Technical University of Denmark

DTU

ODICIS (One Display for a Cockpit Interactive Solution) - Final public progress report

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Final public progress report

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REFERENCED DOCUMENTS

Ref.	Code	Description
[1]	TA	ODICIS Technical Annex or Annex I "Description of Work"
[2]	ODC_D412_THAV	Concept of use and HMI strategy
[3]	MIL-HDBK-217F	"Reliability Prediction of Electronic Equipment - Notice F" / Airborne Inhabited Cargo 45°C Quality level 3

1. INTRODUCTION

1.1. Purpose and scope of ODICIS

The ODICIS project aims at developing a single display cockpit associated with adequate means of interaction.

This addresses three current major aeronautics needs: the system architecture flexibility, the useful surface optimisation and the information continuity. Therefore the project will improve the operational safety and efficiency while reducing the aircraft development cost.

The first objective is to prove the technical feasibility of an avionics large seamless display, which can possibly be curved. This involves optical but also graphic generation challenges. The design of the display must take into account as much as possible user wishes and aircraft possibilities.

Once the display is available, the proper means of interaction must be defined and implemented. At this point, a complete technological mock-up of a single display cockpit will be available.

Meanwhile, the concepts of use, that stimulated the idea of a single display cockpit, will be reviewed, deepened and tested on the mock-up. Human factors evaluations will seek to ascertain the safety and efficiency gains produced by this novel cockpit concept based on use of a single display.

1.2. Purpose and scope of this document

The purpose of this deliverable is to provide an overview of the activities performed over the whole duration of the ODICIS project that is from month 1 to month 36 (May 2009 to April 2012).

2. OBJECTIVES FOR THE REPORTING PERIOD

The following table presents the expected status of the different work packages of the ODICIS project at the end of the first reporting period according to the description of work [1].

	WP title	Expected Status	Expected result
WP0: Management			
0.0	Project Management	Closed	D0.0 Project Management Guidelines D0.1.1 First progress report with cost statements D0.2.1 First public progress report
WP1: General Requirements			
1.1	Displays & system requirements	Closed	D1.1 Report on display and system requirements to design a single display cockpit
1.2	Operational requirements	Closed	D1.2 Report on operational requirements to design a single display cockpit
1.3	Safety requirements	Closed	D1.3 Report on safety/certification requirements to design a single display cockpit
1.4	Preliminary Evaluation Plan	Closed	D1.4 Preliminary plan for part tasks evaluations
WP2: Technologies			
2.1	Technologies monitoring & studies	Closed	D2.1 Report on innovative display and interaction technologies potentially able to fly
2.2	Technologies definition	Closed	D2.2 Report on the chosen interactive projector configuration and subassemblies
2.3	Technologies prototyping	Closed	D2,3 Description of prototyped interactive single display
2.4	Part tasks evaluation	Closed	D2.4 Technological part tasks evaluation report
WP3: Display system			
3.1	System specification	Closed	D3.1 System architecture: strategy to build a single display flight deck
3.2	Graphic generation	Closed	D3.2 Assessment report of graphics generation for a single display cockpit
3.3	Safety analysis for system aspects	Closed	D3.3 Technical safety constraints of the single display cockpit system
3.4	System integration	Closed	D3.4 Integration report: strategy to merge all the hardware components
3.5	Part tasks evaluation	Closed	D3.5: System part tasks evaluation report
WP4: Concept of Use			
4.1	Single display cockpit concept	Closed	D4.1.1 Mechanical design to address a single display cockpit D4.1.2 Report on concept of use and HMI strategy related to a single display cockpit
4.2	Functions selection & case studies	Closed	D4.2 Report on selected functions and associated case studies
4.3	Safety analysis for operational aspects	Closed	D4.3 Functional safety constraints related to the built concept of use
4.4	HMI prototyping	Closed	D4.4 Specifications of HMI for single display cockpit
4.5	Part tasks evaluation	Closed	D4.5 HMI part tasks evaluation report
WP5: Validation			
5.1	Detailed evaluation plan	Closed	D5.1 Evaluation plan
5.2	Final integration hardware & HMI	Closed	D5.2.1 Integration report with strategy on merging of the HMI with the cockpit hardware D5.2.2 Complete fixed based mock-up
5.3	Technical evaluation	Closed	-
5.4	Operational evaluation	Closed	-
5.5	Assessment results	Closed	D5.5 Assessment report and recommendations
WP6: Exploitation and Dissemination			
6.1	Stakeholders assessment & dissemination issues	Closed	D6.0 Dissemination and communication plan D6.1.1 First report on dissemination activities D6.1.2: Final report on dissemination activities
6.2	Exploitation roadmap & market perspective	Closed	D6.2.1 Intermediate exploitation roadmap D6.2.2: Final exploitation roadmap

Table 1: expected outcome at the end of the project

3. WORK PROGRESS DURING THE REPORTING PERIOD

3.1. WP0 – Management

3.1.1. ODICIS Work Breakdown Structure

The ODICIS work breakdown structure is presented in Figure 1.
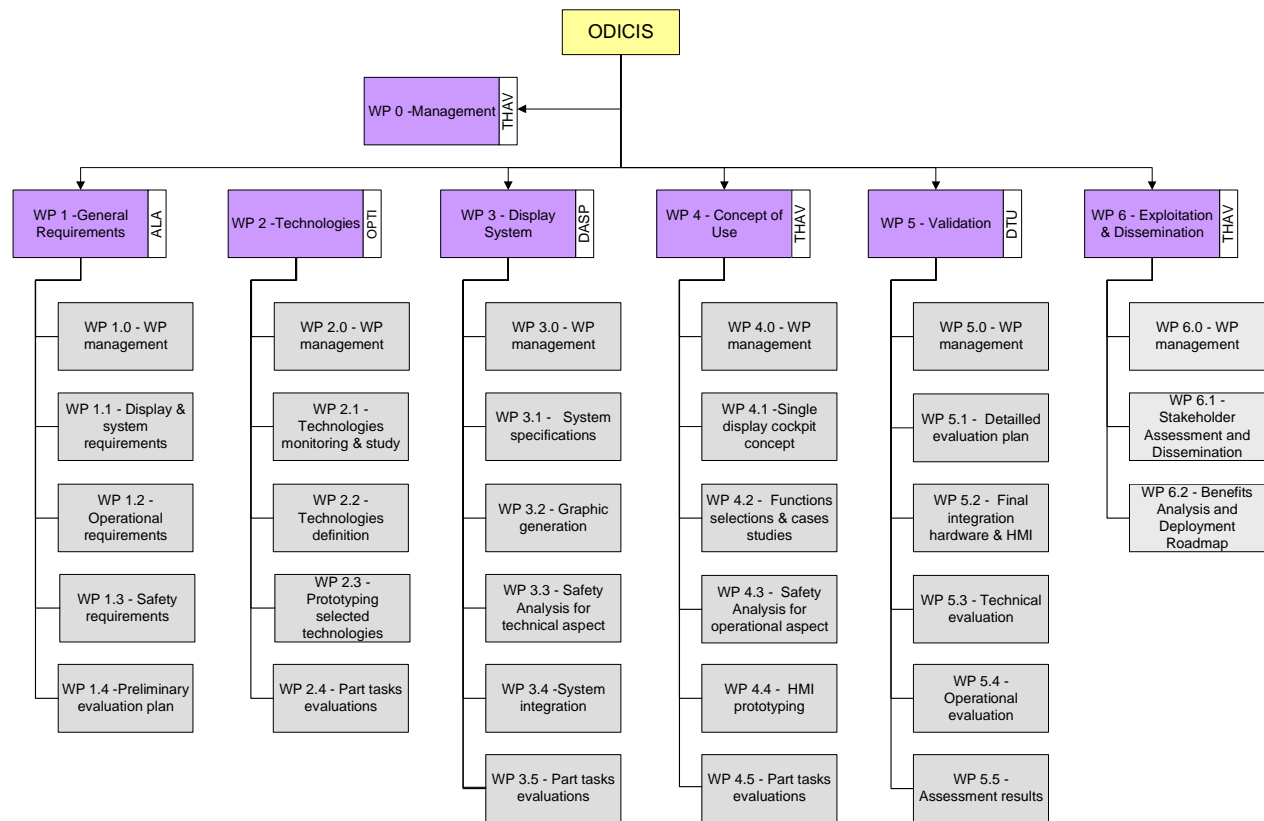

Figure 1: ODICIS work breakdown structure

3.1.2. Project high-level progress overview

All the workpackages except WP0 have been completed with a project extension of 4 months compared to the initial duration of 30 months. Some tasks related to costs declaration will need to be completed after this document is issued.

3.2. WP1 Requirements

WP1 has pursued two objectives:
- To define the different requirements the single display cockpit should achieve;
- To issue a first evaluation plan for the mock-ups validations.

The first objective has considered different viewpoints from which deriving requirements, including: equipment, aircraft integration, certification and safety. Requirements definition has considered both existing guidelines and standards as well as expertise of Consortium Partners to adapt/define specific

requirements suitable for a state-of-the-art large cockpit display. Figure 2 provides the regulatory basis that Partners took as reference for requirement definition.

