NATIONAL TRANSPORTATION SAFETY BOARD
Office of Research and Engineering
Washington, DC

Conti Peridot Kinematics Parameter Extraction Study

September 11, 2015

D.A. Crider

A. ACCIDENT: DCA-15-MM-017

Accident Type:	Collision
Location:	Houston Ship Channel, Morgan’s Point, Texas
Date:	March 9, 2015
Time:	Approximately 17:30
Vessel:	*Conti Peridot* and *Carla Maersk*

B. GROUP IDENTIFICATION:

No group was formed for this activity

C. SUMMARY

See the IIC's accident summary

D. DETAILS OF INVESTIGATION

Introduction

The *Conti Peridot* and *Carla Maersk* collided after the *Conti Peridot* underwent a period of course oscillations from one side of the channel to the other. The motion of the ships is shown in fig 1 taken from the *Conti Peridot* and *Carla Maersk* Motion Study.

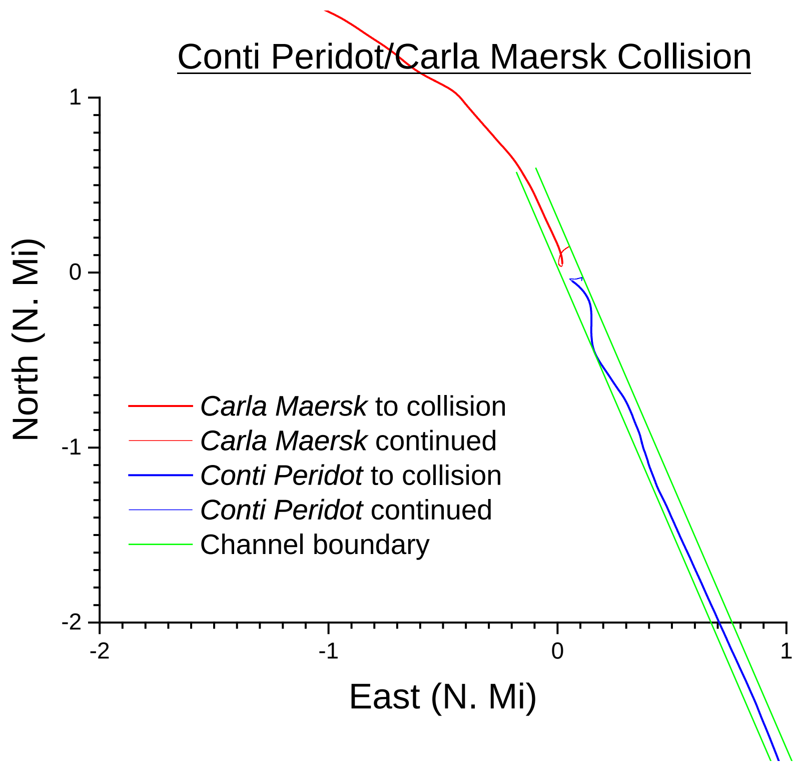

Figure 1 Conti Peridot/Carla Maersk paths (at GPS antenna)

A kinematic parameter extraction study was conducted to determine the forces and moments acting on the ship and correlate these forces and moments with rudder position and position in the channel.

Fig 2 illustrates the physics involved in turning a ship. To turn a ship rudder is first applied. This rudder angle produces a yawing moment which rotates the ship about its vertical axis producing a sideslip angle. As shown in fig 2, sideslip angle is the angle between the ship's heading and the direction of its motion through the water. This sideslip angle in turn produces a side force that turns the path of the ship. The sideslip angle also changes the yawing moment on the ship. This change in yawing moment with sideslip angle is dependent on the ship's hull shape, loading and squat effects (depth and speed).

