Specific Technical Requirements

Laser Obstacle Warning System
(LOWS)

Table of contents:

Figures:

Tables:

1 General

1.1 Purpose and Scope

This performance specification defines the minimum performance expected from a Laser Obstacle Warning System (LOWS). The performance of a specific equipment may be enhanced or superior to this specification depending on the intended application and configuration.

Chapter 1 describes typical equipment applications and operational objectives and is the basis for the performance criteria specified in Chapter 2 and Chapter 3. Definitions essential to proper understanding of this document are also provided in Chapter 1.

Chapter 2 contains general design requirements.

Chapter 3 contains the minimum performance specification for the equipment, defining performance under standard operating conditions.

Chapter 4 describes the environmental test conditions which provide a laboratory means of determining the performance characteristics of the equipment under conditions representative of those which may be encountered in actual operations.

Chapter 5 gives guidance for the equipment integration.

Chapter 6 describes procedures for functional tests of this type of equipment.

1.2 Application

Compliance with this minimum operational performance specification by manufacturers, installers and users is recommended as a means of ensuring that the equipment will satisfactorily perform its intended function under the condition normally encountered in routine helicopter operation as well as in abnormal conditions.

Any regulatory application of this document in whole or in part is the sole responsibility of the appropriate government agencies.

1.2.1 Mandating and Recommendation Phrases

a) „Shall“
The use of the word SHALL indicates a mandated criterion; i.e. compliance with the particular procedure or specification is mandatory and no alternative may be applied.

b) „Should“

The use of the word SHOULD (and phrases such as „IT IS RECOMMENDED THAT ….“, etc.) indicates that the procedure or criterion is regarded as the preferred option. Alternative procedures, specifications or criteria may be applied, on condition that the manufacturer, installer or tester can provide information or data to adequately support and justify the alternative.

1.2.2 Applicable Documents

If not stated otherwise, the latest issue of the reference documents valid at the date of issue of this document is to be used.

Reference	Document	Doc.-No.
[DO160]	RTCA: Environmental Conditions and Test Procedures for Airborne Equipment (Appendix A Environmental Test Identification)	ED14 ( ) / DO-160 ( )
[DO178]	RTCA: Software Considerations in Airborne Systems and Equipment Certification	ED12 ( ) / DO-178 ( )
[LAK]	DIN: Safety of laser products – Part 1: Equipment classification, requirements and user's guide	EN60825-1

1.2.3 Abbreviations

BIT	Build in test
DIN	Deutsches Institut für Normung e.V.
ENOHD	Extended nominal ocular hazard distance
FOR	Field of regard
FOV	Field of view
LOS	Line of sight
LOWS	Laser obstacle warning system
MMI	Man machine interface
NOHD	Nominal ocular hazard distance
RTCA	Radio Technical Commission for Aeronautics

1.3 Description of System

The LOWS is a **flight aid** for the pilot under **visual flight conditions** at day and night (The remark: "VFR Only" shall be included in the Pilots Manual) intended mainly for usage in slow flying vehicles like helicopters. It is designed to warn the pilot about obstacles in the flight path or close by, e.g. power lines, cable ways, poles or towers. The system provides information on which the pilot may initiate evasion maneuvers on his own judgment, **continuing to apply visual flight rules**. This information can be generated in 3 different levels: ADVISORY, CAUTION and WARNING. The level WARNING shall be realized as a minimum. Obstacle information at the level WARNING require immediate pilot's action (Evaluate obstacle situation and initiate a VFR evasion maneuver, if required).

The system must not generate any resolution advisories.

The LOWS emits short laser pulses redirected by a two-dimensional deflection unit (scanner) illuminating objects in the field of view. The reflected light is detected and a propagation time measurement is performed, giving the distance to the respective object points.

This distance information is analyzed by dedicated procedures for data interpretation to produce obstacle information for the pilot if necessary.

2 General Design Requirements

2.1 Airworthiness

The equipment shall not, under either normal or failure conditions, impair the airworthiness of the helicopter in which it is installed.

