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RADE-2P Experimental Report

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Abstract

The present document provides the results report for the RADE-2 prototype simulations (RADE-2P).

The prototype experiments were successful in showing the feasibility of carrying out RA downlink experiments in an interactive setting. TCAS Resolution Advisories (RA) could be elicited satisfactorily and with sufficient simulation realism by the subject matter experts (SME) within the proposed simulation environment.

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CONTENTS

EXECUTIVE SUMMARY

The present document provides the results report for the RADE-2 prototype simulations (RADE-2P) that was conducted in from June 27 to July 1, 2005. This report will briefly outline:

- the set-up of the study
- the choice of participants
- the findings of the study

Eventually, basic findings documented in this report will be incorporated in the final report for the RADE-2 project.

The prototype experiments were successful in showing the feasibility of carrying out RA downlink experiments in an interactive setting. TCAS Resolution Advisories (RA) could be elicited satisfactorily and with sufficient simulation realism by the subject matter experts (SME) within the proposed simulation environment.

During RADE-2P the final simulation configuration was determined to be a dual controller working position (CWP) set-up with positions for a planner and the executive controller.

Furthermore, the usefulness of both the independent experiment variables and dependent measurements was studied. This resulted in a proposal for an experiment design in which mainly the RA downlink condition and the quality of the pilot report are varied. An extra variable to be considered in the analysis of simulation outcome is the controller role. The proposed dependent measures mainly investigate situation awareness and controller workload as well as subjective feedback on perceived benefits of RA downlink and the applied concept.

Other results concerned the process of executing the simulations and capturing the simulation data.

List of Abbreviations

ACAS	Airborne Collision Avoidance System
AGAS	EUROCONTROL Action Group on ATM Safety
ATC	Air Traffic Control
ATCo	Air Traffic Controller
ATM	Air Traffic Management
AudioLAN	Innovative Internet Technology-based Voice Communication System
CWP	Controller Working Position
EATMP	European Air Traffic Management Programme
eDEP	Early Demonstration and Evaluation Platform
FARADS	Feasibility of ACAS Resolution Advisory Downlink Study
HMI	Human Machine Interface
InCAS	Interactive Collision Avoidance Simulator
ISA	Instantaneous Self Assessment
NASA	National Aeronautics and Space Administration
NLR	Nationaal Lucht- en Ruimtevaartlaboratorium
R/T	Radio Telephony
RA	Resolution Advisory
RADE	RA Downlink Experiments
RADE-2A	RA Downlink Experiments for Area Control
RADE-2P	RA Downlink Prototype Experiments
RADE-2T	RA Downlink Experiments for Terminal Control
SA	Situational Awareness
SAGAT	Situation Awareness Global Assessment Technique
SASHA	Situational Awareness Rating Scale for SHAPE
SHAPE	Solutions for Human Automation Partnership in European ATM
SME	Subject Matter Expert
STCA	Short Term Conflict Alert

TCAS	Traffic Alert and Collision Avoidance System
TLX	Task Load Index

1. INTRODUCTION AND BACKGROUND

The Feasibility of ACAS Resolution Advisory Downlink Study (FARADS) is investigating the feasibility of showing simplified ACAS Resolution Advisories (collision avoidance advice given to pilots) on controller screens (Ref. [2] and [3]). The Resolution Advisory Downlink Experiments (RADE) are part of FARADS.

The present document concerns the RADE-2 experiments, which are a follow-up of RADE-1 conducted in November 2003. The aim of the RADE-2 experiments is to further investigate the impact of Resolution Advisory (RA) downlink on controller performance, situation awareness, and workload. Furthermore, an initial evaluation of one (or more) different operational concepts proposed in the RA Downlink Operational Concept is part of the work of RADE-2.

The RADE-2 set of experiments comprises the following empirical studies:

- An initial or prototype study in which the viability of the proposed experimental approach is tested (RADE-2P),
- An experiment in which the impact of RA Downlink is assessed for Area Control (RADE-2A), and
- An experiment in which the impact of RA Downlink is assessed for Terminal Control (RADE-2T).

The present document provides the report of results of the RADE-2P prototype study which focused on the viability of the proposed experimental approach and led to conclusions regarding the set-up of the simulation environment and the conduct of the RADE-2A and RADE-2T simulations. This document includes:

- A summary of the intermediate experiment plan for the RADE-2A and RADE-2T experiments (cf. Ref. [7] and [8]) and the determination of its feasibility in the RADE-2P study;
- A description of findings of the RADE-2P study and their consequences for the re-definition of the experiment plan for the RADE-2A and RADE-2T experiments.

2. AIMS AND OBJECTIVES OF RADE-2 EXPERIMENTS

2.1 General Aim

The RADE-2 experiments are supposed to continue the previous evaluation work as done in the RADE-1 experiment, but differ in the following aspects from RADE-1:

- Instead of a non-interactive setting, in which the controller monitors a developing situation toward the emergence of a re-constructed real RA event, the RADE-2 experiments aim at incorporating an interactive setting in which controllers control air traffic in a generic sector.
- Realistic means to facilitate the occurrence of an RA encounter against the efforts of the controller to avoid such a situation need to be explored. This requires:
  - A careful planning of the traffic scenarios,
  - Real-time initiation of non-nominal events in order to increase controller workload and degrade situation awareness which eventually causes a loss of separation,
  - Instructing controllers that they are not evaluated for their performance.
- Rather than assessing four different Human Machine Interfaces (HMI) for RA downlink, the RADE-2 experiments will concentrate on one HMI for RA downlink. This HMI was selected on the basis of feedback obtained in RADE-1. It was stated that the HMI should comprise all information considered as relevant and should avoid unnecessary distraction. The RA downlink HMI will be compared with an HMI in which no RA information is available.
- In RADE-1 the quality of the pilot report (timely/correct vs. delayed/incorrect) was not systematically investigated. The RADE-2 experiment will include the quality of the pilot report as a further experimental variable. The assumption is that the benefits of RA downlink are larger in case of an unreliable (that is, a delayed, missing or incorrect) pilot report than in case of a reliable (that is, timely and correct) pilot report.
- Controller roles have to be considered in the experimental planning when more than one controller is active in a sector.
- In contrast to RADE-1, the functioning of short-term conflict alerting (STCA) will be more controlled during the simulations.
- Participants will be provided with an operational concept for RA downlink. This operational concept will describe in which way the RA information is to be used by the pilot and by the controller.

The general aim of the RADE-2P simulations is to test the general simulation set-up, including platform, environment, participant roles, and data capturing tools in such a way that the RADE-2A and RADE-2T simulations have the potential to provide meaningful and relevant results under the above-mentioned conditions.

2.2 Objectives

The RADE-2 experiments aim at further investigating the possible benefits and drawbacks of RA downlink for controller performance.

This overall validation aim can be broken down into a number of more specific validation objectives. These validation objectives are formulated as a set of research questions to be investigated:

1. Does RA downlink prevent the controller from issuing contradictory clearances to an aircraft involved in the RA?
2. Does RA downlink facilitate the planning of the post-alert situation (e.g., the controller providing instructions to third-party aircraft or traffic information to conflict and third-party aircraft)?
3. Does RA downlink have an impact on the likelihood of follow-up conflicts?
4. Does RA downlink improve the controllers' situational awareness (i.e., understanding of the conflict geometry, understanding of the RAs issued, and understanding of the further development of the traffic situation)?
5. What is the effect of RA downlink on controller workload?
6. Does RA downlink capture the controllers' attention for a duration that is longer than optimal at the expense of neglecting other aircraft under their control?
7. Does the effect of RA downlink depend on the quality of the pilot report (reliable vs. unreliable)?
8. What is the controllers' opinion on the proposed operational concept for RA downlink?
9. What are the advantages and disadvantages of the chosen operational concept as compared to other possible concepts?

In order to investigate these research questions the specific objectives of the RADE-2P prototype study are to:

- Determine the experimental conditions for the RADE-2A and RADE-2T experiments, meaning that the independent experimental variables and the dependent measurements need to be determined or confirmed.
- Determine the operational environment and the simulation set-up to carry out the RADE-2A and RADE-2T experiments, including operational concept, HMI, and controller roles and tasks.
- Assess the feasibility of carrying out the experiments in an interactive setting, i.e. determining whether it is possible to elicit RAs within the proposed simulation environment.
- Evaluate the possibilities of gathering data for analysis of RADE-2 results, meaning that questionnaires need to be tested and output data has to be reviewed for completeness.
- Evaluation and tuning of candidate traffic scenarios to be used for the setup of the validation exercise plan.
- Assessment of training requirements for participating air traffic controllers (ATCo).
- Determining if interactive validation exercises should be run in a single controller working position (CWP) configuration involving only the executive controller, or in dual CWP configuration involving both an executive and a planning controller.

