Kennedys

HEADING FOR AUTOMATED MARITIME NAVIGATION LAW

Olivia Delagrange

Jose Pellicer

ABSTRACT: For many years merchant vessels have been undergoing an unstoppable process of automation that is drastically reducing the number of crew members. Therefore, it is easy to foresee the objective of this nautical automation: operate a vessel without a crew. An objective that will not be possible without recourse to Artificial Intelligence. Here we will analyse the impact of this technology on the *status quo* of the current Spanish legislation of Maritime Navigation Law.

OPINION: Observing the prototypes of automated vessels reveals aerodynamic designs with rounded decks that would make it impossible for crew to walk on, as well as the absence of any superstructure to accommodate the crew. Nevertheless, prior to launching these modern "ghost vessels" it will be necessary to guarantee that, as a minimum, they are as secure as conventional vessels. Until then the "superstructure" will continue to be more than a "skeuomorphic" ornament (so that a vessel continues to look like a vessel rather than a futuristic floating arc) because without a support crew on board the vessel Classical Maritime Law would be left in thin air. Our laws are not founded on an automated concept but rather on anthropocentric maritime navigation. Transferring the leadership of a vessel to an Artificial Intelligence Operating System or converting the vessel into a remote control toy gives rise to legal problems that can only be tackled from an international perspective. Although these vessels aim to be a cure for human error (the principal cause of maritime accidents) it is true that they share the fallibility of their human creators and furthermore can be the victims of cyber-attacks, a threat that without doubt will form part of the legal catalogue of "Perils of the Seas". The path towards the legalisation of automated vessels may not be the yellow brick road but there is a horizon dreamt of (and also feared) by sailors: a return to land. From a legal point of view, we would highlight that this article enters into a legal map that would have been marked with "Hic Sunt Dracones" by medieval cartographers.

SUMMARY: I. PURPOSE. II. STARTING POINT. III. IMPACT. IV. LIABILITY.

I. PURPOSE.

His name was Joshua Brown, he was 40 years old and when he died he was a watching a Harry Potter movie. In the same way as the British philosopher Alfred North Whitehead, Joshua Brown believed that *"Civilization advances by extending the number of important operations which we can perform without thinking of them."*

It was precisely that faith that on the 7th May 2016 led to his auto-piloted Tesla S model becoming encrusted like an accordion against an 18 wheeled trailer in

Williston, Florida. In another age, this pioneer would have had a plaque or even a statue but currently his death only serves to fill 10 minutes in the TV programme “1000 ways to die”.

A hero to some, an idiot to others, Joshua Brown, in the same was as Giordano Bruno or Miguel Servet died in his own way defending a heresy. A technological heresy that foresees a day when cars, planes and vessels will be auto-piloted. A heresy that, in its own way, is already a reality in maritime world.

In this article we propose to analyse the technical fact of “automated maritime navigation” and its impact on the legal *status quo*, with a particular interest on liability arising from such navigation. We would highlight that this article enters into a legal map that would have been marked with “Hic Sunt Dracones” by medieval cartographers.

II. STARTING POINT.

1. What is automated maritime navigation?

By automated maritime navigation we understand it to be navigation that is carried out, to some extent, by way of industrial control systems and artificial intelligence. The presence of industrial control systems on board is not a new phenomenon in the maritime navigation world. For decades merchant vessels have been undergoing an unstoppable process of automation that has drastically reduced the number of crew.

In accordance with the rules issues by the International Maritime Organization (IMO), the Spanish Maritime Authorities set the minimum number of crew aboard a vessel based on parameters such as its grade of automation. Therefore, it is easy to foresee the objective of the process of nautical automation: operate a vessel without a crew.

An objective that will not be possible without recourse to Artificial Intelligence (with its “machine learning” algorithms), the latest discipline of this science which according to the dictionary is known as “Automatic” and tries to replace a human operator with mechanical or electronic machines. The result of applying this science to maritime navigation has to be measured with reference to a certain evolutionary scale.

2.- Automation Scale.-

In effect, in accordance with the grade of automation, and simplified to the maximum, we can find up to three categories of maritime navigation:

(a) Manual, Crewed and Assisted. Many current vessels are navigated manually with crew members on board assisted by automatic machines;

(b) Automated by Remote Control, whether crewed or not. The next step is to achieve that a manually navigated vessel can be changed to “remote control” and vice versa in accordance with needs, which will only require a minimum crew. In addition, there are vessels that exist that are operated exclusively by remote control (in which case, the on-board crew are replaced by a land based crew or crew on board another vessel);

(c) Autonomous, whether manned or not. The extreme point *en route* to automation is known as autonomous navigation, where the vessel takes its own decisions by way of an algorithmic system of artificial intelligence (without prejudice to the fact of the presence of minimum crew for safety).

