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TREN/ 07 / FP6/ S07. 73580 / 037179

ART

Advanced Remote Towers

STReP

Research area 4 “Increasing the operational capacity and safety of the air transport system”, 4.g Innovative Air Traffic Management Research.

Final activity report

Period covered:
2007-11-01 to 2010-02-28

Date of preparation:
2010-04-09

Start date of project:
2007-11-01

Duration:
28 months

Project coordinator name:
Mr Mats Sundberg

Project coordinator organisation name:
Saab AB

Revision:
01.00

Table of contents

1 Scope

1.1 Identification

This document is the final activity report of the ART project

1.2 Purpose

The purpose of this report is to:

- Provide a summary description of project objectives and contractors involved
- Describe the execution of the project including work performed, result, conclusions and "lessons learnt" in relation to the objectives.
- Describe the dissemination and use

1.3 Document overview

This document is the Final Activity Report for the ART project, according to contract no TREN/ 07 / FP6/ S07. 73580 / 037179 in the six framework programme between European Community represented by the Commission of the European Communities and the Project Consortium represented by Saab Security Systems AB.

1.4 Revision history

Issue index	Issue date	Author(s)	Revision description
01.00	2010-04-09	Saab, LFV and NLR	Final issue

2 Project Execution

2.1 Overview

2.1.1 Objectives

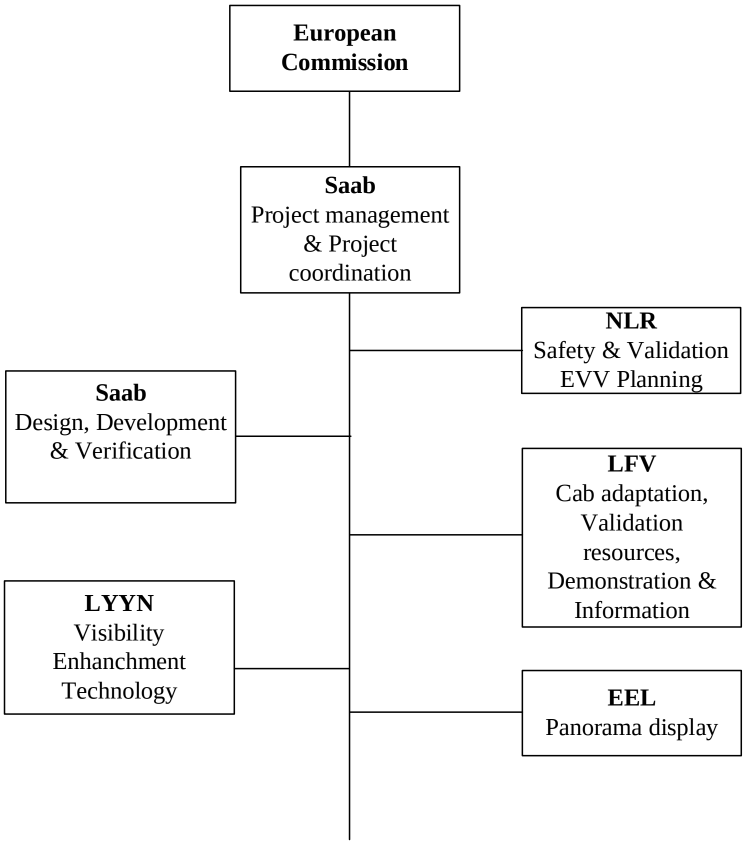
ATC at airports has undergone no major change to its basic concept since the early days of air traffic control. The concept of placing the controller at the airport in a high building looking out of the windows to get an overview of the area of responsibility has remained unchanged. Saab has developed a proof of concept platform for remote operations of a tower (the ROT project), were the controller controls the tower at the airport from a RTC. The purpose of ART is to develop, implement and validate a set of new features provided to the controller in this new operational environment.

The ART objectives are to:

- Remotely operate an airport ATC unit
- Combine remote operation with enhanced visibility and composite presentation of view and operational data
- Evaluate operational pros and cons of the remote airport concept

2.1.2 Contractors involved

In the ART project, five participants are involved. The following diagrams describes the project organisation



2.1.3 Coordinator contact details

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2.1.4 Others

A web site has been created (www.adv.remote-tower.net) where information about produced and ongoing work is presented.

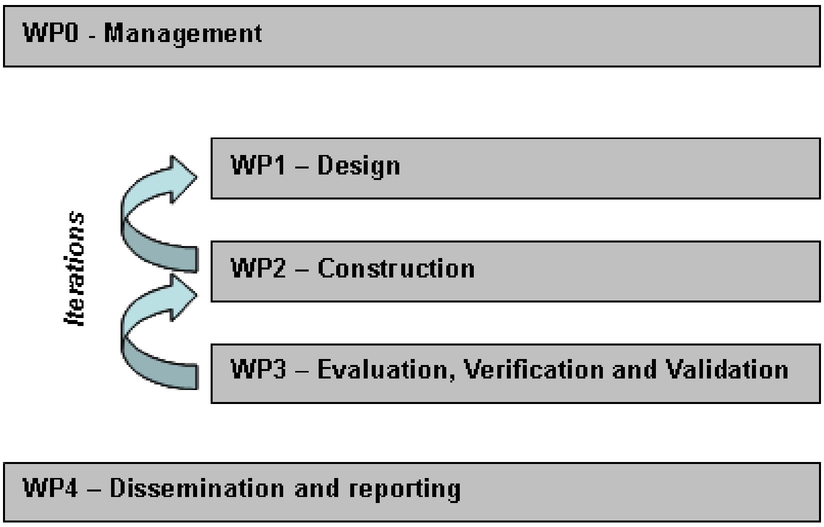
A project logo has been created with the following style:

2.2 Work performed

The ART proposal will study the concept of remotely operated ATC units and supporting technologies in order to enhance regularity during low visibility operations and to substantially decrease the ATC related costs at airports.

The purpose is to explore the concept of remotely operated towers and to test and validate additional sensors that will enhance the air traffic controllers' situational awareness at reduced visibility conditions due to weather and darkness. Promising new technologies, as well as technologies of today, applied and presented in an innovative and more efficient manner, will be explored. The enhanced situational awareness is one of the main prerequisites for enhanced regularity at the aerodrome, which has proven to be one of the bottlenecks in today's ATM system.

The ART project is divided into a number of work packages. The relationship between the main work packages is described in the picture below.