3. EXPERIMENTAL DESIGN ISSUES

3.1 Independent Variables

For the RADE-2P experiment, the following candidate independent variables for the experimental design of the validation exercises were considered:

1. RA downlink condition (RA downlink present vs. not present),
2. ACAS theme (pilot error, high vertical rate before level-off, or controller error),
3. Quality of the pilot report (timely/correct vs. delayed/incorrect/missing),
4. The traffic load (low vs. high).

Furthermore, it was discussed whether ”operational concept” and ”STCA” should be held constant over experimental conditions. For RADE-2P it was suggested to only use one operational concept and one STCA condition (STCA enabled).

Given the specific objectives of RADE-2P and the fact that the series of exercises were performed by only two controllers it should be noted that not all of the above-mentioned variables were manipulated in the RADE-2P experiment in a rigorous way. Instead, in the following, these experimental variables are discussed with a focus on methodological difficulties for the target validation exercise plan to be implemented in the succeeding RADE-2A/2T experiments.

3.1.1 RA Downlink Condition

There are two RA downlink conditions:

- No RA downlink: This is the baseline condition. RAs will not be presented to the controller on the screen. The only source of information on the RA is the pilot report.
- RA downlink: This is the experimental condition. RAs generated in the cockpit will be displayed on the controller screen.

The specific HMI chosen for the experimental condition was based on feedback obtained in RADE-1. In RADE-1 it was stated that the HMI ”should comprise all information considered as relevant and should avoid unnecessary distraction”. Thus, for RADE-2P the HMI consisted of a visual alert indicating that a pair of aircraft received an RA, together with the direction of the RA.

3.1.2 ACAS Themes

The second manipulation in the experiment concerns the conditions that led to the RA being issued. These conditions are referred to as ”ACAS themes”. Considering the constraints of the project it was suggested to use three different ACAS themes in the RADE-2P experiment:

- Theme I (Level off): The RA is triggered by fast climbing/fast descending aircraft (aircraft were following the ATC clearance).
- Theme II (ATC error): An incorrect ATC clearance, instruction or action (e.g. an undetected incorrect pilot read-back) caused the RA.

- Theme III (Pilot error): The pilot did not follow an ATC clearance or instruction resulting in an RA being issued.

In the RADE-1 experiment, there were two further ACAS themes: (1) false alarms (i.e., false RA generated in the cockpit, and displayed on the ground), and (2) a combination of controller and pilot error. One of the conclusions of the RADE-1 experiments was that the potential of downlinking false RAs may be less hazardous if the transfer of separation responsibility occurs upon pilot report rather than upon RA display (Ref. [5], pp. 88 ff.). The potential negative consequences of false alarms particularly evolve if the controllers solely rely on the RA display and ignore other information sources which contradict the presence of a true conflict (e.g. no potentially conflicting aircraft in the vicinity, contradicting Mode C information). Although such an indication of over-reliance referred to as ”automation bias” (Ref. [11]) is a valid Human Factors concern with automated decision aids, essential contributing factors are rather difficult to handle in the design of the validation exercises. Therefore, it was decided to not consider false alarms in the RADE-2 experiments. Also, the combination of controller and pilot error was not looked at as this ACAS theme represents highly unlikely non-nominal situations that are hard to reproduce in an interactive simulation environment as being employed in RADE-2.

In reality, an RA is a rare event. If such an event is realised repeatedly during a simulation, the participants’ expectations and, consequently, their responses to the event can change. This possible change in controllers’ expectations and responses was also addressed in the prototype study.

3.1.3 Quality of Pilot Report

The quality of the pilot report was manipulated on two levels:
- Pilot report delivered timely and correct,
- Pilot report delivered delayed, incorrect or missing.

The quality of the pilot report is a relevant variable as it can be assumed that benefits of RA downlink will strongly depend on whether the pilot reported the RA correctly and in due time. If a timely and correct report is given, the additional benefits of RA downlink can be considered as rather marginal. In case of an incomplete, wrong or delayed pilot report, in contrast, there could be a substantial benefit of RA downlink for the controllers’ performance and situation awareness. Furthermore, as real recordings of pilots’ RA reports show, there is in fact a substantial amount of incorrect, incomplete or delayed reports.

3.1.4 Traffic Load

It can be hypothesised that both the potential cost and benefits of RA downlink will be moderated by traffic load. Thus, the RA downlink may facilitate traffic awareness in high traffic load situations in particular. However, the potential adverse of RA downlink to distract controller attention from other traffic may also exaggerate with increasing traffic load.

The ”traffic load” variable can be manipulate on two levels
- Low traffic load, and
- High traffic load.

However, such a two-level variable of traffic load would need to be crossed with the other two-level variables under scrutiny, i.e. presence vs. absence of RA downlink and timely vs. delayed pilot report, in order to derive valid conclusions as to their relative contribution to the observed effects. Thus, it would need to be ensured that RAs will be encountered in low traffic situations as often as in high traffic situation. In a real-time simulation such a requirement is almost impossible to be met. Therefore, for the RADE-2P experiment it was decided not to manipulate traffic load between scenarios. All traffic scenarios envisaged in RADE-2P were moderate to high traffic load scenarios, with a low traffic load phase at the beginning (when traffic builds up). Some scenarios had two peaks of high traffic load with an intermediate period of low traffic load. It was decided to start efforts to facilitate RAs in periods of high traffic load.

3.2 Dependent Variables

With respect to dependent variables, the following measurements were considered for the RADE-2P experiment:

1. Recordings of controller instructions during the RA event,
2. Ratings of controller workload,
3. Ratings of situational awareness (e.g., on the basis of SHAPE scales [12]),
4. Number of separation losses in the sector (induced RA events as well as other separation losses),
5. Controller feedback on the perceived benefits and drawbacks of RA downlink,
6. Controller feedback on the operational concept (and on other alternative concepts).

3.2.1 Controller Instructions during the RA Event

It was suggested to record R/T during the RADE-2P simulations. The analysis of these R/T recordings was restricted to instructions issued during the RA event (with a certain margin before and after the event) in order to find answers to the following questions:

- Did the controller issue a clearance to the conflicting aircraft?
- What kind of instruction was issued to the conflicting aircraft (if any)?
- Was the clearance or instruction contradictory to the earlier TCAS RA?
- Did the controller provide traffic information (or any other service information) to one of the conflicting aircraft?
- Did the controller provide traffic information to third-party aircraft?

This yielded the following measurements:

- Number of clearances to conflict aircraft
- Number and type of contradictory clearances to conflict aircraft
- Number and type of non-contradictory clearances to conflict aircraft
- Number of R/T involving traffic (service) information to conflict aircraft
- Number of R/T involving traffic (service) information to third-party aircraft

R/T data was analysed immediately after the experimental run. The controller was subjected to a think-aloud session (interview) after the trials. In this session, the RA event (±2 minutes) was replayed to the controller. The interviewer used the replay and an observational record sheet to record the data specified above. Cases in which the observer was unsure about the coding of instructions could thus be discussed with the controller. Furthermore, the prototype study needed to investigate whether such a think-aloud session would be an intrusive instrument and would change controllers' behaviour during later experiments.

3.2.2 Controller Workload

Two means of collecting subjective ratings of controller workload were proposed to be used for RADE-2P:
1. Instantaneous self-assessment technique (ISA) and
2. a rating scale of the experienced level of stress.

3.2.2.1 Instantaneous Self-Assessment Technique

Initially, it was considered to collect Instantaneous Self Assessment (ISA) scores during the RADE-2P simulations at two minutes intervals with a flashing red light indicating when an input has to be made. The ISA would have required the participant to rate the experienced level of workload on a scale from 1 to 5:

ISA Level	Workload	Spare Capacity
1	Under-utilised	Very Much
2	Relaxed	Ample
3	Comfortable	Some
4	High	Very Little
5	Excessive	None

Table 3-1: ISA Levels

However, it was decided that this measurement technique would be far too intrusive for the RA event itself and probably would not be accurate enough too capture the interesting time period shortly before and after the RA event, as RA events are of rather short duration. Therefore, ISA scores were not collected in RADE-2P and no replacement questionnaire was considered. However, for RADE-2A it was suggested to collect subjective workload ratings with the NASA-Task Load Index (TLX, see Ref. [9]).

3.2.2.2 Ratings of Experienced Stress during RA Event

Initially, it was suggested to ask controllers to rate their experienced level of stress during the RA event in the think-aloud session. However, it was found that it might be less intrusive to capture these ratings in post-exercise questionnaires. Thus, the RADE-2P experiments were used to investigate what the better option is.

