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**On**

**Technical Features and Technology Relevant for Simulation of AtoN**

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Technical Features and Technology Relevant for Simulation of AtoN

# Introduction

IALA’s Guideline No. 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 Aids to Navigation (AtoN) authorities in understanding how simulation tools can assist them in planning and implementing AtoN. This Guideline should be seen as a more technical guideline supplementing Guideline No. 1058.

Users of this guideline are mainly expected to be AtoN designers, developers, researchers and testers, including mariners. This group wishes to know to what extent a given simulator system is providing the required quality and fidelity to suit the purpose of simulation studies and investigations.

Today’s modern technology and the pace at which the technology developed for computer based simulation systems are progressing is providing users with a high level of fidelity and realism. On the other hand this technology has its limitations. With the present Guideline, users will be provided with an overview of current status of simulation technology with focus on capabilities and limitations of simulation software, visual systems, visualization media and other relevant systems. The Guideline will also identify a collection of features that are important to consider when specifying objectives of a simulation study for planning, research and test of AtoN.

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

# Scope

This Guideline covers:

* User needs and requirements;
* Modelling and simulation of AtoN;
* Visual presentation technology such as:
  + Projectors, monitors, screens, hand-held displays, Light-Emitted Diode, LED, technology, virtual reality techniques etc.;
  + Projection theatres;
  + Video walls;
  + Infrared and night vision.
* Radar simulation;
* Sound simulation;
* Simulation of Ship Navigation systems, including Electronic Chart Display and Information System, ECDIS, Portable Pilot Units, PPU, virtual AtoN and e-Navigation systems.

Reference is made in Section 4 to relevant IALA Recommendations and Guidelines, where phenomena relevant for simulation of AtoN are addressed.

# Definitions

Throughout this guideline the following definitions are used:

* **Stimulation.** A real world system, such as for example a radar, need to believe that it lives in a real world. Stimulation is used when a real radar video signal is produced in a simulator model and feed as in real life into a real radar display identical to those used onboard real ships.
* **Emulation** is applied, if for example, the whole radar sub-system, both antenna and display is modelled and not being 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* (Ref /2/).Thus it is critical that the model be designed in such a way that the model behavior mimics the response behavior of the real system to events that take place over time (Ref/3/).

R.E: Shannon considers simulation as a process combining modelling and simulation. This definition stems from the field of operations research and seems less adequate for the simulation of AtoN. Instead anoher approach will be usedwhich is to split the process of modelling and simulation into two activities of equal importance by using the following definition of simulation:

Simulation is the imitation of the operation of a real-world process or system over time (Ref/1/). The act of simulating something first requires that a model be developed; this model represents the key characteristics or behaviors 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 model being a representation of a system.
* **Mathematical model**
* **Numerical model**
* **Presentation.** The continuous state of the simulation model needs to be presented to the system operator, i.e. the navigator, using realistic and relevant stimuli as used in real world operations.

# User needs and requirements

Simulation is in the context of the present guideline focusing on the needs and requirement used in conjunction with:

* Research;
* Development;
* Design; and
* Test

of individual or combinations of AtoN.

This guideline is based on user needs and requirements expressed by members of the ANM and EEP committees.

In addition, important and relevant knowledge for the real and practical aspect of AtoN is found in the comprehensive set of existing IALA Recommendations and Guidelines. The Recommendations and Guidelines have been used for identification of user needs and requirements and are listed in Section 4.1 and Appendix A.

## Relevant IALA Recommendations and Guidelines

The following recommendations and guidelines have been reviewed and identified as relevant for the simulation of AtoN.

ANNEX A, provides a summary list of phenomena discussed in the IALA Recommendations and Guidelines of relevance for modelling and simulation of AtoN.

### 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 Retroflecting 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

### 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

# Modelling and Simulation of AtoN

One of the real strengths of simulation is the fact that it is possible to simulate AtoN that already exist as well as those that might be brought into existence in the future, i.e. those in the preliminary or planning stage of development and design.

Simulation is providing a cost efficient flexible tool that can support the abovementioned activities listed in section 4. Thereby, it is presumably the next best thing to observing the real AtoN in operation as it allows the user to study the AtoN even though the user is unable to experiment directly with the real AtoN, either because the AtoN does not yet exist or because it is too difficult or expensive to directly work with it.