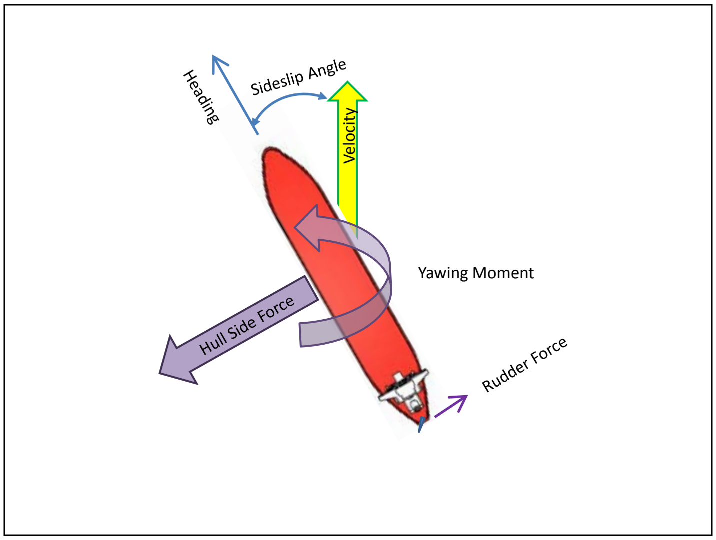

Figure 2 Ship Turning Dynamics

When near the side of a channel, additional effects on yawing moment come into play. These effects increase with ship speed. When approaching the side of a channel at an angle a bank cushion effect may develop which pushes the bow away from the bank (fig 3). When the ship's course is more parallel to the side of the channel, a suction effect may develop towards the stern which again turns the bow away from the bank (fig 4).

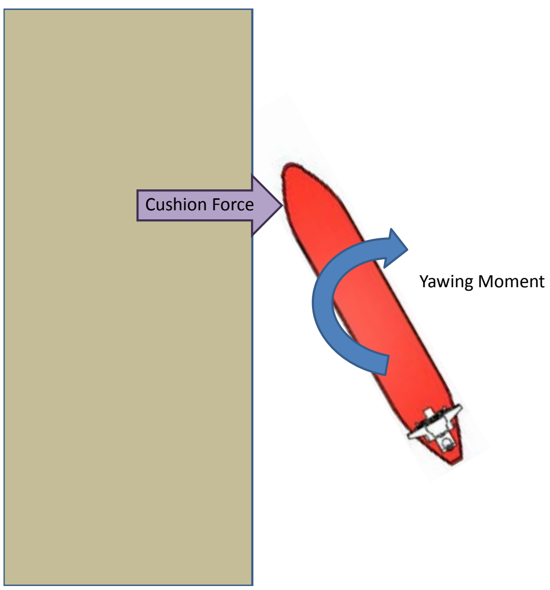

Figure 3 Bank cushion effect

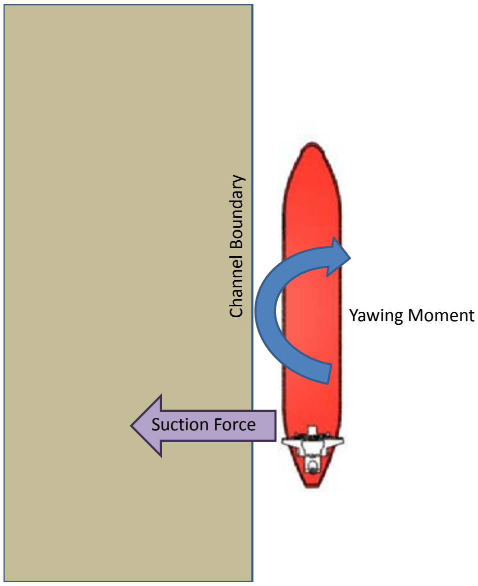

Figure 4 Bank suction effect

Referring to fig 2, sideslip angle, yawing moment and side force determine the motion of a ship in a turn. These parameters in turn are affected by rudder (often with the influence of power) as the primary control with position, orientation and speed in the channel the correlating factors for channel effects.

Sideslip angle, yawing moment and side force for the study were determined with a kinematics parameter extraction. Kinematics parameter extraction is a simulation based technique that solves the equations of motion for the forces and moments that caused the recorded motion. Note that this determination of required forces and moments is independent of the ship's simulation model. It is only dependent on the ship's motion, weight and inertia. Unlike forces and moments, the extracted sideslip angle[1] shown in this report is dependent on ship's modeling. Routinely, in simulation, parameters in the models are adjusted to match test data. Accordingly, to ensure accurate sideslip estimates the model, primarily the variation of side force with sideslip parameter, was adjusted to match the magnitude of the sideslip estimated from recorder heading and course. This match will be shown later in this report.

Available Data

Data available from the *Conti Peridot* Voyage Data Recorder (VDR) used in the kinematics extraction are plotted below. Speed is plotted in fig 5 while heading and course is plotted in fig 6.

[1] Sideslip is negative drift angle.

