

Maneuvering Motion Simulation to Support Berthing Operation of Small Crafts ~Proposal of a Berthing Operation Support System~

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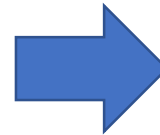
1. Introduction

Berthing Operation :

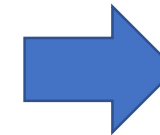
- Bring a Ship to a Berth in a Port

Small Crafts :

- Ship operators maneuver crafts alone.
- Distances of navigation are short.
- Berthing Operation is repeated frequently.
- Crafts are affected by external disturbance such as wind.



Heavy Burden on
Ship Operators

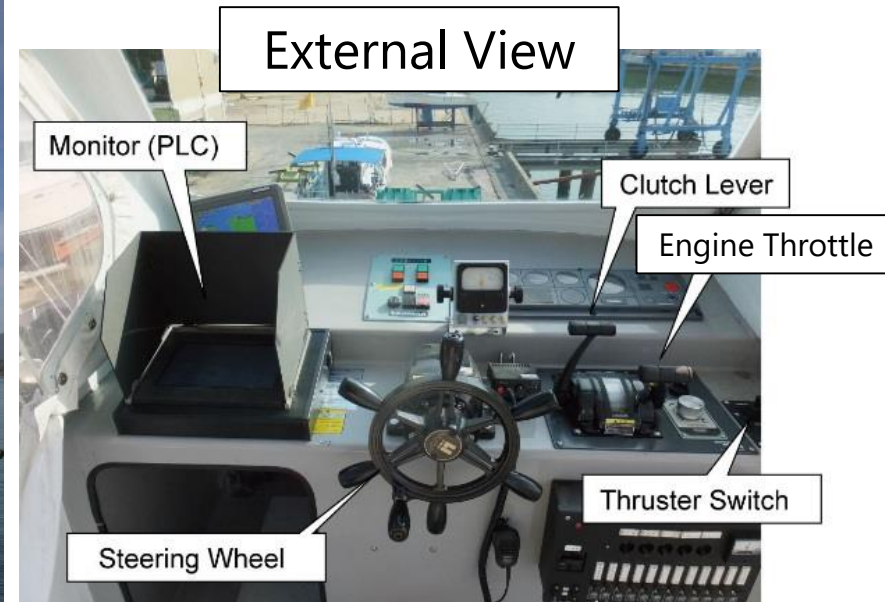


Maneuver Based on
their Experiences
while Considering
the Disturbance



**Effective to Develop a Berthing Operation Support
System That Enables Safe Operation for
Inexperienced Ship Operators**

2. Example of Berthing Operation of Small Craft



Principal Dimensions of Small Craft

- Length over All: 16.5 m
- Gross Tonnage: 17.0 tons

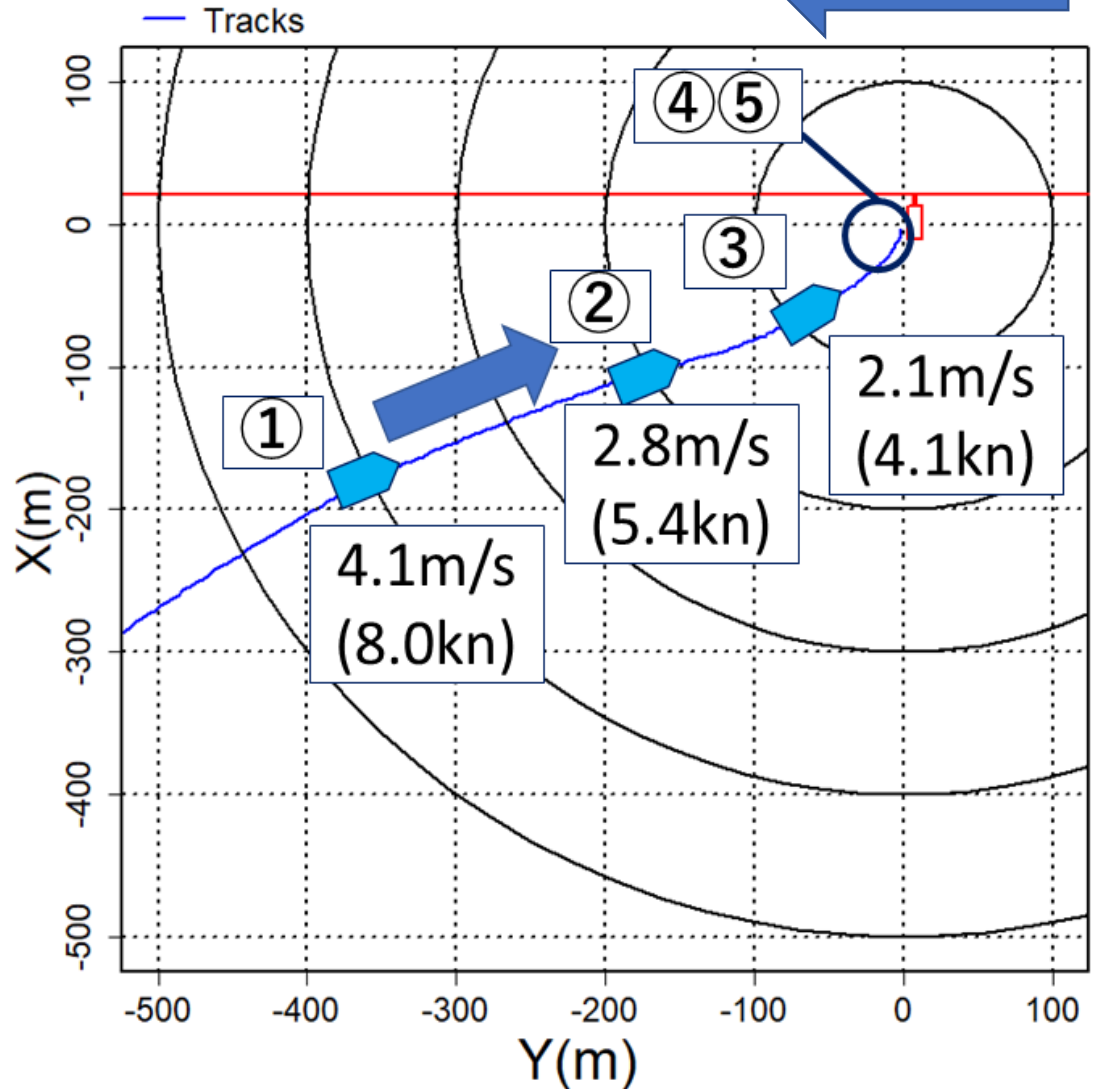
Analysis of Berthing Operation of Small Craft