2.2 Operation of Controls

The operation of controls intended for use during flight, in all possible positions, combinations and sequences, shall not result in a condition whose presence or continuation would be detrimental to the continued safe operation of the equipment.

Operating the system shall not significantly affect the workload of the air crew.

2.3 Design of Controls

Controls and indicators intended for use by flight crew shall be of suitable design for the intended cockpit environment / philosophy (e.g. size, readability, illumination). Requirements for colors and other display related parameters can be found in JTSO-C113 and JAR 27.1322

2.4 Effects of Tests

Unless otherwise provided, the design of the equipment shall be such that, subsequent to the application of the specific tests, continued safe operation of the equipment is guaranteed.

2.5 Digital Computer Techniques

If the equipment design is implemented using digital computer techniques, the computer software package shall follow guidelines contained in EUROCAE document ED-12B „Software Considerations in Airborne Systems and Equipment Certification“. The RTCA equivalent document DO-178B, or later editions of both ED-12B and DO-178B, may be used.

2.6 Complex Hardware Development

Guidance on the development of complex hardware can be found in EUROCAE document ED-80 (Design Assurance Guidance for Airborne Electronic Hardware) (identical to RTCA–DO-254).

3 Minimum Performance Specification under Standard Conditions

3.1 General

The Laser Obstacle warning System (LOWS) shall meet the basic requirement not to interfere with on-board systems.

It shall be ensured that the equipment can neither become a source of danger in themselves nor threaten the proper functioning of any essential system or service.

3.2 System Specific Parameters

3.2.1 Hardware

The minimum requirements for the hardware of the sensor are given in the following table.

Requirement	Value	Remark
Laser Classification	Class 1	according to EN 60825-1
NOHD / ENOHD (Extended) Nominal Ocular Hazard Distance EN 60825-1	0 m / 0 m	eye safe at any distance, even if optical instruments are used
FOR (Field of Regard) horizontal vertical	$\geq$ 30° Azimuth $\geq$ 60° Elevation	Total field covered by FOV and LOS–steering below
FOV (Field of View) horizontal vertical	$\geq$ 30° Azimuth $\geq$ 30° Elevation	Angle scanned without LOS-steering
LOS (Line-of-Sight)-steering, if required to fulfill FOR requirement above	$\geq$ +15° $\leq$ - 15° in Elevation	LOS-steering shall be automatically controlled by flight state data
Time of LOS adjustment	$\leq$ 0,5 sec	
Frame(1) Repetition Rate	$\geq$ 2 Hz	without LOS adjustment
Sensor Detection Range for wires(2) ∅ 10mm and large objects (3)	For both types of targets: $\geq$ 500 m at visibility (4) 5km $\geq$ 300 m at visibility (4) 1,2km	Distance, at which the probability of detection exceeds 98% for a single laser pulse hitting the target
Minimum Detection Range D_{min}	$\leq$ 50 m	

Table 3.2-1: Sensor Hardware Requirements

(1) A frame is a scan over the complete field of view

(2) Wires shall have an extension of at least 6°. The reflectivity ρ^{req} of wires shall be assumed with $\geq$ 40% at 0° incidence, $\geq$ 38% at 15° incidence and $\geq$ 25% at 30° incidence for wavelengths in the 1,5µm - region.

(3) Large objects are any objects with an extension of $\geq$ 1,7° in both, azimuth and elevation (houses, trees, towers, forest, hills, etc.). The reflectivity ρ^{req} of large objects shall be assumed with $\geq$ 10% at 0° incidence and lambertian behavior for wavelengths in the 1,5 µm - region.