Across each WP1 deliverable, a common method for requirement numbering and identification has been adopted in order to facilitate requirement traceability.

The definition of a framework for mock-up validation activities was the focus of the second objective. Such framework was conceived considering the prototype development phases as well as the opportunity for demonstrating that the design requirements would have been captured into the final large display mock-up.

Overall, 351 requirements were generated, which benefited from the involvement of Consortium engineering expertise, presence of End User and EEAG Members.
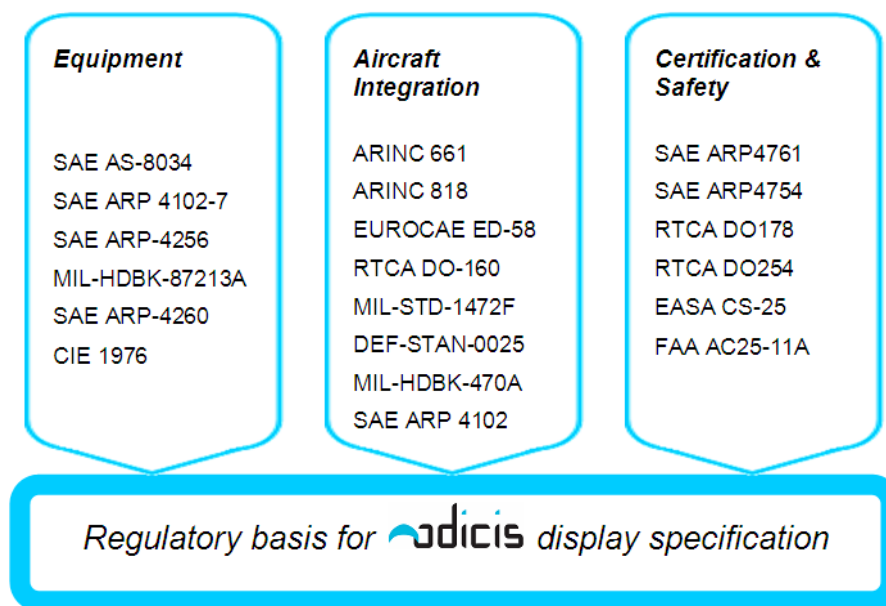
Figure 2: Regulatory basis for requirements definition

3.2.1. WP1.1 Display and system requirements

During the execution of WP1.1 system requirements of flight decks displays as well as existing trends in display technologies were gathered and analysed.

The activity allowed to:
- Define 134 requirements covering single display equipment related aspects;
- Provide a preliminary description of the display system architecture.

The display shall allow multi-touch tactile interaction over the whole display to allow both crewmembers to provide inputs at the same time.

3.2.2. WP1.2 Operational requirements

WP1.2 tackled the definition of requirements relevant to operational aspects. These have been according to three categories: general, related to Direct End Users (i.e. aircrews), related to indirect End Users (i.e. company or airport operators).

The activity allowed to define 132 requirements.

The set relevant to General category tackled aspects that are tied to display integration/operation into the aircraft and have impact on display design. In accordance to the requirement subject, they have been grouped under the following specific sets: Operation, Interaction, Means of control, Use of colour, Lighting control and Reversion.

Direct end-user requirements focussed on the pilot tasks. A widely accepted, top-level classification of such tasks includes to Aviate, to Navigate and to Communicate. Consequently, this section addressing direct end-user requirements was divided into three subsections, namely Aviate Task, Navigate Task, and Communicate Task.

The requirements have been derived from design guidelines and certification requirements; for those aspects that are innovative and peculiar to ODICIS display, expertise from Consortium Partners and from dedicated interviews with aircrews was considered. In this respect a questionnaire was prepared to enquire, among Partner Company aircrews, on aspects like display lighting, means of interaction, tactile feedback, information presentation.

Answers were consolidated once they had the opportunity of interacting with a display prototype.

Indirect End-Users include those Users that interact with the display on ground to assure that the equipment is on condition and operational for service. Typically Indirect End-Users include airline or airport operators performing routine and non-routine maintenance tasks. In this case requirements were categorised as follows: General requirements, Accessibility, Mechanical installation, Electrical installation.

3.2.3. WP1.3 Safety requirements

Activities tied to WP1.3 were related to the identification and analysis of safety guidelines and conditions of certification of an airborne cockpit display. The relevant deliverable provided 85 requirements and tackled the following aspects:

- Identification of suitable guidelines to perform the safety analysis;
- Preliminary safety analysis at cockpit system level;
- Preliminary safety analysis at equipment level;
- Qualitative safety analysis of the projection based system;
- Certificability requirements at equipment level.

It is worth noting that the qualitative safety analysis of the projection-based system focused on those basic components that are original to the large display object of this project. In particular the main elements considered were relevant to the projection system and included LED Light source, Micro display panel.

It is finally noted that the requirements were derived against large display technical requirements only.

Preliminary discussion/sharing of results with EEAG members provided positive feedback on the adopted approach.

3.2.4. WP1.4 Preliminary evaluation plan

WP1.4 has produced a deliverable proposing a structured approach to designing the test scenarios to be used to assess the expected advantages and potential disadvantages of the target system across the whole project.

Three types of evaluation were proposed, including:

- Technical evaluation, considering the evaluation of physical-technical characteristics of either components or integrated systems and independent of the intended use context. The characteristics include: Image quality, modulation transfer function (MTF), distortion, brightness, power consumption, latency time of medias etc.
- Operational evaluation, considering the evaluation of pilot interaction with the demonstrator (i.e. the final, integrated prototype) in a sufficiently realistic operational context. Pilots' performance indicators, such as workload, situation awareness, correct input to cockpit systems will help to determine the overall efficiency of the single display.
- Part task evaluation, referring to the evaluation of pilots' interaction with system components while performing isolated tasks – e.g. interaction with the FMS. Tasks are realistic but are performed outside a complete flight scenario context.

For each evaluation type a template to be used for detailing the test requirements has been proposed.

Finally a matrix, allowing to trace the means of compliance to be provided to validate WP1 requirements has been proposed as a framework to be progressively populated as the project develops.

3.3. WP2 Technologies

The general objectives of the work package "Technologies" are:
- To define and build adequate display hardware fitting the single display cockpit requirements based on projection display.
- To define and build the adequate means of interaction, such as multitouch or haptics.

3.3.1. WP2.1 Technologies Monitoring and study

The purpose of this WP was to identify the most appropriate media technologies that are able to fly and to interact with the single display surveying the relevant evolutions in display technologies. The key aspects pursued by this workpackage are summarized in the following points:
- To provide an overview the state of the art tactile technologies used to interact with the display that must preserve high quality viewing and finger tracking accuracy.
- To provide an overview of possible haptic solutions and define tactile sense of specific controls.
- To formulate the functionality requirements of media technologies used by the pilots as input to the display (keyboards, cursor control device (CCD) for point-and-click, tactile, etc).
- To propose a suitable optical engine technology and the associated light source.
- To review the projection technologies matching the optical engine and the light source.

3.3.1.1. Optical Engine architecture and Illumination system

Optical Engine is a common word to describe the projection system assembly going from the light source to the projection lens. Generally speaking an Optical Engine is made of three parts, namely the illumination system, the colour management with the Micro display panels and the imagery part.

The choice of the best architecture is manly related to the Micro Display type. In our case, LCOS technology is the most promising in terms of resolution and availability for the project as well as for future applications.

When a LED light source is used, we have to recombine the colours from the R, G & B LEDs in order to properly illuminate the colour quad.
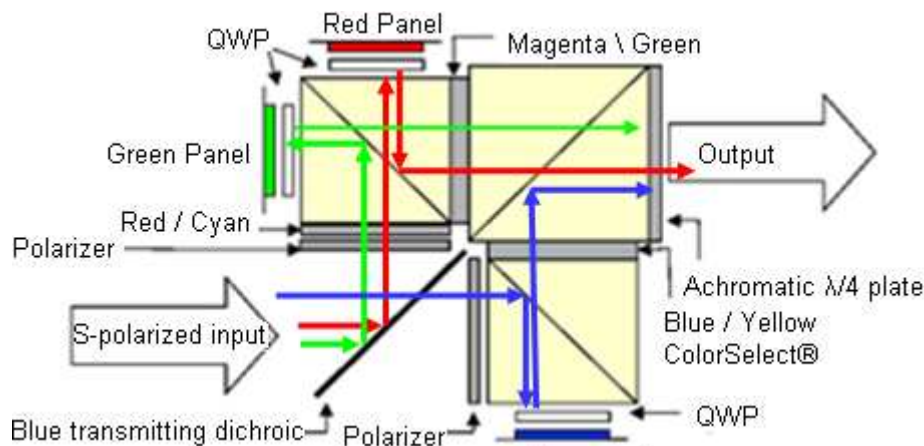
Figure 3: Colour Quad System

The use of LEDs as light sources in projection systems has rapidly gained popularity in recent years. Focus is of course on smaller systems (mostly pico-projectors and slightly larger) because the light output of LEDs is still not up to par with arc lamps. However, the display sizes envisaged in this project fit exactly with the capabilities of the LEDs.

