International Association of Marine Aids to Navigation and Lighthouse Authorities

IALA

AISM Association Internationale de Signalisation Maritime

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On

Technical Features and Technology Relevant for Simulation of AtoN

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Document Revisions

Revisions to the IALA Document are to be noted in the table prior to the issue of a revised document.

Date	Page / Section Revised	Requirement for Revision

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Technical Features and Technology Relevant for Simulation of AtoN

1 INTRODUCTION

IALA's Guideline 1058 On the use of simulation as a tool for waterway design and AtoN planning is intended to be a high level, strategic document to assist Competent Authorities in understanding how simulation tools can assist in planning and implementing AtoN. This Guideline should be seen to provide greater technical guidance, supplementing IALA Guideline 1058.

Users of this Guideline are expected to be AtoN designers, developers, researchers and testers, including mariners. Users of simulator systems are encouraged to understand to what extent a given simulator system is providing the required quality and fidelity to suit the purpose of simulation studies and investigations.

The rapidly developing technology for computer-based simulation provides users with an increasing level of fidelity and realism; on the other hand, this technology will always have its inherent limitations. This Guideline provides an overview of the current status of simulation technology with a focus on capabilities and limitations of simulation software, visual systems, visualization media and other relevant systems. It also identifies a collection of features that are important to consider when specifying the objectives of a simulation study for planning, research and testing of AtoN.

This Guideline represents the technological status at the time of publication. As maritime simulation tools include several elements of particular types of technology that are under constant and rapid development, users should be aware that the technology described in certain parts of this Guideline may have advanced further at the time of reading. Thus, it is recommended that users consult simulator system producers for information on latest developments.

2 SCOPE

This Guideline covers:

- user needs and requirements;
- modelling and simulation of AtoN;
- visual simulation;
- display technology:
  - projection theatres;
  - video walls;
  - infrared and night vision;
- radar simulation;
- sound simulation;
- simulation of Ship Navigation systems.

3 DEFINITIONS

Throughout this guideline the following definitions are used:

- **Stimulation** is used when a real radar video signal is produced in a simulator model and feeds, as in real life, into a real radar display identical to those used onboard real ships.
- **Emulation** is the replication of a real-world system using software and hardware. For example, the whole radar sub-system, both antenna and display is modelled and appears identical to a real onboard system.
- **Simulation.** In IALA Guideline 1058 the following definition has been used:

  Simulation is the process of designing a model of a real system and conducting experiments with this model for the purpose either of understanding the behaviour of the system or of evaluating various strategies (within the limits imposed by a criterion or set of criteria) for the operation of the system [1].

  Thus the model must be designed to mimic the response behaviour of the real system to events that take place over time [2]. Therefore, for the purposes of this Guideline, a more accurate definition is as follows:

  Simulation is the imitation of the operation of a real-world process or system over time [3]. The act of simulating something first requires that a model be developed; this model represents the key characteristics or behaviours of the selected physical or abstract system or process. The model represents the system itself, whereas the simulation represents the operation of the system over time.
- **Modelling** is the process of developing a schematic description of a system, theory, or phenomenon that accounts for its known or inferred properties and may be used for further study of its characteristics.
- **Conceptual models** aim to provide a mental breakdown of a system into smaller subsystems that are easier to understand. The primary objective of a conceptual model is to convey the fundamental principles and basic functionality of the system which it represents. Also, a conceptual model must be developed in such a way as to provide an easily understood system interpretation for the models users.
- **Mathematical models** represent the behaviour of the system subject to: the present state of the system, controls, external influences and disturbances; usually a set of differential equations.
- **Numerical models** are computer implementations of mathematical models. Although simulation of a dynamic system is perfectly possible using analogue components, digital computer technology is much cheaper and much more versatile. Mathematical models are then converted to discrete forms, i.e. the system state is calculated in discrete time steps instead of continuously.
- **Presentation** is the continuous state of the simulation model presented to the system user with realistic and relevant stimuli as used in real world operations.

4 USER NEEDS AND REQUIREMENTS

This Guideline is based on user needs and requirements identified by members of the ANM and EEP Committees. In determining the needs of the user, the following classification should be considered.

Table 1 Classification of user needs

Applications/Users	Mariners	Engineers/Scientists
Research	Vessel behaviour, such as turning point, under keel clearance, impact of bridge systems on navigation	Visual comparison of colour, intensity, flash characteristics
Development		Comparison of light sources, evaluation of surface colours
Design and Testing	Fairways/channel, Marking schemes	Buoy design, movement, vertical divergence

In addition to the user requirements identified, important and relevant information can be found in existing IALA Recommendations and Guidelines. These Recommendations and Guidelines have been used to identify the models and practical applications and are listed in ANNEX A.

5 MODELLING AND SIMULATION OF AtoN

One of the real strengths of simulation is the development of future AtoN systems in conjunction with existing systems.

Simulation provides a cost-efficient and flexible tool that can support activities discussed in section 4. Simulation is considered the next best thing to observing real AtoN in operation. It allows the user to study the AtoN when it is not possible or too costly to experiment directly with the real AtoN.

Major advantages of simulation are: new designs can be tested without committing resources to their implementation; it allows insight into how AtoN works in operation; to experiment with unfamiliar situations; and, answer 'what if' questions. The simulation must provide adequate levels of accuracy and thus credibility. The more the simulation resembles real world situations, the easier it is for end users and decision makers to relate to it. Characteristics of AtoN should be captured as closely as possible to enable well-founded decisions.

Even though simulation has many advantages, users should understand the capabilities and limitations of the individual elements of a simulation system. The quality of the result of a simulation study is dependent on the quality of the model, the skill of the user, and the quality of the input data.

Guideline 1058 (see ANNEX A) highlights the importance of careful consideration of when, and to what extent, the end-users/mariners shall be involved in the simulation for planning, execution and evaluation of the results of a simulation study.

Ideally, the probability of detecting an AtoN will be identical, or similar, in the simulated and the real world. Despite a high accuracy of the simulated model, it is not possible to generate a like-for-like situation. The user should understand the gap between the real and the simulated world to maximise the benefits of simulation.

Figure 1 depicts the four channels through which information can be transferred from AtoN to the user. For each channel the media, model and data required are illustrated. Each channel requires individual means of modelling and presentation and is discussed in the following sections.

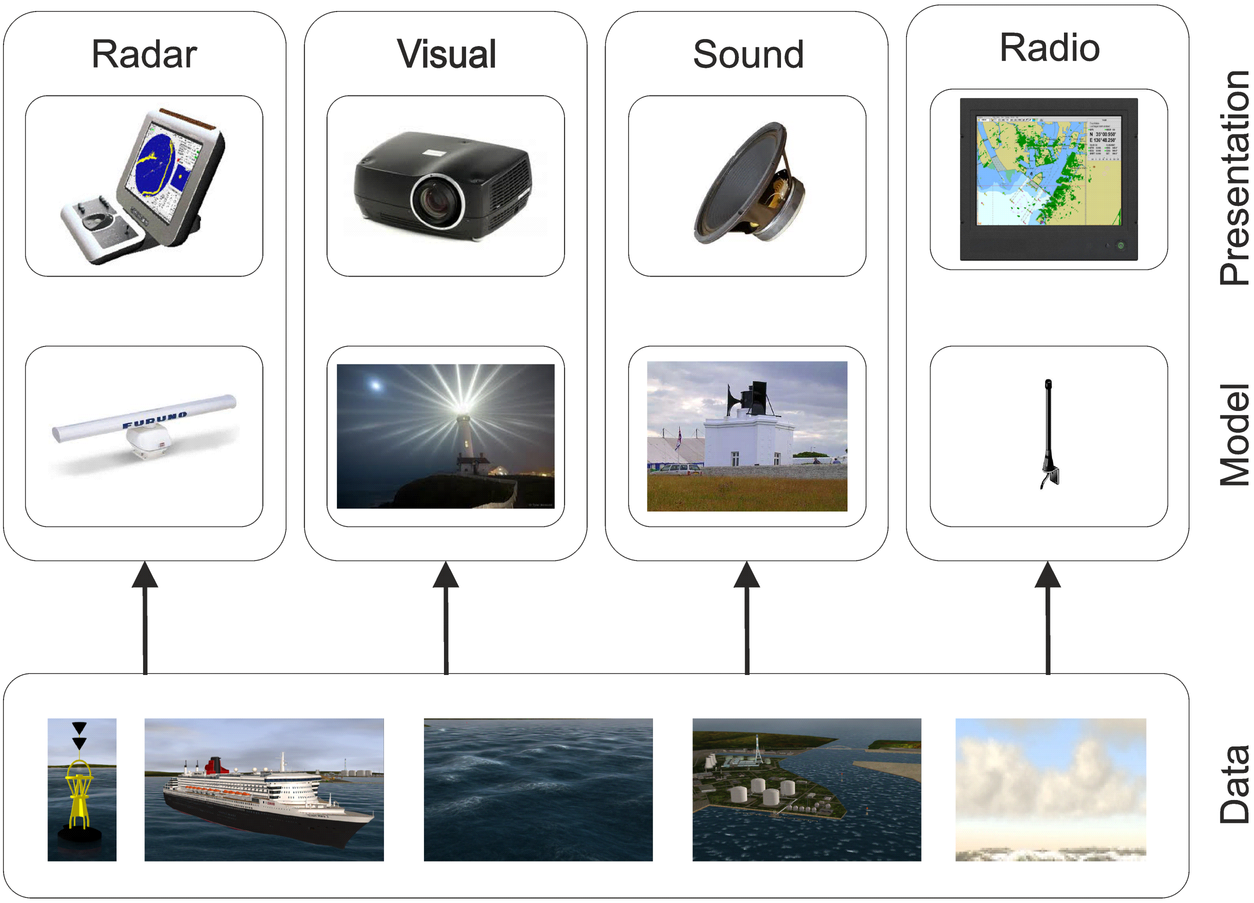
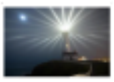