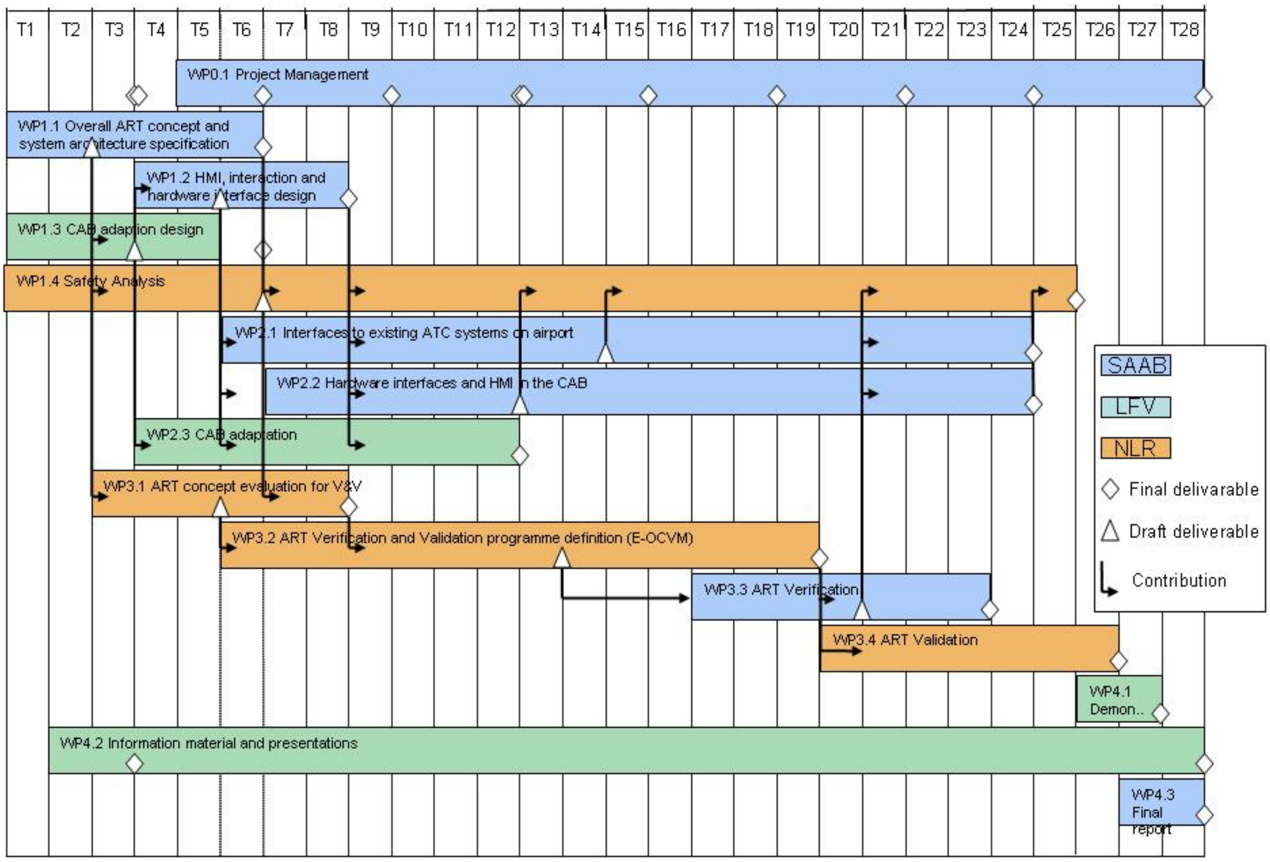


Since the nature of the ART project is focused on research, there has been an iterative process between the work packages WP1, WP2 and WP3.

The project has been divided into the following sub-work packages:

WP No	Title
WP0 – Management	
0.1	Project management
WP1 – Design	
1.1	Overall ART concept and system architecture specification
1.2	HMI, interaction and hardware interface design
1.3	Cab adaptation design
1.4	Overall ART concept and system architecture specification
WP2 – Construction	
2.1	Interfaces to existing ATC systems on airport
2.2	Hardware interfaces and HMI in the cab
2.3	Cab adaptation
WP3 – Evaluation, Verification and Validation	
3.1	ART concept evaluation for V&V
3.2	ART Verification and Validation programme definition (E-OCVM)
3.3	ART Verification
3.4	ART Validation
WP4 – Dissemination and reporting	
4.1	Demonstration
4.2	Information material and presentations
4.3	Final report

The time table of the ART project:



2.2.1 WP 0.1 Project management

2.2.1.1 Objectives

Manage the ART project

2.2.1.2 Work performed

The following has been performed in project management:

- Produced a project management plan.
- Co-ordination between partners in the consortium and between the consortium and the European Commission.
- Risk management
- Organize progress meetings and progress reporting

2.2.2 WP 1.1 Overall ART concept and system architecture specification

2.2.2.1 Objectives

Establish a concept and system architecture suitable for the ART concept through iterative design.

2.2.2.2 Work performed

During startup of this WP, three technical meetings were performed at Malmö Sturup with representatives from Saab, LFV, NLR and LYYN.

The purpose of these meetings was especially to form the fundamental basis for the operational concepts within the first draft of “the operational concept and overall architecture”.

The tower ATC tasks was analyzed and worked out by Saab and LFV; preference is for a top-down approach. A first draft of the document D1.1.1 was available in the end of January 2008.

After the first draft the work continued:

- Visibility conditions were defined by LFV conforming ICAO definitions.
- Refine the operational concepts and clarify and more clearly address the SESAR KPAs within the second draft of “the operational concept and overall architecture”.

The second draft of the document D1.1.1 was reviewed and released in May 2008.

A technical and operational meeting was performed in Växjö the 27th of March 2008, with participants from LFV and Saab. The purpose with the meeting was to identify details to be clarified before the D1.1.1 could be released

The final release of the document D1.1.1 was reviewed and released in May 2008.

2.2.3 WP 1.2 HMI, interaction and hardware interface design

2.2.3.1 Objectives

The interface design will be based on a human centred philosophy to provide evaluation of 360 degree outside-the-window-view projection with the possibility to validate new features such as superimposing camera data streams over sensor data and fusing it with synthetic ATC data. The interface design will also support a standard definition of communication with the remote airport ATC functions.

2.2.3.2 Work performed

The production of the document D1.2.1 Interface and Design document was started in February of 2008, with input from the results from WP1.1 and WP1.3.

Technical Meeting, representatives from LYYN and Saab participated at a Technical Meeting the 10th of March 2008, in Lund, to introduce LYYN to the present ROT camera implementation and to discuss interface related issues for the Visual Enhancement Technology.

In cooperation with LFV 10 main functions was defined:

1. 360 degree circular panorama display
2. Visual enhancement technology
3. Presentation of airport and geographical information
4. Presentation of weather information
5. Sensor data fusion
6. Presentation of aircrafts and vehicles
7. Pan-tilt-zoom camera
8. Record and replay
9. Status monitoring and presentation
10. Airport transfer

The document was reviewed in June by Saab, LFV and NLR and the release of the document was in the end of July 2008.

2.2.4 WP 1.3 Cab adaptation design

2.2.4.1 Objectives

Establish and plan what parts of the existing remote tower cab that will have to be adapted in order to transfer it to an ART cab.

2.2.4.2 Work performed

The work in this WP started at the beginning of the project, in November 2007. The start-up and progress including design work of the visualization as well as the Air Traffic Controllers (ATCO) working position (work-station).

Several working meetings were held of how to optimize the placement of equipment in the operator position. Projector tests were also performed.

A potential large screen video projector was on test from the project partner EEL. The testing has covered the overall operational and technical performances, as well as different solutions for physical applications and how installations into the Remote Tower Center facility room should be designed.

The first drafts of drawings were redesigned after input from other participants. A prototype of the operator position was constructed.

A preliminary report of suggested solutions and requirements was produced and reviewed in the project.

A meeting was performed in Littlehampton UK and the purpose with the meeting was to discuss the implementation of the ART 360 degree circular presentation system. After the meeting there were detailed discussions on the realisation.

The work resulted in the D1.3.1 official version 01.00 of the cab adaptation plan in April 2008.

A Critical Design Review meeting of the ART 360 panorama display system was fulfilled by Saab, LFV and Equipe in June 2008.

2.2.5 WP 1.4 Preliminary Safety Analysis

2.2.5.1 Objectives

The objective of this PSA task is to identify potentially dangerous spots in the ART operational concept and design (system and procedures).

2.2.5.2 Work performed

This WP started with a safety brainstorm session on January 28th and 29th 2008, Sturup Malmö. ATCO's and technical ART specialists from Saab, LFV and NLR participated. The remote tower operations were discussed from different approaches. The unstructured brainstorm gave attendees opportunity to bring forward any safety critical item for remote operations. The results from the meeting were processed in to the Preliminary Safety Assessment document.

A first draft of the D1.4.1 ART Safety Assessment document was produced in March 2008.

NLR then continued with safety analyses, starting with the Functional Hazard Analysis Report.

Fault trees were worked out and supplied by NLR with data provided by LFV and the first official draft was delivered in June 2008.