Graphically, we can consider that there are three progressive levels of automation on the following scale:

SCALE OF AUTOMATED NAVIGATION		
LEVEL 1	MANUAL AND ASSISTED	MANNED
LEVEL 2	REMOTE CONTROL	MANNED
		UNMANNED
LEVEL 3	AUTONOMOUS	MANNED
		UNMANNED

In this article we will be concerned with those vessels that present greater legal problems for the *status quo* of the current regulation, which are those of levels 2 and 3 of the Automation scale. Although, it is also necessary to evaluate that vessels will be prepared to carry out navigations in any of the three levels of automation, changing the “operating mode” based on the needs of different sections of a voyage.

3.- Distinction between Automated Vessel, Autonomous Vessel and a Unmanned Vessel.

Taking into account the scale of automation, it is appropriate to differentiate between:

(a) “Automated Vessel”, a general concept for all vessels whose functioning have been totally or partially automated (levels 1, 2 and 3); (b) “Autonomous Vessel”, a specific concept to define – as will be seen later- a vessel that has been totally automated (level 3); and (c) “Unmanned vessel” as a singular concept that covers all automated vessels without a crew on board.

Although it is frequent that the term “unmanned vessel” is used as a synonym for “autonomous vessel” we believe, however, that this leads to confusion for two reasons:

(i) A vessel can be autonomous but nevertheless crewed. Although from a technical point of view it is possible to have a totally autonomous vessel that does not need any crew, the legal regulation can (and surely must, as we will see later) continue to demand a minimum crew on board for safety, capable of taking control of the vessel at any time, overriding any functional autonomy;

(ii) There are vessels without any crew on board that are not necessarily autonomous, we are referring to vessels that navigate via remote control (level 2). In such cases, the on board crew is replaced by another one “on land” that controls the vessel remotely.

Therefore: (i) not all automated vessels are unmanned vessels; (ii) not all automated vessels are autonomous vessels; (iii) not all autonomous vessels are unmanned vessels; and (iv) not all unmanned vessels are autonomous vessels. Following the above preliminary clarifications we are going to focus on levels 2 and 3 in the automation scale, excluding assisted manual maritime navigation (level 1).

4. Automated Maritime Navigation by Remote Control

This is level 2 of the Automated Maritime Navigation Scale. This type of navigation by remote control is based on two pillars:

(a) "*Situational Awareness*"

The vessel is controlled by a "Remote Operator", whether from land or from another vessel. In order to control the vessel, the remote operator needs to know the situation of the vessel. This situation awareness is supplied by a sophisticated fusion of sensors (i.e. HD cameras, IR Thermic Cameras, conventional radars, short reach radars, LIDAR laser scanners, microphones, GPS, AIS, ECDIS etc….) that provide information about the surroundings of the vessel in real time that allows an "obstacle map" to be created. But with more sensors, more information has to be processed. An overwhelming flow of data.

(b) Constant, bidirectional, rapid (and low latency) secure connectivity. In effect, the technical challenge is not concerned with achieving that the vessel navigates by remote control (something already achieved by tele-operations or dynamic position) but rather in guaranteeing the constant, bidirectional, rapid (and low latency) secure connectivity between the collection of sensors on the vessel and the land based station of the remote control.

Without the flow of data that is supplied by the sensors it would be impossible to control the vessel remotely. This flow (which will be even greater with a greater number of sensors on board and with a greater number of automated vessels being operated) should be channelled via land based networks rather than broad-band satellite networks which are vulnerable to meteorology and cyber-attacks.

Connectivity can be the achilles heel of this sophisticated technology. In our opinion, the vulnerability and intrinsic limitation of the communication networks could be the incentive for legislators demanding at all times the presence of a minimum crew on board (which would be in addition to the crew controlling the vessel remotely).

Navigation by way of remote control could be the most recommendable mode of operation when dealing with complex situations or scenarios with elevated maritime traffic (e.g. in port waters) where autonomous navigation presents more risks with the technology available, as we will see below.