(4) The intensity of a laser beam propagating for a distance R through the atmosphere is attenuated exponentially according to $\exp(-\sigma_{vis}R)$. The attenuation coefficient σ_{vis} depends on meteorological visibility vis (measured in visible part of spectrum) and wavelength λ:

$$\sigma_{vis} = (3.91 / vis) * (\lambda / 0.55\mu m)^{-0,585\,[vis\wedge(1/3)]} \qquad \text{(vis in [km])}$$

(from: *Wolfe and Zissis: „The Infrared Handbook“, Washington 1978, page 23-10)*

3.2.2 System

The system shall generate obstacle information for the pilot. This information can be given in 3 different levels: Advisory, Caution and Warning. At least the level Warning shall be realized. The different levels can be split into sub-levels to generate more detailed obstacle information. The number of different levels and sub-levels shall be adequate to the given information.

Requirement	Value	Remark
Object Detection Delay	≤ 2 sec	for targets inside the detection range given in Table 3.2-1
Object Detection Probability (5)	≥ 99%	Detection after the Object Detection Delay above, for wires ∅ ≥ 10mm and large objects inside the detection range
Operating Modes	≥ 2	The pilot shall be able to select at least two operating modes to adapt the warning behavior to predefined flight conditions or to special flight maneuvers. One mode (APPROACH) for flight tasks which do require to fly in close proximity to obstacles (low level flight, takeoff and landing). The other mode (NORMAL) for flight tasks which do not require to fly in close proximity to obstacles (transfer-flights)
Obstacle Information Levels or Sub-Levels	≥ 2	At least two information levels or sub-levels for each operational mode shall be provided. At least one information shall be classified as warning.
False Alarm Rate (6)	≤ 1 in 2 hours ≤ 2 in 2 hours	for highest level as a sum for all but the highest level
BIT		Operation of the LOWS shall be continuously or frequently checked; BIT shall include electronics including range measuring circuit, optical components including optical test of laser and receiver, performance of mechanical systems (scanner, fan), internal temperature
BIT display		In case of errors a global BIT result shall be reported to the pilot by activating a display of the helicopter
BIT error detection time	≤ 1 sec	Maximum delay time between occurrence of an BIT error and reporting it in the caution display

Table 3.2-2: System Requirements

(5) This requirement combines the detection probability for a single shot hitting the target, the geometrical probability that a shot is actually hitting the target (given by dot distribution of the scan mechanism) and the evaluation capability of the software. If the dot distribution of the scan mechanism varies within the FOV, the region resulting in the lowest detection probability has to be considered.

(6) Alarm generated by the LOWS without objects present. Applies for day and night, blue or overcast sky and differently structured background (town, wood, hills, sky, clouds, but all background objects at a distance larger than the detection range)

3.2.3 Definition of Safety Volume

For generation of an obstacle information for each level and sub-level in each operational mode a safety volume in front of the helicopter is defined dependant on the horizontal and vertical components of the actual true ground flight vector v_h and v_v (positive up). The safety volumes are defined by the parameters in Table 3.2-3 and Table 3.2-4. Each safety volume is the volume enclosed by:

- A vertical plane in front of the helicopter perpendicular to the ground projection of the flight vector at distance D_{min}
- A vertical plane Q in front of the helicopter perpendicular to the ground projection of the flight vector at distance $v_h * T_{max}$
- Two vertical planes parallel to the flight vector at distance $S(v_h)$ to the left and right of the helicopter
- A plane parallel to the flight vector and to the artificial horizon at distance $H(v_h)$ above the helicopter
- A plane U parallel to the flight vector and to the artificial horizon at distance $L(v_h)$ below the helicopter
- A plane W [1] below the helicopter, parallel to the artificial horizon, crossing plane U in b at distance v_h*T_1 and crossing plane Q at a distance of $v_{climb}*(T_{max} – T_1)$ above b, where v_{climb} is the larger one of v_{up} and v_v.

