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The Company of Master Mariners of Canada
Newfoundland and Labrador Division
Introduction

The Company of Master Mariners of Canada was incorporated by Federal Charter on May 11th, 1967, with its National Office in the City of Vancouver, British Columbia, Canada. The Company was established to encourage and maintain the high and honourable standards of the Nautical Profession, further the efficiency of the sea service and uphold the dignity and prestige of Master Mariners.

The Company provides the opportunity for discussion and systematic study of Safety of Life at Sea, Navigation and its associated systems and methods. In general it provides the opportunity to encourage and develop education, training and qualification of Officers and people for the Merchant Service. The business of The Company is non-political and is carried out without any pecuniary gain to its members. All income accruing to The Company is applied towards the promotion of the objects of The Company as set out in the Letters Patent.

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Contributions to the Proceedings are welcome from authors who wish to promote discussion and study related to the aims of The Company. The Division especially invites Nautical Students and candidates for the Bachelor of Maritime Studies to submit abridged versions of their term papers for publication in the Proceedings.

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For information on how to submit papers or on how to obtain additional copies of the Proceedings, please contact the Divisional Secretary at the following address:

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Forward

The Newfoundland and Labrador Division is pleased to publish the third issue of its biennial Proceedings. We believe that the Proceedings provides a unique forum for our members to share their views with others. We also find that the Proceedings is a great vehicle to promote excellence amongst nautical science students by providing a means through which their academic efforts can be published and shared with professionals in the industry.

For the first time, this issue contains a paper which was supplied from an author outside of the Division. Capt. Peter Turner’s paper on the impacts of electronic navigation on watchkeeping and training was presented at the International Federation of Ship Master Associations (IFSMA) Annual Meeting in Rio de Janeiro. With the pending revision of the STCW Convention and Code in 2010, the need to review and strengthen the training provided to watchkeeping officers in electronic navigation must be critically examined.

Our Division sincerely hopes that the Proceedings will attract additional papers from other Divisions and ultimately become an annual publication which illuminates views and positions of the Company as we move forward with the implementation of our national strategic plan. We are pleased to continue our tradition of publishing a student paper from the Marine Institute’s third year nautical science class. The paper we have selected also deals with a key issue being debated by the IMO, namely the incorporation of the existing patchwork of industry standard related to Dynamic Positioning into SOLAS and STCW. With the vital importance of DP vessels to operations on the Grand Banks, we believe that the survey conducted by the students will provide important information to our members.

Over the past few years, the potential of conducting increased maritime operations in Arctic regions has grabbed the attention of the general public and has attracted the attention of the shipping and oil and gas industries. As a reflection of the upsurge in Arctic issues within our industry, the Proceedings contains two papers on Arctic topics. The first paper looks at issues related to icebreaking services which would be required to facilitate trade in the Canadian Arctic. The second looks at the process of improving training systems for Arctic operators by improving the mathematical basis of ice navigation simulators.

Finally, the Proceedings contains a transcript of a speech which the Division presented at the World Maritime Day in Halifax. Our Division sets a broad agenda for improving professionalism by addressing gaps in the methods which are used to develop professional attitudes, development of a Code of Ethics, and the management of competence.
An Examination of the Sufficiency of Regulations Pertaining to Dynamically Positioned Vessels

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Summary

Dynamic positioning (DP) is increasingly used in the offshore and specialty ship sectors of the shipping industry. Despite the rapid growth of the DP sector, few regulations have been enacted pertaining to DP. This report examines the current regulatory regime of DP operations and explores the actions industry has been taking to mitigate the risks associated with DP. In addition, the authors assess the perceived and actual effectiveness of industry’s risk mitigation strategy.

The authors designed and administered a survey instrument for DP personnel. The survey was completed by DP operators with a range of experience and fields of specialty. The data collected was both quantitative and qualitative. The authors used the data provided by the survey to evaluate the perception that DP operators have of various elements of DP safety, including safety, training, certification, and levels of incidents and accidents.

The International Maritime Organization (IMO) defines dynamic positioning (DP) as “a unit or a vessel which automatically maintains its position (fixed location or predetermined track) exclusively by means of thruster force (IMO, 1994, p. 3). It follows then that a dynamic positioning system is a computer controlled system used to maintain the ship’s position automatically, using the ship’s own resources such as its propellers and thrusters.

DP systems have sensors that measure the forces of wind, waves and current. The data from the sensors are then fed into a computer and a mathematical model is created of the forces acting on the vessel. The computer system controls the vessel’s equipment to maintain the ship’s position. The main manufacturers of DP systems are Kongsberg Maritime, Converteam (formerly Alstom), and L-3 Communications (formerly Nautronix). The major elements of the DP system are computer, control console, position reference system, heading reference, environmental reference, power system and propulsion system.

Vessels utilizing DP fall under three different classes depending on their level of redundancy. The IMO provides guidelines for three different DP equipment classes. Class 1 has the least amount of redundancy, Class 2 is more redundant, and Class 3 has the greatest redundancy. The class of vessel utilized for a particular operation is left to the discretion of the ship owner and offshore installation operator. The self-selecting of required classes is one example of how the DP sector is self-regulating.

Aside from the training regime designed by the Nautical Institute, there are very few guidelines for the training of DP operators. The Nautical Institute’s scheme includes DP theory, ship-based familiarization, simulations, and a period of supervised operations. The assessment of a potential DP operator is done by the Master of the ship on which the trainee is serving, not by a Nautical Institute approved instructor. Currently, most employers demand that a DP operator be certified by the Nautical Institute as a condition...
of employment. There is a considerable amount of data collected from the survey indicating that there is room for improvement of the Nautical Institute training scheme.

The shipping industry is subject to many international regulations; however, the DP sector is not subject to many additional regulations, despite the fact that DP ships perform specialized operations, often in close proximity to another ship or structure. Additionally, DP ships have specialized equipment that is integral to the safety of DP operations, but no regulations exist regarding this equipment. This report examines the Safety of Life at Sea (SOLAS) convention, looking for regulations that would apply to DP ships, should the equipment carried by DP ships become governed by SOLAS.

Additionally, there are no international regulatory requirements for DP operators to be assessed and certified in their competencies. This is a polarizing issue within the DP community – the International Transport Workers’ Federation (ITF) believe that DP operators should be certified under the Standards of Training and Certification of Watchkeepers (STCW) convention, but the International Marine Contractors Association (IMCA) is opposed to the idea, saying that industry is doing a satisfactory job of producing DP operators. Many details of the STCW convention and its accompanying code are discussed, with particular attention paid to regulations that would need to be complied with if training was regulated by the STCW.

Several industry associations have played an important role in the formation of guidelines and recommendations in the DP sector of the marine industry. The International Marine Contractors’ Association (IMCA), one of the major associations, has published several key documents that have been accepted by IMO and are used as industry best practices. The annual reports published by IMCA containing DP incidents have played an important role in isolating the primary causes of DP incidents. Another association that has had quite an impact on the DP industry is the Marine Technology Society (MTS), which helped establish a successful link between governments, industry, and its members. This partnership has allowed for the exchange of information for the purpose of increasing safety. The annual conferences held by MTS aim to solve existing issues in the DP industry as well as other industries.

It appears as if international regulatory bodies have noticed that the DP sector is self-regulating and has rewarded them, so far, by allowing industry to continue to self-regulate as new safety concerns arise. A rising proportion of DP incidents are due to equipment failure, with the next largest primary cause being human error. These facts lend credence to the notion that the DP industry may benefit from some additional regulations, particularly with regards to equipment carriage. The Nautical Institute training scheme is largely successful, but responses from the survey indicate that it can be improved. Data collected from the survey instrument show that respondents want changes made in the training scheme, particularly in the areas of emergency preparedness and shiphandling.

The possibility of regulating DP training was brought to the IMO by the International Transport Workers’ Federation, but IMCA defends industry’s record stating.
that there is no need to regulate DP training. The authors can see the benefits of both sides – leaving training unregulated makes it easier for industry to react to changes in technology, but creating worldwide, enforceable standards will ensure that DP is safe worldwide, without regard to the cost of implementing standards.

After examining the data from the survey instrument, the current regulatory regime and the actions that industry is taking to mitigate risk, the authors have the following recommendations:

1. Equipment carriage requirements for DP vessels should be included in SOLAS.
2. DP systems should be required to adhere to the same standards as Integrated Bridge Systems.
3. DP operators should be assessed on their ship handling competence, either in DP training or as part of OOW certification.
4. Within the Nautical Institute training scheme, the following changes should be made
   a. Emergency situations should be further addressed, either by
      i. Including more situations in the current training regime or
      ii. Adding a third course designed for Senior DPOs, which focuses on emergency situations and includes close quarters ship handling training.
   b. Experience should be gauged by the hours logged at the DP console, not by the number of days signed on to a vessel.
   c. Formal assessments of a candidate’s knowledge and competence should be conducted during the training period.
   d. DP instructors should be certified instructors and DP operators.
5. DP training should be included in STCW, Chapter V.
6. Any inclusion of DP training requirements in the STCW need not require a DPO to be a certificated OOW.

1.0 Introduction

1.1 Purpose
Dynamic positioning (DP) is increasingly utilized by specialized ships, particularly ships serving offshore installations. Compared to the marine transportation industry as a whole, the dynamic positioning elements of shipboard operations have relatively few codes and regulations governing operational procedures, certification, and equipment carriage requirements. The aim of this paper is threefold. It explores what national and international codes and regulations currently exist. As well, it examines what steps industry is taking to mitigate any risks associated with DP operations, taking into account operational procedures, training DP operators, and providing an acceptable level of equipment redundancy. Additionally, the authors assess the perceived and actual effectiveness of industry’s response to current regulations.

1.2 Background
As early as 1961, some vessels were using DP to maintain their position instead of using conventional mooring or anchoring techniques (Centre for Marine Simulation,
Dynamically positioned vessels have been defined by the International Maritime Organization as “a unit or vessel which automatically maintains its position (fixed location or predetermined track) exclusively by means of thruster force” (1994, p.3). As hydrocarbon exploration and sea floor development increased, the number of vessels relying on DP for safe positioning also increased. DP is now commonly found in use on vessels such as shuttle tankers, offshore supply vessels (OSV), dive support vessels (DSV), cable layers, dredges, pipe layers, even hydrocarbon exploitation vessels like drill rigs and floating, production, storage and offloading (FPSO) vessels.

Dynamically positioned vessels often operate in situations where collision, pollution, or loss of life could be the consequence of an incident involving DP equipment failure or operator error. There are, however, very few codes or regulations specific to DP equipment requirements, DP operator training or certification, or industry best practices.

Despite the lack of regulations, individual companies and the DP sector as a whole have taken steps to mitigate the risks associated with DP operations. Industry associations, such as the International Marine Contractors Association (IMCA) have developed and published guidelines for DP operations and training of DP operators (IMCA, 1999). Many companies operating DP vessels have created or adopted operational procedures for DP operations. Additionally, offshore installations often provide operational parameters that DP vessels must meet before DP operations can begin.

The Nautical Institute developed a training scheme for DP operators that includes a mixture of classroom instruction, simulated DP operations, and supervised DP operations on a vessel (Bray, 1998). This training program also requires that candidates acquire six months of supervised experience before the candidate successfully completes the program. This program is recognized by much of the marine industry as a standard of competency, and many companies require that DP operators obtain this standard of competency before shipboard employment begins.

Industry has also worked with regulatory bodies in the past to develop new guidelines for DP operations (Hill, 2003). Between 2001 and 2003, operators of DP vessels that serve offshore installations in the Gulf of Mexico worked closely with the United States Coast Guard (USCG) when the USCG delivered an opinion that DP vessels were in violation of the Code of Federal Regulations part 156.120, a regulation that requires vessels to be moored during oil transfer operations (Office of Federal Register, 2006). Since DP vessels conducted oil transfer operations while in DP mode and not moored, the USCG believed that any vessel not moored was in violation of the regulation. Industry performed many risk assessments and developed suggested minimum equipment requirements for OSVs working in the Gulf of Mexico. After working closely with industry, these suggestions were eventually released by the USCG as part of a new policy letter suggesting that vessels meeting the minimum equipment requirements would be in compliance with the CFR 156.120.
1.3 Scope

This report provides an overview of the functionality of dynamic positioning and will identify the hardware components integral to safe DP operations. Some common uses of DP are discussed as well as possible risk factors associated with each type of application. Existing national and international codes and regulations as they relate to the operation of dynamically positioned vessels are detailed, as is the training scheme implemented by the Nautical Institute. In addition to this industry-driven training scheme, the report discusses other methods with which industry is mitigating the risks associated with DP operations, such as creating procedures manuals and equipment redundancy requirements. The report also explores situations where industry worked in tandem with regulatory bodies to improve the safety of DP operations without the introduction of new legislation.

Finally, the authors evaluated data from a survey instrument that was distributed to stakeholders in the dynamic positioning community, such as DP operators, regulators, classification societies, and offshore installation managers. It was designed to quantify the perceived level of safety of DP operations as well as any perceived need for further legislation. The report also includes conclusions about the current level of legislation existing for DP operations and will make recommendations concerning additional legislation.

1.4 Methodology and Resources

Although there is ample information available in secondary sources about the general topic of dynamic positioning, there is very little available in traditional media specific to the topics addressed in this paper. As such, much of the information in this paper was acquired from secondary sources such as conference papers, trade association guidelines, company procedure manuals, codes and regulations, and course syllabi. Trade journals, texts, and the internet were also used in the research process. Access to the texts, journals and other resources at the Marine Institute’s Dr. C.R. Barrett Library were invaluable in researching this report.

In addition to the secondary sources, primary sources were also used. A survey instrument provides both quantifiable and quantitative data about stakeholders’ perceptions of the safety of DP operations and the stakeholders’ views on current and possible legislation. The Marine Institute provided web space for the survey instrument and IMCA provided information about the survey to its membership via email.

2.0 Survey Instrument

The authors administered an online survey designed to gain insight into the perceptions of DP operators currently working in the field. The survey instrument gathered information about the respondents’ professional experience with regards to safety during DP operations and also examined the perceived sufficiency of the current Nautical Institute training scheme.

The survey was hosted on the Marine Institute’s online server and was freely available to people invited to complete the survey. In addition to the authors requesting
specific people to participate in the study, IMCA sent a Marine Information Note to its membership notifying recipients about the survey. As a result, the respondents come from a broad cross-section of the DP industry, with significant proportions of respondents working on semi-submersible mobile offshore drilling units (MODU), offshore construction and pipe-laying, and anchor handling/supply vessels. The average seagoing experience of survey respondents was 11 years, with an average of seven years experience using DP.

The survey instrument consisted of several statements, to which respondents indicated their level of agreement. Responses were gauged on a scale of one to seven, with seven indicating strong agreement and one indicating strong disagreement. For the purpose of this report, the authors will refer to degrees of agreement (from one to seven respectively) as follows: strongly disagree, disagree, somewhat disagree, neutral, somewhat agree, agree, strongly agree. Additionally, there were several short answer type questions with respondents providing their opinion on areas in which their training could be improved and how it excelled. Free form responses were also collected regarding respondents’ professional experiences and comments on any near misses or incidents in which they had been involved. Finally, the instrument collected data on the frequency and severity of the types of near misses and incidents. Results from the survey instrument are interspersed throughout this report in the sections to which the questions are most relevant. A copy of the survey instrument can be found in Appendix I – Survey Instrument.

3.0 Overview of DP Technology

The IMO defines a dynamically positioned vessel as “a unit or a vessel which automatically maintains its position (fixed location or predetermined track) exclusively by means of thruster force (IMO, 1994, p.3). It follows then that a dynamic positioning system is a computer controlled system used to maintain the ship’s position automatically, using the ship’s own resources such as its propellers and thrusters. Information is provided to the computer via position reference sensors, wind sensors, current sensors, and gyro compasses. The computer uses these sensors to determine the ship’s position, and the direction and magnitude of environmental forces affecting the ship. The computer then creates a mathematical model of forces acting on the vessel that includes information pertaining to wind and current drag. This model, combined with the information fed immediately from sensors, allows the computer to determine the angle and pitch of the thrusters needed to maintain the ship’s position. The ability to maintain a precise position and to make predetermined moves using the DP system allows operations at sea where anchoring and mooring is not feasible due to deep water, sea bottom condition, and other problems (Bray, 1999).

3.1 History of DP

DP was first introduced in the 1960’s for use in the offshore drilling sector. With the search for offshore resources moving into deeper water, anchoring became less and less economically feasible. The drillship Cuss I was the first vessel to attempt drilling a well without anchoring. Fitted with four steerable propellers, the Cuss I found it possible to stay in position above the well off La Jolla, California in a water depth of 948 meters.
After *Cuss 1*, five wells were drilled of the coast of Guadalupe, Mexico. These wells were the deepest ever drilled, at a depth of 3500 meters, using basic DP principles. The vessel used radar to find accurate ranges from a floating buoy and an underwater sonar system to range beacons on the seafloor. The vessel, using this information, was able to maintain a radius of 180 meters over the well being drilled.

The drillship *Eureka* was launched later that following year; this drillship had an analogue control system that was interfaced with a taut wire reference system, making it a true DP vessel. The first DP vessels had analogue control systems and lacked redundancy. Since then, vast improvements have been made in DP technology. Today, DP technology is not limited to the offshore drilling and oil exploration industry but is also used in the cruise ship, survey, and construction industries (Wikipedia, 2008).

### 3.2 DP Systems and Manufacturers

The main manufacturers of DP systems are Kongsberg Maritime, Converteam (formerly Alstom), and L-3 Communications (formerly Nautronix).


Kongsberg now delivers systems for positioning, surveying, navigation, and automation to merchant vessels. Kongsberg’s DP systems are run on Windows-based computer systems. Kongsberg is, by far, the market leader in DP systems.

Alstom also provides DP systems that can be used in simplex, duplex, and triplex applications.

Alstom has developed the new A-series DP system which is an upgraded version of the older A-series 900 model. This product offers mode features and performance updates that meet today’s offshore oil and gas industry’s demand. The Alstom DP systems are run on a proprietary computer system (Alstom, 2008). In Figure 1 – *DP Control System*, two DP control systems are shown: on the right a Kongsberg Simrad, and on the left an Alstom A-series.