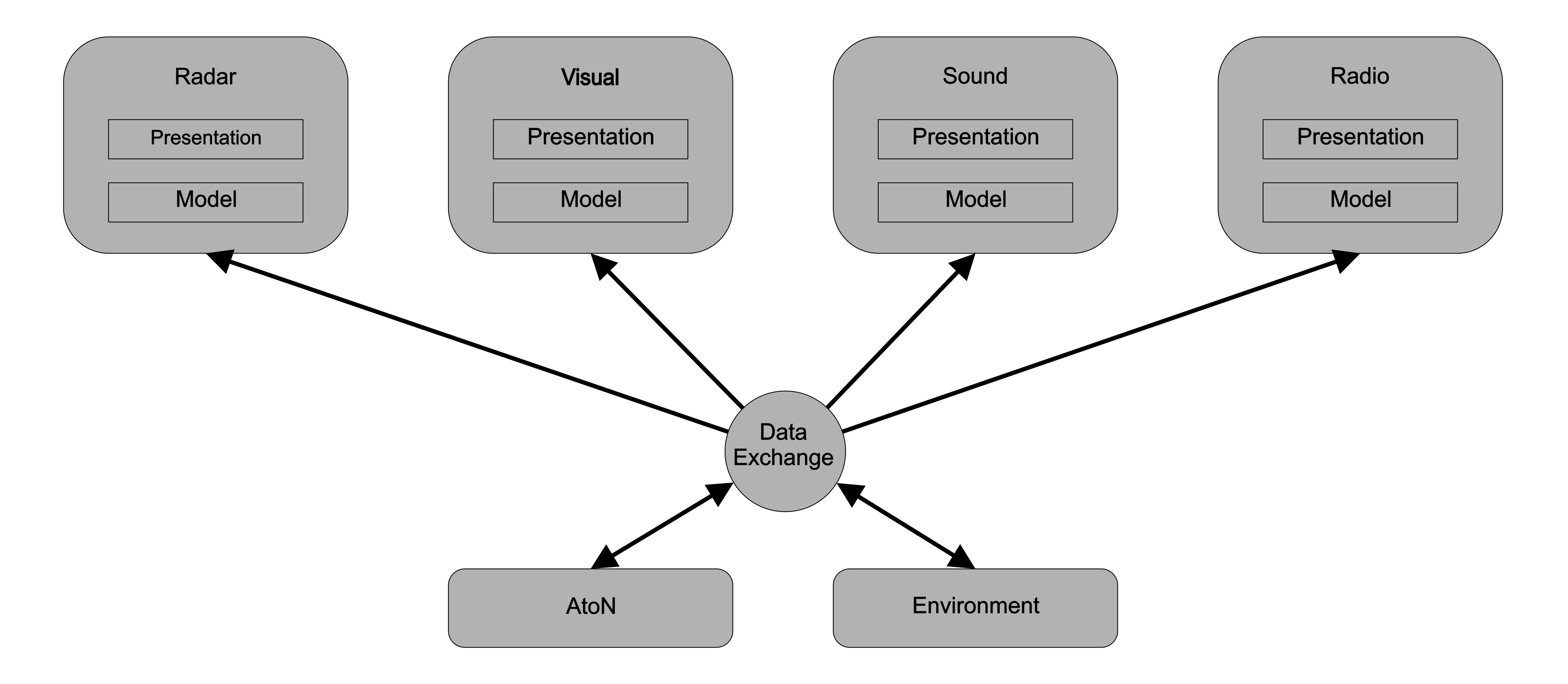
Simulation has a number of advantages. First of all, simulation are considered to be quite accurate and thus credible, because it’s behavior has been compared to the real world and only a few simplifying assumptions are made, whereas more true characteristics of the AtoN is captured under the simulation study. This often makes it easier for end users and decision makers to relate to the simulated world. Secondly, new designs can be tested without committing resources to their implementation. In addition to that, simulation allows us to gain insight how AtoN works in operation and to experiment with unfamiliar situations and answer “what if” questions.

Even though simulation has many advantages, the users shall take due care to understand the capabilities and limitations of the individual elements of a simulation system. The quality of the results of a simulation study depends highly on the quality of the model, the skill of the user, and the quality of the input data. Using inadequate input data can make the outcome of a simulation study questionable. Thus, simulation should be considered as a tool for analysis of the behavior of a system under conditions specified by the user.

As for all simulation studies it is also very important to carefully consider when and to what extend the end-users/mariners shall be involved in the simulation for planning, execution and evaluation of the results of a simulation study. Reference is made to IALA Guideline 1058 for a discussion of this subject.

Ideally the probability of detecting an AtoN shall be identical or similar in the simulated and real world. End users have a natural desire to achieve this level. However, despite a high accuracy of the simulated model, it is not possible to generate a one-to-one situation. This Guideline is intended to provide an insight that should assist the user in understanding the gap between the real and the simulated world and thereby to benefit the most from the simulation technology.

The present Guideline covers the four sub-domains of receiving information from AtoN as depicted in Figure 1. Each method requires individual means of modelling and presentation and will be discussed in the following sections of this guideline.



1. AtoN modelling and presentation

# Visual System

## Presentation Technology

### Introduction

The Presentation Technology is the system that is responsible for the transmission of the visual cues to the mariner on the simulator bridge.

A number of presentation technologies are available, ranging from a single monitor display to a LED (Light Emitting Diode) video wall. All have their specific strengths and limitations and some are much more expensive than others.

For a simulation to be effective the mariner must be able to derive all relevant information from the visual stimuli – thus the resolution of the display may be more important that 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 information’ will be. Then, from the available technologies the most cost-effective alternative that is able to transfer this information may be chosen. In the simulation models the limitations of the presentation technology can be compensated to some extent. If the information cannot be sufficiently transferred by any of the available technologies, an additional not necessarily visual feedback to the mariner could be provided – of course, only to the extent to compensate for the limitation of the visual presentation.

Of course, the final testing may include laboratory and in-site measurements to overcome the limitations of digital simulation but in view of the costs involved this will be limited to the best options as found from the simulation.

### Display systems

#### Present limitations

The following sections will go further into different technical possibilities for presentation of images for simulation. In general, the limitations refer to the following aspects:

* *Resolution*: The resolution of the eye is 1’ whereas simulated images reach about 10’;
* *Illuminance* of objects: in the real world up to 10,000 cd/m2, simulated images up to 300 cd/m2. The full range of background illumination in real world conditions extends from 10-3 cd/m2 on an overcast, moonless night to 105 cd/m2 in direct sunlight;
* *Contrast*: real-world contrast ratios are up to 1:107, simulator images reach 1:104;
* *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 **Error! Reference source not found.**) optimised use of the display capabilities can be achieved.

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.

