Innovation is at the heart of activities and Airbus ensures that its aircraft benefit from the most advanced technology available. During the end of 2002, Airbus decided to provide the HUD (Head-Up Display) as an option on its commercial aircraft (and as the basic instrument to operate the Airbus A400M military transport aircraft). A new generation HUD, called MPP (Multi-Programme Project) HUD, has been developed and proposed on the A320, A330/ A340 aircraft families, as well as on the A380. This MPP HUD, based on proven technologies already available on all aircraft within the Airbus Fly-By-Wire family, is being further optimized for the A350 XWB and will be proposed as an option at its Entry-Into-Service.
The Head-Up Display (HUD) system

The fundamental element of the HUD system is a conformal head-up display that presents essential flight information and guidance to the pilot in his forward field of view for all flight phases. The HUD is a see-through device which helps the pilots to fly more accurately, displaying collimated flying symbols overlaying the real outside world view. The new generation HUD systems are from a single source SFE (Supplier Furnishing Equipment).

System overview

COCKPIT INTEGRATION

The HUD System is fully integrated into the existing cockpits. Either single or dual installation configurations for the MPP HUD (on A320, A330/A340 aircraft families and the A380) are available as a forward fit. Only the dual installation configuration is currently proposed for the A350XWB. The HUD system comprises a:

- Head-Up Display Computer (HUDC): For data collection, display management, graphics generation and BITE (Built-In Test Equipment) management on A320, A330/A340 aircraft families and A380, or a Display Unit (DU) on A350XWB (basically installed),
- Head-up Projection Unit (HPU): Display device, drive electronics and projection optics,
- Head-up Combiner Unit (HCU): Optical element (glass plate), mounted behind the windshield which reflects the projected image towards the pilot. Whilst the superimposed image (to infinity) provides flight information to the pilot, he can continue to see external scenes in a completely normal way (through the HCU’s glass plate). The PMM allows the memorization of the electronic bore-sighting parameters. This electronic process consists in aligning the optical references of the HUD cockpit equipment with those of the aircraft.
- Personalization Memory Module (PMM): For memorization of the electronic bore-sighting parameters.

The HUDC receives data from the aircraft’s sensors and generates the display symbology. The HPU includes a LCD (Liquid Crystal Display) imager that projects the image onto the HCU. The HCU is an optical element (a glass plate), mounted between the pilot’s head and the windshield which reflects the projected image towards the pilot. Whilst the superimposed image (to infinity) provides flight information to the pilot, he can continue to see external scenes in a completely normal way (through the HCU’s glass plate). The PMM allows the memorization of the electronic bore-sighting parameters. This electronic process consists in aligning the optical references of the HUD cockpit equipment with those of the aircraft.

The certifications of the new MPP HUD system were achieved on the following dates:

- A318 (PW): 23rd Nov 2007,
- A320 & A318 (CFM): 17th Dec 2007,
- A319 (CFM): 18th March 2008,

The certifications on A319 and A320 aircraft with IAE engines are forecasted by the end of 2010. The certification on other aircraft models (e.g. A330/A340 Family and A321) will depend on the customers’ requests.
MPP HUD (MULTI-PROGRAMME PROJECT HEAD-UP DISPLAY)

The single installation configuration is composed of one HUD set (HUDC + HPU + HCU + PMM) installed on the Captain’s side. For the dual installation, one HUD set installed on the First Officer’s side completes the single installation.

In accordance with the MPP HUD development policy, one of the most ambitious challenges was that one same HUD be installed in the A320, A330/A340 aircraft families and A380 aircraft cockpits, despite their different architectures. This target has been achieved since the HUD part numbers remain the same, whatever the Airbus aircraft. This offers the benefit of having the Airbus cockpit commonality and brings cost savings to the operators in terms of maintenance and spares.

A350XWB HUD

The dual installation configuration (upon the A350XWB basic configuration) is composed of two HUD cockpit equipment sets (HPU, HCU and PMM).

The HUD part numbers for the A350XWB are specific to this aircraft because the HUDC is no longer needed, as the software is hosted in the Head Down Display as part of the Display Global Work Package (see A350XWB HUD overall system architecture), therefore saving space and weight.

The MPP HUD system was the first fully digital HUD certified on a civil aircraft. Indeed, it is the first HUD based on the LCD (Liquid Crystal Display) technology and not on the commonly used CRT (Cathode Ray Tube) technology. For the HUD, the LCD technology provides an increased reliability and a great image luminosity. It also provides advantages in volume, weight and consumption savings that greatly reduces the operational costs when the aircraft is equipped with such a system. The LCD technology offers additional graphic capabilities without time disruptions (reverse video, halosing effect, priorities, line thickness, grey level, etc.) and a good quality and legibility of the symbols.
The main benefits introduced by the new A350 HUD compared to the MPP product are:

- Weight savings and volume linked to the integrated architecture as part of the Display Global Work Package (no additional HUDC),
- More integrated solutions in the cockpit layout (linings, etc.),
- Better reliability based on LED backlighting (instead of lamps) for the LCD display,
- Better optical performances (e.g. with regards to the eyes' motion box defining the three dimensional area in space in which the centre of the HUD virtual display can be viewed with at least one eye).

**HUD core function (symbology)**

The primary aim of the HUD symbology is to provide essential flight data and information needed for the safe and effective control of the aircraft. It is necessary for the symbology to accurately represent the outside (conformal) view, while not obstructing this outside view.

