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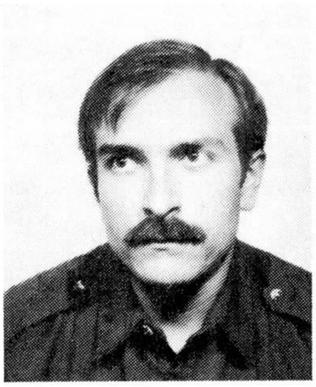
Modeling Ship Manoeuvres in Arbitrary Fluid Domains

Modèle de manoeuvre dans un domaine fluide arbitraire

Simulation von Schiffsmanövern in willkürlichen Strömungsbereichen

A. S. ARCILLA
Prof. Dr.-Ing.
University of Barcelona
Barcelona, Spain



A. S. Arcilla got his civil engineering degree at the University of Madrid. He followed postgraduate courses at several European Universities and defended his Ph. D. Thesis at the University of Barcelona. For five years he was involved in environmental conditions for the design of maritime structures. Now he is professor of Ocean Engineering.

SUMMARY
The motion of a ship as it advances towards a bridge or structure is performed in a fluid domain of varying geometry. The numerical simulation of this problem requires a different spatial discretization at each time step. To simplify the calculations a modified set of governing equations is presented here. The paper explains how to obtain these equations and their advantages.

RÉSUMÉ
Le mouvement d'un bateau à l'approche d'un pont ou d'une structure, est réalisé dans un domaine fluide à géométrie variable. La simulation numérique de ce problème nécessite une discrétisation spatiale différente pour chaque intervalle de temps. Pour simplifier les calculs, une version modifiée des équations de base est présentée. L'article montre le calcul de des équations et leurs avantages.

ZUSAMMENFASSUNG
Die Bewegung eines Schiffes in der Nähe einer Brücke oder Struktur wird in einem willkürlichen Strömungsbereich mit wechselnder Geometrie untersucht. Die numerische Simulation dieser Aufgabe erfordert eine räumliche und zeitliche Diskretisierung der Hauptgleichungen. Eine vereinfachte Berechnung wird mit deren Vorteilen vorgeschlagen.

1. INTRODUCTION

The motion of a ship in the vicinity of a structure, even to the point of collision, is a problem of great practical significance but difficult to simulate numerically. To illustrate this we shall consider both ship and structure as rigid bodies which means that the model is valid up to the instant of collision. The fluid domain in which the ship moves varies with time. Therefore, the boundary of this domain is different at each time step and a new spatial discretization is required at each time level. Furthermore, the motion of the ship, resulting from waves, current and wind action and the corresponding rudder and propeller forces, will be far from sinusoidal. This fact, together with the non-linearity of the system, precludes an analysis in the frequency domain as is usual for sea-keeping studies. On the other hand, most of the models dealing with the motion of a ship in the time domain are suitable for just two cases:

- The fluid domain geometry is constant at each time step. This happens when the ship performs small oscillatory motions from a stationary average position. A typical example could be a moored ship.([1], [2]).

- The ship performs small oscillations superposed to a rectilinear, uniform motion, as e.g. when she is under way. The corresponding equations are shown in [2] but they are not intended for arbitrary fluid domains. The reason is that the main aim of the model were the motions of a ship under way, subject to wave action, and this usually happens in relatively deep water.

In other words, most of time-domain analyses, reviewed in [3] and [4] are not prepared to tackle with ships moving very near a structure and performing a highly irregular motion due to waves, currents, winds and the corresponding actions of propellers and rudders. The model introduced in this paper develops the governing equations for this problem. It will be organised as follows:

- Brief review of currently used mathematical models.
- The proposed formulation.
- References.

2. REVIEW OF CURRENTLY USED MODELS

Models used to predict the motion of a rigid body are based on Newton's second law. The main difficulty arises from the hydrodynamic forces on the body. These forces depend on the geometry of the domain and on the environmental disturbances acting (e.g. waves and current). There are two approaches to solve this problem:

- The well-known method of hydrodynamic coefficients in which forces are expressed as a combination of variables significant to the problem affected by the appropriate coefficients.

- The development of a mathematical model starting from a set of basic hypothesis.

The first method is not recommended for restricted fluid domains with arbitrary geometry as many of the coefficients do not have a clear physical meaning and must be evaluated through model tests ([5]). This situation worsens if the geometry varies at each time step. The second approach starts considering that the hydrodynamic forces on the body are associated to inertial, gravitational and viscous effects. The latter will be modelled here with a standard velocity squared law [6], to focus the attention on the first two. The corresponding forces will be called "potential" for, since viscosity is left out of this part of the analysis, the resulting fluid motion will be described in terms of a potential function $\emptyset$. The standard models to evaluate potential forces in restricted waters are not able to deal with a ship moving in the vicinity of a structure, from a certain distance apart right up to the point of collision. There are two reasons:

- The variation, with time, of the domain geometry in which the ship moves.

- The boundary condition on the immersed surface of the ship. This condition must be imposed on the exact position of the surface ([7]). Only if the motion consists of small oscillations from a stationary average position, can the condition be imposed on this average surface.

3. PROPOSED FORMULATION

The proposed model will obviate some of these difficulties by solving an alternative problem in which the ship remains fixed in space and it is the fluid and the rest of the boundaries that perform a motion equal and opposite to that of the ship. This situation (S2) is obtained from the real one (S1) by applying to every element of the system the additional accelerations $(-\ddot{x}_j)$, j=1-6, in which the $(\ddot{x}_j)$ define the motion of the ship. In order to include an average trajectory plus the wave-induced motions the six degrees of freedom must be retained throughout the development. The first three (j=1, 2, 3) denote translations and the remaining ones (j=4, 5, 6) rotations with respect to the same axes. The problem, as it has been said, will be solved in the time domain by means of the impulse-response-function technique ([4]). In each time step the potential equation, $\nabla^2 \emptyset = 0$, will be solved with a 3D sink-source technique, described, e.g. in [8]. Now it is necessary to calculate the "differential forces", if any, between the real (S1) and fictitious (S2) situations. These forces will be due to the additional accelerations, $(-\ddot{x}_j)$, j=1-6. Consider now the translatory motion defined by $(\ddot{x}_j)$, j=1-3. These accelerations (in the fluid domain) must be generated by a force field per unit volume:

$-p\ddot{x}_j$, j=1, 2, 3; p being the mass density of the fluid. This force field must be generated by a pressure gradient in the j-direction (j=1, 2, 3): $p\ddot{x}_j$.

The resulting pressure field is: $p\ddot{x}_j x_j$, for a fixed j (j=1, 2, 3). Therefore, the generalised "differential force" in mode k(k=1-6) due to an acceleration in mode j (j=1-3) is $DF_{kj} = -\iint_s p\ddot{x}_j x_j n_k ds = -p\ddot{x}_j \iint_s x_j n_k \, ds = -p\ddot{x}_j a_{kj}$ in which s is the immersed surface of the ship and n_k is the unit nomal vector, positive towards the fluid. The coefficient a_{kj} is a function only of the immersed surface geometry because $(\ddot{x}_j)$ is constant in the fluid domain.

The evaluation of these DF_{kj} has been quite simple in this "purely translational" case because, in this case, the fluid motion is irrotational and, thus, the resulting hydrodynamic pressures, normal to S. The differencial forces (DF's) associated to the rotational case are somewhat more difficult to calculate unless the tangential component of the pressure is neglected. This has been done in [9] based on the fact that the DF coming from the accelerations of rotation affects the viscous force, while the emphasis of the model was in the potential force.

The resulting expressions are:

$$DF_{kj} = -p\ddot{x}_j \, b_{kj} - p(\dot{x}_j)^2 \, c_{kj} \quad k=1-6 \ , \ j=4-6$$

It should be noted that, if the impulse function technique is applied potential forces on the ship can be calculated either in S1 or S2. This is because in each time step only impulsive motions are performed in which no linear accelerations exist. Observe that, with this model structure, the only "correction" for the potential force comes from the DF_{kj}, j=1, 2, 3. Summarizing, in each time step the potential problem is solved as it would be done for a ship with a stationary average position ([1]). Next, the resulting hydrodynamic forces on the ship in each time step are composed linearly. Let us assume that, in time step i, the instantaneous potential force is PI_k^i (t), k=1-6, and the "differed" one, due to the memory effect introduced by the free-surface, is PD_k^i $(t-Z_i)$. Z_i is the instant in which time step i ended ([9]). The total potential force, P, can then be evaluated as:

$$P_k^i \ (t) = PI_k^i \ (t) + \sum_{l=1}^{i-1} PD_k^l \ (t-Z_l) \qquad k=1-6$$

Substituting these expressions, together with the "differential forces", in the equations of motion the following structure is obtained:

$$E_k^i \ (t) = A_{kj}^i \ \ddot{x}_j + D_{kjl}^i \ \dot{x}_j\dot{x}_l + P_{kj}^i\dot{x}_j + C_{kj}^i x_j + f_k^i(t); k, \ j,l=1-6$$

in which:

$E_k^i(t)$ is the external exciting force, in time step i, and may include the action of waves, currents, tug-boats, etc.

f_k^i (t) is the memory function due to the free-surface effect.

The precise formulation of the function f_k^i (t), together with that of the coefficients A_{kj}^i, D_{kjl}^i, P_{kj}^i, and C_{kj}^i may be found in [9].

4. SUMMARY AND CONCLUSIONS

A formulation to predict the motion, with 6 degrees of freedom, of a rigid body in a restricted fluid domain has been proposed. The problem has been solved in the time domain, the emphasis being placed on the potential reaction.

It is recognised the need to develop a similar model for the viscous reaction. Due attention should also be paid to the "external exciting force" and to the numerical propagation of errors, which is now being studied for the proposed model.