#### Projectors

A projection system involves a light source from which an image is projected onto a screen. The mariner observes the screen and as such the image transfer is indirectly. The projection screen is usually at a distance of several metres from the observer position which may enhance the sense of reality. A drawback is that the radiation losses and reflection losses limit the luminance of the image such that the simulated conditions resemble at best dusk lighting with accordingly small contrast.

The projector techniques used determine the light production at the source, contrast and colour resemblance, response speed, etc. Continuing developments are stimulated mainly by the gaming industry and digital cinema and supported by the constant increase of computer power (‘Moore’s law’). 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 mariner’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 and prices differ widely.

For digital cinema and gaming the resolution is usually not the prime issue whereas the costs *per pixel* rise dramatically with increasing image resolution. Normal image resolutions for this application are UXGA (1600 x 1200) and at the high end QXGA (2048 x 1536). Most recent development at this moment is the so-called 4K technology, indicating a 4096 pixels wide image.

Some configurations available today:

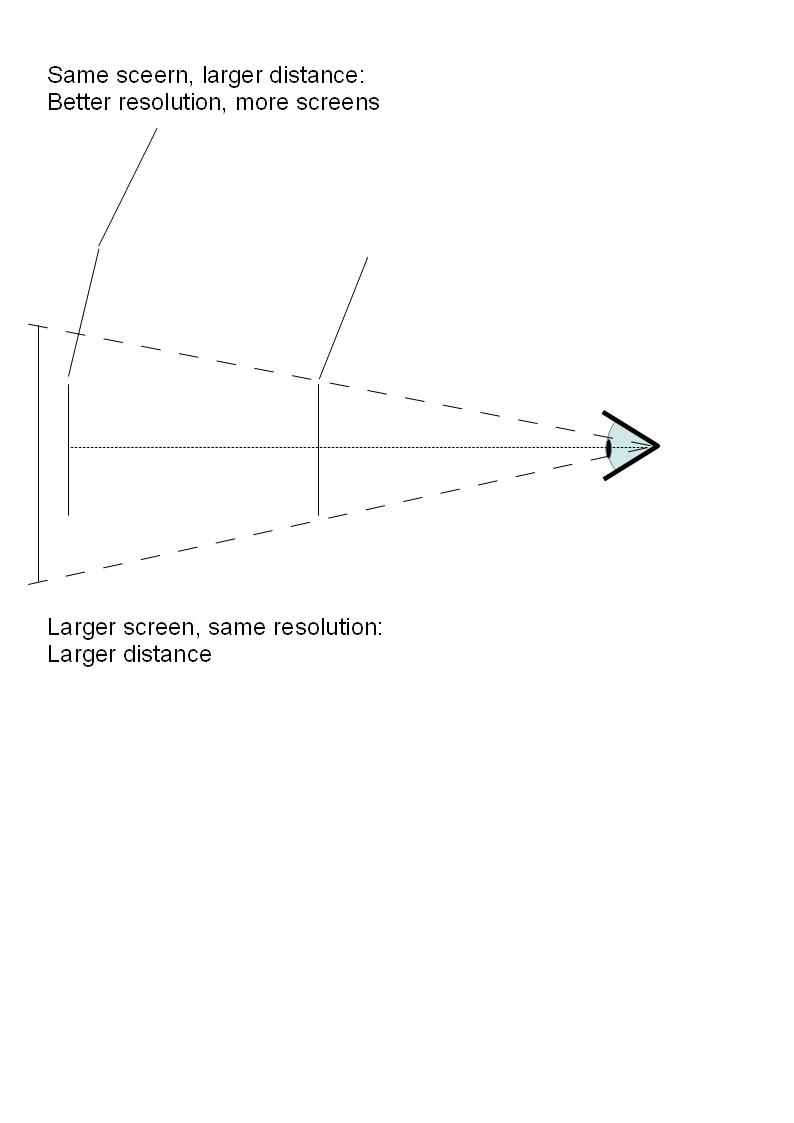
1. Example specifications of existing projectors

|  |  |  |  |
| --- | --- | --- | --- |
| Projector type | Resolution | Contrast ratio | Max light output  Ansi lumen |
| 3 CRT | Max 2500 x 2000 |  | 800 |
| 3 chip DLP | 2048 x 1080 | 2000 | 30000 |
| 3 chip DLP | 1920 x 1200 | 2000 | 12000 |
| 1 chip DLP | 1920 x 1200 | 2000  10,000 with night goggle |  |
| LCoS | 1536 x 2048 | 6,000,000 |  |
| LCoS (low-cost) | 1920 x 1080 | 50,000 | 1300 |
| LCD (low-cost) | 1400 x 1050 | 7,500 | 7500 |

#### Monitors

When the simulated image is presented on one or more monitors, the radiation and reflection losses attached to projection are avoided. The monitors can be in place of the bridge windows, the window sills giving a natural separation of the adjacent monitors. On the downside, the sense of reality will usually be somewhat less. The mariner’s position on the bridge should be fixed; otherwise the absence of parallax would be apparent from the window sills.

An advantage of monitors over a projection system is that pixels are not distorted by optical aberrations, so that the resolution is not reduced by blurring of the pixel images. Also the usually very laborious adjustment process to get the best possible projected image is avoided. However, depending on the distance between the mariner 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 mariner and the screens, the better the sense of reality gets (approaching that of a projected image). If a large field of view is needed, the space needed for the navigator himself poses lower limits on the distance. 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 deg 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 performance.