5.- Autonomous Maritime Navigation.

Here we are at level 3 of the Automated Maritime Navigation Scale. The most extreme. The navigation that we mentally visualise when we hear "autonomous vessels" or "unmanned vessels". The modern ghost ships piloted by "machine learning" algorithms. Understanding how these algorithms work, somewhat fascinating, would take us far from the objective of this article, obliging us to utilise nomenclature intimidating for any lay person in the subject matter.

When faced with this technology, anybody can identify with the primates in the film Space Odyssey 2001 when they contemplated open-mouthed the enigmatic black monolith; from there it is necessary to talk about a “black-box” effect given that nobody knows very well what kind of “magic” occurs in the interior of these ominous black boxes that supposedly are designated to pilot our vessels; for that reason we do not trust them (and surely with reason).

In any case, to understand better how an autonomous vessel functions it is necessary to refer a discipline that is being created: Machine Learning. The experts in Machine Learning (a branch of Artificial Intelligence) are rushing to construct systems that, learning from historical records (captured by sensors), predicting and executing the best decision for a given scenario, even computing the uncertainty and randomness of the same.

In this sense, the crux of any decision, whether human or artificial, hinges on being able to understand complex situations that surround us to make the best decision possible; something which requires the availability of all (not only a part) information which enables more precise predictions to be made as to how a situation will develop, also taken into account the factor of luck (stochastic analysis).

In the same way, an autonomous vessel is supported in the massive processing and the correct interpretation of the data flow provided by the fusion of sensors on the vessel, for the purpose of knowing the situational awareness, predicting and adopting the most convenient nautical decision.

For example, the vessel has to interpret the images provided by the cameras, radars and scanners as well as the sounds captured by microphones, creating 3D obstacle maps, predicting collision trajectories and executing the necessary evasive manoeuvres.

Nevertheless, manoeuvres that are routine for a human captain, such as entering and mooring in port, could prove to be a huge challenge for a virtual captain based on algorithms of artificial intelligence. In fact, with the technology currently available it is considered that the autonomous vessel would only be viable on the high seas or in areas of scarce traffic because it is not capable of adequately distinguishing between the obstacles that are present, nor predicting the risks or tracing anti-collision routes fully in complex port scenarios, characterised by the presence of many variable obstacles.

In any case, we can say that the autonomous vessel represents the last stage or final evolutionary level that an autonomous vessel can reach, which is that the *making of nautical decisions* has become totally automated, independent of humans.

Even if an autonomous vessel is totally independent of human intervention it does not mean to say that it is not susceptible to human intervention. It is perfectly conceivable that the autonomous vessel is manned so that crew members could take eventual control over the same in the event that change in operating mode is necessary (i.e. change to manual or remote control, levels one and 2 of the scale).

In addition, we should not lose sight of the fact that autonomous vessels will have a super-computer on board that will rapidly process (in real time) an enormous volume and variety of data to be able to make an appropriate nautical decision all of the time.

This super-computer could be similar to "Watson". Manufactured by IBM in 2011, "Watson" took up the space of a bedroom. Today it is the size of three pizza boxes. Nevertheless, for however small it is, the super-computer needs to be connected. Therefore, the connectivity (and its risks) reappears as a key factor in autonomous navigation (in the same way as occurs with remote control navigation).

The potential vulnerability or fragility of the connectivity, both from cyber-risks and traditional "risks of the seas", should guide *(lege ferenda)* that, at least in the early transitional stages of the move from manual to autonomous navigation, that all autonomous vessels are accompanied by a minimum crew.

Autonomous navigation has a long technical path before being able to prove that it is sufficiently safe and trustworthy to be able to have the privilege of being truly independent from the human factor (a statement that extends to any supposed autonomous vehicle).

6.- Principles of Transfer of Control, Equivalent Safety and Profitability.

From the above technical analysis an obvious corollary can be detected: automated maritime navigation looks to transfer the control of the vessel (Principle of the Transfer of Control). When discussing navigation by remote control (level 2), this transfer is to the detriment of the on-board crew in favour of the land based crew (remote operator). Whilst in relation to (level 3), the transfer is from the human to a machine.

In any of the cases, the transfer of control is conditioned for reasons of safety, with it being necessary to accredit that the automated navigation is as a minimum as secure as the manual navigation that it seeks to replace (*"Principle of Equivalent Safety").* We could also talk about a *"Principle of User Expectations"* given that the ship-owner expects that the autonomous vessels (without prejudice to the fact that there are reservations and/or warnings in the "instruction manual") are in general safer than manual vessels.

