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Deliverable D9 – Safecrafts Project Executive Report

DELIVERABLE WP9

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The report, by TNO, titled "*Safecrafts Project*, *Executive Report*", presents an outline of the Safecrafts project and its results.

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Contents

1. Preamble

Safecrafts is an EU sponsored research and development project, concerned with evacuation systems on passenger ships. A presentation of the project results was held at the 52nd session of DE working group of IMO. This report is a transcription of this presentation. The project was executed by a group of 18 partners, consisting of academia, research institutions, ship owners, shipyards and classification societies (Figure 1).

Figure 1 Safecrafts consortium members

The two main reasons to reconsider ship evacuation systems are:

1. Costs associated with ship evacuation systems,
2. The increasing size of cruiser passenger ships.

Costs of Life Saving Equipment are frustrating, because it is always a pity to spend money on something you hope never to use.

Ships increase in size over the years. Over the last century the length of passenger ships has increased by about 100 metres. The number of passengers has increased from 3000 to 5600 (Table 1). Together with the crew, ships may have a complement of up to 8000 people. Although the ships obviously become bigger their length does not increase to same ratio as the number of complement.

Table 1 Ship sizes over time

	L	B	T	# complement
Freedom of the Seas	338.80	38.60	8.50	5670.00
Vision Class	268.33	32.21	7.55	3577.00
RMS Mauretania	240.80	26.80		2967.00

As a consequence there is a lack of ship length to stow enough conventional life boats. The picture (Figure 2) shows the size of passenger ships compared to other 'objects'.

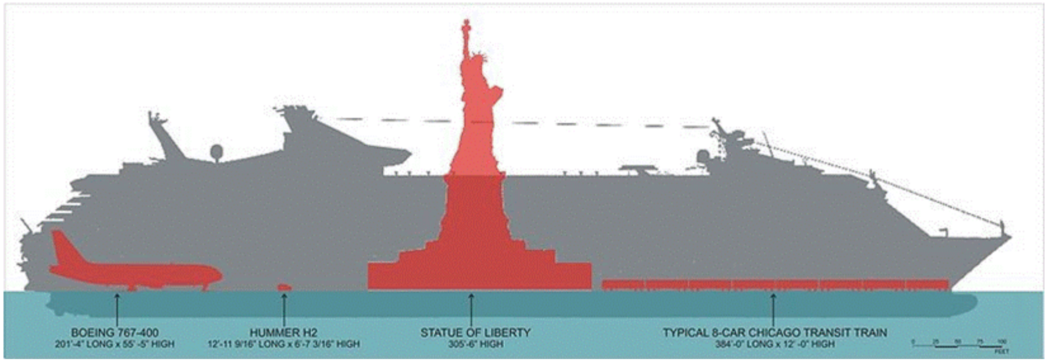

Figure 2 Ship size, relative to other 'objects'

This means we need alternatives. A good start is reviewing what we currently do in the area of ship evacuation. Although from a scientific point a view it is unfortunate, fortunately accident statistics are very scarce for the simple reason that there are not enough accidents happening. Therefore we need to use a slightly more scientific approach and cannot rely on empiricism only.

Apart from a need to address this subject, there is also good news:

Regulators (Flag states and IMO) are quite open to innovative alternatives in this area. It is even acceptable not to comply with the rules in a prescriptive fashion, provided it can be demonstrated that the safety levels, intended to be safeguarded by the rules, are still attained.

Concepts such as 'equivalent safety' are quite acceptable (as can be read in chapter 1 Part A regulation 5 of SOLAS)

Even some guidance already exists on how to deal with alternatives, and how to demonstrate the appropriateness of these alternatives (SOLAS Chapter 3, Part C regulation 38, and guidelines as given in MSC.1/Circ.1212).

Other concepts such as Goal Based Standards and Formal Safety Assessment are now encouraged within IMO.

Designers and scientists are encouraged to identify novel concepts, and provide technical evidence demonstrating their safety level equivalence.

