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Maritime Electronics Supporting Unmanned Vessels

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Agenda

- Positioning Technologies for Vessel's position
- Technologies for sensing around vessels
- Track Control System
- Communication technologies between Ship-to Ship, Ship-to-Shore
- Technologies to Avoid Collision
- Summary

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GNSS and Its applications

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Multiple GNSS Services

- Global: GPS, Galileo, GLONASS, BeiDou
- Regional: QZSS, NAVIC

Satellite Compass

- Combination of multiple GNSS antennas and inertial sensors enable to provide attitude information.

Satellite Compass SC-50
(THD(ISO22090-3) standard)

Speed log using GNSS

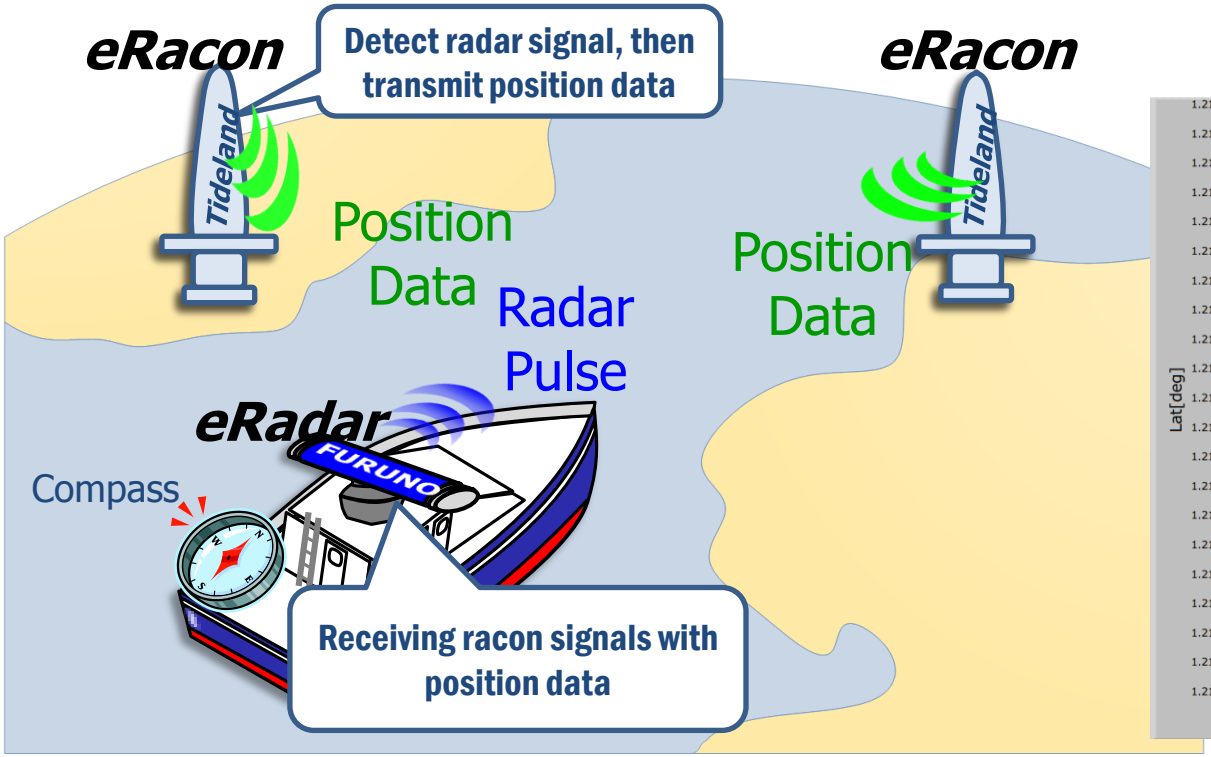
- High accurate SOG and attitude using GNSS signals
  - Transverse Speed at bow and stern as well as longitudinal speed
  - Transverse speed at any position of ship
- Speed accuracy ±0.02kn

