Chapter 4 – AIRCRAFT NVG AIRWORTHINESS

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4.1 NVG AIRWORTHINESS TESTING

A guideline for NVG airworthiness testing for the Canadian forces was developed by Aeronautical Engineering and Testing Establishment (AETE) and is presented here briefly in Sections 4.1.1 to 4.1.8.2.

In order to conduct NVG operations safely, each aircraft must be suitably configured. Determining the suitability of an aircraft for NVG flight operations is a complex task involving extensive ground and flight tests. The aim is to outline the various tests that are typically conducted prior to authorizing a single aircraft or a fleet for employment in NVG flight operations. These tests will also determine the effectiveness of the airborne platform for future NVG research programs, as these tests will highlight any deficiencies in aircraft lighting or other systems (e.g. rad alt) which may limit NVG research.

The aim of initial ground testing is to provide NVIS compatibility proof of compliance recommendations based on NVIS Visual Acuity measurements. In addition, all aircraft cockpit lighting systems and sub-systems must demonstrate an acceptable level of NVG compatibility, unaided and aided night detection capability, and daytime high ambient light readability.

4.1.1 Essential Test Items

The equipment listed in this section is suggested for NVG airworthiness testing based on availability in North America. Equivalent systems may also be used where available.

- **Hoffman Engineering Model ANV-20/20**. The Hoffman 20/20 test kit is a portable reference device that facilitates accurate NVG acuity adjustments under simulated moonlight and starlight illumination levels.
- **Visual Acuity Resolution Charts**. Typically the modified USAF Tri-Bar Chart can be used to test the minimum level of detail that can be seen by the pilot. The chart was designed to be placed 20-ft from the test subject and can be used to quickly determine the NVIS visual acuity under varying lighting conditions.
- **Hoffman LM-33-80 Starlight Projector (or equivalent-see above for NVG lighting)**. A light projector used to illuminate the VA targets. This projector provides very precise control of lighting source intensity and colour spectrum.
- **Pritchard 1530-AR Spot Photometer (or equivalent)**. This instrument is used to measure the luminance level of the visual acuity board. It can be focused on a very small area thereby allowing the user to measure luminance on a specific portion of the VA target.

- **Hoffman NVG-103 Inspection Scope**. This meter is used to determine if any cockpit lighting is incompatible, as determined by MIL-L-85762A (U.S. Navy, 1993). With the cockpit lighting set to operationally representative levels, the cockpit should be scanned to determine if any lighting source is brighter than the internal reference.
- **Hoffman ANV 410-B Night Sky Night Vision Illumination Meter**. The ANV-410 measurement system is a self-contained, hand held photometer for measuring night sky illumination levels. The device provides a direct reading in milliLUX. This device is used to measure test facility and target illuminance.

4.1.2 NVG Acuity Assessments

The ground test facility must be light tight such that the illumination of the visual acuity targets can be precisely controlled. The test subjects must be familiar with the set-up and operation of the test NVG and Hoffman 20/20 test kit. Between two and six individuals should be tested to determine the system visual acuity. The acuity of the NVG should be adjusted using a calibrated Hoffman 20/20 test kit to obtain maximum visual acuity. The internal cockpit lighting should be adjusted to operationally representative intensity levels. Test subjects with NVIS flight experience must determine the intensity levels. A 50% contrast USAF 1951 Medium Contrast Resolution Resolving Power Target (USAF Tri-Bar Chart) or a modified 50% contrast NVG Resolution Chart developed for cockpit lighting evaluations by Armstrong Laboratory typically should be used to test NVG acuity. During the evaluation, the Tri-Bar Chart targets should be set up at a distance from the observer so that a resolution pattern midway between the largest and the smallest pattern is just visible in the goggles. Care should be taken to ensure that the light falling on the acuity chart (from the Hoffman LM-33-80) is at levels appropriate to starlight, moonlight and an intermediate value between moonlight and starlight.

4.1.3 Daylight Readability

Daylight readability of the instrument panel with the naked eye must be assessed as part of an NVIS compatibility evaluation. Filters intended to make cockpit lighting NVIS compatible often result in reduced display contrast and the ability of the display to attract attention during daytime. A minimum of 2 people should be used to assess daylight readability. A light tight facility is not required for the assessment, which may be performed during daytime. The evaluators should identify any deficiencies in reading the displays, or failures to identify that a display was illuminated (e.g. caution indications) with sunlight falling on the instrument panel at a variety of angles.