Following the above considerations the Safecrafts project was initiated with two objectives:

1. Develop an assessment method for evaluating the performance of Life Saving Appliances, which can cope with systems of very different concept,
2. Generate two viable novel concepts.

Because of the requirement that systems bases on very different concepts should be assessed and compared with each other, the only viable approach was to take the humans to be evacuated as a basis for the assessment method. Figure 3 shows the subjects of study throughout the project, which implies a radical change with the past.

Figure 3 Cruise passengers in a muster drill.

Chapter 2 describes the assessment method, developed for ship evacuation systems. Chapter 3 explains about hardware mechanics and human mechanics, while chapter 4 shows how tests data was obtained for validation purposes. Two novel concepts are described in chapter 5. Conclusions are given in chapter 6.

2. Assessment method

One of the main challenges -and objective of this project- is to find a way to asses ship evacuation systems. This way is paved by identifying a parameter which quantifies the performance of ship evacuation systems. In order to be able to compare systems the parameter should be system non specific. This can be achieved by understanding that the only factor the systems have in common is the human factor. Whatever an evacuation system looks like, it always has to deal with humans which have to be evacuated (evacuees). So in the end the only thing that matters is the well being of these humans. Well being can be quantified with a parameter which we have called the Human Health Status (HHS). This parameter is a four element vector specifying the human health. Each element gives the fraction of humans in each particular health status, the sum of the fractions in each of the 4 elements is always 1.0. Table 2 describes the elements of the HHS vector.

Table 2 Human Health Status, HSS

HSS	Symbol	Category	Description	Related Mobility
Good Health	**α**	GH	Good physical and mental health	Good mobility
Moderate Injury	**β**	MI	Superficial scratches and moderate bleeding	Degraded mobility
Severe Injury	**χ**	SI	Fractures and/ or traumas	Mobility only with assistance
Deceased	**δ**	D	Fatal injury	No mobility

The health status elements are: Good Health, which means that people in this element are able to help themselves and assist others, Moderate Injury, implying that that people can still help themselves, but are not able anymore to assist others, Severe Injury which means people need help from others, and finally Deceased where one does not require help anymore, but still there is the requirement to be taken ashore for final honours.

The fraction of humans in a particular status changes during the evacuation. An evacuation is considered as a number of obstacles which need to be negotiated by the evacuees. A sub-script can used to each HHS element which then denotes the number of obstacles negotiated. While passing an obstacle a part of the evacuees may get injured which 'degrades' them into a lower health status (Figure 4). The method is further described in [7].

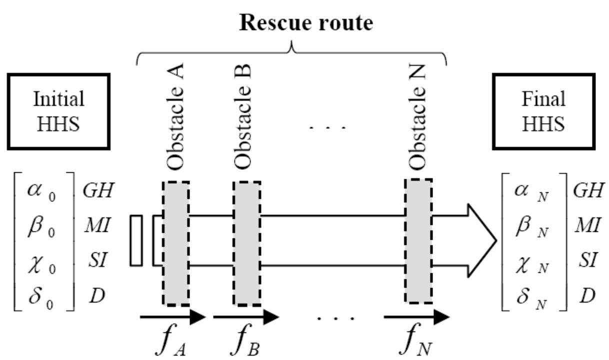

Figure 4 Mathematical representation of evacuation

Typical obstacles in case of a lifeboat are:

- boarding the life boat; where people may sprain ankles or fall into a boat and injure themselves,
- launching the life boat while fully loaded with people, where people may get injured due to accelerations when the boat hits the side of the mother ship (Figure 5),
- clearing from the mother ship, which may fail due to engine failure,
- survival at sea, where people may get dehydrated due to sea sickness induced vomiting and as a consequence lose strength to remain mobile, in some severe sea states people may not be able to remain seated en fall on top of each other (being tossed around), causing injury,
- coming alongside the rescue ship which mail fail due to engine failure,
- keeping position along side the rescue ship which may cause severe accelerations due to waves and impact against the hull of the rescue ship.