Some variants of screen layouts are show in the figure

Some examples of available monitors are:

1. Example specifications of some existing monitors

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Display type | Dimensions | Resolution; Pixel pitch | Contrast ratio | Max luminance  Cd / m2 |
| LED 28’ | 500 x 500 mm | 2048 x 2048;  0.25 mm | 1000 | 300 |
| LCD 30’ | 640 x 400 mm | 2560 x 1600; 0.25 mm | 1000 | 250 |
| LPD (Laser Phosphor Display) | 3048 x 1524 mm | 1920 x 960;  1.6 mm | 100000 | 800 |

#### 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 mariner 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.

Examples of tiles are given.

1. Example specifications of some existing LED display tiles

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Display type | Dimensions | Resolution; Pixel pitch | Contrast ratio | Max luminance  Cd / m2 |
| 4 mm pitch 3-in-1 | 448 x 504 mm | 96 x 108;  4 mm | 4000 | 2000 |
| 16 mm pitch 3 led | 448 x 504 mm | 60 x 60;  16 mm | 7000 | 6000 |

#### Head-mounted and Hand-held Displays

If a mariner would use binoculars on the simulator bridge he would probably be able to distinguish the image pixels more clearly. But that’s not what we want: the binoculars should improve the image resolution. Of course, this may be simulated also. In that case the binoculars would contain electronic displays and a sensor to determine the target being aimed at. The displays are fed with the calculated, ‘enlarged’ image.

Somewhat along the same line the Virtual Reality techniques can be seen. Instead of creating a very large projection wall for the image, we might provide the mariner with a small display showing everything he should be able to see at that moment. This display is then built into a VR helmet which the mariner wears on his head, blocking the view on his real surroundings. Like the detection of the target of the binoculars, the helmet must sense the position of the mariners head and the direction of his eyesight. This information must lead to the adaptation of the image very fast, as the latency (the time the image lags behind) must be less then 50 ms for the mariner to keep the illusion that he is really looking around.

This technique is used also in flight simulators.

#### Stereoscopic view

If both the eyes of the navigator are fed with a slightly different image, a stereoscopic view may be generated. This can be done with the VR Helmet and binoculars as discussed in 6.1.2.5 or with other techniques found in the 3D cinema and TV consumer market. There are many people that cannot digest these images without problems (like developing nausea), so there should be fall –back options if 3D information has to be transferred in a simulation. However, at the distances relevant in navigation the stereoscopic cues can be expected to be minimal.

#### Combination of techniques

A simulation may make use of a combination of the techniques described above. Examples are the binoculars as mentioned before, but other combinations may also be applied to solve specific lacks of information. As an example, a separate monitor could be used to fill in the rear view on a projected 270 degree view bridge. Possibly the lights of AtoN could be superimposed on a projected outside view with separate laser beams, allowing for high contrast and high resolution values.

When a projected outside view is combined with additional monitors for rear view or bridge wing view, a point of concern is the inherent difference in luminance and contrast of the displays.

### Projection Theatres

On a full-mission bridge simulator a large viewing angle, preferably round vision, 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, as discussed earlier, some specific issues relate to the composition of the image in such a theatre. Although there are specialised companies that provide solutions, some aspects are discussed briefly here.

### Warping and blending

The projected image of each projector should ideally be a perfect cylinder section, all colours sharp and aligned throughout the entire image. As the projectors cannot all be exactly in the centre of the cylinder section distortions must be compensated. Also, 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 for the solution providers, although days of adjustment may be involved and at regular intervals to maintain an optimal image.

Fig.X Warping a visual channel image making it correct at the projection screen

Fig. X Blending two channels by reducing light in the overlap zone

#### Colour matching

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

Peter?

#### Stitching and transitions

As for colour matching, if the outside view consists of multiple images, the transition from one image to the other should not be noticeable. In a projection theatre the projectors cannot be placed in the centre of the screen so perspective distortions have to be corrected. The process of connecting overlapping images to one continuous image is known as stitching. However, in this case the stitching only applies to the projection of the images as all images are calculated from the same 3D model.

At the transition of projected images, the adjacent images will overlap somewhat to avoid holes in the image. To make the transition smooth, the luminance of the images should both decrease linearly in this transition area

Peter?

#### Dynamic perspective

When the mariner moves about on 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 of the mariner and changing the perspective of the projected image accordingly. This could be continuous but usually in discrete conditions are distinguished, e.g. when the pilot enters the bridge wing, the viewing point shifts to that side.

### Video walls

A video wall consists of a number of video monitors. Additional aspects compared to those mentioned under monitors are the edges between adjacent monitors which must not be noticeable. The powering and control of the displays may be a technical challenge.

### IR and Night Vision

Mainly intended for simulation of military operations, the visualisation of IR and night vision is available from some manufacturers. This will involve a separate display unit (or two, when using binoculars) for which a specific image is generated.

## Modelling

In the following sections relevant phenomena’s are presented in a conceptual model hierarchy.

This guideline recommends considering these phenomena when using simulation systems as an assessment tool of AtoN, to the least.

As also stated later, a model of phenomena may contain elements that compensate for the deficits in the visual presentation system.

### The human vision

#### Luminance

The human vision is a highly sensitive sensor system.

Light can be detected at intensities as low as **0.2 µ lux**.

The eye has an static contrast ratio of **10.000:1**.

This can dynamically be adjusted to effectively provide a dynamic contrast of **1.000.000:1**

#### Colour resolution

According to /1/, the human eye can distinguish about 10 million different colors.