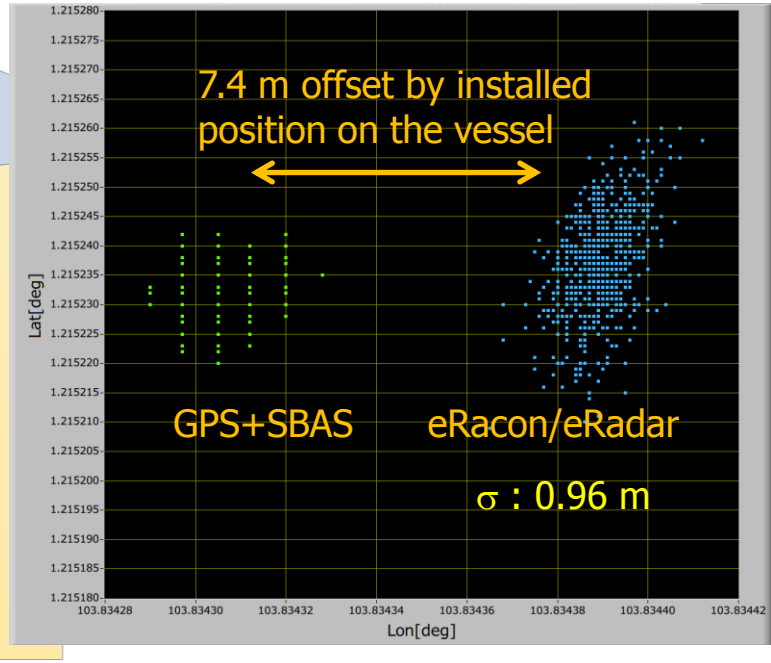
Speed log GS-100
(SDME(IEC61023), THD(ISO22090-3) standard)

Backup System for Resilient PNT

- Discussion of necessary of resilient positioning system based on the concept of e-Navigation
- Backup system which is completely independent from GNSS
- e(enhanced)-Loran , R-mode, Radar positioning
- E-Loran exhibits 10 – 20 m accuracy and wider coverage.
  - Trial in UK. Korea will start trials in 2017.
- R-mode utilizes DGPS and wireless beacon in MF. Feasibility studies have been done in EU funded test-bed. Accuracies of σ 2m-10m have been obtained in 50-70 km range. There are some issues during night time(Skywave).

Radar Positioning





Trial results at Singapore port

- Original proposal from DMA(Danish Maritime Authority)
- Obtain ship's position using position information of eRacon based on triangulation.
- Completely independent positioning system from GNSS.
- Three trials have been done in Denmark, UK and Singapore.
- High accuracy of σ 1m is comparable with DGPS(SBAS).

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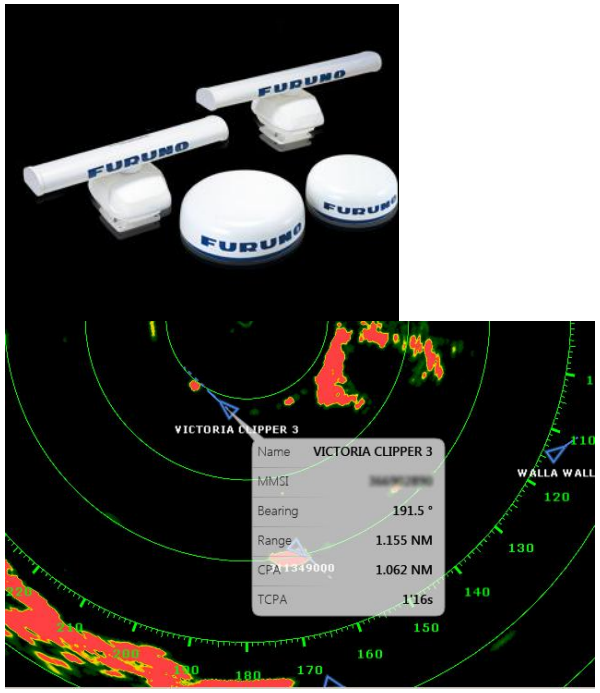
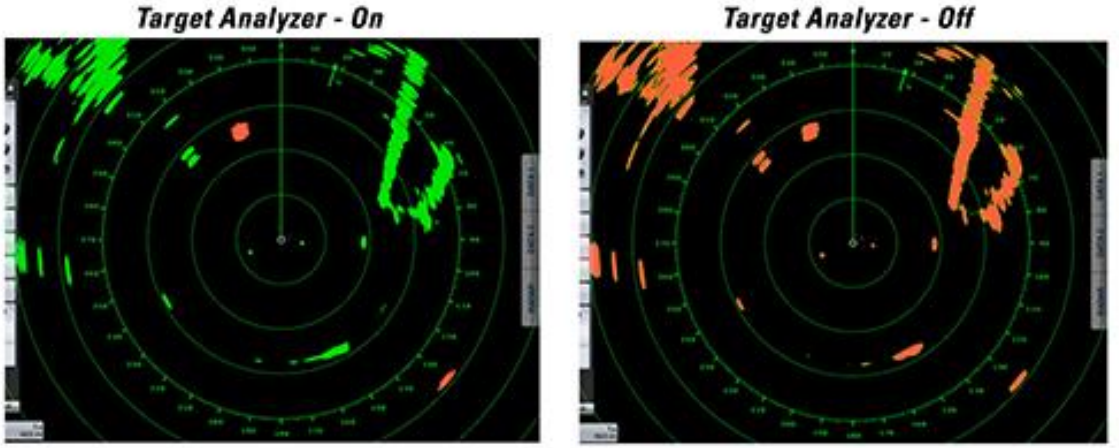
Navigation radars

