The way forward is clear

Head-Up Display system

Article by
Hélène da COSTA GOMES
HUD Multi-Programme Project Task Leader
AIRBUS
Helene.Dacosta@airbus.com

The Head-Up Display (HUD) has been available on Airbus aircraft since 2006 (see FAST 46).This visual guidance system has been shown to significantly increase pilots' situational awareness, particularly during the approach and landing phases by showing trajectory related symbols superimposed on a transparent screen in the pilot's forward-field view. Service experience confirms that the HUD is a very good means to stabilize the aircraft during the approach phase.

The fully digital processing of the HUD system also offers view enhancement and the ability to display video images together with symbols. These technologies are being used concurrently to develop an Enhanced Vision System (EVS) and a Synthetic Vision System (SVS).

Airbus' programme to make Head-Up Display technology available to all Airbus aircraft, has received extra encouragement from recent decisions made by the Civil Aviation Administration of China (CAAC), requiring that airlines be equipped with at least one HUD. This decision which applies to Chinese airlines may also affect other aircraft flying in Chinese airspace.

A growing number of airports are ready to propose specific procedures for aircraft equipped with Head-Up Display. China's impressive air traffic growth has pushed the CAAC to release an implementation roadmap extending to 2025.

During this time frame, airports' capacities will be assessed, HUD operations will be normalized and fleets will be updated conforming to the new requirements, operators will be trained and HUD operations in China normalized.

The evolving Airbus HUD offer

Going one step further than the CAAC's roadmap, Airbus is gradually incorporating dual HUD into all Airbus aircraft as part of their 'symmetrical cockpit philosophy.

Beyond this Airbus reviewed the HUD policy to include the following improvements:

A320 Family

A new HUD standard (L5) was certified in February 2015. This standard upgrades the system to restore compatibility with the latest developments in functions such as:

- Runway Overrun Prevention System (ROPS - see FAST #55)
- Required Navigation Performance Authorisation Required (RNP AR) step 3 (down to 0.1 Nautical Miles)
- Auto-Pilot/Flight Director Traffic alert and Collision Avoidance System (AP/FD TCAS)
- Advisory runway ahead
- Soft go-around
- Reversible Back-Up Speed Scale (BUSS)

Moreover, this standard enables the integration of a dual HUD configuration on single aisle family aircraft and proposes symbology improvements. The dual HUD configuration has been proposed on single-aisle aircraft (except A321) since March 2015.

By the beginning of 2016, the HUD offer will be extended to the A321 model.

A330 Family

Development was launched in 2013 to certify dual HUD on long range family aircraft. The long range HUD standard will be based on the latest certified single-aisle standard and proposes the latest functionalities to keep the highest symbology and operations' commonality throughout Airbus' fleet.

A350 Family

HUD was part of the cockpit development from the very beginning; so the HUD is more integrated in the overhead panel. Space provisions have been enlarged to provide best head-clearance for pilots. The system has been designed with a new Liquid-Crystal Display (LCD) technology projector with Light-Emitting Diode (LED) backlights. HUD software is integrated in the display system.

The A350 already proposes the dual HUD as an option since Entry-Into-Service.

A380

The A380 proposes a dual HUD option in the catalogue. A new standard is being developed to propose the latest display functionalities.

Head-Up Display main operational benefits

- **Improved situation awareness**
- **Better Instrument Meteorological Conditions (IMC)/ Visual Meteorological Conditions (VMC) transition**
- **Enhanced stability of manually flown approaches**
- **Reduced take-off minima**
- **Reduced landing minima**

Cockpit integration – operational policy

The policy review which standardized the integration of dual Head-Up Display (HUD), also indicates that the information shown on the Primary Flight Display (PFD) - known as the Head-Down Display (HDD) - is also developed for the HUD.

Airbus' HUD is included in the aircraft Type Certificate (TC). It is fully integrated as an additional display in the avionics suite. The guidance displayed in the HUD are generated by the flight controls' computers, which provide all Airbus aircraft with Auto-Pilot (AP), and Auto-Land (AL) CAT III capability.

Thanks to this architecture with the guidance laws hosted by the flight control computers, the current Airbus HUD product answers eligibility requirements for special CAT I and CAT II operations. Airbus' Flight Operations department supports airlines for special authorization approvals.

The HUD is fully integrated with the different aircraft systems. Pilots flying a HUD equipped aircraft must follow a dedicated training course that integrates the HUD in cockpit operations.

In Airbus' catalogue, the HUD is a Supplier Furnished Equipment (SFE) option supplied by Thales.

Dual Head-Up Display is part of Airbus' symmetrical cockpit philosophy

Airports are categorized CAT I, CAT II, CAT III, Special CAT I and Special CAT II, based on their Instrument Landing System.

ICAO (International Civil Aviation Organization) classifies ILS approaches as being in one of the following categories:

Approach category	Decision Height (DH) or alert height (minimum above runway threshold or touchdown zone)	Runway Visual Range (RVR)	Visibility minimum	Notes
CAT I	200 feet (61 metres)	1,800 feet (550 metres) (1,200 feet is approved at some airports), increased to 1,600 feet (800 metres) for single crew operations	1,600 feet (800 metres) or 1,200 feet in Canada	Either visibility not less than 2,400 feet (800 metres) or a runway visual range (RVR) not less than 1,800 feet (550 metres) on runway with touchdown zone and centerline lighting
CAT II	100 feet (30 metres)	1,200 feet (370 metres)	N/A	ICAO and FAA: 1,150 feet (350 metres) or JAA: 980 feet (300 metres)
CAT IIIa	No DH	700 feet (210 metres)	N/A	
CAT IIIb	No DH	150 feet (46 metres)	N/A	
CAT IIIc	No DH	No RVR	N/A	As of 2012 this category is not yet in operation anywhere in the world as it requires guidance to taxi in zero visibility as well. Category IIIc is not mentioned in EU-OPS.

