Emerging Technology and Maritime Piloting,

The technology is here; how should we utilize it?

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Abstract

Technology is being incorporated into all phases of maritime port and ship operations and management. Maritime piloting, the business of navigating ships safely within port confines, is an area where opportunity remains to utilize technology to develop more robust navigation safety systems. One often-discussed approach would be to use technology to enable shore-based pilots to provide navigation assistance to vessels. Certain European pilotage authorities have instituted limited shore-based piloting programs. But, those systems rely on older, less accurate radar-based input, and have not been updated to take advantage of newer navigation and communication technologies. Moreover, the industry in general has resisted any move toward shore-based pilotage, citing their belief that the traditional system with a pilot physically on board the vessel will always be safer. This paper explores ways that emerging navigation and communication technologies might be applied to the business of piloting ships with a goal of increasing marine safety and efficiency. The objective of this paper is to spark discussion aimed at moving this issue forward by asking: “What might be possible?”

Keywords: piloting, remote piloting, shore-based piloting, navigation, portable pilot unit, and technology.
There’s a tussle brewing in a change-averse industry that is steeped in tradition. The clash centers on the issue of how to utilize emerging technology that promises to improve safety and efficiency in maritime piloting. On one side of the debate are the practitioners, maritime pilots who for centuries have boarded ships and guided them into and out of ports throughout the world. On the other side of the debate are various interests such as ship owners, port authorities, regulators, and other maritime stakeholders, who advocate for new technology-driven methodologies to navigate vessels within port confines.

Maritime port operations are inherently global in nature. Professionals from different nations and cultures and speaking different languages work in concert under a complex system of international cooperation and professional collaboration. Multiple disciplines and maritime skills are brought together at the operational level, and because the stakes are so high, consistency in marine safety and professionalism from both vessel leadership and port leadership is required.

Historically, the shipmaster is ultimately responsible for the safety of the vessel, including its safe navigation. Port professionals are responsible for providing arriving vessels with a reasonably safe port and for protecting the port’s infrastructure. A complex, but interdependent relationship of shared responsibilities and cooperation is critical to navigate vessels successfully and safely within port confines. Toward this common goal, both shipmasters and port authorities rely, in large part, on the knowledge, skill and expertise of individual maritime pilots to ensure vessel navigation is conducted safely during port passages.

Recently, technology advancements have been integrated into standard shipboard operations at an ever-increasing pace. Ships are fitted with global positioning systems (GPS) and electronic charting and display information systems (ECDIS). Together they provide a
broad array of information including precise positioning, speed and course made good, and a graphic display of the vessel’s future position and predicted track. Shipboard automatic identification systems (AIS) transmit information from one ship to another and to coastal authorities. Increased computing power and wireless device-to-device communications are continuously expanding our capability to transfer and process data in the ship-to-ship and ship-to-shore domains. Increasingly, maritime pilot organizations are incorporating these new technologies into “portable pilot units” (PPU’s) that can be carried aboard ship and used to more precisely navigate and provide data feeds directly to shore-based navigation stations.

While the maritime piloting industry has taken initial steps to adopt emerging technologies, there remain unrealized opportunities for further advancements. The industry has evolved to a place where it might be time to critically assess the current state of its traditional processes and procedures and seek to understand what else might be possible? More specifically, the time might be at hand to question whether there are opportunities to better utilize emerging technology to improve the operational effectiveness and safety of maritime piloting. And, conversely, to question whether a failure to investigate new methodologies for utilizing rapidly evolving technology might rob the industry of an opportunity to elevate marine safety overall.

Safety is at the heart of this analysis, but many other, less obvious factors cloud and confuse the fundamental issues. Piloting with technology is a controversial subject. It immediately raises displacement fears among pilots. Maritime pilots, who have traditionally practiced their craft of directing navigation from the ship’s deck aside the vessel master, have all heard of the Google Car. They fear similar technologies introduced into maritime will pave the way for them to become shore-based pilots, instructing ships from a desk, or worse yet, be
displaced and/or replaced. Steeped in tradition and a deep sense of individualism, maritime is a change-resistant industry. While maritime pilots have adopted technology to a point, they remain particularly reluctant to allow technology to fundamentally change their time-proven practices. Consequently, the very people who possess the knowledge, skill, and experience necessary to evaluate the benefits of integrating technology into the profession in a meaningful way are inherently reluctant to do so.

Undeniably, technology’s rate of change has increased exponentially over recent years and will further improve marine safety and efficiency in years to come. Future technology-driven process enhancements might improve maritime piloting safety in a number of ways, including: enabling more precise navigation when visibility is reduced, either due to weather or vessel size in relation to the waterway; eliminating any need for maritime pilots to embark and disembark vessels at offshore locations during bad weather; supporting procedures and systems that would elevate the performance of vessel bridge teams; and providing a more meaningful double-check mechanism that would increase the likelihood of trapping a single-person error, particularly during passage segments where risk is elevated. For these reasons alone, the industry’s careful consideration of new and innovative piloting methodologies aided by technology is worthwhile.

**Literature Review**

The technology necessary to support remote shore-based piloting currently exists. And while shore-based piloting systems have been implemented in a handful of European ports, there remains much debate about the feasibility of remote piloting. The discussion has focused on whether and under what circumstances a maritime pilot should be allowed to guide ships into a harbor from a remote location. Most resistance is predicated on safety and those opposed to the
idea believe that technology-enabled remote piloting can never provide a sufficiently safe alternative to the traditional approach. Additionally, other non-technical obstacles, such as political, commercial, organizational, and cultural concerns, continue to confound implementation (Hadley & Pourzanjani, 2003, p. 181). Before any real discussion of the feasibility or practicality of a remote system can take place, it is helpful to review the duties and obligations of the maritime pilot vis-à-vis the shipmaster, and define the concept of remote pilotage.

The relationship between the shipmaster and the maritime pilot

A maritime pilot is a mariner with expert knowledge of the local waterways and specialized shiphandling skills (Hadley, 1999, p. 1; NRC, 1994, p. 70). Pilots have a long tradition of assisting ships with navigation in fairways and within port confines, and possess specialized skills to move ships in tight quarters (Bruno & Lützhöft, 2009, p. 429). In short, maritime pilots contribute geographic-specific knowledge and skills to assist ships’ bridge teams while navigating through areas designated as “pilotage grounds” where vessel navigation is particularly challenging.

When a pilot is aboard, the responsibility for the safe conduct of the vessel is shared between the shipmaster and the pilot (NRC, 1994, p. 70). The International Maritime Organization (IMO) describes this shared responsibility as follows:

49 Despite the duties and obligations of pilots, their presence on board does not relieve the master or the officer in charge of the navigational watch from their duties and obligations for the safety of the ship . . . .

50 If in any doubt as to the pilot’s actions or intentions, the officer in charge of the navigational watch shall seek clarification from the pilot and, if doubt still exists, shall
notify the master immediately and take whatever action is necessary before the master arrives. (IMO. Maritime Safety Committee, 1996, p. 149)

Legally, the shipmaster remains responsible for ensuring safety of navigation when a pilot is aboard. In most cases, maritime pilots direct vessel navigation and the bridge team is obligated to support the pilot’s navigational decision-making. Nonetheless, it is a long-standing tradition in the industry and a legal requirement that the shipmaster must be prepared to act if the pilot’s direction endangers the ship (Hadley, 1999, p. 2; NTSB, 2013, p. 96). Specifically, the shipmaster is obligated to intervene in the rare circumstance where the pilot is manifestly incompetent or incapacitated or the vessel is in immediate danger (in extremis) due to the pilot's actions. With that limited exception, the shipmaster is obligated to "cooperate closely with the pilot and maintain an accurate check on the ship's position and movement" (American Pilots Association, n.d.).

**Shore-based vis-à-vis traditional piloting**

Traditional piloting calls for a maritime pilot to board a vessel in person. A shore-based piloting system allows the pilot to perform his or her piloting duty from a location other than on board the vessel using some form of communication link with the ship’s bridge team. According to the European Maritime Pilots’ Association, "Shore Based Pilotage is an act of pilotage carried out in a designated area by a pilot licensed for that area from a position other than on board the vessel concerned to conduct the safe navigation of that vessel" (2012, §1.6.b). Another definition originates from the United States and defines shore-based pilotage as, “provision of maneuvering advice or orders from a site external to the vessel being provided pilotage services” (NRC, 1994, p. 29).
For the purposes of our analysis, the terms “shore-based pilot” and “remote pilot” will have the same meaning. It shall also be assumed that a shore-based pilot has the same set of skill, knowledge, and competence as that of an onboard pilot. In most instances, the definition of shore-based pilot will exclude vessel traffic service (VTS) operators, because “[i]t would be difficult, if not impossible, for VTS watchstanders who are not already skilled in marine navigation and piloting to acquire sufficient skills to undertake such a role” (NRC, 1994, p. 214).