Together with security reasons it will also be necessary to ponder real costs savings that the change to automation will bring *("Profitability Principle"*). On the one hand, it is pointed out that the ship-owner will be able to reduce human errors (the principal cause of maritime accidents, and thus in theory reduce insurance premiums), reduce waste on board, save crew costs and crew space and with it increase cargo space.

Nevertheless, on the other hand, additional investment will be required for other resources (i.e. the remote operations centre, training of operators by virtual simulators, maintenance teams for the vessels' sensors, unloading and loading supervisors or experts in cyber-security and communications); without prejudice to the fact that a minimum safety crew will be required on board despite their role being redundant.

On balance it may be that, in the short/mid-term, that autonomous navigation is neither safer nor more profitable. It appears that there are reasons so that ship-owners and their insurers place a more conservative focus on this phenomenon, as is occurring with legislators. The technical-legal transition towards automated navigation will be very gradual. If the leap from on-board human control to remote human control is already delicate, let's imagine the leap towards a vessel that acts as its own guardian.

Removing on-board human control squarely impacts Classic Maritime Law, as we will see below.

III. IMPACT.

Here we will analyse the legal impact, both for remote control and autonomous navigation, that the current national ([1]) and international ([2]) rules could have in Spain. We fear that a simple change of mentality will not be sufficient and that the Official State Gazette will have to be put to work. It is also clear that without a uniform international regulation (that has to be pushed by the International Maritime Organisation) that automated navigation will sink without trace.

The principal disrupting factor for the current regulation for automated navigation is related to the principle of Control Transfer, leadership and control of the vessel. The underlying, traditional premise of the current legislation is that it is based on anthropocentric navigation whereas automation seeks to minimise or replace this human factor in navigation. Current regulation does not imagine anything other than a crewed vessel and, for safety reasons (whilst nothing to the contrary exists), there is no acceptance of control of either a remote crew or a machine (for however "intelligent" that it may be).

Under these anthropocentric conditions, vessels with remote control or autonomous vessels would see their activities in Spanish ports restricted with prohibitions or conditions related to their entry or stay (sections 7,10 LMN, 25.2 UNCLOS), their launch (section 18 LMN), their forced arrival (section 9 LMN), their right to navigate in national maritime territory (section 19 LMN) or their innocent passage through territorial seas (section 37 LMN, 17 UNCLOS), being treated in a way not very

[1] Prinicipally made up of two laws: (a) Spanish Law 14/2014 from the 24th July on Maritime Navigation (**LMN**) and (b) Spanish Royal Decree 2/2011 from the 5th September which approved the Consolidated Text of State Ports and the merchant Navy.

[2] We will review the principal International Maritime Conventions (e.g. **SOLAS, UNCLOS, MARPOL, COLREGS, ISM, ISPS, STCW, MLC, PARIS MOU, FAL, SALVAGE**).

different to nuclear propelled vessels (section 13 LMN) or those vessels that transport radioactive (section 14 LMN) or dangerous (section 15 LMN) substances.

Neither would the vessels without a crew be able to provide assistance to people in danger on the seas (section 183.2 LMN, 98.1 UNCLOS, 33 SOLAS, 10.1 SALVAGE) nor advise of the presence of stowaways or provide them with the care, accommodation or medical and legal assistance that is required (section 11 LMN, FAL)

Although the absence of a crew would not affect the current definition of a vessel (section 56 LMN), it is true that this circumstance would reduce the main attraction of the "flags of convenience" and "second registrations" which offer more lax work regulation (allowing the employment of "low cost" sailors).

The hardware and the software (the operating system) should be considered as "elements" of the vessel, unless otherwise agreed, both for effects of a sale (sections 62 y 117 LMN) as well as for a naval mortgage (section 134.1 LMN), as they are essential elements and not mere accessories.

In the sales where it is not necessary to replace crew it can be speculated that a virtual delivery will be possible with a handover of access codes to the vessel's operating system (whether remote control or autonomous), without prejudice to prior physical inspections to be made by the purchaser. Neither would it be ridiculous to include the land based remote control facilities in the purchase/mortgage, and even in the maritime privileges (section 122 LMN).

