

# Advisory Circular

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## HEAD-UP DISPLAY (HUD) / ENHANCED VISION SYSTEM

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### GENERAL

Advisory Circulars (ACs) are issued by the Director-General of Civil Aviation (DGCA) from time to time to provide practical guidance or certainty in respect of the statutory requirements for aviation safety. ACs contain information about standards, practices and procedures acceptable to CAAS. An AC may be used, in accordance with section 3C of the Air Navigation Act (Cap. 6) (ANA), to demonstrate compliance with a statutory requirement. The revision number of the AC is indicated in parenthesis in the suffix of the AC number.

### PURPOSE

This AC provides guidance to demonstrate compliance with the requirements regarding, and information related to an application for, an approval for operations using automatic landing system, combined vision system, enhanced vision system, synthetic vision system or head-up display in accordance with ANR-98.

### APPLICABILITY

This AC is applicable to the operator seeking an approval for HUD/EVS operations.

### RELATED REGULATIONS

This AC relates specifically to Division 5 in Part 2 of ANR-98.

### RELATED ADVISORY CIRCULARS

- AC 98-1-1 Application for an Approval to Conduct a Special Operation
- AC 98-4-1 Low Visibility Operations (LVO)

### CANCELLATION

This AC supersedes AC AOC-17.

**EFFECTIVE DATE**

This AC is effective from 1 October 2018.

**OTHER REFERENCES**

- ICAO Annex 6 Part 1 Attachment H Automatic landing systems, head-up display (HUD) or equivalent displays and vision systems (EVS)
- RTCA DO-315 / EUROCAE ED-179 Minimum aviation system performance standards (MASPS) for enhanced vision systems, synthetic vision systems, combined vision systems and enhanced flight vision systems

## 1 INTRODUCTION

A HUD, vision systems and hybrid systems may be installed and operated to provide guidance, enhance situational awareness and/or to obtain an operational credit by establishing minima below the aerodrome operating minima, for approach ban purposes, or reducing the visibility requirements or requiring fewer ground facilities as compensated for by airborne capabilities. HUD and vision systems may be installed separately or together as part of a hybrid system. Any operational credit to be obtained from their use requires the operator to obtain prior approval from the DGCA.

Note 1.— “Vision systems” is a generic term referring to the existing systems designed to provide images, i.e. enhanced vision systems (EVS), synthetic vision systems (SVS) and combined vision systems (CVS).

Note 2. — Operational credit can be granted only within the limits of the design approval.

Note 3. — Currently, operational credit has been given only to vision systems containing an image sensor providing a real-time image of the actual external scene on the HUD.

## 2 HUD AND EQUIVALENT DISPLAYS

### 2.1 General

2.1.1 A HUD presents flight information into the pilot’s forward external field of view without significantly restricting that external view.

2.1.2 A variety of flight information may be presented on a HUD depending on the intended flight operation, flight conditions, systems capabilities and operational approval. A HUD may include, but is not limited to, the following:

- (a) airspeed;
- (b) altitude;
- (c) heading;
- (d) vertical speed;
- (e) angle of attack;
- (f) flight path or velocity vector;
- (g) attitude with bank and pitch references;
- (h) course and glide path with deviation indications;
- (i) status indications (e.g. navigation sensor, autopilot, flight director); and
- (j) alerts and warning displays (e.g. ACAS, wind shear, ground proximity warning)

### 2.2 Operational applications

2.2.1 Flight operations with a HUD can improve situational awareness by combining flight information located on head-down displays with the external view to provide pilots with more immediate awareness of relevant flight parameters and situation information while they continuously view the external scene. This improved situational awareness can also reduce errors in flight operations and improve the pilot’s ability to transition between instrument and visual references as meteorological conditions change. Flight operations applications may include the following:

- (a) enhanced situational awareness during all flight operations, but especially during taxi, take-off, approach and landing;

- (b) reduced flight technical error during take-off, approach and landing; and
- (c) improvements in performance due to precise prediction of touchdown area, tail strike awareness/warning and rapid recognition of and recovery from unusual attitudes.