**Shore-based piloting alters the control in a complex system of information management.**

Many think of ship piloting as more of an art than a science. But, some experts have offered a more science-based description. Bruno & Lützhöft describe successful piloting as maintaining control of “complex, socio-technical systems consisting of both human operators and technical artefacts [sic]” with the objective of keeping the ship properly positioned relative to her surroundings at any given time in a harbor or fairway (2009, pp. 428-430). Van Westrenen describes control tasks as having four major components: “observing the state of the system, comparing this state to the desired state, deciding on necessary changes, and implementing these changes” (1999, p. 1). When analyzing the pros and cons of remote piloting, it is helpful to understand that piloting a ship is primarily a control function.

Under the traditional piloting approach, the pilot exercises near total control over the vessel’s navigation. As the person controlling the movement of the vessel, the pilot directs the bridge team and the bridge team is expected to support the pilot’s decision making by executing his/her orders. The inevitable effect of splitting the control function between two separate locations, as would be necessary with shore-based piloting, will be inferior feedback to the pilot that will result in less efficient overall control of the system if everything else remains the same.
Bruno & Lützhöft defined the fundamental control problem with remote pilotage as a less effective construct for the bridge team and inferior feedback to the pilot (2009, p. 431). They conducted an empirical study to explore these control problems by interviewing various maritime pilots, VTS operators, and personnel from the Swedish Maritime Administration (n.d., p. 2). The study’s cohort believed that the pilot’s rapport with the bridge team, gained through personal contact, was an important condition for successful pilotage, and a prerequisite for safe operations (n.d., p. 2). The pilot must be able to evaluate and trust the crew’s competence. Conversely, the crew must be able to evaluate and trust the pilot’s knowledge (n.d., p. 2). The cohort believed that the pilot’s face-to-face communication with the bridge team afforded a better opportunity to evaluate and develop mutual trust. The cohort also concluded that in-person communication was vital to confirm whether the ship’s personnel understood what was said, to form a clear understanding of the passage plan, and avoid any uncertainty (n.d., p. 2). They also believed that a pilot’s knowledge added an extra dimension of safety generally and that a pilot’s presence on board enabled him/her to gain an understanding of the ship’s status, judge the navigation and maneuvering equipment, and notice any physical discrepancies in the fairway (n.d., pp. 2-3).

The VTS operators noted that they did not use a standard language or standardized communication routines, but marine safety would markedly increase if they did implement such protocols (Bruno & Lützhöft, n.d., pp. 3-4). They also believed that it was difficult to establish trust and perform more complicated tasks over a radio link without insight into the other party’s competence. However, they noted that airline pilots and air traffic controllers were able to do so, and they believed that employing standardized communication routines and training would achieve a similar result in the maritime domain (n.d., p. 3). Bruno & Lützhöft defined trust as “a
belief that the other party would be competent and knowledgeable, and behave in a predictable way” (n.d., p. 5).

Few disagree with the hypothesis that modern communication and navigation systems can be employed to exercise adequate technical control over a vessel from a remote location. But, many fear that removing the pilot from the wheelhouse will irrevocably interfere with the socio control realized through personal, face-to-face communication between pilot and bridge team. Moving a pilot to a remote location will require reallocating some of the pilot’s control function to the bridge team (Bruno & Lützhöft, 2009, p. 432). If the degradation of socio and technical controls can be quantified, and if management measures can be developed to restore the system to an equivalent level of safety, a shore-based system might function as safely as traditional piloting in certain circumstances (Bruno & Lützhöft, 2009, p. 439).

Management measures to mitigate the risk of degraded control

Bruno & Lützhöft concluded that remote pilotage in fairways for selected vessels will be feasible once management measures are implemented to mitigate the control problems identified in their study (2009, p. 436). The human aspects associated with effective communication and building trust with the bridge team are likely more critical than the technical control issues associated with remote pilotage (Bruno & Lützhöft, n.d., p. 5). They outlined four principal ways to mitigate the risks associated with remote pilotage from a socio control perspective (2009, p. 432).

The first measure they outline is developing criteria to qualify ships to receive shore-based pilot services (2009, p. 432). They noted that variations in equipment, maneuverability, and crew competence are significant in the general ship population, and some ships may always require the services of an onboard pilot (2009, p. 433). At the same time, they found that “many
of the ships taking a pilot . . . are well equipped and have such well prepared crews that they in principle could manage without a pilot onboard” (n.d., p. 3). Under most systems, such vessels are obliged to take a pilot even if they might not need one, and these ships should obviously be capable of using a remote pilot (2009, p. 433).

Second, they recommended providing enhanced information support to the ship’s crews in the form of a more detailed passage plan. This could entail the pilot sharing passage information that may not be published in official hydrographic volumes but is known by the pilot to be critically important. An enhanced passage plan could be either text-based or uploaded directly into the ship’s navigation equipment. The latter approach could include detailed track information, cross-track error limits, wheel-over points, no-go areas, etc., and would mitigate many problems associated with the crew not having immediate personal access to the pilot’s local knowledge (2009, p. 433).

Third, they propose adopting technology-based quality improvements to the information feedback that is available to the shore-based pilot (2009, p. 434). Maritime pilots have traditionally relied on a combination of visual cues, instrumentation, and direct communication with the ship’s bridge team to obtain feedback from the navigating environment. This combined feedback enables them to very accurately observe the state of the system. Based on this feedback, pilots apply their local knowledge and specialized skill to determine what actions are necessary to maintain the desired state and navigate the vessel safely. Visual cues, the direct observation of the surrounding environment, have always been the source of feedback that pilots prefer (Van Westrenen, 1999, p. 59). But, as equipment quality has improved, pilots are increasingly relying on instrumentation to augment and support visual feedback. Nonetheless, they are reluctant to completely exclude visual cues and rely solely on feedback through a
computer screen combined with radio communication (Bruno & Lützhöft, 2009, p. 432). The obvious concern is whether instrument-based feedback alone will be suitable to develop an accurate understanding of the system state and support remote decision-making. In an early study, Van Westrenen concluded that radar alone does not provide sufficient feedback to a shore-based pilot to enable short-term navigation decision-making (1999, p. 132). A decade later, however, Bruno & Lützhöft suggest that currently available and improved navigation systems that employ accurate position fixing, electronic chart displays, and predictive capabilities could provide the high-quality feedback necessary to pilot remotely (2009, p. 434). With continuing exponential advances in technology, intuition militates toward concluding that if the technology is not sufficient today, it will be very soon.

Fourth and lastly, Bruno & Lützhöft recommend using standardized procedures and communication routines to integrate the functions exercised by the ship’s crew and the remote pilot into a coordinated control system (2009, p. 434). Clearly understood standard procedures would build trust and reduce risks associated with inevitable misunderstandings (2009, p. 434). Communication is a basic requirement to maintain control over any system and standardized protocols will be required due to industry-wide language differences (2009, p. 434). When radio transmissions replace face-to-face communication, the non-verbal portion of the message is lost. This is exacerbated when communicating in a non-native language, as is typical in the maritime domain. Standardized phraseology and routines, such as IMO recommended phrases and closed-loop communications, can significantly decrease the likelihood of a misunderstanding (n.d., p. 4). The airline industry has successfully overcome similar issues and can provide valuable guidance for resolving communication challenges in the maritime domain (n.d., p. 4).
Non-technical barriers to shore-based piloting

In another study, Hadley & Pourzanjani concluded that once solutions are found to address the technical problems associated with shore-based piloting, the remaining obstacles are political, commercial, organizational, and cultural (2003, p. 181). As a basis for their study, they assumed that any remote piloting system would operate at an agreed level of safety, would involve instructing a shipmaster transiting without a pilot, would not have general application to all vessels, and would require an onboard docking pilot (2003, p. 185). They concluded that the technology necessary to remotely pilot a ship is now largely available but that non-technical issues remain, such as size and type of vessel, equipment fit and state, crew capability and training, language, fatigue, legislative framework, and liability (2003, p. 186).

Acknowledging that all ports are different geographically, Hadley and Pourzanjani recommended that each port should conduct a risk assessment to develop unique criteria for determining which size and type of vessels and which waterway configurations would be appropriate for remote piloting (2003, p. 186). Acknowledging that substandard vessels do exist, ports would need to judge each vessel on a case-by-case basis against pre-defined minimum equipment standards (2003, p. 187). Ports would need to vet crew capability and training, and both the remote pilot and the ship’s bridge officers would need specialized training in remote piloting standards, procedures, phraseology, and emergency protocols (2003, p. 187). The absence of a common shipboard operating language presents one of the biggest stumbling blocks to implementing a remote piloting system and individual language challenges would need to be evaluated and screened beforehand (2003, p. 188). According to Hadley & Pourzanjani, technology development continues to outpace the development of necessary technical standards, performance standards, and legislative measures (2003, p. 189). The liability aspects of remote
pilotage are presently uncertain and, as with any new endeavor, will need to be clarified (2003, p. 192).

