

Air Traffic Controller working position

A comparison between a single large display and a multiple display set-up

Customer

Esterline Control & Communication Systems

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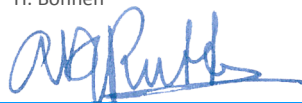
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Summary

This document is prepared by the National Aerospace Laboratory NLR and contains the research study for Esterline Control & Communication Systems to study the effects of display size on operator working experience. The goal of this research is to come to an independent assessment on the difference in perceived working experience of air traffic controllers in two different controller working positions:

1. Multiple display arrangement: Regular-sized (2K x 2K) controller working position with a primary radar control screen supported by one auxiliary display (i.e. multiple display arrangement); and
2. Single display arrangement: Large screen display with both radar and auxiliary information integrated into one screen (i.e. single display arrangement).

NLR performed an experimental study in which six air traffic controllers experienced working with both working positions. The experiment was performed in a simulated operational setting; i.e. NLR's air traffic control simulator NARSIM radar. Working experience was defined by measuring operator performance aspects such as workload, (eye) fatigue, situation awareness, usability, and task performance.

The study results show that the perceived ATCO working experience in a multiple display arrangement is preferred over the experience in a single display arrangement. This is supported by the situation awareness findings that show that the situation awareness was higher in the multiple display arrangement than in the single display arrangement. It is also supported by the workload findings that show the trend that the workload was perceived lower in the multiple display arrangement than in the single display arrangement.

Air Traffic Controller working position



Zoom in of NLR's traffic control simulator NARSIM

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Abbreviations

Abbreviation	Description
ACC	Area Control Centre
ATCO	Air Traffic COntroller
ATM	Air Traffic Management
AT-SAT	Air Traffic Selection And Training
CARS	Controller Acceptance Rating Scale
dpi	dots per inch
FAA	Federal Aviation Administration
ISA	Instantaneous Self-Assessment
NARSIM	NLR's Air Traffic Control Research SIMulator
NLR	National Aerospace Laboratory
R/T	Radio/Telephony
SART	Situation Awareness Rating Technique
SASHA	Situation Awareness for SHApE
SHAPE	Solutions for Human Automation Partnerships in European ATM
SSR	Secondary Surveillance RADAR
TID	Tactical Information Display
TFT	Thin Film Technique
TLX	Task Load Index

1 Introduction

1.1 Purpose of this document

This document is prepared by the National Aerospace Laboratory NLR and contains the research study for Esterline Control & Communication Systems to study the effects of display size on the perceived working experience in the controller working position. The goal of this experimental study is to come to an independent advice for two different controller working positions:

- One working position representing the regular-sized controller working position with a primary control radar screen (2K x 2K) supported by one auxiliary display.
- The other working position displaying radar and auxiliary information on one large screen display.

1.2 Document outline

Chapter 2 highlights the background of the experimental study. The main focus here is the controller working position. Chapter 3 provide the study description, mainly focusing on the research methods. Chapters 4 and 5 present the study results and conclusions.

2 Study background

Safeguarding the high standards of safety and reliability in air transport is a demanding job. As a result the working position of an ATCO is highly specialised. Due to the high demands for safety and reliability, the high costs of replacing legacy equipment, and the strong personal preferences of controllers, the working position of a primary radar controller in an Area Control Centre (ACC) has remained remarkably similar since the round dial set-up for the primary radar displays became obsolete.

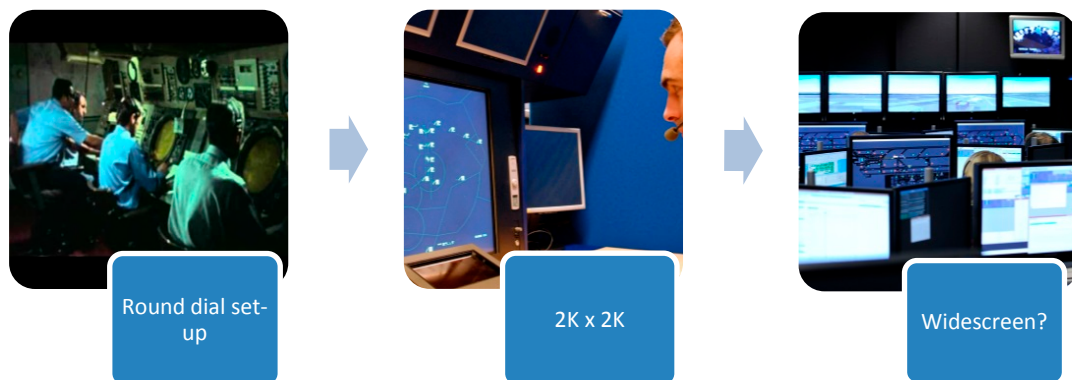


Figure 2-1: Evolution in primary radar displays

The standard controller working position currently consists of one high-resolution primary display complemented by one or more auxiliary displays. Most primary displays have a 4 megapixel resolution (2K x 2K), with a 1:1 (square) screen ratio, and contain the information of the primary radar and Secondary Surveillance Radar (SSR). All additional information is displayed on separate displays. Input can be given via a mouse and keyboard or via a trackball and Tactical Information Display (TID) set-up.

Recently, a new type of display has become feasible for use in ATC: 4K x 2K (3,840 pixels wide and 2,160 pixels high) widescreen displays. Due to the larger screen estate, such a screen could incorporate primary and auxiliary displays in a single screen. This research provides insight in the differences between the conventional 2K x 2K display and the large screen 4K x 2K display with respect to operator working experience. The assessment of operator working experience involves many aspects, including (perceived) workload, operator (eye) fatigue, situation awareness, usability, and task performance. Two of these aspects are briefly discussed below.

An important factor with respect to the operator working experience is (eye) fatigue. Fatigue can have serious safety implications as it slows the response of the controller and decreases the controller's problem solving capabilities. Moreover, fatigue makes an ATCO less vigilant which potentially leads to decreased situation awareness. The environment the ATCO is in (e.g. temperature, lighting) and the controller working position (e.g. displays, chair) all influence the perceived fatigue level. Eye tracking technology including eye blink rates and eye movements provide a good measure of eye fatigue (Van Hienen & Zon, 2009) (Langan-Fox, Sankey, & Canty, 2009). In addition, tracking the controller's movements provides insight in the experienced (dis)comfort.

