INTEGRATION AND TEST OF A DEGRADED VISUAL ENVIRONMENT SYSTEM ON H145

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Abstract

This paper reports on the integration, test and evaluation of a Degraded Visual Environment (DVE) system installed on an Airbus H145 (BK117 D-2) civil certified helicopter. The DVE system consists of a LiDAR sensor, an EVS camera and a head-tracked helmet mounted display system (HMD) integrated into the onboard HELIONIX® digital avionics suite. The DVE system combines sensor enhanced and synthetic elements of the external scene and provides an accurate representation of the real world for visual reference and safe manoeuvring in DVE. All systems were prototypically integrated into the H145 demonstrator in a serial-like manner, allowing for a potential serialization of the system. Extensive flight trials were conducted focusing on military as well as on civil HEMS missions and were used to verify the intended function and evaluate installed DVE system performance.

The activities described herein are partially performed in the frame of a research project supported by the German Federal Office of Bundeswehr Equipment, Information Technology and In-Service Support (BAAINBw). Between November 2018 and March 2019 the system was successfully deployed in both ground and flight tests.

1. INTRODUCTION

Today, most civil and military H/C operations are performed in Visual Meteorological Conditions (VMC) according to Visual Flight Rules (VFR) using primarily external visual references for maintaining H/C control and safe separation from terrain, obstacles and traffic. In modern H/C, such operations are aided by additional cockpit information and displays that can enhance situational awareness such as a simple attitude direction indicator or more advanced systems such as digital map or terrain awareness and warning systems [1]. The H/C operating minima in the VFR regime are clearly defined by VMC visibility and distance from cloud minima. In the event that weather conditions fall below the specified minima, the VFR only certified H/C shall abandon the flight whereas H/C equipped and certified for IMC operations may also convert to a flight conducted under IFR. It is obvious, that the latter severely restricts the operational usage of the H/C and is not always an option (e.g. for military operations).

More generally, operations in degraded visual environments prevent the crew from using external visual references for conducting a safe flight thereby compromising flight safety and mission efficiency. The term DVE commonly refers to reduced visibility conditions wherein situational awareness and aircraft control cannot be maintained as comprehensively as in good visual conditions. DVE can be caused by a variety of natural (e.g. precipitation, lighting conditions) and aircraft induced conditions (e.g. brownout / whiteout) that all impair the visibility and usable cueing environment of the aircrew. Especially when operating at low height above ground in a complex obstacle environment, there is an imminent risk of spatial disorientation, loss of control and controlled flight into terrain (CFIT).

Since long, the aeronautical industry has been trying to develop technology solutions that can reliably support helicopter flight in DVE conditions by enhancing the pilot's view and restoring situational awareness. A good example has been the introduction of Night Vision Goggles (NVG) in military and civil night-VFR operations that has significantly enhanced flight safety for night operations. The use of aviator NVGs is widespread in the military domain and the benefits are well recognized. The proliferation to civil H/C operations has however taken a long time, not in the least because of regulatory and rule making challenges. Today, the use of NVG in civil flight operations is defined as an aid to VFR flight not intended to expand the H/C's operational envelope or operational capabilities.

Technological advancements in sensors, processing and display means have in recent years resulted in the

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development and introduction of more advanced support systems and capabilities. Typically developed for the military first, these emerging technologies include Sensor-Enhanced, Synthetic (computer-generated) or Combined Vision Systems (EVS/SVS/CVS), Obstacle Warning Systems (OWS) and HMDs for augmenting the crew's natural vision by head-up display of symbology and imagery. Recent studies on the DVE subject initiated by NATO provided a comprehensive overview and system classification of DVE system technologies [2]. It also emphasized the importance of improved stabilization, handling qualities and control automation to increase the precision and ease of control of the H/C and to reduce the related workload. The attentional resources that are freed, are used for other tasks than controlling the H/C including improving situational awareness [3].

The majority of military systems however comes at a considerable cost and different development and qualification standards often complicate the certification of the these systems on civil H/C. Interesting to note in this context is however the development and deployment of enhanced flight vision (EFVS) on civil fixed wing aircraft that enable the pilot to "see" the terrain and landing area earlier also in degraded visual conditions. This development is fuelled by the operational credit (reduction of approach minima) that can be obtained when using these systems for instrument approaches in IMC conditions. When displayed on the appropriate display means, the system indications can be used in lieu of the natural visual reference for approach and landing, rather than just for improvement of situational awareness. Although fixed wing and helicopter operations are by nature different, the introduction in fixed wing operations will leverage the development of such systems for helicopter operations. At rulemaking level, there are several initiatives already launched that will address the extension of the rotorcraft usage domain when having such technology available.

