The sinking and abandoning of the Costa Concordia brought perplexity and shame to the Maritime community and seafarers all around the world because of the actions or omissions of the Master. Shortly after another sinister, the South Korean ferry Sewol put the competence of masters in handling emergencies in the spot light.

Besides the professional interest in the subject, it also has a personal connotation for me: in 1992 a fellow student from the Naval Academy died in the sinking of the MV Guantanamo. He was the second mate. More recently in 2011 another fellow student and friend also died when he sank with the ship under his command, the MV Helga, while en route to Honduras.

All four cases are different but they all share a common reason for the loss of life: a wrong assessment of the situation and or a hesitation in giving the order to abandon the ship.

A brief summary of the four cases:

On 10/03/1995, the MV Guantanamo loaded with a shipment of scrap or mill scale bound for Santander, while passing some 500 miles south of Azores with heavy seas during the night, experienced a shifting of cargo and a substantial list. Eventually the ship sank with the crew at the embarking deck awaiting the order for abandoning the ship. A sole survivor, the electrician, at some point decided not to wait any longer and put a life raft afloat. According to his declarations - subsequent to the accident and his rescue after more than 20 days at sea - the ship was listing over 30 degrees. Fatalities: out of 26 crewmembers, 25 died.

On 19/03/2011, the MV Helga sailed Mexico with a shipment of salt bound for Honduras and shortly after the departure, it was apparent she had hit the bottom and there was ingress of water. The Master assessed that the ship could reach Honduras as the water ingress seemed to be contained to the double bottom tank and continued the passage. Just when passing Belize, the ship lost buoyancy and sank only three miles away from an island. The crew was effectively evacuated, but the Master, Chief Engineer and a helmsman didn’t make it out. The last time he was sighted he was carrying the passports and ready to abandon last. Fatalities: out of 11 crewmembers, 3 died.

On 13/01/2012, the Passenger ship Costa Concordia while doing a coastal passage in the Tyrrhenian Sea deviated from its route to get a closer sight, resulting in the hull hitting the rocks at night in calm seas on her port side. The ship turned and headed or drifted toward shallower waters and ran aground, developing a massive list and sinking the accommodation on starboard side. The master abandoned the ship without leading the passenger’s evacuation, many of whom perished in the lower deck waiting for the master and crew's orders. Fatalities: out of 3229 passengers and 1023 crewmembers, 32 died.

On 16/04/2014, the Ferry Sewol sailed mainland South Korea, Incheon bound for Jeju with a number of passengers, many of them students and cargo consisting of containers and probably cars too. The ship had been subject to modifications altering its stability performance.According to the news, the ship was overloaded and the cargo poorly lashed. In order to take the extra cargo, the ship carried only some 580 out of the 2030 tons of ballast recommended. After a sharp turn in the morning with calm seas apparently, the cargo shifted and the ship developed a large list and started taking water in. The master asked the passengers to remain in their cabins reportedly to avoid contact with the frigid waters which was about 12 degrees. While he was abandoning the ship, hundreds of teenagers were trapped in the lower decks unable to evacuate due to the excessive inclination. Fatalities: out of 476 passengers and crewmembers, 300 died.

The four cases put into evidence a wrong assessment of the situation in terms of likelihood of sinking and time available for abandoning, and a delayed decision making.

Before discussing when it is the right time to abandon the ship , in other words when it is too early and when it is too late and how can the Master assess the right timing and actions, there are two facts to consider: Not all ships founder the same and not always the same ship founder the same way. Moreover, depending on the type of ship he commands, he is expected to have an idea on how his own ship will founder in each condition.

I use the word founder and not sink as in a generic sense: the loss of the ship either by sinking or capsizing, but for more technical and comprehensive purposes I will divide the possible loss into two: loss of buoyancy and loss of stability:

LOSS OF BUOYANCY

I will refer to the loss of buoyancy beyond the maximum applicable load line, compromising the floatability of the ship.

For this event to happen there has to be ingress of water, be from excessive embankment of water through main deck faulty hatch covers or faulty shell doors; be from structural damage or failure. The excess of water in one or several compartments will increase the ship's displacement and will reduce the freeboard expected for the season / navigation zone. The water is taking the ship's reserve of buoyancy.

At that stage if one of the compartments is totally flooded, the ship might be expected to survive afloat. Damaged stability criteria call for ships to stand the flooding of any single compartment, including the foremost cargo hold.