/1/ Judd, Deane B.; Wyszecki, Günter (1975). *Color in Business, Science and Industry*. Wiley Series in Pure and Applied Optics (3rd ed.). New York: [Wiley-Interscience](http://en.wikipedia.org/wiki/Wiley-Interscience" \o "Wiley-Interscience). p. 388. [ISBN](http://en.wikipedia.org/wiki/International_Standard_Book_Number" \o "International Standard Book Number) [0-471-45212-2](http://en.wikipedia.org/wiki/Special:BookSources/0-471-45212-2).

#### Visual Acuity

Cone spacing in the human eye is measure to approximately 28 seconds of arc.

According to the conditions the visual acuity may be cited as from .4 minutes of arc up to a maybe more realistic value of 1 minute of arc.

A rather comprehensive description can be found in /2/.

/2/ <http://webvision.med.utah.edu/book/part-viii-gabac-receptors/visual-acuity/>

#### Afterimage effects

After exposure to strong light in their sensitivity range, [photoreceptors](http://en.wikipedia.org/wiki/Photoreceptor_cell" \o "Photoreceptor cell) of a given type become desensitized. For a few seconds after the light ceases, they will continue to signal less strongly than they otherwise would. Colors observed during that period will appear to lack the color component detected by the desensitized photoreceptors. This effect is responsible for the phenomenon of [afterimages](http://en.wikipedia.org/wiki/Afterimage" \o "Afterimage), in which the eye may continue to see a bright figure after looking away from it, but in a [complementary color](http://en.wikipedia.org/wiki/Complementary_color" \o "Complementary color). As lighting conditions changes rather slowly, this phenomenon is not considered of importance.

### Conceptual model

The conceptual model relevant for visual simulation is devised at the top level as

* AtoN
  + Fixed AtoN
    - Lights
      * Point
      * Line
      * Surface
    - Construction
      * Geometry
      * Surface materials
      * Local illumination
  + Floating AtoN
    - Mooring system
    - Environmental forces
    - Floating body
      * Construction
        + Geometry
        + Surface materials
        + Local illumination
    - Lights
      * Point
      * Line
      * Surface
* Environment
  + Terrain and man-made constructions
    - Geometry
    - Surface material
    - Lights
  + Ships
    - Geometry
    - Surface material
    - Lights
  + Ocean
  + Weather
  + Atmosphere
  + Sun and moon

For each of the conceptual models the following phenomena should be considered

#### Navigation Point Lights

Navigation lights are lights, typical considered as point lights either fitted on floating aids, beacons, light houses and on ships that to be model to the highest possible level. The model of a navigation light shall include the possibility for specifying the

* Colour;
* Nominal range/ or luminance;
* The vertical divergence;
* The sectors and their cut-off precision. High precision cut-off must be possible PEL lights;
* Oscillating lights;
* Flashing characteristics, including flickering, synchronised and sequential lights;

The maximum flickering frequency that a system can represent relates to the so-called Frame Rate (FPS). Table X in annex Y can be used to estimate the maximum flicker frequency for an individual frame rates taking into account the Nyquist sampling theorem up to the Flicker-fusion frequency. It may be of importance if the flashing characteristic is achieved though 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 long range and low intensities. For accessing the feasibility of AtoN the focus shall be on the representation on the long range. Observed at close range high intensity navigation lights may illuminate nearby structures. However, this not considered of major relevance at longer distances.
* Switch on and off schema, such as day light, night time, all time.
* The type of the light source may influence the scattering of the light under various atmospheric conditions.
* Service allowance.

#### Navigation Line - and Surface Lights

For close range observations the extent of a navigation light may be of importance and it must be modelled as such….

#### Geometry

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

#### Surface Materials

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

Bands of reflective material assisting in the identification of the floating aids 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 therefor of major importance for the conspicuity both at day and night.

The surface material shall also reflect indirect lighting from spot lights providing flood lighting,

#### 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 night time may be pre-calculated achieving good realisim at low computational cost.

#### Floating AtoN

A floating AtoN shall be influenced by the:

* Wind;
* Waves;
* Current;
* Tide;
* Mooring system;

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

A real time simulator is most likely not used for the designing of a specific buoy and the required mooring system.

However, generic or specific motion response data models, such as RAO’s may be imported into a real time simulator in order to assessment of the suitability of the floating platform as a stable carrier of a navigation light and as a daymark in the required environmental conditions. Making detailed motions calculations in real time for a large number of floating aids in various wave climates may be very computational challenging.

#### Terrain and Man-made constructions

Cultural lights may be considered as rival to the navigation lights. Cultural lights shall be included as appropriate. For inbound studies near shore they can most likely not be neglected. The cultural lights may appear form:

* Houses;
* Large flashing screens and advertise signs;
* Moving cars, aircrafts, cranes, etc.;
* Offshore structures;
* Wind turbines  
  Wind turbines shall have rotating blades when considered relevant for the study, as they may interfere with lights at longer distance.

Objects shall appear with the correct perspective. So-called billboards may be used for objects in the far distance for which the perspective doesn’t change significantly.

#### Ships

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

The conspicuity is influenced by the following elements by other ships

* The above water structure of moving ships obstructing the visual observation of the AtoN
* Lanterns, 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 of importance. In this case the other ships dynamics shall be modelled as **own ships.** Otherwise other ships can be modelled as **traffic ships**.

#### Ocean

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

The model shall include the effect of:

* Tide;

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

* Sea state;

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

* Current;

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

* Reflection in calm water surface.

#### Weather

Wind influencing the floating aids is considered having a minor effect compared to that of current and sea state.

Clouds scatters light from the sun and the moon influencing the global lighting in the environment.