- Mainly two bands(3 GHz/9.4 GHz) are utilized.
- Several output powers are available as well as antenna sizes.
- Emerging new technology using solid state devices having longer lifetime. Doppler information is also available.
- Wave radars are also available to obtain wave height, period and directions in real time.



Target Tracking+AIS



Application using Doppler information

Technologies of Optical Electronics

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＜IR-Camera＞

- Visibility during night and cooperation with radar.
- Range is depended on effects of environments

＜High sensitivity Camera＞

- Performances CMOS devices are improved due to compatibilities with process of LSI. A few mile range is available(Depended on performance of Lens).

<Lidar>

- High resolution performances due to their short wavelength.

- Performances of all optical sensors are limited by conditions of circumstances such as fog and rain. and the sensors require technologies of stabilizations when installed on vessels.

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Control of Vessel Position by TCS

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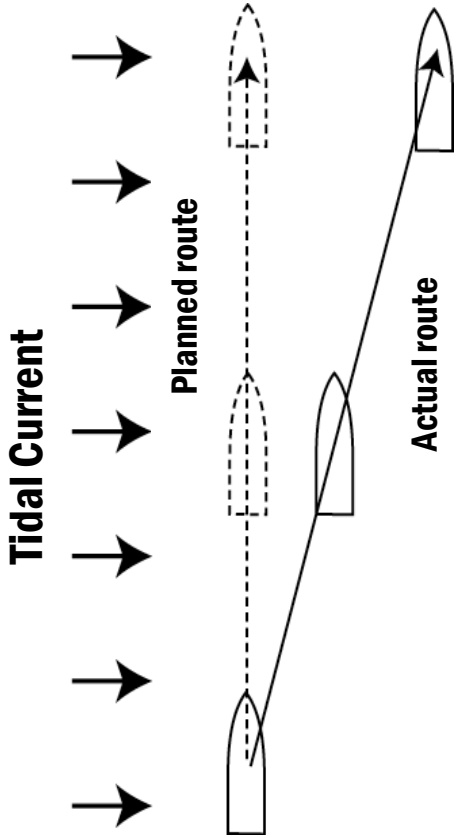
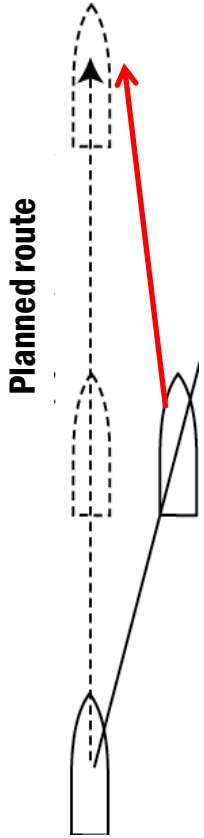
Track Control System（TCS）