When passenger ships are designed, the subdivision is calculated by determining the floodable length: A line is drawn 75 centimeters below the bulkhead deck line (the deck up to which watertight internal subdividing bulkheads are raised). This is a margin line. The idea is that the length of each compartment is such that if flooded, the ship would not submerge beyond this line.

SOLAS in Chapter II-I, Part B1, establishes a different method for calculating subdivision on other types of ships: The attained subdivision index A has to be greater than the required subdivision index R. The index A is calculated considering the probability of flooding the compartment and the probability of survival after the flooding. Each one of these two variables, in turn, is calculated considering location of the flooded compartments, distances, stability parameters, etc.

Regardless of the method used in calculating the subdivision at the design process, from the point of view of the Masters when the ingress of water sets in, first to assess is where: forward, center or aft. If the lost buoyancy is forward, it will result in a change of trim. If as result of this - even when the water is restricted to a certain volume - the water line exceeds the bulkhead deck, the water pressure in the damaged compartment could force off hatches extending the flooding to adjacent compartments and leading to the eventual loss of the ship. Accordingly flooding of foremost compartments should be regarded as more critical and dangerous than centered compartments.

The amount of water admitted to a compartment not only depends on the volume but also on the permeability; this is the ratio between the volume that is floodable and the total volume (from 0 to 1). Knowing the content of the compartment flooded (cargo, liquid, stores, and accommodation stuff) will give an idea of the possible extent of water ingress.

When flooding is not symmetrical, because of the existence of a longitudinal bulkhead that has not been compromised, cross flooding is recommended (flooding an opposite compartment symmetrical to it). While this method is recommended for flooding to avoid large angles of heel sacrificing buoyancy for the sake of stability, it is not recommended when cargo shifting occurs which could shift back to the opposite side with the added heeling moment of the flooded compartment.

When the loss of buoyancy occurs without loss of balance or stability; be because there is no asymmetrical flooding, because GM did not change significantly and or because the compartment flooded completely and the free surface is not having an impact; the ship might rest afloat for a considerable amount of time before sinking. This would be true if in addition to keeping an adequate transversal stability condition, the loss of longitudinal balance (excessive trim) is not a factor.

In this case, it is true the adage long taught to seaman that the ship is the best life boat and to remain on it for as long as possible. However, caution should be paid to two aspects: first, given the amount of subdivisions and design, how long would a specific vessel remain afloat and second, when possible structural failure is the cause of ingress of water, how reliable is the ship or how fast can the failure propagate.

- **Floatability of certain types of vessels: Ro – Ro ships as special type.**

Not all ships are built the same, and when it comes to subdivisions, different criteria can apply.

As above mentioned, the subdivision for passenger ships is such that in case of flooding a single compartment, the ship would not reach the bulkhead deck.

The method as per SOLAS Chapter II-I, Part B1 is a “probabilistic” one. The merit of the method is that it uses statistics related to collisions collected by IMO, so it has a more realistic approach. Some specialists nonetheless have reservations toward this method, rather complex and still calculate the floodable length when determining the subdivision on a specific design.

In a cargo ship the bulkhead deck would be the main deck, but in a Ro-Ro ship above the bulkhead deck there is the cargo space or garage for cars, without same subdivision as below it. The freeboard, which runs to the bulkhead deck, is rather low and close to the water line. The vast amount of enclosed space without subdivisions poses the following challenges:

<u>Design</u>: Vast void spaces undivided at ro-ro deck level, with improved but limited drainage capacities. The cargo access doors and the low freeboard could cause eventual ingress of water if the water tightness of the doors system is compromised by collision with other objects or impact from loose cargo.

Safety: Fire is a particular peril considering the lack of subdivision at the ro-ro deck level, the cargoes (cars, trucks, machinery) having fuel in the tanks. If propagated, the fire could disable many of the safety features like monitoring systems, flooding alarms, even door integrities that are critical to these ships.

In terms of floatability, the biggest challenge for ro-ro ships is the volume of the cargo space – Ro-Ro deck – and the access to it. If the access doors to the cargo space were to be opened or damaged, a massive amount of water could invade these spaces, compromising the seaworthiness in terms of reduction of buoyancy, and loss of stability. The loss of stability will be seen further ahead with loss of balance, and the implications of large inclinations and free surface, but the loss of buoyancy alone would pose a threat to the ship.