Average Wind Speed :
2.4 m/s

Wind Direction

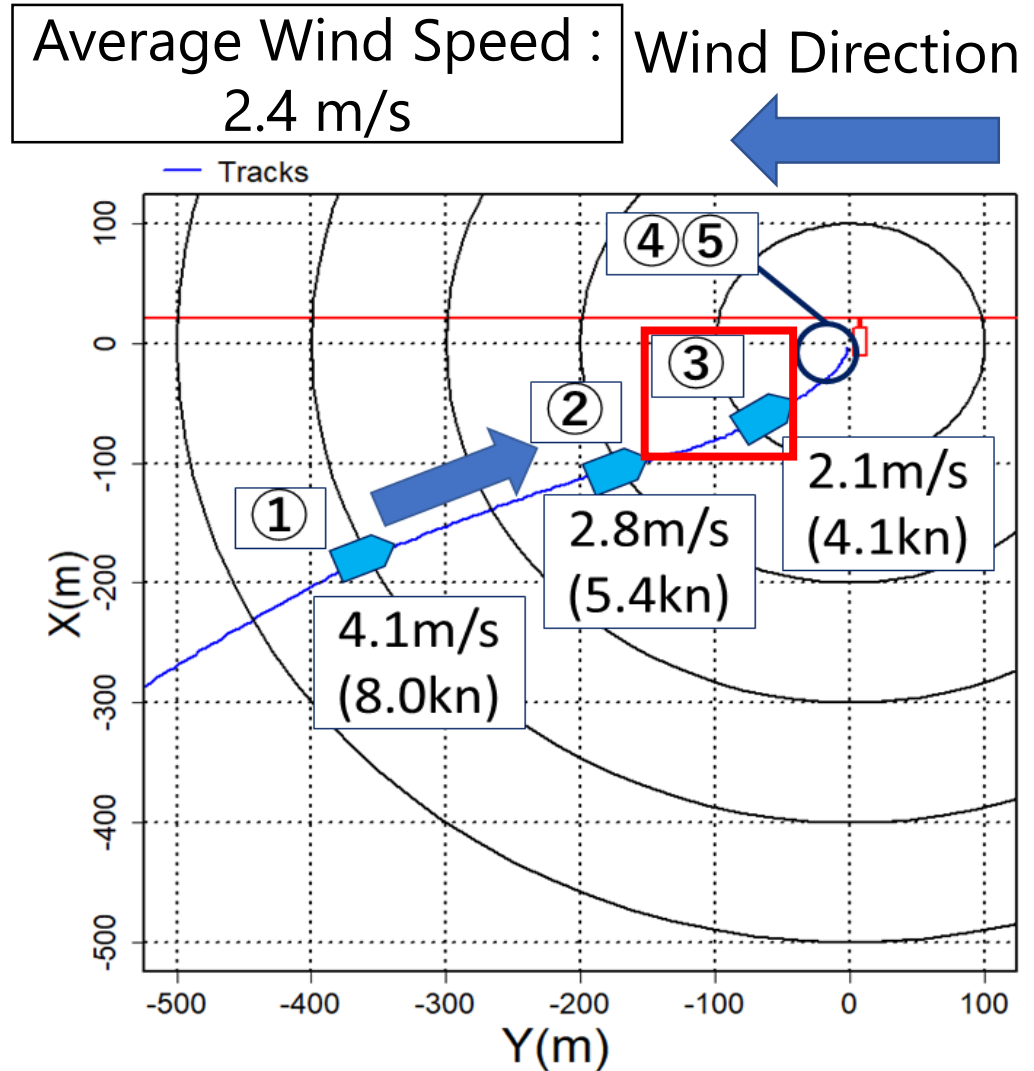


- ① Enters Berthing Operation Aiming at Slightly Outside of a Berth
- ② Decreases an Engine Speed to Idling Level
- ③ Sets a Clutch Lever into Neutral