Precipitation and fog scatters light as clouds do but also and not least significantly the man-made lighting and reflected light from objects in the environment, including navigation and cultural lights. A so-called glare effect will appear for light emitters both navigation lights and cultural lights from cities or other man-made constructions.

Fog and various type of precipitation such as rain and snow should be available for simulating various weather situations. The effect of such particles is describe in the following section for the atmosphere.

Feasibility studies of AtoN may be made for various weather conditions.

#### Astronomical objects

The Sun and the Moon are important light sources during day and night providing illumination of the scene.  
The scattering of the light through the atmosphere is of paramount importance for these to ‘lights’ and cannot be separated. The high intensity light emitted by the sun, reduces the relative intensity of navigation lights perceivable in the static range the human eye adapts to.

The simulation shall 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.

#### Atmosphere

Whereas weather phenomena such as precipitation and fog may be considered as low altitude atmospheric phenomena, the light from the sun and the moon is also scattered by phenomena’s through the entire atmosphere. This may include the following effects:

* Humidity and Pollutants  
  Particles in the atmosphere scatter light, both incoming sun light 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 wave length and the Mie model for larger particles. The scattering of light causes the sky to have its gradual shading from white to blue and the aerial perspective making objects is the distance less saturated and little more blue.
* Temperature  
  Local temperature variations may diffract the emitted light making the scene a little blurred, reducing visual acuity. Importance? (very little)

The evident frequency dependent scattering of light in the atmosphere may also be relevant for scattering of light from AtoN by weather phenomena’s.

### Real Time Considerations

The quality of graphics presentation that is 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 visual simulation. The production of CGI based movies may use thousands of PC’s rendering frames, need at 25 Hz at a far from real time pace.

For achieving real time rendering some simplification are needed, of which the most prominent are:

* The costly ray tracing used in moves is at the moment not feasible for real time application 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 details that can be applied to model appearance of objects in the scene need to be administered rather strictly.

#### Shadows and ambient occlusion

To be defined

### Compensation for Presentation System Limitations

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

One such technology is called Tone Mapping. Tone mapping technology adjust the rendered image such that the human brain is lured to believe that the image observed on a Low Dynamic Range display is perceived as if it was displayed on a system having a much Higher Dynamic Range for colour and contrast.

The tone mapping can be explained as making a model of the human eye that will adjust LDR images as if they were HDR images.

As described in the section on software implementation, limitations in software and supporting graphics hardware are becoming fewer and fewer while still being able to meet the real time performance criterion of not less than 30 frames per second.

### Software implementation

#### Hierarchical implementation

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

* Application  
  The top level layer implements most of the specific features describe in the previous sections about the 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 API  
  The two main Low Level API’s for 3D graphics are OpenGL and DirectX. Both are closely related to the graphic driver that must support the API’s
* Graphics Driver.  
  This software layer is produced by the graphics hardware layer as these two are tightly connected.

HDR or LDR

* + Current standard graphics API using 3x8 bit colour LDR (Low Dynamic Range):
  + Modern graphics API using 3x? bit colour space HDR (High Dynamic Range).

# Simulation of Radars

## Presentation

For the presentation of radar images there is a choice between an entirely computer-generated image and a computer-stimulated radar display unit. The advantages of the latter option are that the RDU can be exchanged easily to fit the user’s needs and that there is no software development involved in modelling the user interface of radar display and plotting aids. On the other hand some extra hardware is needed.

For both methods the simulation model has to decide what information can be derived from the – simulated – outside world, given the limitations of the radar working principles. There is a difference in the modelling required: for the stimulated radar display the modelling should be aimed at producing a raw radar signal including disturbances, whereas for the entirely computer-generated setup the filtering and corrections of the simulated radar set should be included in the model.

## Modelling

### Modelling of intrinsic radar flaws and limitations

A number of limitations stem from the basis working principles of radar. To understand these, the important elements are recollected first. The effects on the radar image information are indicated in italics.

* The radar transmits a pulse of electromagnetic waves, with a certain duration (pulse width).  
  *The echo of an object extends radially to represent half the length of the duration of the pulse, multiplied by the propagation speed of the radar waves.  
  Two echoes become disjunct when their radial distance exceeds this length.*
* The radar waves are transmitted in a concentrated bundle, where the dimensions of the bundle are determined mainly by the scanner width.  
  *The horizontal beam width of the main lobe of the bundle determines the minimum radial distance between objects to become separated echoes. This width is approximately 69\*(radar wavelength / scanner width) (in degrees). A displayed object will be enlarged with twice the horizontal beam width.*
* After the pulse transmission and a shut-off interval the reception of returning echoes starts.  
  *Echoes returning before the reception starts will not be displayed. This applies for very nearby objects. The result is a blind distance which is dependent on the selected range and pulse length (which are usually coupled).*
* The scanner orientation can be regarded as fixed during one transmission-reception cycle (the time needed for an object at a range of 12 NM is about 0.15 ms).   
  *An object would normally return a number of successive pulses, by which an object could be mathematically distinguished from disturbances as noise, sea clutter and rain clutter. The number of pulses returned in one scan depends on pulse repetition frequency, beam width, scanner rotation speed and the azimuth size of the object.*
* Also sea waves, raindrops, birds, etcetera return echoes.  
  *These kinds of (unwanted) echoes have some specific characteristics that may make them recognisable or mathematically suppressable. E.g. the echoes of waves are related to the dominant crest direction and thus show up mainly in and with the direction of the wind. Echoes of raindrops only show up on X-band (3cm wavelength) radar but may attenuate the signal of S band radar. The rain clutter is suppressed by using a signal differentiator (Fast Time Constant - FTC) because the signal through a rain area remains at a more or less constant level.*
* More?