Figure 1. AtoN modelling and presentation

Table 2 Presentation media comparison

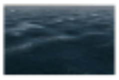
Channel		Presentation media	
		Reality	Simulated
	Radar	Monitor / PPI	Monitor
	Visual	Sun, lamps, etc.	Projector, monitor, etc.
	Sound	Fog horns, bells, etc.	Loud speakers
	Radio	Monitor	Monitor

Table 3 Simulation model

Channel		Simulation model
	Radar	Simulates how the radar transceiver, transmit pulses and receives echoes in the data model of the 3D world.
	Visual	Simulates how light in the scene, either direct or reflected, scatters and enters the eye before visual perception.
	Sound	Simulates how sound is received from sound emitters, like fog horns, sound from weather phenomena, sound on board ships, etc. are received before the 'presentation' by the sound speaker.
	Radio	Simulates how radio waves from radio stations are received, interpreted by the receiver and finally displayed on the ECDIS or other navigation information display.

A single representation of the simulated world is used by all 4 channels, although each channel focuses on specific aspects of the data model.

Table 4 Data Models

Channel		Data Model
	AtoN	Positions, colour, flashing characteristics, buoy geometry, etc. are part of the data model for AtoN.
	Ships	Ship manoeuvring characteristics, visual appearance, navigation lights are part of the data model for ships.
	Ocean	The ocean wave climate, currents, bathymetry including tide are examples of elements in the data model of the ocean.
	Terrain	The terrain model includes the landscape, vegetation, buildings, and emissive light sources providing background lighting.
	Atmosphere	Reflected sun light and light from navigation lights are scattered by the actual weather, such as fog, haze, clouds, etc. Background sky colours changing over the day affects the conspicuity. Correct data for these effects is part of the total data model.

6 SIMULATION OF A VISUAL SYSTEM

6.1 Presentation technology

6.1.1 Introduction

The presentation technology is the system responsible for the transmission of visual cues to the mariner on the simulator's bridge.

A number of presentation technologies are available, ranging from a single monitor display to a LED video wall. All have their specific strengths and limitations.

For a simulation to be effective, the user must be able to derive all relevant visual information from the stimuli – thus the resolution of the display may be more important than its luminance, although there may be some interaction due to the physical characteristics of the human eye.

The first question to be answered before choosing a presentation technology is what the aforementioned 'relevant visual information' will be. Then, from the available technologies, the most cost-effective alternative may be chosen. In the simulation models, the limitations of the presentation technology can be compensated to some extent. If the visual information cannot be sufficiently transferred by any of the available technologies, an additional, not necessarily visual feedback to the user could be provided.

All the technologies discussed in the following sections use digital technology, which has a finite resolution. As the number of pixels available is an inherent part of the hardware used, it must be considered carefully.

6.1.2 Reflective systems (Projector based)

6.1.2.1 Projectors

A projection system involves a light source from which an image is projected onto a screen. The user observes the screen and as such the image transfer is indirect. The projection screen is usually at a distance of several metres from the observer position, which enhances the sense of reality through perspective. A drawback is that the radiation and reflection losses limit the luminance of the image such that the simulated conditions resemble, at best, dusk lighting.

The projector techniques used determine the light output at the source, contrast and colour accuracy, response speed, etc. Continuing developments are stimulated mainly by the gaming industry and digital cinema and supported by the constant increase of computer power. Probably the most important parameter for simulation of visual AtoN is the resolution – and as all this is about digital imagery, this is determined by the number of pixels per minute of arc seen from the user's position.

For the generation of the image the available techniques are CRT (Cathode Ray Tube), LCD (Liquid Crystal Display), DLP (Digital Light Processor) and LCoS (Liquid Crystal on Silicon). All have their pros and cons.

The cost *per pixel* rises dramatically with increasing image resolution. Typical image resolutions for simulation are 1600 x 1200 (UXGA) and at the high end 2048 x 1536 (QXGA). The most recent development is the 4K technology, indicating a 4096 pixels wide image.

Some configurations available today:

Table 5 Example specifications of existing projectors

Projector type	Resolution	Contrast ratio*	Max light output (ANSI lumen)	Referenced specifications
3 CRT	Max 2500 x 2000	30,000	1300	Sony vph-G90u
3 chip DLP	2048 x 1080	2000	33000	Barco DP2k-32B
3 chip DLP	1920 x 1200	2000	10000	ProjectionDesign F82
1 chip DLP	1920 x 1200	2000		Barco SIM5W
LCoS	1536 x 2048	4000**	2800	Barco SIM 7Q HB
LCoS	4096 x 2160	4000**	2000	Sony VPL-VW1000ES
LCoS (low-cost)	1920 x 1200	1000	4000	Canon REALiS-WUX4000
LCD	1920 x 1200	5000	7000	Epson Z8450WU
LCD (low-cost)	1920 x 1080	1000**	2000	Panasonic PT-AE7000

* quoted figure is the native or static contrast ratio, i.e. the maximum ratio within one picture. The dynamic contrast ratio refers to the ratio that can be produced over time and is usually much higher (up to 6,000,000) by dynamically reducing the image illumination or applying a diaphragm

** based on general information from Displaymate.com (http://www.displaymate.com/LCoS_ShootOut_Part_D.htm)

6.1.2.2 Projection Theatres

On a full-mission bridge simulator, a large viewing angle (preferably 360-degree) is desirable. A frequently applied setup is a circular projection screen with a number of projectors underneath or on top of the simulator bridge, each one being responsible for a sector of the outside view. Besides the characteristics of the projectors, some specific issues relate to the composition of the image in such a theatre.

6.1.2.3 Warping and blending

The projected image of each projector should ideally be a perfect cylindrical section, all colours sharp and aligned throughout the entire image. As the projectors cannot all be in the centre of the cylinder section, for example due to obstructions such as a wheelhouse, the image generation system must compensate for this. In addition, the projection of a flat image source would lead to a flat projected image, so the focus must be corrected for the cylindrical image. These corrections are fairly standard, although many hours of adjustment may be involved to setup and maintain an optimal image.

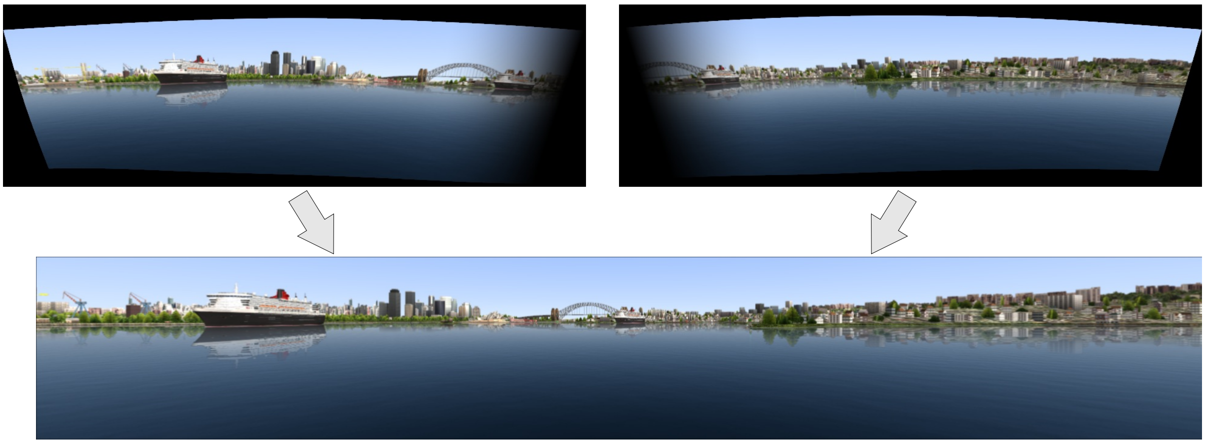


Figure 2. Warping and blending two visual channel images making it correct at the projection screen

6.1.3 Emissive Systems

6.1.3.1 Monitors

When a simulated image is presented on one or more monitors, the radiation and reflection losses associated with projection are avoided. The monitors can replace bridge windows, the window frames giving a natural separation from the adjacent monitors. Having the displays at close range decreases the impression of perspective. The user's position on the bridge should be fixed, otherwise the absence of parallax would be apparent from the window frames.