4.1.4 Night-Time Readability

Night-time readability of the NVG compatible instrument panel with the naked eye is a subjective determination of the legibility of the displays under night-time operational conditions. Displays also are evaluated for their ability to attract attention, and the presence of glare, shadows or reflections. As with daylight readability, a minimum of two subjects must assess night-time readability. Prior to commencing the assessment, each subject must dark adapt for a minimum of 20 minutes, then adjust the cockpit lighting to operationally representative levels. With the subject seated in the cockpit, the data gatherer should consult a data sheet and should tell the subject which panel, display, etc., to view. Subjects should make comments on readability and the cause of any deficiencies should be recorded.

4.1.5 NVIS Radiance

MIL-L-85762A specifies that NVIS radiance be measured from the cockpit displays. Maximum allowable NVIS radiance theoretically represents the amount of energy within the spectral response of the NVGs that would be reflected from a defoliated tree under starlight conditions. MIL-L-85762A establishes NVIS radiance limit values to ensure that the cockpit lighting is no brighter than the outside scene during this

operating condition. NVIS radiance limit values are specified in Table IX of MIL-L-85762A. Any lighting that produces radiance greater than the specified NVIS radiance value is incompatible by definition.

NVIS radiance can be measured using a Hoffman NVG-103 Inspection Scope. The cockpit lighting should be adjusted to an operationally representative level by a dark-adapted subject and then measured by the evaluator using the inspection scope. The inspection scope's internal reference source should be adjusted to 1.6x 10^{-10} NR_B[1] or as specified in MIL-L-85762A Table IX. The cockpit should be scanned to identify any light sources appearing brighter than the reference source. Any bright light sources should then be measured, and the results should be recorded on data sheets. **NOTE:** MIL-L-85762A specifies that a spectroradiometer be used to measure radiance, and that NVIS radiance is then computed. Because of their size, it should not be feasible to use a spectroradiometer during this evaluation. Although the NVG-103 is not as accurate as a spectroradiometer, it is specifically designed for making field measurements. NVIS radiance is usually the last assessment of the evaluation because, unlike daylight readability, night-time readability, or NVG-aided VA, the results are less likely to be affected by evaluator fatigue.

As a part of the NVIS radiance inspection, the evaluators should also examine the cockpit for the following issues:

- Light leaks;
- Luminance uniformity and balance; and
- Reflections.

4.1.6 Human Factors Analysis

Human factors associated with the internal lighting and external lighting systems and associated aircrew equipment should be evaluated concurrently with the airworthiness ground and flight tests of the NVG system. The assessment should consider the following:

- Normal Entry and Egress (Emergency egress must also be included);
- Workspace Requirements;
- Crew Station Layout;
- Internal and External Field of View; and
- Lighting Controls.

4.1.7 Flight Tests

The following sections will deal with the specific flight tests required to assess the airworthiness of the NVGs[2]. It should be noted that the flight test profiles specified in Section 4.1.7.4 cover a broad range of NVG operations. Some of these tests may not be required if they are not part of the normal operations of the flight test organisation or the end goggle users. Similarly, NVG HUD or symbology testing would not be required if the NVG system does not have or support symbology.

4.1.7.1 Objectives

The objectives of the NVG acceptance flight test are as follows:

- Perform limited qualitative assessments of the readability of the aircraft's internal lighting to include any displays during daytime flight, during unaided night-time flight and during NVG flight;

[1] Night vision radiance for class B NVG filters.

[2] Reising, Antonio and Fields (1996) also describe a series of procedures that can be used to conduct field evaluations of NVG/aircraft compatibility.

- Perform limited qualitative assessments of the impact of the aircraft's internal and external lighting on external visual references and eye strain in unaided and aided night lighting conditions;
- Perform limited qualitative assessments of an NVG HUD to include assessments of the symbology for suitability in the designated aircraft role (as required); and
- Determine the widest safety-of-flight envelope of operations for all relevant operational and training flight profiles.