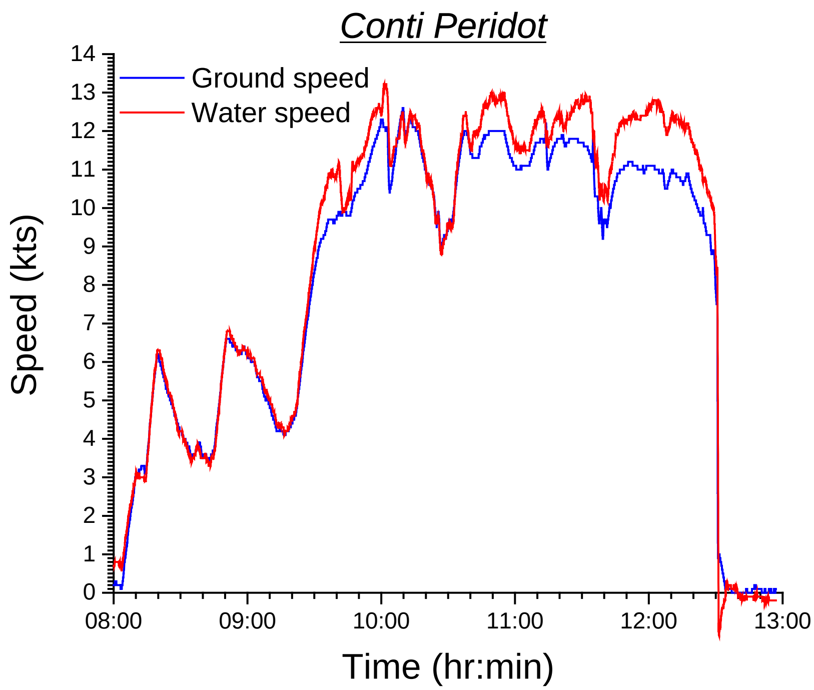

Figure 5 Speed

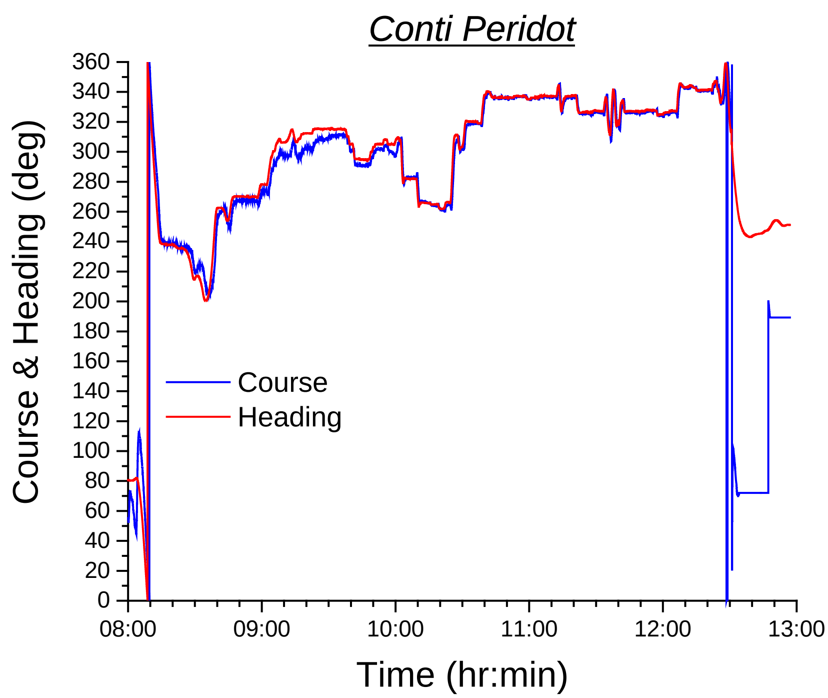

Figure 6 Course & heading

Water depth (surface to bottom) is given in fig 7. While not a parameter input into the kinematics extraction, it is nevertheless a parameter important to the hydrodynamic forces on the ship.