*.*

### Modelling of the scenery

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

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

The returned radar power is governed by the Radar Equation. In short, returned fraction is proportional to the radar cross section area of an object and inversely proportional to the square of the range to the object.

### AtoN echoes

Normally AtoN will have a specified radar performance which will be used directly in the simulation model. A radar reflector is specified with its radar cross section. The Radar Equation as mentioned before describes the power returned from the AtoN.

### Racons and Ramarks

The response of a Racon is shown as a radial (Morse) pattern behind the position of the beacon (starting at about 50 m due to a small time delay). The length of the pattern represents a fixed object size (usually a few nautical miles) and thus scales with the range setting.

The Ramark signal shows as a continuous radial pattern from the centre to the edge of the PPI.

Wind farm echoes

The influence of offshore wind farms on radar performance has been studied extensively for MCA in 2004[[1]](#footnote-1). At smaller ranges the turbine poles 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, say, 100 m height of a turbine pole is illuminated by the radar beam, and despite of the usually round form a large amount of energy is returned. The turbine itself also produces a strong echo, depending on the orientation of the nacelle. Because of this effective 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 a shifted bearing. Reflections between turbine poles (multipath) can cause spurious echoes at larger ranges than the real object.

Weak objects behind a wind farm could be overseen 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 ‘swallowed’ by the echo of a turbine. Of course, the limitations originating from the beam width apply here also, but because of the strong reflection of the turbine the reflection outside the nominal beam width (half-power limits) the beam width seams to be enlarged.

As in the real life setup, the simulated radar system include two elements

* Radar Transceiver and
* Radar Display

Refer to IALA guideline on radar simulation /x/

## Presentation by Radar Display

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 **stimulated** real radar display. If stimulated radar displays are used no modelling of the real system is made of, features, like ARPA, trial manoeuvres, overlays and to some extend signal processing, that can influence the realism provided to the mariner.

7.1.1 Emulated radar display

If emulated radar displays are used in the simulator setup it must be considered if real system performance characteristics are relevant and available. As mentioned above this need less consideration if a real and approved display is made available at the simulator bridge.

The performance standard for Radar/ARPA displays /X/ includes features like,

* ARPA
* True and relative motion
* Head up, course up and north up presentation
* Trails
* Trial manoeuvres
* Sensor monitoring and alarms
* AIS overlays
* ECDIS overlays

## Modelling of Radar Transceiver

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, in required to convert the radar return representation into the proper format of video signals slightly different among radar producers.

The overall representation of the scenery as observed and sensed by the radar antenna, can by today’s technology be done in 3-dimensions, effectively sharing a large part of the same database as used by visual system for the out-of-the-window visual sensing.

A 3-dimension database will ensure correct shielding of AtoN by ships, terrain or seaway compared to a simplified 2-dimensional representation.

The following effect should be included in the antenna/transceiver model as also required by “IALA xxxx”

* X and S band transmission and reception
* Proper modelling of PRF and PL  
  These parameters influences the radar discrepancy
* 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-dof motions in a seaway   
  Correct 3-d geometric and material modelling including side lobes, multiple echos
* Lobe characteristic modelling, including vertical and horizontal extend and variation
* Rain clutter by local or global precipitation of various types
* Sea clutter
* AtoN model
* Return from floating aids moving in the seaway and fixed aids 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

# Simulation of sound

This section is limited to the possibilities of simulating the sound of AtoN – audible signals.

## Presentation

### Speaker systems

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

### Sound Reception Systems

On vessels with enclosed bridges, typical cruise vessels, a sound reception system are used to attenuate the sounds encountered by a vessel. By use of 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.

The sound reception system has been developed to simulators providing the same functionality as in the real world.

Advanced systems adopted from military aircrafts can via speakers or advanced headsets give the mariner an indication of the direction and distance to a sound emitting device at a level that the mariner will not have by just using his own senses.

## Modelling

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

1. the sound level emitted from an AtoN;
2. the distance and direction to the sound emitting AtoN;
3. the ambient noise level at the position where the mariner 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 mariner’s position on the bridge will affect the reception of AtoN sound signals. The reception is also affected if the mariner is located inside a fully enclosed bridge or on an open bridge or in the open bridge wings.
4. Environmental conditions affecting the speed of sound such as air humidity, presence of snow, rain or fog. Ice bergs with snow, cliffs covered with ?????
5. Physical environment in case sound dampening elements are present close to the vessel (e.g. snow covered icebergs, stand covered formations etc.). Steep formations and other elements can give reflections (echo).

A given sound from an AtoN is recoded digitally and can be reproduced with the correct time pattern through speaker systems in the simulator. The sound level, the degradation of the sound level due to the factors described above can be implemented in a simulator and if, for instance, quadraphonic speakers are used the direction of the sound can be reproduced in the simulator.

Various algorithms are used to ensure a high level of realism including the effect of environmental conditions. Obviously, if such algorithms are not used or if the speaker system is not providing sufficient quality supporting the input or if only one speaker or stereo speakers are provided the directional element will be missing. Likewise, if the initial production or recording of a given sound is of low quality any given high quality sound and speaker system cannot remedy this condition.

Please refer to IALA Guideline XXXX on the use of Audible Signals as Aids to Navigation for details that should be considered when simulating sound signals and IALA Recommendation E-109 for the calculation of the range of sound signals.