The maritime community and IMO recognized very early the problems involved with safety on board ro-ro ships. Accidents like *Herald of Free Enterprise, European Gateway* and *Estonia*, with massive loss of life prompted a number of investigations, research and SOLAS amendments that improved safety on Ro-Ro ships. The paper **IMO and Ro-Ro Safety**, dated January 1997 is very explicit and detailed.

Some of those amendments were: a second line of defense or an inner door, increasing drainage, better lashing and securing, audible alarms for doors, etc. The fact is that despite a number of safety measures put into place by IMO, Ro-Ro ships in order to operate and fulfill their task are to be designed in a way that make them more vulnerable to massive ingress of water and a rapid loss of buoyancy than others when the integrity of the hull is breached. The *Estonia* sank in just few minutes and more than 900 lives were lost.

While the amendments from IMO to ferries and Ro-Ro ships internationally operated brought a tremendous improvement in Safety, same didn't happen for domestic operated ferries and Ro-Ro ships like the Sewol, governed by national regulations. The amount of accidents involving domestic ferries in the Far East continues to be excessive.

When the floatability of the ship has been compromised, a quick thought should be given to the location and extent of the damage causing the ingress of water and the ship design and subdivision to give an idea of how reliable it is to stay on board and how much time we can count on to deploy the life saving appliances.

- **Structural damage and failure. Crack propagation**

Limited ingress of water can result from structural damage when encountering severe weather. If the cargo hatches were not battened down and secured properly or the acting cleats not regulated, the water tightness would be affected to a varying degree, with the eventual ingress of water. Even if a whole panel is misplaced and massive amounts of water gain access to the hold, the water would still be confined to a certain space between watertight subdivisions (the transversal bulkhead) and the ship would be able to survive such damaged condition.

However, another cause of structural damage leading to ingress of water- and more severe – would be cracks on the hull resulting from impact (collision, grounding).

The science of Fracture Mechanics studies the causes, origin and propagation of cracks, fatigue, and fatigue life. For the sake of brevity, I will only point out few facts.

Commercial steels used in the naval industry posses a number of qualities such as ductibility, toughness, etc to stand loads for a large number of cycles. At the same time, defects are inherent to such materials and further defects arise in the process of ship's building.

Two main factors affect the fatigue life: stress and cycles. In order to reduce stress and possible fracture for each structure at the design process improved geometry is selected to keep the stress concentration factor to a minimum (in as much as practical considering the large stress concentration details), load paths are calculated, crack arrestors included, safety factors taken into consideration and materials of proper strength selected.

Fatigue life is calculated to exceed the useful life of the structure. At the design process it is possible to predict the stress field certain structure will be exposed to, based on certain wave height distribution or wave spectrum, and to roughly calculate the number of cycles to failure, the annual damage and the fatigue life.

Those calculations not only form part of the design but may also be part of the operating specifications for ships built under class rules. In the documentation made available to those operating the ships, the Master and officers, specification will be given about the longitudinal stress limits in still and sea going condition (bending moments and shear forces). The Master and the officers will then calculate the weight distribution not to exceed such limits.

It also stands for the unlikely event of flooding. Calculations are made to assess the amount of stresses after the flooding of one single compartment. When loading the vessel, the master has to check the damaged stability condition to avoid overloading of any compartment in case of flooding. To do this the computer uses predetermined values of permeability.

All the above is to say that even in extreme weather conditions and flooding of any single compartment, the ship is designed to maintain its structural integrity.

Despite the above, cracks may appear. According to research on the origin and propagation of cracks, by the time a crack is visible, the structure has already used most of its fatigue life. Structural designs are also oriented to stop or slow in as much as possible the propagation of small cracks through geometries serving as crack arrestors. The use of crack arrest holes in connections (stiffener to transverse frames, frames to brackets, etc) and crack arrest strakes are an example.

But massive structural deformations and changes in geometries would affect the stress concentration and accelerate the crack propagation. Moreover, such crack arrestors are ineffective in preventing the propagation of fatigue or fast running cracks.

There are mathematical tools for calculating the crack growth and stability. The Paris Law equation, Fracture Assessment Diagrams, and other tools are used by those in the field of Fracture Mechanics to calculate the critical and maximum length of the crack after a number of cycles, and time to reach that length. On board a ship it is not feasible to do such calculations.

Therefore, when a ship sustains a structural damage resulting in cracks it is not possible to ascertain whether the crack has already reached the critical length and the possibilities of crack propagation and failure.