The objectives of the Research & Technology project described in this paper were manifold. Starting from a theoretical investigation of system safety and certification objectives, it includes the prototypical integration of a DVE system in a civil certified Airbus H145 platform typically used both in civil and military operations. This paper reports on the integration, test and evaluation of the DVE system.

2. DVE SYSTEM CONCEPT

2.1. Operational Need

The operational need for military operations w.r.t. DVE system support differs from the needs from civil operators. Military missions, although depending on target platform, often include tactical operations in ground vicinity (e.g. Nap-of-the-Earth) in a possibly unknown threat and obstacle environment. The urgency and nature of the mission often complicates the alternatives available (e.g. change flight height, mission abortion) when weather conditions turn bad and the acceptable level of risk is generally higher. Military missions are typically performed under VFR and visibility is often the limiting factor in these operations. The flight profiles in terms of speeds and height above ground are typically different from civil missions which might impact the DVE system requirements. Although the primary objective is to increase flight safety, the ultimate objective is to create a tactical advantage by operating 'VFR-like' in DVE conditions for concealment when hostile forces cannot.

Civil H/C operations differ from this, in that flight profiles for typical civil missions are different. Operations in unknown environment and ground vicinity are avoided when possible and the acceptable level of risk is lower. In system design, there is no compromise on system safety and stringent certification requirements apply. Most civil missions are performed under VFR und degraded weather conditions (e.g. inadvertent flight in IMC) are a common cause for mission cancellation and aviation accidents [4]. The operational need is for system support to increase flight safety and ultimately to extend the VFR regime by reduction of VFR minima. However, as civil H/C operations also increasingly include IFR operations or IFR parts within the operation, there is also an interest to extend the IFR regime for H/C operations in analogy to the reduction of IFR minima for fixed wing applications.

Aiming for operational credit i.e. extension of the operational H/C usage beyond what is allowed under current regulations, will impose most stringent requirements on system performance, integrity and certification. Also the regulatory framework needs to be adapted to allow for such operations. It is obvious, that these systems will come at a considerable cost. A much preferred approach introducing such novel technologies is an incremental approach of adding capabilities with certification risk reduction. In a first step, these systems are intended to only support the flight crew providing operational benefit in terms of an increase in flight safety and mission effectiveness. After having successfully deployed the technology, the scope can then be extended in a second step to include the application for operational credit for the use of such systems (e.g. extension of VFR/IFR operations).

2.2. DVE System Architecture

The DVE system under investigation in this project consists of the following subsystems:

Hensoldt SFERION® system including:

- SferiSense® 500 LiDAR Obstacle Warning Sensor (OWS)
- SferiAssist® Processing hardware (HW) and software (SW) providing sensor-data fusion and SVS symbology generation

Elbit ClearVision™ system including:

- HeliEVS™ multispectral Enhanced Vision System (EVS) sensor
- SkyVis™ Helmet Mounted Display (HMD) system or Skylens™ Head Wearable Display (HWD)

The intended function of the DVE system is to support the crew by providing an optimally resolved and

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accurate representation of the real world based on sensor enhanced and synthetic elements of the external scene. For this purpose the DVE system combines different sensor inputs and data sources. Through the hybridization of multiple, redundant albeit dissimilar information the weaknesses of each information source can be mitigated, a means for detecting erroneous information or undesired events is provided and the effect of single point failures is minimized.

The selection of subsystem components was based on system performance, maturity and (planned) system safety objectives also to support the long term objective of operational credit. The following figure illustrates schematically the integration of the DVE subsystems in the H145 architecture as well as the main functions.

