

# **Final publishable report**

## **Executive summary**

### **Research objectives and their achievement**

The main idea of the SuSy project is to develop well-known submarine rescue technology into systems to be used for merchant ships in emergency situations and for lifting sunken vessels. This required the development of three main modules, which are:

- Gas generators
- High air pressure devices.
- Balloons made of high tech textiles.

Modules design options were compared on a theoretical and experimental basis in order determine appropriate candidates and an integrated package realising a functional prototype of the SuSy system was built and tested.

Further to this accident scenarios were reviewed in order to define application scenarios, mathematical models of the structure and hydrodynamics were developed and selected application scenarios were tested in real sea conditions.

### **Project outcome and main innovations**

A prototype rescue system was developed for preventive installation use on board merchant ships in emergency situations and as salvage tools. Two modes of deployment were tested in sea trials: Firstly, 'Internal' where balloons installed in protective covers within the double-bottomed test compartment were inflated, keeping it afloat until repairs or other emergency measures are implemented; Secondly, 'Salvage' where external balloons and gas generator packs were attached, providing support sub-surface and allowing the test compartment to be recovered to the surface. The systems successfully deployed during testing, structural loadings were within acceptable limits and stabilisation was achieved.

In addition to the main outcome of a functioning prototype system there were several secondary outcomes namely:

- Development of a time domain model of ship damage propagation under wave loading. This has potential in risk based ship design and accident investigation.
- Development of a hydrodynamic model and sliding mode controller for controlling the raising of sunken ships.
- Development of improved methods of life cycle modelling and application within SuSy. The enhancements to this system have potential within more general consulting work.

### **Dissemination and exploitation for the results**

The project has also resulted in a patented system for providing additional buoyancy to near surface objects such as damaged vessels or submarines.

### **KPIs**

KPI	VALUE
# of commercial products	
# of businesses launched	1
# of patents registered	1
# of successful trials conducted	2
# of papers in scientific publications, industry magazines	47
# of events attended. (Papers have been accepted for two events that will be attended after the project is finished)	9+2



*FP7 Grant Agreement No: 234151*  
*Project Title: SUSY*

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## Introduction to the project (Summary description of project context and objectives.)

### Concept and objectives

As stated in the original project proposal:

The propagation of spillages is one of the biggest environmental problems after a ship disaster. Instead of cleaning the dirty areas the SUSY system will avoid the spillages by stabilizing vessels immediately after an accident. Additionally the same technology should be used to lift sunken vessels by spending less effort than today. The main idea of the proposed project SuSy is to develop well known submarine rescue technology into systems to be used for merchant ships in emergency situation.

Different application scenarios / concepts can be envisaged,

- preventive installation of rescue systems on ships with hazardous cargo
- equipment for coast guard and rescue squads to quickly stabilize capsized ships
- equipment for teams to lift sunken ships
- The technical challenges where research is needed to develop the envisaged systems are
  - developing a hydro-dynamical model for the different possible scenarios
  - developing a thermo-dynamical model as basis for a controlled process under the different scenarios foreseen
  - find the right material to cope with the pressure the temperature and the dynamic loads of a rescue scenario
  - define a life-cycle cost model to assure the design of a low cost modular system
  - simulate the different scenarios to provide input for the design optimisation
  - develop fitting technologies for submarines to apply the SUSY system to sunken vessels
  - test of the fitting technologies with available submarines (see partner HCMR)
  - Develop and test the system based on liquid or solid fuel boosters combined with air pressure and new balloon textile technologies.

Finally SUSY will build a prototype to proof the concept in real sea test.

### Budget breakdown

Project Number	234151	Project Acronym	SuSy					
One Form per Project								
Participant number in this project	Participant short name	Estimated eligible costs (whole duration of the project)					Total receipts	Requested EC contribution
		RTD / Innovation (A)	Demonstration (B)	Management (C)	Other (D)	Total A+B+C+D		
1	BMT	234.669,37	0,00	186.299,85	75.000,00	495.969,22	0,00	378.634,54
3	BAL	377.058,85	0,00	0,00	82.800,00	459.858,85	0,00	365.594,13
5	HCMR	148.526,08	73.000,00	0,00	17.614,92	239.141,00	0,00	165.509,36
6	NTUA	573.201,35	91.200,00	5.000,00	9.600,00	679.001,35	0,00	493.101,01
8	DCNS	308.962,00	50.000,00	0,00	32.308,00	391.270,00	0,00	211.789,00
9	UGS	479.968,80	0,00	4.000,00	0	483.968,80	0,00	363.976,60
11	BV	273.630,64	0,00	0,00	15.965,04	289.595,68	0,00	152.780,36
12	ASTRIUM	420.340,00	180.000,00	2.500,00	76.600,00	679.440,00	0,00	379.270,00
13	DSB	193.690,00	85.000,00	0,00	0	278.690,00	0,00	139.345,00
<b>TOTAL</b>		<b>3.010.047,09</b>	<b>479.200,00</b>	<b>197.799,85</b>	<b>309.887,96</b>	<b>3.996.934,90</b>	<b>0,00</b>	<b>2.650.000,00</b>

## Consortium overview and roles

### Project website:

[www.su-sy.eu](http://www.su-sy.eu)

#### **BMT Group Ltd** (BMT UK)

##### **Main Roles**

Project coordinator, Modelling task leader

**Contact:** Rory Doyle <rdoyle@bmtmail.com >

#### **EADS Astrium** (Astrium Germany)

##### **Main Roles**

Development of rescue systems (gas generators)

**Contact:** Thomas Langer <Thomas.Langer@astrium.eads.net>  
Ostrowski, Thorge von' <Thorge.vonOstrowski@astrium.eads.net>

#### **BALance Technology Consulting** (BAL Germany)

##### **Main Roles**

Life-cycle cost analysis, project management

**Contact:** Reinhard Ahlers <reinhard.ahlers@bal.eu>  
Niklas Fischer <niklas.fischer@bal.eu>

#### **Deutsche Schlauchboot GmbH** (DSB Germany)

##### **Main Roles**

High tech textile research and production

**Contact:** Markus Bolay <mbolay@survitecgroup.com>  
Markus Schwarz <markus.schwarz@survitecgroup.com>

#### **Hellenic Centre for Marine Research** (HCMR Greece)

##### **Main Roles**

Testing, underwater robot application, rescue support experts.

**Contact:** Chris Smith <csmith@her.hcmr.gr>

#### **National Technical University of Athens** (NTUA Greece)

##### **Main Roles**

Maritime research, thermodynamic modelling specialists

**Contact:** Vassilios Papazoglou <papazog@deslab.ntua.gr>  
Elias Chatzidouros <elchat08@central.ntua.gr>

#### **DCNS** (DCNS)

##### **Main Roles**

Development of rescue systems (pressure air devices)

**Contact:** Boris Vautrin <boris.vautrin@dcnsgroup.com>

#### **Bureau Veritas** (BV France)

##### **Main Roles**

Classification society, HazID Analysis

**Contact:** Philippe Corrigan <philippe.corrigan@bureauveritas.com>

#### **Universities of Glasgow and Strathclyde** (UGS UK)

##### **Main Roles**

Maritime research, development of simulations

**Contact:** George Mermiris <g.mermiris@na-me.ac.uk>  
Nigel Baltrop <n.baltrop@eng.gla.ac.uk>

## Project overview – Work performed

### Work package 1: Scenario Definition and Analysis of Disasters History (UGS)

*This work package followed an evidence-based process where historic ship disasters were analysed and clustered so as to define of scenarios for buoyancy rescue concepts which were both valuable, and plausible from a technical, and regulatory standpoint.*

#### Task 1.1 Analysis of ship disasters (UGS, BMT, BV)

Quantitative data was collected from publicly available sources in the World Wide Web. More specifically, 909 records of accidents were collected from the web sites of Titan Salvage ([www.titansalvage.com](http://www.titansalvage.com)), Smit ([www.smit.com](http://www.smit.com)), Marine Accident Investigation Branch ([www.maib.gov.uk](http://www.maib.gov.uk)), BV database and IMO. These were then classified by ship type, ship size and accident type. The location relative to shore, weather situation and ship condition at time of incident were also analysed so as to provide input into the development of typical scenarios. This approach was then supplemented with structured interviews with experts from BV Emergency Response System and Titan Salvage in order to provide a richer qualitative description of real world scenarios.

Finally a series of event trees for bulk carriers, tankers, passenger ships, container ships and general cargo ships were developed.

The findings were summarised in D.1.1 which concluded that ‘general cargo ships seem to dominate the database records but the analysis shows that passenger and container ships are the most susceptible to all three kinds of accidents (Remark: collision, grounding and fire/explosion). On the other hand, the data presented for the fishing industry demonstrate that number of lives and vessels lost on annual basis surpass every other maritime sector. From a salvage point of view, the SuSy concept can be deployed towards reducing uncertainty in an emergency operation and allowing wider window for planning and execution’.

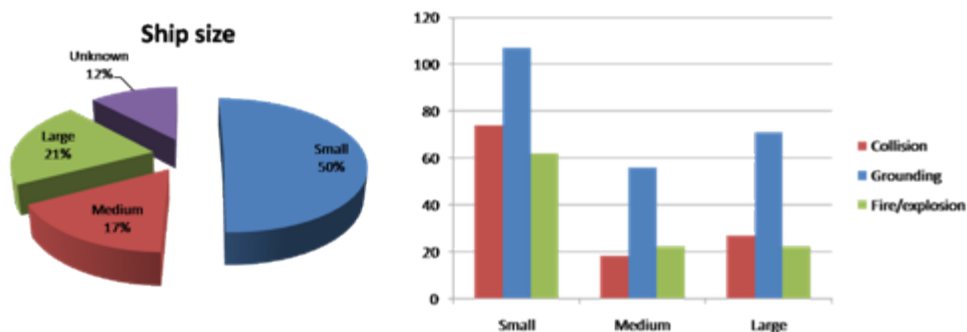


Figure 3-1: Correlation between ship size and accident type

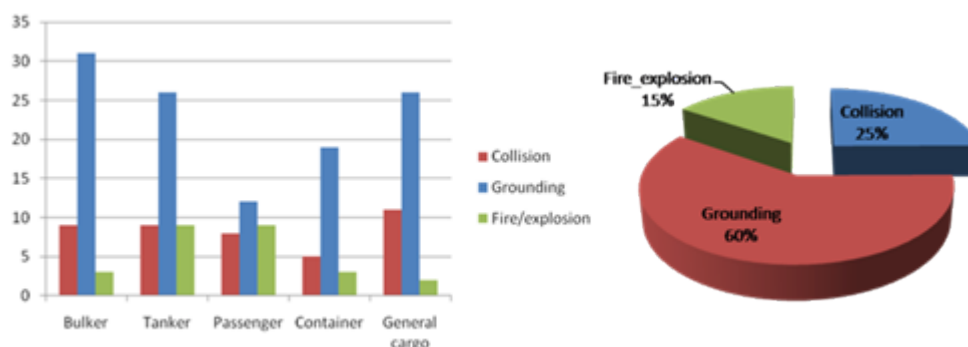
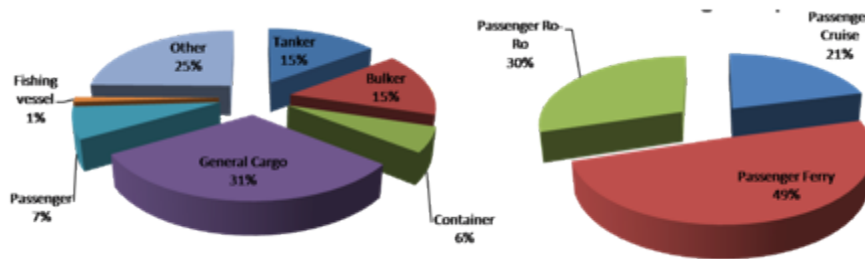


Figure 3-2: Correlation between ship type and accident type



**Figure 3-3: Ship types related to accidents (right figure: detailed breakdown of passenger vessel group)**

It is important that readers note that the analysis and the conclusions reflect only the accident records in the database and they are not related to any generalization or abstraction of worldwide statistical data.