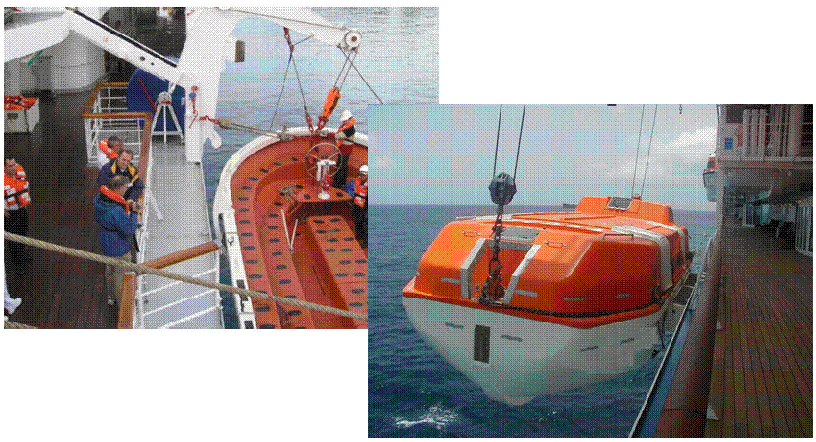

Figure 5 Typical obstacles, boarding and launching

For inflatable rafts obstacles can be identified of a similar nature.

The final obstacle is recovery of people, which in many cases needs to be done by using a pilot ladder (Figure 6), where people may not have the physical strength to climb.

Figure 6 Typical obstacle, climbing a rope ladder towards rescue

The assessment of life saving appliances is largely influenced by the choice of the evacuation scenarios. In the safecrafts project we defined 5 typical scenarios, each with an equal probability of occurrence as shown in Table 3. List and trim values are taken from IMO's LSA code. Trim seems to be extremely high, at ten degrees trim by the stern the poop deck would be well below the water line. It can be argued that evacuation in icy waters should also be considered as a scenario because of the increase of cruises in arctic waters.

Table 3 Scenarios considered

			Abandoned ship		
Scenario	Sea state	Period at sea	Heading angle	List (°)	Trim (°)
Sc 1	0-1		../.	0	0
Sc 2	3		Beam	0	0
Sc 3	5	24 h	Head	10	5
Sc 4	5		Beam	20	10
Sc 5	6		Beam	20	10

The other parameter which is of great influence on the assessment method, is the probability of failure of the various subsystems such as davit mechanism, falls, brakes mechanism, etc..

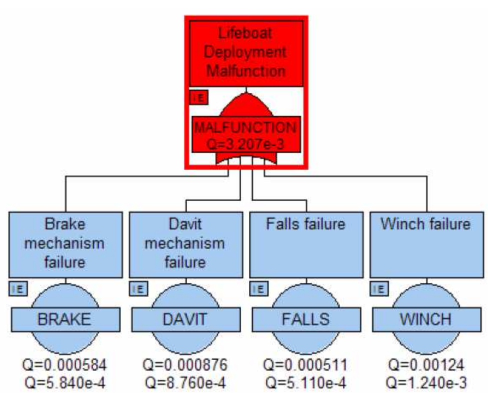

Figure 7 Typical probability calculation

Usually such probabilities are established through a failure mode and effect analysis 'FMEA', illustrated by Figure 7. Fortunately there are insufficient accidents to produce any meaningful statistics, therefore the FMEA based on systematic test results, is the only way to establish probabilities.