3.2.3 Situation Awareness

Situational Awareness (SA) is the key performance area of concern in RADE. From an operational perspective, there is a particular interest in the question: "Does RA downlink provide improve SA and hence improve operational decision making of the controller upon an RA encounter?”   SA refers to”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. Ref. [1]). These three elements or levels of SA, i.e. perception, comprehension, and anticipation constitute sources for a potential loss of SA (cf. [10]):

- Level 1: Failure to perceive information or misperception of the situation
- Level 2: Failure to adequately integrate or comprehend the situation
- Level 3: Failure to adequately project future system states (actions, events)

For the purpose of this study, SA will relate to:

- Unawareness of the fact that an RA has been issued (level 1)
- An understanding of the aircraft intentions during the RA, e.g. their vertical movements (level 2)
- An understanding of the situation that led to the RA, i.e. an identification of the aircraft in conflict and their conflicting intentions before the RA (level 2)
- The ability to predict the evolution of the traffic situation (level 3).

To fully account for the overall SA that a controller needs to keep on doing the job, it has to be considered that the task of responding to an RA occurs in the context of other concurrent tasks. This implies the possibility that an improved “local” SA, i.e. a better awareness of items pertinent to the RA event may be obtained at the expense of deteriorated “global” SA, i.e. poorer SA for aspects of the traffic situation unrelated to the RA.
Three assessment methods were chosen to evaluate these issues:

- A *memory test* on details of the RA situation (see Appendix A.2) was chosen to particularly address the “local” SA issue. The memory test, which was already applied in RADE-1, served to assess whether the controller fully understood the situation that led to the RA, as well as the type of RAs issued and the pilot’s response to it. In this way, the memory test can be considered an objective (i.e., memory-based) measurement of situation awareness similar to the Situation Awareness Global Assessment Technique (SAGAT) proposed by Endsley (see also Ref. [12]). This test was given to both the planner and the executive controller.

- A *Situation Awareness Self-rating scale*: The self-rating scale is a modified and shortened version of SASHA (Situation Awareness for SHAPE), EUROCONTROL’s questionnaire for self-assessment of situation awareness. This questionnaire addresses both local and global SA aspects. The scale consists of a set of questions on different aspects of situational awareness that need to be answered on a 5-point rating scale. In addition to the questions used in RADE-1 five additional questions were added that specifically address the impact of the display of RA downlink information on subjective SA. These ratings were taken from both the planning and the executive controller.

- *Post-exercise interview session*: In addition, situational awareness was targeted in the post-exercise session, which was supported by a replay of the RA situation. For that purpose the replay was forwarded to a time stamp of 1-2 minutes before the RA event and viewed by the controller until 1-2 minutes after the RA event. When replaying the RA situation to the controllers, controllers were instructed to report their perception of what had happened during the situation and what their thoughts at that time were. Participants were instructed to try to separate their knowledge at the time of the replay from their knowledge state at the moment of the RA event. In case participants had realised afterwards that their original understanding of the traffic situation was incorrect, they nevertheless were encouraged to report this incorrect knowledge.

3.2.4 Number of STCAs and Separation Losses in the Simulation

One of the arguments put forward against RA downlink is that the display of RA information may create a tunnel vision. As a consequence, the controller may fail to monitor other traffic in the sector and miss to detect safety-critical situations. In order to test whether the level of safety can be negatively affected by RA downlink, it was suggested to analyse the number of STCAs in the sector as an indicator of safety in RADE-2P.

If there were differences between the RA downlink condition and the baseline condition, then these differences should only become manifest after an RA event occurred. For this reason, the experiments especially focused on STCAs and separation losses that occurred after the RA event (if any).

Additional measurements were proposed to be analysed such as response times to pilot calls, or timely hand-over of traffic leaving the sector. These data were not recorded automatically, but it was suggested to capture and score this data from the recorded simulation data.

3.2.5 Controller Feedback on RA Downlink and Operational Concepts

Controllers were questioned about their assessment of RA downlink, including the perceived advantages and disadvantages using draft versions of the final RADE-2 questionnaires. It was of particular interest to see whether controllers' opinions in RADE-2 differ from those obtained during RADE-1. Note that, in RADE-2, controllers are presented with an operational concept for the use of RA information, they are presented with an HMI that takes into account previous criticisms, and they experience RA downlink in an interactive setting. This was not the case in RADE-1.

Controllers were provided with an operational concept for using RA information. The specific operational concept used during the simulation was critically discussed in the general debrief at the end of the simulation. Alternative operational concepts were sketched, and controllers were asked to comment on them.

4. EXPERIMENT ENVIRONMENT AND CONDUCT

RADE-2P lasted 5 days and took place from June 27 to July 1, 2005. In the following, the main features of the RADE-2P set-up will be described.

4.1 Simulator Configuration

All RADE-2 experiments are executed on the Early Demonstration and Evaluation Platform (eDEP) situated at the Human Factors Lab of EUROCONTROL Experimental Centre in Brétigny, France. This platform is a lightweight, web-enabled ATM simulator, offering a rapid prototyping environment for advanced concept research projects. The basic programming language of eDEP is Java. For the RADE-2 project eDEP is configured to facilitate a small-scale simulation environment with a TCAS server that replicates CAS logic in the ground system for realistic TCAS event generation on the controller screen. Furthermore, the EUROCONTROL AudioLAN system is used in RADE-2 for communication with both pseudo-pilots and adjacent control sectors which are controlled by Subject Matter Experts (SME).

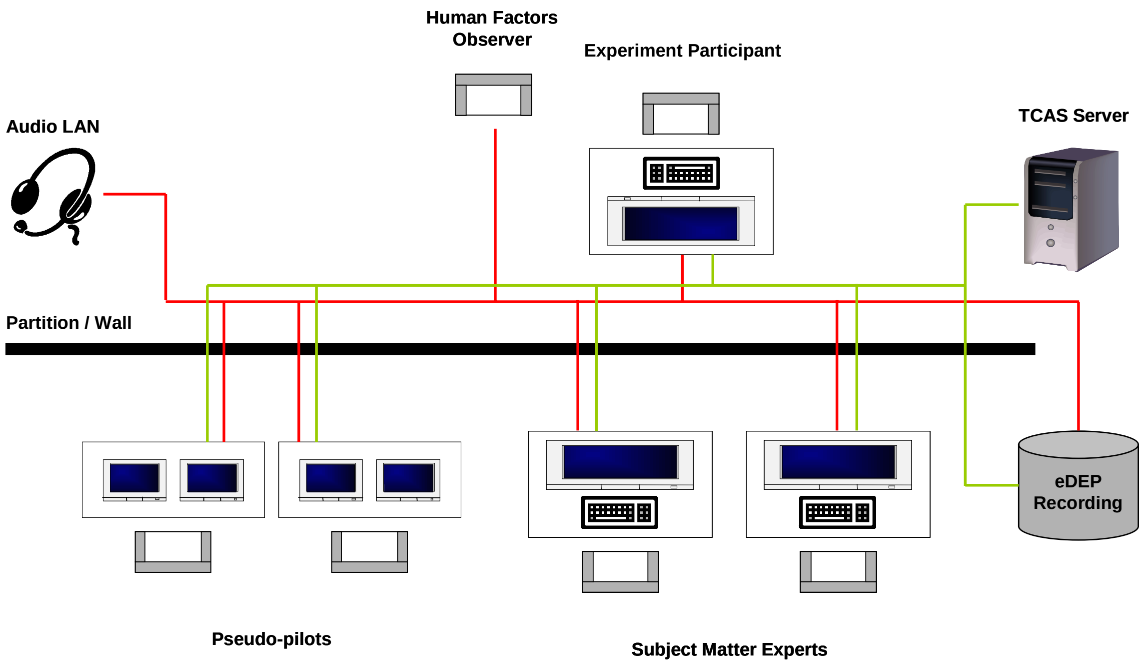

Figure 4-1: RADE-2 Single Configuration Environment

During the RADE-2P experiments the platform was used in two different configurations, the so-called single and dual configurations.

In the single configuration two experiment participants could work individually as executive controller at the same time in two identical and independent sectors. There was no interaction between the sectors. For each sector, there were the following experimental roles: one controller, one Human Factors (HF) expert, one or two Subject Matter Experts, and two pseudo-pilots (see Figure 4-1). Controller responsibilities consisted of separation of traffic in the sector, radio communications with the pilots, co-ordination with other sectors through a designated AudioLAN telephone connection and system updates through label inputs.

The dual configuration (see Figure 4-2) allowed for a single simulation environment with an executive and planning controller working in one sector. While the executive controller was responsible for separation of aircraft in the sector and radio communication with the pilots, the planning controller was responsible for resolving planning conflicts, co-ordinating with other sectors through the previously mentioned telephone connection, and assisting the executive in the provision of traffic separation.

