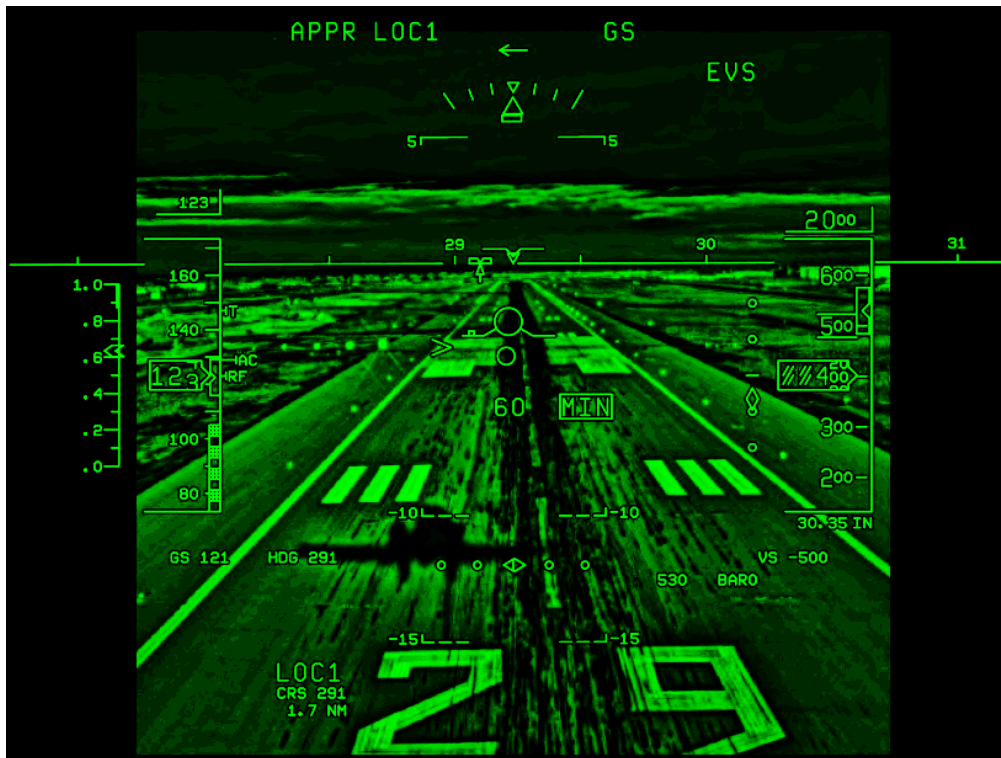




EUROPEAN AVIATION SAFETY AGENCY



Operational Evaluation Board Report

ROCKWELL COLLINS MODEL 6605 HEAD-UP DISPLAY (HUD) & ENHANCED VISION (EVS) SYSTEM

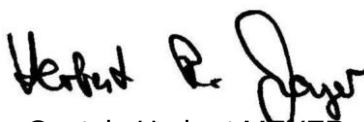
OEB Report Rev. 2

08 August 2012

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ROCKWELL COLLINS MODEL 6605 HEAD-UP DISPLAY (HUD) & ENHANCED VISION (EVS) SYSTEM

Operational Evaluation Board (OEB)



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Revision Record

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Original	Initial Evaluation	15 Oct 2009
Rev. 1	Report Update	22 Feb 2010
Rev. 2 Draft	Model 6605 HUD & EVS modifications	22 May 2012
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Acronyms

AFM	Airplane Flight Manual
CAT I	Category I approach
CAT II	Category II approach
CPD	Common Procedures Document for conducting Operational Evaluation Boards, dated 10 June 2004
CBT	Computer Based Training
EASA	European Aviation Safety Agency
EICAS	Engine Indicating and Crew Alerting System
EU-OPS	Commission Regulation (EC) No 859/2008 of 20 August 2008 amending Council Regulation (EEC) No 3922/91 as regards common technical requirements and administrative procedures applicable to commercial transportation by aeroplane.
EVS	Enhanced Vision System
FAF	Final Approach Fix
FCOM	Flight Crew Operating Manual
FMS	Flight Management System
FPS	Flight Path Symbol
HGS	Head up Guidance System
HDD	Head Down Display
HUD	Head-up display
IFR	Instrument Flight Rules
IR	Infra-Red
LED	Light Emitting Diode
MFD	Multi-function Display
MMEL	Master Minimum Equipment List
OEB	Operational Evaluation Board
OEI	One Engine Inoperative
Part-FCL	Commission Regulation (EU) No 1178/2011 of 3 November 2011 laying down technical requirements and administrative procedures related to civil aviation aircrew pursuant to Regulation (EC) No 216/2008 of the European Parliament and of the Council.
PF	Pilot Flying
PFD	Primary Flight Display
PIC	Pilot In Command
PNF	Pilot Not Flying