Another aspect to be discussed here is the situation awareness of the controller. Situation awareness consists of three fundamental aspects: the perception of the environment (1), an understanding of the current situation (2), and a prediction of future events (3) (Endsley, 1988). The type of display (not taking into account changes in the human machine interface) influences the ATCO's perception of the operational context. A lack of situation awareness can cause the controller to miss important events, make erroneous decisions and be unable to correctly anticipate on events.

3 Study description

3.1 Approach

This research study focuses on the perceived working experience of ATCOs in two different controller working positions. One working position represents the regular controller working position with a primary control screen (i.e. radar) supported by one auxiliary display. The other working position displays radar and auxiliary information on one large screen display. The study assesses the influence of screen size on the user. All other factors, including human machine interface, are kept constant or as similar as possible. The experimental set-up, including scenarios, is validated by an experienced ATCO up front.

3.2 Experimental design

The ATCOs operate both working positions. Two groups are formed to ensure that the order in which the ATCO performs both experimental runs is not of influence on the study results. The inclusion for either group is randomized.

Group 1: ATCOs -> multiple display arrangement -> single display arrangement

Group 2: ATCOs -> single display arrangement -> multiple display arrangement

3.3 Participating ATCOs

A total of six male ATCOs participated in the experiment. Of the six ATCOs three are in active service, two perform active service with functional age activities, and one has recently retired. The average age is 46.5, with the youngest ATCO being 28 and the oldest 69. The work experience varies between 2.5 years and 36 years and is on average 19.4 years.

3.4 Simulated operational ATCO setting

The experiment was performed in a simulated operational setting using NLR's air traffic control simulator NARSIM radar. NARSIM was operated by ATCOs. More detailed information on NARSIM is provided in Appendix A.

The human machine interface on the single display arrangement is designed and integrated based on the standard interface used for the 2K x 2K set up with one auxiliary display. The large screen display is built into the NARSIM set-up. Therefore, both controller working positions were set-up identically (e.g. concerning temperature and lighting); except for the different research conditions on the used displays. Participating ATCOs were informed to adjust their chair position

and settings to their own preferences. They were allowed to change position during the experiment.

3.4.1 Experimental controller working positions / display arrangements

Regular controller working position with a primary control screen supported by one auxiliary display

A 2K x 2K EG Electronic FD2K-2824 display with one auxiliary display (24 inch, Dell Ultrasharp U2412M, 1920 x 1200) was used. The 2K x 2K display gives 103 dots per inch (dpi), which makes the angular aperture approximately 0.2466 mm.



Figure 3-1 Multiple display arrangement

Large screen display with both radar and auxiliary information integrated into one screen

A large screen display (40 inch Phillips BDM4065UC 3840 x 2160) was used. This screen provides 111 dpi. By placing the screen 6 cm closer to the operator, the angular aperture is comparable to the 2K x 2K display (0.2288 mm).



Figure 3-2 Single display arrangement

3.4.2 Experimental traffic scenarios

Two scenarios were required within the experiment; one for the run on the regular controller working position and one on the large screen display. The scenarios were randomized between display arrangements to minimize the possible effects of scenario sequence. The used scenarios each have a duration of 30 minutes with increasing traffic levels; i.e. starting with low density traffic, working towards medium density of traffic (approach). Radio/Telephony (R/T) was performed with actors representing the pilots in the area under control.

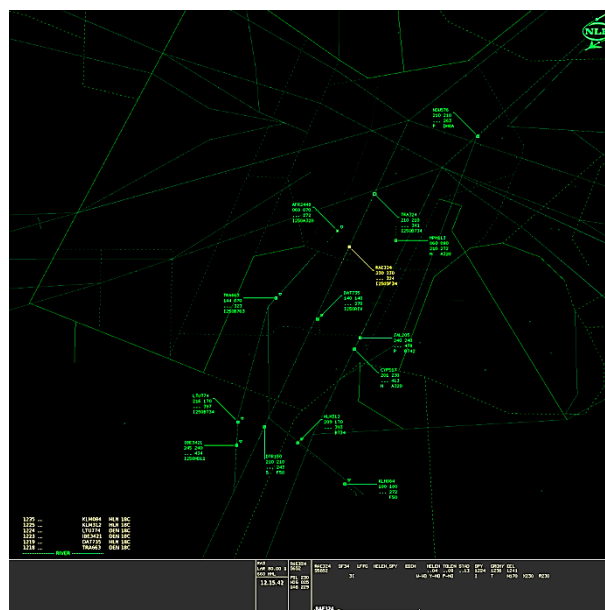


Figure 3-3 Primary ATC task

3.4.3 Secondary tasks

To be able to compare the two controller working positions it was necessary to control the use of the auxiliary display as the scenarios unfold. Therefore, secondary tasks (displayed and performed on the auxiliary display) for the ATCO were included in the scenarios. Three different tasks have been selected from the ATCPrep suite for their unique qualities and their relation to the ATC task. This suite is used for preparing for the Federal Aviation Administration (FAA) Air Traffic Selection and Training (AT-SAT) screening for Air Traffic Controllers in the USA. The selected tasks were (see Appendix B for a more detailed description of the secondary tasks):

3. ATC test. Compared with the two other tests, this test resembles the controller's task best. It is a simplified ATC task including aircraft leaving the airspace and aircraft that desire to land on one of the two landing strips (see Figure 3-6).

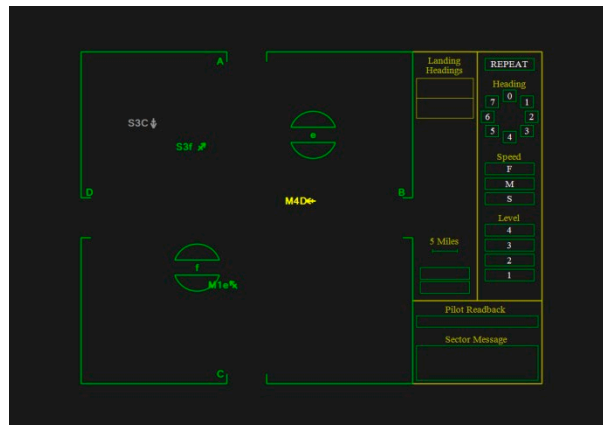


Figure 3-6 ATC test

Before starting the experiment, the ATCOs practiced each task 2.5 minutes. This was considered sufficient to learn how to perform the secondary tasks.