L-3 Communications is the third largest DP system provider. DP systems became a part of L-3 Communications after the company purchased the Nautronix Group in 2006. Based in Houston, Texas the company serves vessels throughout the world with DP systems. The products range from a simple joystick used for thruster control to a highly sophisticated redundant DP system. (L-3 Communications, n.d).

### 3.3 Forces Involved

A sea-going vessel is subject to the forces of wind, waves and current. In a DP system these forces are taken into account and a calculation is made by the DP computer controller to react to the forces and control the motion of the vessel.

A ship is considered to have six degrees of freedom in its motion. Three of these are considered translational: surge (forward and aft movement), sway (starboard and port movement), and heave (up and down movement). The other three degrees of movement
are considered rotational: roll (rotation about surge axis), pitch (rotation about sway axis),
and yaw (rotation about heave axis) (Kongsberg, 2008).

DP systems are capable of controlling the ship in the horizontal plane, meaning the surge, sway and yaw axes. To create an effective DP system, the designer must understand and predict the movements of the vessel due to the environment acting on the vessel’s hull. All forces acting on the vessel, including environmental, control devices and any attached structure to the vessel, need to be defined and equations of motion solved. After solving these equations, the DP system will apply thrust in a specified direction and force to counteract the external force (Stress Engineering Services Inc, 2008).

3.4 Elements of a DP system

The DP system can be classified by seven major elements: computer, control console, position reference system, heading reference, environmental reference, power system and propulsion system.

3.4.1 Computers.

DP computers can be installed in three configurations: single, double, and triple computer units. The number of units solely depends on the level of redundancy required for the owner’s and vessel’s needs. In all DP systems, these computers are dedicated to only one function - the DP system. One computer can be installed if a simplex system is required as there is no redundancy necessary in a simplex DP system. If a duplex DP system is required, two DP computers will be installed, as these computers will provide some of the redundancy required in a duplex system. If one DP computer fails, the system will automatically switch to the second computer and continue functioning normally. When a triplex DP system is needed to provide triple redundancy, a DP system with three computers is provided. If one computer fails, the results from all three computers will be compared; in turn, the computer that is different than the other two will be ‘voted out’ and the data from that unit will no longer be used (IMCA, 2008).

3.4.2 Control Console.

As one might imagine, the control console is where the DPO controls the operation of the DP system. The facility provided for the DPO to send and receive data. It is the location of all buttons, switches, alarms, and display all data. Position panels, thruster...
communications will be located next to the DP console giving the DPO a single station from which to control all of the ship’s maneuvering systems. The DP consoles vary from panels full of push buttons to computer screens that are touch sensitive to Windows-based systems with pull-down menus enabled by roller balls or by mouse.

Even though the DP system is closely related to other bridge systems, DP consoles are not always located on the bridge of a ship. In a triplex DP system there will be three DP consoles. Two of these consoles will be located on the bridge of the ship, but one will be located in a different location. This is done to ensure the safety of the vessel; if a fire engulfed the vessel’s bridge, the DPO can operate the vessel from another location onboard the ship (IMCA, 2008).

3.4.3 Position Reference Systems.

The main function of the position reference system is to determine and collect data about the vessel’s movement, and relay this data to the DP computer controller. Position data may be received in many different forms; two different co-ordinate systems are used to describe the vessel’s position: Cartesian and geodetic.

The Cartesian system is a system of measurements taken from a local defined reference origin. The Cartesian system takes measurements in meters, either north/south or east/west from this local origin.

The geodetic system is a measurement system that measures distance from a fixed point on earth using latitude and longitude (IMCA, 2008).

Reference systems can be divided into two main types: absolute positioning and relative positioning. Absolute positioning provides a position based on the ship’s location on the earth, while relative positioning provides information about the ship’s position relative to another object, like an offshore structure or a positioning beacon. The most common reference systems in use are: Differential Global Positioning System (DGPS), taut wires, Hydroacoustics Positioning Reference (HPR), High Precision Acoustic Positioning (HIPAP), and line of sight laser or microwave systems like Radius and Fanbeam (IMCA, 2008).

There are many factors taken into account by the DPO when position reference systems are selected. Some of these factors include level of redundancy needed for a specific task, risk involved in operation, and the consequences of loss of one or more position references.

3.4.4 Heading References.

Heading reference is provided to the DP system by a gyro compass. The DP system is fed this data so the heading of the ship can be controlled by the DP system. The requirements for different classes of redundant vessels vary; a simplex vessel is only required to carry a single gyro compass although on many vessels two are installed. Class two and class three redundant vessels are required to carry at least three gyros according to the IMO guidelines (IMO, 1994). When three gyros are installed, the DP control computer can use a two out of three voting process that will take the unusable gyro out of the DP console and allow no further use of the gyro (IMCA, 2008).
3.4.5 Environmental Reference Systems.

Environmental reference systems are used to measure the environmental forces acting upon the ship. The main types of environmental reference sensors used by the DP computer to measure these effects are Vertical Reference Sensors (VRS), Vertical Reference Unit (VRU), Motion Reference Unit (MRU), wind sensor, and current sensors (CMS, 2004).

3.4.6 Power Systems.

Power generation, supply and distribution are central to a DP system. Power has to be supplied to thrusters, DP control unit and reference systems. Diesel-electric power plants are commonly fitted on most DP vessels. The electric generators that are connected to the diesel engine powers the thrusters and the other DP equipment. A diesel engine and the electric generator combined are known as a diesel generator set.

A vessel may also use twin screws as part of the thruster system that are driven directly by diesel engines. Then, using power from the shaft alternators, the bow and stern thrusters are powered (IMCA, 2008).

Most DP vessels increase their redundancy level regarding power loss or blackout, by the inclusion of an uninterruptible power supply (UPS). The UPS will provide the DP system with battery power for 30 minutes after a power loss takes place.

3.4.7 Thrusters.

A DP system can use up to three types of common thrusters to provide thrust. These three types are main single or twin propellers, tunnel thrusters and azimuth thrusters. Main propellers that are fitted on a DP vessel are often of a controllable pitch propeller (CPP) type system. On these CPP units the pitch can change almost instantaneously; when the pitch is changed, combined with the vessel’s rudders, the forward and astern movements can be controlled. Most of these vessels are fitted with high-lift rudders that have a rudder angle of up to 70 degrees; however, some vessels, like a semi-submersible drill ship, may not have any rudders at all, only azimuth thrusters (IMCA, 2008).

Tunnel thrusters are commonly located on the bow of DP vessels. Some DP vessels will have upwards of two or three well placed bow thrusters used to control the bow movement of the system when in DP control. The tunnel thruster can only apply a directional force to port and starboard. Figure 2 – Typical Propulsion System Layouts shows typical propulsion system layouts for three different purpose vessels.
Azimuth thrusters are usually placed on the vessel’s stern. Azimuth thrusters are lowered from the ship’s hull to a depth under the keel. The azimuth thruster can be turned in a 360 degree motion; therefore, it can apply a directional force in 360 degrees. Propeller movement of the azimuth thruster is by bevel gearing from above. The azimuth can be retracted back into the hull while sailing at higher speeds or when docking in a shallow water port (IMCA, 2008).

### 3.5 Types of Vessels Using DP

It is interesting to note the types of vessels using DP and the function of these vessels. In 1980, the number DP capable vessels was about 65, while by 1985 the number of vessels had increased by 150. In 2002, the DP vessel count was over a thousand vessels and still increasing (Wikipedia, 2008). A current, but not complete list of DP vessel activities would include coring, exploration drilling, production drilling, diver support, pipe lay, cable lay and repair, multi-role, rock dumping, dredging, platform supply, shuttle tanker off-take, and seabed mining.

### 4.0 Vessel Classification

Vessels fitted with DP fall under specific classes depending on their redundancy as well as function. According to the International Maritime Organization (IMO), there are three classes of DP vessels (IMO, 1994). The Maritime Safety Committee (MSC) of the IMO released a circular, MSC/Circ 645, in 1994 entitled “Guidelines for Vessels with Dynamic Positioning System”. Within these guidelines put forth by the IMO are specifications for redundancy levels, most commonly referred to as “equipment class”. 

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Source: http://www.imca-int.com/divisions/marine/reference/intro03.html
DP class 1 means the vessel has no redundancy and loss of position may occur from a single system fault. This type of system is generally found on vessels operating in moderate climates and involved in low risk operations. DP class 2 vessels are designed to ensure that loss of position will not occur as a result of a single fault in an active component such as thrusters, generators, switchboards, etc. However, loss of position may occur as a result of failure in static systems such as manual valves, pipelines, or cables (IMO, 1994). Ships that are commonly involved in operations where a system failure can result in large scale environmental damage or loss of life are generally fitted with DP class 3 systems. This class of vessel must withstand flooding or fire in any compartment and still effectively maintain position (Kongsberg, 2008). Ships most commonly utilizing class 3 are drill rigs and dive support vessels. Maintaining station is essential for these vessels as a rig could break clear from a well, spilling oil into the sea, and dive support vessels are involved in operations where human life is potentially at risk.

Classification societies such as American Bureau of Shipping (ABS), Lloyds’ Register (LR), and Det Norske Veritas (DNV) issue their own class notation for DP capable vessels. Although the notations from each of the societies, as well as the associated equipment carriage requirements, vary, they all comply with the IMO equipment classes (DNV, n.d). The duty of assigning which class of vessel is to be utilized in a particular operation is left to the parties involved such as the ship owner, operator, and any national authorities (Holger Røkeberg, 1997). Usually, the client decides which class of vessel is required to perform a given operation. This deflects any liability that may arise in cases where accidents have occurred as a result of a DP ship being used in conditions where a higher class vessel may have been more suitable for the operation. As an example, class 1 DP vessels are not permitted within a certain zone around certain offshore installations, like in the Gulf of Mexico, because of the potential risk of system failure and possible damage to the vessel, installation, and environment (Hill, 2003).

The guidelines for classification of DP vessels were established to protect the marine environment as well as the lives of seafarers worldwide. By introducing vessel class, the risk associated with operations involving DP vessels was greatly reduced. The requirements for equipment class have remained almost the same over the past twenty years (Røkeberg, 1997). Although the original requirements for each class came from the IMO, individual classification societies have ‘personalized’ each class to suit their own safety standards. This industry-driven initiative is a good example of industry mitigating risk in order to limit their exposure to liability.

When it came to the question of safety in DP operations, the DP operators who completed the authors’ survey instrument answered decisively – 93% of respondents agreed to some extent that DP operations are conducted safely on their vessel, with nearly half of all respondents (46%) strongly agreeing. Similarly, respondents overwhelmingly agreed that the operational limits for their vessels are safe, given the ship’s capabilities. Seventy nine percent of respondents either agreed or strongly agreed and no respondents either disagreed or strongly disagreed. Based on this perceived level of safety, it makes
sense that 64% of respondents either agreed or strongly agreed that safety was a higher priority on their vessel than commercial pressures. These figures certainly lend credence to the notion that classifying DP vessels and allowing operators to determine the level of redundancy will improve the safety of DP operations.

5.0 Nautical Institute Training Scheme

The growth of the offshore industry has substantially increased the demand for dynamic positioning operators (DPOs) in recent years. New DP equipped ships are being built with greater frequency than ever before. In order to fulfill this growing demand it is essential that training institutions turn out properly qualified DPOs, ready to handle any situation they may encounter.

Capt L.J. Skagemo (2003) states that human error is the underlying cause of many DP related incidents; therefore, a properly qualified DPO is essential in maintaining the safety of the ship while operating in DP mode. This creates pressure on training institutes and industry alike to ensure that their DPOs have all the necessary skills and requirements to meet the growing demand.

The pressure is applied to training institutes by the DP sector to deliver high quality training because, aside from the training regime designed by the Nautical Institute, there are very few regulations actually governing the certification of DP operators. As an example of how prevalent the Nautical Institute’s training regime is, three out of four survey respondents who identified what training they had received indicated that they had received training according to the Nautical Institute training scheme.

The Nautical Institute is based in London and a monograph written by Capt. D.J. Bray (1999) outlines the institute’s training standards for certification of DPOs. The institute’s regime has six phases, the first of which is a shore-based introduction course, followed by a thirty day sea going familiarization on board a DP capable vessel. The student then returns to the classroom for another shore-based advanced operator’s course, followed by a six month term of supervised DP operations on board ship. Once the student has successfully completed phases one through four, s/he must obtain verification from the master of his/her DP capable ship that they are suitable for DP watch keeping onboard. Once this requirement is met, a certificate is issued. During the training period, no written assessments are performed, nor are there any assessments by a qualified instructor as to a student’s competence in simulation or in practice. As such, the primary tool used to assess a candidate’s suitability for receiving a DP certificate is the DP logbook, signed by the Master.

5.1 Training Phases

Capt D.J. Bray (1999) then describes each phase of the regime starting with the introduction phase. This phase, sometimes known as induction, gives a very basic understanding of DP systems and how they operate and explains some of the reference systems used. It is basically designed so that watch keepers, with no prior understanding of DP, can gain the basic knowledge required to further their DP career. The introduction
course is usually four to five days in duration and is intended to be completed by qualified officers, but no restriction exists against non-certificated seafarers from taking the course. At the end of the induction course the trainee will be expected to understand the basic principles of DP, be able to set up and operate position sensors, to recognize alarms and warnings and to understand the capability plots and footprints. The Nautical Institute’s DP logbook is also issued at this time, and a space is left inside to record the successful completion of the course.

The Nautical Institute recognizes that some DPOs may have served on board a DP capable ship without completing the institute’s training regime. Therefore, one option is for the DPO to skip the introduction phase of the regime and move directly into the other phases of the program (Bray, 1999). However, before the DPO can do this, an assessment must take place to ensure that the student has gained the necessary knowledge from their experiences to continue along the training regime.

The second phase of the training regime consists of 30 days of DP familiarization on board a DP capable vessel. During this stage the DPO is treated as a cadet or an observer and is there to simply learn the basics of DP in a real life environment. The DP logbook, issued by the Nautical Institute, lists a range of tasks that must be completed and signed off by the master during this phase. It may not be necessary for the vessel to be engaged in DP operations for the whole of the 30 days as some of the tasks can be completed while steaming or alongside (Bray, 1999). In fact, the Nautical Institute counts all days signed on to a DP ship towards the trainee’s seateime. There are no requirements as to how long a trainee must actually spend in DP mode, at the DP console, in order to receive his/her certificate.

Once the trainee has successfully completed phase two, he/she then moves back to the classroom to continue with phase three. This phase is conducted in a shore based simulator and, like the introduction course is four to five days in duration. The use of the simulator allows the trainee to conduct DP operations and learn to handle many realistic DP failures in a safe environment (Bray, 1999). The instructors give the trainees a wide range of scenarios to handle which tests the trainees understanding of the DP systems. It is essential that this phase of the regime is conducted in a center with a highly sophisticated simulator facility in order to gain the necessary knowledge.

Despite the fact that the simulator course focuses on emergency situations, there was a very wide spread of responses about whether or not survey respondents felt capable, when they received their DP certificate, of handling an emergency situation relating to DP operations. Half of all respondents answered very neutrally – between somewhat disagree and somewhat agree – while only 32% agreed or strongly agreed.

Once phase three is completed, the trainee is ready for supervised DP watch keeping for a period of six months (Bray, 1999). In this phase the trainee acts as a member of the watch keeping team on the bridge. Responsibility varies with the preference of the company; however, the trainee usually acts as a second or third man on the bridge during DP operations. It is essential that the trainee be left with a qualified
DPO in order to gain sufficient experience. As in phase two, a space is left in the logbook to confirm completion of this phase.

Recently, debate has arisen concerning the amount of time actually spent at the DP console in phases two and four. As a result of the Nautical Institute’s not requiring a certain number of hours at the DP console, some companies have created their own form of DP logbook that records the actual number of hours spent at the DP console. Under the Nautical Institute’s regime, it is up to the trainee to pursue enough experience at the DP console to demonstrate competence in each task, so the Master will sign off all necessary tasks. However, the Nautical Institute is only concerned with the number of days spent on a DP capable vessel, leaving it up to the trainee to get the necessary tasks signed off.

Lastly, the trainee is assessed on his/her abilities by the master of the ship on which the trainee completed phase four. The Master’s evaluation is then entered in the Nautical Institute’s DP logbook and is the only assessment the trainee receives throughout the entire training regime. Once it is completed, it is sent off to the Nautical Institute in London where, shortly after, a DP operator’s certificate is issued.

There is no clear consensus from survey respondents about the current levels of assessment – 46% of respondents were either neutral about the issue or somewhat agreed or disagreed that a Master’s signature in a DP logbook indicated that a DP operator (DPO) was competent to perform a given task. Only 32% of respondents agreed or strongly agreed with the preceding statement. There appears to be a little more agreement to the notion that written tests should be a part of formal DP training – 43% responded that they agreed or strongly agreed and 33% were either neutral or somewhat agreed.

This training schedule or regime is used in marine training centers worldwide, including the Marine Institute, and is regarded as the accepted way of training DPOs.

5.2 DP Logbook

The DP logbook issued by the Nautical Institute, is given out free of charge at the beginning of the introduction course. The log contains all the necessary information on the trainee including date of birth, discharge book number, and passport number. As previously mentioned, the logbook contains spaces for entry of the successful completion of each phase of the training regime. Each phase must be signed or stamped by the instructor (during shore-based training) or master (during sea-based training). Section F of the DP logbook is left for the master’s final assessment on the trainee and is then sent to the Nautical Institute. Once received, the institute looks to see that the trainee has completed the necessary courses and required sea time and that it is properly endorsed. Section F is also checked to ensure the master has properly completed the assessment and that it is satisfactory. The institute also looks into the vessels and system types that the trainee gained his/her experience on. It is also a policy of the Nautical Institute to carry out extra vetting by contacting companies, institutions and masters to ensure that the information given is correct and valid (Bray, 1999).
Despite the fact that the primary tool for assessment of trainee DPOs is the DP logbook, only 36% of respondents strongly agreed that they completed all required tasks.

5.3 Assessment of Training Regime

Survey respondents were somewhat mixed in their overall assessment of whether the Nautical Institute’s training scheme produces competent DP operators. Sixty eight percent of responses were between somewhat disagree and somewhat agree although nearly half of all responses were in agreement to some degree. Additionally, only one third of all respondents agree to any extent that the simulator course provides adequate training for emergency situations relating to DP operations. Additionally, 41% either disagreed or strongly disagreed that DP training courses provide enough information for a graduate to be a competent DP operator.