QRH Quick Reference Handbook
 RVR Runway Visual Range
 TAWS Terrain Awareness Warning System
 TCAS Traffic Collision Avoidance System
 TDZE Touch Down Zone Elevation
 UA Unusual Attitude
 VFR Visual Flight Rules

OEB Group Composition

Name	Capacity	Task
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Ron TIDY ¹⁾	TCCA	OE Chairman

¹⁾ Aug 2009 / Feb 2010, Rockwell Collins Model 6605 HUD evaluation

²⁾ Dec 2011 / Jan 2012, Rockwell Collins Model 6605 HUD & EVS evaluation

Note on references and reference texts:

Where references are made to requirements and where extracts of reference texts are provided, these are at the amendment state at the date of publication of the report.

EXECUTIVE SUMMARY

The European Aviation Safety Agency (EASA) participated in an evaluation of the Rockwell Collins Model 6605 Head-up Display System (HUD) and the Rockwell Collins Model 6605 Enhanced Vision System (EVS) in August 2009 using a Bombardier Challenger CL-605 Level D simulator and CL-605 aircraft at Bombardier's Flight Test facility in Wichita, Kansas. A follow up evaluation was conducted during December 2011 at the Bombardier training facility Dallas, Texas and January 2012 from Rockwell Collins' Cedar Rapids, Iowa base following a significant upgrade to the EVS.

The evaluations were carried out jointly by the Flight Standardisation Board of the Federal Aviation Administration (FAA), the Operational Evaluation Board of Transport Canada Civil Aviation (TCCA), and the Operational Evaluation Board of the European Aviation Safety Agency (EASA). The 3 individual boards are responsible for reporting their findings to their National Authorities in separate reports. This report is the EASA OEB report.

This report consists of two parts:

- **PART 1 HEAD-UP DISPLAY (HUD)**
- **PART 2 ENHANCED VISION SYSTEM (EVS)**

EASA found the Rockwell Collins Model 6605 HUD operationally suitable for all phases of flight, including low visibility takeoff, CAT I and CAT II operations. The detailed description of recommendations for training, checking and currency are contained in this report.

PART 1 HEAD-UP DISPLAY (HUD)

1. ROCKWELL COLLINS MODEL 6605 HEAD-UP DISPLAY (HUD) SYSTEM

- 1.1 The European Aviation Safety Agency participated in an evaluation of the Rockwell Collins Model 6605 Head-up Display System (HUD) in August 2009 using a Bombardier Challenger CL-605 Level D simulator and CL-605 aircraft. At Bombardier's Flight Test facility in Wichita, KS, the OEB completed numerous HUD approaches at several different airports, using CAT I procedures during day and night.
- 1.2 EASA found the Rockwell Collins Model 6605 HUD operationally suitable for all phases of flight and for CAT I operations.
- 1.3 Low visibility takeoff and CAT II operations using the HUD were evaluated and found suitable during the operational evaluation of December 2011 and January 2012.

2. PREREQUISITES FOR HUD TRAINING

- 2.1 A prerequisite to HUD training in a Bombardier Challenger CL-605 airplane, is prior training, type rating and currency in the Bombardier Challenger CL-605, unless the HUD training is integrated with, or occurs sequentially preceding an initial type rating skill test.

3. HUD TRAINING - GENERAL

- 3.1 The HUD pilot training requirements consist of those related to initial and recurrent ground and flight training. It should be noted that the HUD training programme focuses principally upon training events flown in the left seat by the PIC as PF. Nevertheless, HUD training of PNF duties in the right seat is required, where there are procedural differences for the PNF, and when the PF is heads up (compared to heads down). PNF HUD familiarization flown in the left seat is recommended.
- 3.2 Flight crewmember training must be accomplished using a CL-605 Level C simulator with a daylight visual display, or a CL-605 Level D simulator, or a CL-605 aircraft equipped with a Rockwell Collins Model 6605 Head-up Display System. Each PIC should receive a minimum of 3 hours of HUD ground school training, followed by a minimum of 3 hours of HUD flight training, in the left seat, in either an approved CL-605 Level C or D simulator or CL-605 aircraft. The 3 hours of ground and 3 hours of flight training is an initial requirement only.
- 3.3 The recommended 3 hours of flight training need not be completed, if a person who progresses satisfactorily through flight training, has been recommended by an instructor, and has successfully completed the appropriate HUD proficiency check under the supervision of a person authorized by the competent Authority.