Hadley & Pourzanjani observed that the maritime industry is resistant to fundamental change of the sort implicated by remote pilotage. That resistance is grounded in concerns about the capability of the technology, the limitations of ships and crews, and protectionism (2003, p. 192). While none of these arguments should be discounted lightly, some believe solutions exist. For example, ship and crew capability issues can be addressed through selection criteria for program participants, as discussed above (2003, p. 192).

But, the protectionist arguments are more difficult to address “as there seems to be an underlying emotional resistance” (Hadley & Pourzanjani, 2003, p. 192). Maritime pilots fear they’ll be made obsolete or lose relevance, and they typically oppose any sort of remote pilotage system. They believe that if they encourage the use of remote pilotage by any definition, they are encouraging their own demise and they offer safety-based arguments to support their position. The European Maritime Pilots’ Association stated that shore-based pilotage “cannot be a substitute for pilotage performed by a pilot on board” (2012, §1.6.b).

**Risks attendant with the current system**

The tradition of pilots boarding ships in person is far from foolproof. Hadley observed that even with pilots on board there is a risk to both the vessel and the individual pilot (1999, p. 1). On most pilot grounds, a pilot tender transports the pilot to an offshore boarding location that is exposed to sea and swell (Van Westrenen, n.d., p. 2). In fine weather, transferring from the pilot tender to the ship’s jacob’s ladder can be somewhat risky, as any fall can result in serious injury or death. As the weather deteriorates and seas increase, this maneuver becomes increasingly risky. When the weather becomes so rough in the boarding area that the pilot
cannot safely embark an arriving vessel, the master must typically hold the vessel offshore or at anchor until the weather subsides sufficiently for the pilot to board (Hadley & Pourzanjani, 2003, p. 183).

Delaying a vessel’s port entry in rough weather carries a degree of risk. An example of this danger was the grounding of an empty wood chip carrier on the Oregon shore in 1999. When M/V NEW CARISSA arrived off Coos Bay, Oregon in gale wind conditions, it was too rough for the pilot to board the ship and he instructed the shipmaster to delay pilot boarding until the following morning (OR New Carissa Review Committee, 2000, p. 1). The shipmaster was not familiar with local port practice and he elected to anchor his ship off the exposed coast. During the night, the wind and swell increased. The ship drug her anchor, grounded on the beach, and eventually broke in half. The resulting fuel oil spill cost US$35 million to remediate and an additional US$25 million to remove the wreck (OR New Carissa Review Committee, 2000, pp. 1-2). Although this accident illustrates an extreme case, whenever a ship is required to delay pilot boarding due to severe weather, risk is inherently elevated.

Maritime pilots also face significant risks when working in rough weather. Commercial pressures incent pilots to attempt embarkation in marginal conditions, occasionally with tragic results. “Between January 2006 and February 2007, four pilots were killed across the United States in falls from pilot ladders” and a fifth person, a pilot boat operator was killed when his boat capsized in rough weather after a pilot transfer (Lipcon Law Firm, 2007). Two of these fatalities were directly related to adverse weather conditions (Lipcon Law Firm, 2007).

Partially due to risks such as these and partially due to trade facilitation, some pilotage authorities will allow a master to navigate his ship inshore of the normal pilot boarding point to a more sheltered position to facilitate pilot embarkation (Hadley & Pourzanjani, 2003, p. 183).
The traditional method has used the pilot tender to lead a ship inshore to calmer waters, possibly in combination with radio and/or radar advice (Hadley & Pourzanjani, 2003, p. 183). This “follow-me-in” approach has been employed in many ports around the world. However, allowing the master to proceed to or from port unaided by a pilot deprives the ship’s crew of the pilot’s local knowledge, skill and competence as they navigate their vessel through constrained waters. The practice is controversial and raises safety and liability concerns.

A 1997 accident provides an illustration of what can go wrong when leading ships through pilotage waters. The Bahamian passenger vessel, ALBATROS, grounded while departing from the Isle of Scilly and being led out to the open sea by the local pilot (Great Britain. MAIB, 1998, p. 10). The accident report revealed that the master and pilot did not employ appropriate management measures to mitigate the risk associated with using a pilot launch to lead a vessel through pilotage waters (1998, p. 35). The investigation into this accident found deficiencies with both the pilot and the bridge team, and determined that their practice of leading a ship out of port was unsatisfactory (1998, p. 40). However, some ports continue this practice rather than offer technology supported advice.

Having a pilot physically aboard does not necessarily guarantee a successful outcome. In 2006, the International Group of P&I Clubs studied pooled information on industry-wide insurance claims over US$100,000 for policy years 1999 to 2003 (2006, p. 3). It found that pilot error caused 260 claims with an overall average cost of US$850,000 per claim (2006, p. 3). The group also developed a database showing the number of piloted ship-moves completed for each of those 260 claims by country. Approximately one out of 39,000 and one out of 98,000 piloted ship-moves resulted in a claim in the U.S. and U.K. respectively (2006, p. 12).
A notable U.S. accident attributed to pilot error was the 2007 allision of a Hong Kong registered containership, COSCO BUSAN, with the San Francisco-Oakland Bay Bridge. The U.S. National Transportation Safety Board (NTSB) determined the accident occurred because, *inter alia*, the pilot used prescription medications that degraded his cognitive performance, the information exchanged between the master and the pilot – both pre-departure and during the voyage – was lacking, and the master did not effectively monitor the pilot’s performance nor the vessel’s progress (2009, p. xi). As a result of this accident, 53,000 gallons of bunker fuel spilled into U.S. navigable waters and total monetary damages exceeded US$70 million (2009, p. xi).

That accident illustrated an issue central to our analysis of remote pilotage. The COSCO BUSAN accident investigators questioned whether cultural differences or route experience might impede a ship’s bridge team from effectively overseeing a pilot. The Chinese master of COSCO BUSAN admitted that he was put off by the pilot’s demeanor and did not feel comfortable questioning the pilot (2009, pp. 67-68). The NTSB concluded that cultural differences and the master’s limited experience navigating on San Francisco Bay adversely influenced his ability to monitor the pilot (2009, pp. 110-111).

The 2013 allision of a tank vessel with the San Francisco-Oakland Bay Bridge was also attributed to pilot error. The NTSB determined that accident occurred because the pilot made a decision to alter the planned transit from one bridge span to another without allowing sufficient time to execute the maneuver, and again, the vessel master failed to properly monitor the pilot (2013, p. 1). These two incidents beg the question – if the bridge team cannot effectively monitor the pilot, then who can?
The current state of shore-based piloting

Several European pilotage authorities already provide limited remote piloting services that are primarily intended to assist vessels entering a port when weather conditions are too severe for a pilot to embark at the regular boarding point (Bruno & Lützhöft, 2009, pp. 427-428). Those remote systems typically use shore-based radar and radio advice to guide ships into calmer waters for boarding (2009, p. 428). The service is offered as a backup to the traditional approach and is not intended to replace regular piloting service (2009, p. 428). But, some believe the time may be at hand to expand the notion of shore-based piloting to cover routine piloting operations in certain less demanding areas such as fairways and approach channels (2009, p. 428).

In The Netherlands, Rotterdam pilots offer remote pilotage service to vessels that meet their qualifying criteria (Port of Rotterdam, 2014, p. 80). The program excludes vessels with a draft over 14.3 meters, tank vessels with length over 125 meters, non-tank vessels with length over 165 meters, and any vessel with a language or communication problem (Port of Rotterdam, 2014, pp. 80-81). A VTS certified pilot uses shore-based radar feedback and a standard VTS console to monitor and direct the qualifying ship’s bridge team (P. van Erve, personal communication, January 28, 2015). Under this shore-based piloting system, qualifying vessels may transit from the normal seaward pilot boarding area to a position with sheltered conditions about 2-1/2 miles inside the breakwater (Port of Rotterdam, 2014, p. 80).

Belgium pilots also offer remote pilotage services in the approaches to Flushing Roads when normal pilot boarding is suspended due to weather (G. Bosker, personal communication, January 26, 2015). Specially trained pilots using shore-based radar and VHF radio communication provide remote assistance to vessels up to 175 meters in length (Agency for
Remote pilotage at Flushing Roads is only available to vessels that meet specific standards and criteria, that are operating in fairways approved for remote pilotage, and that follow pre-agreed procedures (Agency for Maritime and Coastal Services, 2012, pp. 1-4). Vessel masters are required to have a certain amount experience on the route, complete a standardized checklist, and agree to follow the shore-based advice (G. Bosker, personal communication, January 26, 2015).

In Germany, pilots on the River Elbe use shore-based radar to guide vessels up to 170 meters in length into port during rough weather. As a result of their radar-based experience, the German pilots concluded, “no amount of technological development could lead to the replacement of on-board pilotage with remote pilotage” (Hadley, 1999, p. 5). In contrast to this opinion, a Danish study concluded that remote piloting is possible in outlying waters on certain selected vessels using standardized procedures and communications and that in certain situations, the negative impact on marine safety would be minimal (Danish Maritime Authority, 2014, p. 8). Intuitively, if technology improves upon the shore-based radar feedback utilized in the current systems, the shore-based services might also be expanded, as the DMA concluded.