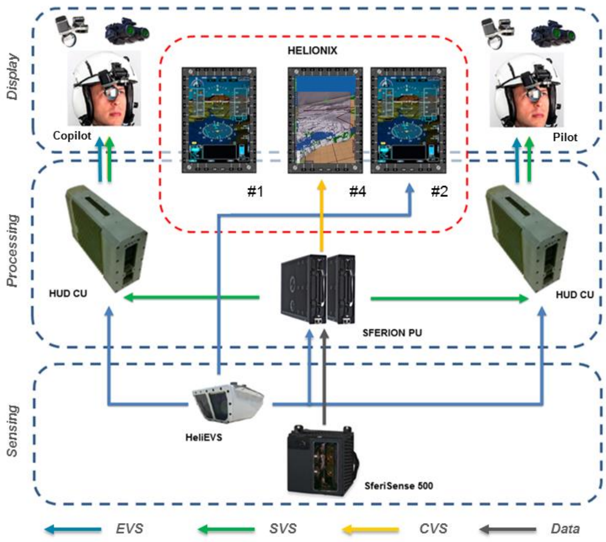

Fig. 1: DVE System diagram

The following figure shows the arrangement of displays and DVE system outputs available in the H145 cockpit. From a flight safety point of view it is important to note the left-most Multi-Function Display (MFD) always displayed the unmodified, certified HELIONIX Primary Flight Display (PFD) for the safety pilot. In the following sections, the different subsystems and components will be briefly described.

Fig. 2: DVE Cockpit displays in H145

2.3. H145 / HELIONIX®

The H145 is the latest civil certified version of the proven BK117 family which includes a shrouded tailrotor (Fenestron) and a novel integrated modular avionics (IMA) suite called HELIONIX. HELIONIX comes with a modern glass cockpit including three MFDs and a 4-axis autopilot with basic stabilization and advanced upper modes based on GPS and FMS guidance. Basic situational awareness functions including SVS, HTAWS and DMAP functions are embedded in the MFDs as well as the display of TCAS transponder information and weather radar data. HELIONIX allows for single pilot IFR operations while still providing two fully equipped piloting positions thereby making the H145 the aircraft of choice for a variety of civil and military missions. For integration of external sub-systems such as a DVE system, the IMA architecture eases the proliferation of relevant data and sensor information on well-defined interfaces within the avionics.

2.4. SFERION System

The SFERION consists of the following components [5]:

- SferiSense 500 LiDAR Obstacle Warning Sensor (OWS)
- SferiAssist Processing hard- and software providing sensor-data fusion and SVS symbology generation

SferiSense 500 LiDAR

The SferiSense 500 OWS is composed of a LiDAR with associated 3D data processing and software algorithms that detect and classify obstacles including wires, poles, isolated trees, and terrain features as well as surface and elevation of the terrain in the flight path or helicopter landing zone. SferiSense 500 is an active scanning long range LiDAR with a maximum range of 1200 m and a qualified detection probability of 99,5% for 5mm wires in a distance >725 m. The sensor covers a field-of-view (FoV) of 36°H x 42°V which is scanned at 3Hz. With automatic line-of-sight (LoS) steering in turns, a field-of-regard (FoR) of 60°Hx42°V is obtained. The SferiSense 500 is a qualified system in operational use on a variety of NH90 Tactical Transport Helicopters.

Fig. 3: SferiSense 500 LiDAR

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SferiAssist

The SferiAssist system retrieves and processes relevant information from the SferiSense 500 sensor and on-board terrain and obstacle databases. A reliable, real-time fusion of SferiSense data and a priori database data (terrain and obstacles) provides the basis for the generation of 3D conformal symbology to be combined with EVS imagery and primary symbology on MFD and HMD. The SferiAssist processing is hosted on the SFERION Processing Unit (PU) Computer HW. The PU is based on Hensoldt's Mission Computer Suite, a collection of certified and qualified HW, software and mechanical components. In combination, SferiSense and SferiAssist support the following main functions briefly described hereafter:

- Provide Terrain and Obstacle Awareness
- Provide Navigation Support
- Provide Take-off and Landing Support

These functions are provided through the following display outputs (see Fig. 1):

- Combined Vision Display of sensor enhanced SVS plus EVS overlay on HELIONIX MFD
- Sensor enhanced SVS for conformal display on HMD

Terrain and Obstacle Awareness

Terrain and obstacle awareness is provided by the display of sensor enhanced obstacles and terrain features. The following figure illustrates the content provided on the head-down CVS display. The SVS display is based on the sensor-enhanced terrain information and is superimposed by the HeliEVS video image in a conformal manner. The combined picture is augmented by overlaying 3D conformal symbology including obstacle symbols for classified obstacles, terrain grid and textures or shaded pixels (voxels) of sensor detected elevated objects, always rendered from the eye point of the EVS video image. The overlay with textures from the database is used to indicate land use and cultural features incl. water bodies, railways, streets etc..