4. HUD INITIAL GROUND TRAINING

4.1 The initial HUD ground training programme should include the following elements:

- a. Classroom instruction covering HUD operational concepts, crew duties and responsibilities and operational procedures including preflight, normal and abnormal operations, Glideslope angle modification in the FMS, EICAS messages, use of AFM Supplement, FCOM, QRH, and checklists, miscompare, and failure flags.
- b. Classroom instruction or CBT on the HUD symbology set and its inter-relationship with airplane aerodynamics, inertial factors, environmental conditions and comparison to the PFD.

An actual HUD video should be used to reinforce training in the following areas:

- (1) Take off and Go Around. Use of the Takeoff Reference Line Indicator (which is not immediately visible) and the Aircraft Reference symbol for takeoff and go around rotation and the transition to the FPS and the Flight Director Guidance Cue.
 - (2) Unusual Attitudes. Transitions to and from the decluttered display, and the use of the Aircraft Reference symbol during the recovery and when to transition back to the FPS.
 - (3) Approach to Stall and Stall Recovery. Use of the Angle-of-Attack Limit Indicator for approach to stall awareness and its use with respect to the FPS during stall recoveries.
 - (4) Glideslope Reference Line. Use of the Glideslope Reference Line and the FPS as the sole final approach reference.
- c. A Rockwell Collins Model 6605 Head-Up Guidance (HGS) pilot guide, Model 6605 HUD/EVS AFM Supplement, or equivalent materials (e.g. FCOM), which explain HUD limitations, modes of operation, descriptions of HUD symbology, limit conditions and failures, and which define crew procedures that delineate PF and PNF duties, responsibilities, and call-outs during all phases of flight in which HUD operations are conducted.
 - d. Special emphasis ground training shall be conducted in the following areas:
 - (1) Crew Coordination;
 - (2) Crew Briefings and Callouts;
 - (3) Duties of PF and PNF; and
 - (4) EICAS messages and use of the QRH and checklists applicable to HUD operations.

5. HUD INITIAL FLIGHT / SIMULATOR TRAINING

- 5.1 Unless integrated with CL-605 initial type rating training, flight training dedicated to HUD familiarization and proficiency is in addition to other required training elements.
- 5.2 All required approaches, utilizing the HUD, should begin no closer than at the FAF for instrument approaches, and should begin no closer than approximately 1,000 feet AGL (3 - 4 NM) to the runway threshold for visual approaches.
- 5.3 The following HUD flight training programme is generic in nature and should be considered as a minimum training requirement only.
- a. Ground Operations:
 - (1) Deployment of HUD and stowage, including installation and removal of the HUD sun visor; and
 - (2) Taxi using HUD under various lighting and visibility conditions.
 - b. Airwork:
 - (1) Straight and level flight, accelerations and decelerations;
 - (2) Normal and steep turns, climbs and descents;
 - (3) Wind Effects on HUD display;
 - (4) Approach to stall recovery; and
 - (5) Recovery from unusual attitudes.
 - c. Visual Take-offs, Approaches and Landings
 - (1) Crosswind take-off and landing;
 - (2) Visual approaches to runways at night with minimal lighting ("black hole" approaches) and use of FPS and Glideslope Reference Line to achieve desired descent angle;
 - (3) Engine failure on take-off;
 - (4) OEI landing; and
 - (5) OEI go-around.
 - d. Instrument Approaches:
 - (1) Approaches to the lowest authorized minima including an approach and landing with OEI;
 - (2) Missed approach OEI; and
 - (3) Non-precision, and circling approaches (if applicable).

NOTE: It is desirable to fly visual and instrument approaches with dissimilar approach and lighting systems.

e. Abnormal/Emergency Operations: (as applicable)

- (1) Wind shear escape;
- (2) TAWS escape;
- (3) TCAS Resolution Advisory;
- (3) HUD failure on approach and its effect on pilot workload and PF/PNF duties and responsibilities; and
- (5) Approaches with the aircraft in a non-normal flap configuration.