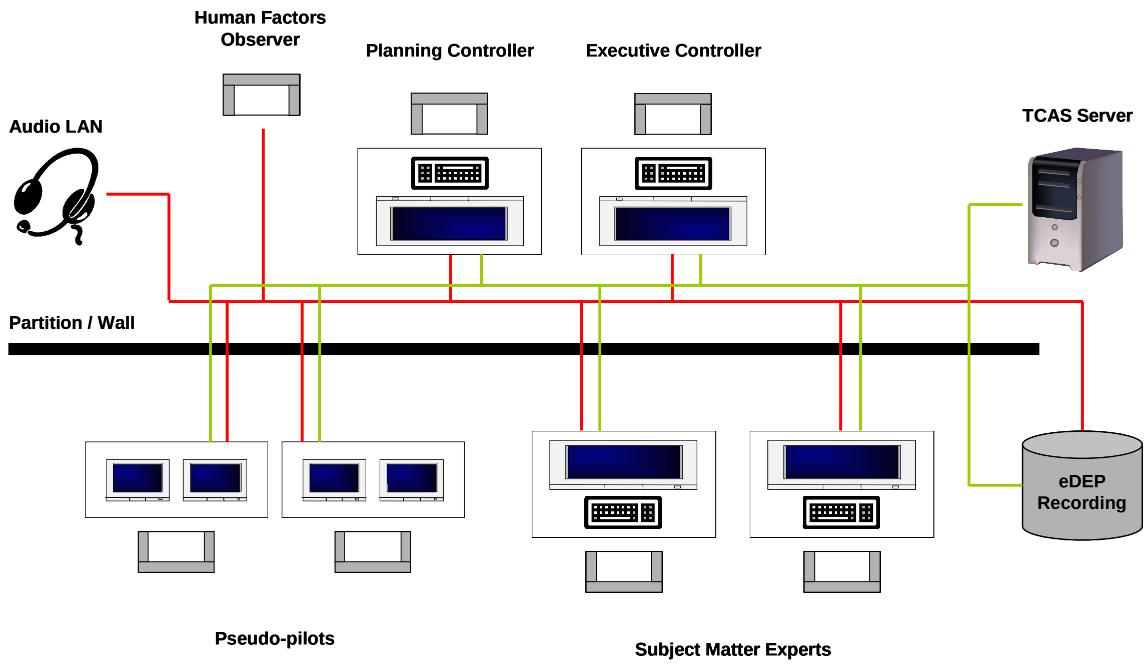

Figure 4-2: RADE-2 Dual Configuration Environment

During the RADE-2P simulations it was discovered that the single configuration proved to be efficient for controller training, as two controllers could work simultaneously in two independent sectors. The dual configuration, however, was considered much more realistic, since it provided a working environment which is comparable to the current controller working environment in many European centres with a planning and an executive role. Therefore, it was decided to perform the measured runs in dual configuration while training runs were done mainly in single configuration.

4.2 Controller Interface Configuration

The controller HMI used for the experiments was based on the standard EATMP HMI. Since this HMI is thoroughly described in the eDEP design document for the controller working position layer (see Ref. [4]) only the more specific parts regarding the label and the TCAS alert display will be described in the following.

In the EATMP HMI of the eDEP platform there were two label presentations depending on whether the label was selected by the controller or not. The selected label contents is shown in Figure 4-3.

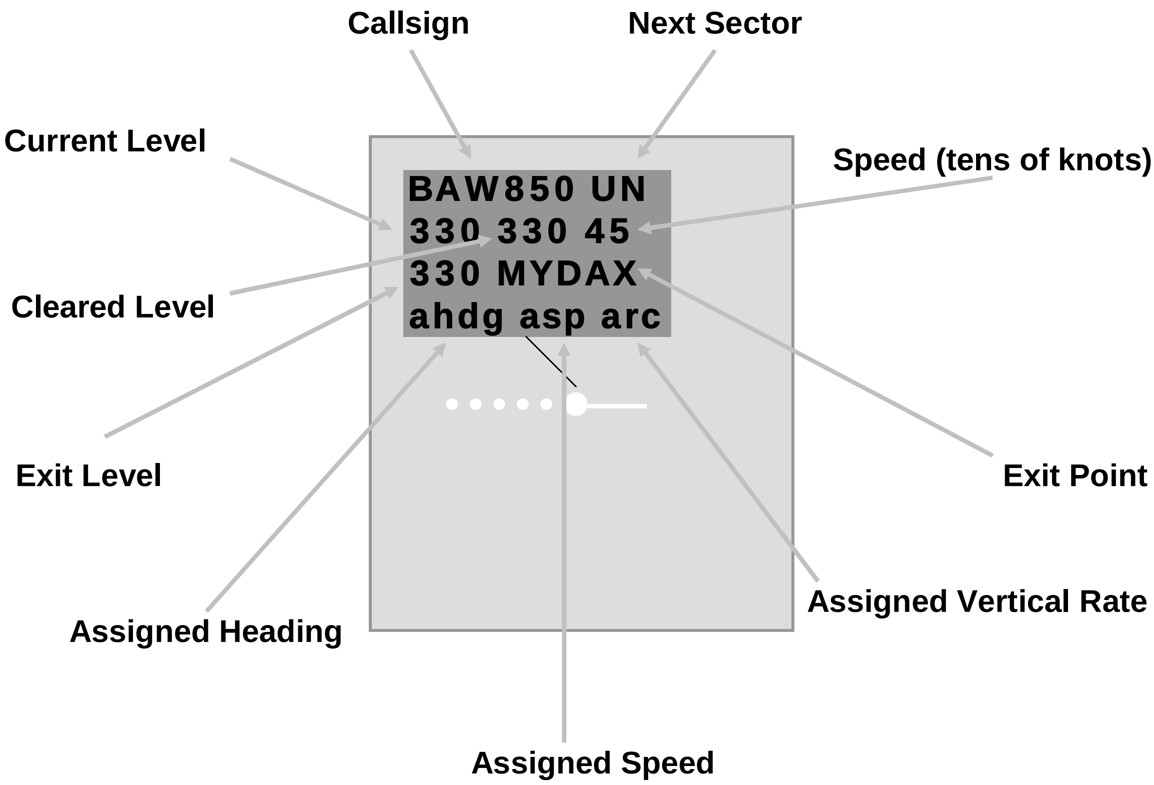

Figure 4-3: RADE-2 HMI – Selected Label Contents

While the selected label contained additional information on assigned heading, speed, and vertical rate as well as exit level, exit point and the cleared level, the minimum label merely contained the basic information, namely the callsign, the next sector and the current level.

As can be seen in Figure 4-3, the track symbol could be displayed with a track vector and track histories, the length of which was controllable via an HMI toolbox.

Short-term conflict alerts (STCA) were shown in the HMI by visually enhancing the callsign part of the label with a red background and yellow letters and by changing the track vector colour to red as can be seen in Figure 4-4. Furthermore, there was an alert window that showed both the STCA and TCAS alerts, i.e. the callsigns involved, type of RA, and the distance of closest approach.

Figure 4-4 also shows the presentation of a TCAS alert. The TCAS alert was added on top of the label, right above the callsign with a distinctive blue background and yellow letters spelling the word TCAS and symbols indicating the type of resolution advisory (and its direction, if applicable). In case of a reversal of the resolution advisory, the previous sense of the advisory was shown in brackets. TCAS information was also shown in the alert window. Usually, both aircraft involved in a conflict would show this information. In case only one aircraft had a TCAS resolution advisory, the intruder was shown with a red frame around the complete label.

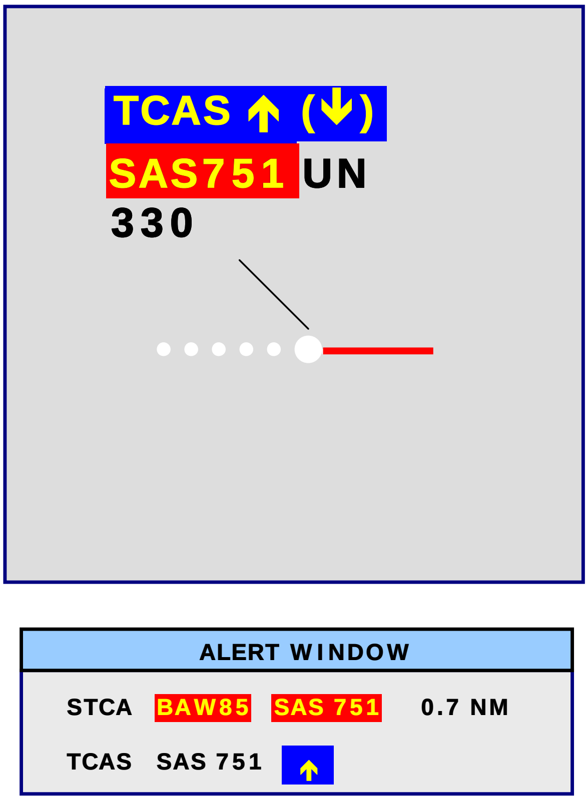

Figure 4-4: STCA and TCAS Alert Display

More information on the presentation of resolution advisories and the types of TCAS events considered can be found in the operational concept document for the FARADS project [6].