Different selection criteria for possible SUSY scenarios have been defined within the project. The amount of accidents is one criterion (fishery vessel) but also the environmental impact (tanker) and the market impact (passenger vessels). Accidents of passenger vessels or ferries are the most spectacular accidents in the maritime transport which can have an impact on the cruiser market.

#### **Task 1.2 Definition of types of accidents suitable for a buoyancy rescue concept (NTUA, HCMR, UGS)**

In this task the general characteristics of vessel types possibly suitable for a buoyancy rescue concept were defined in terms of representative general arrangements, stability and damaged stability. Preliminary analysis found that in principal the “SUSY” system can be used in any accident scenario where the extent of damage exceeds a ship’s Damage Stability Requirements (e.g. two compartment or three compartment vessels). Damage Stability requirements for all vessel types are subject to Regulations, namely SOLAS 90 or for new ships SOLAS 2009.

#### **Task 1.3 Structuring of ship disasters and scenario definition (NTUA, BMT, UGS)**

The disasters scenarios were group into typical scenarios so as to allow generalization of application and avoidance of cumbersome case-by-case analyses with little added value to the project. The outcome of this process was a matrix of concepts for each ship type and scenario type as shown below.

	on-board fixed (preventive installation)	moveable	retrofit	Structure failure leading to flooding	Capsize & foundering	collision	sinking	risk control options
<b>Fishery vessel</b> (3-prototype)	<b>X</b> outside installation				<b>X</b> very fast process			<b>X</b> regulatory requirements
<b>Tankers</b> (2-simulation) (3-prototype)	<b>X</b> inside installation			<b>X</b> environmental				<b>X</b> regulatory requirements
<b>RoPAX vessels</b> (2-simulation)	<b>X</b> inside installation		<b>X</b> almost done			<b>X</b>		<b>X</b>
<b>salvage team equipment</b> (3-prototype)		<b>X</b>		<b>X</b>			<b>X</b>	

**Figure 3-4: Most interesting areas for SUSY system applications**

#### Task 1.4 Scenario evaluation and system concept specification (BV, ASTRIUM, DCNS, DSB, HCMR, BMT NTUA, BAL, UGS)

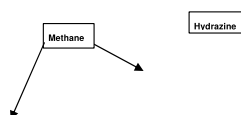
The use of the SuSy concept of inflatable bags onboard a ship is subject to the respect of Regulations, Rules and Flag administration requirements. Work in this task considered the SUSY concept from a regulatory and environmental perspective, reviewing the different scenarios resulting from task 1.3, and thus to ensuring their appropriateness. The feasibility (hydrodynamics, logistics), applicability (rules and Regulations) and producible (laboratory tests) aspects were considered. The scenarios were selected on a basis of which scenarios are likely to have the greatest potential for reducing environmental damage if these systems were available. On the basis of this preferred scenarios were selected, on a regulatory point of view, and on a technical analysis of benefits and disadvantage for the selected scenarios.

#### Work Package 2: Feasibility study and concept definition for the SuSy system (HCMR)

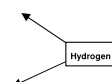
While the previous work package defined and clarified the problem in terms of scenarios this feasibility study defined the technical components of the SUSY concept through lab tests and design work. That is deciding on how gas for buoyancy will be provided, deciding on materials for construction of buoyancy carriers and deciding on how SUSY systems will be used to stabilise or recover vessels.

##### Task 2.1 Analysis of different buoyancy generating media (ASTRIUM, DCNS, NTUA)

This task analysed both pressurised and catalytic systems. The outcome of this task was a series of property tables detailing the chemical and thermodynamic properties of media for both pressurised and catalytic gas generation systems. This allowed comparison of performance characteristics (differences in specific volume) as well as a clear statement of hazards associated with candidate buoyancy generating media in term of both storage and combustion products.



■ Press. Sys. "S"  
▲ Cat. Sys. "dec"  
▲ Cat. Sys. "ad"  
● Sol. Sys. "ad"  
◆ Liq. Sys. "ad"



▲ Cat. Sys. "dec"  
▲ Cat. Sys. "ad"  
● Sol. Sys. "ad"  
● Sol. Sys. "ad"  
◆ Liq. Sys. "ad"  
◆ Liq. Sys. "ad"

Figure 3-5 Cold gas

Figure 3-6 Hot gas

##### Task 2.2 Analysis different materials suitable for the buoyancy carriers (DSB)

This task analysed different materials suitable for the buoyancy carriers, divided into analysis of coatings, reinforcement fabrics and finished materials. Analysis was in the context of inflation scenarios and therefore special focus was given to following main characteristics:

- Temperature resistance to cope with any temperatures arising during the inflation sequence
- Tensile, puncture and tear strengths of the material to withstand the loads occurring during the inflation process and affected by environmental conditions
- Suitable material coatings with good chemical properties able to withstand filling media and seawater.
- The total weight of the material.
- Manufacturing properties.

Materials and combinations of materials were scored and ranked on different scenarios and the results presented as a matrix. Preliminary recommendation of FKM coating on PA-Aramid Reinforcement Fabric for high temperature



systems and CSM/CR on PA-Armid as a lower cost alternative capable of withstanding high temperatures for a shorter period of time.

### Task 2.3 Requirement for the vessel design selected in the typically scenarios (NTUA)

While the previous tasks considered the components of the SUSY system (gas generation and buoyancy carriers) this task considered the design of the system itself. Three SUSY deployment concepts were developed from a naval architecture perspective; external deployment by salvage teams to provide additional buoyancy to a damaged Aframax tanker, internal fixed installation deployment within the double bottom of the tanker and a pre-installed 'curtain' to subdivide the car deck of a ROPAX ferry to reduce the free surface effect and thus prevent capsizing. Simulations found of the von misses stress at the double bottom found no effect on residual strength as shown below.

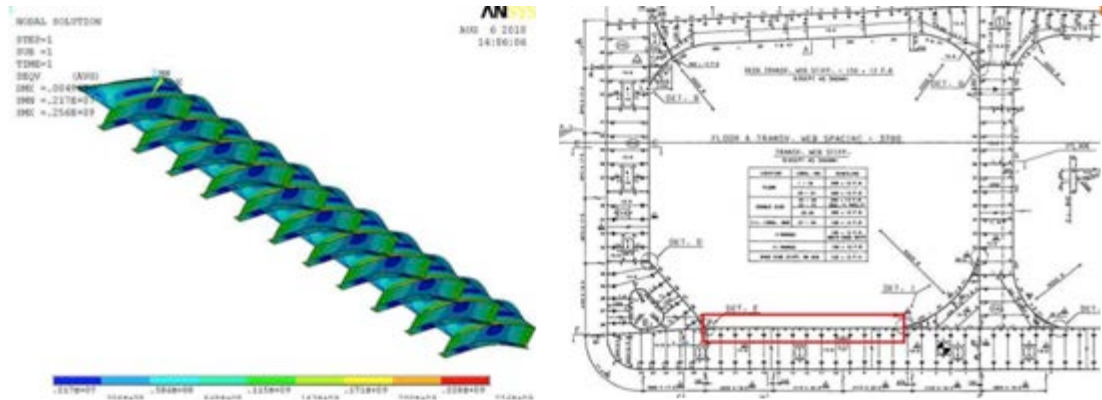


Figure 3-7: Simulation of Von Misses stress at the double bottom

### Task 2.4 Definition of a buoyancy rescue concept for three scenarios (ASTRIUM, DCNS, DSB, UGS, HCMR, BAL, BMT,NTUA)

This task provided a preliminary design for the system concepts namely:

- Internal deployment of twin 7.38m<sup>3</sup> cylindrical balloons composed of textile materials (KK1000 and KK2000) within each section of the double bottom of an AFRAMAX tanker with a inflation speed of a few minutes. Simulations found that there is no impact regarding the residual structural strength of the double bottom.
- External deployment of balloons with attachment to fore and rear bulkhead of hold 4P and even distribution of the SuSy devices along the webs and the bulkheads on hold. Finite element analysis found that stresses were acceptable in both cases and application of the SuSy devices on webs exhibited over 50% less average stresses compared to ballasting, on hopper plating, relevant longitudinal stiffeners and side skin, situated on the damaged side.
- Salvage system for raising sunken ships using a sliding mode controller and venting to keep the rate of ascent below 0.6 m/s.

## Work Package 3: Concept realisation and system simulation (ASTRIUM)

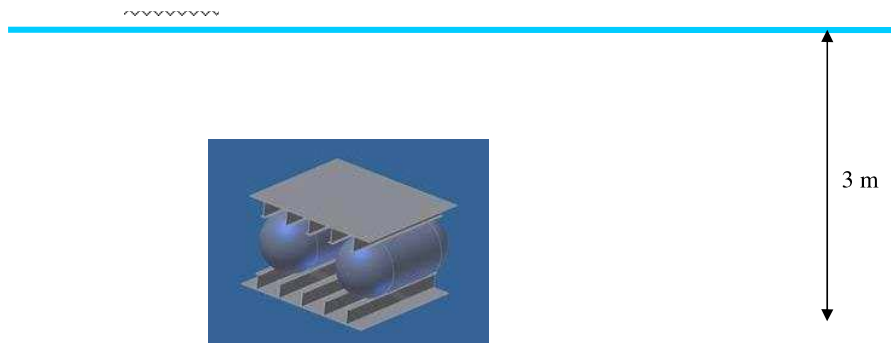
*This work package took the preliminary conceptual designs from WP2 and developed them into full engineering designs. This required detailed thermodynamic and hydrodynamic calculations as well as determination of details such as pipework, attachment points and controller mechanisms. Moreover lab tests were conducted in order to validate design and material choices. Finally initial plans for demonstration were defined.*

### Task 3.1 Evaluation test of fuel packages and combination with high pressure air (DCNS, ASTRIUM)

Work in this task designed and evaluated a fuel package in combination with high pressure air for double bottom and pontoon tests. Two systems were designed; an installed system within the double bottom of taking the AFRAMAX tanker as a reference case; a deep water salvage package taking a test pontoon to deep water.