In the United States, some pilot groups have begun using a slightly different approach to remote piloting wherein a shore-based pilot monitors and supports the decision-making of the onboard pilot. This “co-pilot” approach has been used effectively during conditions that might otherwise disrupt unaided navigation, such as during reduced visibility or when moving a very large vessel through a confined waterway (CA Office of Spill Prevention and Response, 2009, p. XVII-5; Hadley, 1999, p. 4). Nonetheless, Hadley noted that in North America there is stiff resistance to remote pilotage as it is conducted in Europe (Hadley, 1999, p. 5).
The maritime realm poses unique challenges to remote piloting.

Many have attempted to draw conclusions about remote pilotage by comparing air traffic control systems (ATC) and vessel traffic services (VTS). Van Erve and Bonner explained that, although there are similarities between ATC and VTS, they are not analogous across the board (2006, p. 359). The major similarities between ATC and VTS are their basic objectives to provide advice and information aimed at preventing collisions, expediting efficient traffic flows, and assisting emergency services (2006, p. 360). They further pointed out that significant differences exist between the aviation and maritime operating environments: under the International Civil Aviation Organization (ICAO), ATC is more regulated and controlled than is VTS under the IMO and the International Association of Lighthouse Authorities (2006, p. 360). Compared to maritime, aviation generally offers a more uniform working environment largely due to the high degree of standardization found in airport infrastructure, airplane design, and air traffic operating procedures (2006, p. 360). Neither seaports nor ships are currently equipped with the standardized sophisticated guidance systems found in today’s airports and airplanes (2006, p. 361). Van Erve and Bonner also differentiated maritime from aviation citing key differences: the reluctance of vessel masters to surrender navigational decision-making to a third party, the presence of non-commercial and non-AIS equipped craft in commercial waterways, and the marine collision avoidance regulations, which place the responsibility to maneuver and avoid collision on the ship’s bridge team vis-à-vis traffic control (2006, pp. 361-362). They also pointed out that while responsibility and liability remain with the vessel master, with remote piloting, the master may not be in the best position to ensure vessel safety if he/she is an infrequent caller to a port, sailing with a marginal crew, or does not have sufficient skill or expertise in maneuvering his vessel in all circumstances and conditions (2006, p. 363).
Where do we go from here?

Hadley discussed the benefits of the various technology drivers that are being, or might be used as tools to provide piloting advice remotely (1999, p. 5). Like Van Westrenen, he noted that shore-based radar lacks the requisite precision and installations are costly, particularly when coverage is required over a large geographic area (1999, p. 5). Hadley reasoned that emerging differential GPS, electronic chart display and information systems (ECDIS), automatic identification of ships (AIS) and other knowledge-based systems in combination, however, offer the accuracy required to remotely pilot vessels (1999, p. 5). He observed:

All the relevant ship motion data would be displayed, or be available, as would the real-time meteorological, hydrological and local hydrographic data. With this common picture available to him, with a system that provides path prediction . . . , which can intelligently apply the port's local rules and is capable of providing multi-ship anti-collision advice, a VTS-based pilot should be well placed to conduct remote pilotage. (1999, p. 5)

Hadley concluded that the most likely initial application for remote piloting will move the pilot boarding area farther inshore (1999, p. 10). The benefits of this would vary from one pilotage ground to another, but could include shorter pilotage distance, safer boarding conditions, fewer trade interruptions, and as will be discussed in this paper, other potential safety benefits associated with heightened bridge team performance and a better system of preventing accidents resulting from pilot error. But more importantly, it will provide a first step toward a more robust system.
The maritime industry is changing

When Richard Henry Dana arrived in San Pedro Bay on the sailing vessel PILGRIM in the 1830’s, there was no formal port, only an anchorage-of-convenience situated near the ubiquitous cattle herds of Southern California (White, 2008, p. 9). For a year and a half, PILGRIM labored up and down the coast, stopping in protected anchorages to trade finished goods brought ’round from Boston. They visited San Diego, San Juan (later named Dana Point), San Pedro Bay, Santa Ventura, Santa Barbara, Monterey and San Francisco (Dana, 1841). After spending Two Years Before The Mast, they arrived back home with holds full of hides bound for the New England tanneries (as perspective, it took Dana and company two years to collect and deliver a cargo that would fill about eight sea-containers today).

Much has changed since then. Convenient anchorages have evolved into mega-gateway ports that today, form part of a worldwide, integrated transportation system handling “a global trade volume of 8 billion tons, which is expected to quadruple in the next few decades” (Burns, 2014, p. 59). As a result, marine terminals anticipate increased cargo flows while faced with space and environmental growth constraints and increasing competitive pressure. Many are implementing new approaches and new technologies to more efficiently move cargo through their facilities without expanding their footprint or their impact on the environment. Higher velocity cargo handling and increased productivity are vitally necessary for a modern port to maintain its competitive position.

Like the ports they serve, ships are growing larger to take advantage of scale economies. Often, the waterways they navigate do not grow proportionally, however (NRC, 1994, p. 56). For example, fifteen years ago the largest container ship calling at the Port of Los Angeles carried approximately 5,000 twenty-foot equivalent units (T.E.U.). Today, vessels with 14,000
T.E.U. capacities are commonplace, and vessels of 18,000 T.E.U are anticipated. Concurrently, the waterways in most ports are becoming more constrained. The larger container cranes necessary to serve super post-panamax ships extend over 240 feet out into the waterways and turning basins. Also, berth extensions and larger vessels encroach into navigable waterways. As the navigator’s ship gets bigger, his/her waterway becomes relatively smaller, and the navigation challenges become greater. Sometimes the ship and its container stack are so high, the pilot cannot see the waterway from the wheelhouse.

**New technologies aid precise navigation.**

To meet these increasing challenges, maritime pilot organizations are turning to new navigation technologies to aid big-ship navigation. Precise positioning technologies are being employed to accommodate smaller margins of error. Pilots are being called upon to move larger ships through waterways that are too confined for traditional unaided methods, and during conditions that would otherwise prevent unaided navigation (e.g., when visibility is restricted by fog or simply due to vessel size in relation to the waterway). Ship piloting has traditionally been associated with human expertise. However, it is becoming increasingly necessary to rely on technology to maximize productivity while maintaining adequate levels of safety.

Pilots have recently begun using new navigation equipment packages called Portable Pilot Unit’s (PPU). This equipment takes many forms and can be tailored to suit the demands of different harbor geographies and environmental conditions. A PPU is typically a laptop or tablet computer with specially designed software capable of running a digital chart program that integrates precise GPS and automatic identification system (AIS) information into an electronic charting display and information system (ECDIS). The end result is a system wherein the ship’s precise position and its predicted motion are depicted graphically on a real-time electronic chart.
A PPU can be configured to receive independent navigation information through its own portable antenna array or it can connect to onboard navigation sensors through the ship’s AIS Pilot Plug. With the corrected GPS receivers found in some stand-alone antenna systems, one-meter position accuracy and 0.2 degree heading accuracy is available. Notably, a ship-to-shore radio is built into some units, which allows data transfer to shore-side monitoring stations. With this feature, a second pilot located at a shore station can view the identical information that is displayed on the shipboard PPU (ARINC, 2009). Additionally, by enabling very accurate navigational feedback to be displayed on a remote console, this technology could take remote piloting based on radar feedback to the next level.

**Many resist the disruption posed by new technologies.**

Maritime is a very traditional industry and mariners as a group tend to cling to proven past practices. In days gone by when ships were made of wood, steering commands were given in the form of helm or tiller orders. When the navigating officer ordered “Hard Port” it meant put the tiller to port, which caused the ship to turn the opposite way - to starboard. Although this regimen made sense on board sailing ships, after wheels and steam replaced tillers and sails, it caused confusion. Nonetheless, mariners clung to their helm orders long after sails and tillers disappeared from the merchant service. After many years and several notable steering-related casualties in the early part of the last century, the U.S. Navy switched to a much less confusing system of rudder orders. The command “Right Rudder” meant turn the wheel to the right, which caused the rudder to move to the right and the ship to turn to starboard (also to the right). But, the merchant men clung to tradition and refused to let go of their helm orders. An early seamanship primer noted:
But seagoing began before the modern day of wheels, and when the wheel came in shellbacks of that ancient period looked upon it with little favor and still insisted upon their helm. Boat practice is a great educator for the helm method of conning the wheel, and so far as we now know, this relic of the past will stick with us for a few hundred years more, or at least until such time when steering is done by radio from the home office and the skipper and mate are simply called the first and second lookouts. (Riesenber, 1922, p. 550)

Seven years later, a federal law passed in 1935 proscribed tiller orders and forced a departure from tradition (74th U. S. Congress, n.d.).