In relation to documentation it appears obvious that advances have to be made at an international level to digitalise the official certificates of a vessel, given that currently Annex 1 of SOLAS requires their physical presence on board.

There is particular interest with the "navigation patent" that in accordance with section 80 LMN identifies the Captain or the person to whom "control of the vessel" has been conferred. In the case of remote control vessels this person will be the "remote operator" (and nothing impedes this being a group of persons working shifts), or the support captain on board (if there is a crew). Whilst in the case of autonomous vessels the control of the vessel will correspond to the support captain (if crewed) and to the land based captain designated by the ship-owner (for unmanned vessels).

The navigation records, machine books will also have to be completed remotely and sent to a confidential database to be made available by the maritime authorities, which would also allow regular inspections by the Port State Control.

An essential section is that of safety and classification of the automated vessels. In application of the "Principle of Equivalent Safety" (which has its legal base in Chapter I of the SOLAS, 5.A) it is foreseeable that automated vessels will be burdened with an avalanche of regulation to guarantee to the said equivalence.

Safety requirements, as well as their official controls (by the authorities), will be particularly rigorous with respect to the automated fleet, which will give rise to the growth in the sector of the classification companies in this sector (section 106 LMN), although for the moment, in the absence of international standards for automated vessels, their classification is not possible (and consequently, neither can they be insured) which will impede the effective commercialization of the said vessels.

It is also foreseeable that there will be an increase in the frequency of automated vessel inspection which could increase the “off hire” periods.

For identical reasons of safety, the profuse regulatory norms on construction and operating requirements of vessels will need to be modified so that they adapt to automated vessels. For example, there will be a need for the norms that require (a) integral information in real time to the captain about the vessels stability (Chapter II-1, 5.1 SOLAS), (b) alarm and warning systems about the functioning of the engines (Chapter II-1, 38 SOLAS), or (c) the obligation to notify dangerous situations for navigation (such a derelicts, drifting loads, pollution, ice, storms, sections 29, 33, 186 LMN, Chapter V SOLAS), or for the vessel itself (Chapter XI SOLAS), where it will be necessary for the automated vessel’s sensors to be able to transmit integral knowledge to the remote operator in real time about situational awareness of the vessel.

In the same way it is necessary that the vessel can transfer from automatic mode to manual in the event of danger in zones of dense traffic or low visibility (Chapter V, 24.1 SOLAS), maintain constant radio communications (Chapter IV SOLAS) as well as having fire detection and fire extinguishing systems (Chapter II-II SOLAS). Highly reliable technical solutions will be necessary to be able to resolve these problems.

In the unmanned vessels the role of the crew (section 156 LMN) and of the Captain (section 171 LMN) will have to be, at least at a technical nautical level, ceded to the “remote crew” (the remote operator) that manages and monitors the vessel from a distance (and who will need to be duly qualified in accordance with new nautical qualifications in Operation Technologies and Industrial Control Systems) with it being doubtful that the same can be included in the current STWC, whilst other obligations such as seaworthiness of the vessel (section 212 LMN), loading and unloading (sections 218, 227 LMN) or the obligation to delivery cargo (section 228) will be transferred to land based port staff of the ship-owner; in this sense the automated navigation will lead to the increase and strengthening of the position, responsibility and importance of the terminal operators (section 329 LMN), of the ship agents (sections 10 and 319 LMN) and the ship managers (section 314 LMN).

It can also be speculated that a flourishing sector or remote management of vessels will be born, where one private operator, freed from the hassles of enrolling sailors, will provide services for various ship-owners, without prejudice to the liability of the latter to third parties and without prejudice to any possible internal recovery actions.

It will be the ship-owner (not the remote operator) that guarantees the sea-worthiness of the vessels for all effects and purposes (sections 192, 194, 212 and 290 LMN).

On the other hand, the technical limitations of these vessels in waters with dense traffic, such as port waters, will maybe require the implementation of a special public-private navigation aids system (section 137 LPEMM), Tow-manoeuvre and/or obligatory remote system for safety reasons (sections 126 and 127 LPEMM).

And it could be that not all ports are equally secure to receive this class of vessel, which would be reflected (and restricted) in charter parties (section 225.1 LMN).

A regulatory barrier for the introduction of the automated navigation would be the COLREGS contention which is applicable by way of 339 LMN. This convention sets out that a vessel is to be controlled in real time by a human. Whether this person is aboard or not does not appear to be an obstacle, whenever there is integral knowledge over the vessel.