For the onboard portion of the Nautical Institute’s training scheme, responses varied greatly, but the average respondent was neutral about whether or not the onboard training component of the scheme was long enough in duration. However, respondents are more certain about the quality of the onboard tasks – 54% disagreed to some degree with the notion that completing the tasks outlined in the DP logbook is sufficient to produce a competent DP operator. Several respondents indicated that the training should include more simulations of emergency situations and that simulations should be more ‘in depth’.

6.0 Regulatory Framework

The shipping industry is highly regulated. Codes and regulations exist nationally and internationally that govern most aspects of shipboard operations. The IMO refers to the International Convention on the Safety of Life at Sea, 1974 (SOLAS), the International Convention on the Standard of Training and Certification of Watchkeepers for Seafarers, 1978/95 (STCW); and the International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto, 1973/78 (MARPOL) as the three pillars of the international regulatory framework. The International Labor Organization (ILO) has recently drafted a document intended to be the fourth pillar of the maritime regulatory framework: the Maritime Labor Convention (MLC) (Mitropoulos, 2006). These four pillars set up the regulatory regime that mariners must adhere to with respect to safety of life, training and certification, pollution prevention, and working conditions.

Like other vessels, ships that operate using dynamic positioning (DP) must adhere to these international conventions, as well as to any flag state codes and regulations. A ship that is operating in DP mode has operational requirements that differ somewhat from a traditional ship that is underway. Some of these additional requirements overlap with areas covered within two of the four pillars: SOLAS and STCW.

6.1 International Convention on the Safety of Life at Sea (SOLAS)

The International Convention on the Safety of Life at Sea (SOLAS) contains regulations pertaining to the construction standards, equipment carriage requirements and performance standards to which ship’s equipment must adhere. Although DP ships must comply with all aspects of SOLAS, most aspects of SOLAS will only relate to DP ships
When operating as a traditional ship. There are certain areas in SOLAS that cover equipment similar to that carried by DP ships, but do not cover the specific equipment that DP ships have. There are also some aspects of the convention that do apply to DP ships though it is unclear as to whether all aspects are being adhered to by DP ships. Finally, integrated bridge systems (IBS) must comply with specific regulations set down by SOLAS, but DP ships traditionally have not been viewed as IBSs.

6.1.1 Areas of SOLAS which could pertain to DP Vessels.

The SOLAS convention specifies construction requirements for vessels, including requirements for navigation equipment and Global Maritime Distress and Safety System (GMDSS) radio equipment. The IMO states that the reason for having GMDSS equipment on board is to “ensure rapid, automated, alerting of shore based communication and rescue authorities, in addition to ships in the immediate vicinity, in the event of a marine distress” (IMO, 2002, paragraph 1). The importance of this equipment is emphasized in Chapter IV, Regulation 13, which states that:

.1 There shall be available at all times, while the ship is at sea, a supply of electrical energy sufficient to operate the radio installations and to charge any batteries used as part of reserve source or sources of energy for the radio installations
.2 A reserve source or sources of energy shall be provided on every ship, to supply radio installations, for the purpose of conducting distress and safety radio communications, in the event of failure of the ship’s main and emergency sources of electrical power (IMO, 2004, p. 347).

Since the GMDSS radio equipment is used for normal and emergency communications, requiring that a source of electrical energy is always present increases the likelihood that a ship in distress has an opportunity to communicate their distress to others. There is no such stipulation in SOLAS for DP systems. The DP system is used to maintain the ship’s position, often within close quarters to another vessel or structure. Therefore, a loss of electrical energy, which would disable the DP system, could easily cause a ship to lose position and collide with a structure or another vessel. Despite the fact that an accident could occur should the electrical power for the DP system fail, there are no regulations within SOLAS pertaining to the power supply to a DP system.

The above example of electrical energy failure is only one example of how the failure of part of the DP system could cause an incident. There are many other pieces of equipment in the DP system whose failure or performance outside of accepted standards could cause or contribute to an incident. Other examples of this type of equipment are position reference systems, environmental sensors (such as anemometer, VRU), and the control console. SOLAS does not include mention of any of the above equipment. In fact SOLAS does not mention dynamic positioning ships or any of the associated equipment specifically at all.

6.1.2 Areas of SOLAS that do apply to DP Vessels.

However, SOLAS does include some provisions that are applicable to DP ships. Chapter V, Regulation 24 provides guidance on the use of heading and/or track control

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systems. Since DP is often used to maintain heading and can be used to control the ship’s track, it can be argued that Regulation 24 applies to vessels using DP systems.

Regulation 24.1 states that in “high traffic density, in conditions of restricted visibility and in all other hazardous navigational situations where heading and/or track control systems are in use, it shall be possible to establish manual control of the ship's steering immediately” (IMO, 2004). All three of the major manufacturers of DP systems have included the ability for the DP operator to switch to manual control immediately in their products. For example, in the Kongsberg Simrad SDP system, the operator needs only to press the Standby button to return the DP system to the Standby mode (Kongsberg, 1999). Once the DP system is in standby mode, the operator will switch one switch to Bridge Control which allows the operator to have immediate local control of all systems previously controlled by the DP system.

Additionally, Regulation 24.2 requires that the OOW have “without delay the services of a qualified helmsperson” in order to take over manual steering in the circumstances required in 24.1 (IMO, 2004). Therefore, when the ship is in a hazardous situation and is in DP mode, a qualified helmsman must be immediately available to take over manual steering.

Finally, Regulation 24.4 requires that the manual steering be tested “after prolonged use of heading and/or track control systems, and before entering areas where navigation demands special caution” (IMO, 2004). The regulations make no reference to precisely how long “prolonged use” is, leaving it unclear as to what intervals are required between manual steering tests. Certainly an FPSO or MODU would need to periodically come out of DP mode to test the manual steering in order to comply fully with this regulation.

Chapter V, Regulation 19 describes carriage requirements for ship borne navigational systems and equipment, while Annex 9 of Chapter V lists navigation equipment which must adhere to certain performance standards (see Appendix II – Equipment listed in SOLAS Chapter V, Annex 9 for a complete listing of equipment and the standards which must be met). DP systems use some of the equipment listed, such as: gyrocompass, global navigation satellite system receiver, rudder / propeller pitch indicators. The list of equipment is quite extensive but does not include some of the more specialized equipment required by DP, such as: anemometers, VRUs, and relative position reference systems.

6.1.3 Integrated Bridge Systems.

One item that is mentioned in Regulation 19.6 of chapter V is the Integrated Bridge System (IBS), which essentially states that if one part of the IBS fails, that failure will not cause other parts to fail; the OOW will be immediately alerted about the failure by audible and visual alarms. Additionally, it shall be possible to operate each part of the IBS separately (IMO, 2004).
It is debatable as to whether or not DP systems fall under the category of IBS. MSC. 64(67) Annex I states that the IBS “should support systems performing two or more of the following operations: passage execution; communications; machinery control; loading, discharging and cargo control; and safety and security” (IMO, 1996, p. 3). DP systems undoubtedly control machinery, but have no control over communications or cargo operations. Although it is technically possible to execute a passage using the DP system, it would be imprudent to do so as collision avoidance measures become more difficult to implement. As for safety and security, it can be argued that DP makes close quarters navigation safer but has no effect on security. These two areas leave it unclear as to whether or not DP systems must adhere to the requirements of an IBS.

Annex I of MSC 64(67) lists, in detail, the IMO's recommendations for IBSs. Section 3.1.2 states that “each ‘part’ of an IBS should meet the relevant requirements of resolution A.694 (17) and their associated technical testing standards” (IMO, 1996, p. 3). Unfortunately, like SOLAS Chapter V, Annex 9, resolution A.694(17) lists equipment used for ‘normal’ navigation and does not include equipment used only in DP operations.

Annex I goes on to list several recommendations for the integration of the different parts of the IBS, with particular attention being paid to ensuring the display of information and the functionality of the system. For example, the IMO recommends that information continuously displayed be kept to a minimum and that there are multiple ways of accessing essential information.

Similarly, there should be multiple ways of performing essential functions; and actions which could cause unintentional consequences should require user confirmation before being performed. Perhaps most significant, if it is decided that DP systems qualify as IBSs, are the provisions in Annex I for power management.

Paragraph 5.3.3 states that the IBS should “maintain the configuration in use and continue automated operation, as far as practicable” upon restoration of a power interruption; however, safety related functions should only be restored by the operator (IMO, 1996, p. 6). Further, if DP systems are IBSs, the missing requirement for constant power is fulfilled by paragraph 5.4.2 which suggests that the power supply for an IBS be provided by both the ship’s main and emergency power sources. Additionally, paragraph 5.4.2 goes further, suggesting that the power be governed by an automated switchover which would prevent accidental shutdown and that the IBS be further supplied by a ‘transitional source of power’ and a reserve power source if necessary. The full contents of MSC 64(67) can be found in Appendix II.

When contacted about the possibility of DP systems being classified as an IBS, Svein Solbakken, a representative of Kongsberg (a major manufacturer of DP systems and IBSs), opined that DP does not classify as an IBS (email, February 8, 2008).

6.2 International Convention on the Standard of Training and Certification of Watchkeepers (STCW)

The STCW convention (and its accompanying code) specifies the competencies required for every seagoing position – from deck or engine rating to Master and Chief
Engineer, from cook to bosun. The set of competencies required for each position are listed, as are the methods of demonstrating each competency. Some competencies can be demonstrated through the simple acquisition of sea time; however, most require an approved training course and/or an exam. There is no certification level listed within the STCW for personnel operating dynamic positioning systems, but there are many skills that DPOs must acquire before they can be competent in operating a DP system. There are also many areas of the STCW that could apply to assessing DPOs, simulator training, ship handling, and instructor qualifications.

6.2.1 The Officer of the Watch as Dynamic Positioning Officer.

It is very common for a dynamic positioning officer (DPO) to be certificated to at least the level of Officer of the Watch (OOW), due partly to the nature of the work and partly to the fact that an OOW must be on the bridge at all times while the ship is underway. Combining the role of DPO and OOW allows that requirement to be met while the ship is operating in DP mode.

Current hiring practice in the DP sector is to employ people who are certified as an OOW and hold a Nautical Institute DP certificate. This hiring practice is supported by the fact that 61% of survey respondents either agreed or strongly agreed that a certificate as a deck officer should be a prerequisite for any DP training course. However, a distinct percentage (21%) of respondents strongly disagreed with the previous statement.

Table II-1 of the STCW Code states that in order for an OOW to be certified to serve on a ship fitted with an automatic radar plotting aid (ARPA) s/he must demonstrate competence by an “assessment of evidence from approved radar simulator and ARPA simulator training plus in-service experience (IMO, 1995 b, p. 31). No such training requirement currently exists for DP operations, despite the fact that the DP system is at least equally as complex and specialized as ARPA.

6.2.2 Ship Handling.

The OOW is also required to demonstrate competence in maneuvering the ship, including knowledge of “the effects of wind and current on ship handling”, “maneuvers and procedures for the rescue of persons overboard”, and “proper procedures for anchoring and mooring” (STCW Code, 1995 a, p. 35). This maneuvering requirement is of particular interest due to the fact that if the DP system fails, or if environmental factors exceed operational limits, the DPO will end up maneuvering the ship – often in very close proximity to an offshore structure or vessel. If the DPO is qualified as an OOW, it can be assumed that, due to the above requirements, s/he has some knowledge of ship handling, but there are no specific requirements in the STCW for an OOW or a DPO to be assessed on their competence in close quarters ship handling.

When asked if ship handling experience should be an element of formal DP training, 82% of respondents agreed that it should, with 46% of all respondents strongly agreeing. Ship handling is not part of the curriculum of either one of the current Nautical Institute training courses, nor is it an element required to be signed off by the ship’s master. As mentioned earlier, actual ship handling experience is not a requirement under
the STCW to receive certification as an officer of the watch. As a result of both of these facts, it is possible for an OOW to become certified as a DPO and have the controls of a ship in close quarters with no previous ship handling experience. Although the Master is always only a phone call away, if something goes wrong in close quarters, immediate action may be required to prevent an incident or accident occurring.

Responses were divided about where the skills to maneuver a ship in close quarters had been acquired. Thirty six percent of respondents either agreed or strongly agreed that, as a result of their DP training, they were capable to maneuver the ship in close quarters if the DP system totally failed. In contrast, 64% of respondents were in agreement that previous experience had provided them with the skills to maneuver the ship in close quarters. These results certainly imply that two thirds of DP operators are acquiring their ship handling skills from sources other than DP training.

One survey respondent who is the Master of a dive support/construction vessel said:

It is important that apart from DP operations, DP operators have practical experience in ship handling and feeling for environmental effects on the vessel. It often happens that I get qualified DP operators on board who are excellent in pushing the buttons, but have absolutely no feeling for the forces acting on the vessel, and thus not able to judge if position keeping is compromised by these forces. Let alone taking control over the vessel when the desk fails. Also consequence analysis of DP operations is not common knowledge amongst DP operators, while this is vital for decision making.

6.2.3 Special Training.

Realizing that DP operations is a relatively specialized type of ship operation, one would assume that any requirements for personnel serving on DP ships would be listed in chapter V of the STCW, which describes special training requirements for personnel on certain types of ships. This chapter lists the mandatory minimum training and certification requirements for officers working on tankers, passenger ships and ro-ro (roll-on/roll-off) passenger vessels. The STCW describes specific training courses, including syllabi covering the minimum amount of knowledge required, that must be completed in order to work on each of the mentioned ship types. Each of these ship types has been singled out for additional training because of hazards unique to that vessel type. For tankers, the hazard derives from the dangerous nature of the cargo; for passenger ships, the danger derives again from the nature of the cargo. Crowd control and the nature of the accommodation spaces require skills in an emergency beyond that required by the OOW certification. Ro-ro vessels have large open under-deck spaces that may retain water if one of the bow/stern doors failed or was not closed properly.

Currently, the STCW lists no specific requirements for DPOs to have demonstrated any competence in the operation of the DP system. However, at the 37th session of the IMO’s Sub-Committee on Standards of Training and Watchkeeping, it was agreed that the IMO would conduct a high priority comprehensive review of the STCW
convention and its accompanying code. Then, in December, 2007 the International Transport Workers’ Federation (ITF) submitted a proposal to the IMO that added “Mandatory minimum requirements for certification of masters, officers and dynamic positioning operators on vessels using dynamic positioning” (STW, 2007, p. 1). The proposal from the ITF recognizes the three classes of DP ships as set out by MSC/Circ. 645 in 1994 and the fact that industry responded to these classes by developing training courses for DP operators and technicians; however, many of these courses were developed specifically for certain types of equipment. The ITF recognizes that the Nautical Institute’s training scheme is generic (i.e. not specific to a certain manufacturer) and also is recognized by many operators of DP vessels as an acceptable level of training. The ITF recognizes the Nautical Institute’s certification system as an “industry best practice” (STW, 2007, p. 3).

The ITF recommends that the following topics are covered in the basic course:

.1 principles of DP;
.2 elements of the DP system;
.3 practical operation of the DP system;
.4 position reference systems;
.5 environment sensors and ancillary equipment;
.6 power generation and supply and propulsion; and
.7 DP operations” (STW, 2007, p. 3).

The current Nautical Institute Induction course covers all of the topics listed. In fact, the Nautical Institute simulation course also covers the material that the ITF suggests for a simulator/advanced course, namely “.1 practical operation of the DP system; .2 DP operations; and .3 DP alarms, warnings and emergency procedures” (STW, 2007, p. 4).

If the Nautical Institute’s method of certification were to be included in the STCW, worldwide application of these standards could be easily achieved, without the re-certification of current DPOs, due to the fact that there are currently over 40 institutions worldwide which are accredited providers of the Nautical Institute’s DP courses (Nautical Institute, 2007).

The suggestion by the ITF that DP training be included in the STCW is very contentious. IMCA’s position on the matter is that “this is not required as the Industry has not expressed a desire for this regulatory change and the current system has a sound record” (Nautical Institute, 2008, p. 2).

Despite IMCA’s statement that the Nautical Institute training scheme has a sound record, survey responses were not strong with regard to whether or not industry is doing a satisfactory job of producing DP operators; just over half of respondents, 54%, were either neutral or somewhat in agreement. However, the question of whether or not DP operators should be government certified was a contentious one; an equal proportion (21%) of responses were either in strong agreement or strong disagreement, with the remainder of respondents spread evenly throughout the spectrum.
6.2.4 Simulators and Instructor Training.

If the ITF’s proposal is accepted by the IMO and mandatory minimum training is required, and if that training requires the use of simulators, Regulation I/6 and Sections A-I/6 and A-I/12 of the STCW Code will apply to the training facilities. Regulation I/6 and Section A-I/6 detail the requirements for assessing candidates and the requirements for assessors, ensuring that instructors are “appropriately qualified for the particular types and levels of training they are providing” (STCW, 1995 a, p.14). This regulation/section would ensure that instructors have practical experience with DP and are trained in assessment methods – a requirement that DP instructors do not currently have to meet.

While there are currently no rules stating that instructors of DP courses must have a teaching certificate, 78% of survey respondents agreed that DP competencies should be tested by a certified instructor. In fact, only one respondent answered that s/he disagreed at all with the preceding statement. If the IMO accepts the ITF’s proposal to add mandatory training of key personnel on DP ships to the STCW, instructors will need to comply with STCW Convention Regulation I/6, which will ensure that DP instructors are qualified to teach the material on which they are assessing students (IMO, 1995).

Additionally, Section A-I/12 would provide guidance as to the requirements of the simulators involved in DP training – again, simulators currently in use do not have to meet this requirement. As it stands now, DP instructors and simulators may well comply with these regulations, but they are not obliged to. To see the complete text of the ITF’s recommendations on DP training, please see Appendix III – Mandatory minimum requirements for certification of masters, officers and dynamic positioning operators on vessels using dynamic positioning.

7.0 Industry Risk Mitigation & Associations

Several major associations have been the key to the creation of guidelines and regulations for DP training, certification, and industry practice worldwide. Some of the most crucial documents in the DP industry have come from the efforts of associations in the offshore sector, whose members have years of industry experience. IMO has recommended several of these documents as guidelines for the basis of training for DPOs and has been encouraging compliance by member governments to help resolve ongoing issues.

