Final Project Report

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Abstract

The 09.29 project has worked on the development of onboard solutions combining Enhanced and Synthetic Vision Systems in order to improve pilots' ability to conduct landing operation in low visibility conditions.

To achieve these goals, the 9.29 project identified all relevant requirements, evaluated available database technologies and formats, defined a system concept, developed business and regional aircraft mock-ups, performed initial concept evaluation through modelling and simulation means and performed technical verification and validation to achieve V2 maturity level of the proposed solutions.

Authoring & Approval

Prepared By - *Authors of the document.*		
Name & Company	Position & Title	Date
[redacted] Honeywell	[redacted]	26/09/2016

Reviewed By - *Reviewers internal to the project.*		
Name & Company	Position & Title	Date
[redacted] Honeywell	[redacted]	23/07/2016
[redacted] Honeywell		26/09/2016
[redacted] Thales		22/09/2016
[redacted] Leonardo		23/09/2016
[redacted] Airbus		26/09/2016

Reviewed By - *Other SESAR projects, Airspace Users, staff association, military, Industrial Support, other organisations.*		
Name & Company	Position & Title	Date
[redacted] Honeywell	[redacted]	26/09/2016

Approved for submission to the SJU By - *Representatives of the company involved in the project.*		
Name & Company	Position & Title	Date
[redacted] Honeywell	[redacted]	22/09/2016
[redacted] Thales		22/09/2016
[redacted] Leonardo		23/09/2016
[redacted] Airbus		26/09/2016

Rejected By - *Representatives of the company involved in the project.*		
Name & Company	Position & Title	Date

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Acronyms

Acronym	Definition
AC	Advisory Circular
AdvCVS	Advanced Combined Vision System
AUO	Airspace User Operations
ATM	Air Traffic Management
CBA	Cost Benefit Analysis
CVS	Combined Vision System
DA	Decision Altitude
DH	Decision Height
EFVS	Enhanced Flight Vision System
EN	Enabler
EUROCAE	European Organisation for Civil Aviation Equipment
FAA	Federal Aviation Administration
HAT	Height Above Touchdown
HMI	Human Machine Interface
IR	Infrared
LVC	Low Visibility Condition
MASPS	Minimum Aviation System Performance Standards
RTCA	Radio Technical Commission for Aeronautics
RVR	Runway Visual Range
SC	Special Committee
SESAR	Single European Sky ATM Research
SJU	SESAR Joint Undertaking
SVGS	Synthetic Vision Guidance System
WA	Work Area
WG	Working Group

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1 Project Overview

The 09.29 project developed a system combining Enhanced and Synthetic Vision Systems in a single onboard solution. The project researched relevant external and design requirements, available database technologies and formats, system concept, system benefits, feasibility from pilots' perspective and partly testing in real environment.

The project focused on two types of aircraft. Honeywell led the work for business aircraft and Thales led the work for regional aircraft. Not all tasks were executed for both aircraft types.

1.1 Project progress and contribution to the Master Plan

The project was divided into six work areas (WA):

- WA1 for requirements
- WA2 for technology evaluation
- WA3 for system definition
- WA4 for mock-up development
- WA5 for verification and validation activities,
- WA6 for Integration and validation

WA3, WA4 and WA5 were conducted separately for Business and Regional aircraft.

Within WA1, the project investigated all possible requirements including requirements for design and external requirements considering regulations. The project collected regulatory, industry and crew requirements relevant to Vision Systems including from European Organisation for Civil Aviation Equipment Working Group 79 (EUROCAE WG-79) / Radio Technical Commission for Aeronautics Special Committee 213 (RTCA SC-213) standardization group. The work area investigated and summarized quantitative and qualitative benefits of vision systems.

WA2 focused on database evaluation. It evaluated Airport Mapping Databases, Navigation databases and Terrain and Obstacles Databases with their formats, contents and accuracies for the purposes of the utilization in the Combined Vision System.

WA3 introduced a system definition of the Combined Vision System, considering the operational, functional, and architectural perspectives. There were two separate definitions for business aircraft and regional aircraft. It included operational and functional points, e.g., different system modes, states.

WA4 developed Combined Vision System (CVS) mock-ups supporting verification and validation of the CVS functions and operational aspects. It included two separate mock-ups, one for Business aircraft and one for Regional aircraft. Mock-ups respect different concepts for both types of aircrafts which came from alternative approach of the project members.