4.3 Additional Tools for Analysis

In addition to the simulator in the Human Factors Lab a tool for ACAS event analysis was available. The Interactive Collision Avoidance Simulator (InCAS) was used to read the radar data recorded on the simulation platform and rebuild aircraft trajectories. In that way TCAS behaviour could be simulated, meaning that it was possible to display, evaluate and analyse TCAS events occurring during a simulation run.

4.4 Area Control Centre and Airspace

Controllers were told that they were to work in Cottam Centre which is a fictitious facility located somewhere in Europe. They were on an afternoon shift in the so-called Haren sector (see Figure 4-5). The Haren sector is surrounded by two feed sectors, one in the North and one in the South. Both feed sectors were controlled by SME participants in a separated room and co-ordination with these sectors could be performed by the planning controller via a designated AudioLAN telephone connection.

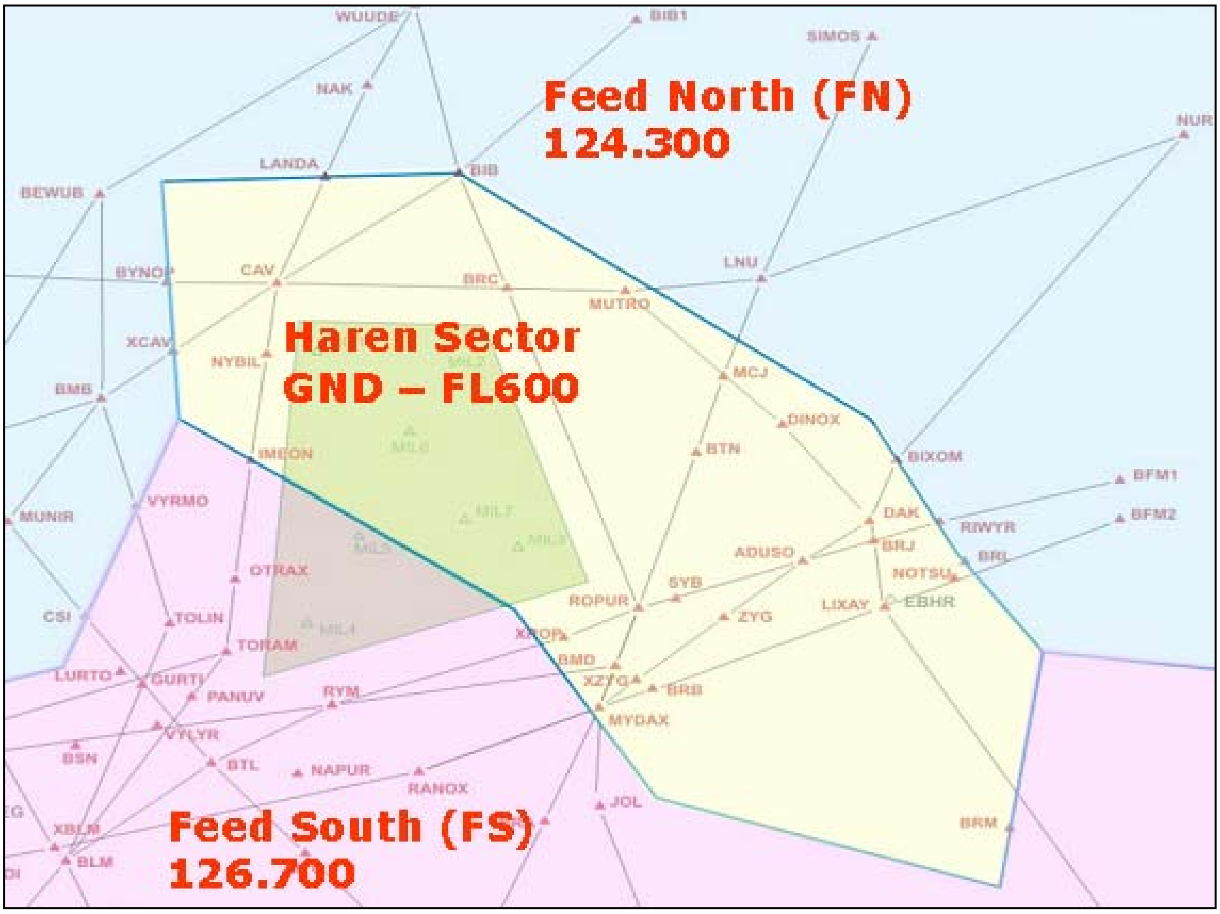

Figure 4-5: Simulated Airspace - Haren Sector in Cottam Centre

A special characteristic of the airspace was the military sector (in green in Figure 4-5). At the beginning and during the simulations the status of the sector could change from non-active to active with a restriction on a range of flight levels. Furthermore, it could be seen that there were major crossing points for traffic streams at CAV, BRC, BIB and ROPUR which would ask the controllers' special attention.

Main traffic flows were presented to controllers during the briefing session before the simulations. They are shortly listed in the following:

- from BYNOP to MUTRO on odd level with some outbound traffic descending to FL190
- from MUTRO to BYNOP on even level with some inbound traffic climbing to requested FL
- from BIB to XCAV on odd level with some inbound traffic climbing to requested FL
- from BIB to MYDAX on odd level changing to even level before exit
- from MYDAX to BIB on odd level changing to even level (FL280) before exit
- from MYDAX to BRL on odd levels
- from LNU to MYDAX on even levels
- from LANDA to IMEON on even levels

4.5 Traffic Samples

A total of 36 candidate traffic samples were prepared for RADE-2P. Appendix B contains the full list including some information on characterising features and on the time-dependent sector loading of the respective traffic sample. A subset of 13 moderately busy traffic samples was chosen. These are marked in Appendix B.

4.6 RA Facilitation Methods

As was anticipated, one of the major challenges of RADE-2P was to facilitate RAs in a realistic way. Multiple means to achieve this were tried out. In general, it was the role of the SME to predict the controller's actions and to identify traffic situations that may allow for the generation of an RA. However, it was decided that repeated attempts on the same aircraft or using the same method should be avoided as controllers would find this annoying. Already during the introductory briefing of the controllers (see below) it was explicitly stated that the design of the simulation scenarios may take them to the point where they experience a situation of "loosing the picture". In order to avoid a negative impact on their self-confidence it was emphasised that their individual performance as a controller would never be judged on the basis of these incidents. It was pointed out that the post-exercise debriefing aimed at receiving feedback on the usefulness of RA downlink in this particular situation rather than reflecting on when and how the controller could have made decisions to avoid the RA beforehand.

4.6.1 Means to Facilitate Controller Error

In case a suitable traffic situation for the facilitation of an RA event emerged, the SME gave, e.g., instructions to the pseudo-pilots in the attempt to increase workload that may eventually lead to controller error. Examples are:

- Requesting a change of flight level due to turbulence
- Maintaining a high vertical rate before a cleared level off
- Requesting direct routing
- Delaying pilot response

- Giving incorrect read-backs

4.6.2 Pilot Error

Another means explored during RADE-2P to facilitate an RA was to deliberately implement wrong or unsafe pilot actions in a conflict-critical situation. The SME, for example, instructed a pseudo-pilot to bust a flight level in order to induce a conflict pattern with a proximate aircraft at an adjacent flight level.

4.6.3 Configuration at the Experimenter's Site

The described facilitation methods are quite labour-intensive for both the SME and the pseudo-pilots. As RA generation was attempted during periods of high traffic load, the high amount of pilot-controller communication added to the burden of communicating an RA generation strategy between SME and pseudo-pilots in real-time. Some alleviations of this problem were achieved with only one pseudo-pilot and two SMEs who acted also as pseudo-pilots. A third SME acted as a counterpart of the planner in the feeder sectors. This configuration was eventually suggested for RADE-2A.

4.7 Participants

Two male controllers participated in RADE-2P. Table 4-1 depicts some relevant biographical background information collected in the pre-experimental questionnaire.

	Controller A	Controller B
Age	33	47
Nationality	British	Polish
Home ACC	EUROCONTROL Maastricht UAC	Warsaw ACC
Time licensed as controller	7 years	18 years
Time working as instructor	4 years	10 years

Table 4-1: RADE-2P Participant Information

Questions regarding knowledge of TCAS II as well as attitude toward RA downlink were asked before and after RADE-2P. One controller rated his knowledge of TCAS II with a 5 on a scale ranging from 1 (poor) to 5 (very good). The rating was the same both before and after RADE-2P. The rating of the other controller increased from a value of 3 before to 4 after the RADE-2P simulations. This controller also changed his acceptance rating towards RA downlink ("How useful do think is the display of RAs to the controller?") from 4 to 5 (absolutely). The other controller gave the highest acceptance rating both before and after RADE-2P. Both controllers indicated to have witnessed two RA events each.

