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# Proposals on chart quality portrayal

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## Background

The objective of the IHO Data Quality Working Group is stated as "*To develop appropriate methods of classifying and depicting the quality of digital hydrographic data.*" and more specifically to "*Investigate ways of ensuring that ECDIS displays provide a clear warning or indication to the mariner on the quality of the underlying survey data, through appropriate use of the attribute CATZOC and/or improvement of the existing display capabilities*" [DQWG TOR].

The DQWG issued a questionnaire which was completed and returned by over 600 mariners. Harper analyzed these responses and concluded [DQWG5 minutes]:

*"1 - Large proportions of ENC users are not using the CATZOC information;*

*2 - The additional S-57 DQ indicator attributes are not understood and not used;*

*3 - Majority of mariners state that they have not received enough training on data quality issues, and that they would like to receive more training."*

Resulting in the following nine recommendations:

*"1 - As a minimum the constituent elements of S-57 CATZOC (positional uncertainty, sounding uncertainty, features detected and seafloor coverage) must be encoded in S-101 ENC for depth areas, as separate attributes*

*2 - All encoded data quality information must be discoverable*

*3 - The data quality of near shore topography (piers/quays, fixed aids to navigation, clearances, etc) should be included, and a method of representing this data quality must be developed*

*4 - Temporal degradation of data should be encoded*

*5 - New representation methods should be able to accommodate inputs such as dynamic tides, under keel allowance and vessel specific indicators. It is understood that international efforts on standardization of display and mariner training address possible issues with user inputs.*

*6 - Where possible, ENC attribute names should be more descriptive (eliminate 6 letter acronyms and make use of camelCase)*

*7 - Visualisation should take advantage of the mariner's preference for an on demand colour overlay*

*8 - Recommend to improve on the ability for mariners to add notes to specific features. This might also change the presentation of the feature (as an addition to the mariners objects)*

*9 - Any representation method should be accompanied by an appropriate education strategy."*

Dorst & Howlett (2012) state that quality information includes

"1 - *measurement uncertainty* (e.g variation between similar measurements at the same location)
2 - *completeness* (e.g. seafloor coverage)
3 - *currency* (e.g. temporal degradation)"

attached to either the entire dataset, a specific area, or individual features.

There are existing S-57 M_QUAL attributes that capture the first two of these, and part of the third. These are (with their proposed mapping to S-101)

| | quality indicator | S-57 | S-101 |
|---|---|---|---|
| 1 - | measurement uncertainty | POSACC<br>SOUACC | positionalUncertainty (uncertaintyFixed; uncertaintyVariable)<br>verticalUncertainty (uncertaintyFixed; uncertaintyVariable) |
| 2 - | completeness | TECSOU | techniqueOfVerticalMeasurement |
| 3 - | currency | nil | categoryOfTemporalVariation |

Dorst & Howlett also state that

1 - "*new indicators have to be useful and easy for the mariner to understand*"
2 - "*the final display will need to use a new composite indicator*"
3 - using "*algorithms that are yet to be devised*"
4 - this composite indicator may "*have an option to contain information from the environment and the ship as well*"
5 - "*the idea of one indicator that includes everything between the ship's keel and the bottom corresponds to the outcome of the mariner's questionnaire*."

Dorst (2012) reported on instructional priorities at CSMART ALMERE, among which is that "*as much work as possible should be done during the earlier steps" (appraisal & planning)*, and that "*CSMART supports the development of a new quality indicator, to improve navigation during the planning step. The composing elements of such an indicator should be discoverable, and all this information should be available well before the actual trip begins.*"

Howlett (2012) requested assistance from our team in "*developing a meaningful and user friendly means of displaying data quality issues to the mariner.*"

We initally proposed five objectives, in response to this request from DQWG:

1 - Determine what constitutes data quality information that would be useful to the mariner, within the context of the DQWG UML model.

2 - Design and investigate possible methods of portraying this data quality information.