Keeping heading of vessel

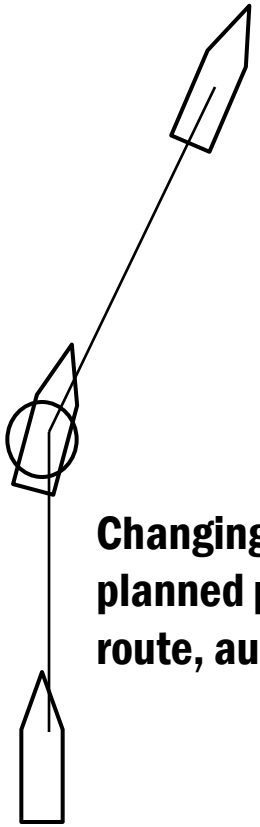


Control only heading

Control by TCS

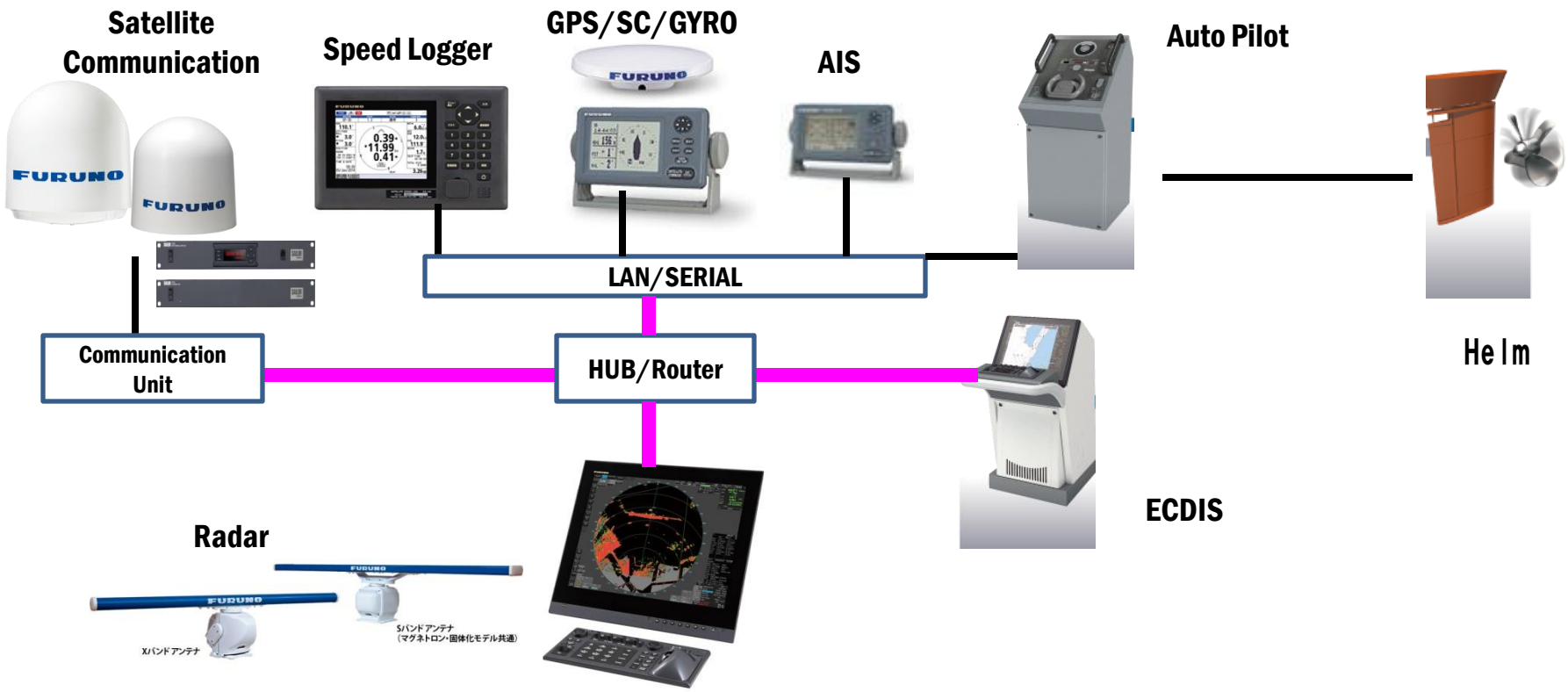


Control to return the planned route automatically.



Changing heading at planned point to keep the route, automatically.

Equipments for TCS



- Necessary to communicate among equipment in real time when considering autonomous shipping and unmanned vessel.
- High speed communication is required. There are several issues regarding cyber securities when we have networks in the vessel.