3. Human and hardware mechanics

The vulnerability of humans -from a mechanical point of view- is an area where knowledge is reasonably well developed. The formula below (Figure 8) can even be found in section 6.17 of the LSA code [1], which can be used to assesses bodily impact motions, *dx*, *dy* and *dz*, are motions imposed on the human body while *sx*, *sy*, and *sz* are acceptable values from an human vulnerability point of view.

$$\sqrt{(dx/sx)^2 + (dy/sy)^2 + (dz/sz)^2} < 1$$

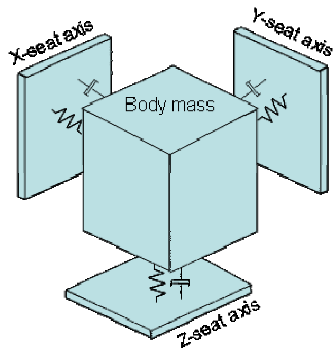

Figure 8 Evaluation formula for bodily accelerations

For vertical accelerations, e.g. during vertical wave impact or impact during launching, allowable limits are available from literature .

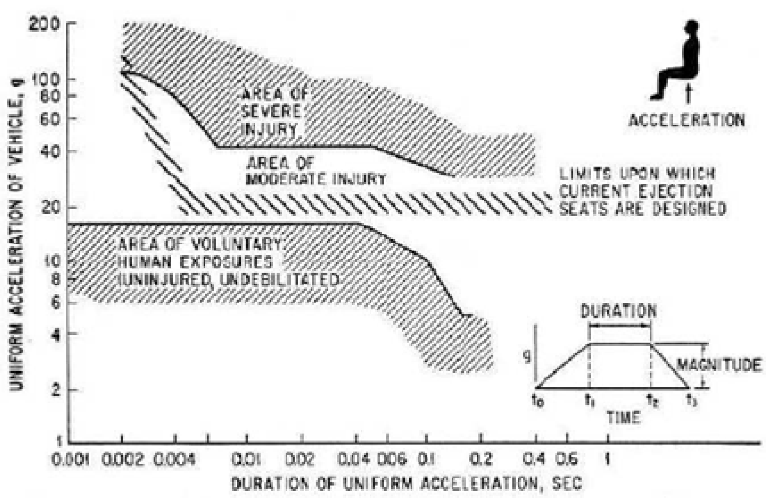

Figure 9 Assessment diagram vertical bodily accelerations

It is interesting to note that in Figure 9 acceleration and duration of the acceleration pulse are leading parameters, while time is ignored in Figure 8.

In most cases, hardware behaviour during evacuation can be predicted through simulation. For validation purposes, tests in model basins are executed.