An advantage of monitors over projection systems is that pixels are not distorted by optical aberrations, so that the resolution is not reduced by blurring of the pixel images. Moreover, the usually very laborious adjustment process to get the best possible projected image is avoided. Depending on the distance between the user and the monitors, the number of monitors needed to provide a reasonable field of view could become rather large and the adjustment of display colours is still a significant task.

The larger the distance between the user and the monitors, the better the sense of reality gets (approaching that of a projected image). The distance and the pixel pitch of the screen together determine the maximum displayable resolution. As an example, if we have a monitor with 0.25 mm pixel pitch and need a resolution of 1' the distance must be at least 86 cm. To get a field of view of 30 degree for one screen the size of the screen has to be 46 cm. A monitor with the same resolution but twice as large (thus having pixel pitch of 0.5mm) may be placed at double the distance to get the same visual representation. The options are illustrated in **Error! Reference source not found.**.

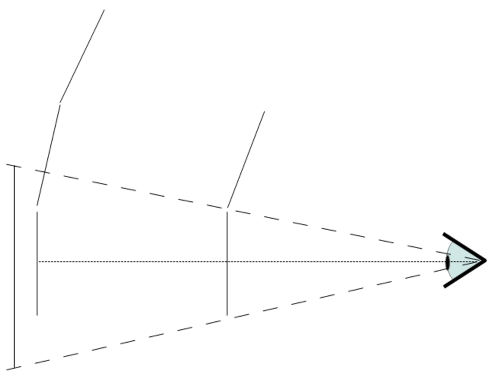


Figure 3. Screen configurations

Some examples of available monitors are:

Table 6 Example specifications of some existing monitors

Display type	Dimensions (mm)	Resolution; Pixel pitch (mm)	Contrast ratio	Max luminance (Cd / m^2)	Referenced specs
LED lit LCD 28'	500 x 500	2048 x 2048; 0.25	1000	300	Barco ISIS MDP-471
LCD 40' (High Brightness)	915 x 526	1920 X 1080; 0.5	3000 (static) 10,000 (dynamic)	700	Samsung 400UXN-3
LCD 30'	640 x 400	2560 x 1600; 0.25	1000	350	NEC PA301W-BK
LPD (Laser Phosphor Display)	3048 x 1524	1920 x 960; 1.6	100,000 (native)	800	Prysm 6x4 TDI-tiles
Plasma 85' high contrast	2269 x 1276	1920 x 1080; 1	40,000 (native)	?	Panasonic TH-85PF12U

6.1.3.2 Video walls

A video wall consists of a number of video monitors. In addition to the aspects mentioned in section 6.1.3.1 the frames of adjacent monitors must not be noticeable. The powering and control of the displays may be a technical challenge.

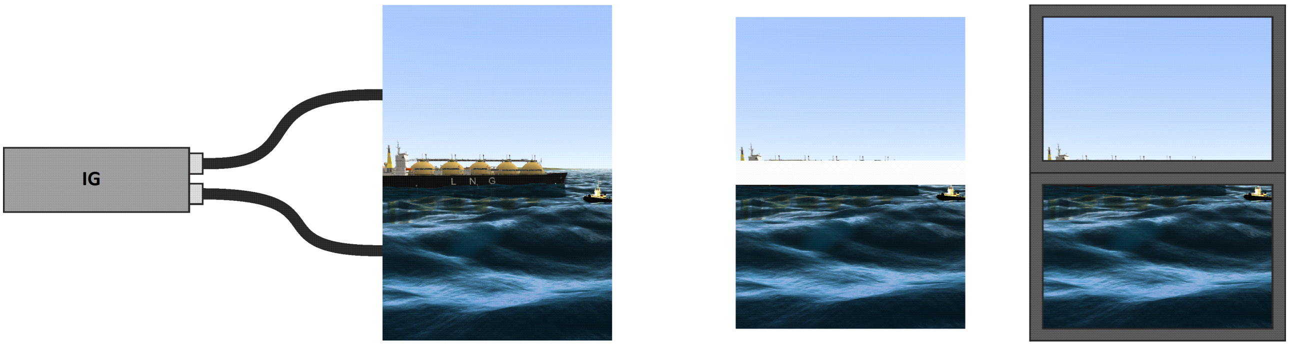


Figure 4. Bezel correction for video walls

Figure 4 illustrates the 'Bezel correction' process of removing pixels behind the frame of multiple monitors. The Bezel correction needs to be carried out if the visual images are rendered by one IG (Image Generator) channel and displayed on several monitors.

6.1.3.3 LED screens

A large number of LED displays may be tiled to form a video wall. Each tile consists of a relatively small number of LEDs, each LED responsible for a single pixel of the image. The image has relatively high luminance and contrast figures. If the resolution of the image has to be 1', then the distance between the user and the wall must be nearly 14 m when using 4 mm LEDs. It is clear that this would lead to a huge amount of tiles for a 360-degree view.

Table 7 gives a few examples of tiled LED systems.

Table 7 Example specifications of some existing LED display tiles

Display type	Dimensions (mm)	Resolution; Pixel pitch (mm)	Contrast ratio	Max luminance (Cd / m^2)	Referenced specs
4 mm pitch 3-in-1	448 x 504	96 x 108; 4	3500	2000	Barco NX4s
16 mm pitch 3 led	960 x 960	60 x 60; 16	7000	6000	Barco TF16BK

6.1.3.4 Head-mounted and Hand-held Displays

If a user utilizes binoculars on the simulator bridge he would probably be able to distinguish individual image pixels. However, binoculars should improve the image resolution, not amplify the display limitations. Of course, this may be simulated: in this case the binoculars would contain electronic displays and a sensor to determine the target being aimed at. The displays are fed with calculated, ‘enlarged’ image.

The same rationale and techniques can be applied with VR (Virtual Reality). Instead of creating a very large projection wall for the image, the user may be provided with small displays showing everything that he should be able to see. The displays are built into a VR helmet that the user wears, excluding his real surroundings. Like the detection of the target for the binoculars, the helmet must sense the position of the user’s head and the direction of his eyesight. This information must lead to very fast adaptation of the image, as the latency (the time the image lags behind) must be less then 50 ms for the user to keep the illusion that he is really looking around.

6.1.4 Combination of techniques

A simulation may use a combination of the techniques described above. As an example, a separate monitor could be used to fill in the rear view on a projected 270-degree view bridge. Furthermore, the lights of AtoN could be superimposed on a projected view with separate laser beams, giving high contrast and high resolution.

When a projected view is combined with additional monitors for rear view, or a bridge wing view, the difference in luminance and contrast of the displays should be considered.

6.1.5 Additional enhancements

6.1.5.1 Light and Colour matching

If the outside view is generated with multiple display systems, the colours and light displayed by individual units have to be carefully adjusted so that there is no noticeable transition in colour and light from one unit to another. Otherwise, the sense of reality would be reduced.

Each projector in a multi-channel projection system has lamps producing light of varying intensity and colour spectrum. Moreover, the colour-wheel used in single chip DLP projectors has individual filter characteristics. Both of these variations will result in projected images of individual intensity and colour. In order to compensate for this, modern projectors use DSP techniques such as light and colour matching. This involves the calibration and setting data for each projector’s colour and light compensations. One commercial implementation of this is known as RealColor™ by projectiondesign. http://www.projectiondesign.com/realcolor.

Using RealColor, all display units in one simulator are tuned to have the same effective overall gamut converted from the inherent gamut of each projector using mathematical transformation. High-end projectors may even have an automatic system that continuously adjusts the conversion.