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Maritime Equipment for Communication

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Satellite Communications

Equipment	Band	Data Rate	
Fleet Broadband	L	432 kbps	Ship-to-shore/Ship-to-Ship 3 I-4 Satellites(except for polar)
VSAT	Ku	1M bps	Gestational satellite Loaming among satellites
Global Xpress	Ka	50Mbps/5Mbps	I-5 launched. Services start in 2016.

AIS/NAVTEX

Equipment	Band	Data Rate	
AIS	150MHz	9.6kbps	Broadcast maritime information 2ch(+2ch Long Range)
NAVTEX	518kHz 490kHz	—	Broadcast maritime information GMDSS，200NM range from shore

From AIS to VDES(e-navigation)

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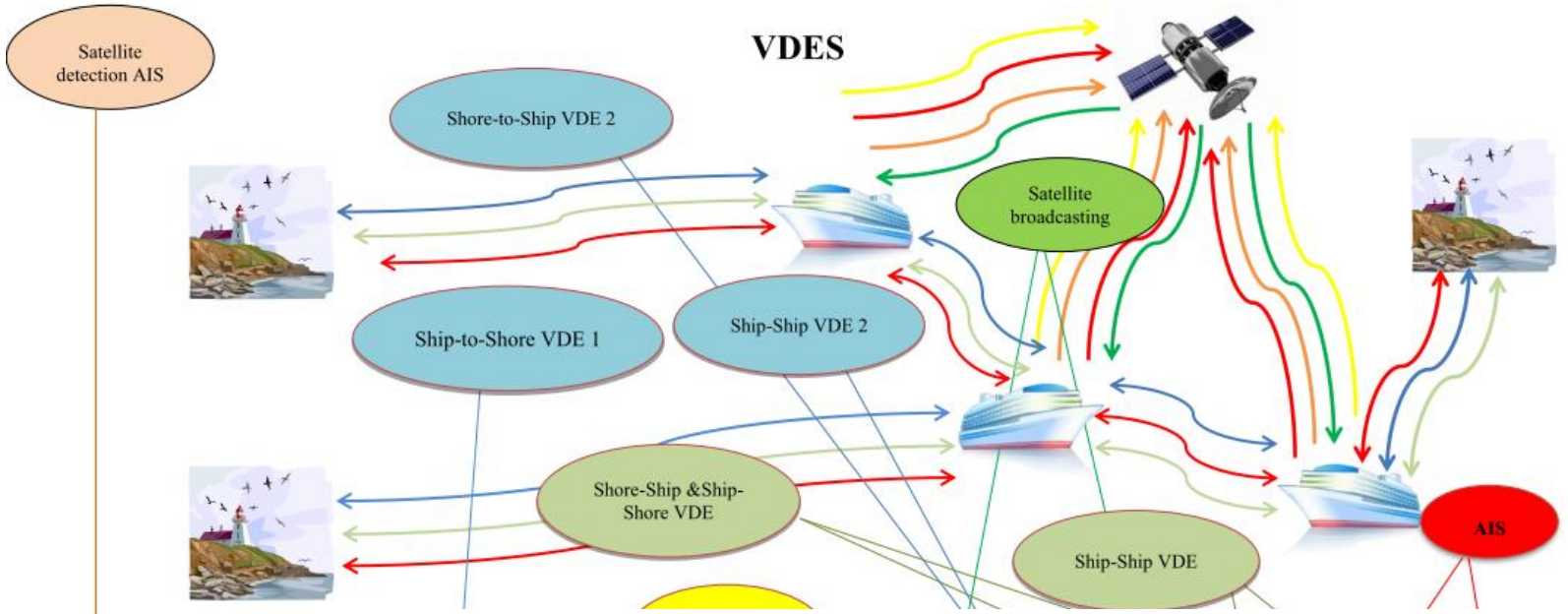
- There are no acknowledgements when using AIS even though maritime information are exchanged.
- Saturated channel capacities in busy ports.
- Discussing new frequencies for VDES among international bodies

Recommendation ITU-R M.2092-0 FIGURE A1-1



E-navigation is defined as *"the harmonized collection, integration, exchange, presentation and analysis of marine information on board and ashore by electronic means to enhance berth to berth navigation and related services for safety and security at sea and protection of the marine environment."*