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Minimizing the Risk with Vessel Traffic Management Systems

Réduction des risques avec des systèmes de gestion de la navigation maritime

Verminderung des Risikos mit Systemen zur Schiffsverkehrssteuerung

John VENDRELL
Master Mariner, MRIN MNI
Vendrell Associates Ltd.
St. Keyne, United Kingdom

John Vendrell is a mariner with some fifty years' deep sea experience. Over the past ten years he has specialised in the offshore energy industry in European continental shelf waters, Brazil, the West Indies, West Africa, Egypt and India. He is a Member of the Royal Institute of Navigation and a Member of the Nautical institute.

SUMMARY
This paper examines the need for sophisticated radar surveillance of marine traffic and, in particular, vessel traffic management at the interface between shipping and the rapidly expanding offshore oil industry with particular reference to the North Sea.

RÉSUMÉ
Cette étude se penche sur la nécessité d'une meilleure surveillance radar de la navigation maritime, et, plus particulièrement, de la gestion de la navigation maritime tenant compte du transport maritime et de la croissance rapide de l'industrie pétrolière en mer, en particulier en Mer du Nord.

ZUSAMMENFASSUNG
Der Artikel untersucht die Notwendigkeit einer besseren Radarüberwachung des Marineverkehrs und besonders der Schiffsverkehrssteuerung, welche die Schiffahrt und die rasch wachsende Meeres-Ölindustrie in der Nordsee berücksichtigt.

1. HISTORICAL

1.1 Traditionally, the principle of freedom of the seas has meant for many centruries, the right of the Shipmaster to navigate his Vessel where and how he deems it to be safe, practicable, and in the best commercial interests of his Owners. If it is conceeded that every Vessel is, at all times, under the conscientious and competent control of an experienced Master and Bridge Watchkeeper, then it would seem that there can be no argument against this long standing concept. Without exception the law of every Maritime Nation places the ultimate responsibility upon the Master of a Vessel for the safe navigation and conduct of his vessel and in such circumstances it cannot be doubted that the Shipmaster must, even where a degree of external control is exercised over his function, be the final arbiter in regard to the handling of his Vessel with due regard to circumstances prevailing at any moment.

1.2 "Experience" with "Competence" on the Bridge of a Vessel unfortunately, is not always sufficient to ensure that catastrophe is avoided. When, in the early post war years, Merchant Vessels were being equipped with Marine Radar there came into existence the term "Radar Assisted Collision", perhaps the first and worst example being the collision between the "Andrea Doria" and "Stockholm" in the open seas off the Nantucket Lightship in July of 1956 when the "Andrea Doria" sank with the loss of 43 lives. The Automatic Steering boon brought with it in many ships the one man watch system displacing the 'lookout' on the grounds that the Bridge Watchkeeper could now concentrate on this duty. The infamous "Torrey Canyon" stranding on the Seven Stones Reef in March 1967 effectively illustrated the fallacy of this principle. Even the introduction of Hyperbolic Navigation lent itself to demonstrations of human failure in that, within the confines of the North Sea; that most treacherous of crowded waters; some Mariners discovered a method of simplifying the use of their Decca Lane Receivers whereby a crossing from one coast to another could be accomplished by setting the Vessel initially on a suitable "Lane" indicated on one of the three Decometers and then, by making small adjustments of course necessary to hold the Vessel on the selected Lane, the crossing became simplified and avoided the need for the inconvenience of plotting on the Chart. Inevitably this gave rise to the extremely precise "Decca Assisted Collision" when ships bound in opposite directions elected to navigate directly towards one another on the same lane.

1.3 Radar Surveillance and direct Control of Aircraft from Ground Stations is universally accepted and, within the confines of Marine Pilotage Waters generally, similar Surveillance and Control is often exercised under the laws of Nations or the bye-laws of the Marine Authorities in whose jurisdiction a particular waterway lies, though it must be stated that very many Authorities still rely more on data gathered from V.H.F. reports and processed by manual plotting than upon the more reliable output of a modern Computerised Radar Facility. In the offshore Sea Lanes however the situation is not so clearly defined and where Surveillance exists, the principle of "Control", is by International agreement, one of "Advice" which may or may not be accepted by the Shipmaster. However, the experience of Shipping in the dense traffic situations of the separation lanes in the Dover Strait and off the Cherbourg Peninsula has, over the years, led to tacit acceptance of the efficiency of the systems of Radar Coverage and precise Advice of the British and French Operators at Dover, Cap Gris Nez and Cherbourg to the point that for all practical purposes the Radar Surveillance 'Advice' within these areas function to a considerable extent as 'Control'. Significantly, collisions in the Dover Strait Seaway show the following statistical decline.

- Collisions during period:-

1956/60	1961/65	1966/70	1971/75	1976/80
62	80	48	21	16

- In addition, the U.S. Coastguard in 1979, estimated that the introduction of "Automated Advanced Surveillance would reduce the incidence of collisions by some 35%.

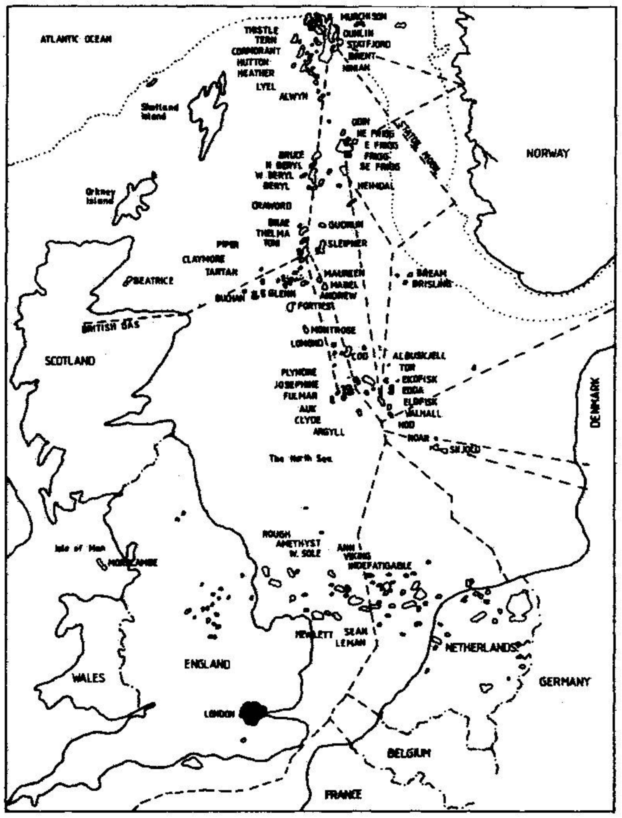
2. THE OFFSHORE ENVIRONMENT

2.1 In commercially modest circumstances prospecting for Hydrocarbon Deposits in the Offshore Environment has proceeded over many years principally in the Gulf of Mexico. Exploration in the North Sea commenced on 26th. December 1964 from the Drilling Rig "Mr. Cap" and the first 'show' of Methane Gas was found by the Rig "Sea Gem" on 20th. September 1965. From that date onwards exploration was stepped up by all Countries bordering the North Sea but proceeded at a leisurely pace while agreement was reached on precise surveying criteria, the establishment of Median Lines and extent of National Zones for exploration and exploitation of discoveries.

2.2 In 1973 the price of Oil rose astronomically. The immediate result was an intense stimulation of offshore Hydrocarbon exploration and development throughout the world, principally and most dramatically in the North Sea, where permanent Platforms and mobile Drilling Rigs have proliferated into and across the shipping lanes. This process continues as Governments lease off blocks in their National Zones and discoveries continue to be made. Paradoxically, the higher the rise in the price of Hydrocarbons, the greater will be the proliferation of Platforms and Drilling Rigs in the North Sea, the English Channel and the Western Approaches to the Channel as, due to better returns on investment, marginal fields become economical to exploit.

2.3 At present, December 1982, the locations of fixed Platforms in the North Sea is as depicted in Figure 1. It will be seen from this Figure that the disposition of permanent structures referred to as "Platforms" is fairly dense down the middle of the North Sea on either side of the median Line separating the British, Norwegian, Danish and German Offshore Zones and directly across every shipping route between the Coasts of Britain and Norway, Denmark and the seaway of the Skagerak. In addition Platform Installations now extend in an arc from the coast of Norfolk in England to a point not far from Ijmuiden in Holland and directly across the main shipping lanes from the Channel to the many European Ports.

Fig. 1



2.4 As well as the permanent "Platforms" both installed and intended, exploration is continuing throughout the area from some forty two essentially mobile Drilling "Rigs"; Jack-up Structures in the more shallow seas of the Southern North Sea and Semi-Submersible moored Structures in the deeper waters further north. Other Semi-Submersible Rigs have been working west of Brest in the approaches to the Channel within a few Nautical Miles of the edge of the Continental Shelf and directly across the access shipping lanes from the Atlantic and the Bay of Biscay, Blocks have been leased off the English Channel south of the Isle of Wight and beyond the limits of the exising Radar Surveillance Systems. it is only a question of time before exploration begins in this area and, if discoveries are made, Permanent platforms will be installed to replace the Exploration Rigs.

3. PLATFORM AND RIG RESPONSIBILITIES

3.1 Similar to the status of the Master of a Vessel or Captain of an Aircraft the Operational and Administrative control of a Platform or Rig is vested by International Law in an "Offshore Installation Manager" (O.I.M.)

3.2 The O.I.M. has total responsibility for all activity on the Installation and for the conduct of shipping within a circular sea area surrounding the Installation out to a radius of 500 metres from the Installation. The particular intention underlining the regulations which govern the appointment of an O.I.M. is one of maximum safety both towards the personnel on the Installation and in the control of environmental hazards resulting from the incidents of Blow-outs experienced in drilling or errors in production proceedures. Ever present is the possibility of a drilling operation striking into a pocket of lethal Hydrogen Sulphide Gas or of highly inflamable Methane or other by-product Gasses of petroleum formation. Heavy inflamable gasses flowing outboard and down wind from an Installation could in theory be ignited by a heat source on a Vessel in the vicinity of the Installation with catastrophic flash-back possibility, and it is specifically for this reason, and the possibility of collision with the structure, that the jurisdiction of the O.I.M. is extended by this arbitrary radius of 500 metres.