3.5 Measurement of perceived working experience

A set of operator performance measures was used during the experiment to gather information on the ATCO working experience for the different working positions. These measures included objective, subjective and performance measures. See Appendix C for the questionnaires and rating scales that were used.

Eye movements

Eye fatigue was objectively measured with the Dikablis Essential eye-tracker manufactured by Ergoneers GmbH. This eye tracker is a monocular eye-tracker with a scene camera that films 768 x 576 pixels and an eye camera that films 384 x 288 pixels and has a refreshment rate of 50Hz.



Figure 3-7 Dikablis essential eye-tracker

People with fatigued eyes blink longer than people with non-fatigued eyes (Homqvist, Nyström, Andersson, Dewhurst, Jarodzka, & Van de Weijer, 2011). Therefore, the percentage of time during which the eyes were closed was measured. Also, the horizontal and vertical eye movement distance was measured. Furthermore, the percentage of time that the participant looked at the primary and at the secondary screen was measured. Finally, the transitions between screens were measured.

Eye fatigue was also subjectively measured with the eye fatigue questionnaire. The participants filled out these questions every ten minutes, after finishing a secondary task (6 times in total).

Situation awareness

The Situation Awareness for SHape (SASHA) questionnaire was used to subjectively measure the ATCOs' situation awareness (Jeannot, Kelly, & Thompson, 2003). It was presented after each secondary task (6 times in total).

Workload

Two subjective tests were used to measure workload, the Instantaneous Self-Assessment (ISA) rating scale (Tattersall & Foord, 1996) and (part of) the NASA Task Load Index (TLX) (Hart & Staveland, 1988). The ISA was presented on a side panel (touch screen) every two minutes during task execution. This scale required participants to indicate their workload at the moment of presentation on a 5-point scale. The TLX was presented after each secondary task (6 times in total).

Comfort of use

Several subjective tests were presented that focussed on the comfort of use for each display. The Controller Acceptance Rating Scale (CARS) was used to measure how suitable the display

arrangement is for executing ATC tasks in a safe manner. Participants were requested to select a rating after each secondary task (6 times in total).

The participants were asked to fill out the USE questionnaire and several open-ended questions after finishing with a display arrangement (2 times in total). The USE questionnaire was used to measure usefulness, ease of use and satisfaction (Lund, 2001). All participants were also asked about their impression of the display arrangement regarding comfort of use after using each display arrangement (2 times in total). At the end of the experiment, the participants were requested to answer the following open questions:

- What are the advantages and disadvantages of each display arrangement?
- What are possible improvements on each display arrangement?

Finally, body movements and trackball movements were used as an objective indication for comfort of use of the participants. An observer registered movement of head, upper body and full-body every two minutes. Furthermore, the amount of metres that were travelled with the trackball was calculated.

3.6 Experimental protocol

The experiment started with an introduction followed by the first display arrangement. For half the participants (3 persons) this was the single screen display arrangement and for the other half (3 persons) the multiple screen display arrangement. After performing the experiment on the first arrangement, the participants switched to the other display arrangement. Figure 3-8 visually displays the experimental set-up.

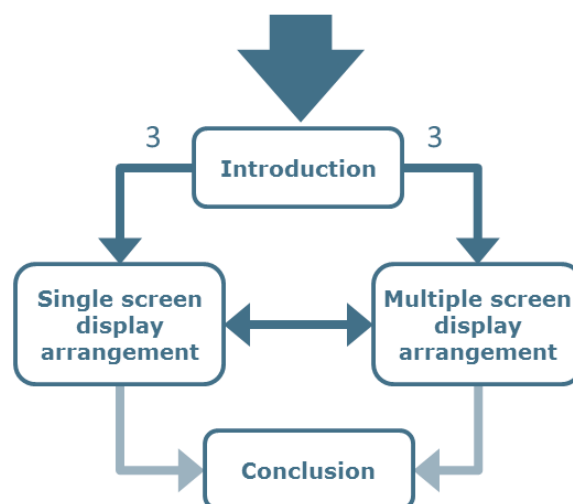
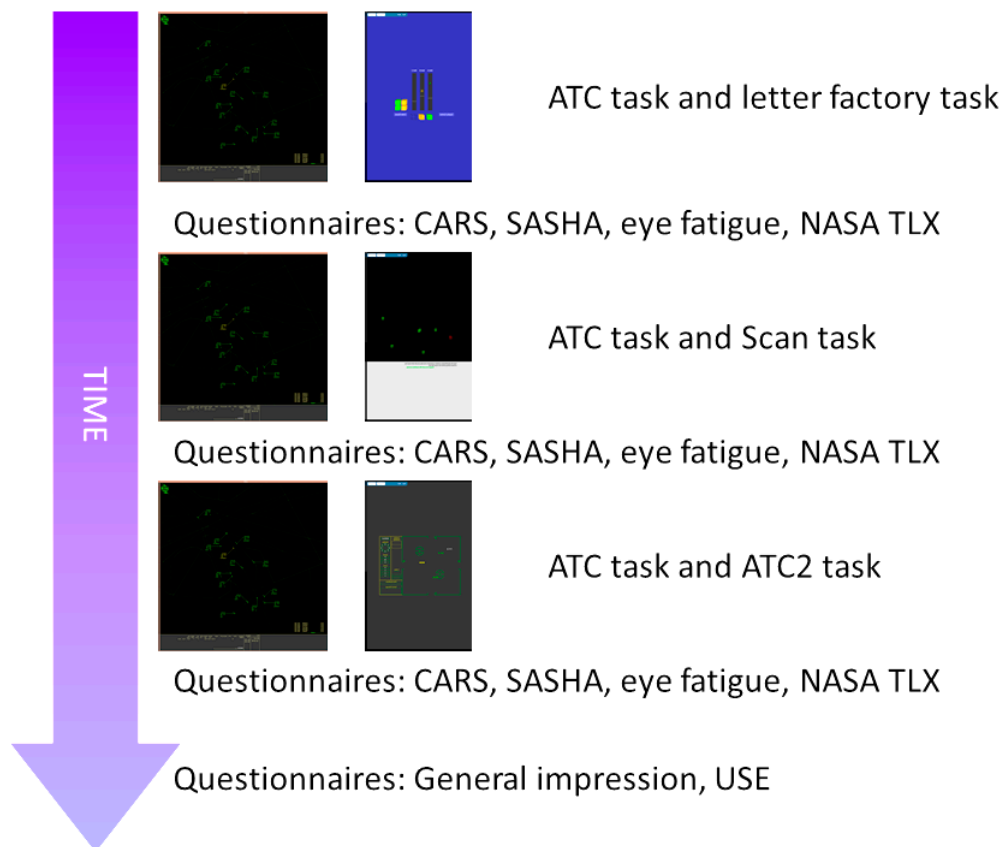