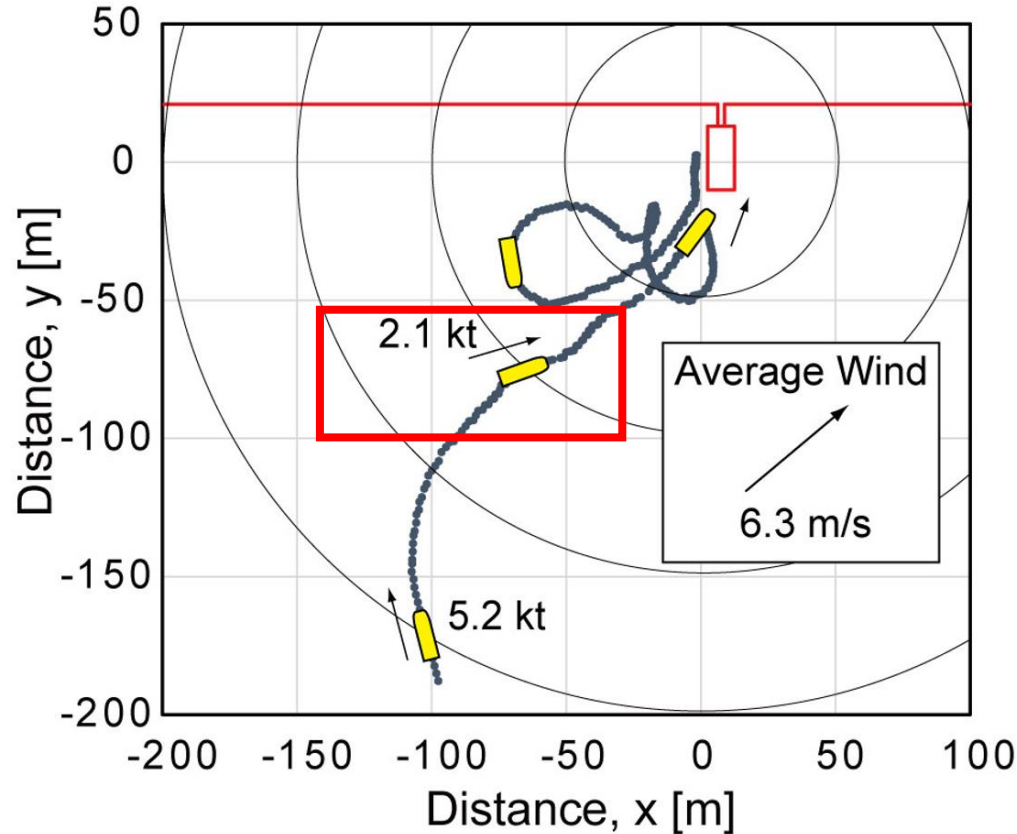
Analysis of Berthing Operation of Small Craft

- ④ Turns Left with a Large Rudder Angle toward the Berthing Point, while Checking Heading, Speed and Distance to the Berth
- ⑤ After Mooring Ropes Were Taken, Operates the Clutch Lever and the Thruster Switch to Adjust Position and Heading



Important to Operate a Small Craft by an Appropriate Course and Speed at Position ③

Example of Failed Berthing Operation



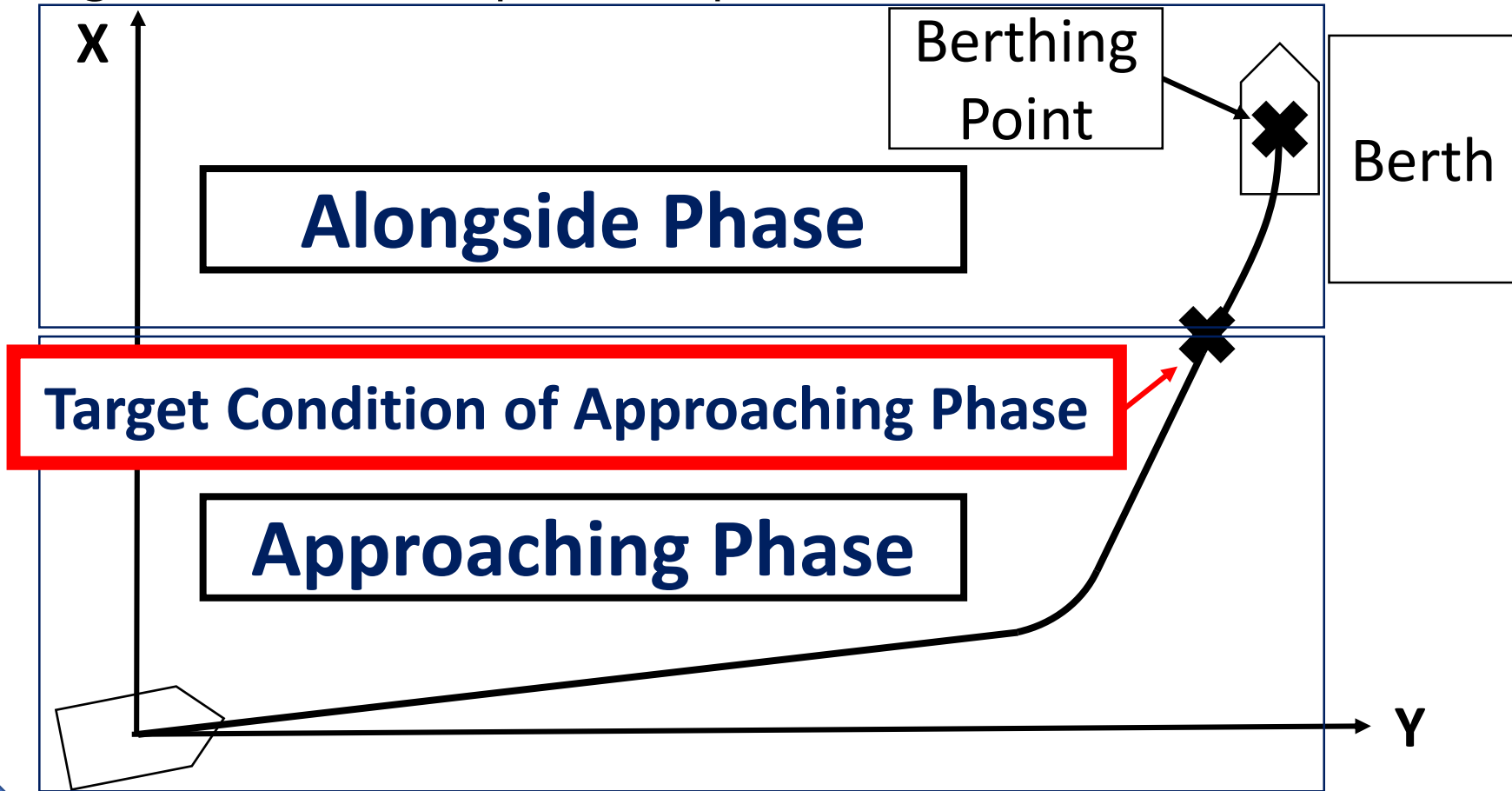
- A speed in red side was too slow and the craft was blew down to leeway.