4.1.7.2 NVG Acceptance Flight Test Criteria

All lighting systems must demonstrate an acceptable level of NVG compatibility, unaided/aided night detection capability, and daytime high ambient light readability. The aircraft anti-collision and position lighting systems must demonstrate an acceptable level of NVG compatibility and provide sufficient visual cueing, for safe and effective flying particularly with respect to in-flight collision avoidance during single-ship and formation operations (if applicable). The various aircraft searchlights should provide sufficient visual cueing to operate safely in all approved NVG profiles, without adversely impacting on the performance of the NVG. All testing must be performed in a variety of lighting conditions representative of day (preferably bright sunlight at a variety of sun incidence angles and overcast if available) and unaided/ aided night (preferably minimum available ambient light) lighting conditions to ensure that the widest range of mission representative conditions are considered.

The test team must qualitatively assess any reductions in visual cueing resulting from any of the internal and external lighting systems during ground tests and during the performance of various low, medium, and high gain flight tasks. Similarly, the test team must qualitatively assess the ease of detection of any of the systems and modifications (internal and external) during ground tests and during the performance of various low, medium, and high gain flight tasks. Specifically, the test team should determine if there is any increased aircrew workload or any unexpected hazard to flight resulting from reduced visual cueing caused by any of these systems.

The flight tests must be conducted in VMC conditions for daylight and night-time flight conditions to ensure safety of flight. The effectiveness of the goggles under degraded conditions could be tested at a later time, with appropriate precautions (ability to revert to instrument flight to return to base).

4.1.7.3 Flight Test Profiles

The specific mission profiles to be performed during the evaluation should be representative of the flight operations associated with the aircraft fleet under test. For a SAR aircraft, the following mission elements/ tests are suggested: forward flight, manoeuvring and continuous turns, approaches and departures, low level (200/50-ft above the highest obstacle (AHO)) and tactical (clear of obstacles or as low as can safely be achieved within the handling qualities limits of the aircraft) navigation and manoeuvring, slinging, hoisting, ship hoisting, confined areas, slope landings, circuits (500-ft (unaided), and 200/50-ft AHO (aided)), mission representative SAR search patterns, over water flight, mountain flying, non-tactical and tactical formation, and any relevant Aeronautical Design Standard (2000) helicopter manoeuvres required to baseline the aircraft's handling qualities in various visual cueing environments[3].

During all NVG testing conducted below 100-ft AHO the non-flying pilot should standby on the flight controls. This will ensure that there are essentially two pilots engaged in fully attended flight operations. All comments made by the test team should be qualitative and should be noted by a designated test team member, typically the flight test engineer (FTE), on board during testing. All test team members should qualitatively assess the following characteristics during the performance of a variety of mission representative tasks:

[3] While some elements of the SAR NVG flight test may be common to many organizations, not all of the tasks will be appropriate to every NVG operation.

- Cockpit compatibility of the lighting system under assessment in daylight and unaided/aided night lighting conditions with direct and indirect sunlight (or moonlight), as applicable;
- Ease of readability of cockpit instruments and gauges, to include all comments related to glare;
- Impact on NVG gain;
- Impact on external visual cueing, particularly with various weather radar image brightness and contrast settings, since this is expected to be one of the least compatible cockpit displays;
- Impact on field of view (FOV) and field of regard (FOR);
- Impact of any observed light leaks;
- Impact on quickly adapting from inside to outside references and vice versa;
- Impact on judging depth perception, obstacle clearances, obstacle closure rates, and aircraft height above ground/water, particularly during hovering and low level flight manoeuvres;
- Impact on reading and interpreting standard aircraft maps and approach plates;
- Impact on transitioning from visual to instrument references, and vice versa;
- Impact on overall cockpit and crew workload; and
- General confirmation of results noted during ground testing.

4.1.7.4 Specific Flight Profiles

The following sections describe some of the basic (e.g. forward flight, hover) and operationally specific (e.g. slung-load, mountain flying) flight test profiles that should be examined to determine the usability of the goggles.