Subjective observations may be used to examine the conversion, but it is recommended the use of a Chroma Meter that measures luminance and chromaticity, such as the Konica Minolta CS-200.

6.1.5.2 Stereoscopic view

If both the user's eyes are fed with a slightly different image, a stereoscopic view will be generated. This can be achieved with a VR Helmet or binoculars as discussed in **Error! Reference source not found.** or with other techniques found in the 3D cinema and TV consumer market. There are many people who cannot digest these images without problems (like developing nausea). There should be fallback options if this occurs. However, at the distances relevant in navigation the stereoscopic cues are expected to be minimal.

6.1.5.3 Dynamic perspective

When a user moves about the bridge, his perspective of the visible part of his ship changes. On a simulator bridge, dynamic perspective involves detection of the actual viewing point and changing the perspective of the projected image accordingly. This could be continuous, but traditionally this is changed on a discrete basis, e.g. when a pilot enters the bridge wing, the viewing point shifts to that side.

6.1.5.4 Infrared and Night Vision

Mainly intended for simulation of military operations, the visualisation of infrared and night vision is available from some manufacturers. This will involve a separate display unit for which a specific image is generated.

6.1.6 Present limitations

The following sections will describe further some different technical possibilities of visual simulation. In general, the limitations refer to the following aspects:

- resolution: The resolution of the eye is 1' (c.f. Guideline 1094) whereas simulated images reach about 2' ;
- illuminance of objects: in the real world up to 10,000 cd/m^2, simulated images up to 300 cd/m^2. The full range of background illumination in real world conditions extends from 10^{-3} cd/m^2 on an overcast, moonless night to 10^5 cd/m^2 in direct sunlight;
- contrast: real-world contrast ratios are up to 1:10^7, simulator images reach 1:10^4;
- colour space: the real-world, continuous spectrum is digitized as a limited number of colours.

With High Dynamic Range (HDR) and Tone Mapping techniques (discussed in 6.2.5) optimised use of the display capabilities can be achieved.

The typical ranges of illuminance covered by the display techniques described above, are depicted in **Error! Reference source not found.**. For comparison, the reflective systems are related to a projection surface of 13.8m^2 (4.30m x 3.20m), which corresponds to 30° viewing angle at an image distance of 8m.

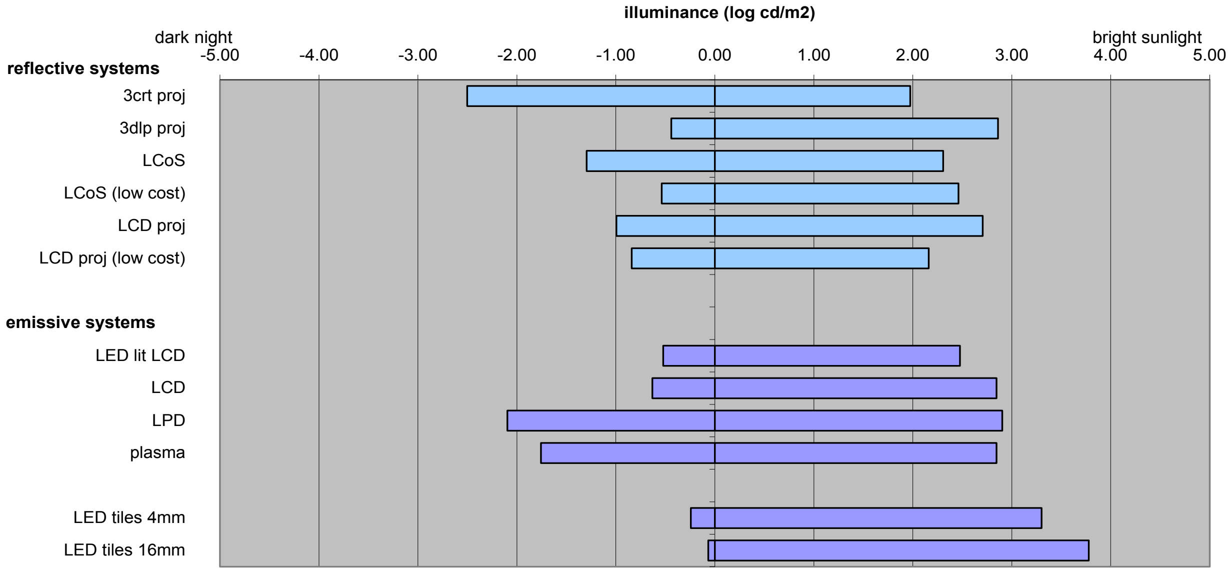


Figure 5. Range of illuminance possible with different display techniques

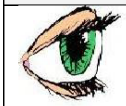
Although technical developments are continuing and systems may exist that perform better, one must bear in mind the nature of these limitations when designing a simulation study.

Intense light may come from monitors on the bridge. After exposure to such light, and for some period afterwards, photoreceptors in the human eye become desensitized. Colours observed during that period will appear differently. This effect is responsible for the phenomenon of afterimages, in which the eye may continue to see a bright image after looking away from it, but in a complementary colour.

6.2 Modelling

When considering the presentation of AtoN, a number of models should be taken into account. Many of these models cannot be considered in isolation because changes in one model may affect the conditions of another model. Each of these models is shown in **Error! Reference source not found.** and is grouped into categories. The following paragraphs will describe each of these models, or combination of models where they affect one another.

Table 8 Conceptual models relevant to simulation

Observer	AtoN	Environment
		 

• Illuminance
• Angular subtense
• Colour
	• Fixed AtoN
	  ○ Lights
	    ▪ Point
	    ▪ Line
	    ▪ Surface
	  ○ Construction
	    ▪ Geometry
	    ▪ Surface materials
	    ▪ Local illumination
	• Floating AtoN
	  ○ Motions
	    ▪ Mooring system
	    ▪ Environmental forces
	  ○ Construction
	    ▪ Geometry
	    ▪ Surface materials
	    ▪ Local illumination
	  ○ Lights
	    ▪ Point
	    ▪ Line
	    ▪ Surface
		• Terrain and man-made constructions
		  ○ Geometry
		  ○ Surface material
		  ○ Lights
		• Ships
		  ○ Geometry
		  ○ Surface material
		  ○ Lights
		• Ocean
		• Weather
		• Atmosphere
		• Celestial

For each of the conceptual models the phenomena described below should be considered.

6.2.1 Observer

Some understanding of human vision is required if models are to compensate for limitations in the presentation system. A basic description of some facets of human vision are described in IALA Guidelines No. 1073 on Conspicuity of AtoN lights at Night and No. 1094 on Daymarks for Aids to Navigation. The relevant sections are reproduced in the next two subsections.

6.2.1.1 Illuminance

The amount of illuminance an AtoN light casts upon the eye of the observer depends upon its intensity, the distance of the AtoN from the observer and the state of the atmosphere. The minimum discernible illuminance at the eye of a photopic observer is often quoted as 0.05 microlux (for a dark-adapted observer in scotopic vision. However, it can be as low as 0.0015 microlux). At these levels, i.e. at the threshold of visual perception, the chances of seeing a light are little better than 50%. The minimum recommended illuminance level for an AtoN light in darkness is 0.2 microlux, based on international agreement in 1933. This is the value from which the nominal range figure is calculated. At this level, the colour and rhythmic character of an AtoN can be recognised with confidence.

It should however be noted that with high levels of background lighting, a higher value of illuminance is required in order to see an AtoN light. At these higher levels, human vision behaves quite differently than at low illuminance levels. Phenomena such as short flashes (strobes), fast repeating flashes and flicker become more conspicuous as illuminance levels increase.

6.2.1.2 Angular Subtense

The subtense angle of the target object is not considered a human factor, but a property of the geometry of size and distance. However, the visual acuity of the eye determines the degree of detection and recognition of an object that has a particular subtense angle.

Viewed from far away, most AtoN lights are point sources and therefore have no discernible size. As the observer gets closer to an AtoN light, the size increases so that the size and shape of the light source become noticeable. If the angle subtending the eye, in other words the angle at the eye from one side of the viewed object to the other side, is less than one minute of arc, it can be said to be a point source.