Important to Plan and Guide That Satisfies Condition in Red Side

3. Proposal of Berthing Operation Support System

- ① Approaching Phase : Maneuver a Ship near a Berth
- ② Alongside Phase : Stop the Ship Parallel to the Berth



The system supports these phases using voice guidance.

3. Proposal of Berthing Operation Support System

- ① Makes Approaching Plan Using Maneuvering Motion Simulation That Satisfies Target Condition of Approaching Phase Consisted of Combinations of Element Maneuvers
- ② Supports the Operators' Operation Using Voice Guidance

3. Proposal of Berthing Operation Support System

Ship Operator : Starts the Support System

Support System : Plans that Passes Passing Points and Guides

X ↑ Start Time :
A Position, Course and Speed when the Operator Starts the System

Start Time

Passing Point 1

Shallow Waters

Passing Point 2

⑥ Engine Speed 20%.

③ Engine Speed 30%.

① Keep Speed.

Target Condition of Approaching Phase

⑤ Turn Left. Course 225.

④ Keep Speed.

② Turn Right. Course 270.

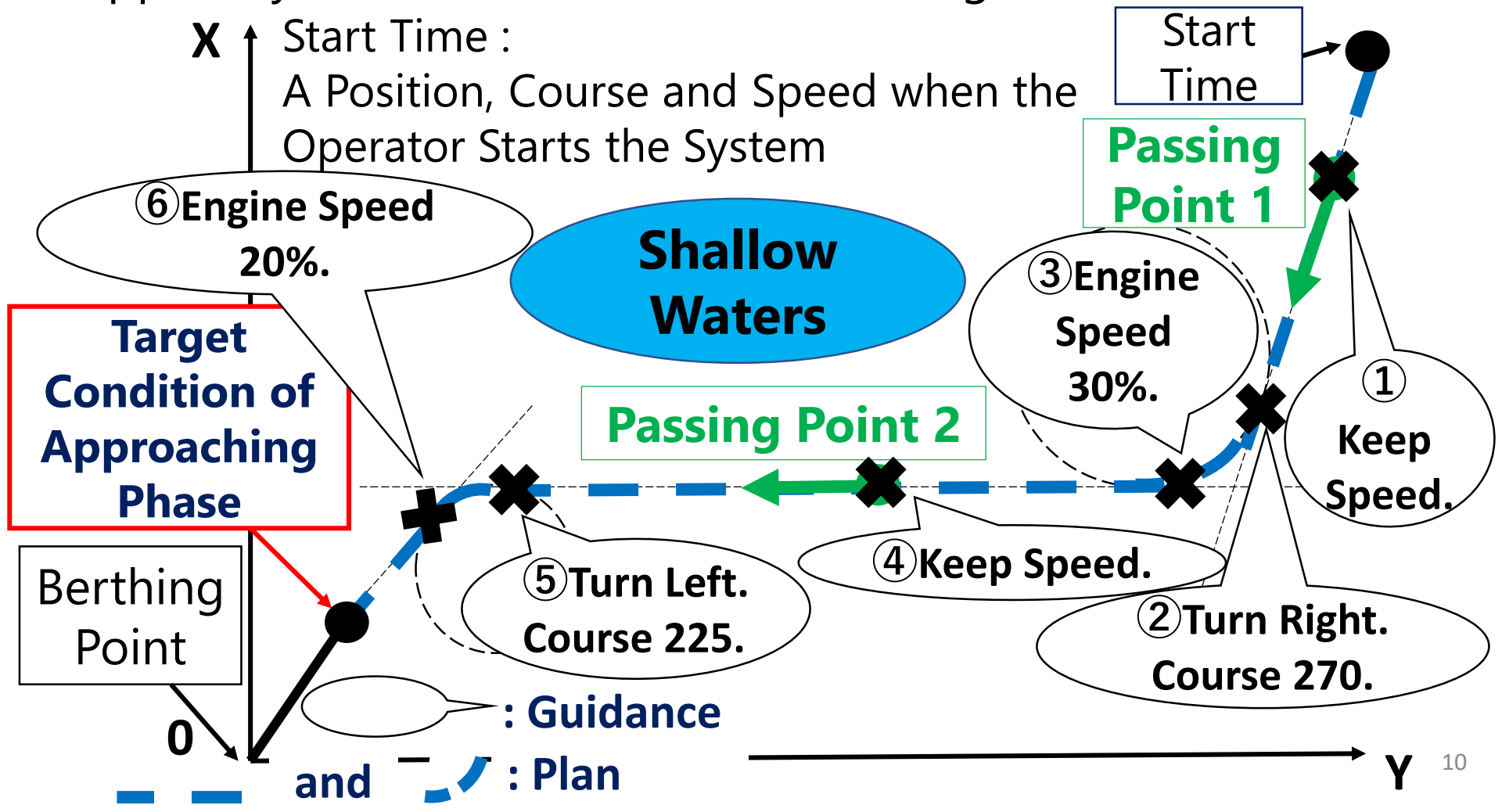
Berthing Point

0

: Guidance

and - - - : Plan

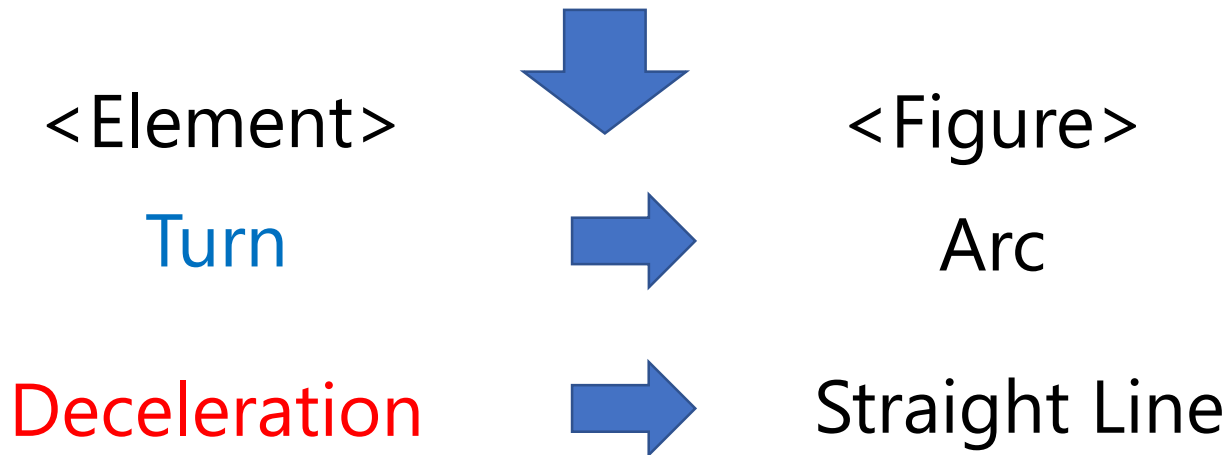
Y 10



① Plan Using Maneuvering Motion Simulation

Element Maneuvers :

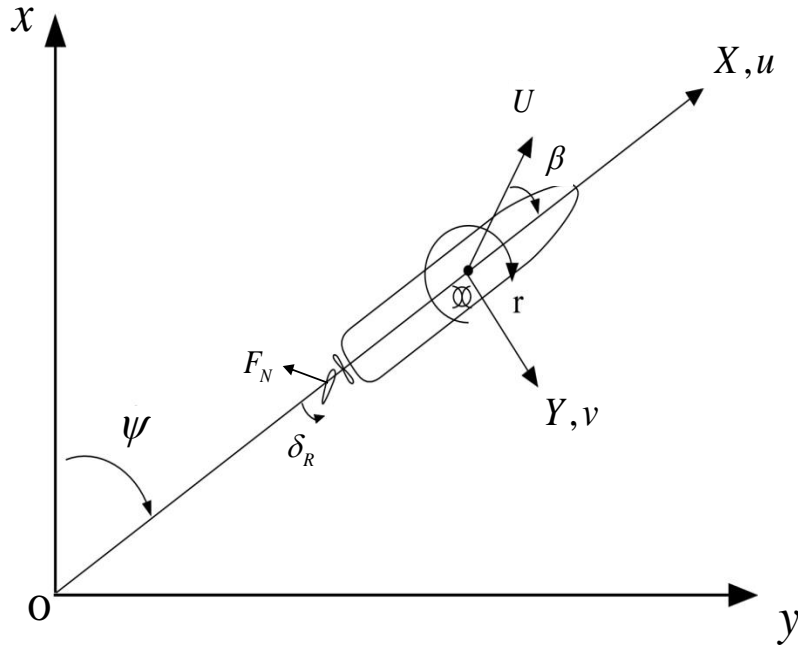
- Turn to Target Courses with a **Rudder Angle**
- Deceleration by Changing an **Engine Speed**



Plan :