For the double bottom depth is only 3m and so pressurised air is sufficient. In order to fill two 7.38m<sup>3</sup> balloons at 1.3 bar assuming isothermal expansion 750L bottle is required at 31bar. This can be done in under a minute though a hose

of inner diameter 8mm. The quick release coupling will be in 1/2' (ND15). Air bottles can be refilled using standard ship compressors within 13.5 min.



**Figure 3-8: General SUSY system architecture**

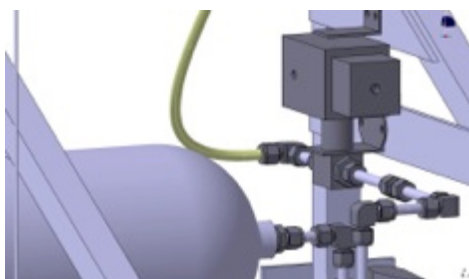
For the pontoon pressure within the balloons is 4bar absolute and so for 3 x 1.9 balloons as is the test case for the pontoon demonstration 900L at 30 bar is required. Due to higher pressures involved a regulator is required and again hose equivalent to 1/4', diameter external: 13,4mm; inner diameter 8,9mm) is sufficient for flow rates. Indeed since time is less critical this is an overrating. Pressurised gas is supplied by a standard medium pressure air device (30 bar – 100 Nm<sup>3</sup>/h).



**Figure 3-9: SUSY system piping installation**

For depths greater than 400m hybrid pressure-gas generation systems which use a combination of pressurised gas combined with a small solid propelled gas generator as a heat source become appropriate.

While the gas generator is able to produce a high volume of gas in a very short time the high pressure air bottles are able to stabilise the high pressure for a longer time. Therefore the high pressure air system and the gas generator system are connected to the same piping system (Figure 3-10).



**Figure 3-10: Connection of the gas generator and the piping system**

### **Task 3.2 Evaluation tests of buoyancy materials (DSB)**

An evaluation test program of the buoyancy material was conducted based on the requirements given by MSC.81(70) chapter 5 for rigid and inflatable life rafts. Additional tests were performed according to RTCA/DO160 (approval testing for airworthy equipment). The tests of material therefore comprised; Tensile Strength, Tear Strength, Adhesion of Coating, Cold Flexibility, Folding, Seam Strength, Air Permeability, Chemical Resistance, Ozone Resistance, Chemical Resistance, Joint (seam), Puncture Resistance. Additionally the high pressure hose assembly including HP-hoses, inlet valve, and pressure relief valve was tested in accordance with ISO 15738:2002. All tests were passed.

### Task 3.3 Design of different attachment technologies considering operational aspects (NTUA, HCMR, BV, NTUA)

The operational aspects of various attachment technologies were considered. These aspects are strongly related to diving limitations, and capabilities of the divers, underwater vehicles and their tooling with reference to open water demonstration. The operational requirements and limitations of divers and ROVs were briefly reviewed then different rigging and attachment technologies considered, namely; wire rope & terminal fittings; chains & connectors. Structural aspects of connectors (welds, bolts, rivets) were then considered. Finally the load factors for the complete attachment system were considered in the context of a balloon with a lifting force of 18.8 tonnes. A good overview was documented in deliverable D-3-3.

While a general design consideration was developed we note that the detailed design of the attachment devices and techniques must be derived for every accident case. The particulars of each accident are unique and every case must be examined separately in particular with regard to local and global residual strength.

### Task 3.4 Development of two packages (Buoyancy devices + solid fuel unit) for different application cases (ASTRIUM, DCNS, DSB)

Work within this task comprised the detailed design and testing of the SuSy Integrated Package (Gas Generator + Buoyancy Carrier). In particular the performance characteristics of the hot and cold gas combination vs. the cold gas combination and its benefits are analysed.

It was found that the ideal solution for all applications consists of the combination of pressurised gas combined with a small solid propelled gas generator as a heat source as depicted below.

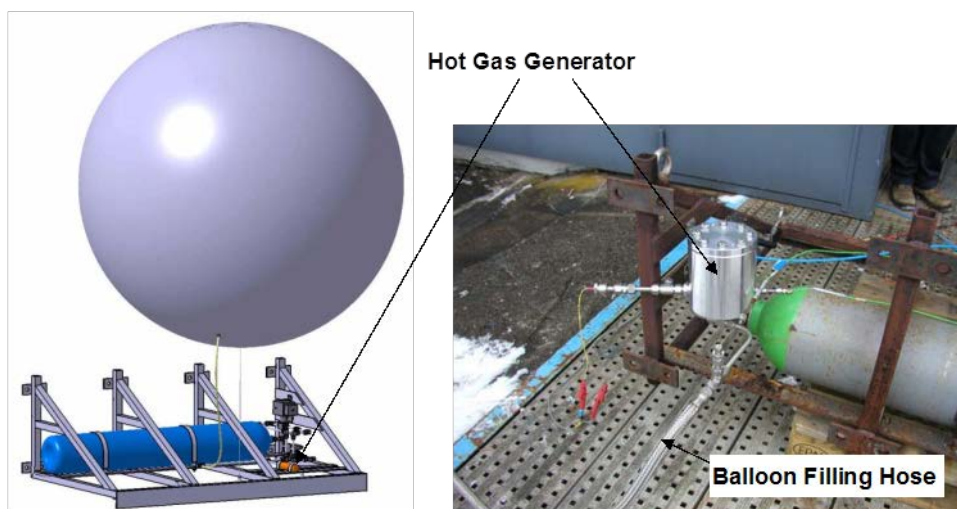


Figure 3-11: SuSy Integrated package

Cold gas inflation tests were conducted under atmospheric conditions at Astrium Test-Site in Trauen, Germany then during water tests were conducted in Greece. The combined system was tested in Astrium Test-Site in Trauen, Germany using a propellant consisting of potassium nitrate ( $\text{KNO}_3$ ), ferric oxide ( $\text{Fe}_2\text{O}_3$ ) and epoxy resin.  $\text{KNO}_3$  is the oxidizer for the epoxy resin. However due to the problematic of hazardous good transportation it was decided not to perform the cold/hot gas combination tests in conjunction with the sea trials

### Task 3.5 System simulation (BMT/UGS)

Two simulation systems were developed. The first was a hydrodynamic model of the salvage operation incorporating breakout or suction force due to the sea floor and additional buoyancy from an inflatable system fitted with a pressure relief valve. The rate of ascent needs to be carefully controlled to avoid rapid heave or pitch motion, which would endanger the salvage operation and exert excess loads on the ship structure. A fuzzy sliding mode controller was therefore designed to control venting rate so as to maintain the stability of the vessel in the diving plane. Numerical results taking the pontoon showed 30% of improvement in the tracking performance when using fuzzy sliding mode controller compared to the conventional sliding mode controller, while maintaining its robustness and requiring less tuning and being more robust to model uncertainty.

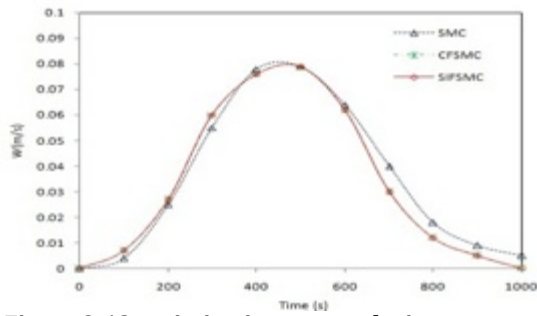


Figure 3-12 variation in ascent velocity

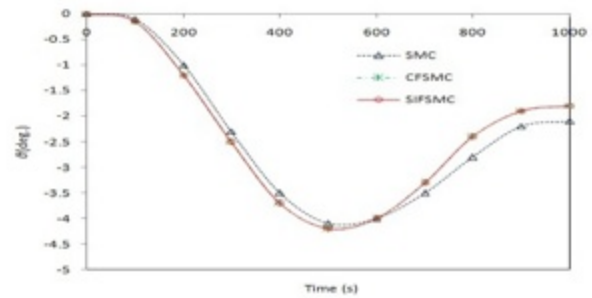


Figure 3-13 variation in pitch

The second was the development of a first-principles methodology for simulating the progressive structural failure and its combination with residual strength analysis in time domain. The output of this software is the “time to break-up”, under different loading and weather conditions which would be very helpful in the context of planning and implementing salvage operations of the damaged ship. The usefulness of the proposed method is demonstrated with the application to an Aframax tanker for three damage cases. Results indicate that the strategy of providing additional buoyancy within a damaged compartment rather than ballasting the opposite side can reduce forces and thus extend survival time. The model has utility in its own right in that it can be used to plan salvage and return to port decisions. We do however caution that the model is highly sensitive to wave height, period and orientation of the ship therefore the range of predictions is large and dependent on uncertain forecasts.

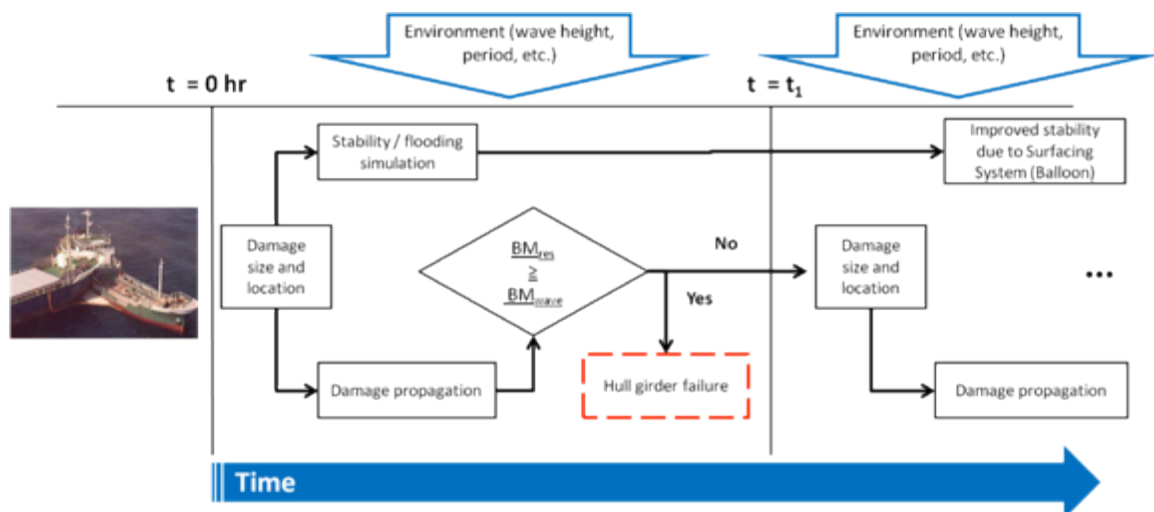


Figure 3-14: Decision support by simulation

### Task 3.6 Specification for demonstrator scenario (DCNS, Astrium, DSB, HCMR)

The demonstrator scenario was determined to be recovery of a specially designed pontoon under a range of flooding conditions. The pontoon would be designed so that individual compartments could be flooded to simulate damage cases and with SUSY systems preinstalled to speed up operations. The salvage experiment would be conducted by mounting the required equipment including compressors on a floating barge. This task clarified functions of each component of the air system located on the floating barge and determined the order of operations for the tests. Safety precautions and operational aspects were also considered.