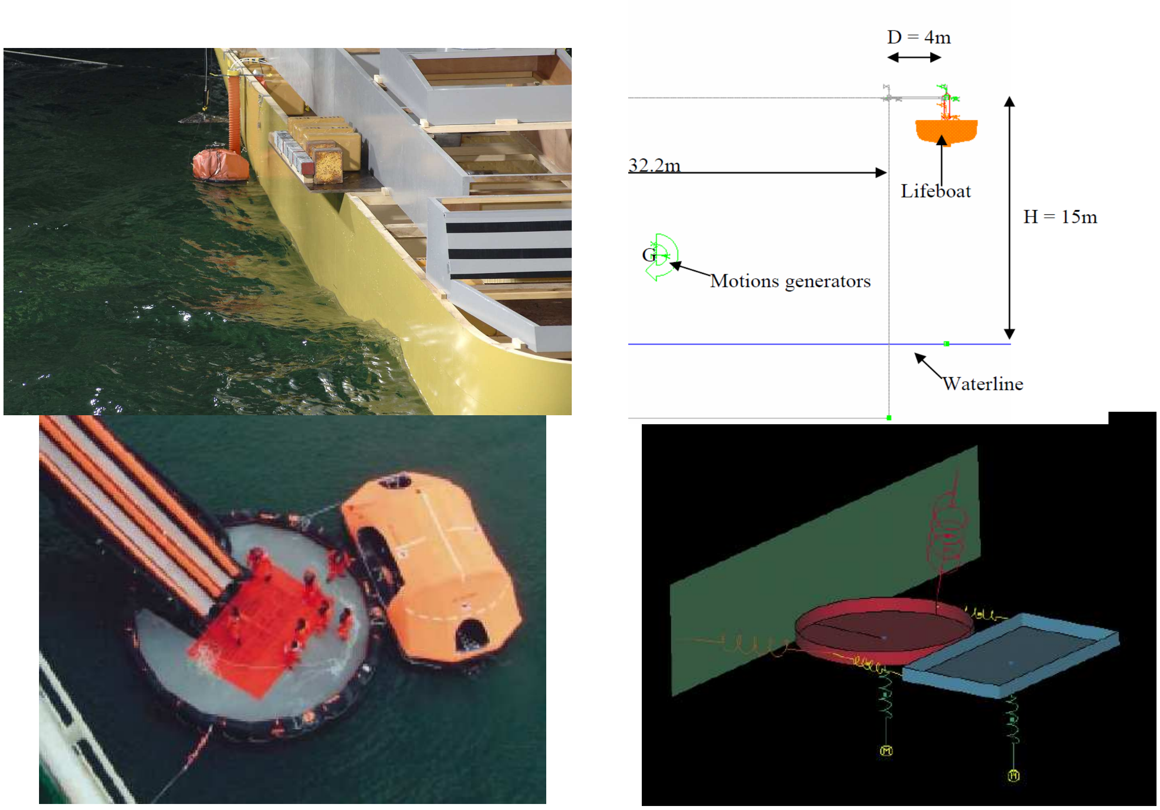

Figure 10 Typical levels of analysis and validation

The pictures above (Figure 10) show (starting upper left, rotating clockwise): model tests with a life raft along side a mother ship, multi body dynamics analysis for a life boat hitting the ships side during launching, marine evacuations system in real life and in a simulation environment.

4. Validation

In spite of valuable information in literature, still many things are uncertain, therefore, tests are required with human subjects.

Figure 11 Motion tests on human subjects

Figure 11 shows examples of the ability of people to remain seated, while they are subjected to motions in a "life boat" or "life raft". For ethical reasons, these tests need to be done with volunteers which is a disadvantage, since there is a self selecting mechanism. Yet, it is already better to have members of general public rather than people from nautical academies or the military.

The mobility of evacuees has also been tested with a temporary facility. Pictures of this temporary facility are shown in Figure 12.

Figure 12 Motion platform for testing human mobility

Figure 13 Motion platform head view and view on "embarkation".

Volunteers were asked to slide down a chute into a life raft, to board a life boat, and to climb a rope ladder from a life boat or a raft to a 'rescue deck'. Tests were done without 'ship motions' and with 'ship motions'. Ship motions were emulated up to 10 degrees roll at a period of 16 seconds.

During the tests, about 350 persons of varying age categories up to the age of 67 were 'processed for evacuation'. During chute evacuation there was only 1 refusal.

It was interesting to note that the mobility of the evacuees was not so much influenced by the roll motion.

From literature and tests with volunteers it has proven possible to determine more or less a relation between motion levels and both human vulnerability and human mobility.

5. Novel concepts

The other goal of the project was to generate 2 novel concepts for ship evacuation. Out of many ideas, two most promising concepts were selected. These concepts have been further developed.