Figure 3-8 Experimental set-up

The introduction consisted of:

- Briefing
- Informed consent
- General questionnaire
- Familiarisation
- Calibrating equipment

For each display arrangement, the following tasks and questionnaires were presented:



The ISA was presented every two minutes during the presentation of the primary tasks.

The conclusion consisted of:

- Open-end questions
- Debriefing

4 Study results

The results for each task were compared between display arrangements for the following tests:

- Eye movement distance
- Percentage time looking at primary screen
- Percentage time looking at secondary screen
- Number of transitions between primary and secondary screen and other visual spaces
- Eye fatigue questionnaire
- SASHA
- NASA TLX
- ISA
- USE questionnaire
- CARS

For example, the results of the NASA TLX after performing the primary task together with the letter factory test on the single display arrangement were compared with the NASA TLX results after performing the primary task and the letter factory test on the multiple display arrangement.

Paired samples t-tests were used to determine if differences between findings were significant. The figures presented below include error bars, which show the mean variability of the answers (e.g. when the mean of the variable is 3 and the mean difference from the answer is .5; the lower end of the error bar is 2.5 and the high end of the error bar 3.5. When the error bars of two means overlap, there is no significant difference).

4.1 Eye movements

The eye movement distance did not differ between display arrangements. However, the participants did look significantly more to their primary screen in the single display arrangement than in the multiple display arrangement when performing the ATC2 task next to the primary ATC task ($t(4) = -2.996, p < .05$, see Figure 4-1).

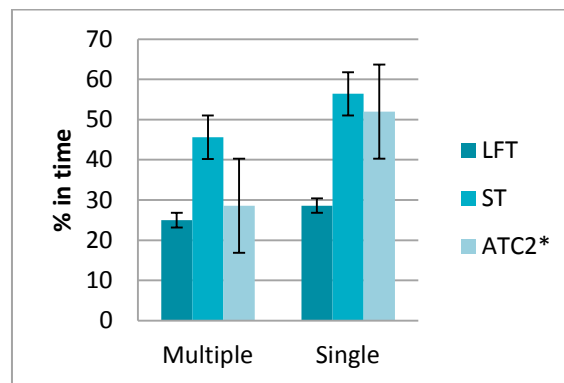


Figure 4-1 Primary screen viewing

* Significant difference $\alpha = .05$

A difference was also found between the arrangements for the number of transitions between the primary and secondary screen and other visual areas for the ATC2 task ($t(4) = 3.411, p < .05$). Participants made less transitions between the primary and secondary screens in the single display arrangement than in the multiple display arrangement during ATC2. These differences were not found for the letter factory task and the scan test.

The subjective test for measuring eye fatigue, the eye fatigue questionnaire, did not yield significant differences between the two display arrangements. The eye closure was consistent with this: it did not differ significantly between display arrangements.

4.2 Situation awareness

The situation awareness during the presentation of the letter factory task and the ATC2 task did not differ significantly between the two display arrangements. However, the situation awareness during the scan test was significantly higher when using the multiple display arrangement than when using the single display ($t(5) = 2.907, p < .05$, see Figure 4-2).

The average deviation from the mean was larger for the ATC2 task compared with the deviation from the mean in the scan test. Therefore, even though figure 4-2 appears to show a higher SASHA rating on the ATC2 task, this difference could be based on randomness. Also, the smaller deviation on the scan test enables a significant difference even though the difference itself is small.

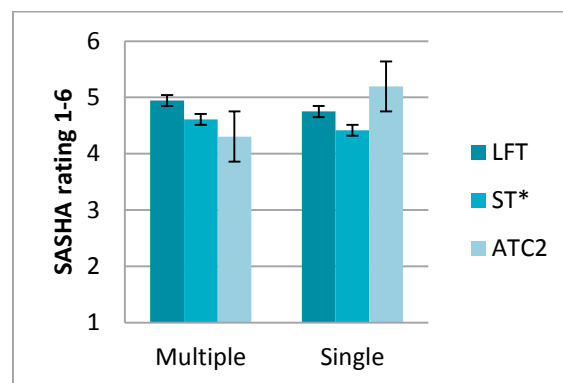


Figure 4-2 Situation Awareness

* Significant difference $\alpha = .05$

4.3 Workload

The ISA and NASA TLX results did not yield significant differences between the display arrangements. However, the ISA results did indicate a trend towards a lower workload in the multiple display arrangement with the ATC2 test ($t(5) = 2.224, p = .077$).

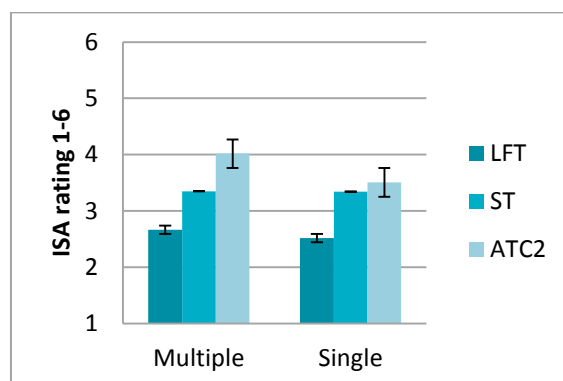


Figure 4-3 ISA ratings

4.4 Comfort of use

Regarding the constructs measured by the comfort of use questionnaire, usefulness, ease of use and satisfaction (based on results of USE questionnaire, no significant differences were found between the two display arrangements. Also, no significant differences were found on the CARS questionnaire.