In the autumn in 2008 the functional hazard analyzes was completed and the first iteration of the preliminary safety assessment was started.

NLR continued work with the functional hazards and the safety requirements in version 00.04 of the PSA document.

The PSA document was reviewed by LFV and Saab and the review process was ended with a safety meeting at Malmö Airport 28th of November 2008. Representatives from NLR, Saab and LFV were participating discussing the functional hazards and the safety requirements defined by NLR and a number of outstanding and not resolved issues were clarified.

The result from this meeting ended up with another draft, 00.06, and was delivered in the beginning of March 2009.

The main part of the safety analysis was then produced.

In the beginning of 2010, results from the verification and validation were added to the document. These changes were reviewed by LFV and Saab and the final version of the D1.4.1 was delivered in February 2010.

2.2.6 WP 2.1 Interfaces to existing ATC systems on airport

2.2.6.1 Objectives

Explore the possibility to remotely control and monitor existing TWR cab interfaces to support the ART concept.

2.2.6.2 Work performed

During September 2008 the HMI for control panel including ILS, airport ground lights, alarms and PTZ camera were harmonized and integrated in the control panel.

The first prototype of the VET system (visual enhancement technology) in analogue mode was delivered from LYYN and was tested at Ängelholm during autumn 2008.

System development in this work package continued during the spring and ended in summer 2009.

VET (visual enhancement):

The base hardware choice, initial development investigations as well as main requirement specifications were finished when the second period started. A number of problems with the prototype hardware board were discovered in the first period. These problems were resolved and all of the requirements were fulfilled during the main development. The software and prototype board were “packaged” in easily mounted box and denoted *Eagle*.

After we finished a beta version of the software, Saab and LYYN performed initial testing of the Eagle unit. During the tests we encountered some connection issues that required modifications of the Eagle unit as well investigations into Saab equipment.

LYYN and SAAB performed more testing and discovered additional connection issues. These issues were resolved by adding external hardware.

After final testing at Saab in Växjö, Saab deployed the Eagle unit at Ängelholm. LYYN did not physically participate in the deployment. The system was connected to one of the cameras. One controller selected the camera that displays the terminal and the apron of the airport. A HMI for controlling the VET system was also implemented by Saab.

LYYN had multiple discussions with SAAB and LFV concerning different use-cases during this phase.

Tracking and sensor data fusion:

The development of the video tracking and the sensor data fusion systems were finalised during the spring 2009. The systems then were improved by fine tuning the sensitivity and the video- and calibration. This was an iterative process during the autumn 2009 by Saab and LFV.

Deliverable D2.1.1:

The consortium decided to merge D2.1.1 (Demonstration Report on Functional Capabilities in the ART Demonstration Platform) and D2.2.1 (Demonstration Report on the Functional Capabilities in regards of Situational Awareness caried out in the ART Demonstration Platform) to one deliverable. This deliverable shows how this system works and what features are implemented. A first draft was presented in January 2010 and was completed in mid-March 2010.

2.2.7 WP 2.2 Hardware interfaces and HMI in the cab

2.2.7.1 Objectives

The construction of the interfaces in the cab is envisaged to provide evaluation of the level of situational awareness and the ability to enhance visibility of targets in reduced visibility conditions in the ART concept.

2.2.7.2 Work performed

The development in this work package started in autumn 2008 with the following result.

- Overlay of airport, geographical and metrological information are implemented.

- Major parts of algorithms and HMI for video tracking and sensor data fusion are implemented.

- Major part of Record & Replay of video and audio (ambient sound) is implemented. This tool has been used also for creating test data for the video tracking function.

System development in this work package continued during the spring and ended in summer 2009.

PTZ:

Functions for calibration, presentation on the 360 panorama screen and automatic tracking of objects in the PTZ camera was completed during April-June months 2009.

Labels:

Finalized the label presentation during the spring 2009. The labels then were improved and adjusted according to the controllers’ requests. This was an iterative process during the autumn 2009 by Saab and LFV.

Record&Reaplay:

A record and replay tool for raw video (from the cameras) was created. This tool was needed to be able to create scenarios for validation of the VET system.

Airport transfer:

The consortium decided just to switch between Ängelholm airport and a recorded scenario (for surrounding video). For the zoom-camera image, another zoom camera system was placed inside the remote tower centre at Malmö Airport. This configuration was created and verified in the beginning of 2010.

2.2.8 WP 2.3 Cab adaptation

2.2.8.1 Objectives

The existing remote tower cab will be adapted to the additional requirements of the ART project.

2.2.8.2 Work performed

A meeting with Equipe Electronics was held at Malmö ATCC on the 10th of July 2008. At the meeting a survey of the RTC room was done, paths for getting equipment into RTC room was checked and also discussions about mounting of the projector gantry was held.

The consortium identified that the RTC needs to be much darker. The ceiling and walls were painted black.

Installation of central beam brackets for connecting the projector gantry and cable ladders was performed in October 2008.

Installation of 360 degree screen and projectors was performed during the last weeks of October 2008.

During the November of 2008 the following were performed:

- The work with a carpet inside the 360 display system was finalized
- Fine tuning of projection system.
- The new operator console was delivered and installed including the CWP and cablings.
- Wall-to wall carpet was put in place.
- The ART CAB adaptation was finalized
- Cab adaptation documentation was delivered for review.

The deliverable D2.3.1 was finalized in April 2009.

2.2.9 WP 3.1 ART concept evaluation for V&V

2.2.9.1 Objectives

The aim of this task is to understand, or, if needed, to rephrase the ART Operational Concept for Verification and Validation purposes.

2.2.9.2 Work performed

The EVV work was started in February 2008. A description of the European Operational Concept Validation Methodology (E-OCVM) was sent to LFV. NLR performed desk research analysing for instance the draft ART Operational Concept and Architecture material available.

NLR contributed to the Remote Tower Operations RapTor workshop organised by DLR on the 8th – 9th of April 2008 in Braunschweig. The ART EVV approach was presented at the meeting.

LFV was started in May 2008 to actively contribute to the planning documentation in these activities.

NLR drafted a first version of the deliverable D3.1.1 ART Problem description and Operational Concept Description. It was discussed with LFV on the 10th of July 2008.

LFV also provided a draft, which is a good start for deliverable D3.2.1 ART Evaluation, Verification and Validation Plan.

Draft deliverable D3.1.1 was sent to partners on June 2008.

The document was then reviewed by LFV and was adjusted and indicates what contribution LFV could give.

The Second draft of ART Problem description and Operational Concept Description was delivered in August 2008.

Technical meetings with representatives from NLR, Saab and LFV were performed at Malmö Airport 26th of November 2008 and 23rd of January 2009.

During this period NLR and LFV continued drafting the Operational Concept and Architecture and ATM Problem Description documentation for ART - WP3, i.e. D3.1.1 - ART Problem description and Operational Concept Description was ready for final review.

The deliverable D3.1.1 was finalized in April 2009.

2.2.10 WP 3.2 ART Verification and Validation programme

2.2.10.1 Objectives

Define the ART Evaluation, Verification and Validation programme (EVV).

2.2.10.2 Work performed

LFV started in summer 2008 to work on a draft document that is well suited as first draft of the deliverable D3.2.1 ART Evaluation, Verification and Validation Plan.

In the beginning of 2009 the work in WP3.2 was intensified. With input from WP3.1, the content for D3.2.1 ART Verification and Validation Plan was defined.

A technical meeting with representatives from NLR, Saab and LFV was performed at Malmö Airport 23rd of March 2009.

The work in WP3.2 was divided into two different phases:

1. Verification definition and planning
2. Validation definition and planning

Phase 1, verification definition and planning:
This phase lasted between February and May 2009. In this phase the ART technical functions needed to be verified were defined, and the requirements of those functions were in detail described. This was performed as an iterative process mainly between NLR and Saab.