2.2.2 A HUD may be used for the following purposes:

- (a) to supplement conventional flight deck instrumentation in the performance of a particular task or operation. The primary cockpit instruments remain the primary means for manually controlling or manoeuvring the aircraft; and
- (b) as a primary flight display;
  - (i) information presented by the HUD may be used by the pilot in lieu of scanning head-down displays. Operational approval of a HUD for such use allows the pilot to control the aircraft by reference to the HUD for approved ground or flight operations; and
  - (ii) information presented by the HUD may be used as a means to achieve additional navigation or control performance. The required information is displayed on the HUD. Operational credit, in the form of lower minima, for a HUD used for this purpose may be approved for a particular aircraft or automatic flight control system. Additional credit may also be allowed when conducting HUD operations in situations where automated systems are otherwise used.

2.2.3 A HUD, as a stand-alone system, may qualify for operations with reduced visibility or RVR or replace some parts of the ground facilities such as touchdown zone and/or centre line lights. Examples and references to publications in this regard can be found in the Manual of All-Weather Operations (Doc 9365).

2.2.4 A HUD equivalent display is one that has at least the following characteristics; a head-up presentation not requiring transition of visual attention from head down to head up; displays sensor derived imagery conformal with the pilot's external view; permits simultaneous view of the EVS sensor imagery, required aircraft flight symbology, and the external view; and display characteristics and dynamics are suitable for manual control of the aircraft. Before such systems can be used, the appropriate airworthiness and operational approvals must be obtained.

## 2.3 HUD training

2.3.1 HUD training should address all flight operations for which the HUD is designed and in accordance with applicable conditions in an approval. Some training elements may require adjustments based on whether the aeroplane has a single or dual HUD installation. Training should include contingency procedures required in the event of head-up display degradation or failure. HUD training should include the following elements as applicable to the intended use:

- (a) an understanding of the HUD, its flight path, energy management concepts and symbology. This should include operations during critical flight events (e.g. ACAS Traffic Advisory/Resolution. Advisory, upset and wind shear recovery, engine or system failure);

- (b) HUD limitations and normal procedures, including maintenance and operational checks performed to ensure normal system function prior to use. These checks include pilot seat adjustment to attain and maintain appropriate viewing angles and verification of HUD operating modes;
- (c) HUD use during low visibility operations, including taxi, take-off, instrument approach and landing in both day and night conditions. This training should include the transition from head down to head-up and head-up to head-down operations;
- (d) failure modes of the HUD and the impact of the failure modes or limitations on crew performance;
- (e) crew coordination, monitoring and verbal call-out procedures for single HUD installations with head-down monitoring for the pilot not equipped with a HUD and head-up monitoring for the pilot equipped with a HUD;
- (f) crew coordination, monitoring and verbal call-out procedures for dual HUD installations with use of a HUD by the pilot flying the aircraft and either head-up or head-down monitoring by the other pilot;
- (g) consideration of the potential for loss of situational awareness due to "tunnel vision" (also known as cognitive tunnelling or attention tunneling);
- (h) any effects that weather, such as low ceilings and visibilities, may have on the performance of HUD; and
- (i) HUD airworthiness requirements.

### **3 VISION SYSTEMS**

#### **3.1 General**

- 3.1.1 Vision systems can display electronic real-time images of the actual external scene achieved through the use of image sensors (EVS) or display synthetic images, which are derived from the on-board avionic systems (SVS). Vision systems can also consist of a combination of these two systems or combined vision systems (CVS). Such a system may display electronic real-time images of the external scene using the EVS component of the system. However, the merging of EVS and SVS into a CVS is dependent on the intended function (e.g. whether or not there is intent to achieve operational credit).
- 3.1.2 The information from vision systems may be displayed on a head-up or head-down display. When enhanced vision imagery is displayed on a HUD, it should be presented to the pilot's forward external field of view without significantly restricting that external view.
- 3.1.3 The enhanced position fixing and guidance provided by SVS may provide additional safety for all phases of flight especially low visibility taxi, take-off, approach and landing operations.

3.1.4 Light emitting diode (LED) lights may not be visible to infrared-based vision systems due to the fact that LED lights are not incandescent and they do not have a significant heat signature. Operators of such vision systems will need to acquire information about the LED implementation programmes at aerodromes where they operate.