4.1.7.4.1 Forward Flight

Qualitatively assess the ease of maintaining a constant targeted altitude (indicated or reference (AHO)) while performing standard pilot transit and navigation duties. During unaided night flight operations, this task should not be flown below 500-ft AGL. During aided night flight operations, this task should be flown at 200-ft AHO initially and should then be stepped down to 50-ft AHO in decrements of 50-ft. Flight below 50-ft AHO should only be performed in 5-ft decrements. IFR transit flight duties should also be performed, when simulating flight in IMC. In all cases, internal lighting must be adjusted to operationally relevant levels. The cockpit displays should be altered to include the weather radar or forward looking infrared information (if applicable), as well as the standard instrument displays in an attempt to assess all possible configurations that may be used operationally. External lighting should be assessed in Normal and NVG modes as applicable. Testing must be performed over varying terrain surfaces and contrast levels to include flat and mountainous terrain, grass, trees, and snow covered land surfaces, and water/ice. Testing must be performed throughout the aircraft's speed range, with emphasis on typical transit speeds for VFR and IFR operations. Flying at slower speeds initially and working up toward faster speeds as required will provide a build-up approach to testing. The crew should assign handling qualities ratings during performance of the task in accordance with the alternative pilot rating scale for NVG evaluations, referred to as the Pilot Rating Scale for Automatic Flight Control Systems and Visual Cueing (PRSA + V). Ratings of 7 or greater should constitute failed test criteria and should result in a cease in testing. A detailed description of this rating scale can be found in Green (1994).

4.1.7.4.2 Manoeuvring and Continuous Turns

Qualitatively assess the ease of maintaining a constant targeted angle of bank (AOB), altitude, and airspeed for both manoeuvring and continuous turns. Manoeuvring turns are considered to be turns limited to aircraft heading changes of 90° or less. Continuous turns are considered to be turns resulting in aircraft

heading changes of more than 90°. Testing must be conducted using a build up approach by starting with small AOB and increasing, typically in 5° increments, to larger AOB. During unaided night flight operations, this task should not be flown below 500-ft AGL. During aided night flight operations, this task should be flown at 200-ft AHO initially and then stepped down to 50-ft AHO in decrements of 50-ft. Testing performed below 50-ft AHO must be performed gradually and in 5-ft decrements. Internal and external lighting considerations, terrain and surface contrast considerations, and airspeed ranges, are to be tested in a similar fashion to the methods described in paragraph 4.1.7.4.1.

4.1.7.4.3 .Approaches and Departures

Qualitatively assess the ease of maintaining sight picture and closure rates during approaches, and aircraft tracking and obstacle clearance/avoidance during departures. This testing should be performed in daylight and unaided/aided night lighting conditions, during dedicated circuits to an airfield and to unlit fields, taxi manoeuvres, as well as during typical field approaches and departures throughout the evaluation. Internal and external lighting considerations, terrain and surface contrast considerations, and airspeed ranges, are to be tested in a similar fashion to the methods described in paragraph 4.1.7.4.1. Handling qualities ratings and pass/fail criteria should also be in accordance with paragraph 4.1.7.4.1.

4.1.7.4.4 Sloping Ground Operations

Qualitatively assess the ease of performing sloping ground operations. This testing should be performed during unaided and aided night lighting conditions. Internal and external lighting considerations should be tested in a similar fashion to the methods described in paragraph 4.1.7.4.1. The crew should assign handling qualities ratings during performance of the task in accordance with the Cooper-Harper Rating Scale, referred to as HQR. The technique for assigning an HQR should be in accordance with the methods described in the U.S. Naval Test Pilot School Flight Test Manual (1995). Ratings of 7 or greater should constitute a failed test criterion and should result in a cease in testing.

4.1.7.4.5 Confined Areas

Qualitatively assess the ease of maintaining sight picture and closure rates during approaches to, and aircraft tracking and obstacle clearance/avoidance during departures from, a confined area as well as to assess the ease of manoeuvring for landing within a confined area. This testing should be performed during unaided and aided night lighting conditions. A build-up will occur by performing this manoeuvre to areas with no less than 2-rotor diameters of clearance initially, then working down to some minimum amount of clearance around the aircraft, in 5-ft decrements. The minimum desired clearance must be based on operational requirements. Internal and external lighting considerations, and terrain and surface contrast considerations, should be tested in a similar fashion to the methods described in paragraph 4.1.7.4.1. Handling qualities ratings and pass/fail criteria should also be in accordance with paragraph 4.1.7.4.1.