In general, the solid-state nature of LEDs makes them ideally suited for the avionics environment, thus providing the natural choice for the project.

3.3.1.2. Screen Technology

In any rear projection mode, the screen is of a great importance for the image rendering. Brightness uniformity, contrast and distortion are related to screen performances.

The Screen technology is available today to project (in rear mode) large images. Here is a list of issues we had to resolve in order to use efficiently rear projection screen in our project for the single cockpit:

- Avoid Moiré and image quality issue with small size projected pixel;
- If Fresnel lens should be used (for each seamless display), then we need to build an assembly of several Fresnel lenses with very small boundaries (less than 1mm).
- And finally the main challenge of screen function (as an image diffuser) is to be also used as Tactile (single or multi touch display). Here is the main challenge, since we had to check if two technologies are compatible when mixed together.

3.3.2. WP2.2 Technologies Definition

The purpose of this WP is to explain the choices made for the different subassemblies of the display hardware as well as for the configuration of the interactive cockpit projection system as a whole.

3.3.2.1. Optical core

For the project, we decided to use LCOS technology, since it is the most suited in terms of availability, and higher resolution comparing to other Microdisplay technologies.

3.3.2.2. Projection optics

Our theoretical results show that it is possible to have a lens design with good performances in term of sharpness and distortion. We also demonstrate that it is possible to have a very short projection distance i.e. a small footprint to be within the specification of nearly 150mm behind the screen.
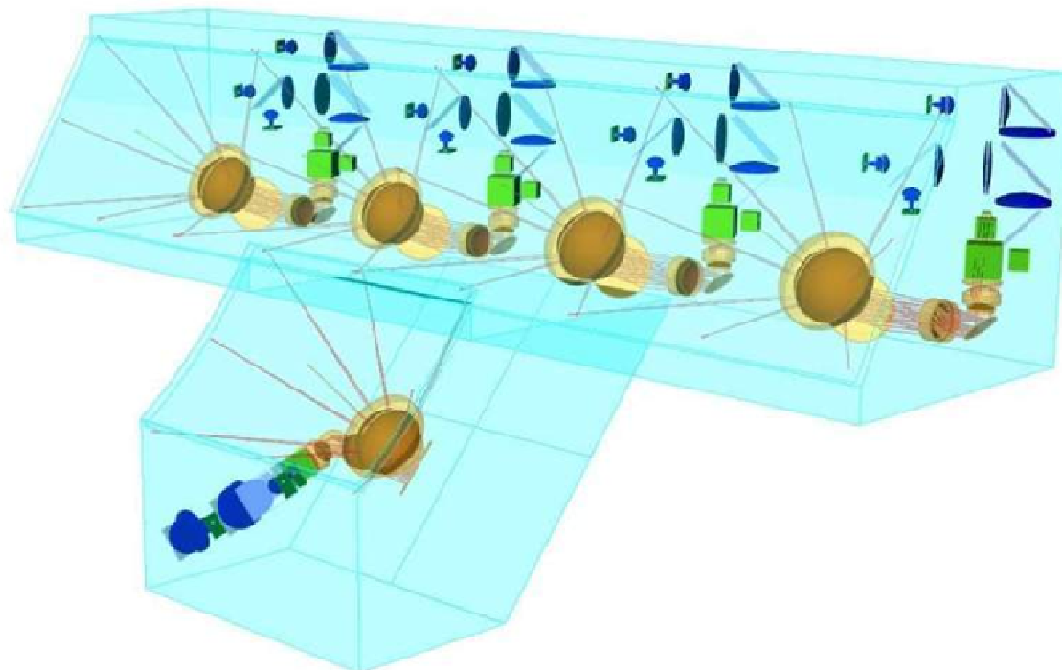

Figure 4: model of projectors integrated in the single display

The main optical performance parameter is the Modulation Transfer Function (MTF), which indicates the level of resolution that is supported by the lens at Nyquist frequency (aka pixel frequency). The simulated optics features an MTF within the specification established in workpackage 1.

3.3.2.2.1 Led Light source and driving

The main markets for LEDs are nowadays general lighting, automotive and backlights for flat panels. Consequently, only a few manufacturers offer LEDS that are specifically developed for use in projection systems.

The main characteristic of an LED developed for projection is its higher luminance, as opposed to the high efficiency that is usually aimed for in general applications. High luminance is beneficial to keep étendue values low, even at high light flux, which is a crucial point in projection technology.

A selection was made based on the matching of étendue between the LED chips and the microdisplays. This ensures a minimum waste of light.

3.3.2.2.2 Screen technology

The screen is a multi-layer subsystem. It is composed of a diffuser, Fresnel lenses, carriers and an anti-reflection treatment on the front carrier.

The primary optical function is performed by the diffuser whose role is to redirect the image from the projector to the viewer. It diffuses the image located in the screen plane into the whole viewing space.

Different technologies are used for this purpose. The simplest one is the diffusing technology where the incident light is diffused in the whole space thanks to the roughness of its surface. The other technology is based on micro-optical structures to increase the screen contrast.

3.3.2.2.3 Interactive technology

The interaction system architecture choice for ODICIS is based on the comparison of currently available multi-touch interaction surfaces as reported in WP2.1 and several requirements set forth in WP1. Additional constraints, which involved overall system footprint minimization, were taken into account in the proposed solution. An all-optical architecture is chosen, as it is capable of delivering full multi-touch access over complex display surfaces while remaining compatible with the aforementioned requirements.

This is achieved by using a number of light sources on the sides of the display and optical sensors behind the screen which pickup characteristic signals as the fingers of the pilot touch the display surface. Such an architecture that allows multiple simultaneous finger interactions relieves limitations imposed by single touch or time multiplexed multi-touch systems.

Figure 5: tactile system principle (left) and whole display sensing (right)

3.3.3. WP2.3 Technologies prototyping

Key parts of the whole system such as the wide angle projection optics and Fresnel lenses were specified by Optinvent and manufactured by specialized companies. In some cases the small number of components did not allow us to drive the manufacturing cost down. This was the case of LED beam shapers. These pieces have been milled by an external company to a rough shape then fine polishing to get an optical was realized by IMEC.

IMEC also designed and tested the LED driving boards. An associated software was designed to adjust the display brightness and colour balance from a remote PC.

TEIP designed all the electronics and optical pieces associated with the tactile system. An image processing software was also developed in order to be able to merge the data of all the optical sensors and extract the touch coordinates.

3.3.4. WP2.4 Part task evaluation

The part task evaluations first started with some measurements of the LED characteristics associated with the LED driver boards.

Figure 6: LEDs optical test bench

Then an evaluation of individual projectors was carried out in terms of image quality by means of dedicated test patterns as shown in the figure below.
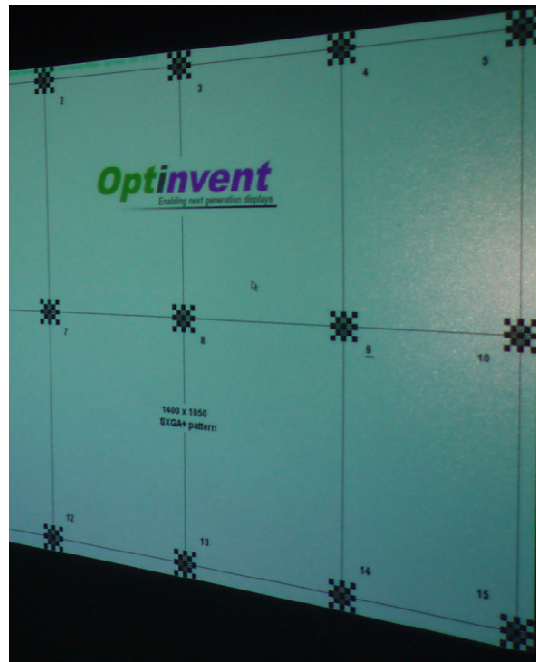
Figure 7: front-projected image of one projector. The apparent keystone is due to the camera and not to the projection lens

Finally an A4 size tactile screen was designed with optical pieces similar to the final display was put in place to develop the image detection algorithms and perform some preliminary performance measurements.

3.4. WP3 Display System

The objective of this workpackage was to design a system architecture, which achieves the single display cockpit requirements. The system architecture defines the hardware components required to allocate the functional components as defined in WP1. In the following step the graphics generator were analysed and designed followed by a safety analysis of the components. A demonstration platform to demonstrate the image management algorithms was developed and integrated with the projection solution provided by WP2.

3.4.1. WP3.1 System specifications

The objective of this work package was to develop the system architecture of a single display cockpit in accordance to the requirements gathered in WP1.1, 1.2, and 1.3. The system architecture consisting of the hardware and software components for the data processing, the graphics generation, the projection system and the interfaces are specified in deliverable "D3.1 System architecture". The results of this workpackage were used by WP3.2 to develop the graphics generator and WP3.4 to integrate the system components.