When asked about the different display arrangements, one ATCO indicated that he preferred the single display arrangement. This was however not clearly motivated by the ATCO. Four ATCOs responded that they prefer to use two screens. The motivation of three of them was that you can change the position of the screens to optimize the angle of view. The other ATCO preferred two

screens because the distinction between the two tasks is clearer, e.g. one task on screen A and one task on screen B. One ATCO did not respond to this question.

When asked about the advantages and the disadvantages, the respondents answered as follows:

Advantages single screen	Advantages multiple screens
<ul style="list-style-type: none"> • The single display arrangement presented all information on one surface • The single display arrangement required less focussing of the eyes when changing screens, this took up less time than switching between screens • The single display had a larger surface which made it possible to present more information 	<ul style="list-style-type: none"> • The multiple display arrangement made it possible to vary the angle of view • The tasks were presented in the centre of the screens in the multiple display arrangement, which made it easier to overview the situation on the screens • The multiple display arrangement made it easier to identify which screen was active and received mouse or keyboard input • The user did not have to physically move towards the second screen in the multiple display arrangement • The tasks were visually separated in the multiple display arrangement which created a feeling of peace and quiet

The participants did not move much in either situation. Furthermore, no significant differences were found between the distance travelled with the trackball.

4.5 Effects over time

An analysis on possible learning effects was performed on the following variables:

- Eye fatigue
- SASHA
- NASA TLX
- ISA
- CARS
- USE
- Trackball movements
- Secondary task performance:
 - Letter factory task

- Scan test
- ATC test

A paired samples t-test was performed to compare the first time a questionnaire was presented and the second time it was presented in an experimental situation irrespective of the display setting that was used.

A significant effect was found in the NASA TLX when performing the primary task in concordance with the letter factory task, $t(5) = 2.831$, $p < .05$, indicating a lower workload when performing the task for the second time. This difference is also found on the ISA index for performing the primary task with the letter factory task, $t(5) = 3.486$, $p < .05$.

Furthermore, significant effects were found on the USE index. Participants gave a higher rating on usefulness in the second setting irrespective of what the second setting was ($t(5) = -2.948$, $p < .05$). Participants also indicated more satisfaction in the second setting ($t(5) = -2.693$, $p < .05$).

5 Discussion and conclusions

The current research study for Esterline Control & Communication Systems studied the effects of display size on working experience in the controller working position. The assessment included the following operator performance aspects: workload, (eye) fatigue, situation awareness, usability, and task performance. Data was gathered objectively (e.g. eye-tracking) and subjectively (e.g. rating scales and questionnaires). Several measures were used to allow different results to provide a coherent impression of the situation (Van Dijk, Van de Merwe, & Zon, 2012).

The study results show that the perceived ATCO working experience in a multiple display arrangement is preferred over the experience in a single display arrangement. Although this study was performed with a relatively small sample size of six ATCOs, significant differences were found between display arrangements. The results for situation awareness show that the situation awareness was higher in the multiple display arrangement than in the single display arrangement. The workload findings show a trend that the workload is lower in the multiple display arrangement than in the single display arrangement. Both findings support the ATCO preference for the multiple display arrangement.

The lower perceived workload in the multiple display arrangement might indicate that the ATCO has more time to spend on the secondary task. This is evidenced by the results. ATCOs look more at the primary screen in the single display arrangement than in the multiple display arrangement (during the ATC2 task). Also, there are more transitions between primary, secondary and other visual spaces in the multiple display arrangement than in the single display arrangement; this again resulted in higher situation awareness in the multiple display arrangement.

People, ATCOs in particular, are conservative regarding changing working environments (MacKay, 1999). It could be the case that this is why ATCOs prefer the multiple displays in the current research; i.e. the current ATCO working position is in line with the multiple display arrangement. All of the participants were experienced ATCOs. Three of them were close to retirement (or had already retired) while the other half were young ATCOs. Older people are expected to be somewhat more conservative compared to younger people who might have a different view on “how things are done”. However, this difference was not found within the current study; i.e. no differences between the older and younger group of ATCOs were detected. It is however interesting to further investigate if multiple displays are still preferred when ATCOs have worked

with a single display arrangement for a longer period of time (giving them more time to adjust to the changes in their working environment).

Interesting to mention is that differences were found between display arrangement per secondary tasks, and not for the complete primary task (i.e. with all secondary tasks). This may be caused by the nature of the primary task (low traffic at the beginning of the task and high traffic density at the end) and the nature of the secondary tasks. The ATCOs remarked during the experiment that the ATC2 task was the hardest, followed by the letter factory task, and then the scan task. However, the letter factory task was presented during the low traffic density period in the primary task. Therefore, it is conceivable that no results were found here because the participant did not have much to do. This also seems to fit with the finding that the workload on the letter factory task was perceived lower on the second time, independent of display arrangement. Thus, the ATCOs may have had time to better learn how to perform the letter factory task, making it easier to perform it the second time. It would have been preferable to randomize the sequence of the different secondary tasks, or to randomly change the traffic density in the primary task, however given the explorative nature of this study this was not feasible.

Further research may also shed light on the differences that we have found on the USE questionnaire over time (independent on display arrangement). It would be interesting to look further into why these differences were found and how we can counter them in the future. It would also be interesting to see if different angles of the secondary screen would result in different findings. Are larger or smaller angles preferred? What is better, a sharp angle or a curved display?

In conclusion, the current research showed that perceived ATCO working experience in a multiple display arrangement is preferred over a single display arrangement.