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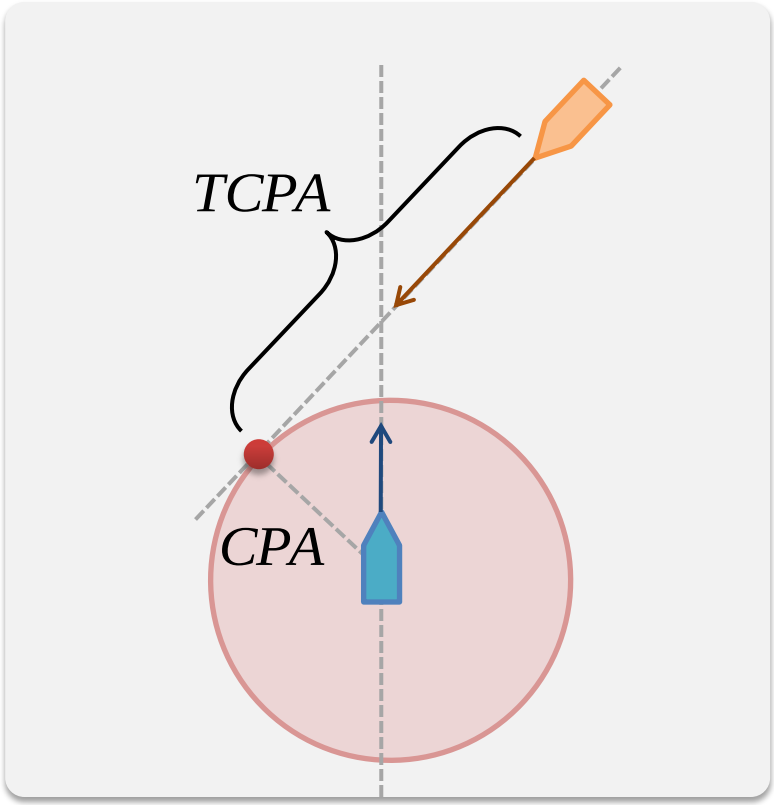
Warning for Collision using CPA/TCPA

◆ Possibilities of overestimations of risk



$$TCPA < TCPA_{min}$$
$$AND$$
$$CPA < CPA_{min}$$

Conditions to generate warning

Rough estimation

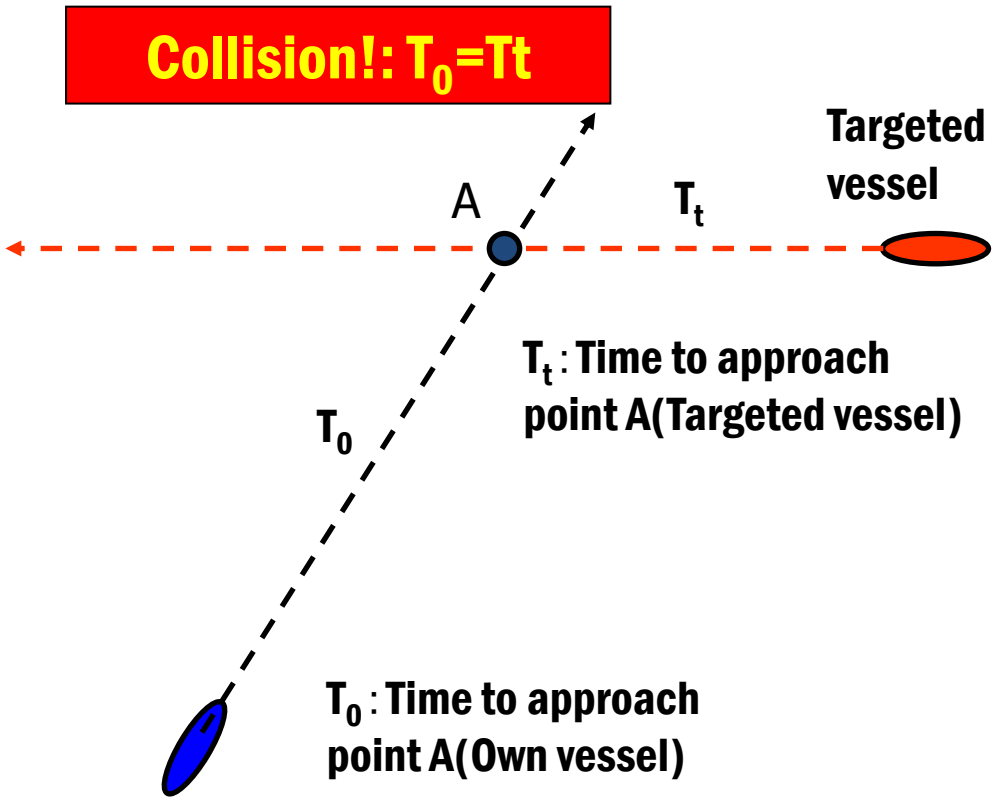
Can not recognize situations in detail.