### Work Package 4: Realisation of the demonstrator (DCNS)

*This work package translated engineering designs for the SUSY system developed in WP3 into functioning prototypes, which were then tested in real open water tests. This entailed both production of the integrated system and detailed planning and organisation of the tests. Finally tests were conducted and results analysed.*

### Task 4.1 Definition of a test plan (NTUA, HCMR, ASTRIUM, DSB, BV, UGS)

This task determined a plan for conducting tests intended to validate the operational parameters of the “SUSY” concept in structures and under real time conditions.

The double bottom installation of the SUSY system will be tested in a 1:1 scaled structure taken from an actual AFRAMAX tanker double bottom design. The inflatable devices will be attached on the upper section of the double bottom, in order for the device to be protected against a grounding event. The structure will be fitted so that strain, flow and video measurements will be taken as the balloons inflate and impose forces on the structure.

- The double bottom will be initially tested in air, meaning that it will be empty and the balloons will inflate in the empty space of the structure. This will be a preliminary test in order to observe inflation time, loads and stresses on the structure and the balloon, monitor the inflation of the balloon etc.
- In the second test the double bottom will be immersed in seawater at a maximum depth of three meters. Seawater will be used in order to have real conditions regarding the flow of the water through the damage openings. In this manner the balloon will have to egress water that is in the flooded double bottom and simultaneously overcome the external hydrostatic pressure of seawater.

In order to test the SuSy floatation technologies a pontoon was designed for open sea tests with multiple compartments so as to allow variable buoyancy configurations from floating to sunk condition. During tests depth, attitude and strain are to be monitored.

The test site initially chosen is located on the West side of the Island of Dia in Heraklion Bay. It is about 7 nautical miles north east of the Port of Heraklion on the island of Crete. This was later changed to Chalkis (Gulf of Euböa) for logistical and regulatory reasons. Operational needs were considered; specifications for floating barge/crane to be hired to support the trials were determined; operational chain of command and safety precautions were detailed.

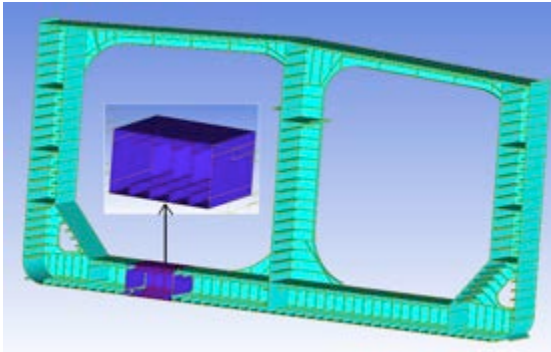
#### **Task 4.2 Preparation of open water tests (HCMR, DCNS, NTUA)**

This was a practical and organisational task designed to prepare for the sea trials of the SUSY system this included:

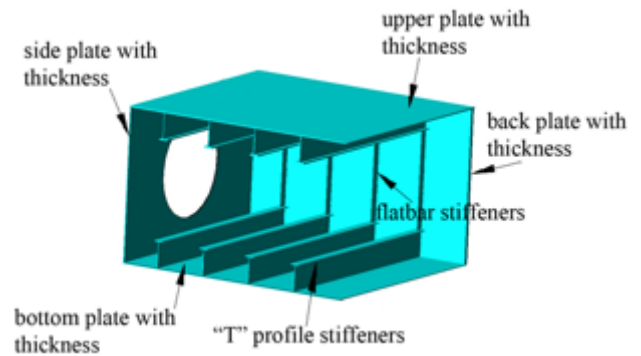
- Design and construction of the test platform
- Instrumenting of platform.
- Fitting of attachment points
- Logistical organisation.
- Safety rating and pressure testing of equipment.
- Obtaining relevant permits
- Liaison with local contractors for supply of staff, compressors, cranes and other equipment
- Definition of program for tests.



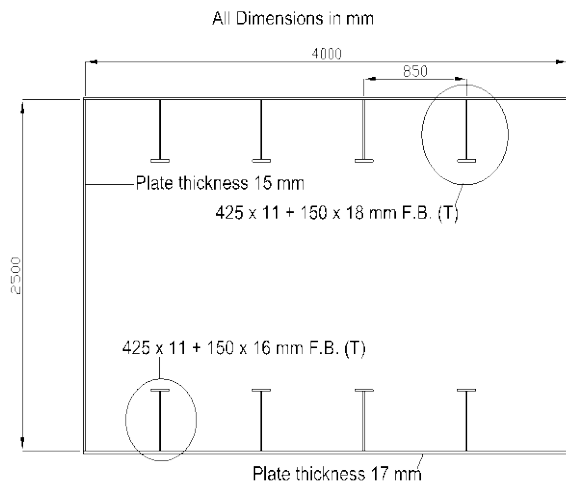
As a test platform a double bottom was designed. The design was based on a AFRAMAX vessel



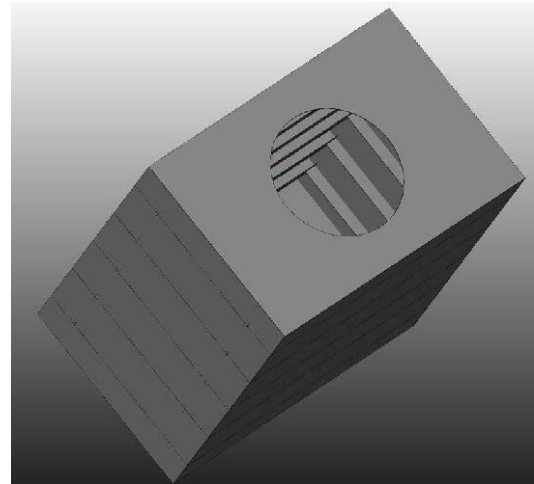
**Figure 3-15: View of a frame Amidships with web and the double bottom structure outlined**



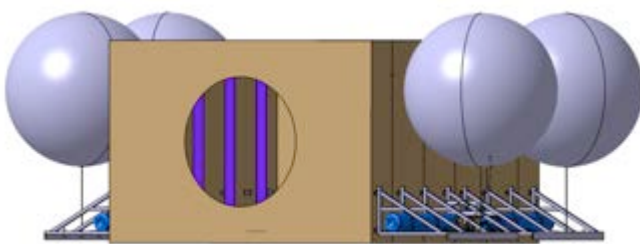
**Figure 3-16: Perspective view of the double bottom structure depicting the various plating and the flat bat and T stiffeners**



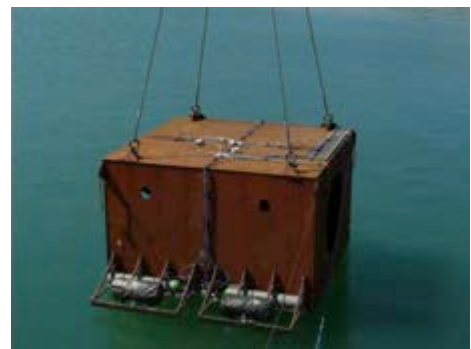
**Figure 3-17: Design of the test platform**



**Figure 3-18: 3-D Model of the test platform**



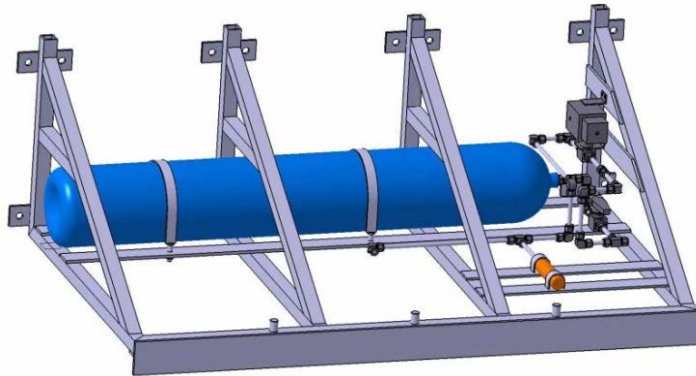
**Figure 3-19: Technical Drawing of the Open Water Test Setup**



**Figure 3-20: Open Water Test Setup right before Submerging**

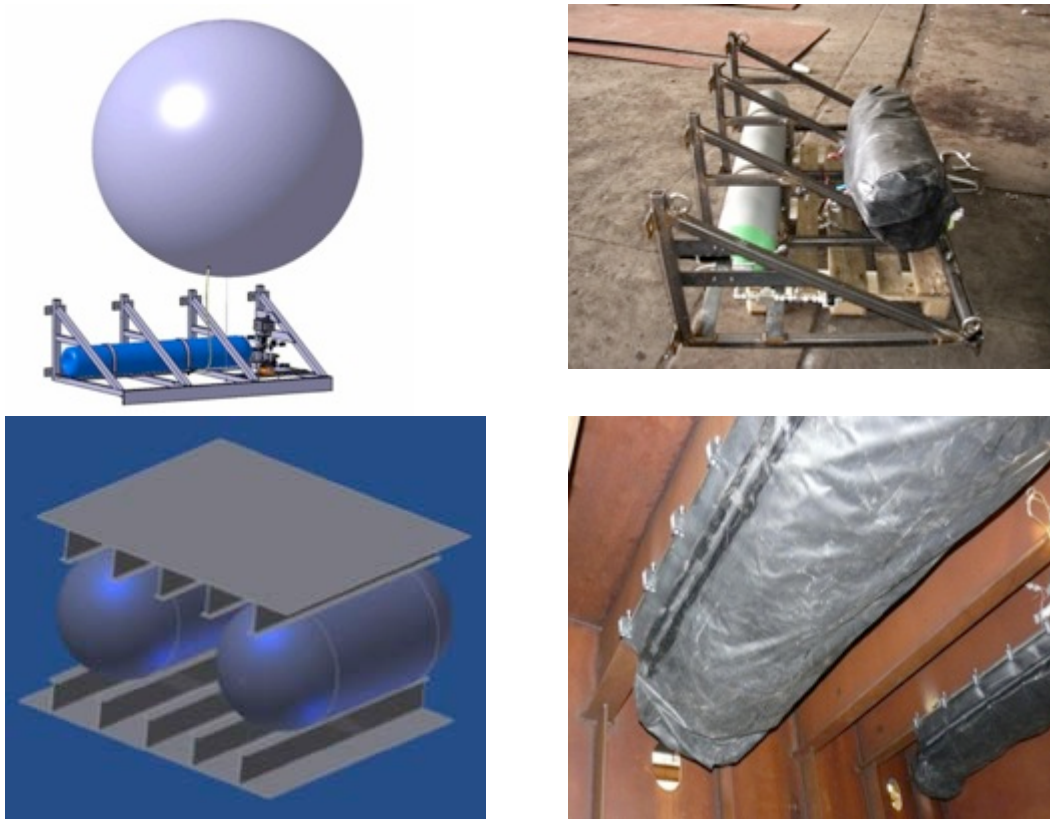
#### Task 4.3 Assembly of an integrated package (ASTRIUM, DSB)

Work within this task consisted of the production and lab testing of pressure based integrated system for inflating balloons as part of the demonstration scenario this was installed in the double bottom and produced as a salvage module as shown below.