7.1 International Marine Contractors Association

The International Marine Contractors Association (IMCA) was formed in 1995 from the merger of the International Association of Offshore Diving Contractors (AODC) and the Dynamic Positioning Vessel Owners Association (DPVOA). Since then, IMCA has expanded from 100 members to over 250 organizations in 2004 (IMCA, 2007). The association is composed of companies as well as organizations involved in the offshore industry such as marine contractors, marine and underwater engineering, oil companies, and vessel owners. IMCA aims to provide solutions to industry wide issues as well as a high level of safety to its members with a balance of risk and cost (IMCA, 2007).
7.1 Guidelines and Recommendations.

Many of IMCA’s members operate ships or are involved in offshore operations that use DP. Up until recent years, there was little guidance regarding the requirements for DP vessels or the standards of training required for DP operators. IMCA produced several publications that gave members a standard to follow with regards to safety, existing regulations, procedures, and industry best practices. The document “Guidelines for the Design & Operation of Dynamically Positioned Vessels” is one of IMCA’s key documents consisting of basic practices and principles to be followed by all vessels equipped with DP including training, characteristics, weather precautions, as well as international regulatory framework. The document also consists of eight chapters highlighting the specific requirements for various types of DP vessels including shuttle tankers, pipe laying vessels, and cable laying vessels. These requirements touch on training, redundancy, operations, alert systems, and personnel responsibilities. The document was first produced in 1991, and has seen a fair amount of revision and updates with changing regulations and technological developments (IMCA, 2007).

IMO’s acceptance of the document, “The Training and Experience of Key DP Personnel”, has also been an important milestone for IMCA and its members. This document was referenced by the IMO in 1996 and noted that the current guidelines established by IMCA regarding the industry standard for the training, competence and experience could act as a basis of training for DP operators. Member governments were encouraged to bring the issue to the attention of all concerned bodies (IMCA, 2007). The guidelines are designed primarily for those vessels involved in operations where loss of position could result in injury or major pollution to the environment. Criteria and qualifications including training are provided for each type of job listed. Input from a range of institutions, including the Nautical Institute, are included in the document giving a detailed outline of the training, certification, and practical experience requirements.

7.1.2 Training Philosophy.

Once the trainee has reached the rank of DPO, it is essential that the level of experience and qualifications is maintained throughout his/her entire career in order to ensure the safety of the industry as a whole.

The International Marine Contractors Association (IMCA), a major industry association, focuses mainly on maintaining this level of competence once the DPO has completed the training course. It is the opinion of IMCA that this is essential in order to maintain the high level of qualifications and expertise required in industry today.

A document issued by IMCA, entitled The Training and Experience of Key DP Personnel (2006), goes further to the Nautical Institutes training regime. It suggests that once a DP operators certificate is obtained it is necessary for the DPO to continue logging his/her level of competency. This is achieved through the use of the IMCA DP logbook which can be obtained on the IMCA website. This logbook acts as a reassurance to the DPOs and companies that their levels of training are adequate and are not fading as their careers progress. This technique is widely employed in today’s industry, and is not only...
limited to DP training. Through the use of computer programs and a wider range of shore based programs, many companies have set up a training matrix to ensure their employees continue to grow in their respective field.

IMCA mentions in its document that the three main issues affecting the personnel experience of DPOs is 1) individual experience/training, 2) the DP vessel itself and its specific operational requirements, and 3) the specific DP systems that are currently employed in industry and the variations between each. Some suggested remedies for these problems is for the DPO to spend a substantial amount of time engaged in DP mode in order to familiarize themselves with the specific operation of the vessel. Also, regular training and practice, either shore- or sea-based, will increase the DPO’s skills. Finally, a formal refresher course can be implemented just to update the DPO on advancements in DP technology to ensure they are kept up to date.

As previously mentioned, IMCA is mainly concerned with the maintenance of experience once a DPO certificate is obtained. In the document they also set down minimum experience standards for personnel serving on a DP capable vessel. They break DP vessels down into two categories: 1) established DP operational vessels and 2) new or unfamiliar vessels. An established vessel is one with a minimum of six months of DP operations with a properly trained, qualified crew. An unfamiliar vessel is a new build, outfitted with the latest technology which may be unfamiliar to the DP personnel. A table is given in the document which outlines the minimum level of experience, in hours and weeks, required by IMCA in order to successfully man a DP vessel and achieve established DP vessel criteria. (See Table 1.)

<table>
<thead>
<tr>
<th>Key Personnel</th>
<th>Previous DP Vessel</th>
<th>Subject DP Vessel</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hours</td>
<td>Weeks</td>
</tr>
<tr>
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<td>10</td>
</tr>
<tr>
<td>Senior DPO</td>
<td>250</td>
<td>10</td>
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<td>4</td>
</tr>
<tr>
<td>ETO/ERO</td>
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<td>10</td>
</tr>
<tr>
<td>Electrician</td>
<td>250</td>
<td>10</td>
</tr>
</tbody>
</table>


In an effort to mitigate and understand the risks involved with DP and to aid in the development of safer systems, IMCA closely monitors station keeping incidents. In partnerships with companies such as Global Maritime, IMCA publishes annual reports outlining the types of DP incidents which occur as well as the most probable causes of such incidents. Members of IMCA who experience DP incidents and allow them to be entered into the annual publications are assured confidentiality (IMCA, 2003). No names
IMCA wants to know about the causes of DP related incidents. The main triggers are computer, environment, generator, operator, reference, thruster, and electrical. When taking into account lost time incidents, external load, design, and insufficient testing are also added to this list (IMCA, 2006). By close examination of the annual reports dating back to 1994, the most common types of incidents can be noted. Trends in DP related incidents can be developed from data recorded from 1994 to 2003. The data indicated the majority of LOP1 incidents occurred as a result of operator error, DP computer, and references. For LOP2, the trend is slightly different. Reference systems are at a higher level as well as thruster problems. This is mainly a result of the nature of redundancy within references and thrusters and their impact on the severity of a position loss (IMCA, 2006 c). Vessels have greater levels of redundancy for thrusters and reference systems due to the pressure from operational guidelines as well as classification societies. The reasoning behind references being the major cause of (LOP2) events is that work is undertaken where loss of position is considered an acceptable risk. An example would be ROV work being conducted away from structures such as rigs or other offshore structures. In cases such as this, where the operator determined that there were not enough references online, he/she may accept the risk because the consequences of a position loss were quite acceptable. It is common for operators to rely only on one reference such as differential global positioning systems (DGPS) when doing ROV work in clear water.

In addition to the incident triggers noted above, it is worthwhile to mention other issues resulting in position loss often encountered in the DP industry. Topical causes such as blackouts can be as a result of equipment or management problems and generally require the examination of how the system was set up onboard the vessel in the first place and if this is what led to the position loss (IMCA, 2006 c). Despite the advances made in DP technology, blackouts continue to occur on a regular basis. The number of blackouts has steadily risen over the past ten years, with a peak in 2000. From 1994 and 1999, most blackouts were reported from DSV, ROV, drilling and pip laying vessels (IMCA, 2006 c). Onwards from 2000, 60% of reported blackouts were in the drilling industry. This is largely due to the fact that deepwater DP drilling increased in activity in this time period. The number of full blackouts vs. partial blackouts is equally split due to the fact that more partial blackouts tend to go unreported than full blackouts. Vessels that are set up with closed bus tie breaker(s) are more likely to experience a full blackout than partial,
although it is difficult to draw conclusions on the effect of the status of the bus tie breaker because blackouts have occurred with the breaker opened as well as closed. The bus tie breaker serves to isolate different systems so that when the breaker is open, a failure of one power source will not affect the operations of items on the other side of the bus tie breaker. More recent studies have shown the effect of the bus tie has little effect over the full blackouts. The change in trend can be attributed to more efficient power management, control, and a better understanding of power management operations (Fougere, 2006).

7.2 Near Misses, Incidents and Accidents

In accordance with the requirements of the International Safety Management (ISM) Code, most companies have policies to record and report near misses, incidents, and accidents. A near miss can be described as an “unplanned event that did not result in injury, illness, or damage - but had the potential to do so” (Wikipedia, 2008). A marine incident is described as an occurrence where either a person falls overboard or cannot perform his or her duties (which are related to the safe operation of the ship) due to incapacitation, the ship touches bottom or is almost in a collision, or a dangerous good is released to the environment. In contrast, an accident is described as an occurrence where a crew member is seriously injured or killed or the ship is in a collision, goes aground, sinks, or suffers a fire or explosion (Transportation Safety Board of Canada, 2007).

Survey respondents reported if they had experienced near misses, incidents, or accidents. Unsurprisingly, there were far more reported near misses than any other type of occurrence. Seventy nine percent of respondents reported having at least one near miss. Forty six percent of all respondents admitted to having a near miss on account of human error. Equipment failure was a much more common cause of near misses, with 64% of respondents attributing a near miss to equipment failure. Only one third of respondents had experienced near misses on account of poor procedures. Although near misses were very prevalent amongst the survey’s respondents, the rate of incidents was much lower, but by no means insignificant, at 39%. Even though this figure is much lower than the rate of near misses, the severity of an incident is, by definition, higher. Again, more respondents attributed an incident to equipment failure than to human error; these were reported at rates of 36% and 18% respectively of all respondents. Only 14% of respondents reported an incident on account of poor procedures.

Finally, 14% of respondents reported at least one accident, with all 14% reporting accidents that caused damage. In addition, 7% reported accidents causing injury and 4% of all respondents reported accidents causing loss of life. Accidents causing pollution were also reported by 7% of all respondents.

The respondents were given an opportunity to add comments on any near misses, incidents, or accidents. The experiences reported are quite varied, with operators describing a multitude of reasons for these experiences. One operator did not follow procedure and began steaming without retracting the HIPAP pole; another reported that while various human errors and equipment malfunctions had occurred, a robustly designed DP system and operators that followed procedures prevented near misses from
occurring. Still another operator, working on a drill ship, described the frailty of their DP system – the operator accidentally contacted the surge button on the DP console, causing the DP system not to control the ship’s position in the fore and aft direction. As a result of this accidental contact the rig “began to drift and an emergency disconnect was initiated causing pollution and loss of time” (Survey respondent, 2008). In this instance, it sounds like procedures were followed and the equipment functioned correctly; the pollution was caused by an accidental touch of one button.

7.3 Marine Technology Society

The Marine Technology Society (MTS) was incorporated in 1963 to provide a link between government, industry, and members. The exchange of information and ideas for the advancement of education, development and services has led to many resolved issues in marine science and offshore exploration. The purpose of MTS is “to promote awareness, understanding, advancement and application of marine technology” (Gilman, 2007). Like IMCA, the MTS is comprised of members from a variety of marine based fields including industry professionals, institutions, technologists as well as students working to develop marine technology for the safe, efficient exploration of ocean resources.

MTS is recognized worldwide for its annual conferences that aim to solve existing issues in the DP industry as well as other industries. Usually, the conferences are held in the fall throughout the U.S as well as Canada. The duration is typically three or four days and comprise of 200-400 technical papers. These conferences provide an opportunity for scientists, engineers and managers in the marine affairs subject area to present and gather information on ocean science, engineering and policy (MTS, 2008). There have been many papers produced on issues regarding DP vessels, training, certification and competence. Many of the conflicting issues in the DP industry have been addressed at these conferences and recommendations to address these common problems have been developed. Presentations have been given by some of the top players in the industry putting forth ideas to members as well as non-members for solutions to common problems experienced in the DP sector of the offshore industry around the globe.

With further advances in DP technology, these annual conferences held by MTS will continue to aid the DP industry in solving common issues as well as developing recommendations for the safe, effective use of DP. With the number of members growing annually, MTS has expanded into a powerful source for the development of guidelines and has been able to target the key problem areas shared in the industry. Further development in key areas have been encouraged by the implementation of scholarship and internship programs for young individuals who have extensive knowledge in the industry, giving them the opportunity to compete in competitions around the world involving the development of marine technology.

7.4 Industry Response to US Coast Guard Policy Paper

As was previously discussed, DP has grown enormously in the last few years. This sudden burst of technology has left governments and industry scrambling to adapt with the changes and draft guidelines to ensure the safety of the industry.
One notice issued by IMCA entitled *US Coast Guard Requirements for DP Vessels Operating in the Gulf of Mexico* focuses mainly on the changing requirements of offshore cargo transfer. Previously this operation was carried out using conventional mooring applications such as anchoring and single point mooring; however, since the rise of DP, many ships are shifting to using it rather than the former. This has prompted the US Coast Guard to issue a policy letter concerning the minimum requirements for mooring during offshore operations.

The US Coast Guard issued an opinion that dynamically positioned vessels operating in the Gulf were violating a federal regulation. Title 33 Code of Federal Regulations 156.120, which outlines pollution prevention measures, requires that “... the vessel’s moorings are strong enough to hold during all expected conditions of surge, current, and weather” during fuel transfer operations. Since many supply boats operate on Dynamic Positioning (DP) and are not moored while transferring fuel, the US Coast Guard was of the opinion these vessels were in violation of this regulation. Industry disagreed, noting that the DP systems in use were designed to hold the vessel in position for all expected conditions of surge, current, and weather during fuel transfer operations.

Different companies operating in the Gulf of Mexico collaborated in risk assessments, safety requirements, and in setting up operational parameters for transferring fuel at offshore installations. These companies then collaborated with the US Coast Guard to implement their recommendations as part of a new policy paper suggesting that industry DP best practices be considered acceptable in regards to CFR 156.120 (Hill, 2003).

In response to the recommendations provided by industry, the US Coast Guard issued a new policy letter. In this letter the Coast Guard recognizes that DP is the way of the future and will replace the older mooring applications. Therefore, they suggest a minimum set of standards be put in place to ensure the safety of persons, property, and environment. Redundancy is the main standard on which the Coast Guard focuses. The level of redundancy ensures the safety of the entire operation. For hazardous materials (HAZMAT) transfers the Coast Guard suggests a minimum of DP class 2 or class 3 vessels. This class level is very unlikely to fail in these operations and, if it should, the operator is given advance warning to discontinue the operation before the vessel drifts off station.

Another alternative the Coast Guard gives is the use of a quick closing valve. This can be used so that even if the system was to fail and the ship drifted off station, the transfer operation would stop and no oil would be released into the environment.

Finally, the Coast Guard states that it is important for specific companies involved in such an operation to take proper precautions and draft up their own guidelines for HAZMAT transfers in order to avoid such an occurrence. This letter also recognizes that human error contributes to the level of safety in the industry and restates that a properly qualified DPO is paramount in avoiding an environmental disaster.
Although this letter is very clear in the setting down of the minimum standards and describing exactly what level of safety is to be maintained, it still leaves much of the responsibility up to the companies and ships themselves. None of these standards will be checked on during inspections or surveys by the Coast Guard, rather, they will only be investigated once an accident or casualty occurs. However, perhaps then it will be too late.

8.0 Conclusions

Dynamic positioning has had a major impact on the marine industry and has been a significant factor in the development of offshore resources. Since 1961, the DP industry has undergone innumerable changes, in part due to continuous improvements in technology and industry requirements for training and certification. Associations such as IMCA, the Nautical Institute and MTS have each produced documents containing guidelines and recommendations designed to mitigate the risks involved in DP operations. Industry has done an acceptable job of mitigating risks and self-regulating DP operations. Regulators appear to have noticed and have, occasionally, allowed operators of DP ships to offer non-regulatory solutions to emerging safety concerns.

The Nautical Institute provides the most widely adopted training scheme in the DP industry. Feedback from the online survey showed that a large number of respondents felt that the current Nautical Institute training scheme is insufficient in producing competent DPOs. The vast majority of respondents felt that ship handling should be an element of formal training, due to the fact that DPOs may be required to take control of the vessel in instances where the system malfunctioned in close quarters situations. Experienced personnel who were surveyed commented on the fact that although junior DPOs are generally quite capable of using the DP systems upon graduation, they lack the knowledge of how to deal with the environmental forces acting on the vessel in an instance where the system failed. The fact that the current training scheme does not involve an examination is also an area which deserves attention. A number of respondents felt that there should be some form of examination to assess the competency of the student.

With regards to the onboard training, the tasks to be completed in the DP logbook are insufficient in producing a competent DPO, according to the vast majority of respondents. Although the majority of responses indicated a need for improvement in the current training scheme, there were mixed responses on the topic that DP operators should be government certified.

When comparing the DP industry with the shipping industry as a whole, government has done little with regards to regulation. Although vessels fitted with DP systems must comply with both national and international regulations governing shipboard operations, there are very few regulations governing the actual DP equipment carriage requirements. The SOLAS convention, under the umbrella of the IMO, specifies construction requirements for vessels, including requirements for navigation equipment and Global Maritime Distress and Safety System (GMDSS) radio equipment. These requirements aim to maximize safety for seafarers when serving onboard ships. However,
there is no mention of DP vessels under SOLAS or any construction requirements for machinery that could have disastrous consequences in the event of a failure of a vital system. Regulation 19.6 of chapter V highlights the requirements for integrated bridge systems and discusses the importance of immediate notification to the officer of the watch in the event of a malfunction by means of audible and/or visual alarms. With regards to DP, incidents have been documented where the trigger for the incident was the operator accidentally initiating a command that did not require confirmation. Similar incidents have resulted from accidental contact with a control, and due to the lack of audio/visual alarms, the operator became unaware of the developing situation.

Although there does not appear to be consensus that DP systems meet the requirements to be integrated bridge systems, it is the authors’ opinion that most DP systems should qualify as integrated bridge systems since the DP computer controls several pieces of machinery related to the maneuvering of the ship, can be used for navigation, and contributes to the safety of working in close quarters.

The wisdom of not including equipment carriage requirements in the SOLAS convention is questionable since a large proportion of recent DP incidents stem from some form of equipment failure. Power systems seem to be particularly vulnerable to failure - many vessels in recent years have suffered power blackouts resulting in a loss of position. It is possible that some blackouts could have been prevented by trained operators, but the possibility of blackouts and other equipment failures should certainly be reduced.

A global, regulated standard for training of DP operators does not currently exist. The IMO’s STCW convention and code lists all certification requirements for personnel serving aboard ships. No requirements are listed for DP operators. Even though it is not required, a large number of DPOs are also qualified deck officers. In addition, a majority of respondents surveyed felt that officer certification should be a prerequisite to the DP training course. Although STCW does not include any requirements with regards to ship handling skills for DPOs, 81% of respondents surveyed felt it should be an element of formal training. A master of a dive support/construction vessel commented in the survey that “it is important that apart from DP operations DP operators have practical experience in Ship handling and feeling for environmental effects on the vessel”.