3 - Consider the use of the Multidimensional User Manual (MUM) approach [Devillers et al 2002] in portraying this data quality information.

4 - Mock up possible methods of portraying data quality in an ECDIS simulator or similar facility.

5 - Use this mockup to investigate mariner's preferences regarding the various portrayal methods, and how these methods affect mariner's decision-making.

These objectives were discussed at a meeting in Niagara Falls on 2012-05-15, attended by four DQWG members (Harper, Hare, Heap, Mong), and three of the above team members (Calder, Alexander, Wells). A report on these discussions is Appendix B to this document.

Our initial objectives have subsequently been further discussed and refined by our team members. The results of these discussions form the remainder of this document.

## Twelve perceived axioms

Our proposals are based on the following perceived axioms (self-evident truths). These are presented intentionally to spark discussion, and not as final axioms.

1 - The purpose of nautical charts is to *facilitate informed decision-making* by mariners and other chart users.

2 - Portrayal of chart quality indicators are most important during voyage planning, less important during voyage monitoring, but may also be important during emergencies. Emergency use may raise appropriate colour table encoding.

3 - It is NOT the purpose of charts and ancillary information complementing charts to replace the mariners and other end users as decision-makers. Information provided with charts should NOT extend into decision-making.

4 - Component quality indicators, whose meaning is transparent to end-users, effectively facilitate informed decision-making.

5 - The three quality components identified in Dorst & Howlett (*measurement uncertainty*; *completeness*; *currency*) represent a good starting point in defining indicators that are useful, intuitive, "mariner-friendly", that is have a *transparent meaning to mariners*.

6 - However the assumption built into the above statement must be tested by eliciting feedback from mariners on the use of these quality components, sooner rather than later.

7 - Since 2.5 of these three quality components are already captured in the S-57 attributes POSACC, SOUACC, TECSOU, and SUREND, there is an opportunity to continue a dialogue with mariners about quality components immediately, using S-57 compliant ENCs.

8 - In general, composite indicators on their own, such as CATZOC, or a replacement for CATZOC, risk incorparating a priori decision-making, which is inappropriate, and has an opaque meaning to end users. It may be that mariners will find a composite indicator useful, when accompanied by its component indicators. But this should be tested.

9 - Past efforts to represent chart quality, whether by source diagrams or CATZOC encodings, represent chart quality in ways that may be useful to a hydrographer, but, as indicated by the DQWG survey results, do not address the needs of, nor are easily interpreted by, a mariner.

10 - Efforts to develop a composite indicator to represent chart quality should proceed gradually, with mariner feedback at each step.

11 - Development of a composite algorithm that combines not only chart quality attributes but also environmental and ship factors as well, goes well beyond the chart quality mandate of the DQWG; will inevitably be complex; and risks being even more opaque to mariners.

12 - Regarding the visualization of chart quality indicators, as indicated in DQWG recommendation 7 above, mariners have uniformly voiced approval and understanding of a scheme that encodes quality values into a green-yellow-red semi-transparent areal overlay. We suggest a fourth color, gray, for areas where quality indicator values are not available. We propose this as a starting point, while we develop and test more sophisticated ways of visualizing quality indicators.

We propose to divide our work into two stages.

The goal of **Stage One** is to develop a demonstration of chart quality indicator depiction quickly, using indicators already available in S-57, concentrating on the component indicators rather than a possible combined indicator, and using a simple Green-Yellow-Red-Gray area overlay for visualization.

The goal of **Stage Two** is look into a possible composite indicator, and possible more sophisticated visualization techniques.

## Stage One Workplan

Stage One is an attempt to pick the "low hanging fruit", and do the easy things first. Hence it adopts only the most obvious S-57 component quality indicators; adopts the most obvious quality indicator encoding; and proposes to develop an MIO as a vehicle to contain this information. A straightforward Likert-scale mariner's questionnaire will be developed, and administered in one or more of several possible ways.