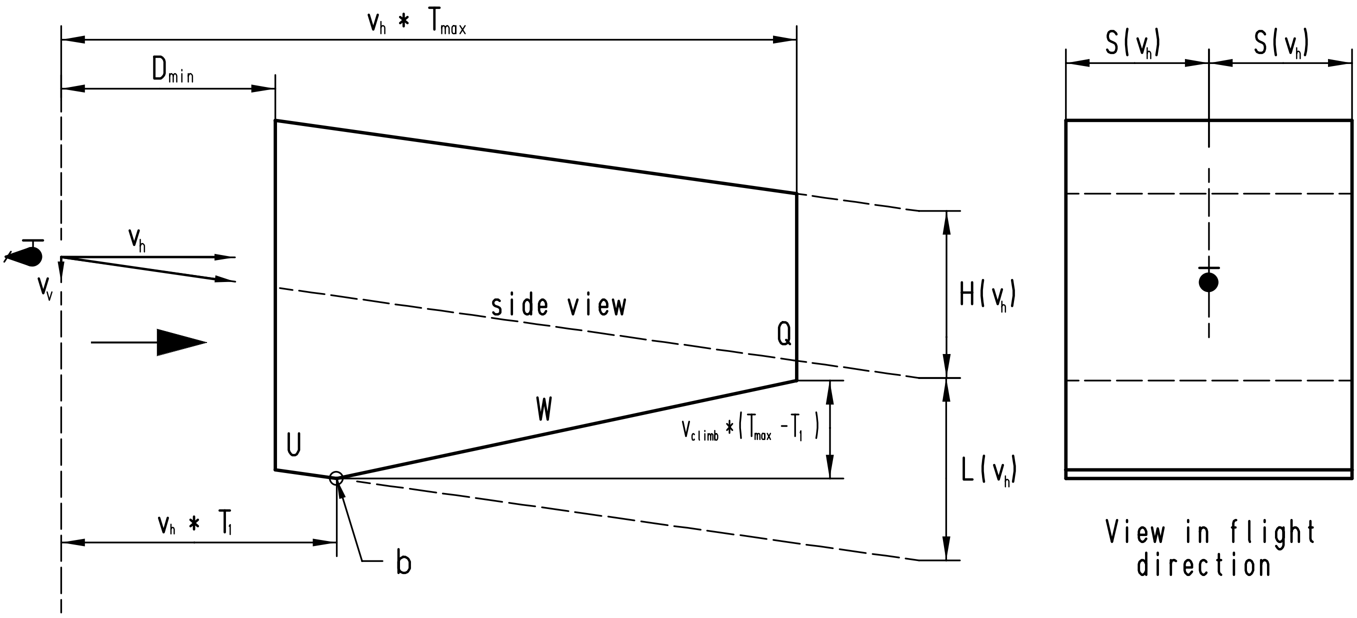

Fig. 3.2-1: Schematic view of the safety volume

[1] The area below plane W can be excluded, because it assumes a climb of the helicopter with v_{climb} climb rate to overfly the obstacle with $L(v_h)$.

The following parameter definition for the minimum safety volume holds for the warning level. If the warning level is subdivided in sub-levels, the definition holds for the sub-level with the lowest criticality.

v_h [kts]	<10 kts	10 kts – 45 kts	>45 kts – 60 kts	> 60 kts
$L(v_h)$	no warning	5 ft	35 ft	35 ft
$H(v_h)$	no warning	35 ft	35 ft	35 ft
$S(v_h)$	no warning	35 ft	35 ft	35 ft
T_1	no warning	2 s	2 s	2 s
T_{max}	no warning	6 s	6 s	6 s
v_{up}	no warning	3 m/s	3 m/s	3 m/s

Table 3.2-3: Parameter definition in dependence on the true ground speed v_h for minimum safety volume in Approach-Mode, first warning level

v_h [kts]	<10 kts	10 kts	>10 kts – 60 kts	> 60 kts
$L(v_h)$	no warning	35 ft	Increasing linear from 35 ft to 80 ft	80 ft
$H(v_h)$	no warning	35 ft	35 ft	35 ft
$S(v_h)$	no warning	35 ft	35 ft	80 ft
T_1	no warning	3 s	3 s	3 s
T_{max}	no warning	6 s	6 s	6 s
v_{up}	no warning	3 m/s	3 m/s	3 m/s

Table 3.2-4: Parameter definition in dependence on the true ground speed v_h for minimum safety volume in Normal-Mode, first warning level

For each level and sub-level an obstacle information (advisory, caution or warning) shall be issued not later than 0,5 seconds after a detected object is within the corresponding safety volume.