The continuing efforts by leading associations in the DP industry such as IMCA and MTS have contributed to the mitigation of risks associated with DP operations. In close partnership with the IMO and other regulators, these associations have developed several key documents containing guidelines and recommendations that represent industry best practices. MTS is recognized worldwide for its annual conferences that aim to solve existing issues in the DP industry as well as other industries. As well, the annual reports published by IMCA have been an effective tool in recognizing the main triggers of DP incidents. These reports are made possible by the efforts of concerned members around the globe who share a common interest in improving the safety level of DP operations.
The efforts of the DP industry to mitigate risk and self-regulate have resulted in DP operations being conducted with a great regard for safety: ship owners conduct risk assessment and ensure that their vessels meet the construction standards and equipment carriage requirements of their classification society; some offshore installations require that only a specific class of DP ship approach the structure; ship owners demand that DP operators receive training prior to employment; finally, the Nautical Institute has developed a largely successful training scheme for DP operators. International regulatory bodies have rewarded these efforts by not including regulations regarding equipment carriage or training requirements in the applicable conventions.

Despite all of these efforts, however, there is clearly room for improvement in the regulatory regime, particularly when it comes to equipment carriage requirements. There is also room to improve the Nautical Institute training scheme, particularly in the areas of emergency preparedness and candidate assessments. Finally, the question of whether to include the training scheme in the STCW convention is contentious, with the ITF suggesting that it be included and IMCA contending that training is being delivered adequately by industry and should be left out of the STCW.

9.0 Recommendations

Industry’s response to the lack of additional regulations for DP vessels is an excellent example of the private sector self-regulating, without much governmental or international intervention, with mainly positive results. This report examined two main areas of DP operations with respect to the current regulatory regime: training and equipment carriage requirements. Based on an examination of the current regulations, industry’s response and the effectiveness of those responses, the authors have drawn several conclusions and are prepared to offer recommendations on how DP safety could be improved.

There are certainly areas of the DP sector that are ‘under-regulated’ when compared to other sectors of the industry. For example, the equipment carriage requirements for DP vessels are not well defined at all under SOLAS. Systems that serve similar partial functions, such as Integrated Bridge Systems, have very explicit requirements under SOLAS. Another example is power requirements; IBSs and GMDSS radio installations have requirements under SOLAS to be powered by alternate power means, in case of blackout. A very large proportion of major DP incidents within the last ten years occurred as a result of equipment failure. Most notable among these failures are power blackouts, which occur when the DP system demands more power than the power system can provide.

Another cause of DP incident is the unintentional execution of a command – operators can sometimes accidentally contact a control which may cause a vessel to lose position unintentionally, even with all equipment functioning correctly. This type of incident could be reduced by adding an audible component to actuating a control that might cause unintended consequences. For example, when pressing the ‘Surge’ button, in addition to a visual acknowledgement of the button being pressed, a noise would be produced, alerting the operator to the action.
Even though there are guidelines produced by the IMO for the construction of DP vessels, these guidelines are mostly enforced by the classification societies, not flag states. As the IMO document provides guidelines only, it cannot be enforced as law. This has left the ‘enforcement’ and interpretation of the guidelines up to the classification societies, DP operators, and operators of installations requiring DP support.

It certainly stands to reason that since a large percentage of DP incidents are due to equipment failure of one sort or another and that industry is currently self-regulating equipment carriage, there is room for an international body to step in and provide definite equipment carriage requirements that are at a level high enough to prevent, or dramatically reduce the frequency of, these incidents. If the international community is satisfied with DP self-regulation, the IMO could easily update their guidelines with an eye to minimizing equipment breakdown. Alternatively, the IMO could include equipment carriage requirements for DP vessels in SOLAS, which would make it mandatory for DP ships belonging to a member state to meet said requirements. These requirements would then be subject to inspection by flag state authorities.

Since vessels operating under DP are often in a position where loss of position could cost a human life – as in dive support; or cause pollution to the marine environment – as in drill rigs and supply vessels transferring fuel; it is the authors’ opinion that equipment carriage requirements should be included in SOLAS. No matter how well trained the personnel are, if the equipment they are using fails, the chance for loss of life, pollution, or damage is too great to leave to the individual skills of the operator.

As DP systems function by integrating several pieces of the ship’s equipment, the requirements that have been established for IBSs are very appropriate to DP systems. IBSs are required to take into account ‘human factors’; for example, ensuring confirmation of essential functions and ensuring that the information displayed to the operator is provided in a clear and concise manner. If DP systems are subject to the same requirements, it is likely that the number of near misses, incidents and accidents will be reduced, since at least some of the near misses reported in a DP survey were caused by accidental operation of a control. The authors recommend that any regulations enacted pertaining to DP should include either reference to the requirements for IBSs or should include the content of said requirements.

This reasoning for more regulatory safeguards is augmented by the fact that there are currently no requirements for DP operators to demonstrate competence at maneuvering a vessel in close quarters. Although many DP operators may well be excellent ship handlers, the point remains that they do not have to demonstrate competence to any authority to become a DP operator. Neither is an officer of the watch examined on his/her ability to maneuver the ship – an OOW will be examined on his/her knowledge of maneuvering but not actually assessed in practice. For these reasons, it makes sense to ensure that DPOs are examined in their ability to handle a ship. This assessment could take place within the DP training regime, but it would also be preferable if it was included in the OOW certification under STCW.
There appears to be little doubt that a DP operator should have the skills of an OOW, but industry appears to be doing a satisfactory job of ensuring that DP operators have these skills. The position of DPO is almost always filled by a certificated OOW; therefore it seems unnecessary to demand that the Nautical Institute (or any government body) only grant DP operator’s certificates to those who hold an OOW certificate or higher.

As for the success of the industry-driven training regime, a DP certificate from the Nautical Institute is almost always a pre-requisite for employment on a DP ship. This indicates that there is widespread acceptance by industry as to the adequacy of the training provided by the Nautical Institute. However, the fact that the Nautical Institute scheme is the only one widely available may exaggerate the actual acceptance rate of this training.

There are strong indications from survey respondents that there is room for improvement in the Nautical Institute training regime, particularly in the areas of emergency preparedness, counting of sea-time, formal assessments (written and practical), and ensuring that instructors are trained properly and have real-world experience with DP operations.

Only one third of survey respondents indicated that as a result of their DP training they felt capable of responding to a DP related emergency situation. Perhaps the current certificate issued should remain a “DP operator” certificate, but an additional layer of training could be required for a “Senior DPO” certificate, which would simulate higher level emergency situations and would include close quarters ship handling. Since there is almost always one senior DPO on shift with a junior or regular level DPO, adding this extra layer of training would ensure that there is always someone on the bridge who is qualified to deal with emergencies, both from a DP and a ship handling standpoint.

The method of counting sea time towards DP certificates is also a contentious one. The Nautical Institute does not require a certain amount of experience using DP in order to receive a certificate, only the days signed-on to a DP ship are counted – provided that the ship is in ‘normal operations’. A more realistic method of ensuring that candidates acquire the pre-requisite experience is to count the hours that a candidate logs at the DP console. This would ensure that the candidate actually operates the DP system for a pre-determined amount of time. The fact that merely counting sea-days may not be adequate is reinforced by the fact that some companies have begun their own in-house method of gauging a DPO’s experience by counting the hours spent operating.

The fact that there are currently no formal assessments in the Nautical Institute’s training scheme is also contentious. Only one third of survey respondents strongly agreed that they had completed all of the required tasks in the DP logbook, the primary tool for assessment under the current regime. This low figure indicates that many DP operators receive their certificate without demonstrating all of the competencies required by the Nautical Institute. The only way to really ensure that candidates demonstrate the required
competencies is to have a properly trained instructor formally assess each candidate on their knowledge and competence.

There currently are no requirements for DP instructors to have any training as an instructor and as a DP operator. Results from the survey of industry professionals strongly agree that instructors should be certified to instruct.

Some debate has arisen in the last few years regarding whether or not DP operators should be certified under the STCW. The International Transport Workers Association has submitted a request to the IMO that DP training be included in chapter V of SOLAS. IMCA has countered, saying that industry has done a satisfactory job of producing trained, qualified DP operators. The decision to regulate the certification of DP operators will, in all likelihood, end up being a political decision. Industry has shown that it has a vested interest in manning DP ships with qualified personnel by requiring operators to have training from the Nautical Institute. If industry can pressure the Nautical Institute to update their training scheme, there may be no need to regulate the certification of DP operators. In some ways it is preferable to keep DP training unregulated, with industry driving the changes. One main reason for this preference is that industry can be much quicker to implement changes in training regimes if changing the regime will reduce the exposure to risk at an acceptable cost to industry. On the other hand, if DP training was to be included in STCW, the training standards would be the same worldwide and would be enforceable by law. Additionally, if the standards are set by an international body, like the IMO, the standards will be set with a regard for safety and not the cost of implementing the standards.

This worldwide standardization of training standards, combined with the notion that IMO derived standards will have safety as paramount leads the authors to recommend that the IMO follow the recommendations of the ITF and include special training for key personnel working on DP in chapter V of STCW.

References


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Nautical Institute. (2008, January). The first meeting... *DP Training Executive Group Newsletter, 1, 2.*


Appendix I – Survey Instrument
Appendix I – Survey Instrument

This is a print representation of the online survey. The content is the same as the online version, but the formatting may not be exactly the same. Survey located at: http://www.mi.mun.ca/students/danderso

This survey is designed to gather information from the marine industry regarding dynamic positioning issues. The results from this survey will form part of a technical thesis produced by final year students in the Nautical Science program at the Marine Institute.

Your cooperation in this survey is highly appreciated. All respondents will remain anonymous.

Current Rank:

Employer:

Years in industry:

Years as DPO:

DP Class of Vessel:

Type of Vessel:

Please list any formal DP training received and certificates acquired, including course provider/issuing agency:

Section One: Training

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<th>5</th>
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<td>3 A Master’s signature in a DP logbook indicates that the DPO is competent in a given task</td>
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<td>5 Holding a certificate as a deck officer should be a prerequisite to any formal DP training course</td>
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<tr>
<td>6 The Simulation course provides adequate training for emergency situations relating to DP operations</td>
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<tr>
<td>7 The DP training courses provide enough information for a graduate to be a competent DP operator</td>
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<tr>
<td>8 The onboard training component of the Nautical Institute DP training scheme is long enough in duration</td>
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<tr>
<td>9 Completed tasks outlined in the DP logbook are sufficient to produce a competent DP operator</td>
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<tr>
<td>10 The Nautical Institute training scheme produces competent DP operators</td>
<td>[ ]</td>
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<tr>
<td>11 DP operators should be government Certified</td>
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</table>
Industry is doing a satisfactory job of producing qualified DP operators

Please describe any areas in which the training you have received could be improved.
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

Please describe any areas in which the training you have received has excelled.
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

Section Two: Professional Experience

Please indicate to what extent you agree with each statement, with 7 indicating strong agreement and 1 indicating strong disagreement.

<table>
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<tbody>
<tr>
<td>15</td>
<td>DP Operations on your vessel are conducted safely</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>16</td>
<td>When you were taking DP training, you performed all tasks in your logbook</td>
<td></td>
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<tr>
<td>17</td>
<td>Safety is considered a higher priority than commercial pressures on your vessel</td>
<td></td>
<td></td>
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<tr>
<td>18</td>
<td>The operational limits your vessel uses are safe considering the ship’s capabilities</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>19</td>
<td>When you acquired your DP Operator’s certificate, you felt capable of handling an emergency situation relating to DP operations</td>
<td></td>
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<tr>
<td>20</td>
<td>As a result of your DP training, you felt capable of manoeuvring the ship in close quarters if the DP system totally failed</td>
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<tr>
<td>21</td>
<td>Prior experience provided you with the skills to manoeuvre the ship in close quarters</td>
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Additional Comments:
________________________________________________________________________
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### Section Three: Near Misses and Incidents

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<tbody>
<tr>
<td>22</td>
<td>A near miss on account of <strong>Human Error</strong></td>
</tr>
<tr>
<td>23</td>
<td>A near miss on account of <strong>Equipment Malfunction</strong></td>
</tr>
<tr>
<td>24</td>
<td>An near miss on account of <strong>Poor Procedure</strong></td>
</tr>
<tr>
<td>25</td>
<td>An incident on account of <strong>Human Error</strong></td>
</tr>
<tr>
<td>26</td>
<td>An incident on account of <strong>Equipment Malfunction</strong></td>
</tr>
<tr>
<td>27</td>
<td>An incident on account of <strong>Poor Procedure</strong></td>
</tr>
<tr>
<td>28</td>
<td>An Accident causing <strong>Injury</strong></td>
</tr>
<tr>
<td>29</td>
<td>An Accident causing <strong>Loss of Life</strong></td>
</tr>
<tr>
<td>30</td>
<td>An Accident causing <strong>Pollution</strong></td>
</tr>
<tr>
<td>31</td>
<td>An Accident causing <strong>Damage</strong></td>
</tr>
</tbody>
</table>

Please provide any relevant details

___________________________________________________________
___________________________________________________________

Thank you for taking the time to complete this survey. Your feedback is appreciated.

If you have any questions please feel free to call:
David Anderson (709) 727-4849; Paul Bishop (709) 589-4195;
Phil Hopkins (709) 586-2350; Brendan Keeping (709) 579-2964
Appendix II – Equipment listed in SOLAS Chapter V, Annex 9
Appendix II – Equipment listed in SOLAS Chapter V, Annex 9

Annex V, Chapter 9 of SOLAS lists equipment, the regulation referring to the equipment, details about the equipment, IMO resolutions, amendment dates, adoption dates, international standards which the equipment must comply with. In the interest of space, only the equipment listed is provided in this Appendix. The whole body of Annex 9 can be found at: https://mcanet.mcga.gov.uk/public/c4/solasv/Annexes/Annex09.htm

Equipment Required by SOLAS, Chapter V, Annex 9:

- Magnetic compass
- Pelorus
- Electronic charts
- Global Navigation Satellite System Receiver (GNSS)
- Electronic Position Fixing System
- Radar Reflector
- Radar Beacons & Transponders
- SARTS
- Sound Reception System
- Daylight Signaling Lamp
- Echo Sounder
- Electronic Plotting Aid (EPA)
- Speed and Distance Measuring Equipment (SDME)
- Transmitting Heading Device (THD)
- Transmitting Heading Device (GNSS)
- Transmitting Magnetic Heading Device (TMHD)
- Automatic Identification System (AIS)
- Gyro Compass
- Gyro Compass- HSC
- Gyro Compass Heading Repeater
- Gyro Bearing Repeater
- Rudder / Propeller / Pitch Indicators
- Automatic Tracking Aid ATA
- Radar - 9 GHz, 3 GHz
- Heading / Track Control System
- Rate of Turn Indicator
- Integrated Bridge Systems
- Voyage Data Recorder (VDR)
- Simplified Voyage Data Recorder (S-VDR)
- Night Vision Equipment

1 INTRODUCTION

1.1 An integrated bridge system (IBS) is defined as a combination of systems which are interconnected in order to allow centralized access to sensor information or command/control from workstations, with the aim of increasing safe and efficient ship’s management by suitably qualified personnel.

1.2 IBS, in addition to meeting the functional requirements contained in applicable IMO instruments, the general requirements in resolution A.694(17)*, should comply with the following performance standards.

2 SYSTEM REQUIREMENT

The IBS should support systems performing two or more of the following operations:

.1 passage execution;
.2 communications;
.3 machinery control
.4 loading, discharging and cargo control; and
.5 safety and security.

3 GENERAL REQUIREMENTS

3.1 General

3.1.1 The IBS should comply with all applicable IMO requirements and recommendations. Parts executing multiple operations should meet the requirements specified for each individual function they control, monitor or perform.

3.1.2 Each “part” of an IBS should meet the relevant requirements of resolution A.694(17) and their associated technical testing standards. In consequence, the IBS is in compliance with these requirements without further environmental testing.

Note: “part” is meant to be - for example - an individual module, equipment or subsystem.

3.1.3 A failure of one part should not affect the functionality of other parts except for those functions directly dependent upon the information from the defective part.

3.2 Integration

The IBS should provide functional integration meeting the following requirements:

.1 The functionality of the IBS should ensure that its operation is at least as effective as for stand-alone equipment.

.2 Continuously displayed information should be reduced to the minimum necessary for safe operation of the ship. Supplementary information should be readily accessible.
.3 Where multifunction displays and controls are used to perform functions necessary for safe operation of the ship they should be duplicated and interchangeable.

.4 It should be possible to display the complete system configuration, the available configuration and the configuration in use.

.5 Each part to be integrated should provide details of its operational status and the latency and validity of essential information. Means should be provided within the IBS to make use of this information.

.6 An alternative means of operation should be provided for essential functions.

.7 An alternative source of essential information should be provided. The IBS should identify loss of either source.

.8 The source of information (sensor, result of calculation or manual input) should be displayed continuously or upon request.

*IEC 945 Publication.

3.3 Data exchange

3.3.1 Interfacing to an IBS should comply with the relevant international marine interface standards.*

3.3.2 Data exchange should be consistent with safe operation of the ship.

3.3.3 The integrity of data flowing on the network should be ensured.

3.3.4 A failure in the connectivity should not affect independent functionality.

3.4 Failure analysis

3.4.1 A failure analysis should be performed, documented and be acceptable.

*IEC 1162 Publication.

4 OPERATIONAL REQUIREMENTS

4.1 Human factors

4.1.1 The IBS should be capable of being operated by personnel holding appropriate certificates.

4.1.2 The Man Machine Interface (MMI) should be designed to be easily understood and in a consistent style for all integrated functions.

4.1.3 Where multifunction displays are used, they should be in colour, and continuously displayed information and functional areas, e.g. menus should be presented in a consistent manner.

4.1.4 For actions which may cause unintended results, the IBS should request confirmation from the operator.

4.2 Functionality

4.2.1 It should always be clear, from where essential functions may be performed.
4.2.2 The system management should ensure, that one user only has the focus of an input or function at the same time. If so, all other users should be informed about that by the IBS.

5 TECHNICAL REQUIREMENTS

5.1 Sensors

In order to ensure an adequate system functionality the sensors employed should ensure communication compatibility in accordance with the relevant international marine interface standard*; and provide information about their operational status and about the latency and validity of essential information.

