Beyond FFL: Rhythmic Character for Range Estimation

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Conversion of Lighthouses to LED

While conspicuity increases, mariners are not always happy:

- Loss of „early warning“ at landfall – no more loom above horizon created by the rotating pencil beam
- Loss of atmospheric reflections of the rotating beam around the lantern room that helped to maintain orientation during the rhythmic character eclipses as a low-intensity marker
- **New arguments opposing conversion of lighthouses to LED: due to sharp edges of LED flash profile, spatial awareness decreases – it is not possible any more to estimate the distance to the AtoN site**

Back to Useful „Flaws“ of Old Technology

- Implementation of rhythmic characters providing fixed AtoN light signal component (fixed and flashing – F.FL, fixed and isophase – F.Iso, etc) brings back the low intensity marker during eclipses (visible at least from the shorter distances)
- **Changing from sharp front of the flash pulse to slow flash front (controlled luminous intensity rise time) while retaining the sharp back end may bring back the ability to estimate distance to the light source with minimum impact on conspicuity (short term, within comparable degradation / service condition)**

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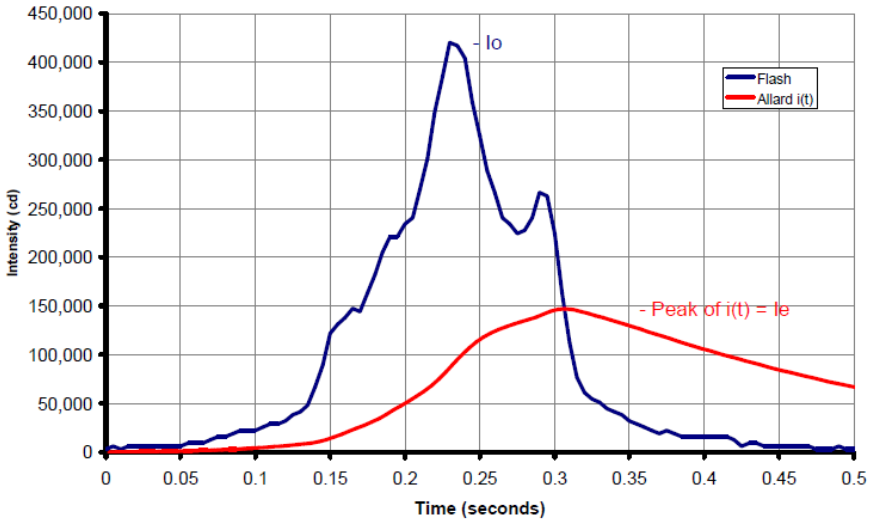
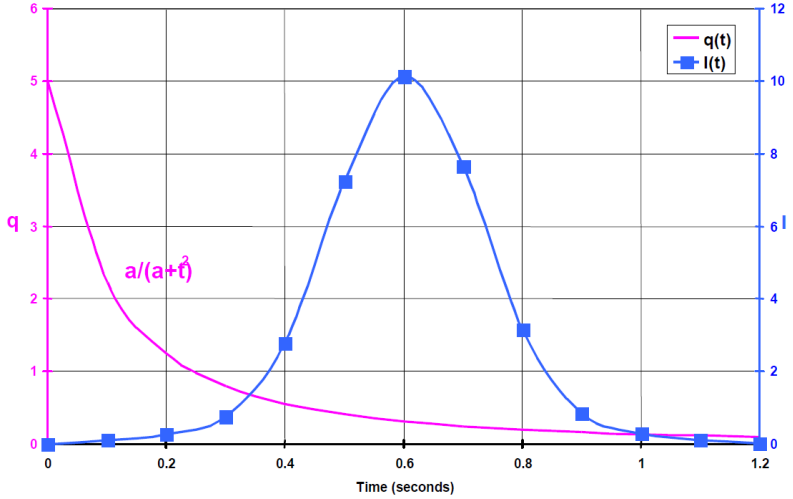
Flash Profiles of Traditional Lights

Flash profiles in IALA Recommendation E-200-4 reveal approximate luminous intensity rise times from 10% to 90% of **0.2 s** (Figure 4) and **0.4 s** (Figure 6, rotating optics)





In comparison, a LED based AtoN light in fixed optics can provide rise times in the order of 10 ns (**0.00000001 s**)