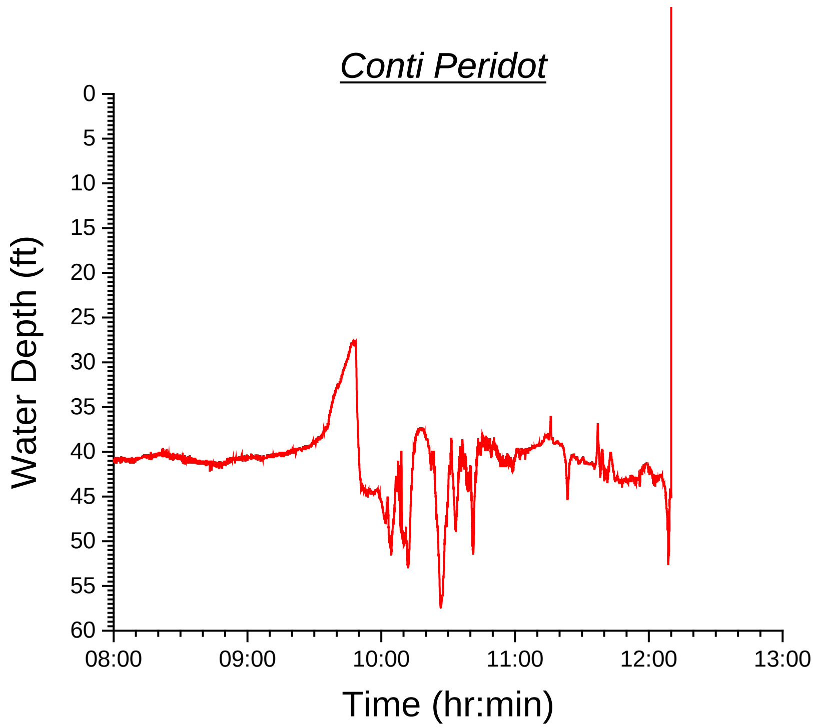

Figure 7 Water depth

Sideslip Match

Sideslip is the angle between the ship's long axis (bow to stern) and the velocity vector of the water. As mentioned above, the variation of side force with sideslip was adjusted to match the magnitude of the sideslip estimated from the difference in recorder heading and course. The match is shown in fig 8.

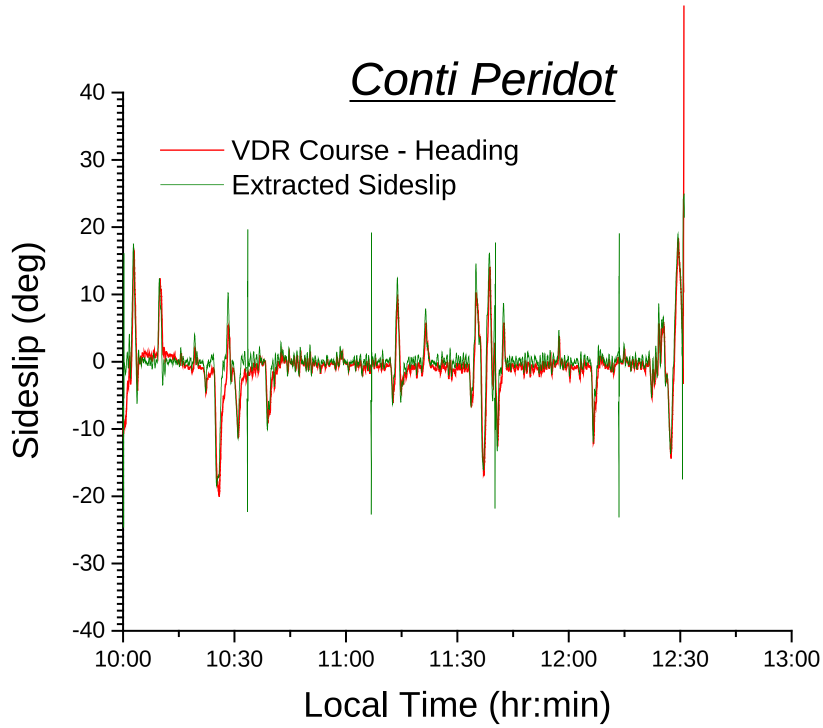

Figure 8 Sideslip match

Kinematics Extraction for the accident

As discussed above (see fig 2), ship turns are caused when rudder and bank effects produce a yawing moment which produces a sideslip angle that results in a side force that changes the ship's path. This sequence of yawing moment, sideslip angle and side force is shown in fig 9, 10 and 11 each of which also show position in the channel, true heading vs. channel course as well as rudder for correlation.