4.1.7.4.6 Slung Load Operations

Qualitatively assess the ease of maintaining sight picture and closure rates during approaches to, and aircraft tracking and obstacle clearance/avoidance during departures from, the slung load area as well as to assess the ease of manoeuvring for pickup and drop off of the slung load. This testing should be performed during unaided and aided night lighting conditions. Testing should be limited to one load, unless it is convenient to operate with different loads. Internal and external lighting considerations, terrain and surface contrast considerations, and airspeed ranges, should be tested in a similar fashion to the methods described in paragraph 4.1.7.4.1. Maximum airspeeds, based on aircraft type and operational requirements, should be adhered to during all slinging operations. Handling qualities ratings and pass/fail criteria should also be in accordance with paragraph 4.1.7.4.1.

4.1.7.4.7 Hoisting Operations

Qualitatively assess the ease of conducting rescue hoist operations in unaided and aided night lighting conditions during over land/water operations. Hoisting should be initially assessed in a similar manner to the method used for assessing confined area operations. The aim of this testing should be to qualitatively assess the ease of maintaining sight picture and closure rates during approaches to, and aircraft tracking and obstacle clearance/avoidance during departures from, the hoist area as well as to assess the ease of conducting the actual hoist operation at a selected hoist area. Ship hoisting should be conducted to the stern and bow of large and small vessels. Testing may include the use of marker flares, in accordance with applicable SAR operations. The use of marker flares for visual reference aids may be included in this test. Internal and external lighting considerations should be tested in a similar fashion to the methods described in paragraph 4.1.7.4.1. Handling qualities ratings and pass/fail criteria should also be in accordance with paragraph 4.1.7.4.1.

4.1.7.4.8 Over-Water Operations

Qualitatively assess the ease of performing shore crawl, forward flight, manoeuvring and continuous turns, transitions, and hovers during over-water flight in unaided and aided night lighting conditions. The range of airspeeds to be tested during shore crawl sequences should include, as a minimum, typical transit speeds for VFR operations in conditions of poor visibility when preparing for alternative action. Safe distances from shore and heights should be governed by aircraft performance (e.g. single engine vs. multiple engines). For military operations, shore crawl, forward flight, and manoeuvring and continuous turns testing should not be performed below 500-ft AGL for unaided night flight operations. These sequences could be performed down to 50-ft AHO during aided military night flight operations. Internal and external lighting considerations should be tested in a similar fashion to the methods described in paragraph 4.1.7.4.1. Handling qualities ratings and pass/fail criteria should also be in accordance with paragraph 4.1.7.4.1.

4.1.7.4.9 Mountain Flying Operations

Qualitatively assess the ease of performing transit flight, approaches, and departures in mountainous terrain. Approaches and departures should be to/from approved, daytime-assessed, mountain landing pads. During mountain flying testing, at least one pilot on board should have completed formal mountain-flying training of some form. This testing may be limited to aided night lighting conditions. Internal and external lighting considerations, terrain and surface contrast considerations, and airspeed ranges, should be tested in a similar fashion to the methods described in paragraph 4.1.7.4.1. Handling qualities ratings and pass/fail criteria should also be in accordance with paragraph 4.1.7.4.1.

4.1.7.4.10 Degraded Modes

Qualitatively assess the ease of flying the aircraft in various degraded lighting and AFCS modes. Degraded lighting modes to be assessed should consist of flight with internal and/or external lighting completely blacked out, as well as with various cockpit caution and warning lights illuminated. All relevant degraded AFCS modes should also be tested. All degraded modes should be assessed in unaided/aided night lighting conditions. In all cases, handling qualities ratings and pass/fail criteria should be in accordance with paragraph 4.1.7.4.1.

4.1.7.4.11 Recirculating Phenomena

Qualitatively assess the ease of maintaining sight picture and closure rates during approaches, and aircraft tracking and obstacle clearance/avoidance during departures in recirculating phenomena such as snow, dust or sand. Testing should also be aimed at qualitatively assessing the ease of maintaining the aircraft's plan position during in-ground-effect (IGE) and out-of-ground-effect (OGE) hovers. This testing should be

performed in unaided and aided night lighting conditions. Handling qualities ratings and pass/fail criteria should be in accordance with paragraph 4.1.7.4.1. Internal and external lighting may be varied in accordance with paragraph 4.1.7.4.1. However, specific emphasis should be placed on assessing the impact of the aircraft's searchlights on external visual references. Recommendations should be provided with respect to where to situate these lights and when they should be specifically selected/de-selected.