Depending on the operational requirements larger safety volumes than the minimum safety volumes defined above may be used.

In each operational mode the safety volume of a level or sub-level with lower criticality shall be identical or larger than the safety volumes of higher criticality; in any case each safety volume shall fully contain the safety volumes with higher criticality.

The manufacturer shall state the limitations of the system by listing the flight states and environmental conditions where a full coverage of the minimum safety volume can be provided by the LOWS.

The manufacturer shall state the achieved warning times for a straight, horizontal flight with an obstacle located in the flight path. It shall cover at least the visibilities 5 km and 1,2 km and at least the true ground speeds of 40 kts, 70 kts and 100 kts. This information shall be included in the flight manual.

True ground speed v [kts]	Visibility 5 km	Visibility 1,2 km
40 kts	5,5 s	5,5 s
70 kts	5,5 s	5,5 s
100 kts	5,5 s	3,5 s (no sufficient warning time possible)

Table 3.2-5: Example of achieved warning times (time to collision) for an equipment just fulfilling the min. requirements of tables 3.2-1,3.2-2 and 3.2-4

3.2.4 Indication of Obstacle Information

For display of the obstacle information a visual indicator shall be provided, either by a dedicated hardware unit or by use of a helicopter display.

The visual indicator shall consist of at least 3 optical display elements which are flashing in case an obstacle is detected in the safety volume. The display elements shall display the direction in which the obstacle is detected relative to the helicopter axis in at least a left, a center and a right sector (see Fig. 3.2-2 for an example). The assignment of theses sectors to angular regions shall be adapted to the horizontal FOV of the LOWS.

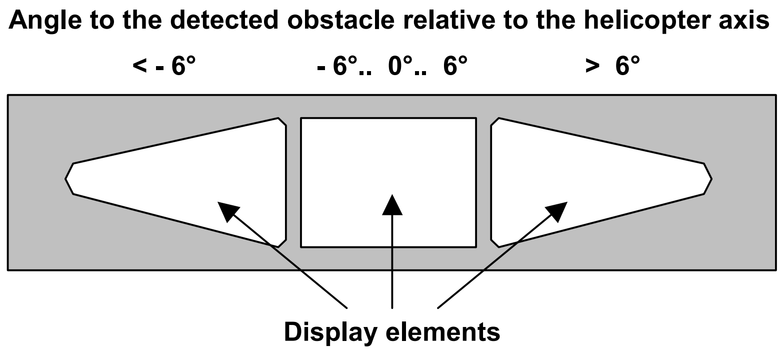

Fig. 3.2-2: Example for a visual indicator

The visual indicator, the number and size of the display elements and the angle range assignments to these elements shall be in coincidence with the overall concept of the helicopter (e.g. NVG).

The colors of the display elements can be found in JTSO-C113 and FAR 27.1322 (Red for warnings, amber for cautions and any other color except of red, amber and green for advisories).

As additional information for the most critical information level or sub-level an acoustic alarm can be issued either by its own or by applying a signal to the helicopter interface.

The acoustic alarm shall be removed as soon as the cause for this alarm is gone, with the constraint that a minimum duration of 1 second should be provided.

3.2.5 Interfaces

Means to disconnect the equipment from power bus shall be provided (i.e. Master Switch) by the design of the equipment itself or by measures described in the installation manual for the case of unexpected interference, fire, smoke or other hazards.

If the system interfaces to other on board equipment, compliance with the interface related requirements for that equipment has to be shown in order to exclude adverse effects on connected systems and the helicopter itself.

If interfaces to external sensors are required, the manufacturer shall state the accuracy and update rate requirements.

Obstacle information shall report to at least one of the following display types:

- one or more dedicated hardware indicators and /or
- one or more display units of the helicopter.

The information provided on different helicopter display units (if applicable) shall be consistent.