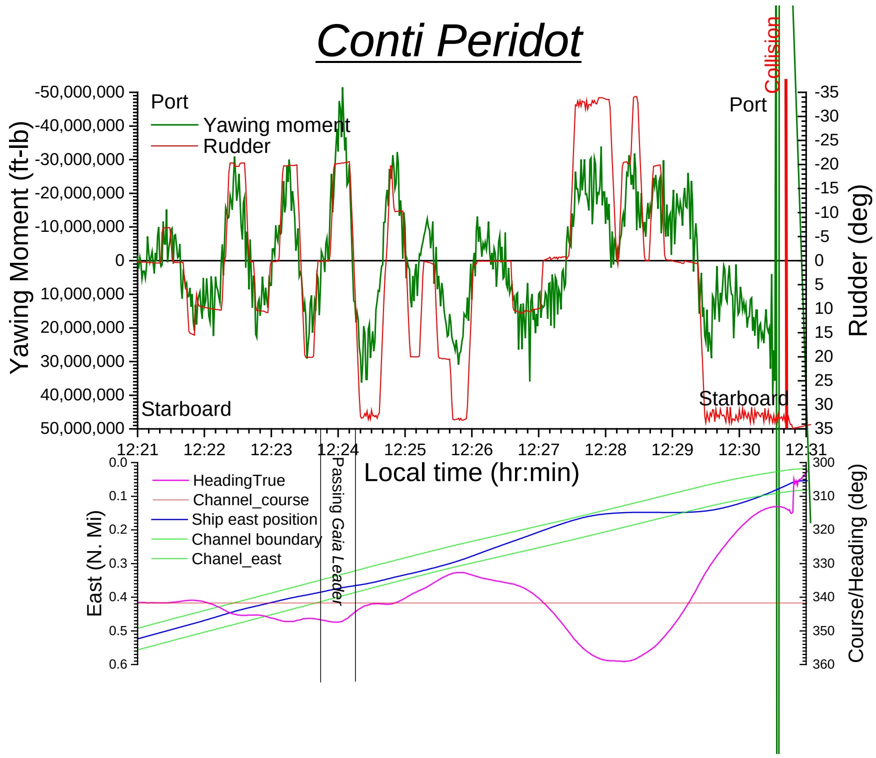

Figure 9 Yawing moment

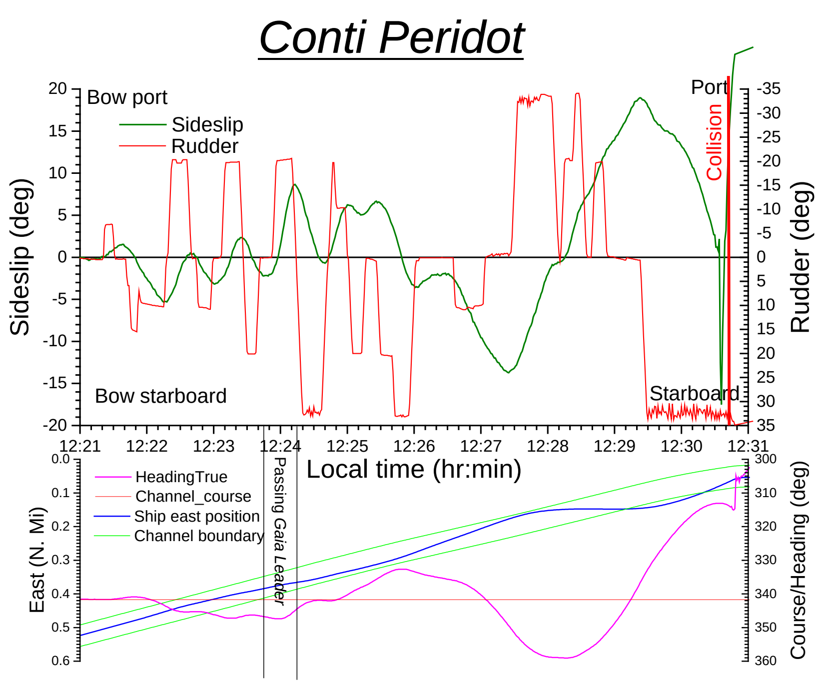

Figure 10 Sideslip angle

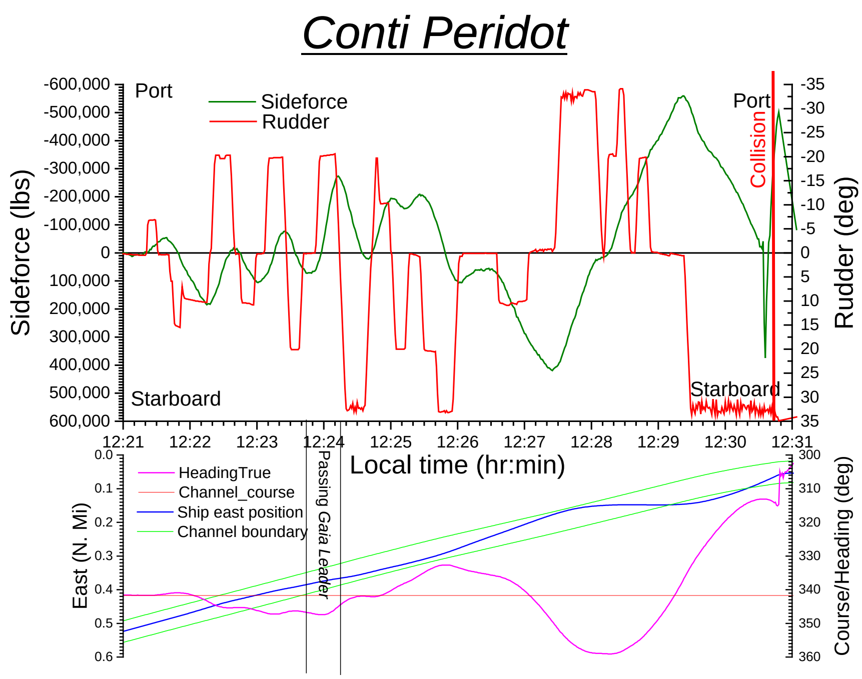

Figure 11 Side force

Examination of the yawing moment shown in fig 9 shows that yawing moment was dependent on bank effects as well as rudder. Deviation from the channel course began about 12:22 just prior to passing the southbound *Gaia Leader* between about 12:23:45 and 12:24:15. The *Gaia Leader* was on the west of the channel while the *Conti Peridot* approached on the east side. Fig 9 shows a nominal yawing moment per deg of rudder during this slight course change until the 20 degree port rudder at about 12:23:50. At this point, there is an additional port yawing moment. The additional port yawing moment continues through the starboard 30 rudder at about 12:24:20. A port yawing moment would be expected as the bow of the *Conti Peridot* clears the stern of the southbound *Gaia Leader*. The additional port yawing moment continues between 12:25 and 12:26 as the ship is closest to the east side of the channel. The additional port yawing moment continues to be seen when rudder is centered at 12:26. This port yawing moment switches to starboard as the bow approaches the west side of the channel before 10 degrees starboard rudder is applied at about 12:26:35. This additional starboard yawing moment continues at 12:27 when rudder is again centered. Additional starboard yawing moment continues through 12:27:30 when hard port rudder was applied. Normal rudder response returned by 12:28:30 to be replaced by additional port yawing moment while hard starboard rudder is applied at 12:29:30 as the ship approaches the east side of the channel.

The longitudinal force that accelerates/decelerates the ship is plotted in fig 12. Note that the decelerating force that begins at 12:29 corresponds to a period of time when the ship is at the starboard side of the channel and that power was increased shortly after this deceleration began.