3.3 Generally speaking Platforms tend to be positioned in groups in that economics mitigate against too many single Platform production system. Figure 2 shows the current disposition of Platforms in the 'Oil Basin' west of the Shetland Islands in the Northern part of the North Sea and also indicates the independent Operators controlling the fields in which the Platforms are located. Since most operating Companies are representative of Partnerships, the listing is by no means exhaustive of the total of all the interests in the area.

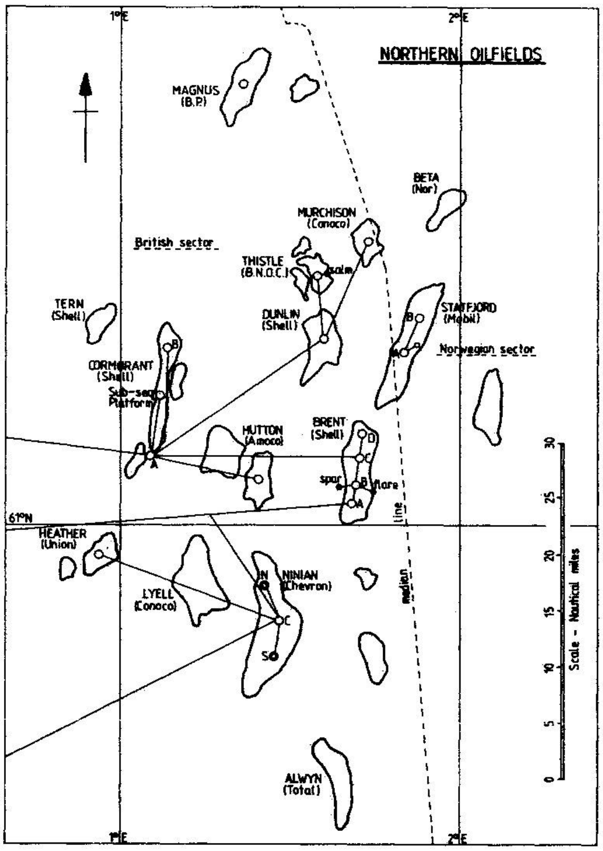


Fig. 2

3.4 Some, though not all, Platforms employ qualified Mariners as "Marine Controllers" to whom the O.I.M. delegates the task of directing the activities of Vessels in the vicinity of the Platform or Installation. In some Fields; notably the large Brent, Dunlin, Cormorant Complex of Shell; the Statfjord Field of Mobil and the Ninian Field of Chevron: a Marine Controller Organisation exists to direct the activities of shipping within the whole Complex. Some, but as yet only a few, have a Radar Installation with which the Marine Controller can achieve a complete appreciation of the shipping situation around his Platform or field including any unauthorised entry into the relevant 500 metre circle zones. The very extensive Shell Complex is one that does not have a Radar Installation on the grounds that the equipment cannot be classed as a productive asset in terms of the main objective: the production of Oil. Appreciation of marine activity in this extensive environment is totally dependant on Radio communications and manual recording.

4. MARINE RADAR AND VESSEL TRAFFIC MANAGEMENT

4.1 Since its introduction into Merchant Vessels in the early post war years Marine Radar has undergone continuous improvement in terms of Scanner Design Display Readability, target Separation, True Motion facility, Automatic Anti-Collision Plotting and other refinements. The inovation of the Electronic CHIP however opened the door to fully Computerised Systems such as the "Data Bridge" anti-collision system and its complementary Fixed Station Control Installation; the Vessel Traffic Management System or VTMS.

4.2 Developed specifically for Marine Traffic Control the VTMS consists essentially of a Computerised Console with a large Daylight Visual Display Unit, colour sensitive for fine definition of fixed and mobile Targets. Through the use of Data Extractor Units and Modems the Computer within a single Consul is provided with the data drawn from up to seven Radar Transceivers whether "S" or "X" band. The Modems permit the transfer of data and control of the remote Radar Systems by signals passed on any narrow band systems ranging from Radio Voice Circuits, Forward Scatter Dish Systems to Telephone Lines. The Data input to the Computer is digested, filtered, colated, offset corrected and displayed on the V.D.U. as a consolidated picture of the entire area scanned or, by Operator selection, a particular section of the area requiring more detailed or closer observation. Permanent features relating to a particular area under surveillance as, for example, sub-sea Well Completions, Pipelines, Wrecks etc., which would not normally be detected by Radar, may also be displayed by incorporating them in the Computer's controlling programme.

4.3 The system is, on selection, fully automatic in that the operator can set parameters which will cause alarms to be activated if and when these parameters are transgressed. In effect this implies that the system will operate as a marine security system unassisted at all times, calling attention to potentional danger by highlighting the transgressing Target or Targets and providing amplification data on a subsiduary Display Cathode Ray Tube. A single Computerised Console is capable of simultaneously handling up to one hundred Moving Targets and one hundred Stationary Targets but by using Consoles in cascade there is practically no limit to the target handling ability of such a system.

4.4 Initially designed for Harbour and Estuary Shipping Control one of the first installations of VTMS was at Teeside in England. Sponsored by Phillips Petroleum for use by the Tees Harbour Control specifically for protection of the Ekofisk to Teeside Oil Pipeline in the anchorage off the Tees, the system has been effective in preventing damage to the main Ekofisk to Teeside Oil Pipeline over the past five years. In addition to Teesport, Harbour Control VTM Systems are being installed as far apart as Bintulu in Malaysia and Gothenburg in Sweden. In the offshore environment installations are being progressed in the Northern North-Sea Fields by British Petroleum on the single Platform of the Magnus Field with input to the Console from two Radar Scanners. By Mobil in the Statfjord Field where the Operator will have the choice of using seven Scanners separately disposed around three Platforms. Conoco, on their Murchison Platform, have fitted only a Standard Marine Anti-Collision Radar.

4.5 By far the most ambitious project being undertaken at present is the installation in the Gulf of Campeche off the coast of Mexico covering a sea area of some 3,900 square Nautical Miles and using six Consoles in cascade the system is designed to enable control of this vast area to be exercised from any one of four widely separated locations.

4.6 Objections that have been leveled against installing Radar Systems on Oil or Gas Platforms have been on three main counts. Firstly, it was assumed that Scanners would need to be installed at a height superior to all other equipment in order to achieve an all round Radar 'view'. The installation of a single basic Marine Radar on the Murchison Platform gave credence to this view but with the ability of a VTMS to collect and process a number inputs this is no longer necessary. Compact Scanner, Transceiver and Data Extractor Units can be mounted in small Box Units and positioned conveniently overside of Platform Modules to achieve total coverage in sectors. Additionally, they may be made to sector scan in order to prevent transmissions radiating into the Structure or part of the Structure. Secondly, it was assumed that the operation of Radar Scanners could cause electrical sparking which would not be acceptable in the designated Gas Hazard areas of a Structure. The ease with which a modern Scanner system can be purged with inert Nitrogen Gas removes any cause for concern in this respect. Finally it has been argued that occasionally a Platform needs to impose Radio Silence when a Radio Controlled Explosive Charge was being lowered and subsequently fired in a drilled well and this would have to include the shutting down of a Radar System. Undoubtedly this would be the case of a Radar Installation on a single Platform. However in the case of an Installation distributed between several Platforms such as that being fitted to the Statfjord Field, coverage is automatically taken over by one or more Scanners on adjacent Platforms. In the Southern North-Sea Fields no surveillance Radar is installed and none is contemplated at the present time.

5. CONCLUSIONS

5.1 In major shipping lanes control of shipping is not only desirable but, where it exists even in the form of "Advice", has been proved to be benifical, is becoming more and more acceptable and has substantially reduced the risk of collision.

5.2 The proliferation of Platforms (Fixed Structures) and Rigs (Mobile Structures) in the Offshore Environment of the North Sea is reaching the point where its interface with shipping routes is becoming so congested that Shipping Control will have to be introduced if, in the long term, serious accident and massive sea polution is to be avoided.

5.3 Marine Control in Offshore Energy Fields, where it exists, is inward looking and directed only at the specific interests of the Platform or Field, being concerned solely with its own dedicated Shipping. The standard of control varies from practically nothing to one of sophistication but, at no point is it directed towards assisting the safe navigation of Shipping not directly concerned with activities inimical to its own particular interests.

5.4 That total Shipping Control must, sooner than later, become essential in the Offshore Energy Fields is apparent. The questions that need to be addressed by National Authorities are therefore.

- In the North Sea, the English Channel and its Western Approaches, can Shipping Control be left to the Energy Industry subject to legislation to improve Control Facilities by the installation of V.T.M.S. on every Energy Field Offshore and formal training of Marine Controllers?

- If the Control can rest with the Energy Industry, how would it be operated in respect of the Mobile Rigs, especially those drilling wildcat or single exploratory wells?

- If Control is to be exercised by a National Agency, then by whom and who would be responsible for financing the installation of VTMS and employment of Controllers?

- Is it practical to try and combine the commercial interests of the Energy Industry with an International Maritime Control Facility or should International Consultative bodies such as IMC be considering setting up independant Radar Control Stations in the Offshore Environment?

6. NOTES

The Dover Strait Routing System commenced in 1967, and VTMS Radar Surveillance in 1971.

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Simulation of Bridge Passage in High Wind
Passage simulé sous un pont en cas de forts vents
Simulierung einer Brückendurchfahrt bei starkem Wind

K. MEURS
Advisor for Shiphandling Research
Maritime Research Institute Netherlands
Wageningen, The Netherlands

J. W. OOSTERBAAN
Head of Safety and Nautical Supp. Dept.
Rotterdam Port Authorities
Rotterdam, The Netherlands

K. Meurs, born 1923, was a marine pilot from 1950 to 1970 in various ports. Since 1970 he has been an advisor for Ship Handling Research and responsible for training on simulators.

J. W. Oosterbaan, born 1922, joined the Royal Neth. Navy as officer. In 1960 he joined the Rotterdam Municipal Port Management as a nautical advisor and became deputy Harbourmaster. He participated in the development of Rotterdam Europoort (nautical aspects).