Special CAT I operation

- Standard instrument approach procedure using the Instrument Landing System (ILS) flown to a DH 150 feet and RVR 1400 feet (nominal CAT I = DH 200 feet / RVR 1800 feet)
- Requires operational approval from flight standards including pilot training
- Must be flown with a HUD down to the DH

Special CAT II operation

- Standard instrument approach procedure using ILS flown to a DH 100 feet and RVR 1200 feet
- Differs from CAT II because it:
  - Allows reduced ground lighting infrastructure
  - Can be flown with Medium Intensity Approach Lighting System (MIALS) with runway alignment indicator lights (MALSR)
  - Does not require runway centreline or runway touchdown lighting.
- Requires operational approval from flight standards including pilot training
- Must be flown with:
  - Automatic landing
  - Or a HUD providing guidance to touch-down

Innovation catalyser

The widespread use and appreciation of HUD by pilots has led to new concepts in information display. The HUD guidance is based on trajectory and energy management while the HDD (Head-Down Display) traditionally provides pitch and thrust data. These differences in flying reference brought a general reflection on the possibility to extend HUD symbols on HDD displays. The operational concept and the technical feasibility are being assessed in Airbus' design offices with the objective to have a mock-up this year that will be evaluated by test pilots with the support of operation and human factor experts. This "enhanced Primary Flight Display" (PFD) will ease HUD to HDD transitions.

In the same mind-set that instigated the CAAC's directive for Chinese airspace, there are several projects to implement new display features to ease guidance during take-off and landing manoeuvres. As a see-through display technology, the HUD enables augmented reality such as synthetic vision, enhanced vision, etc., but also a lot of possible conformal symbols to improve situation awareness. Airbus is assessing the feasibility of new symbols.

Boresighting

The aim of the HUD boresighting, or 'harmonisation procedure', is to adjust the components making up the HUD to guarantee the conformity of the HUD display with the outside world and component interchangeability.

The Mounting TRay (MTR), support of the HUD projector and combiner, is mechanically installed with an accuracy of 5 mrad (milliradian) on the aircraft's pitch, roll and yaw axis.

The projected image is then electronically calibrated by the HUD system itself bringing the tolerance down to 3.5 mrad

Pitch/roll measurement on the Air Data Inertial Reference System (ADIRS) rack and on the MTR using a clinometer.

Yaw calibration measurement is done using a panel aligned with the aircraft axis and a telescope mounted on the MTR.

Head-Up Displays can group information from several HDD screens

Aircraft	HUD	Forward Fit		Retrofit	
		Single	Dual	Single	Dual
A318	MPP*	Yes	Yes	Yes	2015
A319		Yes	Yes		
A320		Yes	Yes		
A321		Yes	Yes	Yes	2016
A330		Not offerable	2015/2018**	Not offerable	2018
A340		Not offerable		Not offerable	
A380		Yes	Yes	N/A	Yes
A350	HUD A350	Not offerable	Yes	N/A	On request

* MPP: Multi Programme Project equipment

** 2015 for complete provisions / 2018 for full installation

Dual HUD on A320 Family neo version as of Entry-Into-Service

New line fit dual HUD offer as of March 2015 on A318 / A319 / A320 / A350/ A380

(A321 in 2016)

Dual HUD on A330 in 2018

Low Visibility Take-Off available on A318 / A319 / A320 / A350

Available HUD configurations on new aircraft

- **Single structural provisions** - Overhead structural drills on Captain's side
- **Dual structural provisions** - Overhead structural drills on Captain's and Flight Officer's sides
- **Complete provisions** - Mechanics, wiring, A-bay space
- **Full installation** - HUD fully installed and activated

Retrofit

Airbus Upgrade Services proposes Service Bulletins (SB) to install the HUD.
The installation of a HUD requires an adaptation to accommodate the HUD equipment, the harnesses and controls, as well as an accurate positioning to ensure conformity of the display with the outside world. Since the first HUD development, Airbus aircraft are currently fitted with structural provisions for the installation of a HUD on the captain's side. Each aircraft programme has a separate Service Bulletin for the system's provisions that simplify HUD retrofits, and a further one for the actual HUD installation. For the aircraft without structural provisions, the SBs are under study. The accuracy of the symbology provided by HUD requires specific installation procedures (boresighting). Already deployed in Airbus' Final Assemble Lines (FAL), these procedures are also listed in the SBs applicable for retrofit. Today this operation is only performed in Airbus' FAL and requires specific skills and tooling. Support services are working on solutions to qualify Maintenance Repair and Overhaul (MRO) organisations and simplify the operation.

Technical contact for sales
Maurice GARNIER
Display, Warning and HUD Systems Manager
AIRBUS
Maurice.Garnier@airbus.com

CONCLUSION

Head-Up display is an evolving technology that provides pilots with the ability to read flight control data projected onto a transparent screen. The main operational benefit is situational awareness due to the exact alignment of guiding information with the pilot's forward-field view.

Recent air traffic constraints coupled with a symmetrical cockpit philosophy have accelerated Airbus' policy to integrate dual Head-Up Displays into all of its manufactured aircraft before 2018.

Head-Up Display has a huge potential. Two technologies that are currently being developed are the Enhanced Vision System (EVS) and the Sythetic Vision System (SVS), that will allow pilots to see runways in otherwise extremely poor visibility conditions.

Head-Up display retrofits are available for all A320 Family aircraft starting from MSN 3000.