### *1 - Test data*

We propose to identify one or more existing fully encoded S-57 ENCs to be used for Stage One. Dorst & Howlett (2012) note that several different scenarios (old data; mobile seafloors; rocky seafloors) should be identified and used.

Assistance will be needed from DQWG members and their organizations, and possibly other HOs, in identifying suitable S-57 (hopefully fully-encoded in the sense of the DQWG's interests) to be used as test data. These test ENCs should collectively represent multibeam, single-beam and lead line survey coverage; examples of "Extreme Event" and "Likely to change" seafloors; and a variety of CATZOC classes. It may be that artificial ENC may have to be created. However, our hope is to defer that until Stage Two.

### *2 - Quality indicator encoding*

Develop Green-Yellow-Red-Gray encodings for each of POSACC, SOUACC, TECSOU, and SUREND. There are high correlations among all four of these indicators, and these must be explained to mariners asked to test their use. The following initial suggestions are intended to start discussions on what encodings will be most appropriate, and useful for mariners:

| POSACC (positionalUncertainty) | if encoded | if only CATZOC encoded |
|---|---|---|
| ≤ 5 m | Green | CATZOC A1 |
| ≤ 20 m | Yellow | CATZOC A2 |
| > 20 m | Red | CATZOC B and worse |

| SOUACC (verticalUncertainty) | if encoded | if only CATZOC encoded |
|---|---|---|
| a ≤ 0.5 m AND b ≤ 1% | Green | CATZOC A1 value @ 30m) |
| a ≤ 1.0 m AND b ≤ 2% | Yellow | CATZOC A2 & B value @ 30 m) |
| a > 1.0 m OR b > 2% | Red | CATZOC C or worse value @ 30 m) |

TECSOU (techniqueOfVerticalMeasurement)

| ID | Meaning | Red-Yellow-Green-Gray encoding |
|---|---|---|
| 3 | found by multi-beam | Green |
| 6 | swept by wire-drag | Green, but only to a certain depth |
| 8 | swept by vertical acoustic system | Green, but only to a certain depth |
| 13 | swept by side-scan sonar | Green, but only to a certain depth |
| 1 | found by echo-sounder | Yellow |
| 2 | found by side scan sonar | Yellow |
| 7 | found by laser | Yellow |
| 4 | found by diver | Red (isolated object(s)) |
| 5 | found by lead-line | Red |
| 9 | found by electromagnetic sensor | Red (reconnaissance quality?) |
| 10 | photogrammetry | Red |
| 11 | satellite imagery | Red |
| 12 | found by levelling | Red |
| 14 | computer generated | Gray |

A “categoryOfTemporalVariation” indicator will be specially developed for some of the ENC to be used for the Stage One testbed, using the following encoding:

categoryOfTemporalVariation (when available)

| | |
|---|---|
| 1. Un-assessed; temporal variation not assessed | Gray |
| 2. Extreme event; no new survey conducted after an event (e.g. hurricane, earthquake, volcanic eruption, landslide, etc), which is considered likely to have changed the seafloor significantly. | Red |
| 3. Likely to change; continuous or frequent change (e.g. river siltation, sand waves, seasonal storms, iceberg scours, etc). | Yellow |
| 4. Not likely to change; significant change to the seafloor is not expected. | Green |

## *3 - Develop a Stage One quality indicator visualization test-bed as a Marine Information Object (MIO)*

This will make use of the above quality indicators, and encodings, to allow the user to select each of the indicators, one at a time, to display as an ENC overlay.

We propose to add a new MIO Sub-category for “Chart Quality” to the MIO General Content Specification, approved by CHRIS 19 in November 2007. This is shown boxed in red on pages 11 and 17 of the proposed new Ed 2.2 for this specification.

More background on MIOs is available at
http://www.hgmio.org/hgmio.html
which is managed by Cameron McLeay, as well in Alexander and Huet (2007), and Alexander (2008).