5.4 Special emphasis flight training shall be conducted in the following areas:

- (1) HUD unique symbology with the autopilot and flight director both off and on, i.e. FPS, Flight Path Acceleration Cue, speed error tape, low and high speed cues, flight mode annunciator, use of non-conformal symbology including the use of the FPS to recognize and recover from flight at high angles of attack, and excessive pitch chevrons;
- (2) Use of the Angle-of-Attack Limit Indicator and the FPS for approach to stall awareness and its use during a stall recovery;
- (3) Use of the unusual attitude (UA) display, automatic changes between UA and normal HUD displays during recovery from unusual attitude encounters, the aircraft reference symbol, the change to a normal display, and when to transition to the FPS during recoveries;
- (4) Transitioning to HDD's and the inclusion of HDD's in the crosscheck including EICAS displays and other cockpit indications;
- (5) Avoidance of fixation on HUD display and symbology elements, particularly during the landing flare manoeuvre and appropriate conditions to turn OFF the HUD display;
- (6) Use of the Takeoff Reference Line Indicator and the Aircraft Reference symbol for the pitch rotation target on takeoff and go-around;
- (7) Use of the Glideslope Reference Line and FPS for visual approaches, and in crosswind landing technique;
- (8) HUD brightness settings for different approach lighting systems; and
- (9) Use of HUD in conjunction with the sun-visor.

6. HUD INITIAL CHECKING REQUIREMENTS

- 6.1 Upon completion of training, a PIC must pass an Operators Proficiency Check (OPC) conducted in a CL-605 Level C simulator with a daylight visual display, or CL-605 Level D simulator, or on a Rockwell Collins Model 6605 HUD system equipped CL-605 aircraft. This proficiency check may be taken in conjunction with a Licensing Skill Test according to Part-FCL or may be administered as a separate test.
- 6.2 Maneuvers to be evaluated during the HUD proficiency check include as a minimum:
- a. One takeoff;
 - b. One departure procedure;
 - c. One instrument approach procedure;
 - d. One missed approach; and
 - e. One landing.
- 6.3 SIC's should be checked on PNF duties during HUD approaches and emergencies.

7. HUD RECURRENT TRAINING REQUIREMENTS

- 7.1 Selected HUD related ground training subjects as outlined in paragraph 4. above should be reviewed on a recurrent basis.
- 7.2 As a minimum, selected HUD related flight training manoeuvres as listed below should be reviewed on a recurrent basis.
- a. Stall recognition and recovery;
 - b. Unusual attitude recovery from de-cluttered display;
 - c. Takeoff with engine failure at V_1 ;
 - d. Approach, either precision or non-precision, with missed approach;
 - e. Approach (with crosswind, if available) and landing; and
 - f. Selected abnormal/emergency manoeuvres (e.g. HUD AFM procedures, approach and landing with OEI, TCAS RA, TAWS escape, etc.).

8. HUD RECURRENT CHECKING REQUIREMENTS

- 8.1 At least annually, in conjunction with a proficiency check required by Part-FCL, a PIC must demonstrate proficiency in using the Rockwell Collins Model 6605 HUD system by satisfactorily performing the manoeuvres listed under paragraph 6.2.

- 8.2 At least annually, SIC's should be evaluated on crew resource management (CRM) responsibilities and procedures as PNF when the PF is conducting HUD operations.

9. HUD CURRENCY REQUIREMENTS

PIC's should have completed at least three takeoffs, approaches, and landings as the PF using the Rockwell Collins Model 6605 HUD system in the Bombardier Challenger CL-605 airplane, or have completed three takeoffs, approaches, and landings as PF using the Rockwell Collins Model 6605 HUD system in a CL-605 Level C simulator with a daylight visual display, or CL-605 Level D simulator, within the previous 90 days before acting as PF using the HUD.