SUMMARY
Car-carriers (beam: 32 m) entering the harbour of Rotterdam have to pass a bridge with a minimum width of 47.2 m to reach the Brittanniehäven for the discharge and loading of cars. Because of their form, the car-carriers are very sensitive to beam winds. To find out whether the bridge can be passed in stronger winds at reduced risk, various types of manoeuvres in different winds were studied using a ship manoeuvring simulator. The results of the study indicate that sailing through the bridge in somewhat stronger beam winds may be possible under certain conditions.

RÉSUMÉ
Les navires transporteurs de voitures (largeur 32 m) entrant dans le port de Rotterdam doivent passer sous un pont d'une largeur minimale de 47,2 m afin de parvenir au Brittaniehäven où s'effectue le chargement et le déchargement des automobiles. Du fait de leur forme, les transporteurs sont très sensibles aux vents de travers. Pour juger de la possibilité de franchir le pont avec des vents assez forts, des études ont été menées avec des vents de force différente à l'aide d'un simulateur de manoeuvres de navire. Les résultats obtenus et les conditions nécassaires sont présentées.

ZUSAMMENFASSUNG
Autotransportschiffe (breiteste Stelle: 32 m), die in den Hafen von Rotterdam einfahren, müssen unter einer Brücke mit einer Mindestbreite von 47,2 m hindurchfahren, um den Britanniehaven zur Ent- und Beladung von Autos zu erreichen. Aufgrund ihrer Form sind die Autotransporter gegenüber Seitenwind sehr anfällig. Um herauszufinden, ob die Brücke bei stärkeren Winden mit verringertem Risiko passiert werden kann, wurden Manöver bei verschiedenen Windstärken mit Hilfe eines Simulators untersucht. Die Ergebnisse der Untersuchung zeigen, daß ein Passieren der Brücke bei etwas stärkeren Seitenwinden unter gewissen Voraussetzungen möglich sein kann.

1. INTRODUCTION

For several decades ships have outgrown their facilities. No matter how large harbours, locks, canals and bridges were built, it did not take long before ships were built large enough to stretch the capacity of their facilities to their limits. Although some harbours and canals can often be widened and deepened, there is not much stretching to do with a concrete lock or with a bridge. One is stuck with it for many decades. Even planners, who looked far enough into the future to build a tunnel instead of a bridge, saw dredgers scrape the top of their tunnel even before they retired.
The above description typically fits the Brittanniëhaven, which is located in the Europoort area of Rotterdam.
The design of the Brittanniëhaven was based on industrial sites North and South of the basin with the main emphasis on petrochemical activities.
The sea transport would consist of tank vessels of medium size.
The construction of the bridge to the north of the Brittanniëhaven, between the basin and the sea, was such that no particular problems could be expected.
However, in due time, the large sites north of the basin were restricted in use by regional authorities for environmental reasons.
As a consequence, the Port of Rotterdam had to shift the activities to those which were acceptable for the environmental authorities. Stevedoring facilities for conventional cargo and multi-purpose vessels were introduced.
This harbour, is a perfect place to discharge and load cars. The bridge through which the ships have to sail to reach this harbour, the Caland bridge,handles about all the truck and train traffic that serves the harbours and industries west of it.
It is the artery of Europort. Damage to this vital would result into economical disaster.
The dimensions of this important bridge are given in Chapter 2.
The critical ship for the bridge is a car carrier. These ships have a very high superstructure to contain the decks for up to 6000 cars. This makes these ships very sensitive to wind. The dimensions of the critical ship are given in Chapter 3. Because of their sensitivity to beam winds there is always the decision to be made between two choices: diverting the ship or to take the risk of passing the bridge. So the Municipal Harbour Authority of Rotterdam ordered MARIN to try and find a way of passing the bridge in stronger winds at reduced risk. This study was carried out by the Ship Handling Group of MARIN. Use was made of all the resources and data available in the nautical support department of the Rotterdam Port Authority.
In the Chapters 6 through 8 an account is given of the study and its results.

2. THE BRIDGE AND THE CHANNEL

The channel has a bottom width of 145 m and a depth of 13.5 m. The direction of the channel is 170 degrees.
The bridge is 42 m east of the centre line of the channel. The width of the bridge between the wooden fenders on either side is 47.2 m. These fenders protect the four pillars on which the bridge can be lifted to above mast height. Additionally these pillars are protected by solid concrete cylindrical dolphins on the four ends of the bridge. The length of the fenders is 87 m.

3. THE SHIP

The critical ship on which the study was focused was a car carrier of 200 m long and 32 m beam and a draft of about 7.5 m, with one right handed diesel driven propeller. The minimum manoeuvring speed was 6 knots at 35 RPM. One of the most

important dimensions, however, is the height of the ship of about 20 m above the water. The shape can, somewhat simply, be described as a normal freighter hull with a shoe-box shaped superstructure over nearly the whole length.
The lateral surface above water of 3900 m^2, is about 2.6 times the surface under water of 1500 m^2. It is the unfavourable relation between surface above and surface below water which makes the ship "crab" through a canal at an angle when the wind is abeam. This drift angle must be larger, the slower the ship sails. If the drift angle is not large enough, the ship will ultimately end up on the leeward shore or collide with the bridge fender. If the drift angle is large enough for the ship's centre of gravity to follow a channel's centre line or a line parallel with it, the swept path will be larger than the ship's beam. The swept path increases with the sine of the drift angle and the length of the ship. In the most favourable condition, without wind, when the drift angle is zero, the ship passes straight through. If she sails exactly on the centre line, there is only one quarter of a ship's beam spare on either side. This is already a rather small margin for aiming errors.

4. THE USE OF TUGS

If it is assumed that the ship has to pass through in line with the channel, tugs have to deliver the same lateral force as the wind, but in opposite direction. One tug forward and one tug aft on a line can deliver a considerable side force if both pull at close to straight angles. This can be done if the speed is low.
Because the bridge is so narrow, unfortunately, during the passage they cannot pull at right angles. They can pull only at very small angles when the ship is windward of the centre line. Then their lateral force is negligible. They can pull at a fairly large angle when the ship is on the centre line or to leeward of it.

5. THE MANOEUVRES

There are two ways the manoeuvre of passing the bridge in strong beam winds can be made: Fast and slow.
The fast way practically eliminates the benefits of tug assistance. By sailing fast, the lateral force by tugs is in fact traded in for the lateral force generated by a drift angle.
The higher the speed, the smaller the drift angle and consequently the swept path. Also the higher the speed the more accurate is the steering. However, if one thinks of the disastrous consequences of one misunderstood rudder order, a misjudgement of the pilot or some mechanical failure, the idea has to be abandoned immediately.
To avoid the chance of high speed collision with the bridge, one has to pass slowly. It is the only way to take maximum advantage of the tugs and avoid the chance of putting the bridge out of service for a long time.

6. THE NAUTICAL STUDY

It will be clear, from the description of the situation in the former chapters, that there was a potential threat of collision all along. However, through careful co-operation between harbour authorities, pilots, tug company and shippers such calamities could so far be avoided.
As a general rule, a beam wind of Bft 6 was the limiting condition for passing the bridge. Besides, even if the wind was less than Bft 6 at the time of arrival, but winds in excess of Bft 6 were forecast, the decision was taken to

head for an alternate basin to avoid the chance of being locked up behind the bridge for the duration of the strong wind.
Part 1 of the study involved on-the-spot observation of pilots, tugs, procedures in identical situations elsewhere, theoretical calculations and interviews. One of the results of this study was, that no drastic improvement was to be expected from expensive constructions like for instance a tunnel-shaped fence to guide ships through the bridge opening by leaning on the fence.
It was feared, that sharp edges like loading doors, scupper guards etc. would lead to excessive wear on the fenders. Instead, it was recommended to try to make better use of tugs. To achieve this, it was suggested, that the pilots give the tug masters better guidance then before, by introducing a simpler and shorter phraseology. In this way part of the initiative was actually diverted from tug master to pilot, who due to his location on the bridge, could overlook the general situation better than the tug masters from their locations.
It was further recommended that a small number of pilots be selected to pilot ships through the bridge and that these pilots be trained on a simulator for that specific job.
After internal discussions among the harbour's operations department and pilots, it was decided to design a research program that could be carried out on a manoeuvring simulator.

7. THE STUDY ON THE SIMULATOR

7.1. The experiment

The experiment was designed for 80 simulator runs; 40 arrivals and 40 departures; 20 were supposed to be made at Bft 5 and 7, 40 at Bft 6, because Bft 6 was considered the limiting and consequently the most important condition.
Because the westerly wind was the prevailing wind, 48 runs were made at westerly and 32 at easterly winds. The experiment was carried out by two groups of two active pilots.
Immediately following the completion of the main experiment eight additional runs were made with a bow thruster available.
Those runs were added to be compared with those eight runs of the main experiment, that were made under otherwise the same conditions.

7.2. Tug Deployment

Like in reality, two tugs of 30 ton bollard pull were fastened; one at the bow and one at the stern on an as short as possible line.
One 12 ton tug was standing by to leeward to push at the forward shoulder before the ship entered the bridge, another one was waiting to push as soon as the ship stuck her bow out at the other side. These 12 ton tugs had not been used in reality.

7.3. The Visual Scene

The position of the ship in relation of the bridge was made visible by showing a bird's eye view of the situation.
This digitally generated picture of the contours of ship and bridge was shown on a large cathode ray tube. The tug forces were seen as vectors.