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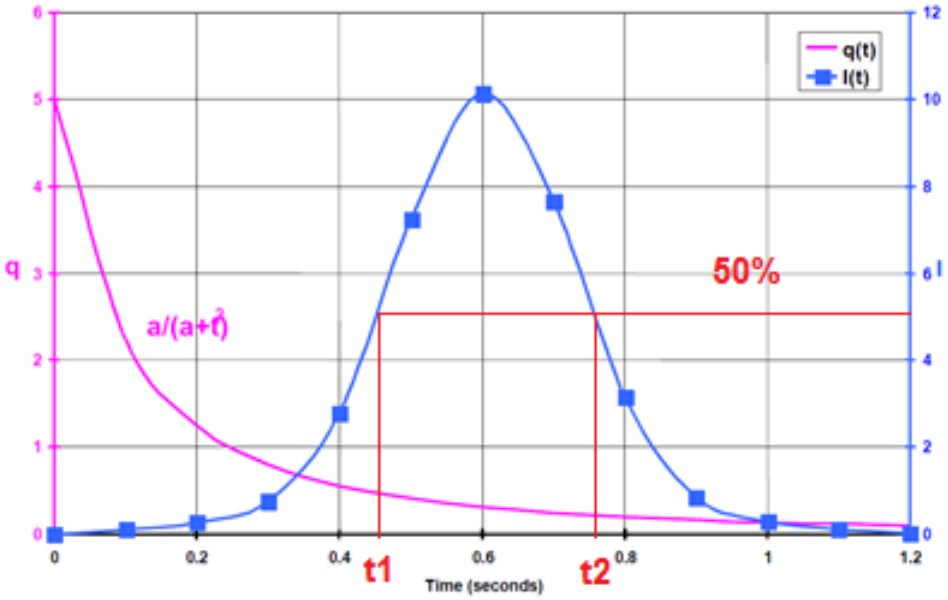
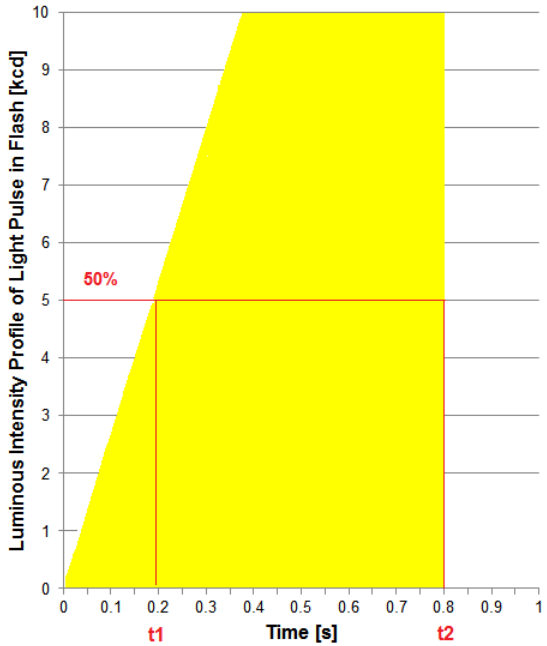
Slow Flash Front (SFF) Pulse Profile

IALA Recommendation E-200-3 on **flash duration**: pulse dwell time between 50% of peak intensity values (11.3)





Controlled (linear?) rise time of the SFF pulse front can be used to maintain the comparable effective intensity between t1 and t2 while keeping the fall time sharp