- Combinations of these Element Maneuvers Using Maneuvering Motion Simulation With Re-Planning

Generally Used Precise Maneuvering Motion Model



m : Mass

m_x : Additional Mass in X Direction

m_y : Additional Mass in Y Direction

u : Velocity in X Direction

v : Velocity in Y Direction

r : Rate of Turn,

x_G : Center of Gravity

I_{ZZ} : Moment of Inertia around Hull Center of Gravity

J_{ZZ} : Additional Moment of Inertia

$X_H \cdot Y_H \cdot N_H$: Hydrodynamic Force and Moment by means of Maneuvering Motion

$X_P \cdot Y_P \cdot N_P$: Hydrodynamic Force and Moment by means of Propellers

$X_R \cdot Y_R \cdot N_R$: Hydrodynamic Force and Moment by means of Rudders

$X_A \cdot Y_A \cdot N_A$: Wind Pressure Resistance

$X_S \cdot Y_S \cdot N_S$: Hydrodynamic Force and Moment by means of Thrusters

$$\begin{cases} (m + m_x)\dot{u} - (m + m_y)vr = X_H + X_P + X_R + X_A + X_S \\ (m + m_y)\dot{v} + (m + m_x)ur = Y_H + Y_P + Y_R + Y_A + Y_S \\ (I_{ZZ} + J_{ZZ})\dot{r} - mx_G(\dot{v} + ur) = N_H + N_P + N_R + N_A + N_S \end{cases}$$

Simplified Model Used in Our Study

$$\begin{cases} (m + m_x)\dot{u} = T_P - R_f \\ (I_{ZZ} + J_{ZZ})\dot{r} = T_r - R_r \end{cases}$$

T_P : Propeller Thrust

R_f : Hull Resistance

T_r : Moment by Rudder Force

R_r : Rotation Resistance

Even with simplified maneuvering motion model, effectiveness for the support can be provided because the plan is modified based on the difference from actual tracks.