7.4. The Execution of the Experiment

Because it was one of the aims of the experiment to find out if better results would be expected with more precise tug orders, it was agreed that tug masters

would only follow pilot's orders.
During the three training runs, which each pilot had to make before the real experiment, it already became clear that in no way the pilot could give the tug master all the orders as to direction and force. Although the pilots tried hard, tugs often got tangled up behind or on the bridge structure. Consequently, the tug masters had to be allowed at least to keep their vessels clear of the bridge and follow the pilot's orders as closely as possible. To approach the bridge slowly, it was necessary to do so with stopped engine and consequently total dependence on tugs. As had already become apparent from test runs and training runs, the low speed made the system very sensitive to changes in tug forces. The distribution of tug forces absorbed nearly all the pilots attention.
To relieve the pilot somewhat from this burden and save some of his mental capacity for other things, the actual passage had to be started from a more or less equilibrium position.
To achieve this, the ship was brought on the axis of the channel, with the strong wind an tug forces more or less in equilibrium and with as little as possible drift or yaw.
This more or less stable condition was, of course, disturbed when the forward tug itself had to move more forward to go through the bridge, thus sacrificing some lateral towing force. This loss was partly evened out by the bow getting some lee from the bridge or by the use of the stand-by pusher tug.
This stand-by tug had to be given the proper orders at the time the pilot had already started to mind engine and rudder to help clear the stern.
Especially immediately before and during the passage, the pilot had to mind too many things in too short a time. This was one of the main reasons why the runs with the Bft 7 beam wind were mostly unsuccessful.
As the majority of these manoeuvres resulted in a collision with parts of the bridge protection, it was decided to cancel the remainder of the Bft 7 runs and sail all those with Bft 4 instead. By doing this, in fact wind force Bft 4, 5 and 6 were investigated, instead of 5, 6 and 7 as originally planned.
After completion of the experiments it was decided, at the request of the pilot, to make four extra runs at Bft 7, with tug masters using their own judgement rather than waiting for pilot's orders. The results are described in Chapter 7.5.

7.5. The Results

The results are shown in Table 1 (Results per wind condition).

Table 1

Wind force in Bft	Wind Direction	Total Runs	Contact with bridge protection				
			No Contact			Contact	
			runs	% of total		light	hard
4	W	6	6	100	80		
	E	4	2	50			2
5	W	18	8	44	50	5	5
	E	12	7	58			5
6	W	22	6	27	39	2	14
	E	16	9	56		2	5
7	W	5					5
	E	1					1

Remark:

Hard contact means ship-bridge protection-contact at a lateral speed = 0.5 knots.

This does not necessarily cause damage, but will lead to heavy wear of timbers.

As expected, the stronger the wind, the more frequent were the contacts of ship and bridge. If only Bft 5 and 6, the wind force at which the bulk of the runs were made, are considered, one sees that a higher percentage of contact were made with westerly winds than easterly winds.
For this there can be no other reason than that the bridge is off the centre at the east side of the channel. In other words, if a bridge is off centre it is easier to pass through it if it is on the windward side of the channel than if it is on the leeward side.
Table 1 also shows, that at Bft 5 in 50 per cent of all runs contact is made.
In reality ships contact approximately 0 per cent in Bft 5 wind. Clearly at Bft 5 the system of low speed, total tug reliance and total tug guidance, as used in the simulator, leads to more contacts than the system of rapid passage at a drift angle and minimal tug reliance, as used in reality.
However, at Bft 6, the latter system starts to become unacceptable due to either too large a drift angle or too high a speed or a combination of both, which could lead to heavy damage.
The system used in the simulation would indeed lead to more, but less severe contacts.
In general the tests consequently showed no advantage for the proposed system, if carried out by the average pilot. However, there are clear indications that the use of it by selected personnel could lead to better results.
It can be seen from Table 3, that for instance pilot number 2 scores 63 per cent of his manoeuvres without contact; twice the percentage of his colleagues numbers 1 and 4.

Table 2

RESULTS OF THE COMPARISON OF 8 RUNS WITH AND 8 RUNS WITHOUT BOW THRUSTER

Heading	Pilot Number	Without thr.		Without thr.	
		West	East	West	East
IN	1	x	0	x	x
	2	0	0	0	0
OUT	3	x	x	x	0
	4	x	0	0	0
Number of good runs		1	3	2	3

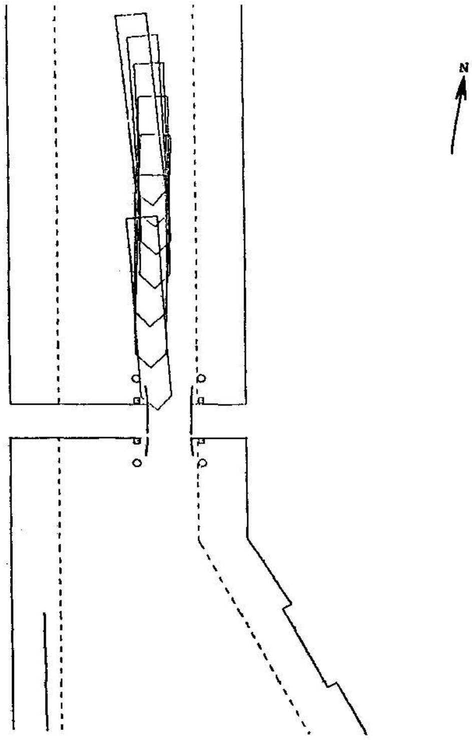
0 = no contact
x = contact at lateral speed 0.5 knots (refer to remark Table 1).

Table 3

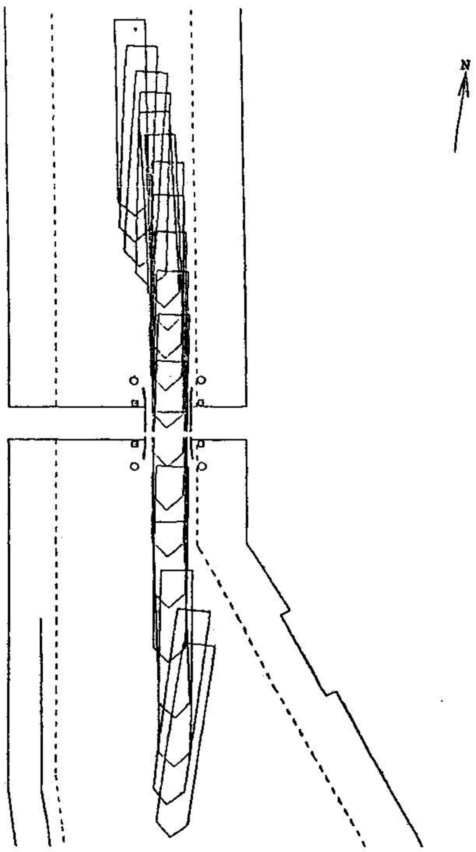
RESULT PER PILOT

Pilot Number	Total Runs	Contact with bridge protection			
		No contact		Light	Hard
1	19	6	32%	3	10
2	19	12	63%	3	4
3	15	7	47%	1	7
4	15	5	33%	3	7

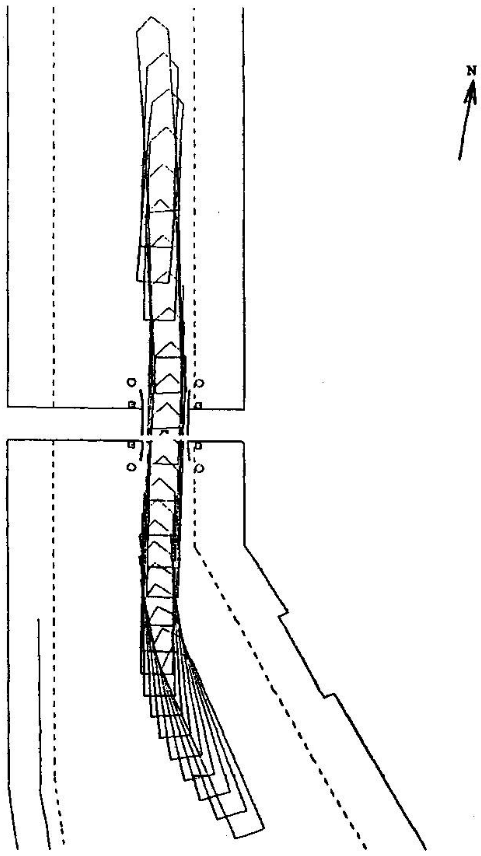
Remark: Refer to Table 1.



CALANDBRUG
Run: 1008 Time: 16.11 Date: 11-Apr-82 Plotted every 30 S
Wind: 5 Bft Wind direction: West



CALANDBRUG
Run: 7001 Time: 13.30 Date: 14-May-82 Plotted every 30 S
Wind: 7 Bft Wind direction: West



CALANDBRUG
Run: 7002 Time: 13.47 Date: 14-May-82 Plotted every 30 S
Wind: 7 Bft Wind direction: West

Table 2, which shows the results of the eight runs at Bft 6, with bow thruster confirms this.
Pilot No. 2 makes all four runs without contact, against No. 3 only one.
Comparing the eight runs made with the bow thruster with the eight runs without, the former showed better results, but not dramatically. The extra four runs, added at the end of the experiment were made in Bft 7 with bow thruster and tug masters using their own judgement without waiting for pilot's orders. These runs were remarkable successfully; only one light contact.
This improved result may be attributed to:

1. co-incidence
2. division of the task between pilot and tug masters
3. bow thruster
4. learning effects during the experiment

or a combination of these.

8. CONCLUSIONS

From the overall results of the study and the simulator tests it can be concluded that sailing through the bridge in somewhat stronger beam winds may be possible, provided the following conditions are met:

1. Change of existing sailing habits
2. Selection of a limited number of pilots with special skills in fast manoeuvring
3. Training of this group.

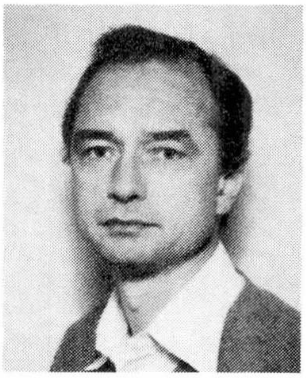
These three conditions are not easily fulfilled. It is not easy, especially for the older pilots to change their routine. Neither is it easy to convince mariners that the skills of one are of a different nature than those of others, although this can be proven by tests on simulators.
Besides, assigning special jobs to selected pilots requires adjustments in their roster, which may be a cause of discussion.
The third condition, training of the selected few is a matter of spending a relatively small amount of money on simulator training and a good deal of effort to convince pilots that their skills can be upgraded by training. But with a positive approach by management and staff, without doubt, good results can be reached. Still a bridge will always remain a bottle neck in a channel and, thus an obstruction to navigation. Nevertheless the Port of Rotterdam set-up a special working group of solving the described problem up to wind force 7 to 8 Bft. The results are not yet known at the moment of the printing of this paper.