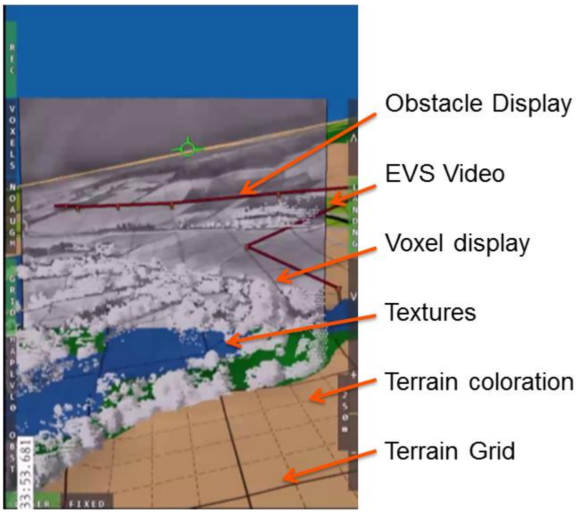

Fig. 4: Terrain and Obstacle Awareness with SferiAssist CVS

In order to augment the crew's outside view, similar information is displayed as SVS overlay on the HMD. A smart declutter function is provided through the use of predefined but configurable display profiles in order to overlay or suppress certain display features.

Navigational Support

Navigational support is provided by the head-up and head-down, conformal display of waypoint (WPT) information from the active flight plan. Flight plan information is retrieved from the Flight Management System (FMS) integrated in HELIONIX.

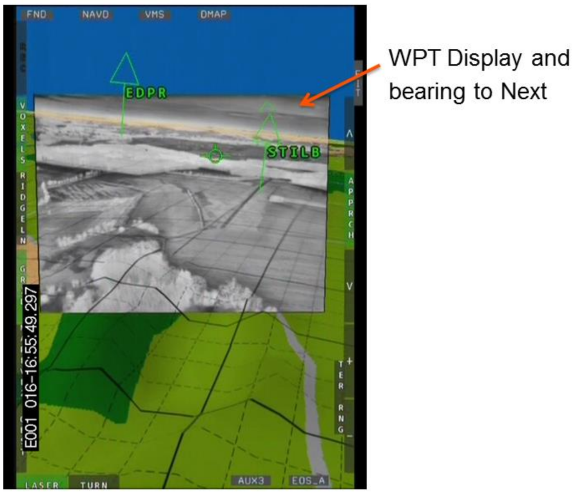

Fig. 5: Navigation Support with SferiAssist CVS

Take-off and Landing Assistance

During take-off and landing, the pilots are supported by 3D outside world conformal visual cues displayed on the MFD and HMDs in order to provide full spatial orientation for the crew. Dedicated take-off and landing symbology supports the pilots in:

- Assessing the obstacle situation in and around the landing zone (LZ)
- Controlling approach path incl. rate of closure, rate of descent and glide slope
- Assessing the landing zone size, slope, shape and roughness
- Controlling position and sideward drift prior to touchdown
- Controlling aircraft attitude prior to touchdown
- Assessing and controlling height above landing point
- Assessing the go-around or take-off zone

The following figure shows the take-off and landing symbology on the head-down CVS display.

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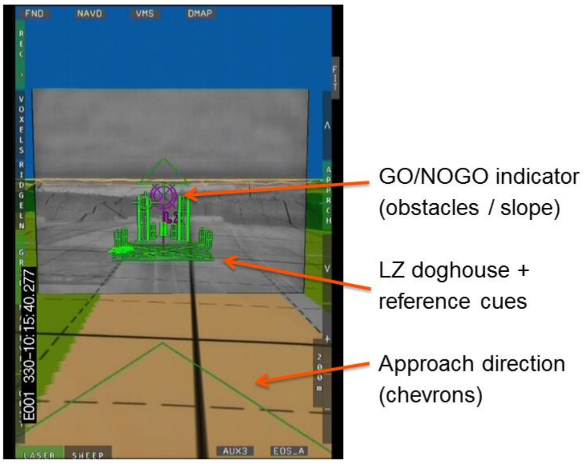

Fig. 6: Take-off and Landing Support with SferiAssist CVS

Selection of the intended landing point is performed either through a predefined waypoint in the FMS or through the point-and-mark functionality using the HMD LoS. An evaluation of the landing zone suitability is performed based on SferiSense measurements in the approach phase. The system verifies that no classified obstacles or elevated objects are within the landing zone and that the measured slope at the landing point does not exceed a predefined value. The slope is calculated as a best fit through the terrain data points within the designated landing area. Flight trials have shown that the 3D data provided by the SferiSense sensor allows for slope estimation with accuracy within ±1° from a slant range exceeding 1500 ft. If the aforementioned conditions are not met, the system displays a NoGo indication for the selected landing point (see Fig. 6).