Concept of Approaching Planning

- Navigation plan is made based on Waypoints and Legs

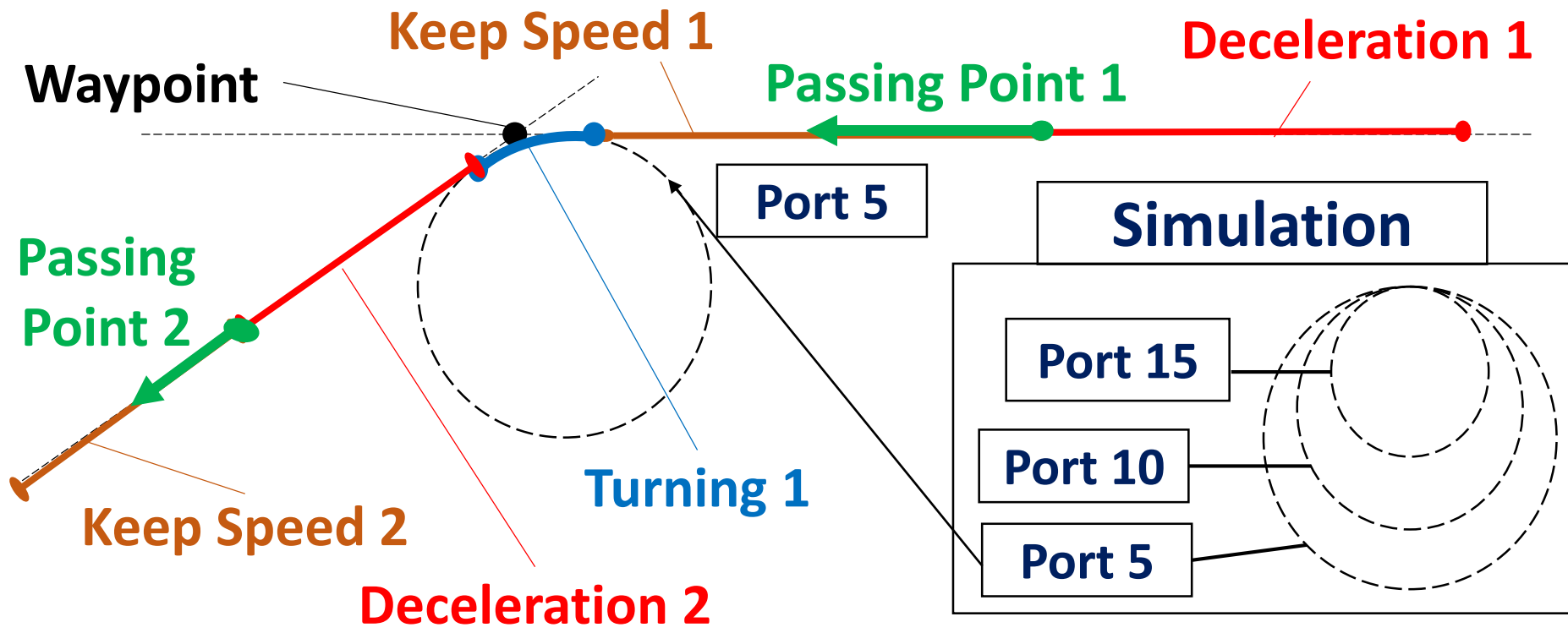
On the other hand,

- Approaching Plan is made based on Passing Points with courses and speeds (optional)

Approaching Planning is as follows:

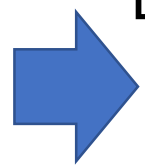
- Waypoints are generated as crossing points of course lines of neighboring Passing Points
- Turning Plan is made at each generated Waypoint

Illustration of Approaching Planning



Support System : at Turning 1

- Determines an Arc from the Selected Rudders Angle Simulation
- Finds Contact Points Using the Arc



Determine Start Points with Guidance of Rudder Angles

The simulation is used to determine turning and deceleration elements.