**Figure 3-21: SuSy integrated package**

The external rescue unit (Figure 3-21) should be used for the support of rescue squads to quickly stabilize capsized ships or for teams to lift sunken ships. It can be screwed or welded on the vessel hull. Therefore the frame is equipped with gas bottles for high pressure air (more than 150 bar). The inflation time can be extremely increased by generating the balloon filling mixing two different gas media. Therefore the framework is prepared for a solid fuel cartridge installation (Figure 9). The cartridge (orange) is in proportion to the pressure cylinder much smaller (200mm long and 50mm in diameter).



**Figure 3-22: SuSy design and implementation**

In addition a theoretical comparison of different gas generators and gas generating systems for the SUSY application was conducted. This found that pressurised gas system is the best option for stabilizing small and large vessels. But the pressurised gas/hot gas solution seems to be the best option, together with the submerged hot gas solution, for deep sea applications.



#### Task 4.4 Open water tests (HCMR, NTUA, ASTRIUM, DSB, BV, BMT,UGS)

The real-time experiments have been conducted in order to establish and validate the operational parameters of the “SUSY” concept and under real time conditions. The results of the described tests will be used for further theoretical evaluations of additional applications.

The test platform bases on a double bottom section used with a variety of internal, external balloons and with medium and high pressure gas through storage bottles incorporating on the double bottom section. The double bottom test studies and validates the operational parameters of the “SUSY” concept in a 1 to 1 scale section of an actual vessel. It may be assumed that after the “SUSY” concept has been validated for the double bottom structure, it can be applied to any part of the structure of the vessel.

The double bottom test platform will be immersed in sea water at a depth of six meters. Sea water will be used in order to have real conditions regarding the flow of the water through the damage openings.

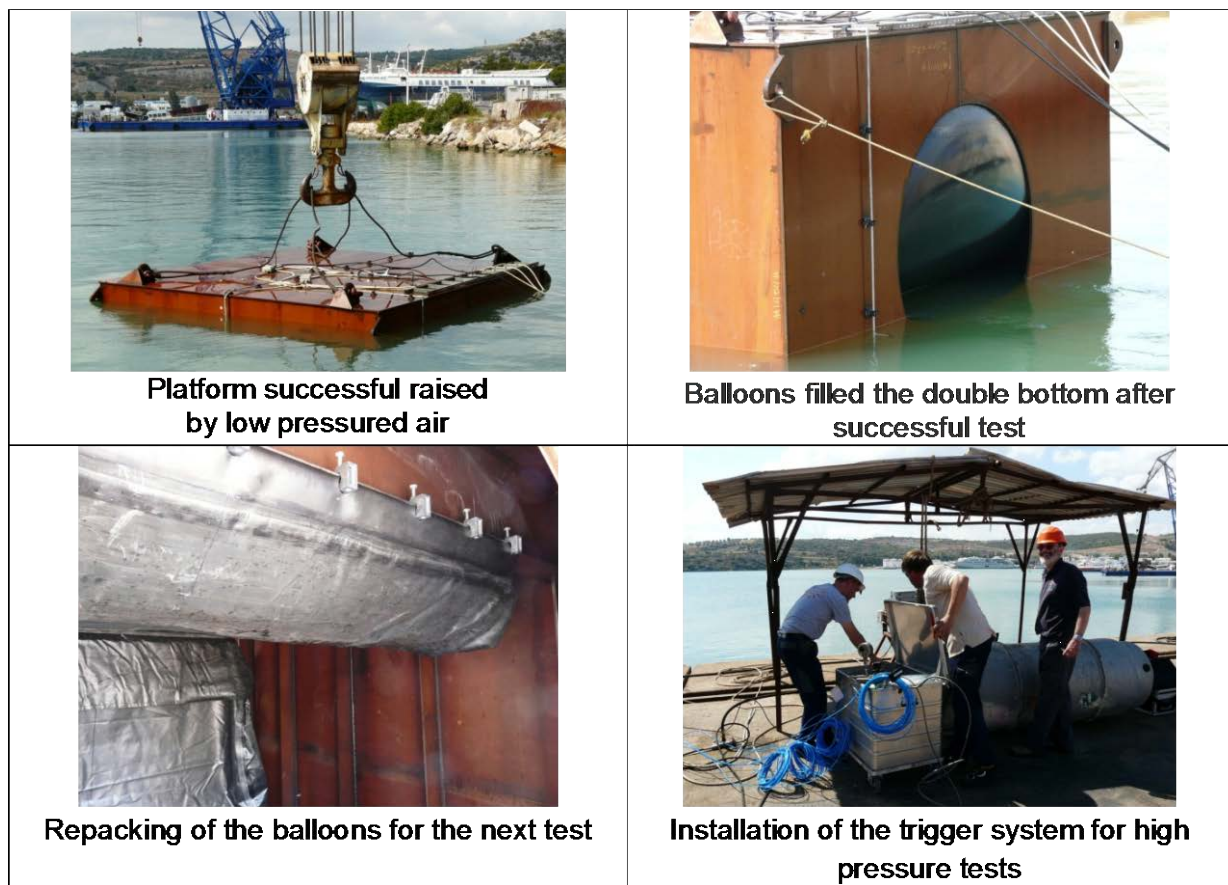
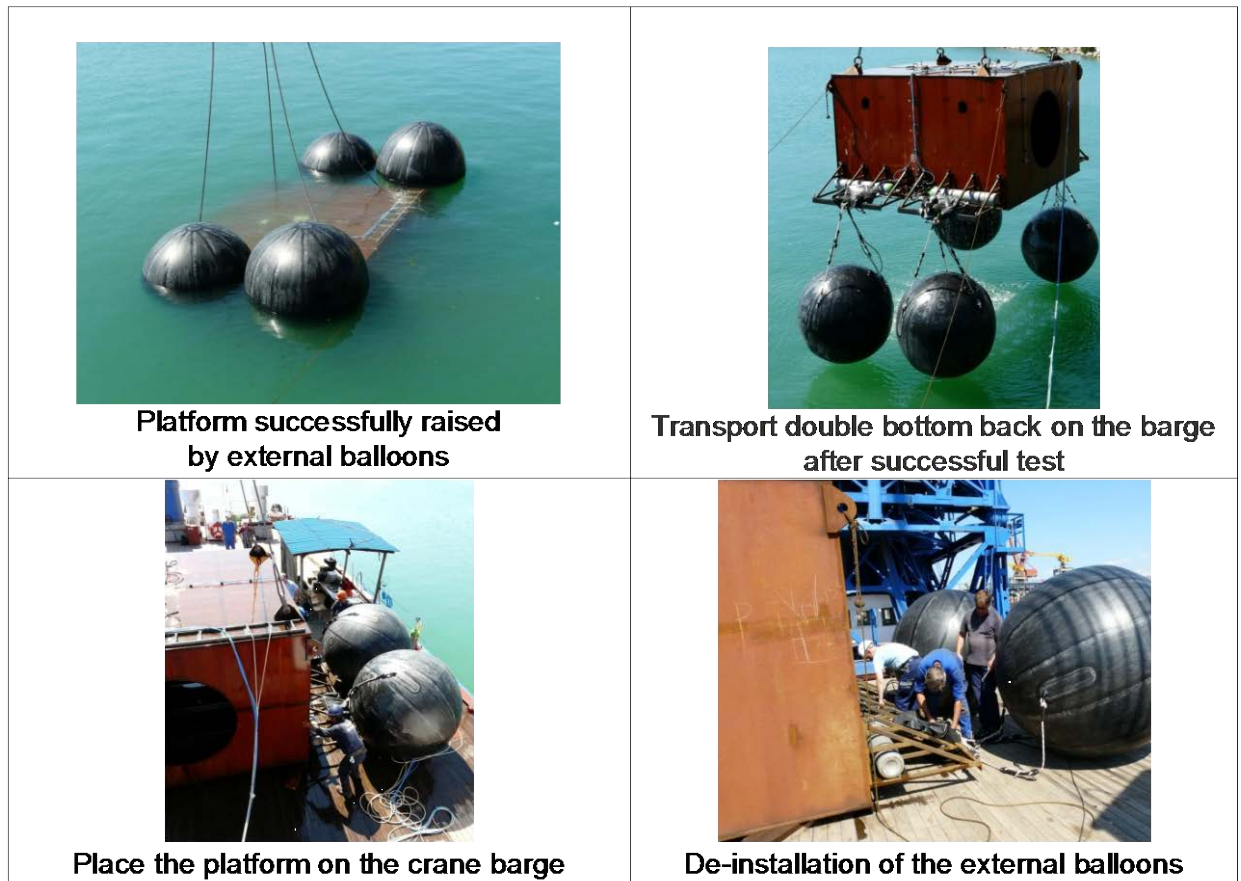


Figure 3-23: Photos of the open water tests (1)



**Figure 3-24: Photos of the open water tests (2)**

#### **Task 4.5 Test evaluation (BV, ASTRIUM, DSB, HCMR, DCNS, NTUA)**

Work within this task reviewed the open water tests measurements and lessons learnt; analysed the result of the gas generation tests and conducted Hazard Identification exercises with respect to the application scenarios in order to determine the risks associated with integration on board a ship.

The detailed measurements of stress during the trials were analysed in terms of von Mises stresses and found to be within design limits. For the external case finite Element Analysis was used in the case of the external modules, in order to evaluate the stresses which result from the force exerted from the inflated balloon. The FE analysis results are validated by the stresses measured from the tests.

#### Hazard identification

The Salvage application HazID workshop was conducted with support of Titan Salvage. The process considered hazards associated with 7 operations shown bellow.

- SuSy system preparation / transport
- SuSy system installation on the sunken ship
- Inflation of balloons and unsticking of the sunken ship from seabed
- Ascending Phase
- Surfacing Phase
- End phase
- Demobilisation

The Tanker application HazID workshop was conducted with support from Emergency Response Service (stability and structure) and in service ship survey. The process considered hazards associated with 4 operations shown bellow.

- Accidental situation in which the SuSy system is to be activated

- Normal ship operation or other accidental situation where the SuSy system is not to be activated
- Ship periodic surveys operations that should not be impeded by the SuSy system
- SuSy system installation and maintenance

The resulting recommendations from these workshops are too detailed to be presented here and are described in D4.5.

### **Work Package 5: Life-Cycle-Cost calculation (BAL)**

*This work package took the conceptual designs from WP3 and modelled the economic, environmental and safety consequences of adopting or not adopting the SUSY concept for a range of scenarios and ship types. Bespoke software was developed to enable probabilistic calculations over a vessel's life span. It therefore provided an economic analysis of the SUSY system and therefore a justification for decision-making on the part of ship owners and builders.*

#### **Task 5.1 Definition of life-cycle cost parameters (BAL, DCNS, HCMR, BMT, NTUA)**

Activity within this task determined relevant cost factors for the overall life-cycle costs of the SuSy system drawing on experience from other projects in the context of several scenarios. Including, maintenance and disposal costs of rescue system, cost of occupied space, cost savings for salvage, environmental penalties for spillage and loss of life. Ship parameters were determined and then necessary parameters for costing SUSY components also defined as a series of datasheets.