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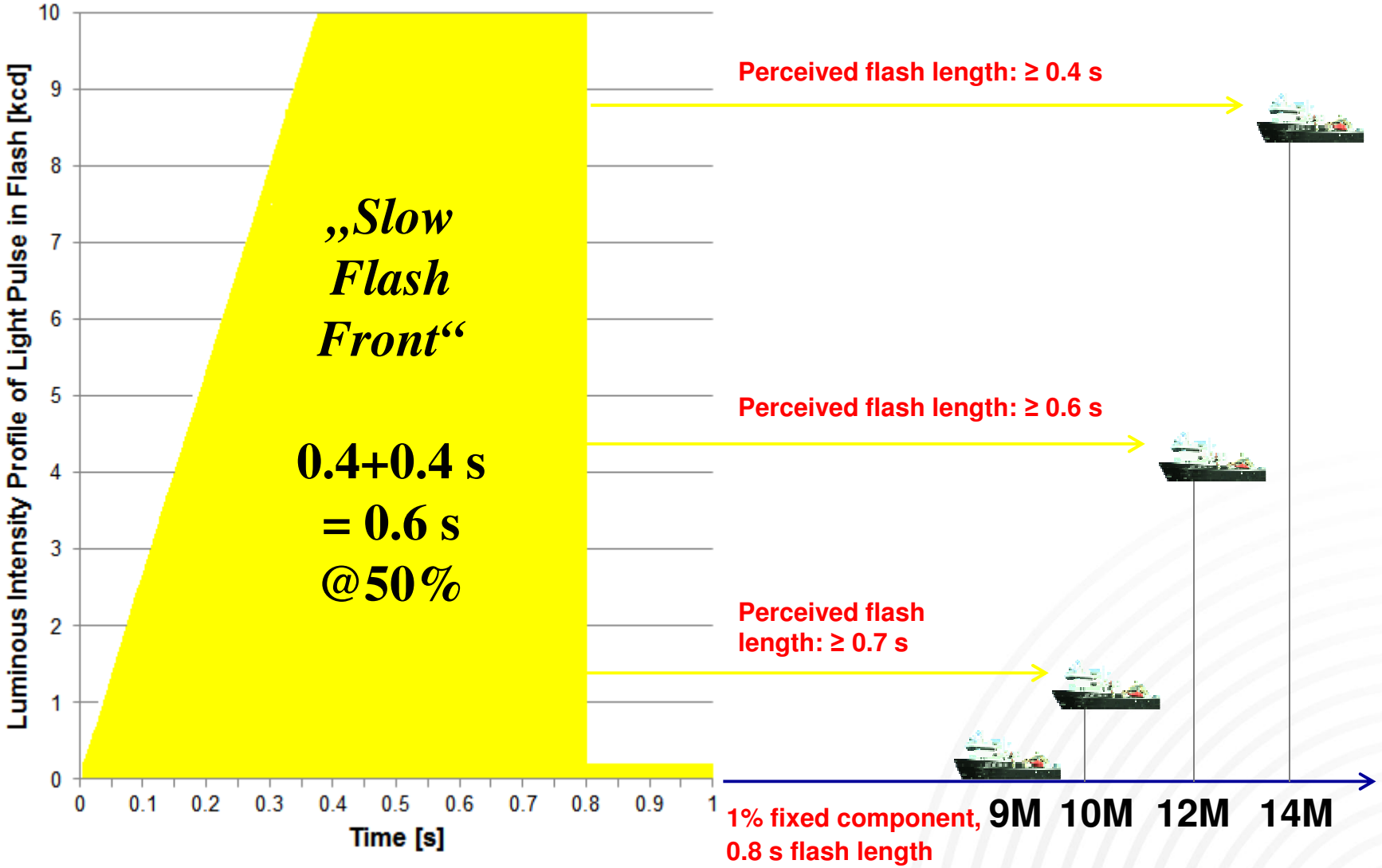
Time-to-Distance Conversion with SFF



Note: Perceived flash lengths and distances shown above are approximate for atmospheric transmissivity $T_M < 0.74$