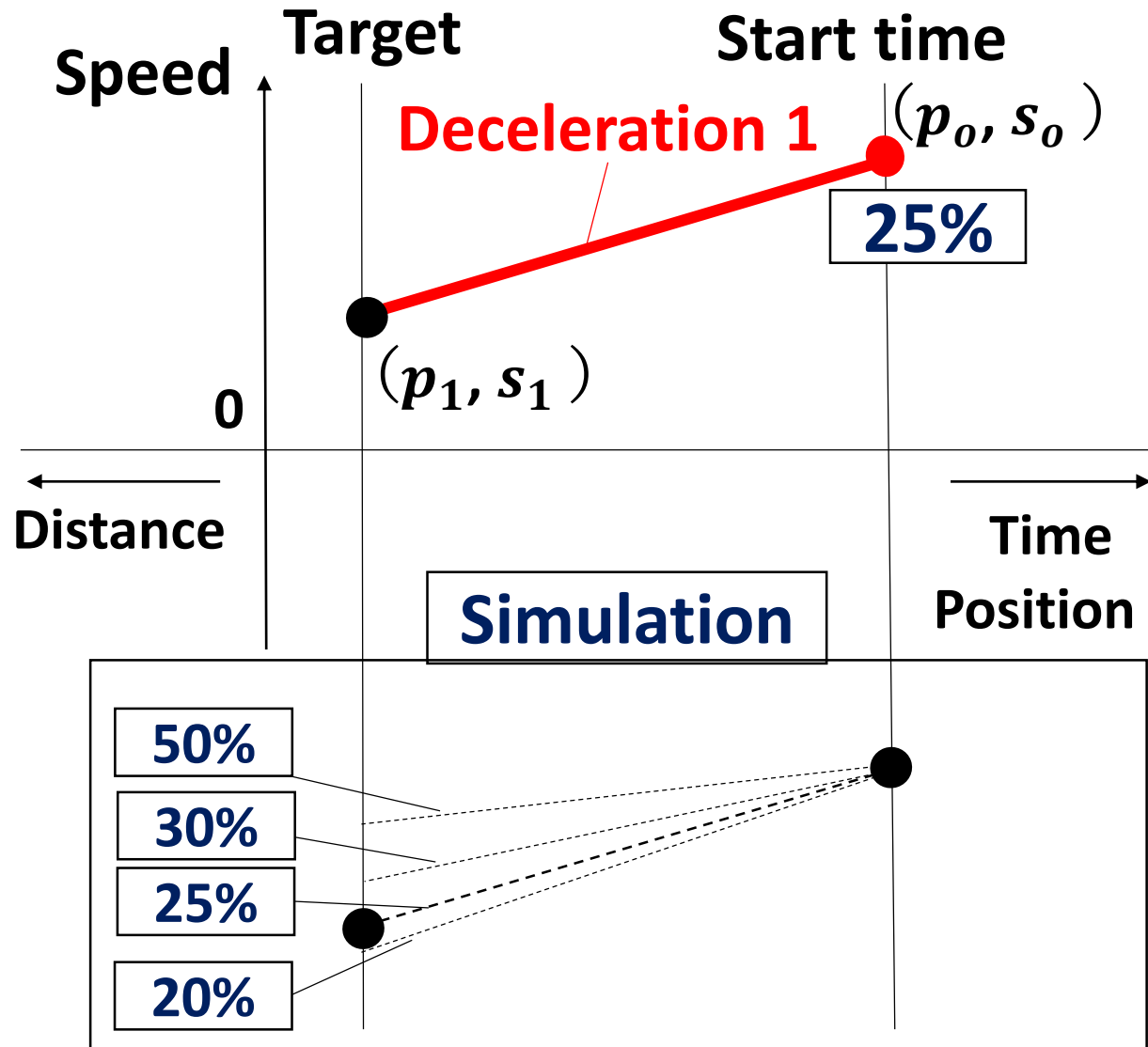
Determination of Deceleration

Support System :

- Plans to Change an Engine Speed at First
- Determines the Engine Speed That Satisfies Craft Speed of Start Time and Target



Generates Voice Guidance for the Engine Speed



p_0 : Start position、 s_0 : Start speed
 p_1 : Target position、 s_1 : Target speed