Few maritime organizations are as steeped in tradition as maritime pilot groups. Maritime pilots represent the pinnacle of their profession. It is typical for a pilot to have had a long and successful career at sea prior to joining a pilot organization. Many do not enter the piloting profession until they are in their late 30’s or early 40’s. They are highly accomplished and respected within their field, and have invested decades to accumulate the in-depth knowledge and expertise necessary to practice their craft. They are also extremely well compensated. Against this backdrop, it is easy to understand their reluctance to embrace any disruptive change that might diminish the value or relevance of their acquired knowledge and skill, or force them into a position where they need to relearn skills, or worse yet, become obsolete and lose their livelihood altogether. These concerns are very real and cannot be lightly dismissed.

Despite recent moves to further incorporate technology into piloting, significant resistance remains within the pilot cadre. Some pilots prefer to pilot ships only in the traditional manner - by eye - and they avoid using technology as best they can. Other pilots believe that
using technology is acceptable up to a point. They will use a PPU to enhance and augment their onboard navigation, but they remain uncomfortable with the prospect of using a PPU to completely replace visual feedback, as is necessary when relying on instruments to navigate in heavy fog. Any suggestion to use these emerging technologies to provide navigational assistance or piloting advice from anyplace other than onboard the vessel typically elicits widespread objection from the pilot community.

Some of the main arguments offered against employing technology to pilot remotely are, 1) one cannot ensure piloting instructions will be understood and executed without face-to-face communications, 2) one cannot achieve an adequate level of navigational control without visual feedback, 3) over-reliance on technology is dangerous because it might fail, and 4) it will always be safer with a pilot physically on board the vessel. While each of these safety concerns must be carefully considered, the U.S. National Research Council noted, “safety is sometimes a surrogate for economic issues that often underlie and stimulate controversy in pilotage” (1994, p. 9).

Another view is that in certain applications and in certain fairway configurations, it is likely that remote pilotage in one form or another could actually improve navigation safety. “It is commonly assumed that shore-based pilotage has the potential to facilitate the flow of traffic and to improve safety” (Bruno & Lützhöft, n.d., p. 1). Furthermore, any sweeping dismissal of the concept as being less safe or prone to failure might rob the maritime industry of any opportunity to realize productivity gains without unreasonably sacrificing marine safety.

**The preservation of acceptable levels of safety is key to this debate.**

The consequence of maritime error has increased over the past several decades, and no one is more aware of this than pilots and shipmasters. Larger ships have expanded the scale of potential harm as well as public outrage and blame. Those responsible for a maritime accident
can expect censorship at best, or loss of livelihood and imprisonment at worst. The pilot who caused COSCO BUSAN, a 900-foot long container ship, to allide with the San Francisco Bay Bridge and discharge approximately 53,000 gallons of oil into San Francisco Bay, was sentenced to serve 10 months in federal prison (U.S. DOJ, 2009).

But, what is an acceptable level of safety for piloting ships? Should we require the absolute highest standard of safety that is currently available? Or can we accept a lower level of safety? If so, how much lower? Initially many are attracted to a “highest standard” requirement, particularly for activities like maritime that carry such high consequences. However, such a standard has been deemed unrealistic and is rarely followed by any industry.

In Industrial Union Department v. American Petroleum Institute, 448 U.S. 607 (1980), the U.S. Supreme Court affirmed that OSHA did not have “the unbridled discretion to adopt standards designed to create absolutely risk-free workplaces, regardless of cost.” The Court took a balancing approach and found that a level of safety lower than the safest level was acceptable in the context of worker safety. Not even the aviation industry subscribes to an “absolute safety standard.” The International Civil Aviation Organization’s Safety Management Manual states:

While the elimination of aircraft accidents and/or serious incidents remains the ultimate goal, it is recognized that the aviation system cannot be completely free of hazards and associated risks. Human activities or human-built systems cannot be guaranteed to be absolutely free from operational errors and their consequences. Therefore, safety is a dynamic characteristic of the aviation system, whereby safety risks must be continuously mitigated. It is important to note that the acceptability of safety performance is often influenced by domestic and international norms and culture. As long as safety risks are
kept under an appropriate level of control, a system as open and dynamic as aviation can still be managed to maintain the appropriate balance between production and protection.

(2013, pp. 2-1)

It is not reasonable, neither from a regulatory standpoint nor from an operational perspective, to require every safeguard available. Just because it is possible to design one more dimple into the hammer handle to prevent it from slipping out of a worker’s hand, does not mean that one more dimple should be required. That would open the door to standards of care that are impossible to satisfy. It is fair to conclude that the safety standard that should be required is an acceptable level of safety, not the absolute highest level of safety.

That being said, a more pertinent question remains: What constitutes an acceptable level of safety? For the sake of discussion, we’ll assume that using acceptable traditional piloting methodologies provides an acceptable level of safety in most ports today. Most would agree that if we hypothetically removed a pilot from the ship and stationed him/her in front of a shore console equipped with radar, a VHF radio, and nothing more, the level of navigational safety would be lower and therefore, would not be acceptable. If we stopped there, few would disagree that the lack of face-to-face communications, the lack of visual feedback to the pilot, the lack of access to onboard navigation systems, and the possibility of an equipment failure would leave us with an unacceptable degree of risk. But, what might we do to return our system safety to an acceptable level? Would it be possible to institute management measures to mitigate the elevated risks and return our system to an equivalent level of safety (ELS)?

ELS does not mean we have returned our system to the exact level of safety that we had initially. Rather, it means we have created a different safety system that provides equal safety. As an analogy, assume a motorist has an acceptable level of safety while driving in clear, dry
weather. If it begins to rain, the risk of an accident increases and the motorist’s level of safety reduces. But, the motorist can take “management measures” to mitigate the risks associated with the rain. By reducing speed, turning on the windshield wipers, increasing following distance, and checking the brakes periodically, the motorist can return his safety system to a level that is different but equivalent to driving in clear, dry conditions. Similarly, maritime pilots employ ELS all the time. When it becomes foggy, they reduce speed. When winds increase, they request additional tugs. When piloting underpowered ships, they take way off early. And when a ship has engine trouble, they proceed at a reduced speed, or with tug assistance, or not at all. All of these management measures are intended to return the pilot’s safety system to an equivalent level of safety. And while not the same, they are equally safe.

Management measures: Communication protocols to ensure information is exchanged

There is deep concern regarding the potential effects associated with replacing traditional face-to-face communications with radio communications between a remote pilot and the ship’s bridge team. This changed operating construct increases the likelihood of miscommunication and increases the difficulty of performing complex tasks. Specifically, radio-enabled communication makes it more challenging for the pilot to establish rapport and trust, ensure instructions are understood and executed properly, understand the ship’s status, assess the ship’s navigation and maneuvering equipment, and notice any physical discrepancies in the pilotage ground. The potential for mistakes resulting from failed communications is perhaps the single largest impediment to establishing a remote piloting system.

Communicating via phone or radio is more difficult than doing so face-to-face. Body language is absent, which oftentimes is the best indicator of understanding. Also lost is the opportunity to use gestures and hand signals to aid understanding when communicating with
people who speak different languages. These challenges, unless mitigated, could significantly degrade the quality of communications. Nonetheless, there are methodologies that could be employed to return radio communications to an equivalent level of safety. More robust preplanning prior to a vessel’s arrival could significantly reduce the need for complex master/pilot communications at the commencement of the passage. For example, the pilot’s passage plan could be sent to the vessel via email well in advance of arrival. Checklists specific to remote piloting and known information, such as berthing details, tug information, radio frequencies, and communication protocols could be included. The pilot could also provide routing information in a standard format that could be loaded directly into the ship’s onboard navigation system. This would allow the ship’s bridge team to display the pilot’s preferred route with specific tracklines, wheel-over points, and margins of error on the ship’s electronic navigation chart. A formal master/pilot information exchange (MPIX) would still be conducted before the vessel entered the pilotage ground. That discussion would afford an opportunity to complete checklists, confirm vessel suitability, and assess shipboard language skills. But, if all known and relevant planning information were provided in advance, the need to engage in complex discussions would be minimized. Lastly, Skype, Facetime, or other video messaging applications are becoming commonplace and could be used as a tool to support and enhance initial ship-shore communications.

Carefully considered checklists and standardized communications must be a central pillar of any remote piloting system. The International Association of Lighthouse Authorities (IALA) has developed a robust vessel traffic service communication protocol that incorporates IMO standard marine phrases with message markers that add clarity to ship-to-shore communications (IALA, 2012, pp. 124-128). Message markers take the form of a spoken word, such as...
“information” or “instruction,” that precedes the message itself. The marker is intended to increase the probability that the purpose of the spoken message that follows is properly understood (IALA, 2012, p. 125). The IALA manual governs VTS operations, and some of the procedures are inconsistent with the objectives of remote piloting. However, many of the communication protocols would cross over. Additional message markers could be developed for remote piloting such as “rudder order” to precede an ordered course change. As an example, the Rotterdam pilot organization adopted the use of IALA message markers into their standardized communication protocols for remote piloting.