Therefore, *a priori* unmanned vessels with a remote control could be acceptable under COLREGS whenever the sensors allow, at all times, that the remote operator has an identical situational awareness as an on-board captain would have. However, autonomous vessels would not fit in with the referenced convention (an author has recommended, somewhat jokingly, that the general anti-collision rule for such vessels would be “to get out of their way immediately”).

It also appears to be difficult to reconcile automated navigation with the International Convention on Salvage (SALVAGE) which is referred to in section 357 of the LMN or the obligation to provide assistance to human life in danger on the seas (section 183.3 LMN) given that the vessels without a crew will not be able to provide any effective help to salvage goods or help lives in danger.

The MARPOL treaty also provides another important regulatory barrier to vessels without a crew due to environmental risks. Unless it is proven without a doubt to the contrary (burden of proof which will fall on ship-owners), the navigation of tankers, chemical and gas transporters without crews will surely be prohibited (and it does not seem sensible that any insurer would cover them). The fact that such vessels already have a high level of automation does not prevent legislation from requiring human supervision on board at all times as a “backup” mode. In the same way, it would appear improbable that passenger vessels without a crew would be authorised.

In essence, under the current regulatory framework, automated unmanned vessels would be an easy target for the regime of sanctions included in Ports Act (sections 305 onwards). At the moment, they would be vessels that are illegal, unsafe, unseaworthy, un-insurable and unsellable.

Will that slow down technical evolution? Yes. Will it stop it? No.

Another aspect which deserves analysis is the civil liability of the ship-owner (and their insurer), which follows in the next section.

IV. CIVIL LIABILITY.

In accordance with section 149 LMN the ship-owner will be liable to third parties for the acts and omissions of the Captain and the crew of the vessel (the so called “acts of barratry”), without prejudice to their limitation right (section 392 LMN).

The fact that such acts of barratry are committed by a remote crew or are attributable to the functioning of a super-computer does not change the scheme of the ship-owner’s liability, but it does increase the number of liable parties that a ship-owner can recover from and also those against whom the affected third party can attempt to claim from via tort.

In effect, together with the ship-owner, the following parties could also be considered as liable: “remote operators”, “suppliers” and “installers” of the software/hardware (whose liability will be as elevated as that of the ship-owner, which should also give them the right to limit their liability).

The ship-owner can also be liable contractually as the carrier in accordance with the Hague Visby Rules (section 277 LMN). Rules which would never be applicable to an unmanned vessel (as they are unseaworthy as per Rule 3.a.b.).

With respect to crewed automated vessels, the liability as carrier should not only fall on the ship-owner (as contractual carrier) but also on a joint and several basis on the “remote operator” (as actual carrier), without prejudice to internal recovery rights (section 278.4 LMN) that we understand can also fall on, when applicable, to the “manufacturer”, “supplier” and/or “installer” of the hardware or software that causes damage to goods.

Under The Hague Visby regime, it is known that the carrier is exonerated if “nautical fault” can be shown (error in the navigation or management of the vessel) but not for the case of “commercial fault” (faults in the care, loading and custody of the cargo).

In our opinion, the nautical fault exemption could be applied (without reservations) to a remote controlled vessel (being invoked by the “remote operator”) but it does not appear that it can be applied to autonomous vessels (where the navigation is carried out by algorithms of artificial intelligence and when the functioning of the same is defective it is the ship-owner who will have strict liability towards third parties, without prejudice to the possibilities of recoveries against the manufacturer, programmer or installer).

It can also be asked whether the ship-owner can invoke the exoneration included in Rule 4.2.p of the Hague Visby (latent defect not discoverable by due diligence) in the event that a container contains frequency inhibitors that are capable of nullifying the IT system on board and damage the rest of the cargo (in which case it could be treated as dangerous cargo).

It does not appear possible that “cyber-risks” form part of the classical concept of “perils of the Sea” under the Hague Visby Rules, unless the same are modified (and section 417 LMN).

Another question open to debate is whether a “cyberattack” (e.g. ransomware, malware, D.o.S.) could be considered as an exception under Hague Visby, either as assimilated “force majeure”, “latent defect not discoverable to due-diligence” (for instance a “Trojan”) or as a cause attribute to a fault of the carrier, agents or representatives (given that some cyberattacks are so sophisticated that they are difficult to prevent even with a minimum diligence). It will all depend on the prior level of “cyber security” that the IMO will impose on each vessel.