PART 2 ENHANCED VISION SYSTEM (EVS)

1. ROCKWELL COLLINS MODEL 6605 ENHANCED VISION SYSTEM (EVS)

- 1.1 The European Aviation Safety Agency (EASA) participated in a joint evaluation of the Rockwell Collins Model 6605 Enhanced Vision System (EVS) in August 2009, December 2011 and January 2012 using a Bombardier Challenger CL-605 Level D simulator and Bombardier Challenger CL-605 aircraft. The evaluation was conducted at Bombardier's Flight Training facility in Dallas, Texas, and from Rockwell Collins' Cedar Rapids, Iowa base. EASA evaluated operations using the EVS to determine operational suitability of the system in accordance with EU OPS 1.440, 1.455 and Appendix 1 (New) to 1.430.
- 1.2 EASA found the Rockwell Collins Model 6605 EVS operationally suitable during ground and flight operations subject to the limitations in the AFM.

2. PREREQUISITES FOR EVS TRAINING

- 2.1 As a prerequisite for EVS training, pilots should have successfully completed Rockwell Collins Model 6605 HUD training in the Bombardier Challenger CL-605 Level C or D simulator, or CL-605 aircraft. These EVS requirements assume that a pilot entering an EVS training programme is trained and proficient in the use of the Rockwell Collins Model 6605 HUD.

Note: This does not preclude the display of the EVS during initial HUD training for purposes of EVS familiarization. However, such familiarization is not creditable toward EVS training as specified in this report.

3. EVS TRAINING – GENERAL

- 3.1 The EVS pilot training requirements consist of those related to initial and recurrent ground and flight training. It should be noted that the HUD and EVS training programmes focus principally upon training events flown in the left seat by the PIC as the PF. Nevertheless, EVS training in the duties of the PNF in the right seat is required. PNF EVS familiarization flown in the left seat is recommended.
- 3.2 Flight crewmember training must be accomplished using a CL-605 Level C simulator with a daylight visual display, or a CL-605 Level D simulator, or a CL-605 aircraft equipped with a Rockwell Collins Model 6605 EVS. EASA has determined that each PIC should receive a minimum of 2 hours of EVS ground school training, followed by a minimum of 2 hours of EVS flight training, in the left seat, in either an approved CL-605 Level C or D simulator or CL-605 aircraft. The 2 hours of ground and 2 hours of flight training is an initial requirement only.

4. EVS INITIAL GROUND TRAINING

- 4.1 The initial ground training programme should include the following elements:
- a. Classroom instruction covering EVS operational concepts, crew duties and responsibilities and operational procedures including preflight, normal and abnormal operations, EICAS messages, use of AFM Supplement, FCOM, QRH, and checklists, and failure modes;
 - b. Classroom instruction or CBT on EVS annunciations, effect of environmental conditions on EVS image, and comparison of the EVS HUD imagery to that of the copilot's MFD; and
 - c. A Rockwell Collins Model 6605 Head-up Guidance (HGS) pilot guide, Model 6605 HUD/EVS AFM Supplement, or equivalent materials (e.g. FCOM, which explain EVS limitations, modes of operation, EVS annunciations, limit conditions and failures, and which define crew procedures that delineate PF and PNF duties, responsibilities, and call-outs during all phases of flight in which EVS operations are conducted.
- 4.2 Special emphasis ground training shall be conducted in the following areas:
- a. Crew briefings, coordination, and callouts;
 - b. Duties of PF and PNF;
 - c. EICAS messages and use of QRH and checklists applicable to EVS operations;
 - d. Transition from EVS imagery to non-EVS visual conditions. Maximum use should be made of videos of actual HUD/EVS approaches. The relative luminosity between infrared imagery and that of approach lighting systems should be identified;

- e. EVS Visual anomalies such as “noise”, “blooming”, sensor saturation, and “fireplace effect” in rain;
- f. Appropriate use of the Clear Switch, CAL button, and brightness and contrast knobs on HUD and EVS panel controls;
- g. Importance of the ‘design eye position’ in acquiring the proper EVS image;
- h. Importance of cross-checking the HUD instrumentation presentations against the EVS visual scene to enable the pilot to recognize malfunctions of the ground based navigational equipment and improper presentation of elements in the visual scene during an approach;
- i. Use of barometric altitude on approach, including FMS temperature correction, if applicable;
- j. Importance of vertical guidance to enhance situation awareness with respect to obstacle environment;
- k. Instruction in the use of the autopilot with auto-throttle coupled approaches allowing for better pilot monitoring of the EVS image;
- l. Effective monitoring by PNF of EVS imagery presented on the MFD;
- m. Adjustments to RVR minima;
- n. Required visual references; and
- o. Limitations of the IR sensor e.g. thermal crossover, LED lights etc.