2.5. ClearVision

The Elbit ClearVision system consists of the following subsystems;

- HeliEVS multispectral Enhanced Vision System (EVS) sensor
- SkyVis Helmet Mounted Display (HMD) system

HeliEVS
Based on the Elbit ClearVision EVS for fixed wing applications, HeliEVS is packaged in a single Line Replaceable Unit (LRU), which autonomously performs the complete Enhanced Vision System capability. Functionality is accomplished through real-time image fusion between multiple sensors at multiple spectral bands. The spectral bands were selected based on multi-year studies of the properties of light penetration through poor weather conditions thus providing best signal to noise ratio at most weather conditions, day and night. The processing is performed in electronics HW to minimize latency. HeliEVS is comprised of two sensors in the Visible / NIR (Near Infra-Red) and LWIR (Long Wave Infra-Red) spectral bands achieving maximum situational awareness. Each sensor is designed to achieve best performance for the EVS application.

Fig. 7: HeliEVS Camera

SkyVis
The SkyVis HMD is a monocular, monochrome display that is mounted on a standard ANVIS NVG mount and allows for rapid removal upon egress. Dedicated displays are provided for unaided (SkyVis Day/Night) and NVG aided flight (SkyVis NVG). The display module combines optics with display source as well as the hybrid optical-inertial tracker components. The display has following characteristics:

- Monocular, monochrome green display for the right eye
- Field-of-View (26°H x 20°V), unrestricted field of regard
- High intensity, high resolution (1280 x 1024px) display
- Compatibility with multiple Inter Pupil Distances (IPDs)
- Compatibility with prescription eyeglasses

Fig. 8: SkyVis Day/Night (left) and SkyVis NVG (right)

The SkyVis NVG uses the same display source as the SkyVis Day/Night which is permanently replacing the eyepiece of the NVG. The display overlays the NVG image provided to the right eye of the user with symbology. With the SkyVis NVG display, the display of EVS video in combination with NVG image is not possible.

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2.6. H145 DVE System Integration

The integration of the DVE system consisted of the mechanical, electrical and functional integration of the aforementioned subsystems in the H145 test aircraft. Figure 9 shows the outboard sensor installation on the nose of the H145. There are various aspects and partly conflicting constraints that have to be considered for the HW integration of the DVE system components including;

- Volume and space available
- Ground clearance
- Parallax effects for sensors
- Field-of-View / Field-of-Regards
- Weight, H/C Center-of-Gravity (CoG)
- Aerodynamics impact (V_{NE})
- Bird strike resistance

Fig. 9: DVE Sensor assembly on H145

Especially the outboard integration of the various sensors is a challenge, when having to consider equipment already installed. One obvious incompatibility is the conflict with a nose-mounted weather radar (not installed on the test H/C), which is a mandatory equipment for some operations and the installation of the SferiSense 500.

The nose installation of the SferiSense 500 is the only position available for a sensor of this size and weight without having a large impact on structural design and incompatibility to existing mission equipment on H145. For the above installation the fixed provisions for the weather radar installation were used. With this installation, the use of wire strike protection systems and a centerline Electro Optical System (EOS) for military or parapublic operators is still possible. Since the 3D data collected by the SferiSense sensor is geo-registered and the SVS is generated based on the viewpoint of the crew, an off centerline installation of the sensor is an option.

For the integration of the HeliEVS camera sensor the parallax between the installation position and the crew's head-position shall be taken into consideration in order to reduce the image offset when displaying the EVS head-up. Unlike the 3D sensor, the 2D imaging sensor cannot compensate for having a different perspective. For fixed wing aircraft, the EVS sensors are typically installed under the nose, staring to the ideal position of the upcoming runway upon arrival in a precision IFR approach. For the H145, the HeliEVS was chosen to be installed upside down above the SferiSense 500 in order to not interfere with the wire installation of the wire strike protection system and centerline EOS and to reduce the vertical parallax when displaying the EVS image head-up.