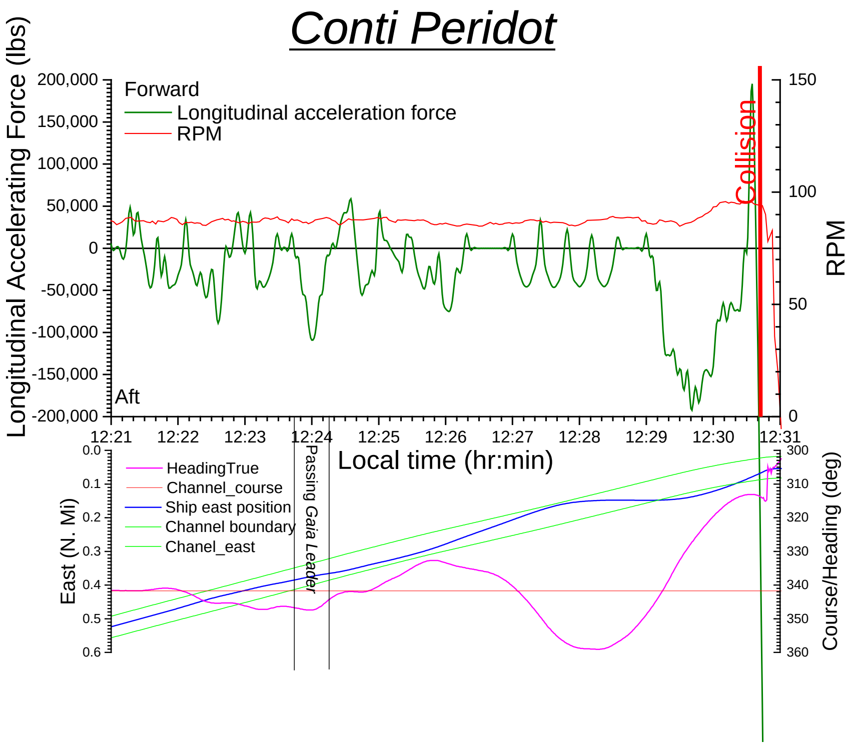

Figure 12 Accelerating force

Earlier Yaw Events

As can be seen in fig 13, in addition to the heading oscillations prior to the collision after passing the *Gaia Leader*, there were earlier heading oscillations beginning at 11:12 and at 11:33. Examination of the *Conti Peridot* PPU shows that the 11:12 event was a turn to the east side of the channel in preparation for passing the southbound *BW Kyoto* in the west side of the channel. The *Conti Peridot* returned normally to the center of the channel after passing the *BW Kyoto* without any overshoot to the west side of the channel.

The yaw oscillation that begins at 11:33 is associated with passing the southbound *Karoline N* from 11:34:44 (bow to bow) to 11:35:21 (stern to stern) and the southbound *Stolt Span* from 11:39:35 (bow to bow) to 11:40:07 (stern to stern). In this case, the *Conti Peridot* gets closer to the east side of the channel before turning port and overshooting the channel center at about 11:36 to the west side of the channel where the *Conti Peridot* turns starboard and overshoots the center of the channel again to be in the west side of the channel before turning back to the center when the *Stolt Span* passed on the east side. After passing the *Stolt Span* the *Conti Peridot* continues to be on the east side of the channel before turning starboard again and reestablishing a constant heading on the channel centerline.

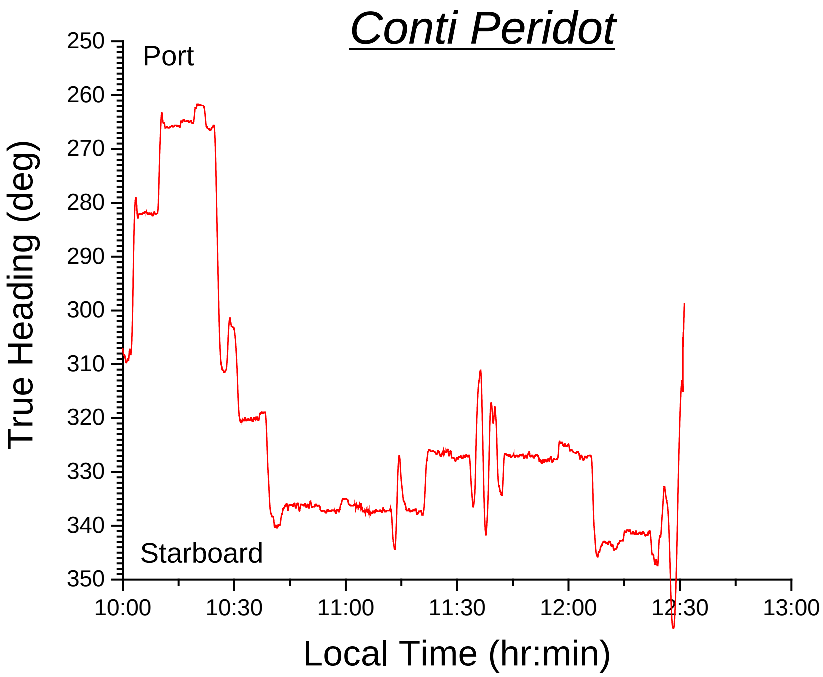

Figure 13 True heading

The extracted yawing moment for the period of the encounter with the *Karoline N* and *Stolt Span* is given in fig 14. As can be seen, there is significantly more port yawing moment at 11:34 than from the 10 degree port rudder alone. The additional port yawing moment continues opposing the effectiveness of the 35 deg starboard rudder at 11:35. Port yawing moment is expected at this time due to the proximity of the east channel boundary. The ship continues port past the centerline where some starboard moment from the channel opposes port rudder at 11:37. The accelerating force for the encounter is plotted in fig 15.