3.4.1.1. Functional components breakdown

Starting with the first functional approach defined in WP1.1 the interfaces and the use cases of the Control and Display System (CDS) were analysed. The interfaces were identified by specifying the actors of the CDS. These are not only the crewmembers or maintenance operators; these are also other aircraft systems, sensors, the aircraft itself, for instance by vibration, or environmental impacts like temperature or sunlight. The following figure shows an overview of the CDS and the related actors.
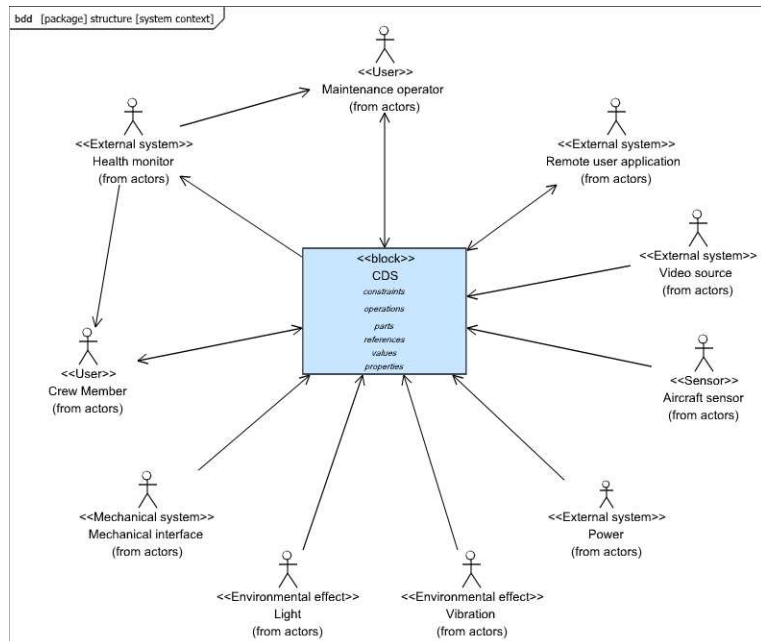
Figure 8: Control and Display System context

For each actor, use cases then identify the way of interaction with the CDS. For this analysis, focus was set to use cases related to the actors "crew member" and "maintenance operator". Based on the actors, their interfaces and related use cases the functions are refined to sub-components and functional blocks.

3.4.1.2. Functional to physical components allocation

In the following step two different physical architectures for the CDS are discussed. These are the
- Smart architecture,
- Dumb architecture.

The following figure gives an overview of the physical architectures.
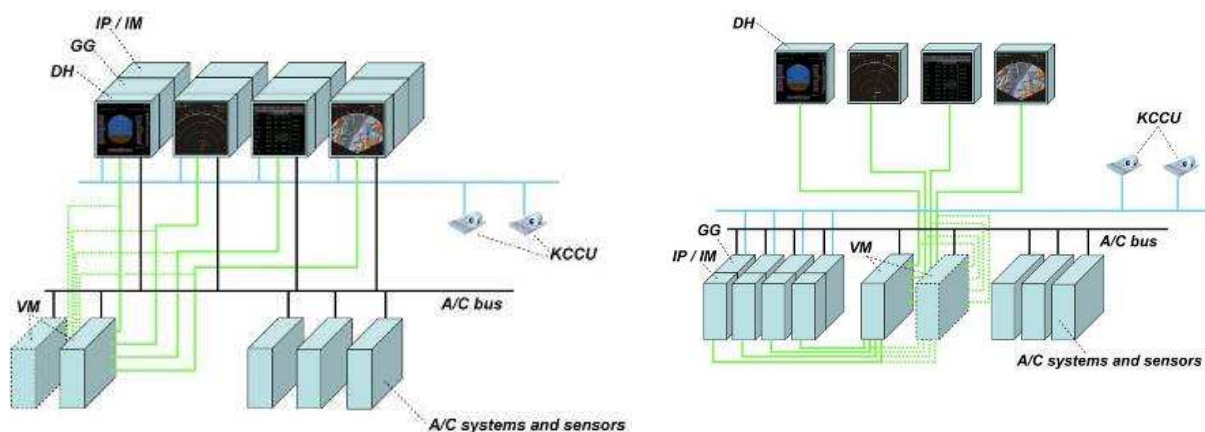
a) Smart architecture   b) Dumb architecture

Figure 9: overview of physical architectures

In a smart architecture all functional components are located in the Display Unit (DU). This architecture provides benefits for performance due to the close arrangement, which allows high-speed interfaces, and for safety due to their redundancy.

In contrast to the smart architecture a dumb architecture locates only the display heads in the cockpit. This provides more versatility in the Line Replaceable Units.

3.4.2. WP3.2 Graphic generation

The two main objectives of this WP were to define a suitable graphics generation and video processing solution based on the result of the WP3.1 chosen system architecture and to build a demonstration platform which allows evaluating and demonstrating the single cockpit display approach.

The following figure shows a first draft of a Graphics Generation Unit based on a standard ARINC600 box.
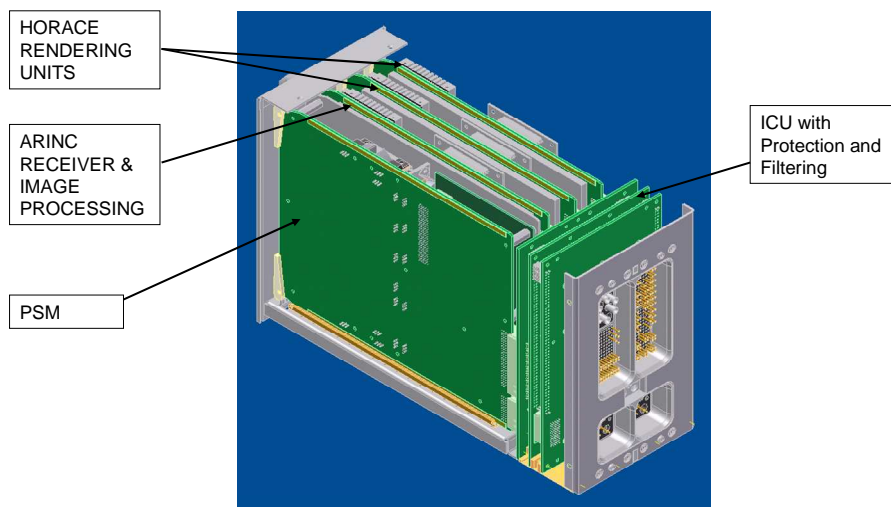
Figure 10: first sketch of a GVPU ARINC 600 box

The following schematic shows the hard- and software layers building the demonstrator platform consisting of multiple clients, named ODC clients, representing the different applications like PFD, ND and so on, the ODC server as middleware between the clients and the demonstrator platform build by a Linux operating system and X11 server.
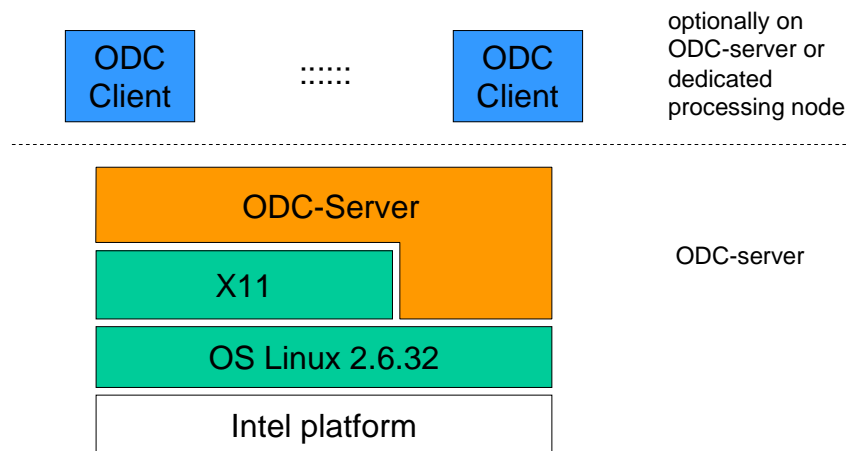
Figure 11: hard- and software layers of the demonstrator platform

The following steps were to integrate
- The images blending and warping algorithms;
- The interface to the touch screen handling;
- The interface for the display brightness control.

3.4.3. WP3.3 Safety analysis for technical aspects

Based on the design results from WP3.2 a preliminary calculation of the "Mean Time Between Failures" according to MIL-HDBK-217F [3] was calculated for the different components of the display system.

This first started with safety-based design to make sure that the objectives of data availability and integrity can be met.

Then a quantitative analysis was performed. In this phase the criticality of the parameters available to the pilots were listed. Fault trees involving the different pieces of equipment were constructed and the minimal required hardware component DAL (Development Assurance Level) was chosen by taking the highest DAL required on each tree leave.

Considering the requirements on the design, Development Assurance Levels, the safety mechanisms and the built-in redundancy, the ODICIS system fulfils the safety requirements.