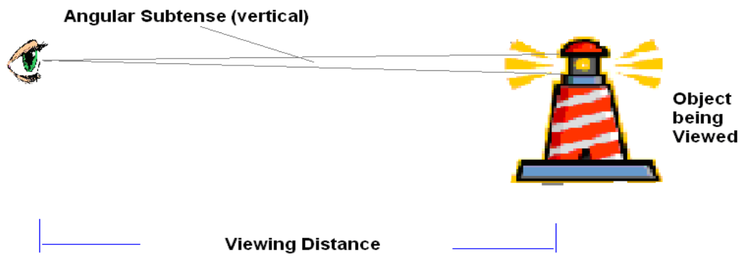


Figure 6. Diagram explaining Angular Subtense

As a rule of thumb, the angular subtense required to recognise a simple shape is three minutes of arc. In order to recognise complex shapes, such as letters, ten minutes of arc is the minimum angular subtense required. These minimum subtense angles may vary with luminance contrast and colour contrast between the AtoN light and the background. Illuminated signs and objects may also cause glare when the illuminance at the eye of the observer is high. This may cause the shape of the lit area to become indistinct.

6.2.2 Aids to Navigation

6.2.2.1 Lights

Navigation lights are lights, typically considered as point lights either fitted on floating AtoN, beacons, or light houses that need to be modelled at the highest possible level. A model of an AtoN light shall include the following attributes:

- colour;
- nominal range/ or luminance;
- vertical divergence;
- sectors and their cut-off precision;

  Narrow sector with high precision cut-off must be possible as for example PEL lights.
- oscillating lights;
- flashing characteristics, including flickering, synchronised and sequential lights;

The maximum flicker frequency that a system can represent relates to the display system frame rate. According to the Nyquist sampling theorem a minimum frame rate of twice the fastest flicker frequency must be sustained.

Additionally, it may be important whether the flashing characteristic is achieved through rotating blinds in front of the light source or by variations in power supplied to the light source.

- appearance at close and long range;

  A suitable model may compensate for the way a point light is perceived at long range and low intensities. Observed at close range, high intensity navigation lights may illuminate nearby structures. However, this is not considered of major relevance at longer distances.

- day time - night time switching;
- the type of light source may influence the scattering of its light under various atmospheric conditions;
- service allowance.

6.2.2.2 Extended Lights Sources

For close range observations, the physical size of an AtoN light may be of importance, and it must be modelled such that the size of the light emitter is represented. IALA Guideline 1043 covers this in chapter 6 Special Applications of Light Sources and IALA Guideline 1073 in section 6.4.5 Shape of Light Sources.

6.2.2.3 Geometry

The physical appearance of daymarks shall be modelled as realistically as possible. For many studies, generic buoys scaled to the correct size may be feasible. However, it is recommended that the conceptual model include the possibility of having the exact appearance of the buoy itself represented.

6.2.2.4 Surface Materials

The surface colours of AtoN shall be modelled as closely as possible to real world colours and in accordance with IALA Recommendations E-106 and E-108 including fluorescent paint.

Bands of reflective material assisting in the identification of the floating AtoN when illuminated at close range are not considered of major importance.

Reflection from glossy surfaces, such as large glass surfaces, may have significant influence on the overall contrast and therefore of major importance for conspicuity at day and night. The surface material shall also reflect indirect lighting from spotlights providing flood lighting.

6.2.2.5 Local illumination

Additional light sources may illuminate part of the supporting structure or daymark improving conspicuity. This is also known as flood lighting. Indirect illumination of daymarks during nighttime may be pre-calculated achieving good realism at low computational cost.

6.2.2.6 Floating AtoN

A floating AtoN will be influenced by:

- wind;
- waves;
- current;
- tide;
- its mooring system.

The motions of a floating AtoN influenced by the above effects, may modulate the flashing characteristics significantly influencing the identification of the AtoN.

A real time simulator is generally not used for the design of a specific buoy and the required mooring system. However, generic or specific motion response data models, for example RAOs[1] may be imported into a simulator in order to assess the suitability of the floating platform as a stable carrier of an AtoN light and as a daymark in the required environmental conditions. RAO's can be pre-calculated reducing the calculation effort during real-time execution. Making detailed motion calculations in real time for a large number of floating AtoN in various wave climates may be very computationally challenging, therefore affecting simulator performance.

6.2.3 Environment

6.2.3.1 Terrain and Man-made constructions

Cultural lights may be considered as rivals to AtoN lights. Cultural lights should be included as appropriate. Cultural light sources include:

- housing;
- greenhouses, public lighting;
- large flashing screens and advertisements;
- moving cars, aircraft, cranes, etc.;
- offshore structures;
- wind turbines.

  Wind turbines should be modelled with rotating blades when considered relevant for the study, as they may interfere with lights at longer distance.

Objects shall appear with the correct perspective. Flat background models (billboards) may be used for objects in the far distance for which the perspective doesn't change significantly.

6.2.3.2 Ships

Other ships navigating the waters to be studied also play a significant role for the conspicuity of AtoN lights and for studying the safe passage and safe distances.

Conspicuity is influenced by:

- the above water structure of moving ships obstructing the visual observation of the AtoN;
- navigation lights, search lights, etc.;
- illumination onboard ships, such as in the accommodation and deck-lighting.

For spatial planning studies where ships operate at close range to each other, the manoeuvring characteristics may be important. In this case the other ships' dynamics should be modelled as own ships. Otherwise other ships can be modelled as traffic ships.

The requirements for high quality modelling of ship manoeuvring are not covered.

6.2.3.3 Ocean

A model for the ocean shall be included when assessing floating AtoN in realistic conditions.

The model should include the effect of:

- tide;

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1 Response Amplitude Operator. An RAO is a transfer function useful for a linearized system. When the RAO is convoluted with the wave field spectrum, this yields the motions spectrum of the object in that wavefield, c.f. [5].

The tide may have a significant influence on relative height of fixed AtoN.

- sea state;

  The sea influences how floating AtoN are moving and thereby observed both at day and night, as also described in section 6.2.2.6 for floating AtoN. The sea state shall include both wind driven waves and swell for developed and non-developed sea states.

- current;

  The current, both tidal and storm surge, may influence the heel of floating AtoN thereby changing the relative vertical divergence of lights, including characteristics and nominal range.

- reflection in calm water surface.

  In particular, in night scenes the reflected background lights may interfere with AtoN or other lights.

6.2.3.4 Weather

Wind influencing floating AtoN is considered to have a minor effect compared to that of current and sea state.

Clouds scatter light from the celestial objects, influencing global lighting in the environment. In addition, precipitation and fog scatter light from man-made lighting including reflected light. A glare effect will appear from light emitters.

Fog and various types of precipitation such as rain and snow should be available for simulating various weather situations.

Feasibility studies of AtoN should be made for various expected weather conditions.

6.2.3.5 Celestial objects

The Sun and the Moon are important light sources during day and night providing illumination of the scene.

The scattering of light passing through the atmosphere is of paramount importance for these light sources and should not be neglected. The high intensity light emitted by the Sun, reduces the relative intensity of AtoN lights.

The simulation should have a correct model of the azimuth and inclination based on time and day for these objects that feed into the scattering equation of light through the atmosphere.

6.2.3.6 Atmosphere

Whereas weather phenomena such as precipitation and fog may be considered as low altitude atmospheric phenomena, the light from celestial and man-made objects is also scattered by atmospheric phenomena. This may include:

- humidity and pollutants;

  Particles in the atmosphere scatter light, both sunlight and local light emissions and reflection in the scene. The scattering is modelled using two supplementary models. The Rayleigh model applies for particles smaller than the wavelength and the Mie model for larger particles. The scattering of light causes the sky to have its gradual shading from white to blue. The aerial perspective makes objects in the distance less saturated and a little more blue. The Ångström model combines both Mie and Rayleigh and includes other factors for aerosols present in the atmosphere close to the sea, further described in IALA Guideline 1073.

- temperature.

  Local temperature variations might diffract the emitted light making the scene a little blurred, reducing visual acuity.

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6.2.4 Real-Time Considerations

The quality of graphical presentation seen in modern movies using CGI technology is very high and can provide much realism. However, such movies must not be compared with the quality that is achievable in real time visual simulation. For achieving real time rendering some simplifications are needed, of which the most prominent are:

- costly ray tracing used in movies is at the moment not feasible for real-time applications and less ambitious lighting models need to be applied;
- detailed hydrodynamic models exist for fluid simulation of the ocean but they do not run in real time;
- the amount of geometric detail that can be applied to model the appearance of objects in the scene needs to be managed to avoid performance problems.

6.2.4.1 Shadows and ambient occlusion

Shadows reduce the light in certain areas of the scene.

Ambient light contribution in the scene is controlled by the ambient occlusion technique.

Both techniques if available for real time rendering will enhance the realism and depth perception in the scenario.