The first draft including the verification part was finalized in the middle of May 2009.

Phase 2, validation definition and planning:
This phase lasted between June and September 2009. In this phase the ART operational concept were analyzed with regards to the ART technical functions that was implemented.
The validation process including an experimental plan and human factors aspects was defined in detail. This was performed as an iterative process mainly between NLR and LFV including operational air-traffic controllers.

The second draft including also the validation part was finalized in the end of September 2009.

The deliverable D3.2.1 was the finalized in January 2010.

2.2.11 WP 3.3 ART Verification

2.2.11.1 Objectives

- Prepare the EVV test platform (cab, airport) for evaluation, verification and validation purposes
- Perform initial ART evaluations with controllers
- Perform the ART verification testing including reporting

2.2.11.2 Work performed

During October 2008 the HMI for control panel including ILS, airport ground lights, alarms, alerts and PTZ camera was verified.

The main activities in work package were performed between May and October 2009. Verification plans from WP3.2 was used as inputs in this work package.

The first task in this WP was to define test cases in detail, including prerequisites, environmental dependencies and test criteria. Around 70 test cases were defined for verify all ART functions.

As a part of the preparation of the ART test platform, a workshop with representatives from Saab and LFV was performed in the middle of April 2009. In the meeting one ATC controller from Ängelholm tower was participating. The purpose of the meeting was to discuss the ART functions from a controller's point of view.

Before starting the integration of the ART function in the ROT-platform, a PFHA was produced. The purpose with this document was to prove that the integration of the new ART features in the existing ROT- platform, would not affect the flight safety.

In beginning of June 2009 the final integration activities were started and lasted in late September. This was performed by Saab.

By safety reasons weather-, flightplan- and radardata from the operating systems of the Ängelholm tower was not able to use. Therefore a weather simulator was developed during spring 2009. A parallel system for radar- and flight-plan information (used for feeding the sensor data fusing system) was also established during this time.

The record and replay ART function was configured too be able to record scenarios to be used during the validation.

The last issue was to perform the verification testing, both on-site as well as in a special test environment. The test result was added to D3.3.1 as a test report. The verification part was mainly performed by Saab and NLR participating in a part of the process.

A Snellen character recognition test was performed at Ängelholm tower and in the RTC at Malmö Airport October 21 2009. The purpose of this test was to determine and verify the distance from which one can recognize a letter in the "real" tower in comparison with the remote tower.

The deliverable D3.3.1 was the finalized in January 2010.

2.2.12 WP 3.4 ART Validation

2.2.12.1 Objectives

Execution and reporting of the ART Validation exercise.

2.2.12.2 Work performed

The main activities in work package were performed between October 2009 and March 2010. Validation plans from WP3.2 were used as inputs in this work package.

The first overall planning was started in spring 2009 with recruiting staff, ATC controllers for the planned validation.
LFV and NLR did also in close cooperation start detailed planning of the validation activities.

During October 2009 an operational improvement run questionnaire was created for the validation exercises and was used to record ATCO's observations and feedback. A validation preparation meeting was held at Malmö Airport October 27 2009 with participants from NLR and LFV.

The validation exercises were performed during November and December 2009 with totally 15 controllers involved. Each controller participated during 2 days including both day and night conditions. LFV acted as exercise leader with NLR and Saab as observers.

An expert judgement workshop was performed 10th of December 2010 where the remote tower concept and the ART validation result were discussed with respect to the KPA's defined by SESAR and cost benefits expected with this kind of remote tower solution.

During the last two month of the project, results, analysis from the validation were summarised in the validation report together with conclusions and recommendations.

The deliverable D3.4.1 was the finalized in March 2010.

2.2.13 WP 4.1 Demonstration

2.2.13.1 Objectives

Demonstrate the ART concept to a wide audience.

2.2.13.2 Work performed

A demonstration of the ART system was performed at Malmö Airport 16th of February 2010. Approximately 45 visitors from several European countries participated in this activity. The main focus of the demonstration was to present a live demo of the ART system as well as the validation result.

2.2.14 WP 4.2 Information material and presentations

2.2.14.1 Objectives

The objectives of this WP are to promote the ART project importance to the ATM and airport community and distribute information regarding the findings and the progress of the project to relevant internal and external bodies. This will be done throughout the project and will be specially addressed upon project completion.

2.2.14.2 Work performed

Two stakeholder meetings with DLR in Braunschweig and one stakeholder meeting with DFS in Malmö/Sturup were performed.

ART web site created.

Information materials concerning ART overview and ART features have been produced.

LFV and FAA had a meeting at Malmö Airport, the 13th-14th of November 2008. The purpose for the meeting was to exchange information between the NextGen and the ART projects.

Representatives from ART (LFV and Saab) and DLR participated at a one day workshop at Malmö Airport, the 20th of November 2008. The purpose for the meeting was to exchange information between the RapTor and ART projects.

High-level seminar at March 5 2009: The ROT rollout was the first time the remote arrival and departure clearance was given from the remote tower centre. Approximately 60 visitors from Europe, US and Asia were participating. A demonstration of the ART functions was also performed.

The Remote tower concept including ART functions has been introduced and demonstrated during the ATC Global Exhibition in Amsterdam both 2009 and 2010.

A lot of mini-demonstrations have been performed during the whole project time. Visitors from for instance Norway, Finland, Germany and Australia as well as curious “drop-in” visitors have been interested in the remote tower solution and the ART project.

Two papers (Visual cues and ART validation result) have been submitted for the IFAC2010 conference.

An article for Janes Airport Review in May 2009 and one for a Dutch magazine (Technish Weekblad) in March 2010 have been produced.

2.2.15 WP 4.3 Final report

2.2.15.1 Objectives

Produce a final report.

2.2.15.2 Work performed

This document

2.3 End Result

2.3.1 Design

In the design phase of the project, first operational and architecture requirement were specified and based on these requirements, the following ART functions were defined:

1. 360 degree circular panorama display
2. Visual enhancement technology
3. Presentation of airport and geographical information
4. Presentation of weather information
5. Sensor data fusion
6. Presentation of aircrafts and vehicles
7. Pan-tilt-zoom camera
8. Record and replay
9. Status monitoring and presentation
10. Airport transfer

The “Status monitoring and presentation”-function was given lower priority than the others and was not implemented due to cost reasons.

2.3.2 Construction

2.3.2.1 360 degree circular panorama display

The outside view panorama consist of a seamless, standing cylindrical projector screen with a diameter of six meters, equipped with one data projector per remote camera. The data projector subsystem contains functions for distortion compensation that enables a smooth geometrically correct presentation of the remote camera videos.

Figure 1 ART system operational environment in the remote tower centre

2.3.2.1.1 Panorama basics

The panorama display system includes a circular array of high-resolution video cameras static mounted on top of a pole at the actual airport. The camera video feeds are encoded (compressed) before transmitted to the RTC, where they are decoded (decompressed) for the purpose of display on data projectors.

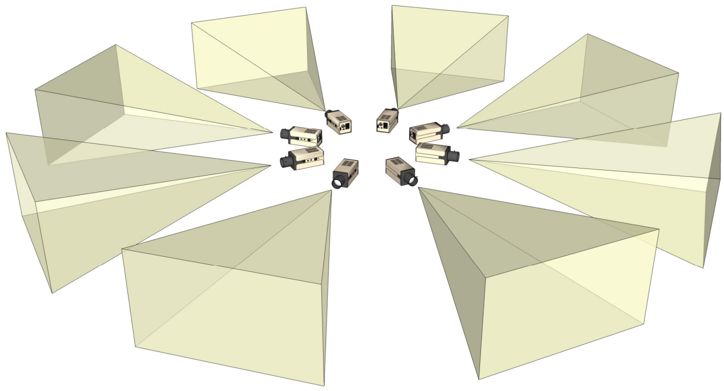


Figure 2 High-res camera array (at the actual airport)

The projector array is mounted hanging from the roof above the controller working position, in the centre of a circular projector screen in RTC (e.g. a standing cylinder screen).