5. EVS INITIAL FLIGHT / SIMULATOR TRAINING

- 5.1 Unless integrated with initial type rating training, flight training dedicated to EVS familiarization and proficiency is in addition to other required training elements.
- 5.2 All required approaches utilizing the EVS, should begin no closer than at the FAF for instrument approaches, and should begin no closer than approximately 1,000 feet AGL (3 - 4 NM) to the runway threshold for visual approaches.
- 5.3 The following EVS flight training programme is generic in nature and should be considered as a minimum training requirement only.
 - a. Ground Operations:
 - (1) Initialization of EVS, including operation of EVS brightness and contrast controls; and
 - (2) Taxi using EVS under various lighting and visibility conditions.

b. Airwork:

There is no requirement for airwork training using EVS.

c. EVS Take-offs, Approaches and Landings:

- (1) Normal takeoff and landing with crosswinds;
- (2) Low Visibility Takeoff (minimum RVR); and
- (3) Visual approaches at night with minimal lighting ("black hole" approaches) and use of FPS and Glideslope Reference Line to achieve desired descent angle.

d. Instrument Approaches: (IFR/VFR day and night conditions)

- (1) Precision and non-precision straight-in approaches to the lowest published minima with missed approaches or landings; and
- (2) Precision and non-precision straight-in approaches to lowest published minima with acquisition of sufficient EVS visibility to continue to 100 feet above Touchdown Zone Elevation (TDZE). Acquisition of required visual references below 100 feet TDZE, followed by a landing or missed approach.

e. Abnormal/Emergency Operations:

- (1) Failure of EVS during approach; and
- (2) Failure of EVS below published minima but above 100 feet above TDZE.

5.4 Special emphasis flight training shall be conducted in the following areas:

- a. Proper use and setting of HUD and EVS contrast and video brightness controls for various ambient conditions;
- b. Crew briefings and callouts with emphasis on the duties of the PF and PNF;
- c. Importance of the 'design eye position' in acquiring the proper EVS image;
- d. Manual and Auto Calibration functions;
- e. Use of the EVS Clear switch;
- f. Continuation of the approach to 100 feet above TDZE in accordance with Appendix 1 (New) to EU OPS 1.430 (h); and
- g. Adjustment to RVR minima in accordance with table 9 of Appendix 1 (New) to EU OPS 1.430 (h).

6. EVS INITIAL CHECKING REQUIREMENTS

- 6.1 Checking requires a PIC proficiency check conducted in a level C simulator or level D with HUD and EVS, or on a HUD and EVS equipped CL-605 aircraft. This proficiency check may be taken in conjunction with a pilot proficiency check conducted in accordance with Part-FCL or may be administered as a separate test.
- 6.2 Manoeuvres to be evaluated during the EVS proficiency check include as a minimum:
- a. One instrument approach and landing with acquisition of the EVS image before published minima and acquisition of required visual references without the aid of EVS below 100 feet above TDZE; and
 - b. One instrument approach with acquisition of the EVS visibility before published minima and failure or loss of the EVS image below published minima requiring a missed approach above 100 feet above TDZE.
- 6.3 SIC's must be checked on PNF duties during EVS approaches and emergencies.

7. EVS RECURRENT TRAINING REQUIREMENTS

- 7.1 Selected EVS related flight training manoeuvres as outlined in paragraph 5 above, should be included in the recurrent training programme for the Bombardier Challenger CL-605.

8. EVS RECURRENT CHECKING REQUIREMENTS

- 8.1 At least annually, in conjunction with a proficiency check required by Part-FCL, a PIC must demonstrate proficiency using the EVS by satisfactorily performing the manoeuvres listed under paragraph 6.2.
- 8.2 At least annually, SIC's must be evaluated on crew resource management (CRM) responsibilities and procedures as PNF when the PF is conducting EVS operations.

9. EVS CURRENCY REQUIREMENTS

Left seat pilots should have completed at least one night takeoff, approach, and landing as the PF using the Rockwell Collins Model 6605 EVS in a Bombardier Challenger CL-605 airplane, or have completed at least one takeoff, approach, and landing as the PF using the Rockwell Collins Model 6605 EVS in a CL-605 Level C simulator with daylight visual displays, or CL-605 Level D simulator, within the previous 90 days before acting as the PF during EVS operations. The EVS currency requirement may be obtained simultaneously with obtaining the currency requirements for Rockwell Collins Model 6605 HUD (ref PART 1 para. 9.).