WA5 evaluated the pilots' performance and workload in the simulated operational environment reflecting the proposed operational concept. For this purpose, the project built the mock-ups with integrated CVS Human Machine Interface (HMI) and functionalities required for defined validation objectives. The pilots then conducted a series of approaches with different display concepts and different flight guidance symbology to get a sufficient amount of data for evaluation. There were two separate validation programs to respect alternative concepts for Business aircraft and Regional aircraft.

WA6 used outcomes from WA5 to update operational and technology concept. The system definition was updated and corresponding mock-up was designed to validate the modified HMI concept. The work also covered the provision of more mature system functionalities. The most mature parts of the developed system were verified on a computer platform with flight test data. Based on the verification activities these parts were integrated into an experimental business jet and validated during flight tests. WA6 covered business aircraft only and specific AdvCVS concept described below with other vision systems.

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Enhanced Flight Vision System (EFVS) provides the flight crew with an enhanced image of the external scene through the use of an imaging sensor. EFVS enables the pilot to transition into the visual segment by providing an electronic means of displaying the visual cues required by the regulation.

Synthetic Vision Guidance System (SVGS) is a combination of flight guidance display technology and high precision position assurance monitors. SVGS allows a lower decision altitude or decision height.

Combined Vision System (CVS) is a combination of synthetic and enhanced vision systems (EFVS + SVGS combination). Depending on its design, it could be used either to extend the visual segment upwards or the instrument segment downwards. This system uses information from an imaging sensors as well as high precision position and databases.

Advanced Combined Vision System (AdvCVS) derives a new source of aircraft positioning assurance from ground features detected through an imaging sensor. This new source of aircraft positioning can be used to improve the integrity of a system whether it is presented in the head-up or head-down location and enable further operational credit.

Code	Name	Project contribution	Maturity at project start	Maturity at project end
AUO-0405	Equivalent Visual Landing operations in Low Visibility Conditions	The project provided operational concept for using Combined Vision System, mixing Enhanced Vision System and Synthetic Vision System. Mock-ups for business and regional aircraft Validation and Verification activities	V1	V2
A/C-23b1	Combined Vision for Equivalent Visual Landing operations in Low Visibility Condition (LVC)	The project provided the Combined Vision enabler for Equivalent Visual Landing operations in LVC	V1 / TRL1	V2 / TRL4

Table above fully corresponds with European ATM Master Plan / DATASET 15.

1.2 Project achievements

The main project achievements were the development, verification and validation of two types of Vision Systems for Business and Regional aircraft potentially extending operational credit for flight crew in the approach instrument segment in low visibility conditions.

The project collected operational, safety and performance requirements and flowed them down to design level requirements. The operational level of requirements was created internally by the project with inputs provided from the A-SMGCS Guidance function project [20].

Database evaluation analysed data elements and accuracy with regard to CVS needs for navigation, terrain, obstacle and airport map database. The study analysed the needs relative to using CVS on runways, taxiways and aprons. Terrain and obstacle data accuracy were also analysed in the close vicinity of runways and other airport movement areas.

The project investigated possible operational benefits of the CVS and provided elements related to the cost of the system. Using concepts with different functionality and capability the qualitative and quantitative benefits of Combined Vision were provided. This report confirms that using the CVS under low visibility conditions will bring benefits to several ATM stakeholders:

- Airspace users:

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- Mainline aircraft operators benefit from the reduction of taxi delay and related costs and from the increase in accessibility of less equipped airports in the LVC.
- Regional airlines obtain up to 60% improvement to be on time at the final destination, which includes reduction of up to 50% of the delays and cancellations and up to 75% reduction in diversions.,
- Business aircraft (values cost of a passenger more than a cost of a system) will benefit from a reduced dependency on weather conditions.

- Airport benefits, expressed in terms of an increase in the number of possible aircraft landings, are up to 50% of the airport capacity increase.
- Overall ATM benefits in terms of increased capacity, reduction of delays, and increased safety are provided due to lower workload of the ATM based on higher aircraft independency on the ATM.
- Crew benefits from a lower workload and higher situational awareness in the LVC, which reduces delays and increases safety of operations on ground.,
- Ultimately, passengers obtain benefits from the CVS deployment thanks to less frequent delays and/or cancellations in bad weather conditions.

The project produced a technical specification of the proposed system, considering the operational, functional, and architectural perspectives. It contained a description of the systems, new functionality and concept of system operations. The system functional and non-functional requirements were defined during the development and establish a baseline for such systems in the future.