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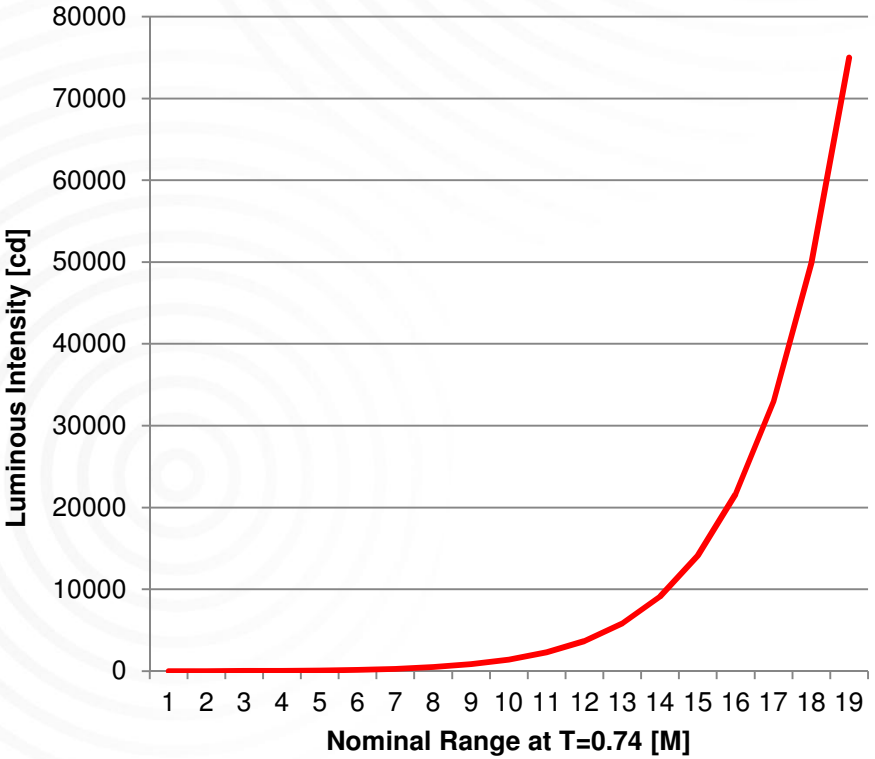
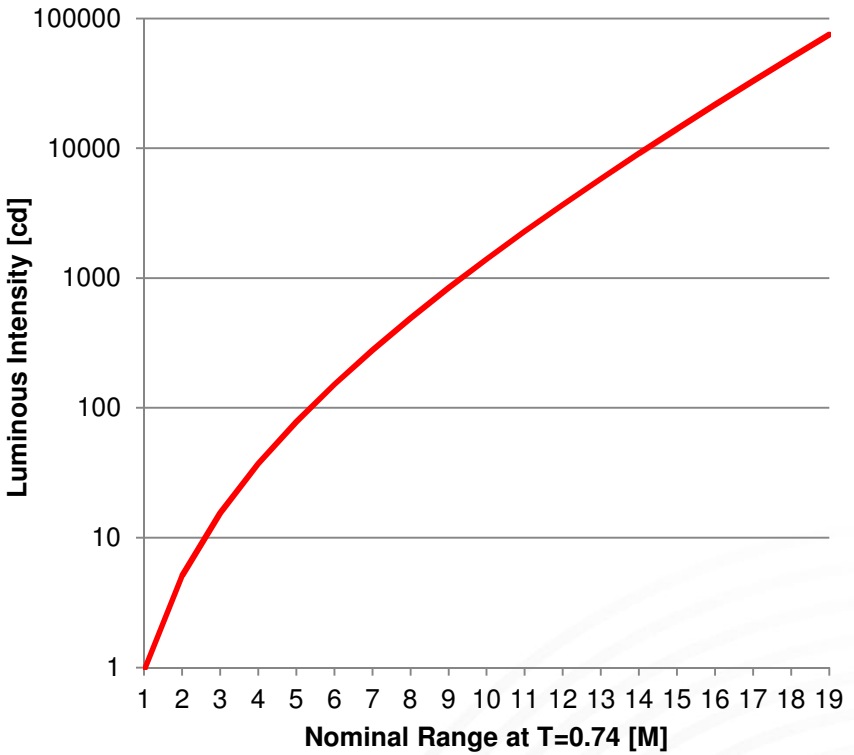
Perceived Flash Length at a Distance

< 9 M **< 10 M** **< 12 M** **< 14 M**

Above visualisation is simplified

AtoN Luminous Intensity / Nominal Range





Relationship between nominal range and luminous intensity of AtoN lights is not linear. The required illuminance of 0.2 µlx at the eye of the observer exceeds typical eye sensitivity > 100x.