② Support Ship Operators Using Voice Guidance

• Turn

Start Point : ②⑤

Turn Right or Left

Rudder Angle and Target Course at the Right Time

• Deceleration

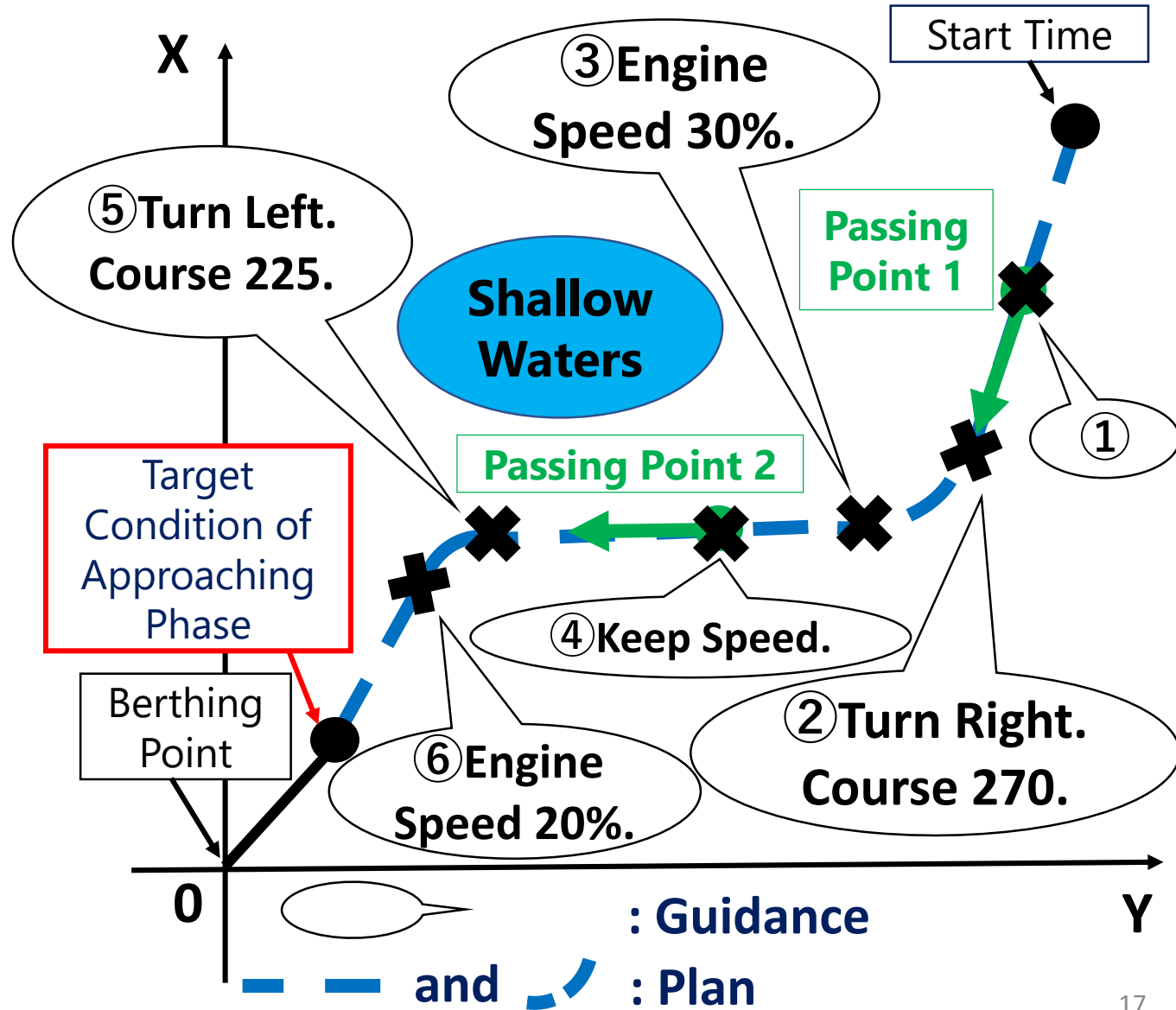
Start Point : ③⑥

Engine Speed's Percentage

Engine Speed at the Right Time

• including Keep Speed :

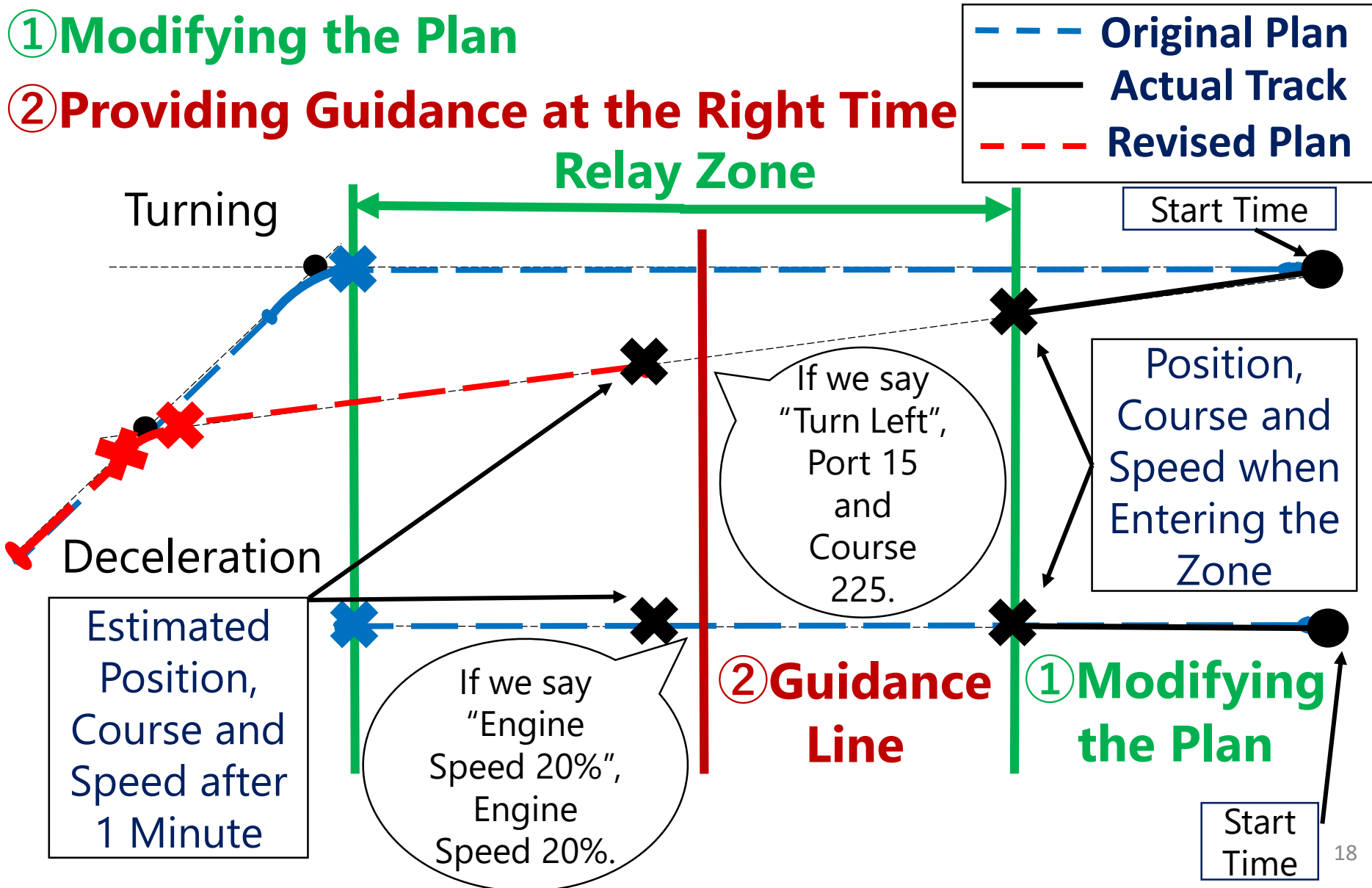
①④



Details of Procedures at Relay Zones between Element Maneuvers

① Modifying the Plan

② Providing Guidance at the Right Time



Berthing Operation Support System for Small Craft



Berthing Support System for Small Craft

National Maritime Research Institute, JAPAN

Oct. 2019

4. Conclusions

We proposed the following support system procedure ;

- Makes Approaching Plans Using Maneuvering Motion Simulation That Satisfies Target Condition for Approaching Phase Consisted of Combinations of Element Maneuvers
- Supports Ship Operators' Operation Using Voice Guidance

Subjects to be resolved :

- How to Guide Considering External Disturbance, Courses and Headings Including Alongside Phase
- How to Guide Actual Maneuvers with Sufficient Margin in Time and Space

Future work :

- Verify the Support System with an Actual Small Craft and Evaluate It's Effectiveness