Because most cases where structural damage and large cracks are involved such as grounding or collisions involve damages to the hull plating with ingress of water resulting in substantial stress, in such cases considerations should be given to the possibility of crack propagation and massive failure or even the split of the ship, and not only to the rate and quantity of water entering.

LOSS OF BALANCE AND STABILITY

The loss of stability, with loss of buoyancy or parallel sinking also involved or not, deserves a different analysis.

The physics of the loss of balance and stability is well known to the Master and deck officers. Inclinations due to rolling after events such as waves or wind gusts make contact with the vessel, start with a shifting of the center of buoyancy, which by not being in the same vertical of the center of gravity creates a moment – uprighting moment with GZ as the arm. This moment which is opposite to the upsetting moment will bring both centers back to the same vertical.

Inclinations due to shifting of weight are different. They start with the shifting of the center of gravity causing the ship to incline; the inclination causes a change in the submerged volume and shifting of the center of buoyancy, and the inclination to stop when the center of buoyancy is in the same vertical as the center of gravity. The ship will remain in this position.

While the first is a temporary phenomenon, the second is permanent as long as the weight doesn't continue to shift or doesn't increase.

In both cases the angle of inclination resulting will depend on parameters such as Displacement and Metacentric height GM and by extension, the vertical position of the center of gravity of the vessel. In the first case, the more displacement and GM - at lower angles of inclination – the more upthrust force and uprigting arm GZ, therefore more uprighting moment. In the second case, the more Displacement, the less transversal shifting of the center of gravity of the vessel resulting from the same weight being shifted (GG1 = (m x d)/ Disp), and the less KG and more GM , the less the angle of inclination for the same shifting of the center of gravity GG1.

Several scenarios can be presented:

1. Large inclination due to ingress of water, resulting in loss of stability: In this case, water has gained access to one or various compartments. If the ship had a previous list, the list will increase as the center of gravity of the mass of water off centered will create an extra heeling moment. The massive free surface in the cargo hold will have the same effect of a vertical shifting of the center of gravity, resulting less GZ and therefore less uprighting moment. If the inclination reaches the flooding angle the ship will be lost either by sinking or capsizing.

   Mariners might have had experienced this when ballasting a cargo hold: If the weights on board are not well balanced, when the amount of water in the ballast hold increases a list will start to develop and increase. The ballast operations have to stop immediately because this has an exponential effect: the more water, the more free surface moment, less stability, more inclination, more transversal shifting of the center of gravity and more inclination.

2. Large inclination due to shifting of weight (cargo): In this case, typical transversal shifting of the center of gravity has the problem that after the shifting of the weight the ship might not rest on that angle. At such angle further shifting might occur, either from faulty lashing of break bulk (cargo units) as a result of transversal accelerations or in the case of bulk cargo as a result of exceeding the angle of repose when it is non-cohesive. If no ingress of water is involved, the degree of inclination will depend on the amount of cargo units breaking loose, or in the case of non-cohesive cargo, it will depend on the dynamic angle of repose.

3. A combination of the two above: Ingress of water causing inclinations and shifting of cargo or a shifting of cargo causes inclination and ingress of water, both cases with the aggravating factor of two combined undesired effects: The heeling moments caused by the shifted cargo and the wedge of water, plus the free surface.

In the case of a Ro-Ro ship, this effect has even worse consequences, as the lack of subdivision in the cargo spaces could trigger a global breaking of the cargo unit lashings and shifting, plus the size of the cargo space causing a massive free surface.

The effect of the free surface in the loss of stability can never be underestimated, as the inertia of a compartment depends on its size. On a typical Laker, the moment of inertia of a center hold can go up to over 30000 M4, at about 50% it would be some 18000 M4 which if not at full displacement, say about 30,000 MT could increase the KG and reduce GM by 0.6 meters, double of the min 0.3 required by SOLAS and the International Code on Intact Stability.

There are two issues related to the transversal inclinations and loss of stability: Possible cargo shifting and possible ingress of water. If the domino effect of cargo shifting and breaking loose happens and ingress of water is involved, it can have an exponential effect as explained above. One extreme but possible scenario:

4. The cargo starts breaking loose and shifting, causing a moderate angle of inclination and rupture of the ship's hull or faulty hatch covers. Water starts gaining access in the cargo hold, increasing the weight and as there was already an inclination, the water will form a wedged adding its own heeling moment. In addition to that, free surface starts taking place. This results in more inclination. More inclination results in greater transversal accelerations causing more cargo to break loose, to shift, to cause the ship to incline even more, more water coming in, and the process repeating until the ship sinks of capsizes.