## *4 - Develop a feedback tool*

This will be a Likert Scale SurveyMonkey questionnaire. It will draw on the experience of previous surveys conducted by USM/UNB (2004); Heap (2007); and Harper (2011). It will use principles of tailored design (Dillman et al 2009), and summated rating scale construction (Spector 1992).

## *5 - Gather Mariner Feedback*

Possible ways of doing this

1 - Demonstrate the test-bed at the Canadian Mariner’s Workshop to be held in February 2013 in Vancouver BC. This is an annual event organized by the Shipping Federation of Canada in collaboration with the Port of Montreal, the Canadian Hydrographic Service, the Canadian Coast Guard, Transport Canada, and Dr. Lee Alexander of the University of New Hampshire. Held each year, this has become a national event that addresses key navigation issues throughout Canada.

2 - Contact the 200 of the 600 mariners who responded to the DQWG questionnaire (those who provided contact information), requesting feedback on a software demonstration of the test-bed.

3 - Contact key mariner educators for response (in North America this would include MiTAGS; CSMART in The Netherlands).

# Stage Two Proposal

Stage Two activities will be informed by the results from Stage One, but wil consist primarily of research into new composite quality indicators (Brian Calder), and research into new visualization techniques (Colin Ware).

Referring back to our original five objectives

## *1. Determine what constitutes chart quality information that would be useful to the mariner.*

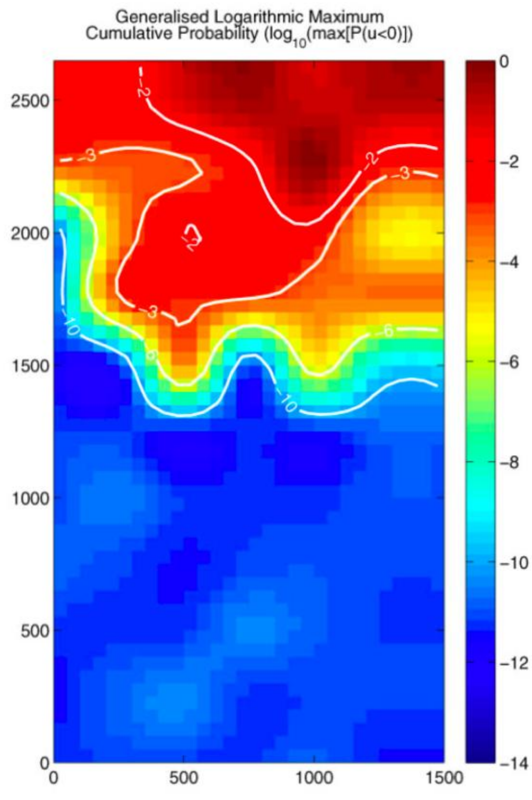
Consider additional / alternative component quality indicators, including those that have already been considered / adopted by DQWG / represented in the DQWG UML model.

Develop a composite quality indicator that includes environmental and ship factors. This will evolve from Calder (2012), briefly summarized here.

Calder considers the problem of how to develop a description of the uncertainty inherent in the depiction of the seafloor in a nautical chart that can include the best available knowledge of the configuration of the seabed in the area.

He characterizes the uncertainty in any given area in a way that takes into account both what we know about the area, and, in the case of sparse (non-multibeam) coverage, what we potentially do not know about the area. The model includes first a kriging-based interpolation between sparsely measured depths, then by assuming distribution functions for possible navigationally significant objects that might be present and undetected. For such objects of geological origin (e.g. rocks and boulders), this distribution function is a Gamma function, predicting more small than large objects. For objects of anthropomorphic origin (e.g. pilings and masts) this distribution function is uniform, predicting many more objects higher off the seabed.

These models dealing with what we do not know require calibration. Calder proposes this could be accomplished by small multibeam patches within each area of sparse coverage, an attractive alternative to complete multibeam resurveying of all sparsely-covered areas.