Standardized routines and systems could be developed to replace the face-to-face feedback that pilots rely on. Prior to commencing the passage, the bridge team should have a clear understanding of the pilot’s basic intentions. This would facilitate a more collaborative approach to conducting the passage. The bridge team would necessarily become more involved in the vessel’s navigation and, therefore, be more engaged in the piloting activity.

Most agree that removing the pilot to a remote location without enhancing his/her communication capability would degrade navigation safety. But, there are likely many communication protocols that could be developed to maintain an effective construct for the bridge team and ensure adequate feedback to the remote pilot. The aviation industry has used standardized communication protocols, checklist-based safety systems, and training to build two-way trust and confidence between ATC and flight crews. And while generic comparisons between ATC and remote piloting are not always valid, this is one area where maritime could look to aviation for guidance and insight.

Training would also build trust and a common understanding of preferred intentions. Special training courses could be required for remote pilots. That training should include
modules such as VTS equipment, communication skills and phrases, advanced traffic management, simulator training, and responding to emergency situations. The Rotterdam pilot organization requires their qualified remote pilots to attend a formal VTS training program. Training could also be required for shipboard personnel as a prerequisite for acceptance into a remote piloting system. Port administration could provide vessels with port-specific training in an electronic format that explains program requirements and expectations.

Clearly new communication protocols and procedures will be required for any remote system. By developing appropriate checklists and standardized communications, we should be able to eliminate miscommunication and move a remote system toward an equivalent level of safety. Detailed checklists could be devised that would allow a remote pilot to develop an understanding of the status of onboard equipment. And asking the right questions would reveal much regarding vessel readiness. A professional and thorough information exchange, even performed remotely through a combination of email and voice communication, would go a long way toward establishing rapport and confidence that the other party is competent and knowledgeable, and will likely behave in a predictable manner.

**Management measures: Improved feedback from the bridge environment**

Another concern with remote piloting is the quality of feedback to the pilot. When piloting in the traditional sense, feedback between the pilot and the ship’s bridge team is constant and continuous. For example, when a pilot gives a rudder command, he can immediately confirm his order is being executed correctly by observing the rudder angle indicator, the action of the helmsman, and the ship’s response. As all pilots know, an improperly executed rudder command can run a ship into danger more quickly than almost any other mistake. If a helmsman puts the rudder over the wrong way, unless the error is detected quickly, it may not be
recoverable. An onboard pilot draws tremendous comfort knowing that he/she can immediately detect and correct any steering error.

A shipboard pilot can also visually prompt the bridge team by pointing to starboard when ordering starboard rudder or raising a clinched fist when ordering “stop engine.” There are many other face-to-face feedback methods and routines that pilots and bridge teams typically employ. They range from first-hand observation of the ship’s instrumentation to subtleties, such as being able to observe a captain’s discomfort during a difficult maneuver in close quarters. Pilots will routinely reduce speed or otherwise adjust their navigation methodology in response to nothing more than a shipmaster’s look of concern. None of this feedback and innuendo will be available to the remote pilot. So the question becomes, can this lost face-to-face feedback be replaced with other routines or systems? Or more precisely, what management measures might be employed to improve the feedback loop between a remote pilot and the bridge environment??

This is one of the more difficult aspects of remote pilotage to consider and assess fairly and without bias. The immediate feedback loop available with traditional piloting is deeply ingrained in every pilot’s understanding of how to properly conduct a ship’s navigation. In general, replacing this direct feedback with a surrogate is a source of tremendous discomfort for pilots. Moreover, measuring the value of many of these traditional routines and the effectiveness of an equivalent is highly subjective and will differ from one pilot to another and from one pilotage area to another. Solutions to this dilemma likely exist but may be difficult to discover.

One possible solution would be to give the shore-based pilot direct access to onboard telemetry. Much or all of the instrumentation feedback that a pilot has access to on a ship could be transmitted ashore or replaced with shore-based data collection. For example, shipboard instrumentation could be transmitted to a shore base station in the same manner that a PPU
transmits navigation information ashore. This would enable a remote pilot to display the same data collected aboard ship, such as rudder angle, rate of turn, course over ground, speed over ground, GPS data, AIS data, wind speed and direction, and other crucial data. Digital shipboard data collection systems enable the transmission of any information a pilot would normally require. Thus, a shore-based pilot could actually observe the ship’s rudder angle indicator in real-time on his shore console, and be immediately assured that the bridge team executed his rudder command properly. Also, appropriately located shore-based radar stations could provide information similar to that provided by onboard radar equipment. Or, given sufficient transmission bandwidth, the shipboard radar information could be digitized and transmitted ashore.

Alternative practices could also be developed to prompt the bridge team and improve the likelihood that they will properly execute the shore-based pilot’s orders. For example, a remote pilot could verbally prompt the bridge team by using message markers to communicate intentions prior to arriving at the wheel over point as follows: “Information. Two hundred meters to wheel over point for a turn to starboard, rate of turn 15 degrees, new course will be 340 degrees.” Using the message markerdifferentiates the informational communication from a rudder command and would alert the bridge team that they will soon be required to execute a turn to starboard. The informational message would be followed with, “Rudder Command. Starboard twenty.” Closed-loop communications would require the bridge team to repeat each order, which would aid their comprehension.

Admittedly regimens like this are more cumbersome and would not be appropriate during more difficult passages. But in less demanding approach channels and fairways, where the
margin of error is greater and decision-making is less time-constrained, a system such as this should function effectively.

**Management measures: Establishing adequate control**

Traditionally, pilots have relied primarily on visual feedback to make navigational decisions. Visual cues, such as landmarks abeam, tell pilots when the vessel has arrived at the wheel over point. Leading lines and ranges tell them whether the ship is to the right or left of track. And the surface of the water and smoke trails reveal the direction and velocity of the wind. When visibility is restricted, pilots occasionally rely on radar to cautiously continue a passage. But, radar feedback is inferior to visual feedback, which is why pilots are reluctant to rely on radar alone to navigate confined waterways during restricted visibility.

Recent advances in technology have greatly improved the quality of feedback from electronic navigation systems. Real-Time Kinematic (RTK) satellite navigation systems provide better positioning information and motion solutions that approach or exceed the quality and detail of feedback based on visual cues. Existing electronic navigation systems provide sufficiently accurate and detailed vessel position and motion information to allow safe navigation with no visual feedback under certain circumstances. Los Angeles pilots, for example, have moved large vessels in excess of 300 meters LOA through confined waterways during zero visibility conditions using only the information available on their RTK PPU’s. These pilots have commented that they could perform the job from their office base station (which displays the exact same information as is available on the PPU) if the same RTK navigation equipment were permanently installed on board the ship. The LA Pilot experience indicates that technology driven solutions enable adequate control to navigate safely within an acceptable margin of error with no visual feedback under certain conditions and upon certain waterways.
Whether or not one can adequately control navigation using only instrument feedback and remain within an acceptable margin of error will, of course, vary from one geographic area to another and with changing environmental conditions. However, it seems that it can be done safely under some circumstances. Hence, the primary point of analysis becomes not whether remote piloting can be done, but rather under what conditions it can be done. This analysis will turn on factors such as how confined the waterway is, the maneuverability of the ship, and to what degree environmental factors exacerbate navigational complexity and decision-making. Ultimately it is difficult to argue against the fact that we currently have the technology available to provide adequate navigational feedback to enable a pilot to control a vessel remotely. In fact, such technology is already incorporated into many of the sophisticated PPU’s currently being used. However, such capabilities are not routinely part of the ship’s onboard equipment package. Nor is there a standard communication protocol linking shipboard navigation systems with shore-based navigation systems.

**Management measures: Over-reliance on technology**

One common argument opposing remote pilotage is that over-reliance on technology is inherently dangerous because the technology might fail. While it is true that any technology could fail at any time, redundancy is typically built into critical systems or contingencies can be devised to prevent an accident in the event of a failure. When piloting a ship, there are multiple contingencies and redundancies for many different failure scenarios. If the ship’s engine or bow thruster fails, the pilot can depend on assist tugs or anchors. If radar fails during foggy conditions, the pilot can slow or stop the ship. If the pilot becomes incapacitated, the master should be able to step in and manage the vessel.
Similarly, redundancies and contingencies can be built into a remote piloting system. Equipment redundancies could be incorporated, such as dual VHF radios for communications, redundant shipboard GPS receivers, and proprietary positioning systems within a port complex to back up the satellite GPS system. These are but a few of many possibilities. And if these redundancies were to fail, a remote pilot could stop the passage, direct the ship to anchor, or request tug assistance. While the options available and their effectiveness would vary from one pilotage area to another, acceptable solutions could be developed for any reasonable failure scenario.