6.2.5 Compensation for Presentation System Limitations

As the total system for the visual presentation of AtoN to an observer is not capable of meeting the specification as found for the real system, new research and development is looking for methods that aim to compensate for such gaps.

Tone mapping methods adjust the rendered image such that the human brain is fooled into believing the image, observed on a Low Dynamic Range (LDR) display, is as if it was displayed on a system having a much Higher Dynamic Range (HDR) for colour and contrast.

6.2.6 Image generating systems

Improvements in software and supporting graphics hardware allow for enhancements while still being able to meet the required real time performance criterion of not less than 30 frames per second.

6.2.6.1 Software

A modern visual simulation system is typically implemented using a layered model consisting of:

- application;

  The top level layer implements most of the specific features described in the previous sections about conceptual models, while the 3 following layers are domain invariant.
- Scene Graph Manager;

  A layer that implements general handling of objects in the scene for effective real-time rendering.
- low level Application Programming Interface (API);

  The two main low-level API's for 3D graphics are OpenGL and DirectX. Both are closely related to the graphics driver that must support the API's
- graphics driver.

  This software layer is produced by the graphics hardware layer as these two layers are tightly connected.

Modern graphic low-level API's such as DirectX and OpenGL have increased the number of bits per colour from 8 to 32 supporting rendering the scene in HDR.

6.2.6.2 Hardware

Modern image generating hardware renders visual images at a certain resolution, i.e. the multiplication of the horizontal and vertical pixel count. The software running on top of the hardware configures the available image memory to run at certain preferred resolution up to the maximum. The best image quality presented in the simulator will typically appear if the resolution of the image generation matches the inherent resolution of the display. Severe image degradation will be evident if the two do not match.

Modern hardware also includes a technique called anti-aliasing, which attempts to compensate for edges of objects and tiny objects that 'fall' in between pixels. Anti-aliasing techniques vary widely in cost and effectiveness.

Figure 7. Detail picture without anti-aliasing (left) and with anti-aliasing (right)

7 SIMULATION OF RADARS

As in the real world, the simulated radar system includes two elements

- radar transceiver;
- radar display.

If proper radar simulation design is applied, the same model for the radar antenna can be used for driving either an emulated or a stimulated radar display.

Several Standards, Guidelines and Recommendations cover radar equipment and radar simulation, such as references [6], [7] and [8].

7.1 Radar Displays

The presentation of the radar return is made using a radar display.

In a ships bridge simulator this may be done using

- an emulated; or
- a stimulated real radar display.

It should be noted that some manufacturers of radar systems place part of the signal processing in the radar antenna unit and that the model of the radar antenna must replicate this signal processing.

7.1.1 Stimulated radar display

If stimulated radar displays are used, no modelling of the real display system is required. Features like ARPA, trial manoeuvres, overlays and to some extent signal processing, that can influence the realism provided to the user, are made using the exact and approved equipment as found onboard real ships. This provides a very realistic setup at the expense of installing real equipment. Various makes of radar displays may be required to fit certain training requirements.

7.1.2 Emulated radar display

If emulated radar displays are used, real signal processing features must be re-engineered to facilitate realistic operation, replicating a real radar display.

The performance standard for Radar / ARPA displays [7] includes features such as:

- ARPA;
- true and relative motion;
- head up, course up and north up presentation;
- trails;
- trial manoeuvres;
- sensor monitoring and alarms;
- AIS overlays;
- ECDIS overlays.

7.2 Modelling of Radar Transceivers

The following effects should be included in the antenna/transceiver model as required in [8]:

- X and S band transmission and reception;
- modelling of Pulse Repetition Frequency and Pulse Length;

  These parameters influence the radar discrimination.

- frequency tuning;
- transmitted power reduction;
- trigger delay;
- receiver noise;
- terrain, vegetation, buildings, bridges, power lines, wind farms, etc., correct 3-D geometric and material modelling of radar return;

  For wind farms the correct rotation and yawing should be included.
- ships using 6 degree of freedom motions in a seaway;

  Correct 3-D geometric, material modelling.
- lobe characteristic modelling, including vertical and horizontal extent and variation;
- multiple echoes;
- rain clutter by local or global precipitation of various types;
- sea clutter;
- return from floating AtoN moving in the seaway and fixed AtoN including radar reflectors.
- racons;
- multiple instances of Navigation sensors, including precision and failure modelling of:
  - GPS and DGPS;
  - GYRO;
  - echo sounder;
  - speed log (water and bottom tracking in dual axes);
  - heel and trim;
  - AIS.

7.2.1 Radar Display Interface

It is possible to use the same model of the radar transceiver for both an emulated and a stimulated radar display. However, a piece of additional hardware, similar to a graphic adapter, is required to convert the radar return representation into a radar video signal which are different amongst radar manufacturers.

7.2.2 Terrain modelling

For the outside view to be generated during the simulation, a 3-D model of the real world terrain has to be specified. This 3-D model can be the basis for the radar image but some extra information should be added. This mainly pertains to the radar reflectivity of the faces of 3-D objects. The same algorithms as used to generate the outside visual view can be used for the radar image, as this is also governed by line of sight, using the scanner position. Instead of colours and shading, radar reflection, scattering and diffraction properties should be used.

Alternatively, separate scenery for the radar image may be defined (spatially matched to the outside view scenery). This could be simplified because not everything in the visible scenery will show up on radar or be relevant for the simulation.

Modern computers are capable of using 3-D models of terrain and other objects. It is strongly advised to use a 3-D database. This ensures that masking of AtoN by ships, terrain or seaway is included in the simulation, when compared to a simplified 2-D representation.

7.2.3 Ships

Other ships may be regarded as a composition of a number of objects, i.e. superstructure, hull, cargo (especially containers), masts and cranes. Each of those objects has specific radar characteristics and the shape of the radar image of a 'target' ship will depend on distance and aspect.

7.2.4 AtoN

Normally, AtoN will have a specified radar performance that will be used in the simulation. A radar reflector is specified by its radar cross section.

7.2.5 Racons

The response of a racon is shown as a radial Morse code pattern extending beyond the position of the racon. The starting position can vary due to a small time delay in triggering. The length of the pattern represents a fixed object size (usually a few nautical miles) and thus changes proportionally with the radar display range setting.

Models of racons should include:

- frequency response;
- pulse length (equivalent to range on display);
- trigger delay;
- polarization;
- sweep mode:
  - slow;
  - fast;
  - frequency agile.

7.2.6 Wind farms

The influence of offshore wind farms on radar performance has been studied extensively for the UK Maritime and Coastguard Agency (MCA) in 2004[2]. At smaller ranges, the turbine towers produce very strong echoes due to their height. In contrast to the horizontal beam width, the vertical beam width of marine radar is quite large. Thus the full height of a turbine tower is illuminated by the radar beam, and despite the usually round form, there is a large amount of reflected energy. The turbine blades also produce strong echoes, which are dependent upon the orientation of the nacelle. Because of this massive reflection, even the much weaker side lobes of the radar beam may produce echoes. These will appear on a PPI as objects at the same range but at shifted bearings. Reflections between turbine towers (multipath) can cause spurious echoes at larger ranges.

Weak objects behind a wind farm could be masked because the radar gain is set at a low value to avoid spurious echoes, while the object echo is further attenuated by the wind farm. A small vessel sailing through a wind farm will frequently be 'swamped' by the echo of a turbine. The limitations of beam width also apply, but because of the strong reflection of the turbine outside the nominal beam width (half-power points), the beam width is effectively extended.

8 SIMULATION OF SOUND

This section is limited to the possibilities of simulating the sounds of AtoN and not sounds from own ship, environment and other ships.

2 See http://www.dft.gov.uk/mca/effects_of_offshore_wind_farms_on_marine_systems-2.pdf

8.1 Presentation

8.1.1 Speaker systems

Modern full mission bridge simulator systems are normally fitted with quadraphonic speaker systems. These are of high quality providing good realism in the representation of AtoN sound and support the perception of distance and direction.

8.1.2 Sound Reception Systems

On vessels with enclosed bridges, typically cruise vessels, a sound reception system is used to attenuate the sounds encountered by a vessel. By using four microphones the sound reception system detects the direction of the incoming signal and a panel on the bridge indicates the direction as well as providing the attenuated sound through speakers. Such sound reception systems are available for simulators, providing the same functionality as in the real world.