4.1.7.4.12 Flight Envelope Definition

The entire safe flight envelope for NVG operations in the aircraft should be defined prior to airworthiness flight testing and modified as required based on test results. The following is a list of the known variables specifically relevant to NVG envelope definition testing that the researcher operator should be aware of:

- Ambient light levels;
- Aircraft internal / external lighting;
- Terrain/topography;
- Surface contrast;
- Flight task gain;
- Weather;
- Aircraft flight control system configuration (i.e. level of augmentation);
- Extent of degraded modes;
- Pilot ability and training; and
- Altitude / Airspeed / Ground speed.

Specific information regarding the NVG envelope parameters should be developed by experienced pilots and researchers based on their own operational constraints. A measured approach to defining the envelope is to start with reasonably safe conditions such as:

- A reasonably high altitude;
- Good visibility conditions (e.g. full moon, no precipitation);
- Highly trained pilots;
- Augmented flight control systems (if available);
- Non-aggressive manoeuvres;
- Compatible aircraft lighting; and
- Level terrain.

Once a reasonable level of confidence is attained in this sort of flight regime, the envelope can begin to expand, in one dimension at a time, to include more diverse flight scenarios (e.g. poorer visibility or more aggressive flight manoeuvres).

4.1.8 Heads Up Display (HUD) Symbology

The HUD display is one of the few instances where the pilot will look through the goggles to view the display. The visibility and utility of the HUD symbology must be assessed through the goggles. The following sections describe possible procedures for determining issues with latency (e.g. lags in the symbology display) and the basic elements of evaluating NVG symbology.

4.1.8.1 Latency Assessments

The emphasis of this assessment should be on display symbology used for maintaining aircraft control. This should include aircraft attitude, heading, altitude (radar and barometric), airspeed, and vertical speed. This portion of testing should also address the torque and rotor rpm displays whenever the aircraft under test possesses adverse characteristics with its torque sensing system, and if the obvious hazards associated with a low inertia rotor exist (e.g. over/underspeed, and difficulties in autorotation). The pilot and/or co-pilot should perform various flight tasks aimed at highlighting the latency of a particular display parameter (e.g. a small step input on the collective). If latency is observed to be a problem, test team personnel on board the aircraft must attempt to hand record the data provided verbally by the pilot or co-pilot. Specifically, the pilot and/or co-pilot should verbally state the NVG HUD displayed value of a given parameter over time and the data recorder should record these values and quickly record the value of the same parameter displayed on the instrument panel. The preferred method of obtaining this data should be to access it directly from a data bus recorder, but if this method is not available, the above-mentioned technique may be used.

4.1.8.2 Symbology Assessments

Symbology assessments should consist of qualitative ground and flight assessments of the suitability of each symbol in the symbology set. This task should be performed in order of priority of symbols, from a safety of flight perspective, to ensure that the most important items are addressed first. The symbols with the highest priority should include aircraft attitude, heading, altitude (radar and barometric), airspeed, and vertical speed. The torque and rotor rpm displays may also be considered as high priority items, for the same reasons mention in Section 4.1.8.1. Testing should consist of evaluating the intuitiveness, ease of interpretation, and the impact on FOV of a particular display symbol. Emphasis should also be placed on power loss or failure mode indications including warning, caution and advisory symbology, as well as display endpoints. Warning, caution, and advisory symbology assessments should include comments from the test team related to their ability to attract the pilot's attention. Display endpoint assessments should attempt to determine if a display indicates zero or its last indicated value prior to stopping once the NVG HUD parameter display range is exceeded or if power to the HUD is lost.

4.1.9 Symbology as an Aid to NVG Systems

Symbology adds a new dimension to NVG operations providing pilots with critical information that normally would be presented heads-down. For nearly all NVG systems, the symbology presentation is accomplished via the attachment of specially designed presentation optics. While testing the symbology can be a highly complicated process worthy of lengthy discussion, the overall goal is to ensure that the information displayed is critical to the pilot and that the pilot can readily see and interpret the symbology. Only a brief overview of NVG symbology[4] testing is presented in this section.