### 3.2 Operational applications

3.2.1 Flight operations with enhanced vision image sensors allow the pilot to view an image of the external scene obscured by darkness or other visibility restrictions. When the external scene is partially obscured, enhanced vision imaging may allow the pilot to acquire an image of the external scene earlier than with natural or unaided vision. The improved acquisition of an image of the external scene may improve situational awareness.

3.2.2 Vision system imagery may also allow pilots to detect terrain or obstructions on the runway or taxiways. A vision system image can also provide visual cues to enable earlier runway alignment and a more stabilised approach.

3.2.3 The combined display of aircraft performance, guidance and imagery may allow the pilot to maintain a more stabilised approach and smoothly transition from enhanced visual references to natural visual references.

### 3.3 Vision systems training

3.3.1 Training should address all flight operations for which the vision system is approved. This training should include contingency procedures required in the event of system degradation or failure. Training for situational awareness should not interfere with other required operations. Training for operational credit should also require training on the applicable HUD used to present the enhanced visual imagery. Training should include the following elements as applicable:

- (a) an understanding of the system characteristics and operational constraints;
- (b) normal procedures, controls, modes and system adjustments (e.g. sensor theory including radiant versus thermal energy and resulting images);
- (c) operational constraints, normal procedures, controls, modes, and system adjustments;
- (d) limitations;
- (e) airworthiness requirements;
- (f) vision system display during low visibility operations, including taxi, take-off, instrument approach and landing; system use for instrument approach procedures in both day and night conditions;
- (g) failure modes and the impact of failure modes or limitations upon crew performance, in particular, for two-pilot operations;
- (h) crew coordination and monitoring procedures and pilot call-out responsibilities;
- (i) transition from enhanced imagery to visual conditions during runway visual acquisition;

- (j) rejected landing: with the loss of visual cues of the landing area, touchdown zone or rollout area;
- (k) any effects that weather, such as low ceilings and visibilities, may have on the performance of the vision system; and
- (l) effects of aerodrome lighting using LED lights.

### 3.4 Operational concepts

3.4.1 Instrument approach operations that involve the use of vision systems include the instrument phase and the visual phase. The instrument phase ends at the published MDA/H or DA/H unless a missed approach is initiated. The continued approach to landing from MDA/H or DA/H will be conducted using visual references. The visual references will be acquired by use of an EVS or CVS, natural vision, or a combination of EVS/CVS with natural vision.

3.4.2 Down to a defined height, typically 30 m (100 ft), the visual references will be acquired by means of the vision system. Below this height the visual references should be solely based on natural vision. In the most advanced applications, the vision system is expected to be able to be used down to touchdown without the requirement for natural vision acquisition of visual references. Using the EVS or CVS does not change the classification of an instrument approach procedure, since the published DA/H remains unchanged and manoeuvring below DA/H is conducted by visual references acquired by means of the an EVS or CVS.

3.4.3 In addition to the operational credit that EVS/CVS is able to provide, these systems may also provide an operational and safety advantage through improved situational awareness, earlier acquisition of visual references and smoother transition to references by natural vision. These advantages are more pronounced for Type A approach operations than for Type B approach operations.

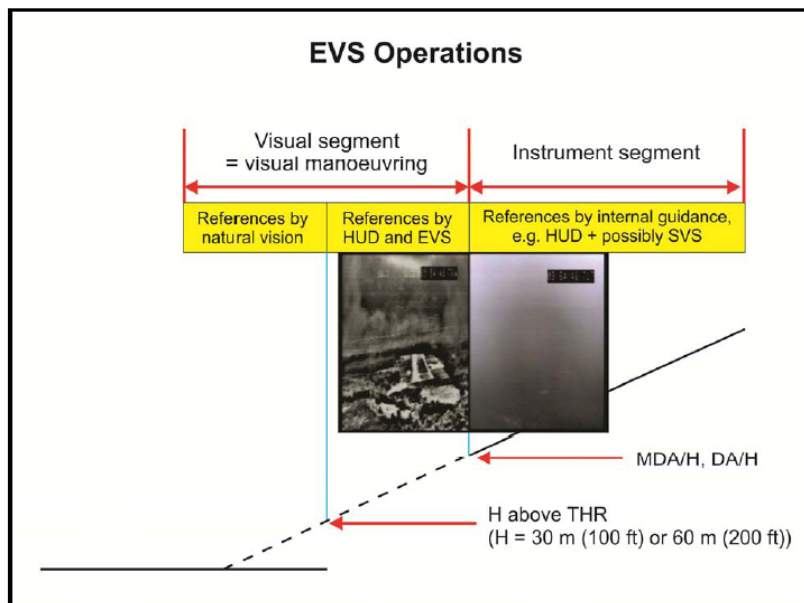


Figure 1. EVS operations — transition from instrument to visual references

3.5 Visual references

3.5.1 The required visual references do not change due to the use of an EVS or CVS, but those references are allowed to be acquired by means of either vision system until a certain height during the approach.