3.4.4. WP3.4 System integration

The goal of this workpackage was to bring together the cockpit mock-up, the projection optics, the tactile system and the ODICIS server that manages the display of images.

The mock-up has been designed in a modular way to ease its transportation. It is composed of:
- The display chassis on which the display is maintained. It is the housing of the projectors; it was initially designed to accommodate some PCs but we found more convenient to leave the PCs outside.
- The pedestal that holds the mini tactile displays, the thrust levers, the speed brakes lever, the cursor control device and the flaps lever;
- The floor that is placed around the display chassis and pedestal;
- The seats that are linked to the floor with the possibility to move back and forth as well as lean forward and backward. The seats are endowed with a side-stick on the external armrest.
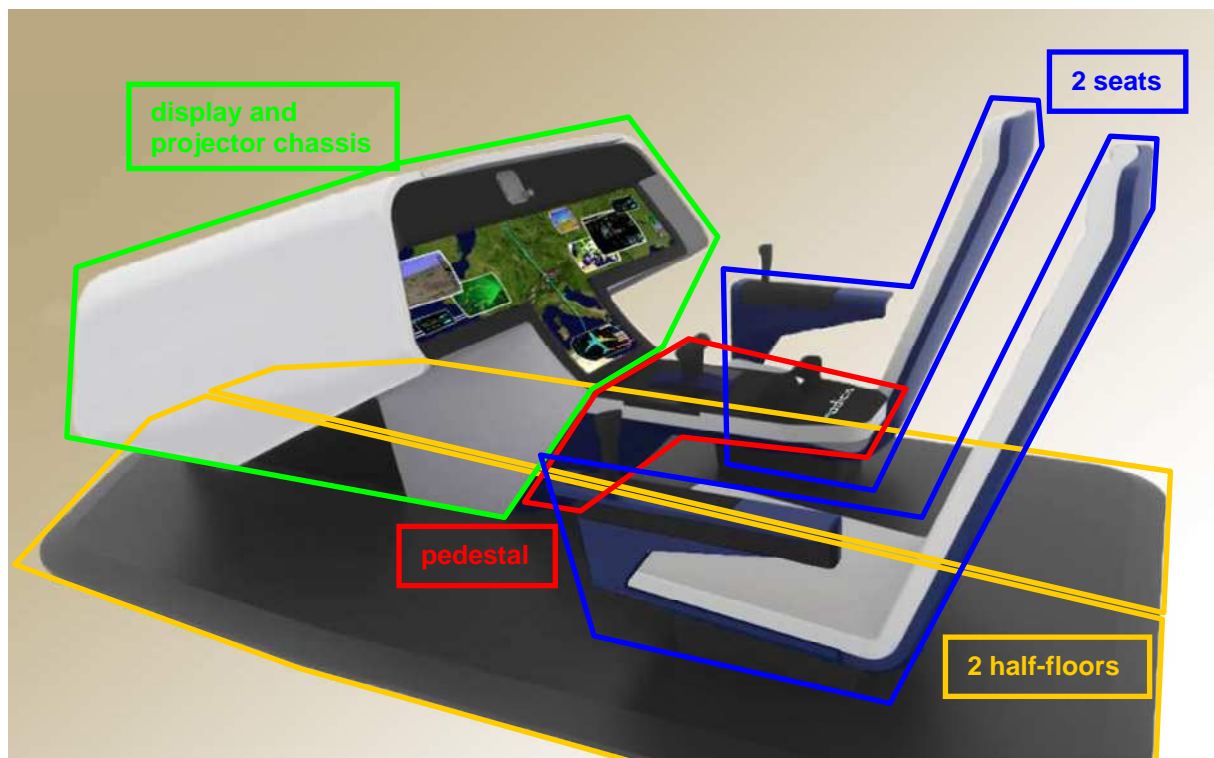
Figure 12: mock-up structure overview

The integration started with the mounting of the projectors on their base plate. The base plate was then inserted into the mock-up. Then, the screen assembly took place in a clean room with the integration of the optical pieces and electronic ones essentially related to the tactile system.

The ODICIS server managing the displayed information was then integrated in the whole system. This allowed performing the final adjustments on image processing and calibrating the tactile system.

3.4.5. WP3.5 Part tasks evaluation

Before the integration of the final mock-up, a simplified demonstrator was designed within Diehl's premises for the part task evaluation of the graphics generation and the functions of the ODICIS server platform. It consisted of 5 commercial projectors embedded in a box with a screen. Due to the focus distance of 110 cm the box was large. The following figure shows the design of the box.
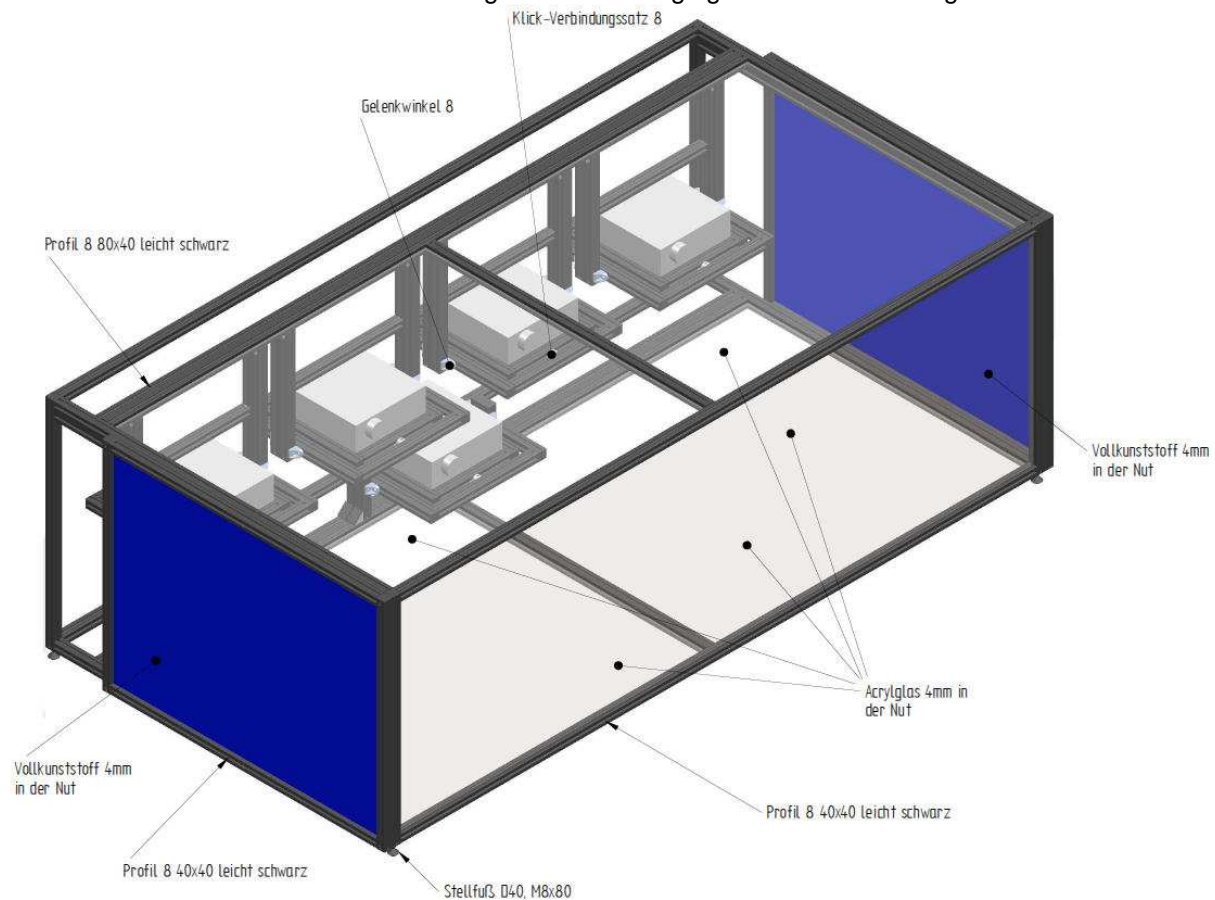
Figure 13: Schematic of graphics generation evaluation platform

The following pictures show the evaluation platform from rear and front:

| Rear view | Front view |

Figure 14: Graphics generation evaluation platform

To test the different communication protocols, these are

- Touch Screen Management configuration and operation protocol,

- Remote Frame Buffer (RFB) protocol,

- Tangible User Interface Objects (TUIO) protocol, and

- ARINC 661 protocol

A dedicated work station was used connected via Ethernet to the ODICIS server platform, see following figure.
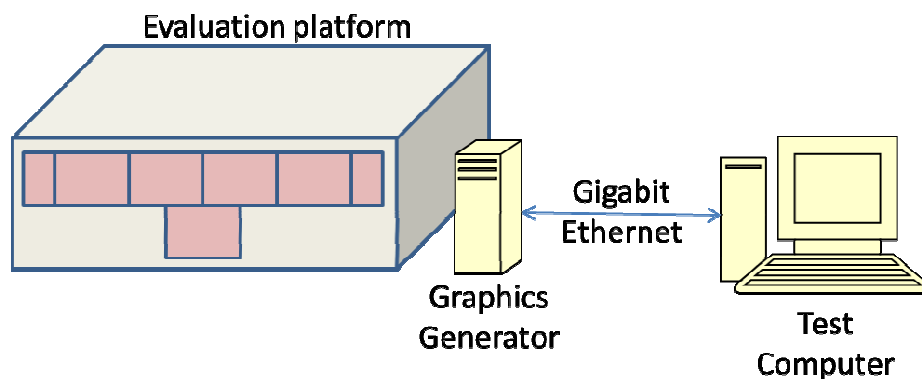
Figure 15: Test environment

Using this environment the functions and interfaces of the ODICIS server platform could be tested.