4.8 Training

Controller training in the morning session of day 1 started with a briefing of approximately two hours duration carried out in two sessions with a 15-minute break in-between. This briefing covered the following aspects:

- Introduction of the RADE-2P team
- Motivation for the RA Downlink
- Objectives of RADE-2P
- ACAS operational briefing
- RA downlink operational concept
- Introduction into main features of the HMI
- Main characteristics of the fictitious “Haren” control sector
- Time schedule

After the briefing the controllers filled in the pre-experiment questionnaire and subsequently familiarised themselves with the working equipment. During the afternoon session, three training runs were performed for each controller. During these training runs, controllers were working in parallel in single configuration, coached by one SME each (see Figure 4-1). After each run a debriefing was completed clarifying any question.

5. EXPERIMENT RESULTS

5.1 Experimental Runs

Although a total of 18 experimental runs were planned for day 2 to day 5, only 13 runs could be completed. The main reason was the fact that 15 minutes for the debriefing was found to be too short. In particular, it was found that the HF experts needed some time to recap the observations together with the SME to better prepare the post-exercise debriefing. RAs were scheduled to be displayed in 11 runs. In the remaining 2 runs (run #10 and #11) no RAs downlink information was supposed to be displayed. In two runs (#8 and #12) no RAs could be elicited after 50 minutes of simulation time.

A complete list of all runs with the encountered ACAS themes and the numbers of RAs is given in (see also Appendix B).

Run No.	Name of Traffic Sample	ACAS Theme*	RAs
1	RADL_A4	CE	1
2	RADL_A5L	HVSLO	1
3	RADL_A7	HVSLO	1
4	RADL_A2L	OE	1
5	RADL_A4	PE, HVSLO	2
6	RADL_A5	HVSLO, OE	2
7	RADL_A7N	CE, CE, CE	3
8	RADL_A5R	-	0
9	RADL_A6L	PE	1
10	RADL_A5RB	HVSLO	1
11	RADL_A7L	HVSLO	1
12	RADL_A7N	-	0
13	RADL_A3	HVSLO, OE	2

Table 5-1: List of Experimental Runs and Results

CE: Controller error
PE: Pilot error
OE: Other error (induced by SME, e.g. bad weather, TCAS error)

HVSLO: High vertical speed level-off

5.1.1 Rated Quality of the Training

As part of the post-experiment questionnaire controllers were asked to assess the quality of the training using the five-point scale from ”poor” to ”very good”. One controller gave a 3, the other a 5. No particular need to improve the training was raised.

5.1.2 Single vs. Double Configuration

The first experimental run was done using the single executive configuration also used during training. The advantage of this configuration was the possibility to perform two runs in parallel. During the second experimental run the possibility of a double configuration was explored involving both controllers, one acting as executive and the other one as planning controller. For that purpose one SME acted as planning controller of the two sectors adjacent to the Haren sector (Feeder North and Feeder South – see Figure 4-5). During the debriefing of the second run the double configuration was generally preferred for its higher level of realism. Therefore, all subsequent experimental runs were performed using the double configuration.

5.1.3 Simulation Realism

Part of the post-experiment questionnaire consisted of questions addressing the controllers' perception of simulation realism. This perception had to be rated on a five-point scale ranging from 1 (not at all) to 5 (absolutely). One controller gave a 4 for the exercises in general, a 3 for the realism of the RA event, and a 3 for the realism of the pilot response to the RA. With regard to the latter he criticised the quality of the phraseology used by the pseudo-pilots. The other found it difficult to provide a general rating as some exercises were experienced rather unrealistic and some were alright. For RADE-2A it was suggested to collect respective ratings during the post-exercise interview. The same was stated for the realism of the RA event. He gave a 4 for the realism of the pilot responses. Both controllers found that in some exercises the drive to generate an RA was too obvious, particularly when one facilitating method was employed repeatedly.

5.2 Data Collection and Assessment Issues

Experiences with these assessment methods and with the logistics of their application made during RADE-2P led to some refinements proposed for RADE-2A.

- It was found useful to administer computerised versions of the questionnaires. It happened quite often that two marking bullets were checked or some questions were left blank. This could be better controlled with computerised forms. Therefore it was recommended to develop electronic questionnaires based on a Microsoft Access database application. This should also facilitate data analysis at later stages of the project.
- Both HF experts found that the post-exercise interview should be tape-recorded as the manual recording of statements or comments made by the controller was found

very impractical for the conduct of an interactive interview. It was suggested to perform the post-exercise interview with the executive controller only.

- It was also found necessary that both the HF expert and the SME shortly brief each other on their views, assessments, observations, etc. on the completed exercise to better prepare the HF expert for the post-exercise interview. Some draft observation sheets used by the HF experts and the SME underwent several refinements to better support this briefing between HF expert and SME. The final version proposed for RADE-2A can be found in Appendix A.4 . In addition it was recommended that the simulation platform specialists provide data sheets for every conflict situation for support of data analysis in a Microsoft Excel sheet format.
- It was suggested for the conduct of RADE-2A that a simulation exercise should aim at the generation of one RA event only, upon which the subsequent SA questionnaires and the post-exercise interview should refer to. Moreover, an artificial high number of such a rare event, albeit desirable for statistical reasons, would lower the realism of the exercise.
- The workload at the experimenter's site was very high particularly when traffic load was high and a traffic situation was detected that the SME judged as appropriate for efforts to facilitate an RA event. Faced with the double burden of responding to both the controller instructions and SME guidance, it soon became evident that pseudo-pilots were not capable of manipulating the quality of the pilot report in the desired way.

6. SUMMARY AND RECOMMENDATIONS

One of the key objectives of RADE-2P was to assess the feasibility of carrying out RA downlink experiments in an interactive setting, i.e. determining whether it is possible to elicit RAs within the proposed simulation environment. This objective was achieved satisfactorily. The feedback obtained by the controllers indicated that a good balance between generation of the desired target situation and simulation realism was achieved. The amount and quality of training was also rated as good. As a result of RADE-2P it was determined that interactive validation exercises in RADE-2A should be run in a dual CWP configuration involving both the executive and the planning controller (see Figure 4-2). Therefore, in addition to the two independent variables envisaged for RADE-2A and RADE-2T, i.e. pilot quality (time vs. delayed) and RA downlink (present vs. absent), a further variable can be differentiated in the experimental design to account for the controller working position (executive vs. planner) at least for those variables for which data will be collected from both controllers (SA memory probe, SA questionnaire, NASA-TLX). For the RADE-2A experimental plan it is proposed to base the randomization scheme on a 2 * 2 * 2 experimental design.

Some modifications were explored at the experimenter's site of the simulation set-up. It was suggested that RADE-2A should run with three SMEs and one pseudo-pilot. One SME should act a counterpart of the planner, the other two should fulfil a double role of acting as a pseudo-pilot and as facilitator of RA events. Assigning SMEs also the role of a pseudo-pilot was suggested to ease the workload associated with the communication of the facilitating tactics at the experimenter's site. This, in particular, was deemed necessary in order to gain sufficient experimental control in manipulating the quality of pilot report as intended in RADE-2P and RADE-2T.

As a caveat, however, it should be noted that the RA facilitation methods used will be inherently prone to yield inconsistent experimental conditions. These inconsistencies may result in undesired confounding, e.g. in terms of an unbalance of ACAS themes across the independent variables of the experimental design.

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Appendix A RADE2-P Questionnaires

During the RADE-2P experiments the questionnaires presented below were applied. It should be noted though, that due to comments from participants the final contents and layout of the questionnaires changed before the execution of RADE-2A and RADE-2 simulations. The final versions of the questionnaires will therefore be presented in the final experiment plan [8].

Appendix A.1 Pre-experimental Questionnaire

Participant-ID:	**Date:**	**Time:**

Note: All data collected during this simulation will be treated with the ***strictest confidentiality***. Only members of the experimental team will have access to the questionnaires; data analysis and report will be done in such a way that responses cannot be traced back to any particular person.

ABOUT YOURSELF

1 – What is your age? ___________________

2 – What is your nationality? ___________________

ABOUT YOUR EXPERIENCE AS AN AIR TRAFFIC CONTROLLER

3 – In which ACC do you work? ______________________________________

4 – What other ratings do you hold or have held? _________________________

5 – How long are you licensed as a controller (in years)? _________________________

6 – How long are you licensed as an area controller (in years)? ___________________

7 – Do you have experience as an instructor (including On-The-Job Training)?