5.2 Alarm management

5.2.1 The IBS alarm management, as a minimum, should comply with the requirements of the Code on Alarms and Indicators, 1995 (resolution A.830(19)).

5.2.2 Appropriate alarm management on priority and functional groups should be provided within the IBS.

5.2.3 The number of alarm types and their release should be kept as low as possible by providing indications for information of lower importance.

5.2.4 Alarms should be displayed so that the alarm reason and the resulting functional restrictions can be easily understood. Indications should be self-explanatory.

5.3 Power interruptions and shut-down

5.3.1 If subjected to an orderly shut-down, the IBS should, upon turn-on, come to an initial default state.

5.3.2 After a power interruption full functionality of the IBS should be available after recovery 000 of all subsystems. The IBS should not increase the recovery time of individual subsystem functions after power restoration.

5.3.3 If subjected to a power interruption the IBS should, upon restoration of power, maintain the configuration in use and continue automated operation, as far as practicable. Safety related automatic functions should only be restored upon confirmation by the operator.

5.4 Power supply

5.4.1 Power supply requirements applying to parts of the IBS as a result of other IMO requirements should remain applicable.

5.4.2 The IBS should be supplied:

1. from the main and emergency sources of electrical power with automated changeover through a local distribution board with provision to preclude inadvertent shut-down;
2. from a transitional source of electrical power for a duration of not less than 1 min; and
3. where required, parts of the IBS should also be supplied from a reserve source of electrical power.

*IEC 1162 Publication.
Appendix IV – Mandatory Minimum Requirements for Certification of Masters, Officers and Dynamic Positioning Operators on Vessels Using Dynamic Positioning.
Appendix IV – Mandatory Minimum Requirements for Certification of Masters, Officers and Dynamic Positioning Operators on Vessels Using Dynamic Positioning.

1 Dynamic positioning has become increasingly important on a wide range of ships from passenger ships to offshore and dive vessels. The equipment used is extremely sophisticated and the level of technology requires skills quite unique from those otherwise required by a ship’s officer.

2 With the adoption by the IMO of guidelines for vessels with dynamic positioning (DP) systems contained in MSC/Circ.645 in June 1994, the following three basic classifications of DP operations were recognized:

.1 Class 1 – Automatic and manual position and heading control under specified maximum environmental conditions;

.2 Class 2 – Automatic and manual position and heading control under specified maximum environmental conditions, during and following any single fault excluding loss of compartment (two independent computer systems); and

.3 Class 3 – Automatic and manual position and heading control under specified maximum environmental conditions, during and following any single fault including loss of a compartment due to fire or flood. (At least two independent computer systems with a separate backup system separated by A60 class division).

3 The industry and manufacturers responded with training courses for DP operators and technicians, however these were often specific to the equipment supplied. A limited number of colleges and notably the Nautical Institute set up courses for DP operator certificates that, whilst in compliance with the requirements of the supplier, considered all classes of operation.

4 The basic course set-up should cover:

.1 principles of DP;

.2 elements of the DP system;

.3 practical operation of the DP system;

.4 position reference systems;

.5 environment sensors and ancillary equipment;
power generation and supply and propulsion; and

DP operations.

5 The simulator/advanced course incorporates the basic skills and lessons learnt in operation and should cover the following topics:

1. practical operation of the DP system;
2. DP operations; and
3. DP alarms, warnings and emergency procedures.

6 DP watchkeeping experience requires not only the rank the DP operator was in at the time the experience was gained but also the class of vessel it has been gained on. Operators only operating on a Class 1 vessel will only be able to apply for a limited certification. There are also reductions in DP time required with intensive simulator training.

7 This certification system set up by the Nautical Institute can be seen as industry best practice and there are a number of other options in other countries that may also provide suitable training. The ITF, however, is not aware of details of these courses or their applicability with different manufacturers’ systems.

8 The ITF recognizes that the crew of offshore vessels are often employed for relatively short periods on any one vessel and operate in many different areas of the world. They may work on vessels with a different DP class, various equipment and configurations and with an assortment of company operational requirements.

9 Given the sophistication of the modern DP operation and the diversification of its use the ITF considers that the generic training competency standards should be included in the STCW Convention ensuring a minimum international standard that is easily recognized and totally transportable.

10 The ITF calls on the industry and training establishments that are currently actively involved in determining training and competency standards for DP operators to submit these standards for the Sub Committee’s consideration

***
RECONFIGURING GLOBAL SUPPLY CHAINS: A STRATEGIC REVIEW OF CANADIAN ICEBREAKER SERVICES

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Abstract
Global warming presages increasingly ice-free waters in the Canadian Arctic and scope for a fundamental reconfiguration of Asia-Europe and Asia-US East Coast supply chain networks. Despite retreating perennial Arctic sea ice the vast geography of the Arctic poses significant challenges in supplying support networks in remote locations. To support future developments, the capabilities of the Canadian Coast Guard (CCG) icebreaker fleet will be crucial. This paper reports on research which aimed to synthesize experts’ perceptions of future marine activity in the Canadian Arctic and to analyze CCG services, principally Arctic icebreaking, in terms of their effectiveness and efficiency in the past, present, and future. A Delphi survey of expert opinions distilled the results of a literature review focused on current and future CCG services, Arctic climate change and its effect on transportation in the region, new icebreaking technology, privatization, and the growing demand for natural resources. The paper concludes by highlighting the requirements needed to ensure timely and uninterrupted marine transportation from vessels operating in these waters.

Keywords: global supply chain strategy, Northwest Passage, privatisation of ice-breaker services, Canadian Arctic, Delphi survey

Introduction
For centuries explorers sought a route through the Arctic linking Europe and Asia. John Cabot proposed a Northwest Passage in 1490 and Roald Amundsen made the first ship transit in 1905 (Pharand, 1984, 38). Interest in the Arctic region, whether stemming from climate change or its abundance of natural resources, is high on the agenda of many nations. The annual extent of Arctic ice coverage is retreating at a notable rate and it is estimated that the Canadian Arctic will experience nearly ice-free summer seasons starting as early as 2050 but probably not before 2100 (Falkingham, 2004, A-5). NASA data shows that Arctic perennial sea ice shrank abruptly by 14% between 2004 and 2005 (Hupp and Brown, 2006). It would be logical to think that less ice should increase the ease and mobility for ships currently working in Arctic regions and also for those ships that may be contemplating future activity. Milder sea ice conditions may present new merchant shipping opportunities by way of the shorter distances available to Europe-Asia and East Coast North America-Asia traffic. In terms of marine transportation, increased activity will probably result in new and increased business as a virtuous circle of business and economic activity appears to be moving northward (National-Research-Council, 2005, 3).

On a global scale, Arctic regions are rich in natural resources, holding about 25% of the world’s undiscovered petroleum resources (Ahlbrandt and McCabe, 2002). On a local
scale, Canada’s Arctic regions are estimated to hold one third of its remaining recoverable natural gas and one quarter of the remaining recoverable light crude oil (Indian-and-Northern-Affairs-Canada, 2006, 7). Cruise ship activity is increasing and fishing fleets have already begun to follow the fish stocks that migrate northward as the ice edge retreats (National-Research-Council, 2005, 24). Any increase in activity will increase the necessity to respond to accidents and create a greater need for law enforcement in ice margin areas, which will increase the need for ice-capable ships in the Arctic (National-Research-Council, 2005, 25).

**Literature Review**

With respect to Canada’s sovereignty and adequate resources to enforce it, Carnaghan and Goody (2006) concluded that the views of Canadian academics differ. Huebert’s (2003) view that Canada presently has insufficient resources to enforce its sovereignty in the Canadian Arctic contrasts with Griffiths’ (2003) view that Canada’s effort in enforcing its sovereignty in the region is sufficient. CCG commissioner G. Da Pont states that, while the CCG currently plays a significant role in the Arctic, nothing is certain as to the extent of its role in the future (Binkley, 2006, 9). He considered that neither Russians nor Canadians have the commercial infrastructure in place to support increased vessel traffic in their respective Arctic waters. Arctic icebreaking vessels constitute a significant financial investment. To rebuild the current Canadian icebreaking capability will cost $CAD 2-3B and to build the fleet required to meet anticipated future demand will cost $CAD 10B (Robertson, 2006). Securing such monies may not be easy for the CCG as it is currently experiencing a funding gap of about $CAD 55M (Department-of-Fisheries-and-Oceans-Canada, 2006). Reports from the office of the Auditor General from 1997 to February 2004 note a lack of adequate and effective management of capital and human resources by the Department of Fisheries and Oceans (DFO) in fleet management of icebreakers in the Maritimes Region of Canada (Clemens et al., 2004, 5). These issues are not new and changes are needed. Cutting edge icebreaking technology is being implemented in new tonnage currently under construction in European and Far East ship yards, for operations in the Arctic regions of the world. Arctic nations such as Sweden, Finland, Russia, and the United States are currently availing themselves of private involvement in the execution of their icebreaking operations. Saunders *et al.* (2007) describe exploratory research as being initially broad but becoming progressively narrower as a result of any, or a combination, of a literature review, the interviewing of experts, and conducting focus group interviews. Our initial review of literature focused on the major themes of Arctic maritime transportation, Arctic resources, climate change, icebreaking technology, the CCG, the Arctic Council, privatization, risk management, and insurance. As a next step, Delphi methods are appropriate to gather data not previously gathered, known or available (Linstone and Turoff, 1975).

**Delphi study**

A Delphi exercise consisting of three rounds of questioning was conducted to enhance research sensitivity. The questions posed in the first round were founded on the results of the literature review and focused mainly on current and future CCG levels of services, Arctic climate change and its affect on transportation in the Arctic regions, new
icebreaking technology, the global status of Arctic icebreakers, privatization, and the growing demand for natural resources in politically stable but rather remote and harsh environments. Potential panellists were identified through the literature review, as well as from personal meetings at conferences related to the research topic. The exercise was carried out independently by panellists using an e-mail based survey. Table 1 shows the number of panellists, questions and the average percentage of majority opinion (APMO) in the Delphi exercise.

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<tr>
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<th>Round 1</th>
<th>Round 2</th>
<th>Round 3</th>
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<tr>
<td>Participants</td>
<td>32</td>
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<td>23</td>
</tr>
<tr>
<td>Questions</td>
<td>32</td>
<td>44</td>
<td>21</td>
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<tr>
<td>APMO (%)</td>
<td>49.26</td>
<td>41.90</td>
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Table 1: Summary of Delphi Exercise

The Average Percentage Majority Opinion (APMO) (Abdel-Fattah et al., 1999; Makukha and Grey, 2004; Islam et al., 2006), enumerated as the ((Aggregate of Majority Agreements + Aggregate of Majority Disagreements)/ Total Opinion expressed x 100), was used to determine whether consensus was reached on each statement provided. In the first round of questioning the APMO of 49.26% generated 44 statements for the second round. At 66.6%, 75% and 85% respectively, 144, 160 and 181 statements would have been generated, deterring most individuals from participating further. The round two APMO of 41.90% generated 21 statements for round three. With an APMO of 37.18%, consensus was attained on 17 of the 21 statements.

Results

Nine major issues summarise the findings of the Delphi study relating to future ice conditions, transit traffic, icebreaker capabilities, CCG services and organisation, vessel movements, icebreaker deployments, privatization and resource issues.

Future ice conditions in Arctic waters (original statement no. 3)

Considerable uncertainty surrounds the extent to which perennial Arctic ice will retreat in terms of geographic location and when the Arctic Ocean may experience ice free summers. However, 12.5% more panellists agreed that the Arctic Ocean will experience ice free summers before the Northwest Passage (NWP). Of those panellists who disagreed, many agreed that parts of the Arctic Ocean along the Russian Northeast Passage (NEP) would be free of summer ice before the NWP. Also, many panellists found it hard to believe that if the Arctic Ocean were to become ice-free, the NWP might not do so. There was strong agreement with the view that as the annual Arctic sea ice reduces it will make it easier for perennial Arctic Ocean ice to move south through the Canadian archipelago and thus block the many straits that vessels would have to transit in traversing the NWP or operating within the archipelago, thus impeding shipping movements.

Transit traffic through the NWP (original statements no. 1, 2)

With respect to vessel traffic traversing the NWP, there was consensus that panama size vessels of approximately 60K DWT would not be able to do so for nine months of the
year with icebreaker assistance by 2020. However, it was expected that such vessels would be able to do so by 2050.

**Arctic traffic and icebreaker capabilities (original statements no. 4, 5, 6, 25, 26)**

In comparing 2006 traffic volumes with anticipated volumes in 2020, there was significant agreement that traffic volumes will more than double in all Arctic regions. In terms of icebreaking capabilities, while the vast majority of panellists agreed that the current capabilities of the Canadian Coast Guard (CCG) are suitable for current Arctic shipping activity, they do not believe that Canada or other Arctic nations currently have the capabilities to meet the anticipated Arctic shipping demands of 2020.

**CCG levels of service (original statements no. 7, 8, 9, 10, 11)**

Although panellists agreed overall that the current level of ice routing and information service would be suitable for Arctic shipping activity in 2020, they did not agree that the current level of route assistance service would be suitable for shipping activity in the Arctic in 2020.

With respect to harbour breakout service, panellists felt that while the CCG does have the capacity to meet current demands, it will require more icebreakers to meet future demands. Further to this, panellists strongly believed that more hydrographic survey work is required in the Arctic and that some harbours will require dredging.

Regarding the limited demands currently made on the CCG in terms of the northern resupply service, panellists agreed that the CCG would be able to satisfactorily continue this service up to 2020 with the icebreaking fleet currently available. However, they did not agree that the same would be true in terms of the sovereignty service.

**Organizational and operational aspects of the CCG (original statements no. 16, 17, 18, 22, 23, 27)**

On 1 April 2005, the CCG became a Special Operating Agency (SOA) within Fisheries and Oceans Canada (FOC). Half of the panellists were unable to comment on whether SOA status would significantly increase the level of services being currently provided in the Arctic, but 43.75% of the remaining panellists agreed that it would not. The reasons noted for this included an unchanged CCG budget, that CCG has not displayed any ability to operate in a more efficient manner, and a lack of funding for the CCG. Notwithstanding the above, panellists did agree that the level of service has remained the same. Panellists also agreed with the statement that the reason why the CCG was made a SOA was to address the marine transportation issue and ensure that CCG funding goes to where the allocation was intended rather than FOC imperatives. However, three times as many panellists agreed that the focus is actually being taken further away from transportation issues.

Considering the funding of icebreakers, panellists agreed that this is inadequate both in Canada and globally. With respect to user service fees, there was overall agreement that the CCG should charge icebreaker service fees north of 60 degrees latitude.
The CCG civilian fleet of approximately 107 vessels is deployed, maintained and operated by five regions spread across Canada with each region operating according to its own practices and management preferences. With respect to this decentralization of fleet operations, approximately 6% more panellists agreed that it resulted in overall significant duplication of human resource effort within FOC with respect to Arctic operations. However, there was significant agreement among panellists that the regions exist to meet the specific needs of distinctly different geographic areas and that since the officers are in a pool and the fleet is multi-tasked the regional approach is probably most effective. In terms of national standards, of the slightly less than 50% of the panellists who commented, all but two agreed that the icebreaker fleet is currently being managed with national standards and the regions are well coordinated. Despite the aforementioned, of the panellists that commented, more agreed that the regions generally ignore national standards where they do exist, national standards are incomplete, there is no internal audit process visible for these standards, and there is still little coordination among the regions. With respect to standardization of practices for the icebreaker fleet and the CCG following the United States Coast Guard (USCG) operational structure of being viewed as a unique asset, of 52% of panellists who commented, approximately four times as many agreed with this view. However, there was significant overall agreement that Canada needs the best, most effective and responsive system for its icebreaker fleet and not one that necessarily matches the USCG. Despite many of the panellists agreeing with the view that the CCG needs to standardize its practices and be viewed as a unique asset, there was overall agreement that the actual USCG structure is not an example for Canada to follow and that it is even less effective than the CCG structure.

The six CCG icebreakers used for Arctic operations are operated out of four regions: Pacific, Quebec, Maritimes, and Newfoundland and Labrador. The fifth region, Central and Arctic, however is responsible for icebreaking in the Arctic. While there was no overall agreement that this decentralization of fleet operations results in ineffective interregional communication and consequently underutilization of vessels in the Arctic, slightly more panellists agreed that it did lead to icebreaker underutilization. Notwithstanding the above, there was overall agreement that vessel utilization is more a function of budget and less of organization, and Arctic deployments of icebreakers are reasonably well coordinated. In addition, there was even greater overall agreement with the view that from an operations perspective a central control point is important for the coordination of six icebreakers operating in a harsh northern environment.

**Merchant vessel movement in the Canadian Arctic (original statements no. 12, 13)**

The movement of merchant vessel traffic is controlled by two conventions. An older and more rigid ‘Zone/Date Shipping Safety Control Scheme’, based on rigid controls stipulating the dates that vessels of various ice strengthening may navigate within the sixteen shipping safety control zones of the Canadian Arctic underpins a more flexible ‘Arctic Ice Regime Shipping System’ (AIRSS) framework indicating whether or not a given set of ice conditions will be safe for a particular vessel. Panellists strongly agree that the Zone/Date system is inappropriate for current day Arctic shipping activity, due to less severe ice conditions during recent summer seasons, and that the AIRSS system is
more appropriate. Vessels are currently allowed to exploit both systems to their advantage when operating in the Canadian Arctic.

**Icebreaker deployment in the Canadian Arctic (original statements no. 14, 15, 21)**
The geographic expanse of the Canadian Arctic is divided into twelve service areas for the provision of the primary levels of service, noted earlier, offered by the CCG throughout the summer season. This system is referred to as the ‘Block Commitment’ system. While half of the first round panellists were unable to comment on the effectiveness of this system, three times as many of those who did comment agreed that the system was effective. However, a significant number agreed that the system was outdated and needed to have greater flexibility and updating given the changing environmental condition in the Arctic. It is also important to note that during subsequent rounds, panellists agreed that the system itself is the result of a limited number of icebreakers and thus not very effective from a service point of view.