3.5. WP4 Concept of Use

The objective of this workpackage was to define and assess a proposal for the use of a single display. It first started with the definition of the shape of a single display and the organisation of the usual controls (thrust lever, landing gear control lever, standby instrument, etc.). The second objective was to propose a Human Machine Interface (HMI) suited to the single display. This process went from the high-level information layout to a detailed proposal of HMI for each fundamental format (Primary Flight Display, Navigation Display, System pages, etc.). Finally a key expected outcome of this workpackage was the definition and prototyping of the ODICIS mock-up.

3.5.1. Human Machine Interface definition

The crew tasks during the various flight phases have been analysed. These phases include engines off (pre-start-up and post shutdown), start-up and shutdown, taxi, take-off, climb, cruise, descent, approach, final approach, landing (and missed approached) and abnormal situations.

Even though the display appears as a single surface, the hardware behind the screen is also an important feature to take into account. The requirement to be able to reconfigure the display in case of projector failure is very important.

In line with certification requirements, it is necessary for the ODICIS display concept to be able to cater for the event of a single projector failure in flight. This implies that the proposal needs to enable the crew to safely continue the flight in such an event. In addition, for operational requirements, it is also required to be able to dispatch the aircraft with a single the event of a projector. This, in turn, implies that the proposed concept is also required to cater for the event that two projectors are unavailable during flight.

Consequently, reversion strategies are being proposed in the event of single and double projector failures following the analysis of the impact of such events. Naturally, this results in degraded operation of the ODICIS HMI concept, where the functionalities are reduced but the impact on the safe continuation of the flight is conceived not to be jeopardised.

3.5.2. WP4.2 Functions selection and case studies

One of its high-level goals was to define the evaluation scenarios that allowed to:
- Assess the acceptability of the single display
- Evaluate the proposed HMI.
- Define the functions that we intended to highlight.

The evaluations took place on desktop computer screens in WP4 and on the ODICIS mock-up in WP5.

The resources allocated to WP4 did not allow us to set-up a flight simulator. Essentially still images were provided and some areas provided a tactile interactivity. Furthermore an operator managed the transition between the different steps of the scenario for example to assess the transition between flight phases.

3.5.3. WP4.3 Safety Analysis for operational aspects

This workpackage has provided an analysis, from safety and certification viewpoints, of the most significant ODICIS display functions. The activity has been carried out by means of the following steps:
- Description of the ODICIS display allocated functional baseline;
- Definition of a set of top level functions, peculiar to ODICIS display;
- Description of the safety analysis method, featuring Functional Failure Modes and Effects Analysis (FMEA), Development Assurance Levels allocation and Common Cause Analysis;
- Description of the certification analysis framework, featuring the European Technical standard Order route and the Type Certificate/Supplemental Type Certificate route;
- Execution of the analysis.

The following conclusions can be derived:

The ODICIS display comprise of a set of technologies/solutions and design solution which are unique of a display for aeronautics purposes; considering such innovations, there is the opportunity of generating a set of recommendations to be considered for further presentation in forums devoted to guidelines and standard update activities.
The integration of such technologies/solutions requires a safety oriented approach which has been outlined by a number of requirements already captured, at prototype level, in the ODICIS display.

3.5.4. WP4.4 Human Machine Interface prototyping

The Human Machine Interface prototyping started ahead of schedule with some low level activity because it was expected that many iterations would be necessary to converge to an acceptable proposal. It is understood that the development of a certified HMI, though out of scope of ODICIS, can actually take many years.

The goal of the ODICIS mock-up and concept of use was to provide a Human Machine Interface that would allow pilots to get a better understanding of how a future single display cockpit could look like

and how they would be able to make the most of it. With this objective the mock-up essentially features still images that represent different flight phases.

In addition to the still images, interactive formats can be displayed to illustrate the tactile capacity of the mock-up and better consider the innovative ways of interaction offered by this technology.

The still images have been designed with Adobe Illustrator, a vector graphics software. The interactive pages have been designed with QML, a JavaScript-based, declarative language for designing user interface–centric applications. It is part of Qt Quick, the user interface creation kit developed by Nokia within the Qt framework.

3.5.5. WP4.5 Part task evaluation

The part task evaluations were realised on two main aspects: the static Human Machine Interface and the interactive one. For the latter, different aspects have been investigated. These include the direct tactile manipulation of a graphical flight plan, interaction on a deported view, tactile input in a turbulent environment and secured tactile inputs.

Considering a direct manipulation of a graphical flight plan, an original experimental approach has been chosen, with an incremental progression from a traditional physical cockpit, to a tactile flight simulator reproducing traditional controls, to a prototype navigation display with direct tactile functionality, first located in the traditional low position, then located in front of pilots in desktop-like set-up.

The ODICIS project has introduced the use of a large single touch-screen as a concept for future airplane cockpit. The human-machine interaction in this new cockpit must be optimised to cope with the different types of normal use as well as changes such as turbulences (which can occur during flights with different levels of severity).

In this part-task evaluation, the focus is set on moderate turbulences. It is understood that in severe turbulences characterised by temporary losses of the control of the aircraft, the only task of the crew is to keep the aircraft flying. Tactile input in turbulences were investigated in an experiment involving a state-of-the-art 22″ (56cm) LCD touch-screen, which was safely mounted on a roller coaster (cf. Figure 16). Participants had to repeatedly solve three basic touch interactions: a single click, a one-finger drag-and-drop, and a zoom operation involving a 2-finger pinching gesture. The completion times of the different tasks as well as the number of unnecessary interactions with the screen constitute user data that were collected. An accelerometer and gyroscope provided sensor data regarding the force impact and direction of the rollercoaster ride.

Figure 16: tactile screen mounted on a rollercoaster

These evaluations provided a better insight into the way to design an HMI suited to turbulences and get pilots "buy in" to the possibility of having large tactile screens onboard aircraft.

3.6. WP5 Validation

Following the various part task evaluations, the goal of WP5 was to provide evaluations on the final mock-up.

The evaluations decomposed into technical evaluations and operational evaluations.

The technical evaluations aimed at assessing aspects such as image quality brightness, viewing angles, power efficiency, response time of the tactile system, etc. One of the key features of projection technology is that it retains a good image quality and colour consistency at large viewing angles.

The operational evaluations took place with pilots from Alitalia and also experts from the External Experts Advisory Group (EEAG). Some questionnaires were filled during the evolution of a scenario involving several flight phases by 4 test persons in December 2011, and then 8 test persons in January 2012 on the last iteration of the interfaces, for a total of 12 participants (N=12).

3.7. WP6 Exploitation and dissemination

The objectives of this work package were to define the industrial exploitation plan, to ensure dissemination of results to stakeholders, European industries and academics and to ensure communication through publications and a website.

The communication and dissemination strategy was transversal to the whole project. Dissemination is essential to ensure that the results of ODICIS reach the widest possible group of European stakeholders and hence secure the biggest possible societal impact in Europe.

The target audience for dissemination were (a) pilots in their role as end-users, aircraft manufacturers as potential customers, (b) the authorities that will be involved in the required rulemaking, safety assessment and certification of the newly developed on-board system and (c) the wider aviation community and general public.

Dissemination and promotion of ODICIS results happened through large-scale communication events (symposiums, publications, web site) and workshops that favoured the exchange of ideas.

Communication events included European scientific symposiums either impacted by the whole ODICIS concept or only part of it such as display technology to present the project results.

Dissemination to a wide audience was also ensured through publications at conferences, in journals and in media.

Promotion of the project was finally achieved by means of a dedicated web site designed to present the scope and objectives of ODICIS.

To stimulate cross-pollination of ideas, workshops were held three times during the project lifetime with an External Expert Advice Group composed of different European airliners, aircraft manufacturers, official organisation and certification experts. The workshops offered the opportunity to exchange on the concept, reliability and the safety of a single display cockpit, using the results of the project.

3.7.1. ODICIS image

The images associated to the ODICIS project identify it and convey its innovative character. That is why a particular attention has been given to the creation of the logo and the artist view representing One Display for Cockpit Interactive Solution (ODICIS).