8.2 Modelling

Gongs, bells, horns and sirens are typical audible signals emitted by AtoN. The user's perception of sound will depend on several factors:

- the sound level emitted by an AtoN;
- the distance and direction to the sound emitting AtoN;
- the ambient noise level at the position where the user is listening to the sound – typically on the ship's bridge;

  Elements such as engine noise, weather noise, radio noise and other noise from devices positioned on the bridge, or close to the user's position on the bridge, will affect the reception of AtoN sound signals. Reception is also affected if the user is located inside a fully enclosed bridge, or on an open bridge;
- environmental conditions affecting the speed of sound such as air humidity, damping elements, reflecting elements, presence of snow, rain or fog, icebergs with snow, cliffs covered with vegetation, etc.

Sounds from AtoN are recorded digitally and reproduced with the correct time pattern through speaker systems in the simulator. The sound level, its degradation and direction, can be part of the simulator model.

Various algorithms are used to ensure a high level of realism, including the effect of environmental conditions. If such algorithms are not used; the speaker system is not providing sufficient quality supporting the input; or, only one or two speakers are provided, the directional element will be missing.

Refer to IALA Guideline 1087 on the use of Audible Signals for details that should be considered when simulating sound signals and IALA Recommendation E-109 for the calculation of the range of sound signals.

9 SIMULATION OF OTHER SHIPBORNE NAVIGATION SYSTEMS

9.1 ECDIS

The Electronic Chart Display and Information System (ECDIS) is a system that shows a digitised version of a nautical chart (an ENC) with extra information superimposed on it – most notably own ship's position and heading. The fitting of ECDIS is mandatory for (nearly all) new ships and will be mandatory on all SOLAS ships after 2014.

The information is organised in layers and users may switch layers on and off to adjust the information presented to their needs.

The IMO document outlining the model course for ECDIS training [8], illustrates the relevant interfaces with other bridge equipment. Not all capabilities will apply to every simulator setup.

ECDIS simulation equipment should be capable of simulating operational ECDIS, and should meet all performance standards adopted by the IMO, and should incorporate the means to:

- handle ENC data, licenses and update files;
- interface with the following emulated or OEM equipment:
    - position indicator, including emulation of fix quality and, in the instance of GNSS, satellite constellation;
    - alternative position source;
    - heading indicator, true and magnetic, with graphic course recording;
    - speed indicator;
    - depth indicator;
    - ARPA tracked target data;
    - AIS, including control of static data and messaging;
    - radar data including raw video, cursor, EBL and VRM;
    - autopilot capable of control by heading, COG and intended track;
    - prediction of the track may be provided through the ECDIS.
- provide radar overlay, with functions operating independently from own ship's radar;

An ECDIS has to comply with the requirements of the IMO Performance Standards, Resolution A.817(19), otherwise it should be indicated as being an ECS (Electronic Chart System).

9.2 Portable Pilot Units

A Portable Pilot Unit (PPU) can be described as a portable version of an ECDIS, with its own accurate position sensors. Using two separately spaced GPS receivers, heading can also be determined accurately. The ideal track and channel boundaries are indicated on the display and parameters like cross-track error, rate of turn, transverse speed fore and aft, can be continuously updated and visualised. Additionally, track prediction can be displayed based on current velocity field, rudder angle and rpm, etc.

The system provides the pilot with all relevant information to advise on navigation. It is even possible to send VTS traffic images to the PPU, providing the pilot with the same traffic information as the VTS.

9.3 AIS as virtual AtoN

Virtual AtoN should be supported in simulation. This allows for testing such aids as it does for physical aids, although these will only be observable on radars, ECDIS, etc.

9.4 e-Navigation services

IMO has developed a strategic vision for e-Navigation, which integrates existing and new navigational tools.

Future e-Navigation services will include the representation of AtoN and it will be possible to integrate these into marine bridge simulators like other navigational instruments. This could serve to test the representation of AtoN.

A few prototypes of e-Navigation systems are currently being produced and could be integrated into simulators. The systems are, by their nature, complex and involve the interaction between several systems, including data transfer systems. The integration of a fully operational and working e-navigation system depends on the simulator's ability to provide input from all sensors and systems connected to the e-Navigation system. A simulator should normally be able to simulate errors and malfunctioning systems.

As the e-Navigation concept is just at the start of its development, large changes may still be expected. Simulation must be set up in a flexible manner to be able to accommodate these future developments.

ANNEX A LIST OF PHENOMENA COVERED IN RELEVANT IALA RECOMMENDATIONS AND GUIDELINES

The following subset of IALA Recommendations and Guidelines covers information of relevance to the simulation of AtoN.

1 IALA RECOMMENDATIONS

R-101 On Maritime Radar Beacons (racons) (January 1995 – Revised 2004)

O-104 On 'Off Station' Signals for Major Floating Aids

E-106 For the Use of Retroreflecting Material on Aids to Navigation Marks within the IALA Maritime Buoyage System

E-107 On Moorings for Floating Aids to Navigation

E-108 For the Surface Colours used as Visual Signals on Aids to Navigation (specifications for ordinary and fluorescent colours)

E-109 For the Calculation of the Range of a Sound Signal

E-110 For the Rhythmic Characters of Lights on Aids to Navigation (Edition 2.0)

E-111 For Port Traffic Signals

E-112 For Leading Lights

A-123 On the Provision of Shore Based AIS

O-133 On Emergency Wreck Marking Buoy (for use on trial basis)

O-138 On the Use of GIS and Simulation by Aids to Navigation Authorities

E-141 On Aids to Navigation Training

E-143 On Virtual Aids to Navigation Edition 1

E-200 On Marine Signal Light, Part 0 - Overview

E-200-1 On Marine Signal Light, Part 1 - Colours

E-200-2 On Marine Signal Light, Part 2 - Calculation, definition and notation of luminous range

E-200-3 On Marine Signal Light, Part 3 - Measurements

E-200-4 On Marine Signal Light, Part 4 - Determination and Calculation of Effective Intensity

E-200-5 On Marine Signal Light, Part 5 - Estimation of the Performance of Optical Apparatus

2 IALA GUIDELINES

1023 For the Design of Leading Lines

1038 On Ambient Light Levels at which Aids to Navigation should Switch On and Off

1041 On Sector Lights

1043 On Light Sources Used in Visual Aids to Navigation

1047 On Cost Comparison of Buoy Technologies

1048 On LED Technologies and their use in Signal Lights

1049 On the Use of Modern Light Sources in Traditional Lighthouse Optics

1051 On the Provision of Aids to Navigation in Built-up Areas

1058 On the Use of Simulation as a Tool for Waterway Design and Aids to Navigation Planning

1061 On Light Applications Illumination of Structures

1065 On Vertical Divergence

1066 On the Design of Floating Aid to Navigation Moorings

1069 On the Synchronization of Lights

1073 On Conspicuity of AtoN lights at Night

1094 On daymarks for AtoN (draft)

The following list of features has been identified in the list of Recommendations and Guidelines above.

References - IALA Recommendations and Guidelines		
1023	**Leading Lines**	
	Lights	Beam width
		Beam fading
		Range fading
		Intensity
		Characteristics
		Daytime
		Night time
	Marks	Range fading Calibrate with table E6-1
1038	**Ambient Light switch on/off**	
	Clouds	
	Fog, snow, etc.	
	Switch to control one or several lights	
	Shadows from eg passing ships	
	Sensor direction	
1041	**Sector Lights**	
	Type of light	
		Point source
		Projected
		Slot
		Range
		Diverged Beam (Laser)
	Sector boundaries	Width
	Oscillating boundaries	
	Intensity variation between sectors	
	Daytime/night time intensity levels	
	Vertical divergence	
	Character	
	Weather	Ice on lens
1043	**Light Sources used in Visual Aids to Navigation**	
	Spectral content	
	Scattering in atmosphere	
	Light Pipes	
	Point Lights	
1047	**Cost Comparison methodology of Buoy Technologies**	
	Radar reflector	
	Vertical divergence	
	Day mark quality	
	Anchor system	
1048	**LED Technologies and their use in Signal Lights**	
	Should colours be different to identify LED light sources?	
	Colour variation due to temperature	
	With or without service allowance	
	Simulate beyond FFF?	