All CCG vessels are multi-tasked. Six of the 17 icebreakers spend the summer months engaged in activities in the Arctic and the winter months engaged in activities along the east and west coasts of Canada. While approximately 10% more panellists agreed that year round utilization of these six icebreakers costs Canadian taxpayers more than only utilizing them during the winter months, there was strong agreement among the panellists that it was best to utilize the hardware and human resource all year round. There was strong agreement that CCG undoubtedly faced high fixed capital and operational costs.

Whilst there was no overall agreement that Canada should immediately acquire icebreaking capability for year-round winter navigation in the Arctic, more panellists agreed with the statement than disagreed. However, while there was overall agreement that operating icebreakers year-round in the Arctic would be very expensive and that currently there are no commercial clients or compelling sovereignty arguments for year-round operations, panellists also agreed that Canada should have this capability by no later than 2015. There was also agreement that the technical requirements for year-round navigation in the Arctic are non-trivial, probably beyond present reach, and that Canada should adopt a staged approach to this. There was also overall agreement that Canada should build more vessels of moderate capacity than one very powerful and costly icebreaker and that icebreakers are needed where commercial vessels will go.

**Privatization of CCG services in the Arctic (original statements no. 19, 20)**
The CCG offers a wide range of services in the Arctic. Even though Canadian taxpayers are burdened with the high financial cost associated with the construction and maintenance of ice breaking vessels, there was overall agreement that it would not be appropriate for the ice breaking component of the CCG range of services, in the Arctic, to be privatized. Notwithstanding this there was overall agreement that private involvement in carrying out the level of services currently provided for by the CCG in the Arctic would not weaken Canada’s position with respect to sovereignty in the Arctic.
Arctic hardware and human resources (original statements no. 24, 28, 29, 30, 31, 32)

There was overall agreement among panellists that the vast geography of the Arctic poses significant challenges to Canada and other maritime nations in terms of human resource management on board their icebreakers working in the Arctic. In addition, there was overall agreement that by 2020 maritime operations in the Arctic will involve a wide range of services, and that given the relatively small human presence stationed on land in the Arctic most of these services will be conducted from mobile floating platforms.

With respect to global icebreaking capacity, there was overall strong agreement that there was no need for all maritime nations of the world to immediately acquire icebreaking capability for either summer or year-round navigation in the Arctic. Further to this, there was overall agreement that while Russia currently has icebreaking capability for year-round navigation in the Arctic, it was not necessary for the seven remaining nations of the Arctic Council to immediately acquire icebreaking capability for year-round navigation in the Arctic.

Conclusions and Recommendations

Currently, the Arctic regions of Canada, and for the most part the entire Arctic region north of 60 degrees latitude, are not conducive to year-round navigation of merchant vessels and to some degree even government owned icebreakers. While future Arctic shipping activity is anticipated to significantly increase with the retreat of perennial Arctic sea ice, the infrastructure required to support global supply chains is notably lacking. While icebreaker capabilities are considered suitable for current merchant shipping activity, they are not suited to the anticipated shipping activity of 2020 and beyond. Much of the Arctic is poorly charted and in some areas no navigational charts are available. Navigational aids are sparse and often only provided seasonally. Vessel repair facilities are sparse and limited in their scope of work. Emergency response capabilities are limited and geographically challenged. Finally, the impact of year-round Arctic shipping activity on the livelihoods of native inhabitants has not been fully addressed.

Through a mix of unilateral and multilateral actions, Canada and other Arctic Council nations need to quickly decide upon and begin to develop, install and enhance relevant infrastructure comprising modern icebreaking capabilities, deepwater ports, repair and refuelling facilities, aids to navigation, and emergency response organizations. Involving the local inhabitants will be imperative.

Further research is required to canvas the in-depth opinions of local experts relating to various models which may underpin the ownership, organisation and management of relevant infrastructure. This research, although initially qualitative and based on grounded theory approaches will require mixed methods supported by a quantitative survey to triangulate the findings and estimate the extent of support for new initiatives.

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Recruiting Seafarers into a Job or a Profession

Captain Anthony Patterson, MM, CMMC

Capt. Patterson served as Director of The Centre for Marine Simulation at the Fisheries and Marine Institute of Memorial University from 2000 – 2007 and currently he is the President and CEO of Virtual Marine Technology, St. John’s, NL

Below is a presentation he gave at the World Maritime Day Symposium 2008 held in Halifax, NS on behalf of The Company of Master Mariners of Canada

It is indeed an honour for the Company of Master Mariners of Canada to be invited to participate at this event.

Our organization would like to take this opportunity to present our views on the very important topic of the link between the ability to recruit seafarers and the view of seafaring as a profession.

The Marine industry has been struggling with chronic labour shortages of senior officers for the past decade. While there have been a number of initiatives to market seafaring as a career of choice to the general population, little progress has been made in stemming the shortage of qualified seafarers. This lack of progress must be met with concern.

Why is it difficult to recruit new entrants into the industry? When one considers that the combined population of Canada and US – alone- is over 300 million people, it is hard to believe that a shortage could exist at all.

We note the marketing efforts concentrate upon promoting seafaring as a good job. Guaranteed employment, high pay, and lots of time off are the usual hooks used to entice recruits. The reality, of course, is that seafaring also involves periods of solitude,
difficult working conditions, and a demanding regulatory environment. When the job of
seafaring is compared with jobs ashore, the negatives seem to be outweighing the
positives. Is it possible that our efforts to promote seafaring as good job are misguided?

The Company of Master Mariners of Canada believes that seafaring is a profession, and
that people enter professions due to reasons of passion, prestige, and heritage rather than
strictly as a means to earn money. Perhaps our efforts would be more successful if we
focused on creating a professional environment which can attract and retain those with a
passion for adventure, travel and challenge.

We believe that addressing the following four points will help to foster a professional
environment at sea:

1. Ensure that appropriate values and attitudes are being instilled in new entrants.
   Nautical schools need to demand that students display appropriate professional
   attitudes as a precondition of graduation. The industry can no longer afford to
delegate the sole responsibility of instilling professional values to the sea phases.
   Most officers on merchant ships do not have the time to ensure cadets get the
   “right stuff” while they are on-board. It is essential that schools become much
   more active in fostering professional attitudes;

2. Implement and enforce a code of ethics. Ethics and integrity are the hallmarks
   of a professional. Ethical standards lead to performance levels which exceed
   that which can be achieved by mere compliance with regulations. Ethical
   standards serve to create a positive self-identity within the profession;
   encourage self-discipline and self-regulation; and foster public trust. Within the
   maritime profession, some bodies have created voluntary codes of ethics. The
   voluntary codes, however, sit outside of the regulatory program, and it is
doubtful that they are having much of an impact on the professional
   environment at sea. It is important that a standard code of ethics be defined
   and enforced by an appropriate professional body as an adjunct to the
   regulatory enforcement of Maritime Administrations;

3. Increase the participation of professional bodies in the management of
   competence including the review and accreditation of training standards and
   programs. The biggest challenge in the administration of competence is keeping
   up with a constantly changing industry. Professional bodies can provide agility to
   schools and regulators by continually reviewing curriculum and participation in
   the accreditation process to ensure that competence standards continue to be
   relevant; and,

Critically review those factors which serve to diminish professionalism at sea, especially
items which reduce the authority of professionals to exercise their craft, or which
impact the passion and spirit of the seafaring life. In particular, the issues of shore leave
and criminalization of seafarers need to be addressed. Shore leave is vital to provide
socialization to seafarers who would otherwise be doomed to a voyage of solitary
confinement. Likewise, the trend towards criminalization of seafarers, particularly of
senior officers, for events which are completely outside of their control is unjust and is
having a devastating impact on the professional environment at sea. Criminalization
does not promote accountability (which is a feature of a profession), it creates a culture
of compliance (which is a feature of a job). Dr. Jordan Cohen, the President of the
Association of American Medical Colleges, makes an interesting observation when he
noted:

“For patients, nothing can substitute of having a trustworthy doctor; not laws, not
regulations, not a patients’ bill of rights, not watchdog federal agencies...nothing.”

The same can be said about our industry. Our surest means to protect life, preserve the
environment, and ensure security are professional ship’s officers, not more checklists.

STCW, ISM and MLC are intended to provide a minimum regulatory framework to
address some of the points that I have raised. While the efforts of the regulators are
commendable, they are not nearly enough to create a culture of professionalism in the
industry. The task of establishing and implementing a professional environment,
surprisingly, is often left to the shipping companies themselves. Some do an excellent
job, some do not. Sadly, in too many situations, the legislated requirements are viewed
as a maximum standard, and the development of a professional culture is inhibited.

The creation of a professional environment at sea is critical to enable the industry to
regenerate itself. Most of us in this room are, or have been, seafarers. We must ask
ourselves, are our children still following the family tradition of pursuing a seagoing
career? More generally, are those at sea today actively encouraging their children to
follow in their footsteps?
In the past, sons have followed their fathers into seafaring careers, or as the American
poet Louise Driscoll wrote:
All the men of Harbury go down to the sea in ships,
The wind upon their faces, the salt upon their lips.
The little boys of Harbury when they are laid to sleep,
Dream of masts and cabins and the wonders of the deep.

Harbury

From discussions I have had with my colleagues, a career in seafaring is not being
promoted to the next generation. This observation is critical. The most influential
opinion leader in choosing a career is the parent. First tier entrants into nautical colleges
are typically those with a seafaring heritage. We must be careful not to interrupt the
social chain which has historically produced our seafarers.
Our organization, the Company of Master Mariners of Canada, is taking strides to
promote a professional environment at sea. We provide a mentoring program for young
professionals; sponsor educational seminars and conferences; and intervene nationally
through our National Administration (Transport Canada) as well as internationally

The Company of Master Mariner...
through the International Federation of Shipmasters’ Associations on matters important to maintaining the professional integrity of our industry.

We are challenged to do more.

We extend the challenge to the other key players in our industry, most notably the regulatory agencies, the shipping companies and the training institutions. If we focus on reinforcing a professional environment, it is possible to revive the passion and spirit of seafaring and thus alleviate our recruitment problem.
Presentation to the Delegates at the IFSMA Annual Meeting
In Rio de Janeiro
6\textsuperscript{th} and 7\textsuperscript{th} May, 2009


\textit{Peter Turner}
\textit{Company of Master Mariners of Canada}

Peter Turner
Company of Master Mariners of Canada

e-Navigation
The early concepts of e-Navigation really came into being when Electronic Charts were first discussed. Initially, e-Navigation was expected to utilise the components that were being used aboard ship at that time. It was assumed that the “e” in e-Navigation stood for electronic.

As a starter this concept was good. However, once this was voiced, many other uses for this were envisaged. Now the “e” in e-Navigation would be better expressed as “enhanced” or “encompassing”

The generally accepted current definition of e-Navigation is:

*the harmonised collection, integration, exchange, presentation and analysis of maritime information onboard and ashore by electronic means to enhance berth to berth navigation and related services for safety and security at sea, and the protection of the marine environment.*

From this definition alone, it can be seen that e-Navigation is a lot more than first envisaged.

Users of e-Navigation will include port authorities, vessel traffic services (VTS), environmental agencies, shipowners, pilotage authorities and of course the navigating watchkeeper.

In December 2008 IMO Maritime Safety Committee (MSC) set a schedule for the implementation of e-Navigation.

- 2009 User needs to be reviewed and prioritised
- 2010 Review of system architecture and GAP analysis
- 2011 Cost benefit and risk analysis
- 2012 Implementation plan to include responsibilities of the various parties and a phased in implementation schedule.

The phased-in implementation of e-Navigation will likely be continued into the decade commencing 2012.

At the same MSC meeting the Committee approved the sub-committee recommendation that the carriage of ECDIS would be mandatory and phased in between 2012 and 2018. Effectively, paper charts will be withdrawn from circulation. e-Navigation can only be implemented after ECDIS is installed.

The capabilities of e-Navigation and displays on ECDIS are considerable, and maybe even greater than those envisaged at present. Some of the present capabilities include:

- Charted water depth updated to give real time water depth;
• Up-to-date Notices to Mariners or Navigation Advisories relating to navigation on approach to harbours;
• Real time current and wave information derived from “Smart Buoys” in approaches;
• Seasonal “Areas to be Avoided” relating to endangered species such as North Atlantic right whales;
• Relayed information from VTS and Coastal Radio stations;
• Specific meteorological and climatological information (ice routing and ice conditions);
• Overlays of radar information including AIS information received from ships;
• Guard contours indicating shallow water through which the vessel cannot navigate;
• Isolated dangers, including shoal waters; and,
• Warning overlays relating to the dimensional particulars of the ship (beam, draft, length, air-draft)

The display can therefore be modified to suit the needs of the navigating watchkeeper or other user, (VTS, Port Authority etc.) However care must be taken to not overload system with the information derived from the other components of e-Navigation, thereby rendering the chart over-informative, cluttered and ineffective. The navigating watchkeeper must retain the ability and right to switch out overlays.

With the information available to the navigating watchkeeper, there may be a tendency to navigate wholly utilising these displays. It cannot be emphasised too strongly that the watchkeeper must maintain a visual lookout, and utilise all means of navigation available to him or her. Information displayed in e-Navigation is susceptible to human error (digital input), mechanical and electronic malfunctions, and failures. With the double redundancy required for the equipment, this risk is low but nonetheless it exists.

Shipowners installing e-Navigation on vessels will expect to see an increase in efficiency, safety and financial return. Undoubtedly, the efficiency will include corrected navigational information, and electronic downloading for corrections for all aspects of navigation. Safety will be enhanced by the practicality of the equipment and the information displayed. Financial return may be obtained, among other things, by being able to load a vessel to a draft at which the vessel can safely navigate the channels allowing for squat and wave action.

**Practicality of e-Navigation on the Bridge**

Information and risk assessment applied to close quarters’ navigation can only enhance safety, but overload of information can render the equipment inefficient and even dangerous. It must therefore be user-friendly, and the development of the equipment must be user-driven. The capability of switching on and off the “overlays” must remain with the user.
Training in the use of all the components must be an essential part of the development of the equipment. In 1962 there was a collision between the USS Kearsage and the Passenger ship Oriana at the entrance to Long Beach harbour in thick fog. At the Court of Inquiry, the question of why the Oriana had employed an apprentice to plot the radar information arose. The apprentice was the only person on the bridge that had completed a Radar Observers’ course. Similar situations must not happen again. All navigating officers must have the appropriate training to utilise e-Navigation equipment.

Bridge design will play a large part in the practicality of the equipment. The placing of displays providing information must be considered. The German company Forschungsgesellschaft fur Angewandte Naturwissenschaften (FGAN) (Research Establishment for Applied Science) and its subsidiary FKEI are developing what they have named an Integrated Navigation System (INS) which undertakes to make the layout ergonomically sound. Similar systems are being developed elsewhere, for example Sperry and the Memorial University of Newfoundland. The purpose is to make the bridge layout fit the e-Navigation equipment and vice versa.

The designers and manufacturers of the equipment will be bound by standards and operating criteria. They will also be required to meet the users’ needs. Those supplying the information will also be required to meet certain standards, criteria and frequencies to meet the international needs of the shipowners and which will enable downloading of information to be of a uniform nature.

Navigational Watchkeeping

e-Navigation will necessitate a review of the standards of training, certification and watchkeeping. The STW sub-committee of IMO must review the syllabi against the existing requirements. e-Navigation brings into question the need for various aspects of the present syllabi for Certificates of Competency. Last year IFSMA debated the need for the continuation of the inclusion of Astro (celestial) Navigation in the syllabi for certification. Not only will it be necessary to add the new requirements to the syllabi, but the redundant subjects must be amended, corrected or removed.

Now, prior to the advent of e-Navigation, is the time for a full review of STCW convention and a complete overhaul of the qualifications required for a watchkeeper and a Master.

The standards required for watchkeeping in the past, as recently as 30 years ago, made it necessary for the watchkeeping officers to have different qualifications in order to operate the ship as well as manage the maintenance and cargo warehousing aboard the ship. Navigation was a science requiring on-the-job training and the deeper understanding of the navigation tools; and the environment in which the ship sailed. The Watchkeeping Mate and Master needed to be conversant with ship construction, cargo stowage factors, stability, marine law etc. As ships have developed the needs for the watchkeepers has changed. The tools for navigation, (eg. Sextant and even bearing compasses) have been surpassed. The outlined e-Navigational equipment are sophisticated computer based
displays allowing input from external sources, and selected overlays to improve the local and immediate knowledge of the navigating watchkeeper. Maintenance of the ship and the stowage and warehousing of the cargo are also computer based and to an ever greater extent directed by personnel from ashore.

I quote from the Conclusion section of the Nautical Institute publication, “From paper charts to ECDIS, a practical voyage plan” by Captain Harry Gale FNI

*The ECDIS concept is a total change from using paper charts and the transition from paper charts to electronic charts will pose some concerns for the industry, particularly for those who have no current experience of electronic charts. Important bridge procedures are significantly affected, and these require careful analysis and consideration. The experiences of those who have been using electronic charts for some time show its use will reduce the navigational workload when compared to using the paper chart. This will enable mariners to execute in a convenient and timely manner all voyage planning, route monitoring and positioning that is currently performed on paper charts.*

The ship must retain the prerogative to navigate in all waters, allowing that relevant information should be obtained from VTS ashore and supplemented by the pilot aboard.

**e-Navigation and the Navigation Watch Aboard.**

When the ships are equipped with e-Navigation, the role of the navigating watchkeeper will change. This needs a great deal of consideration, and will affect both the hierarchy aboard ship and the training courses required for certification. There are fundamental differences between the requirements in the existing system and those of the future. The future navigating watchkeeper will need to have enhanced computer skills, understanding of the offered downloads and overlays and the capability to interpret the maritime information provided on the displays. The navigating watchkeeper will probably never use a sextant, nor calculate a great circle course. Therefore there will be a need to review the STCW, the international safety regulations, and modification of the collision regulations.

**Future Requirements for Navigating Watchkeeping and Responsibilities**

There can be no doubt that most commercial shipping operations now rely upon the office staff ashore, superintendents, and specialised contractors to undertake many of the duties which in the past have been the domain of the navigating watchkeeper when the ship arrives in port. Some of those responsibilities must remain with the ship, others will be undertaken by technology utilising computer programmes. However, the hierarchy system aboard ship is becoming outdated. Some of the skills being taught are redundant, while others are taught as add-on courses, required beyond the Certificates of Competency. (eg ARPA and GMDSS.)