Accordingly when assessing the effects of the list, it has to be taking into account also the possibility of that inclination aggravating.

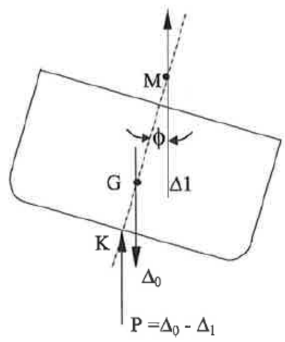
I don't know of any literature or article where it is written the max angle of heel or list which if exceeded the ship is beyond self uprighting or the angle which if exceeded the ship has to be salvaged but this angle would be reached even before the angle of flooding. A hint could be found in the SOLAS and the International Grain Code: after the shifting of the grain, the angle of heel should never exceed 12 degrees. That gives an idea that any angle of heel or list exceeding 10 to 15 degrees should be deemed as rendering the ship unseaworthy.

- **Loss of stability during grounding**

Mentioned above is the role of the Metacentric height GM and righting moment in the way ships respond to inclinations. A reduction in GM and the uprighting arm GZ will result in a loss of stability or poorer response to inclinations.

The grounding (intentional or unintentional) will affect both the Metacentric height and the righting moment. When the ship rests partially or totally on the bottom, there will be a loss of buoyancy. While the force of gravity acting on the center of gravity equals the initial displacement, the buoyancy uptrust acting on the center of buoyancy and through the transverse Metacentre M will be equivalent to the displacement at the new draft.

These two opposite forces will create a couple, forcing the ship to right up. But now the couple is not the same as the uprighting moment is not as large as the heeling moment. On the other hand, at the resting point, a new uprighting force equal to the difference between the initial and new displacement P= Δ0 - Δ1 will act but opposite to the uprighting force as it will act in the opposite side of the righting moment and gravity force couple (P on keel centre K, Δ0 on centre of gravity G and Δ1 on Metacentre M), reducing even more the righting moment



Accordingly the grounding will result in loss of stability and unless the ship has all the weights perfectly balanced and the bottom is perfectly and horizontally flat, will result in inclinations. This is very well known to Masters and officers: before going to dry-dock, the ship's staff will seek to have a positive and substantial GM and no residual list.

All the above to say that the assessment of the urgency of the situations and the best course of action is complex: The Master of the passenger ship could have better decided to let the ship sink slowly in the open sea, in calm waters, given the subdivisions on his ship, instead approaching the already shallow waters running aground, losing stability and inclining. The Master of the Ro-Ro ship should have proceeded with the evacuation of the personnel without delay, given also the kind of subdivision on his ship and the history of previous accidents on Ro-Ro ships. The Master of the cargo vessel that listed while crossing the Atlantic should have known that after certain angle of list there was nothing to do but to take the crew to safety. The Master of the cargo vessel that hit the bottom should have stopped and seek refuge to assess the extent of the damages before continuing the passage.

ABANDONMENT

The above paragraph is not a judgment; there is no question that the urgency of the moment and the responsibility should be overwhelming. As I write these lines, I try to imagine what these Masters had in mind at least in the first moments: I can save the ship and avoid the abandonment. I can relate to that feeling or hope. But looking at the events in retrospective, the outcome proved them wrong and we have to learn from that.

The online news magazine *Shiptalk* published interesting articles in the wake of the Sewol's accident (*Newsletter, May 2014*). An expert in the Marine Industry Michael Grey in his newsletter *Great Expectations* asked few tough and real questions about how to prepare for the unthinkable. At the end of his article, he wrote referring to the Sewol: Just as happened on the Concordia, it seems there is "wishful thinking" lag – a delay in which the Master hopes against all hope that the situation can be saved.

I fully agree with Mr. Grey. There has to be a reason for all the above cases and many others to hesitate in giving the ultimate order at sea, resulting in lives lost. He gave one answer, hope.

Why the hope? Because anyone who ever had to launch a lifeboat in moderate seas or embark on them knows how difficult and risky this could be, let alone doing it at night in stormy seas. But most importantly because as Seamen we are educated to protect the ship and the crew, and believing the ship will be saved, means the crew on it can be saved too.

This "wishful thinking" lags at subconscious level might lay on the reluctance to accept the unavoidable, which in psychological terms is called denial or abnegation, it can be simple denial or minimization, and it was postulated by Sigmund Freud as a psychological defense mechanism.