References - IALA Recommendations and Guidelines

1049	**The Use of Modern Light Sources in Traditional Light Optics**	
	Correct CIE colour for each	Lamp
		Lens
1051	**Provision and Identification of Aids to Navigation in Built-up Areas**	
	background lighting	Flashing, cars, street lights, commercial, houses
	Shadowing	
	Obstruction	
	atmospheric pollution	
1061	**Illumination of structures**	
	Direct	
	Indirect	
	Auto switch on/off (light level)	
1065	**Aids to Navigation Signal Light Beam Vertical Divergence**	
	geographical range for fixed platforms	
	geographical range for floating platforms	
	Dynamic effects for buoys	geometry, mass and mooring system
	wind, waves, current	
	Vertical intensity profile	
	Spherical model of the Earth	
1066	**Design of Floating Aid to Navigation Moorings**	
	Chains	Thrash, rider, ground, bridle, etc.
	Elastic	
	Sinker	
	Anchor	
	Environmental loads	wind, current, waves
1069	**Synchronization of Lights**	
	Synchronized	
	Sequential	
	Synchronization methodology	Master-slave, GPS, etc.
	Failure modes	
R-101	**Marine Radar Beacons (racons)**	
	Polarization	
	Frequency agility and swept	
	Character	
	Duration and periodicity	
	Range	
O-104	**'Off Station' Signals for Major Floating Aids**	
	Relevance of provision of such signals	Spheres
		Red lights
		Flags
		Flares
E-106	**The Use of Retroreflecting material on Aids to navigation Marks**	
	Shall buoy models include the retroreflective material codes (stripes)	
E-107	**Moorings for Floating Aids to Navigation**	
	Referring to guideline 1066 and 1024	
E-108	**The Surface Colours used as Visual Signals on Aids to Navigation**	
	Glossiness	
	Colour type	fluorescent, ordinary
	Symbols and characters	
	CIE chart matching	

References - IALA Recommendations and Guidelines		
E-109	**Recommendation on the calculation of the range of sound signal**	
	Frequencies	Harmonics
	Intensity	
	Dispersion	
	Transmitivity	
	Obstacles	
	platform motions	
E-110	**Rhythmic Characters of Lights on Aids to Navigation**	
	temporal variations	rotation ON/OFF
	Model	incandescence and nigrescence
	frequency limits	Flickering
E-111	**Recommendation on Port Traffic Signals**	
	3 lights on top of each other	colours, characters
E-112	**On Leading Lights**	
	Light point model	
	Day mark with illumination	
O-133	**Emergency Wreck Marking Buoy**	
	Lights, buoys, AIS, racons, sound	
O-138	**The Use of GIS and Simulation by AIDS to Navigation Authorities**	
	No technical input	
E-141	**Standards for Training and Certification of AtoN Personnel**	
O-143	**Virtual Aids to navigation**	
	Real AIS	
	Synthetic AIS	
	Virtual AIS	
E-200	**Marine Signal Light**	
E-200-0		**Overview**
E-200-1		**Colours**
	Chromaticity coordinates of light source and filter	
E-200-2		**Luminous Range**
	Nominal range	
	Luminance as function of	Range
		meteorological visibility
	Service allowance	
E-200-3		**Measurement**
E-200-4		**Effective Range**
	Effective range	Function of frequency and spectral content
E-200-5		**Optical Apparatus**
	Horizontal and vertical beam intensity variation	
	Rotations performing character generation	
	Filters (boundaries)	

ANNEX B LIST OF ABBREVIATIONS

AIS	Automatic Identification System
ARPA	Automatic Radar Plotting Aid
AtoN	Aids to Navigation
CGI	Computer Graphics Imagery
CRT	Cathode-Ray Tube
DLP	Digital Light Processor
ECDIS	Electronic Chart Display and Information System
FPS	Frames Per Second (Frame rate)
HDR	High Dynamic Range
IR	Infrared
LCD	Liquid Crystal Display
LCoS	Liquid Crystal on Silicon
LDR	Low Dynamic Range
LED	Light-Emitting Diode
LPD	Laser Phosphor Display
PEL	Port Entry Light
PPU	Portable Pilot Unit
QXGA	Quad Extended Graphics Array
RAO	Response Amplitude Operator
UXGA	Ultra Extended Graphics Array

ANNEX C TERMS AND DEFINITIONS

Lighting units

The **lumen** (symbol: lm) is the SI derived unit of luminous flux, a measure of the total 'amount' of visible light emitted by a source. Luminous flux differs from power (radiant flux) in that luminous flux measurements reflect the varying sensitivity of the human eye to different wavelengths of light, while radiant flux measurements indicate the total power of all light emitted, independent of the eye's ability to perceive it.

The lumen is defined in relation to the candela as 1 lm = 1 cd·sr

Illuminance is the total luminous flux incident on a surface, per unit area. It is a measure of how much the incident light illuminates the surface, wavelength-weighted by the luminosity function to correlate with human brightness perception.

In SI derived units Illuminace is measured in lux derived from Lumens per square metre (Lm/m^2)

Luminance is a photometric measure of the luminous intensity per unit area of light travelling in a given direction. It describes the amount of light that passes through or is emitted from a particular area, and falls within a given solid angle. The SI unit for luminance is candela per square metre (cd/m2 or nit) The luminance indicates how much luminous power will be detected by an eye looking at the surface from a particular angle of view. Luminance is thus an indicator of how bright the surface will appear. In this case, the solid angle of interest is the solid angle subtended by the eye's pupil.

In SI derived units luminace is measured in candelas per square metre[S1] ($cd \cdot /m^2$).

Brightness is an attribute of visual perception in which a source appears to be radiating or reflecting light [1]. In other words, brightness is the perception elicited by the luminance of a visual target. This is a subjective attribute/property of an object being observed. 'Brightness' was formerly used as a synonym for the photometric term luminance.

Luminous intensity is a measure of the wavelength-weighted power emitted by a light source in a particular direction per unit solid angle, based on the luminosity function, a standardized model of the sensitivity of the human eye. The SI unit of luminous intensity is the candela (cd), an SI base unit.

Gamut

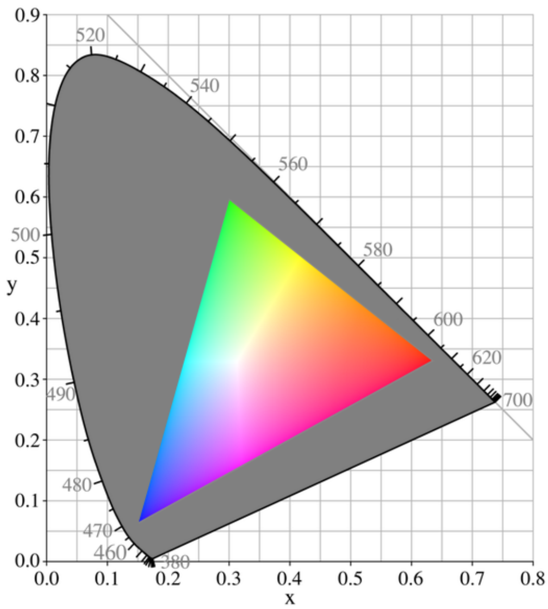

Figure 8. Gamut available to a typical computer monitor or projector

The greyed-out horseshoe shape is the entire range of possible chromaticities, displayed in the CIE 1931 chromaticity diagram format as used by IALA. The coloured triangle is the gamut available to a typical computer monitor or projector; it does not cover the entire space. The corners of the triangle are the primary colours for this gamut. At each point, the brightest possible RGB colour of that chromaticity is shown, resulting in the bright Mach band stripes corresponding to the edges of the RGB colour cube.

http://en.wikipedia.org/wiki/Gamut

Own ships
In ships bridge simulators this identifies ships steered by users at the ships bridge, having a working environment as close as possible to reality. Motions are modelled using 6 degree-of-freedom equations.

Traffic ships
Are ships not steered from a ship's bridge. They are mainly controlled by the simulator operator or running autonomously by computers. Traffic ships are modelled using simplified equations of motions compared to own ship models and are used to get a proper traffic density in the scenario.

ANNEX D LIST OF REFERENCES

[1] Shannon, R.E. (1975). '*System Simulation: the art and science'.* Prentice Hall.

[2] Shannon, R.E. (1998). '*Introduction to the Art and Science of Simulation'.* Proceedings of the 1998 Winter Simulation Conference

[3] J. Banks, J. Carson, B. Nelson, D. Nicol (2001). 'Discrete-Event System Simulation'. Prentice Hall. p.3. ISBN 0-13-088702-1.

[4] Faltinsen, O. M. (1990). *'Sea Loads on Ships and Offshore Structures.'* Cambridge University Press. ISBN 0-521-45870-6.

[5] IEC 62388: 'Maritime navigation and radiocommunication equipment and systems – Shipborne radar – Performance requirements, methods of testing and required test results'

[6] IMO MSC 192 (79) '*Adoption of the Revised Performance Standards for Radar Equipment'*

[7] DNV standard for certification no. 2.14 *'Maritime Simulator Systems'*, January 2011

[8] IMO STW Operational use of Electronic Chart Display and Information Systems (ECDIS) STW 43/3/1, 2011