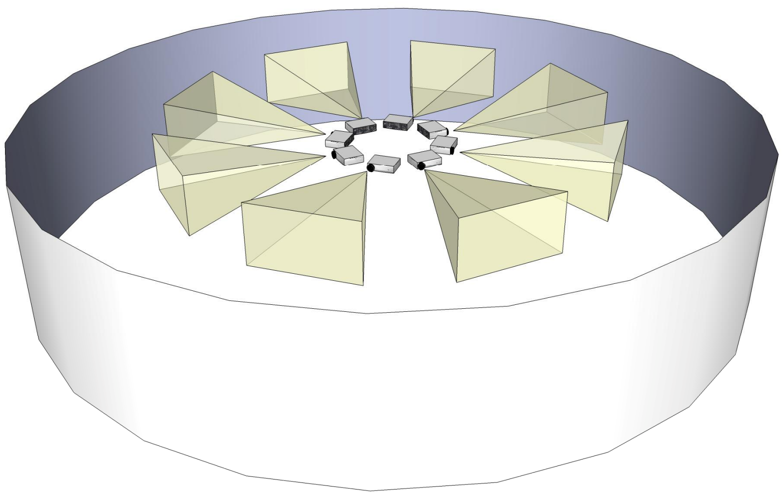


Figure 3 Projector array and circular projector screen (at RTC)

2.3.2.1.2 Promap display conversion

Compensation for outside view camera distortion due to camera optics and the cylindrical projector screen is performed by the Promap units. The Promap units are inserted between the presentation mixers (that renders camera video + overlaid graphics) and the data projectors, where they compensate for several types of distortions that affect the camera video display:

Vignette effects
The lens housings on the cameras may cast shades on the camera sensors. This causes slightly darker corners that are corrected by variable gain adjustments.

Figure 4 Vignette effects, before (left) and after (right) correction

Perspective
The cameras field of view is not pointing in the same relative direction as the projector beams shining on the circular panorama wall screen. This causes perspective distortions that are corrected for by geometry realignment.

Figure 5 Perspective effects, before (left) and after (right) correction

Lens distortions
Imperfections in the lens optics may cause the cameras field of view to bend outwards (barrel distortion) or inwards (pincushion distortion). This is corrected by a radial displacement algorithm.

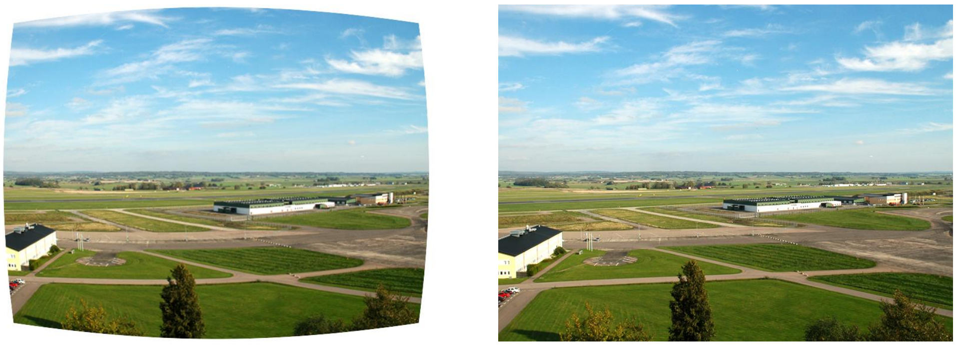


Figure 6 Barrel distortion, before (left) and after (right) correction

Cylindrical mapping
The camera sensor inside the camera is geometrically flat (i.e. a plane). The circular projection screen is of course geometrically circular (a standing cylinder). The fact that the camera sensor and the projector screen have different basic geometry is also compensated for by the Promap units. It transforms the flatness of the camera plane to fit the circular projector screen, so it looks normal to a human observer when projected.

Figure 7 Geometrical correction from flat (left) to circular (right)

Stitching of camera pairs
There is a circular array of cameras covering the 360 degree full field of view. Each camera has a slight overlap with each of its neighbours. For each consecutive camera pair, the Promap units stitches the two cameras together by a smooth blending mask function.

Figure 8 Left camera with blending mask

Figure 9 Right camera with blending mask

Figure 10 Left+Right camera stitched together

2.3.2.2 Airport and geographical information

Overlaid vector based graphical data on top of the live camera video enables enhanced interpretation of the visual orientation of the remote airport, especially during low-light conditions. Different types of static data may be presented; typical examples include runway, taxiways and apron markings. Different type of geographical topology data may also be included.

Figure 11 Airport and geographical information overlay

The lines representing different overlay objects were drawn using a simple CAD software with screen dumps as background. The resulting coordinates were stored in database files. Each line was given a colour type. Definition of which colour to use for each colour type was stored in colour scheme files. Through a HMI the different colour scheme could be selected to adjust to actual situation. The overlay could also be turned off, if unnecessary.

2.3.2.3 Weather information

Real-time presentation of weather data gives quick access to relevant information when needed, strategically positioned near the actual sensors and/or particular points of interest in the video. Typical weather data includes current wind direction and speed.

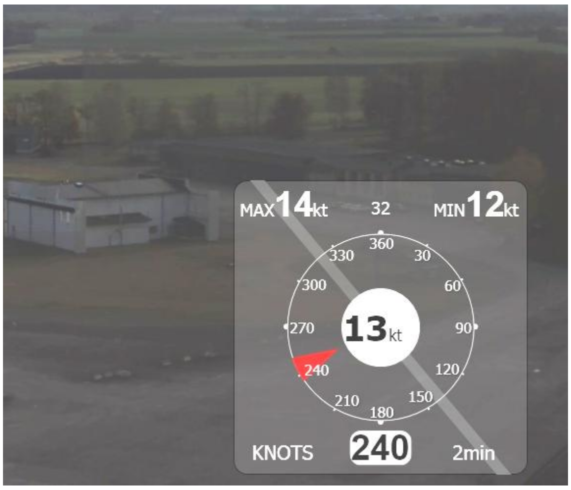


Figure 12 Actual wind direction and speed

Figure 13 RVR values

2.3.2.4 Visual enhancement technology (VET)

Video enhancement functions enable continuous operation during bad weather and/or low-light conditions. The enhancement functions are applied directly at the video camera source, i.e. at the actual airport. The operations of the enhancement algorithm are manual selected for area and level of enhancement.

The aim for most visual enhancement algorithms is to restore the colour balance in the degraded camera video, and to make it look as natural as possible. This is because our human eyes and brain perceives the details of an image at absolutely best when the colour balance is ‘natural’. An example is shown in the figure below.