6 References

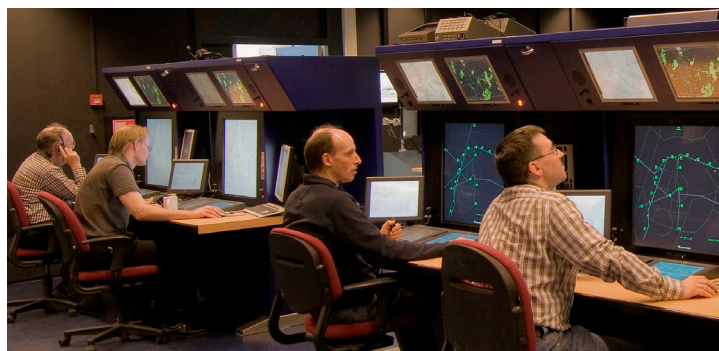
- Endsley, M. (1988). Design and evaluation for situation awareness enhancement. *Proceedings of the Human Factors Society 32nd Annual Meeting* (pp. 97-101). Santa Monica, CA, US: Human Factors Society.
- Hart, S., & Staveland, L. (1988). Development of NASA-TLX (Task Load Index): Results of empirical and theoretical research. *Advances in Psychology*, 52, 139-183.
- Homqvist, K., Nyström, M., Andersson, R., Dewhurst, R., Jarodzka, H., & Van de Weijer, J. (2011). *Eye tracking: A comprehensive guide to methods and measures*. New York, USA: Oxford University Press.
- Jeannot, E., Kelly, C., & Thompson, D. (2003). *The development of situation awareness measures in ATM systems*. Brussels: Eurocontrol.
- Langan-Fox, J., Sankey, M., & Canty, J. (2009). Human factors measurement for future air traffic control systems. *Human Factors*, 51(5), 595-637.
- Lund, A. (2001). Measuring usability with the USE questionnaire. *Usability Interface*, 8(2), 3-6.
- MacKay, W. (1999). Is paper safer? The role of paper flight strips in air traffic control. *ACM Transactions on Human Computer Interaction*, 6(4), 311-340.
- Tattersall, A., & Foord, P. (1996). An experimental evaluation of instantaneous self-assessment as a measure of workload. *Ergonomics*, 39(5), 740-748.
- Van Dijk, H., Van de Merwe, K., & Zon, G. (2012). A coherent impression of the pilot's situation awareness. *International Journal of Aviation Psychology*, 21(4), 343-356.
- Van Hienen, C., & Zon, G. (2009). *Workload in an ATC simulation measured by: subjective rating, oscillatory activity, P3a, blink rate frequency and the relationship between these measures*. Amsterdam, the Netherlands: National Aerospace Laboratory.

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Appendix A NARSIM

NLR has developed a real-time air traffic control research simulator (called NARSIM radar) to enable research and development in the field of ATM. With NARSIM the ATC process can be simulated with the ATCO and the pilot-in-the-loop. NARSIM allows for easy configuration and integration of third party systems whilst maintaining scalability and performance. All software is developed fully in-house with a focus on modularity and configuration, resulting in a platform which can be used to simulate various current and, more importantly, future ATC concepts and working positions.

In the development process of ATM systems, concepts and procedures, real-time simulations are a prerequisite for the assessment of ATCO workload and acceptance. In the validation of operational components, NARSIM serves as a simulation environment for an operational (sub)system or can be used to perform shadow mode trials. In all these cases, the NARSIM facility has proven to be a flexible, scalable and modular ATC simulator.



Impression of NLR's traffic control simulator NARSIM

Controller working positions

The NARSIM radar facility currently features eight generic ATCO working positions each equipped with one 28 inch TFT display with 2K x 2K resolution and up to seven different size auxiliary panels, optionally equipped with touch sensitive layers. The number of working positions can be configured and scaled up on demand. Depending on the experiment, each working position can be equipped with touch input devices, trackballs or mouse and a keyboard. Each working position can act as a tactical, planner or feeder position for controlling en-route, area or approach (terminal area) traffic. An integrated R/T system allows the controller to contact pilots, other controllers or neighbouring sectors or centres. Automated questionnaires for expert opinion feedback, run-time ISA, eye point of gaze (eye and head-tracking equipment) and other

Air Traffic Controller working position

physiological parameters to measure the human factors effects are available at every working position. Together with other system performance indicators they are used to analyse the concepts or tools at hand.

Pseudo pilot working positions

A separate pseudo pilot area with 15 positions is in use at NLR. Each pseudo pilot working position allows the pseudo pilots to control up to 20 aircraft. The pseudo pilot in its working environment is an important factor in the design and execution of the experiment or training. Each working position can be tailored for its specific role or task and the number of positions can be scaled up on demand.

Appendix B Secondary tasks

A more detailed description of the secondary tasks is presented in this Appendix, including the performance measurements that were used and the custom settings that were configured for this study.

Letter Factory Test *Getting started*

Letter Factory Test is an approach to measure two aptitudes closely associated with the air traffic controller profession: Thinking and planning Ahead and Decision Making.

Task

A primary task complemented by three concurrent subtasks constitutes Letter Factory Test. You are presented with a factory assembly line environment on your screen. The factory produces the letters, A, B, C and D in different colours. The primary task is to pick up letters from the conveyor belts of the assembly line and place them into boxes of the corresponding colour (e.g. orange letters into orange boxes, purple letters into purple boxes). Each box can accommodate four letters and has to be loaded with one A, one B, one C, and one D.

Along with primary task you have to handle three subtasks:

1. Box management: you have to make sure enough and appropriate boxes are prepared for loading.
2. Loading boxes: letters being processed on the conveyor belts have to be loaded into boxes of a corresponding colour after they passed the availability line but before they arrive at the end of the belt.
3. Quality control: the throughput of our letter factory may contain deficient parts that have to be sorted out manually. Any letter that is not an A, B, C or D – regardless of its colour – is considered a deficient part that must not be loaded into a box.

Operation

1. Box management: to take a box from the depot into the loading area you have to click the box of the respective colour with your mouse. If only one more box of a colour remains available click 'Order Boxes' button to stock up.
2. Loading boxes: to place a letter into a box you have to select it on the conveyor belt with your mouse first, then click on the box you intend to sort the letter into.

