
(Please tick one box only)	❑	❑	❑	❑	❑	❑

If not agreed or slightly agree, please explain:

- **I was able to handle the traffic in the simulation efficiently.**

	Completely disagree	*Mostly disagree*	*Slightly disagree*	*Slightly agree*	*Mostly agree*	*Completely agree*
(Please tick one box only)	❑	❑	❑	❑	❑	❑

If not agreed or slightly agree, please explain:

- **I was able to use the runway capacity optimally.**

	Completely disagree	*Mostly disagree*	*Slightly disagree*	*Slightly agree*	*Mostly agree*	*Completely agree*
(Please tick one box only)	❑	❑	❑	❑	❑	❑

If not agreed or slightly agree, please explain:

- **I was ahead of the traffic and able to predict the evolution of the traffic situation.**

	Completely disagree	Mostly disagree	Slightly disagree	Slightly agree	Mostly agree	Completely agree
(Please tick one box only)	❑	❑	❑	❑	❑	❑

If not agreed or slightly agree, please explain:

- **I felt that I was fully in control of the traffic situation.**

	Completely disagree	Mostly disagree	Slightly disagree	Slightly agree	Mostly agree	Completely agree
(Please tick one box only)	❑	❑	❑	❑	❑	❑

If not agreed or slightly agree, please explain:

- **I was able to plan and organise my work as I wanted.**

	Completely disagree	Mostly disagree	Slightly disagree	Slightly agree	Mostly agree	Completely agree
(Please tick one box only)	❑	❑	❑	❑	❑	❑

If not agreed or slightly agree, please explain:

- **I experienced my workload during the simulation as:**

	Very low	Low	Slightly on the low side	Slightly on the high side	High	Very high
(Please tick one box only)	❑	❑	❑	❑	❑	❑

If not agreed or slightly agree, please explain:

Post-run de-briefing

Efficiency

1. Were you able to handle the traffic efficiently?
2. Were you able to use the runway capacity optimally?

Situation Awareness

3. Did you have a complete overview of the traffic and the intention of the different aircraft?

Workload

4. How did you experience your workload in comparison with current procedures?

Team Co-ordination (in case of no baseline run)

5. How did you experience the allocation of tasks between the FDR/DCO and the ARR? Were there any differences in the task distribution in comparison to current procedures?

Assessment of the SII Procedure (in case of no baseline run)

6. What is your general impression during the simulation? Is the procedure feasible?
7. Did you encounter any problems with the procedure (in addition to the ones you may have mentioned before)?
8. How could these problems be possibly overcome?
9. Did you specifically experience problems between inbound and outbound traffic? What did you do in order to solve the problems?

General de-briefing

SII Procedures general

1. What do you think of the lat/lon position of the RNAV routes?
2. Does the short-cut on the RNAV routes (SUGOL – MICOL) give you enough flexibility to separate the traffic safely and efficiently?
3. Is the proposed phraseology sufficient?
4. Does your task as an ARR controller change with CDAs? Think, for instance, about monitoring, conflict detection and solution, and trying to build an optimal sequence.
5. Does your task as a FDR/DCO controller change with CDAs? Think, for instance, about monitoring, conflict detection and solution, trying to build an optimal sequence.
6. Does the distribution of tasks between FDR/DCO and ARR controller change with CDAs? Are there tasks that are shifted from one role to the other?
7. As it is now, there is a violation of separation between the inbound streams to parallel runways. Do you have any idea how this problem could be solved?
8. Because of the low-noise departure procedures, aircraft climb longer before increasing their speed (at 5000 ft instead of approx. 3000 ft). Does this affect the separation with the inbounds? In which way?
9. Do you have any idea how the problem of separating inbounds and outbounds can be solved?

Approach Procedure II

1. What is your general opinion on **approach procedure II** (CDA with standard glide slope, without speed constraints)? Is it workable?
2. How did you experience the speed constraints in procedure II?
3. What are the advantages of approach procedure, in comparison to current procedures, but also to the other experimental procedures?
4. What are the disadvantages of approach procedure II, in comparison to current procedures, but also to the other experimental procedures?
5. Could this procedure be used in real operation? Why/why not?

Approach Procedure II-A

1. What is your general opinion on **approach procedure II-A?** Is it workable?
2. What are the advantages of approach procedure II-A, in comparison to current procedures, but also to the other experimental procedures?
3. What are the disadvantages of approach procedure II-A, in comparison to current procedures, but also to the other experimental procedures?
4. Could this procedure be used in real operation? Why/why not?

Approach Procedure V

1. What is your general opinion on **approach procedure V** (CDA with standard glide slope)? Is it workable?
2. How did you experience the speed constraints in procedure V?
3. What are the advantages of approach procedure, in comparison to current procedures, but also to the other experimental procedures?
4. What are the disadvantages of approach procedure V, in comparison to current procedures, but also to the other experimental procedures?
5. Could this procedure be used in real operation? Why/why not?

SII tools

There were two new controller tools in the experimental condition: ghosting, and MONA.

1. What is your opinion of **ghosting**? Do you find it useful or not?
2. Did you use the ghosting information during the simulation runs? If so: in which situations? If not: Why did you not use it?
3. Did you have problems with the use of ghosting? Can they be improved in any way?
4. What is your opinion of **MONA**? Do you find it useful or not?
5. Did you use the MONA information during the simulation runs? If so: in which situations? If not: Why did you not use it?
6. Did you have problems with the use of MONA? Can it be improved in any way?
7. Do you miss any tools that would be helpful for CDAs?