Nautical Aspects and Risk of Collisions for Offshore Structures

Environnement marin et risques de collisions avec des constructions en mer

Schiffsverkehrsaspekte und Risiken einer Kollision mit »Offshore«-Bauten

V. LIGTHART
Dep. Navig. Res. and Shiphandling
MARIN
Rotterdam, The Netherlands



Vincent Ligthart, born 1942, Nautical College, Air Transport Pilot Rating. Experience as Ships Officer and Air Transport Pilot. Since 1974 working with MARIN in the field of risk analysis and navigation research.

SUMMARY
A group of oil exploitation platforms has been installed near Texel Traffic Separation Scheme. Before the platforms were installed it was necessary to assess their impact on the safety of shipping in this busy area and also to estimate the probability that a platform would be hit. The results of this study would be used to determine whether or not safety measures should be taken. The paper briefly describes the methods applied in this study and some of the results.

RÉSUMÉ
Un ensemble de plates-formes pétrolières a été réalisé près de Texel en Mer du Nord. Avant leur construction, il a été nécassaire de déterminer les effets des plates-formes sur la sécurité du trafic maritime dans la région et d'estimer la probabilité qu'une plate-forme ne soit touchée. Les résultats de l'étude devait déterminer les mesures de sécurité. L'article présente les méthodes et résultats de l'étude.

ZUSAMMENFASSUNG
Eine Gruppe von Bohrplattformen für Explorationszwecke wurde in der Nähe von »Texel Traffic Separation Scheme« aufgebaut. Vor deren Aufbau war es nötig, die Auswirkungen dieser »Offshore«-Bauten auf die Sicherheit des Schiffsverkehrs in dieser verkehrsreichen Gegend zu berechnen und die Wahrscheinlichkeit einer Kollision mit einer Bohrinsel abzuschätzen. Die Resultate der Studie haben zu Sicherheitsmaßnahmen geführt. Es wird über Methoden und Resultate berichtet.

A few years ago oil was found on the Dutch part of the Continental shelf in the North Sea.
The area where it was discovered was right in the weaving zone of Texel Traffic Separation Scheme where many vessels a day pass through and a rather complicated traffic pattern already exists. At least two production platforms were planned to be installed in this field with the possibility of two additional ones (Figure 1.).
The smallest distance between the platforms would be two miles. This distance is large enough to expect that some vessels may plan to pass right through the group of platforms while others may judge it safer to proceed around them. In the past, observations have been made with respect of traffic behaviour around offshore constructions. However, these obstructions were isolated ones whilst near Texel there would be a cluster of obstructions.
The Dutch Ministry of Transport and Public Works needed an answer to the following questions:

i) what is the risk of a platform being hit by vessels (excluding fishing vessels) passing through.
ii) what is the effect of the platforms on the risk of collisions between vessels passing through.
iii) if necessary what measures can be taken to reduce these risks.

MARIN was asked to provide answers to these questions.
To get some insight in the traffic pattern which might be expected after installation of the platforms, simulations were carried out on the radar training simulator of the Nautical College at Amsterdam.
Visual simulation on this simulator is not possible and restricted visibility generally creates a more dangerous situation. Therefore it was decided to simulate restricted visibility when navigation is primarily done by Radar and Decca Navigator.
Vessels proceeding along pre-programmed tracks were generated on the simulator. Four independently operated vessels, each manned by its own navigator, were added. Orders given for course, speed, power and rudder, were recorded.
The tracks and speeds of the preprogrammed vessels were such that a realistic impression of the average traffic near Texel T.S.S. was presented to the navigators of the 4 independent vessels.
The independent vessels were of the following types:

containership	37.600 ton dw.	(ship nr. 1)
coaster	3.000 ton dw.	(ship nr. 2)
tanker in ballast	250.000 ton dw.	(ship nr. 3)
bulkcarrier	54.600 ton dw.	(ship nr. 4)

The navigators of the independent vessels had Radar and Decca at their disposal. Altogether 4 runs were made. In each run the 4 independent vessels proceeded simultaneously, each manned by an experienced navigator. For each run different navigators manned the vessels.

The navigators had to carry out the following tasks:

Ship nr. 1: To proceed from Texel T.S.S to North Hinder T.S.S.
Ship nr. 2: To proceed from South of Texel T.S.S. (coming from North Hinder T.S.S.) to Wilhelmshaven.
Ship nr. 3: To proceed from Texel T.S.S. to Maas Center T.S.S.
Ship nr. 4: To proceed from South of Texel T.S.S. (coming from the Thames area) to Wilhelmshafen.

Figure 2 shows the general direction of these tracks.
The navigators were asked to plot their intended track on the chart before the simulation run started. The positions of the four platforms were shown in the chart. Figures 3 and 4 give the tracks which the navigators intended to follow.

Conclusions arrived at were:

i) in the same situation different navigators planned different course lines. Some planned to go through the group of platforms others preferred to pass around them.

ii) Although the traffic situation was complicated and visibility was supposed to be poor some navigators planned their course lines rather close to the platforms (e.g. ship 1 of run 1 planned to pass a platform at 0,3 miles which is barely more than the minimal allowed passing distance).

Figures 5 through 8 show the intended and actual tracks during each run. It appears that:

i) All navigators took some action for collision avoidance.

ii) Because of the traffic situation some navigators had to deviate considerably from their planned course line.

iii) Two navigators actually passed a platform at a rather close distance. One (run 3 ship 1) planned to pass a platform at a distance of 1,1 mile but eventually the distance turned out to be 0,2 mile.

After the simulation runs the navigators were asked to give their opinion on the situation. The results were:

Objections to the future situation	:	4
No objections to the future situation	:	5
Neutral response (w'll accept it)	:	6
No answer	:	1
		16

Some navigators gave suggestions to improve the situation. Most of them favoured the creation of a sort of traffic separation zone which contained the whole group of platforms. The results of the simulation led to the conclusion that unless measures were taken some traffic could be expected to pass right through the group of platforms at rather close distances whilst other traffic would pass around the group. This would create a rather complicated traffic pattern. Also it could be expected that a seizable part of the navigators passing through the area would consider it an annoying situation.

To determine the risk of collision for the platforms various methods are available. The choice of method was determined mainly by the question whether there would be sufficient data to apply it.
The method chosen was to use data from other situations where offshore objects have been exposed to the risk of being hit by passing traffic.
For each situation the collision ratio is determined from traffic data giving the number of passing ships and the number that hit the object.
From the beginning it was clear that a comparable situation would be difficult to find. Therefore it was decided to try to find situations which could be considered safer than the situation in Q-1 and ones which could be considered unsafer. Thus an optimistic and a pessimistic estimate of the actual collision risk could be found.

1. The situation which can be expected to be safer than the one in Q-1.

In our opinion this situation existed in the vicinity of five light vessels in Dover Strait and the Southern North Sea, namely the three Goodwin lightvessels and the lightvessels West Hinder and Sunk.
The situation near these lightvessels can be considered safer because:

- Except one (West Hinder), the lightvessels lie in an area where a great part of the traffic is local and is well aware of the situation.

- In the area near the Goodwin and Sunk lightvessels, many ships which are not local traffic take a pilot. Therefore an even greater part is familiar with the situation.
- The situation near Texel T.S.S. is worse because a great part of the traffic visits the area less frequently and few vessels have a pilot on board.

Based on traffic and collision data for these lightvessels a collision ratio was found of 1 in about 100.000 vessels passing at less than ½ mile distance.

2. The situation which can be expected to be less safe than the one in Q-1.
We assume that in the present traffic situation in Q-1 the ship-ship collision risk, given an encounter, is higher than that to be expected for the platforms. Reasons are:
i) the traffic pattern is complicated and busy
ii) in the period 1973-1977 three collisions took place. The number of encounters during that period was calculated to be about 35.000. The collision-encounter ratio thus found was about 1 in 12.000 which is considerably higher than the ratio usually found for fixed structures in busy areas.

3. The situation which is comparable with that of the future platforms.
We assume that in the period 1961-1972 the Texel lightvessel which is situated in Q-1, was in a situation which is comparable with that of the platforms as far as collision risk per encounter is concerned.
The reasons is, that in the period 1961-1972 (which was before the implementation of the Texel T.S.S.) the lightvessel was situated in a traffic pattern which was similar to that in which the platforms will be located, namely in an area where the traffic from Northern Europe and the Southern North Sea meets.
A difference between a platform and a lightvessel is that the former is surrounded by a safety zone (radius 500 m) and the latter not. It is, however, another matter whether in open seas these safety zones reduce the number of throughgoing vessels passing at less than 500 m. Reason is that when en route in open sea it is normally not the custom to plan to pass objects at less than 500 meters. Vessels passing at distances less than 500 m do so more likely because of an error of judgement or insufficient look out. Therefore we suppose that in similar circumstances at open sea the traffic distribution of throughgoing traffic within ½ mile distance of a platform with a safety zone around it is about the same as that around a lightvessel.
It should be mentioned here that it is not our opinion that safety zones are useless. Platforms do attract fishing vessels because the amount of fish in their vicinity. Also in more confined waters vessels will tend to pass closer to obstructions.
Without a safety zone around platforms it would probably be rather busy in their vicinity.
It was estimated that during the period 1961-1972 about 80.000 vessels passed the lightvessel Texel at a distance of less than ½ mile. Three ships collided with the lightvessel. The collision ratio was therefore 1/27.000 encounters.
Summarising: the collision ratio is expected to lie between 1/100.000 and 1/12.000 and is probably about 1/27.000 encounters.