The following items are unique to HUD symbology:

- Conformal display elements: Some HUD symbols are designed to overlay the real world as seen by the pilot through the HUD Combiner,
- Viewing position: The HUD is designed to be viewed from the cockpit Eye Reference Point and a head movement area around that point, called the “Eye Motion Box”;
- Viewing into the sun: The HUD is designed to be able to project symbology that can be seen against a very bright background (34000 Cd/m²). The pilots can use the dedicated sun-visor to reduce the intensity of the sun and can set the brightness of the symbology so that it can be seen (or use an automatic brightness feature).
The core symbols of the HUD is the attitude/energy box, mainly composed of the:

- Aircraft attitude (pitch, roll, side-slip and heading).
- The FPV (Flight Path Vector) also commonly named 'bird'.
- The Total FPA (Flight Path Angle).
- The speed delta (on the left side of the FPV).

The Flight Path Vector (FPV) indicates the actual aircraft’s trajectory through the aircraft Flight Path Angle (FPA) as the longitudinal component and the aircraft drift angle as the lateral component.

The Total FPA (or total energy 'chevrons') indicates the actual total energy of the aircraft (potential and kinetic). On top, it provides the acceleration/deceleration status of the aircraft.

The velocity vector FPV associated to the total energy (Total FPA) assist the pilot to control the speed and path stability during the approach.

One of the other fundamental elements of the HUD is the conformal approach symbology which allows enhancement of the pilots’ situational awareness, by showing conformal trajectory related symbols superimposed to the external scene.

The angle between the LOC (Localizer) axis and the horizon indicates the lateral deviation of the aircraft’s position with the runway centre line.

The position of the Approach Reference Flight Path symbol versus the touchdown point, indicates the aircraft’s vertical position versus its ideal approach path.

The symbology set described on the left, including the Primary Flight Display-like symbology (altitude, speed scale, Flight Mode Annunciator, etc.) is the primary display mode of the HUD.
Some special symbology sets have been developed and are optimized so as the HUD adapts itself to the current flight phase and provides the associated display modes:

- Taxi (ground speed, acceleration cue, etc.),
- Take-Off (lateral raw data and guidance, tail strike limit for A380, etc.),
- Climb, cruise, descent for mainly weather avoidance (windshear warning, TCAS RA (Traffic Alert and Collision Avoidance System Resolution Advisory) warning, etc.,
- Approach (mainly composed of the here-above described symbology),
- Roll-Out (ground deceleration scale, etc.).

Each display mode has various ‘de-cluttered’ level functions of the flight phases, in order to favour see-through capability of the HUD.

**Operational benefits**

The HUD system improves the crews’ situational awareness (therefore contributing to safety) in providing:

- Situational information for the manual visual approaches and landings. With the display of the approach reference path marks, the HUD can replace airport aids such as the VASIS (Visual Approach Slope Indicator System) or PAPI (Precision Approach Path Indicator), enabling the pilot to precisely calibrate and follow a desired approach path without external aids.
- Enhanced stability of manually flown approaches (instrument and visual approaches) and the accuracy of the landing touchdown, by providing the velocity vector associated to the total energy in the HUD; this facilitates the pilots’ control of speed and path stability during the approach.
- An enhancement in flying seamlessly Instrument Meteorological Condition (IMC) to Visual Meteorological Condition (VMC), flying head-up.
- Enhanced pilot situational awareness when close to the ground by showing conformal trajectory related symbols superimposed to the external scene (aircraft trajectory in poor visibility as seen on the previous HUDs),
- Situational information for the monitoring of automatic approaches with Autoland (CAT II & CAT III approaches with ‘Autoland’ and roll-out).
- Reversionary means for roll-out in the event of an untimely ‘Autopilot’ disconnection or a failure of a system affecting automatic roll-out, following an automatic approach and landing.
- A wider field of view (35° x 26°) in high crosswind conditions.
The Head-Up Display (HUD) contributes significantly to increasing the pilot situational awareness, particularly during the approach and landing phases by showing trajectory related symbols superimposed on the pilot’s actual external view. The experience in service confirmed that the HUD is a very good means to stabilize the aircraft during the approach phase, assuming that the flight crews follow a dedicated HUD training. The HUD system also offers enhancement with a video image support. Indeed, the fully digital processing allows the HUD to display the video image as well as the symbols without any constraints (particularly on graphic capability and flexibility which are not time constraining). The HUD is designed to support future technologies such as the EVS (Enhanced Video System), SVS (Synthetic Vision System) or SGS (Surface Guidance System) that will enhance surface operations and obstacle awareness. Thanks to HUD capabilities, these future growing evolutions will reinforce the enhancement of flight safety on all Airbus aircraft models.

In addition to these improvements, the HUD system also brings some operational credits, such as:

- The lateral guidance information for take-off roll, in low visibility (certified on the A320 Family, on-going development for the A380). As with the Para-Visual Indicator (PVI), the lower take-off minima can be reduced from a 125m Runway Visual Range (RVR) for EASA (500ft. for FAA) to a 75 meters RVR for EASA (300ft. for FAA), thanks to this lateral guidance information.
- The HUD is eligible in approach, for reduction of CAT I Approach minima, down to CAT II Approach minima (conducted with Auto-Pilot engaged) on Type 1 airport installations as per FAA Order 8400.13B or EASA NPA OPS-41. This operational benefit requires an operational approval from the operator’s airworthiness authority.
- Final approach trajectory (through the control system with the HUD approach symbols) very clear and appreciated (exact flight path of the aircraft).
- Reference mark of the runway slope (conformal approach symbols) very helpful,
- Ground deceleration scale to monitor ‘Autobrake’ action or control manual braking during roll-out done with ease,
- During taxi, the indication of the ground speed and the energy ‘chevrons’ (Total FPA), highly appreciated.

In regards to the operational feedback (Entry-Into-Service in 2009), the customers with aircraft equipped with HUD highlighted the following:

- The HUD installation is retrofittable. The retrofit conditions have to be defined and agreed by the involved aircraft programme.