# Simulation of Shipborne navigation systems

## ECDIS

The Electronic Chart Display and Information System (ECDIS) is essentially a system that shows some portion of a digitised version of a nautical chart (an ENC) with extra information projected on top of it – most notably the 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 within a few years.

The information is organised in layers, and the mariner may switch layers on and off to adjust the information presented to his needs.

The IMO document outlining the model course for ECDIS training, STW 43/3/1, illustrates the relevant interfaces with other bridge equipment. Of course, not all capabilities will apply to every simulator setup:

ECDIS simulation equipment should be capable of simulating the operational capabilities of ECDIS which meet all applicable performance standards adopted by the Organization, and should optimally 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 emulated raw video, cursor, EBL and VRM
  + autopilot capable of control by heading (course), COG, and track, where monitored track may be provided through both instructor control and alternatively through ECDIS at ownship
* provide radar overlay, with functions operating independently from ownship radar
* provide audio for navigation and assessment systems when fitted
* provide VHF communications between all ownships and instructor
* permit all ownships to interact with one another, depending on the exercise design
* provide for viewing visual scene by scrolling in all directions horizontally and vertically, or horizontally without scrolling where fixed visual channels cover 360 degrees
* provide for taking accurate visual bearing
* permit simultaneous navigation on paper charts associated with area databases as appropriate to ECDIS watchstanding
* provide adequate and well-lit surface for plotting on paper charts as the required means of backup required for single ECDIS installation

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).

## PPU

The Portable Pilot Unit (PPU) can be described as a portable version of an ECDIS, with its own accurate position sensors. Using two spaced GPS receivers the heading can also accurately be determined. The ideal track and the 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 a track prediction can be displayed based on current field, rudder angle and rpm.

The system is meant to provide the pilot with all relevant information to stay in control of the process. It is even possible to send VTS traffic images to the PPU, providing the pilot with the same traffic information as the VTS.

## AIS as Virtual AtoN

Although virtual AtoN are not really ship-borne, there is no corresponding object in the simulated 3D world. The VAtoN comes into existence only in the simulation of the AIS reception and subsequent display on the ECDIS. In such a simulation the way mariners handle the information provided by the VAtoN and the absence of a physical AtoN may be analysed.

## e-Navigation systems

IMO has developed a strategic vision for e-navigation, to integrate existing and new navigational tools, in particular electronic tools, in an all-embracing system that will contribute to enhanced navigational safety while simultaneously reducing the burden on the navigator. As the basic technology for such an innovative step is already available, the challenge lies in ensuring the availability of all the other components of the system, including electronic navigational charts, and in using it effectively in order to simplify, to the benefit of the mariner, the display of the occasional local navigational environment. e-Navigation would thus incorporate new technologies in a structured way and ensure that their use is compliant with the various navigational communication technologies and services that are already available, providing an overarching, accurate, secure and cost-effective system with the potential to provide global coverage for ships of all sizes.

Future e-navigation systems will include the representation of AtoN and such systems will be possible to integrate to marine bridge simulators like other navigational instruments both for test of such systems including the test of proper representation of AtoN and eventually as part of the total package of instruments representing the instrumentation of a ship’s bridge.

A few prototypes of e-navigation systems are currently being produced and could be integrated to simulators. The systems are by nature complex and involve the interaction between several systems including data transfer systems. The integration of a fully operational and working e-navigation system is depending on the simulators 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. It is not fully understood at this point to what extend this is possible to replicate in a simulator.

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

# Conclusions

1. LIST OF PHENOMENA COVERED IN RELEVANT IALA RECOMMENDATIONS AND GUIDELINES

Preliminary list of phenomena covered in relevant IALA Recommendations and Guidelines. Keywords need to be elaborated.

|  |  |  |
| --- | --- | --- |
| 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 swith 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? |  |
|  |  |  |
| **1049** | **The Use of Modern Light Sources in Traditional Light Optics** | |
|  | Correct CIE colour for each | Lamp |
|  |  | Lens |
|  |  |  |
| **1051** | **Provision and Identification of AIA 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 | Trash, 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 Retroflecting material on Aids to navigation Marks** | |
|  | Shall buoy models include the retroflective 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 |  |
|  |  |  |
| **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) |  |
|  |  |  |

1. LIST OF ABBREVIATIONS

AIS Automatic Identification System

AtoN Aids to Navigation

CRT Cathode-Ray Tube

DLP Digital Light Processor

ECDIS Electronic Chart Display and Information System

FPS Frame rate Per Second??

HDR High Dynamic Range

IR Infrared

LCD Liquid Crystal Display

LCoS Liquid Crystal on Silicon

LDR Low Dynamic Range

LED Light-Emitted Diode

LPD Laser Phosphor Display

PEL Physics and Engineering Laboratory (where they were invented)?????

PPU Portable Pilot Unit

QXGA Quad Extended Graphics Array

RAO Response Amplitude Operator

UXGA Ultra Extended Graphics Array

1. LIST OF REFERENCES
2. J. Banks, J. Carson, B. Nelson, D. Nicol (2001). *Discrete-Event System Simulation*. Prentice Hall. p. 3. [ISBN](http://en.wikipedia.org/wiki/International_Standard_Book_Number) [0-13-088702-1](http://en.wikipedia.org/wiki/Special:BookSources/0-13-088702-1).
3. Shannon, R.E. (1975). *System Simulation: the art and science*. Prentice Hall.

1. See <http://www.dft.gov.uk/mca/effects_of_offshore_wind_farms_on_marine_systems-2.pdf> [↑](#footnote-ref-1)