### Task 5.2 Set-up of the cost calculation system (BAL)

A software system was developed using the Eclipse RCP (rich client program) as the base user interface platform. The user interface will mainly consist of four areas, which can be freely resized by the user as described bellow:

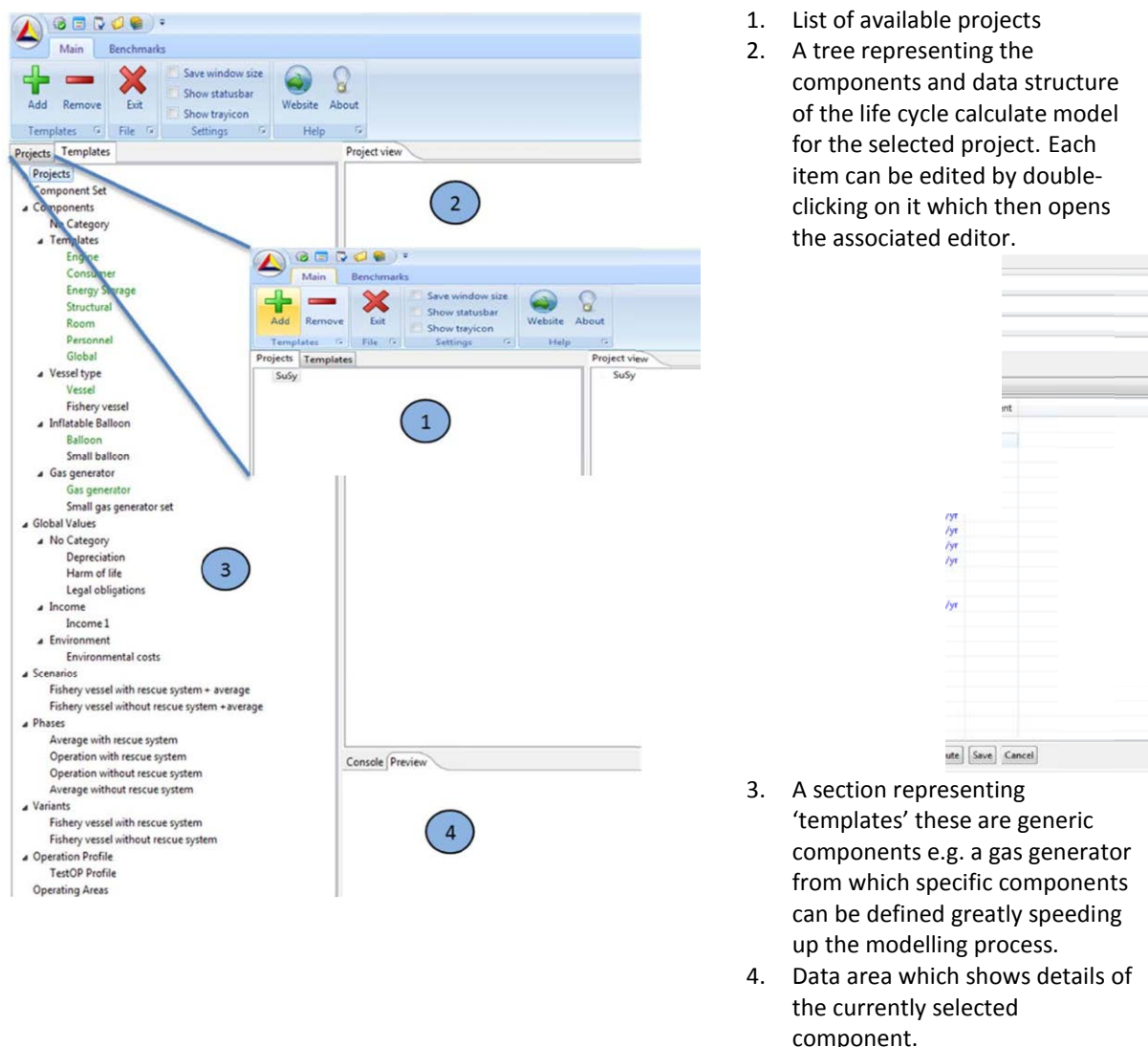


Figure 3-25: Life cycle cost calculation system

The model once built can then be used to produce a graph of result variables against time for multiple scenarios for example corresponding to different system designs.

### Task 5.3 Life cycle cost calculation for different scenarios (BAL, BV BMT)

Work within this task considered two business model scenarios derived from the application scenarios. One scenario deals with using SuSy as a tool to uplift sunken ships from the seabed. The other scenario deals with using SuSy as a safety measure to prevent ships from sinking or capsizing. For each scenario all expenditures and all income over the entire lifetime of a SuSy system were considered.

The lifetime cost was then calculated using an expected net present value approach to take into the account the time value of money and the probabilities of different outcomes. For example the probabilities of incidents as estimated from  $F(h)$  frequency in historic data sets. On this basis the business opportunities were judged and proposals are made which option should be used in the different scenarios.

Some prerequisites must be fulfilled in this case so that it cannot be a general tool for salvage operations. The calculations show nevertheless that, in its segment, SuSy would offer a financial benefit to the user as it could speed up the salvage operations. According to the simulation the investment costs will amortise already during the first use so that the system should be very interesting for salvage specialists all around the world.

The second application would be the installation of on-board systems that are used as an emergency response system to stabilize the ship in case of a severe accident. If in place it could give the crew a larger time window to safely abandon the ship, help to prevent a vessel from sinking and mitigate consequences. However in this case the probability of serious accidents are so low that with insurance there is no strong motivation for an individual ship owner.

## **Work Package 6: Dissemination (BAL)**

*This work package raised awareness about the project and managed relations with scientific and other stakeholders so as to ensure dissemination of the project results.*

### **Task 6.1 : Awareness measures and conferences (BMT, DCNS, ASTRIUM, BAL, HCMR, NTUA, BV, UGS)**

A public website was designed and built providing information about the project and access to deliverables.

Conferences were attended and papers presented including; maritime brokerage event, maritime salvage and casualty conference, design and operation of tankers conference, ICCAS - International Conference on Computer Applications in Shipbuilding, The Motorship, Conference on the Stability of Ships and Ocean Vehicles (STAB), DC - International Marine Design Conference, New strategies and technologies for the safety of navigation in the Mediterranean sea. Press releases were distributed resulting in a number of articles in Baird Maritime, Ocean new and technology, Lloyds ship manager, London press service and several others.

A poster, leaflets describing the trials and an information paper on the water tests were also produced and distributed. Moreover relations with other relevant projects were developed and maintained as part of this task.

### **Task 6.2: Demonstration (HCMR, ASTRIUM, DSB)**

During the demonstration all SuSy components were open for public viewing. It is envisaged to show the pontoon and carry out a scenario that shows how the system works under realistic conditions. However for safety reasons only a few local representatives were invited to witness the trials themselves. A leaflet describing the trials was produced and 500 copies distributed. Moreover a press release was created to disseminate the results more widely.

### **Task 6.3: Technology Implementation Plan (BMT, all partners)**

A formal Dissemination and Exploitation plan for the products adapted & developed within the SuSy framework was developed. Much of this is confidential and specific to consortium members and is hence not included in this project report. We are however pleased to announce that at least patent has been granted so far as a key step to protecting the concept and enabling exploitation of results.

## **Work Package 7: Project Management**

*This work package was purely managerial and administrative comprising:*

- *Legal and administrative project management*
- *Project planning and management*
- *Quality assurance*

*It entailed the production of project plans, quality plans and reports as well as the day-to-day project management of the consortium. That is organisation of meetings and coordination of project partners as required by the needs of the project. Further administration in regards to contracts, amendments, financial control and reporting was also covered by this work package.*



## Potential impact

According to statistics for Lloyds open form<sup>1</sup> report 2012 there were 997 cases over the 2000-2010 period and the total salvaged value under LOF contract was possibly in excess of \$5bn while actual costs of economic, environmental and personal damage were significantly higher.

We also note that the variance of accident costs is extremely high with single incidents having a huge impact on the total. For example the costs of the salvage operation for the Costa Concordia are estimated to exceed \$400 million while the cleanup costs for the Prestige disaster are estimated to have exceeded \$2.8 billion.

Further social costs include

<ul style="list-style-type: none"> <li>Cleaning and restoration</li> </ul>	Direct cost of the cleanup.
<ul style="list-style-type: none"> <li>Fisheries and related sectors</li> </ul>	Calculation of the direct impact on fisheries, aquaculture and shellfish requires detailed biological analysis to work out the medium and long term effect on fisheries and biodiversity in addition to straight forward comparison of catch and effort before and after the spill. The impact on downstream fish processing activities should also be considered.
<ul style="list-style-type: none"> <li>Tourism</li> </ul>	This can mainly be estimated in terms of decrease in use. However while hotel stays can be easily compared unregulated accommodation such as holiday homes, apartments, weekend residences or family homes are also subject to loss.
<ul style="list-style-type: none"> <li>Non-use or passive use</li> </ul>	<p>We are mainly concerned here with damage to ecosystems and habits. Here clearly we have loss of things that people value but which cannot be easily quantified.</p> <ul style="list-style-type: none"> <li><i>Existence values</i>: the value that society assigns to preserving a resource, even though any current use or future use will not be carried out.</li> <li><i>Altruistic values</i>: when individuals show certain concern about the availability of the resource for the benefit of others.</li> <li><i>Value of legacy</i>: concern about future generations and a desire for them to have the option of enjoying the environmental resource.</li> </ul>

Therefore it is clear that while from the perspective of any given ship owner the likelihood of an accident may seem low and the consequences insurable against<sup>2</sup>. From a wider societal perspective the likelihood and costs of even a single incident dwarf the costs of investment in accident prevention and mitigation systems. Major shipping accidents are classical black swans – unexpected and of huge impact.

In our analysis here we have focussed on the costs associated with breakup or sinking of an oil tanker. The consortium decided that a fixed installation of the system on board a cruise ship would be difficult due to the premium put on space (in particular water frontage) and the possibility that externally inflating buoyancy aids

<sup>1</sup> Leading international standard for salvage contracts

<sup>2</sup> The reader is advised to consult the relevant regulation limiting maximum damages.

would impede evacuation. However the tanker scenario is directly addressed within the SUSY project through demonstration of the system operating within a double bottom and through simulations. The findings were that the SUSY system could be used to prevent sinking and to prevent breakup through crack propagation. This is not to say that all accidents can be mitigated against - since for instance the impact of extreme weather cannot be neglected - but rather that for a number of likely scenarios the consequences of damage can be mitigated by the SuSy system.

The forgoing analysis was from the perspective of total societal costs. However from the perspective of an investor deciding whether to install the system on a new build or retrofit a more narrow focus is in order.

To try and estimate the potential value of accident mitigation consider that awards to Salvors attributable to accidents due to flooding and collision (which may also include flooding) – were \$171 million over this period. This cost is directly related to the difficulty of the salvage operation and condition of the ship at time of salvage and is therefore directly effected by damage mitigation strategies.