Figure 14 An example of unnatural colour balance, histogram to the right

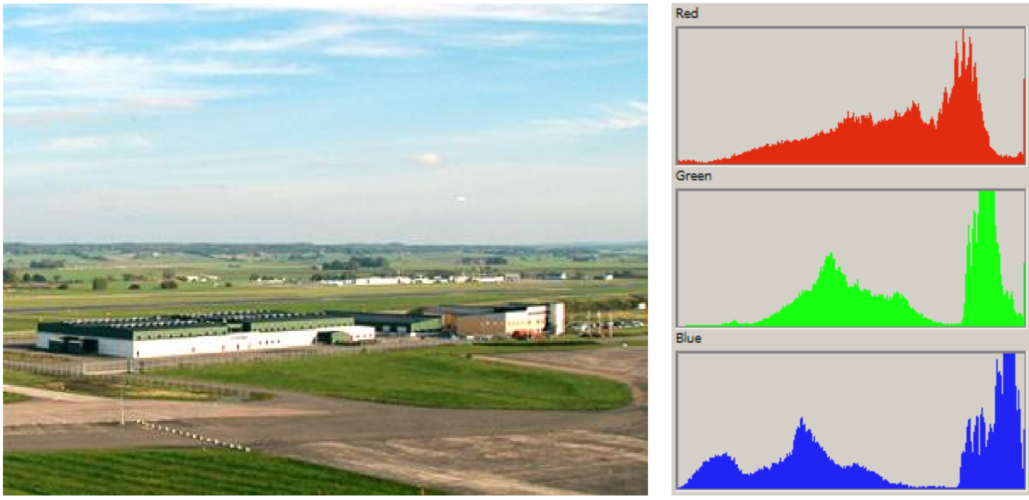


Figure 15 Restored colour balance, histogram to the right

As seen in the first accompanying histogram, the individual primary colour channels (red, green, blue) are biased. The green channel is strongest (most to the right), and therefore one have got a green tint in the picture. Also, neither channel uses all of the full available dynamic range (from left to right).
By stretching the individual histograms to use their full dynamic range, natural colour is restored in the picture. This can be seen in the second accompanying histogram.

2.3.2.5 Aircraft and vehicle tracking with sensor data fusion

Aircraft and vehicles that are seen moving in the camera videos are automatically positioned and tracked by moving target trackers. The targets seen in each individual camera is combined in a central multi-sensor tracking unit, forming a complete situational picture. A MSSR radar sensor is also feed into the multi-sensor tracker, and fused with the camera target tracks. The output from the multi-sensor tracker is sent to the circular panorama display for presentation. The presented target may additionally be labelled with dynamic flight plan related data.

Figure 16 Aircraft and vehicle tracking on ground

Figure 17 Aircraft tracking in the air

2.3.2.6 Pan-Tilt-Zoom (PTZ) camera panorama inlay and control

An inlaid windowed display of the PTZ camera video feed shows the view from the PTZ camera on top of the static camera videos. The windowed display is sizeable and moveable within each cameras part of the panorama. Double-clicking on the window will hide. An enhanced camera control function allows the PTZ camera to automatically follow identified camera target tracks as the move along their taxi routes, takeoff and in air. Aiming on specific positions within the panorama will also bring up the windowed view on that camera.

Figure 18 PTZ camera inlay on top of static camera

2.3.2.7 Record and Replay

All camera video feeds, external sound and tracking information can be continuously recorded on a storage computer. A reply facility enables full replay of previously recorded situations. This function is not intended to increase the situational awareness for the operators, like most other new functions. Its main use is to enable real-world like training of personnel, and possibly enhanced incident investigation

2.3.2.8 Airport transfer

The airport transfer was implemented as a switching between: live data feed from Ängelholm; to replay of earlier recorded data. It was shown that the visual and audio system could be switched. Additionally an extra PTZ server and PTZ unit was used locally at the RTC facility to show how other system could be switched. No other airport system was switched as no second airport was installed, thus there were no real system switch possible other than visual, audio and PTZ control. This limited airport transfer implementation was selected due to installation safety issues.

2.3.3 Verification

The ART Verification Plan is specified in this document following the European Operational Concept Validation Methodology (E-OCVM v 2, 2007). Use is made of preceding Deliverables D3.1.1, ART (ATM) Problem Description and Operational Concept Description, the Overall ART Concept of Operation and System Architecture Description (ref. ART D1.1.1), the ART Interface Document (ref. ART D1.2.1) and the D3.2.1 ART Evaluation, Verification and Validation Plan.

The particular ATM problems that ART attempts to solve are the following:

1. Automatically correlating the approach radar picture with the camera picture as to provide continuous and automatic tracking of targets.

2. Improving the Situation Awareness (SA) of ATCOs through automatic labelling of targets in the projected 360-degrees outside view.
3. Improving the projected outside view through image processing in order to increase the fidelity of the projection (in terms of similarity with the outside view from the actual tower).
4. Increasing the visibility of the outside projected view through image processing as to lower the minimum RVR (‘visibility threshold’) at which Low Visibility Procedures (LVP) would come into effect, which in turn enables the continued operation under normal visibility procedures.
5. Further enhancing SA by presenting weather/wind information in the outside projected view, thereby decreasing the need for the ATCO to attend to separate weather displays.

Verification activities focus on the checking of performance specifications for the ART equipment. Verification is done to ensure that requirements are met and precedes validation activities. ART verification is mainly concerned with the technical performance of the ART enhancements like contrast ratio, resolution and latency.

2.3.3.1 360 degree circular panorama display

Verification of image resolution and contrast had design/test criteria object recognition that should be good enough. While controllers in real tower could recognize Snellen letters at more than 500 m distance, Remote Controllers were restricted to about 200 m or even less.

Although it could be up to a discussion about what “good enough” is, it was decided that the resolution need to be increased in the future.

2.3.3.2 Visibility Enhancement Technology

The visual or visibility enhancement technology did not fulfil expectations. In the few occasions of low visibility it did not increase visibility. It seems that the used VET-solution not improved the visibility at larger distances.
Technically the management of VET performed as required.

*) VET is not used on all pictures in the present facility, and when acting on a part of the image, the effect of VET is clearly observable. A VET awareness procedure needs to be investigated in the future.

2.3.3.3 Presentation of airport and geographic information

This ART feature performed according to specification. It is recommended to investigate techniques in the future that do not draw lines over tracked objects.

2.3.3.4 Presentation of weather information

This ART feature performed according to specification. The presentation of wind should be further developed. Simulated data was used.

2.3.3.5 Sensor data fusion

This ART feature performed according to specification. The video tracking and sensor data fusion is in an evaluation phase (as planned) and will be further developed.

2.3.3.6 Presentation of aircraft and vehicles

This ART feature performed according to specification, target and label presentation shall be further investigated.

2.3.3.7 Pan-Tilt-Zoom (PTZ) camera

This ART feature performed according to specification. The maturity of the Pan Tilt Zoom camera is high.

2.3.3.8 Record and Replay

The R&R functionality operated as required, simultaneously R&R not tested.

2.3.3.9 Airport Transfer

Tested ART feature performed according to specification.

2.3.3.10 Overall ART functional integration

The video tracking and sensor data fusion is in an evaluation phase (as planned) and will be further developed. The test passed in this context.

2.3.4 Validation

ART evaluates and validates functions in an operational context. In previous project stages ART has developed the operational concept for use of these advanced functions in D1.1.1 ART System Architecture and D3.1.1 ART (ATM) Problem Description and Operational Concept Description. The ART Validation results including the ART Experimental Plan are following the European Operational Concept Validation Methodology (E-OCVM v 2, 2007). Use is made of preceding Deliverables D3.2.1, ART Evaluation, Verification and Validation Plan that specifies the ART objectives and hypotheses for validation.

Solutions to the particular ATM problems that ART attempts to solve are the following:

1. Automatically correlating the approach radar picture with the camera picture as to provide continuous and automatic tracking of targets.
2. Improving the Situation Awareness (SA) of ATCOs through automatic labelling of targets in the projected 360-degrees outside view.
3. Improving the projected outside view through image processing in order to increase the fidelity of the projection (in terms of similarity with the outside view from the actual tower).
4. Increasing the visibility of the outside projected view through image processing as to lower the minimum RVR (‘visibility threshold’) at which Low Visibility Procedures (LVP) would come into effect, which in turn enables the continued operation under normal visibility procedures.
5. Further enhancing SA by presenting weather/wind information in the outside projected view, thereby decreasing the need for the ATCO to attend to separate weather displays.
6. Record and replay beneficial for incident/accident investigation and for training.