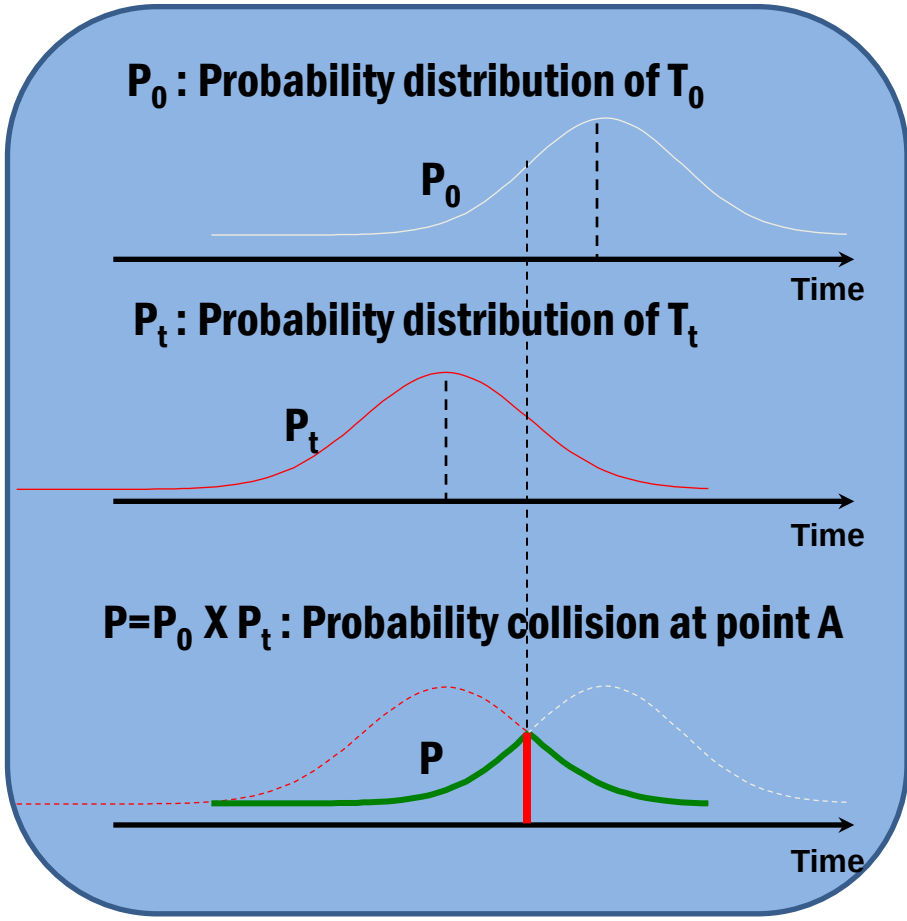
We have safe situations even though we have satisfied conditions mentioned above.

CPA: Closest Point to Approach
TCPA: Time to CPA

Concept of OZT(Obstacle Zone by Target)