Special care was also taken to minimize the impact on the existing shape of the nose section not to disturb too much the related airflow and induce aerodynamic effects that could penalize the handling qualities or performance of the aircraft (e.g. lower velocity never exceed V_{NE}) or interfere with the pitot static system.

As for the inboard installation of all DVE system components and peripheral equipment (e.g. switches, circuit breakers) a dedicated rack was designed and installed in the cargo compartment. The rack enabled easy access to the different LRUs which greatly simplified the harness design and supported troubleshooting and replacement of components.

Fig. 10: DVE System rack in the cabin

The functional integration of the DVE system includes the provision of all necessary in- and output for the DVE subsystem. Input provided to the DVE system consists of:

- H/C navigation information (from FMS)
- H/C state information (from AHRS and IRS)
- Command and Control (from MFD and crew collective controls)
- Vehicle management information from MFDs
- DVE output to Flight Test Instrumentation (FTI) system

DVE system outputs were limited to the various video outputs as presented schematically in Fig. 1. The inputs needed by the DVE system were provided either by the onboard sensors directly or by the HELIONIX avionics system. This IMA architecture of HELIONIX greatly simplified the integration of the DVE system in that needed inputs such as altitudes, position information and engine settings are provided on well-defined

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interfaces, at minimum latency and in a consolidated manner. In order to provide all necessary input for the DVE displays, the HELIONIX software was prototypically modified.

The aforementioned integration aspects demonstrate the complexity of integrating a DVE system and to secure the integrated performance of the individual subsystems. The best single subsystem can operationally be of not much use if not properly installed or if not provided with the right quality of inputs. Considering the level of complexity and integration of the DVE system, the OEM shall master these challenges and secure installed system performance and intended function. A typical example is the dependency of the DVE system performance on the quality of positioning and attitude information provided by the H/C for the correct processing of sensor data and conformal display generation. In order to secure overall system performance at H/C level, these interdisciplinary challenges ask for a system of systems approach where the needs of each subsystem have to be carefully assessed.

3. TEST AND EVALUATION

After a successful integration phase in the H/C, the operational test and evaluation phase of the system started in December 2018. The objectives of this phase were twofold:

- Evaluate installed performance and functionality of the different DVE subsystems
- Evaluate intended function and concept of operations of DVE system in a representative environment

Prior to the integration of the subsystem components on the H145 test platform, all components were integrated in a high-fidelity, hardware-in-the-loop simulator environment to test already at an early stage all interfaces and to offer the flight crew a first familiarization with the system. Before commencing flight testing, several safe-for-flight ground tests were performed including modal testing and electromagnetic interference testing of the installed system. Prior to commencing the evaluation flight testing, the impact of the DVE system installation on H/C performance and handling qualities was verified in flight and DVE system calibration flights were performed. For the evaluation flights, a reference mission was defined in the area of Donauwörth, Germany which included a variety of representative mission tasks for which the support by the DVE system was evaluated. The reference mission was defined such that it includes a variety of terrain features and obstacle types. Although flights were restricted to VMC, several marginal VMC conditions were encountered during testing and exploited to also test the system performance under more DVE conditions. Flights were conducted both at day and night. In order to recreate more degraded visual conditions for the flight crew, a semi-transparent foil was placed over the helmet's clear-visor and SkyVis HMD.

For the operational system evaluation flights, the flight test crew consisted of an Airbus safety pilot seated on the left and an evaluation pilot seated on the right. Thanks to the segregation of the HELIONIX avionics, the safety pilot had the unmodified avionic system available and was able to take over immediate control of the H/C under all circumstances. Additionally a working station was installed in the cabin for the flight test engineer to monitor the system status. Circa 15 evaluation pilots have been testing the system with the trials still ongoing at the time of writing of this report. Evaluation pilots included Airbus test pilots and pilots from selected operators from the Police, HEMS and Military segment.

For the evaluation of test results different (post-flight) questionnaires were used to get a subjective perception of the level of situational awareness and to get feedback on system performance and integration. The following sections provide first results of the trials as well as a first synthesis of the feedback received.

3.1. Test Results

In general, the quantification of sensor performance in flight under various weather conditions is difficult and was not part of the objectives of the flight test campaign. All sensor outputs and related displays were however recorded on the FTI installation and were used for a more qualitative evaluation of sensor performance.