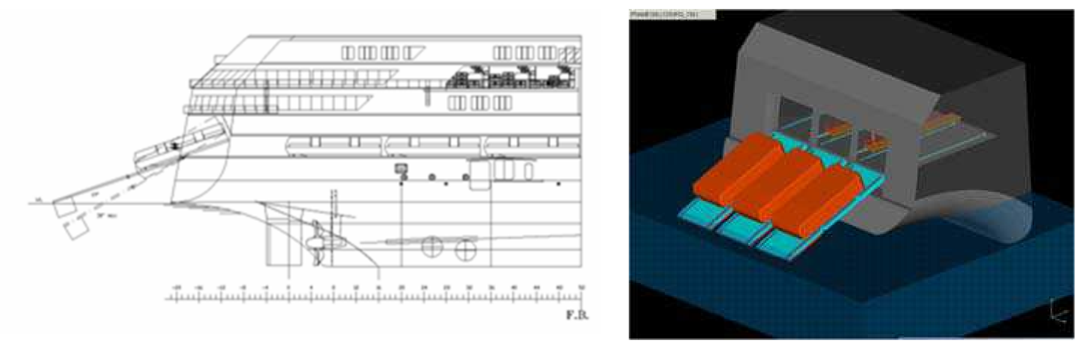

Figure 14 Self Propelled Survival Craft

One concept, called the Self Propelled Survival Craft (SPSC) (Figure 14) consists, of multiple modules. These modules are stored at or near the centre line, in the aft of the mother ship. The modules are ejected over the stern, and slide along a ramp towards the water. The SPSC concept requires an amount of space similar to conventional boats, however the space is now located inside the ship, which is less valuable from an operational commercial point of view. Deck space, required for conventional life boats, is the most valuable space in the ship. A slide ramp as a launching mechanism, is considered less vulnerable, compared to a davit based launching system. Especially in terms of control, complexity of the mechanics and maintenance.

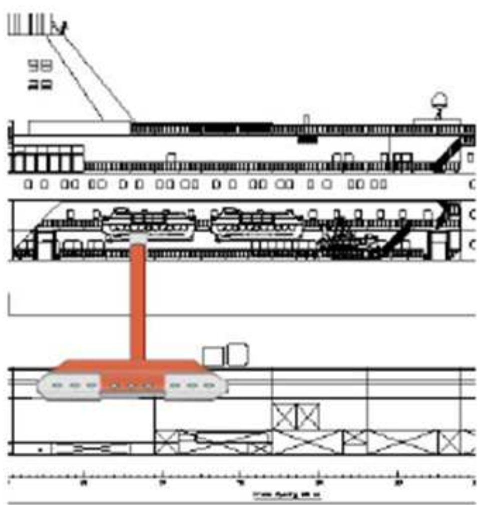

Figure 15 Haslir alongside

The SPSC concept was generated within the context of the SAFEDOR project [5] and was adopted for further investigation by the SAFECRAFTS project.

The other concept is a life raft with partially rigid sides (Figure 15). This concept is called HArd Sided LIfe Raft (HASLIR). The rigid sides contain propulsion, by means of small diesel engines or electric motors propelling thrusters. Effectively, thus a self propelled life raft is created. The HASLIR is still located at the 'boat' deck, however, the space required for storage is substantially smaller than the space required for life boats. Moreover, unlike lifeboats, only one deck level is affected for storage. Also the launching mechanism is very simple because of the HASLIRS low weight, a simple stores crane will be sufficient.

Both concepts would typically carry about 400 persons per module.

In order to assess the feasibility of both novel concepts, prototypes were built. The size of the prototypes was reduced. For the SPSC the prototype was scaled 1:2 and for the HASLIR the scale was 1:3.

Figure 16 Prototype testing SPSC

Figure 16 shows the SPSC about to be launched (top left) and entering the water (bottom right). These tests were carried out at the IJsselmeer. The lake proved to be an excellent test basin for the scaled models. Tests could be done in sea states up to sea state 3, emulating a sea state 4-5 at full scale.

The SPSC prototype could be manned. Both launching and sailing conditions were tested. The tests were used to prove the principal feasibility.

Moreover, the SPSC was used for some debarkation tests.

Figure 17 Prototype testing Haslir

The scaled model of the HASLIR (1:3) is showed in Figure 17. The prototype was used for sailing tests, manoeuvring tests, clearance tests, and wave riding tests. The concept was tested in single waves with a typical height of 1 meter (3 meters full scale).

6. Conclusion

The basic findings of the project are that the concept of equivalent safety actually works.

Two novel concepts were developed and assessed according to this method. Both concepts can hold about 400 evacuees. They can be stored in convenient places on board the mother ship.