Validation activities focus on the operational use of the ART system. The controller judgement and appreciation plays here the mayor role. In the context of ART, live trials were conducted in passive shadow mode.
Once the appropriate functioning of basic system components and ART-introduced functions and technologies were verified (D3.3.1), the ART solutions to the earlier identified ATM problems have been validated, focussing on the two main operational benefits:

1. Improved Situation Awareness of the Air Traffic Controller (ATCo) through improved flight data presentation by automatically correlating the radar tracks derived from approach radar with video tracks derived from the camera picture as to provide continuous and automatic tracking of targets, and
2. Improved outside view during decreased visibility through display of synthetic elements and Visibility Enhancement Technology.

ART objectives and hypotheses were defined using E-OCVM. After verification of the proper functioning of the ART functions, the validation was conducted by real time observation of traffic at the Ängelholm airport in the southern part of Sweden. The ART functions have been evaluated and validated in passive shadow mode by 15 air traffic controllers, each spending two days in the remote cabin in groups of two to three controllers. Recordings of live traffic situations were used to evaluate less frequently occurring visibility conditions.

The ART functions were validated by controllers at a medium maturity level as the ART project is just a stepping stone on the way to real remote tower operations. The validation prototyping results can be summarized as follows:

2.3.4.1 360 degree circular panorama display

The controllers accepted the panorama display for single flights only. Efficiency and capacity is now judged lower than for the real tower. Further research and development is recommended to increase 3-dimensional awareness and resolution and to develop additional procedures. This should not be restricted to a circular projection screen. It could explore high resolution LCD screens with high dynamic contrast.

2.3.4.2 Visibility Enhancement Technology

The contrast improvement by VET did not fulfil controller expectations. Indications are that this technology will have benefits in some applications e.g. in combination with PTZ.

2.3.4.3 Presentation of airport and geographic information

Controllers accepted most of these enhancements especially in poor visibility but warned for the risk to obscure traffic with the extra geometric information. Suggestions were done to try other line styles and to analyse better what really has to be accented.

2.3.4.4 Presentation of weather information

The controllers were rather neutral with the presented solutions. Suggestions were to bring the style and design towards existing LFV meteorological information displays.

2.3.4.5 Sensor data fusion

This function was validated in conjunction with presentation of aircraft and vehicles.

2.3.4.6 Presentation of aircraft and vehicles

Controllers appreciated the on-screen labels. Suggestions to improve the labels concerned the positioning of labels on the screens and the correlation of the label content with the Electronic Flight Strips. The size of the target symbol could be an indication of the range of the observed object.
The video tracking and data fusion with radar tracks indicated that there are good chances to improve the tracking up to the level of full acceptance by controllers. Video tracking served well for automatic target following by for instance the PTZ camera.

If video tracking is performing well it could lower the requirements for high resolution and contrast.

2.3.4.7 Pan-Tilt-Zoom (PTZ) camera

Controllers were most happy with the PTZ and the PTZ operations. It is the most mature ART function and might see broad application in manned towers too.

2.3.4.8 Record and Replay

This ART function was used extensively for performing the ART validation using pre-recorded scenarios for consecutive groups of controllers. Record and Replay was not evaluated for possible use in accident investigations and training.

2.3.4.9 Airport Transfer

The airport switch over function was tested by switching from real to recorded images and vice versa. It did not encompass controller operational validation and was only verified on technical (system) level.
The integration of all ART functions learned that the HMI needs continued development to better stay ahead of the traffic. Also the integration with Electronic Flight Strips is recommended.

2.3.4.10 Expert Judgement Workshop

An Expert Judgement Workshop served as opinion gathering on topics like that can not directly be derived from limited field trials. The participant's opinions were in line with the results and recommendation from the shadow mode trials. Cost benefit is expected for other applications (contingency towers, AFIS, military applications). The availability of remote tower service might attract new users of remote fields. The experts recommended continuing with research and development for multiple remote airport control from one remote control centre and research of the ART functions for manned towers.

2.4 SESAR

The project has been coordinated with the SESAR programme. The KPAs addressed in this project has been more clearly stated and was reported at the coordination meeting in Brussels November 2007.

ART and SESAR agreed on the following impacts:

Elements	Safety	Environmental	Security	Efficiency	Predictability	Flexibility	Capacity	Cost Effectiveness	Access & Equity	Participation	Interoperability
Impact ART	++			+	+	+	++	++			

Blank = neutral
+ = positive impact
++ = substantially positive impact

2.5 Conclusions

This chapter is based on input from partners and the Project Manager and is a reflection of the project work in terms of “what was good” and “what was not so good”.

The cooperation between all partners in the ART consortium has been good. With good climate and open dialogues the project succeeded in resolving the few existing disagreements.

The size of the consortium has been just the right level to implement the project effectively.

2.5.1 Lessons learnt

The result has shown which useable and not useable ART features in future remote tower systems.

The project has provided experience in working conditions for air traffic controllers especially in remote tower application.

The consortium has acquired knowledge about how to manage an EU-project with many participants. This knowledge will be useful in the SESAR program.

The project team learnt about the importance and difficulties in setting up the validation activities in the most suitable context. This includes setting objectives, hypothesis and questionnaires, as well as the conduction of the day to day validation activities, so all participating parties or individuals are properly trained for their tasks, and fully understand the purpose with their participation. The Validation analyses activities based on these results will otherwise be unnecessary complicated.

The ART project brought more knowledge about the visual observation process as applied by Air Traffic Tower Controllers. The consortium knows now better what they want to survey and under which circumstances. That knowledge has been used already in the ART project to enhance the remote visual surveillance. This knowledge may have spin off in other application areas: military remote ATC (hazardous environment, quick deployment), remote control of waterway bridges, remote lighthouses, contingency towers and application of visual enhancement techniques in manned ATC towers.

2.5.2 Benefits

Early co-ordination with SESAR programme has made remote tower to one of the important areas in SESAR JU.

The possibility to be a part of the 6th frame work programme has given opportunities to disseminate remote tower to a wide “audience” and stakeholders. This dissemination has made great interest throughout the world and shown that remote tower is an alternative to conventional air traffic control.

2.5.3 The methodologies and approaches employed and relating the achievements of the project to the state-of-the-art

The European Operational Concept Validation Methodology (E-OCVM) has been used. This method, created by EUROCONTROL, aims to provide a common approach to be applied by Research and Development organisations in support of the development and validation of operational Air Traffic Management (ATM) applications as they mature from simple concepts.

The approach of developing and testing the ART concept has been more implementation oriented than research oriented. Practical tests have been carried out in a near-operational environment.

2.5.4 The impact of the project on its industry or research sector

The project has demonstrated that remote tower has a future in the air traffic management domain and what opportunities are available with the ART features within remote tower systems concerning situational awareness and safety vs. conventional tower operation.

3 Dissemination and use

3.1 Exploitable knowledge and its Use

Exploitable Knowledge	Exploitable product(s) or measures	Sector(s) of application	Timetable for commercial use	Patents or other IPR protection	Owner & other partners involved
The ART operational result	*Useable and not useable features*	*Aviation, Air traffic control*	*2012+*		*LFV, SAAB, NLR, LYYN, Equipe*
Knowledge about the use of video in ATC environment	*Targeted sales efforts*	*ATC environment*	*2010*		*LYYN*
Knowledge about hardware design and video interfaces for LYYN HD video products	*LYYN HD video product*	*1. Security surveillance 2. Subsea applications for ROVs*	*2010 2011*		*LYYN*
Knowledge about video tracking	*”SESAR”*		*2011+*		*Saab*
Knowledge about overlay of various information	*Remote tower applications*		*2011+*		*Saab*

3.1.1 The ART validation report

What the exploitable knowledge is
The operational and technical outcomes of the ART project are reported in the ART Validation report. This forms the fundamental basic Operational knowledge of Air traffic control for airports via remote control functionalities.