The tort liability of the ship-owner for Collison (section 340 LMN) gives rise to the most complex challenge: how to incorporate the quasi-metaphysic concept of “good-seamanship” in algorithms? Is it possible that an algorithm of machine-learning can re-programme itself to contravene the rules of COLREGS whenever it is considered convenient to breach them? These algorithm decisions are not easy and neither are such decisions for human sailors.

The negligence for collision will be attributable to the ship-owner for vessels without a crew, without prejudice to recovery actions against the remote operator, the manufacturer or the installer of the hardware or software that causes the accident.

The liability for pollution would be strict for the ship-owner for the mere fact for causing it (section 386 LMN), again without prejudice to internal recovery prospects against the liable party. Nevertheless, we insist that third parties will also try to sue the remote operator, supplier/installer of the software/hardware as possible liable parties for pollution damage, therefore it would be advisable to grant them the same benefits to limit their liability that are enjoyed by the ship-owner. Such a right would also give rise to the need to guarantee insurance coverage for these new liable parties, as well for potential catastrophes of this new technology.

In effect, although the automated vessel attempts to remove the influence of “human error” in maritime accidents, there will always be a liable party for “human errors” in the manufacture of the vessel. The legal system, in the same way as human nature, does not easily accept that there is no guilty party. There needs to be a liable human.

To some extent neither force majeure nor being the victim of opaque events that cannot be understood are not accepted. It will be difficult to accept that human liability is lost in a cryptic cloud of algorithms. In this sense, autonomous vessels are a paradigm of “opacity”, stirring up a “black box” effect, given that many users will continue to be without any clear idea as to how they function and will therefore demand that somebody indemnifies them for the losses that the “black box” could provoke.

The potential catastrophe of these autonomous navigation systems, their cyber-vulnerability and their opacity will conspire at the end of the day to justify the establishment of a regime of strict liability, quantitatively limited, of the ship-owner. Therefore, only a regime of strict liability will guarantee the indemnity of the injured parties and incentivise the diligence of the ship-owner. And only a regime of limited liability will allow the potential catastrophic risk from autonomous navigation to be insured.

But that regime of limited liability, as we have mentioned, has to be extended to the new potential liable parties beyond the ship-owner, without prejudice to the fact that the latter is the primary liable party towards the third party. Excluding the concurrence of force majeure, the liable party for the damage will vary according to the type of Automatic Vessel; we can distinguish between various scenarios:

1. In Remote Control Vessels with crews the cause of an accident can have its origin in: (a) Human error of the Remote Operator (that forms part of what we can call the "remote crew" of the vessel) when operating the vessel at distance; (b) A human error of a crew member on board (which we can call the "back-up" crew) when they have effective control of the vessel; (c) A human error of the back-up crew by not retaking/assuming control on time (whether advised by the system or not); (d) Human error in the maintenance of the vessel (both in respect of the hardware and software). This error could be individual or on a joint and several basis with the ship-owner, shipyard or equipment supplier, on a case by case basis; (e) A defect or poor functioning of the system (hardware/software) of the remote control (for example: not advising the back-up crew that they should retake control; a breakdown in the tele-directional system or sensors etc.). In those cases, the liability would not fall on the remote crew or the back-up crew but rather on the manufacturer or the installer, depending on the case; (f) The action of a third party (not attributable to a remote operator, back-up crew or operating system of the vessel). Included under this point would be accidents caused by the fault of other vessels (whether automated or not) and above all cyber-attacks (foreseeable and avoidable); (g) A combination of the other causes. Cases of concurrent causes and contributory negligence will probably be the source of numerous disputes between ship-owners, operators, shipyards and manufacturers.

2. On the Remote Controlled Vessels without a Crew an accident can have its origins in: (a) human error of the remote operator; (b) human error in the maintenance of the vessel (hardware/software); (c) a defect or poor functioning of the remote control system (hardware/software); (d) actions of third parties not related to the remote operator (e.g. a hacker or fault of another vessel); (e) a combination of the other causes.