3.7.1.1. Logo

It was used in the heading of the documents produced during the project and for communication activities (leaflet, folders, website, etc.).
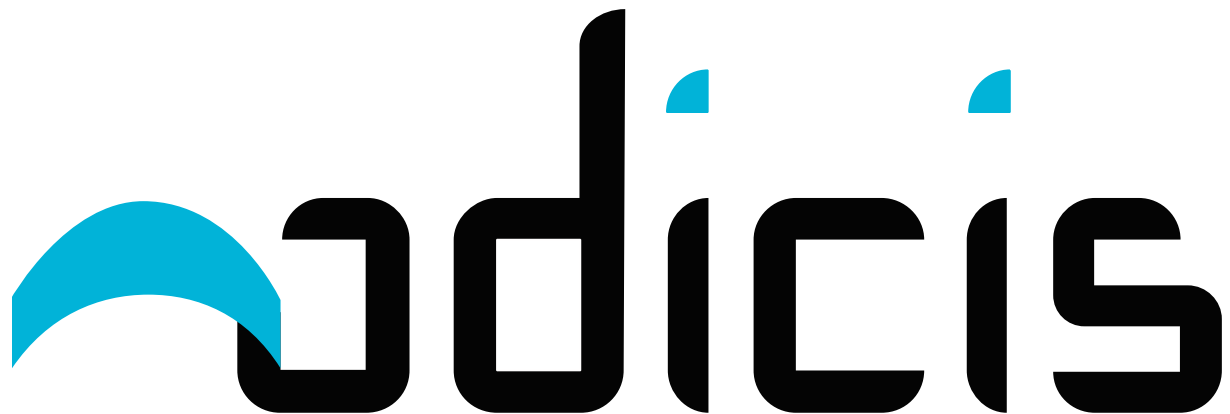
Figure 17: ODICIS logo

3.7.1.2. Artist view

The artist view was used in every presentation (.ppt, etc.) on the introduction slide. It is also used in every dissemination activity. It is now well associated to ODICIS project in people minds.

It has been requested by journalists and scientists to illustrate their articles or presentations involving ODICIS.
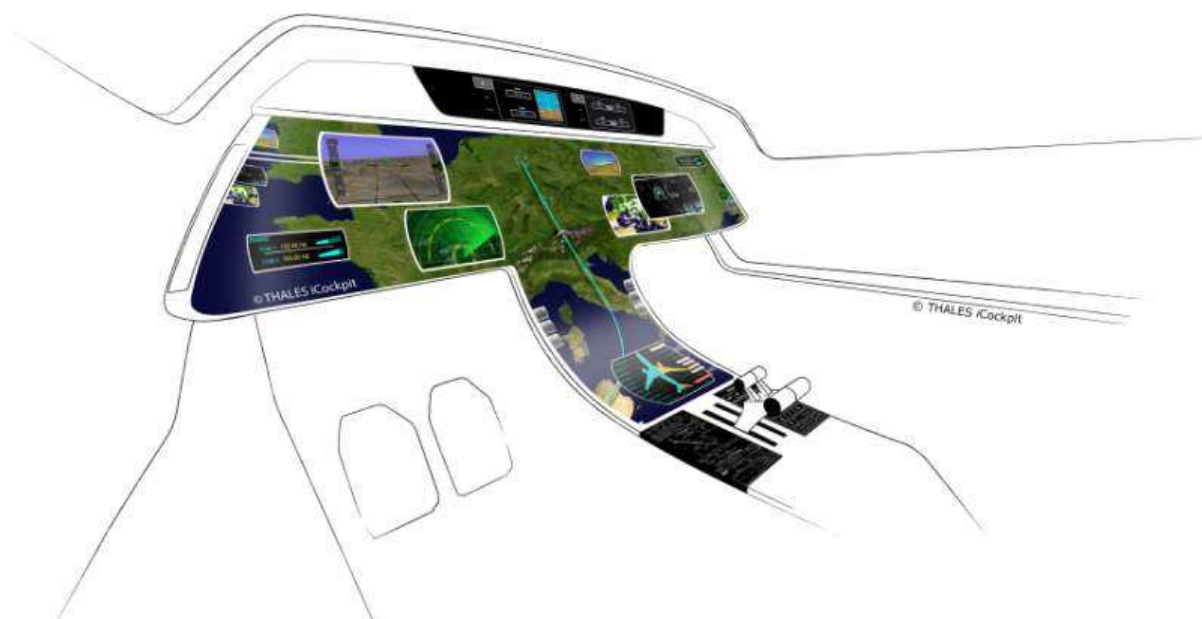
Figure 18: Artistic view of ODICIS display

3.7.1.3. Pictures

Since the mock-up is available, the pictures below (Figure 19 and Figure 20) have been used to illustrate dissemination activities about the ODICIS project. These pictures are also transmitted to journalists who ask for it.

Figure 19 : picture of the ODICIS mock-up

Copyright: Thales Avionics / Philippe Coni

Figure 20: picture of the ODICIS mock-up

3.7.2. Website

The main source of information for the project was the website, available at www.odicis.org. It provides a place of reference for people interested in the project as well as a repository for documents shared between the partners involved.

The website structure is very simple to use, with a menu on the left used for navigation. The different pages that can be accessed include the project description page, which provides an overview of the whole project. Another page introduces the partners of the project, while the news page and events page are meant to keep the users up to date with what is going on with the project. Publicly available documents are available on the documents page, which also allows logged-in users to access other documents available only to partners. Logged-in users also have access to specific work package documents and to other published documents. Finally, in the "contact us" area all the partners contact details are listed.

Figure 21: ODICIS website home page

3.7.3. Leaflet

The leaflet is an overview of the project printed on a single A4 sheet of paper, in landscape mode and meant to be folded in 3. It presents the context, objectives and consortium of ODICIS. It was intended to be distributed during workshops or promotion activities.

The final version was approved by all the partners in July 2009 and has been available for download on the ODICIS web site since then.

Below is a link to the ODICIS leaflet.

https://www.odicis.org/files/file_download.php/ODC_WP6AF_THAV_ODICIS_leaflet_web_site_v1.01.
pdf?FileID=44

Figure 22: leaflet – recto

Figure 23: leaflet – verso

3.7.4. Overview presentation

An overview presentation has been made for dissemination purpose. This presentation is available on ODICIS website and can be sent to anyone interested in the project.

Below is a link to this presentation.

https://www.odicis.org/files/file_download.php/ODICIS_project_overview_presentation.pdf?FileID=5

3.7.5. Press Releases

Many press releases have been published. The full list is available in deliverable D612 and in the overview Table 4.

3.7.6. 2011 Paris Air Show

20th – 26th June 2011

Le Bourget, France

Figure 24: advertisement for the 2011 PAS on the ODICIS website

Figure 25: presentation of ODICIS as a European Project

Figure 26: mock-up installation on Thales stand

The ODICIS mock-up was the Focus Point of the Thales stand and was a real success. It was visited by numerous people including CEOs of major aeronautics actors.

The presentation of the ODICIS mock-up at the 2011 Paris Air Show was also a success regarding the number of press releases produced during the show: 14 articles released.

2011-06-17_Air et Cosmos_Le cockpit du futur selon Thales.pdf
2011-06-20_AIN Paris Airshow News_Thales has 20-20 vision for cockpit of the future.pdf
2011-06-20_AINonline_Paris 2011-Thales Exploring Future Cockpit Displays with Odicis.pdf
2011-06-20_Flight Daily News_Thales displays cockpit vision.pdf
2011-06-21_Avionics Intelligence_New Thales single-display cockpit concept showcased at Pari.pdf
2011-06-21_Bright Side Of News_Thales Presents Star Trek-like Cockpit for Planes and Helic.pdf
2011-06-21_Flight Daily News_PARIS-Thales presents single screen cockpit in Le Bourget.pdf
2011-06-21_IHS Jane's_Paris Air Show 2011 - Thales unveils seamless future cockpit concept.pdf
2011-06-21_Les Echos_Un seul ecran tactile pour le cockpit du futur.pdf
2011-06-22_Flight Daily News_PARIS-Thales's flightdeck of the future on show at Paris.pdf
2011-06-23_Euronews_Is it a plane- Is it a helicopter- No it's the X3_en.pdf
2011-06-23_Objectif News_Thales invente le cockpit du futur et recrute à Toulouse.pdf
2011-06-24_www.militaryaerospace.com_Honeywell Primus avionics system viewed above 20,000 .pdf
2011-06-26_France3 Aquitaine_Le cockpit du futur presente au Bourget.pdf

Table 2: list of press releases during the Paris Air Show

As a conclusion, one can say that, when confronted to the ODICIS mock-up, people were generally impressed.

3.7.7. External Expert Advisory Group

An EEAG is a very good tool for dissemination: as successfully implemented in the FLYSAFE project, the EEAG workshops enable interest groups, potential users and specialist groups to be informed about the goals, work progress and results of the project. The meetings also contributed to cross-pollination of ideas and to get valuable inputs or steering from outside the consortium.

The expected members of the Advisory Group are European airliners, aircraft manufacturers, official organisations and aviation safety experts. To maximise the audience, the ODICIS consortium reimbursed the expenses (travel, meal, accommodation) of the external parties, as they have no budget for those activities.