In case of the HASLIR, the modules take substantially less space than conventional boats. This implies that the mother ship can increase in size because the storage space problem for evacuation systems is resolved. This is very important benefit for passenger ships, since deck space is the most valuable space there is on board. Money is also saved in this case since the HASLIR is relatively cheap.

In case of the SPSC, the modules as well as the launching system are in a range of expenses similar to boats. Nevertheless, the SPSC doesn’t require expensive deck space. This is a very valuable advantage. Also, the evacuation and launching system is very ‘customer friendly’. Moreover the system is not normally exposed to the weather which reduced maintenance costs considerably.

The Safecrafts project has managed to produce an assessment method which can be used to compare the performance of novel concepts with existing ship evacuation systems. The method uses an unambiguous parameter, called the human health status (HSS) to make such an assessment. Various novel concepts have been identified, of which two were further developed up to the level of scaled prototypes (1:2 and 1:3).

7. Acknowledgements

We would like to thank commission of the EU for the opportunity to do this necessary research. IMO is acknowledged for providing the discussion platform. We would also like to thank all the partners for their investments in time and capacity. Ever since Titanic the world is still very concerned by accidents occurring with passenger ships. With the increase in ships size this research was necessary and the results are worth the effort!

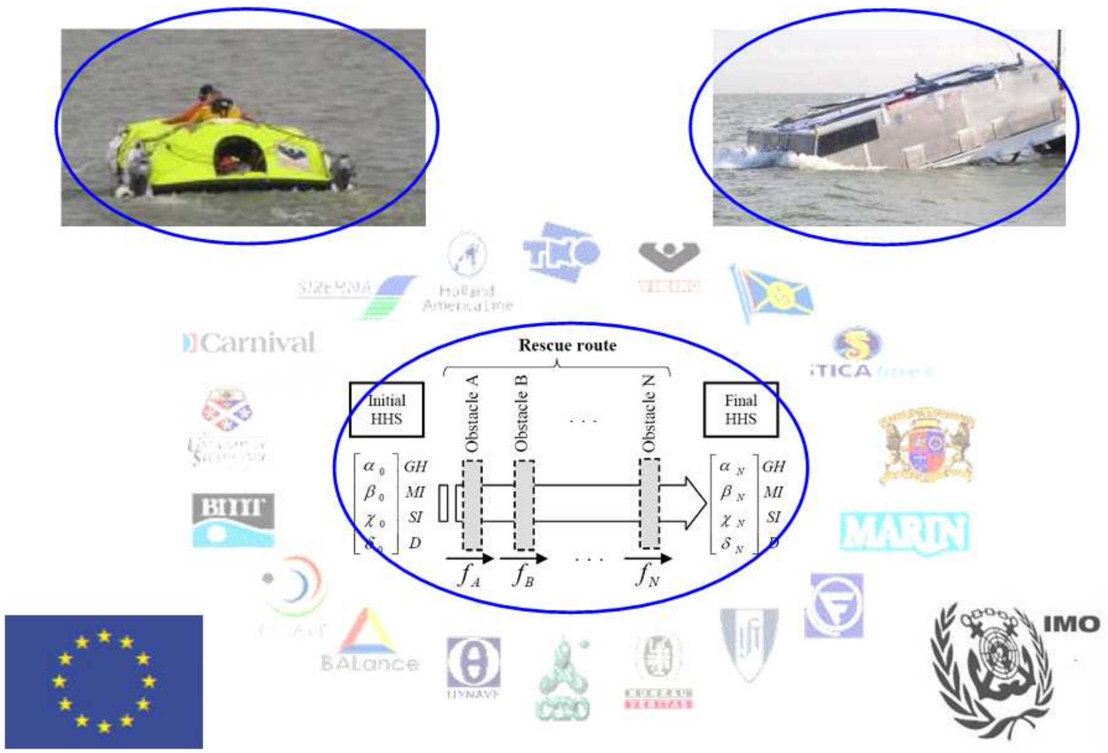

Figure 18 Acknowledgements

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