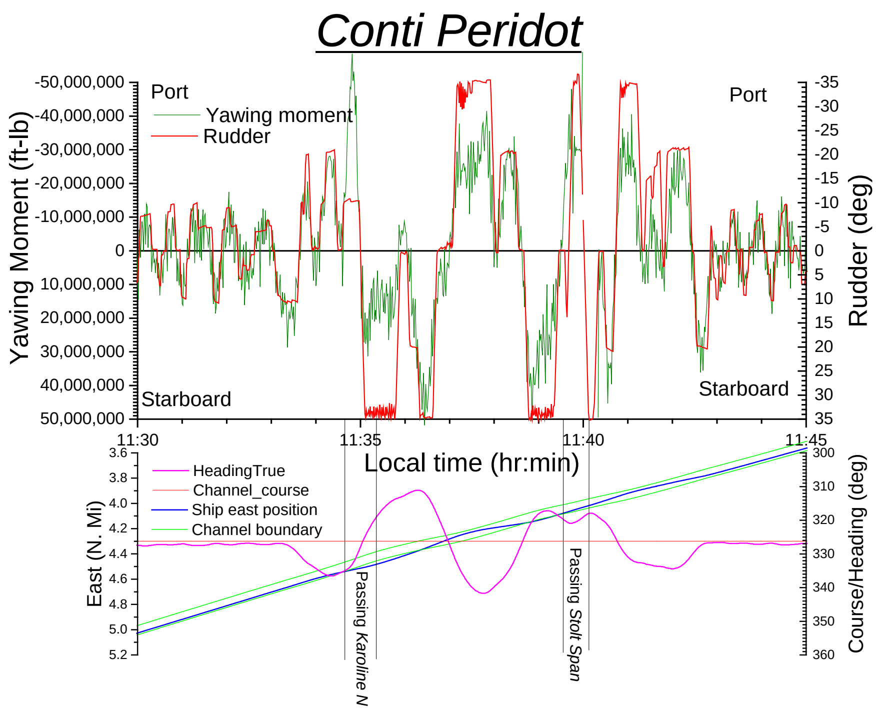

Figure 14 Yawing moment for *Karoline N* and *Stolt Span* encounters

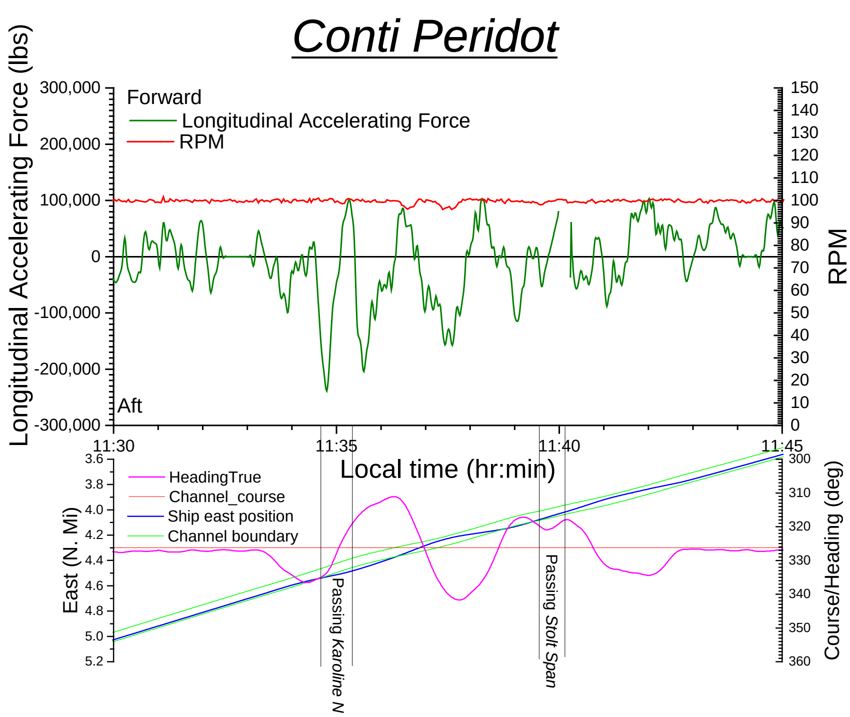

Figure 15 Accelerating force for *Karoline N* and *Stolt Span* encounters

Summary

The accident sequence began with the *Conti Peridot* altering course to starboard generating clearance to the southbound *Gaia Leader* traveling on the west side of the channel. The *Conti Peridot* experienced port yawing moment from the *Gaia Leader* and the east bank beginning as the ships passed. Additional starboard rudder was available to counter this yaw during this period. The *Conti Peridot* then approached the west side of the channel where bank effects produced a starboard yawing moment which turned the ship towards the east side of the channel where bank effects moved the ship to port and into the southbound *Carla Maersk* despite application of full starboard rudder. The accident occurred during the second yaw oscillation across the width of the channel during the transit up the channel involving hydrodynamic forces from the channel walls.