3.5.2 In regions that have developed requirements for operations with vision systems, the visual references are indicated in Figure 1.

**Table 1.**

<b>OPERATIONS BELOW DA/DH OR MDA/MDH</b>	
Example 1	Example 2
<p>For procedures designed to support Type A operations, the following visual references for the intended runway must be distinctly visible and identifiable:</p> <ul style="list-style-type: none"> <li>• the approach lighting system; or</li> <li>• the runway threshold, identified by at least one of the following:               <ul style="list-style-type: none"> <li>– the beginning of the runway landing surface;</li> <li>– threshold lights; or</li> <li>– runway end identifier lights; and</li> </ul> </li> <li>• the touchdown zone, identified by at least one of the following:               <ul style="list-style-type: none"> <li>– the runway touchdown zone landing surface;</li> <li>– touchdown zone lights;</li> <li>– touchdown zone markings; or</li> <li>– runway lights.</li> </ul> </li> </ul>	<p>For procedures designed to support 3D Type A and Type B Cat I operations, the following visual references should be displayed and identifiable to the pilot on the EVS image:</p> <ul style="list-style-type: none"> <li>• elements of the approach lighting system; or</li> <li>• the runway threshold, identified by at least one of the following:               <ul style="list-style-type: none"> <li>– the beginning of the runway landing surface;</li> <li>– threshold lights;</li> <li>– threshold identification lights; or</li> </ul> </li> <li>– the touchdown zone, identified by at least one of the following:               <ul style="list-style-type: none"> <li>• the runway touchdown zone</li> <li>• landing surface;</li> <li>• touchdown zone lights</li> <li>• touchdown zone</li> <li>• runway lights</li> </ul> </li> </ul>
Operations below 60 m (200 ft) above touchdown zone elevation –	Operations below 60 M (200 ft) above threshold elevation –
No additional requirements apply at 60 m (200 ft).	For procedures designed to support 3D Type A operations, the visual references are the same as those specified below for Type B Cat I operations.
Operations below 30 m (100 ft) above touchdown zone elevation –	Operations below 30 m (100 ft) above threshold elevation –
<p>The visibility must be sufficient for the following to be distinctly visible and identifiable to the pilot without reliance on the EVS:</p> <ul style="list-style-type: none"> <li>• the lights or markings of the threshold; or</li> <li>• the lights or markings of the touchdown zone.</li> </ul>	<p>For procedures designed to support Type B Cat II operations, at least one of the visual references specified below should be distinctly visible and identifiable to the pilot without reliance on the EVS:</p> <ul style="list-style-type: none"> <li>• the lights or markings of the threshold; or</li> <li>• the lights or markings of the touchdown zone.</li> </ul>



## 4 HYBRID SYSTEMS

- 4.1 A hybrid system generically means that two or more systems are combined. The hybrid system typically has improved performance compared to each of the component systems, which in turn may qualify for operational credit. Vision systems are normally part of a hybrid system, e.g. EVS is typically combined with a HUD. Including more components in the hybrid system normally enhances the performance of the system.
- 4.2 Table 2 provides some examples of hybrid system components. Any combination of the listed systems may constitute a hybrid system. The degree of operational credit that may be given to a hybrid system depends on its performance (accuracy, integrity and availability) as assessed and determined by the certification and operational approval processes.