**Won’t it always be safer with a pilot on board?**

Another common argument against remote pilotage is that any system of remote pilotage will always be less safe than the traditional system with a pilot aboard the ship. This position ignores reasonableness, however. Any safety-based system can be made safer. One more dimple can always be added to the hammer handle. Using the same argument, we could claim to need two pilots on every job in case one pilot became disabled. No one would believe that was a reasonable approach however, and reasonableness should form the basis of any standard of care. And while safety should never be sacrificed for expediency, any systemic analysis should recognize that the objective is to achieve a reasonable or acceptable level of safety.

**Could remote piloting improve productivity and marine safety?**

Remote piloting is not a blanket solution and may not be appropriate for every waterway, at least not yet. Navigation complexity, vessel control requirements, and the consequence of a failure vary from one waterway to another. Factors such as proximity to the grounding line, environmental conditions, and constraints on maneuvering room are among the many factors that must be assessed prior to implementing a remote system. Intuitively, the first choice for remote
piloting would be the offshore fairways in harbor approaches. Approach fairways are typically less challenging for navigators, and the consequences of a failure are oftentimes less immediate and less severe. A remote system covering harbor approaches would reduce the risks associated with boarding pilots in foul weather and with ships loitering offshore when boarding was not possible. It would also eliminate the incentive to use inferior methods, such as leading ships into port or allowing shipmasters to navigate into port without pilot assistance.

Some European ports (Rotterdam and Flushing Roads) have been practicing limited remote piloting to move the pilot boarding point farther inshore during periods of rough sea conditions. Those systems provide remote pilot assistance that allows the ship to transit from the normal pilot boarding point to more sheltered waters, typically inside the harbor entrance, where a pilot boards to navigate the ship during its in-harbor transit. These systems reduce the risk to pilots and ships and eliminate costly delays.

But, these long established remote piloting systems still rely on shore-based radar to monitor transiting vessels and VHF radio to provide course and speed advice. They do not make use of the newest technologies, and many of the pilots consider the remote system inferior to having a pilot on board. Therefore, they only offer the service when sea conditions become too dangerous to board vessels at the normal offshore boarding points. This begs the question, what about the safety of the pilot while boarding ships during weather that is almost, but not quite bad enough to shut down normal operations?

Nearly every pilot has stories about dangerous boardings and near misses. As the seas increase, so does the danger. In a report for the Australian Transport Safety Bureau, Weigall noted:
The pilot’s task of transferring between vessels at sea using the pilot ladder has long been recognised as hazardous. This has resulted in marine pilot fatalities and serious and disabling medical conditions from body stressing, being hit, and falls. (2006, p. 1)

A pilot’s primary fear is falling from the ladder onto his pilot boat, or worse, falling into the water and being pulled under the pilot boat. But, no pilot wants to be responsible for stopping the flow of commerce, and the economics of shipping put pressure on pilots to attempt boardings during marginal sea conditions every winter.

It seems obvious that one benefit of remote piloting is it would eliminate boardings in rough weather and significantly increase pilot safety. Rather than board a pilot at an exposed offshore location subject to rough sea and swell, could we provide remote pilotage using the newest cutting edge technology to assist bridge teams to navigate from offshore fairways to an inshore location where pilot boarding would be safer? Hadley noted, “pilots can also be in favor of it [remote pilotage] because it reduces risks when boarding” (Hadley, 1999, p. 4). As noted, the European pilot groups are already using shore-based radar to accomplish this in limited circumstances. But, if better technology were employed, it is likely that those systems could be expanded to cover a wider population of vessels and become a normal routine rather than an exception during rough weather.

The feasibility of this approach would depend on three factors: 1) the configuration of the waterway and the corresponding margins of error, 2) vessel/crew suitability, and 3) installing the necessary equipment aboard ship and similar compatible equipment at a shore station. Whether a remote piloting solution could be employed on a particular approach waterway would have to be carefully evaluated using a risk assessment methodology, but intuitively, approach
channels would be an appropriate starting point for any program and would reap immediate benefits in pilot safety and reduced vessel delays.

Vessel and crew suitability will always be a concern with remote piloting. A pre-screening and vetting system would need to be developed to assure the quality of participating ships and bridge teams. The assumption is not all ships would qualify for participation.

Pilots need assurance that a particular vessel and/or shipmaster will be suitable for remote pilotage. Pilots need to be familiar with the shipmaster’s abilities and the ship’s capabilities, and the master should have some degree of familiarity with the waterway and the remote system requirements. The European pilot groups that currently practice remote piloting require a shipmaster to make a certain number of trips over the route with a traditional pilot prior to receiving remote assistance. This enables each party to form a baseline understanding of the other’s requirements and proficiency. And as discussed above, this vetting process should include bridge team training provided in electronic format as well as a more formalized vetting process. For obvious reasons, it would be easier to vet liner traffic. One-time callers might not be able to participate in a remote system.

The European pilot groups also pre-screen ships and crews using threshold requirements for participation that include limits on vessel size, vessel type, cargo, and the shipmaster’s experience on the waterway. They currently offer remote service only to smaller vessels that are easier to control, typically less than 200 meters in length. However, if newer monitoring technologies were utilized, larger vessels might become eligible as well.

When a pre-screened ship is preparing to participate in a remote system, they complete a thorough checklist with the shore-based pilot. This provides the pilot an opportunity to verify
that all the ship’s equipment is in good working order, the language and communications are clear, and the ship is ready to proceed.

By using a thorough vetting and pre-screening system, any ship allowed into the system is known and understood. This goes a long way toward building mutual trust, cited as necessary for safe navigation. It also places a limited vetting and training role with the pilots and port authorities, a process that in itself, could go a long way toward improving navigation safety by improving the bridge teams’ competence, expanding their understanding of local requirements, and creating a shared mental model between local pilots and arriving shipmasters.

**Could remote piloting elevate bridge team engagement?**

A remote piloting system will necessarily reduce the pilot’s level of control, and this makes most pilots uneasy. Many pilots believe that but for their presence in the wheelhouse, all would be lost. Their experience tells them that the bridge teams are not up to the task of navigating their own ships in confined waters, not even with remote assistance. This assumption is not necessarily valid however, and even if it were, could it be changed? Firstly, most bridge teams have been given little opportunity to demonstrate their ability to navigate in port because as soon as a pilot boards, he/she takes over the navigational duty. The bridge teams are then relegated to a supporting role. In truth, despite the precepts of bridge resource management, piloting has typically been a “one man show” and there has been little incentive for the bridge teams to engage beyond a basic level. If given the opportunity, particularly with competent monitoring and assistance from ashore, it is clear that bridge team engagement in navigation would increase. As a result, the bridge teams’ increased level of control could very well replace the pilots’ reduced control, and the system could remain equally safe.
By elevating the bridge teams’ level of engagement through a more collaborative approach to in-port navigation, systemic navigation safety may improve. Bridge team skill and competence would likely increase, which would enable them to monitor the navigation more effectively when a pilot is aboard. This would enable better systemic error-trapping, provide a more meaningful double-check of the in-port navigation, and decrease the likelihood of an accident caused by a one-person error.

Remote piloting could also be extended to a form of remote co-piloting during the piloted portion of a port passage. To err is human and we all make mistakes. Thus any high-consequence operation should realistically incorporate a system of double-checks. No one would want to fly as a passenger in an airplane without a co-pilot. But, a maritime pilot has very little backup. Under the current system, once a pilot boards, in-port navigation effectively becomes a one-person show. There is no one to double-check critical decision-making.

While a pilot is in control of the vessel’s navigation, it is natural for the bridge team to let their guard down somewhat. Moreover, due to their limited understanding of the nuance and intricacy of the pilot’s plan, should the pilot make a critical error, it is unlikely the bridge team will detect the miscue in sufficient time to take corrective action. Because they are disengaged from the vessel navigation, the bridge teams are often not in a position to effectively monitor the pilot’s action.

The result is a high-consequence operation that relies on self-checking with no external safety net. Our present reality - that the bridge team provides an effect backstop in the event of pilot error – is oftentimes a false reality. And, despite the fact that all humans are fallible, vessels are navigated within port confines in reliance on an “immaculate maritime pilot”, i.e., one that never or rarely errs.
A remote pilot could serve as a more effective monitor of pilot intentions and actions. Having the skill and expertise to pilot ships on the route, a remote pilot would possess sufficient skill and understanding (contra a VTS operator) to provide meaningful assistance to the onboard pilot when necessary, practice collaborative decision-making, and double-check navigational progress. Such a system could be employed as a routine practice, or it could be limited to the more difficult segments of a passage, such as during periods of restricted visibility, passing through bridge spans, or maneuvering very large ships in confined turning basins. A remote co-pilot protocol would greatly reduce the likelihood of a one-person error by providing a second set of qualified “eyes” to double-check the onboard pilot’s actions and decision-making. Arguably, had a remote co-pilot system been in place the night COSCO BUSAN allided with the San Francisco-Oakland Bay Bridge, the accident might not have occurred.