The fact that shipping is a high risk business both from an economical and operational point of view is widely acknowledged. Taking into consideration the very nature of maritime industry and the market conditions, it appears that a system that could mitigate the consequences of an accident by providing additional buoyancy and stability to a damaged ship would facilitate more efficient safeguards against any harm to life, property and environment.

Generally the major impact of the SuSy system comprises

- Avoiding loss of life by preventing ships from sinking or further structural damage at least long enough to allow a safe evacuation.
- Saving money by avoiding the loss of ships and cargo
- Avoiding pollution caused by hazardous cargo, oil or other material that could be spilled from the ship into the sea.
- Transferring the results into the world-wide maritime industry in order to promote these impacts also into countries that are not directly related to the project

## Exploitation activities

The project has resulted in a patent of the core technology platform (DP102010035749 Vorrichtung zur Stabilisierung von Schiffen über aufblasbare Auftriebskörper), considerable interest from a number of international naval organizations.

Since this work is sensitive we will not go into detail on these activities here. Rather the exploitation plans will be described in the confidential section of this report.

## Dissemination activities

### Journal and conference papers

Event	Organiser	Presentation title	Place	Date
FP7 Maritime brokerage event	Ship builders and ship repairers association	Surfacing System for Ship Recovery	London, UK	Sept. 2010
Demonstracion Tecnologica den Industria Auxiliar del Naval	Aux Navalia	The Ship Stability Research Centre (SSRC) Expertise	Spain	Jan. 2011
Design & Operation of Tankers	RINA	Simulation of External Application of SuSy devices on an Aframax Tanker that has been Structurally Compromised	Athens, Greece	June 2011
UK Marine Technology Postgraduate Conference (UK MTPC 2011)	University of Southampton	Dynamics analysis of a raising sunken vessel	Southampton UK	June 2011
London, Maritime Salvage and Casualty Response	ACI	Managing Risk and Controlling Casualty in Salvage operations	London, UK	Sept. 2011
The RINA Int. Conference on Computer Applications in Shipbuilding (ICCAS)	RINA	Sliding Mode Controller for Salvaging of Sunken Vessels	Trieste, Italy	Sept. 2011
The 11 <sup>th</sup> Int. Marine Design Conference (IMDC 2012)	University of Strathclyde	A New Ship Recovery Concept and Design Using Adaptively Controlled Buoyancy Systems	Glasgow, UK	June 2012
2012 Conference on the Stability of Ships and Ocean Vehicles (STAB)	NTUA	Surfacing System for Ship Recovery	Athens, Greece	Sept. 2012
New strategies and technologies for the safety of navigation in Mediterranean sea	ARGOMARINE	Surfacing System for Ship Recovery	Elba, Italy	Nov. 2012
6 <sup>th</sup> International Conference on Collision and Grounding of Ships and Offshore Structures	ICCGS	Stabilisation of vessels with the support of balloons	Trondheim, Norway	June 2013
TRA Transport Solutions: from Research to Deployment - Innovate Mobility, Mobilise Innovation!	TRA-Transport Research Arena	TBA	Paris, France	April 2014

### Trade journal articles

2013

Organisation	Link/Item
BYM Marine & Maritime News	<a href="http://www.bymnews.com/news/newsDetails.php?id=115086">http://www.bymnews.com/news/newsDetails.php?id=115086</a>
Seadiscovery: U/W Technology and Ocean Science News	<a href="http://www.seadiscovery.com/mtStories.aspx?ShowStorry=1087382124">http://www.seadiscovery.com/mtStories.aspx?ShowStorry=1087382124</a>
Marine Insight	<a href="http://www.marineinsight.com/shipping-news/pan-european-susy-ship-stability-project-completes-sea-trials/">http://www.marineinsight.com/shipping-news/pan-european-susy-ship-stability-project-completes-sea-trials/</a>
Aerospace and Defence Index	<a href="http://www.aerospace-index.com/pressdet.php?id=4976">http://www.aerospace-index.com/pressdet.php?id=4976</a>
Ground Systems index	<a href="http://www.groundsystems-index.com/pressdet.php?id=4976">http://www.groundsystems-index.com/pressdet.php?id=4976</a>
Marine Technology Reporter	<a href="http://former.seadiscovery.com/mt/mtStories.aspx?ShowStorry=1087382124">http://former.seadiscovery.com/mt/mtStories.aspx?ShowStorry=1087382124</a>
Maritime Security Asia	<a href="http://maritimesecurity.asia/free-2/maritime-security-asia/pan-">http://maritimesecurity.asia/free-2/maritime-security-asia/pan-</a>



	europaean-susy-ship-stability-project-completes-sea-trials/
Il Mare (sea, boating fishing, diving news)	<a href="http://www.ilmare24ore.com/en/general-news/post.asp?id=greece-pan-european-susy-ship-stability-project-completes-sea-trials_338184">http://www.ilmare24ore.com/en/general-news/post.asp?id=greece-pan-european-susy-ship-stability-project-completes-sea-trials_338184</a>
Maritime Global News	<a href="http://maritimeglobalnews.com/news/shipstability-project-completes-trials-afgbn1">http://maritimeglobalnews.com/news/shipstability-project-completes-trials-afgbn1</a>
Marine Link (Maritime Reporter and Marine News Online)	<a href="http://www.marinelink.com/news/shipstability-completes351809.aspx">http://www.marinelink.com/news/shipstability-completes351809.aspx</a>
Marine Log - on-line shipping/maritime magazine	<a href="http://marinelog.com/index.php?option=com_content&amp;view=article&amp;id=3639:eu-project-develops-balloon-based-ship-rescue-system-&amp;catid=1:latest-news&amp;Itemid=195">http://marinelog.com/index.php?option=com_content&amp;view=article&amp;id=3639:eu-project-develops-balloon-based-ship-rescue-system-&amp;catid=1:latest-news&amp;Itemid=195</a>
Maritime Executive – on-line shipping/maritime magazine	<a href="http://www.maritime-executive.com/article/PanEuropean-SuSy-ShipStability-Project-Completes-Sea-Trials/">http://www.maritime-executive.com/article/PanEuropean-SuSy-ShipStability-Project-Completes-Sea-Trials/</a>
Maritime Journal - on-line shipping/maritime magazine	<a href="http://www.maritimejournal.com/news101/industry-news/susy-awakens-ship-stability-possibilities">http://www.maritimejournal.com/news101/industry-news/susy-awakens-ship-stability-possibilities</a>
Maritime Index	<a href="http://www.maritime-index.com/pressdet.php?id=4976">http://www.maritime-index.com/pressdet.php?id=4976</a>
Sailors Club (Merchant Navy network)	<a href="http://www.sailors-club.net/index.php?option=com_content&amp;view=article&amp;id=25269:susy-awakens-ship-stability-possibilities&amp;catid=7:news">http://www.sailors-club.net/index.php?option=com_content&amp;view=article&amp;id=25269:susy-awakens-ship-stability-possibilities&amp;catid=7:news</a>
Marine & Offshore Technology	<a href="http://www.marineoffshoretechnology.net/health-safety-environment/new-rescue-system-distressed-ships-tested-successfully">http://www.marineoffshoretechnology.net/health-safety-environment/new-rescue-system-distressed-ships-tested-successfully</a>
Marine Circle Shipping News	<a href="http://www.marinecircle.com/news/detail.jsp?id=c39418b9b80c4f65b47a1f6738cc64c4">http://www.marinecircle.com/news/detail.jsp?id=c39418b9b80c4f65b47a1f6738cc64c4</a>
Sustainable Shipping	<a href="http://www.sustainableshipping.com/news/i119992/EU_develops_balloon_based_ship_rescue_system">http://www.sustainableshipping.com/news/i119992/EU_develops_balloon_based_ship_rescue_system</a>
Bunkerworld – shipping and maritime transport	<a href="http://www.bunkerworld.com/news/i119992/EU_develops_balloon_based_ship_rescue_system">http://www.bunkerworld.com/news/i119992/EU_develops_balloon_based_ship_rescue_system</a>
Handy Shipping Guide (Global freight and shipping)	<a href="http://www.handyshippingguide.com/shipping-news/freight-and-passenger-ships-can-now-avoid-that-sinking-feeling-and-a-fish-that-seeks-out-pollution_4419">http://www.handyshippingguide.com/shipping-news/freight-and-passenger-ships-can-now-avoid-that-sinking-feeling-and-a-fish-that-seeks-out-pollution_4419</a>
Seas & Ocean (Poland)	<a href="http://morzaioceany.pl/start/świat-i-europa/1404-susy-awakens-ship-stability-possibilities.html">http://morzaioceany.pl/start/świat-i-europa/1404-susy-awakens-ship-stability-possibilities.html</a>
De Telegraaf (Netherlands)	<a href="http://www.telegraaf.nl/vaarkrant/21377480/___Airbag_voor_scheepen_in_de_maak_.html">http://www.telegraaf.nl/vaarkrant/21377480/___Airbag_voor_scheepen_in_de_maak_.html</a>
BNR (Netherlands)	<a href="http://www.bnr.nl/nieuws/987978-1303/airbag-moet-titanictaferelen-voorkomen">http://www.bnr.nl/nieuws/987978-1303/airbag-moet-titanictaferelen-voorkomen</a>
Schuttevaer (Netherlands)	<a href="http://www.schuttevaer.nl/nieuws/techniek/nid18743-airbags-maken-schip-onzinkbaar-.html">http://www.schuttevaer.nl/nieuws/techniek/nid18743-airbags-maken-schip-onzinkbaar-.html</a>
Shippotters (Netherlands)	<a href="http://www.shippotters.nl/viewtopic.php?f=3&amp;t=1259&amp;start=75">http://www.shippotters.nl/viewtopic.php?f=3&amp;t=1259&amp;start=75</a>
Lexisnexis (Press information, Singapore)	<a href="http://www6.lexisnexis.com/publisher/EndUser?Action=UserDisplayFullDocument&amp;orgId=614&amp;topicId=16319&amp;docId=1:1848743488&amp;Em=7&amp;start=29">http://www6.lexisnexis.com/publisher/EndUser?Action=UserDisplayFullDocument&amp;orgId=614&amp;topicId=16319&amp;docId=1:1848743488&amp;Em=7&amp;start=29</a>
Setcorp (shipbuilding, energy and transport, Romania)	<a href="http://www.setcorp.ru/?language=english&amp;when=3">http://www.setcorp.ru/?language=english&amp;when=3</a>

## 2012

Organisation	Link/Item
Transport Research (buoyancy rescue concepts)	<a href="http://www.transport-research.info/Upload/Documents/201204/20120405_230626_86293_SUSY%20D-2-4%20Definition%20of%20buoyancy%20rescue%20concepts_public.pdf">http://www.transport-research.info/Upload/Documents/201204/20120405_230626_86293_SUSY%20D-2-4%20Definition%20of%20buoyancy%20rescue%20concepts_public.pdf</a>
Newsodrome (on-line blog)	<a href="http://newsodrome.com/boating_news/kevlar-balloons-to-raise-sinking-ships-22614330">http://newsodrome.com/boating_news/kevlar-balloons-to-raise-sinking-ships-22614330</a>
Argomarine Conference Online Presentation	<a href="http://www.slideshare.net/ARGOMARINE/argomarine-final-conference-susy-presentation">http://www.slideshare.net/ARGOMARINE/argomarine-final-conference-susy-presentation</a>