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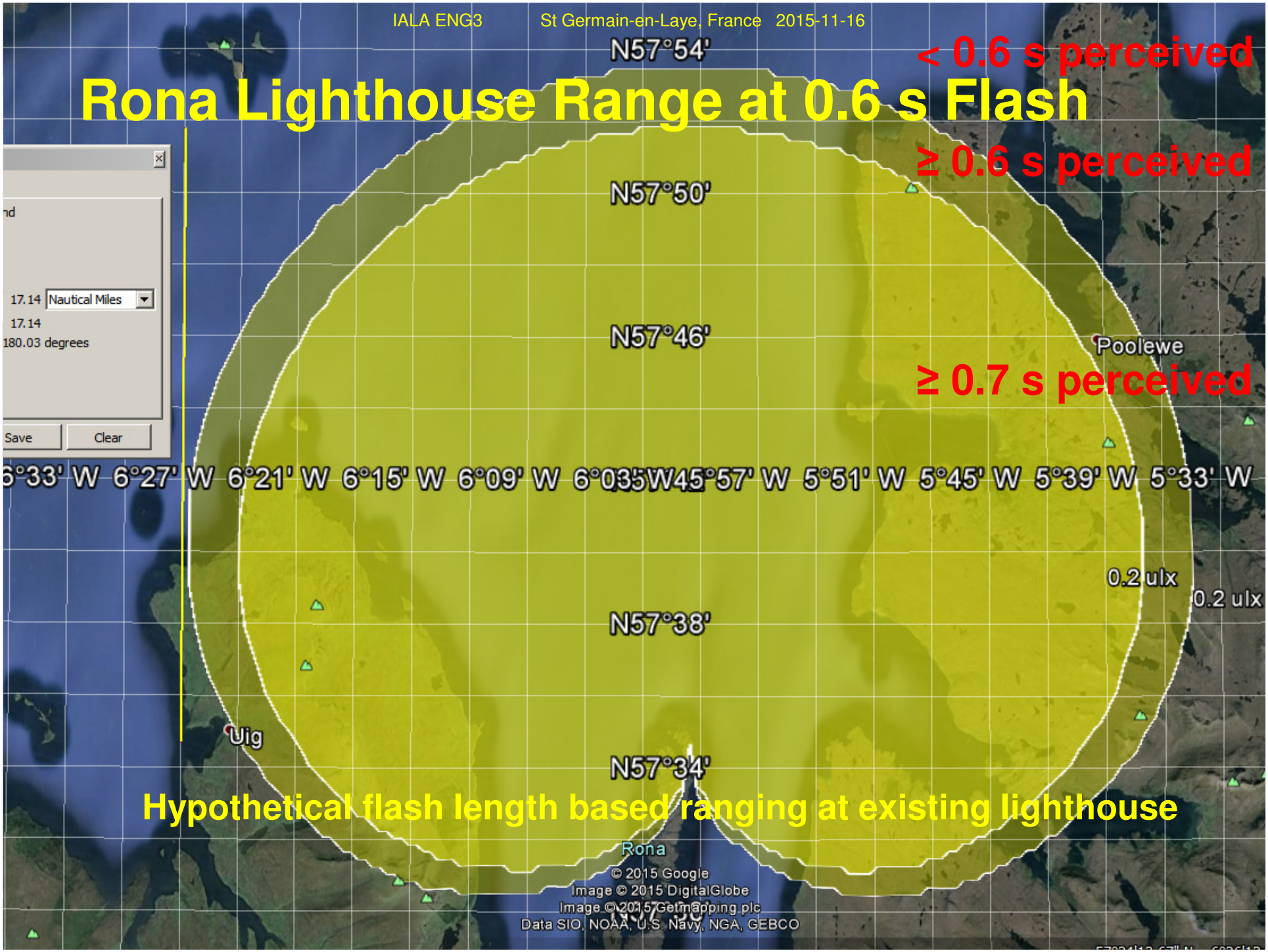
Rona (Scotland) Lighthouse Example

- Range 19M, white light signal (Fl.W)
- Operating at single 0.6 s flash, 11.4 s eclipse, period 12 s
- Night time luminous intensity for 19 M range at T=0.74 is approximately **75 kcd** (60 – 89.8 kcd, E-200-2, Table 1)
- Anticipated luminous intensity in 0.6 s flash: **100 kcd**
- Considering the rotating beam flash profile (E-200-5), duration of the light flash from nil to nil **exceeds 0.6 s**
- Next: range estimation with current flash profile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Rona Lighthouse Range at 0.6 s Flash
< 0.6 s perceived
≥ 0.6 s perceived
≥ 0.7 s perceived
N57°54'
N57°50'
N57°46'
N57°38'
N57°34'
6°33' W
6°27' W
6°21' W
6°15' W
6°09' W
6°03' W
5°57' W
5°51' W
5°45' W
5°39' W
5°33' W
17.14 Nautical Miles
17.14
180.03 degrees
Save
Clear
Poolewe
Uig
Rona
0.2 ulx
0.2 ulx
Hypothetical flash length based ranging at existing lighthouse
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Data SIO, NOAA, U.S. Navy, NGA, GEBCO

Demonstration: SFF 0.4+0.4=0.6s Flash

Peak luminous intensity in flash: 28 cd
Rectangular flash rise time: < 6 µs

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Conclusions and Challengens

- Application of fixed+ rhythmic characters returns the „halo“ effect of rotating lighthouse optics
- Application of slow flash front would further improve the **spatial awareness and identification** of particular AtoN while extending the LED lifetime, but questions remain:
  - Would the mariners be able to judge the environmental conditions properly to benefit from slow raise time?
  - Would a high precision luminous intensity rise time algorithm add value at the near end?
  - How to describe the rhythmic character formally?
  - Who would be willing to engage into field testing?

Thank you for your attention. Questions?

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