Partner(s) involved in the exploitation, role and activities
LFV: Will manage the follow up in the Operational project in SESAR
SAAB: Will manage the follow up in the Technical projects in SESAR
NLR: Will use the operational knowledge of ART for improving remote tower operational concepts and solutions (future projects on validation and safety assessment)

How the result might be exploited (products, processes) - directly (spin offs etc) or indirectly (licensing) – on an individual basis or as a consortium/group of partners

Within the EC Single European Sky Air traffic management Research (SESAR) programme. The ART operational outcome will form (are actually) forming the baseline for the further research under work package 6.9.3 and 12.4.6/12.4.7/12.4.8

Further additional research and development work, including need for further collaboration and who they may be;
See the last answer above

Intellectual Property Rights protection measures (patents, design rights, database rights, plant varieties, etc
----

Any commercial contacts already taken, demonstrations given to potential licensees and/or investors and any comments received (market requirements, potential etc.);

A memorandum of Cooperation (MOC) have been signed after the outcome of ART between SAAB as well as LFV with the Australian Air service provider (Air Services Australia) for further joint development activities on new live platforms and trials in Australia, within the area of Remote Towers.

The Federal Aviation Administration (FAA) in US have paid a sincere interest of our research, and have visited the project twice, since similar ideas are now planned for the so called Next generation of Air traffic control for the US (NextGen).

Where possible, also include any other potential impact from the exploitation of the result (socio-economic impact).
A successful outcome of ART will have a potential outcome to be able to keep more airports open and available for commercial traffic in rural areas of Europe, then else, since this technology and operational methods will reduce the costs for the provision of Air traffic control considerably.

3.1.2 Knowledge about the use of video in the ATC industry

What the exploitable knowledge is
LYYN AB has acquired a significant amount of knowledge about the use, and non-use, of video in the air traffic control (ATC) industry. This knowledge will help us target our development and sales efforts in a more efficient way going forward.

Partner(s) involved in the exploitation, role and activities
The main knowledge disseminators were SAAB and LFV.

Obstacles
The ATC industry is very dependent on public regulations, this typically leads to long development cycles due requirements on regulatory approval. A consequence of this is that product development targeted specifically at the ATC

industry is very expensive and time-consuming and this is in turn means that very few SME’s have the necessary capital.

3.1.3 Knowledge about hardware design and video interfaces for LYYN HD video products

What the exploitable knowledge is
LYYN AB designed, developed and manufactures a HD video version of LYYN video enhancer. This single unit, which in itself is not market ready, enables us to design and develop a finished product with the right features during 2010.

Partner(s) involved in the exploitation, role and activities
SAAB participated in the prototype design with requirement specifications as well as testing. LFV enabled and managed the end-user testing and gave valuable feedback on features.

Obstacles
The ATC industry is very dependent on public regulations, this typically leads to long development cycles due requirements on regulatory approval. A consequence of this is that product development targeted specifically at the ATC industry is very expensive and time-consuming and this is turn means that very few SME’s have the necessary capital. Any HD video product that LYYN develops must thus be targeted at significantly broader market than the ATC industry.

3.1.4 Knowledge about video tracking

What the exploitable knowledge is
SAAB has designed and developed as video tracking system. The maturity of this system is currently on a low level and will be further developed within the SESAR programme.

Partner(s) involved in the exploitation, role and activities
SAAB: Will manage the follow up in the Technical projects in SESAR.

How the result might be exploited (products, processes) - directly (spin offs etc) or indirectly (licensing) – on an individual basis or as a consortium/group of partners
Within the EC Single European Sky Air traffic management Research (SESAR) programme. The ART operational outcome will form baseline for the further research under work package 12.4.6.

Further additional research and development work, including need for further collaboration and who they may be;
See the last answer above

3.1.5 Knowledge about overlay of various information

What the exploitable knowledge is
SAAB has acquired experience and knowledge of how to overlay digital information in a moving image, both moving and not moving information.

Partner(s) involved in the exploitation, role and activities
Depending on future technical and safety requirements Saab will develop and add overlay functionality in remote tower systems.

Further additional research and development work, including need for further collaboration and who they may be;
See the last answer above

Intellectual Property Rights protection measures (patents, design rights, database rights, plant varieties, etc
----

Any commercial contacts already taken, demonstrations given to potential licensees and/or investors and any comments received (market requirements, potential etc.);
Saab has been selected to deliver a first remote tower pilot system to LFV. In this system some overlay information will be used.

3.2 Dissemination of knowledge

Actual dates	Type	Type of audience	Countries addressed	Size of audience	Partner responsible/ involved
Oct-Nov 2008	Stakeholder workshops and mini-seminars	Identified Specific Remote TWR specialists	Germany Norway Finland USA (FAA)	Groups of up to max 8 per session	SAAB/LFV/
March 2009	High Level Seminar	CEOs from several European ANSP, Airlines	Some 15 European counties, and US	50	SAAB/LFV
March 2009	ATC Global Exhibition	ANSPs, Industry and ATCO:s	Global	Approx. 100 with special interest	SAAB/LFV
	Web-site: adv.remote-tower.net	Any	All	Any	All
Dec 2009	Expert judgement seminar	Identified Specific Remote TWR specialists/ stakeholders, managers and ATCO:s	Swedish	10-15	SAAB/LFV/ NLR/LYYN/ EEL
Febr 2010	ART major Demonstration results & Dissemination seminar	ANSPs, R&D org, Industry, EC represenatatives	Especially Germany, Norway, Denmark,Sweden	40	SAAB/LFV/ NLR/LYYN/ EEL
March 2010	ATC Global Exhibition	ANSPs, Industry and ATCO:s	Global	Approx. 100 with special interest	SAAB/LFV
April 2010	ART validation results, etc via Publications, video-clips etc	Any	Wide spread within ANS and Industry community	Any	SAAB/LFV/ NLR/LYYN/ EEL

Aug 2010	ART results; Two papers and speeches at IFAC conference in France	Specialists	Any	100+	NLR

3.3 Publishable results

Exploitable Knowledge	**Result description**	**Stage of development**
The ART operational result	*The ART validation report, ref [10]*	*Demonstrator*
Knowledge about the use of video in ATC environment	*N/A*	
Knowledge about hardware design and video interfaces for LYYN HD video products	*N/A*	
Knowledge about video tracking	*The ART Demonstration report, ref [5]* *The ART verification report, ref [9]*	*Demonstrator*
Knowledge about overlay of various information	*The ART Demonstration report, ref [5]* *The ART verification report, ref [9]*	*Demonstrator*

Annex A – References

Ref. no	Document
1	D1.1.1 Concept of operation and System architecture
2	D1.2.1 Interface Design
3	D1.3.1 Cab adaptation plan
4	D1.4.1 Safety Assessment
5	D2.1.1 Demonstration report of functional capabilities in the ART demonstration platform
6	D2.3.1 Cab Adaptation Documentation
7	D3.1.1 ART (ATM) Problem Description and Operational Concept Description
8	D3.2.1 ART Evaluation, Verification And Validation Plan
9	D3.3.1 ART Verification report
10	D3.4.1 ART Validation report
11	D.4.1.1 ART Demonstration
12	D0.1.1 Project Management Plan

Annex B - Acronyms and definitions

Acronym	Definition
ART	Advanced Remote Towers
ATC	Air Traffic Control
EC	European Commission
E-OCVM	European-Operational Concept Validation Methodology
EU	European Union
EVV	Evaluation, Verification and Validation
HMI	Human Machine Interface
ILS	Instrument Landing System
N/A	Not applicable
PSA	Preliminary Safety Assessment
ROT	Remotely Operated Tower
RTC	Remote Tower Centre
VET	Visual Enhancement Technology
WP	Work Package