Workshops were held three times during the project lifetime.

Month	Venue	Topic
6 (12/10/2009)	Paris, Charles de Gaulle Airport	The group reviewed the requirements issued in WP1 to design a single display cockpit. The related deliverables were sent to the experts before the meeting while the questions from all the partners were sent before week 37 (2nd week of September). At such an early period in the project, the focus was on receiving practical inputs from member's daily experience and on identifying incompatibilities and deficiencies regarding the whole project.
15 (29/07/2010)	Malta	The second meeting was held nearly in the middle of the project duration and was an opportunity to review the concept of use and operational impacts of the single display cockpit. During this design phase, the objective was to get the feedback of the experts on interim results.
33 (01/2012)	Le Haillan, France	During the final meeting, the group made operational evaluations on the mock-up and associated human machine interface. Experts were divided in two groups for two people. The evaluations took 1 day for each group.

Table 3: EEAG meetings schedule

The conclusions allowed iterating within the impacted WP. For instance, the workshop about the concept of use and operational impacts provided inputs for iteration in WP4.

3.7.8. Dissemination Overview

Dates	Type	Type of audience	Countries addressed	Size of Audience	Partner responsible / involved
02/06/2009	Presentation on LCOS at 2009 SID International Symposium: "LCOS devices for professional Projection Displays"	Display industry	International	N/A	IMEC
01/08/2009	ODICIS preliminary website goes online (www.odicis.org)	www	International	N/A	TEIP
15/08/2009	ODICIS leaflet available on ODICIS website	www	International	N/A	THAV
07/09/2009	ODICIS project overview presentation available on ODICIS website	www	International	N/A	THAV
08/09/2009	Presentation given at the German Air and Space Congress	Aviation Experts	German	30	DASP
26/09/2009	Presentation given at the International Scientific Conference: eRA-4 The SynEnergy Forum	Scientific Experts	International	25	TEIP
12/10/2009	First EEAG meeting at Paris Charles de Gaulle Airport	Aviation Experts	European	6	UOM
20/11/2009	Article published on Aviation Week website	Aviation industry	International	N/A	-
03/2010	Use of the ODICIS picture in a presentation given by Darmstadt University	Display industry	Germany	?	THAV
19/04/2010	ODICIS project registered on press4transport website	Transport industry	European	N/A	THAV
23/04/2010	Article published in Air & Cosmos magazine n°2215	Aviation industry	France	N/A	THAV

Dates	Type	Type of audience	Countries addressed	Size of Audience	Partner responsible / involved
01/06/2010	Article published on Aviation International News website	Aviation industry	International	N/A	THAV
06/2010	Article published in Volare magazine	Aviation industry	Italy	N/A	-
22/06/2010	Public dissemination event in Brussels	Aviation Experts	European	30	THAV
27/06/2010	Press release published on Press4Transport website	Transport industry	European	N/A	THAV
18/07/2010	Article published on Trend Hunter website	www	International	N/A	-
29/07/2010	Second EEAG meeting in Malta	Aviation Experts	European	6	UOM
29/11/2010	Video published on DR1 TV channel	General public	Denmark	N/A	DTU
01/12/2010	Presentation given at International Display Workshops 2010	Display industry	International	?	IMEC, OPTI
04/12/2010	Article published on Videnskab dk website	General public	Denmark	N/A	DTU
23/02/2011	Presentation given at 2011 ECA Aviation Safety Day	Aviation industry	International	?	THAV
30/03/2011	Presentation given at Aerodays 2011	Aviation industry	International	40	THAV
30/03/2011	Posters displayed at Aerodays 2011	Aviation industry	International	>100	THAV
17/06/2011	Article published in Air & Cosmos magazine n°2270	Aviation industry	France	N/A	-
20/06/2011 26/06/2011	ODICIS mock-up presented at the 2011 Paris Air Show on Thales stand	Aviation industry	International	>1000	THAV
20/06/2011	Article published on Aviation International News website	Aviation industry	International	N/A	-
20/06/2011	Article published in Aviation International News newspaper dedicated to the Paris Air Show	Aviation industry	International	N/A	-
20/06/2011	Article published in Flight Daily News, a Flight Global newspaper dedicated to the Paris Air Show	Aviation industry	International	N/A	-
21/06/2011	Article published on Flight Global website	Aviation industry	International	N/A	-
21/06/2011	Article published on Military & Aerospace website	Military & Aerospace industry	International	N/A	-
21/06/2011	Article published on IHS Janes's website	Defense & Security industry	International	N/A	-
21/06/2011	Article published in Les Echos newspaper	Financial industry	France	N/A	-
21/06/2011	Article published on Bright Side of News website	General public	International	N/A	-
22/06/2011	Article published on Flight Global website	Aviation industry	International	N/A	-
23/06/2011	Article published on Objectif News website	Financial industry	France (Midi-Pyrénées region)	N/A	-

Dates	Type	Type of audience	Countries addressed	Size of Audience	Partner responsible / involved
23/06/2011	Video published on Euronews TV channel and website	General public	International	N/A	-
24/06/2011	Article published on Military & Aerospace website	Military & Aerospace industry	International	N/A	-
26/06/2011	Video published on France3 Aquitaine TV channel and website	General public	France	N/A	THAV
27/06/2011	Press release published on Press4Transport website	Transport industry	European	N/A	THAV
01/07/2011	Article published in Defence Helicopter magazine	Aviation industry	International	N/A	-
07/2011	Article and video published on Thales Onboard online magazine	Aviation industry	International	N/A	THAV
23/08/2011	Article published in IMEC Newsletter	General public	International	N/A	IMEC
31/08/2011	Article published in La Revue du Design	Design industry	France	N/A	-
01/09/2011	Article published on The Engineer website	General public	International	N/A	IMEC and THAV
20/09/2011	Presentation given at 2011 AIAA Aviation Technology, Integration, and Operations (ATIO) Conference	Aviation industry	International	?	UOM
10/2011	Article published in Objectif Aquitaine	General public	France (Aquitaine region)	N/A	-
04/12/2011	Article published in Sud Ouest newspaper	General public	France (South West area)	N/A	THAV
06/12/2011	Video published on Aeronews TV website	Aviation industry	France	N/A	THAV
09/12/2011	Article published in Rotor Hub magazine	Aviation industry	International	N/A	-
13/12/2011	Article published on T-human website	General public	Russia	N/A	-
02/01/2012	Article and full report published on Aviation International News website	Aviation industry	International	N/A	-
19/01/2012	Third EEAG meeting, Le Haillan, France	Aviation Experts	European	4	THAV
12/09/2012	Paper accepted to be presented at HCI-Aero 2012 Conference	Aviation Industry	European	?	DTU

Table 4: overview of all the dissemination activities

4. CONCLUSION

This document has presented an overview of the activities that took place during the 34 months from the project launch to the closure meeting in February 2012.

A set of requirements has first been established and have been used at mock-up level to drive the key design aspect. Other requirements more related to a final product have been included in order to keep in mind the ultimate goals of a single display but also to be used as a reference for future developments.

A projection-based single display has been prototyped. It features an LED illumination system and a sophisticated shape, not limited to borders at right angle but rather one that can adapt to the available space within a cockpit dashboard. For optimised viewing angles in the lower area, a curve shape has been proposed. The mock-up allowed demonstrating that it was possible to achieve a continuous display by merging the images provided by adjacent projectors. The image features a good contrast, wide colour gamut and large viewing angles.

For easier interactivity a custom tactile system has been developed. It is based on infrared illumination of the display surface and detection by cameras located near the projectors. This architecture is highly scalable, capable to address curve displays, truly multitouch and unlike many other tactile systems it does not need an additional layer above the screen which maximises the contrast of the display.

To drive a single display cockpit, a graphics generation architecture has been conceived. It is scalable and reconfigurable. A safety analysis has been conducted to make sure that the chosen architecture is capable of meeting the requirements in terms of availability and development assurance level. Even though this study was a theoretical one, the algorithms and data flows have been modelled and implemented in the final mock-up.

For better immersion into a future single display concept, a mock-up has been manufactured. It is supported by the hardware and software developed in the technical workpackages and proposes a human machine interface that benefits from the absence of physical boundaries on the display surface. The availability of information is guaranteed by the reconfiguration of information in case of display failure.

The mock-up and the single display concepts were very well perceived by the end users during the dedicated evaluations or the various dissemination events such as the Paris Air Show 2011 that took place throughout the project.

ACRONYMS

CDS	Control and Display System
DOW	Description of Work
DU	Display Unit
EEAG	External Experts Advisory Group
fh	flight hour
GVPU	Graphics and Video Processing Unit
ICU	InterConnection Unit
IME	Integrated Modular Electronics
IPU	Image Processing Unit
LRU	Line Replaceable Unit
LCOS	Liquid Crystal On Silicon
PGGU	Processing / Graphics Generation Unit
PRU	Processing and Rendering Unit
PSM	Power Supply Module
PM	Person·Month
PWM	Pulse Width Modulation
TBD	To Be Defined
VMU	Video Merging Unit