**Table 2. Examples of hybrid system components**

<b>Systems based on image sensors</b>	<b>Systems not based on image sensors</b>
EVS	SVS
<ul style="list-style-type: none"> <li>• Passive infrared sensors</li> <li>• Active infrared sensors</li> <li>• Passive millimeter wave radiometer</li> <li>• Active millimeter wave radar</li> </ul>	Auto-flight systems, flight control computers, automatic landing systems
	Systems for position fixing
CVS (where the EVS component as above qualifies for operational credit)	CVS (the SVS component)
	HUD, equivalent display
	ILS, GNSS

## 5 OPERATIONAL CREDITS

- 5.1 Aerodrome operating minima are expressed in terms of minimum visibility/RVR and MDA/H or DA/H. With respect to operational credit this means that the visibility/RVR requirements, established in the instrument approach procedure, may be reduced or satisfied for aircraft equipped with appropriately approved vision systems such as EVS. Reasons for granting operational credit may be when aircraft are better equipped than what was originally considered when designing the instrument approach procedure or when runway visual aids considered in the design of the procedure are not available but can be compensated by on-board equipment.
- 5.2 Credits related to visibility/RVR can be given using at least three concepts. The first concept is to reduce the required RVR which will allow the aircraft to continue the approach beyond the approach ban point with a reported RVR lower than what was established for the approach procedure. Where a minimum visibility is prescribed, a second concept to grant operational credit may be used. In this case, the required minimum visibility is kept unchanged, but it is satisfied by means of the on-board equipment, typically an EVS. The result of both these concepts is that operations are allowed in meteorological conditions where otherwise they would not be possible. A third concept is to give operational credit by allowing operations in visibility/RVR which are not lower than those established for the approach procedure, but the approach operation is conducted with less facilities on the ground. One example of the latter is to allow category II operations without touchdown and/or centre line lights, compensated by additional on-board equipment, e.g. a HUD.

- 5.3 Granting operational credits does not affect the classification of an instrument approach procedure since instrument approach procedures are designed to support a given instrument approach operation (i.e. Type, Category). However, the design of those procedures should not take into consideration on-board equipment that may compensate for facilities on the ground.
- 5.4 In order to provide optimum service, the ATS may have to be informed about the capabilities of better-equipped aircraft, e.g. which is the minimum RVR required.
- 5.5 In addition to the operational credit that a HUD, vision systems and hybrid systems are able to provide, these systems will also provide an operational and safety advantage through improved situational awareness, earlier acquisition of visual references and smoother transition to references by natural vision. These advantages are more pronounced for 3D Type A approach operations than for Type B approach operations.

## **6 OPERATIONAL PROCEDURES**

- 6.1 It is not prohibited to use vision systems in connection with circling. However, due to the system layout of a vision system and the nature of a circling procedure, key visual references can be obtained only by natural vision, and operational credit is not feasible for existing vision systems. The vision system may provide additional situational awareness.
- 6.2 The operational procedures associated with the use of a HUD, vision systems and hybrid systems should be included in the operations manual. The instructions in the operations manual should include:
  - (a) any limitation that is imposed by the airworthiness or operational approvals;
  - (b) how operational credit affects:
    - (i) flight planning with respect to destination and alternate aerodromes;
    - (ii) ground operations;
    - (iii) flight execution, e.g. approach ban and minimum visibility;
    - (iv) crew resource management that takes into account the equipment configuration, e.g. the pilots may have different presentation equipment;
    - (v) standard operating procedures, e.g. use of auto-flight systems, call-outs that may be particular to the vision system or hybrid system, criteria for stabilised approach;
    - (vi) ATS flight plans and radio communication.

## 7 APPROVALS

### 7.1 General

- 7.1.1 An operator that wishes to conduct operations with a HUD or equivalent display, vision system or hybrid system will need to obtain an approval from the DGCA. The extent of the approval will depend on the intended operation and the complexity of the equipment.
- 7.1.2 Enhanced vision imagery may be used to improve situational awareness without a specific operational approval. However, the standard operating procedures for these types of operations need to be specified in the operations manual. An example of this type of operation may include an EVS or an SVS on a head-down display that is used only for situational awareness of the surrounding area of the aircraft during ground operations where the display is not in the pilot's primary field of view. For enhanced situational awareness, the installation and operational procedures need to ensure that the operation of the vision system does not interfere with normal procedures or the operation or use of other aircraft systems. In some cases, modifications to these normal procedures for other aircraft systems or equipment may be necessary to ensure compatibility.
- 7.1.3 When a vision system or a hybrid system with vision systems imagery is used for operational credit, operational approvals will typically require that the imagery be combined with flight guidance and presented on a HUD. An operational approval may include a condition that this information also be presented on a head-down display. Operational credit may be applied for any flight operation, but credit for instrument approach and take-off operations is most common.
- 7.1.4 Operators should be aware that some States may require some information about the operational credit(s) which has been granted by the DGCA.