**Recommendations**

Whether now is the time to shift traditional piloting toward increased reliance on remote piloting is a difficult question to answer conclusively. With so many diametrically opposed opinions, competing motivations, fears, human emotions, and general uncertainties at play, gaining consensus seems very remote. Some in the maritime industry see the promise of technology as an opportunity to do more and to be better at what they do. As the venerable Steve Jobs articulated, technology provides “the power to be your best.” Others in the maritime industry see things very differently, however. They believe that technology in piloting doesn’t offer benefits worth the pain of disrupting a system that’s working. They stand by the old adage: “if it ain’t broke, don’t fix it.” Festering beneath this outlook is the belief that remote piloting represents a personal threat to their very livelihood. Many pilots fear it will be difficult or
impossible to learn new skills at this stage in their careers. They worry they will be incapable of adapting to new systems and are even suspicious that technology will replace them outright.

While it is unlikely that technology will adversely affect pilot livelihood in such an extreme manner, it is clear that it will change their job requirements, just as technology has altered responsibilities in almost every other business sector it has enhanced. Technology is not likely to replace pilots with machines or computers – rather, integration of technology will likely enable enhanced performance that will result in a better, more efficient and safer system of piloting for all involved. Using remote piloting techniques empowered by technology, pilots can improve performance, increase marine safety and enhance port efficiency. To realize these benefits, pilots must be willing to learn how to use the latest technologies and adapt their work processes to take advantage of them. Perhaps this is the real source of consternation. The tussle is not about being displaced – that’s an extremely unlikely scenario. Rather, the resistance more likely flows from a universal truth about human nature: change is daunting, and it is hard.

It seems inevitable that some sort of technological evolution in piloting will occur in the near future. Competition among ports and the realities of business will demand performance enhancements that only technology can deliver. Port leadership is advancing our industry toward automated marine terminals, electronic cargo tracking systems, and virtual aids to navigation. Perhaps it is time for piloting to advance as well.

History provides insight into where this evolution may take us. Like remote piloting today, when radar was first introduced on ships, many masters refused to use it. They did not trust it. They did not know how to use it. And, fearing a “radar assisted collision,” they would not allow younger officers to use it. Instead, they stood on the bridge wing taking bow/beam bearings to determine the ship’s distance from shore, just like they had always done. Adoption
of radar technology was eventually enforced, and operational radar is now considered so vital to navigation safety that ships are not allowed to leave port without it. Global economics and advancements ultimately prevailed over human resistance, as it has throughout history.

Although the eventual adoption of technology in piloting is inevitable, it will likely occur only after prolonged struggle, resistance, and discomfort, all of which naturally occur with any change process, particularly one that carries the implications of remote piloting. Rather than view this transitional phase as a negative experience, perhaps we can shift our perspective to envision how struggle and resistance will ultimately benefit the adaptation process. Struggle will force careful and thoughtful consideration of the safety and training issues, which will ultimately lead to a better outcome, albeit only after a bumpy journey. And resistance will force the conversation to focus on the benefits of technology in piloting. Discomfort will simply be a part of the process.

As the discourse around remote piloting continues to percolate and expand, pilot groups will continue to take center stage in the debate. They hold the knowledge necessary to assess the impact of any proposed change in a meaningful manner. To steer the ultimate outcome toward workable solutions that improve systemic marine safety (and mitigate struggle), pilot groups should collaborate now with port authorities and other stakeholders – they should embrace this debate in an intellectually meaningful manner rather than ignore or resist technology that will inevitably be incorporated into their job functions.

Any truly effective remote pilot system will require onboard equipment installations that integrate with shore-side equipment in real time in addition to new procedures and protocols. And since the maritime industry is so global in nature, development and implementation of a robust remote piloting system will require input and involvement from port authorities, harbor
masters, Coast Guard, ship-owners, vessel traffic services, and underwriters throughout the world. It will necessarily be a collaborative process.

Developing a robust remote piloting system may seem like a daunting task now - one that many would prefer to ignore while simply maintaining status quo. But, others in the industry believe in the promise of technology and feel that the time has come to ask, “what is possible?” To argue that remote pilotage is impossible under any circumstances is not a realistic position. Equally unrealistic is the idea that pilots can shift from the wheelhouse to a shore console without significant change in systems and procedures. Reality lies somewhere between these two extremes.

The fact is, technology is here to stay and it is evolving at a blistering pace. As an industry, we need to evaluate and understand the question: How will we use this new technology to benefit our industry? Unfortunately, there are no “bright line” answers to this question, which only adds to our collective discomfort as we work to evolve the safety and efficiency of an industry reluctant to embrace change. Such is the nature of evolution.

**Summary**

This project analyzes the future use of technology in maritime piloting generally, and the benefits of using emerging navigation and communication technologies to pilot ships remotely within harbors specifically. Technology has advanced at a rapid rate in recent years and it is undeniable that we now possess the ability to control ships remotely. However, there are many barriers to implementation, the least of which are technical. Pilots have been navigating ships using traditional methodologies for hundreds of years. The success of these methodologies depends in large part on the pilot’s ability to effectively interact with differing nationalities, cultures, and languages. Physically removing the pilot from the vessel and having him/her
practice their craft remotely constitutes a structural change to an age-old system that will require careful consideration and reassessment of current practices.

When assessing the effect of new technology-based systems in the maritime domain, it is always attractive to make comparisons with aviation. The two industries seem very similar on the surface, but they differ in many ways. First, aviators operate standardized platforms in standardized environments. Commercial aircraft and airports are built to standard specifications and a pilot can move from one cockpit to another, or from one airport to another with relative ease. Also, modern aircraft carry sophisticated navigation systems that are integrated with the equipment in the air traffic control towers. This creates an informational relationship between the aircraft captain and the local experts in the tower that is absent in the maritime industry. In maritime, the local expert, a maritime pilot, has no sophisticated navigation link with the ship. Thus, the local expert must be physically present onboard the vessel to assist with its navigation. The absence of a standardized information link integrating ship and shore navigation systems will be a threshold requirement for introducing remote piloting on a systemic basis.

This paper discusses many potential benefits associated with remote piloting, but it does not make any attempt to ascertain the costs associated with system implementation or the savings that might accrue. Implementing a remote piloting system will require a concerted effort involving many stakeholders. It is not something that a piloting organization could do in isolation. Regulations will need to be changed, and new standards will need to be developed, perhaps on an international level. Moreover, to fully develop our ability to control vessels remotely, we will need to integrate shipboard and shore-based navigation and communication equipment. Such tasks are well beyond the capability of an individual pilot group.
Nor does this paper address the legal implications of a remote piloting system. Many legal issues will undoubtedly arise. Under the current system, the pilot has certain responsibilities associated with the task of directing the movement of the vessel. But, if a remote pilot is providing radio advice to a shipmaster, how would that affect their respective responsibilities under the law? Likely this, and other legal questions, can be analyzed beforehand. But it is doubtful they will be answered with any degree of certainty until after a system is in place.

The various pilot organizations will play a key role in the development of any remote system, as they are the repositories of the knowledge necessary to foster change. Although they cannot be reasonably expected to implement a system themselves, they do hold the key that will either unlock the door necessary to move this process forward, or keep the door tightly closed for years to come. Without their support and input, it will be very difficult to move any remote piloting concept forward. Ironically, maritime pilots worry that they stand to lose the most if they engage in this process. And that is a frightening prospect. It is their work practices that would be disrupted and changed. It is their acquired knowledge that could become irrelevant. It will take tremendous courage for pilots to embrace a change of this magnitude.

The objective of this paper is to start a dialogue. Only with dialogue, disagreement, and struggle will we have any chance of moving any concept forward. And that dialogue should begin within and between the various pilot groups. As a pilot myself, it has been very difficult for me to write about this controversial topic. But, I believe we owe it to our profession to begin an intellectually honest conversation and seek solutions by looking at the various obstacles in an objective manner. No one can predict with any degree of certainty where the process will take us. But, having the conversation itself will likely take us to a better place professionally, and
prepare us to address the many emerging technology issues that are hurtling toward us like a freight train.

The logical next step in our discussion would be to identify waterways where remote pilotage might be implemented. The focus could be approach waterways that are less challenging from a navigation standpoint, and ports that offer opportunities for immediate savings associated with moving the pilot boarding point farther inshore. Obvious first choices would be ports with seasonal boarding delays or expensive helicopter operations. Another step that individual pilot groups could take would be to utilize their existing carry-on equipment to augment the decision-making of the onboard pilot during difficult segments of the passage. A remote co-pilot program could elevate marine safety immediately. It would also afford an opportunity to gain foundational experience and develop internal procedures that would form the basis for future remote piloting protocols.


Dana, R. H. (1841). *Two years before the mast*. London, UK: Published by J. Cunningham, Crown Court, Fleet-Street.
Danish Maritime Authority. (2014). *Technological assessment on the possibility of shore based pilotage in Danish waters*. Denmark.