Furthermore a warning trigger can be sent to the acoustic generator of the helicopter or activate an own acoustic alarm, if the warning level with the highest criticality is activated.

The system must not issue resolution advisories.

A continuously or frequently performed built in test shall monitor the functionality of the LOWS. At least a GO/NOGO information shall be displayed on a helicopter display.

4 Minimum Performance Specification under Environmental Test Conditions

4.1 Introduction

The environmental tests and performance requirements described in this chapter provide a laboratory means of determining the performance characteristics of the equipment under conditions representative of those which may be encountered in actual operations.

The Laser Obstacle Warning System (LOWS) needs to comply to environmental tests as far as it is necessary to ensure that the equipment cannot become a source of danger under environmental conditions and can perform its tasks as a flight aid under environmental conditions.

Some of the tests contained in this chapter are identified with the phrase „if required". They do not have to be performed unless the manufacturer wishes to qualify the equipment to these additional environmental conditions or if requested by the responsible authority.

Unless otherwise specified, the test procedures applicable to a determination of equipment performance under environmental test conditions are contained in document RTCA/DO-160D (EUROCAE ED 14D) „Environmental Conditions and Test Procedures for Airborne Equipment". It is also necessary to take into account the required mission conditions. Sensor and electronic units mounted outside may be subject to different test procedures than equipment mounted inside the helicopter.

4.2 Equipment Performance Compliance

The performance requirements as defined in chapter 3 are not required to be tested under all of the conditions contained in ED-14D/DO-160D. Details have to be agreed with the responsible authority. The minimum performance under environmental test conditions shall be proven by:

- monitoring all built-in tests of the equipment
- check of the sensor data to verify the functionality of the laser, the receiver and the scanning mirrors
- verifying the stability of distance measurements by monitoring the distance measured on an optical delay line, e.g. realized by an optical fiber of defined length.

When exposed to high temperature and/or pressure as well as power input and voltage spike test, it shall be ensured that there is no risk of fire, smoke or similar induced by the equipment.

The performance verifications possible under test conditions are highly dependant on the actual LOWS design. Therefore details of the performance verification shall be agreed with the responsible authority.

4.3 Performance Tests

The equipment is sorted in two categories. The first one, category 1 is for devices which are to be installed outside, such as the sensor and/or the electronic unit. The second one, category 2 is for equipment installed inside the helicopter, e.g. operating controls or warning indicators, if applicable. Qualification tests for both categories are listed in table 4.3-1.

Section	RTCA-DO160D Test	Category 1	Category 2
4.	Temperature and Altitude	+	+
4.5.4	In-Flight Loss of Cooling	+	-
5.	Temperature Variation	+	+
6.	Humidity	+	+
7.	Operational Shocks/Crash Safety	+	+
8.	Vibration	+	+
9.	Explosion Proofness	+	-
10.	Waterproofness	+	-
11.	Fluids Susceptibility	+	-
12.	Sand and Dust	+	-
13.	Fungus Resistance	+	+
14.	Salt Spray	+	-
15.	Magnetic Effect	+	+
16.	Power Input	+	+
17.	Voltage Spike	+	+
18.	Audio Frequency Conducted Susceptibility Power Inputs	+	+
19.	Induced Signal Susceptibility	+	+
20.	Radio Frequency Susceptibility	+	+
21.	Emission of Radio Frequency Energy	+	+
22.	Lightning Induced Transient Susceptibility	-	-
23.	Lightning Direct Effects	-	-
24.	Icing	+	-
25.	Electrostatic Discharge	+	+

+ : mandatory test

- : if required

Table 4.3-1: Listing of Environmental tests according to RTCA/DO-160D (EUROCAE ED 14)

The tests marked with “if required” may become mandatory in case of specific technical reasons. This shall be agreed with the responsible authority.

4.4 Laser Safety

The laser classification provided by the manufacturer shall be approved according to [LAK].

5 Equipment Integration

5.1 Integration of Sensor Unit

General guidance on installation which can be found in FAA AC25-10, 25-16, 43.13-1b (or later editions) should be applied.