- ❑ Yes, for _______ years
- ❑ No

8 – Have you ever witnessed any incidents where a serious violation of separation minima has occurred or could have occurred? (This can either concern traffic under your responsibility or under responsibility of adjacent sectors/your colleagues)

- ❑ Yes; please indicate how many __________
- ❑ No

If you responded “yes”, please proceed with Question 9. If you responded “no”, please proceed with Question 13.

9 – In case you have witnessed (an) incident(s): were there any Resolution Advisories (RAs) generated in these situations?

- ❑ Yes; in _______ out of ________ case(s)
- ❑ No
- ❑ I don’t know

10 – In case you responded “yes” to the previous question, how did you come to know about these RAs?

- ❑ Pilot reporting it on R/T
- ❑ Through an investigation
- ❑ Don’t remember

11 – In the incidents witnessed by you, did RAs help to resolve the conflict situation?

Not at all	☐	☐	☐	☐	☐	Absolutely

12 – In case your experiences with RAs differ (that is, in one incident it might have helped, in another, it might not), please specify.

13 – Have you ever been informed by the pilot about RAs that were nuisance alerts (e.g., due to fast climbing or fast descending aircraft)?

- ❑ Yes; please indicate how many __________
- ❑ No

14 – Have you ever been informed by the pilot about RAs that were false alerts (i.e., there was no other traffic in the vicinity)?

- ❑ Yes; please indicate how many __________
- ❑ No

ABOUT THE SIMULATION OBJECTIVES

15 – How would you assess your knowledge of TCAS II?

Poor ☐ ☐ ☐ ☐ ☐ Very good

16 – How familiar are you with the concept of RA downlink?

Not at all ☐ ☐ ☐ ☐ ☐ Absolutely

17 – How useful do you think is the display of RAs to the controller?

Not at all ☐ ☐ ☐ ☐ ☐ Absolutely

18 – What are – in your opinion – the operational advantages of displaying RAs to the controller?

19 – What are – in your opinion – the operational disadvantages of displaying RAs to the controller?

Thank you very much!

Appendix A.2 Post-exercise Questionnaire

Participant-ID:	Date:	Run-no.:
RA-Downlink No RA-Downlink	Scenario no.:	Executive Controller Planning Controller

In your opinion, what was/were the reason/s for the RA-incident in the previous scenario? (Multiple answers possible)

- ❑ ATC error
- ❑ Pilot error
- ❑ TCAS error (that is, an alert without any aircraft in the vicinity)
- ❑ Fast climbing/fast descending aircraft
- ❑ Don’t know
- ❑ Other, namely ____________________

Please describe the situation by filling in the table below.

	1	2	3
Aircraft involved in the situation (Callsign or Airline 3-Letter Code)?			
Cleared Level?			
Climb/level/descend prior to RA/incident? (please mark)	↑ → ↓	↑ → ↓	↑ → ↓
Approximate Heading?			
Did pilot report RA?			
Was RA information displayed on the screen?			
Type of RA issued to aircraft?			

Did aircraft follow RA?			
Did RA reverse its sense?			
Did pilot manoeuvre yield any new conflicts? If so, describe.			

Appendix A.3 Situation Awareness Questionnaire

Participant-ID:	Date:	Run-no.:
☐ RA-Downlink ☐ No RA-Downlink	Scenario no.:	☐ Executive Controller ☐ Planning Controller

Q1: - Did you have the feeling that you were ahead of the traffic and able to predict the evolution of the traffic?

Not at all ☐ ☐ ☐ ☐ ☐ Absolutely

Comments:…………………………………………………………………………………………
……………………………………………………………………………………………………..
……………………………………………………………………………………………………..

Q2: - Did you have the feeling that you were able to plan and organise your work as you wanted?

Not at all ☐ ☐ ☐ ☐ ☐ Absolutely

Comments:…………………………………………………………………………………………
……………………………………………………………………………………………………..
……………………………………………………………………………………………………..

Q3: - Have you been surprised by an a/c call that you were not expecting?

Not at all ☐ ☐ ☐ ☐ ☐ Absolutely

Comments:…………………………………………………………………………………………
……………………………………………………………………………………………………..
……………………………………………………………………………………………………..

Q4: - Did you have the feeling of starting to focus too much on a single problem and/or area of the sector?

Not at all ☐ ☐ ☐ ☐ ☐ Absolutely

Comments:…………………………………………………………………………………………
……………………………………………………………………………………………………..
……………………………………………………………………………………………………..

Q5: - Did you forget to transfer any aircraft?

Not at all ☐ ☐ ☐ ☐ ☐ Absolutely

Comments:…………………………………………………………………………………………
……………………………………………………………………………………………………....

Q6: - Did you have any difficulty finding an item of (static) information?

Not at all ☐ ☐ ☐ ☐ ☐ Absolutely

Comments:……………………………………………………………………………………
…………………………………………………………………………………………..
…………………………………………………………………………………………..

(* to be answered only if RA information was displayed on the screen, if not proceed to Q12)

*Q7: - Did the RA information help you to have a better understanding of the situation?

Not at all ☐ ☐ ☐ ☐ ☐ Absolutely

Comments:……………………………………………………………………………………
…………………………………………………………………………………………..
…………………………………………………………………………………………..

*Q8: - Did you feel distracted by the RA information (from attending other relevant aspects of the traffic situation)?

Not at all ☐ ☐ ☐ ☐ ☐ Absolutely

Comments:……………………………………………………………………………………
…………………………………………………………………………………………..
………………………………………………………………………………………….

*Q9: - Did the RA information help you to focus on the safety-relevant aspects of the traffic situation?

Not at all ☐ ☐ ☐ ☐ ☐ Absolutely

Comments:……………………………………………………………………………………
…………………………………………………………………………………………..
…………………………………………………………………………………………..

*Q10: - Did the RA information influence your plans for <u>separating</u> aircraft (both the aircraft involved in the RA encounter and the surrounding traffic under your control)?

Not at all ☐ ☐ ☐ ☐ ☐ Absolutely

Comments:……………………………………………………………………………………
…………………………………………………………………………………………..
…………………………………………………………………………………………..

*Q11: - Did you have any difficulty in interpreting the sense of the RA?

Not at all ☐ ☐ ☐ ☐ ☐ Absolutely

Comments:………………………………………………………………………………………
…………………………………………………………………………………………………..
…………………………………………………………………………………………………..

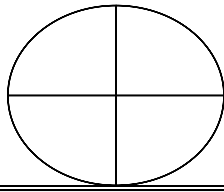
Q12: - Finally, how would you rate your overall situation awareness during this exercise?

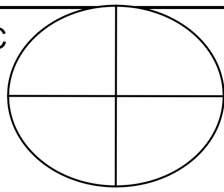
Poor ☐ Quite poor ☐ Okay ☐ Quite good ☐ Very good ☐

Comments:………………………………………………………………………………………
…………………………………………………………………………………………………...
…………………………………………………………………………………………………..

Appendix A.4 HF Observer Notebook

Participant-ID:	Observer	Date:
❑ RA-Downlink ❑ No RA-Downlink		Scenario no.: Run-no.: Start Time: End Time:



Scripted ATC events:	
Event: Time event started: A/C concerned:	Approximate position of A/C on radar screen
Context Description of ATCO's response (detection, recovery, verbal remarks, actions, etc.)	
Event: Time event started: A/C concerned:	Approximate position of A/C on radar screen 

Context   Description of ATCO’s response (detection, recovery, verbal remarks, actions, etc.)

Appendix A.5 Replay-Supported Interview

Participant-ID:	Date:
Scenario with RA-Downlink Replay with RA-Downlink Replay without RA-Downlink	Scenario no.: Run-no.:

Facilitating questions

1 – When did you first perceive the conflict that created the RA event?

- ❑ Prior to STCA
- ❑ After the STCA

2 – Please, describe how you dealt with the conflict?

3 – What circumstances, if any, prevented you from optimally dealing with the conflict?

4 (Ask if scenario had no RA-Downlink) – Observing the replay with RA downlink, in what way would this have changed your work? Think in terms of pros and cons with respect to dealing with the conflict and other aspects of the traffic that needed your attention!

5 (Ask if scenario had RA-Downlink) – Observing the replay without RA downlink, in what way would this have changed your work? Think in terms of pros and cons with respect to dealing with the conflict and other aspects of the traffic that needed your attention!

Appendix A.6 Post-Experiment Questionnaire

Participant-ID:	Date:	Run-no.:
RA-Downlink No RA-Downlink	Scenario no.:	Executive Controller Planning Controller

GENERAL ATTITUDE ON TCAS

After attending the experiment, we would like you to give us your opinion on the potential advantages and disadvantages of RA downlink again.

1 – How would you assess your knowledge of TCAS II?

Poor ☐ ☐ ☐ ☐ ☐ Very good

2 – How familiar are you with the concept of RA downlink?