### 7.2 Approvals for operational credit

To obtain operational credit, the operator will need to specify the desired operational credit and submit an application to the DGCA. The content of such an application should include:

- (a) Applicant details — required for all approval requests. The official name and business or trading name(s), address, mailing address, e-mail address and contact telephone/fax numbers of the applicant.
- Note: For AOC holders, the company name, AOC number and e-mail address should be required.
- (b) Aircraft details — required for all approval requests. Aircraft make(s), model(s) and registration mark(s).
- (c) Operator's vision system compliance list. The contents of the compliance list are included in Table 3. The compliance list should include the information that is relevant to the approval requested and the registration marks of the aircraft involved. If more than one type of aircraft/fleet is included in a single application a completed compliance list should be included for each aircraft/fleet.
- (d) Documents to be included with the application. Copies of all documents referred to in column 4 of the operator's vision system compliance list (Table 3)

should be included when returning the completed application form to the civil aviation authority. There should no need to send complete manuals; only the relevant sections/pages should be required.

- (e) Name, title and signature.

**Table 3. Example of an AOC vision system compliance list**

<b>Main Heading</b>	<b>Expanded areas to be addressed by the application</b>	<b>Sub-requirements</b>	<b>Operator's operations manual reference or document reference</b>
1.0 Reference documents used in compiling the submission	The submission should be based on current up-to-date regulatory material.  A compliance statement showing how the criteria of the applicable regulations and requirements have been satisfied.		
2.0 Aircraft flight manual (AFM)	A copy of the relevant AFM entry showing the aircraft certification basis for the vision system and any operational conditions.		
3.0 Feedback and reporting of significant problems	An outline of the process for the reporting of failures in the operational use of procedures.  <i>Note. — In particular, significant problems with the vision system/ HUD systems, reporting on circumstances/locations where the vision system was unsatisfactory.</i>		
4.0 Instrument approach chart provider and operating minima	The name of the provider of the relevant Instrument approach charts.  Confirmation that all aerodrome operating minima are established in accordance with the method acceptable to the relevant authority.		

<p>5.0 Operations manual entries and standard operating procedures</p>	<p>Manufacturer/operator developed.</p> <p>Manufacturer's procedures are recommended as a starting point and should include at least the items in the sub-requirements column.</p>	<p>Definitions.</p> <p>Check that crew members are qualified for vision system/HUD operations.</p> <p>MEL handling.</p> <p>Equipment required for vision system operations.</p> <p>Types of approach where vision systems can be used.</p> <p>Statement that the autopilot/flight director should be used whenever possible.</p> <p>Minimum visual references for landing. Approach ban and RVR.</p> <p>Stabilised approach criteria.</p> <p>Correct seating and eye position.</p> <p>Crew coordination, e.g. duties of the pilot flying and the pilot not flying:</p> <ul style="list-style-type: none"> <li>• limitations;</li> <li>• designation of handling and non handling pilots;</li> <li>• use of automatic flight control system;</li> <li>• checklist handling;</li> <li>• approach briefing;</li> <li>• radio communications handling;</li> <li>• monitoring and cross-checking of instruments and radio aids; and</li> <li>• use of the repeater display by the pilot not flying.</li> </ul> <p>Contingency procedures including:</p> <ul style="list-style-type: none"> <li>• failures above and below decision height;</li> <li>• ILS deviation warnings; <ul style="list-style-type: none"> <li>• autopilot disconnect;</li> </ul> </li> <li>• auto-throttle disconnect;</li> <li>• electrical failures;</li> <li>• engine failure;</li> <li>• failures and loss of visual references at or below decision height;</li> <li>• vision system/HUD failure below normal decision height;</li> <li>• wind shear;</li> <li>• ACAS warnings;</li> <li>• EGPWS warnings.</li> </ul>	
<p>6.0 Safety risk assessment</p>		<p>Operator's safety risk assessment.</p>	