The sensor unit shall be integrated into the front part of the helicopter. Mounting shall be carried out so that there is no shading of the sensor's field of regard.

The mounting points at the helicopter shall meet the equipment specific tolerances for integration, especially regarding the mounting angles. Alternatively, special alignment tools or angular adjustment procedures have to be provided.

If interfaces to external sensors are required, the manufacturer shall state the relative position and alignment requirements.

5.2 Integration of Display and Control Parts

If dedicated hardware indicators are provided, they shall be mounted within the pilot's field of view when looking outside in heading direction. However, the indicators shall not impair the pilot's view.

The switch for selecting the operating modes provided shall be installed into the cockpit, for example into the center console.

A switch to reset the acoustical alarm may be installed readily accessible for the pilot.

6 Special Test Procedures

Verification of system performance in flight tests will typically issue high risk to the pilots, the management will be a tedious affair due to visibility and target constraints and, furthermore, the results are often difficult to reproduce even at the same location.

Therefore, proof of the functional performance should be carried out in three stages:

- Proof of sensor hardware performance in the detection of the obstacles and false alarm rate by flight and/or field test.
- Proof of system performance (signal processing, warning generation, MMI chain) by real-time off-line stimulation and/or simulation using raw data of the quality verified in the first step.
- Flight tests with selected scenarios for verification of the system behavior proved off-line.

The aim of this procedure is to provide a complete and reproducible proof of system performance, particularly warning probability and false alarm rate.

6.1 Sensor Hardware Performance

Verification of the performance requirements given in chapter 3.2.1 may be difficult, because the required visibility vis, wire diameter ∅ or wire reflectivity ρ are not available. The manufacturer should perform the test at the same Range R, but under actual environmental conditions (index act), using an attenuation filter with transmission T^{act} to scale the results to the environmental conditions required (index req). T^{act} is given by:

$$T^{act}\ (R, vis^{act}, \rho^{act}, \varnothing^{act}) = \frac{\exp(-2\ \sigma_{vis}^{req}\ R)\ \ \rho^{req}\ \ \varnothing^{req}}{\exp(-2\ \sigma_{vis}^{act}\ R)\ \ \rho^{act}\ \ \varnothing^{act}}$$

with the extinction coefficient $\sigma_{vis} = (3.91 / vis) * (\lambda / 0.55\mu m)^{-0{,}585\ [vis\wedge(1/3)]}$ (vis in [km]).

The filter transmittance T^{act} applies for a single filter used either in the receiver or in the transmitter path. The necessary attenuation may also be achieved by using filters in both path's; in that case, the product of the two transmission values shall be equal to T^{act}.

Note: The calculated filter transmittance T^{act} is only valid for one target distance R.

If ρ^{act} is not known, $\rho^{act} = \rho^{req}$ (see chapter 3.2.1) shall be assumed, if real objets representing the required targets are used.

A similar formula applies to large objects:

$$T^{act}\ (R, vis^{act}, \rho^{act}) = \frac{\exp(-2\ \sigma_{vis}^{req}\ R)\ \ \rho^{req}}{\exp(-2\ \sigma_{vis}^{act}\ R)\ \ \rho^{act}}$$

Using this method, the required sensor hardware performance given in Table 3.2-1 shall be verified by statistical evaluation of the raw data. The manufacturer shall disclose the statistical methods used.

The sensor raw data recorded should be used as input data for proof system performance.

6.2 System Performance

It has to be proved that the signal processing chain and the MMI generate the warnings in accordance with the performance features on the basis of the raw data determined in chapter 6.1.

To this purpose the LOWS has to be stimulated with the recorded raw data so that it receives the original data flow existing in the flight in correct sequence at the identical interfaces as in normal operation.

6.3 Proof of System Behavior in Flight Test

The system behavior proved in sections 6.1 and 6.2 shall be selectively demonstrated in flight tests.

It is not intended to verify parameters that have been already verified in laboratory tests, but to demonstrate the over all system performance in flight.