The first step in evaluating the symbology is to determine if there are any obvious factors that may detract from the interpretation of the symbology such as the following:

- Symbols or alphanumeric characters are too big or too small;
- Symbols or characters are unclear (blurred or flicker);
- Too many symbols resulting in a cluttered visual field;
- Symbols or characters are too crowded or too far apart; and
- Display and update of the symbology is not subject to significant lags.

[4] Most aspects of NVG symbology testing discussed in this section will also apply to other types or modes of symbology presentation such as non-NVG helmet mounted displays or cockpit fixed heads-up displays.

Each of these types of deficiencies can impact the pilot's ability to use the display, by making it difficult to read, or by presenting data too late to be of use. Time lags may lead to poorly tuned control responses or require that the pilot adopt a more open-loop control strategy (i.e. make an input and wait to see what happens before making the next control input).

The next test of the symbology set would be to determine whether the presentation interferes with the pilot performance (i.e. does the pilot perform a given task better with or without the symbology). If the information is not important to the pilot on a regular basis, it should not be presented on an NVG HUD because it may get in the way (of the NVG image) or distract the pilot. In most cases where the pilot has a good NVG image, the pilot may only need a nominal symbology display. QinetiQ in the UK have developed an adjustable filter for NVGs, allowing them to regulate the quality of the NVG image by varying the amount of light coming into the goggles. By degrading the NVG imagery, the pilot needs to focus on the symbology to perform the task(s) (Thorndycraft & Craig, 2004, Thorndycraft, Jennings & Craig, 2005). Using this technology, the symbology can also be evaluated by determining how clear (e.g. bright, high contrast, noise free) the NVG image has to be in order for the pilot to achieve a given level of performance. For example, the best symbology would allow the pilot to manoeuvre the helicopter by using only the symbology without additional visual references (i.e. no NVG image). If the pilot continually increases the amount of light coming into the goggle to obtain a better NVG image and thereby improve performance, the symbology may not be very useful. If the pilot continues to achieve the desired level of performance even with degradations to the NVG imagery, the symbology has proven itself effective for the task.

While symbology sets are often tested as a whole, the manoeuvres chosen need to stimulate one or more dimensions of the symbology. For example, a hover task may not be useful in assessing airspeed symbology, but may be useful in evaluating a velocity vector and a height above ground display. Not only must the task stimulate the dimension being tested, the researcher must also determine what aspect of the task is being measured. For example, the effectiveness of the symbology could be determined by rating the cueing the symbology provides, by the precision of performance of the task, the speed with which the task can be performed or by various components of task performance (e.g. control inputs). It is difficult to determine the effectiveness of symbology based on workload measurements. If the symbology provides good cueing, the pilot's workload may increase, but if the symbology is difficult to interpret, the pilot's workload will likewise increase. The difference between these two conditions will be resolved by task performance, which should improve in the former case. However, workload (and situational awareness) should still be assessed to attempt to quantify how much the pilot is compensating for the symbology and whether the pilot is concentrating too much on a given aspect of the symbology.

The AETE test document presented at the beginning of this chapter noted that priority in the assessment be given to the symbol(s) that are used most often by the pilot or to the symbols that are the most critical for a given phase of flight. If a new symbol is being added, or an existing symbol is being modified, the new symbol will need to be assessed in the context of the whole display. Care must be taken to ensure that the new symbol does not detract from the pilot's situational awareness.

In terms of symbology evaluation methodologies, many of the tests used to evaluate symbology for helmet mounted displays can be applied to testing NVG symbology. A short list[5] of references is presented below in which parts (e.g. or whole symbology concepts were tested, using a variety of methods (see Atencio et al., 2002; Ercoline et al., 2002; Grunwald et al., 2006; Hughes et al., 2002, 2003; Self et al., 2003; Swenson et al., 1994; Szoboszlay & Moralez, 2006; Szoboszlay et al., 2004; Thorndycraft, 2006; Thorndycraft & Craig, 2004; Thorndycraft et al., 2005).

[5] This list is by no means complete.