Not at all ☐ ☐ ☐ ☐ ☐ Absolutely

3 – How useful do you think is the display of RAs to the controller?

Not at all ☐ ☐ ☐ ☐ ☐ Absolutely

4 - What are – in your opinion – the operational advantages of displaying RAs to the controller?

5 - What are – in your opinion – the operational disadvantages of displaying RAs to the controller?

6 – Having experienced a lot of TCAS training and TCAS events over these two days, do you think it would be generally beneficial for air traffic controllers to get additional training on TCAS?

Not at all ☐ ☐ ☐ ☐ ☐ Absolutely

7 – If so, please specify concerning which topics:

TCAS IN DIFFERENT SITUATIONS

In this section, we are interested in the specific situations in which RA downlink might be helpful, and the situations in which it might be less helpful.

8 – Do you think RA downlink would be helpful in case of a false TCAS alert?

Not at all ☐ ☐ ☐ ☐ ☐ Absolutely

9 – Do you think RA downlink would be helpful in case the RA has been triggered by a high vertical rate before level off?

Not at all ☐ ☐ ☐ ☐ ☐ Absolutely

10 – Do you think RA downlink would be helpful in case of an ATC error?

Not at all ☐ ☐ ☐ ☐ ☐ Absolutely

11 – Do you think RA downlink would be helpful in case of a pilot error?

Not at all ☐ ☐ ☐ ☐ ☐ Absolutely

12 – Do you think RA downlink would be helpful in case of a pilot not following the RA correctly?

Not at all ☐ ☐ ☐ ☐ ☐ Absolutely

13 – Do you think RA downlink is more helpful as situations become more complex?

Not at all ☐ ☐ ☐ ☐ ☐ Absolutely

14 – Do you think RA downlink would be helpful in case the pilot *does not* report the RA?

Not at all ☐ ☐ ☐ ☐ ☐ Absolutely

15 – Do you think RA downlink would be helpful in case of the pilot *does* report the RA?

Not at all ☐ ☐ ☐ ☐ ☐ Absolutely

HUMAN-MACHINE INTERFACE

The questions below refer to the way in which the RA information was provided to you, that is, the human-machine interface.

16 – What is your evaluation of the HMI with the RA in yellow on blue?

Poor ☐ ☐ ☐ ☐ ☐ Very good

17 – What is your evaluation of how the HMI indicates the sense of the RA?

Poor ☐ ☐ ☐ ☐ ☐ Very good

18 – Have you ever been confused about the RA information and the actual movement of the aircraft?

Yes ☐
No ☐

Please explain:………………………………………………………………………………………
…………………………………………………………………………………………………..
…………………………………………………………………………………………………..

19 – Do you recommend that the RA message should blink?

Yes ☐
No ☐

Please explain:………………………………………………………………………………………
…………………………………………………………………………………………………..
…………………………………………………………………………………………………..

20 – Do you recommend additional audible alerts?

Yes ☐
No ☐

Please explain:…………………………………………………………………………………
…………………………………………………………………………………………………..
…………………………………………………………………………………………………..

21 – Do you think the display should indicate more information on the content of the RA (for example clear-of-conflict notification)?

Yes ☐
No ☐

Please explain:…………………………………………………………………………………
…………………………………………………………………………………………………..
…………………………………………………………………………………………………..

22 – Do you think the display should indicate only corrective RAs, no preventive RAs?

Yes ☐
No ☐

Please explain:…………………………………………………………………………………
…………………………………………………………………………………………………..
…………………………………………………………………………………………………..

23 – Do you have any suggestions for improving the Human-Machine Interface?

PROCEDURES RELATED TO RA DOWNLINK

24 – The duration of the transfer of separation responsibility was unambiguous?

Not at all ☐ ☐ ☐ ☐ ☐ Absolutely

The following statements describe the controller's role during an RA encounter according to current procedures. Please rate to what extent the RA downlink concept implemented in the simulation experiment help to accomplish this role.

25 – The controller shall cease to issue clearances to the generating aircraft. The RA downlink concept improves to accomplish this role.

Not at all ☐ ☐ ☐ ☐ ☐ Absolutely

26 – The controller may provide traffic information. The RA downlink concept improves to accomplish this role.

Not at all ☐ ☐ ☐ ☐ ☐ Absolutely

27 – The controller will acknowledge any voice report of the RA from the aircrew. The RA downlink concept improves to accomplish this role.

Not at all ☐ ☐ ☐ ☐ ☐ Absolutely

ON THE SIMULATION

In this section, we want your feedback on the content and the organisation of the experiment.

28 – Do you consider the traffic situations shown in the simulation as realistic?

Not at all ☐ ☐ ☐ ☐ ☐ Absolutely

Please indicate why: ____

____

29 – Do you consider the RA events that occurred in the simulation as realistic?

Not at all ☐ ☐ ☐ ☐ ☐ Absolutely

Please indicate why: ____

____

30 – Do you consider the “pilot” responses to RA events as realistic?

Not at all ☐ ☐ ☐ ☐ ☐ Absolutely

Please indicate why: ____

____

31 – How do you assess the quality of the training (i.e. the presentations)?

Poor ☐ ☐ ☐ ☐ ☐ Very good

What could be improved? ____

____

32 – How do you assess the organisation of the simulation, in terms of the travel and the accommodation?

Poor ☐ ☐ ☐ ☐ ☐ Very good

What could have been improved? ____

____

33 – How do you assess the organisation of the simulation, in terms of the daily schedule you had?

Poor ☐ ☐ ☐ ☐ ☐ Very good

What could have been improved? ____

____

34 – Are there any aspects of the simulation you particularly liked?

35 – Are there any aspects of the simulation you particularly disliked?

36 – Do you see a need for more research on RA downlink and further experiments?

Not at all ☐ ☐ ☐ ☐ ☐ Absolutely

37 – Are there any other comments on the simulation you would like to make?

Appendix B RADE-2P Traffic Samples

Appendix B.1

Traffic Sample Name	Characteristics						Remarks NVC = not very complicated NVB = not very busy L = light
	Randomised	Military Traffic in Haren Sector	Military Restricted Area	Light traffic Density	Training exercise	Scripted events	
RADL_A2							Converging and crossing scenarios, NVC.
RADL_A2C							Opposite direction traffic on some airways and descending traffic into EBBR. Busier exercise than RADL_A2.
RADL_A2CL				☒			Converging and crossing scenarios, L.
RADL_A2L				☒			Opposite direction traffic on some airways and descending traffic into EBBR. Busier exercise than RADL_A2.
RADL_A3							Busier again and more complex at particular times. Good for error inputs.
RADL_A3L				☒			L traffic at times moderately busy.
RADL_A3M1		☒					With Military flights more complex at particular times. Good for inputs.
RADL_A3M1L		☒		☒			L With Military flights and at particular times. Good for inputs

RADL_A3R	☒						A3 randomised, nav st. times changed, and complex and busy at 17:20 (simulation time). Ideal time for error inputs.
RADL_A3RL	☒			☒			A3 randomised, L traffic, at times moderately busy traffic.
RADL_A3RM4	☒	☒					A3 randomised, with military traffic, nav st. times changed. Complex and busy at 17:20 (simulation time). Ideal time for error inputs
RADL_A3RM4L	☒	☒		☒			A3 randomised, L traffic, at times moderately busy traffic.
RADL_A4							Busy with variations to conflict times.
RADL_A4L				☒			Moderately busy traffic at times.
RADL_A4M3		☒					Busy with Military traffic.
RADL_A4M3L		☒		☒			Moderately busy traffic at times.
RADL_A4R	☒						A4 randomised, nav st. times changed, complex and busy at times.
RADL_A4RL	☒			☒			Moderately busy traffic at times.
RADL_A5							Complex and busy.
RADL_A5L				☒			Moderately busy traffic at times.
RADL_A5R	☒						A5 randomised, slow start, NVC
RADL_A5RB	☒						A5 change of times of conflicts, slow start, busy and complex at 17:30 (simulation time).
RADL_A5RBL	☒			☒			Moderately busy traffic at times.
RADL_A5RL	☒			☒			Moderately busy traffic at times.
RADL_A5R_Mil	☒	☒		☒		☒	With scripted military traffic.
RADL_A6							Busy at times.

RADL_A6L				☒			Moderately busy traffic at times.
RADL_A6M2		☒					Busy at times.
RADL_A6M2L		☒		☒			Moderately busy traffic at times.
RADL_A7							Complex and busy.
RADL_A7L				☒			Moderately busy traffic at times.
RADL_A7R	☒						Different Nav st. times, complex and busy.
RADL_A7RL	☒			☒			Moderately busy traffic at times.
RADL_MIL			☒				With traffic in Military area.
RADL_TRAIN1					☒		Familiarisation
RADL_TRAIN2					☒		Familiarisation

Table 7-1: RADE-2P Traffic Samples