3. Quality control: click quality control button anytime you notice a letter that is not an A, B, C or D.

Performance measurements

Performance on the LTF task is measured using the following parameters:

- Letters in correct box
- Letters in wrong box
- Letters already existing in box
- Letters placed too early
- Letters falling off
- Quality control

Custom settings

General

- Duration - 10 minutes
- Feedback: show feedback during test – Disabled
- Mode: Continue section after situational awareness questions

Subtasks

- Box management – Enabled
- Quality control – Enabled
- Loading boxes – Enabled
- Situational Awareness Questions – Disabled

Task set-up

- Conveyor belts: number – 3
- Conveyor belts: speed – Medium
- Speed varies by random – Enabled
- Loading stations – 3
- Letter frequency – Low
- Letters correspond to belt position – Disabled
- Box colors – 2
- Maximum letter count – 4
- Add boxes automatically for letters dropped of belts – Disabled

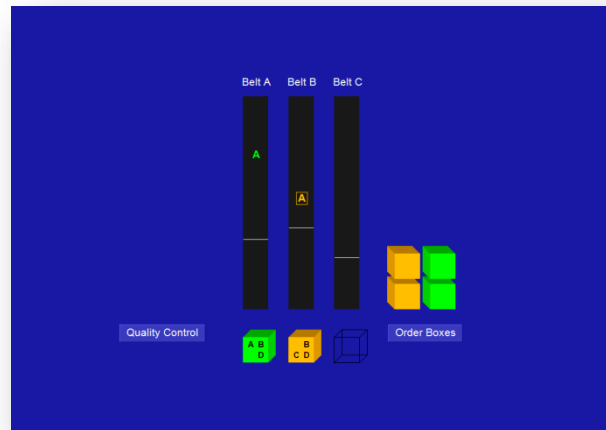
Situational awareness questions

- Frequency – Medium
- Count per section – 4
- Difficulty – Easy

- Deny switching to factory - Disabled

Display options

- Screen update rate – Smooth



Scan Test

Getting started

Scan test is an approach to determine selective perception abilities. You are presented with up to twelve discrete data blocks representing aircraft heading towards different directions on your screen. Data blocks carry an identification code and state current airspeed of the aircraft.

Task

You have to monitor the action on screen and respond to aircraft travelling at a speed beyond a given range of tolerance.

Operation

Data blocks are addressed by the numbers in their identifiers. To respond to an identified data block you have to type in the identifier number and confirm with enter. Be advised a correction can only be made by Del-key but not by backspace.

Performance measurements

Performance on the LTF task is measured using the following parameters:

- Aircraft removed correctly
- Average response time for removing aircraft

Custom settings

General

- Duration – 10 minutes
- Feedback: show feedback during test – Enabled
- Pause test when visible – Disabled

Task types

- Single range: identify numbers beyond the range (default setting) – Disabled
- Single range: identify numbers within the range – Enabled
- Double range: identify numbers beyond both ranges – Disabled
- Double range: identify numbers within both ranges – Disabled

Task set-up

- Show aircraft simultaneously – 10
- Speed of aircraft – Slow
- Speed information of aircraft may change during test – Disabled
- Increment speed information – multiple of 10
- Frequency of changing given speed range – 2
- Change after random time – Disabled

Display options

- Screen update rate – Smooth
- Background – Black
- Range panel: Grey
- Aircraft: Light green



ATC test

Getting started

Air Traffic Scenarios is an ATC radar simulation that updates in slideshow motion roughly every seven seconds. You are assigned control over an airspace sector with the task of managing incoming traffic as safely, swiftly and efficiently as possible. Aircraft are represented by data blocks on the radar screen.

Task

The coordination and separation of traffic is achieved by communication with the aircraft. Instructions to the aircraft regarding speed, heading or altitude are submitted using the computer mouse and the options in the control area.

Operation

Aircraft can be addressed with instructions to change heading, speed or flight level. Instructions are given in two steps:

1. Single out the aircraft you intend to address by mouse click.
2. Submit instruction using the options of the control panel.

Performance measurements

- Performance on the ATC task is measured using the following parameters:
- Exiting airspace destination correct
- Exiting airspace altitude correct
- Landing destination correct
- Landing speed correct
- Landing altitude correct

Custom settings

General

- Duration – 10 minutes
- Feedback: show feedback during test – Disabled

Subtasks

- Route aircraft efficiently to exits or airports – Enabled
- Avert conflicts – Enabled
- Verify pilot readback – Disabled

Task set-up

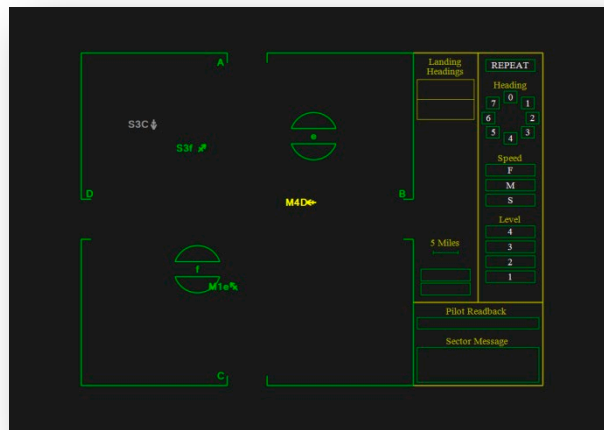
- Average number of aircraft – 3
- Change destination by random – Disabled
- Number of airports – 2

Air Traffic Controller working position

- Random position – Disabled
- Restriction of landing direction – Disabled
- Landing direction may change – Disabled
- Alternative approach from – N/S

Simulation

- Pilot readback acoustical – Disabled
- Pilot readback visual – Enabled
- Speed – Slow
- Screen update rate – Choppy
- Hide affected aircraft – Enabled



Appendix C Questionnaires and rating scales

Various measurement tools have been used to gather information on the on the working experience for both display arrangements. The questionnaires and rating scales are described here.

Eye fatigue questionnaire

How much do you agree with the following statements?	Not at all	Not	Neutral	Agree	Agree fully
My eyes feel fatigued					
I have an uncomfortable feeling in my eyes					
I feel nauseated					
I have trouble focussing my eyes					
I have a headache					

Figure App-C 1 Eye fatigue questionnaire

SASHA

In the previous working period(s)...	Never	Seldom	Sometimes	Often	More often	Always
... I was ahead of traffic						
... I started to focus on a single problem or a specific area of the sector						
... there was a risk of forgetting something important (like transferring an a/c on time or communicating a change to an adjacent sector)						
... I was able to plan and organise my work as I wanted						
... I was surprised by an event I did not expect (like an a/c call)						
... I had to search for an item of information						

Figure App-C 2 SASHA questionnaire

ISA

Rating	Workload	Description
1	Very low	Nothing to do, pretty boring
2	Low	Plenty of time for the tasks. Less than 50% of the time active on ATC tasks.
3	Reasonable	All tasks are under pressure. Busy, but in a stimulating pace. Could continue on this level for a long time
4	High	Non-essential tasks receive less attention. Cannot work at this level for a long time
5	Very high	Falling behind on tasks, losing oversight.