For this example, the probability for a large-ship model has been down-sampled and generalized such that smooth contours of probability can be generated with the property that they always generalize in the 'safe' direction of predicting higher uncertainty than is known to exist. The labelled contours indicate grounding probabilities of one in a hundred ($10^{-2}$), one in a thousand ($10^{-3}$), and one in ten billion ($10^{-10}$)

Calder also models the potential effects of motion extrema, waterlevel variations, and dynamic variations of draught as a function of motion upon underkeel clearance. These effects are combined to form a plausible estimate of underkeel clearance, weighted according to a cost (or loss) function to compute an estimate of mathematical risk associated with the ship's motion.

He discusses several use cases, one of which (Section III-C *Area based risk maps*) is appropriate for this project. It may well be that the full model could be reduced to a solely chart quality composite model, by suppressing the factors due to waterlevel and draught.

These effects are combined to form a plausible estimate of underkeel clearance, weighted according to a cost (or loss) function to compute an estimate of mathematical risk associated with the ship's motion.

## *2. Design and investigate possible methods of portraying this chart quality information.*

We start from an understanding of the neurophysiology of vision, and the visual cortex, which is structured with four visual "orthogonal processing channels": color channels (a) red/green and (b) yellow/blue; and a black/white channel that includes capabilities for (a) detecting form and texture, and (b) detecting motion. Visualization techniques designed to make use of all these channels have a "wider human visual perception bandwidth" than simpler techniques.

QuickTime™ and a
decompressor
are needed to see this picture.

Three high level channels: colour; elements of form and texture; motion. Between channels there is visual separation. Within channels there is visual interference. Verbal and acoustic channels assist visual channels, when present. [Ware, 2012]

QuickTime™ and a
decompressor
are needed to see this picture.

Low resolution feature maps guide eye movements. [Ware, 2012]

One way of adding orthogonal attributes in a way that minimally impacts the legibility of existing information is to use a visual channel not currently utilized (Ware 2012, Bartram et al. 2003). The most promising candidate is to use time varying (motion) portrayal.

We propose to implement a simplified (artificial) electronic chart mockup, containing point, line, area, and text features, and then to implement a number of quality indicator portrayal methods including the following:

- ***Static color coding***: For example, using border color for symbols, and colored texture overlays for area features.
- ***Dynamic color coding:*** For example, using time varying border color and colored texture overlays for area features. The variation in time may be smooth to make the effect less irritating.
- ***Dynamic non-color coding:*** For example, using periodic blinking, or smooth temporal variation.

Indicators for the portrayal will be determined through a (simplified) optimization process (Mitchell et al, 2009).

## *3. Consider the use of the Devillers et al 2002 "Multidimensional User Manual (MUM)" approach in portraying this chart quality information.*

We will subject the DeVillers approach to serious consideration and analysis.

## *4. Mock up possible methods of portraying chart quality in an ECDIS simulator or similar facility.*

We will continue to make use of both the test-bed developed in Stage One, modified and enhanced to include the results of Stage Two objectives 1, 2 and 3 above, as well as a test-bed constructed of artificial data (which facilitates testing).

## *5. Use this mockup to investigate mariner's preferences regarding the various portrayal methods, and how these methods affect mariner's decision-making.*

We will continue to use the contacts developed in Stage One to obtain feedback from mariners.

## Action List

| | |
|---|---|
| Provide NOAA ENCs which are appropriate for use with Stage One Test Plan | Sean Legeer |
| Locate earlier attempt at a data quality MIO | Cameron McLeay |
| Use MIO website to distribute information on Stage One project | Cameron McLeay |
| Provide methodology and eventually full report on Mariner's Questionnaire | Sam Harper |
| Provide Devillers-type references University of Utrecht | Leendert Dorst |
| Provide information on possible involvement of Plymouth University | Sam Harper |
| Mariner contacts for demo / survey | all |
| Keep DQWG members informed of progress | Wells |
| Present report at 2013 meeting | Wells |
| Mona Lisa 2 European project as possible sponsor for Ware | Eivind Mong (complete) |
| Dutch study similar to Brian Calder's work | Leendert Dorst (complete) |

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