Figure 11 provides a collection of recordings from the FTI daylight camera mounted on the roof and HeliEVS sensor for various environmental conditions. The LWIR sensor significantly enhanced the visibility under foggy conditions and at low light levels. The VIS/NIR sensor coves a broad spectral range which enables the detection of both incandescent and LED lighting. It has to be noted that the FoV of the daylight camera in the beginning of the campaign did not match the FoV of the HeliEVS. The reduced FoV of the FTI camera is indicated in red in the HeliEVS image.

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Fig. 11: HeliEVS (right) and corresponding daylight camera recording (left) under foggy, night and bright sunlight conditions

In addition to the 2D imagery provided by the HeliEVS, the SFERION system provides a sensor-enhanced, conformal presentation of terrain and obstacle information for conformal display head-up for both crew members and head-down on the middle MFD. The following figures provide a composition of FTI videos that present very well the support provided by the active sensor information.

Fig. 12: SferiAssist MFD output (left) with corresponding FTI camera (upper right) and HeliEVS image (lower right)

Figure 12 shows the approach to different overhead powerlines. In this recording the voxel display is enabled showing the sensor returns of elevated objects that are not classified as part of the terrain. The voxels belonging to the classified wire are coloured orange and the voxels belonging to a pole class of objects are coloured red (the powerline mast). Figure 13 shows a similar composition during approach to Donauwörth heliport (EDPR). The visualization of voxels head-down was shown to clearly support the crew in the detection of (smaller) obstacles that are not classified by the system and not displayed symbolically. On the head-down display this information can be displayed without cluttering the outside view of the crew.

Fig. 13: SferiAssist output during EDPR approach (left) with corresponding FTI camera (upper right) and HeliEVS image (lower right)

The SkyVis HMD display enables the head-up, eyes out display of SferiAssist SVS or HeliEVS EVS imagery. A combined vision display was technically not realizable within the current project. The following figure shows the HMD display output combined in real-time with a helmet camera image to recreate the pilot's view through the HMD. The upper image shows the conformal SVS display with the display of LiDAR voxels enabled. The lollipop symbol of the selected landing zone is also visible. The lower image shows the HeliEVS image displayed conformally head-up. This display is obviously limited to the field-of-view of the fixed installed HeliEVS camera.

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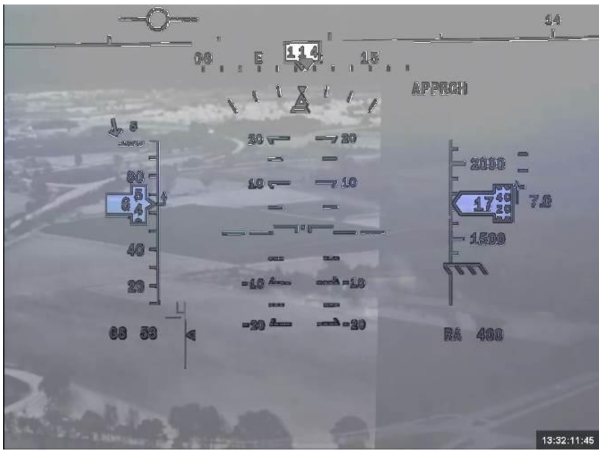

Fig. 14: SkyVis HMD display of SferiAssist SVS (top) and partial display of HeliEVS EVS (bottom)

3.2. General Feedback

In addition to the qualitative results presented in the previous section, there are general remarks that can be made on different DVE system aspects supported by over 50 hours of flight and the evaluation of a broad spectrum of evaluation pilots.

Sensor Performance

Sensor performance was not quantified during the tests and only qualitatively evaluated. Generally, sensor performance of both HeliEVS and SferiSense sensor significantly enhances the Situational Awareness of the crew. The HeliEVS enhances the vision of the crew in a natural and intuitive manner and provides a benefit over the natural vision (only) under reduced visibility conditions (e.g. fog, night etc.). The SferiSense sensor detected terrain features and obstacles that even under good visual conditions are not easily detectable by the crew. Both sensors are however not all-weather capable and have shown their limitations under more severe DVE conditions.

Head-down Display

The SFERION CVS display on the middle MFD was much appreciated by the crews even though only displayed as a missions display. It offers on the complete MFD screen size an intuitive display a maximum level of content without the risk of cluttering the outside view. The use of colour in the display clearly helps to distinguish the different content. The display of voxels was highly appreciated to display sensor data which is not classified and displayed symbolically

The HELIONIX PFD is the preferred display for the display of head-down CVS in combination with all primary flight information. Care must be taken that the display of the greyscale EVS image does not interfere with the display of primary flight symbology

Head-up Display

The ability of displaying primary flight information head-up is considered an important support for VFR operations especially in challenging conditions (e.g. operations in ground vicinity, hovering close to obstacles). The HMD increases the head-up, eyes-out time and thereby significantly enhances the situational awareness of the crew.