At a conscious level, might also lay on a poor assessment of the situation and the notion that announcing and preparing for the abandonment is the very last resource, the point of non-return.

This whole article so far is an attempt to remind us as Masters of a more careful assessment of the situation, of the many aspects to consider. Next paragraphs deal with the process of abandonment itself.

With all the above in mind, the question arises: when is it right to abandon the ship; when is it too early or too late? If attempting the abandonment one second too late could have consequences to the safety of the lives of the crew and passengers, it could be infer that it always has to be too early.

The process of abandonment when time and circumstances so permit (which was the case in the accidents discussed) should not be seen as a single step process, but a series of steps, some of which can be taken before the actual abandonment.

I personally think that as long as we keep thinking of abandonment as the last resource when it is still unclear, the extent of the damages and the gravity of the situation, human losses will continue to happen. We will continue to wait for clearer signals that the ship cannot be saved and we have to abandon.

The paradox is that when the signals are clear, it might be very difficult if not impossible to abandon. What are those signals after all? A massive list which render the boats on the davits useless; or the ship capsizing; or the ship splitting in two.

The **first step** when the danger and the urgency of the situation are imminent is to bring the personnel to the embarking decks and to make the life saving appliances ready to receive them. I might sound like I am pointing out the obvious, but it wasn't obvious to the Masters of the Concordia and the Sewol.

We can see that while the process of sinking can take even several hours, in many cases the situation can turn dramatically in a matter of seconds: the onset of larger, exponential inclinations until capsizing or sudden split of the vessel.

In any case, there is no question in my mind about one thing: the place not to be would be in an enclosed space in the lower decks. In case of capsizing or flooding, interiors could trap them with the water rushing in, without chances of escaping.
In both cases, the Costa Concordia and the Sewol, keeping the passengers in the lower decks condemned them to a premature death and deprived them from the right to fight for their lives and survive.

The life saving appliances should be made ready because once large inclinations set on, they are difficult if not impossible to deploy. An inclined surface is not the place to unlash and maneuver a life boat, plus the tension on the cables from the inclination would make it extremely difficult.

This might not be the case for freefall boats, but passenger ships still relay on davits and few commercial ships still do too. There is a max list for launching, but in practical terms I believe at lists of 15 degrees or above while physically possible it is very difficult to perform that task.

As a **second step**, if the situation continues to deteriorate - the list developing, the ingress of water increasing or the buoyancy reducing despite efforts to revert the situation - and there are still doubts of the outcome, the non-essential crew should be evacuated using the life saving appliances already deployed or made ready to deploy. This, in addition to buying time, will allow the crew to rescue the staff still on the ship should the situation turn to the worst or vice versa.

This could sound controversial: deploying life saving devises in perhaps rough seas when it is uncertain the ship has to be abandoned. But as stated above, the alternative is having people lose their lives because they didn't have enough time to abandon. During this operation, there could be heavy damages to the boats, or life rafts, if the situation can be turned around, the recovery can be difficult or impossible (for the boats or rafts, not the personnel). But again it is a better alternative than waiting until it is too late. The electrician of the MV Guantanamo who deployed and embarked a life raft on his own in the middle of a storm while his comrades awaited the orders, lived to prove it.

Finally the **third step**, as the situation develops will be clear whether the situation can be corrected with own means and the non-essential crew and life saving appliances retrieved or the final abandonment for the reminder of the crew on board has to take place.

I see the abandoning of the ship as a phased process, rather than stay or leave kind of decision. It is not possible to establish guidelines, the assessment of the situation and sound judgment is essential, but I strongly believe that as long as we turn to the lifeboats only when the water is up our knees, lives will continue to be lost.

As human beings we are bound to err. But a debate on this and other issues where human errors result in loss of live and property will bring collective intelligence and experience together to minimize them. This is my small contribution to this debate and I hope others will join too.

For the writing of this article I had extended conversations with seasoned ship Masters, Naval Architects and specialists. References were taken from the book *Maritime Engineering Reference Book, Prof Molland A.F., University of Southampton, UK* and *Floating structures: a guide for design and analysis, Prof Barltrop N.Ed., University of Strathclyde, UK*, as well as notes from courses in Naval Architecture (A1) and Material and Structural Response to the Marine Environment (B4), MTEC, Universities of Southampton and Strathclyde.

This article is a tribute to Capt. Arturo Edreira Cuza, who perished at sea while trying to save his crew and being the last to abandon.

Capt Francisco Juarrero