3. On Autonomous Vessels with a crew an accident can have its origins in: (a) a human error of the back-up crew when steering or assuming/retaking control on time (the operating system of autonomous navigation with a crew has to be designed to minimise risks, advising the crew as to when control has to be assumed or retaken); (b) a defect or poor functioning of the autonomous navigation system (hardware/software) (could be attributable to the manufacturer or the shipyard installer); (c) a human error with vessel maintenance (software/hardware) attributable to the party on whom the corresponding obligations falls (whether that be ship-owner, shipyard or manufacturer); (d) the action of a third party (impossible to prevent or control by the ship-owner); (e) a combination of the previous causes.

4. On Autonomous Vessels without a Crew an accident can have its origins in: (a) a human error with the maintenance of the hardware or software on board (e.g. let's suppose that a compulsory software update for autonomous navigation is not carried out) attributable to the party upon whom the corresponding obligation falls (whether ship-owner, shipyard or manufacturer); (b) a defect or poor functioning of the autonomous navigation system that could be attributable to the manufacturer, supplier or shipyard installer; (c) the action of a third party (e.g. an IT pirate that carries out a D.o.S attack which nullifies the vessel's propulsion or installs a ransomware virus on board which demands a ransom to free the vessel from its cyber kidnapping); (e) a combination of the previous causes.

The above causes can be summarised in the following table:

LIABILITY FOR DAMAGE CAUSED BY AN ACCIDENT OF AN AUTOMATED VESSEL		
LEVEL	**CAUSE**	**LIABLE PARTY**
REMOTE NAVIGATION **Manned / Unmanned**	HUMAN ERROR IN HANDLING	REMOTE CREW OR BACK-UP CREW
	HUMAN ERROR IN SOFTWARE/HARDWARE MAINTENANCE	SHIPOWNER, SHIPYARD, MANUFACTURER
	DEFECTIVE HARDWARE/SOFTWARE	MANUFACTURER, INSTALLER
	ACTION OF A THIRD PARTY	THIRD PARTY
AUTONOMOUS NAVIGATION **Manned**	HUMAN ERROR IN HANDLING	BACK-UP CREW
	HUMAN ERROR IN SOFTWARE/HARDWARE MAINTENANCE	SHIPOWNER, SHIPYARD, MANUFACTURER
	DEFECTIVE HARDWARE/SOFTWARE	MANUFACTURER, INSTALLER
	ACTION OF A THIRD PARTY	THIRD PARTY
AUTONOMOUS NAVIGATION **Unmanned**	HUMAN ERROR IN SOFTWARE/HARDWARE MAINTENANCE	SHIPOWNER, SHIPYARD, MANUFACTURER
	DEFECTIVE HARDWARE/SOFTWARE	MANUFACTURER, INSTALLER
	ACTION OF A THIRD PARTY	THIRD PARTY

Whilst the liability for a defect or poor functioning of the "hardware" (i.e. the physical machines of the vessel, its sensors etc.) does not give rise to great legal doubts, liability for defective "software" does give rise to more complexities. Software could be defective as it contains code errors (bugs), for a lack of compulsory updates or for defective design (i.e. the program does not fulfil the needs for which it was designed).

Nevertheless, when we speak about "machine learning" another problem can arise: the algorithm requires learning and requires a certain level of accumulated experience to know how to react.

Kennedys

For that reason the market will offer algorithms of different qualities where the best ones, the most expert ones, will prevail. It remains to be seen whether the authorities, as has occurred with pharmaceutical products, will permit the commercialisation of autonomous navigation systems based on algorithms that have not been sufficiently tested. In our opinion, only the *machine learning* systems that have passed a series of prior official quality controls should be authorised, otherwise the safety of maritime navigation will be put at risk.

A different question, that we will now consider, is the "ethical programming" of the algorithm where the manufacturer decides which legal right takes priority in the event of a conflict; a question which has been brought to life in the sphere of driverless vehicles (on this point the report prepared by a commission of experts – bishops included – for the German Transport ministry can be consulted www.bmvi.de).

In this sense it can be speculated, for example, about designs of a programed algorithm to comply with rules on "general average", salvage of human life on the seas, anti-collision or pollution prevention, giving priority to the legal rights in danger.

When required, is it better to have a tanker sank in the high seas instead of crashed against coastal rocks? Should the tanker collide with a gas carrier rather than a passenger cruise liner? Should it collide with a moored vessel to reduce its uncontrolled inertia rather than crash against a wharf and open like a tin can? Should it divert to provide assistance to a drifting dingy of immigrants?

At the end of the day it seems that together with naval engineers, the ship-owners of the future will need to employ "hackers", experts in robotics, lawyers and philosophers.