Effect of weather conditions on collision risk
In the table below the effect of weather conditions on collisions and near misses with Dutch Light Vessels and Light platforms are stated.

Collisions and near misses with Dutch Lightvesssels and Light platforms Period 1961-1975.

	no. of collisions	no. of near misses	no. of collisions and near misses	% of total	% of time during which weather condition prevails
Good visibility [1])	3	1	4	30	98
Bad visibility [2])	2	1	3	20	2
Wind Bft 7 of more[3])	0	1	1	10	4
Condition unknown	3	3	6	40	-
Total	8	6	14		

[1]) Visibility of ≧ 0,5 mile
[2]) Visibility of < 0,5 mile
[3]) In wind Bf 7 or more visibility is most times 0,5 mile or more. Off the Dutch Coast the condition of ≧Bf 7 and bad visibility occurs for only 0,1% of the time.

Even if one assumes that collisions and near misses under unknown conditions took place during good visibility the relative share of them in the total number is smaller than the percentage of time during which good visibility prevails.
Admittedly the numbers are small. However they indicate a trend which is found in many other collision and grounding statistics. Namely that under conditions of bad visibility the collision and grounding risk per unit of time and also per vessel movement is higher than during other weather conditions.

To determine the expected collision frequency, the number of passages within half a mile of the platforms had to be estimated.

A high estimate was found by supposing that the traffic pattern would remain the same and that the number of vessels which presently passes within half a mile of the future position of the platforms remains the same.
A low estimate was found by considering the traffic measurements made near an isolated platform in the North sea which were carried out by the North Sea Directorate of the Department of Transport and Public works (Figure 9).
This picture gives the actual and theoretical passing distance of nearly 350 vessels passing the exploration platform.
The theoretical passing distance is the distance at which the vessels would have passed if they had continued on their original course and had not taken any avoidance action. From this picture we can conclude that within 0,5 mile distance the traffic intensity is reduced by about a factor 3. This figure is considered optimistic because the platform was an isolated one, in an area where plenty searoom was available. Near Texel there is a group of platforms. The traffic passing through this group has less space available and some of the the traffic passing around them may wish to cut corners. Therefore more vessels may be expected to pass within half a mile than in the case of an isolated platform. For these reasons we expect that a realistic estimate of the traffic within half a mile of the platforms is found by supposing that the number of vessels presently passing withing this distance is reduced by a factor 1.5.
Because of the small difference between the low and the high estimate of the encounter values we considered the realistic estimate of the encounters more reliable than the realistic estimate of the collision ratio.
Therefore the realistic estimate of the encounter rate was multiplied by the optimistic, pessimistic and realistic values of the collision ratio to obtain the estimates of the collision frequencies.

For one of the platforms the collision frequencies thus found were as follows: (rounded off figures).

Optimistic estimate: once in 50 years
Realistic estimate: once in 10 years
Pessimistic estimate: once in 5 years

Because of these values it was decided to change the Texel T.S.S. in such a way that the platforms would be situated in the separation zone.

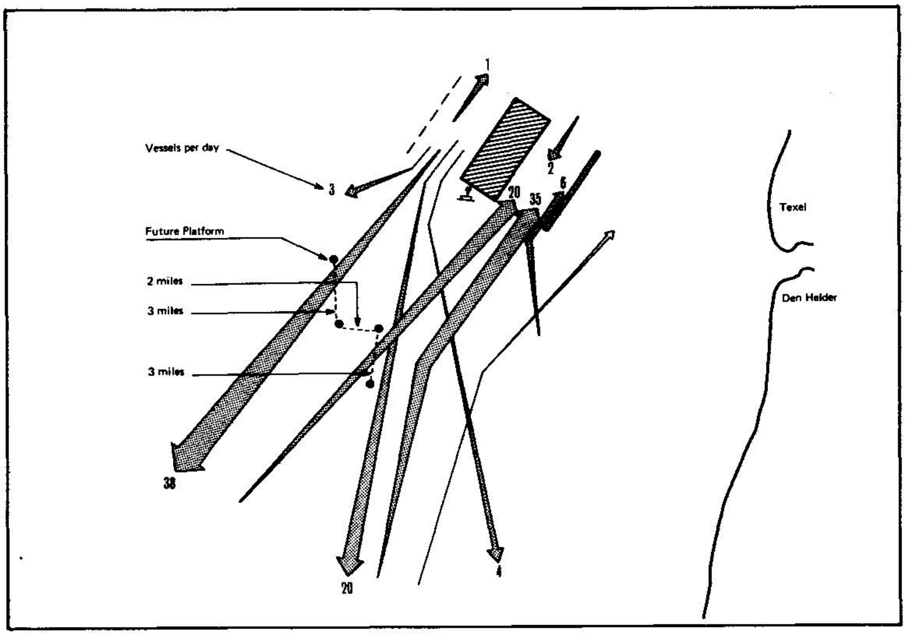


Figure 1.: Traffic Pattern South of Texel T.S.S.

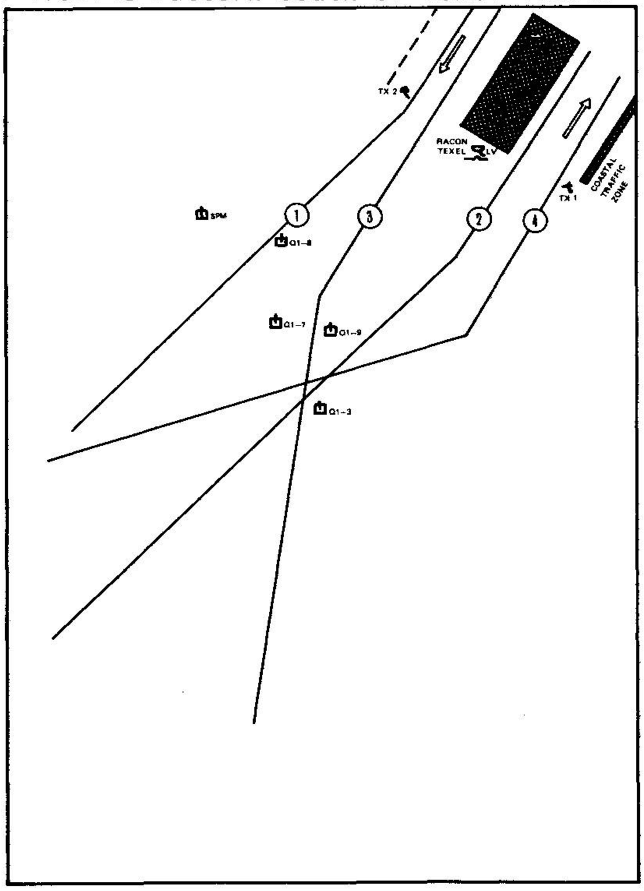


Figure 2.: General direction of tracks to be followed.

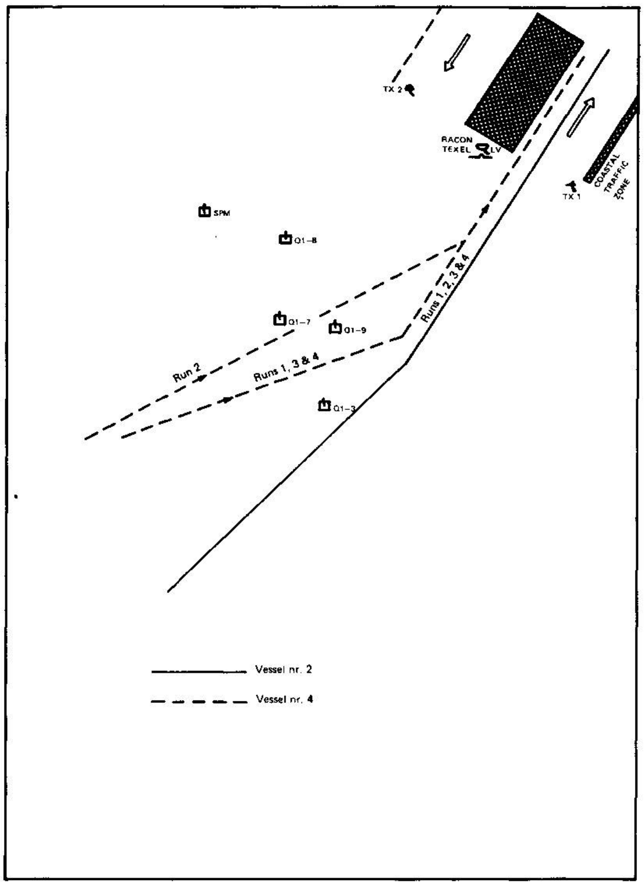


Figure 3.: Intended tracks.

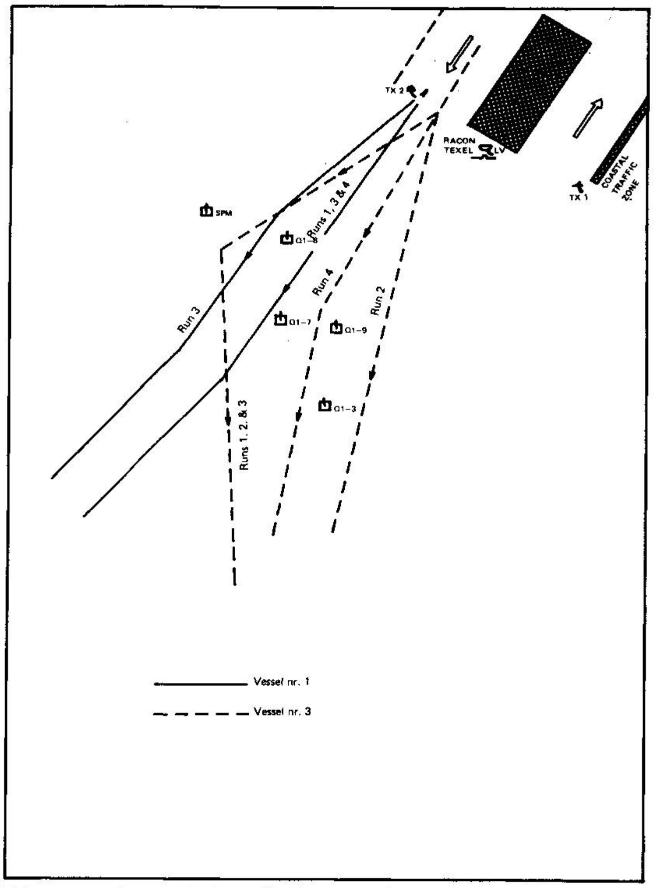


Figure 4.: Intended tracks.