The advent of e-Navigation will require new skills to be taught, not only to the candidates for the Certificates of Competency, but also to the examiners!
Now, before the implementation of e-Navigation, is the time when the whole hierarchy structure aboard ship should be considered and the following, no doubt controversial questions asked.

Speculating that the examinations for the pertinent skills for Certificates of Competency are fast becoming redundant, it is certain that the navigational skills required for Certificates of Competency will change with the advent of e-Navigation.

- Prior to the implementation of e-Navigation should the syllabi for Certificates of Competency change to reflect the future needs for trained navigating watchkeepers?

While it has been the practice for a hierarchy of watchkeepers (Mate, 2\textsuperscript{nd} Mate, 3\textsuperscript{rd} Mate) to be established on board a ship, the duties relating to bridge watchkeeping remain the same for each.

- Should all navigating watchkeepers be qualified to the same standard?
- Would the efficiency of having watchkeepers of equal standards and a “day-work” senior officer who has a superior qualification be more cost effective than the present hierarchy system?

If the watchkeeper meets the requirements, and as such is certificated to keep a navigational watch; the other responsibilities related to Certificates of Competency can be undertaken by an officer who has been examined in these required skills and as such will be able to fulfill the duties, (Return of the ‘four mate ship’) thereby reducing the likelihood of watchkeepers being affected by fatigue.

- Should the “Master” and “Mates” (those not keeping a navigational watch) be trained and examined to a standard which will include all the additional requirements of the international regulations, and those required by flag states as well as management skills?
- Must the “Master” be the officer with the navigational skills to take the con of the ship in congested or restricted waters?

\textit{The Nautical Institute has published the document “FROM PAPER CHARTS to ECDIS a Practical Voyage Plan” by Captain Harry Gale FNI, and I recommend this document to you.}

Authors note for further consideration.

In the section entitled above, “Practicality of e-Navigation on the Bridge” I have made reference to the need for the equipment design to be user driven. The users of course are not only the navigator on the bridge, but also those who will be using the equipment in Vessel Traffic Services, and other port operational venues. However, it is my opinion that his will need to be closely controlled. As in the past with navigational equipment, the
developed has produced a highly technical piece of equipment, persuaded the owner that this is what the industry standard is, and that it should be fitted. e-navigation equipment is far more than a simple means of navigation, and its complexity will require that the end users are heavily involved in the design, both of the display and the data processing available to the user.
Developing Dynamic Ice Models

Institute of Ocean Technology and Centre for Marine Simulation working together

Captain Christopher Hearn
Director of CMS

The Marine Institute’s Centre for Marine Simulation (CMS), located in St. John’s, Newfoundland, has embarked on a multi-year project to improve its ability to model and simulate harsh environments for training and applied research purposes. A major component is the improvement of mathematical models for the various interactions of ships manoeuvring in ice and modifications to the visual delivery. The result of this project will assist CMS with improved ice navigation training ability, route studies, vessel and ice interaction, ice berg mitigation (towing), and strategic planning for ice operations. This paper will seek to describe the reasoning behind this strategy and provide an overview of the ongoing process to achieve the set goals.

Seasonal shipping activity in the Arctic and high latitudes has always dealt with the risks of operating in and around ice covered water. While much of the polar region remains locked in impenetrable ice, the environmental phenomenon of global warming has the ice cap coverage receding. Areas that were before unreachable can now be explored and developed and with this the density and duration of vessel traffic will increase. The establishment of sovereignty and the rights to resources will place great emphasis on access to arctic waters. This increase in vessel density and activity will introduce new generations of seafarers to the issues of navigating in ice and ice covered waters.

Despite advances made in the understanding of ice mechanics and the delivery of stronger vessels, operations in ice poses significant hazards and challenges to the vessel and crew. To address the concerns of the arctic community and interested groups, a working committee of government and regulatory bodies including Transport Canada have developed the Code for Polar Navigation or Polar Code. This code identifies the unique problems facing Arctic operations. The Code presents an innovative view that all considerations and regulations mandatory to the building of a ship including design, construction, crewing and operation can be integrated into a single set of guidelines. In 1998, this code was submitted to the International (IMO) for study and has since been renamed the Guidelines for Ships Operating in Arctic Ice Covered Waters. Having undergone many committee reviews and recommendations, it will, when combined with the International Association of Classification Societies Unified Requirement for Polar Ships (IACS UR), present an international recognized standard for ships operating in arctic ice covered waters. While these guidelines remain recommendatory at the present time, many of the arctic nations are pushing for their adoption by all operators pursuing development in ice covered waters.

In any navigational circumstance it is required that the Officer Of The Watch (OOW) has at all times a full awareness of their vessel situation, it’s position, and its operation in
reference to the surrounding environment, conditions, and any hazards. This comes through years of intense training and education. The training regimes and guidelines involved in ensuring this knowledge are well known and understood. If one also looks to specific vessels or specialist trades, such as the Offshore Supply or Sub Sea construction, there are many operational requirements, which they must meet. The crews have specific training over and above regular requirements, such as Dynamic Positioning certification. It should also be demanded of any persons regularly sailing in ice covered waters and has the responsibility for the conduct of the vessel that they have knowledge about navigation in ice. The officer on watch should understand the limitations of the ship and the procedures of navigating in an ice field. Following the recommendations and direction from experienced personnel is a good start, but this does not eliminate the need for a basic understanding of ice on the part of the individual. For officers regularly sailing in icy waters, ice navigation training is very important. But for those visiting the area once or infrequently there should also be a medium of knowledge or training available. An ability to develop and deliver a training package should therefore be able to meet needs of people who will operate in ice regularly and those who will only occasionally experience ice and stay within the recommended scope.

Ice Navigation training is still very much in it’s infancy in terms of an industry wide acceptance. There are several leading institutions internationally that have developed training programs to address the shortfall in ice experienced navigators. Traditionally, such courses relied heavily on curriculum based on the technical aspects of the types of vessels and equipment, ice nomenclature and detection, the accepted or recommended procedures for operating in ice, and delivered with the practical knowledge of ice experienced Masters. What is needed to assist this delivery process is a manner of re-enforcing the visual, ship handling, and operational aspects. The advent of computerized assisted training and in particular marine simulation can assist in this pursuit. As operating systems and visual capacity to simulate not only a marine environment but also the ships and facilities involved have become an accepted means of practical training it should follow that this great tool be also used to assist in ice navigation. The challenge is to recreate the visual and operating conditions faced by vessels in ice. The technology to model with sufficient fidelity the interactions between a structure such as a ships hull and ice, whether in a static or dynamic mode, is only now becoming a reality. The challenge is the ability to capture this information and then to subsequently create a useful simulation. The advantages to this are many as simulation ability can be used not only as training tool but also for experimental and validation processes in research and development.

CMS has been offering ice navigation training since the late 1990’s. In the early development and offering of this training, CMS made use of its full motion, full mission bridge simulator. This unit allows the realism of a typical full mission bridge with the added realism of being based on an aircraft training motion platform. At that time the operating system for the unit was the Kongsberg NMS 90. The operating system, while advanced at the time allowed for very basic representation of ice. It began with the removing of the internal barrier that prevented ship simulations from sailing off the water and onto the land. The land was then coloured and re rendered to look like ice, creating a
basic ice field, albeit with several issues. Chief among these issues was the fact that radar could not effectively detect the ice as it would in real life. An important facet of ice navigation training is the ability to detect various ice signatures on a radar screen. Thus, while a good first step, the ice simulations were far from perfect. Another advance was made when it was discovered that the segments of land could be formed into small and large ice pieces. This created an ability to make the representation more realistic in terms of looking at pieces of ice as opposed to a continuous field of white. With the use of multiple pieces placed together this produced a basic view of a “strip” or segment of ice piece, their sizes corresponding to various ice floe types. By taking the original idea of land coloured to represent ice and opening up patches and channels in this field, the small ice pieces could be added to the blank spaces. This allowed for a greater degree of reality in representing a series of ice fields and floes, to which a ship model could be placed.

The land/ice model with small floes could be manipulated and changed to match the visual legitimacy required for demonstrating ice coverage and ship manoeuvring; this in effect allowed for a greater degree of student participation. In order to effectively stop the vessel, the instructor at the control station would increase the thickness of the ice (land) until the ship model’s hull would not make any more progress. While some results were satisfactory for an image based training process, there were other issues. The most recurrent of these was the low reflective properties of the ice on a radar screen. A requirement of any ice navigation course includes the demonstration of detecting and identifying (by assistance of radar) varying ice types and density. Early detection by radar, especially in poor visibility is often the first warning sign of approaching ice. Navigators are taught to associate various target signatures with levels of ice coverage. CMS’s pseudo ice fields had very little surface features to paint a realistic image on the bridge radars.

By this point CMS had naturally grown beyond its original mandate of supplying marine simulation for training. It had also moved into advanced and larger scale simulation and scenario development for clients requiring more specific training and evaluation work. Projects involving more ship modelling, complex geographic databases, and environmental inputs were now being undertaken. In keeping with the increasing technologies, a program of improving display and delivery software began. The NMS 90 operating system for the full motion Bridge was replaced with the latest version available. This Polaris system allowed for a higher fidelity in what can be termed as a dramatic increase in overall simulation ability. As part of the upgrading, a new version of ice was ordered. The new program contained two types of ice available to the operator. The first type allowed for various size target pieces which could be selected and entered into a simulation database. These target ice pieces could be as large as icebergs with a good degree of visual representation for larger masses. The other type was an updated version of the old land to ice method but instead of turning land into ice sheets, the operator turns the visual sea into ice, literally painting it white. With this new technology, CMS began to refine its “library” of ice imagery and databases. Several clients involved with shipping in Arctic regions were looking for more specific training for senior staff using their own prescribed conditions. While outside of the ice navigation course these projects did allow for increased use of the ice simulation applications and instructors became more familiar.
with its advantages and limitations. Although there was now an easier process that could allow for designating large fields of variable ice, there were still several limitations. The effect of integration, especially between the ships hull and pieces of ice, was exaggerated to some degree. The visible horizon exceeded that of the allowable ice horizon, such that in order to see continuous fields the instructor would reduce visibility conditions to close in field of view. While overall graphics were better, there were still comments as to realism of the ice especially in fields or pack ice. As a vessel moved through the ice, there was no clear visible track left behind. The instructors would still increase ice thickness to stop the ship. The other big issue facing CMS was that the ice, when interacting with the virtual ship model’s hull in a real-time simulation, did not effectively capture the forces, impacts, and vibrations that occur with the real event. There was no effective or available means to be able to transform the multiple points of contact along the hull and their effect on the ice. In short, there was no dynamic and active result of what the ice would do.

Since 2005 CMS has embarked on a multi-year project to improve its ability to model and simulate harsh environments for training and research purposes. This includes the improvement of mathematical models for the various interactions of ships manoeuvring in ice and modifications to the visual delivery. The result of this project will assist CMS not only with improved ice navigation training ability but also moving into areas of route studies, human performance in harsh environments, ice berg mitigation (towing), and strategic planning for ice operations.

To accomplish the set objectives of the project, CMS has partnered with the Institute of Ocean Technology (IOT) of the National Research Council of Canada (NRC), an internationally recognized leader in ocean engineering research. IOT operates the largest ice tank and model tow tanks in the world. Years of experimentation and research into hull forms in diverse controlled marine environments has established IOT as a centre of expertise. By combining technology and experience of both CMS and IOT, a groundbreaking approach to the in-depth analysis of ice and ship interaction has occurred. As math algorithms form the basis of any simulation, the first goal of the collaboration was to identify and establish the numerical data to better predict the interactions of a ship manoeuvring in an ice field. The next goal was to integrate this model data into the CMS simulation environment. This joint project, entitled ‘Manoeuvring in Ice’ was divided into three tasks. The first task involved the development of a simple generic model to predict ship manoeuvres in ice, and included various tests, numerical analyses, and mathematical modelling. The second task involved extending the first single model to various ship forms and manoeuvres through extensive testing and optimization with a final aim being validation and fine tuning of data. The last task, yet to be completed, will involve the adaptation of the completed math models into CMS simulators for use in the development and delivery of new and updated training.
Task 1.

The focus of this task is the development of the simple analytical/mathematical model to help in predicting ship manoeuvres and identifying the most significant effects and forces in ice. In considering the multiple and complex loads involved the known data available was not extensive. Benchmark information was needed in order to begin making inroads into developing the modelling. A scale model icebreaking hull mounted on a moving carriage was towed at controlled motions through level ice fields (Diagram 1). Motions, forces and moments were captured by sensory equipment. Video recordings of the manoeuvres from two vantage points on the port and starboard sides looking at water line interactions and ahead contact were captured. The ice sheets used were produced under the standard guidelines established by IOT. During each data collection process the ice sheet was monitored for flexural, compressive and shear strengths to assist in establishing comparison curves.

Diagram 1 (Ice breaking hull on PPM. Courtesy IOT)

These trials were carried out successively over a period of a year. The first hull model was joined by a second ice breaking form and a series of expanded testing began. Straight line towing study now included looking at the effects of turning the models in the ice sheets. The trials were run in a series of conditions of ice coverage ranging from open water to continuous level ice, and also included broken ice (captured through a pre-sawn condition).

Results

The testing has shown that when the hull moves on a straight run through an unbroken field of ice, at the bow point of first contact, small individual pieces break off and rotate downward, while being carried down the length of the hull to be cleared out aft of the vessel. This process is repeated along the hull as the model sides enter the ice. It is this action that clears away a space in the ice sheet to allow for forward motion. While this
might seem a basic statement the data surrounding this process was invaluable not in terms of an icebreaking hull evaluation but in terms of the beginnings to create the mathematical modelling process. Of particular value were the results that were gathered for a vessel manoeuvring in a turning circle. The location of ice contact with the hull and thus the ice breaking load on the leading side of the turning motion could now be identified. Subsequent runs provided data at larger and smaller angles of turn at various metric points of the hull. The breaking forces, buoyancy and clearing forces that allow a ship to move in ice and their relation to overall performance were in hand. The project team now had the fundamental information for straight line and turning run analysis that could form the mathematical framework to begin building the models.

Task 2

Task 2 took the basic analytical model developed under Task 1 and looked to expand this through extensive testing using additional hull forms and further manoeuvres. As a fine tuning of the valuable data gathered under the preliminary trial period, the processes of this phase of the project would serve as a refinement prior to the integration of data into the real time modelling and simulation of ice-hull interaction. Two series of model testing were carried out at IOT using their ice tank and PPM procedure. Testing included further examination of resistance during turning at various rates and speeds. Manoeuvring also included turns based on a sinusoidal pattern, which presented new data input under varying speeds and rates of turn. As before, the hull was fitted with sensory equipment to capture the forces. Of particular interest were the difficulties to run the model in the ice in an exact sinusoidal pattern. This would of course match the problems of performing this action in a real life situation given ice thickness, hull form, and available ship speed versus power.

In addition, a series of trials using podded propulsion were undertaken. A podded unit extending below the model hull was operated in the level ice. This particular study added a new study area to the overall project and the data gathered will serve to improve the ability to create a model under various propulsive configurations.

Results

As a result of further testing, the distributions of the ice breaking force, buoyancy force and clearing force and their application into predictive calculations allowed for a new Ice Hull Interaction (IHI) model for real time simulations of ice to be developed. Based and tested on the initial and refined trials, the new model was expected to be a valid forecaster of a hull interaction in level ice. This is of particular value to developing a real time computer based simulation of a ship operating in ice. The new IHI predictive mathematics was tested against actual runs in the tanks, again performing with good accuracy. What was required now was to examine the value of the new model process against that used in the CMS simulator operating system as a comparison of modeling ability in real time. Over a period of continuous evaluation CMS and IOT staff gained a good understanding of how the Polaris system modeled the ice load on a vessel hull. A
trial comparison was carried out using typical first year ice conditions of the IHI developed versus the perceived Polaris method. (Diagram 2).

**Diagram 2 (Polaris vs IOT Model test)**

The graphed data shows the results of the comparative process. It displays the deficiency of the current version of Polaris ice load prediction and the ability of the CMS/IOT model to select appropriate ice coefficients to make the Polaris version match the actual data from hull/ice tests. The calibration process to obtain the above correlation for simulation ability requires a series of reference simulations that would give values for ice coefficients that would then be compared with model test data. The project has reached a significant turning point in the goal of establishing a viable math modelling process that could not only provide a basic example of a ship manoeuvring in ice but also could now be extended out to predictive modelling of other hull forms.

Verification of this math modeling is ongoing with a completion date of late June 2008. A beta version of the model with a time domain simulation will be available in June 2008 with further refinements. By June 2009, it is expected that further hydrodynamic and propulsion models will be ready to begin Task 3.

**Task 3**

Task 3 will be the integration of the new model data into the CMS full motion bridge simulator. This process will include an overall improvement not only to create the actions and forces of a vessel operating in level ice but also an improvement in the ability to visually reproduce the ice with a higher degree of fidelity. This process is expected to see completion by March 2010. The representation of the ice itself will be a critical component in this task. As discussed, the current simulation ability has sections or sheets
of ice floes painted through which the vessel manoeuvres. The break up of the ice is poorly represented as the hull impacts its edge. The cracking, splintering, rafting and opening of leads that occur in level ice sheets is not present on the current simulation scenarios. In order to begin steps to correct this issue CMS will look to incorporate elements of DECICE in its simulation ability. DECICE is owned by Oceanic Consulting of St. John’s and operates a numerical code to model a wide range of ice scenarios. Its value is that it can include non prescribed actions (such as ice failure, cracking, splintering); individual floes or uncontrolled items such as ice bergs can be represented as discrete elements. Ships can also be presented as elements, with a more complex presence that would include control and environmental loads applied. All elements experience interaction forces based on contact with each other such that some can fail, such as ice. CMS will also have to reconsider how it represents ice in graphical terms. The current practice of painting sections and pieces white and appointing them to act as small floes will be changed in order to match the new ability. This will itself require a committed re-evaluation of the current library of ice scenarios.

Conclusions

In this paper the multi-year project that the Centre for Marine Simulation is engaged in to advance its ice modelling and simulation was presented. By entering into a partnership with the Institute for Ocean Technology a multi faceted study was made of the forces surrounding the interaction of a hull and level ice. A simple model was derived, which formed the basis for more involved and complex modelling to include other hull forms in a predictive pattern. These results when further refined will then be included into CMS simulators to allow for more realistic ice navigation studies.

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