The monocular display was found to be suitable for display of 2D flight information as well as conformal display of SVS and EVS imagery. When displaying SVS information on a monochrome display, special care shall be taken to the appearance of this symbology, not to interfere with the display of primary flight information. E.g. the concurrent display of SVS grid, line obstacles and horizon line can become confusing if not properly distinguished.

The utilization of information provided on a monocular display was generally appreciated by most of the evaluation pilots. However, different factors influence the efficient use of augmenting the pilot’s view on one eye including eye dominance, display brightness, head/helmet fitting etc. The level of training of the crew is expected to play an important role in the acceptance and hence successful deployment of such a system.

DVE System Integration

Command and control is getting increasingly difficult with adding more subsystems each having their own dedicated controls. This increases the pilot workload operating the system and the risk for improper control. A consolidation of controls for the DVE system should be investigated as well as the automation of command and control (e.g. switching between display modes).

The DVE system indications need to be adapted to the target platform. This for example applies to the display of primary flight information head-up which needs to be displayed in an equivalent manner as on the head-down PFD. The display of similar information on HMD and MFD shall be consistent and follow the same HMI philosophy. The DVE system indications (e.g. landing symbology) shall also take into consideration the handling qualities of the H/C. The visual cues presented for a certain task can be less and different for a highly stabilized platform such as the H145 with advanced autopilot modes compared to more legacy H/C with minimum stabilization and poor handling qualities.

Due to the superior handling qualities of the H145 and the use of flight control system stabilization and upper modes in critical phases of flight, the flight crew was able to pay more attention to DVE system indications to develop the appropriate situational awareness (e.g. terrain, obstacle environment). This confirms again the importance of handling qualities and flight control system support in the DVE solution scope.

To ease the integration of a DVE system especially on smaller H/C, the industry should focus efforts on reducing the size, weight and number of LRUs to be installed. Today, all subsystems bring their own computer HW, control panel etc. Modularity and flexibility in HW and SW design is required to e.g. also use already available (computing) resources on the aircraft.

4. CONCLUSIONS

This paper reported on the integration and flight trial evaluation of a DVE system installed on the Airbus H145 light twin, multirole H/C. The DVE system supports the crew by providing an augmented representation of the real world based on sensor enhanced and synthetic elements of the external scene. For this purpose the DVE system combines multiple redundant but dissimilar information sources including the SferiSense 500 LiDAR Obstacle Warning System and HeliEVS multispectral EVS sensor. The system output is displayed head-down on the available MFDs and head-up on the SkyVis HMD in a conformal, look-through manner.

After a successful integration on the H/C, the DVE system was extensively flight tested in a range of environmental conditions and geographical settings representative for civil and military H/C operations. The system was operationally evaluated by a large group of evaluation pilots with a diverse operational background. The evaluation of test data and pilot's questionnaires has confirmed the improvement in situational awareness provided by the implementation of the DVE system and has provided valuable feedback on subsystem performance and integrational aspects. In combination with optimal handling qualities and autopilot support of the H145, the DVE system indications allowed for effective manoeuvring and obstacle avoidance in DVE. Although not quantitatively evaluated in flight, the trials provided a wealth of information and better understanding of sensor performance under different environmental conditions. The H145 has also proven to be an ideal test-bed for the DVE trials capable of mechanically integrating a range of sensors as well the functional integration of the DVE system with onboard HELIONIX avionics. The project demonstrated the potential of the H145 for DVE operations and the maturity of the various subsystems.

A future deployment of this DVE capability is expected to be an incremental approach of adding capabilities with certification risk reduction. Although these systems are expected to only increase flight safety and mission effectiveness initially, they will have to provide operational credit in the long run for the operators to have a quantifiable benefit and return on invest for such an expensive installation (in terms of weight, monetary cost etc.). To enable the long-term objective of obtaining credit (e.g. VFR/IFR minima reduction), not only does the technology need to be mature, also the rulemaking needs to keep up with the technological advances. Although on the rule-making there can be potential synergies with what is currently developed for fixed wing applications, H/C specific missions and operations need to be specifically addressed.

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