Figure App-C 3 ISA rating scale

NASA TLX

Mental demand How mentally demanding was the task?

Very low Very high

Physical demand How physically demanding was the task?

Very low Very high

Temporal demand How hurried or rushed was the pace of the task?

Very low Very high

Performance How successful were you in accomplishing what you were asked to do?

Very low Very high

Effort How hard did you have to work to accomplish your level of performance?

Very low Very high

Frustration How insecure, discouraged, irritated, stressed, and annoyed were you?

Very low Very high

Figure App-C 4 NASA TLX

USE

How much do you agree with the following statements?

	Not at all	Not	Neutral	Agree	Agree fully
The display arrangement helps me be more effective					
The display arrangement helps me be more productive					
The display arrangement is useful					
The display arrangement gives me more control over the activities in my work					
The display arrangement makes the things I want to accomplish easier to get done					
The display arrangement saves me time when I use it					
The display arrangement does everything I would expect it to do					
The display arrangement is easy to use					
The display arrangement is user friendly					
The display arrangement requires the fewest steps possible to accomplish what I want to do with it					
I am satisfied with the display arrangement					
I would recommend the display arrangement to a friend					
The display arrangement is fun to use					
The display arrangement works the way I want it to work					
The display arrangement is wonderful					
I feel I need to have the display arrangement					
The display arrangement is pleasant to use					

Figure App-C 5 USE

CARS

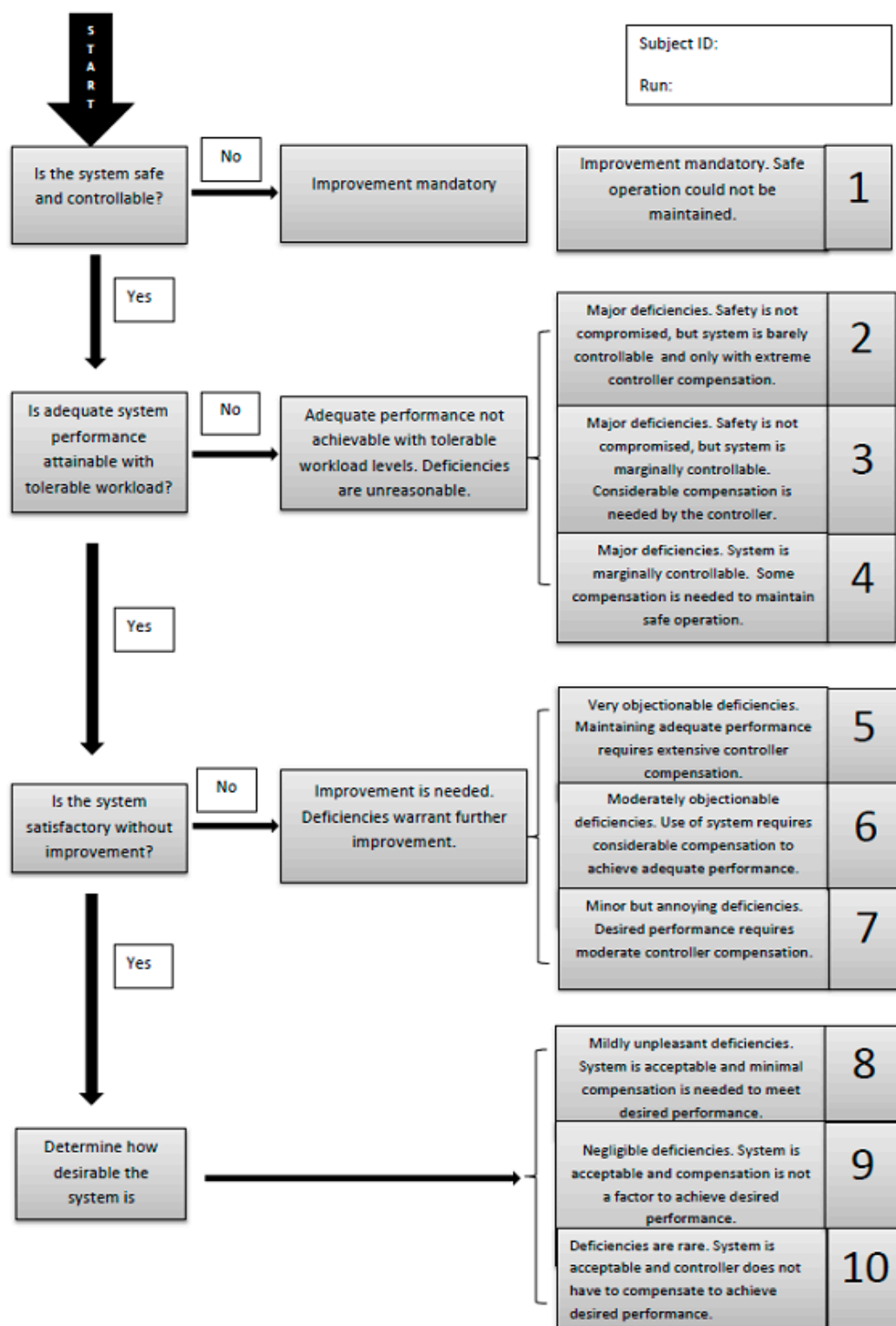


Figure App-C 6 CARS

WHAT IS NLR?

The NLR is a Dutch organisation that identifies, develops and applies high-tech knowledge in the aerospace sector. The NLR's activities are socially relevant, market-orientated, and conducted not-for-profit. In this, the NLR serves to bolster the government's innovative capabilities, while also promoting the innovative and competitive capacities of its partner companies.

The NLR, renowned for its leading expertise, professional approach and independent consultancy, is staffed by client-orientated personnel who are not only highly skilled and educated, but also continuously strive to develop and improve their competencies. The NLR moreover possesses an impressive array of high quality research facilities.



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