## 2011

Organisation	Link/Item
Shipping Reporter	SuSy Comes to the rescue of sinking vessels. 21 December
London Press Service	Airbags to boost rescue system for ships in peril. 23 June
Lloyds Ship Manager	BMT leads salvage research group. 11 March.
Baird Maritime	New technology to rescue sinking vessels. 6 January
Ocean News & Technology	<a href="http://virtual.ocean-news.com/publication/?i=60148&amp;p=16">http://virtual.ocean-news.com/publication/?i=60148&amp;p=16</a>

(Jan/Feb 2011 Magazine Issue)	
Passenger Ship Technology	<a href="http://content.yudu.com/Library/A1v7pa/PassengerShipTechnology/resources/62.htm">http://content.yudu.com/Library/A1v7pa/PassengerShipTechnology/resources/62.htm</a>
Machinery and Materials	<a href="http://www.hkmaschine.com.hk/newspage.asp?id=22449">http://www.hkmaschine.com.hk/newspage.asp?id=22449</a>
Motorship: global shipping journal	<a href="http://www.motorship.com/news101/comment-and-analysis/keep-damaged-ships-afloat">http://www.motorship.com/news101/comment-and-analysis/keep-damaged-ships-afloat</a>
Focus Issue 1: BMT Newsletter	<a href="http://www.bmt.org/media/432997/BMTFOCUS-Issue12011.pdf">http://www.bmt.org/media/432997/BMTFOCUS-Issue12011.pdf</a>
UK MTPC 2011 On-line Abstracts	Dynamics analysis of a raising sunken vessel - Arun Kumar. D. V., Dept. of Naval Architecture & Marine Engineering, University of Strathclyde <a href="http://www.southampton.ac.uk/assets/imported/transforms/peripheral-block/UsefulDownloads_Download/772EFD991EF24D32913D05298E6489DC/uk_mtpc_2011_publication.pdf">http://www.southampton.ac.uk/assets/imported/transforms/peripheral-block/UsefulDownloads_Download/772EFD991EF24D32913D05298E6489DC/uk_mtpc_2011_publication.pdf</a>

## 2010

Organisation	Link/Item
gCaptain: Maritime and offshore news	<a href="http://gcaptain.com/kevlar-balloons-raise-sinking/">http://gcaptain.com/kevlar-balloons-raise-sinking/</a>
Motorship: global shipping journal	<a href="http://www.motorship.com/news101/industry-news/will-susy-rescue-sinking-vessels">http://www.motorship.com/news101/industry-news/will-susy-rescue-sinking-vessels</a>
Yoursutal (Japanese shipping blog)	<a href="http://oxakwdqve.exblog.jp/16393835/">http://oxakwdqve.exblog.jp/16393835/</a>
BlogMercante (Merchant shipping blog, Brasil)	<a href="http://www.blogmercante.com/2010/12/baloes-de-kevlar-para-salvar-navios/">http://www.blogmercante.com/2010/12/baloes-de-kevlar-para-salvar-navios/</a>
Ocean	SUSY to rescue of sinking vessels. 14 December
BMT News	<a href="http://www.bmt.org/news/2010/12/bmt-group-and-susy-come-to-the-rescue-of-sinking-vessels/">http://www.bmt.org/news/2010/12/bmt-group-and-susy-come-to-the-rescue-of-sinking-vessels/</a> <a href="http://www.bmtcordah.pl/News/?/214/0/758">http://www.bmtcordah.pl/News/?/214/0/758</a>
LondonMatters: Maritime London Newsletter	<a href="http://www.maritimelondon.com/londonmatters13december10.htm">http://www.maritimelondon.com/londonmatters13december10.htm</a>

## Dissemination events and meetings

Several workshops were carried out through the project with industry representatives, concerning dissemination, feedback and potential exploitation.

### Workshop with Titan Salvage, January 2011

The meeting covered the important task of having feedback from a key potential exploiter of the SuSy technologies. TITAN Salvage is a worldwide emergency response, marine salvage and wreck removal company. The meeting with Titan was held in location with SuSy project participants. Discussion included general ideas for salvage and considerations for the SuSy concept:

### Demonstration Chalkis Shipyards, December 2011

The short trials were carried out over a period of 3 days during which all demonstrations were open to observers from within the shipyard including workers, contractors and ship operators.

### Workshop with Meyer-Werft, April 2012

The SUSY concept and status of development has been presented to the technical design department of Meyer Werft. The shipyard is one of the world wide leading shipyards for cruise vessels. The goal of the meeting was

- 1) Receive feedback from a practical point of view.
- 2) Discussion on installation opportunities on-board cruise vessels

Some recommendations for system improvements have been collected and partly included in the final project phase. The recommendations included general rescue strategies, new safety concepts based on the SUSY systems and also ideas for marketing strategies.

### Demonstration Chalkis Shipyards, September 2012

The main trials were carried out over a period of 5 days during which all demonstrations were open to observers from within the shipyard including workers, contractors and ship operators.



Chalkis Shipyards, location for demonstration trials.



Deploying the trial platform during the demonstration trials.



Short trials: observers



Main trials: observers

**Figure 6-26: Photos of the open water tests (3)**

#### Workshop with Titan Salvage, November 2012

Titan Salvage participated to the hazard identification workshop organised in Teddington on 8th and 9th November 2012. The outcome of this workshop was a set of safeguards and recommendations for the salvage application, as detailed in deliverable D4.5.

#### Leaflets

A SuSy flier was produced documenting the project, objectives and results of the trials. The flier was double sided A4 and folded for a 3 section standard letter size format. 1000 copies were professionally printed, with 500 copies distributed amongst the partners who in turn distributed them direct to the clients of the business partners and 500 were kept by HCMR for dissemination through the Thalassocosmos complex (HCMR Crete, with the public aquarium at Cretaquarium). Already there have been enquiries about product availability.

## Poster

During the early stages of the project a general 'project information poster' was produced and used during presentations and events.



Following completion of the sea trials a SuSy Trails Poster was produced documenting the project, objectives and results of the trials (similar to the flier). The poster was produced in a 200 x 85 mm format. Two copies were professionally printed, with self-erecting stands. One has been exhibited in the principal meeting building of EADS Astrium in Bremen and in the BAL headquarters also Bremen. The second poster is on display at the Thalassocosmos complex (HMCR Crete, with the public aquarium at Cretaquarium).



LIST OF SCIENTIFIC (PEER REVIEWED) PUBLICATIONS, STARTING WITH THE MOST IMPORTANT ONES										
NO	Title	Main author	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of publication	Relevant pages	Permanent identifiers <sup>3</sup> (if available)	Is/Will open access <sup>4</sup> provided to this publication?
1	Simulation of External Application of SuSy devices on an Aframax Tanker that has been Structurally Compromised	Zilakos I.K., Karatzas V.A., Chatzidouros E.V., Papazoglou V.J.	Design & Operation of Tankers	8 - 9 June 2011	RINA	Athens, Greece	2011	145-156		
2	Sliding Mode Controller for Salvaging of Sunken Vessels	A K D Velayudhan, N Srinil and N Barltrop, University of Strathclyde, UK	15th International Conference on Computer Applications in Shipbuilding.	20-22 September 2011	RINA	Trieste, Italy	2011	361- 370		

<sup>3</sup> A permanent identifier should be a persistent link to the published version full text if open access or abstract if article is pay per view ) or to the final manuscript accepted for publication (link to article in repository).

<sup>4</sup> Open Access is defined as free of charge access for anyone via the internet. Please answer "yes" if the open access to the publication is already established and also if the embargo period for open access is not yet over but you intend to establish open access afterwards.



LIST OF CONFERENCES, FAIRS, WORKSHOPS, ATTENDED OR ORGANISED BY THE CONSORTIUM							
NO	Event	Organiser	Presentation title (if applicable)	Audience	Place	Date	Access provided to this publication (if applicable)
1	FP7 Maritime brokerage event	Ship builders and ship repairers association	Surfacing System for Ship Recovery	European Maritime Industry	London, UK	Sept. 2010	
2	Maritime Salvage and Casualty Response	ACI - Active Communications International	Managing Risk and Controlling Casualty in a salvage operation	Salvage Industry	London, UK	Sept. 2010	
3	Demonstracion Tecnologica den Industria Auxiliar del Naval	Aux Navalia	The Ship Stability Research Centre (SSRC) Expertise	Spanish Maritime Industry	Santiago de Compostela, Spain	Jan. 2011	
4	Design & Operation of Tankers	RINA	Simulation of External Application of SuSy devices on an Aframax Tanker that has been Structurally Compromised	European Maritime Academia and Industry	Athens, Greece	June 2011	
5	UK Marine Technology Postgraduate Conference (UK MTPC 2011)	University of Southampton	Dynamics analysis of a raising sunken vessel	European Maritime Academia	Southampton, UK	June 2011	
6	Maritime Salvage and Casualty Response	ACI - Active Communications International	Managing Risk and Controlling Casualty in Salvage operations	Salvage Industry	London, UK	Sept. 2011	
7	Int. Conference on Computer Applications in Shipbuilding (ICCAS) 2011	RINA	Sliding Mode Controller for Salvaging of Sunken Vessels	International Maritime Industry	Trieste, Italy	Sept. 2011	
8	The 11 <sup>th</sup> Int. Marine Design Conference (IMDC 2012)	University of Strathclyde	A New Ship Recovery Concept and Design Using Adaptively Controlled Buoyancy Systems	European Maritime Academia and Industry	Glasgow, UK	June 2012	
9	2012 Conference on the Stability of Ships and Ocean Vehicles (STAB)	NTUA	Surfacing System for Ship Recovery	European Maritime Academia and	Athens, Greece	Sept. 2012	

				Industry			
10	New strategies and technologies for the safety of navigation in Mediterranean sea	ARGO-MARINE	Surfacing System for Ship Recovery	European Maritime Industry	Elba, Italy	Nov. 2012	
11	SMM - International trade fair for shipbuilding, machinery and marine technology	Messe Hamburg	Poster, flyer and video on the BALance booth	International Maritime Industry	Hamburg, Germany	Sept. 2012	
<i>Abstracts submitted/accepted for the following conferences</i>							
12	<i>Int. Conference on Computer Applications in Shipbuilding (ICCAS) 2013</i>	<i>RINA</i>	<i>Development of a life cycle cost optimised safety system for stabilising damaged vessels or lifting sunken vessels</i>	<i>International Maritime Industry</i>	<i>Busan, Korea</i>	<i>Sept. 2013</i>	
13	<i>TRA Transport Solutions: from Research to Deployment - Innovate Mobility, Mobilise Innovation!</i>	<i>TRA-Transport Research Arena</i>	<i>Stabilisation of vessels with support of balloons</i>	<i>European Transport Industry and Academia</i>	<i>Paris, France</i>	<i>April 2014</i>	



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