＜Definition of collision risk in OZT＞





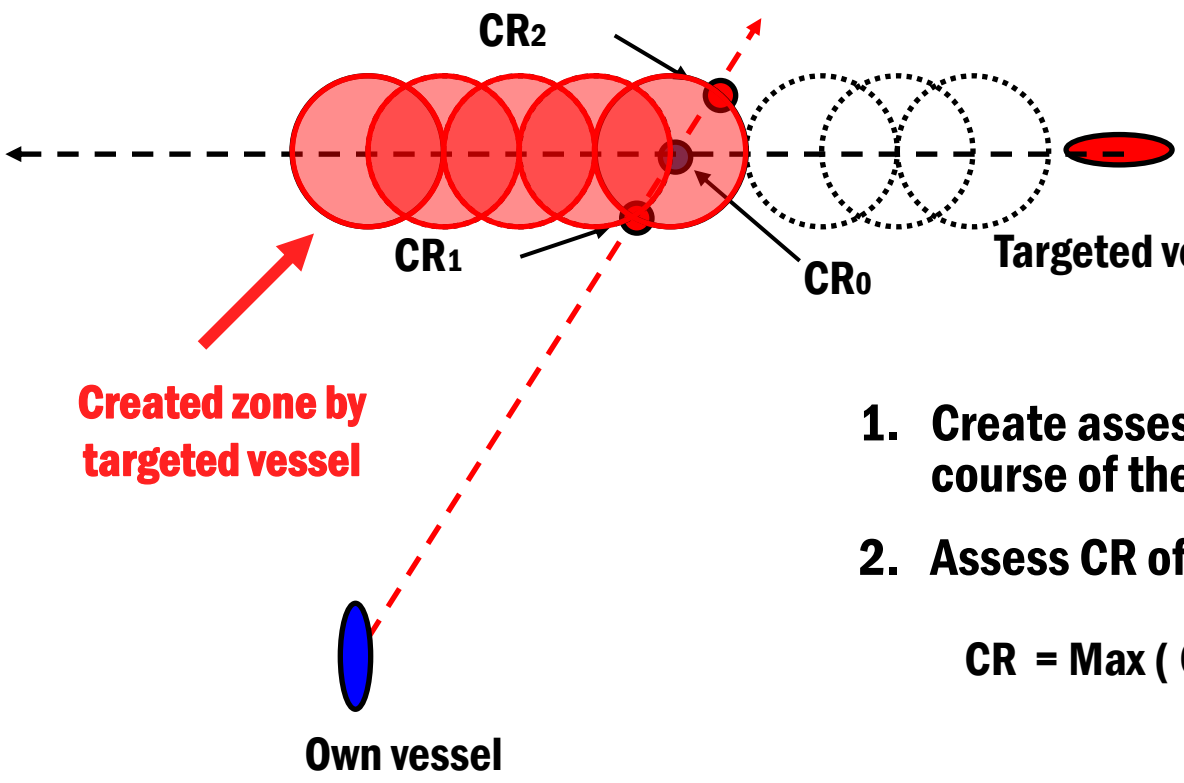
Collision Risk(CR)

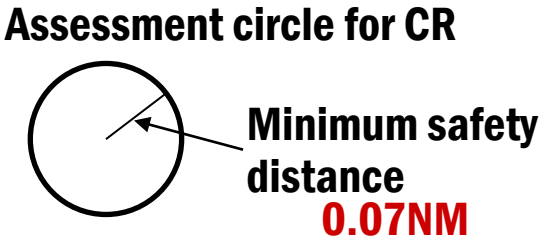
$$CR_i = \int P\,dt$$

Courtesy of J. Fukuto of NMRI

Collision Risk in OZT

Calculation method of CR using OZT





1. Create assessment circles on estimated course of the targeted vessel
2. Assess CR of each circle

   $CR = Max (CR_0, CR_1, CR_2)$

3. For example, display the circle by red when a value of CR exceeds beyond threshold one. This area is defined as OZT.

Courtesy of J. Fukuto of NMRI

Summary

- GNSS is used for positioning of vessels. Regional GNSS satellites are available as well as Global multiple GNSS systems. Based on IMO recommendation, resilient PNT is considered as a part of e-navigation.
- New radar technologies using solid-state devices are emerging. Doppler information can be used to identify movements of echoes. Optical sensors such as IR-camera are considered as useful tools to watch around own vessels.
- Must consider and discuss cyber security when TCS is applied to autonomous/unmanned vessels.
- Satellite communications could be treated as main ways to communicate ship-to-shore/ship-to-ship from a view point of data speed rate. On the other hand, discussions about VDES are on-going to expand channel capacities of AIS.
- CPA/TCPA is used as a technique to generate collision warning, but OZT is under consideration as alternative approach .

Thank you
for your kind attention.