Two Mock-ups were built for validation activities, each representative of an aircraft type: business and regional. The pilot-in-the-loop validation exercises were conducted to investigate the impact on pilot workload and performance while completing particular tasks.

The most mature system parts were integrated and validated on computer platform using data from real environment. The final phase validated the same integration during flights flown by an experimental business aircraft to investigate system performance in real operations. Results confirmed TRL4 maturity of system parts for defined purposes.

The development provided TRL4 maturity of proposed systems and also indicated areas that should be investigated further to reach TRL5/6 maturity under a future development project.

1.3 Project Deliverables

The following table presents the relevant deliverables that have been produced by the project.

Reference	Title	Description
D13	Updated Technical specification	The document provides an updated technical specification based on the previous validation exercise. The specification considered the operational, functional, and architectural perspectives. The document contains a description of the systems, new functionality and updated operational concept. The system functional and non-functional requirements were defined during development and should establish a baseline for such systems in the future.

The project provided fifteen deliverables to the SESAR Joint Undertaking (SJU) throughout the project execution. All deliverables were successfully accepted.

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1.4 Contribution to Standardisation

Project members represented SESAR 9.29 at the joint EUROCAE WG79/RTCA SC-213 committee, participated to plenary meetings and contributed to:

- RTCA DO-315 Minimum Aviation System Performance Standards (MASPS) for Enhanced Vision Systems, Synthetic Vision Systems, Combined Vision Systems and Enhanced Flight Vision System [24]
- RTCA DO-359 Minimum Aviation System Performance Standards (MASPS) for Synthetic Vision Guidance System [25]
- RTCA DO-341 Minimum Aviation System Performance Standards (MASPS) for Enhanced Flight Vision System to Enable All-Weather Approach, Landing, and Roll-Out to a Safe Taxi Speed [26]

RTCA DO-359 and FAA Advisory Circular - Airworthiness Approval of Synthetic Vision Guidance System AC 20-185 [27] provide a path to use SVGS to enable operations to a Missed Approach Point as low as 150ft HAT. SESAR 9.29 provides technical solutions to enable operations down to 100ft. Extension of SVGS operations down to 100ft HAT is part of EUROCAE WG79/RTCA SC-213 work plan. However, activity concerning current concept SVGS down to 100ft is on hold as OEM sees reaching of 150ft with SVGS as priority.

Based on validation results, the Approach Lighting System information is required for the aircraft positioning part of AdvCVS algorithms. Honeywell suggested extensions of Aerodrome database to the ED-99revD [28] / DO-272revD [29] draft standard during the EUROCAE Open Consultation process. One or more light sources located on the ground that provide visual assistance for air and ground navigation were defined as one item in the Aerodrome database. Therefore Approach Lighting System information will be covered by the database. The extension was published in document ED-99revD / RTCA DO-272D in September 2015. This activity should also drive the collection of data for all airports and runways under consideration..

1.5 Project Conclusion and Recommendations

This project made significant progress in the development of visions systems combining enhanced vision systems using external sensor with synthetic vision systems providing synthetic scene. The developments were targeting mainly business and regional aircraft, but the proposed system architecture and functionality can be used by other aircraft types. Architecture and algorithms were implemented on a PC platform and flight tested with the most mature parts of the system. Extensive simulations were performed to support V2 maturity for the defined concept.

Conclusions and recommendations are summarized here:

- Using visions systems such as CVS, SVGS and EFVS under low visibility condition brings benefits to several Air Traffic Management (ATM) stakeholders as airspace users, airports, flight crew and passengers at the end
- There are multiple ways to implement a Combined Vision System: either as a pure vision system combining sensor and synthetic vision images on a display (e.g. regional aircraft concept), or as a vision and navigation system using sensor image to improve the integrity of the synthetic vision image and/or aircraft guidance (e.g. business aircraft concept).
- The Infrared (IR) sensors have generally limited penetration during low visibility conditions. Therefore other sensor types should be further considered
- Close cooperation with standardization groups like joint RTCA Special Committee (SC) 213 and EUROCAE Working Group (WG) 79 should continue and project outcomes should be presented

The project faced many challenges over the course of the project run and concepts were adjusted along the way. Finally, the flight tests at the end of the project showed that the technology is ready to reach

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maturity level V3 under a future development project and subsequent development/deployment in the European ATM system.

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