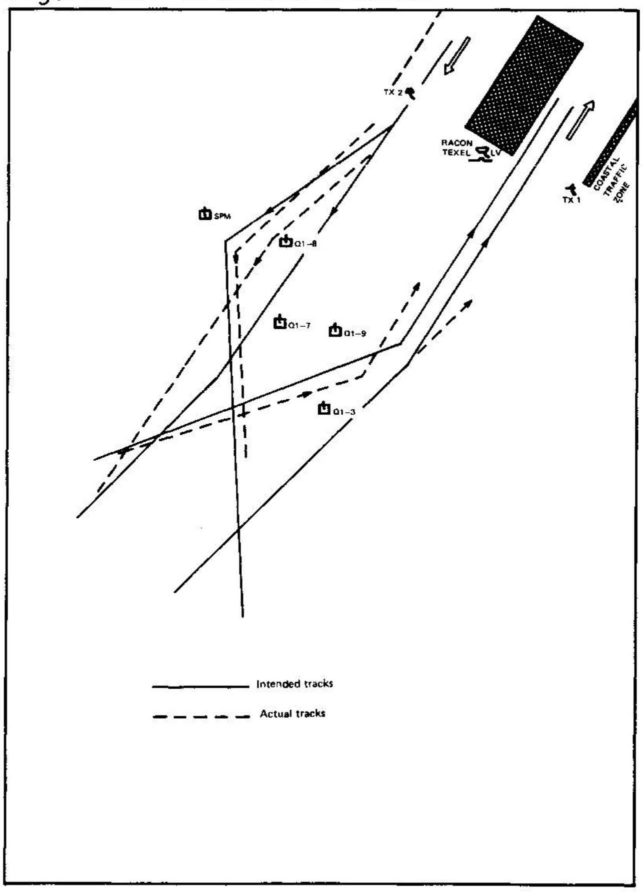


Figure 5.: Simulation run nr. 1.

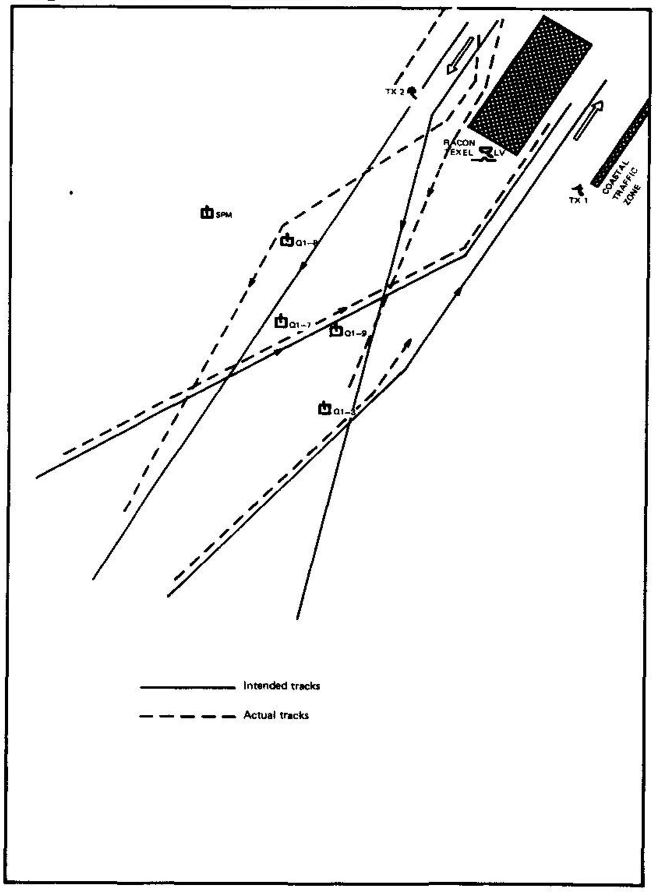


Figure 6.: Simulation run nr. 2.

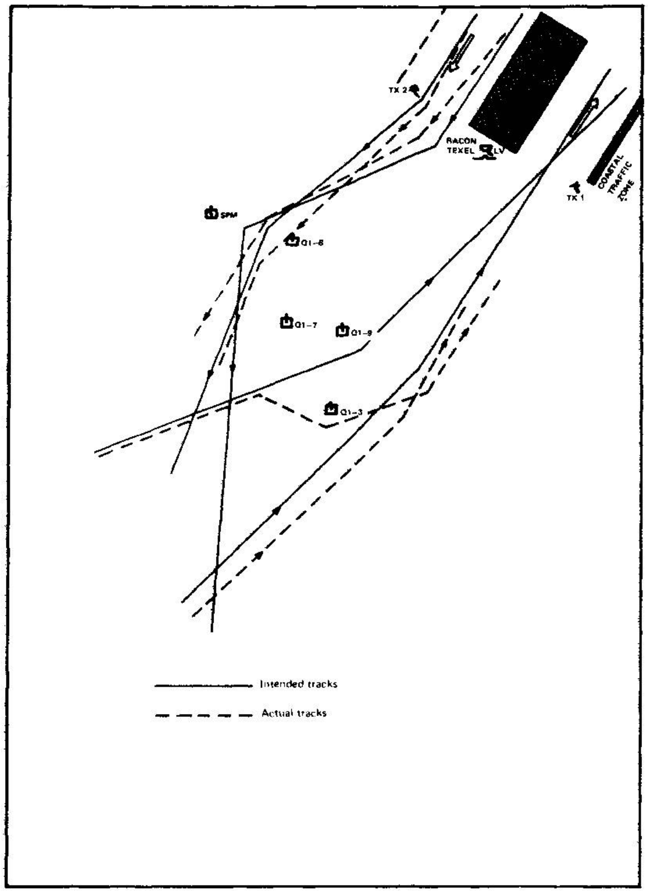


Figure 7.: Simulation run nr. 3.

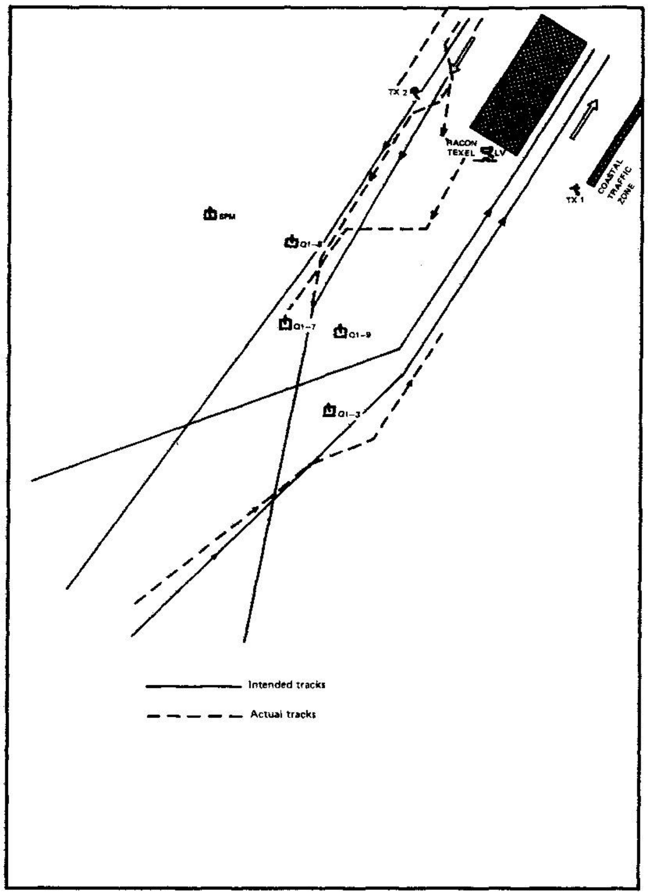


Figure 8.: Simulation run nr. 4.

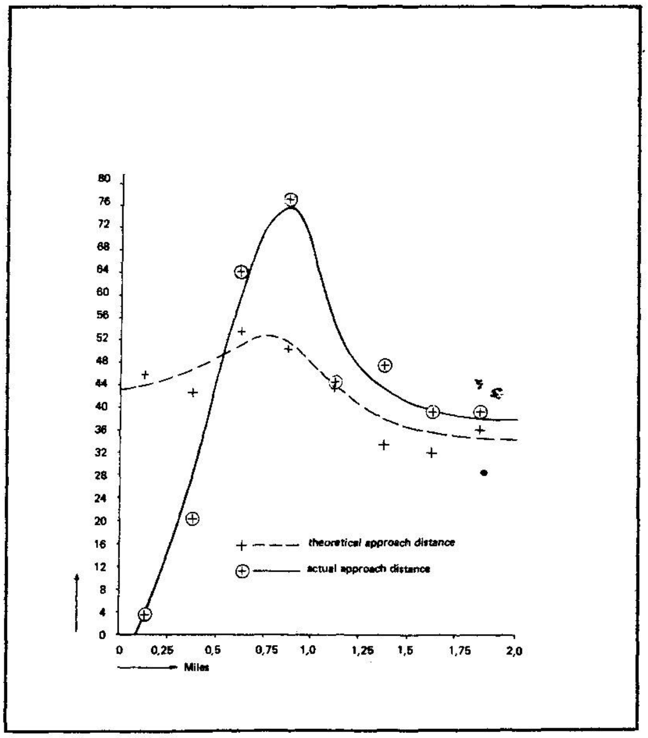


Figure 9.: Theoretical and actual approach distance of 343 vessels passing the Divy Gamma platform.